APPENDIX B

STOCK ASSESSMENT AND FISHERY EVALUATION REPORT

FOR THE GROUNDFISH RESOURCES OF THE GULF OF ALASKA

Compiled by

The Plan Team for the Groundfish Fisheries of the Gulf of Alaska

with contributions by

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Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska

Table of Contents

Summary

by

The Plan Team for the Groundfish Fisheries of the Gulf of Alaska

Introduction

The *National Standard Guidelines for Fishery Management Plans* published by the National Marine Fisheries Service (NMFS) require that a stock assessment and fishery evaluation (SAFE) report be prepared and reviewed annually for each fishery management plan (FMP). The SAFE reports are intended to summarize the best available scientific information concerning the past, present, and possible future condition of the stocks and fisheries under federal management. The FMPs for the groundfish fisheries managed by the Council require that drafts of the SAFE reports be produced each year in time for the December North Pacific Fishery Management Council (Council) meetings.

The SAFE report for the Gulf of Alaska (GOA) groundfish fisheries is compiled by the Plan Team for the Gulf of Alaska Groundfish FMP from chapters contributed by scientists at NMFS Alaska Fisheries Science Center (AFSC) and the Alaska Department of Fish and Game (ADF&G). The stock assessment section includes recommended acceptable biological catch (ABC) levels for each stock and stock complex managed under the FMP. The ABC recommendations, together with social and economic factors, are considered by the Council in determining total allowable catches (TACs) and other management strategies for the fisheries.

The GOA Groundfish Plan Team met in Seattle on November 17-21st, 2014 to review the status of stocks of twenty three species or species groups that are managed under the FMP. The Plan Team review was based on presentations by ADF&G and NMFS AFSC scientists with opportunity for public comment and input. Members of the Plan Team who compiled the SAFE report were James Ianelli (chair), Craig Faunce, Sandra Lowe, Chris Lunsford, Jon Heifetz, Kristen Green, Janet Rumble, Mark Stichart, Mike Dalton, Nancy Friday, Ian Stewart, Paul Spencer, Jim Armstrong and Obren Davis. Leslie Slater was unable to attend

Background Information

Management Areas and Species

The Gulf of Alaska (GOA) management area lies within the 200-mile U.S. Exclusive Economic Zone (EEZ) of the United States (Fig. 1). Formerly, five categories of finfishes and invertebrates were designated for management purposes: target species, other species, prohibited species, forage fish species and non-specified species. Effective for the 2011 fisheries, these categories have been revised in Amendments 96 and 87 to the FMPs for Groundfish of the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA), respectively. This action was necessary to comply with requirements of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to prevent overfishing, achieve optimum yield, and to comply with statutory requirements for annual catch limits (ACLs) and accountability measures (AMs). Species and species groups must be identified "in the fishery" for which ACLs and AMs are required. An ecosystem component (EC) is also be included in the FMPs for species and species groups that are not

1) targeted for harvest
2) likely to become overfished or subject to overfishing, and
3) generally retained for sale or personal use.

The effects of the action amended the GOA and BSAI groundfish FMPs to:

1) identify and manage target groundfish stocks "in the fishery"
2) eliminate the "other species" category and manage (GOA) squids, (BSAI and GOA) sculpins, (BSAI and GOA) sharks, and (BSAI and GOA) octopuses separately "in the fishery";
3) manage prohibited species and forage fish species in the ecosystem component category; and

4) remove the non-specified species outside of the FMPs.

Species may be split or combined within the "target species" category according to procedures set forth in the FMP. The three categories of finfishes and invertebrates that have been designated for management purposes are listed below.

In the Fishery:

1) Target species – are those species that support a single species or mixed species target fishery, are commercially important, and for which a sufficient data base exists that allows each to be managed on its own biological merits. Accordingly, a specific total allowable catch (TAC) is established annually for each target species or species assemblage. Catch of each species must be recorded and reported. This category includes walleye pollock, Pacific cod, sablefish, shallow and deep water flatfish, northern and southern rock sole, rex sole, flathead sole, arrowtooth flounder, Pacific ocean perch, shortraker rockfish, rougheye/blackspotted rockfish, northern rockfish, "other " rockfish, dusky rockfish, demersal shelf rockfish, thornyhead rockfish, Atka mackerel, squid, sculpin, sharks, octopus, big skates, longnose skates, and other skates.

Ecosystem Component:

2) Prohibited Species – are those species and species groups the catch of which must be avoided while fishing for groundfish, and which must be immediately returned to sea with a minimum of injury except when their retention is authorized by other applicable law. Groundfish species and species groups under the FMP for which the quotas have been achieved shall be treated in the same manner as prohibited species.
3) Forage fish species – are those species listed in the table below, which are a critical food source for many marine mammal, seabird and fish species. The forage fish species category is established to allow for the management of these species in a manner that prevents the development of a commercial directed fishery for forage fish. Management measures for this species category will be specified in regulations and may include such measures as prohibitions on directed fishing, limitations on allowable bycatch retention amounts, or limitations on the sale, barter, trade or any other commercial exchange, as well as the processing of forage fish in a commercial processing facility.
4) Grenadiers – The grenadier complex (family Macrouridae), also known as "rattails", are comprised of at least seven species of grenadier known to occur in Alaskan waters, but only three are commonly found at depths shallow enough to be encountered in commercial fishing operations or in fish surveys: giant grenadier (*Albatrossia pectoralis*), Pacific grenadier (*Coryphaenoides acrolepis*), and popeye grenadier (*Coryphaenoides cinereus*).

The following lists the GOA stocks within these FMP species categories:

In the Fishery	
Target Species[1]	Walleye pollock, Pacific cod, Sablefish, Flatfish (shallow-water flatfish, deep-water flatfish, northern and southern rock sole, rex sole, flathead sole, arrowtooth flounder), Rockfish (Pacific ocean perch, northern rockfish, shortraker rockfish, rougheye/blackspotted rockfish, other rockfish, dusky rockfish, demersal shelf rockfish[3], thornyhead rockfish), Atka mackerel, Skates (big skates, longnose skates, and other skates), Squids, Sculpins, Sharks, Octopus
Ecosystem Component	
Prohibited Species[2]	Pacific halibut, Pacific herring, Pacific salmon, Steelhead trout, King crab, Tanner crab
Forage Fish Species[4]	Osmeridae family (eulachon, capelin, and other smelts), Myctophidae family (lanternfishes), Bathylagidae family (deep-sea smelts), Ammodytidae family (Pacific sand lance), Trichodontidae family (Pacific sand fish), Pholidae family (gunnels), Stichaeidae family (pricklebacks, warbonnets, eelblennys, cockscombs, and shannys), Gonostomatidae family (bristlemouths, lightfishes, and anglemouths), Order Euphausiacea (krill)
Grenadiers[5]	Macrouridae family (grenadiers)

[1] TAC for each listing. Species and species groups may or may not be targets of directed fisheries
[2] Must be immediately returned to the sea
[3] Management delegated to the State of Alaska
[4] Management measures for forage fish are established in regulations implementing the FMP
[5] The grenadier complex was added to both FMPs as an Ecosystem Component in 2014

This SAFE report describes stock status of target and non-target species in the fishery. Amendments 100/91 added grenadiers to the GOA and BSAI FMPs. Descriptions and assessments of forage fish and the grenadier complex are provided in Appendices 1 and 2

A species or species group from within the fishery category may be split out and assigned an appropriate harvest level. Similarly, species in the fishery category may be combined and a single harvest level assigned to the new aggregate species group. The harvest level for demersal shelf rockfish in the Eastern Regulatory Area is specified by the Council each year. However, management of this fishery is deferred to the State of Alaska with Council oversight.

The GOA FMP recognizes single species and species complex management strategies. Single species specifications are set for stocks individually, recognizing that different harvesting sectors catch an array of species. In the Gulf of Alaska these species include pollock, Pacific cod, sablefish, Pacific ocean perch, flathead sole, rex sole, arrowtooth flounder, northern rockfish, shortraker rockfish, dusky rockfish, Atka mackerel, big skates, and longnose skates. Other groundfish species that are usually caught in groups have been managed as complexes (also called assemblages). For example, other rockfish, rougheye and blackspotted rockfish, demersal shelf rockfish, thornyhead rockfish, deep water flatfish, shallow water flatfish, and other skates have been managed as complexes.

Beginning in 2011, squids, sculpins, octopus, and sharks are managed as individual complexes (previously they were managed as “other species”). Also in 2011, the rockfish categories were reorganized: widow and yellowtail rockfish were removed from the pelagic shelf rockfish complex leaving dusky rockfish as a single species category. Widow and yellowtail rockfish were added to the 15 species that were part of the former “other slope” rockfish group to form a new category in the Gulf of Alaska, “other rockfish”. Previously, yellowtail and widow rockfish were part of the “pelagic shelf” rockfish group in the Gulf of Alaska, which no longer exists (for assessment purposes) since 2012. Both shortraker rockfish and “other rockfish” were presented as separate SAFE chapters in 2013. Separating these two chapters responds to recommendations from the Gulf of Alaska Plan Team and the NPFMC Scientific and Statistical Committee.

The FMP authorizes splitting species, or groups of species, from the complexes for purposes of promoting the goals and objectives of the FMP. Atka mackerel was split out from “other species” beginning in 1994. In 1998, black and blue rockfish were removed from the GOA FMP and management was conferred to the ADF&G. In 2008, dark rockfish were similarly removed from the GOA FMP with sole management taken over by the ADF&G. Beginning in 1999, osmerids (eulachon, capelin and other smelts) were removed from the “other species” category and placed in a separate forage fish category. In 2004, Amendment 63 to the FMP was approved which moved skates from the other species category into a target species category whereby individual OFLs and ABCs for skate species and complexes could be established.

Groundfish catches are managed against TAC specifications for the EEZ and near coastal waters of the GOA. State of Alaska internal water groundfish populations are typically not covered by NMFS surveys and catches from internal water fisheries generally not counted against the TAC. The Team has recommended that these catches represent fish outside of the assessed region, and should not be counted against an ABC or TAC. Beginning in 2000, the pollock assessment incorporated the ADF&G survey pollock biomass, therefore, the Plan Team acknowledged that it is appropriate to reduce the Western (W), Central (C) and West Yakutat (WY) combined GOA pollock ABC by the anticipated Prince William Sound (PWS) harvest level for the State fishery. The 2001 through 2015 W/C/WY pollock ABCs have been reduced by the PWS GHL as provided by ADF&G, before area apportionments were made. At the 2012 September Plan Team meeting, ADFG presented a proposal to set the PWS GHL in future years as a fixed percentage of the W/C/WY pollock ABC of 2.5%. That value is the midpoint between the 2001-2010 average GHL percentage of the GOA ABC (2.44%) and the 1996 and 2012 levels (2.55%). The Plan Team accepted this proposal, but noted concern regarding the lack of a biomass-based allocation in PWS. The Team encouraged the State to work with the AFSC in order to provide a biomass-based evaluation for PWS prior to fixing a percentage in regulation. In the interim, the Plan Team will deduct a value for the 2015 and 2016 PWS GHL (equal to 2.5% of the recommended 2015 and 2016 W/C/WY pollock ABCs) from the recommended 2015 and 2016 W/C/WY pollock ABCs (listed in the summary table), before area apportionments are made. It is important to note that the value of the PWS GHL is dependent on the final specified W/C/WY pollock ABC. The values used by the Plan Team to derive the 2015 and 2016 W/C/WY pollock apportioned ABCs are listed in the pollock summary under *Area apportionment*.

The Plan Team has provided subarea ABC recommendations on a case-by-case basis since 1998 based on the following rationale. The Plan Team recommended splitting the EGOA ABC for species/complexes that would be disproportionately harvested from the West Yakutat area by trawl gear. The Team did not split EGOA ABCs for species that were prosecuted by multi-gear fisheries or harvested as bycatch. For those species where a subarea ABC split was deemed appropriate, two approaches were examined. The point estimate for WY biomass distribution based on survey results was recommended for seven species/complexes to determine the WY and East Yakutat/Southeast Outside subarea ABC splits. For some species/complexes, a range was recommended bounded by the point estimate and the upper end of the 95% confidence limit from all three surveys. The rationale for providing a range was based on a desire to incorporate the variance surrounding the distribution of biomass for those species/complexes that could potentially be constrained by the recommended ABC splits.

No Split	Split, Point Estimate	Split, Upper 95% Cl
Pacific cod	Pollock	Pacific ocean perch
Atka mackerel	Sablefish	Dusky rockfish
Shortraker rockfish	Deep-water flatfish	
Rougheye/blackspotted rockfish	Shallow-water flatfish	
Thornyhead	Rex sole	
Northern rockfish	Arrowtooth flounder	
Demersal shelf rockfish	Flathead sole	
All skates	Other rockfish	

Biological Reference Points

A number of biological reference points are used in this SAFE. Among these are the fishing mortality rate (*F*) and stock biomass level (*B*) associated with MSY (F_{MSY} and B_{MSY}, respectively). Fishing mortality rates reduce the level of spawning biomass per recruit to some percentage P of the pristine level ($F_{P\%}$). The fishing mortality rate used to compute ABC is designated F_{ABC}, and the fishing mortality rate used to compute the overfishing level (OFL) is designated F_{OFL}.

Definition of Acceptable Biological Catch and the Overfishing Level

Amendment 56 to the GOA Groundfish FMP, approved by the Council in June 1998, defines ABC and OFL for the GOA groundfish fisheries. The new definitions are shown below, where the fishing mortality rate is denoted *F*, stock biomass (or spawning stock biomass, as appropriate) is denoted *B*, and the *F* and *B* levels corresponding to MSY are denoted F_{MSY} and B_{MSY} respectively.

Acceptable Biological Catch is a preliminary description of the acceptable harvest (or range of harvests) for a given stock or stock complex. Its derivation focuses on the status and dynamics of the stock, environmental conditions, other ecological factors, and prevailing technological characteristics of the fishery. The fishing mortality rate used to calculate ABC is capped as described under “overfishing” below.

Overfishing is defined as any amount of fishing in excess of a prescribed maximum allowable rate. This maximum allowable rate is prescribed through a set of six tiers which are listed below in descending order of preference, corresponding to descending order of information availability. The SSC will have final authority for determining whether a given item of information is reliable for the purpose of this definition, and may use either objective or subjective criteria in making such determinations. For tier (1), a pdf refers to a probability density function. For tiers (1-2), if a reliable pdf of B_{MSY} is available, the preferred point estimate of B_{MSY} is the geometric mean of its pdf. For tiers (1-5), if a reliable pdf of *B* is available, the preferred point estimate is the geometric mean of its pdf. For tiers (1-3), the coefficient α is set at a default value of 0.05, with the understanding that the SSC may establish a different value for a specific stock or stock complex as merited by the best available scientific information. For tiers (2-4), a designation of the form “$F_{X\%}$” refers to the F associated with an equilibrium level of spawning per recruit (SPR) equal to X% of the equilibrium level of spawning per recruit in the absence of any fishing. If reliable information sufficient to characterize the entire maturity schedule of a species is not available, the SSC may choose to view SPR calculations based on a knife-edge maturity assumption as reliable. For tier (3), the term $B_{40\%}$ refers to the long-term average biomass that would be expected under average recruitment and $F=F_{40\%}$.

Tier

1) Information available: *Reliable point estimates of B and B_{MSY} and reliable pdf of F_{MSY}.*
   - 1a) Stock status: $B/B_{MSY} > 1$
     - $F_{OFL} = \mu_A$, the arithmetic mean of the pdf
     - $F_{ABC} \leq \mu_H$, the harmonic mean of the pdf
   - 1b) Stock status: $\alpha < B/B_{MSY} \leq 1$
     - $F_{OFL} = \mu_A \times (B/B_{MSY} - \alpha)/(1 - \alpha)$
     - $F_{ABC} \leq \mu_H \times (B/B_{MSY} - \alpha)/(1 - \alpha)$
   - 1c) Stock status: $B/B_{MSY} \leq \alpha$
     - $F_{OFL} = 0$
     - $F_{ABC} = 0$

2) Information available: *Reliable point estimates of B, B_{MSY}, F_{MSY}, $F_{35\%}$, and $F_{40\%}$.*
   - 2a) Stock status: $B/B_{MSY} > 1$
     - $F_{OFL} = F_{MSY}$
     - $F_{ABC} \leq F_{MSY} \times (F_{40\%}/F_{35\%})$
   - 2b) Stock status: $\alpha < B/B_{MSY} \leq 1$
     - $F_{OFL} = F_{MSY} \times (B/B_{MSY} - \alpha)/(1 - \alpha)$
     - $F_{ABC} \leq F_{MSY} \times (F_{40\%}/F_{35\%}) \times (B/B_{MSY} - \alpha)/(1 - \alpha)$
   - 2c) Stock status: $B/B_{MSY} \leq \alpha$
     - $F_{OFL} = 0$
     - $F_{ABC} = 0$

3) Information available: *Reliable point estimates of B, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$.*
   - *3a) Stock status:* $B/B_{40\%} > 1$
     - $F_{OFL} = F_{35\%}$
     - $F_{ABC} \leq F_{40\%}$
   - *3b) Stock status:* $\alpha < B/B_{40\%} \leq 1$
     - $F_{OFL} = F_{35\%} \times (B/B_{40\%} - \alpha)/(1 - \alpha)$
     - $F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - \alpha)/(1 - \alpha)$
   - *3c) Stock status:* $B/B_{40\%} \leq \alpha$
     - $F_{OFL} = 0$
     - $F_{ABC} = 0$

4) Information available: *Reliable point estimates of B, $F_{35\%}$, and $F_{40\%}$.*
   - $F_{OFL} = F_{35\%}$
   - $F_{ABC} \leq F_{40\%}$

5) Information available: *Reliable point estimates of B and natural mortality rate M.*
   - $F_{OFL} = M$
   - $F_{ABC} \leq 0.75 \times M$

6) Information available: *Reliable catch history from 1978 through 1995.*
   - *OFL = the average catch from 1978 through 1995, unless an alternative value is established by the SSC on the basis of the best available scientific information*
   - $ABC \leq 0.75 \times OFL$

Overfished or approaching an overfished condition is determined for all age-structured stock assessments by comparison of the stock level in relation to its MSY level according to the following two harvest scenarios (Note for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Overfished (listed in each assessment as scenario 6):

In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2014 or 2) above ½ of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

Approaching an overfished condition (listed in each assessment as scenario 7):

In 2015 and 2016, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2027 under this scenario, then the stock is not approaching an overfished condition.)

For stocks in Tiers 4-6, no determination can be made of overfished status or approaching an overfished condition as information is insufficient to estimate the MSY stock level.

Overview of Stock Assessments

The current status of individual groundfish stocks managed under the FMP is summarized in this section. The abundances of Pacific cod, Dover sole, flathead sole, northern and southern rocksole, arrowtooth flounder, Pacific ocean perch, rougheye and blackspotted rockfish, northern rockfish, and dusky rockfish are above target stock size. The abundances of pollock and sablefish are below target stock size. The target biomass levels for deep-water flatfish (excluding Dover sole), shallow-water flatfish (excluding northern and southern rocksole), rex sole, shortraker rockfish, other rockfish, demersal shelf rockfish, thornyhead rockfish, Atka mackerel, skates, sculpins, squid, octopus, and sharks are unknown.

Summary and Use of Terms

Tables 1 and 2 provide a summary of the current status of the groundfish stocks, including catch statistics, ABCs, and TACs for 2014, and recommendations for ABCs and overfishing levels (OFLs) for 2015 and 2016. Fishing mortality rates (*F*) and OFLs used to set these specifications are listed in Table 3. ABCs and TACs are specified for each of the Gulf of Alaska regulatory areas illustrated in Figure 1. Table 4 provides a list of species for which the ABC recommendations are below the maximum permissible. Table 5 provides historical groundfish catches in the GOA, 1956-2014.

The sum of the preliminary 2015, 2016 ABCs for target species are 685,597 and 731,049 t respectively which are within the FMP-approved optimum yield (OY) of 116,000 - 800,000 t for the Gulf of Alaska. The sum of 2015 and 2016 OFLs are 870,064 and 910,895 t, respectively. The Team notes that because of halibut bycatch mortality considerations in the high-biomass flatfish fisheries, an overall OY for 2015 will be considerably under this upper limit. For perspective, the sum of the 2014 TACs was 499,274 t, and the sum of the ABCs was 640,675 t (and catch through November 8th, 2014 was just below 300,000 t.

The following conventions in this SAFE are used:

(1) "Fishing mortality rate" refers to the full-selection *F* (i.e., the rate that applies to fish of fully selected sizes or ages). A full-selection *F* should be interpreted in the context of the selectivity schedule to which it applies.

(2) For consistency and comparability, "exploitable biomass" refers to projected age+ biomass, which is the total biomass of all cohorts greater than or equal to some minimum age. The minimum age varies from species to species and generally corresponds to the age of recruitment listed in the stock assessment. Trawl survey data may be used as a proxy for age+ biomass. The minimum age (or size), and the source of the exploitable biomass values are defined in the summaries. These values of exploitable biomass may differ from listed in the corresponding stock assessments if the technical definition is used (which requires multiplying biomass at age by selectivity at age and summing over all ages). In those models assuming knife-edge recruitment, age+ biomass and the technical definitions of exploitable biomass are equivalent.

(3) The values listed as 2013 and 2014 ABCs correspond to the values (in metric tons, abbreviated "t") approved by NMFS. The Council TAC recommendations for pollock were modified to accommodate revised area apportionments in the measures implemented by NMFS to mitigate pollock fishery interactions with Steller sea lions and for Pacific cod removals by the State water fishery of not more than 25% of the Federal TAC. The values listed for 2015 and 2016 correspond to the Plan Team recommendations.

(4) The exploitable biomass for 2013 and 2014 that are reported in the following summaries were estimated by the assessments in *those* years. Comparisons of the projected 2015 biomass with previous years' levels should be made with biomass levels from the revised hindcast reported in each assessment.

(5) The catches listed in the following summary tables are those reported by the Alaska Regional Office Catch Accounting System (CAS, http://alaskafisheries.noaa.gov/sustainablefisheries/catchstats.htm) unless otherwise noted.

(6) The values used for 2015 and 2016 were from modified assessments for selected species, rolled over (typically for Tiers 4-6) or based on updated projections. Note that projection values often assume catches and hence their values are likely to change (as are the Tiers 4-6 numbers when new data become available and/or is incorporated in the assessment).

(7) The Plan Team noted that for thornyheads (and a number of other species), it is critically important to the assessment that the GOA trawl surveys continue and that they extend to 1000 m in order to more completely cover deepwater habitat. Full resource assessment surveys have not been completed, and usually the deepest stations are the ones that are omitted.

(8) In general, for all flatfish assessments, the Plan Team recommends that new available maturity information be evaluated and incorporated as appropriate.

Two year OFL and ABC Determinations

Amendment 48/48 to the GOA and BSAI Groundfish FMPs, implemented in 2005, made two significant changes with respect to the stock assessment process. First, annual assessments are no longer required for rockfish, flatfish, and Atka mackerel since new data during years when no groundfish surveys are conducted are limited. Since 2014 is an off-year for the NMFS GOA groundfish trawl survey, only summaries for most of the GOA species were produced.

The second significant change is that the proposed and final specifications are for a period of at least two years. This requires providing ABC and OFL levels for 2015 and 2016 (Table 1). In the case of stocks managed under Tier 3 and for which a modified assessments was produced, 2015 and 2016 ABC and OFL projections are typically based on the output for Scenarios 1 or 2 from the standard projection model using assumed (best estimates) of total year catch levels. For stocks managed under Tiers 3, 4 and 5 for which only a summary was produced, the latest survey data (2013) was reported and for Tier 5 species used for ABC and OFL calculations. Tier 6 stocks may have alternatives based on updated catch information.

The 2016 ABC and OFL values recommended in next year’s SAFE report are likely to differ from this year’s projections for 2016 because data from the 2015 surveys are anticipated and a re-evaluation on the status of stocks will improve on the current available information for recommendations.

Economic Summary of the GOA commercial groundfish fisheries in 2012-13

The real ex-vessel value of all Alaska domestic fish and shellfish catch, including the estimated value of fish caught almost exclusively by catcher/processors, decreased from $2150.5 million in 2012 to $1924.2 million in 2013. The first wholesale value of 2013 groundfish catch was $2169.9 million. The 2013 total groundfish catch increased by 2.3% while the total first-wholesale value decreased by 14.6% relative to 2012.

In terms of ex-vessel value, the groundfish fisheries accounted for the largest share (45.7%) of the ex-vessel value of all commercial fisheries off Alaska, while the Pacific salmon (*Oncorhynchus spp*.) fishery was second with $679.5 million or 35.3% of the total Alaska ex-vessel value. The value of the shellfish fishery amounted to $238.4 million or 12.4% of the total for Alaska and exceeded the value of Pacific halibut (*Hippoglossus stenolepis*) with $111.5 million or 5.8% of the total for Alaska.

The Economic SAFE report (appendix bound separately) contains detailed information about economic aspects of the groundfish fisheries, including figures and tables, catch share fishery indicators, product price forecasts, a summary of the Alaskan community participation in fisheries, an Amendment 80 fishery economic data report (EDR) summary, market profiles for the most commercially valuable species, a summary of the relevant research being undertaken by the Economic and Social Sciences Research Program (ESSRP) at the Alaska Fisheries Science Center (AFSC) and a list of recent publications by ESSRP analysts. The figures and tables in the report provide estimates of total groundfish catch, groundfish discards and discard rates, prohibited species catch (PSC) and PSC rates, the ex-vessel value of the groundfish catch, the ex-vessel value of the catch in other Alaska fisheries, the gross product value of the resulting groundfish seafood products, the number and sizes of vessels that participated in the groundfish fisheries off Alaska, vessel activity, and employment on at-sea processors. Generally, the data presented in this report cover the years 2009 through 2013, but limited catch and ex-vessel value data are reported for earlier years in order to illustrate the rapid development of the domestic groundfish fishery in the 1980s and to provide a more complete historical perspective on catch. Several series have been discontinued and new price/revenue tables from an alternative source are presented in Appendix A: Ex-vessel Economic Data Tables: alternative pricing based on CFEC fish tickets.

The Economic SAFE report updates the data associated with the market profiles for pollock, Pacific cod, sablefish, and yellowfin sole that display the markets for these species in terms of pricing, volume, supply and demand, and trade. In addition, the Economic SAFE contains links to data on some of the external factors that impact the economic status of the fisheries. Such factors include foreign exchange rates, the prices and price indices of products that compete with products from these fisheries, domestic per capita consumption of seafood products, and fishery imports.

The Economic SAFE report also updates a section that analyzes economic performance of the groundfish fisheries using indices. These indices are created for different sectors of the North Pacific, and relate changes in value, price, and quantity across species, product and gear types to aggregate changes in the market.

The data used to compile the tables from this and past Economic SAFE reports are available online at

http://www.afsc.noaa.gov/refm/Socioeconomics/SAFE/default.php

Decomposition of the change in first-wholesale revenues from 2012-13 in the GOA

The following brief analysis summarizes the overall changes that occurred between 2012-13 in the quantity produced and revenue generated from GOA groundfish. According to data reported in the 2014 Economic SAFE report, the ex-vessel value of GOA groundfish dropped from $242.5 million in 2012 to $180.5 million in 2013 (Fig. 2), and first-wholesale revenues from the processing and production of groundfish in the Gulf of Alaska (GOA) fell from $373.9 million in 2012 to $328.9 million in 2013, a decrease of 12.0% (Fig. 3). At the same time, the total quantity of groundfish products from the GOA decreased from 106.8 thousand metric tons to 99.3 thousand metric tons, a difference of 7.4 thousand metric tons. These changes in the GOA account for part of the change in first-wholesale revenues from Alaska groundfish fisheries overall which decreased by $372.8 million, a relative difference of -14.7% in 2013 compared to 2012 levels.

By species group, a negative quantity effect of $19.6 million for Pacific cod was the largest change in first-wholesale revenues from the GOA for 2012-13 (Fig. 4). Negative price effects of $16.6 million for sablefish and $11.4 million for rockfish were also important. By product group, negative price and quantity effects were concentrated in the whole head & gut category in the GOA first-wholesale revenue decomposition for 2012-13.

In summary, first-wholesale revenues from the GOA groundfish fisheries decreased by $44.9 million from 2012-13. Major drivers of this decrease were a strong negative quantity effect for Pacific cod and negative price effects for sablefish and rockfish concentrated in the whole head & gut product group. In comparison, first-wholesale revenues decreased by $327.8 million from 2012-13 in the BSAI due to an enormous negative price effect for pollock.

Ecosystem Considerations-Gulf of Alaska

The Ecosystem Considerations chapter (appendix bound separately) consists of three sections: executive summary, ecosystem assessment, and ecosystem status and management indicators. The ecosystem assessment section combines information from the stock assessment chapters with the indicators followed in this chapter to summarize the climate and fishery effects on the ecosystem. A new Gulf of Alaska ecosystem assessment following the procedure and format of the Eastern Bering Sea and Aleutian Island assessments is awaiting final approvals. Until then, we summarize GOA contributions to the ecosystem considerations chapter below. New trends highlighted in the 2014 Ecosystem Considerations chapter include:

Physical

- The upper ocean in this region was fresher than usual with a relatively strong pycnocline.
- The coastal winds were upwelling favorable in an anomalous sense, which helped maintain relatively normal SST along the coast as compared with the much warmer than normal water offshore.
- The sub-arctic front was farther north than usual, which is consistent with the poleward surface currents shown in the Ocean Surface Currents - Papa Trajectory Index.
- Eddy Kinetic Energy (EKE) levels in the western Gulf of Alaska were particularly weak in summer of 2014. Thus, phytoplankton biomass were likely more tightly confined to the shelf in those years and cross-shelf transport of heat, salinity and nutrients were probably weak.
- In the northern Gulf, relatively high eddy kinetic energy was observed in the summer of 2014.
- It now appears the filtered PAPA Trajectory Index may shift back to northerly flow, which would indicate that the recent period of predominantly southern flow (mid-2000s to present) will have been the shortest and weakest in the time series.

Ecosystem

- The highest density of euphausiids was consistently observed in Barnabas Trough during acoustic surveys in 2003, 2005, 2011, and 2013. The highest overall abundance was observed in 2011, with lowest euphausiid abundance in 2003.
- Total Icy Strait zooplankton density was anomalously low for all months during the 2013 summer survey. Density anomalies were mostly negative from 1997-2005, positive in 2006-2009, and negative in 2010-2013.
- Icy Strait zooplankton were numerically dominated by calanoid copepods. In 2013, large calanoids and larvaceans were anomalously high while small calanoids were anomalously low.
- In the Alaskan Shelf region sampled by the continuous plankton recorder, copepod community size and mesozooplankton biomass anomalies became negative in 2013 while large diatom abundance anomalies remained positive.
- Overall catch rates of juvenile pollock in the 2013 smallmesh survey were the highest since 1979, although eulachon, herring, and pink shrimp catches remained low.
- Temporal patterns in sand lance captured by puffins provisioning chicks show that sand lance were most prevalent from the mid 1990s to the mid 2000s in the central and western GOA. In contrast, sandlance were most prevalent in the mid-1990s and have been decreasing since then in the eastern GOA.
- Although the estimated total mature herring biomass in southeastern Alaska has been above the long term (1980-2013) median of 90,495 tons since 2003 through 2013, an apparent decrease in biomass has been observed since the peak in 2011. The most notable drop in biomass was observed in Hoonah Sound.
- The total number of salmon harvested in 2013 was the largest going back to 1962. Marine survival of Prince William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts. Marine survival in 2010 (2008 brood year) was at an all-time high since 1977 but dropped in 2011 and 2012.
- Ecosystem indicators predict a low pink salmon harvest in 2014 of about 30 M fish.
- A new Southeast Alaska Coastal Monitoring project Chinook salmon index is the abundance estimate of ocean age-1 fish sampled in Icy Strait, lagged two years later to their ocean year of recruitment as ocean age-3 fish, the age when most reach legal size. Based on this Chinook index,

June 1-ocean abundance has been below average in 8 of the past ten years. Most recently, Chinook salmon fishery recruitment appears weak in 2014 and 2016, but strong in both 2013, and particularly in 2015.
- Ecosystem indicators predict below average recruitment events for age-2 sablefish in 2013 and 2015, and a slightly above-average recruitment event in 2014.
- Length-weight residuals for most groundfish species were positive in the first two years of the survey (1985-1987). The residuals have been mixed for all species since then, but generally smaller and varying from year to year. Most species were generally in better condition in the Kodiak area, especially southern rock sole. Fish condition was generally worse in the southeastern area than other areas of the GOA.
- ADF&G received no reports of "mushy" halibut during the 2014 fishing season.
- The depth distribution of rockfish in the Gulf of Alaska has remained constant for each species over time with the exception of shortraker rockfish, which have moved toward shallower water. Since 2007, the range of mean-weighted temperatures where rockfish are found has narrowed. In past contributions, a shift in the distribution of rockfish from the eastern and SE areas of the Gulf of Alaska was noted; however, in the 2013 bottom trawl survey data this trend was not significant.
- Arrowtooth flounder, flathead sole, and other flatfish continue to dominate the biomass in the ADF&G trawl survey. A decrease in overall biomass is apparent from 2007 to 2013 from years of record high estimates seen from 2002 to 2005.
- In 2013, overall gadid biomass in the ADF&G trawl survey has slightly increased in offshore area of Barnabus Gully, but decreased in the inshore areas of Kiliuda and Ugak Bays. Below average anomaly values for Tanner crabs, arrowtooth flounder, and flathead sole were recorded for both inshore and offshore areas, while Pacific cod were well above average. Skates and Pacific halibut were above average for offshore areas, while remaining below average inshore.
- The leading principal component of 18 biological time series from the GOA shows a transition to lower-magnitude positive values around 2006. Recent scores show a linear relationship with winter SST, thus reflecting a possible response to recent changes in climate.

Fisheries
- Discarded tons of groundfish have remained relatively stable in the past few years with the exception of fixed gear, in which discard rates jumped from 6% to 21% in 2013. Improved observer coverage on vessels less than 60' long and on vessels targeting IFQ halibut may account for the increase.
- Assorted invertebrates comprise the majority of non-target catch in groundfish fisheries in the GOA. Catches of Schyphozoan jellies have alternated annually between above and below-average since 2007. Catches of HAPC biota and assorted invertebrates have varied little since 2003.

Other Plan Team discussions

The "hot topic" feature of the presentation this year was the "Warm Blob", or the area of abnormally high temperatures in the Gulf of Alaska. In addition, seabird reproduction in the western Gulf was abnormally successful. Birds nested earlier in the year which led to good survival of the offspring possibly due to favorable winter pre-conditioning or summer foraging; murres in the eastern Gulf were less successful.

1. Walleye pollock

Status and catch specifications (t) of pollock and projections for 2015 and 2016. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014. **In contrast to previous years' tables, the GOA-wide and W/C/WYAK ABCs listed in this table do not include reductions for the Prince William Sound GHL**. However, the federal TACs include reductions due to State waters GHL. State waters GHL is presently computed as 2.5% of the total W/C/WYAK ABC.

Area	Year	Age 3+ Bio.	OFL	ABC	TAC	Catch
GOA	2013	1,029,676	165,183	123,873	121,046	93,733
	2014	1,028,861	228,831	179,139	174,976	139,753
	2015	1,940,031	273,378	203,934		
	2016		337,900	263,449		
W/C/WYAK	2013	981,791	150,817	113,099	110,272	93,733
	2014	972,750	211,998	166,514	162,351	139,752
	2015	1,883,920	256,545	191,309		
	2016		321,067	250,824		
SEO	2013	47,885	14,366	10,774	10,774	0
	2014	56,111	16,833	12,625	12,625	1
	2015	56,111	16,833	12,625		
	2016		16,833	12,625		

Changes from the previous assessment

The age-structured assessment model used for GOA W/C/WYAK pollock assessment implemented several model changes relative to the model used for the 2013 assessment. The 2014 model implemented the following changes, each added to sequential models in a cumulative manner, based on the 2012 CIE review, SSC, and Plan Team comments, and other considerations: 1) starting the model in 1970 rather than 1964 and removing fishery length composition data for 1964-1971, 2) removing summer bottom trawl surveys in 1984 and 1987 and Shelikof Strait acoustic surveys in 1981-1991, 3) estimating summer bottom trawl catchability using a prior rather than fixing catchability and modeling selectivity with an asymptotic curve, 4) using a random walk for changing fishery selectivity parameters rather than time blocks, 5) using an age-specific mortality schedule with higher juvenile mortality, and 6) modeling age-1 and age-2 pollock in the winter acoustic surveys as separate indices. All composition data sets were "tuned" so that input sample sizes were close to the harmonic mean of effective sample size. Many of these changes were implemented following SSC and Plan Team recommendations, including age-specific mortality, removing older data that had been difficult to fit, and estimating summer bottom trawl catchability. To obtain an age-specific natural mortality schedule, an ensemble approach was used which averaged the results for six methods, three multispecies models and three "theoretical empirical" methods, and then rescaled the age-specific values so that natural mortality for fish greater than or equal to age 5 was equal to 0.3, the value of natural mortality used in previous pollock assessments. The Plan Team accepted the authors' recommended final model configuration that incorporated all of these changes.

The authors also explored using a net selectivity correction for acoustic surveys calculated from field experiments using pocket nets. The Team agreed with the authors that additional model exploration was needed before recommending this model. In addition, the method for making the net selectivity correction to the historical surveys needs to be reviewed prior to incorporating the revised estimates in the model.

This year's pollock assessment features the following new data: 1) 2013 total catch and catch-at-age from the fishery, 2) 2014 biomass and age composition from the Shelikof Strait acoustic survey, 3) 2013 age composition from the NMFS bottom trawl survey, 4) 2014 biomass from the ADFG crab/groundfish trawl survey, 5) total catch for all years was re-estimated from original sources, and 6) fishery catch at age and weight at age were re-estimated for 1975-1999. Model fits to fishery age composition data are adequate in most years. The largest residuals tended to be at ages 1-2 of the NMFS bottom trawl survey due to inconsistencies between the initial estimates of abundance and subsequent information about year class size. Model fits to biomass estimates are similar to previous assessments, and general trends in survey time series are fit reasonably well. It is difficult for the age-structured model to fit the rapid increase in the Shelikof Strait acoustic survey and the NMFS survey in 2013. In contrast, the model expectation is close to the ADFG survey in 2013 and 2014. The fit to the age-1 and age-2 acoustic indices appeared adequate though variable. There is an indication of non-linearity in the fit to age-1 index that needs to be explored further.

Spawning biomass and stock trends

The model estimate of spawning biomass in 2015 is 309,869 t, which is 39.7% of unfished spawning biomass (based on average post-1977 recruitment) which is just below the $B_{40\%}$ estimate of 312,000 t.

The 2014 biomass estimate for Shelikof Strait is 842,138 t, which is a 6% decrease from 2013, but is still larger than any other biomass estimate in Shelikof Strait since 1985. The ADFG crab/groundfish survey 2014 biomass estimate is close to the 2013 estimate (2% lower). The estimated abundance of mature fish is projected to remain stable near $B_{40\%}$ or to increase over the next five years. From 2009-2013 the stock has shown an upward trend from 24% to 47% of unfished stock size, but declined to 38% of unfished stock size (spawning biomass) in 2014.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

The Plan Team accepted the author's recommendation to reduce F_{ABC} from the maximum permissible using the "constant buffer" approach (first accepted in the 2001 GOA pollock assessment). Because the model projection of female spawning biomass in 2015 is below $B_{40\%}$, the W/C/WYAK Gulf of Alaska pollock stock is in Tier 3b. The projected 2015 age-3+ biomass estimate is 1,883,920 t (for the W/C/WYAK areas). Markov Chain Monte Carlo analysis indicated the probability of the stock being below $B_{20\%}$ will be negligible in the near future.

The 2015 ABC for pollock in the Gulf of Alaska west of 140° W lon. (W/C/WYAK) is 191,309 t. This is an increase of 14% from the 2014 ABC. In 2016, the ABC based on an adjusted $F_{40\%}$ harvest rate is 250,824 t. The OFL is 256,545 t in 2015 and 321,067 t in 2016. The 2015 Prince William Sound (PWS) GHL is 4,783 t (2.5% of the 2015 ABC of 191,309 t); the 2016 PWS GHL is 6,271 t (2.5% of the 2016 ABC of 250,824 t).

For pollock in southeast Alaska (East Yakutat and Southeastern areas), the ABC for both 2015 and 2016 is 12,625 t and the OFL for both 2015 and 2016 is 16,833 t. These recommendations are based on a Tier 5 assessment using the estimated biomass in 2015 and 2016 from a random effects model fit to the 1990-2013 bottom trawl survey biomass estimates in Southeast Alaska, and are unchanged from last year.

Status determination

The Gulf of Alaska pollock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

Area apportionment

The assessment was updated to include the most recent data available for area apportionments within each season (Appendix C of the GOA pollock chapter). The Team concurred with these updates since they are more likely to represent the current distribution. Area apportionments, reduced by 2.5% of the ABC (4,783 t in 2015 and 6,271 t in 2016) for the State of Alaska managed pollock fishery in Prince William Sound, are tabulated below:

Area apportionments (**with ABCs reduced by Prince William Sound GHL**) for 2015 and 2016 pollock ABCs for the Gulf of Alaska (t).

Year	610	620	630	640	650	
	Western	Central	Central	WYAK	SEO	Total
2015	31,634	97,579	52,594	4,719	12,625	199,151
2016	41,472	127,936	68,958	6,187	12,625	257,178

2. Pacific cod

Status and catch specifications (t) of Pacific cod in recent years. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014.

Year	Age 0+ biomass	OFL	ABC	TAC	Catch
2013	449,300	97,200	80,800	60,600	51,792
2014	422,000	107,300	88,500	64,738	59,633
2015	583,800	140,300	102,850		
2016		133,100	102,850		

Changes from the previous assessment

The fishery catch data series was updated for 1997-2014 (projected for 2014 expected total year catch) and updated 1997-2012 seasonal and gear-specific catch-at-length. The fishery length composition data were updated for 1997-2014 (preliminary for 2014).

The 2014 GOA Pacific cod assessment evaluated four models. Model 1 is identical to the final model configuration from 2013. Model 2 is identical to Model 1 but uses the recruitment variability multiplier. The two new models (S1a and S1b) also use the recruitment variability multiplier. In addition, these models treat the bottom trawl survey as a single source of data instead of splitting the sub 27 and 27-plus data for lengths and ages, include survey age data as conditional age-at-length data. Instead of incorporating 12 blocks of logistic survey selectivity, Model S1a uses 3 blocks of non-parametric survey selectivity and Model S1b uses cubic spline based survey selectivity.

Spawning biomass and stock trends

According to Model S1a, $B_{40\%}$ for this stock is estimated to be 126,600 t, and projected spawning biomass in 2015 is 155,400 t. Estimated age-0 recruitment has been relatively strong since 2005 with the 2008 and 2012 year classes being the strongest over the entire time series since 1978. Stock abundance is expected to be stable in the near term.

Tier determination/ Plan Team discussion and resulting ABC and OFL recommendations

Models S1a and S1b were preferred over Models 1 and 2 because S1a and S1b used all the survey data instead of only the 27 plus portion. Model S1a was selected by the author as the preferred model primarily because it fit the data better than S1b. The Plan Team accepted the author's recommendation to use Model S1a as the preferred model.

Since 2015 spawning biomass is estimated to be greater than $B_{40\%}$, this stock is in Tier 3a. The estimates of $F_{35\%}$ and $F_{40\%}$ are 0.626 and 0.502, respectively.

The maximum permissible ABC estimate (117,200 t) is a 32% increase from the 2014 ABC. The Plan Team recommends that a value lower than the maximum permissible be used for 2015 for the following reasons:

- Additional age-composition data (2013 GOA bottom trawl survey) was provided after the assessment was completed and a comparative analysis was done by the author to evaluate the impact of these data on results. When incorporated, these data reduced the estimated abundance at age (~ 8% of biomass) relative to the selected model in the assessment without the 2013 survey age data.
- A retrospective pattern indicates a consistent downward adjustment for the recent years as more data are added. This suggests that estimates tend to be biased high.

Therefore, as an intermediate step, the Team recommends that ABC for 2015 be set at a value half way between the maximum permissible ABC in the assessment and the 2014 ABC which is 102,850 t. The approximate F_{ABC} at this level is 0.441.

Status determination

The stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

Area apportionment

In the 2013 assessment, the random effects model (which is similar to the Kalman filter approach, and was recommended in the Survey Average working group report which was presented to the Plan Team in September 2013) was used; this method was used for the ABC apportionment for 2014. The SSC concurred with this method in December 2013. Using this method with the trawl survey biomass estimates through 2013, the area-apportioned ABCs are:

Year	Western	Central	Eastern	Total
2015	38,702	61,320	2,828	102,850
2016	38,702	61,320	2,828	102,850

3. Sablefish

Status and catch specifications (t) of sablefish in recent years. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014.

Year	Age 4+ biomass	OFL	ABC	TAC	Catch
2013	167,000	14,780	12,510	12,510	11,945
2014	149,000	12,500	10,572	10,572	10,375
2015	130,000	12,425	10,522		
2016		11,293	9,558		

Changes from the previous assessment

There are no changes in the 2015 assessment model relative to 2014. New data for 2015 includes relative abundance and length data from the 2012 longline survey, relative abundance and length data from the 2011 longline and trawl fisheries, age data from the 2011 longline survey and fixed gear fishery, updated catch from 2005-2013 and new 2014-2016 catch estimates. The fishery abundance index decreased 13% from 2012 to 2013. The longline survey abundance index increased 15% from 2013 to 2014 following a 25% decrease from 2011 to 2013.

Spawning biomass and stock trends

Female spawning biomass increased from a low of 32% of unfished biomass in 2002 to 35% of unfished biomass projected in 2015. Spawning biomass is projected to decrease in the near future, and then stabilize. The 1997 year class has been an important contributor to the population; however, it is predicted to comprise less than 7% of the 2015 spawning biomass. The 2000 year class appears to be at 16% of the spawning biomass in 2015 and may be the largest contributing year class to the population. The 2008 year class will comprise 10% of spawning biomass in 2015 though it is only 60% mature.

Tier determination/Plan Team discussions and resulting ABCs and OFLs

$B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 104,908 t (combined across the EBS, AI, and GOA), 0.095, and 0.112, respectively. The projected 2015 female spawning biomass (combined areas) is 91,183 t (88% of $B_{40\%}$), placing sablefish in Tier 3b. The maximum permissible value of F_{ABC} under Tier 3b is 0.082, which results in a 2015 ABC (combined areas) of 13,657 t. The OFL fishing mortality rate is 0.098 which translates into a 2015 OFL (combined areas) of 16,128 t. The Team accepted the authors' recommended model and corresponding OFL and ABC values.

Status determination

The Alaska-wide sablefish stock is not overfished and is not approaching an overfished condition.

Area apportionment

Apportioned based on a 5-year exponential weighting of the survey and fishery abundance indices. The same method is used to apportion the 2015 and 2016 ABC and OFL.

	2014				2015		2016	
Region	OFL	ABC	TAC	Catch*	OFL	ABC	OFL	ABC
W	--	1,480	1,480	1,195	--	1,474	--	1,338
C	--	4,681	4,681	4,706	--	4,658	--	4,232
**WYAK	--	1,574	1,574	1,655	--	1,708	--	1,552
SEO	--	2,837	2,837	2,818	--	2,682	--	2,436
GOA	12,500	10,572	10,572	10,375	12,425	10,522	11,293	9,558
BS	1,584	1,339	1,339	315	1,575	1,333	1,431	1,211
AI	2,141	1,811	1,811	817	2,128	1,802	1,934	1,637
Total	16,225	13,722	13,772	11,507	16,128	13,657	14,658	12,406

* Catch through November 8th 2014.

** 95:5 split in the EGOA following the trawl ban in SEO

4. Shallow water flatfish

Status and catch specifications (t) of shallow water flatfish and projections for 2015 and 2016. The shallow water complex is comprised of northern rock sole, southern rock sole, yellowfin sole, butter sole, starry flounder, English sole, sand sole and Alaska plaice. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. Catch data are through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	433,869	55,680	45,484	37,077	5,519
2014	384,134	50,007	40,805	33,679	4,389
2015	287,534	54,207	44,205		
2016		48,407	39,205		

Changes from the previous assessment

An executive summary for shallow water flatfish was presented which included updated 2013 catch and the partial 2014 catch as well as projections using the updated results from the northern and southern rock sole assessment. The Team noted that 2014 catches of southern rock sole were substantially lower than catches in 2013.

Changes to the rock sole assessment model input data included updating the fishery catches for 2013 and 2014, including catch-at-length for 2014, adding GOA bottom trawl survey age compositions data from 2013 and compiled survey age data by length to accommodate the option for model fitting based on conditional age-at-length. The fishery catch data was portioned 50% to each of the northern and southern analyses (rather than 60% for both assessment models in 2013).

Several changes were made to the technical implementations of the rock sole stock assessment models in response to SSC and Team recommendations from 2013. These included estimation of natural mortality rates separately for males (females were fixed at 0.2), a change in both models from using selectivity-at-length to selectivity-at-age and using the number of trips or hauls as the primary input sample size (rather than the number of fish). Both models internally estimated the growth and selectivity parameters.

Spawning biomass and stock trends

The rock sole species assessment model estimates are used for trend and spawning biomass estimates whereas the remaining species in this complex are based on the NMFS bottom trawl surveys. The most recent survey was 2013. Survey abundance estimates for the entire shallow-water complex were lower in 2013 compared to 2011; decreasing by 35,156 t. Model estimates of northern and southern rock sole spawning biomass have also shown slight declines in recent years.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Northern and southern rock sole are in Tier 3a while the other species in the complex are in Tier 5. An updated projection model for northern and southern rock sole was run this year; the remaining shallow water flatfish biomass estimates are from the 2013 survey. The Team noted that changes in the growth parameter estimates (relative to the externally estimated values used in the previous assessment) led to large changes in the *F* reference points for northern rock sole, as well as the total biomass in the southern rock sole assessment.

For the shallow water flatfish complex, ABC and OFL for southern and northern rock sole are combined with the ABC and OFL values for the rest of the shallow water flatfish complex. This yields a combined ABC of 44,205 t and OFL of 54,207 t for 2015. For 2016, the combined ABC is 39,205 t and the OFL is 48,407 t.

The GOA Plan Team agrees with authors' recommended ABC for the shallow water flatfish complex which was equivalent to maximum permissible ABC.

Status determination

Information is insufficient to determine stock status relative to overfished criteria for the complex. For the rock sole species, the assessment model indicates they are not overfished nor are they approaching an overfished condition. Catch levels for this complex remain below the TAC and below levels where overfishing would be a concern.

Area apportionment

The recommended apportionment percentages based on the 2013 survey biomass abundances by area were unchanged for 2014.

Year	Western	Central	WYAK	SEO	Total
2015	22,074	19,297	2,209	625	44,205
2016	19,577	17,115	1,959	554	39,205

5. Deepwater flatfish complex (Dover sole and others)

Status and catch specifications (t) of deepwater flatfish (Dover sole and others) and projections for 2015 and 2016. Biomass for each year is for Dover sole only and corresponds to the model estimate associated with the ABC for that year. Catch data in this table are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	77,531[a]	6,834	5,126	5,126	242
2014	182,727[b]	16,159	13,472	13,472	348
2015	182,160[b]	15,993	13,334		
2016		15,803	13,177		

[a] In 2013 Dover sole biomass was based on Tier 5 calculations.

[b] For 2014 and 2015, Dover sole biomass is based on the author's preferred model and assigned to Tier 3a.

Changes from the previous assessment

The deepwater flatfish complex is comprised of Dover sole, Greenland turbot, and deepsea sole. This complex is assessed on a biennial schedule to coincide with the timing of survey data. This year is an off-year thus an executive summary of the assessment was presented. Dover sole are assessed as a Tier 3a species and the projection model was run using updated 2013 catch and new estimated catches for 2014-2016. Greenland turbot and deepsea sole fall under Tier 6. ABCs and OFLs for Tier 6 species are based on historical catch levels and therefore these quantities are not updated. ABCs and OFLs for the individual species in the deepwater flatfish complex are determined as an intermediate step and then summed for the purpose of calculating complex-level OFLs and ABCs.

Spawning biomass and stock trends

The model estimate of 2015 spawning stock biomass for Dover sole is 67,156 t, which is well above $B_{40\%}$ (28,218 t). Spawning stock biomass and total biomass are expected to remain stable through 2016. Stock trends for Greenland turbot and deepsea sole are unknown.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Starting in 2013, the Dover sole stock has been assessed using an age-structured model and is determined to be in Tier 3a. Both Greenland turbot and deepsea sole are determined to be in Tier 6. The 2015 and 2016 Dover sole ABCs are 13,151 t and 12,994 t, respectively. The Tier 3a 2015 and 2016 OFLs are 15,749 t and 15,559 t, respectively. The Tier 6 calculation (based on average catch from 1978–1995) for the remaining species in the deepwater flatfish complex ABC is 183 t and the OFL is 244 t for 2015 and 2016. The GOA Plan Team agrees with the authors' recommendation to use the combined ABC and OFL for the deepwater flatfish complex for 2015 and 2016. This equates to a 2015 ABC and OFL of 13,334 t and 15,993 t respectively for deepwater flatfish. The ABC is equivalent to the maximum permissible ABC.

Status determination

Gulf of Alaska Dover sole is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. Information is insufficient to determine stock status relative to overfished criteria for Greenland turbot and deepsea sole. Catch levels for this complex remain well below the TAC and below levels where overfishing would be a concern.

Area apportionment

Area apportionments of deepwater flatfish are based on the relative abundance (biomass) of each species in the stock complex in each management area.

Area apportionments of deepwater flatfishABCs for 2015 and 2016 are based on the fraction of the 2013 survey biomass in each area for Dover sole, Greenland turbot, and deepsea sole.

Year	Western	Central	WYAK	SEO	Total
2015	301	3,689	5,474	3,870	13,334
2016	299	3,645	5,409	3,824	13,177

6. Rex Sole

Status and catch specifications (t) of rex sole and projections for 2015 and 2016. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. Catch data are current through November 8th, 2014.					
Year	Biomass	OFL	ABC	TAC	Catch
2013	86,684	12,492	9,560	9,560	3,706
2014	84,702	12,207	9,341	9,341	3,507
2015	82,972	11,957	9,150		
2016		11,733	8,979		

Changes from the previous assessment

Rex sole are assessed on a biennial schedule to coincide with the timing of survey data. This year is an off-year thus an executive summary of the assessment was presented. The projection model was run using updated 2013 catch and new estimated total year catches for 2014-2016. Additionally, new apportionments were computed based on the 2013 NMFS bottom trawl survey biomass distributions.

Spawning biomass and stock trends

The model estimate of female spawning biomass in 2015 is 49,804 t, which is a 6% decline from 2014, but well above $B_{40\%}$ (22,159 t). The assessment model total biomass estimates (age 3+) decreased from 84,702 t in 2014 to 82,972 t in 2015 and a projected decrease into 2016 is expected.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

In 2005, the Plan Team adopted a Tier 5 approach (using model estimated adult biomass) for rex sole ABC recommendations due to unreliable estimates of $F_{40\%}$ and $F_{35\%}$. ABCs and OFLs are calculated using the catch equation applied to beginning year biomass values estimated by the age structured model. Using $F_{ABC} = 0.75M = 0.128$ results in a 2015 ABC of 9,150 t. The 2015 OFL using $F_{OFL} = M = 0.17$ is 11,957 t. The Plan Team concurs with the author's recommended maximum permissible ABCs for 2015 and 2016.

Status determination

The Gulf of Alaska rex sole is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. Catches are well below TACs and below levels where overfishing would be a concern.

Area apportionment

Area apportionments of rex sole ABC's for 2015 and 2016 are based on the fraction of the 2013 GOA bottom trawl survey biomass in each area.

Year	**Western**	**Central**	**WYAK**	**SEO**	**Total**
2015	1,258	5,816	772	1,304	9,150
2016	1,234	5,707	758	1,280	8,979

7. Arrowtooth flounder

Status and catch specifications (t) of arrowtooth flounder and projections for 2015 and 2016. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. Catch data in this table are current through November 8th, 2014.

Year	Biomass[1]	OFL	ABC	TAC	Catch
2013	2,055,560	247,196	210,451	103,300	21,620
2014	1,978,340	229,248	195,358	103,300	35,026
2015	1,957,970	226,390	192,921		
2016		217,522	185,352		

[1] Age 3+ biomass from the age-structured projection model.

Changes from the previous assessment

There were no changes in assessment methodology since this was an off-cycle year. Parameter values from the previous year's assessment model, projected catch for 2014, and updated 2013 catch were used to make projections for ABC and OFL estimates.

Spawning biomass and stock trends

Female spawning biomass in 2015 was estimated at about 2 million t and is expected to decrease slightly in 2016. The 2014 catch of arrowtooth was the highest on record. This is partially due to recent changes to regulations (Amendment 95) of the halibut trawl prohibited species catch (PSC) limits. For the Amendment 80 fleet in the GOA, unused halibut PSC limits are now allowed to be rolled from one season to the next, which allows catcher processors to spend more time targeting arrowtooth flounder without constraints due to halibut PSC. In addition, new regulations have moved the deep-water flatfish fishery closure date later in the year for all trawl vessels. These changes will likely result in continued higher arrowtooth flounder catches than previous years, similar to the current year.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Arrowtooth flounder is estimated to be in Tier 3a. Projections are based on an estimated 2014 catch (39,744 t) that is also used for 2015 and 2016. The 2015 ABC ($F_{40\%}$=0.172) is 192,921 t, which is a slight decrease from the 2014 ABC of 195,358 t. The 2015 OFL ($F_{35\%}$=0.204) is 226,390 t. The 2016 ABC is 185,352 t and OFL is 217,522 t. The Plan Team agrees with the authors' recommended ABC.

Status determination

The stock is not overfished nor approaching an overfished condition. Catch levels for this stock remain below the TAC and below levels where overfishing would be a concern.

Area apportionment

The recommended area apportionment percentages are identical to last year because there was no new survey information. Area apportionments of arrowtooth flounder for 2015 and 2016 based on the fraction of the 2013 survey biomass in each area:

Year	Western	Central	WYAK	East Yakutat/SE	Total
2015	30,752	114,170	36,771	11,228	192,921
2016	29,545	109,692	35,328	10,787	185,352

8. Flathead sole

Status and catch specifications (t) of flathead sole and projections for 2015 and 2016. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. Catch data are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	236,745	61,036	48,738	30,496	2,816
2014	252,361	50,664	41,231	27,746	2,497
2015	254,602	50,792	41,349		
2016		50,818	41,378		

Changes from the previous assessment

Flathead sole are assessed on a biennial schedule to coincide with the timing of survey data. This year is an off-year thus an executive summary of the assessment was presented. The projection model was run using updated 2013 catch and new estimated total year catches for 2014-2016.

Spawning biomass and stock trends

The 2015 spawning biomass estimate (83,818 t) is above $B_{40\%}$ (35,532 t) and projected to be stable through 2016. Total biomass (3+) for 2015 is 254,602 t and is projected to slightly increase in 2016.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Flathead sole are determined to be in Tier 3a. For 2015 the Plan Team concurred with the authors' recommendation to use the maximum permissible ABC of 41,349 t from the updated projection. The F_{OFL} is set at $F_{35\%}$ (0.61) and gives an OFL of 50,792 t.

Status determination

The Gulf of Alaska flathead sole stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. Catches are well below TACs and below levels where overfishing would be a concern.

Area apportionment

Area apportionments of flathead sole ABCs for 2015 and 2016 are based on the fraction of the 2013 GOA bottom trawl survey biomass in each area.

Year	Western	Central	WYAK	SEO	Total
2015	12,767	24,876	3,535	171	41,349
2016	12,776	24,893	3,538	171	41,378

9. Pacific ocean perch

Status and catch specifications (t) of Pacific ocean perch and projections for 2015 and 2016. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current as of November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	345,260	18,919	16,412	16,412	13,183
2014	410,712	22,319	19,309	19,309	17,368
2015	416,140	24,360	21,012		
2016		24,849	21,436		

Changes from the previous assessment

Pacific ocean perch (POP) are assessed on a biennial schedule to coincide with the timing of survey data. During on-cycle (odd) years, a full assessment model with updated assessment and projection model results are presented. However, a full age-structured model was provided in 2014 that incorporates new and historical maturity data within the assessment model. Changes in the input data include updated weight-at-age and an updated size-at-age conversion matrix, updated catch for 2013, and new catch estimates for 2014-2016.

Spawning biomass and stock trends

The 2015 spawning biomass estimate (142,029 t) is above $B_{40\%}$ (113,326 t) and is projected to increase in 2016. Total biomass has been increasing since the early 1980s.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

The GOA Pacific ocean perch stock was determined to be in Tier 3a. The Team accepted the author recommended model resulting in an estimated maximum permissible ABC of 21,012 t (with $F_{ABC} = F_{40\%}$ of 0.119). The F_{OFL} is specified to be equal to the $F_{35\%}$ estimate (0.139) and results in an OFL of 24,360 t.

Status determination

The stock is not overfished, nor is it approaching an overfished condition.

Area apportionment

From 1996 to 2014 apportionment of ABCs was based on a weighted average of biomass distribution for each area using the three most recent trawl survey estimates. The random effects model proposed by the survey averaging working group was used to apportion 2015 ABCs. Using the random effects model, estimates of survey biomass the apportionment results in 11.0% for the Western area, 75.5% for the Central area, and 13.5% for the Eastern area. The recommended 2015 ABC's are 2,302 t for the Western area, 15,873 t for the Central area, and 2,837 t for the Eastern area based on the random effects model.

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. Since POP are caught exclusively with trawl gear, there is concern that the entire Eastern area TAC could be taken in the area that remains open to trawling (between 140° and 147° W longitude). Thus, the Team recommends that a separate ABC continue to be set for POP in WYAK using the weighted average of the upper 95% confidence interval for W. Yakutat. This results in the proportion of biomass in the W. Yakutat area (between 140° W and 147° W) being 0.71, up from the 0.48 estimate used in 2011 and 2012. This corresponds to a 2015 ABC of 2,014 t for WYAK and 823 t for the eastern area (East Yakutat/Southeast Outside area).

POP are determined to be in Tier 3a ($F_{OFL} = F_{35\%}$=0.139) and OFL is equal to 24,360 t. In 2012, area OFLs were combined for the Western, Central, and West Yakutat (W/C/WYAK) areas, while the East

Yakutat/Southeast (SEO) OFL was separated due to stock structure concerns. The 2012 OFL apportionment method is recommended for 2015 resulting in overfishing levels for W/C/WYAK area of 23,406 t (96%) and 954 t (4%) in the SEO area.

Area apportionment of 2015-2016 ABC and OFL for POP in the Gulf of Alaska:

Year		Western	Central	WYAK	SEO	Total
2015	ABC	2,302	15,873	2,014	823	21,012
2016	ABC	2,358	16,184	2,055	839	21,436

Year		Western/Central/WYAK	SEO	Total
2015	OFL	23,406	954	24,360
2016	OFL	23,876	973	24,849

10. Northern Rockfish

Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014. Note that for management purposes, the northern EGOA ABC is combined with other rockfish. The ABC for 2015 and 2016 listed below deducts that value (1 t).

Year	Age 2+ biomass	OFL	ABC	TAC	Catch
2013	99,089	6,124	5,130	5,130	4,880
2014	102,893	6,349	5,322	5,322	4,212
2015	98,409	5,961	4,999		
2016		5,631	4,722		

Changes from the previous assessment

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in alternate (even) years an executive summary is provided to recommend harvest levels for the next two years. New data added to the projection model included updated 2013 catch and new estimated total year catches for 2014-2016.

Spawning biomass and stock trends

The 2015 spawning biomass estimate (39,838 t) is above $B_{40\%}$ (30,073 t) and projected to decrease to 37,084 t in 2016.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Northern rockfish are estimated to be in Tier 3a. The Plan Team agreed with the authors' recommendation to use the maximum permissible 2015 ABC and OFL values of 4,999 t and 5,961 t, respectively.

Status determination

The stock is not overfished, nor is it approaching an overfished condition.

Area apportionment

Apportionment of the 2015 and 2016 ABC is based on the same method used last year (3 survey weighted average) resulting in the following percentage apportionments by area: Western 24.52%, Central 75.45% and Eastern 0.03%. Note that the small northern rockfish ABC apportionments from the Eastern Gulf are combined with other rockfish for management purposes. Northern rockfish area apportionments for ABCs in 2015-2016:

Year	Western	Central	Eastern	Total
2015	1,226	3,772	1	4,999
2016	1,158	3,563	1	4,722

11. Shortraker rockfish

Status and catch specifications (t) of shortraker rockfish and projections for 2015 and 2016. Biomass estimates are based on the average of the 3 most recent trawl surveys (2009, 2011, and 2013). The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current as of November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	48,048	1,441	1,081	1,081	730
2014	58,797	1,764	1,323	1,323	649
2015	58,797	1,764	1,323		
2016		1,764	1,323		

Changes from the previous assessment

Shortraker rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. No new assessment information was available in this off-survey year, therefore the 2013 estimates are rolled over for the next two years. Catches were updated for 2013 and 2014.

Spawning biomass and stock trends

Averaging the biomass estimates from the last three Gulf of Alaska trawl surveys (2009, 2011, and 2013) results in an exploitable biomass of 58,797 t for shortraker rockfish.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Shortraker rockfish are Tier 5 species for specifications where $F_{\mathrm{ABC}} = 0.75M = 0.0225$, and $F_{OFL} = 0.03$. Applying this definition to the exploitable biomass of shortraker rockfish results in a 2015 ABC of 1,323 t and an OFL of 1,764 t.

Status determination

Information is insufficient to determine stock status relative to overfished criteria. Catch levels for this stock remain below levels where overfishing would be a concern.

Area apportionment

The apportionment percentages are the same as in the 2013 assessment (3 survey weighted average). The following table shows the recommended apportionment for 2015 and 2016.

Western	Central	Eastern	Total
6.98%	29.94%	63.08%.	**100%**
92	397	834	1,323

12. Dusky rockfish

Status and catch specifications (t) of dusky rockfish and projections for 2015 and 2016. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014.

Year	Age 4+ biomass	OFL	ABC	TAC	Catch
2013	63,515	5,746	4,700	4,700	3,159
2014	69,371	6,708	5,486	5,486	3,050
2015	66,629	6,246	5,109		
2016		5,759	4,711		

Changes in assessment methods and data

Dusky rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. The 2014 "off-year" assessment consists of updating the catch data and re-running the projection model from the 2013 assessment. There have been no changes in the assessment methods.

New data added to the projection model included updated 2013 catch of 3,158 t, and estimated 2014-2016 total year catches of 3,106 t, 3,379 t, and 3,124 t, respectively. The authors noted recent changes in the seasonal fishing patterns in the western GOA and made appropriate adjustments in providing catch estimates for 2014.

Spawning biomass and stock status trends

The 2015 projected spawning biomass estimate (27,345 t) is above $B_{40\%}$ (20,906 t) and projected to decrease slightly to 25,344 t in 2016.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Dusky rockfish are in Tier 3a. The Plan Team agreed with the authors' recommendation of maximum permissible ABC and OFL of 5,109 t and 6,246 t for 2015. This ABC is 7% lower than the 2014 ABC of 5,486 t but similar to the ABC of 5,081 t projected for 2015 in the 2014 assessment.

Status determination

Dusky rockfish are not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

Area apportionment

The methodology for apportioning the dusky rockfish ABC among areas was unchanged from the 2013 assessment model (3 survey weighted average):

			Eastern		
Year	Western	Central	WYAK	SEO	Total
	5.8%	65.3%	25.2%	3.7%	100%
2015	296	3,336	1,288	189	5,109
2016	273	3,077	1,187	174	4,711

13. Rougheye and blackspotted rockfish

Status and catch specifications (t) of rougheye and blackspotted rockfish and projections for 2015 and 2016. Biomass for each year corresponds to the projections given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current as of November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	42,883	1,482	1,232	1,232	574
2014	42,810	1,497	1,244	1,244	733
2015	36,584	1,345	1,122		
2016		1,370	1,142		

Changes from the previous assessment

Rockfish are typically assessed on a biennial stock assessment schedule to coincide with the timing of new survey data. During on-cycle (odd) years, a full assessment model with updated assessment and projection model results is typically presented but last year there was a lapse, hence a full assessment was compiled this year. Three assessment models were evaluated. Model 0 is the last full assessment base model from 2011. Model 1 is an intermediate model which uses new and updated data but keeps the previous longline survey abundance index. Model 2 uses new and updated data, a new longline survey abundance index, and the updated conversion matrices. The authors and Plan Team recommend Model 2 for the 2014 assessment based on improved overall model fit to the data and the recommendation from the 2009 sablefish CIE to use the RPN index for the longline survey.

New and updated data in the 2014 assessment included updated catch estimates (2011-2013), new catch estimates (2014-2016), new fishery ages (2009 and 2012), new fishery lengths (2011), a new trawl survey estimate (2013), updated trawl survey ages (2009), new trawl survey ages (2011), and revised longline survey abundance estimates and length frequencies. The assessment also included relative population numbers (RPNs) rather than relative population weights (RPWs) to represent the longline survey abundance. New biological data on growth and aging error were also used to update the weight-at-age estimates, the size-at-age conversion matrix, and the aging error matrix.

Spawning biomass and stock status trends

Female spawning biomass (12,480 t) is above $B_{40\%}$ (8,980 t) and projected to remain stable. The 2013 trawl survey estimate was the lowest of the time series at 40% below average. The 2014 longline survey RPN (and abundance index), was above the long-term average for that series and increased from 2013.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

The rougheye/blackspotted complex qualifies as a Tier 3a stock. For the 2015 fishery, the Plan Team accepts the authors' recommended maximum permissible ABC of 1,122 t ($F_{ABC} = F_{40\%} = 0.038$) and OFL ($F_{OFL}=F_{35\%} = 0.045$) of 1,345 t.

Status determination

The stock is not overfished, nor is it approaching an overfished condition.

Area apportionment

The 2015 apportionment values are based on a three survey weighted average approach used in previous assessments. A random effects model for RE/BS rockfish was evaluated for 2015. In general, the random effects model fits the area-specific survey biomass in the Western and Eastern GOA reasonably well although the model failed to estimate any process error for the Central GOA which contains the bulk of the biomass and has the smallest sampling error. The random effects model will be further evaluated and considered for future assessments.

The 2015 apportionment values for rougheye and blackspotted rockfish ABCs are: Western area, 10.3%; Central area, 56.3%; and Eastern area, 33.4%.

Year	Western	Central	Eastern	Total
2015	115	632	375	1,122
2016	117	643	382	1,142

14. Demersal shelf rockfish

Status and catch specifications (t) of demersal shelf rockfish and projections for 2015 and 2016. Biomass for each year corresponds to the survey biomass estimates given in the SAFE report issued in the preceding year(s). The 2014 catch data are current as of November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	14,588	487	303	303	218
2014	13,274	438	274	274	104
2015	10,933	361	225		
2016		361	225		

Changes from the previous assessment

Harvest specifications are set based on the most recent ROV and submersible density estimates of yelloweye rockfish in each management area using historical methods with one exception. Authors decided to remove NSEO data and use 2012 CSEO density as a proxy. Catch information and average weights from the commercial fishery were updated. Surveys in 2014 were cancelled due to weather problems. State funding for this project is expected to end in 2015. An initial exploration of an age-structured model for yelloweye rockfish in southeast outside Alaska waters was presented as an appendix. See Plan Team minutes for further discussion of the age-structured model.

Spawning biomass and stock trends

Biomass trends for yelloweye rockfish have been declining.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Under Tier 4, $F_{ABC} \leq F_{40\%}$ and $F_{OFL}=F_{35\%}$. The overfishing level (OFL) was set using $F_{35\%}$=0.032; which was 361 t for 2015 compared to 438 for 2014. The maximum ABC for 2015 is 293 t. The authors recommend an *F=M* harvest rate lower than the maximum permissible and the Plan Team concurred. Due to decreases in average body weight (based on fishery data) and updated biomass projections, the recommended ABC is 225 t for 2015, down slightly from that recommended for 2014. For subsistence use, 8 t was deducted from the ABC for DSR caught resulting in 217 t. This was then divided among sport and commercial fisheries (84:16) according to a Board of Fish decision. This resulted in 182 t for commercial fisheries and 35 t allocated to sport fisheries.

Status determination

The DSR stock complex in the southeast outside district of the Gulf of Alaska is not being subjected to overfishing. Information is insufficient to determine stock status relative to overfished criteria as estimates of spawning biomass are unavailable.

Area apportionment

The ABC and OFL for DSR are for the SEO Subdistrict. DSR management is deferred to the State of Alaska and any further apportionment within the SEO Subdistrict is at the discretion of the State.

15. Thornyheads

Status and catch specifications (t) of thornyheads in recent years. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. Catch data for 2014 are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	73,990	2,220	1,665	1,665	1,153
2014	81,816	2,454	1,841	1,841	1,121
2015	81,816	2,454	1,841		
2016		2,454	1,841		

Changes from previous assessment

Thornyheads are assessed on a biennial schedule to coincide with the timing of survey data. In this off-cycle year, estimates from 2013 are rolled over for the next two years. An executive summary was presented. New catch information includes updated 2013 and estimated 2014 catch.

Spawning biomass and stock trends

Estimates of spawning biomass are unavailable for thornyheads. The 2013 GOA bottom trawl survey covered depths shallower than 701 m, similar to what was done in 2011. To correct for this, the 2013 survey biomass estimate was inflated to account for the lack of sampling in the 701-1000 m depth stratum, identical to the method used in the 2011–2013 assessments. This results in a total estimated biomass of 81,816 t. Trends appear to be stable.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

The Gulf-wide catch of thornyheads increased 50% from 2013, but still was only 61% of the ABC. Thornyhead rockfish are in Tier 5. The Plan Team concurred with the author's recommendation for OFL and ABC for 2015 and 2016. The 2015 (and 2016) ABC recommendation (F_{ABC} =0.0225) is 1,841 t and the OFL (F_{OFL} =0.03) is 2,454 t.

Status determination

The thornyhead complex is not being subjected to overfishing. Information is insufficient to determine stock status relative to overfished criteria as estimates of spawning biomass are unavailable. Catch levels for this stock remain below the TAC and below levels where overfishing would be a concern.

Area apportionment

Area apportionments for this assessment and are based upon the relative distribution of biomass by area from the 2013 GOA bottom trawl survey. Area apportionments of the 2015-2016 ABC for thornyhead rockfish are:

Western	Central	Eastern	Total
235	875	731	1,841

16. Other rockfish

Status and catch specifications (t) of other rockfish. In 2013, the seven species of DSR rockfish were included in the WGOA and CGOA areas. Biomass estimates are based on the three most recent trawl survey estimates. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014. Note that 1 t of northern rockfish has been added for management purposes to “other rockfish” in the EGOA.

Year	Survey biomass	OFL	ABC	TAC	Catch
13	85,774	05	·,045	,080	819
14	83,383	47	·,081	,811	,030
15	83.383	47	·,080		
16		47	·,080		

Changes from the previous assessment

There were no changes in assessment inputs or methodology since this was an off-cycle year.

Spawning biomass and stock trends

The estimated biomass of 83,383 t is based on an average from the three most recent GOA trawl surveys. Surveys indicate stability for this complex.

Tier determination/ Plan Team discussion and resulting ABC and OFL recommendations

GOA other rockfish are managed as a Tier 4/5 stock complex. Sharpchin rockfish are Tier 4, the other rockfish are Tier 5. The Plan Team agreed with the authors’ recommendation of an OFL of 5,347 t and a maximum permissible ABC of 4,080 t for 2015 and 2016 (including the 1 t from the northern rockfish category).

Status determination

The “other rockfish” complex is not being subjected to overfishing. Information is insufficient to determine stock status relative to overfished criteria as estimates of spawning biomass are unavailable. Catch levels for this stock remain below the TAC and below levels where overfishing would be a concern.

Area apportionment

The Plan Team again recommends a single ABC for the combined WGOA and CGOA areas to address concerns about the ability to manage smaller ABCs in the WGOA. The recent overages in the WGOA prior to 2014 have not been viewed as a conservation concern because the catch in this region has consisted primarily of harlequin rockfish, which generally occur in untrawlable grounds. Thus, the biomass in this area is likely underestimated due to lack of sampling in untrawlable areas. The apportionments recommended for 2015 and 2016 are:

Other Rockfish	W/C GOA	E GOA		Total
		WYAK	EYAK/SE	
ABC (t)	1,031	580	2,469*	4,080
OFL (t)				5,347

*Note for management purposes this includes 1 t of northern rockfish from the northern rockfish stock EGOA allocation.

17. Atka mackerel

Status and catch specifications (t) of Atka mackerel in recent years. Atka mackerel are managed under Tier 6 because reliable estimates of biomass are not available. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	-	6,200	4,700	2,000	1,277
2014	-	6,200	4,700	2,000	981
2015	-	6,200	4,700		
2016	-	6,200	4,700		

Changes from the previous assessment

Atka mackerel are assessed on a biennial schedule to coincide with the timing of survey data. The last full assessment was in 2011. New information includes updated 2013 and 2014 catches. Since the 2013 stock assessment, ages from the 2013 survey and 2013 fishery have become available and are comprised mostly of fish from the 2006 and 2007 year classes which are also prevalent in the Aleutian Islands. There are no changes to the methodology used to assess GOA Atka mackerel.

Spawning biomass and stock trends

Estimates of spawning biomass are not available for Gulf of Alaska Atka mackerel. The very patchy distribution of GOA Atka mackerel results in highly variable estimates of abundance. Therefore survey biomass estimates are not considered reliable indicators of absolute abundance or indices of trend.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Since 1996, the maximum permissible ABC has been 4,700 t under Tier 6 and the OFL has been 6,200 t. The Plan Team continues to recommend that GOA Atka mackerel be managed under Tier 6. The Plan Team recommends a 2015 ABC for GOA Atka mackerel equal to the maximum permissible value of 4,700 t. The 2015 OFL is 6,200 t under Tier 6.

Due to concerns over uncertainty with the ABC estimates using Tier 6, a low TAC is recommended to provide for anticipated incidental catch needs of other fisheries, principally for Pacific cod, rockfish and pollock fisheries.

Status determination

Information is insufficient to determine stock status relative to overfished criteria. Catches are below ABC and below levels where overfishing would be a concern.

18. Skates

Status and catch specifications (t) of skates in recent years. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data are current through November 8th, 2014.

Species	Year	Biomass	OFL	ABC	TAC	Catch
Big Skate	2013	50,229	5,023	3,767	3,767	2,504
	2014	50,155	5,016	3,762	3,762	1,379
	2015	43,398	4,340	3,255		
	2016		4,340	3,255		
Longnose Skate	2013	34,995	3,500	2,625	2,625	1,777
	2014	38,349	3,835	2,876	2,876	1,418
	2015	42,911	4,291	3,218		
	2016		4,291	3,218		
Other Skates	2013	27,061	2,706	2,030	2,030	1,879
	2014	26,518	2,652	1,989	1,989	1,559
	2015	29,797	2,980	2,235		
	2016		2,980	2,235		

Changes from the previous assessment

Skates are normally assessed on a biennial schedule, with full assessments presented in odd years to coincide with the timing of survey data; however, a full assessment was conducted this year.

New this year was the 2013 survey biomass estimates and the use of the random effects model to estimate biomass for 2015 and 2016. These model results were compared to the survey estimates and the 3-survey average estimates. The Team concurred with the author that the random effects model characterized the biomass information well and should be used.

Spawning biomass and stock trends

The 2013 survey biomass estimates for longnose skate and “other skates” increased substantially relative to the 2011 estimate. The estimate for longnose skates is the highest in the 1984-2013 time series. The 2013 survey biomass estimate for big skate was down considerably from 2011.

Catches have been below Gulf-wide ABC for all skate species, however, the ABC for big skate in the CGOA was exceeded from 2010 to 2013, and in 2014, big skate in the CGOA was closed to retention early in the season, and the catch did not exceed the 2014 ABC.

Catch estimates for longnose skates have exceeded ABC in the WGOA in 4 of the years since 2005 but these ABC’s and catches are significantly lower than the CGOA.

Estimates of incidental catches increased substantially for longnose skates and “other skates” in 2013, mainly in the IFQ halibut target fishery. For longnose skates, most of the increased catch occurred in the EGOA. For “other skates” the increased catches occurred in the CGOA and EGOA. It is likely that this increased level of catch is due to the increased catch reporting from the halibut IFQ fishery as a result of increased observer coverage in 2013.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Skates are managed in Tier 5. Applying M=0.1 and 0.75M to the estimated biomass from the random effects models for each stock component, gives stock specific OFLs and ABCs. Note that while it has little or no effect presently, the 2001 survey was omitted from the computation because the EGOA was not surveyed in that year. The Team concurred with this approach which differs from the previous method based on simple 3-survey average biomass.

Status determination

Catch as currently estimated does not exceed any gulf-wide OFLs, and therefore, is not subject to overfishing. It is not possible to determine the status of stocks in Tier 5 with respect to overfished status.

Area apportionment

The Team concurred with the use of the random effects model for estimating proportions by area. Big and longnose skates have area-specific ABCs and gulf-wide OFLs; other skates have a gulf-wide ABC and OFL.

		ABC				
Year	**Species**	**Western**	**Central**	**Eastern**	**Total**	**OFL**
2015 and 2016	Big skate	731	1,257	1,267	3,255	4,340
2015 and 2016	Longnose skate	152	2,090	976	3,218	4,291
2015 and 2016	other skates				2,235	2,980

19. Sculpins

Status and catch specifications (t) of GOA sculpins and projections for 2015 and 2016. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data for 2014 are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	34,732	7,614	5,884	5,884	1,959
2014	33,550	7,448	5,569	5,569	1,075
2015	33,550	7,448	5,569		
2016		7,448	5,569		

Changes from the previous assessment

GOA sculpins are assessed on a biennial stock assessment schedule to coincide with the timing of the NMFS bottom trawl survey. An executive summary is presented in this SAFE Report with last year's key assessment parameters and projections for 2015 and 2016. New information includes catch data updated for 2013 and partial data for 2014, by target fishery and area. The OFL and ABC recommendations were adjusted slightly from last year reflecting updates and corrections to the data.

There were no changes to the Tier 5 approach used in 2013. The biomass estimate was based on the average biomass estimate of the last four NMFS bottom trawl surveys in 2007, 2009, 2011, and 2013.

Spawning biomass and stock trends

The stock trends appear to be stable based on survey data.

Tier determination/Plan Team discussion and resulting ABC and OFL recommendations

The Plan Team concurred with the Tier 5 approach, including the biomass estimates based on the most recent 4 surveys, and the authors' recommendations for ABC and OFL. Based on the Tier 5 approach the Gulfwide OFL and ABC for the sculpin complex in 2015 and 2016 are 7,448 t and 5,569 t respectively.

Status determination

There is insufficient data to determine if the sculpin complex is in an overfished condition. Recent catches of sculpins have been well below the ABC first established for the sculpin complex in 2011 hence the sculpin complex is not currently being subjected to overfishing.

Area apportionment

The GOA sculpins are managed gulf-wide.

20. Sharks

Status and catch specifications (t) of the GOA shark complex. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data for 2014 are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	76,979	8,037	6,028	6,028	2,166
2014	76,452	7,986	5,989	5,989	1,188
2015	76,452	7,986	5,989		
2016		7,986	5,989		

Changes from the previous assessment

There was no change in assessment methodology. The GOA shark complex (spiny dogfish, Pacific sleeper shark, salmon shark, and other/unidentified sharks) are assessed on a biennial stock assessment schedule to coincide with the timing of the NMFS bottom trawl survey. The biomass estimates were updated to include the 2013 GOA biennial trawl survey data. The total catch for GOA sharks from 2003 through 2014 was updated, including catch data through November 8, 2014. The last full shark assessment was done in 2011.

Spawning biomass and stock trends

Reliable total biomass estimates for the shark complex are unavailable, and little is known about spawning biomass or stock status trend.

Status determination

Sharks are caught incidentally in other target fisheries. Catches of sharks from 1992 through 2014 have been well below the ABC first established for the shark complex in 2011.

As a Tier 6 stock complex, there are insufficient data to determine if the shark complex is in an overfished condition or being subject to overfishing, and therefore the status is unknown.

Tier determination/Plan Team discussion and resulting ABC and OFL recommendations

For ABC/OFL estimates, a Tier 5 approach was used for the spiny dogfish component while the other components were treated as Tier 6 species. The Team concurred with the authors' recommendation to continue with this approach.

Area apportionment

GOA sharks are managed Gulf-wide.

21. Squid

Status and catch specifications (t) of GOA squid. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data for 2014 are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	-	1,530	1,148	1,148	321
2014	-	1,530	1,148	1,148	92
2015	-	1,530	1,148		
2016		1,530	1,148		

Changes from the previous assessment

There were no changes to the modified Tier 6 assessment method used since 2011. This method uses maximum historical catch during 1997-2007 as the basis for OFL and ABC calculations. An executive summary was presented in this SAFE report.

Spawning biomass and stock trends

Reliable estimates of spawning biomass and stock trends are unavailable.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

Since reliable estimates of biomass do not exist, the squid complex is in Tier 6. The Plan Team concurred with the author's recommendation to set the OFL equal to the maximum historical catch between 1997 and 2007 (1,530 t) and the ABC equal to 0.75 x OFL (1,148 t).

Total squid catches for years which data are available, from 1990 through 2014, have been well below the ABC first established for the squid complex in 2011, with the exception of 2006, the year in which the highest historical catch was observed (1,530 t, the basis for the OFL level adopted). There is no directed fishery for squid and historically the majority of squid catch has usually occurred as incidental catch in the pollock fishery. Most of the catch in recent years has occurred in NMFS Area 620.

Status determination

As a Tier 6 stock, there is insufficient data to determine if the squid complex is in an overfished condition or being subject to overfishing and therefore the status is unknown.

Area apportionment

GOA squid are managed Gulf-wide.

22. Octopus

Status and catch specifications (t) of GOA octopus. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team. Catch data for 2014 are current through November 8th, 2014.

Year	Biomass	OFL	ABC	TAC	Catch
2013	-	1,941	1,455	1,455	421
2014	-	2,009	1,507	1,507	1,057
2015	-	2,009	1,507		
2016		2,009	1,507		

Changes from the previous assessment

The GOA octopus stock complex consists of at least seven species of octopus. GOA octopuses continue to be on a biennial stock assessment schedule to coincide with the timing of the NMFS bottom trawl survey. However, a full assessment was provided this year including 2013 survey biomass data. Catch data were updated for 2013 and partial data reported for 2014. There are no proposed changes in assessment methodology.

Spawning biomass and stock trends

The estimated survey biomass of all octopus species for the GOA in 2013 was 2,686 t, 90% of which was identified as *E. dofleini*. This biomass is lower than seen in the 2009 and 2011 surveys, but similar to other historical surveys. Biomass estimates for this stock complex are generally unreliable but survey data are used as a “minimum” estimate.

Octopuses are taken as incidental catch in trawl, longline, and pot fisheries. The highest octopus catch rates are from Pacific cod pot fisheries in the CGOA and WGOA.

Tier determination/Plan Team discussion and resulting ABCs and OFLs

The status quo assessment method is a modified Tier 6 approach that includes a conservative natural mortality estimate (0.53) and a minimum biomass estimate using the average of the last three surveys. Using a Tier 5-like calculation of OFL, average minimum B×M (3,791 t × 0.53 = 2,009 t) and the ABC equal to 0.75 × OFL (1,507 t) is estimated.

Status determination

As reliable total biomass estimates for octopuses do not exist, there can be no determination of spawning biomass or stock status trends. There is insufficient data to determine whether the complex is being subjected to overfishing, is currently overfished, or is approaching a condition of being overfished.

Additional Plan Team recommendations

The Plan Team continues to recommend that a stock structure template be completed by next September.

Area apportionment

The GOA octopus complex is currently managed Gulf-wide.

Appendix 1: Grenadiers

An abbreviated stock assessment of grenadiers is provided in Appendix 1. Amendments 100/91 to the BSAI and GOA FMPs placed grenadiers in the FMPs as an ecosystem component (EC). As an EC component, ABCs and OFLs are not required.

Seven species of grenadiers are known to occur in Alaska. The giant grenadier is the most abundant and has the shallowest depth distribution on the continental slope. The assessment focused on the giant grenadier as it is the most common grenadier caught in both the commercial fishery and longline and trawl surveys. Pacific grenadiers and popeye grenadiers are occasionally caught.

The estimated annual catches of grenadiers in Alaska for the years 1997-2013 ranged between 11,000-21,300 t. The 2013 catch was 15,500 t. Thus far in 2014 the catch is 7,860 t. Highest catches have consistently been in the GOA. By region, annual catches have ranged between 5,600 -14,700 t in the GOA, 1,600-5,000 t in the EBS, and 1,300-4,600 t in the AI. By region estimated biomass for 2015 is 524,600 t in the GOA and 1,286,700 t in the BSAI. As an indication of stock status and potential conservation concern, the catches are substantially below unofficial Tier 5 values for ABC and OFLs.

The Team recommends that an abbreviated assessment be produced every other year (even years) for both regions (BSAI, GOA)

Appendix 2. Forage fish

An assessment for forage fish in the Gulf of Alaska is provided in Appendix 2. The forage fish category in the Gulf of Alaska FMP contains over sixty species with diverse characteristics. Many of the species in this category are rare and poorly sampled with standard survey methods, therefore it is likely that the FMP forage species list is not comprehensive and the exact number and types of all GOA forage fish is uncertain. Species in the forage fish category have been identified as having ecological importance as prey, and directed fishing is prohibited for the group. Beginning in 2011, forage fishes in the GOA are designated as "Ecosystem Components" in the GOA FMP; as such, they are outside of the specification process and stock assessments are not conducted for this category.

The Plan Team continues to recommend maintaining the forage fish chapter as a SAFE appendix to be updated similar to groundfish stock assessments as new information becomes available in the off year, or in the interim as new information and issues arise, noting that forage fish are essential ecosystem components, important to seabirds, marine mammals and commercially important groundfish.

Tables

Table 1. Gulf of Alaska groundfish 2015 - 2016 OFLs and ABCs, 2014 TACs, and 2014 catch (reported through November 8th, 2014).

Species	Area	2014 OFL	2014 ABC	2014 TAC	2014 Catch	2015 OFL	2015 ABC	2016 OFL	2016 ABC
Pollock	W(61)	-	36,070	36,070	13,318		31,634		41,472
	C(62)	-	81,784	81,784	83,049		97,579		127,936
	C(63)	-	39,756	39,756	42,068		52,594		68,958
	WYAK	-	4,741	4,741	1,317		4,719		6,187
	Subtotal	211,998	162,351	162,351	139,752	256,545	191,309	321,067	250,824
	EYAK/SEO	16,833	12,625	12,625	1	16,833	12,625	16,833	12,625
	Total	228,831	174,976	174,976	139,753	273,378	203,934	337,900	263,449
Pacific Cod	W		32,745	22,922	20,910		38,702		38,702
	C		53,100	39,825	38,429		61,320		61,320
	E		2,655	1,991	294		2,828		2,828
	Total	107,300	88,500	64,738	59,633	140,300	102,850	133,100	102,850
Sablefish	W		1,480	1,480	1,195		1,474		1,338
	C		4,681	4,681	4,706		4,658		4,232
	WYAK		1,716	1,716	1,655		1,708		1,552
	SEO		2,695	2,695	2,819		2,682		2,436
	Total	12,500	10,572	10,572	10,375	12,425	10,522	11,293	9,558
Shallow-Water Flatfish	W		20,376	13,250	243		22,074		19,577
	C		17,813	17,813	4,144		19,297		17,114
	WYAK		2,039	2,039	1		2,209		1,959
	EYAK/SEO		577	577	1		625		554
	Total	50,007	40,805	33,679	4,389	54,207	44,205	48,407	39,205
Deep-Water Flatfish	W		302	302	68		301		299
	C		3,727	3,727	271		3,689		3,645
	WYAK		5,532	5,532	5		5,474		5,409
	EYAK/SEO		3,911	3,911	4		3,870		3,824
	Total	16,159	13,472	13,472	348	15,993	13,334	15,803	13,177
Rex Sole	W		1,270	1,270	124		1,258		1,234
	C		6,231	6,231	3,382		5,816		5,707
	WYAK		813	813	1		772		758
	EYAK/SEO		1,027	1,027	-		1,304		1,280
	Total	12,207	9,341	9,341	3,507	11,957	9,150	11,733	8,979
Arrowtooth Flounder	W		31,142	14,500	1,875		30,752		29,545
	C		115,612	75,000	33,085		114,170		109,692
	WYAK		37,232	6,900	50		36,771		35,328
	EYAK/SEO		11,372	6,900	16		11,228		10,787
	Total	229,248	195,358	103,300	35,026	226,390	192,921	217,522	185,352
Flathead Sole	W		12,730	8,650	212		12,767		12,776
	C		24,805	15,400	2,284		24,876		24,893
	WYAK		3,525	3,525	1		3,535		3,538
	EYAK/SEO		171	171	-		171		171
	Total	50,664	41,231	27,746	2,497	50,792	41,349	50,818	41,378

Table 1 (continued)

Species	Area	2014 OFL	2014 ABC	2014 TAC	2014 Catch	2015 OFL	2015 ABC	2016 OFL	2016 ABC
Pacific ocean perch	W		2,399	2,399	2,063		2,302		2,358
	C		12,855	12,855	13,434		15,873		16,184
	WYAK		1,931	1,931	1,871		2,014		2,055
	W/C/WYAK	19,864		17,185	17,368	23,406		23,876	
	SEO	2,455	2,124	2,124	-	954	823	973	839
	E(subtotal)					-	-	-	-
	Total	22,319	19,309	19,309	17,368	24,360	21,012	24,849	21,436
Northern Rockfish*	W		1,305	1,305	802		1,226		1,158
	C		4,017	4,017	3,410		3,772		3,563
	E		-		-		0*		0*-
	Total	6,349	5,322	5,322	4,212	5,961	4,998	5,631	4,721
Shortraker Rockfish	W		92	92	73		92		92
	C		397	397	323		397		397
	E		834	834	253		834		834
	Total	1,764	1,323	1,323	649	1,764	1,323	1,764	1,323
Dusky Rockfish	W		317	317	134		296		273
	C		3,584	3,584	2,825		3,336		3,077
	WYAK		1,384	1,384	87		1,288		1,187
	EYAK/SEO		201	201	4		189		174
	Total	6,708	5,486	5,486	3,050	6,246	5,109	5,759	4,711
Rougheye and Blackspotted Rockfish	W		82	82	25		115		117
	C		864	864	536		632		643
	E		298	298	172		375		382
	Total	1,497	1,244	1,244	733	1,345	1,122	1,370	1,142
Demersal shelf rockfish	Total	438	274	274	104	361	225	361	225
Thornyhead Rockfish	W		235	235	237		235		235
	C		875	875	666		875		875
	E		731	731	218		731		731
	Total	2,454	1,841	1,841	1,121	2,454	1,841	2,454	1,841
Other rockfish (Other slope)*	C		-				-		-
	W/C		1,031	1,031	940		1,031		1,031
	WYAK		580	580	53		580		580
	EYAK/SEO		2,470	200	37		2,469		2,469
	Total	5,347	4,081	1,811	1,030	5,347	4,080	5,347	4,080
Atka mackerel	Total	6,200	4,700	2,000	981	6,200	4,700	6,200	4,700
Big Skate	W		589	589	135		731		731
	C		1,532	1,532	1,150		1,257		1,257
	E		1,641	1,641	94		1,267		1,267
	Total	5,016	3,762	3,762	1,379	4,340	3,255	4,340	3,255
Longnose Skate	W		107	107	51		152		152
	C		1,935	1,935	1,031		2,090		2,090
	E		834	834	336		976		976
	Total	3,835	2,876	2,876	1,418	4,291	3,218	4,291	3,218
Other Skates	Total	2,652	1,989	1,989	1,559	2,980	2,235	2,980	2,235
Sculpins	GOA-wide	7,448	5,569	5,569	1,075	7,448	5,569	7,448	5,569
Sharks	GOA-wide	7,986	5,989	5,989	1,188	7,986	5,989	7,986	5,989
Squids	GOA-wide	1,530	1,148	1,148	92	1,530	1,148	1,530	1,148
Octopuses	GOA-wide	2,009	1,507	1,507	1,057	2,009	1,507	2,009	1,507
Total		790,468	640,675	499,274	292,544	870,064	685,597	910,895	731,049

*Note 1 t of moved from the northern rockfish stock EGOA allocation to EGOA “other rockfish” category

Table 2. Gulf of Alaska 2015 ABCs, biomass, and overfishing levels (t) for Western, Central, Eastern, Gulfwide, West Yakutat, and Southeast Outside regulatory areas.

Species/Assemblage	Area	2015 ABC	2015 Biomass	2015 OFL
Pollock	W(61)	*31,634* [a]		
	C(62)	*97,579* [a]		
	C(63)	*52,594* [a]		
	WYAK	*4,719* [a]		
	Subtotal	191,309	1,883,920	256,545
	EYAK/SEO	12,625	56,111	16,833
	Total	203,934	1,940,031	273,378
Pacific Cod	W	38,702		
	C	61,320		
	E	2,828		
	Total	102,850	583,800	140,300
Sablefish	W	1,474		
	C	4,658		
	WYAK	1,708		
	EY/SEO	2,682		
	Total	10,522	130,000	12,425
Shallow water Flatfish	W	22,074		
	C	19,297		
	WYAK	2,209		
	EYAK/SEO	625		
	Total	44,205	287,534	54,207
Deepwater Flatfish	W	301		
	C	3,689		
	WYAK	5,474		
	EYAK/SEO	3,870		
	Total	13,334	182,160	15,993
Rex sole	W	1,258		
	C	5,816		
	WYAK	772		
	EYAK/SEO	1,304		
	Total	9,150	82,972	11,957
Arrowtooth Flounder	W	30,752		
	C	114,170		
	WYAK	36,771		
	EYAK/SEO	11,228		
	Total	192,921	1,957,970	226,390
Flathead sole	W	12,767		
	C	24,876		
	WYAK	3,535		
	EYAK/SEO	171		
	Total	41,349	254,602	50,792

[a] The Prince William Sound GHL (2.5% of ABC; 4,783 t) is deducted from these area apportioned ABCs.

Table 2. Continued…

	2015			
Species/Assemblage	Area	ABC	Biomass	OFL
Pacific ocean perch	W	2,302		
	C	15,873		23,406
	WYAK	2,014		
	EY/SEO	823		954
	Total	21,012	416,140	24,360
Northern rockfish	W	1,226		
	C	3,772		
	E	0[1]		
	Total	4,998	98,409	5,961
Shortraker	W	92		
	C	397		
	E	834		
	Total	1,323	58,797	1,764
Dusky rockfish	W	296		
	C	3,336		
	WYAK	1,288		
	EYAK/SEO	189		
	Total	5,109	66,629	6,246
Rougheye/blackspotted rockfish	W	115		
	C	632		
	E	375		
	Total	1,122	36,584	1,345
Demersal shelf rockfish	Total	225	10,933	361
Thornyhead rockfish	Western	235		
	Central	875		
	Eastern	731		
	Total	1,841	81,816	2,454
Other rockfish	W/C	1,031		
	WYAK	580		
	EY/SEO	2,469[1]		
	Total	4,080	83,383	5,347
Atka mackerel	Total	4,700	-	6,200
Big skates	W	731		
	C	1,257		
	E	1,267		
	Total	3,255	43,398	4,340
Longnose skates	W	152		
	C	2,090		
	E	976		
	Total	3,218	42,911	4,291
Other Skates	Total	2,235	29,797	2,980
Sculpins		5,569	33,550	7,448
Sharks		5,989	76,452	7,986
Squid		1,148	-	1,530
Octopus		1,507	-	2,009
Total		685,597	6,232,408	870,064

[1]For management purposes 1t of northern rockfish are moved into “other rockfish” in the eastern GOA.

Table 3. Summary of fishing mortality rates and overfishing levels for the Gulf of Alaska, 2014.

Species	Tier	F_{ABC}[1]	Strategy	F_{OFL}[2]	Strategy
Pollock (W/C/WYAK)	3b	0.20	F_{ABC}	0.28	$F_{35\%}$
(SEO)	5	0.225	F=0.75M	0.30	F=M
Pacific cod	3a	0.441	F_{ABC}	0.626	$F_{35\%}$
Sablefish	3b	0.082	$F_{40\%}$ adjusted	0.098	$F_{35\%\ adjusted}$
Deepwater flatfish	3a, 6[3]	0.10	$F_{40\%}$, F_{ABC}[3]	0.12	$F_{35\%}$, F_{OFL}[4]
Rex sole	5	0.128	F=0.75M	0.17	F=M
Flathead sole	3a	0.47	$F_{40\%}$	0.61	$F_{35\%}$
Shallow water flatfish (excl. rocksoles)	5	0.15	F=0.75M	0.20	F=M
Northern rocksole	3a	0.374	$F_{40\%}$	0.452	$F_{35\%}$
Southern rocksole	3a	0.204	$F_{40\%}$	0.243	$F_{35\%}$
Arrowtooth	3a	0.172	$F_{40\%}$	0.204	$F_{35\%}$
Pacific ocean perch	3a	0.119	$F_{40\%}$	0.139	$F_{35\%}$
Rougheye and blackspotted rockfish	3a	0.038	$F_{40\%}$	0.045	$F_{35\%}$
Shortraker rockfish	5	0.0225	F=0.75M	0.03	F=M
Other rockfish (“other slope” rockfish)	4, 5[5]	0.065, 0.0015-0.075	$F_{40\%}$, F=0.75M[5]	0.079, 0.02-, 0.10	$F_{35\%}$, F=M[6]
Northern rockfish	3a	0.061	$F_{40\%}$	0.073	$F_{35\%}$
Dusky rockfish[7] (formerly “pelagic shelf” rockfish)	3a	0.098	$F_{40\%}$	0.122	$F_{35\%}$
Demersal shelf rockfish	4	0.02	F=M	0.032	$F_{35\%}$
Thornyhead rockfish	5	0.0225	F=0.75M	0.03	F=M
Atka mackerel	6	NA	F_{ABC}[8]	NA	F_{OFL}[9]
Skates	5	0.075	F=0.75M	0.10	F=M
Sculpins	5	0.166	F=0.75M	0.222	F=M
Squid	6	NA	F_{ABC}[10]	NA	F_{OFL}[11]
Octopus	6	0.3975	F=0.75M[12]	0.53	F=M[13]
Sharks	6[14]	0.073	F=0.75M,F_{ABC}[14]	0.097	F=M,F_{OFL}[15]

1/ Fishing mortality rate corresponding to acceptable biological catch.
2/ Maximum fishing mortality rate allowable under overfishing definition.
3/ $F_{40\%}$ for Dover sole (Tier 3a), ABC=0.75 x average catch (1978-1995) for other deepwater flatfish (Tier 6).
4/ $F_{35\%}$ for Dover sole (Tier 3a), average catch (1978-1995) for other deepwater flatfish (Tier 6).
5/ $F_{40\%}$ for sharpchin rockfish (Tier 4), F=0.75M for other rockfish species (Tier 5). The other rockfish category (formerly the “other slope” rockfish category now includes widow and yellowtail rockfish.
6/ $F_{35\%}$ for sharpchin (Tier 4), F=M for other species (Tier 5). The other rockfish category (formerly the “other slope” rockfish category now includes widow and yellowtail rockfish.
7/ Dusky rockfish were formerly in the “pelagic shelf” rockfish category which no longer exists. Widow and yellowtail rockfish which were in the former “pelagic shelf” category have been moved to the other rockfish category.
8/ ABC for Atka mackerel is equal to 0.75 x average catch from 1978 to 1995. This maximum permissible ABC is intended for bycatch in other target fisheries and to minimize targeting.
9/ OFL for Atka mackerel is equal to average catch from 1978 to 1995.
10/ ABC for squid is equal to 0.75 x the maximum catch of squid from 1997-2007. This is a modified Tier 6 recommendation.
11/ OFL for squid is equal to the maximum catch of squid from 1997-2007. This is a modified Tier 6 recommendation.
12/ ABC for octopus is equal to F=0.75M x the average estimate of biomass from the 2009, 2011, and 2013 surveys. This is a modified Tier 6 recommendation.
13/ OFL for octopus is equal to F=M x the average estimate of biomass from the 2007, 2009, and 2011 surveys. This is a modified Tier 6 recommendation.
14/ F_{ABC} = 0.073 for spiny dogfish (Tier 6). While spiny dogfish are a Tier 6 species, a Tier 5 approach is used. They are not a Tier 5 because the trawl survey biomass is not considered reliable for the species. ABC for other sharks is equal to 0.75 x average catch from 1997-2007 (Tier 6). This time frame differs from the standard Tier 6 time frame of 1978-1995.
15/ F=M for spiny dogfish (Tier 6). While spiny dogfish are a Tier 6 species, a Tier 5 approach is used. They are not a Tier 5 because the trawl survey biomass is not considered reliable for the species. OFL for other sharks is equal to the average catch from 1997-2007 (which differs from the standard Tier 6 time frame of 1978-1995).

Table 4. Maximum permissible fishing mortality rates and ABCs as defined in Amendment 56 to the GOA and BSAI Groundfish FMPs, and the Plan Team's 2015 recommended fishing mortality rates and ABCs, for those species whose recommendations were below the maximum.

Species	Tier	2015 *Max* F_{ABC}	*Max* ABC	F_{ABC}	2015 ABC
Pollock[1]	3a	0.24	222,774	0.20	191,309
Pacific cod	3a	0.502	117,200	0.441	102,850
Demersal shelf rockfish	4	0.026	293	0.02	225

1/ The Plan Team recommended 2015 W/C pollock ABC of 191,309 t listed here, has not been reduced as in past years' tables, to accommodate the Prince William Sound (PWS) GHL. The 2015 PWS GHL value is 2.5% of the W/C pollock ABC (0.025 x 191,309 = 4,783 t). This value is deducted from 191,309 t for apportionments which are listed in the pollock summary.

Table5. Groundfish landings (metric tons) in the Gulf of Alaska,1956-2012.

Year	Pollock	Pacific cod	sablefish	Flatfish	Arrowtooth Flounder	Slope rockfish[a]
1956			1,391			
1957			2,759			
1958			797			
1959			1,101			
1960			2,142			
1961			897			16,000
1962			731			65,000
1963			2,809			136,300
1964	1,126	196	2,457	1,028		243,385
1965	2,749	599	3,458	4,727		348,598
1966	8,932	1,376	5,178	4,937		200,749
1967	6,276	2,225	6,143	4,552		120,010
1968	6,164	1,046	15,049	3,393		100,170
1969	17,553	1,335	19,376	2,630		72,439
1970	9,343	1,805	25,145	3,772		44,918
1971	9,458	523	25,630	2,370		77,777
1972	34,081	3,513	37,502	8,954		74,718
1973	36,836	5,963	28,693	20,013		52,973
1974	61,880	5,182	28,335	9,766		47,980
1975	59,512	6,745	26,095	5,532		44,131
1976	86,527	6,764	27,733	6,089		46,968
1977	112,089	2,267	17,140	16,722		23,453
1978	90,822	12,190	8,866	15,198		8,176
1979	98,508	14,904	10,350	13,928		9,921
1980	110,100	35,345	8,543	15,846		12,471
1981	139,168	36,131	9,917	14,864		12,184
1982	168,693	29,465	8,556	9,278		7,991
1983	215,567	36,540	9,002	12,662		7,405
1984	307,400	23,896	10,230	6,914		4,452
1985	284,823	14,428	12,479	3,078		1,087
1986	93,567	25,012	21,614	2,551		2,981
1987	69,536	32,939	26,325	9,925		4,981
1988	65,625	33,802	29,903	10,275		13,779
1989	78,220	43,293	29,842	11,111		19,002
1990	90,490	72,517	25,701	15,411		21,114
1991	107,500	76,997	19,580	20,068		13,994
1992	93,904	80,100	20,451	28,009		16,910
1993	108,591	55,994	22,671	37,853		14,240
1994	110,891	47,985	21,338	29,958		11,266
1995	73,248	69,053	18,631	32,273		15,023
1996	50,206	67,966	15,826	19,838	22,183	14,288
1997	89,892	68,474	14,129	17,179	16,319	15,304
1998	123,751	62,101	12,758	11,263[I]	12,974	14,402
1999	95,637	68,613	13,918	8,821	16,209	18,057
2000	71,876	54,492	13,779	13,052	24,252	15,683
2001	70,485	41,614	12,127	11,817	19,964	16,479
2002	49,300[J]	52,270	12,246	12,520	21,230	17,128
2003	49,300	52,500	14,345	10,750	23,320	18,678
2004	62,826	43,104	15,630	7,634	15,304	18,194
2005	80,086	35,205	13,997	9,890	19,770	17,306
2006	70,522	37,792	13,367	14,474	27,653	20,492
2007	51,842	39,473	12,265	15,077	25,364	18,718
2008	51,721	43,481	12,326	16,393	29,293	18,459
2009	42,389	39,397	10,910	17,360	24,937	18,621
2010	75,167	58,003	10,086	13,556	24,334	21,368
2011	79,789	62,475	11,148	10,043	30,890	19,612
2012	101,356	56,520	11,914	8,909	20,714	22,334
2013	93,733	51,792	11,945	12,283	21,620	19,367
2014[H]	139,753	59,633	10,375	10,741	35,026	22,962

a/ Catch defined as follows: (1) 1961-78, Pacific ocean perch (*S.alutus*) only;(2)1979-1987, the 5 species of the Pacific ocean perch complex; 1988-90, the 18 species of the slope rock assemblage;1991-1995, the 20 species of the slope rockfish assemblage.
b/Catch from Southeast Outside District.
c/Thornyheads were included in the other species category, and are foreign catches only.
d/Other species category stabilized in 1981 to include sharks, skates, sculpins, eulachon, capelin (and other smelts in the family Osmeridae and octopus. Atka mackerel and squid were added in 1989. Catch of Atka Mackerel is reported separately for 1990-1992; thereafter Atka mackerel was assigned a separate target species.

Table5. (cont'd) Groundfish landings (metric tons) in the Gulf of Alaska,1956-2012.

Year	Pelagic Shelf rockfish	Demersal shelf rockfish[b]	Thornyheads[c]	Atka mackerel[e]	Skates[k]	Other species[d]	Total
1956							1,391
1957							2,759
1958							797
1959							1,101
1960							2,142
1961							16,897
1962							65,731
1963							139,109
1964							248,192
1965							360,131
1966							221,172
1967							139,206
1968							125,822
1969							113,333
1970							84,983
1971							115,758
1972							158,768
1973							144,478
1974							153,143
1975							142,015
1976							174,081
1977			0	19,455		4,642	195,768
1978			0	19,588		5,990	160,830
1979			0	10,949		4,115	162,675
1980			1,351	13,166		5,604	202,426
1981			1,340	18,727		7,145	239,476
1982		120	788	6,760		2,350	234,001
1983		176	730	12,260		2,646	296,988
1984		563	207	1,153		1,844	356,659
1985		489	81	1,848		2,343	320,656
1986		491	862	4		401	147,483
1987		778	1,965	1		253	146,703
1988	1,086	508	2,786	-		647	158,411
1989	1,739	431	3,055	-		1,560	188,253
1990	1,647	360	1,646	1,416		6,289	236,591
1991	2,342	323	2,018	3,258		1,577	247,657
1992	3,440	511	2,020	13,834		2,515	261,694
1993	3,193	558	1,369	5,146		6,867	256,482
1994	2,990[f]	540	1,320	3,538		2,752	232,578
1995	2,891	219[g]	1,113	701		3,433	216,585
1996	2,302	401	1,100	1,580		4,302	199,992
1997	2,629	406	1,240	331		5,409	231,312
1998	3,111	552	1,136	317		3,748	246,113
1999	4,826	297	1,282	262		3,858	231,780
2000	3,730	406	1,307	170		5,649	204,396
2001	3,008	301	1,339	76		4,801	182,011
2002	3,318	292	1,125	85		4,040	173,554
2003	2,975	229	1,159	578		6,339	180,173
2004	2,674	260	818	819	2,912	1,559	171,734
2005	2,235	187	719	799	2,710	2,294	185,211
2006	2,446	166	779	876	3,501	3,526	195,594
2007	3,318	250	701	1,453	3,498	2,928	174,887
2008	3,634	149	741	2,109	3,606	2,776	184,149
2009	3,057	138	666	2,222	7,020	2,870	169,604
2010	3,111	128	565	2,417	5,056	2,042	215,833
2011	2,531	82	612	1,615	4,437	2,362	225,596
2012	4,012	178	746	1,187	4,107	1,940	233,927
2013	3,978	218	1,153	1,277	6,160	6,766	230,292
2014[H]	4,080	104	1,121	981	4,356	4,971	294,103

e/Atka mackerel was added to the Other Species categoryin1988andseparatedoutin1994
f/PSR includes lightdusky, yellowtail, widow, dark, dusky, black, and blue rockfish; black and blue excluded in 1998, dark in 2008, widow and yellowtail in 2012 (note only dusky remains in PSR since 2012)
g/Does not include at-sea discards.
h/Catch data reported through November 8th,2014.
i/Includes all species except arrowtooth.
j/Does not include state fisheries
k/Includes all managed skates species

Figures

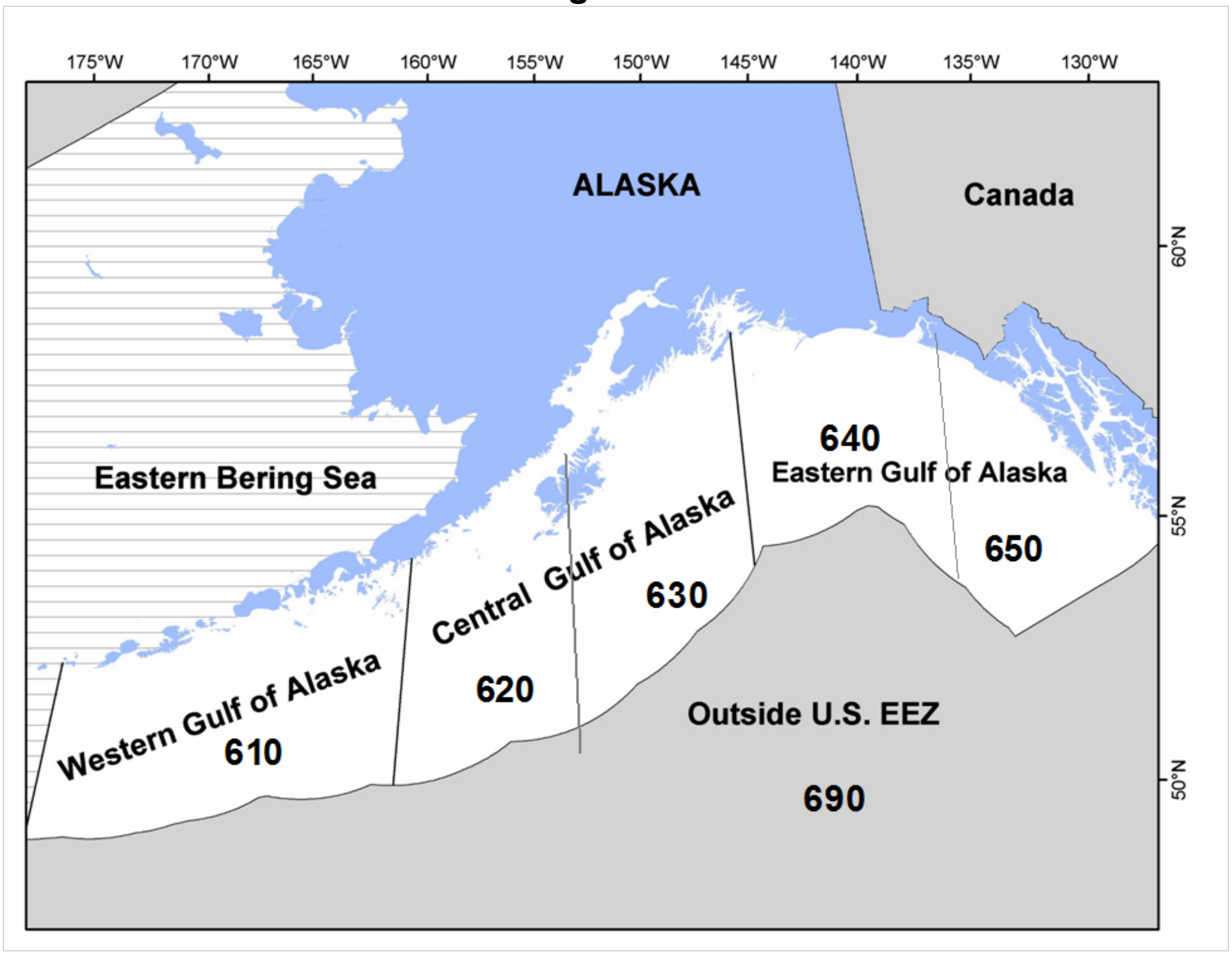

Figure 1. Gulf of Alaska statistical and reporting areas.

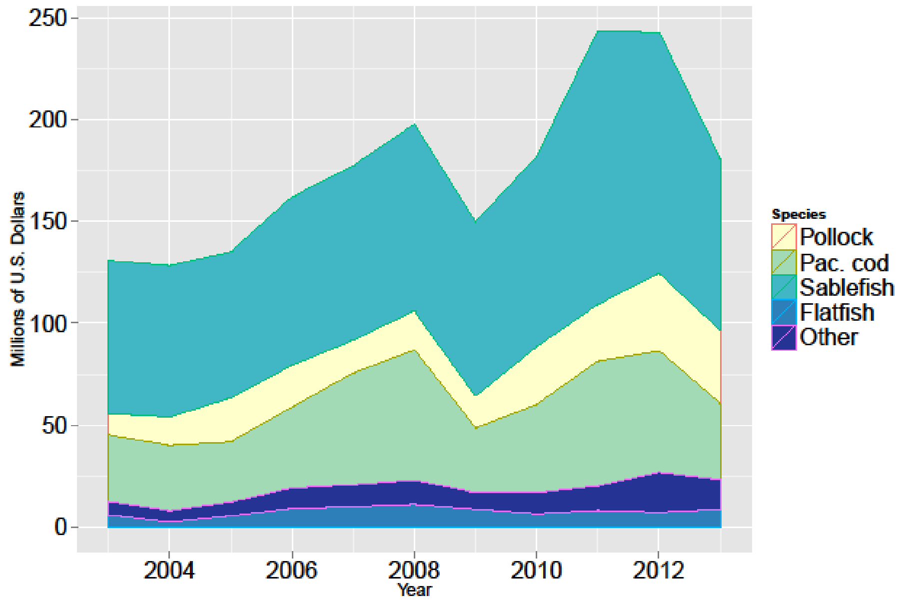

Fig. 2. Real ex-vessel value of the groundfish catch in the domestic commercial fisheries in the GOA area by species, 2003-2013 (base year = 2013).

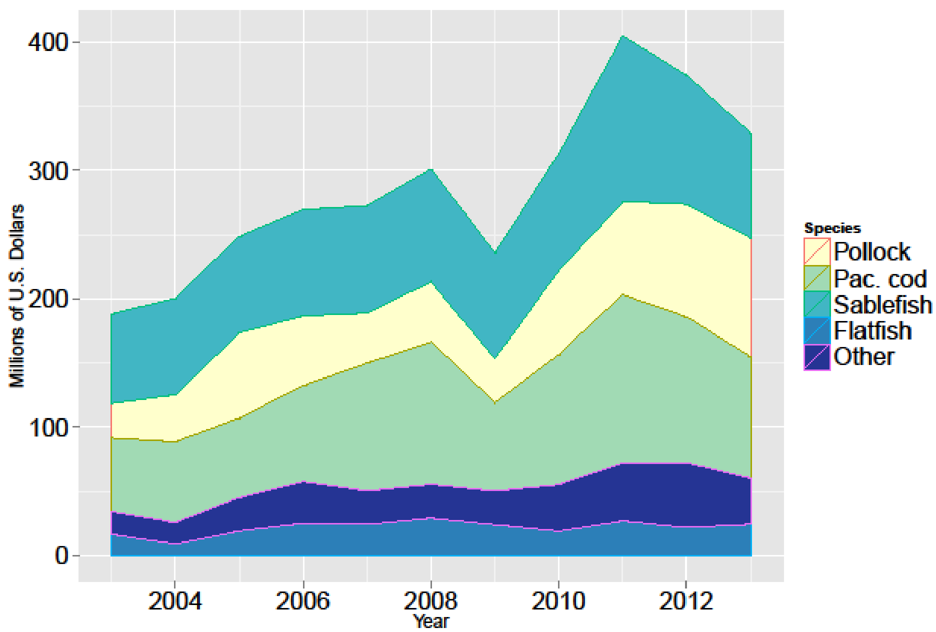

Figure 3. Real gross product value of the groundfish catch in the GOA area by species, 2003-2013 (base year = 2013).

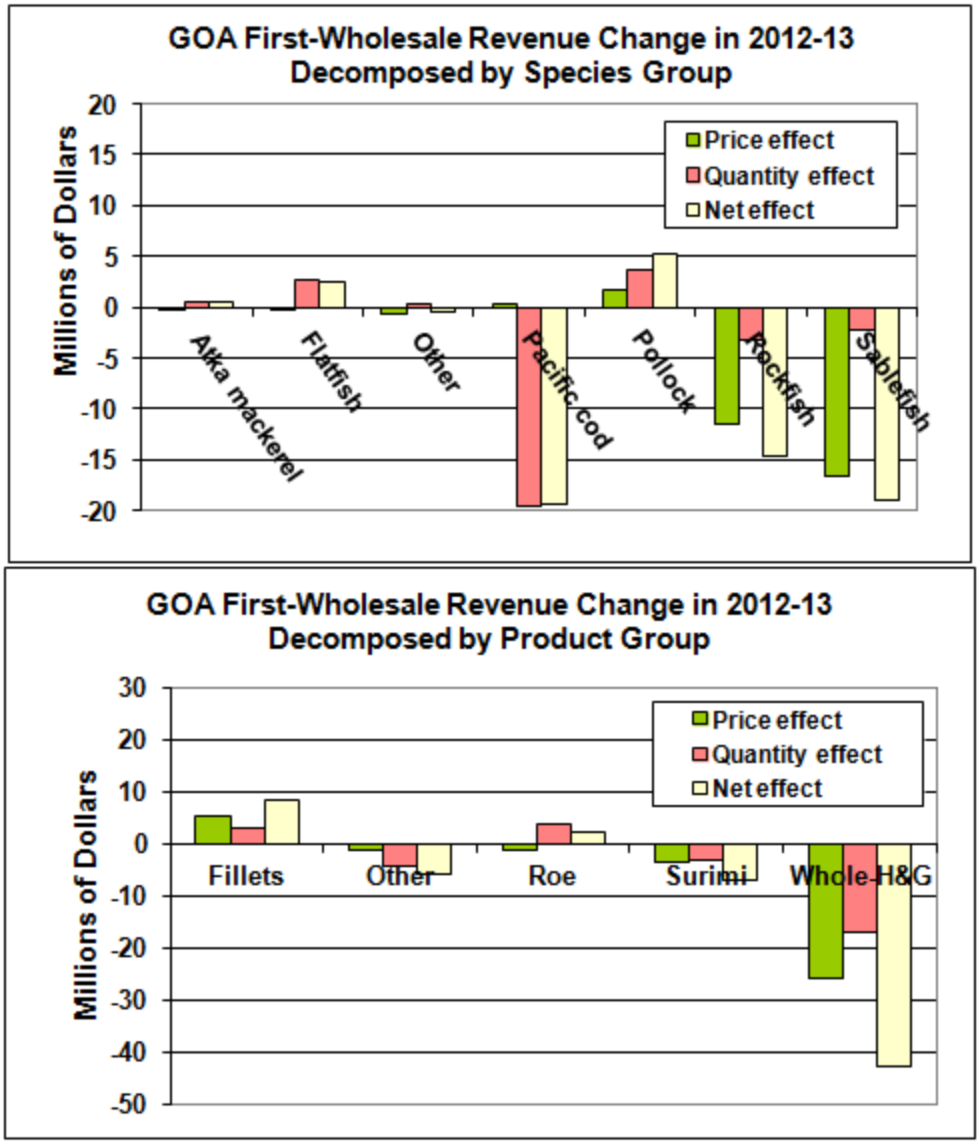

Figure 4. Decomposition of the change in first-wholesale revenues from 2012-13 in the GOA area. The first decomposition is by the species groups used in the Economic SAFE report, and the second decomposition is by product group. The price effect refers to the change in revenues due to the change in the first-wholesale price index (current dollars per metric ton) for each group. The quantity effect refers to the change in revenues due to the change in production (in metric tons) for each group. The net effect is the sum of price and quantity effects. Year to year changes in the total quantity of first-wholesale groundfish products include changes in total catch and the mix of product types (e.g., fillet vs. surimi).

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Chapter 1: Assessment of the Walleye Pollock Stock in the Gulf of Alaska

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Executive Summary

Summary of Changes in Assessment Model Inputs

Changes in input data

1. Fishery: 2013 total catch and catch at age.

2. Shelikof Strait acoustic survey: 2014 biomass and age composition.

3. NMFS bottom trawl survey: 2013 age composition.

4. ADFG crab/groundfish trawl survey: 2014 biomass.

5. Total catch for all years was re-estimated from original sources

6. Fishery catch at age and weight at age were re-estimated for 1975-1999 from primary databases maintained at AFSC.

Changes in assessment methodology

The age-structured assessment model is similar to the model used for the 2013 assessment and was developed using AD Model Builder (a C++ software language extension and automatic differentiation library). The 2014 model implemented the following changes based on the 2012 CIE review, SSC and Plan Team comments, and other considerations: 1) starting the model in 1970 rather than 1964 and removing fishery length composition data for 1964-1971, 2) removing summer bottom trawl surveys in 1984 and 1987 and Shelikof Strait acoustic surveys in 1981-1991, 3) estimating summer bottom trawl catchability using a prior and modeling selectivity with an asymptotic curve, rather than fixing catchability at 1.0 and assuming a dome-shaped selectivity curve, 4) using a random walk for changing fishery selectivity parameters rather than time blocks, 5) using an age-specific mortality schedule with higher juvenile mortality, 6) modeling age-1 and age-2 pollock in the winter acoustic surveys as separate indices. All composition data sets were tuned so that input sample sizes were close to the harmonic mean of effective sample size.

Summary of Results

The base model projection of female spawning biomass in 2015 is 309,869 t, which is 39.7% of unfished spawning biomass (based on average post-1977 recruitment) and below $B_{40\%}$ (312,000 t), thereby placing Gulf of Alaska pollock in sub-tier “b” of Tier 3. There were two surveys in 2014: the Shelikof Strait acoustic survey and the ADFG crab/groundfish survey. The 2014 biomass estimate for Shelikof Strait is 842,138 t, which is a 6% decrease from 2013, but is still larger than any other biomass estimate in Shelikof Strait since 1985. The ADFG crab/groundfish survey 2014 biomass estimate is close to the 2013 estimate (2% lower). The estimated abundance of mature fish is projected to remain stable near $B_{40\%}$ or to increase in over the next five years.

The author's 2015 ABC recommendation for pollock in the Gulf of Alaska west of 140° W lon. (W/C/WYK) is 191,309 t, which is an increase of 14% from the 2014 ABC. This recommendation is based on a more conservative alternative to the maximum permissible F_{ABC} introduced in the 2001 SAFE applied to the base model. In 2016, the ABC based on an adjusted $F_{40\%}$ harvest rate is 250,824 t. The OFL in 2015 is 256,545 t, and the OFL in 2016 if the recommended ABC is taken in 2015 is 321,067 t.

For pollock in southeast Alaska (East Yakutat and Southeastern areas), the ABC recommendation for both 2015 and 2016 is 12,625 t (see Appendix A) and the OFL recommendation for both 2015 and 2016 is 16,833 t. These recommendations are based on a Tier 5 assessment using the estimated biomass in 2015 and 2016 from a random effects model fit to the 1990-2013 bottom trawl survey biomass estimates in Southeast Alaska, and are unchanged from last year.

Status Summary for Gulf of Alaska Pollock in W/C/WYK

	As estimated or specified *last* year for		As estimated or specified *this* year for	
Quantity/Status	2014	2015	2015	2016
M (natural mortality rate)	0.3	0.3	0.3	0.3
Tier	3a	3b	3b	3a
Projected total (age 3+) biomass (t)	972,750	1,723,060	1,883,920	1,927,010
Female spawning biomass (t)				
Projected				
Upper 95% confidence interval	379,861	319,342	406,382	432,820
Point estimate	308,541	267,477	309,869	330,497
Lower 95% confidence interval	250,611	224,035	236,081	253,194
$B_{100\%}$	726,000	726,000	779,000	779,000
$B_{40\%}$	290,000	290,000	312,000	312,000
$B_{35\%}$	254,000	254,000	273,000	273,000
F_{OFL}	0.26	0.22	0.28	0.28
$maxF_{ABC}$	0.22	0.20	0.24	0.24
F_{ABC}	0.20	0.17	0.20	0.22
OFL (t)	211,998	248,384	256,545	321,067
maxABC (t)	183,943	210,071	222,774	272,165
ABC (t)	167,657	185,830	191,309	250,824
	As determined *last* year for		As determined *this* year for	
Status	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Responses to SSC and Plan Team Comments in General

The SSC in its December 2012 minutes recommended that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL.

We evaluated six methods to estimate the age-specific pattern of natural mortality external to the assessment model, and recommended an ensemble average for use in the assessment model. A more integrated approach to estimating natural mortality using a predation index is under development in a PCCRC project in collaboration with UAF researchers.

The SSC in its December 2013 minutes recommended that assessment authors give greater attention to how current year catch is determined.

Previously the assessment assumed that the full ABC/TAC would be taken in the current year. This year we averaged the percent of ABC taken in the previous five years, and applied that percentage (95%) to the current year ABC.

The SSC in its December 2013 minutes recommended that projections for two future years be shown on the phase plot figure.

The phase plot figure was modified as recommended.

The SSC in its December 2013 minutes recommended use of the random effects approach to determine area apportionments.

The appendix includes recommendations for apportioning the ABC by region for Western and Central stock using the random effects model to obtain smoothed biomass estimates by region for the summer bottom trawl survey. The random effects model was evaluated but not used for the winter apportionment calculations due to concerns about how the model performed with short, highly variable time series.

Responses to SSC and Plan Team Comments Specific to this Assessment

The GOA Plan Team suggested in its November 2012 minutes that inter-annual smoothing be used instead of blocks to avoid the undesirable effect of highly correlated recruitments between years. The SSC in its December 2012 minutes agreed with the Plan Team and recommended that the assessment authors explore whether there is a tradeoff between parsimony and introduction of retrospective error when using time blocks versus a penalized random walk for time varying selectivity.

We reintroduced random walks in the parameters governing the ascending portion of the selectivity curve with stiffer penalties on the amount that the parameter can change from one year to the next. The descending portion of the fishery selectivity curve is not allowed to vary based on our concern that changes in the descending portion of the curve were more likely to track error rather than signal.

The GOA Plan Team noted in its November 2012 minutes that the assumption of the multinomial error assumption for all ages is questionable. The Team suggested that younger ages, age-1 and possibly age-2, might be better treated separately, similar to the approach used for the eastern Bering Sea pollock model for both acoustic and bottom-trawl surveys. The SSC in its December 2012 minutes concurred with the Plan Team recommendation.

We separated the age-1 and the age-2 pollock from the remaining age classes for the Shelikof Strait acoustic survey biomass and age composition. New age-1 and age-2 indices were created by combining the Shelikof Strait and the Shumagin Island estimates for years when both surveys were conducted. These indices were fit with separate log-normal likelihood components in the model.

The SSC in its December 2012 minutes recommended that the assessment authors explore if there are variations in female relative abundance that may explain variations in spatial distributions by management areas.

We were unable to make progress on this recommendation in this assessment. It is unclear to us what kind of analysis is being recommended.

In their November 2013 minutes, the GOA Groundfish Plan Team recommends considering the results from the Plan Team stock-recruitment working group when determining which year classes to use when computing reference point. The SSC in its December 2013 minutes agreed with the Plan Team and noted a discrepancy between including the 2012 recruitment in projections but not in calculating the $B_{100\%}$ *reference point. The authors are encouraged to provide a justification for this approach and the Plan Team to discuss the need for a unified approach across stocks.*

After considering the results of the stock-recruitment working group we decided it was appropriate to maintain our practice of omitting the final year estimate of age-1 recruitment in calculation of average recruitment for status determination, but using that estimate for projecting ABCs and OFLs.

Introduction

Walleye pollock (*Gadus chalcogramma*) is a semi-pelagic schooling fish widely distributed in the North Pacific Ocean. Pollock in the Gulf of Alaska are managed as a single stock independently of pollock in the Bering Sea and Aleutian Islands. The separation of pollock in Alaskan waters into eastern Bering Sea and Gulf of Alaska stocks is supported by analysis of larval drift patterns from spawning locations (Bailey et al. 1997), genetic studies of allozyme frequencies (Grant and Utter 1980), mtDNA variability (Mulligan et al. 1992), and microsatellite allele variability (Bailey et al. 1997).

The results of studies of stock structure in the Gulf of Alaska are equivocal. There is evidence from allozyme frequency and mtDNA that spawning populations in the northern part of the Gulf of Alaska (Prince William Sound and Middleton Island) may be genetically distinct from the Shelikof Strait spawning population (Olsen et al. 2002). However significant variation in allozyme frequency was found between Prince William Sound samples in 1997 and 1998, indicating a lack of stability in genetic structure for this spawning population. Olsen et al. (2002) suggest that interannual genetic variation may be due to variable reproductive success, adult philopatry, source-sink population structure, or utilization of the same spawning areas by genetically distinct stocks with different spawning timing. An evaluation of stock structure for Gulf of Alaska pollock following the template developed by NPFMC stock structure working group was provided as an appendix to the 2012 assessment (Dorn et al., 2012). Evidence tended to support the current approach of assessing and managing pollock in the eastern portion of the Gulf of Alaska separately from pollock in the central and western portions of the Gulf of Alaska.

Fishery

The commercial fishery for walleye pollock in the Gulf of Alaska started as a foreign fishery in the early 1970s (Megrey 1989). Catches increased rapidly during the late 1970s and early 1980s (Table 1.1). A large spawning aggregation was discovered in Shelikof Strait in 1981, and a fishery developed for which pollock roe was an important product. The domestic fishery for pollock developed rapidly in the Gulf of Alaska with only a short period of joint venture operations in the mid-1980s. The fishery was fully domestic by 1988.

The pollock target fishery in the Gulf of Alaska is entirely shore-based with approximately 90% of the catch taken with pelagic trawls. During winter, fishing effort targets pre-spawning aggregations in Shelikof Strait and near the Shumagin Islands (Fig. 1.1). Fishing in summer is less predictable, but typically occurs in deep-water troughs on the east side of Kodiak Island and along the Alaska Peninsula.

Incidental catch in the Gulf of Alaska directed pollock fishery is low. For tows classified as pollock targets in the Gulf of Alaska between 2009 and 2013, on average about 95% of the catch by weight of FMP species consisted of pollock (Table 1.2). Nominal pollock targets are defined by the dominance of pollock in the catch, and may include tows where other species were targeted, but pollock were caught instead. The most common managed species in the incidental catch are arrowtooth flounder, Pacific cod, flathead sole, Pacific ocean perch, squid, and shallow-water flatfish. The most common non-target species are eulachon and other osmerids, miscellaneous fish, and jellyfish. Bycatch estimates for prohibited species over the period 2009-2013 are given in Table 1.3. Chinook salmon are the most important prohibited species caught as bycatch in the pollock fishery. The spike in Chinook salmon bycatch in 2010 led the Council to adopt management measures to reduce Chinook salmon bycatch, including a cap of 25,000 Chinook salmon bycatch in directed pollock fishery. Estimated Chinook salmon bycatch since 2010 has been less than half of the 2010 spike.

Kodiak is the major port for pollock in the Gulf of Alaska, accounting for about 70% of the 2009-2013 landings. In the western Gulf of Alaska, Sand Point, King Cove, and Akutan are important ports, sharing

25% of recent landings. Minor ports, including Seward, Dutch Harbor, Homer, Sitka, Cordova, and Ketchikan account for only 2% of landings.

Since 1992, the Gulf of Alaska pollock Total Allowable Catch (TAC) has been apportioned spatially and temporally to reduce potential impacts on Steller sea lions. The details of the apportionment scheme have evolved over time, but the general objective is to allocate the TAC to management areas based on the distribution of surveyed biomass, and to establish three or four seasons between mid-January and fall during which some fraction of the TAC can be taken. The Steller Sea Lion Protection Measures implemented in 2001 established four seasons in the Central and Western GOA beginning January 20, March 10, August 25, and October 1, with 25% of the total TAC allocated to each season. Allocations to management areas 610, 620 and 630 are based on the seasonal biomass distribution as estimated by groundfish surveys. In addition, a harvest control rule was implemented that requires suspension of directed pollock fishing when spawning biomass declines below 20% of the reference unfished level.

Data Used in the Assessment

The data used in the assessment model consist of estimates of annual catch in tons, fishery age composition, NMFS summer bottom trawl survey estimates of biomass and age composition, acoustic survey estimates of biomass and age composition in Shelikof Strait, and ADFG bottom trawl survey estimates of biomass and age composition. Binned length composition data are used in the model only when age composition estimates are unavailable, such as the most recent surveys. The following table specifies the data that were used in the GOA pollock assessment:

Source	*Type*	*Years*
Fishery	Total catch biomass	1970-2013
Fishery	Age composition	1975-2013
Shelikof Strait acoustic survey	Biomass	1992-2014
Shelikof Strait acoustic survey	Age composition	1992-2014
NMFS bottom trawl survey	Area-swept biomass	1990-2013
NMFS bottom trawl survey	Age composition	1990-2013
ADFG trawl survey	Area-swept biomass	1989-2013
ADFG survey	Age composition	2000, 2002, 2004, 2006, 2008, 2010, 2012

Total Catch

Total catch was re-estimated in this assessment from original sources, which included INPFC and ADFG publications, and databases maintained at the Alaska Fisheries Science Center and the Alaska Regional Office. Foreign catches for 1963-1970 are reported in Forrester et al. (1978). During this period only Japanese vessels reported catch of pollock, though there may have been some catches by Soviet vessels. Foreign catches 1971-1976 are reported by Forrester et al. (1983). During this period there are reported pollock catches for Japanese, Soviet, Polish, and ROK vessels in the Gulf of Alaska. Foreign and joint venture catches for 1977-1988 are blend estimates for the NORPAC database maintained by the Alaska Fisheries Science Center. Domestic catches for 1970-1980 are reported in Rigby (1984). Domestic catches for 1981-1990 were obtained from PacFIN (Brad Stenberg, pers. comm. Feb 7, 2014). A discard ratio (discard/retained) of 13.5% was assumed for all domestic catches prior to 1991 based on the 1991-1992 average discard ratio. Estimated catch for 1991-2013 was obtained from the Catch Accounting System database maintained by the Alaska Regional Office. These estimates are derived from shoreside electronic logbooks and observer estimates of at-sea discards (Table 1.4). Catches include the state-managed pollock fishery in Prince William Sound (PWS). Since 1996 the pollock Guideline Harvest Level (GHL) for the PWS fishery has been deducted from the Acceptable Biological Catch (ABC) by the NPFMC Gulf of Alaska Plan Team for management purposes. Non-commercial catches are reported in Appendix D.

Fishery Age Composition

Catch at age was re-estimated in this assessment for 1975-1999 from primary databases maintained at AFSC. A simple non-stratified estimator was used, which consisted of compiling a single annual age-length key and the applying the annual length composition to that key. Estimates were made separately for the foreign/JV and domestic fisheries in 1987 when both fisheries were sampled. There were no major discrepancies between the re-estimated age composition and estimates that have built up gradually from assessment to assessment. A more complex analysis using spatial and temporal strata was considered for the re-analysis, but this was regarded as lower priority because very few of the pre-2000 fish are present in the current population age structure.

Methods for estimating age composition from 2000 onward are documented in the assessments available online at http://www.afsc.noaa.gov/REFM/stocks/Historic_Assess.htm. Estimates of fishery age composition were derived from at-sea and port sampling of the pollock catch for length and ageing structures (otoliths). All length composition and age data was downloaded from the NORPAC tables. Pollock otoliths collected during the 2013 fishery were aged using the revised criteria described in Hollowed et al. (1995), which involved refinements in the criteria to define edge type. Catch age composition was estimated using methods described by Kimura and Chikuni (1989). Age samples were used to construct age-length keys by sex and stratum. These keys were applied to sex and stratum specific length frequency data to estimate age composition, which were then weighted by the catch in numbers in each stratum to obtain an overall age composition. Age and length samples from the 2013 fishery were stratified by half year and statistical area as follows:

Time strata		Shumagin-610	Chirikof-620	Kodiak-630	W. Yakutat and PWS-640 and 649
1st half (A and B seasons)	No. ages	207	355	177	12
	No. lengths	1011	1919	921	55
	Catch (t)	5,885	35,994	9,046	5,524
2nd half (C and D seasons)	No. ages	106	240	360	----
	No. lengths	601	1304	2046	----
	Catch (t)	1,825	17,121	20,966	----

Sample sizes for both length and otoliths dropped substantially in 2013 due to implementation of the new observer deployment plan. Observer sampling instructions were changed to address this issue by increasing the number of ages and lengths collected per sampled haul, but this will only affect sample sizes in 2014 and later.

The catch-at-age in 2013 was primarily ages 5-7, with the age-6 fish (2007 year class) dominant (Fig. 1.2). A mode of age-3 fish was also present in most strata. Fishery catch at age in 1976-2013 is presented in Table 1.5 (See also Fig. 1.3). Sample sizes for ages and lengths are given in Table 1.6.

Gulf of Alaska Bottom Trawl Survey

Trawl surveys have been conducted by Alaska Fisheries Science Center (AFSC) every three years (beginning in 1984) to assess the abundance of groundfish in the Gulf of Alaska (Table 1.7). Starting in 2001, the survey frequency was increased to every two years. The survey uses a stratified random design, with 49 strata based on depth, habitat, and management area (Martin 1997). Area-swept biomass estimates are obtained using mean CPUE (standardized for trawling distance and mean net width) and stratum area. The survey is conducted from chartered commercial bottom trawlers using standardized poly-Nor'eastern high opening bottom trawls rigged with roller gear. In a typical survey, 800 tows are completed. On average, 70% of these tows contain pollock (Table 1.8).

The time series of pollock biomass used in the assessment model is based on the surveyed area in the Gulf of Alaska west of 140° W lon., obtained by adding the biomass estimates for the Shumagin, Chirikof, Kodiak INPFC areas, and the western portion of Yakutat INPFC area. Biomass estimates for the west Yakutat region were obtained by splitting strata and survey CPUE data at 140° W lon. (M. Martin, AFSC, Seattle, WA, pers. comm. 2011). For surveys in 1984 and 1987, the average percent in West Yakutat in the 1990-99 surveys was used. The average was also used in 2001, when West Yakutat was not surveyed.

An adjustment was made to the survey time series to account for unsurveyed pollock in Prince William Sound. This adjustment was derived from an area-swept biomass estimate for PWS from a trawl survey conducted by ADFG in 1999, using a standard ADFG 400 mesh eastern trawl. The 1999 biomass estimate for PWS was 6,304 t ± 2,812 t (95% CI) (W. Bechtol, ADFG, 1999, pers. comm.). The PWS biomass estimate should be considered a minimum estimate because ADFG survey gear is less effective at catching pollock compared to the NMFS survey gear (fishing power correction = 3.84, SE = 1.26) (von Szalay and Brown 2001). For 1999, the biomass estimates for the NMFS bottom trawl survey and the PWS survey were simply added to obtain a total biomass estimate. The adjustment factor for the 1999 survey, (PWS + NMFS)/NMFS, was applied to other triennial surveys, and increased biomass by 1.05%.

Bottom Trawl Survey Age Composition
Estimates of numbers at age from the bottom trawl survey are obtained from random otolith samples and length frequency samples (Table 1.9). Numbers at age are estimated by INPFC area (Shumagin, Chirikof, Kodiak, Yakutat and Southeastern) using a global age-length key and CPUE-weighted length frequency data by INPFC area. The combined Shumagin, Chirikof and Kodiak age composition is used in the assessment model (Fig. 1.4). Ages are now available for the 2013 survey, and show very high estimates of age-1 pollock abundance in all areas (Fig. 1.5). In the Central and Western portion of the Gulf of Alaska, pollock of ages 4-8 were relatively abundant in all areas. After excluding the age-1 fish, mean age decreased from Shumagin area (6.7 years) to the Southeast area (4.1 years).

Shelikof Strait Acoustic Survey

Acoustic surveys to assess the biomass of pollock in the Shelikof Strait area have been conducted annually since 1981 (except 1982 and 1999). Survey methods and results for 2014 are presented in a NMFS processed report (Jones et. al. in review). Biomass estimates using the Simrad EK echosounder from 1992 onwards were re-estimated to take into account recently published work of eulachon acoustic target strength (Gauthier and Horne 2004). Previously, acoustic backscatter was attributed to eulachon based on the percent composition of eulachon in trawls, and it was assumed that eulachon had the same target strength as pollock. Since Gauthier and Horne (2004) determined that the target strength of eulachon was much lower than pollock, the acoustic backscatter could be attributed entirely to pollock even when eulachon were known to be present. In 2008, the noise-reduced *R/V Oscar Dyson* became the designated survey vessel for acoustic surveys in the Gulf of Alaska. In winter of 2007, a vessel comparison experiment was conducted between the *R/V Miller Freeman* (MF) and the *R/V Oscar Dyson*

(OD), which obtained an OD/MF ratio of 1.132 for the acoustic backscatter detected by the two vessels in Shelikof Strait.

The 2014 biomass estimate for Shelikof Strait is 842,138 t, which is a 6% decrease from 2013, but is still larger than any other biomass estimate in Shelikof Strait since 1985. The biomass of pollock ≥43 cm (a proxy for spawning biomass) is 17% lower than the 2013 estimate, but there were fewer areas surveyed in 2014. In addition to the Shelikof Strait survey, acoustic surveys in winter 2014 covered the Shumagin Islands spawning area, Sanak Gully, Marmot Gully, and Izhut Bay. Several other surveys had been planned for winter of 2014, including Pavlof Bay, and Chirikof, but were unable to be completed due to scheduling issues with the *R/V Oscar Dyson*. The following table provides results from the 2014 winter acoustic surveys:

Area	Biomass ≥43 cm (t)	Percent	Total biomass (t)	Percent
Sanak Gully	7,318	1.3%	7,319	0.8%
Shumagin Islands	5,899	1.1%	37,346	4.1%
Shelikof Strait	539,990	96.8%	842,138	93.3%
Marmot Gully	4,605	0.8%	14,992	1.7%
Izhut Bay	178	0.0%	454	0.1%
Total	557,990		902,249	

In comparison to 2013, biomass estimates in Sanak Gully and the Shumagin Islands were much lower (45% and 59% percent declines respectively), while the decline in Marmot Gully was more modest (25% decline) (Fig. 1.6). These results suggest that spawning has become much more concentrated in Shelikof Strait than in previous years.

Acoustic Survey Age Composition
Estimates of numbers at age from the Shelikof Strait acoustic survey (Table 1.10, Fig. 1.7) were obtained using an age-length key compiled from random otolith samples and applied to weighted length frequency samples. Otoliths collected during the 1994-2014 acoustic surveys were aged using the criteria described in Hollowed et al. (1995). Sample sizes for ages and lengths are given Table 1.11.

Net selectivity corrected biomass and age composition
The selectivity of midwater trawl used during acoustic surveys was evaluated using pocket nets attached to different locations on the net. Experiments conducted in Shelikof Strait using the *R/V Miller Freeman* in 2007 and the *R/V Oscar Dyson* in 2008 and 2013 indicated that there was substantial escapement of juvenile pollock through the net mesh, resulting in a bias in estimated length composition and biomass. A hierarchical Bayesian model was developed to model net selectivity (Williams et al. 2011). The model was used to infer the true length composition from samples of fish retained in the net, resulting in corrections to both the biomass time series and estimated length and age composition. Revised biomass and age composition estimates for acoustic surveys in Shelikof Strait for 1993-2014 were evaluated in the assessment model.

Alaska Department of Fish and Game Crab/Groundfish Trawl Survey

The Alaska Department of Fish and Game (ADFG) has conducted bottom trawl surveys of nearshore areas of the Gulf of Alaska since 1987. Although these surveys are designed to monitor population trends of Tanner crab and red king crab, walleye pollock and other fish are also sampled. Standardized survey methods using a 400-mesh eastern trawl were employed from 1987 to the present. The survey is designed to sample a fixed number of stations from mostly nearshore areas from Kodiak Island to Unimak Pass, and does not cover the entire shelf area. The average number of tows completed during the survey is 360. Details of the ADFG trawl gear and sampling procedures are in Blackburn and Pengilly (1994).

The 2014 biomass estimate for pollock for the ADFG crab/groundfish survey was 100,158 t, down 2% from the 2013 biomass estimate (Table 1.7).

ADFG Survey Age Composition
Ages were determined by age readers in the AFSC age and growth unit from samples of pollock otoliths collected during the 2000, 2002, 2004, 2006, 2008, 2010, and 2012 ADFG surveys (N = 559, 538, 591,588, 597, 585, and 562) (Table 1.12, Fig. 1.8). Comparison with fishery age composition shows that older fish (> age-8) are more common in the ADFG crab/groundfish survey. This is consistent with the assessment model, which estimates a domed-shaped selectivity pattern for the fishery, but an asymptotic selectivity pattern for the ADFG survey.

Datasets considered but not used

Egg Production Estimates of Spawning Biomass
Estimates of spawning biomass in Shelikof Strait based on egg production methods were produced during 1981-92 (Table 1.7). A complete description of the estimation process is given in Picquelle and Megrey (1993). The annual egg production spawning biomass estimate for 1981 is questionable because of sampling deficiencies during the egg surveys for that year (Kendall and Picquelle 1990). Egg production estimates were discontinued in 1992 because the Shelikof Strait acoustic survey provided similar information. The egg production estimates are not used in the assessment model because the surveys are no longer being conducted, and because the acoustic surveys in Shelikof Strait show a similar trend over the period when both were conducted.

Pre-1984 bottom trawl surveys
Considerable survey work was carried out in the Gulf of Alaska prior to the start of the NMFS triennial bottom trawl surveys in 1984. Between 1961 and the mid-1980s, the most common bottom trawl used for surveying was the 400-mesh eastern trawl. This trawl (or variants thereof) was used by IPHC for juvenile halibut surveys in the 1960s, 1970s, and early 1980s, and by NMFS for groundfish surveys in the 1970s. Von Szalay and Brown (2001) estimated a fishing power correction (FPC) for the ADFG 400-mesh eastern trawl of 3.84 (SE = 1.26), indicating that 400-mesh eastern trawl CPUE for pollock would need to be multiplied by this factor to be comparable to the NMFS poly-Nor'eastern trawl.

In most cases, earlier surveys in the Gulf of Alaska were not designed to be comprehensive, with the general strategy being to cover the Gulf of Alaska west of Cape Spencer over a period of years, or to survey a large area to obtain an index for group of groundfish, i.e., flatfish or rockfish. For example, Ronholt et al. (1978) combined surveys for several years to obtain gulfwide estimates of pollock biomass for 1973-6. There are several difficulties with such an approach, including the possibility of double-counting or missing a portion of the stock that happened to migrate between surveyed areas. Due to the difficulty in constructing a consistent time series, the historical survey estimates are no longer used in the assessment model.

Multi-year combined survey estimates indicate a large increase in pollock biomass in the Gulf of Alaska occurred between the early 1960s and the mid 1970s. Increases in pollock biomass between the1960s and 1970s were also noted by Alton et al. (1987). In the 1961 survey, pollock were a relatively minor component of the groundfish community with a mean CPUE of 16 kg/hr (Ronholt et al. 1978). Arrowtooth flounder was the most common groundfish with a mean CPUE of 91 kg/hr. In the 1973-76 surveys, the CPUE of arrowtooth flounder was similar to the 1961 survey (83 kg/hr), but pollock CPUE had increased 20-fold to 321 kg/hr, and was by far the dominant groundfish species in the Gulf of Alaska.

Mueter and Norcross (2002) also found that pollock was low in the relative abundance in 1960s, became the dominant species in Gulf of Alaska groundfish community in the 1970s, and subsequently declined in relative abundance.

Questions concerning the comparability of pollock CPUE data from historical trawl surveys with later surveys probably can never be fully resolved. However, because of the large magnitude of the change in CPUE between the surveys in the 1960s and the early 1970s using similar trawling gear, the conclusion that there was a large increase in pollock biomass seems robust. Early speculation about the rise of pollock in the Gulf of Alaska in the early 1970s implicated the large biomass removals of Pacific ocean perch, a potential competitor for euphausid prey (Somerton 1979, Alton et al. 1987). More recent work has focused on role of climate change (Anderson and Piatt 1999, Bailey 2000). Model results suggest that population biomass in the 1960s, prior to large-scale commercial exploitation of the stock, may have been lower than at any time since then.

Qualitative trends

To assess qualitatively recent trends in abundance, each survey time series was standardized by dividing the annual estimate by the average since 1987. Shelikof Strait acoustic survey estimates prior to 2008 were rescaled to be comparable to subsequent surveys conducted by the *R/V Oscar Dyson*. Although there is considerable variability in each survey time series, a fairly clear downward trend is evident to 2000, followed by a stable, though variable, trend to 2008 (Fig. 1.9). All surveys indicate a strong increase since 2008.

Indices derived from fisheries catch data were also evaluated for trends in biological characteristics (Fig. 1.10). The percent of females in the catch is close to 50-50, but shows a slight downward trend, which may be related to changes in the seasonal distribution of the catch. The percent female was 52.8% in 2013, which may indicate a reversal in the trend. The mean age shows interannual variability due to strong year classes passing through the population, but no downward trends that would suggest excessive mortality rates. The percent of old fish in the catch (nominally defined as age 8 and older) is also highly variable due to variability in year class strength. The percent of old fish increased to a peak in 1997, declined due to weaker recruitment in the 1990s and increases in total mortality (both from fishing and predation), but increased from 2005 to 2008 as the large 1999 and 2000 year classes entered the old fish category. The percent of old fish had been decreasing since 2008 as the fishery began to catch greater numbers of young fish from year classes recruiting to the fishery, but increased in 2013 when the 2005 year became 8 years old. Under a constant $F_{40\%}$ harvest rate, the mean percent of age 8 and older fish in the catch is approximately 7%. An index of catch at age diversity was computed using the Shannon-Wiener information index,

$$-\sum p_a \ln p_a \,,$$

where p_a is the proportion at age. Increases in fishing mortality would tend to reduce age diversity, but year class variability would also influence age diversity. The index of age diversity is relatively stable during 1976-2013 (Fig. 1.10).

McKelvey Index

McKelvey (1996) found a significant correlation between the abundance of age-1 pollock in the Shelikof Strait acoustic survey and subsequent estimates of year-class strength. The McKelvey index is defined as the estimated abundance of 9-16 cm fish in the Shelikof Strait acoustic survey, and is an index of year class strength in the previous year (Table 1.13). The correlation between the abundance of age-1 pollock in the Shelikof Strait acoustic survey and subsequent estimates of year-class strength remains relatively strong based on surveys conducted after 1992 (r =0.71), and there is a stronger correlation between the abundance of age-1 pollock in the Shumagin Islands survey and year-class strength (r = 0.73). The estimate of age-1 pollock abundance in 2014 is 0.58 billion fish, which is the eighth highest in the time series. In addition, 0.13 billion age-1 pollock were estimated for the acoustic survey of the Shumagin Islands in 2014. These values are suggestive of more modest age-1 recruitment in 2014.

Analytic Approach

Model Structure

An age-structured model covering the period from 1970 to 2014 (45 yrs) was used to assess Gulf of Alaska pollock. The modeled population includes individuals from age 1 to age 10, with age 10 defined as a "plus" group, i.e., all individuals age 10 and older. Population dynamics were modeled using standard formulations for mortality and fishery catch (e.g. Fournier and Archibald 1982, Deriso et al. 1985, Hilborn and Walters 1992). Year- and age-specific fishing mortality was modeled as a product of a year effect, representing the full-recruitment fishing mortality, and an age effect, representing the selectivity of that age group to the fishery. The age effect was modeled using a double-logistic function with time-varying parameters (Dorn and Methot 1990, Sullivan et al. 1997). The model was fit to time series of catch biomass, survey indices of abundance, and estimates of age and length composition from the fishery and surveys. Details of the population dynamics and estimation equations are presented in Appendix B.

Based on recommendations of the July 2012 CIE review of the Gulf of Alaska pollock assessment, several changes were implemented in the 2012 assessment model: the model includes ages 1-10 rather than ages 2-10 in previous assessments; an accumulator age was added to initial age composition and stronger equilibrium assumptions were used to initialize the model; mean unbiased log-normal likelihoods are used for survey biomass indices; the historical trawl data (pre-1984) was removed from the model; reduced weights (input sample size) were used for the fishery age composition data.

Model parameters were estimated by maximizing the log likelihood of the data, viewed as a function of the parameters. Mean-unbiased log-normal likelihoods were used for survey biomass and total catch estimates, and multinomial likelihoods were used for age and length composition data.

Likelihood component	*Statistical model for error*	*Variance assumption*
Fishery total catch (1970-2014)	Log-normal	CV = 0.05
Fishery age comp. (1975-2013)	Multinomial	Year-specific sample size = 20-200
Shelikof acoustic survey biomass (1992-2014)	Log-normal	CV = 0.20
Shelikof acoustic survey age comp. (1992-2014)	Multinomial	Sample size = 60
NMFS bottom trawl survey biom. (1990-2013)	Log-normal	Survey-specific CV = 0.12-0.38
NMFS bottom trawl survey age comp. (1990-2013)	Multinomial	Sample size = 60
ADFG trawl survey biomass (1989-2014)	Log-normal	CV = 0.25
ADFG survey age comp. (2000, 2002, 2004, 2006, 2008, 2010, 2012)	Multinomial	Sample size = 30
Recruit process error (1970-1977, 2013, 2014)	Log-normal	σ_R =1.0

Recruitment

In most years, year-class abundance at age 1 was estimated as a free parameter. Initial age composition was estimated with a single log deviation for recruitment abundance, which was then decremented by natural mortality to fill out the initial age vector. A penalty was added to the log likelihood so that the log deviation in recruitment for 1970-77, and in 2013 and 2014 would have the same variability as recruitment during the data-rich period (σ_R =1.0). Log deviations from mean log recruitment were estimated as free parameters in other years. These relatively weak constraints were sufficient to obtain fully converged parameter estimates while retaining an appropriate level of uncertainty.

Modeling fishery data

To accommodate changes in selectivity we estimated year-specific parameters for the slope and the intercept parameter for the ascending logistic portion of selectivity curve. Variation in these parameters was constrained using a random walk penalty.

Modeling survey data

Survey abundance was assumed to be proportional to total abundance as modified by the estimated survey selectivity pattern. Expected population numbers at age for the survey were based on the mid-date of the survey, assuming constant fishing and natural mortality throughout the year. Standard deviations in the log-normal likelihood were set equal to the sampling error CV (coefficient of variation) associated with each survey estimate of abundance (Kimura 1991).

Survey catchability coefficients can be fixed or freely estimated. The base model estimated the NMFS bottom trawl survey catchability, but used a log normal prior with a median of 0.85 and log standard deviation 0.1 as a constraint on potential values (Fig. 1.11). Catchability coefficients for other surveys were estimated as free parameters.

The Simrad EK acoustic system has been used to estimate biomass in the acoustic surveys since 1992. Earlier surveys (1981-91) were obtained with an older Biosonics acoustic system (Table 1.7). For models where the entire time series was used, it was split into two periods corresponding to the two acoustic systems, and separate survey catchability coefficients were estimated for each period.

A vessel comparison (VC) experiment was conducted in March 2007 during the Shelikof Strait acoustic survey. The VC experiment involved the *R/V Miller Freeman* (MF, the survey vessel used to conduct Shelikof Strait surveys since the mid-1980s), and the *R/V Oscar Dyson* (OD), a noise-reduced survey vessel designed to conduct surveys that have traditionally been done with the *R/V Miller Freeman*. The vessel comparison experiment was designed to collect data either with the two vessels running beside one another at a distance of 0.7 nmi, or with one vessel following nearly directly behind the other at a distance of about 1 nmi. The methods were similar to those used during the 2006 Bering Sea VC experiment (De Robertis et al. 2008). Results indicate that the ratio of 38 kHz pollock backscatter from the *R/V Oscar Dyson* relative to the *R/V Miller Freeman* was significantly greater than one (1.13), as would be expected if the quieter OD reduced the avoidance response of the fish. Because this difference was significant, several methods were evaluated in the 2008 assessment for incorporating this result in the assessment model. The method that was adopted was to treat the MF and the OD time series as independent survey time series, and to include the vessel comparison results directly in the log likelihood of the assessment model. This likelihood component is given by

$$\log L = -\frac{1}{2\sigma_S^2}\left[\log(q_{OD}) - \log(q_{MF}) - \delta_{OD:MF}\right]^2,$$

where $\log(q_{OD})$ is the log catchability of the *R/V Oscar Dyson*, $\log(q_{MF})$ is the log catchability of the *R/V Oscar Dyson*, $\delta_{OD:MF}$ = 0.1240 is the mean of log scale paired difference in backscatter, mean[log(s_AOD)-log(s_AMF)] obtained from the vessel comparison, and σ_S = 0.0244 is the standard error of the mean.

Ageing error

An ageing error conversion matrix is used in the assessment model to translate model population numbers at age to expected fishery and survey catch at age (Table 1.14). Dorn et al. (2003) estimated this matrix using an ageing error model fit to the observed percent reader agreement at ages 2 and 9. Mean percent agreement is close to 100% at age 1 and declines to 40% at age 10. Annual estimates of percent agreement are variable, but show no obvious trend; hence a single conversion matrix for all years in the assessment model was adopted. The model is based on a linear increase in the standard deviation of ageing error and the assumption that ageing error is normally distributed. The model predicts percent agreement by taking into account the probability that both readers are correct, both readers are off by one year in the same direction, and both readers are off by two years in the same direction (Methot 2000). The probability that both agree and were off by more than two years was considered negligible. A recent study evaluated pollock ageing criteria using radiometric methods and found them to be unbiased (Kastelle and Kimura 2006).

Length frequency data

The assessment model was fit to length frequency data from various sources by converting predicted age distributions (as modified by age-specific selectivity) to predicted length distributions using an age-length conversion matrix. This approach was used only when age composition estimates were unavailable. Because seasonal differences in pollock length at age are large, several conversion matrices were used. For each matrix, unbiased length distributions at age were estimated for several years using age-length keys, and then averaged across years. A conversion matrix was estimated using 1992-98 Shelikof Strait acoustic survey data and used for winter survey length frequency data. The following length bins were used: 5-16, 17 - 27, 28 - 35, 36 - 42, 43 - 50, 51 - 55, 56 - 70 (cm). Age data for the most recent survey is now routinely available so this option does not need to be invoked. A conversion matrix was estimated using second and third trimester fishery age and length data during the years (1989-98), and was used when age composition data are unavailable for the summer bottom trawl survey, which is only for the most recent survey in the year that the survey is conducted. The following length bins were used: 5-16,25 - 34, 35 - 41, 42 - 45, 46 - 50, 51 - 55, 56 - 70 (cm), so that the first four bins would capture most of the summer length distribution of the age-1, age-2, age-3 and age-4 fish, respectively. Bin definitions were different for the summer and the winter conversion matrices to account for the seasonal growth of the younger fish (ages 1-4).

Parameters Estimated Outside the Assessment Model

Pollock life history characteristics, including natural mortality, weight at age, and maturity at age, were estimated independently outside the assessment model. These parameters are used in the model to estimate spawning and population biomass and obtain predictions of fishery catch and survey biomass. Pollock life history parameters include:

- Natural mortality (*M*)
- Proportion mature at age
- Weight at age and year by fishery and by survey

Natural mortality

Hollowed and Megrey (1990) estimated natural mortality (*M*) using a variety of methods including estimates based on: a) growth parameters (Alverson and Carney 1975, and Pauly 1980), b) GSI (Gunderson and Dygert, 1988), c) monitoring cohort abundance, and d) estimation in the assessment model. These methods produced estimates of natural mortality that ranged from 0.22 to 0.45. The maximum age observed was 22 years. Up until this assessment, natural mortality has been assumed to be

0.3 for all ages.

Hollowed et al. (2000) developed a model for Gulf of Alaska pollock that accounted for predation mortality. The model suggested that natural mortality declines from 0.8 at age 2 to 0.4 at age 5, and then remains relatively stable with increasing age. In addition, stock size was higher when predation mortality was included. In a simulation study, Clark (1999) evaluated the effect of an erroneous *M* on both estimated abundance and target harvest rates for a simple age-structured model. He found that "errors in estimated abundance and target harvest rate were always in the same direction, with the result that, in the short term, extremely high exploitation rates can be recommended (unintentionally) in cases where the natural mortality rate is overestimated and historical exploitation rates in the catch-at-age data are low." Clark (1999) proposed that the chance of this occurring could be reduced by using an estimate of natural mortality on the lower end of the credible range, which is the approach used in this assessment.

In this assessment, several methods to estimate of the age-specific pattern of natural mortality were evaluated. Two general types of methods were used, both of which are external to the assessment model. The first type of method is based initially on theoretical life history or ecological relationships that are then evaluated using meta-analysis, resulting in an empirical equation that relates natural mortality to some more easily measured quantity such as length or weight. The second type of method is an age-structured statistical analysis using a multispecies model or single species model where predation is modeled. There are three examples of such models for pollock in Gulf of Alaska, a single species model with predation by Hollowed et al. (2000), and two multispecies models that included pollock by Van Kirk et al. (2010 and 2012). These models were published in the peer-reviewed literature, but likely did not receive the same level of scrutiny as stock assessment models. Although these models also estimate time-varying mortality, we averaged the total mortality (residual natural mortality plus predation mortality) for the last decade in the model to obtain a mean age-specific pattern (in some cases omitting the final year when estimates were much different than previous years). Use of the last decade was an attempt to use estimates with the strongest support from the data. Approaches for inclusion of time-varying natural mortality will be considered in future pollock assessments. The three theoretical/empirical methods used were the following:

Brodziak et al. 2011—Age-specific M is given by

$$M(a) = \begin{cases} M_c \dfrac{L_{mat}}{L(a)} & for\ a < a_{mat} \\ M_c & for\ a \geq a_{mat}, \end{cases}$$

where L_{mat} is the length at maturity, M_c = 0.30 is the natural mortality at L_{mat}, L(a) is mean length at age for the summer bottom trawl survey for 1984-2013.

Lorenzen 1996—Age-specific M for ocean ecosystems is given by

$$M(a) = 3.69\ \overline{W}_a^{-0.305},$$

where $\overline{W}_a$ is the mean weight at age from the summer bottom trawl survey for 1984-2013.

Gislason et al. 2010—Age-specific M is given by

$$\ln(M) = 0.55 - 1.61 \ln(L) + 1.44 \ln(L_\infty) + \ln(K),$$

where L_∞ = 65.2 cm and K = 0.30 were estimated by fitting von Bertalanffy growth curves using the NLS routine in R using summer bottom trawl age data for 2005-2009 for sexes combined in the central and western Gulf of Alaska.

Results were reasonably consistent and suggest use of a higher mortality rate for age classes younger than the age at maturity (Table 1.15 and Fig. 1.12). Somewhat surprisingly the theoretical/empirical estimates were similar on average to predation model estimates. To obtain an age-specific natural mortality schedule for use in the stock assessment, we used an ensemble approach and averaged the results for all methods. Then we used the tip recommended by Clay Porch in Brodziak et al (2011) to rescale the age-specific values so that the average for range of ages equals a specified value. Age-specific values were rescaled so that a natural mortality for fish greater than or equal to age 5, the age at 50% maturity, was equal to 0.3, the value of natural mortality used in previous pollock assessments.

Maturity at age

Maturity stages for female pollock describe a continuous process of ovarian development between immature and post-spawning. For the purposes of estimating a maturity vector (the proportion of an age group that has been or will be reproductively active during the year) for stock assessment, all fish greater than or equal to a particular maturity stage are assumed to be mature, while those less than that stage are assumed to be immature. Maturity stages in which ovarian development had progressed to the point where ova were distinctly visible were assumed to be mature (i.e., stage 3 in the 5-stage pollock maturity scale). Maturity stages are qualitative rather than quantitative, so there is subjectivity in assigning stages, and a potential for different technicians to apply criteria differently. Because the link between pre-spawning maturity stages and eventual reproductive activity later in the season is not well established, the division between mature and immature stages is problematic. Changes in the timing of spawning could also affect maturity at age estimates. Merati (1993) compared visual maturity stages with ovary histology and a blood assay for vitellogenin and found general consistency between the different approaches. Merati (1993) noted that ovaries classified as late developing stage (i.e., immature) may contain yolked eggs, but it was unclear whether these fish would have spawned later in the year. The average sample size of female pollock maturity stage data per year since 2000 from winter acoustic surveys in the Gulf of Alaska is 358 (Table 1.16).

Estimates of maturity at age in 2014 from winter acoustic surveys were much below the long-term average for ages 4-5, but slightly above average for age 6 (Fig. 1.13). Inter-annual changes in maturity at age may reflect environmental conditions, pollock population biology, effect of strong year classes moving through the population, or simply ageing error. Because there did not appear to be an objective basis for excluding data, the 1983-2014 average maturity at age was used in the assessment.

Logistic regression (McCullagh and Nelder 1983) was also used to estimate the age and length at 50% maturity at age for each year. Annual estimates of age at 50% maturity are highly variable and range from 3.5 years in 1983 to 6.1 years in 1991, with an average of 4.9 years. Length at 50% mature is less variable than the age at 50% mature, suggesting that at least some of the variability in the age at maturity can be attributed to changes in length at age (Fig 1.14). Changes in year-class dominance could also potentially affect estimates of maturity at age. There is less evidence of trends in the length at 50% mature, with only the 1983 and 1984 estimates as unusually low values. The average length at 50% mature for all years is approximately 44 cm. Since 2008 there has been an increase in the length at 50% mature to 48 cm, possibly reflecting the increase in pollock growth.

Weight at age

Year-specific weight-at-age estimates are used in the model to obtain expected catches in biomass. Where possible, year and survey-specific weight-at-age estimates are used to obtain expected survey biomass. For each data source, unbiased estimates of length at age were obtained using year-specific age-length keys. Bias-corrected parameters for the length-weight relationship, $W = a L^b$, were also estimated. Weights at age were estimated by multiplying length at age by the predicted weight based on the length-weight regressions. A plot of weight-at-age from the Shelikof Strait acoustic survey indicates that there has been a substantial increase in weight at age for older pollock (Fig. 1.15). For pollock greater than age 6, weight-at-age has nearly doubled since 1983-1990. However, weight at age in the last four years, 2011-2014, has been stable to decreasing. Further analyses are needed to evaluate whether these changes are a density-dependent response to declining pollock abundance, or whether they are environmentally forced. Changes in weight-at-age have potential implications for status determination and harvest control rules.

Parameters Estimated Inside the Assessment Model

A large number of parameters are estimated when using this modeling approach. More than half of these parameters are year-specific deviations in fishery selectivity coefficients. Parameters were estimated using AD Model Builder (Version 10.1), a C++ software language extension and automatic differentiation library (Fournier et al. 2012). Parameters in nonlinear models are estimated in ADModel Builder using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. The optimizer in AD Model Builder is a quasi-Newton routine (Press et al. 1992). The model is determined to have converged when the maximum parameter gradient is less than a small constant (set to 1 x 10^{-6}). AD Model Builder includes post-convergence routines to calculate standard errors (or likelihood profiles) for any quantity of interest.

A list of model parameters is shown below:

Population process modeled	*Number of parameters*	*Estimation details*
Recruitment	Years 1970-2014 = 45	Estimated as log deviances from the log mean; recruitment in 1970-77, and 2013 and 2014 constrained by random deviation process error.
Natural mortality	Age-specific= 10	Not estimated in the model
Fishing mortality	Years 1970-2014 = 45	Estimated as log deviances from the log mean
Mean fishery selectivity	4	Slope parameters estimated on a log scale, intercept parameters on an arithmetic scale
Annual changes in fishery selectivity	2 * (No. years-1) = 88	Estimated as deviations from mean selectivity and constrained by random walk process error
Survey catchability	No. of surveys + 1 = 6	Catchabilities estimated on a log scale. Two catchability periods were estimated for the acoustic survey.
Survey selectivity	8 (acoustic survey: 2, BT survey: 2, ADFG survey: 2)	Slope parameters estimated on a log scale.
Total	108 estimated parameters +88 process error parameters + 10 fixed parameters = 206	

Results

Model selection and evaluation

Model Selection

This year a number of changes were implemented to the assessment model based on the 2012 CIE review, SSC and Plan Team comments. In our response to the CIE review, we articulated several general principles to guide improvements to the assessment moving forward. Two of these principles were 1) to reduce data sets to those that are informative about current status by removing earlier and more questionable data sets, 2) improve relative weightings given to different data sets. Additionally changes were considered that would make the assessment model more realistic biologically and reduced dependence on strong assumptions. To accomplish these goals we stepped through a series of models beginning with the base model from last year's assessment. Each model in the list below adds a feature to the previous model. Generally we tried to address the objective of removing earlier and more questionable data sets first, and then considered whether changes in the model configuration were an improvement. This is, of course, one of many possible paths that could have been evaluated, but it seemed the most straightforward and logical approach to us.

Alternative models that were evaluated are listed below (note that for each model the changes are cumulative):

Model 1—include all new data.
Model 2—use the revised total catch, catch at age, and weight at age estimates, correct several minor coding errors.
Model 3—start the model in 1970, and exclude length composition data for 1964-1971.
Model 4—remove summer bottom trawl surveys for 1984 and 1987, and Shelikof Strait acoustic surveys for 1981-1991.
Model 5—estimate summer bottom trawl catchability using a prior, and assume asymptotic selectivity.
Model 6—use random walks in fishery selectivity parameter to model fishery selectivity instead of blocks, and assume no interannual variation in the descending portion of the curve.
Model 7—use age-specific natural mortality.
Model 8—use indices for the age-1 and age-2 in the acoustic survey.
Model 9—iteratively tune age composition data (this is the proposed base model).
Model 10—evaluate a net selectivity correction for acoustic surveys.

Estimated spawning biomass was plotted for each model in a series of plots, Models 1-4 (Fig. 1.16), Models 4-7 (Fig. 1.17), and Models 7-10 (Fig. 1.18). Models 1-4 showed similar patterns of spawning biomass. Neither the new data nor the re-estimated historical data had a strong influence on model results. Shifting the initial year of the assessment model to 1970 also did not have a strong influence on model results. Removing the summer bottom trawl surveys for 1984 and 1987, and Shelikof Strait acoustic surveys for 1981-1991 had a larger influence on the spawning biomass trend, but mostly during 1980-85 period.

Models 4-7 also showed similar patterns of spawning biomass. In previous assessments, the bottom trawl survey was modeled with assumed catchability of 1.0 and a domed shaped selectivity pattern. However the domed-shaped selectivity was difficult to estimate reliably. Similar biomass levels biomass levels are estimated under the assumption of asymptotic selectivity and estimated catchability, which in our view is a better way of modeling the survey. Some experimentation with estimating catchability as a free parameter, i.e., without using a prior, indicated it was feasible but that likelihood surface was very flat across a broad range of catchabilities, and the maximum could change substantially with slight changes to model assumptions. Therefore use of a prior was considered necessary to obtain a stable outcome. Due to the flatness of the likelihood surface, the posterior estimate of catchability was 0.86, very close to the prior median of 0.85.

Models 7-10 also showed similar patterns of a spawning biomass. Use of an age-specific pattern of natural mortality increases the size of estimated age-1 recruitment by a factor of about five. Selectivity patterns for the fishery and the survey also shift when a higher juvenile mortality is assumed, but the overall effect on biomass trends and management parameters is minor. Modeling the age-1 and age-2 pollock as separate indices rather including them in the age-composition multinomial likelihood also had minor effects on the model, but this was considered a better approach because it will allow evaluation of non-linearity in the relationship between the acoustic age-1 and age-2 indices and recruitment.

Model 9, which used iterative reweighting of composition data, was developed by first standardizing the input sample sizes by data set to provide initial weights for the tuning procedure. Fishery age composition was given an initial sample size of 200 except when the age sample in a given year came from fewer than 200 hauls, in which case the number of hauls was used. This scheme gave lower weight to age composition in the first couple of years of data, 1975-77, and during most years during the period 1985-1998, when the number of hauls sampled tended to be low. Both the acoustic survey and the bottom trawl were given an initial sample size of 60, and the ADFG crab/groundfish survey was given a weight of 30. Only several steps were needed for the input sample size to approximate the harmonic mean of effective N. Fishery age composition was down weighted to a sample size of 107, the bottom trawl age composition was down weighted to sample size of 28, and 3+ acoustic age composition was down weighted to sample size of 10. The ADFG survey age composition input sample size did not need to be changed. The age-1 and the age-2 acoustic indices were also iteratively reweighted using RMSE as a tuning variable. Ultimately the tuning process did not change the estimated biomass trends, but there were improvements to the fit to the survey biomass time series as a result of reweighting.

Model 10, which used the net-selectivity corrected acoustic biomass, resulted in slightly higher spawning biomass (about 15% higher over the last five years of the assessment model). Selectivity increased for the age-1 pollock, and catchability for the older pollock declined. The model estimates that less than 50% of the adult biomass spawns in Shelikof Strait (i.e., catchability<0.5), which is difficult to reconcile with information from acoustic surveys conducted elsewhere in the Gulf of Alaska. There were improvements in the fit to the age-1 and age-2 pollock indices, but the RMSE for the biomass index increased, indicating a worse fit. Ultimately we decided that additional model exploration was needed before recommending model 10. In addition, the method for making the net selectivity correction to the historical surveys needs to be reviewed prior to incorporating the revised estimates in the model. There are other issues that need to be resolved as well, such as whether other acoustic surveys the GOA need to be corrected, and how these corrections may impact the calculations for apportioning the TAC in the A and B seasons. Therefore we concluded that Model 9 should be used as the base model for model evaluation, reporting of time series estimates, and developing ABC and OFL recommendations.

Model Evaluation

Model fit to age composition data was evaluated using plots of observed and predicted age composition in the fishery (Fig. 1.19), Shelikof Strait acoustic survey (Fig. 1.20), the NMFS trawl survey (Fig. 1.21), and the ADFG trawl survey (Fig. 1.22). Model fits to fishery age composition data are adequate in most years. The largest residuals tended to be at ages 1-2 the NMFS bottom trawl survey due to inconsistencies between the initial estimates of abundance and subsequent information about year class size.

Model fits to biomass estimates are similar to previous assessments, and general trends in survey time series are fit reasonably well (Figs. 1.23 and1.24). It is difficult for the model to fit the rapid increase in the Shelikof Strait acoustic survey and the NMFS survey in 2013 since an age-structured pollock population cannot increase as rapidly as is indicated by these surveys. In contrast, the model expectation is close to the ADFG survey in 2013 and 2014. The fit to the age-1 and age-2 acoustic indices appeared adequate though variable (Fig. 1.25). There is an indication of non-linearity in the fit to age-1 index needs to be explored further.

Time series results

Parameter estimates and model output are presented in a series of tables and figures. Estimated survey and fishery selectivity for different periods are given in Table 1.17 (see also Figure 1.26). Table 1.18 gives the estimated population numbers at age for the years 1970-2014. Table 1.19 gives the estimated time series of age 3+ population biomass, age-1 recruitment, and harvest rate (catch/3+ biomass) for 1977-2014 (see also Fig. 1.27). Table 1.20 gives coefficients of variation and 95% confidence intervals for age-1 recruitment and spawning stock biomass. Stock size peaked in the early 1980s at approximately 60% of the proxy for unfished stock size ($B_{100\%}$ = mean 1979-2013 recruitment multiplied by the spawning biomass per recruit in the absence of fishing (SPR@F=0)). In 1998, the stock dropped below the $B_{40\%}$ for the first time since the early 1980s, reached a minimum in 2003 of 20% of unfished stock size. Over the years 2009-2013 stock size has shown a strong upward trend from 24% to 47% of unfished stock size, but declined to 38% of unfished stock size in 2014.

Retrospective comparison of assessment results

A retrospective comparison of assessment results for the years 1993-2014 indicates the current estimated trend in spawning biomass for 1990-2013 is consistent with previous estimates (Fig. 1.28, top panel). All time series show a similar pattern of decreasing spawning biomass in the 1990s, a period of greater stability in 2000s, followed by an increase starting in 2008. There appear to be no consistent pattern of bias in estimates of ending year biomass, but assessment errors are clearly correlated over time, such that there are runs of over estimates and under estimates. Because of the high survey biomass estimates in 2013, a moderate retrospective pattern is evident between the current assessment and the last three assessments, where the spawning biomass has been revised upwards with each assessment. The estimated 2014 age composition from the current assessment is reasonably consistent with the projected 2014 age composition in the 2013 assessment (Fig. 1.28, bottom panel). The largest change is the estimate of the age-1 fish (2013 year class), which is much higher due to the change in the natural mortality schedule. The 2013 year class was estimated by the assessment model to be slightly below the mean based on Shelikof Strait survey results.

Retrospective analysis of base model

A retrospective analysis consists of dropping the data year-by-year from the current model, and provides a different perspective than a comparison of current assessment with previous assessments. Figure 1.29 shows a retrospective plot with data sequentially removed back to 2004. There is up to 40% error in the assessment (if the current assessment is accepted as truth), but usually the errors are much smaller. There is no consistent retrospective pattern to errors in the assessment.

Stock productivity

Recruitment of Gulf of Alaska pollock is more variable (CV = 0.88) than Eastern Bering Sea pollock (CV = 0.62). Other North Pacific groundfish stocks, such as sablefish and Pacific ocean perch, also have high recruitment variability. However, unlike sablefish and Pacific ocean perch, pollock have a short generation time (~8 yrs), so that large year classes do not persist in the population long enough to have a buffering effect on population variability. Because of these intrinsic population characteristics, the typical pattern of biomass variability for Gulf of Alaska pollock will be sharp increases due to strong recruitment, followed by periods of gradual decline until the next strong year class recruits to the population. Gulf of Alaska pollock is more likely to show this pattern than other groundfish stocks in the

North Pacific due to the combination of a short generation time and high recruitment variability.

Since 1980, strong year classes have occurred every four to six years, although this pattern appears much weaker since 2004 (Fig. 1.27). Because of high recruitment variability, the functional relationship between spawning biomass and recruitment is difficult to estimate despite good contrast in spawning biomass. Strong and weak year classes have been produced at high and low level of spawning biomass. Spawner productivity is higher on average at low spawning biomass compared to high spawning biomass, indicating that survival of eggs to recruitment is density-dependent (Fig. 1.30). However, this pattern of density-dependent survival only emerges on a decadal scale, and could be confounded with environmental variability on the same temporal scale. These decadal trends in spawner productivity have produced the pattern of increase and decline in the GOA pollock population. The last two decades have been a period of relatively low spawner productivity, though some increase is apparent since 2004.

Harvest Recommendations

Reference fishing mortality rates and spawning biomass levels

Since 1997, Gulf of Alaska pollock have been managed under Tier 3 of NPFMC harvest guidelines. In Tier 3, reference mortality rates are based on the spawning biomass per recruit (SPR), while biomass reference levels are estimated by multiplying the SPR by average recruitment. Estimates of the F_{SPR} harvest rates were obtained using the life history characteristics of Gulf of Alaska pollock (Table 1.21). Spawning biomass reference levels were based on mean 1978-2013 age-1 recruitment (5.889 billion), which is more than five times the post-1977 mean in the 2013 assessment due to the use of new natural mortality schedule. Spawning was assumed to occur on March 15th, and female spawning biomass was calculated using mean weight at age for the Shelikof Strait acoustic surveys in 2009-2014 to estimate current reproductive potential. A substantial increase in pollock weight-at-age has been observed (Fig. 1.15), which may be a density-dependent response to low abundance or due to environmental forcing. The SPR at F=0 was estimated as 0.132 kg/recruit at age one. Again this value is much lower than previous estimates due to the change in natural mortality schedule. F_{SPR} rates depend on the selectivity pattern of the fishery. Selectivity has changed as the fishery evolved from a foreign fishery occurring along the shelf break to a domestic fishery on spawning aggregations and in nearshore waters (Fig. 1.1). For SPR calculations, selectivity was based on the average for 2009-2013 to reflect current selectivity patterns.

Gulf of Alaska pollock F_{SPR} harvest rates are given below:

		Equilibrium under average 1978-2013 recruitment				
F_{SPR} rate	*Fishing mortality*	*Avg. Recr. (Million)*	*Total 3+ biom. (1000 t)*	*Female spawning biom. (1000 t)*	*Catch (1000 t)*	*Harvest rate*
100.0%	0.000	5889	2728	779	0	0.0%
40.0%	0.243	5889	1617	312	235	14.5%
35.0%	0.285	5889	1515	273	254	16.8%

The $B_{40\%}$ estimate of 312,000 t represents a 7% increase from the $B_{40\%}$ estimate of 290,000 t in the 2013 assessment, which is a mostly a result of incorporating the larger 2012 recruitment in the average. As expected, the change in the natural mortality rate had little influence on the reference point estimates. The base model projection of female spawning biomass in 2015 is 309,869 t, which is 39.7% of unfished spawning biomass (based on average post-1977 recruitment) and below $B_{40\%}$ (312,000 t), thereby placing Gulf of Alaska pollock in sub-tier “b” of Tier 3.

2015 acceptable biological catch

The definitions of OFL and maximum permissible F_{ABC} under Amendment 56 provide a buffer between the overfishing level and the intended harvest rate, as required by NMFS national standard guidelines. Since estimates of stock biomass from assessment models are uncertain, the buffer between OFL and ABC provides a margin of safety so that assessment error will not result in the OFL being inadvertently exceeded. For Gulf of Alaska pollock, the maximum permissible F_{ABC} harvest rate is 85.1% of the OFL harvest rate. In the 2001 assessment, based on an analysis that showed that the buffer between the maximum permissible F_{ABC} and OFL decreased when the stock is below approximately $B_{50\%}$, we developed a more conservative alternative that maintains a constant buffer between ABC and F_{ABC} at all stock levels (Table 1.22). While there is always some probability of exceeding F_{OFL} due to imprecise stock assessments, it seemed unreasonable to reduce the safety margin as the stock declines.

This alternative is given by the following

Define $B^* = B_{40\%} \frac{F_{35\%}}{F_{40\%}}$

Stock status: $B / B^* > 1$ *, then* $F = F_{40\%}$

Stock status: $0.05 < B / B^* \le 1$ *, then* $F = F_{40\%} \times (B/ B^* - 0.05) / (1 - 0.05)$

Stock status: $B / B^* \le 0.05$ *, then* $F = 0$

This alternative has the same functional form as the maximum permissible F_{ABC}; the only difference is that it declines linearly from B^* (= $B_{47\%}$) to $0.05B^*$ (Fig. 1.31).

Projections for 2015 for F_{OFL}, the maximum permissible F_{ABC}, and an adjusted $F_{40\%}$ harvest rate with a constant buffer between F_{ABC} and F_{OFL} are given in Table 1.23.

ABC recommendation

The recommended ABC was based on a model projection using the base model and the more conservative adjusted $F_{40\%}$ harvest rate described above. The author’s recommended 2014 ABC is therefore 191,309 t, which is an increase of 14% from the 2014 ABC. In 2016, the ABC based an adjusted $F_{40\%}$ harvest rate is 250,824 t. The OFL in 2015 is 256,545 t, and the OFL in 2016 if the recommended ABC is taken in 2015 is 321,067 t.

In last year’s assessment, the magnitude of the 2012 year class was a major issue when deciding which ABCs and OFLs to recommend. New information about this year class came from winter acoustic surveys in 2014 in Shelikof Strait and in the Shumagin Island. This new information indicates that this year class is still very abundant. The 2014 Shelikof Strait acoustic survey estimate of age-2 pollock is 3.6 billion, which is the second largest in time series. The 2014 Shumagin acoustic survey estimate of age-2 pollock is largest in the time series. This year, all of this information is incorporated into the assessment using age-1 and age-2 abundance indices. In last year’s assessment, the possibility of setting the 2012 year class equal to the average was considered but not recommended. The new information about the magnitude of the 2012 year class added in 2014 tends to support the decision that was made in last year's assessment. Therefore we have continued the approach of using the 2012 year class abundance as estimated to project ABCs and OFLs.

To evaluate the probability that the stock will drop below the $B_{20\%}$ threshold, we projected the stock forward for five years using the author's recommended fishing mortality schedule. This projection incorporates uncertainty in stock status, uncertainty in the estimate of $B_{20\%}$, and variability in future recruitment. We then sampled from the likelihood of future spawning biomass using Markov chain Monte Carlo (MCMC). A chain of 1,000,000 samples was thinned by selecting every 200th sample. Analysis of the thinned MCMC chain indicates that probability of the stock dropping below $B_{20\%}$ will be negligible in all years (Fig. 1.32).

Projections and Status Determination

A standard set of projections is required for stocks managed under Tier 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For each scenario, the projections begin with the 2014 numbers at age at the start of the year as estimated by the assessment model, and assume the 2014 catch will be equal to 159,149 t (95% of the TAC). In each year, the fishing mortality rate is determined by the spawning biomass in that year and the respective harvest scenario. Recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments during 1978-2013 as estimated by the assessment model. Spawning biomass is computed in each year based on the time of peak spawning (March 15) using the maturity and weight schedules in Table 1.21. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios are used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2015, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to the F_{ABC} recommended in the assessment.
>
> *Scenario 3*: In all future years, F is set equal to the five-year average F (2010-2014). (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 4*: In all future years, F is set equal to $F_{75\%}$. (Rationale: This scenario represents a very conservative harvest rate and was requested by the Regional Office based on public comment.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2014 or 2) above 1/2 of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished)

Scenario 7: In 2015 and 2016, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be 1) above its MSY level in 2016, or 2) above 1/2 of its MSY level in 2016 and above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

Results from scenarios 1-5 are presented in Table 1.23. Under all harvest policies, mean spawning biomass is projected to remain stable or to increase in over the next five years (Fig. 1.33). Plots of individual projection runs are highly variable (Fig. 1.34), and may provide a more realistic view of potential pollock abundance in the future.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

The catch estimate for the most recent complete year (2013) is 96,363 t, which is less than the 2013 OFL of 150,817 t. Therefore, the stock is not subject to overfishing.

Scenarios 6 and 7 are used to make the MSFCMA's other required status determination as follows:

Under scenario 6, spawning biomass is estimated to be 340,111 t in 2014, which is above $B_{35\%}$ (273,000 t). Therefore, Gulf of Alaska pollock is not currently overfished.

Under scenario 7, projected mean spawning biomass in 2016 is 320,665 t, which is above $B_{35\%}$ (273,000 t). Therefore, Gulf of Alaska pollock is not approaching an overfished condition.

Ecosystem considerations

Prey of pollock

An ECOPATH model was assembled to characterize food web structure in Gulf of Alaska using diet data and population estimates during 1990-93. We use ECOPATH here simply as a tool to integrate diet data and stock abundance estimates in a consistent way to evaluate ecosystem interactions. We focus primarily on first-order trophic interactions: prey of pollock and the predators of pollock.

Pollock trophic interactions occur primarily in the pelagic pathway in the food web, which leads from phytoplankton through various categories of zooplankton to planktivorous fish species such as capelin and sandlance (Fig. 1.35); the primary prey of pollock are euphausiids. Pollock also consume shrimp, which are more associated with the benthic pathway, and make up approximately 18% of age 2+ pollock diet. All ages of GOA pollock are primarily zooplanktivorous during the summer growing season (>80% by weight zooplankton in diets for juveniles and adults; Fig 1.35). While there is an ontogenetic shift in diet from copepods to larger zooplankton (primarily euphausiids) and fish, cannibalism is not as prevalent in the Gulf of Alaska as in the Eastern Bering Sea, and fish consumption is low even for large pollock (Yang and Nelson 2000).

There are no extended time series of zooplankton abundance for the shelf waters of the Gulf of the Alaska—though Seward Line monitoring now extends from 1998 to the present, and efforts are underway at AFSC to develop Euphausiid abundance indices from acoustic surveys in the Gulf of Alaska. Brodeur and Ware (1995) provide evidence that biomass of zooplankton in the center of the Alaska Gyre was twice as high in the 1980s than in the 1950s and 1960s, consistent with a shift to positive values of the PDO since 1977. The percentage of zooplankton in diets of pollock is relatively constant throughout the 1990s (Fig. 1.36). While indices of stomach fullness exist for these survey years, a more detailed bioenergetics modeling approach would be required to examine if feeding and growth conditions have changed over time, especially given the fluctuations in GOA water temperature in recent years, as water temperature has a considerable effect on digestion and other energetic rates.

Predators of pollock

Initial ECOPATH model results show that the top five predators on pollock >20 cm by relative importance are arrowtooth flounder, Pacific halibut, Pacific cod, Steller sea lion (SSL), and the directed pollock fishery (Fig. 1.37). For pollock less than 20cm, arrowtooth flounder represent close to 50% of total mortality. All major predators show some diet specialization, and none depend on pollock for more than 50% of their total consumption (Fig. 1.38). Pacific halibut is most dependent on pollock (48%), followed by SSL (39%), then arrowtooth flounder (24% for juvenile and adult pollock combined), and lastly Pacific cod (18%). It is important to note that although arrowtooth flounder is the largest single source of mortality for both juvenile and adult pollock (Fig 1.39), arrowtooth depend less on pollock in their diets then do the other predators.

Arrowtooth consume a greater number of smaller pollock than do Pacific cod or Pacific halibut, which consume primarily adult fish. However, by weight, larger pollock are important to all three predators (Fig. 1.39). Size composition of pollock consumed by the western stock of Steller sea lions tend towards larger fish, and are similar to the size of cod and halibut consumed (Zeppelin et al. 2004). The diet of Pacific cod and Pacific halibut are similar in that the majority of their diet besides pollock is from the benthic pathway of the food web. Alternate prey for Steller sea lions and arrowtooth flounder are similar, and come primarily from the pelagic pathway.

Predation mortality, as estimated by ECOPATH, is extremely high for GOA pollock >20cm. Estimates for the 1990-1993 time period indicate that known sources of predation sum to 90%-120% of the total production of walleye pollock calculated from 2004 stock assessment growth and mortality rates; estimates greater than 100% may indicate a declining stock (as shown by the stock assessment trend in the early 1990s; Fig 1.40, top), or the use of mortality rates which are too low. Conversely, as >20cm pollock include a substantial number of 2-year olds, it may be that mortality rate estimates for this age range is low. In either case, predation mortality for pollock in the GOA is much greater a proportion of pollock production than as estimated by the same methods for the Bering Sea, where predation mortality (primarily pollock cannibalism) was up to 50% of total production.

Aside from the long-recognized decline in Steller sea lion abundance, the major predators of pollock in the Gulf of Alaska are stable to increasing, in some cases notably so since the 1980s (Fig. 1.40, top). This high level of predation is of concern in light of the declining trend of pollock with respect to predator increases. To assess this concern, it is important to determine if natural mortality may have changed over time (e.g. the shifting control hypothesis; Bailey 2000). To examine predator interactions more closely than in the initial model, diet data of major predators in trawl surveys were examined in all survey years since 1990.

Trends in total consumption of walleye pollock were calculated by the following formula:

$$Consumption = \sum B_{pred,size,subregion} \cdot DC_{pred,size,subregion} \cdot WLF_{pred,size,GOA} \cdot Ration_{pred,size}$$

where B(pred, size, subregion) is the biomass of a predator size class in the summer groundfish surveys in a particular survey subregion; DC is the percentage by weight of pollock in that predator group as measured from stomach samples, WLF is the weight frequency of pollock in the stomachs of that predator group pooled across the GOA region, calculated from length frequencies in stomachs and length-weight relationships from the surveys. Finally, ration is an applied yearly ration for that predator group calculated by fitting weight-at-age to the generalized von Bertalanffy growth equations as described in Essington et al. (2001). Ration is assumed fixed over time for a given size class of predator.

Fig. 1.40 (bottom) shows annual total estimates of consumption of pollock (all age classes) in survey years by the four major fish predators. Other predators, shown as constant, are taken from ECOPATH modeling results and displayed for comparison. Catch is shown as reported in Table 1.1. In contrast, the line in the figure shows the historical total production (tons/year) plus yearly change in biomass (positive or negative) from the stock assessment results. In a complete accounting of pollock mortality, the height of the bars should match the height of the line. As shown, estimates of consumption greatly surpass estimates of production; fishing mortality is a relatively small proportion of total consumption. Overestimates in consumption rates could arise through seasonal differences in diets; while ration is seasonally adjusted, diet proportions are based on summer data. Also, better energetic estimates of consumption would improve these estimates. In terms of the stock assessment, underestimates of production could result from underestimating natural mortality, especially at ages 2-3, underestimating the rate of decline which occurred between 1990-present, or underestimates of the total biomass of pollock; this analysis should be revisited using higher mortality at younger ages than assumed in the current stock assessment.

To better judge natural mortality, consumption was calculated for two size groups of pollock, divided at 30cm fork length. This size break, which differs from the break in the ECOPATH analysis, is based on finding minima between modes of pollock in predator diets (Fig. 1.41). This break is different from the conversion matrices used in the stock assessment; perhaps due to differences in size selection between predators and surveys. For this analysis, it is assumed that pollock<30cm are ages 0-2 while pollock ≥30cm are age 3+ fish.

Consumption of age 0-2 pollock per unit predator biomass (using survey biomass) varied considerably through survey years, although within a year all predators had similar consumption levels (Fig. 1.42, top). Correlation coefficients of consumption rates were 0.98 between arrowtooth and halibut, and 0.90 for both of these species with pollock. Correlation coefficients of these three species with cod were ~0.55 for arrowtooth and halibut and ~0.20 with pollock. The majority of this predation by weight occurred on age 2 pollock.

Plotted against age 2 pollock numbers calculated from the stock assessment, consumption/biomass and total consumption by predator shows a distinct pattern (Fig. 1.42, lower two graphs). In "low" recruitment years consumption is consistently low, while in high recruitment years consumption is high, but does not increase linearly, rather consumptions seems to level out at high numbers of juvenile pollock, resembling a classic "Type II" functional response. This suggests the existence bottom-up control of juvenile consumption, in which strong year classes of pollock "overwhelm" feeding rates of predators, resulting in potentially lower juvenile mortality in good recruitment years which may amplify the recruitment. However, this result should be examined iteratively within the stock assessment, as the back-calculated numbers at age 2 assume a constant natural mortality rate. Assuming a lower mortality rate due to predator satiation would lead to lower estimates of age 2 numbers, which would make the response appear more linear.

Consumption of pollock ≥30cm shows a different pattern over time. A decline of consumption per unit biomass is evident for halibut and cod (Fig. 1.42, top). Arrowtooth shows an insignificant decline; it is possible that the noise in the arrowtooth trend, mirroring the consumption of <30cm fish, is due to the choice of 30cm as an age cutoff. As a function of age 3+ assessment biomass, consumption per unit biomass and total consumption remained constant as the stock declined, and then fell off rapidly at low biomass levels in recent years (Fig. 1.42, middle and bottom). Again, this result should be approached iteratively, but it suggests increasing predation mortality on age 3+ pollock during 1990-2005, possibly requiring increased foraging effort from predators.

There has been a marked decline in Pacific halibut weight at age since the 1970s that Clark et al. (1999) attributed to the 1977 regime shift without being able to determine the specific biological mechanisms that produced the change. Possibilities suggested by Clark et al. (1999) include the physiological effect of an increase in temperature, intra- and interspecific competition for prey, or a change in prey quality. The two species most dependent on pollock in the early 1990s (Pacific halibut and Steller sea lion) have both shown an exceptional biological response during the post-1977 period consistent with a reduction in carrying capacity (growth for Pacific halibut, survival for Steller sea lions). In contrast, the dominant predator on pollock in the Gulf of Alaska (arrowtooth flounder) has increased steadily in abundance over the same period and shows no evidence of decline in size at age. Given that arrowtooth flounder has a range of potential prey types to select from during periods of low pollock abundance (Fig. 1.37), we do not expect that arrowtooth would decline simply due to declines in pollock.

Taken together, Figs. 1.41 and 1.42 suggest that recruitment remains bottom-up controlled even under the current estimates of high predation mortality, and may lead to strong year classes. However, top-down control seems to have increased on age 3+ pollock in recent years, perhaps as predators have attempted to maintain constant pollock consumption during a period of declining abundance. It is possible that natural mortality on adult pollock will remain high in the ecosystem in spite of decreasing pollock abundance.

Ecosystem modeling

To examine the relative role of pollock natural versus fishing mortality within the GOA ecosystem, a set of simulations were run using the ECOPATH model shown in Fig. 1.35. Following the method outlined in Aydin et al. (2005), 20,000 model ecosystems were drawn from distributions of input parameters; these parameter sets were subjected to a selection/rejection criteria of species persistence resulting in approximately 500 ecosystems with nondegenerate parameters. These models, which did not begin in an equilibrium state, were projected forward using ECOSIM algorithms until equilibrium conditions were reached. For each group within the model, a perturbation experiment was run in all acceptable ecosystems by reducing the species survival (increasing mortality) by 10%, or by reducing gear effort by 10%, and reporting the percent change in equilibrium of all other species or fisheries catches. The resulting changes are reported as ranges across the generated ecosystems, with 50% and 95% confidence intervals representing the distribution of percent change in equilibrium states for each perturbation.

Fig. 1.43 shows the changes in other species when simulating a 10% decline in adult pollock survival (top graph), a 10% decline in juvenile pollock survival (middle graph), and a 10% decline in pollock trawl effort. Fisheries in these simulations are governed by constant fishing mortality rates rather than harvest control rules. Only the top 20 effects are shown in each graph; note the difference in scales between each graph.

The model results indicate that the largest effects of declining adult pollock survival would be declines in halibut and Steller sea lion biomass. Declines in juvenile survival would have a range of effects, including halibut and Steller sea lions, but also releasing a range of competitors for zooplankton including rockfish and shrimp. The pollock trawl itself has a lesser effect throughout the ecosystem (recall that fishing mortality is small in proportion to predation mortality for pollock); the strongest modeled effects are not on competitors for prey but on incidentally caught species (Table 1.2), with the strongest effects being on sharks.

The results presented above are taken from Gulfwide weighted averages of consumption; Steller sea lions and the fishing fleet are central place foragers, making foraging trips from specific locations (ports in the case of the fishing fleet, and rookeries or haulouts for Steller sea lions). Foraging bouts (or trawl sets) begin at the surface, and foragers attack their prey from the top down. For such species, directed and local changes in fishing may have a disproportionate effect compared to the results shown here.

In contrast, predation by groundfish is not as constrained geographically, and captures are likely to occur when the predator swims upwards from the bottom. Changes in the vertical distribution of pollock may tend to favor one mode of foraging over another. For example, if pollock move deeper in the water column due to surface warming, foraging groundfish might obtain an advantage over surface foragers. Alternatively, pollock may respond adaptively to predation risks from groundfish or surface foragers by changing its position in the water column.

Of species affecting pollock (Fig. 1.44), arrowtooth have the largest impact on adult pollock, while bottom-up processes (phytoplankton and zooplankton) have the largest impact on juvenile pollock. It is interesting to note that the link between juvenile and adult pollock is extremely uncertain (wide error bars) within these models.

Finally, of the four major predators of pollock (Fig 1.45), all are affected by bottom-up forcing; Steller sea lions, Pacific cod, and Pacific halibut are all affected by pollock perturbations, while pollock effects on arrowtooth are much more minor.

Pair-wise correlations in predator trends were examined for consistent patterns (Fig. 1.46). For each pair-wise comparison, we used the maximum number of years available. Time series for Steller sea lions and Pacific cod begin in mid 1970s, while other time series extend back to the early 1960s. We make no attempt to evaluate statistical significance (biomass trends are highly autocorrelated), and emphasize that correlation does not imply causation. If two populations are strongly correlated in time, there are many possible explanations: both populations are responding to similar forcing, one or other is causative agent, etc.

Pollock abundance, fishery catches, and Steller sea lions are positively correlated (Fig. 1.46). Since the harvest policy for pollock is a modified fixed harvest rate strategy, a positive correlation between catch and abundance would be expected. The Steller sea lion trend is more strongly correlated with pollock abundance than pollock catches, but this correlation is based on data since 1976, and does not include earlier years of low pollock abundance. The only strong inverse correlation is between arrowtooth flounder and Steller sea lions. A strong positive correlation exists between Pacific cod and Pacific halibut, and, from the 1960s to the present, between Pacific halibut and arrowtooth flounder.

Several patterns are apparent in abundance trends and the diet data. First, the two predators with alternate prey in the benthic pathway, Pacific cod and Pacific halibut, covary and have been relatively stable in the post-1977 period. Second, the correlation between Pacific halibut and arrowtooth flounder (with quite different diets apart from pollock) may be due to similarities in their reproductive behavior. Both spawn offshore in late winter, and conditions that enhance onshore advection, such as El Niños, may play an important role in recruitment to nursery areas for these species (Bailey and Picquelle 2002).

Finally, it is apparent that the potential for competition between Steller sea lions and arrowtooth flounder is underappreciated. Arrowtooth flounder consume both the primary prey of Steller sea lions (pollock), and alternate pelagic prey also utilized by Steller sea lions (capelin, herring, sandlance, salmon). Arrowtooth predation on pollock occurs at a smaller size than pollock targeted by Steller sea lions. The arrowtooth flounder population is nearly unexploited, is increasing in abundance, may be increasing it's per unit consumption of pollock, and shows no evidence of density-dependent growth. And lastly, since 1976 there has been a strong inverse correlation between arrowtooth flounder and Steller sea lion abundance that is at least consistent with competition between these species.

Data Gaps and Research Priorities

Based on the 2012 CIE review of the Gulf of Alaska pollock assessment, the following research priorities are identified. Additional details on recommended pollock research are included in a document provided to the GOA Plan Team in September 2013 that summarized and responded to the CIE review.

- Reduce data sets to those that are informative about current status by removing earlier and more questionable data sets, and reducing the influence of the inconsistent data earlier in the time series.
- Improve relative weightings given to different data sets.
- Consider alternative modeling platforms.
- Conduct research to develop informative priors on acoustic and trawl survey selectivity and catchability, and consider different ways to model selectivity.
- Evaluate alternative ways to model fishery and survey selectivity (including asymptotic selectivity).
- Explore implications of non-constant natural mortality on pollock assessment and management.

Literature Cited

Alton, M. S., M. O. Nelson, and B. A. Megrey. 1987. Changes in the abundance and distribution of walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska. Fish. Res. 5: 185-197.

Alverson, D. L. And M. J. Carney. 1975. A graphic review of the growth and decay of population cohorts. Cons. int. Explor. Mer, 133-143.

Anderson, P. J. and J. F. Piatt 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Mar. Ecol. Prog. Ser. 189:117-123.

Aydin, K., G.A. McFarlane, J.R. King, B.A. Megrey, and K.W. Myers. 2005. Linking oceanic food webs to coastal production and growth rates of Pacific salmon (*Oncorhynchus* spp.), using models on three scales. Deep-sea Res, II. 52: 757-780.

Bailey, K.M., P.J. Stabeno, and D.A. Powers. 1997. The role of larval retention and transport features in mortality and potential gene flow of walleye pollock. J. Fish. Biol. 51(Suppl. A):135-154.

Bailey, K.M., T.J. Quinn II, P. Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, *Theragra chalcogramma*. Advances in Mar. Biol. 37: 179-255.

Bailey, K.M. 2000. Shifting control of recruitment of walleye pollock *Theragra chalcogramma* after a major climatic and ecosystem change. Mar. Ecol. Prog. Ser 198:215-224.

Bailey, K. M and S. J. Picquelle. 2002. Larval distribution of offshore spawning flatfish in the Gulf of Alaska: potential transport pathways and enhanced onshore transport during ENSO events. Mar. Ecol. Prog. Ser. 236:205-217.

Baranov, F.I. 1918. On the question of the biological basis of fisheries. Nauchn. Issed. Ikhtiologicheskii Inst. Izv. 1:81-128.

Blackburn, J. and D. Pengilly. 1994. A summary of estimated population trends of seven most abundant groundfish species in trawl surveys conducted by Alaska Department of Fish and Game in the Kodiak and Alaska Peninsula areas, 1988 through 1993. Alaska Department of Fish and Game, Regional Information Report No. 4K94-31. 19p.

Brodeur, R. D. and Ware, D.M. 1995. Interdecadal variability in distribution and catch rates of epipelagic nekton in the Northeast Pacific Ocean. pp. 329-356 in R. J. Beamish [Ed.] Climate change and northern fish populations. Canadian Special Publication of Fisheries and Aquatic Sciences 121. National Research Council of Canada, Ottawa.

Brodziak, J., J. Ianelli, K. Lorenzen, and R.D. Methot Jr. (eds). 2011. Estimating natural mortality in stock assessment applications. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-119, 38 p.

Clark, W.G. 1999. Effects of an erroneous natural mortality rate on a simple age-structured model. Can. J. Fish. Aquat. Sci. 56:1721-1731.

Clark, W. G., S. R. Hare, A. M. Parma, P. J. Sullivan, and R. J. Trumble. 1999. Decadal changes in growth and recruitment of Pacific halibut (*Hippoglossus stenolepis*). Can. J. Fish. Aquat. Sci. 56(2): 242-252.

Deriso, R.B., T.J. Quinn II, and P.R. Neal. 1985. Catch-age analysis with auxiliary information. Can. J. Fish. Aquat. Sci. 42: 815-824.

De Robertis, A., Hjellvik, V., Williamson, N. J., and Wilson, C. D. 2008. Silent ships do not always encounter more fish: comparison of acoustic backscatter recorded by a noise-reduced and a conventional research vessel. – ICES Journal of Marine Science, 65: 623–635.

Dorn, M. W., and R. D. Methot. 1990. Status of the coastal Pacific whiting resource in 1989 and recommendation to management in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-182, 84 p.

Dorn, M.W., S. Barbeaux, B, M. Guttormsen, B. Megrey, A. Hollowed, M. Wilkins, and K. Spalinger. 2003. Assessment of the walleye pollock stock in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Dorn, M.W., K. Aydin, S. Barbeaux, D. Jones, K. Spalinger, and W. Palsson. 2012. Assessment of the walleye pollock stock in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Doubleday, W.G. 1976. A least-squares approach to analyzing catch at age data. Res. Bull. Int. Comm. Northw. Atl. Fish. 12:69-81.

Fournier, D. and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 39:1195-1207.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Fritz, L. W. 1993. Trawl locations of walleye pollock and Atka mackerel fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska from 1977-92. AFSC Processed Report 93-08. NMFS, AFSC, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.

Gauthier, S. and J. K. Horne 2004. Acoustic characteristics of forage fish species in the Gulf of Alaska and Bering Sea. Can. J. Aquat. Fish. Sci. 61: 1839-1850.

Gislason, H, N. Daan, J. C. Rice and J. G. Pope. 2010. Size, growth, temperature and the natural mortality of marine fish. Fish and Fisheries 11:149–158.

Grant, W.S. and F.M. Utter. 1980. Biochemical variation in walleye pollock *Theragra chalcogramma*: population structure in the southeastern Bering Sea and Gulf of Alaska. Can. J. Fish. Aquat. Sci. 37:1093-1100.

Greiwank, A., and G.F. Corliss (eds.) 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan. 6-8, Breckenridge, CO. Soc. Indust. and Applied Mathematics, Philadelphia.

Gunderson, D. R. and P. H. Dygert. 1988. Reproductive effort as a predictor of natural mortality rate. J. Cons. int. Mer, 44:200-209.

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York, N.Y. 570 p.

Hollowed, A.B. and B.A. Megrey. 1990. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1991 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Hollowed, A.B., B.A. Megrey, P. Munro, and W. Karp. 1991. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1992 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Hollowed, A.B., E. Brown, P. Livingston, B.A. Megrey and C. Wilson. 1995. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska As Projected for 1996. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Hollowed, A.B., E. Brown, J. Ianelli, B.A. Megrey and C. Wilson. 1998. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Hollowed, A.B., J.N. Ianelli, P. Livingston. 2000. Including predation mortality in stock assessments: a case study for Gulf of Alaska pollock. ICES J. Mar. Sci. 57:279-293.

Jones, D., M.A, Guttormsen, A. McCarthy. In review. Results of the February-March 2012 Echo Integration-Trawl Surveys of Walleye Pollock (Theragra chalcogramma) Conducted in the Gulf of Alaska, Cruises MF2012-01 and MF2012-04. AFSC Processed Rep. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Kastelle, C. R. and D. K. Kimura. 2006. Age validation of walleye pollock (*Theragra chalcogramma*) from the Gulf of Alaska using the disequilibrium of Pb-210 and Ra-226. ICES Journal of Marine Science 63:1520-1529.

Kendall, A.W. Jr. and S.J. Picquelle. 1990. Egg and larval distributions of walleye pollock *Theragra chalcogramma* in Shelikof Strait, Gulf of Alaska. Fish. Bull., U.S. 88:133-154.

Kimura, D.K. 1989. Variability, tuning, and simulation for the Doubleday-Deriso catch-at-age model. Can. J. Fish. Aquat. Sci. 46:941-949.

Kimura, D.K. 1990. Approaches to age-structured separable sequential population analysis. Can. J. Fish. Aquat. Sci. 47:2364-2374.

Kimura, D.K. 1991. Improved methods for separable sequential population analysis. Unpublished. Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, Washington 98115.

Kimura, D. K. and S. Chikuni. 1989. Variability in estimating catch-in-numbers-at-age and its impact on cohort analysis. *In* R.J. Beamish and G.A. McFarlane (eds.), Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108:57-66.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49:627-647.

McCullagh, P., and J. A. Nelder. 1983. Generalized linear models. Chapman and Hall, London. 261 p.

McKelvey, D. 1996. Juvenile walleye pollock, *Theragra chalcogramma*, distribution and abundance in Shelikof Strait–What can we learn from acoustic survey results? p. 25-34. *In* U.S. Dep. Commer. NOAA Tech. Rep. NMFS 126.

McKelvey, D.R. 1996. Juvenile walleye pollock, *Theragra chalcogramma*, distribution and abundance in Shelikof Strait—what can we learn from acoustic surveys. Ecology of Juvenile Walleye Pollock, *Theragra chalcogramma*. NOAA Technical Report NMFS 126, p 25-34.

Martin, M.H. 1997. Data Report: 1996 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-82, 235 p.

Megrey, B.A. 1989. Exploitation of walleye pollock resources in the Gulf of Alaska, 1964-1988: portrait of a fishery in transition. Proc. International Symp. on the Biology and Management of Walleye Pollock, Lowell Wakefield Fisheries Symp., Alaska Sea Grant Rep. 89-1, 33-58.

Merati, N. 1993. Spawning dynamics of walleye pollock, *Theragra chalcogramma*, in Shelikof Strait, Gulf of Alaska. Unpublished MS thesis. University of Washington. 134 p.

Methot, R.D. 2000. Technical description of the stock synthesis assessment program. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-43, 46 p.

Mueter, F.J. and B.L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. Fish. Bull. 100:559-581.

Mulligan, T.J., Chapman, R.W. and B.L. Brown. 1992. Mitochondrial DNA analysis of walleye pollock, *Theragra chalcogramma*, from the eastern Bering Sea and Shelikof Strait, Gulf of Alaska. Can. J. Fish. Aquat. Sci. 49:319-326.

Olsen, J.B., S.E. Merkouris, and J.E. Seeb. 2002. An examination of spatial and temporal genetic variation in walleye pollock (*Theragra chalcogramma*) using allozyme, mitochondrial DNA, and microsatellite data. Fish. Bull. 100:752-764.

Pauly, D.. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. int. Explor. Mer, 39(2):175-192.

Press, W.H., S.A. Teukolsky, W.T. Vetterling, and B.P. Flannery. 1992. Numerical recipes in C. Second ed. Cambridge University Press. 994 p.

Picquelle, S.J., and B.A. Megrey. 1993. A preliminary spawning biomass estimate of walleye pollock, *Theragra chalcogramma*, in Shelikof Strait, Gulf of Alaska, based on the annual egg production method. Bulletin of Marine Science 53(2):728:749.

Ronholt, L. L., H. H. Shippen, and E. S. Brown. 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass 1948 - 1976 (A historical review). Northwest and Alaska Fisheries Center Processed Report.

Saunders, M.W., G.A. McFarlane, and W. Shaw. 1988. Delineation of walleye pollock (*Theragra chalcogramma*) stocks off the Pacific coast of Canada. Proc. International Symp. on the Biology and Management of Walleye Pollock, Lowell Wakefield Fisheries Symp., Alaska Sea Grant Rep. 89-1, 379-402.

Somerton, D. 1979. Competitive interaction of walleye pollock and Pacific ocean perch in the northern Gulf of Alaska. *In* S. J. Lipovsky and C.A. Simenstad (eds.) Gutshop '78, Fish food habits studies: Proceedings of the second Pacific Northwest Technical Workshop, held Maple Valley, WA (USA), 10-13 October, 1978., Washington Sea Grant, Seattle, WA.

Sullivan, P.J., A.M. Parma, and W.G. Clark. 1997. Pacific halibut assessment: data and methods. Int. Pac. Halibut Comm. SCI. Rept. 97. 84 p.

Tribuzio, C.A., S. Gaichas, J. Gasper, H. Gilroy, T. Kong, O. Ormseth, J. Cahalan, J. DiCosimo, M. Furuness, H. Shen, K. Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Van Kirk, K., Quinn, T.J., and Collie, J. 2010. A multispecies age-structured assessment model for the Gulf of Alaska. Canadian Journal of Fisheries and Aquatic Science 67: 1135 – 1148

Van Kirk, K., Quinn, T.J., Collie, J., and T. A'mar. 2012. Multispecies age-structured assessment for groundfish and sea lions in Alaska. In: G.H. Kruse, H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, P.A. Livingston, D. Woodby, and C.I. Zhang (eds.), Global Progress in Ecosystem-Based Fisheries Management. Alaska Sea Grant, University of Alaska Fairbanks.

von Szalay, P. G., and E. Brown. 2001. Trawl comparisons of fishing power differences and their applicability to National Marine Fisheries Service and the Alaska Department of Fish and Game trawl survey gear. Alaska Fishery Research Bulletin

8:85-95.

Williams, K., Punt, A. E., Wilson, C. D., and Horne, J. K. 2011. Length-selective retention of walleye pollock, Theragra chalcogramma, by midwater trawls. ICES Journal of Marine Science, 68: 119–129.

Yang, M-S. and M. W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

Zeppelin, TK., DJ. Tollit, KA. Call, TJ. Orchard, and CJ. Gudmundson. 2004. Sizes of walleye pollock (*Theragra chalcogramma*) and Atka mackerel (*Pleurogrammus monopterygius*) consumed by the western stock of Steller sea lions (Eumetopias jubatus) in Alaska from 1998 to 2000. Fish. Bull. 102:509-521.

Table 1.1. Walleye pollock catch (t) in the Gulf of Alaska. The ABC for 2014 is for the area west of 140 ° W lon. (Western, Central and West Yakutat management areas) and includes the guideline harvest level for the state-managed fishery in Prince William Sound (4,163 t). Research catches are reported in Appendix D.

Year	*Foreign*	*Joint Venture*	*Domestic*	*Total*	*ABC/TAC*
1964	1,126			1,126	---
1965	2,746			2,746	---
1966	8,914			8,914	---
1967	6,272			6,272	---
1968	6,137			6,137	---
1969	17,547			17,547	---
1970	9,331		48	9,379	---
1971	9,460		0	9,460	---
1972	38,128		3	38,131	---
1973	44,966		27	44,993	---
1974	61,868		37	61,905	---
1975	59,504		0	59,504	---
1976	86,520		211	86,731	---
1977	117,833		259	118,092	150,000
1978	94,223		1,184	95,408	168,800
1979	103,278	577	2,305	106,161	168,800
1980	112,996	1,136	1,026	115,158	168,800
1981	130,323	16,856	639	147,818	168,800
1982	92,612	73,918	2,515	169,045	168,800
1983	81,318	134,171	136	215,625	256,600
1984	99,259	207,104	1,177	307,541	416,600
1985	31,587	237,860	17,453	286,900	305,000
1986	114	62,591	24,205	86,910	116,000
1987		22,823	45,248	68,070	84,000
1988		152	63,239	63,391	93,000
1989			75,585	75,585	72,200
1990			88,269	88,269	73,400
1991			100,488	100,488	103,400
1992			90,858	90,858	87,400
1993			108,909	108,909	114,400
1994			107,335	107,335	109,300
1995			72,618	72,618	65,360
1996			51,263	51,263	54,810
1997			90,130	90,130	79,980
1998			125,460	125,460	124,730
1999			95,638	95,638	94,580
2000			73,080	73,080	94,960
2001			72,077	72,077	90,690
2002			51,934	51,934	53,490
2003			50,684	50,684	49,590
2004			63,844	63,844	65,660
2005			80,978	80,978	86,100
2006			71,976	71,976	81,300
2007			52,714	52,714	63,800
2008			52,584	52,584	53,590
2009			44,247	44,247	43,270
2010			76,745	76,745	77,150
2011			81,357	81,357	88,620
2012			103,982	103,982	108,440
2013			96,363	96,363	113,099
2014					167,657
Average (1977-2013)				101,601	117,952

Table 1.2. Incidental catch (t) of FMP species (upper table) and non-target species (bottom table) in the walleye pollock directed fishery in the Gulf of Alaska in 2009-2013. Species are ordered according to the cumulative catch during the period. Incidental catch estimates include both retained and discarded catch.

Managed species/species group	*2009*	*2010*	*2011*	*2012*	*2013*
Pollock	39334.5	73032.9	77297.5	99643.9	91436.2
Arrowtooth Flounder	761.0	2066.8	2008.5	1328.6	1764.2
Pacific Cod	552.6	1497.2	1500.5	1267.0	1041.7
Flathead Sole	215.7	359.9	217.3	189.5	381.4
GOA Shallow Water Flatfish	17.0	78.5	289.4	171.2	182.8
Squid	320.9	129.0	208.8	6.7	346.6
Pacific Ocean Perch	36.1	96.6	172.3	294.5	426.9
GOA Rex Sole	35.5	60.3	90.0	48.8	151.1
GOA Skate, Big	33.8	47.1	92.6	47.8	211.9
Shark, pacific sleeper	31.1	155.6	3.6	3.8	15.5
Shark, salmon	6.9	103.7	5.7	53.2	3.9
GOA Shortraker Rockfish	26.2	9.4	24.4	21.8	22.6
GOA Rougheye Rockfish	12.9	30.5	34.5	21.2	8.9
Shark, spiny dogfish	17.9	19.8	16.5	19.2	11.3
Sculpin	5.0	5.9	76.0	14.3	46.8
GOA Skate, Longnose	35.1	9.8	35.0	9.0	25.2
Northern Rockfish	11.7	2.2	13.7	60.9	5.6
Sablefish	0.1	1.3	32.5	6.7	12.6
GOA Pelagic Shelf Rockfish	1.5	5.8	19.1	4.1	6.5
GOA Deep Water Flatfish	2.4	2.9	14.6	3.0	12.8
Shark, Other	10.4	3.7	1.1	3.7	1.0
Skate, Other	2.6	7.0	1.9	5.5	23.9
GOA Skate, Other	2.6	7.0	1.9	5.5	23.9
Other Rockfish	0.2	0.4	6.8	0.8	0.8
Octopus	0.1	0.8	2.3	0.4	0.3
GOA Thornyhead Rockfish	0.1	0.1	1.8	0.5	0.6
Atka Mackerel	0.0	0.4	0.1	0.3	0.4
Percent non-pollock	*5.2%*	*6.0%*	*5.9%*	*3.5%*	*4.9%*

Non target species/species group	*2009*	*2010*	*2011*	*2012*	*2013*
Eulachon	214.61	227.22	308.87	193.76	28.31
Other osmerids	146.29	6.78	78.59	88.59	12.46
Misc fish	42.05	42.44	43.49	49.89	384.76
Jellyfish	11.30	121.72	7.67	132.45	38.36
Giant Grenadier	26.30	1.93	108.99	15.75	67.56
Grenadier	0.00	9.21	7.94	70.89	0.00
Sea star	0.00	4.64	3.64	0.74	5.34
Capelin	0.01	0.00	7.94	0.02	0.02
Pandalid shrimp	0.17	1.12	0.12	0.07	0.01
Sea anemone unidentified	0.00	0.47	0.54	0.00	0.32
Snails	0.01	0.00	0.06	0.01	0.55
Stichaeidae	0.00	0.08	0.00	0.07	0.63
Benthic urochordata	0.00	0.00	0.09	0.02	0.35
Eelpouts	0.13	0.09	0.00	0.01	0.21
Bivalves	0.00	0.06	0.04	0.00	0.27
Hermit crab unidentified	0.00	0.09	0.00	0.14	0.00
Misc crabs	0.00	0.01	0.11	0.00	0.00
Sea urchins, sand dollars, sea cucumbers	0.00	0.00	0.00	0.00	0.01
Sponge unidentified	0.00	0.00	0.00	0.00	0.04
Invertebrate unidentified	0.00	0.00	0.00	0.00	0.04

Table 1.3. Bycatch of prohibited species for trawls where pollock was the predominant species in the catch in the Gulf of Alaska during 2009-2013. Herring and halibut bycatch is reported in metric tons, while crab and salmon are reported in number of fish.

Species/species group	*2009*	*2010*	*2011*	*2012*	*2013*
Bairdi Tanner Crab (nos.)	6,612	120	10,151	729	7,993
Blue King Crab (nos.)	0	0	0	0	0
Chinook Salmon (nos.)	3,188	44,862	14,781	18,880	13,513
Golden (Brown) King Crab (nos.)	0	0	0	0	0
Halibut (t)	63.4	48.3	191.2	94.6	257.7
Herring (t)	8.1	0.9	10.7	1.3	10.6
Non-Chinook Salmon (nos.)	317	752	1247	283	752
Opilio Tanner (Snow) Crab (nos.)	0	0	0	0	0
Red King Crab (nos.)	0	0	0	0	6

Table 1.4. Catch (retained and discarded) of walleye pollock (t) by management area in the Gulf of Alaska during 2003-2013 compiled by the Alaska Regional Office.

Year	*Utilization*	*Shumagin 610*	*Chirikof 620*	*Kodiak 630*	*West Yakutat 640*	*Prince William Sound 649 (state waters)*	*Southeast and East Yakutat 650 & 659*	*Total*	*Percent discard*
2003	Retained	16,346	18,970	12,225	940	1,118	0	49,601	
	Discarded	166	672	210	4	31	0	1,083	2.1%
	Total	16,512	19,642	12,435	944	1,149	0	51,937	
2004	Retained	23,226	24,221	13,896	215	1,100	0	62,658	
	Discarded	282	438	428	11	26	0	1,186	1.9%
	Total	23,508	24,659	14,324	226	1,127	0	63,844	
2005	Retained	30,791	27,418	18,986	1,876	740	0	79,811	
	Discarded	136	622	350	9	50	0	1,167	1.4%
	Total	30,927	28,040	19,336	1,885	790	0	80,978	
2006	Retained	24,489	26,409	16,127	1,570	1,475	0	70,070	
	Discarded	203	750	951	2	1	0	1,906	2.6%
	Total	24,691	27,159	17,078	1,572	1,476	0	71,976	
2007	Retained	17,470	18,848	13,777	84	1,046	0	51,224	
	Discarded	262	516	701	3	8	0	1,490	2.8%
	Total	17,731	19,363	14,478	87	1,055	0	52,714	
2008	Retained	15,099	18,692	13,336	1,155	613	1	48,896	
	Discarded	2,160	378	1,121	6	20	2	3,688	7.0%
	Total	17,260	19,070	14,456	1,161	633	3	52,584	
2009	Retained	14,475	13,578	10,974	1,190	1,474	0	41,692	
	Discarded	604	422	1,496	31	1	0	2,554	5.8%
	Total	15,079	14,000	12,470	1,222	1,476	0	44,247	
2010	Retained	25,960	28,015	18,373	1,625	1,660	2	75,635	
	Discarded	91	234	761	12	9	2	1,110	1.4%
	Total	26,051	28,250	19,134	1,637	1,669	4	76,745	
2011	Retained	20,472	36,112	18,987	2,268	1,535	0	79,374	
	Discarded	125	1,113	741	3	1	0	1,983	2.4%
	Total	20,597	37,225	19,728	2,271	1,536	0	81,357	
2012	Retained	27,355	44,596	25,089	2,353	2,622	0	102,014	
	Discarded	538	500	896	28	5	1	1,969	1.9%
	Total	27,893	45,095	25,986	2,381	2,627	1	103,982	
2013	Retained	7,644	52,602	28,134	2,927	2,605	0	93,913	
	Discarded	67	513	1,833	13	22	2	2,450	2.5%
	Total	7,711	53,115	29,967	2,940	2,628	2	96,363	
Average (2003-2013)		20,724	28,693	18,127	1,484	1,470	1	70,611	

Table 1.5. Catch at age (millions) of walleye pollock in the Gulf of Alaska in 1975-2013.

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1975	0.00	2.59	59.62	18.54	15.61	7.33	3.04	2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.69
1976	0.00	1.66	20.16	108.26	35.11	14.62	3.23	2.50	1.72	0.21	0.00	0.00	0.00	0.00	0.00	187.47
1977	0.05	6.93	11.65	26.71	101.29	29.26	10.97	2.85	2.52	1.14	0.52	0.07	0.06	0.00	0.00	194.01
1978	0.31	10.87	34.64	24.38	24.27	47.04	13.58	5.77	2.15	1.32	0.57	0.05	0.04	0.01	0.00	164.99
1979	0.10	3.47	54.61	89.36	14.24	9.47	12.94	5.96	2.32	0.56	0.21	0.08	0.00	0.00	0.01	193.33
1980	0.49	9.84	27.85	58.42	42.16	13.92	10.76	9.79	4.95	1.32	0.69	0.24	0.09	0.03	0.00	180.55
1981	0.23	4.82	35.40	73.34	58.90	23.41	6.74	5.84	4.16	0.59	0.02	0.04	0.03	0.00	0.00	213.53
1982	0.04	9.52	41.68	92.53	72.56	42.91	10.94	1.71	1.10	0.70	0.05	0.03	0.02	0.00	0.00	273.80
1983	0.00	6.96	42.29	81.51	121.82	59.42	33.14	8.72	1.70	0.18	0.44	0.10	0.00	0.00	0.00	356.28
1984	0.71	5.28	62.46	66.85	81.92	122.05	43.96	14.94	4.95	0.43	0.06	0.12	0.10	0.00	0.00	403.84
1985	0.20	11.60	7.43	36.26	39.31	70.63	117.57	36.73	10.31	2.65	0.85	0.00	0.00	0.00	0.00	333.55
1986	1.00	6.05	14.67	8.80	19.45	8.27	9.01	10.90	4.35	0.74	0.00	0.00	0.00	0.00	0.00	83.26
1987	0.00	4.25	6.43	5.73	6.66	12.55	10.75	7.07	15.65	1.67	0.98	0.00	0.00	0.00	0.00	71.74
1988	0.85	8.86	12.71	19.21	16.11	10.63	5.93	2.72	0.40	5.83	0.48	0.11	0.06	0.00	0.00	83.91
1989	2.94	1.33	3.62	34.46	39.31	13.57	5.21	2.65	1.08	0.50	2.00	0.20	0.06	0.05	0.02	106.99
1990	0.00	1.15	1.45	2.14	12.43	39.17	13.99	7.93	1.91	1.70	0.11	1.08	0.03	0.10	0.19	83.37
1991	0.00	1.14	8.11	4.34	3.83	7.39	33.95	3.75	19.13	0.85	6.00	0.40	2.39	0.20	0.83	92.29
1992	0.11	1.56	3.31	21.09	22.47	11.82	8.56	17.75	5.44	6.10	1.13	2.26	0.39	0.47	0.40	102.86
1993	0.04	2.46	8.46	19.94	47.83	16.69	7.21	6.86	9.73	2.38	2.27	0.54	0.92	0.17	0.30	125.80
1994	0.06	0.88	4.16	7.60	33.41	29.84	12.00	5.28	4.72	6.10	1.29	1.17	0.25	0.07	0.06	106.90
1995	0.00	0.23	1.73	4.82	9.46	21.96	13.60	4.30	2.05	2.15	2.46	0.41	0.28	0.04	0.12	63.62
1996	0.00	0.80	1.95	1.44	4.09	5.64	10.91	11.66	3.82	1.84	0.72	1.97	0.34	0.40	0.20	45.76
1997	0.00	1.65	7.20	4.08	4.28	8.23	12.34	18.77	13.71	5.62	2.03	0.88	0.50	0.14	0.04	79.49
1998	0.56	0.19	19.38	33.10	14.54	8.58	9.75	11.36	16.51	12.01	4.33	0.91	0.59	0.16	0.12	132.08
1999	0.00	0.75	2.61	22.91	34.47	10.08	7.53	4.00	6.20	8.16	4.70	1.18	0.58	0.13	0.08	103.40
2000	0.08	0.98	2.84	3.47	14.65	24.63	6.24	5.05	2.30	1.24	3.00	1.52	0.30	0.14	0.04	66.48
2001	0.74	10.13	6.59	7.34	9.42	12.59	14.44	4.73	2.70	1.35	0.65	0.83	0.61	0.00	0.04	72.14
2002	0.16	12.31	20.72	6.76	4.47	8.75	5.37	6.06	1.33	0.82	0.43	0.30	0.33	0.22	0.13	68.16
2003	0.14	2.69	21.47	22.95	5.33	3.25	4.66	3.76	2.58	0.54	0.19	0.04	0.09	0.04	0.05	67.79
2004	0.85	6.28	11.91	31.84	25.09	5.98	2.43	2.63	0.77	0.22	0.25	0.00	0.00	0.00	0.00	88.24
2005	1.14	1.21	5.33	6.85	41.25	21.73	6.10	0.74	0.91	0.35	0.18	0.13	0.00	0.00	0.00	85.91
2006	2.20	7.79	4.16	2.75	5.97	27.38	12.80	2.45	0.83	0.46	0.23	0.10	0.07	0.03	0.00	67.22
2007	0.82	18.89	7.46	2.51	2.31	3.58	10.19	6.70	1.59	0.29	0.23	0.09	0.00	0.00	0.01	54.68
2008	0.32	6.29	21.94	6.76	2.15	1.16	2.27	5.60	2.84	0.87	0.36	0.21	0.06	0.04	0.02	50.89
2009	0.24	6.38	14.84	13.47	3.82	1.19	0.72	0.95	1.90	1.45	0.47	0.06	0.01	0.00	0.00	45.50
2010	0.01	5.29	23.35	21.32	18.14	3.68	1.11	0.73	0.92	1.02	0.64	0.05	0.06	0.01	0.00	76.31
2011	0.00	2.49	12.18	26.78	20.88	13.12	2.97	0.61	0.38	0.21	0.36	0.35	0.07	0.00	0.00	80.40
2012	0.03	0.66	4.64	13.49	29.83	21.43	8.94	1.95	0.43	0.18	0.23	0.16	0.04	0.07	0.08	82.15
2013	0.58	2.70	10.20	5.31	13.00	17.18	12.57	5.13	1.01	0.53	0.30	0.18	0.28	0.22	0.04	69.23

Table 1.6. Number of aged and measured fish in the Gulf of Alaska pollock fishery used to estimate fishery age composition (1989-2013).

	Number aged			*Number measured*		
Year	*Males*	*Females*	*Total*	*Males*	*Females*	*Total*
1989	882	892	1,774	6,454	6,456	12,910
1990	453	689	1,142	17,814	24,662	42,476
1991	1,146	1,322	2,468	23,946	39,467	63,413
1992	1,726	1,755	3,481	31,608	47,226	78,834
1993	926	949	1,875	28,035	31,306	59,341
1994	136	129	265	24,321	25,861	50,182
1995	499	544	1,043	10,591	10,869	21,460
1996	381	378	759	8,581	8,682	17,263
1997	496	486	982	8,750	8,808	17,558
1998	924	989	1,913	78,955	83,160	162,115
1999	980	1,115	2,095	16,304	17,964	34,268
2000	1,108	972	2,080	13,167	11,794	24,961
2001	1,063	1,025	2,088	13,731	13,552	27,283
2002	1,036	1,025	2,061	9,924	9,851	19,775
2003	1,091	1,119	2,210	8,375	8,220	16,595
2004	1,217	996	2,213	4,446	3,622	8,068
2005	1,065	968	2,033	6,837	6,005	12,842
2006	1,127	969	2,096	7,248	6,178	13,426
2007	998	1,064	2,062	4,504	5,064	9,568
2008	961	1,090	2,051	7,430	8,536	15,966
2009	1,011	1,034	2,045	9,913	9,447	19,360
2010	1,195	1,055	2,250	14,958	13,997	28,955
2011	1,197	1,025	2,222	9,625	11,023	20,648
2012	1,160	1,097	2,257	11,045	10,430	21,475
2013	683	774	1,457	3,565	4,084	7,649

Table 1.7. Biomass estimates (t) of walleye pollock from acoustic surveys in Shelikof Strait, NMFS bottom trawl surveys (west of 140 W. long.), egg production surveys in Shelikof Strait, and ADFG crab/groundfish trawl surveys. An adjustment of +1.05% was made to the NMFS bottom trawl biomass time series to account for unsurveyed biomass in Prince William Sound. In 2001, when the NMFS bottom trawl survey did not extend east of 147° W lon., an expansion factor of 2.7% derived from previous surveys was used for West Yakutat.

	Shelikof Strait acoustic survey					
	R/V Miller Freeman					
Year	*Biosonics*	*EK500*	*R/V Oscar Dyson*	*NMFS bottom trawl west of 140° W lon.*	*Shelikof Strait egg production*	*ADFG crab/groundfish survey*
1981	2,785,755				1,788,908	
1982						
1983	2,278,172					
1984	1,757,168			720,548		
1985	1,175,823				768,419	
1986	585,755				375,907	
1987				732,660	484,455	
1988	301,709				504,418	
1989	290,461				433,894	214,434
1990	374,731			825,609	381,475	114,451
1991	380,331				370,000	
1992		713,429			616,000	127,359
1993		435,753		755,786		132,849
1994		492,593				103,420
1995		763,612				
1996		777,172		666,521		122,477
1997		583,017				93,728
1998		504,774				81,215
1999				607,409		53,587
2000		448,638				102,871
2001		432,749		219,072		86,967
2002		256,743				96,237
2003		317,269		398,469		66,989
2004		330,753				99,358
2005		356,117		358,017		79,089
2006		293,609				69,044
2007		180,881		282,356		76,674
2008			208,032			83,476
2009			265,971	669,505		145,438
2010			429,730			124,110
2011				667,131		100,839
2012			335,836			172,007
2013			891,261	957,817		102,406
2014			842,138			100,158

Table 1.8. Survey sampling effort and biomass coefficients of variation (CV) for pollock in the NMFS bottom trawl survey. The number of measured pollock is approximate due to subsample expansions in the database. The total number measured includes both sexed and unsexed fish.

				Number aged			*Number measured*		
Year	*No. of tows*	*No. of tows with pollock*	*Survey biomass CV*	*Males*	*Females*	*Total*	*Males*	*Females*	*Total*
1984	929	536	0.14	1,119	1,394	2,513	8,985	13,286	25,990
1987	783	533	0.20	672	675	1,347	15,843	18,101	34,797
1990	708	549	0.12	503	560	1,063	15,014	20,053	42,631
1993	775	628	0.16	879	1,013	1,892	14,681	18,851	35,219
1996	807	668	0.15	509	560	1,069	17,698	19,555	46,668
1999	764	567	0.38	560	613	1,173	10,808	11,314	24,080
2001	489	302	0.30	395	519	914	9,135	10,281	20,272
2003	807	508	0.12	514	589	1,103	10,561	12,706	25,052
2005	839	516	0.15	639	868	1,507	9,108	10,893	27,114
2007	820	554	0.14	646	675	1,321	10,018	11,638	24,768
2009	823	563	0.15	684	870	1,554	13,084	14,697	30,876
2011	670	492	0.15	705	941	1,646	11,852	13,832	27,327
2013	548	439	0.21	763	784	1,547	14,941	16,680	31,880

Table 1.9. Estimated number at age (millions) from the NMFS bottom trawl survey. Estimates are for the Western and Central Gulf of Alaska only (Management areas 610-630).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1984	0.93	10.02	67.81	155.78	261.17	474.57	145.10	24.80	16.59	1.66	0.21	1.32	0.00	0.00	0.00	1159.96
1987	25.45	363.02	172.99	138.97	91.13	168.27	78.14	43.99	175.39	22.41	7.81	3.51	1.82	0.00	0.00	1292.88
1989	208.88	63.49	47.56	243.15	301.09	104.43	54.47	28.39	26.14	5.98	10.66	0.00	0.00	0.00	0.00	1094.23
1990	64.04	251.21	48.34	46.68	209.77	240.82	74.41	110.41	26.13	34.23	5.03	27.73	5.70	1.07	1.63	1147.19
1993	139.31	71.15	50.94	182.96	267.12	91.51	33.12	68.98	76.62	26.36	11.85	6.29	3.82	1.82	4.41	1036.25
1996	194.23	128.79	17.30	26.13	50.04	63.18	174.41	87.62	52.37	27.73	12.10	18.46	7.16	9.68	19.70	888.90
1999	109.73	19.17	20.94	66.76	118.94	56.80	59.04	47.71	56.40	81.97	65.18	9.67	8.28	2.50	0.76	723.85
2001	412.83	117.03	34.42	33.39	25.05	33.45	37.01	8.20	5.74	0.59	4.48	2.52	1.28	0.00	0.18	716.19
2003	75.46	18.40	128.41	140.74	73.27	44.72	36.10	25.27	14.51	8.61	3.23	1.79	1.26	0.00	0.00	571.77
2005	270.37	33.72	34.41	35.86	91.78	78.82	45.24	20.86	9.61	9.98	4.81	0.57	0.64	0.00	0.00	636.68
2007	174.01	95.96	88.59	37.11	19.23	18.90	54.98	31.11	6.64	3.04	2.78	1.00	1.13	0.00	0.00	534.48
2009	222.94	87.33	106.82	129.35	101.26	27.21	17.59	26.60	53.90	29.46	9.68	7.00	2.78	1.61	0.00	823.53
2011	249.43	96.71	110.68	101.79	163.62	107.99	33.24	7.14	5.69	8.61	19.29	6.62	0.00	0.00	0.55	911.36
2013	750.15	62.07	47.95	65.43	84.78	144.80	157.23	115.85	25.15	5.46	2.42	2.49	3.86	3.10	0.94	1471.68

Table 1.10. Estimated number at age (millions) for the acoustic survey in Shelikof Strait.

Year	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*Total*
1981	77.65	3,481.18	1,510.77	769.16	2,785.91	1,051.92	209.93	128.52	79.43	25.19	1.73	0.00	0.00	0.00	0.00	10,121.37
1983	1.21	901.77	380.19	1,296.79	1,170.81	698.13	598.78	131.54	14.48	11.61	3.92	1.71	0.00	0.00	0.00	5,210.93
1984	61.65	58.25	324.49	141.66	635.04	988.21	449.62	224.35	41.03	2.74	0.00	1.02	0.00	0.00	0.00	2,928.07
1985	2,091.74	544.44	122.69	314.77	180.53	347.17	439.31	166.68	42.72	5.56	1.77	1.29	0.00	0.00	0.00	4,258.67
1986	575.36	2,114.83	183.62	45.63	75.36	49.34	86.15	149.36	60.22	10.62	1.29	0.00	0.00	0.00	0.00	3,351.78
1988	17.44	109.93	694.32	322.11	77.57	16.99	5.70	5.60	3.98	8.96	1.78	1.84	0.20	0.00	0.00	1,266.41
1989	399.48	89.52	90.01	222.05	248.69	39.41	11.75	3.83	1.89	0.55	10.66	1.42	0.00	0.00	0.00	1,119.25
1990	49.14	1,210.17	71.69	63.37	115.92	180.06	46.33	22.44	8.20	8.21	0.93	3.08	1.51	0.79	0.24	1,782.08
1991	21.98	173.65	549.90	48.11	64.87	69.60	116.32	23.65	29.43	2.23	4.29	0.92	4.38	0.00	0.00	1,109.32
1992	228.03	33.69	73.54	188.10	367.99	84.11	84.99	171.18	32.70	56.35	2.30	14.67	0.90	0.30	0.00	1,338.85
1993	63.29	76.08	37.05	72.39	232.79	126.19	26.77	35.63	38.72	16.12	7.77	2.60	2.19	0.49	1.51	739.61
1994	185.98	35.77	49.30	31.75	155.03	83.58	42.48	27.23	44.45	48.46	14.79	6.65	1.12	2.34	0.57	729.49
1995	10,689.87	510.37	79.37	77.70	103.33	245.23	121.72	53.57	16.63	10.72	14.57	5.81	2.12	0.44	0.00	11,931.45
1996	56.14	3,307.21	118.94	25.12	53.99	71.03	201.05	118.52	39.80	13.01	11.32	5.32	2.52	0.03	0.38	4,024.36
1997	70.37	183.14	1,246.55	80.06	18.42	44.04	51.73	97.55	52.73	14.29	2.40	3.05	0.93	0.46	0.00	1,865.72
1998	395.47	88.54	125.57	474.36	136.12	14.22	31.93	36.30	74.08	25.90	14.30	6.88	0.27	0.56	0.56	1,425.05
2000	4,484.41	755.03	216.52	15.83	67.19	131.64	16.82	12.61	9.87	7.84	13.87	6.88	1.88	1.06	0.00	5,741.46
2001	288.93	4,103.95	351.74	61.02	41.55	22.99	34.63	13.07	6.20	2.67	1.20	1.91	0.69	0.50	0.24	4,931.27
2002	8.11	162.61	1,107.17	96.58	16.25	16.14	7.70	6.79	1.46	0.66	0.35	0.34	0.15	0.13	0.00	1,424.45
2003	51.19	89.58	207.69	802.46	56.58	7.69	4.14	1.58	1.46	0.85	0.28	0.00	0.10	0.00	0.00	1,223.60
2004	52.58	93.94	57.58	159.62	356.33	48.78	2.67	3.42	3.32	0.52	0.42	0.00	0.66	0.00	0.00	779.84
2005	1,626.13	157.49	55.54	34.63	172.74	162.40	36.02	3.61	2.39	0.00	0.76	0.00	0.00	0.00	0.00	2,251.71
2006	161.69	835.96	40.75	11.54	17.42	55.98	74.97	32.25	6.90	0.83	0.75	0.53	0.00	0.00	0.00	1,239.57
2007	53.54	231.73	174.88	29.66	10.14	17.27	34.39	20.85	1.54	1.05	0.69	0.00	0.00	0.00	0.00	575.74
2008	1,368.02	391.20	249.56	53.18	12.01	2.16	4.07	10.66	6.69	2.01	0.53	0.00	0.00	0.00	0.00	2,100.10
2009	331.94	1,204.50	110.22	98.69	60.21	9.91	2.90	0.86	5.07	6.13	1.37	0.24	0.00	0.00	0.00	1,832.03
2010	90.04	305.57	531.65	84.46	78.93	28.52	11.78	5.46	5.25	10.82	9.36	3.45	0.00	0.00	0.00	1,165.29
2012	94.94	851.52	43.49	76.89	95.78	46.24	29.21	4.49	1.14	0.27	0.09	0.53	0.00	0.00	0.00	1,244.57
2013	6,324.25	149.42	803.34	60.86	68.82	114.18	65.16	49.14	11.92	5.40	5.74	0.61	1.69	4.82	2.61	7,667.95
2014	575.69	3,640.17	19.09	295.35	86.87	58.48	99.51	54.93	25.79	17.75	7.40	0.71	2.30	0.00	0.67	4,884.69

Table 1.11. Survey sampling effort and estimation uncertainty for pollock in the Shelikof Strait acoustic survey. Survey CVs based on a cluster sampling design are reported for 1981-91, while relative estimation error using a geostatistical method are reported for 1992-2014.

Year	*No. of midwater tows*	*No. of bottom trawl tows*	*Survey biomass CV*	*Number aged Males*	*Females*	*Total*	*Number measured Males*	*Females*	*Total*
1981	38	13	0.12	1,921	1,815	3,736	NA	NA	NA
1983	40	0	0.16	1,642	1,103	2,745	NA	NA	NA
1984	45	0	0.18	1,739	1,622	3,361	NA	NA	NA
1985	57	0	0.14	1,055	1,187	2,242	NA	NA	NA
1986	39	0	0.22	642	618	1,260	NA	NA	NA
1987	27	0	---	557	643	1,200	NA	NA	NA
1988	26	0	0.17	537	464	1,001	NA	NA	NA
1989	21	0	0.10	582	545	1,127	NA	NA	NA
1990	28	13	0.17	1,034	1,181	2,215	NA	NA	NA
1991	16	2	0.35	468	567	1,035	NA	NA	NA
1992	17	8	0.04	784	765	1,549	NA	NA	NA
1993	22	2	0.05	583	624	1,207	NA	NA	NA
1994	44	9	0.05	553	632	1,185	NA	NA	NA
1995	22	3	0.05	599	575	1,174	NA	NA	NA
1996	30	8	0.04	724	775	1,499	NA	NA	NA
1997	16	14	0.04	682	853	1,535	5,380	6,104	11,484
1998	22	9	0.04	863	784	1,647	5,487	4,946	10,433
2000	31	0	0.05	422	363	785	6,007	5,196	11,203
2001	17	9	0.05	314	378	692	4,531	4,584	9,115
2002	18	1	0.07	278	326	604	2,876	2,871	5,747
2003	17	2	0.05	288	321	609	3,554	3,724	7,278
2004	13	2	0.09	492	440	932	3,838	2,552	6,390
2005	22	1	0.04	543	335	878	2,714	2,094	4,808
2006	17	2	0.04	295	487	782	2,527	3,026	5,553
2007	9	1	0.06	335	338	673	2,145	2,194	4,339
2008	10	2	0.06	171	248	419	1,641	1,675	3,316
2009	9	3	0.06	254	301	555	1,583	1,632	3,215
2010	13	2	0.03	286	244	530	2,590	2,358	4,948
2012	8	3	0.08	235	372	607	1,727	1,989	3,716
2013	29	5	0.05	376	386	778	2,198	2,436	8,158
2014	19	2	0.05	389	430	854	3,940	3,377	10,841

Table 1.12. Estimated proportions at age for the ADFG crab/groundfish survey, 2000-2012.

Year	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*Sample size*
2000	0.0372	0.0260	0.0948	0.0781	0.1171	0.1766	0.1078	0.0539	0.0651	0.0613	0.0985	0.0595	0.0167	0.0056	0.0019	538
2002	0.0093	0.0743	0.1840	0.1933	0.1487	0.1171	0.1059	0.0706	0.0446	0.0186	0.0149	0.0093	0.0037	0.0037	0.0019	538
2004	0.0051	0.0084	0.0572	0.1987	0.2626	0.1498	0.1077	0.0673	0.0589	0.0387	0.0152	0.0135	0.0084	0.0084	0.0000	594
2006	0.0051	0.0423	0.1117	0.0829	0.1472	0.3012	0.1658	0.0592	0.0355	0.0288	0.0118	0.0034	0.0017	0.0000	0.0034	591
2008	0.0000	0.0352	0.4070	0.1340	0.0536	0.0670	0.0436	0.1541	0.0452	0.0134	0.0218	0.0184	0.0034	0.0034	0.0000	597
2010	0.0017	0.0444	0.1402	0.2650	0.2598	0.0838	0.0564	0.0188	0.0376	0.0291	0.0359	0.0137	0.0068	0.0034	0.0034	585
2012	0.0177	0.0212	0.0637	0.1027	0.1575	0.2991	0.1823	0.0708	0.0301	0.0212	0.0124	0.0071	0.0071	0.0053	0.0018	565

Table 1.13. Predictions of Gulf of Alaska pollock year-class strength. The McKelvey index is the estimated abundance of 9-16 cm pollock (billions) from the Shelikof Strait acoustic survey.

Year class	*Year of acoustic survey*	*McKelvey index*	*Rank abundance of McKelvey index*
1980	1981	0.078	18
1981			
1982	1983	0.001	30
1983	1984	0.062	21
1984	1985	2.092	4
1985	1986	0.579	7
1986			
1987	1988	0.017	28
1988	1989	0.399	9
1989	1990	0.049	26
1990	1991	0.022	27
1991	1992	0.228	13
1992	1993	0.063	20
1993	1994	0.186	14
1994	1995	10.688	1
1995	1996	0.061	22
1996	1997	0.070	19
1997	1998	0.395	10
1998			
1999	2000	4.484	3
2000	2001	0.291	12
2001	2002	0.008	29
2002	2003	0.051	25
2003	2004	0.053	24
2004	2005	1.626	5
2005	2006	0.162	15
2006	2007	0.054	23
2007	2008	1.368	6
2008	2009	0.332	11
2009	2010	0.090	17
2010			
2011	2012	0.095	16
2012	2013	6.324	2
2013	2014	0.576	8

Table 1.14. Ageing error transition matrix used in the Gulf of Alaska pollock assessment model.

		Observed Age									
True Age	*St. dev.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1	0.18	0.9970	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.23	0.0138	0.9724	0.0138	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.27	0.0000	0.0329	0.9342	0.0329	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.32	0.0000	0.0000	0.0571	0.8858	0.0571	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.36	0.0000	0.0000	0.0000	0.0832	0.8335	0.0832	0.0000	0.0000	0.0000	0.0000
6	0.41	0.0000	0.0000	0.0000	0.0001	0.1090	0.7817	0.1090	0.0001	0.0000	0.0000
7	0.45	0.0000	0.0000	0.0000	0.0000	0.0004	0.1333	0.7325	0.1333	0.0004	0.0000
8	0.50	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.1554	0.6868	0.1554	0.0012
9	0.54	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.1747	0.6450	0.1775
10	0.59	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0052	0.1913	0.8035

Table 1.15. Estimates of natural mortality at age using alternative methods. The rescaled average has mean natural mortality of 0.30 for ages greater than or equal to the age at maturity.

Age	*Length (cm)*	*Weight (g)*	*Brodziak et al. 2010*	*Lorenzen 1996*	*Gislason et al. 2010*	*Hollowed et al. 2000*	*Van Kirk et al. 2010*	*Van Kirk et al. 2012*	*Average*	*Rescaled Avg.*
1	15.3	26.5	0.97	1.36	2.62	0.86	2.31	2.00	1.69	1.39
2	27.4	166.7	0.54	0.78	1.02	0.76	1.01	0.95	0.84	0.69
3	36.8	406.4	0.40	0.59	0.64	0.58	0.58	0.73	0.59	0.48
4	44.9	752.4	0.33	0.49	0.46	0.49	0.37	0.57	0.45	0.37
5	49.2	966.0	0.30	0.45	0.40	0.41	0.36	0.53	0.41	0.34
6	52.5	1154.2	0.30	0.43	0.36	0.38	0.28	0.47	0.37	0.30
7	55.1	1273.5	0.30	0.42	0.33	0.38	0.30	0.46	0.36	0.30
8	57.4	1421.7	0.30	0.40	0.31	0.38	0.29	0.43	0.35	0.29
9	60.3	1624.8	0.30	0.39	0.29	0.39	0.29	0.42	0.35	0.28
10	61.1	1599.6	0.30	0.39	0.28	0.39	0.33	0.40	0.35	0.29

Table 1.16. Proportion mature at age for female pollock based on maturity stage data collected during winter acoustic surveys in the Gulf of Alaska (1983-2014).

Year	2	3	4	5	6	7	8	9	10+	Sample size
1983	0.000	0.165	0.798	0.960	0.974	0.983	0.943	1.000	1.000	1333
1984	0.000	0.145	0.688	0.959	0.990	1.000	0.992	1.000	1.000	1621
1985	0.015	0.051	0.424	0.520	0.929	0.992	0.992	1.000	1.000	1183
1986	0.000	0.021	0.105	0.849	0.902	0.959	1.000	1.000	1.000	618
1987	0.000	0.012	0.106	0.340	0.769	0.885	0.950	0.991	1.000	638
1988	0.000	0.000	0.209	0.176	0.606	0.667	1.000	0.857	0.964	464
1989	0.000	0.000	0.297	0.442	0.710	0.919	1.000	1.000	1.000	796
1990	0.000	0.000	0.192	0.674	0.755	0.910	0.945	0.967	0.996	1844
1991	0.000	0.000	0.111	0.082	0.567	0.802	0.864	0.978	1.000	628
1992	0.000	0.000	0.040	0.069	0.774	0.981	0.990	1.000	0.983	765
1993	0.000	0.016	0.120	0.465	0.429	0.804	0.968	1.000	0.985	624
1994	0.000	0.007	0.422	0.931	0.941	0.891	0.974	1.000	1.000	872
1995	0.000	0.000	0.153	0.716	0.967	0.978	0.921	0.917	0.977	805
1996	0.000	0.000	0.036	0.717	0.918	0.975	0.963	1.000	0.957	763
1997	0.000	0.000	0.241	0.760	1.000	1.000	0.996	1.000	1.000	843
1998	0.000	0.000	0.065	0.203	0.833	0.964	1.000	1.000	0.989	757
2000	0.000	0.012	0.125	0.632	0.780	0.579	0.846	1.000	0.923	356
2001	0.000	0.000	0.289	0.308	0.825	0.945	0.967	0.929	1.000	374
2002	0.000	0.026	0.259	0.750	0.933	0.974	1.000	1.000	1.000	499
2003	0.000	0.029	0.192	0.387	0.529	0.909	0.750	1.000	1.000	301
2004	0.000	0.000	0.558	0.680	0.745	0.667	1.000	1.000	1.000	444
2005	0.000	0.000	0.706	0.882	0.873	0.941	1.000	1.000	1.000	321
2006	0.000	0.000	0.043	0.483	0.947	0.951	0.986	1.000	1.000	476
2007	0.000	0.000	0.333	0.667	0.951	0.986	0.983	1.000	1.000	313
2008	0.000	0.000	0.102	0.241	0.833	1.000	0.968	0.952	1.000	240
2009	0.000	0.000	0.140	0.400	0.696	1.000	1.000	1.000	1.000	296
2010	0.000	0.000	0.357	0.810	0.929	1.000	1.000	1.000	1.000	314
2012	0.000	0.000	0.204	0.659	0.885	1.000	1.000	1.000	1.000	372
2013	0.000	0.000	0.240	0.896	0.941	0.950	0.939	1.000	1.000	622
2014	0.000	0.000	0.074	0.086	0.967	0.952	1.000	1.000	1.000	430
Average										
All years	0.000	0.016	0.254	0.558	0.830	0.919	0.965	0.986	0.992	
2004-2014	0.000	0.000	0.276	0.580	0.877	0.945	0.987	0.995	1.000	
2009-2014	0.000	0.000	0.203	0.570	0.883	0.980	0.988	1.000	1.000	

Table 1.17. Estimated selectivity at age for Gulf of Alaska pollock fisheries and surveys. The fisheries and surveys were modeled using double logistic selectivity functions.

Age	*Foreign (1970-81)*	*Foreign and JV (1982-1988)*	*Domestic (1989-2000)*	*Domestic (2001-2007)*	*Recent domestic (2008-2014)*	*Acoustic survey*	*Bottom trawl survey*	*ADF&G bottom trawl*
1	0.001	0.004	0.002	0.015	0.006	0.450	0.125	0.004
2	0.011	0.028	0.013	0.087	0.046	0.865	0.212	0.037
3	0.123	0.183	0.075	0.372	0.275	1.000	0.339	0.271
4	0.632	0.624	0.334	0.773	0.740	1.000	0.494	0.784
5	0.955	0.925	0.758	0.954	0.960	0.999	0.653	0.973
6	0.997	0.991	0.958	0.994	0.996	0.997	0.787	0.997
7	1.000	1.000	1.000	1.000	1.000	0.987	0.883	1.000
8	0.991	0.992	0.998	0.992	0.991	0.947	0.944	1.000
9	0.879	0.880	0.886	0.880	0.879	0.812	0.980	1.000
10	0.347	0.347	0.349	0.347	0.347	0.509	1.000	1.000

Table 1.18. Total estimated abundance at age (millions) of Gulf of Alaska pollock from the age-structured assessment model.

	Age									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1970	1,220	304	188	130	92	69	51	38	29	85
1971	3,287	304	152	116	88	63	49	36	27	84
1972	3,712	819	152	94	78	60	45	35	26	82
1973	10,753	924	410	92	57	46	37	28	21	74
1974	2,192	2,678	462	245	54	32	26	21	16	63
1975	2,210	546	1,338	274	136	28	17	14	11	51
1976	8,712	550	273	806	165	79	16	10	8	42
1977	11,881	2,169	275	163	463	89	44	9	6	34
1978	14,600	2,958	1,084	163	90	236	47	23	5	25
1979	25,906	3,635	1,478	643	91	47	127	25	13	20
1980	13,022	6,451	1,818	883	375	51	27	73	15	21
1981	7,251	3,243	3,230	1,104	547	222	31	17	45	24
1982	7,339	1,806	1,624	1,967	701	338	141	20	11	47
1983	5,282	1,827	903	983	1,253	444	222	92	13	41
1984	6,032	1,315	912	539	609	772	283	141	60	38
1985	15,278	1,501	654	537	322	356	466	171	86	64
1986	4,708	3,803	749	390	320	180	203	264	98	95
1987	1,857	1,172	1,902	456	255	210	122	138	181	138
1988	5,029	462	587	1,166	304	171	146	85	96	230
1989	11,962	1,252	232	360	779	205	120	102	60	238
1990	8,431	2,979	627	142	239	519	141	82	71	216
1991	3,295	2,100	1,493	386	95	159	353	96	56	206
1992	2,416	821	1,052	918	259	62	105	230	63	185
1993	1,594	602	411	647	614	168	41	68	151	175
1994	1,731	397	301	252	429	397	110	27	45	227
1995	6,493	431	199	185	167	278	261	72	18	193
1996	3,171	1,617	216	122	124	112	190	178	50	152
1997	1,440	790	810	133	82	84	77	131	123	146
1998	1,405	359	395	496	87	52	53	48	83	184
1999	1,726	350	179	238	307	49	29	29	27	172
2000	6,176	430	175	108	150	179	29	17	17	134
2001	6,748	1,538	215	106	70	92	111	18	10	105
2002	871	1,679	767	129	66	42	57	68	11	80
2003	749	217	835	457	81	42	27	37	45	65
2004	699	186	108	499	293	53	28	18	25	78
2005	1,880	174	92	63	313	187	35	19	12	73
2006	5,441	467	86	53	38	192	119	22	12	60
2007	5,215	1,352	231	50	32	24	122	75	14	51
2008	6,872	1,297	670	136	31	21	16	81	51	46
2009	3,808	1,710	646	399	86	20	14	11	55	69
2010	1,697	948	854	389	261	58	14	10	7	90
2011	6,003	422	473	511	250	170	39	10	7	70
2012	818	1,495	211	285	328	162	114	26	6	55
2013	15,058	204	748	128	183	209	106	75	18	44
2014	4,134	3,750	102	454	83	118	139	71	51	44
Average	5,780	1,423	674	409	254	159	101	64	41	98

Table 1.19. Estimates of population biomass, recruitment, and harvest of Gulf of Alaska pollock from the age-structured assessment model. The harvest rate is the catch in biomass divided by the total biomass of age 3+ fish at the start of the year.

Year	3+ total biomass (1,000 t)	Female spawn. biom. (1,000	Age 1 recruits (million)	Catch (t)	Harvest rate	2013 Assessment results 3+ total biomass	Female spawn. biom.	Age 1 recruits	Harvest rate
1977	757	138	11,881	118,092	16%	774	160	2,748	15%
1978	915	130	14,600	95,408	10%	966	162	2,947	10%
1979	1,280	133	25,906	106,161	8%	1,431	174	5,103	7%
1980	1,743	174	13,022	115,158	7%	1,954	238	2,791	6%
1981	2,694	179	7,251	147,818	5%	2,871	243	610	5%
1982	2,935	270	7,339	169,045	6%	3,284	352	839	5%
1983	2,771	407	5,282	215,625	8%	2,941	521	365	7%
1984	2,425	464	6,032	307,541	13%	2,459	591	682	13%
1985	1,983	446	15,278	286,900	14%	1,848	547	2,686	16%
1986	1,624	404	4,708	86,910	5%	1,483	462	1,003	6%
1987	1,996	377	1,857	68,070	3%	1,703	396	225	4%
1988	1,910	384	5,029	63,391	3%	1,714	380	462	4%
1989	1,731	426	11,962	75,585	4%	1,594	400	2,302	5%
1990	1,575	408	8,431	88,269	6%	1,370	381	1,294	6%
1991	1,757	405	3,295	100,488	6%	1,498	374	498	7%
1992	2,118	375	2,416	90,858	4%	1,795	341	305	5%
1993	1,845	407	1,594	108,909	6%	1,605	369	196	7%
1994	1,539	453	1,731	107,335	7%	1,332	412	253	8%
1995	1,286	410	6,493	72,618	6%	1,113	370	1,289	7%
1996	1,077	373	3,171	51,263	5%	910	328	451	6%
1997	1,108	327	1,440	90,130	8%	939	279	202	10%
1998	982	251	1,405	125,460	13%	849	213	227	15%
1999	782	224	1,726	95,638	12%	672	193	222	14%
2000	689	207	6,176	73,080	11%	588	179	1,184	12%
2001	655	201	6,748	72,077	11%	539	173	948	13%
2002	821	170	871	51,934	6%	679	144	152	8%
2003	1,025	157	749	50,684	5%	796	134	131	6%
2004	835	166	699	63,844	8%	699	141	103	9%
2005	687	208	1,880	80,978	12%	582	178	472	14%
2006	588	218	5,441	71,976	12%	496	182	893	15%
2007	561	196	5,215	52,714	9%	485	162	783	11%
2008	856	192	6,872	52,584	6%	723	161	1,300	7%
2009	1,292	188	3,808	44,247	3%	1,067	163	534	4%
2010	1,468	253	1,697	76,745	5%	1,269	230	209	6%
2011	1,367	299	6,003	81,357	6%	1,203	279	758	7%
2012	1,263	326	818	103,982	8%	1,105	306	156	9%
2013	1,321	366	15,058	96,363	7%	1,074	340	4,084	9%
2014	1,201	297	4,134						
Average									
1977-2013	1,412	290	6,051	101,601	8%	1,308	288	1,065	9%
1978-2013			5,889					963	

Table 1.20. Uncertainty of estimates of recruitment and spawning biomass of Gulf of Alaska pollock from the age-structured assessment model.

Year	*Age-1 Recruits (millions)*	*CV*	*Lower 95% CI*	*Upper 95% CI*	*Spawning biomass (1,000 t)*	*CV*	*Lower 95% CI*	*Upper 95% CI*
1970	1,220	0.26	736	2,023	140	0.26	84	232
1971	3,287	0.36	1,650	6,547	134	0.27	79	226
1972	3,712	0.30	2,082	6,618	123	0.29	71	214
1973	10,753	0.14	8,234	14,042	103	0.32	55	191
1974	2,192	0.25	1,361	3,532	89	0.31	49	162
1975	2,210	0.23	1,409	3,469	88	0.25	55	143
1976	8,712	0.16	6,360	11,935	120	0.17	87	167
1977	11,881	0.16	8,772	16,092	138	0.16	101	190
1978	14,600	0.15	10,805	19,727	130	0.19	90	189
1979	25,906	0.13	20,098	33,392	133	0.20	89	197
1980	13,022	0.16	9,494	17,861	174	0.19	120	251
1981	7,251	0.19	4,967	10,585	179	0.17	129	248
1982	7,339	0.19	5,040	10,685	270	0.15	203	360
1983	5,282	0.27	3,116	8,952	407	0.14	311	532
1984	6,032	0.25	3,700	9,834	464	0.15	350	617
1985	15,278	0.13	11,801	19,780	446	0.16	326	611
1986	4,708	0.22	3,066	7,228	404	0.18	287	570
1987	1,857	0.34	969	3,557	377	0.17	271	523
1988	5,029	0.19	3,483	7,262	384	0.15	285	518
1989	11,962	0.12	9,489	15,079	426	0.13	331	549
1990	8,431	0.13	6,500	10,935	408	0.12	323	515
1991	3,295	0.21	2,182	4,975	405	0.12	321	512
1992	2,416	0.21	1,599	3,652	375	0.11	299	469
1993	1,594	0.23	1,012	2,510	407	0.11	332	500
1994	1,731	0.22	1,131	2,649	453	0.10	373	551
1995	6,493	0.10	5,318	7,928	410	0.10	337	499
1996	3,171	0.14	2,433	4,134	373	0.10	306	453
1997	1,440	0.19	988	2,099	327	0.10	267	399
1998	1,405	0.18	993	1,990	251	0.11	202	310
1999	1,726	0.16	1,260	2,364	224	0.11	179	280
2000	6,176	0.10	5,101	7,478	207	0.12	164	260
2001	6,748	0.09	5,656	8,050	201	0.12	158	256
2002	871	0.23	557	1,360	170	0.13	132	220
2003	749	0.20	508	1,105	157	0.13	122	202
2004	699	0.21	463	1,057	166	0.11	134	205
2005	1,880	0.14	1,418	2,493	208	0.11	169	257
2006	5,441	0.11	4,363	6,785	218	0.11	175	271
2007	5,216	0.12	4,109	6,621	196	0.12	154	249
2008	6,872	0.12	5,415	8,720	192	0.13	150	247
2009	3,808	0.16	2,798	5,184	188	0.12	148	240
2010	1,697	0.27	1,004	2,869	253	0.11	203	316
2011	6,003	0.22	3,901	9,237	299	0.11	241	371
2012	818	0.63	265	2,526	326	0.11	261	407
2013	15,058	0.34	7,832	28,950	366	0.12	289	463
2014	4,134	0.84	992	17,233	297	0.13	232	381

Table 1.21. Gulf of Alaska pollock life history and fishery vectors used to estimate spawning biomass per recruit (F_{SPR}) harvest rates. Spawning weight at age is based on an average from the Shelikof Strait acoustic survey conducted in March. Population weight at age is based on a average for the bottom trawl survey conducted in June to August. Proportion mature females is the average from winter acoustic survey specimen data for 1983-2014.

			Weight at age (kg)			
	Natural mortality	*Fishery selectivity (Avg. 2009-2013)*	*Spawning (Avg. 2009-2014)*	*Population (Avg. 2009-2013)*	*Fishery (Avg. 2009-2013)*	*Proportion mature females*
1	1.39	0.005	0.010	0.038	0.125	0.000
2	0.69	0.044	0.084	0.244	0.378	0.000
3	0.48	0.272	0.285	0.495	0.642	0.016
4	0.37	0.741	0.613	0.919	0.978	0.254
5	0.34	0.960	0.925	1.202	1.218	0.558
6	0.30	0.996	1.271	1.481	1.497	0.830
7	0.30	1.000	1.582	1.640	1.665	0.919
8	0.29	0.991	1.792	1.766	1.898	0.965
9	0.28	0.879	1.949	1.924	2.096	0.986
10+	0.29	0.347	2.032	2.068	2.143	0.992

Table 1.22. Methods used to assess Gulf of Alaska pollock, 1977-2013. The basis for catch recommendation in 1977-1989 is the presumptive method by which the ABC was determined (based on the assessment and SSC minutes). The basis for catch recommendation given in 1990-2013 is the method used by the Plan Team to derive the ABC recommendation given in the SAFE summary chapter.

Year	*Assessment method*	*Basis for catch recommendation in following year*	*B40% (t)*
1977-81	Survey biomass, CPUE trends, M=0.4	MSY = 0.4 * M * Bzero	---
1982	CAGEAN	MSY = 0.4 * M * Bzero	---
1983	CAGEAN	Mean annual surplus production	---
1984	Projection of survey numbers at age	Stabilize biomass trend	---
1985	CAGEAN, projection of survey numbers at age, CPUE trends	Stabilize biomass trend	---
1986	CAGEAN, projection of survey numbers at age	Stabilize biomass trend	---
1987	CAGEAN, projection of survey numbers at age	Stabilize biomass trend	---
1988	CAGEAN, projection of survey numbers at age	10% of exploitable biomass	---
1989	Stock synthesis	10% of exploitable biomass	---
1990	Stock synthesis, reduce *M* to 0.3	10% of exploitable biomass	---
1991	Stock synthesis, assume trawl survey catchability = 1	FMSY from an assumed SR curve	---
1992	Stock synthesis	Max[-Pr(SB<Threshold)+Yld]	---
1993	Stock synthesis	Pr(SB>B20)=0.95	---
1994	Stock synthesis	Pr(SB>B20)=0.95	---
1995	Stock synthesis	Max[-Pr(SB<Threshold)+Yld]	---
1996	Stock synthesis	Amendment 44 Tier 3 guidelines	289,689
1997	Stock synthesis	Amendment 44 Tier 3 guidelines	267,600
1998	Stock synthesis	Amendment 44 Tier 3 guidelines	240,000
1999	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	247,000
2000	AD model builder	Amendment 56 Tier 3 guidelines	250,000
2001	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	245,000
2002	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	240,000
2003	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	248,000
2004	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC}, and stairstep approach for projected ABC increase)	229,000
2005	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible FABC)	224,000
2006	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible FABC)	220,000
2007	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	221,000
2008	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	237,000
2009	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	248,000
2010	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	276,000
2011	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	271,000
2012	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	297,000
2013	AD model builder	Amendment 56 Tier 3 guidelines (with a reduction from max permissible F_{ABC})	290,000

Table 1.23. Projections of Gulf of Alaska pollock spawning biomass, full recruitment fishing mortality, and catch for 2014-2027 under different harvest policies. All projections begin with estimated age composition in 2014 using the base run model with a projected 2014 catch of 159,149 t (95% of the ABC). The values for $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 779,000, 312,000 and 273,000 t, respectively.

Spawning biomass (t)	*Max F_{ABC}*	*Author's recommended F*	*Average F*	*$F_{75\%}$*	*F = 0*	*F_{OFL}*	*Max F_{ABC} for two years, then F_{OFL}*
2014	340,111	340,111	340,111	340,111	340,111	340,111	340,111
2015	307,899	309,869	314,535	317,301	321,152	305,746	307,899
2016	320,665	330,497	357,339	373,684	397,609	309,565	320,665
2017	342,977	357,051	412,328	444,724	494,109	323,091	340,489
2018	359,084	372,885	464,341	516,131	598,293	330,175	344,612
2019	349,307	361,603	479,224	546,771	658,336	316,122	326,113
2020	340,484	352,826	484,365	563,399	698,559	307,530	313,250
2021	337,374	349,711	488,031	575,420	729,062	305,201	308,296
2022	335,835	348,101	489,344	582,432	749,409	304,281	305,886
2023	334,333	346,520	488,155	584,249	758,365	303,199	304,044
2024	333,790	345,938	487,280	585,626	765,519	302,926	303,378
2025	335,255	347,365	488,417	588,359	772,498	304,453	304,699
2026	338,099	350,241	491,590	592,951	780,649	307,162	307,298
2027	338,170	350,279	492,357	594,937	785,586	306,982	307,058

Fishing mortality	*Max F_{ABC}*	*Author's recommended F*	*Average F*	*$F_{75\%}$*	*F = 0*	*F_{OFL}*	*Max F_{ABC} for two years, then F_{OFL}*
2014	0.17	0.17	0.17	0.17	0	0.17	0.17
2015	0.24	0.20	0.12	0.07	0	0.28	0.24
2016	0.24	0.22	0.12	0.07	0	0.28	0.24
2017	0.24	0.24	0.12	0.07	0	0.29	0.29
2018	0.24	0.24	0.12	0.07	0	0.28	0.29
2019	0.24	0.22	0.12	0.07	0	0.26	0.27
2020	0.22	0.21	0.12	0.07	0	0.25	0.25
2021	0.22	0.21	0.12	0.07	0	0.24	0.25
2022	0.22	0.20	0.12	0.07	0	0.24	0.24
2023	0.22	0.20	0.12	0.07	0	0.24	0.24
2024	0.22	0.20	0.12	0.07	0	0.24	0.24
2025	0.22	0.20	0.12	0.07	0	0.24	0.24
2026	0.22	0.20	0.12	0.07	0	0.24	0.24
2027	0.22	0.20	0.12	0.07	0	0.24	0.24

Catch (t)	*Max F_{ABC}*	*Author's recommended F*	*Average F*	*$F_{75\%}$*	*F = 0*	*F_{OFL}*	*Max F_{ABC} for two years, then F_{OFL}*
2014	159,149	159,149	159,149	159,149	159,149	159,149	159,149
2015	222,774	191,309	114,537	67,485	0	256,545	222,774
2016	272,165	250,824	147,426	89,224	0	307,150	272,165
2017	264,986	266,206	153,308	95,355	0	294,778	306,619
2018	258,976	261,455	157,512	100,180	0	282,741	291,479
2019	249,963	243,091	158,838	102,596	0	261,639	269,941
2020	239,779	232,891	159,841	104,191	0	251,158	255,157
2021	235,636	229,597	160,693	105,545	0	248,436	250,157
2022	225,721	219,686	152,261	99,487	0	239,729	240,202
2023	227,144	221,045	153,423	100,588	0	241,680	241,815
2024	229,576	223,700	154,303	101,180	0	244,868	244,898
2025	231,950	225,817	155,365	101,901	0	247,321	247,331
2026	232,797	227,051	155,479	102,036	0	248,402	248,405
2027	229,537	223,573	154,175	101,332	0	244,489	244,490

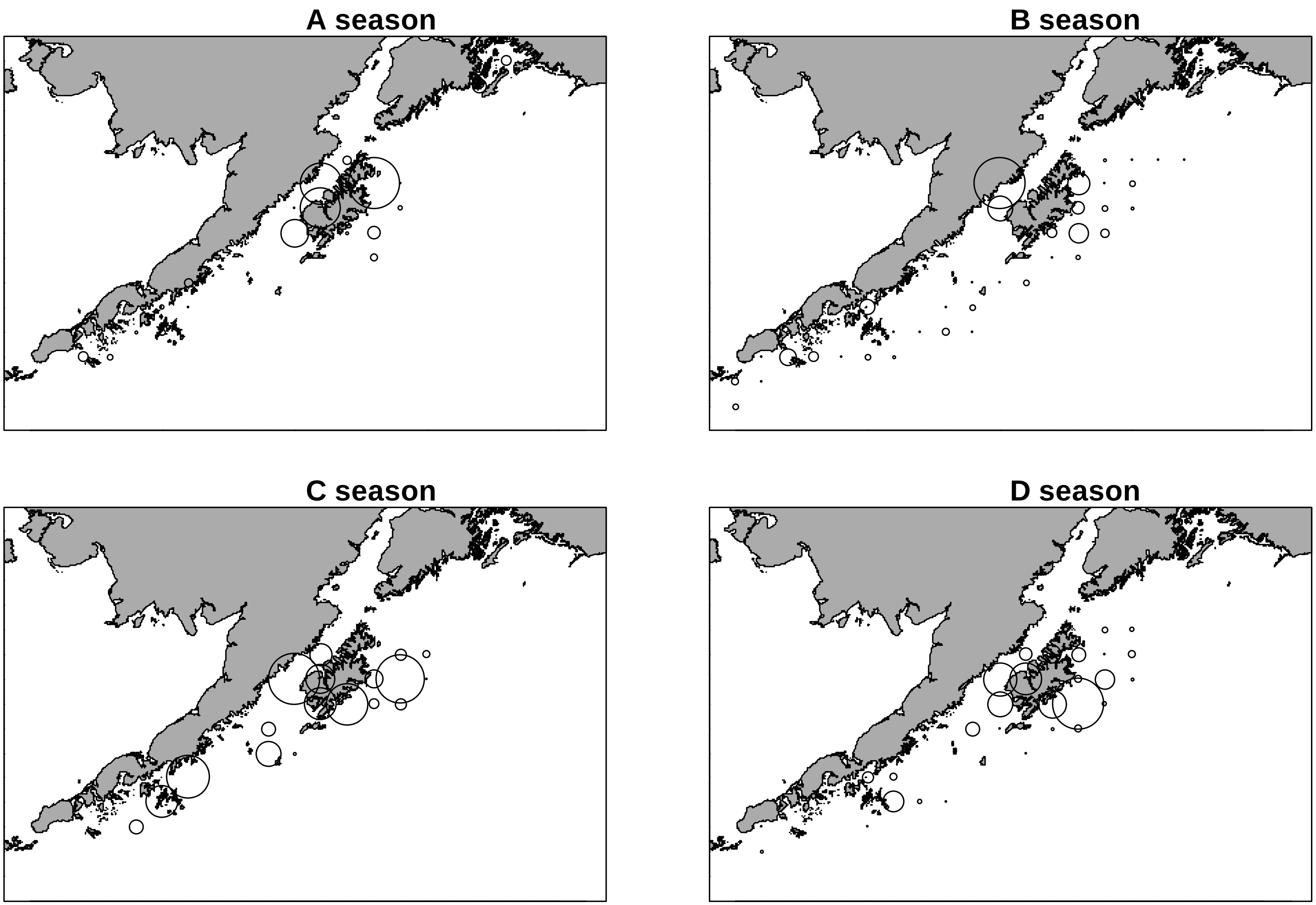


Figure 1.1. Pollock catch in 2013 for 1/2 degree latitude by 1 degree longitude blocks by season in the Gulf of Alaska as determined by fishery observer-recorded haul retrieval locations. Blocks with less than 1.0 t of pollock catch are not shown. The area of the circle is proportional to the catch.

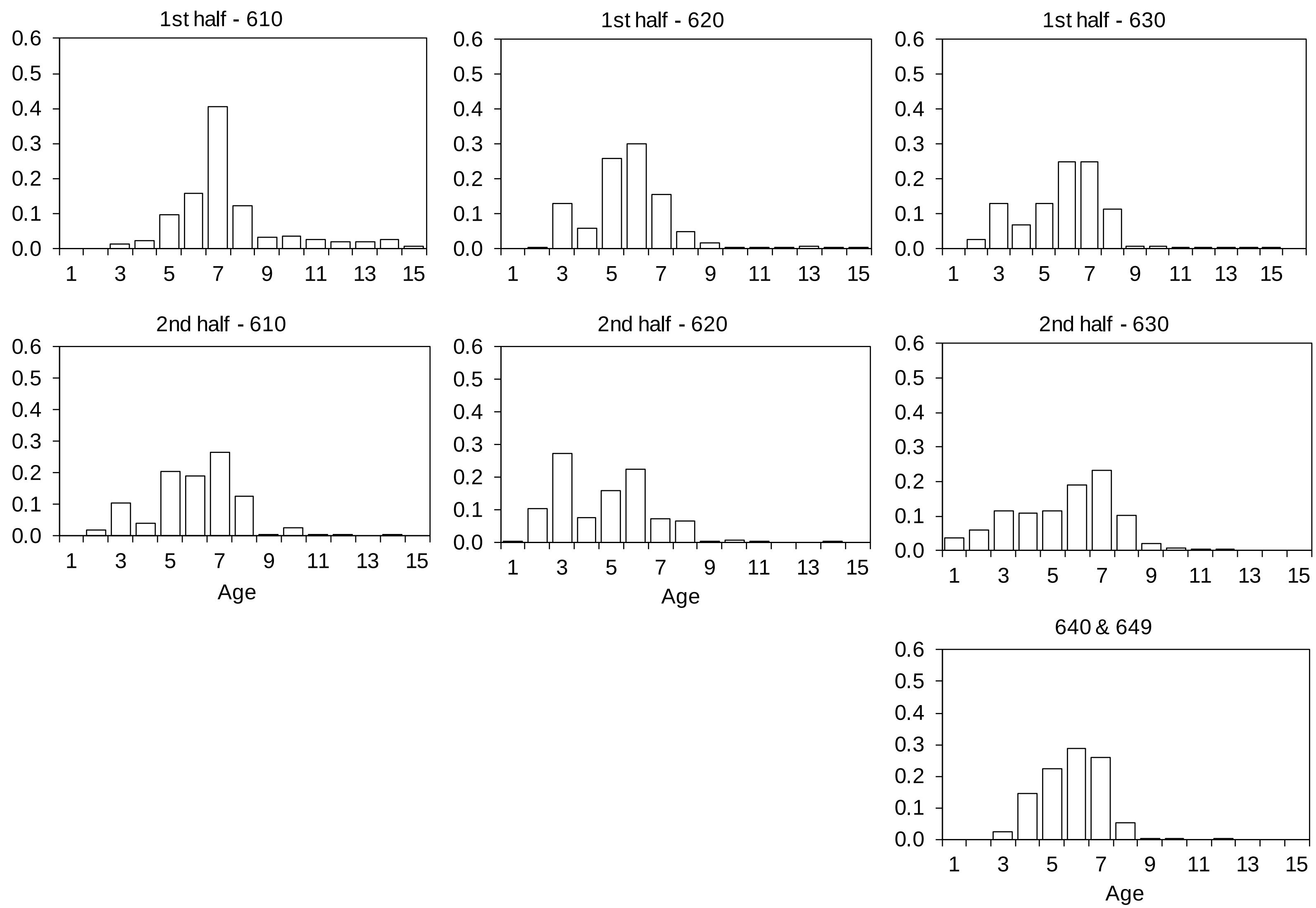


Figure 1.2. 2013 fishery age composition by half year (January-June, July-December) and statistical area.

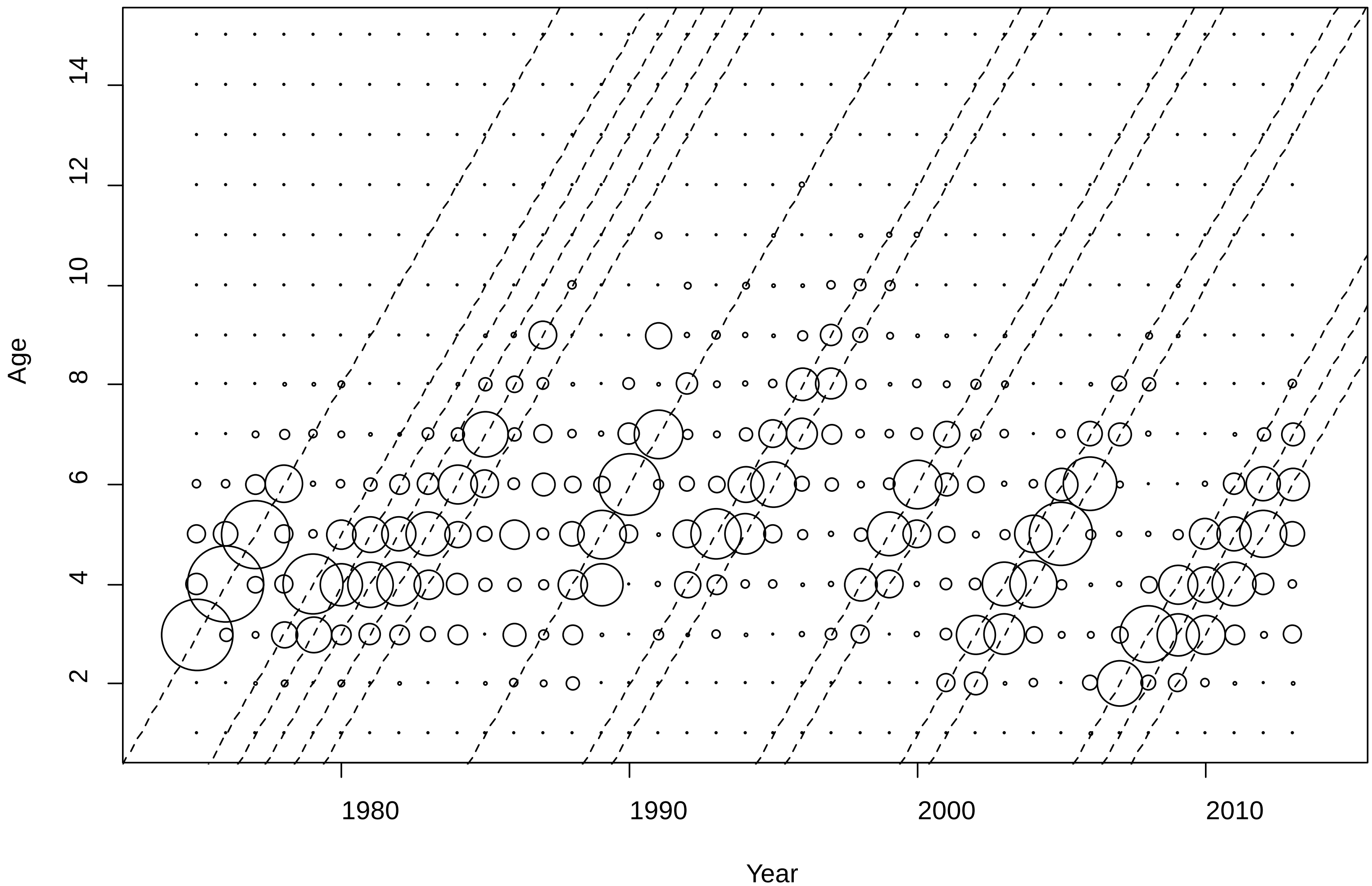


Figure 1.3. Gulf of Alaska pollock fishery age composition (1975-2013). The diameter of the circle is proportional to the catch. Diagonal lines show strong year classes (1972, 1975, 1976, 1977, 1978, 1979, 1984, 1988, 1994, 1995, 1999, 2000, 2005, 2006, and 2007).

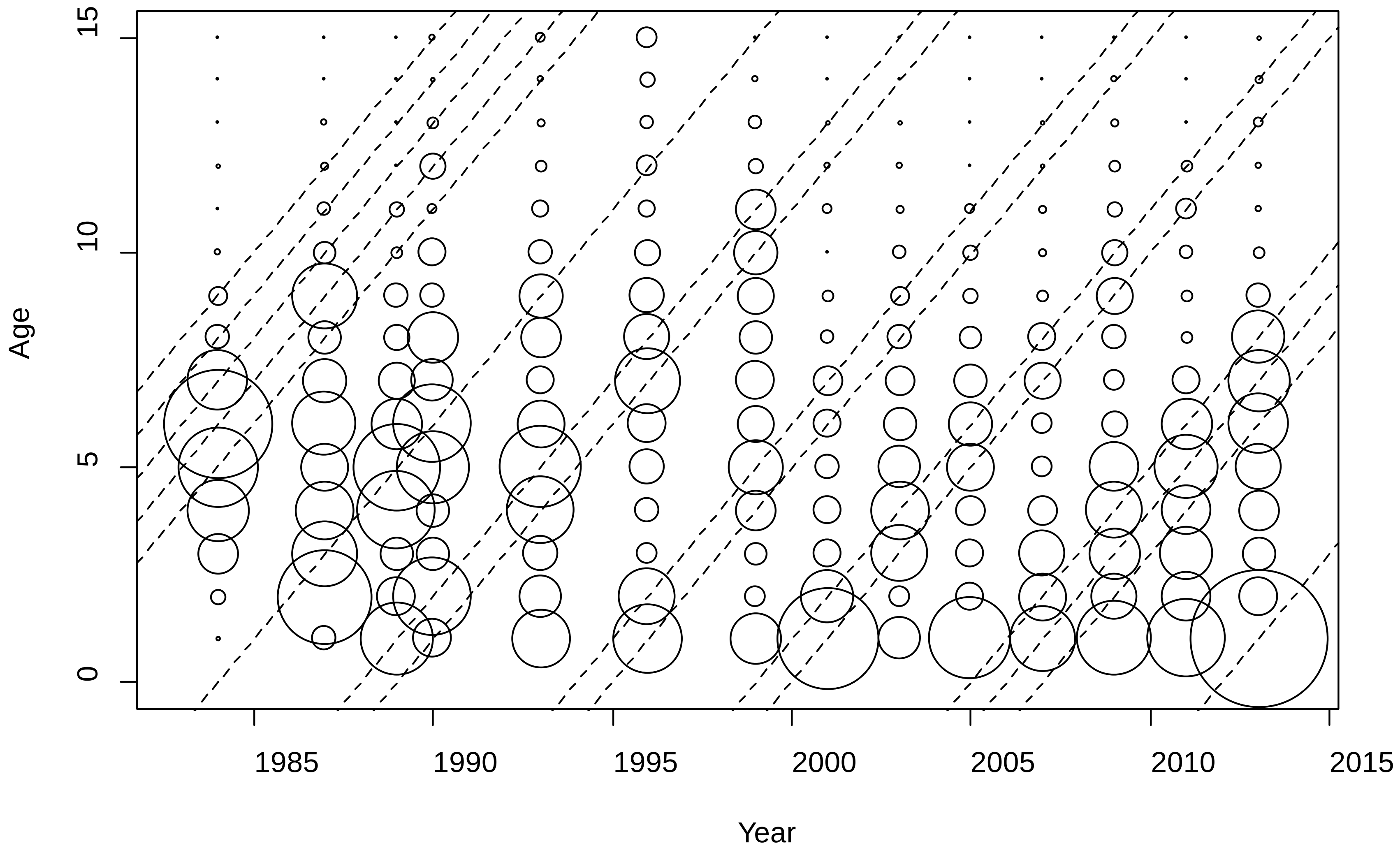


Figure 1.4. Estimated abundance at age in the NMFS bottom trawl survey (1984-2013). The area of the circle is proportional to the estimated abundance.

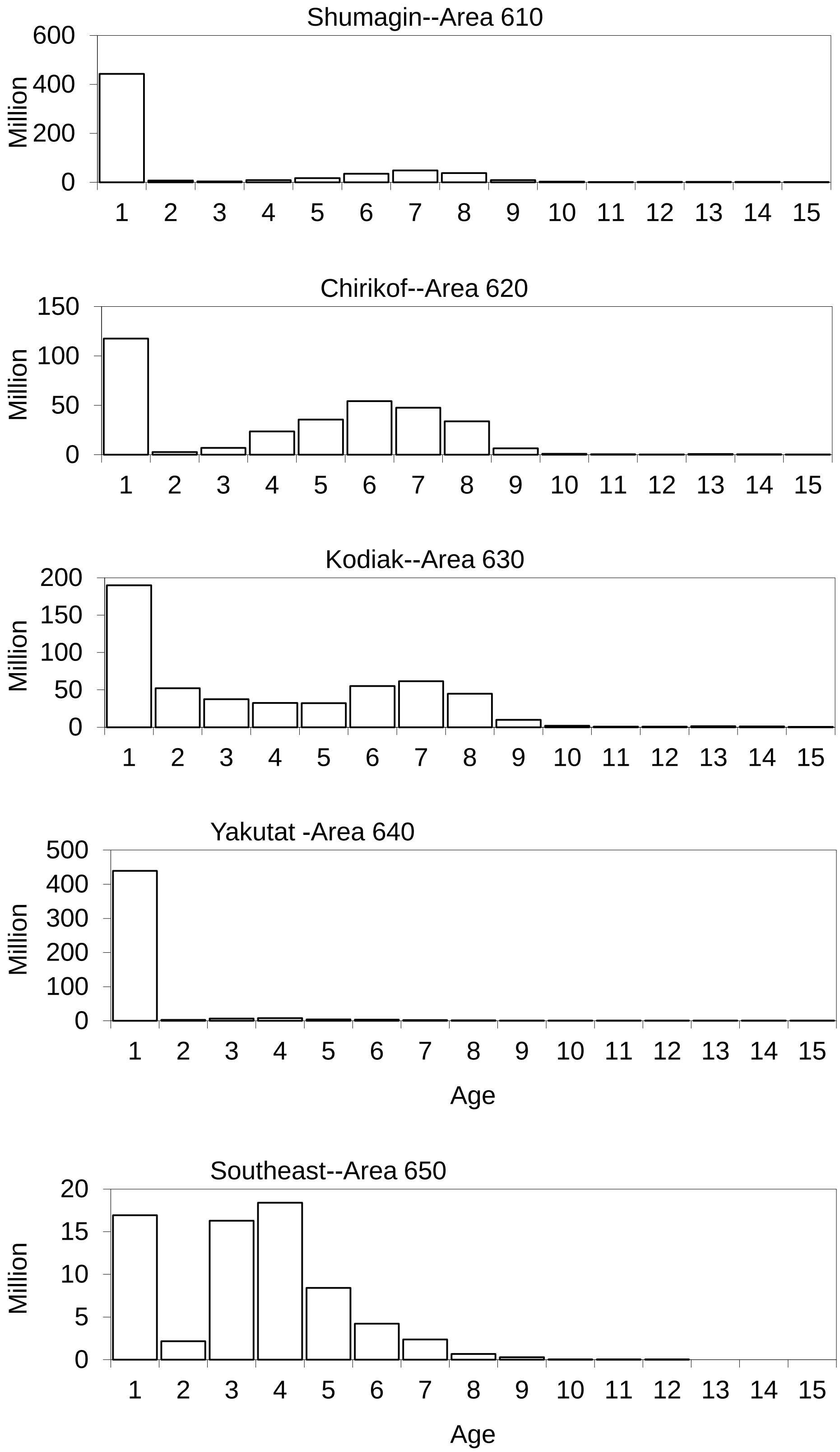


Figure 1.5. Age composition of pollock by statistical area for the 2013 NMFS bottom trawl survey.

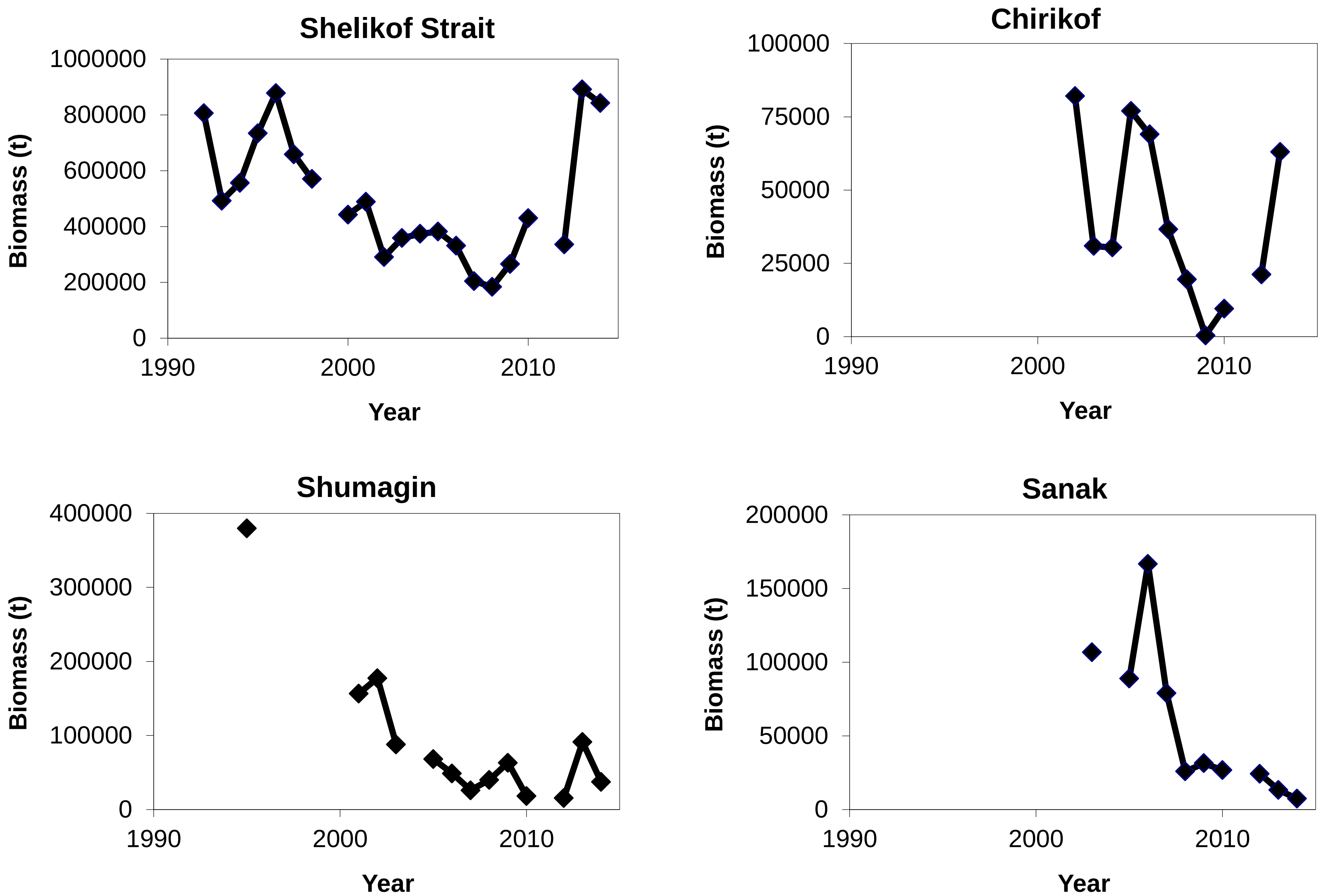


Figure 1.6. Trends in biomass estimates from winter acoustic surveys of pre-spawning aggregations of pollock in the Gulf of Alaska. No survey was conducted in the Chirikof area in 2014.

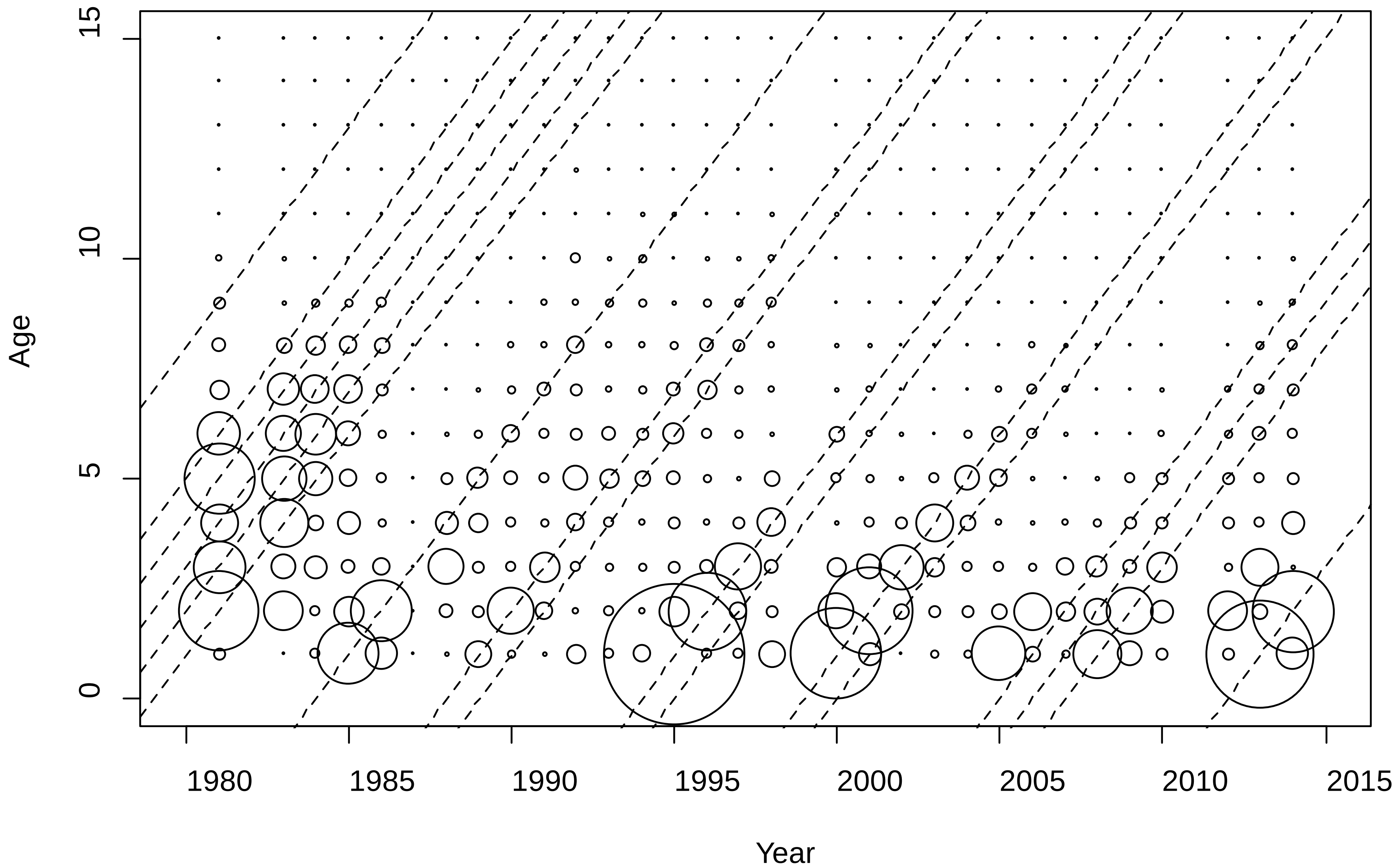


Figure 1.7. Estimated abundance at age in the Shelikof Strait acoustic survey (1981-2014, except 1982, 1987, 1999, and 2011). The area of the circle is proportional to the estimated abundance.

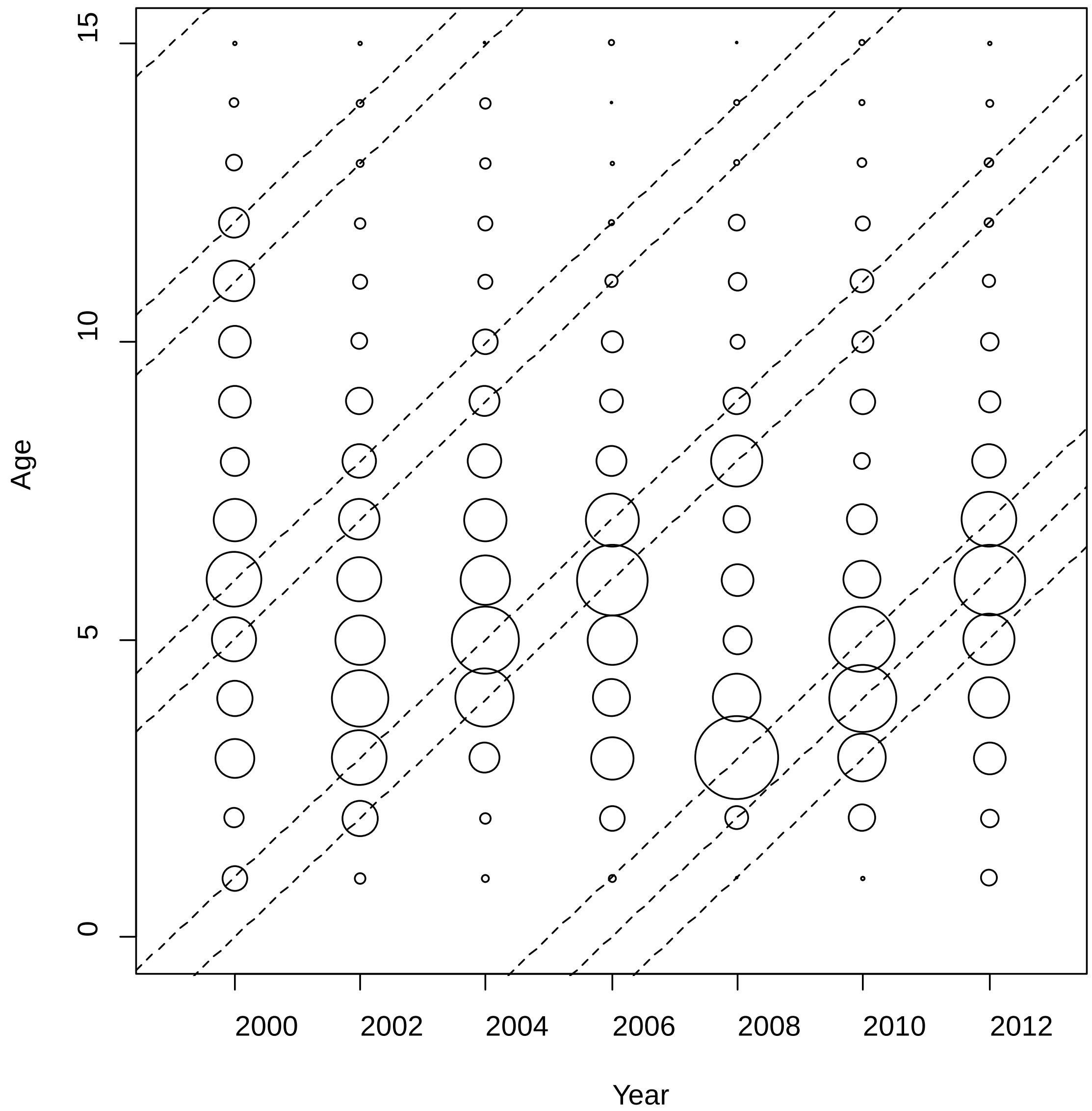


Figure 1.8. Estimated proportions at age in the ADF&G crab/groundfish survey (2000-2012). The area of the circle is proportional to the estimated abundance.

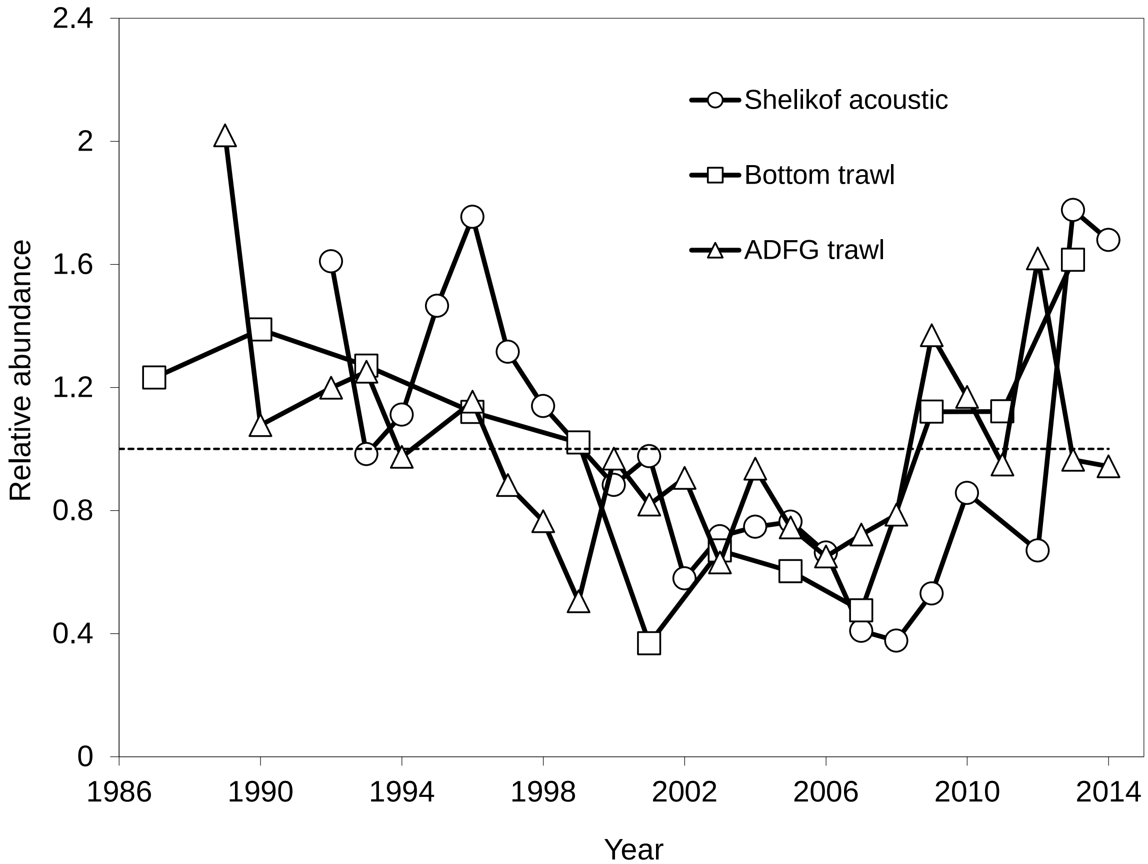


Figure 1.9. Relative trends in pollock biomass since 1987 for the Shelikof Strait acoustic survey, the NMFS bottom trawl survey, and the ADFG crab/groundfish trawl survey. Each survey biomass estimate is standardized to the average since 1987. Shelikof Strait acoustic surveys prior to 2008 were re-scaled to be comparable to the surveys conducted from 2008 onwards by the *R/V Oscar Dyson*.

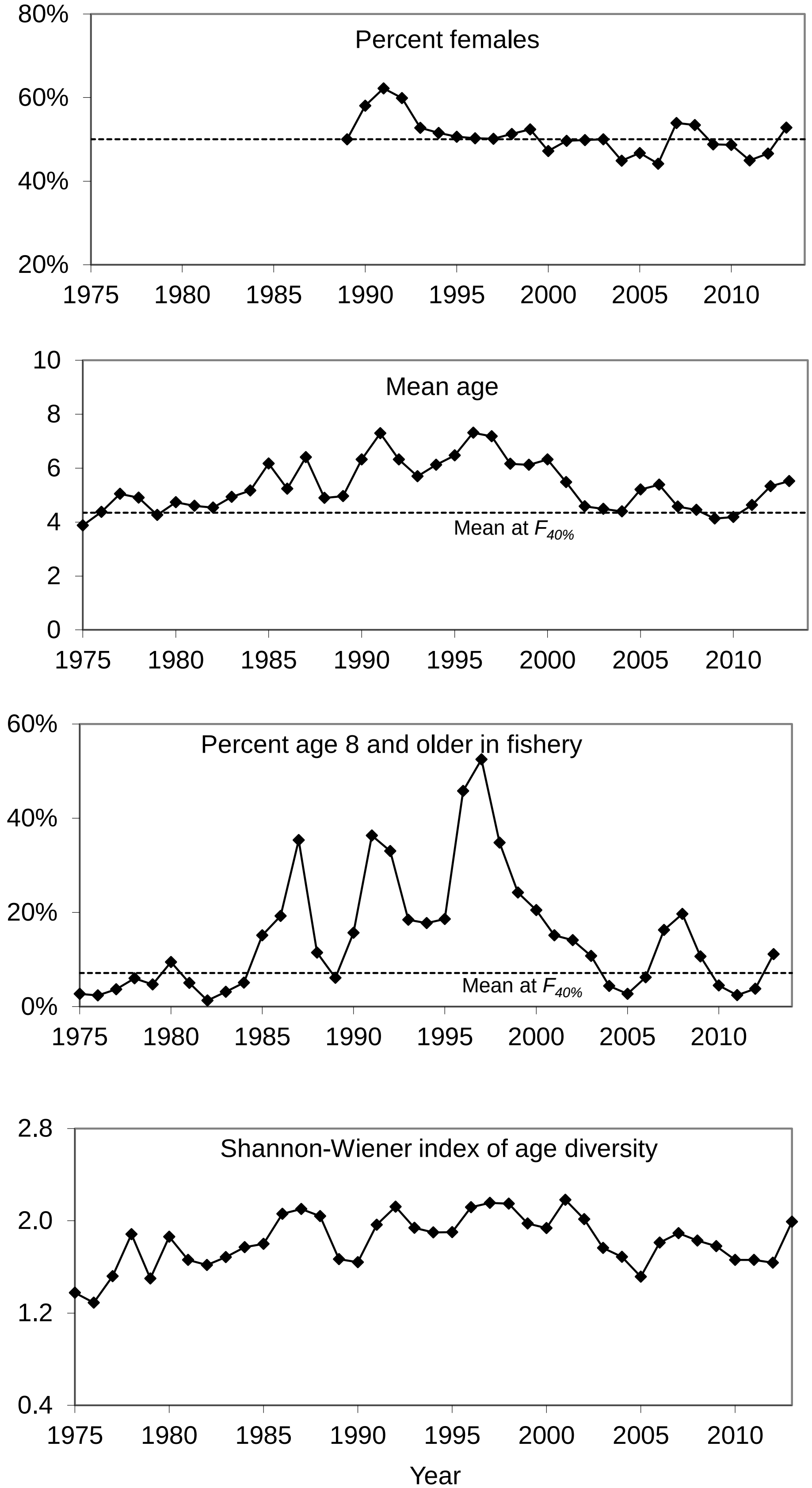


Figure 1.10. Gulf of Alaska pollock fishery catch characteristics.

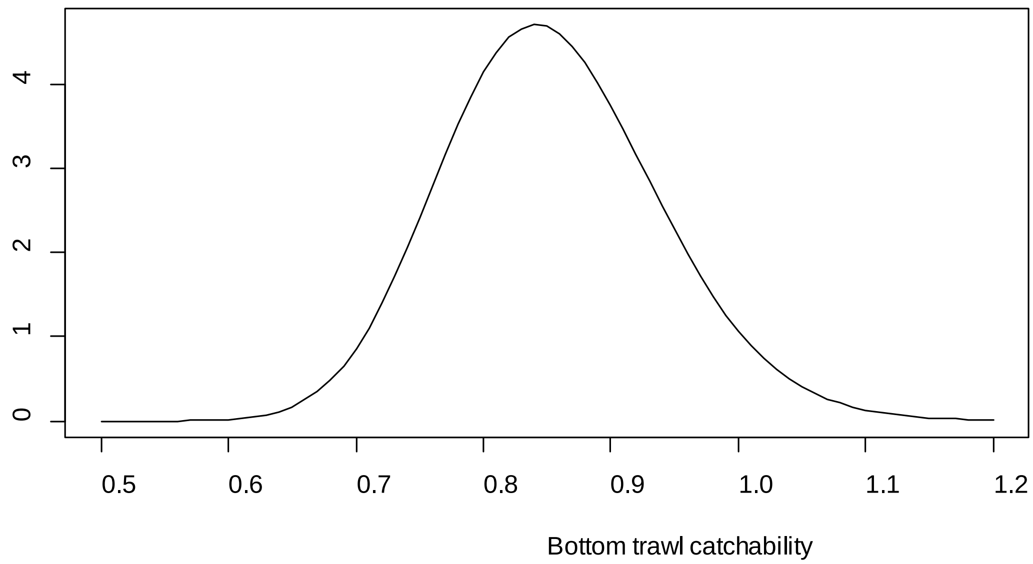


Figure 1.11. Prior on bottom trawl catchability used in the base model.

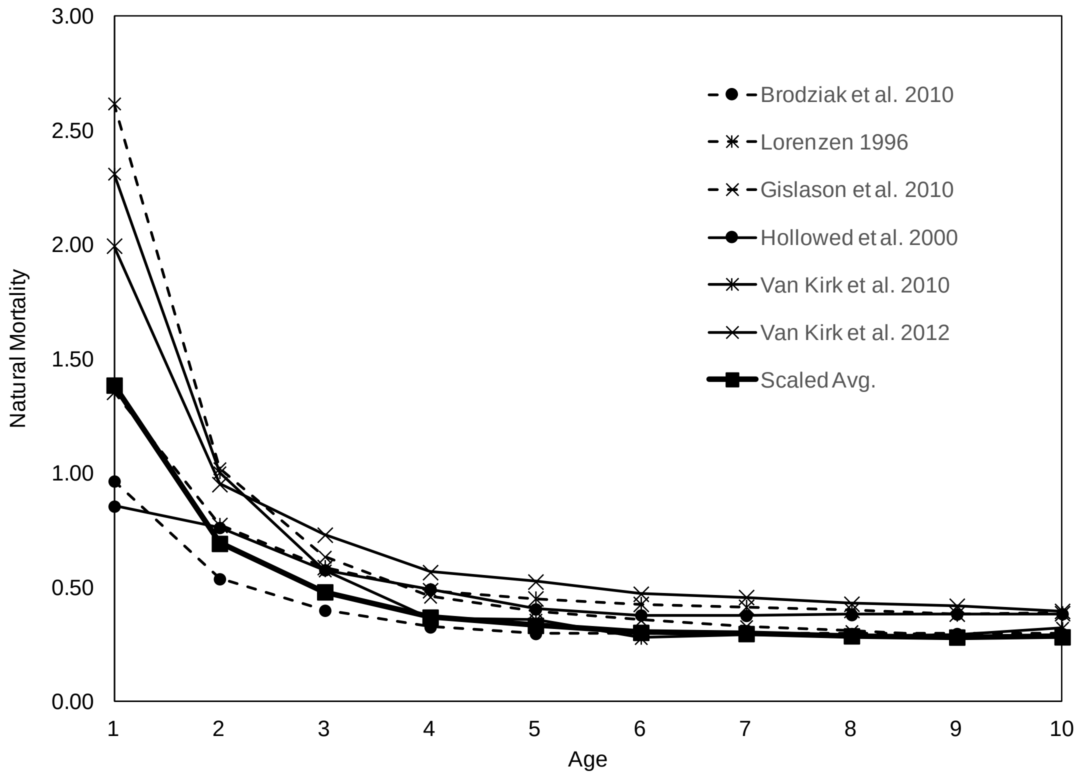


Figure 1.12. Alternative estimates of age-specific natural mortality. The scaled average was used in the stock assessment model.

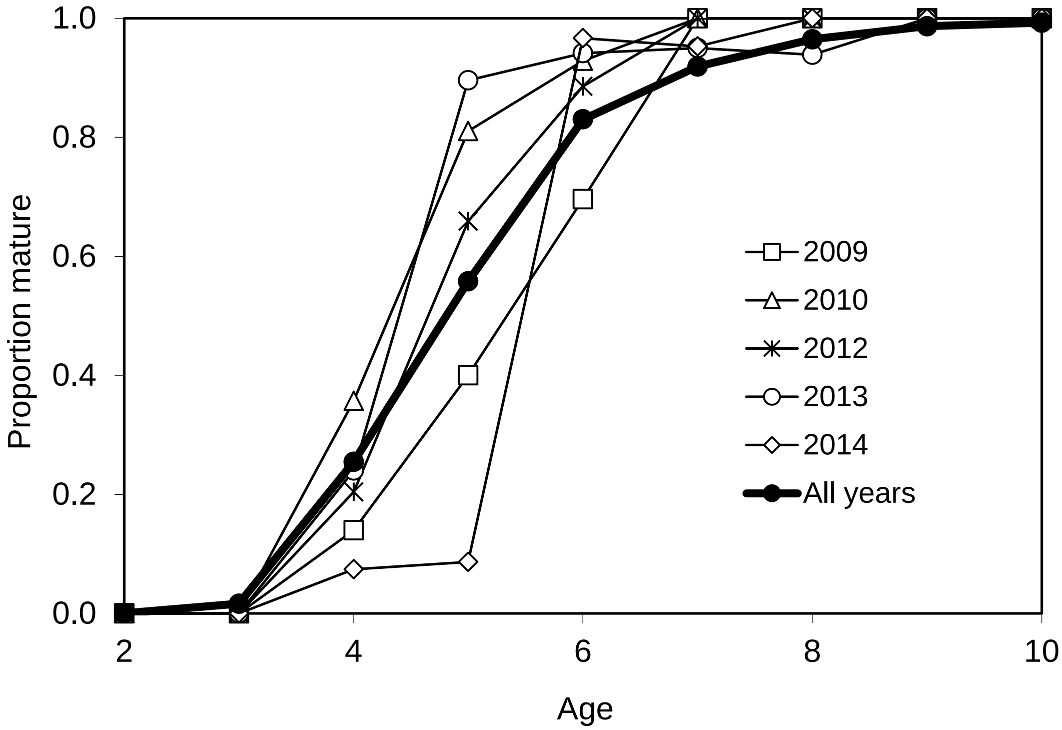


Figure 1.13. Estimates of the proportion mature at age from visual maturity data collected during 2009-2014 winter acoustic surveys in the Gulf of Alaska and long-term average proportion mature at age (1983-2014).

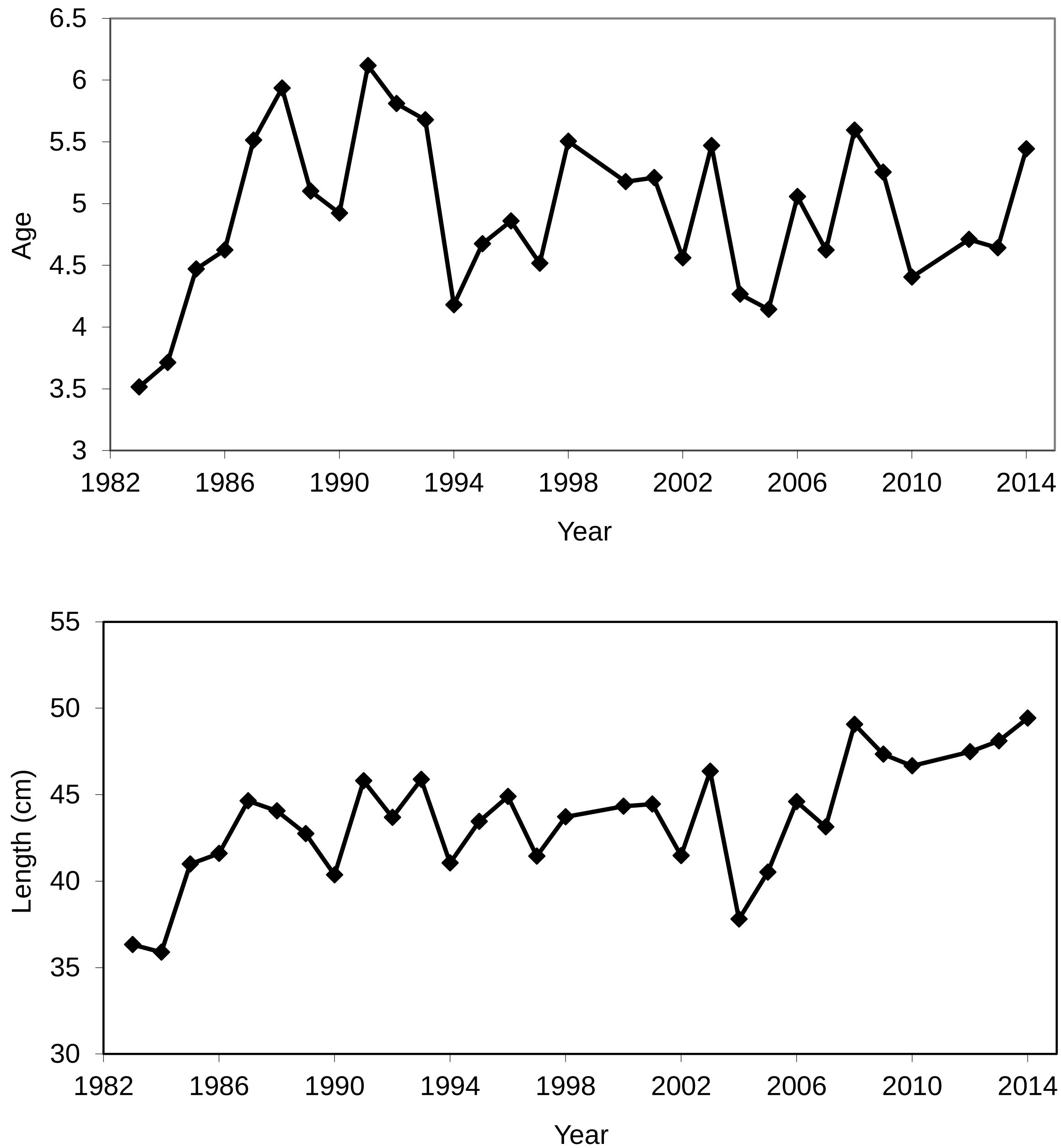


Figure 1.14. Age at 50% mature (top) and length at 50% mature (bottom) from annual logistic regressions for female pollock from winter acoustic survey data in the Gulf of Alaska, 1983-2014.

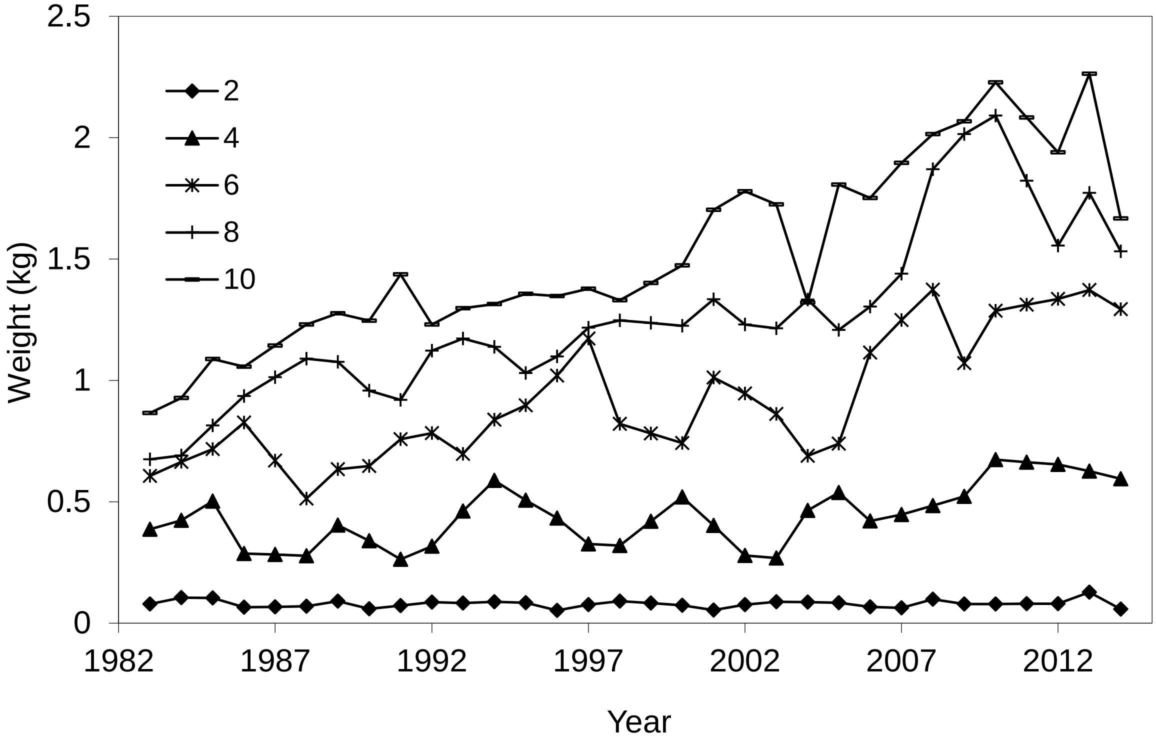


Figure 1.15. Estimated weight-at-age of Gulf of Alaska pollock (ages 2, 4, 6, and 10) from Shelikof Strait acoustic surveys in 1983-2014 used in the assessment model. In 1999 and 2011, when the acoustic survey was not conducted, weights-at-age were interpolated from adjacent years.

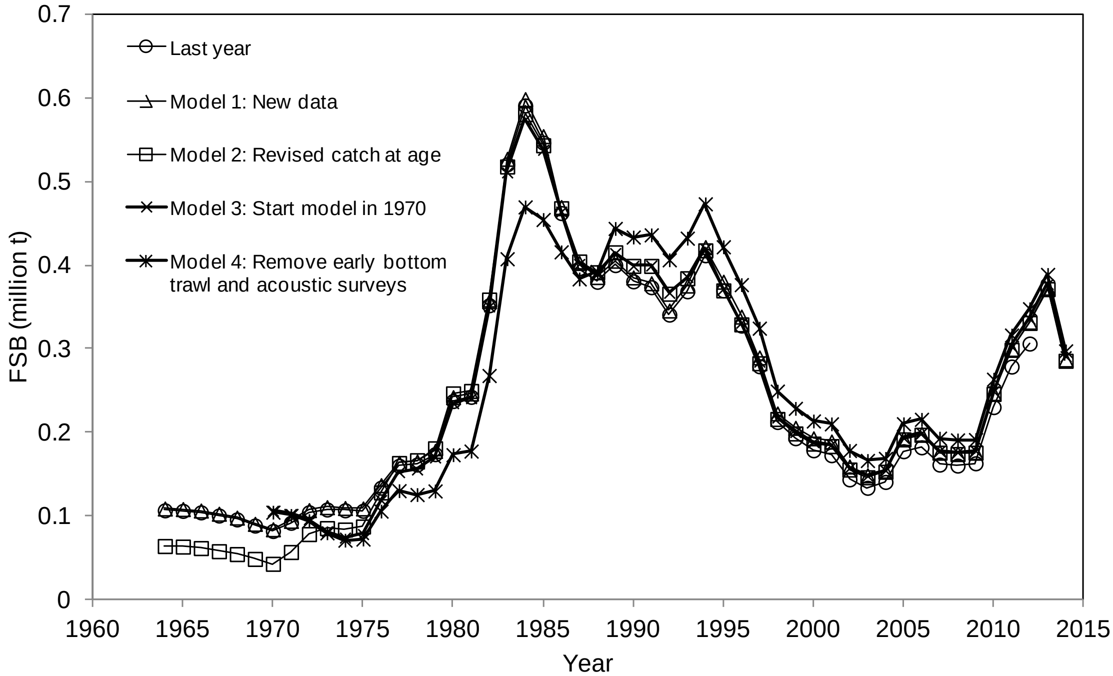


Figure 1.16. Comparison of estimated spawning biomass from alternative models. Model 1 updates the 2013 assessment model with new data but makes no changes to the model configuration. Model 2 incorporates re-estimated total catch, catch at age and fishery weight at age for 1975-1999 and corrects several minor coding errors. Model 3 starts in 1970 and remove fishery length composition data for 1964-1971. Model 4 removes bottom trawl surveys in 1984 and 1987, and acoustic surveys in Shelikof Strait for 1981-1991. Model changes are cumulative, i.e., each model includes the features of previous models.

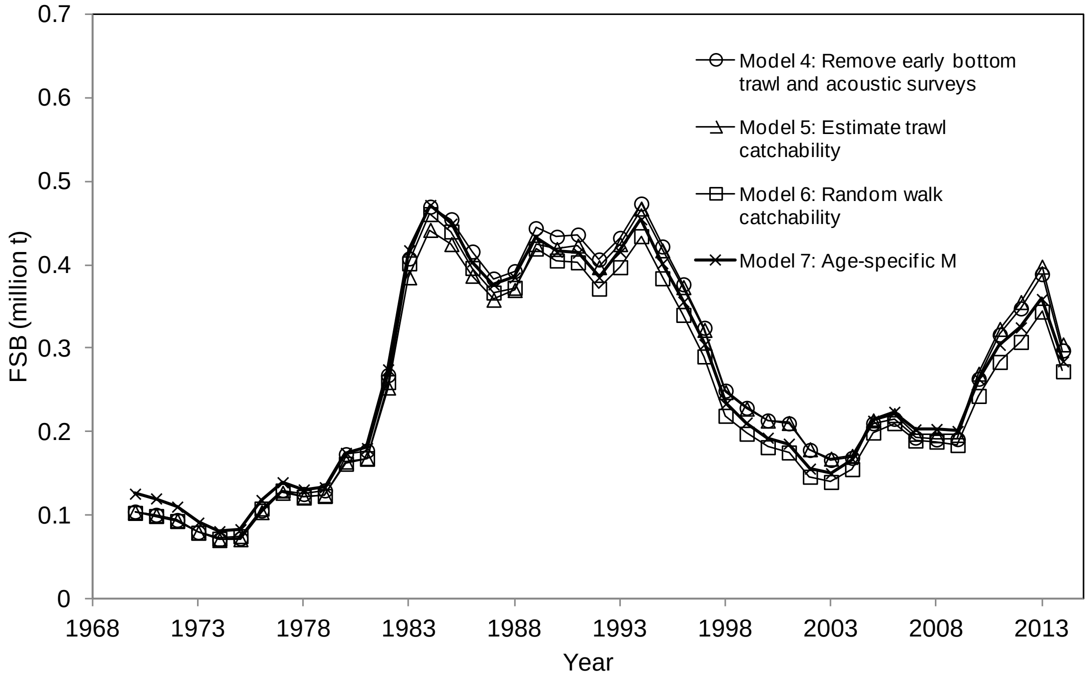


Figure 1.17. Comparison of estimated spawning biomass from alternative models. Model 4 removes bottom trawl surveys in 1984 and 1987, and acoustic surveys in Shelikof Strait for 1981-1991. Model 5 estimates summer bottom trawl survey catchability, adds prior for catchability to the likelihood function, and assumes that selectivity is asymptotic for the trawl survey. Model 6 uses random walks in fishery selectivity parameters to model fishery selectivity instead of blocks, and assume no interannual variation in the descending portion of the curve. Model 7 uses an age-specific natural mortality schedule based on an ensemble average of several methods. Model changes are cumulative, i.e., each model includes the features of previous models.

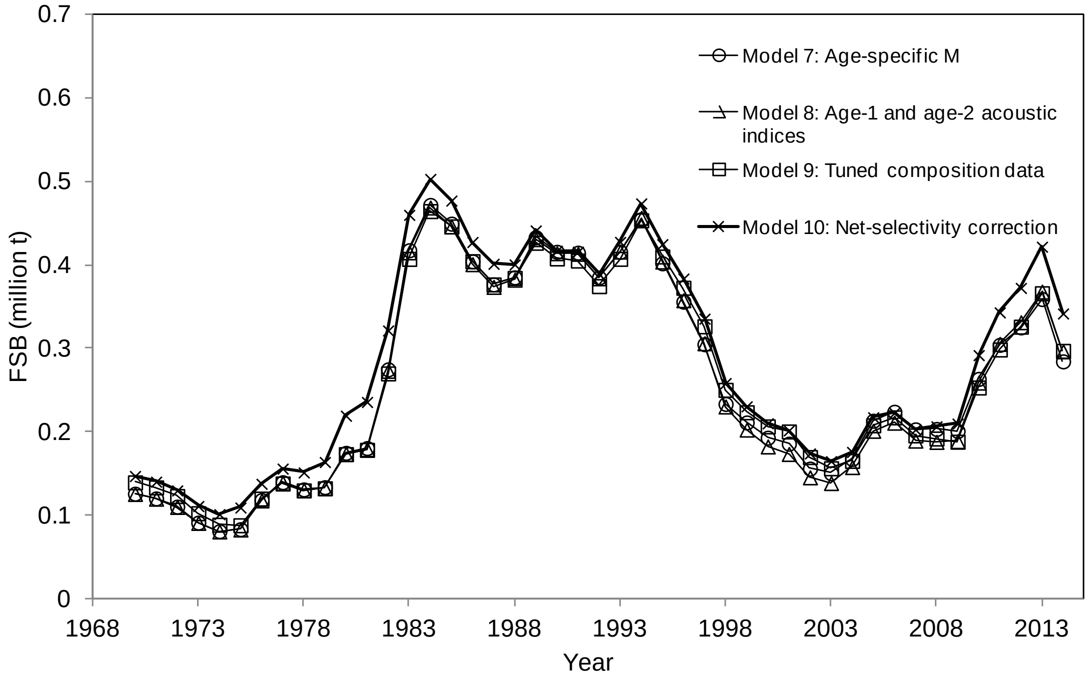


Figure 1.18. Comparison of estimated spawning biomass from alternative models. Model 7 uses an age-specific natural mortality schedule based on an ensemble average of several methods. Model 8 uses separate indices for age-1 and age-2 pollock in the acoustic survey. Model 9 iteratively tunes the age-composition data so that the input sample size is close to the harmonic mean of effective sample size. Model 10 evaluates acoustic biomass and age-composition estimates corrected for net selectivity. Model changes are cumulative, i.e., each model includes the features of previous models.

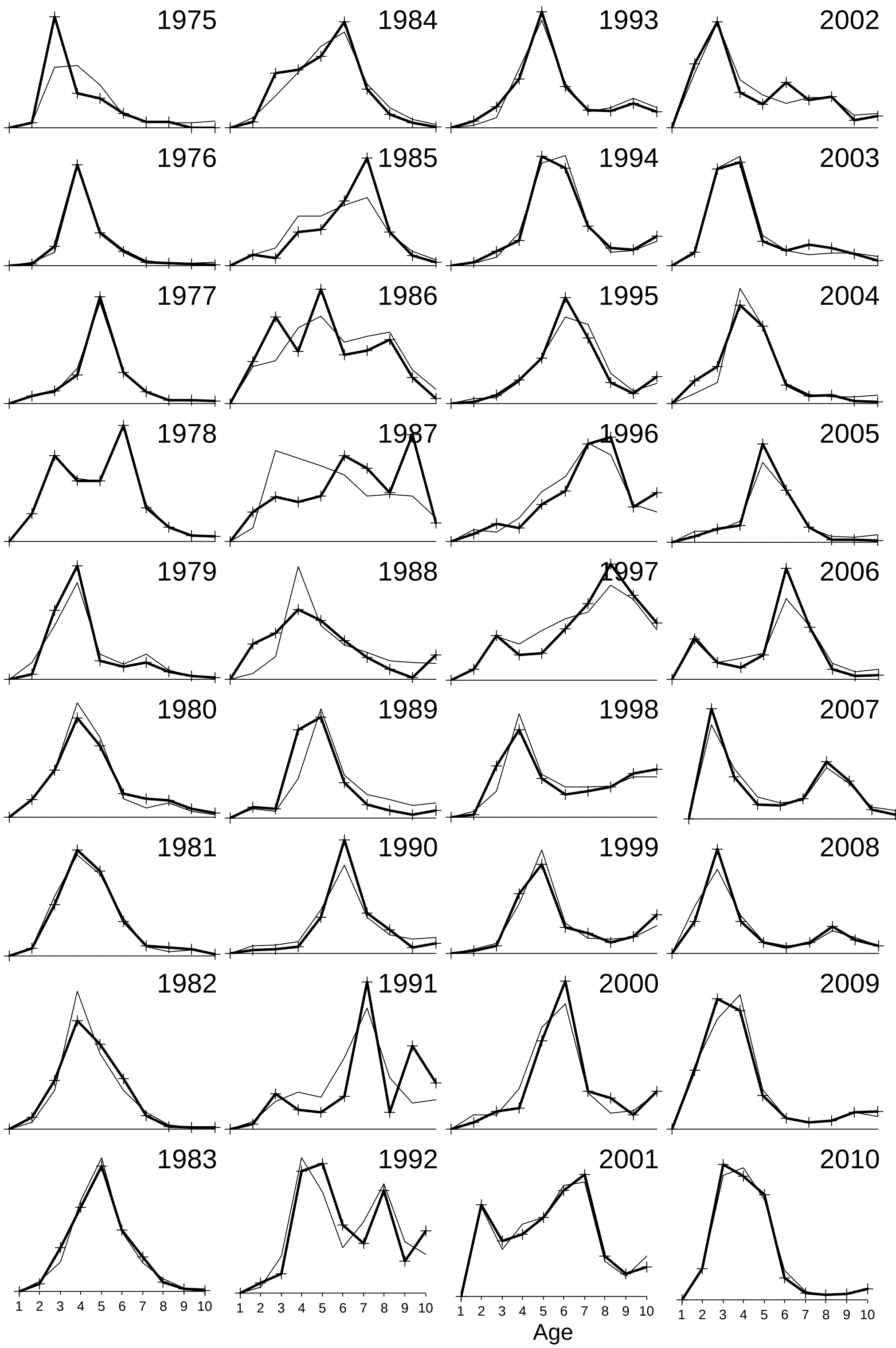


Figure 1.19. Observed and predicted fishery age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbol are observed proportions at age.

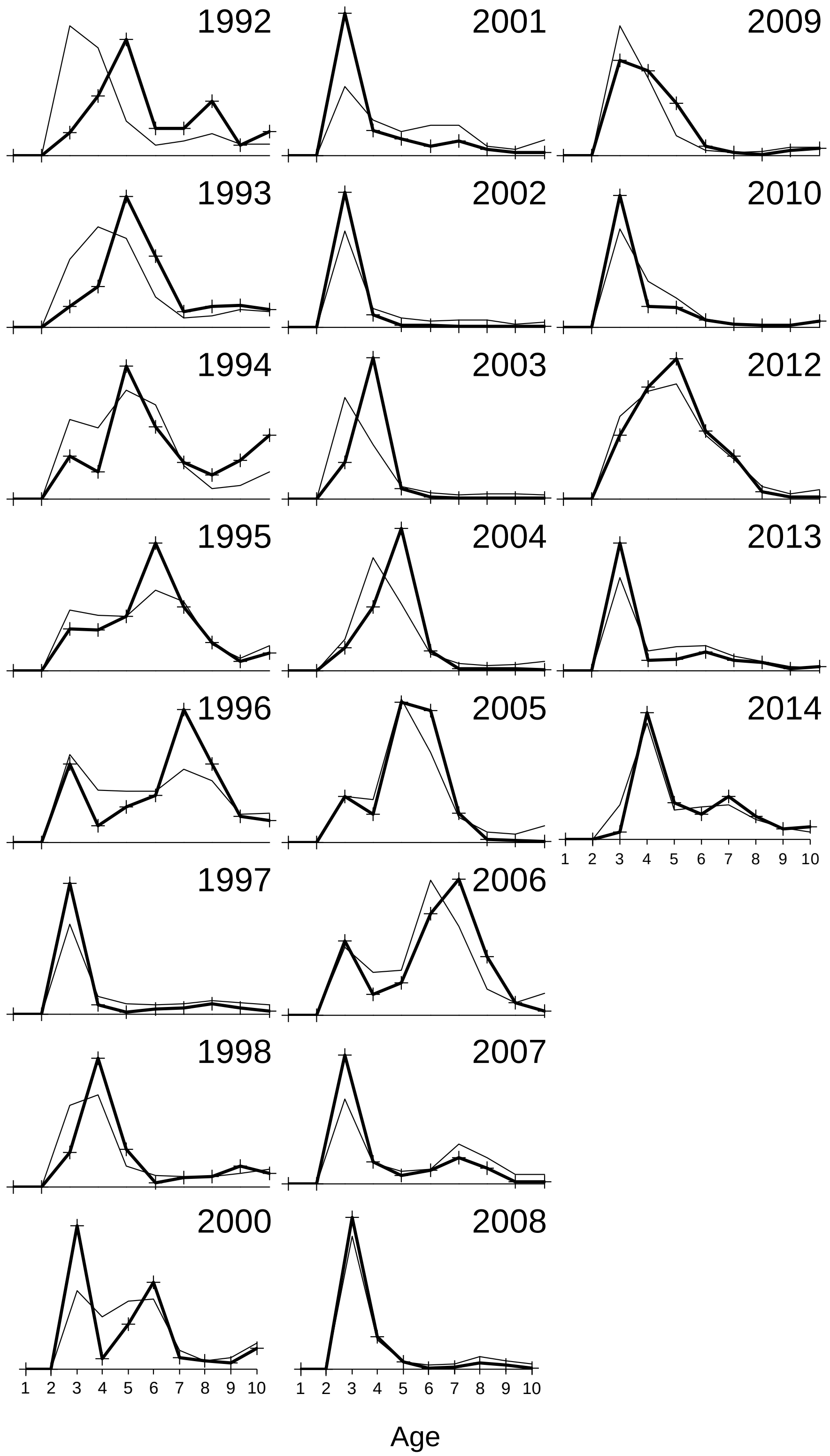


Figure 1.20. Observed and predicted Shelikof Strait acoustic survey age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbol are observed proportions at age.

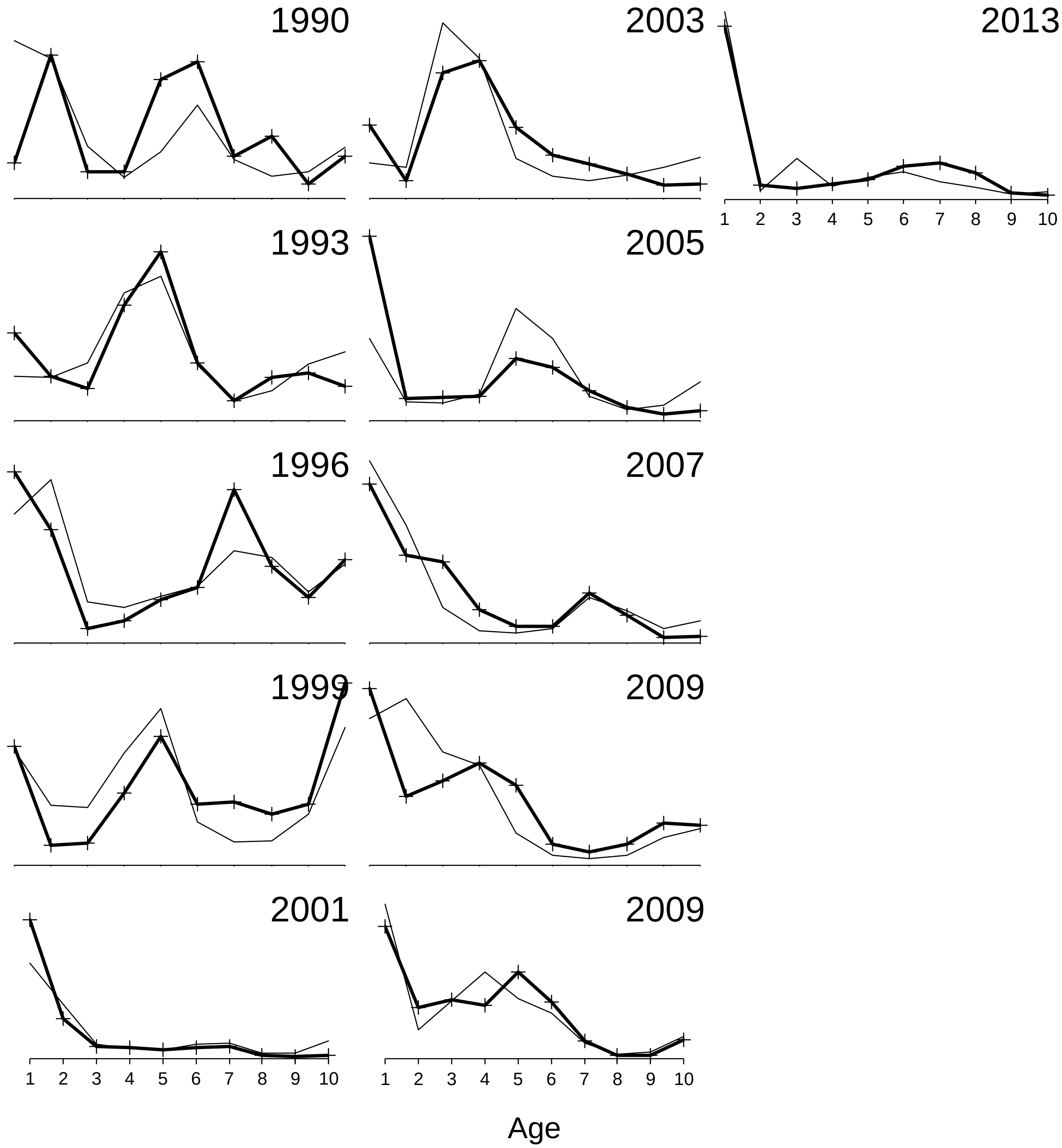


Figure 1.21. Observed and predicted NMFS bottom trawl age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbol are observed proportions at age.

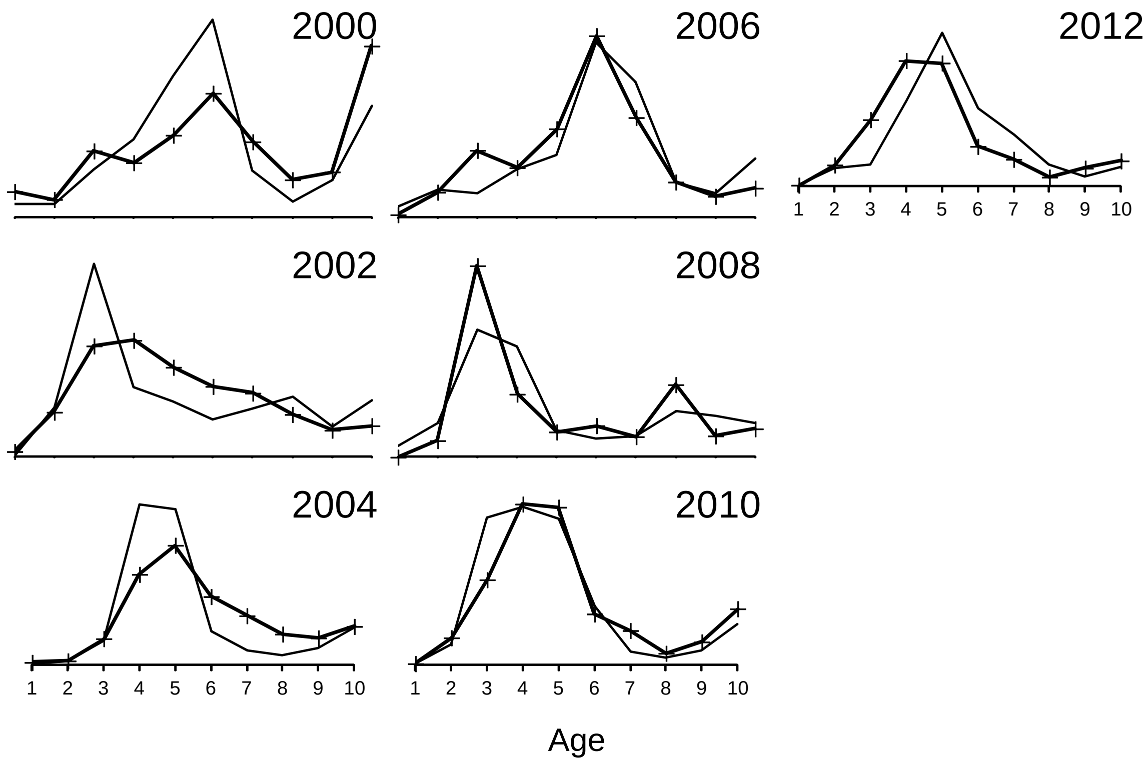


Figure 1.22. Observed and predicted ADFG crab/groundfish survey age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbols are observed proportions at age.

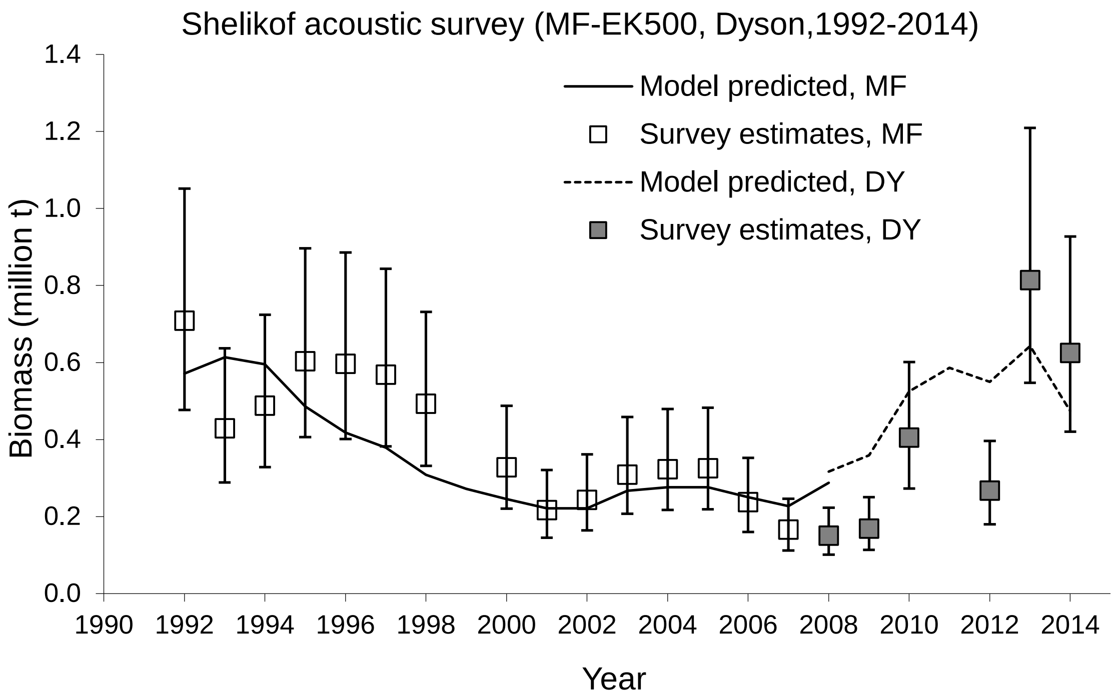


Figure 1.23. Model predicted and observed survey biomass for the Shelikof Strait acoustic survey for the base model. The Shelikof acoustic survey is modeled with two catchability periods corresponding to the estimates produced by the *R/V Miller Freeman* (MF) in 1992-2007 and the *R/V Oscar Dyson* (DY) in 2008-2014. Error bars indicate plus and minus two standard deviations. A CV of 0.2 is assumed for all acoustic surveys when fitting the model.

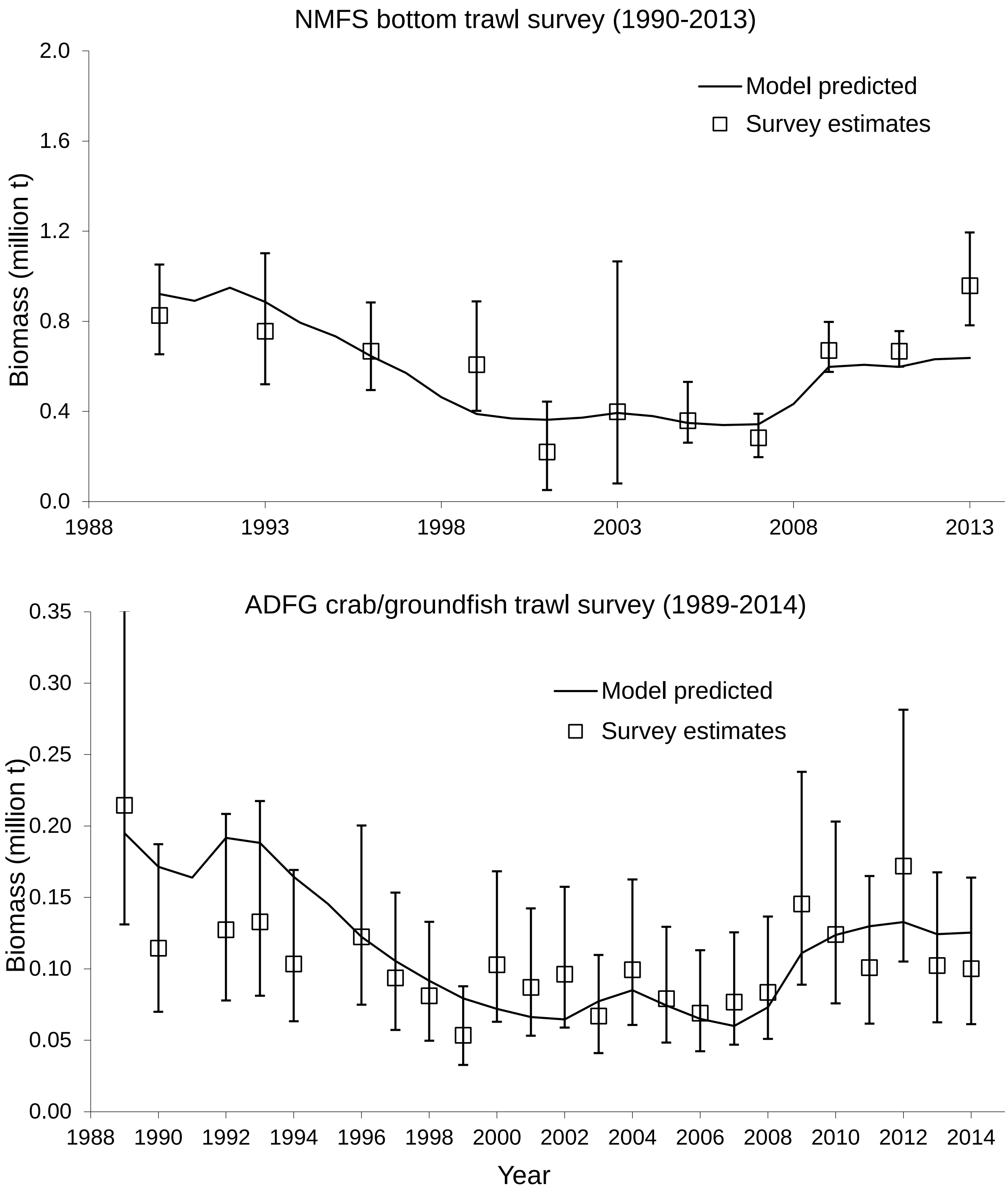
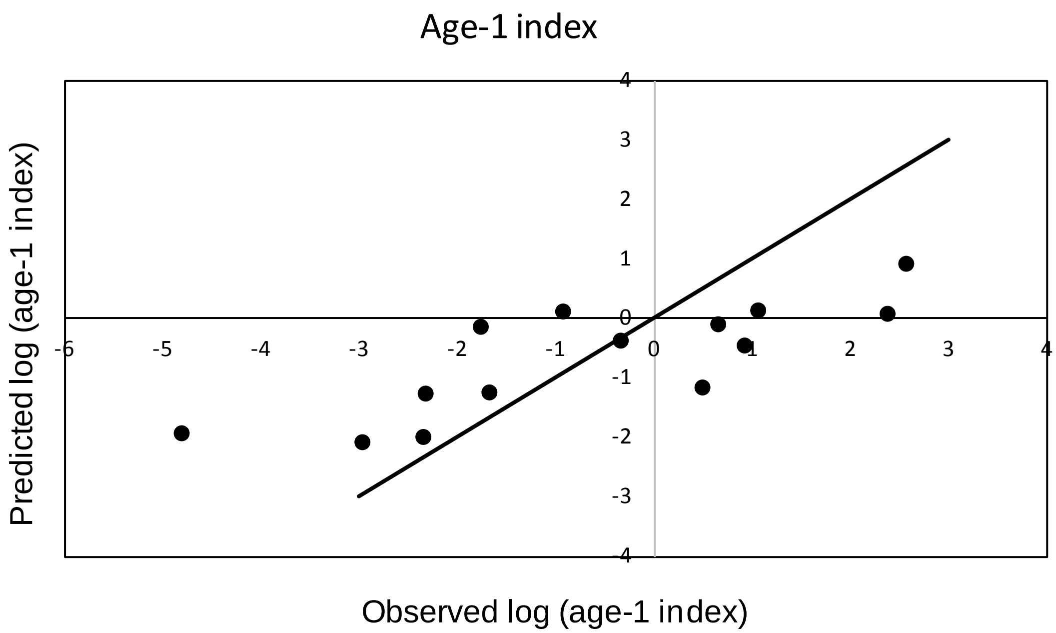


Figure 1.24. Model predicted and observed survey biomass for the NMFS bottom trawl survey (top), and the ADFG crab/groundfish survey (bottom) for the base model. Error bars indicate plus and minus two standard deviations. Since variance estimates are unavailable for ADFG biomass estimates, an assumed CV of 0.25 is used in the assessment model.



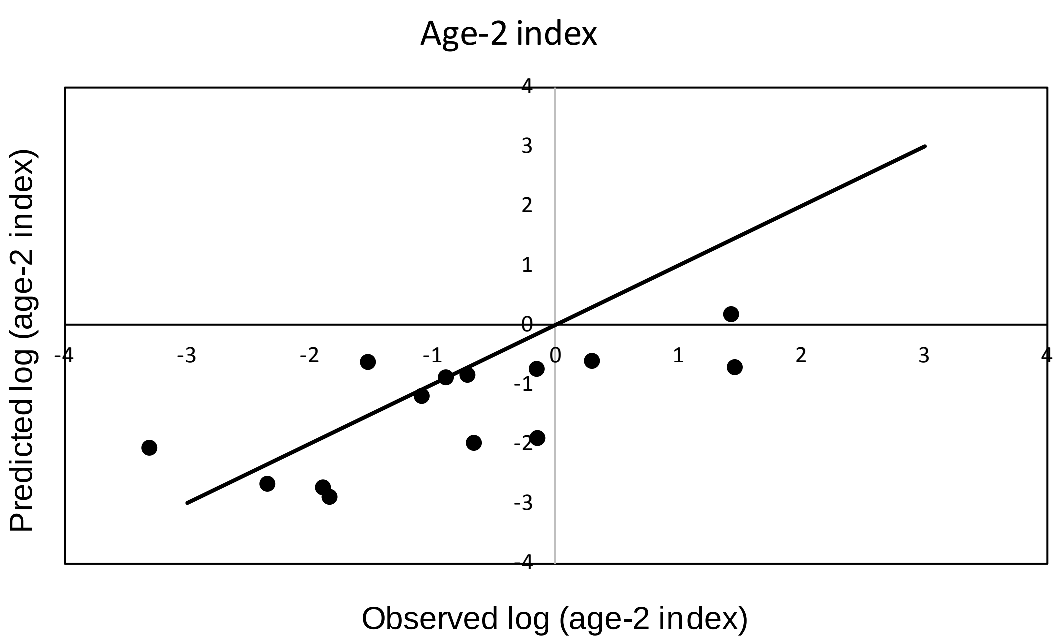


Figure 1.25. Observed and model predicted age-1 (top) and age-2 indices (bottom) for the winter acoustic estimates combined for Shelikof Strait and the Shumagin Islands.

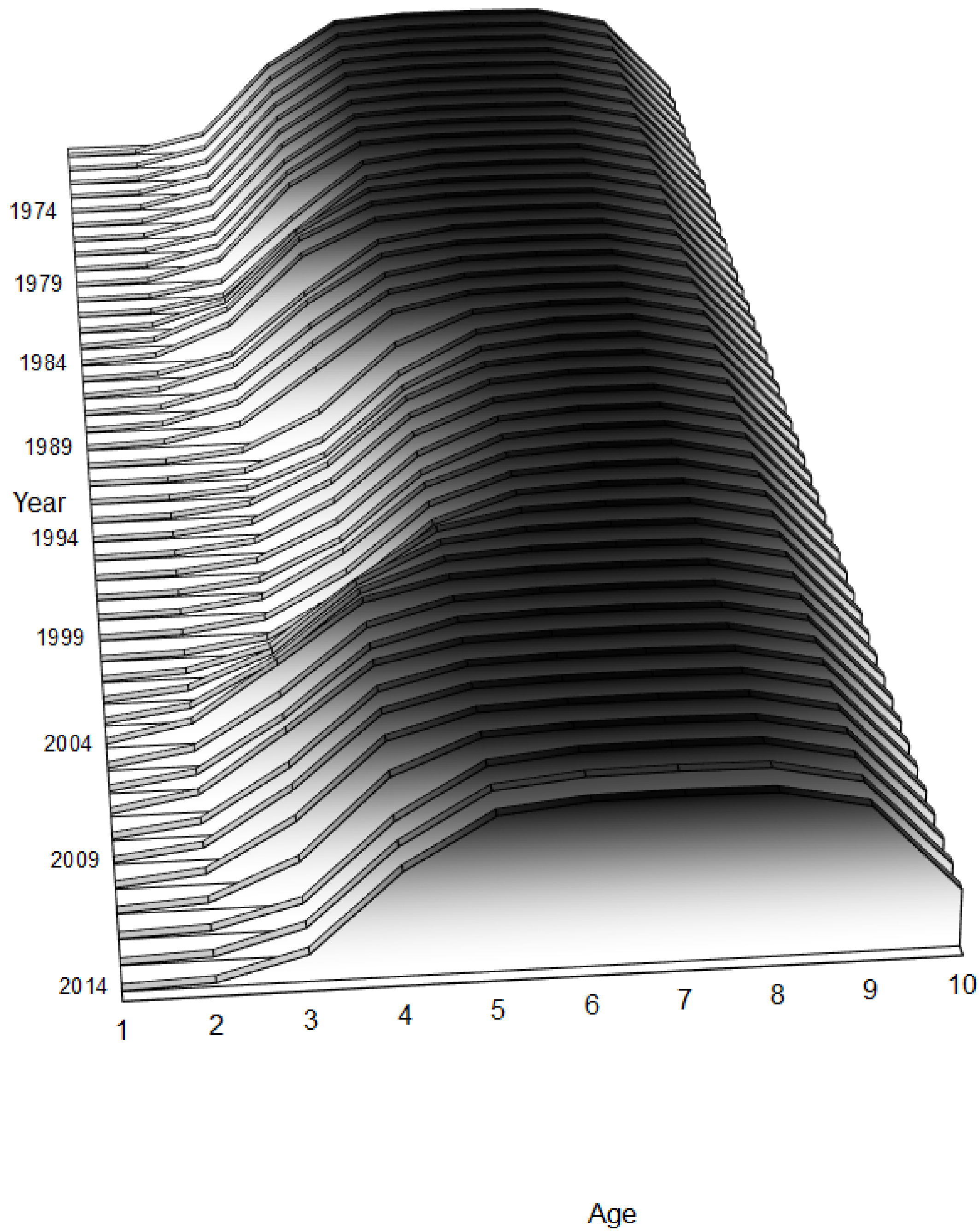
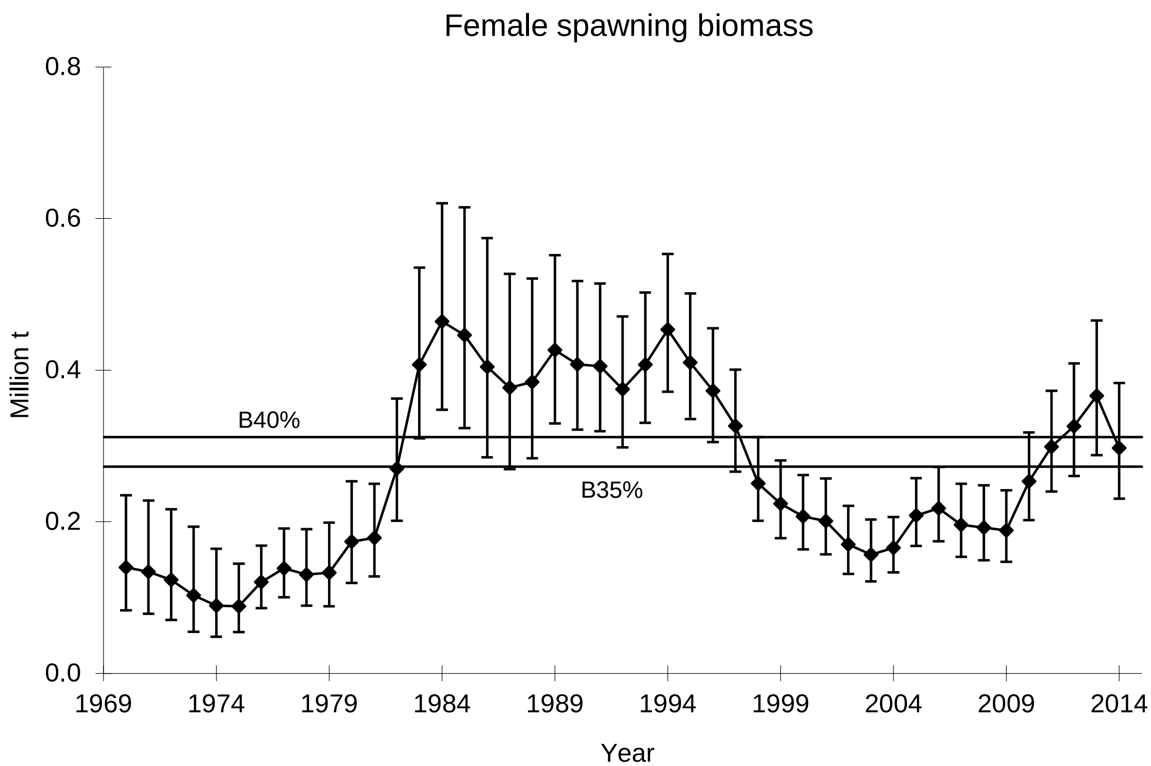


Figure 1.26. Estimates of time-varying fishery selectivity for Gulf of Alaska pollock for the base model. The selectivity is scaled so the maximum in each year is 1.0.



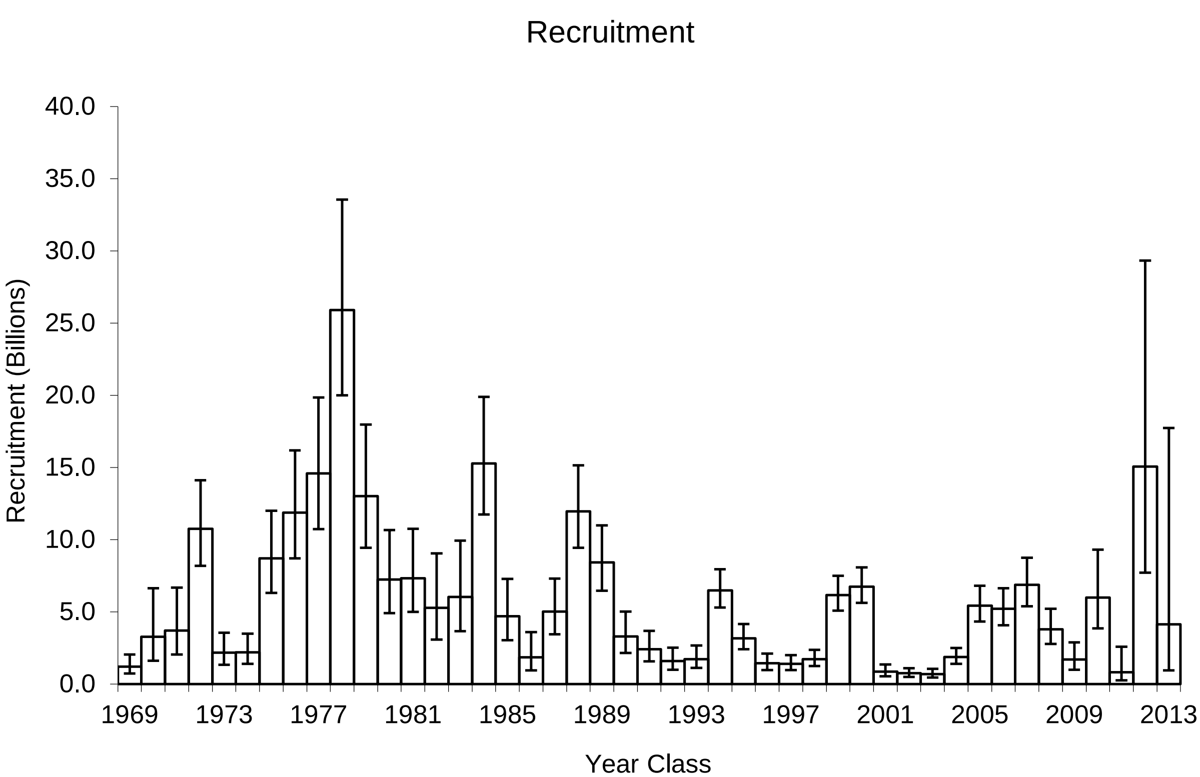
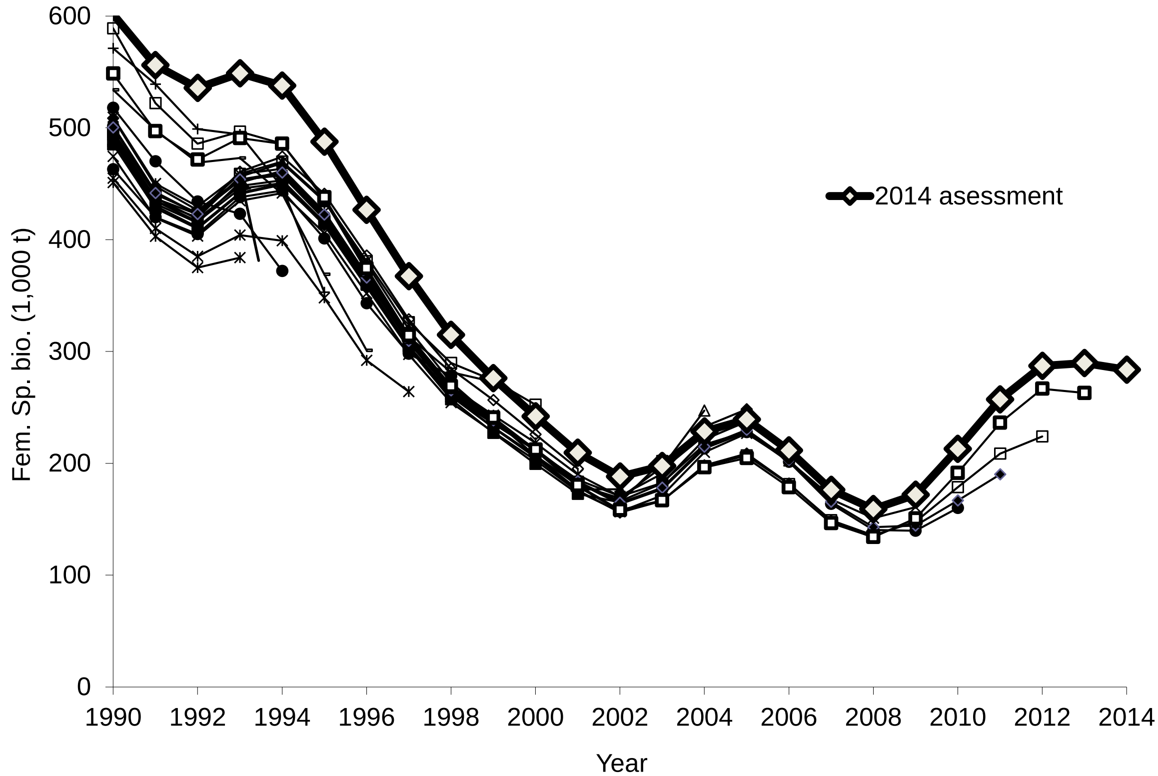


Figure 1.27. Estimated time series of Gulf of Alaska pollock spawning biomass (million t, top) and age-1 recruitment (billions of fish, bottom) from 1970 to 2014 for the base model. Vertical bars represent two standard deviations. The $B_{35\%}$ and $B_{40\%}$ lines represent the current estimate of these benchmarks.



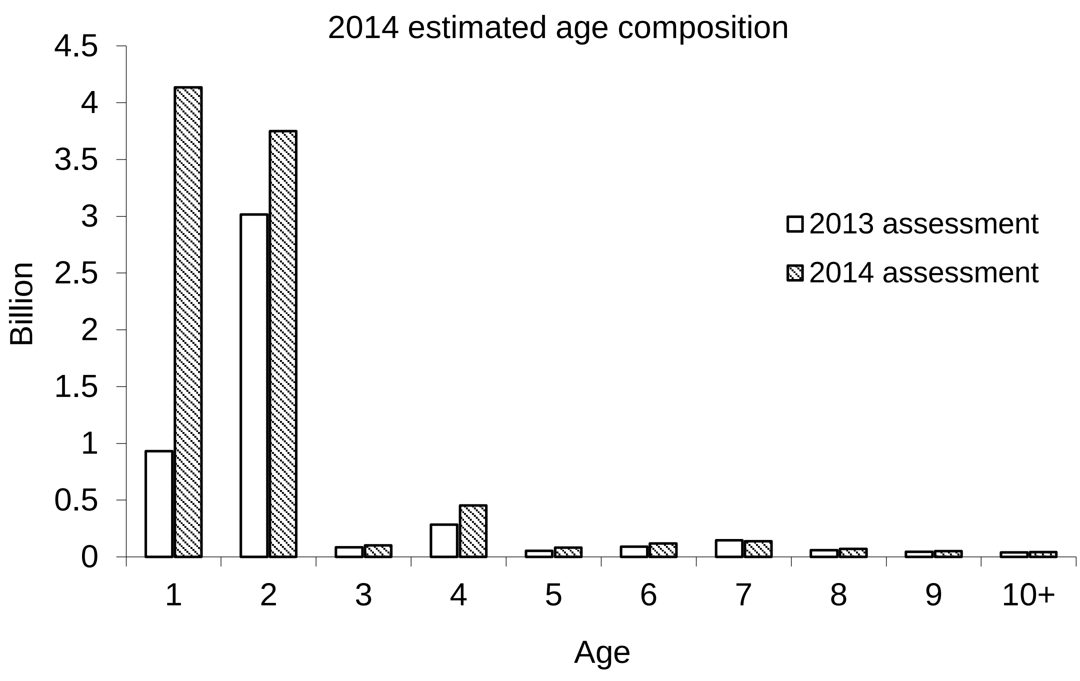


Figure 1.28. Retrospective plot of estimated Gulf of Alaska pollock female spawning biomass for stock assessments in the years 1993-2014 (top). For this figure, the time series of female spawning biomass was calculated using the same maturity and spawning weight at age for all assessments to facilitate comparison. The bottom panel shows the estimated age composition in 2014 from the 2013 and 2014 assessments.

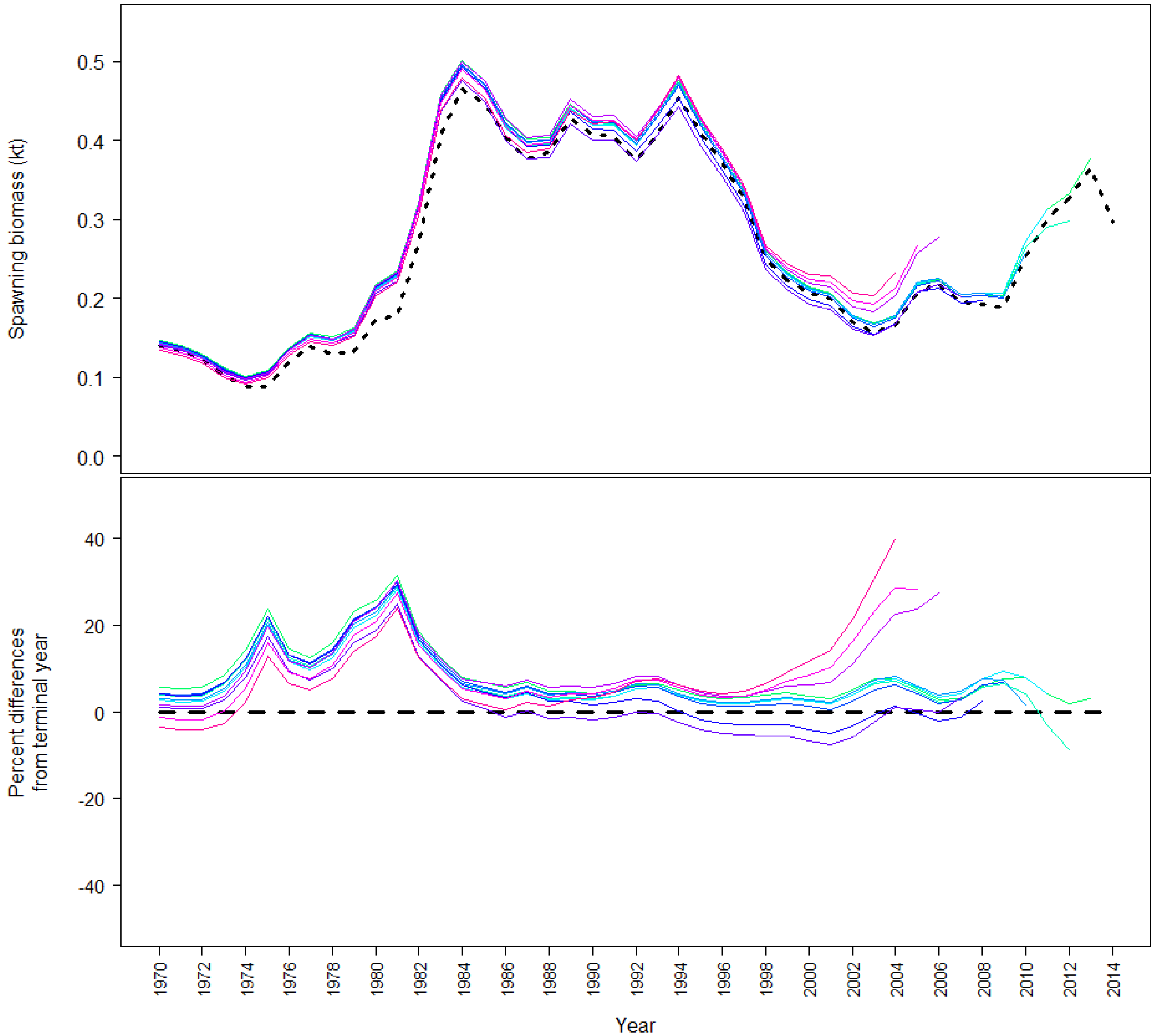
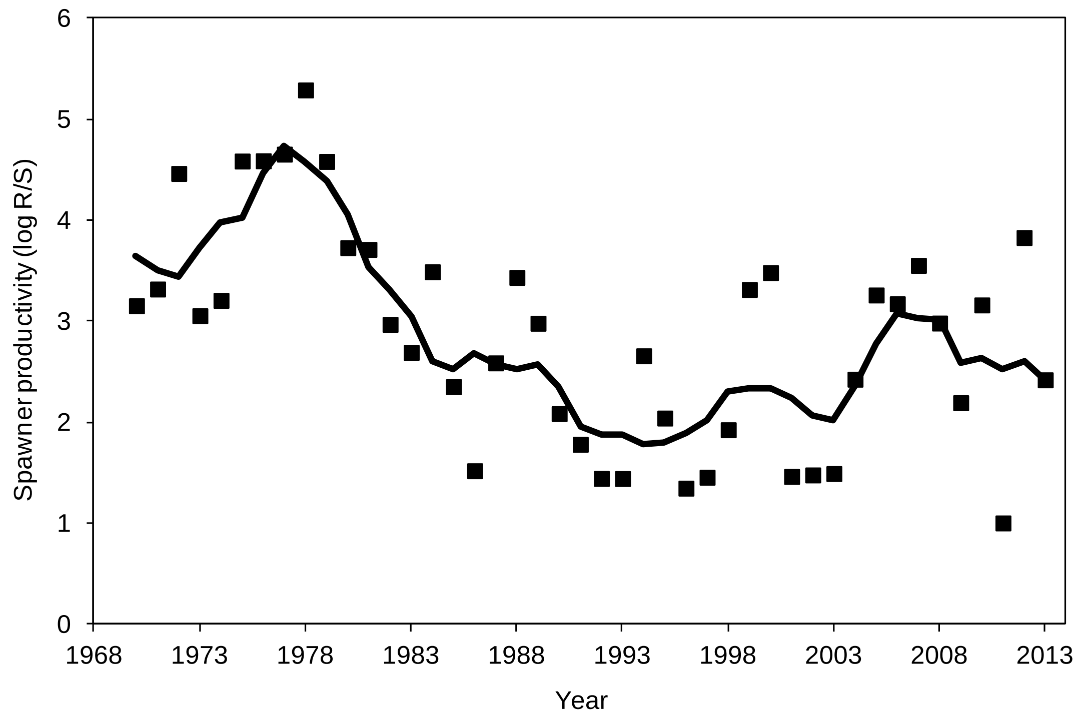


Figure 1.29. Retrospective plot of spawning biomass for the years 2004-2014 for the 2014 assessment model.



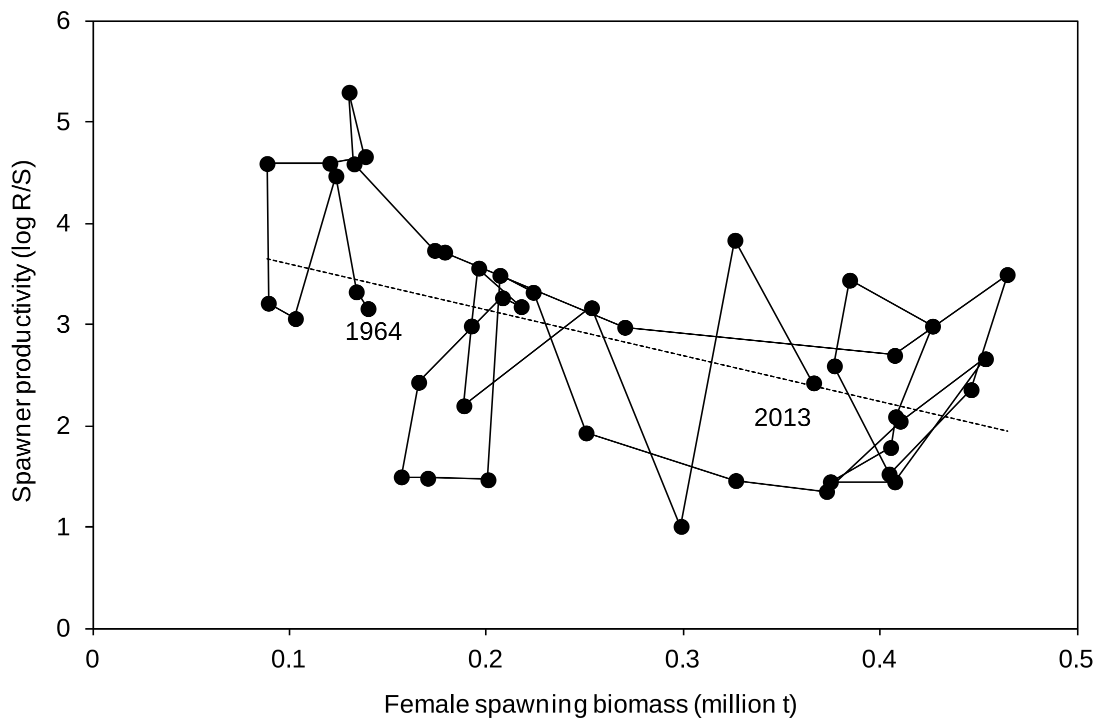
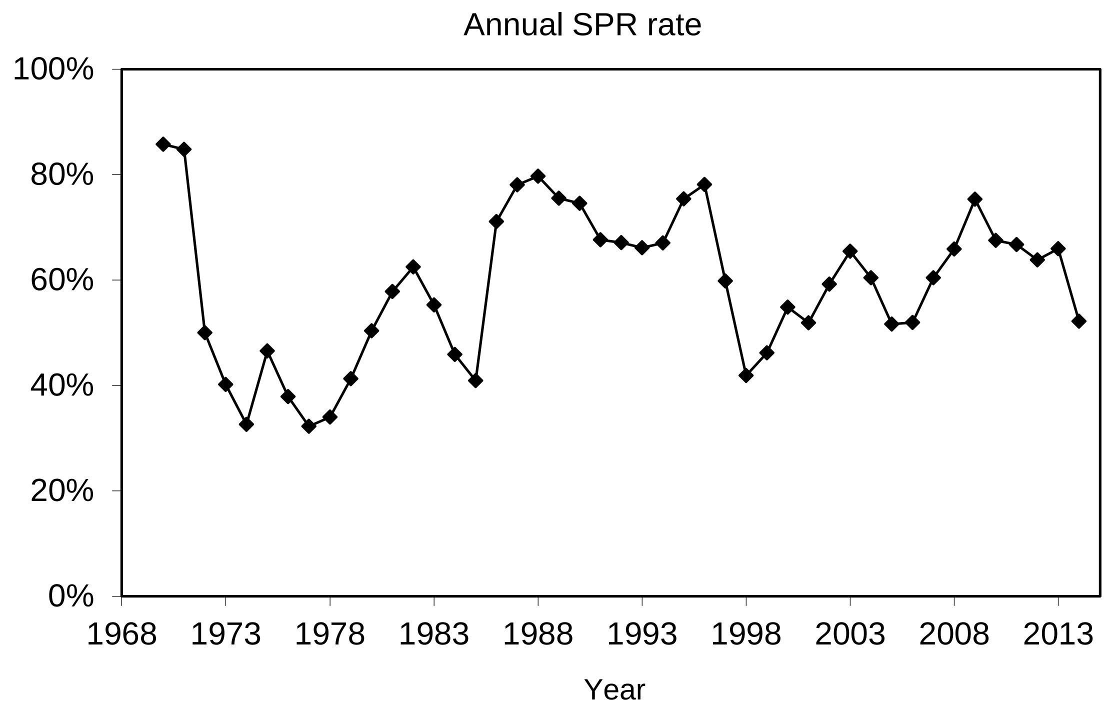


Figure 1.30. Gulf of Alaska pollock spawner productivity, *log(R/S)*, in 1970-2013 (top). A five-year running average is also shown. Spawner productivity in relation to female spawning biomass (bottom). The Ricker stock-recruit curve is linear in a plot of spawner productivity against spawning biomass.



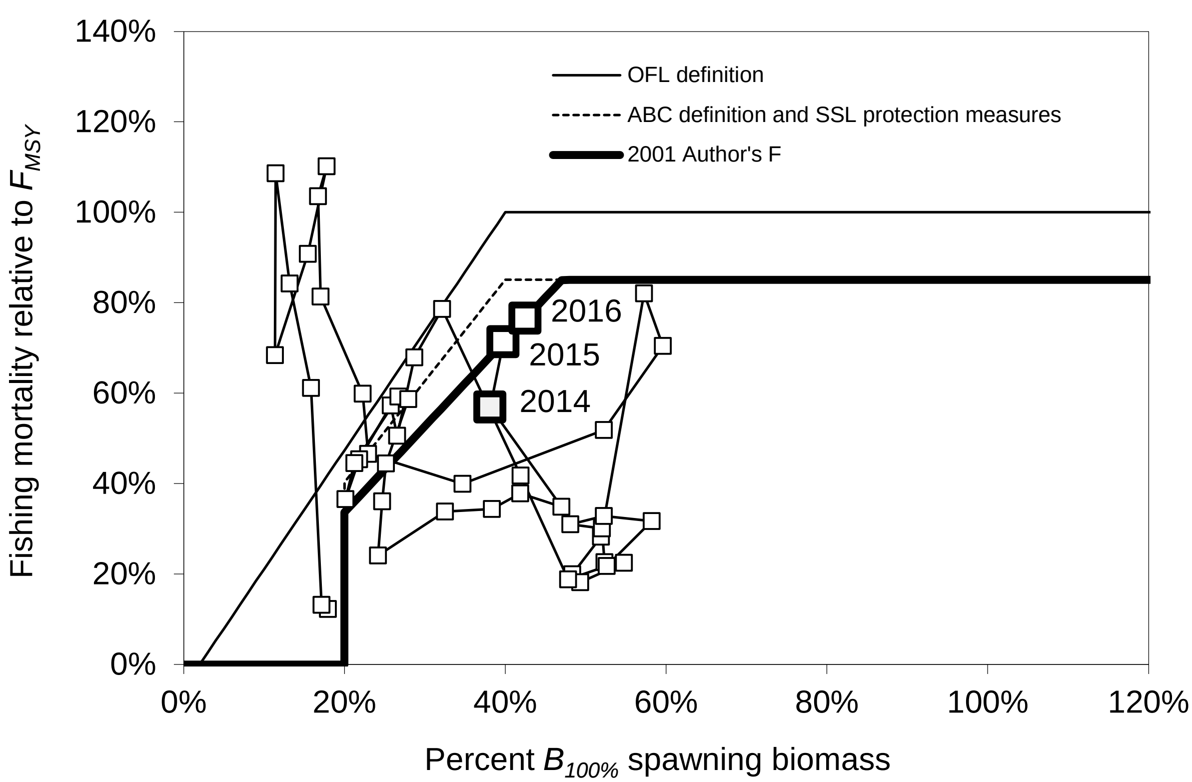


Figure 1.31. Annual fishing mortality as measured in percentage of unfished spawning biomass per recruit (top). Gulf of Alaska pollock spawning biomass relative to the unfished level and fishing mortality relative to F_{MSY} (bottom). The ratio of fishing mortality to F_{MSY} is calculated using the estimated selectivity pattern in that year. Estimates of $B_{100\%}$ spawning biomass are based on current estimates of maturity at age, weight at age, and mean recruitment. Because these estimates change as new data become available, this figure can only be used in a general way to evaluate management performance relative to biomass and fishing mortality reference levels.

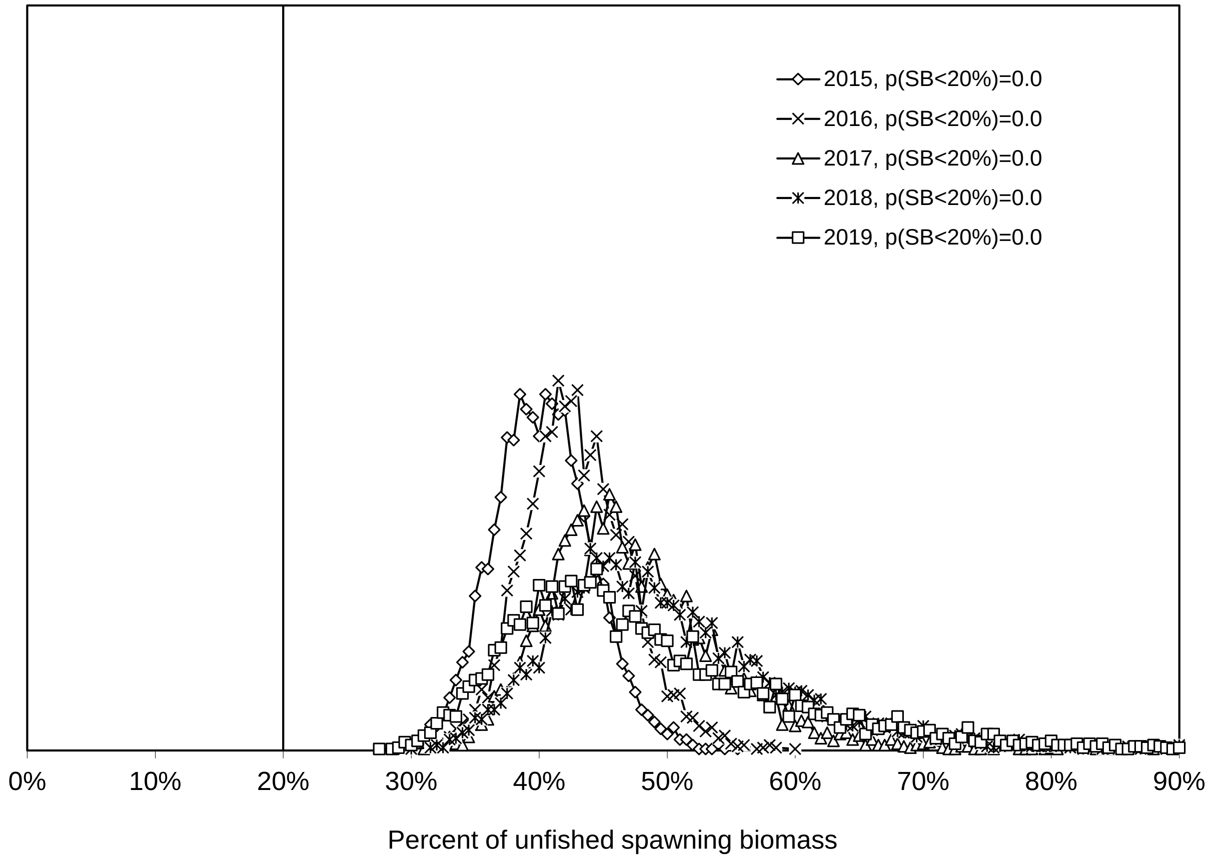


Figure 1.32. Uncertainty in spawning biomass in 2015-2019 based on a thinned MCMC chain from the joint marginal likelihood for the base model where catch is set to the author's recommended F_{ABC}.

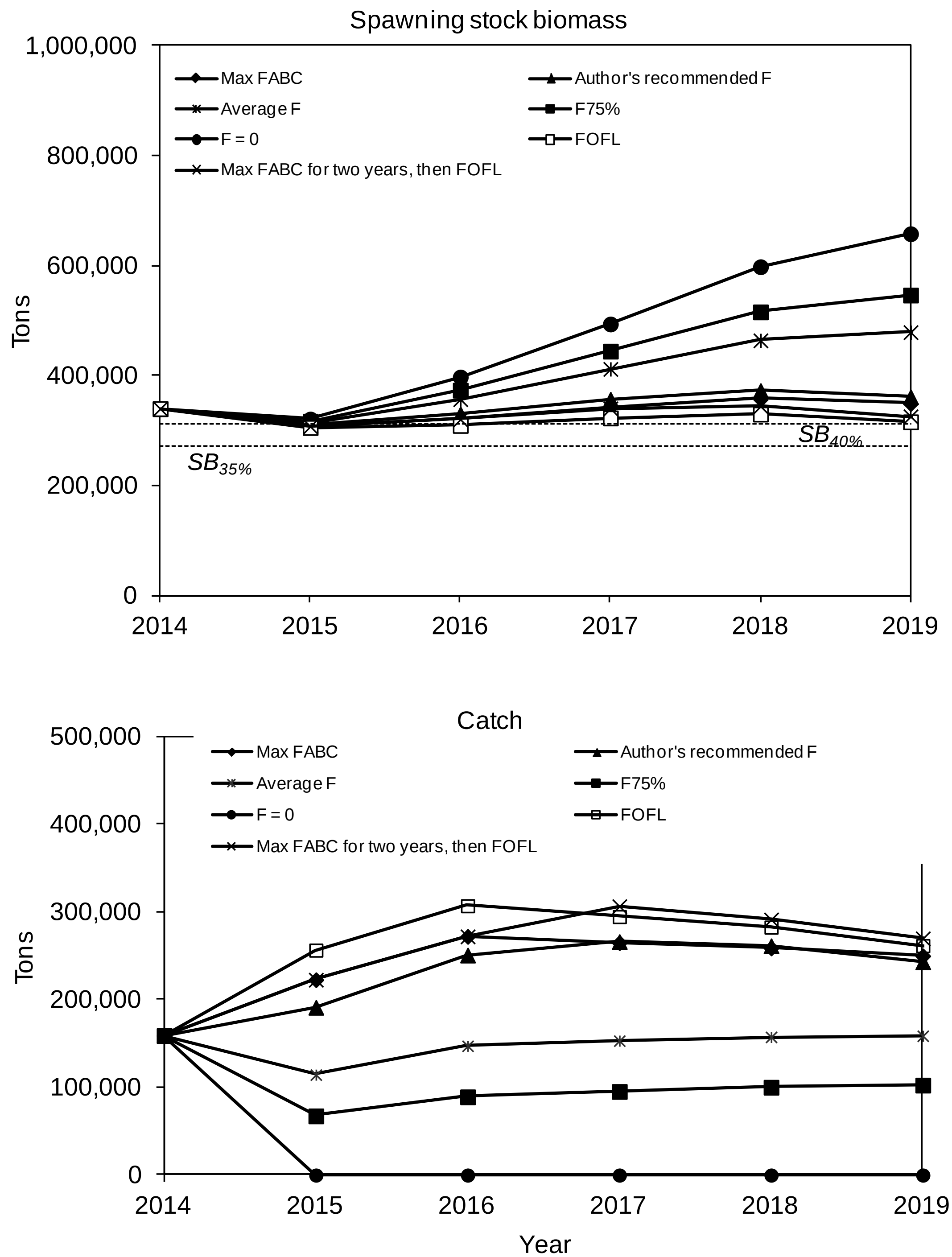


Figure 1.33. Projected spawning biomass and catches in 2015-2019 under different harvest rates.

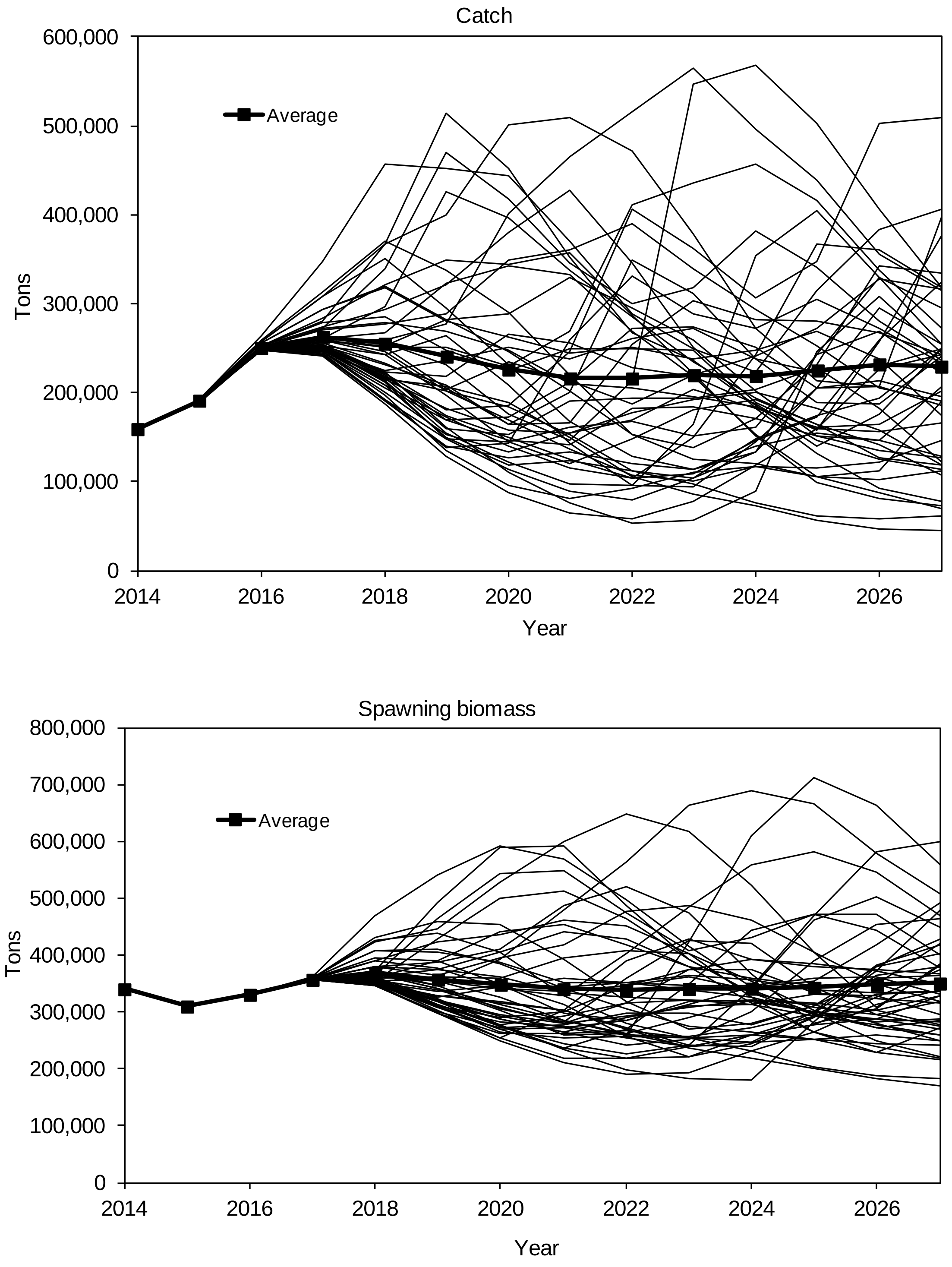


Figure 1.34. Variability in projected catch and spawning biomass in 2015-2027 for the base model under the author's recommended F_{ABC}.

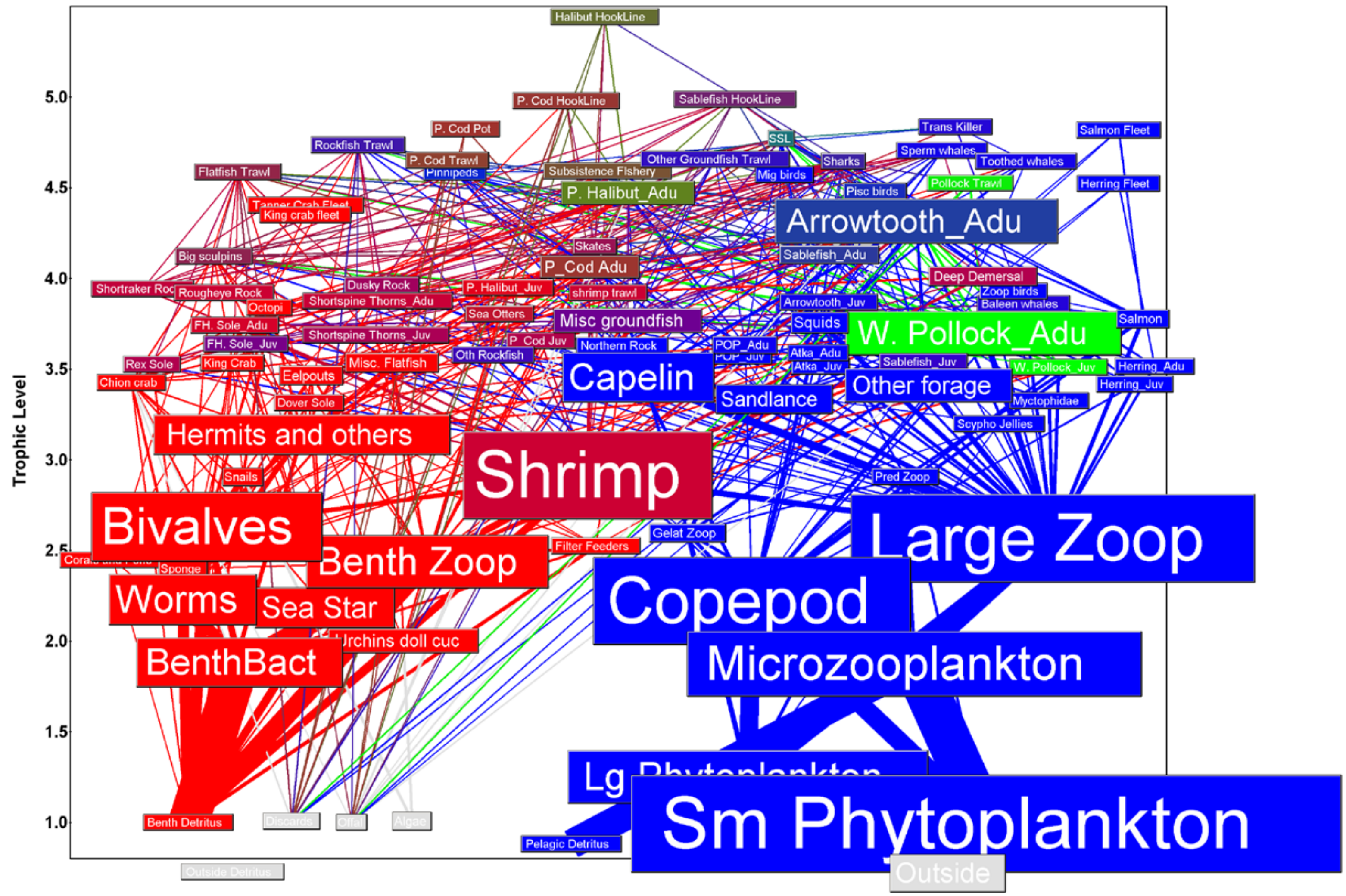
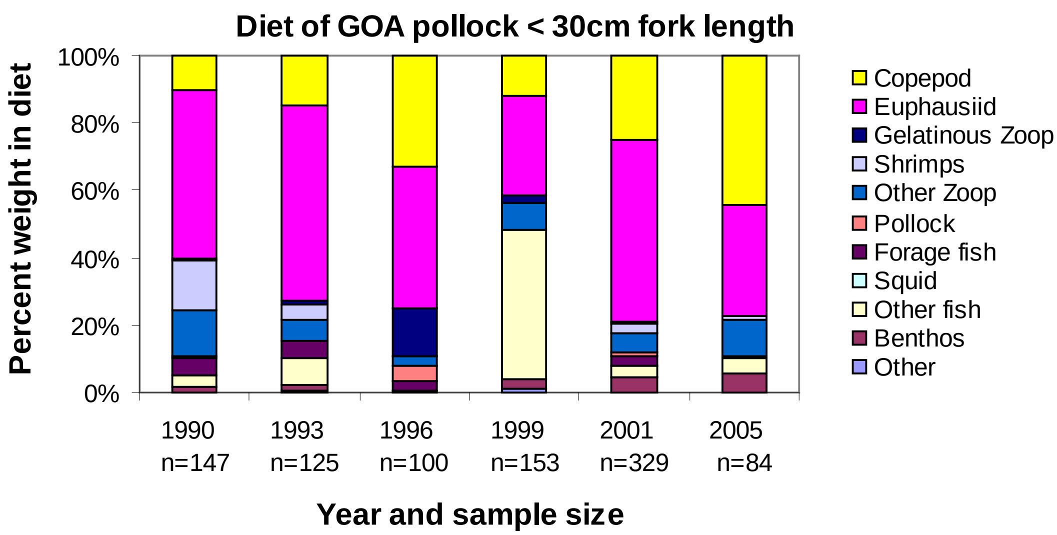


Figure 1.35. Gulf of Alaska food web showing demersal (red) and pelagic (blue) pathways. Walleye pollock is shown in green. Pollock consumers stain green according to the importance of pollock in their diet.



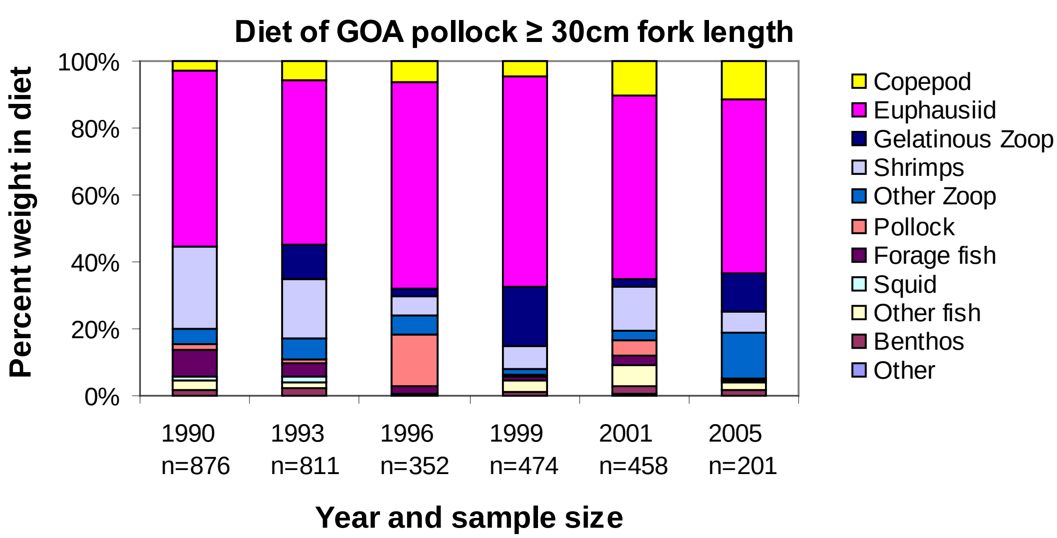
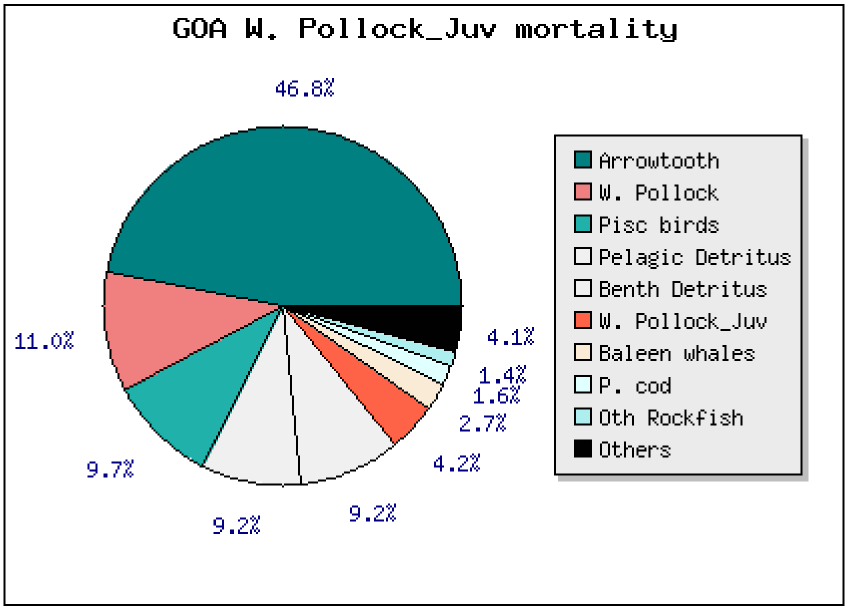


Figure 1.36. Diet (percent wet weight) of GOA walleye pollock juveniles (top) and adults (bottom) from summer food habits data collected on NMFS bottom trawl surveys, 1990-2005.



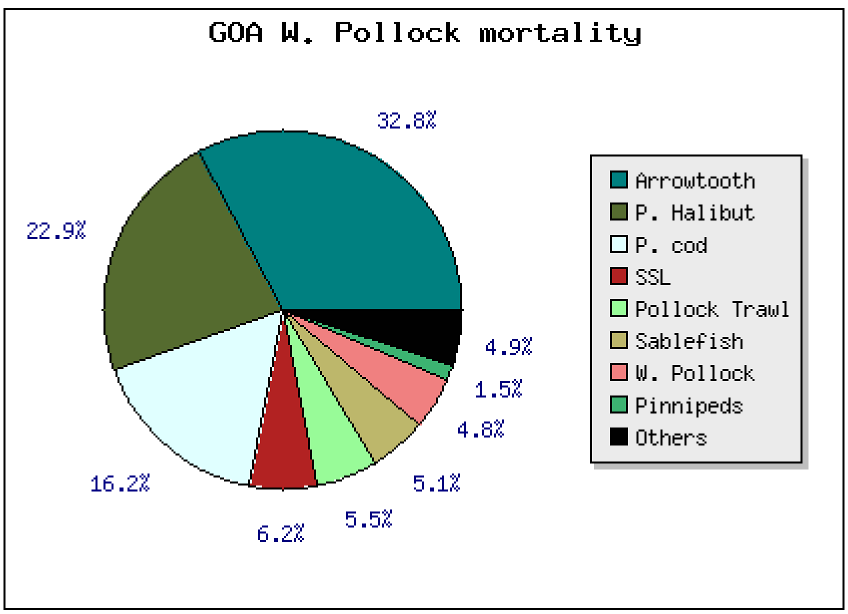


Figure 1.37. Sources of mortality for walleye pollock juveniles (top) and adults (bottom) from an ECOPATH model of the Gulf of Alaska. Pollock less than 20cm are considered juveniles.

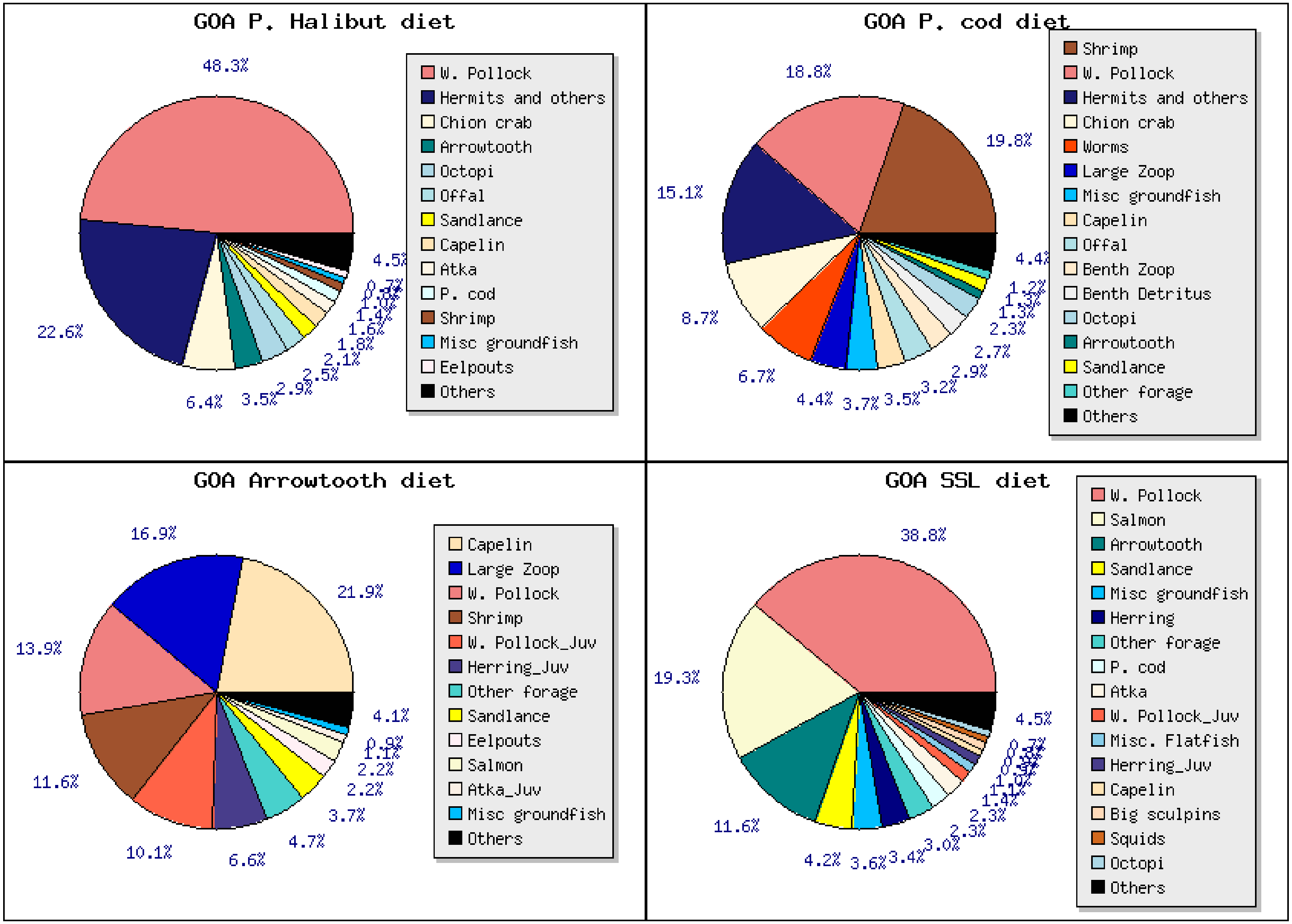


Figure 1.38. Diet diversity of major predators of walleye pollock from an ECOPATH model for Gulf of Alaska during 1990-94.

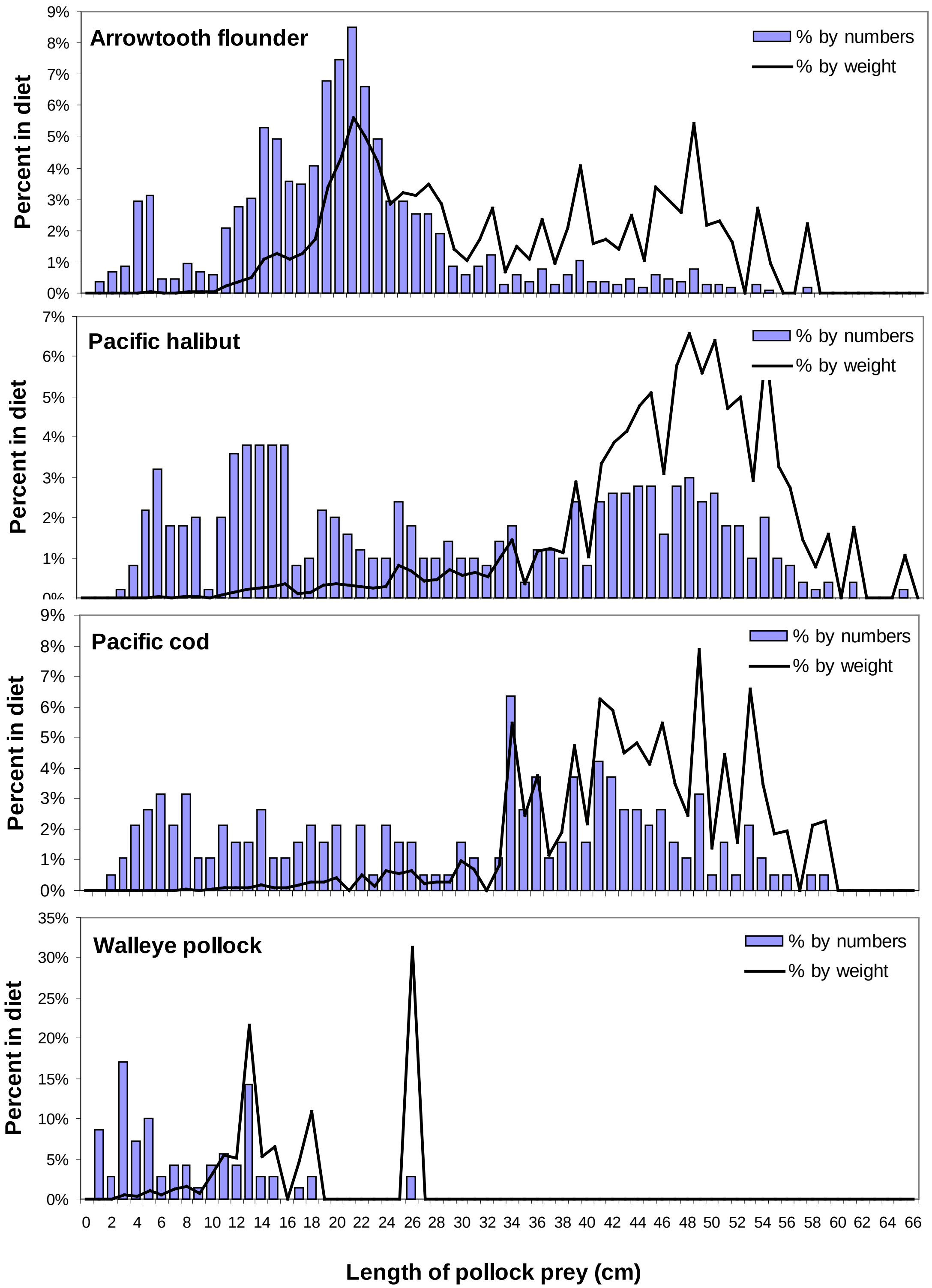
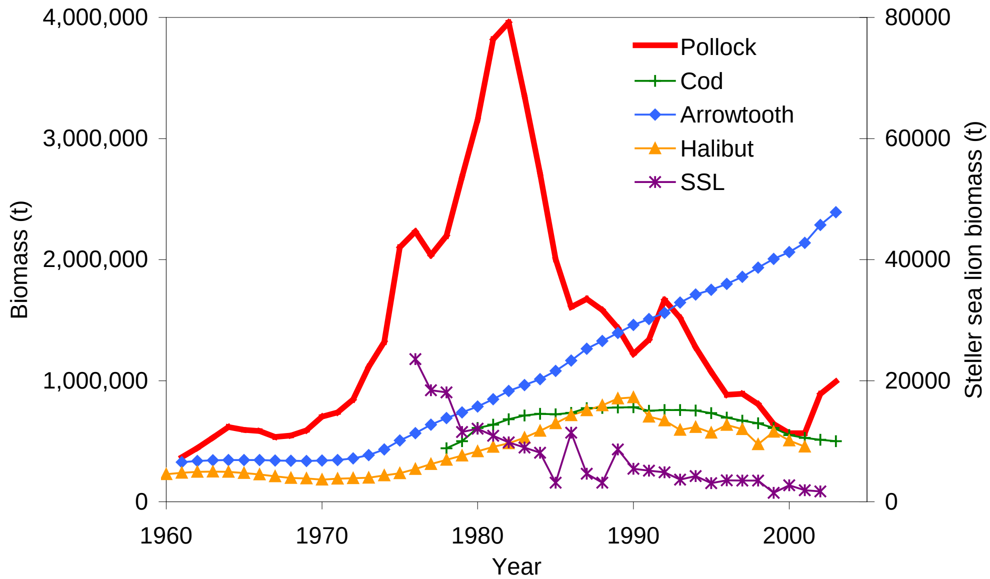


Figure 1.39**.** Length frequencies and percent by weight of each length class of pollock prey (cm fork length) in stomachs of four major groundfish predators, from AFSC bottom-trawl surveys 1987-2005. Length of prey is uncorrected for digestion state.



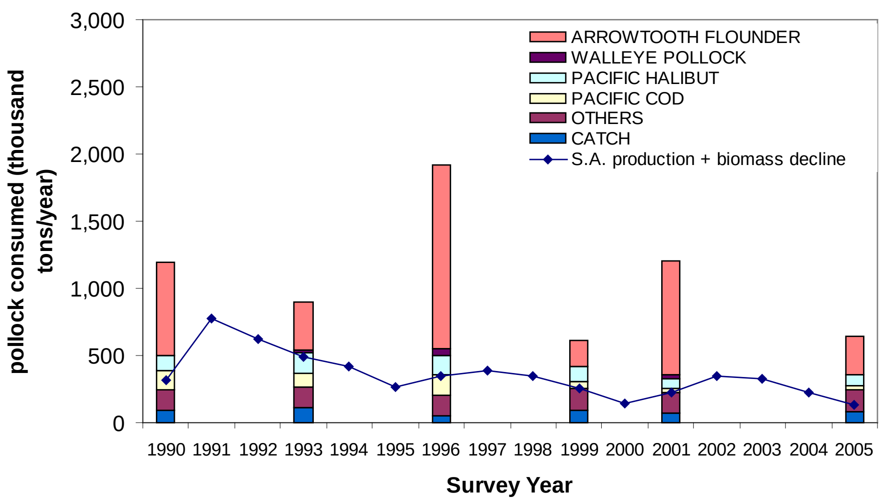


Figure 1.40. (Top) Historical trends in GOA walleye pollock, Pacific cod, Pacific halibut, arrowtooth flounder, and Steller Sea Lions, from stock asesseement data. (Bottom) Total catch and consumption of walleye pollock in survey years (bars) and production + biomass change as calculated from the current stock assessment results (line). See text for calculation methods.

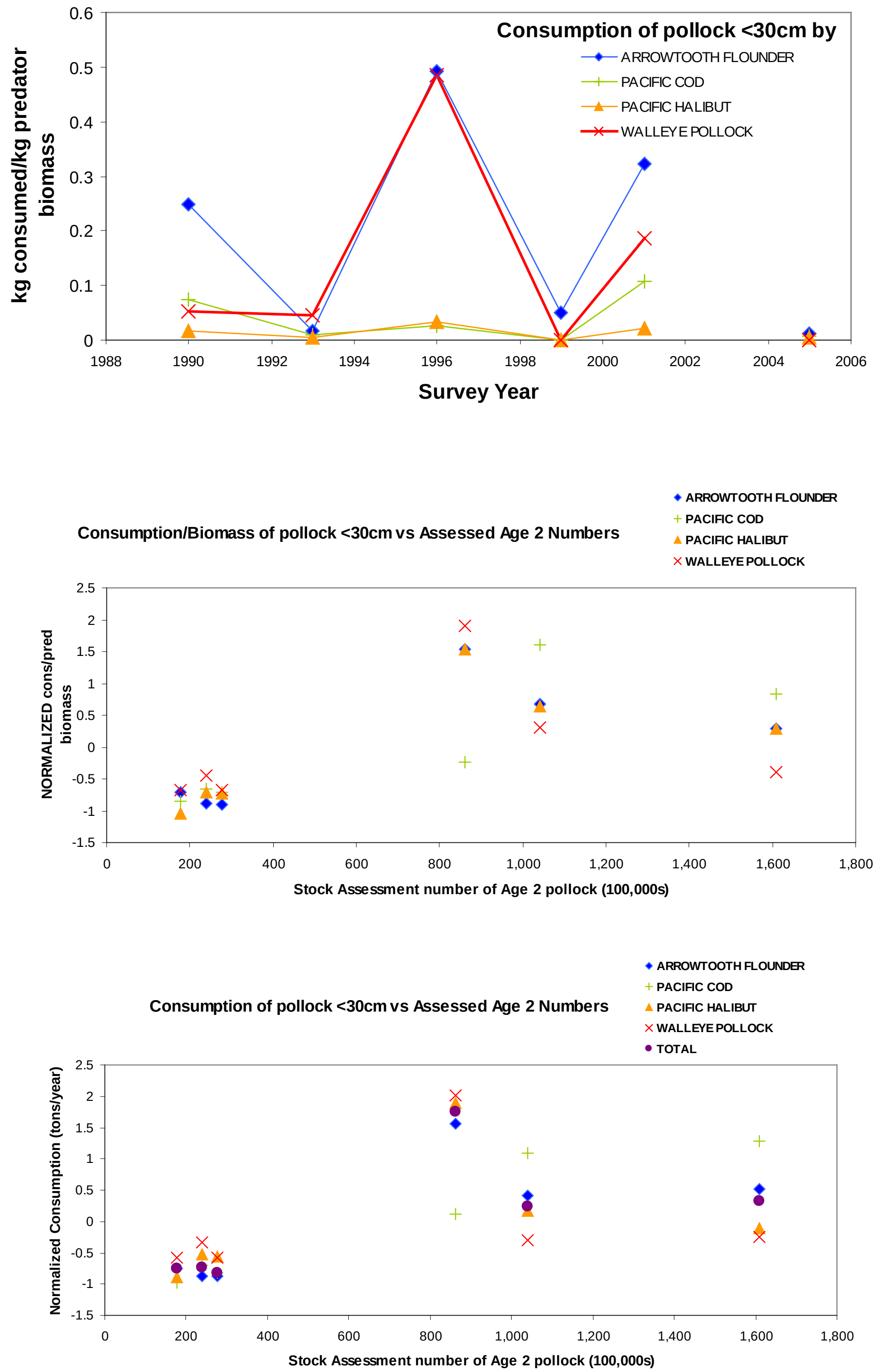
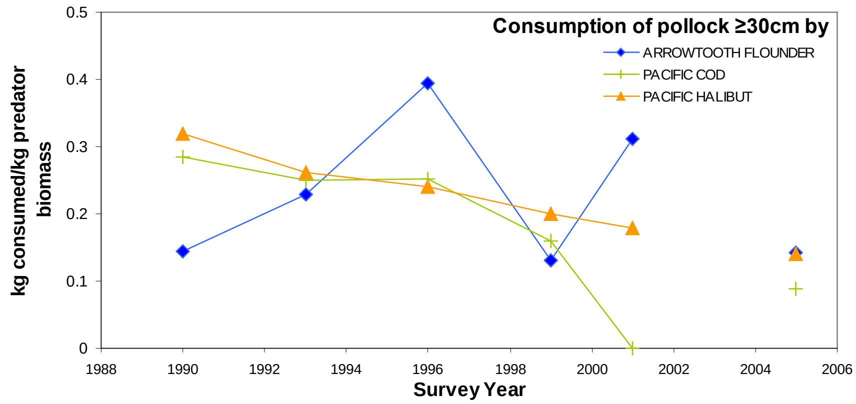
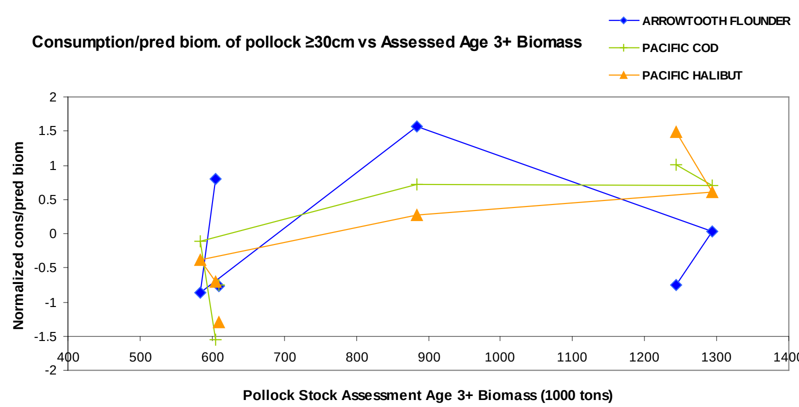


Figure 1.41. (Top) Consumption per unit predator survey biomass of GOA walleye pollock <30cm fork length in diets, shown for each survey year. (Middle and bottom) Normalized consumption/biomass and normalized total consumption of pollock <30cm fork length, plotted against age 2 pollock numbers.





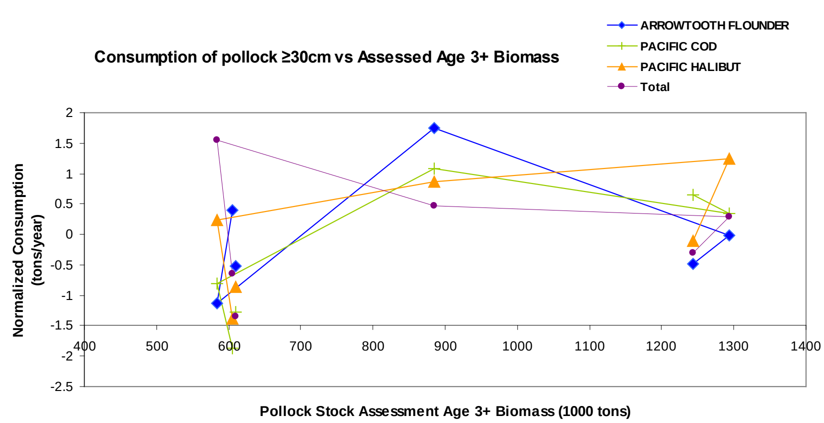


Figure 1.42. (Top) Consumption per unit predator survey biomass of GOA walleye pollock ≥30cm fork length in diets, shown for each survey year. (Middle and bottom) Normalized consumption/biomass and normalized total consumption of pollock ≥30cm fork length, plotted against age 3+ pollock biomass.

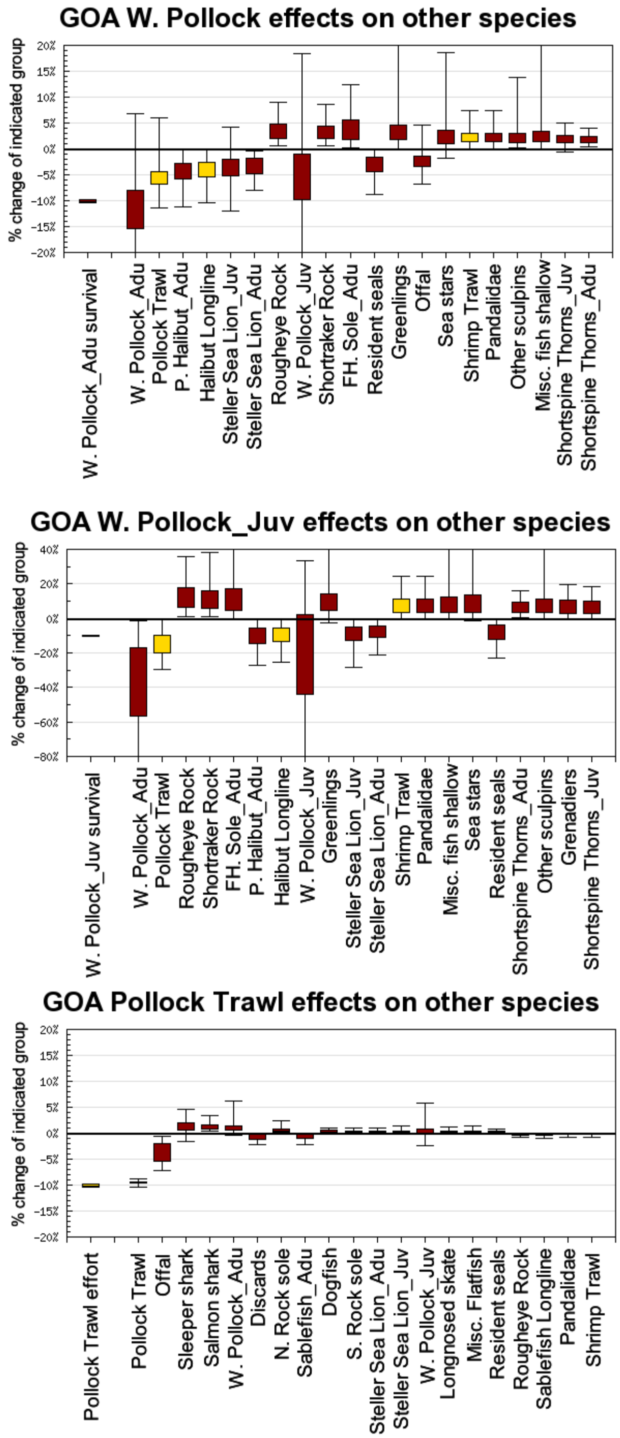
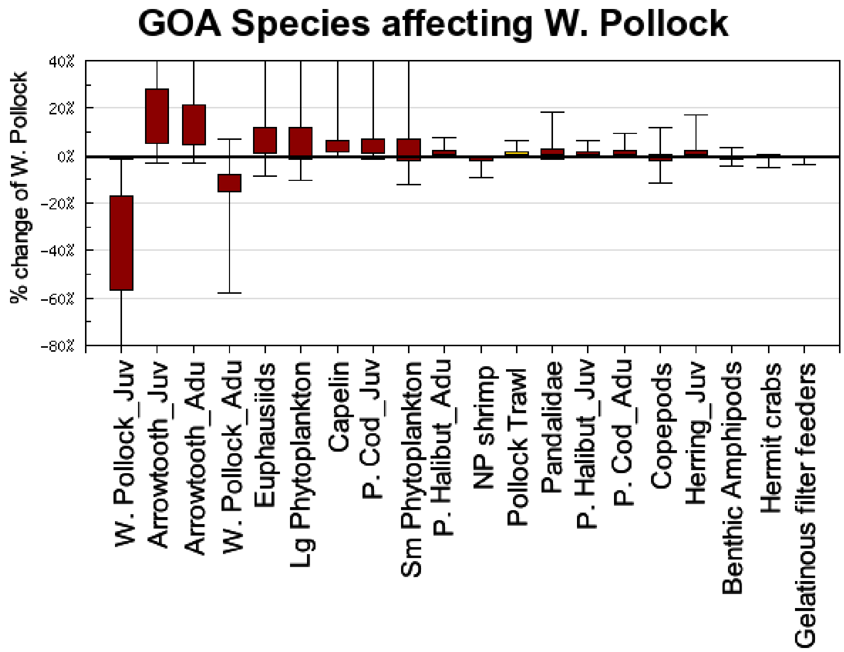


Figure 1.43. Ecosystem model output (percent change at future equilibrium of indicated groups) resulting from reducing adult pollock survival by 10% (top graph), reducing juvenile pollock survival by 10% (middle graph), and reducing pollock trawl effort by 10%. Dark bars indicate biomass changes of modeled species, while light bars indicate changes in fisheries catch (landings+discards) assuming a constant fishing rate within the indicated fishery. Graphs show 50% and 95% confidence intervals (bars and lines respectively) summarized over 20,000 ecosystems drawn from error ranges of input parameters (see Aydin et al. 2005 for methodology). Only the top 20 effects, sorted by median, are shown for each perturbation.



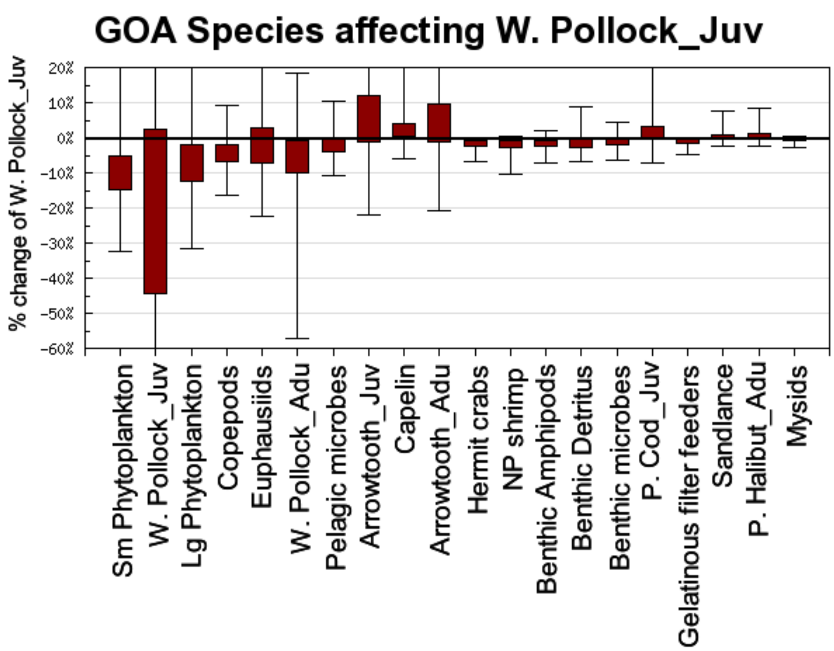


Figure 1.44. Ecosystem model output, shown as percent change at future equilibrium of adult pollock (top) and juvenile pollock, resulting from independently lowering the indicated species' survival rates by 10% (dark bars) or by reducing fishing effort of a particular gear by 10% (light bars). Graphs show 50% and 95% confidence intervals (bars and lines respectively) summarized over 20,000 ecosystems drawn from error ranges of input parameters (see Aydin et al. 2005 for methodology). Only the top 20 effects, sorted by median, are shown for each perturbation.

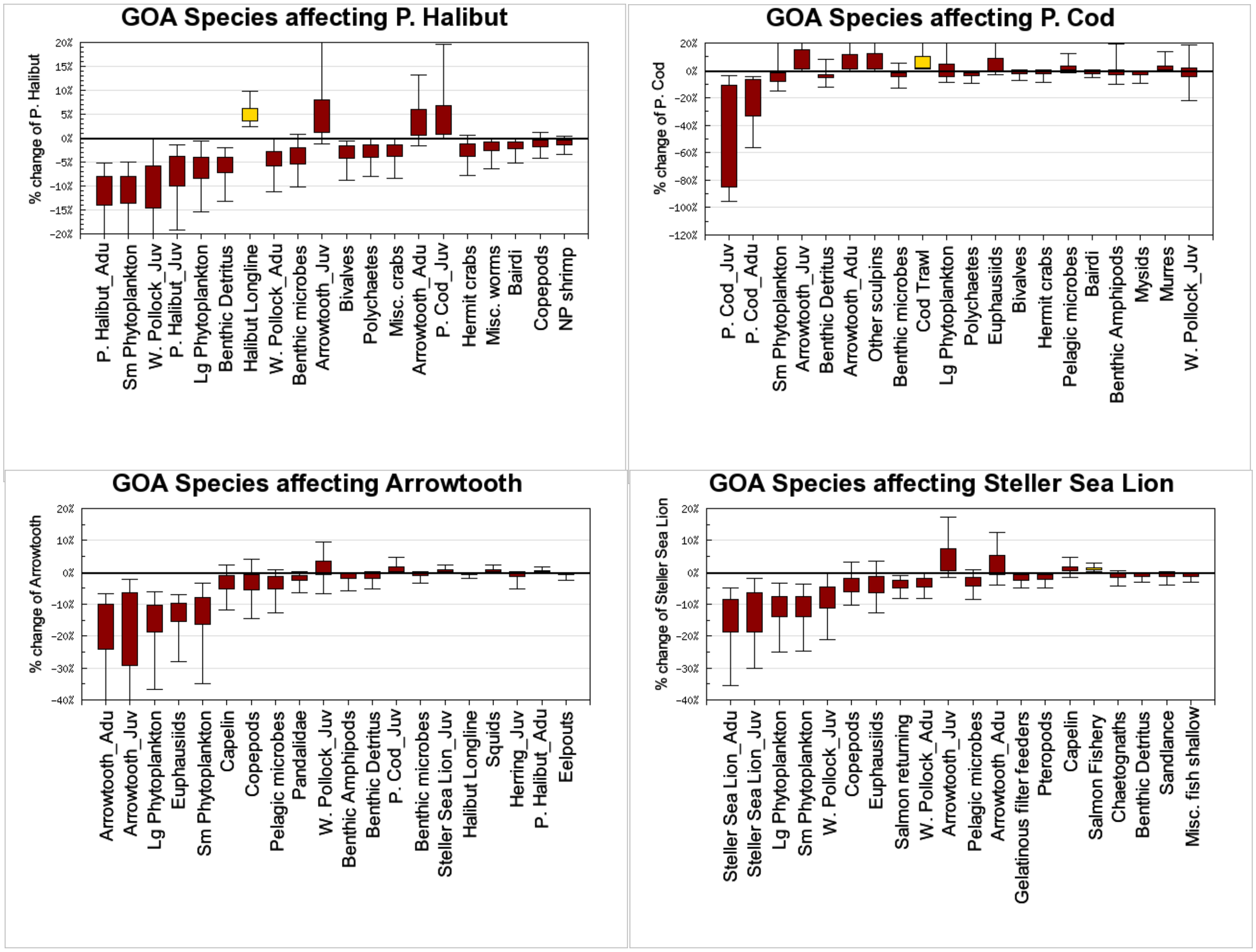


Figure 1.45. Ecosystem model output, shown as percent change at future equilibrium of four major predators on walleye pollock, resulting from independently lowering the indicated species' survival rates by 10% (dark bars) or by reducing fishing effort of a particular gear by 10% (light bars). Graphs show 50% and 95% confidence intervals (bars and lines respectively) summarized over 20,000 ecosystems drawn from error ranges of input parameters (see Aydin et al. 2005 for methodology). Only the top 20 effects, sorted by median, are shown for each perturbation.

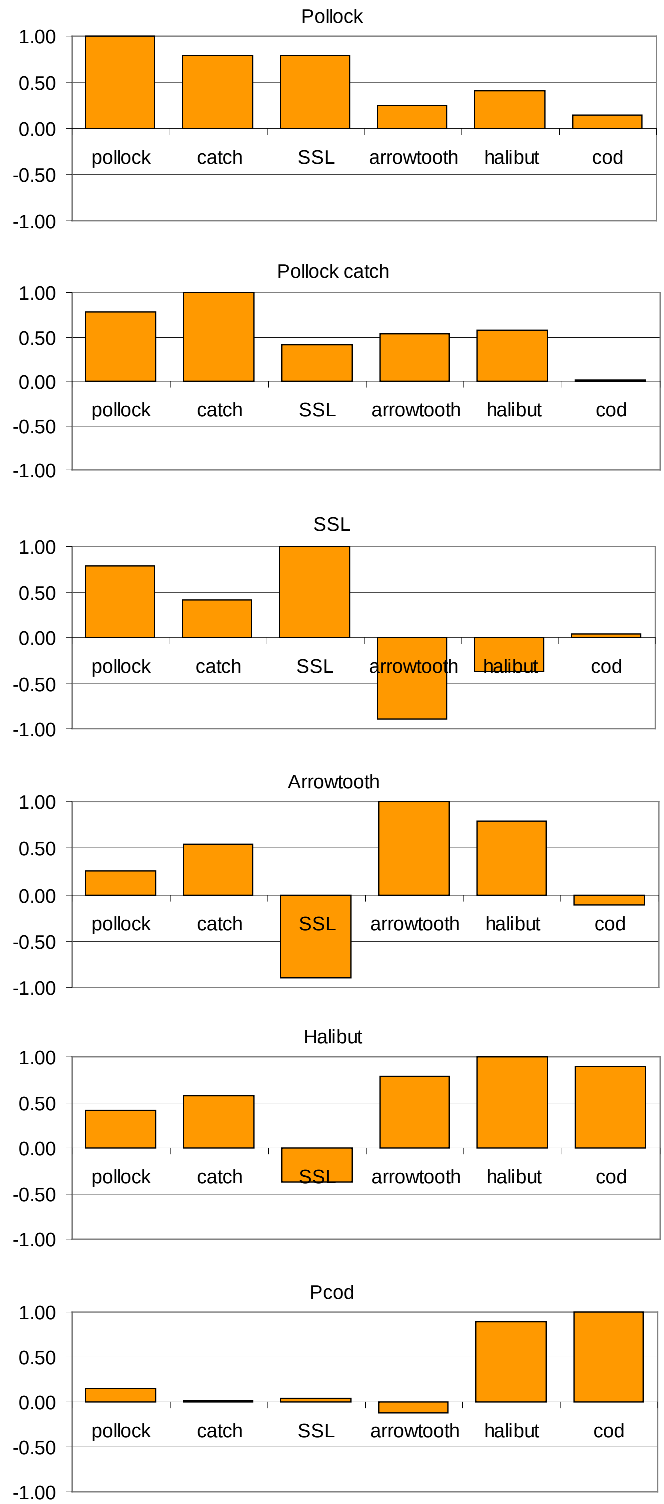


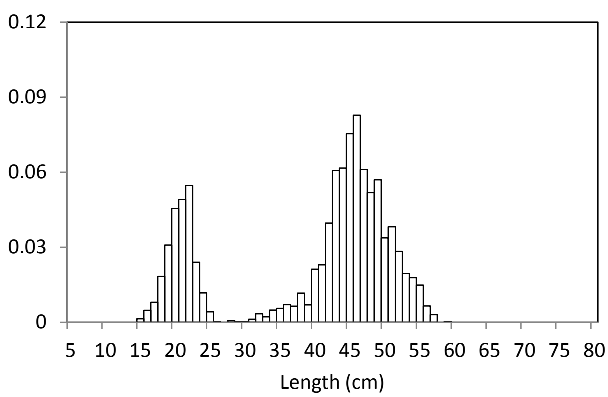
Figure 1.46. Pair-wise Spearman rank correlation between abundance trends of walleye pollock, pollock fishery catches, Steller sea lions, arrowtooth flounder, Pacific halibut, and Pacific cod in the Gulf of Alaska. Rank correlations are based on the years in which abundance estimates are available for each pair.

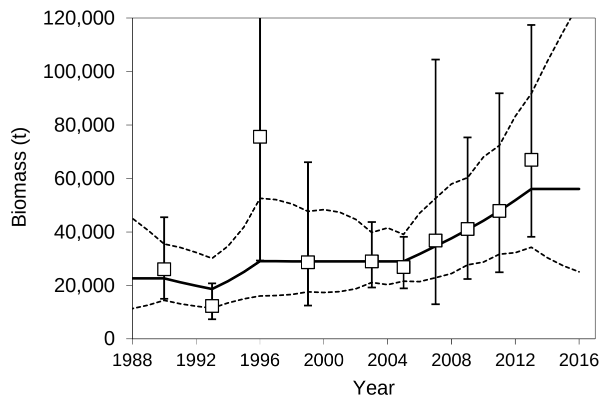
Appendix A: Southeast Alaska pollock

Bottom trawl surveys indicate a substantial reduction in pollock abundance east of 140° W. lon. Stock structure in this area is poorly understood. Bailey et al. (1999) suggest that pollock metapopulation structure in southeast Alaska is characterized by numerous fiord populations. In the 2013 bottom trawl survey, higher pollock CPUE in southeast Alaska occurred primarily from Cape Ommaney to Dixon Entrance, where the shelf is broader. Pollock length composition in the 2013 bottom trawl survey showed a mode of age-1 pollock, and a mode at 46 cm (Appendix Fig. A.1). Larger pollock (> 55 cm) were uncommon. Juveniles in this area are unlikely to influence the population dynamics of pollock in the central and western Gulf of Alaska. Ocean currents are generally northward in this area, suggesting that juvenile settlement is a result of spawning further south. Spawning aggregations of pollock have been reported from the northern part of Dixon Entrance (Saunders et al. 1988).

Historically, there has been little directed fishing for pollock in Southeast Alaska (Fritz 1993). Pollock catch the Southeast and East Yakutat statistical areas has averaged about 1 t since 2002 (Table 1.4). The ban on trawling east of 140° W. lon. prevents the development of a trawl fishery for pollock in Southeast Alaska.

Biomass in Southeast Alaska was estimated by splitting survey strata and CPUE data in the Yakutat INPFC area at 140° W. lon. and combining the strata east of the line with comparable strata in the Southeastern INPFC area. Surveys since 1996 had the most complete coverage of shallow strata in southeast Alaska, and indicate that stock size is approximately 25-75,000 t (Appendix Fig. A.1). There is a gradual increase in biomass since 2005, but confidence intervals are large. A random effects model was fit to the 1990-2013 bottom trawl survey biomass estimates in southeast Alaska. We recommend placing southeast Alaska pollock in Tier 5 of NPFMC harvest policy, and basing the ABC and OFL on natural mortality (0.3) and the biomass estimate from the random effects model in 2014 (56,111 t). **This results in a 2015 ABC of 12,625 t (56,111 t * 0.75 M), and a 2015 OFL of 16,833 t (56,111 t * M). The same ABC and OFL is recommended for 2016.**





Appendix Figure A.1. Pollock size composition in 2013 (left) and biomass trend in southeast Alaska from NMFS bottom trawl surveys in 1990-2013 (right). Error bars indicate plus and minus two standard deviations. The solid line is the biomass trend from the random effects model, while dotted lines indicate the 95% confidence interval.

Status Summary for Southeast Alaska Pollock

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)	0.3	0.3	0.3	0.3
Tier	5	5	5	5
Biomass (t)				
Upper 95% confidence interval	103,745	114,876	114,876	125,584
Point estimate	56,111	56,111	56,111	56,111
Lower 95% confidence interval	30,348	27,408	27,408	25,071
F_{OFL}	0.30	0.30	0.30	0.30
$maxF_{ABC}$	0.23	0.23	0.23	0.23
F_{ABC}	0.23	0.23	0.23	0.23
OFL (t)	16,833	16,833	16,833	16,833
maxABC (t)	12,625	12,625	12,625	12,625
ABC (t)	12,625	12,625	12,625	12,625
Status	As determined *last* year for: 2011	2012	As determined *this* year for: 2013	2014
Overfishing	No	n/a	No	n/a

Appendix B: Gulf pollock stock assessment model

Population dynamics

The age-structured model for pollock describes the relationships between population numbers by age and year. The modeled population includes individuals from age 1 to age 10, with age 10 defined as a "plus" group, i.e., all individuals age 10 and older. The model extends from 1970 to 2013 (45 years). The Baranov (1918) catch equations are assumed, so that

$$c_{ij} = N_{ij} \frac{F_{ij}}{Z_{ij}} [1 - \exp(-Z_{ij})]$$

$$N_{i+1\, j+1} = N_{ij} \exp(-Z_{ij})$$

$$Z_{ij} = \sum_k F_{ij} + M$$

except for the plus group, where

$$N_{i+1,10} = N_{i,9} \exp(-Z_{i,9}) + N_{i,10} \exp(-Z_{i,10})$$

where N_{ij} is the population abundance at the start of year *i* for age *j* fish, F_{ij} = fishing mortality rate in year *i* for age *j* fish, and c_{ij} = catch in year *i* for age *j* fish. A constant natural mortality rate, *M*, irrespective of year and age, is assumed.

Fishing mortality is modeled as a product of year-specific and age-specific factors (Doubleday 1976)

$$F_{ij} = s_j f_i$$

where s_j is age-specific selectivity, and f_i is the annual fishing mortality rate. To ensure that the selectivities are well determined, we require that $\max(s_j) = 1$. Following previous assessments, a scaled double-logistic function (Dorn and Methot 1990) was used to model age-specific selectivity,

$$s'_j = \left(\frac{1}{1 + \exp[-\beta_1 (j - \alpha_1)]} \right) \left(1 - \frac{1}{1 + \exp[-\beta_2 (j - \alpha_2)]} \right)$$

$$s_j = s'_j \,/\, \max(s'_j)$$

where α_1 = inflection age, β_1 = slope at the inflection age for the ascending logistic part of the equation, and α_2 , β_2 = the inflection age and slope for the descending logistic part.

Measurement error

Model parameters were estimated by maximum likelihood (Fournier and Archibald 1982, Kimura 1989, 1990, 1991). Fishery observations consist of the total annual catch in tons, C_i, and the proportions at age in the catch, p_{ij} . Predicted values from the model are obtained from

$$\hat{C}_i = \sum_j w_{ij}\, c_{ij}$$

$$\hat{p}_{ij} = c_{ij} \,/\, \sum_j c_{ij}$$

where w_{ij} is the weight at age *j* in year *i* . Year-specific weights at age are used when available.

Log-normal measurement error in total catch and multinomial sampling error in the proportions at age give a log-likelihood of

$$\log L_k = -\sum_i [\,\log(C_i) - \log(\hat{C}_i)\,]^2 / 2\sigma_i^2 + \sum_i m_i \sum_j p_{ij} \log(\hat{p}_{ij} / p_{ij})$$

where σ_i is standard deviation of the logarithm of total catch (~ CV of total catch) and m_i is the size of the age sample. In the multinomial part of the likelihood, the expected proportions at age have been divided by the observed proportion at age, so that a perfect fit to the data for a year gives a log likelihood value of zero (Fournier and Archibald 1982). This formulation of the likelihood allows considerable flexibility to give different weights (i.e. emphasis) to each estimate of annual catch and age composition. Expressing these weights explicitly as CVs (for the total catch estimates), and sample sizes (for the proportions at age) assists in making reasonable assumptions about appropriate weights for estimates whose variances are not routinely calculated.

Survey observations consist of a total biomass estimate, B_i, and survey proportions at age π_{ij}. Predicted values from the model are obtained from

$$\hat{B}_i = q \sum_j w_{ij}\, s_j\, N_{ij} \exp[\,\phi_i Z_{ij}\,]$$

where q = survey catchability, w_{ij} is the survey weight at age *j* in year *i* (if available), s_j = selectivity at age for the survey, and ϕ_i = fraction of the year to the mid-point of the survey. Although there are multiple surveys for Gulf pollock, a subscript to index a particular survey has been suppressed in the above and subsequent equations in the interest of clarity. Survey selectivity was modeled using a either a double-logistic function of the same form used for fishery selectivity, or simpler variant, such as single logistic function. The expected proportions at age in the survey in the *i*th year are given by

$$\hat{\pi}_{ij} = s_j N_{ij} \exp[\phi_i Z_{ij}] / \sum_j s_j N_{ij} \exp[\phi_i Z_{ij}]$$

Log-normal errors in total biomass and multinomial sampling error in the proportions at age give a log-likelihood for survey *k* of

$$\log L_k = -\sum_i [\log(B_i) - \log(\hat{B}_i) + \sigma^2/2]^2 / 2\sigma_i^2 + \sum_i m_i \sum_j \pi_{ij} \log(\hat{\pi}_{ij} / \pi_{ij})$$

where σ_i is the standard deviation of the logarithm of total biomass (~ CV of the total biomass) and m_i is the size of the age sample from the survey.

Process error

Process error refers to random changes in parameter values from one year to the next. Annual variation in recruitment and fishing mortality can be considered types of process error (Schnute and Richards 1995). In the pollock model, these annual recruitment and fishing mortality parameters are generally estimated as free parameters, with no additional error constraints. We use process error to describe changes in fisheries selectivity over time. To model temporal variation in a parameter γ , the year-specific value of the parameter is given by

$$\gamma_i = \bar{\gamma} + \delta_i$$

where $\bar{\gamma}$ is the mean value (on either a log scale or an arithmetic scale), and δ_i is an annual deviation subject to the constraint $\sum \delta_i = 0$. For a random walk where annual *changes* are normally distributed, the log-likelihood is

$$\log L_{Proc.Err.} = -\sum \frac{(\delta_i - \delta_{i+1})^2}{2\sigma_i^2}$$

where σ_i is the standard deviation of the annual change in the parameter. We use a process error model for the two parameters for the ascending portion of the fishery double-logistic curve. Variation in the intercept selectivity parameter is modeled using a random walk on an arithmetic scale, while variation in the slope parameter is modeled using a log-scale random walk.

The total log likelihood is the sum of the likelihood components for each fishery and survey, plus a term for process error,

$$\text{Log}\, L = \sum_k \text{Log}\, L_k + \sum_p \text{Log}\, L_{Proc.\,Err.}\,.$$

Appendix C: Seasonal distribution and apportionment of walleye pollock among management areas in the Gulf of Alaska

Since 1992, the Gulf of Alaska pollock TAC has been apportioned between management areas based on the distribution of biomass in groundfish surveys. Both single species and ecosystem considerations provide the rationale for apportioning the TAC. From an ecosystem perspective, apportioning the TAC will spatially distribute the effects of fishing on other pollock consumers (i.e., Steller sea lions), potentially reducing the overall intensity of any adverse effects. Apportioning the TAC also ensures that no smaller component of the stock experiences higher mortality than any other. Although no sub-stock units of pollock have yet been identified in the Gulf of Alaska, it would be precautionary to manage the fishery so that if these sub-units do exist they would not be subject to high fishing mortality. Protection of sub-stock units would be most important during spawning season, when they are spatially separated. The Steller sea lion protection measures implemented in 2001 require apportionment of pollock TAC based on the seasonal distribution of biomass.

Walleye pollock in the Gulf of Alaska undergo an annual migration between summer foraging habitats and winter spawning grounds. Since surveying effort has been concentrated during the summer months and prior to spawning in late winter, the dynamics and timing of this migration are not well understood. Regional biomass estimates are highly variable, indicating either large sampling variability, large interannual changes in distribution, or, more likely, both. There is a comprehensive survey of the Gulf of Alaska in summer, but historically surveying during winter has focused on the Shelikof Strait spawning grounds. Recently there has been expanded acoustic surveying effort outside of Shelikof Strait in winter, but no acoustic survey has been comprehensive, covering all areas where pollock could potentially occur.

Winter apportionment

An annual acoustic survey on pre-spawning aggregations in Shelikof Strait has been conducted since 1981. Since 2000, several additional spawning areas have been surveyed multiple times, including Sanak Gully, the Shumagin Islands, the shelf break near Chirikof Island, and Marmot Bay. Although none of these spawning grounds are as important as Shelikof Strait, especially from a historical perspective, in some years the aggregate biomass surveyed outside Shelikof Strait has been comparable to that within Shelikof Strait.

As in previous assessments, a "composite" approach was used to estimate the percent of the total stock in each management area. The estimated biomass for each survey was divided by the total biomass of pollock estimated by the assessment model in that year and then split into management areas for surveys that crossed management boundaries. The percent for each survey was added together to form a composite biomass distribution, which was then rescaled so that it summed to 100%. Model estimates of biomass at spawning took into account the total mortality between the start of the year and spawning, and used mean weight at age from Shelikof Strait surveys.

Since time series of biomass estimates for spawning areas outside of Shelikof Strait are now available, we used the four most recent surveys at each spawning area, and used a rule that a minimum of three surveys was necessary to include an area. These criteria are intended to provide estimates that reflect recent biomass distribution while at the same time providing some stability in the estimates. The biomass in these secondary spawning areas tends to be highly variable from one year to the next. Areas meeting these criteria were Shelikof Strait, the shelf break near Chirikof Island, the Shumagin area, Sanak Gully, Morzhovoi Bay, and Marmot Bay. While the spawning aggregations found in 2010 along the Kenai Peninsula and in Prince William Sound are clearly important, before including them in the apportionment calculations the surveys in these areas need to be repeated to confirm stability of spawning in these areas

There are also several potentially difficult issues that would need to dealt with, for example, whether including biomass along Kenai Peninsula would lead increased harvests on the east side of Kodiak, both of which are in area 630. In addition, the fishery inside Prince William Sound (area 649) is managed by the State of Alaska, and state management objectives for Prince William Sound need to be taken into account.

Vessel comparison experiments conducted between the *R/V Miller Freeman* and the *R/V Oscar Dyson* in Shelikof Strait in 2007, and in the Shumagin/Sanak area in 2008 found significant differences in the ratio of backscatter between the two vessels. The estimated *R/V Oscar Dyson* to *R/V Miller Freeman* ratio for the Shelikof Strait was 1.132, while the ratio for the Shumagin and Sanak areas (taken together) was 1.31. Since the *R/V Oscar Dyson* was designed to minimize vessel avoidance, biomass estimates produced by *R/V Oscar Dyson* should be considered better estimates of the true biomass than those produced by the *R/V Miller Freeman*. When calculating the distribution of biomass by area, multipliers were applied to surveys conducted by the *R/V Miller Freeman* to make them comparable to the *R/V Oscar Dyson* (Appendix Table C.1). Multipliers were needed only for Morzhovoi Bay because all other areas have been surveyed at least four times with the *R/V Oscar Dyson*. A vessel specific multiplier of 1.31 was applied in Morzhovoi Bay because the fish in these areas were at similar depths as at the Sanak and Shumagin area.

The sum of the percent biomass for all surveys combined was 65.46%, which may reflect sampling variability, or interannual variation in spawning location, but also reflects the recent trend that the aggregate biomass of pollock surveyed acoustically in winter (at least in those areas that have been surveyed repeatedly) is lower than the assessment model estimates of abundance. After rescaling, the resulting average biomass distribution was 7.99%, 83.21%, 8.80% in areas 610, 620, and 630 (Appendix Table C.1). In comparison to last year, the percentage in area 610 is 4.2 percentage points lower, is 4.6 percentage points higher in area 620, and is 0.4 percentage points lower in area 630.

This year we evaluated using a random effects model rather than averaging to obtain the biomass distribution by area, but decided not to use it because of concerns about the performance of the random effects model when biomass estimates were highly variable and occasionally close to zero.

A-season apportionment between areas 620 and 630

In the 2002 assessment, based on evaluation of fishing patterns which suggested that the migration to spawning areas was not complete by January 20, the Gulf of Alaska plan team recommended an alternative apportionment scheme for areas 620 and 630 based on the midpoint of the summer and winter distributions in area 630. This approach was not used for area 610 because fishing patterns during the A season suggested that most of the fish captured in area 610 would eventually spawn in area 610. The resulting A season apportionment is: 610, 7.99%; 620, 67.11%; 630, 24.90%.

Summer distribution

The NMFS bottom trawl is summer survey (typically extending from mid-May to mid-August). Previously apportionment of pollock TAC was based upon an unweighted average of four most recent NMFS summer surveys, however in this assessment we considered the recommendation of the survey averaging working group to evaluate random effects models to fit smoothed biomass trends for each management area. Performance of the random effects model appeared satisfactory (Fig. C.1). The apportionment was based on the 2013 smoothed biomass estimates by area, which resulted in a biomass distribution of 26.13%, 31.37%, 39.97%, 2.53% in areas 610, 620, 630, and 640 (Fig. C.2). In comparison to previous apportionment method of using a four survey average, percent in area 610 dropped by 6.5 percentage points, while 620 increased by 0.7 percentage points, and 630 increased 6.2 percentage points.

Apportionment for area 640

The apportionment for area 640, which is not managed by season, is based on the summer distribution of the biomass in the NMFS bottom trawl survey. The percentage (2.53%) of the TAC in area 640 is subtracted from the TAC before allocating the remaining TAC by season and region.

Example calculation of 2015 Seasonal and Area TAC Allowances for W/C/WYK

Warning: This example is based on hypothetical ABC of 100,000 t.

1) Deduct the Prince William Sound Guideline Harvest Level.

2) Use summer biomass distribution for the 640 allowance:

640 0.0253 x Total TAC = 2,526 t

3) Calculate seasonal apportionments of TAC for the A, B, C, and D seasons at 25 %, 25%, 25%, and 25% of the remaining annual TAC west of 140° W lon.

A season 0.25 x (Total TAC – 2,526) = 24,369 t
B season 0.25 x (Total TAC – 2,526) = 24,369 t
C season 0.25 x (Total TAC – 2,526) = 24,369 t
D season 0.25 x (Total TAC – 2,526) = 24,369 t

4) For the A season, the allocation of TAC to areas 610, 620 and 630 is based on a blending of winter and summer distributions to reflect that pollock may not have completed their migration to spawning areas by Jan. 20, when the A season opens.

610 0.0799 x 24,369 t = 1,946 t
620 0.6711 x 24,369 t = 16,353 t
630 0.2490 x 24,369 t = 6,069 t

5) For the B season, the allocation of TAC to areas 610, 620 and 630 is based on the composite estimate of winter biomass distribution1

610 0.0799 x 24,369 t = 1,946 t
620 0.8321 x 24,369 t = 20,277 t
630 0.0880 x 24,369 t = 2,145 t

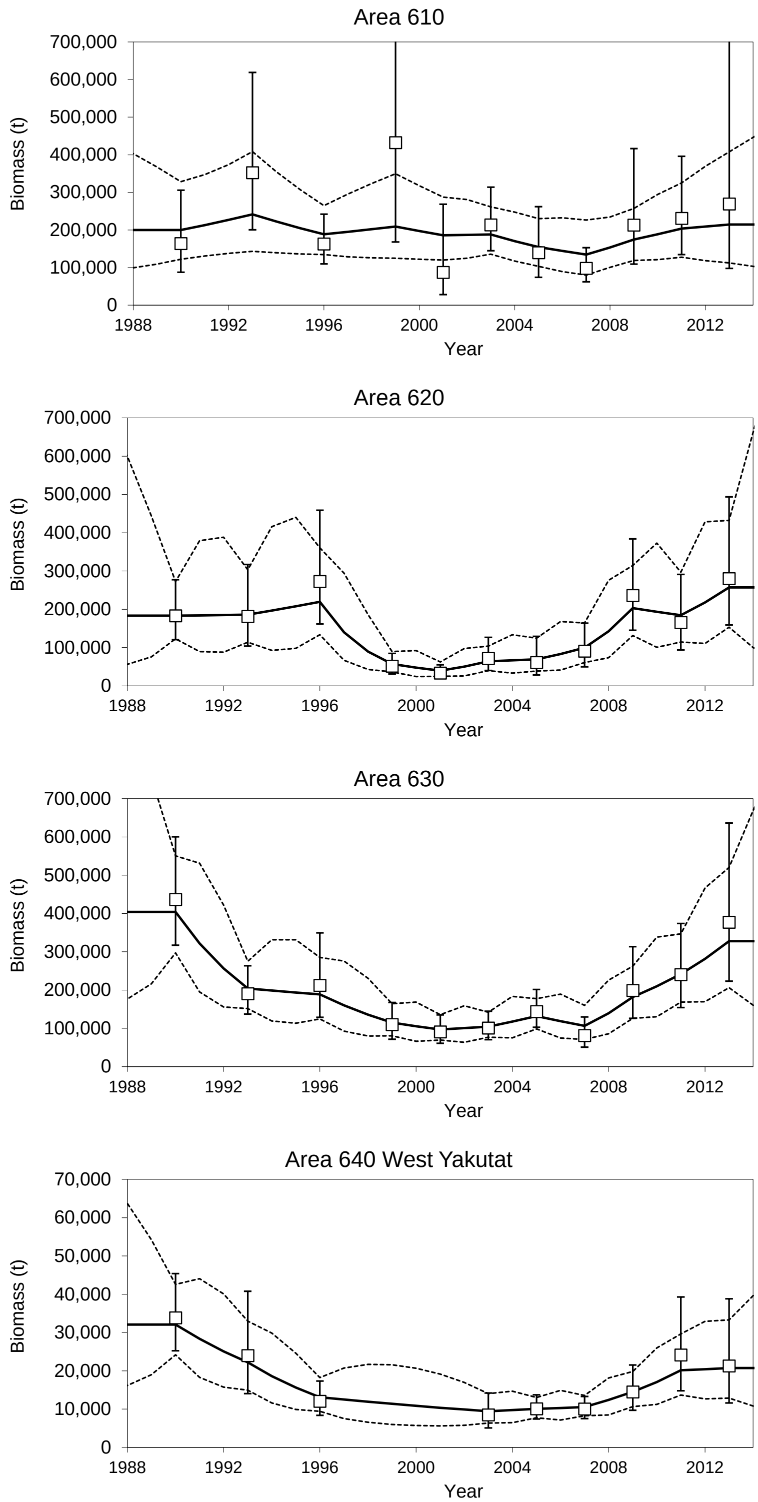
6) For the C and D seasons, the allocation of remaining TAC to areas 610, 620 and 630 is based on the biomass distribution in areas 610, 620, 630, and 640 in 2913 based on the random effects model of 26.13%, 31.37%, 39.97%, and 2.53%.

610 0.2613 / (1 – 0.0253) x 24,369 = 6,534 t
620 0.3137 / (1 – 0.0253) x 24,369 = 7,843 t
630 0.3997 / (1 – 0.0253) x 24,369 = 9,992 t

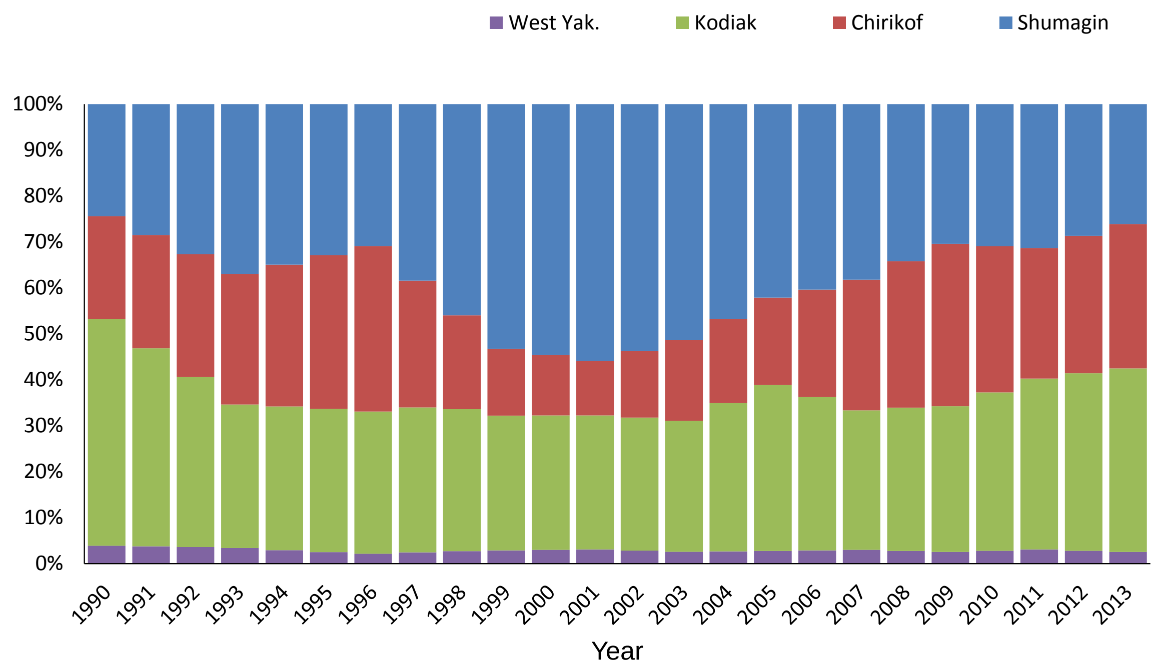
610 0.2613 / (1 – 0.0253) x 24,369 = 6,534 t
620 0.3137 / (1 – 0.0253) x 24,369 = 7,843 t
630 0.3997 / (1 – 0.0253) x 24,369 = 9,992 t

Appendix Table C.1. Estimates of percent pollock in areas 610-630 during winter acoustic surveys in the Gulf of Alaska. The biomass of age-1 fish is not included the acoustic survey biomass estimates.

Survey	*Year*	*Model estimates of total 2+ biomass at spawning*	*Survey biomass estimate*	*Multiplier from vessel comparison (OD/MF)*	*Percent*	*Percent by management area* *Area 610*	*Area 620*	*Area 630*
Shelikof	2010	1,062,110	429,730	1.00	40.5%	0.0%	93.7%	6.3%
Shelikof	2012	1,103,010	335,836	1.00	30.4%	0.0%	96.0%	4.0%
Shelikof	2013	1,187,700	831,486	1.00	70.0%	0.0%	95.0%	5.0%
Shelikof	2014	1,057,580	883,177	1.00	83.5%	0.0%	96.7%	3.3%
Shelikof	Average				56.1%	0.0%	95.4%	4.6%
	Percent of total 2+ biomass					0.0%	53.3%	2.6%
Chirikof	2009	818,555	396	1.00	0.0%	0.0%	0.0%	100.0%
Chirikof	2010	1,062,110	9,544	1.00	0.9%	0.0%	0.0%	100.0%
Chirikof	2012	1,103,010	21,181	1.00	1.9%	0.0%	13.0%	87.0%
Chirikof	2013	1,187,700	63,008	1.00	5.3%	0.0%	70.2%	29.8%
Chirikof	Average				2.0%	0.0%	20.8%	79.2%
	Percent of total 2+ biomass					0.0%	0.4%	1.6%
Marmot	2009	818,555	19,759	1.00	2.4%	0.0%	0.0%	100.0%
Marmot	2010	1,062,110	5,585	1.00	0.5%	0.0%	0.0%	100.0%
Marmot	2013	1,187,700	19,899	1.00	1.7%	0.0%	0.0%	100.0%
Marmot	2014	1,057,580	13,403	1.00	1.3%	0.0%	0.0%	100.0%
Marmot	Average				1.5%	0.0%	0.0%	100.0%
	Percent of total 2+ biomass					0.0%	0.0%	1.5%
Shumagin	2010	1,062,110	18,081	1.00	2.3%	94.9%	5.1%	0.0%
Shumagin	2012	1,103,010	15,501	1.00	1.9%	88.0%	12.0%	0.0%
Shumagin	2013	1,187,700	47,388	1.00	4.0%	55.2%	44.8%	0.0%
Shumagin	2014	1,057,580	36,160	1.00	3.4%	54.7%	45.3%	0.0%
Shumagin	Average				2.9%	73.2%	26.8%	0.0%
	Percent of total 2+ biomass					2.1%	0.8%	0.0%
Sanak	2010	1,062,110	26,678	1.00	2.5%	100.0%	0.0%	0.0%
Sanak	2012	1,103,010	24,252	1.00	2.2%	100.0%	0.0%	0.0%
Sanak	2013	1,187,700	12,967	1.00	1.1%	100.0%	0.0%	0.0%
Sanak	2014	1,057,580	7,319	1.00	0.7%	100.0%	0.0%	0.0%
Sanak	Average				1.9%	100.0%	0.0%	0.0%
	Percent of total 2+ biomass					1.9%	0.0%	0.0%
Mozhovoi	2006	554,369	11,679	1.31	2.8%	100.0%	0.0%	0.0%
Mozhovoi	2007	558,567	2,540	1.31	0.6%	100.0%	0.0%	0.0%
Mozhovoi	2010	1,062,110	1,650	1.00	0.2%	100.0%	0.0%	0.0%
Mozhovoi	2013	1,187,700	1,520	1.00	0.1%	100.0%	0.0%	0.0%
Mozhovoi	Average				1.2%	100.0%	0.0%	0.0%
	Percent of total 2+ biomass					1.2%	0.0%	0.0%
Total					65.46%	5.23%	54.47%	5.76%
Rescaled total					100.00%	7.99%	83.21%	8.80%



Appendix Figure C.1. Random effects models fit to summer bottom trawl biomass estimates by management area for 1990-2013.



Appendix Figure C.2. Percent biomass by management area based on random effects models.

Appendix D: Supplemental catch data

To comply with the Annual Catch Limit (ACL) requirements, estimates have been developed for non-commercial catches and removals from NMFS-managed stocks in Alaska. Research catches have been routinely reported in the pollock assessment, but these catches are only for survey data that have been included in RACEBASE, and are not a comprehensive accounting of all research removals (Appendix Table D.1). One new data set is more a comprehensive accounting of research removals than had been available previously. This data set is relatively complete only for 2010 and 2011 (Appendix Table D.2). Comparison of research catches from RACEBASE with the more comprehensive information in 2010 and 2011 suggests that research catches have been substantially underreported. The estimates from RACEBACE ranged between 25% and 30% of the total research catch. Annual large-mesh and small-mesh trawl surveys conducted by ADFG account for most of the missing research catch of pollock. Even if research catches are four times those reported in RACEBACE, they would still amount to less than 1/2 of a percent on average of the ABC during 2002-2011, and would have a negligible effect on the pollock stock or the stock assessment.

An attempt was made using methods described in Tribuzio et. al (2011) to estimate the incidental catch of groundfish in the Pacific halibut fishery. Based on Plan Team recommendations, these estimates will not be continued. Estimates of pollock bycatch in the Pacific halibut fishery during 2001-2010 averaged 12.2 t, with a minimum of 0.9 t and a maximum of 62.4 t, suggesting that the bycatch of pollock (or the estimates thereof) are low and highly variable. Since some halibut fishery incidental catch as enters into the catch accounting system, it is unclear whether these catches have already been taken into account in the reported catch. However this seems unlikely for pollock. It is important to note that there is unreported incidental catch of pollock in other fisheries in Alaska, such as the salmon fishery, which, based on anecdotal reports, may be substantial on occasion.

Appendix Table D.1. Estimates of pollock research catch (t) in the Gulf of Alaska from RACEBASE during 1977-2011.

Year	*Catch (t)*
1977	89.2
1978	99.7
1979	52.4
1980	229.4
1981	433.3
1982	110.4
1983	213.1
1984	310.7
1985	167.2
1986	1201.8
1987	226.6
1988	19.3
1989	72.7
1990	158.0
1991	16.2
1992	39.9
1993	116.4
1994	70.4
1995	44.3
1996	146.9
1997	75.5
1998	63.6
1999	34.7
2000	56.3
2001	77.1
2002	77.6
2003	127.6
2004	53.0
2005	71.7
2006	63.5
2007	47.1
2008	26.2
2009	89.9
2010	37.4
2011	43.0

Appendix Table D.2. Estimates of pollock research catch (t) in the Gulf of Alaska by survey or research project in 2010 and 2011.

	Year	
Survey/research project	*2010*	*2011*
ADFG large-mesh trawl	83.0	81.3
ADFG small-mesh trawl	20.1	23.4
IPHC annual survey	0.8	0.3
NMFS Shelikof Strait acoustic survey	12.0	
NMFS Shumagin Islands acoustic survey	25.4	
NMFS bottom trawl survey		43.0
NMFS sablefish longline survey	2.5	1.4
GOA IERP research	0.1	
Western GOA cooperative acoustic survey	12.4	
Total	156.3	149.3

Chapter 2: Assessment of the Pacific cod stock in the Gulf of Alaska

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Executive Summary

Summary of Changes in Assessment Inputs

Relative to last year's assessment, the following changes have been made in the current assessment:

Changes in the input data

1. Federal and state catch data for 1997 – 2013 were updated and preliminary federal and state catch data for 2014 were included
2. Commercial federal and state fishery size composition data for 1997 – 2013 were updated, and preliminary commercial federal and state fishery size composition data for 2014 were included

Changes in the methodology

One of the models in this year's assessment is the 2013 final model. An alternative version of the 2013 model which uses the recruitment variability multiplier (sigmaR multiplier) for recent recruits is also presented.

Two additional models which differ significantly from the 2013 final model are also presented. These differences include:

- Using all of the GOA NMFS bottom trawl survey as a single source of data instead of being split into sub-27 and 27-plus, for the abundance estimates and the length- and age-composition data;
- Using 3 blocks of non-parametric or cubic spline-based survey selectivity-at-age instead of 12 blocks of double normal selectivity-at-age;
- Including the survey age data as conditional age-at-length data instead of age composition and mean size-at-age data; and
- Using the recruitment variability multiplier (sigmaR multiplier) for recent recruits

Summary of Results

Quantity	As estimated or *specified last* year for:		As estimated or *specified this* year for:	
	2014	2015	2015	2016
M (natural mortality rate)	0.38	0.38	0.38	0.38
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	422,000	397,000	583,800	558,200
Female spawning biomass (t)				
Projected	120,100	111,500	155,400	150,400
Upper 95% confidence interval	142,800	132,500	215,400	210,400
Lower 95% confidence interval	97,500	90,500	95,400	90,400
$B_{100\%}$	227,800	227,800	316,500	316,500
$B_{40\%}$	91,100	91,100	126,600	126,600
$B_{35\%}$	79,700	79,700	110,700	110,700
F_{OFL}	0.69	0.69	0.626	0.626
$maxF_{ABC}$	0.54	0.54	0.502	0.502
F_{ABC}	0.54	0.54	0.502	0.502
OFL (t)	107,300	101,800	140,300	133,100
maxABC (t)	88,500	84,100	117,200	110,700
ABC (t)	88,500	84,100	117,200	110,700
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Area apportionment

In 2012 the ABC for GOA Pacific cod was apportioned among regulatory areas using a Kalman filter approach based on trawl survey biomass estimates. In the 2013 assessment, the random effects model (which is similar to the Kalman filter approach, and was recommended in the Survey Average working group report which was presented to the Plan Team in September 2013) was used; this method was used for the ABC apportionment for 2014. The SSC concurred with this method in December 2013. Using this method with the trawl survey biomass estimates through 2013, the area-apportioned ABCs are:

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	37.63	59.62	2.75	100.00
2015 ABC	44,102	69,875	3,223	117,200
2016 ABC	41,656	65,999	3,044	110,700

Responses to SSC and Plan Team Comments in General

SSC, December 2014: "*During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment.*"
Response: This figure is included as Figure 2.26.

Responses to SSC and Plan Team Comments Specific to this Assessment

Plan Team, September 2014: "*The PT concurred with the author to bring forward three models to the November Plan Team meeting: Models P1, S1a, and S1b. These three models give a reasonable portrayal of stock dynamics. The major differences in the S1 models compared to the P1 model (last year's model) is the use of a conditional age at length key for survey data, treating bottom trawl survey data as one source (i.e. sub 27 and 27 plus size groups combined), and the inclusion a recruitment variability multiplier (sigma r multiplier) applied to recent recruitment estimates,. Model P1 omits the sub 27 survey data. Model S1b includes the use of splines to estimate selectivity curves.*"
Response: The three models have been brought forward, along with an additional model which is the 2013 model with the recruitment variability multiplier for recent recruits.

Plan Team, September 2014: ***"For all models, the Plan Team recommends that starting values for sample weights for compositional data (i.e. age and length data) be based on the number of hauls or trips rather than the number samples. These starting values should be the upper limit of sample weights."***
Response: The sample sizes for the fishery catch-at-length data are based on the number of hauls or trips; the sample sizes for the survey length and age composition data and conditional age-at-length data are the number of hauls.

Plan Team, September 2014: ***"The Plan Team recommends that the authors explore the use of the "10% selectivity rule" presented by Grant Thompson as the year class to start applying the sigma r multiplier."***
Response: Using the average of the survey selectivity-at-age curves from the 2013 model, the result of the "first age = round[(0.05/M) + A10%] calculation is 1.4, or age 1. However, in the two new models, the survey selectivity at age 2 is lower than selectivity at age 1 in most years, so age 2 was used as the cutoff. This change resulted in age-0 recruits being estimated through 2011, and the sigmaR multiplier being applied to the 2012, 2013, and 2014 age-0 recruits.

Plan Team, September 2014: ***"The Plan Team also recommends exploration of the use of longline survey data as an additional source of abundance index data for adult Pacific cod."***
Response: This exploration is still ongoing. Dana Hanselman provided a preliminary figure for this analysis, and is included as Figure 2.27.

SSC, October 2014: "*The assessment author presented 5 alternative models, and the Plan Team recommended that Models P1, S1a and S1b be brought forward to the November plan team meeting. Model P1 is last years' model. The S1 models differ in that they use conditional age at length for survey data and include a recruitment variability multiplier. Model S1b uses non-parametric selectivity functions (cubic splines). The Plan Team recommends that the starting values for composition sample weights be based on the number of hauls or trips, rather than the number of samples. The Plan Team also recommends the author explore the use of the 10% selectivity rule for determining the recruitment vector, and explore the use of the IPHC set-line survey data as an index for adult Pacific cod.* ***The SSC agrees with all the recommendations made by the Plan Team.***"
Response: The recommendations made by the Plan Team have been addressed.

Introduction

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over Gulf of Alaska (GOA), as well as the eastern Bering Sea (EBS) and the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and GOA. Recent research indicates the existence of discrete stocks in the EBS and AI (Canino et al. 2005, Cunningham et al. 2009, Canino et al. 2010, Spies 2012). Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the GOA. The Pacific cod stock in the GOA is managed as one stock.

Review of Life History

Pacific cod eggs are demersal and adhesive. Eggs hatch in about 15 to 20 days. Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near bottom. Eggs sink to the bottom after fertilization and are somewhat adhesive. Optimal temperature for incubation is 3° to 6°C, optimal salinity is 13 to 23 parts per thousand (ppt), and optimal oxygen concentration is from 2 to 3 ppm to saturation. Little is known about the optimal substrate type for egg incubation.

Little is known about the distribution of Pacific cod larvae, which undergo metamorphosis at about 25 to 35 mm. Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow.

Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shoreline to 500 m, although occurrence in depths greater than 300 m is fairly rare. Preferred substrate is soft sediment, from mud and clay to sand. Average depth of occurrence tends to vary directly with age for at least the first few years of life. However, in the GOA trawl survey, the percentage of fish residing in waters less than 100 m tends to increase with length beyond about 90 cm. The GOA trawl survey also indicates that fish occupying depths of 200-300 m are typically in the 40-90 cm size range.

It is conceivable that mortality rates, both fishing and natural, may vary with age in Pacific cod. In particular, very young fish likely have higher natural mortality rates than older fish (note that this may not be particularly important from the perspective of single-species stock assessment, so long as these higher natural mortality rates do not occur at ages or sizes that are present in substantial numbers in the data). For example, Leslie matrix analysis of a Pacific cod stock occurring off Korea estimated the instantaneous natural mortality rate of 0-year-olds at 910% per year (Jung et al. 2009). This may be compared to a mean estimate for age 0 Atlantic cod (*Gadus morhua*) in Newfoundland of 4.17% per day, with a 95% confidence interval ranging from about 3.31% to 5.03% (Gregory et al. in prep.); and age 0 Greenland cod (*Gadus ogac*) of 2.12% per day, with a 95% confidence interval ranging from about 1.56% to 2.68% (Robert Gregory and Corey Morris, *pers. commun.*).

Although little is known about the likelihood of age-dependent natural mortality in adult Pacific cod, it has been suggested that Atlantic cod may exhibit increasing natural mortality with age (Greer-Walker 1970).

At least one study (Ueda et al. 2006) indicates that age 2 Pacific cod may congregate more, relative to age 1 Pacific cod, in areas where trawling efficiency is reduced (e.g., areas of rough substrate), causing their selectivity to decrease. Also, Atlantic cod have been shown to dive in response to a passing vessel (Ona and Godø 1990), which may complicate attempts to estimate catchability or selectivity. It is not known whether Pacific cod undertake a similar response.

As noted above, Pacific cod are known to undertake seasonal migrations, the timing and duration of which may be variable (Savin 2008).

Fishery

During the two decades prior to passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, the fishery for Pacific cod in the GOA was small, averaging around 3,000 t per year. Most of the catch during this period was taken by the foreign fleet, whose catches of Pacific cod were usually incidental to directed fisheries for other species. By 1976, catches had increased to 6,800 t. Catches of Pacific cod since 1991 are shown in Table 2.1; catches prior to that are listed in Thompson et al. (2011). Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Trawl gear took the largest share of the catch in every year but one from 1991-2002, although pot gear has taken the largest single-gear share of the catch in each year since 2003 (not counting 2013, for which data are not yet complete). Figure 2.1 shows landings by gear and season since 1977. Table 2.1 shows the catch by jurisdiction and gear type.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate commercial catches in Table 2.2. For the first year of management under the MFCMA (1977), the catch limit for GOA Pacific cod was established at slightly less than the 1976 total reported landings. During the period 1978-1981, catch limits varied between 34,800 and 70,000 t, settling at 60,000 t in 1982. Prior to 1981 these limits were assigned for “fishing years” rather than calendar years. In 1981 the catch limit was raised temporarily to 70,000 t and the fishing year was extended until December 31 to allow for a smooth transition to management based on calendar years, after which the catch limit returned to 60,000 t until 1986, when ABC began to be set on an annual basis. From 1986 (the first year in which an ABC was set) through 1996, TAC averaged about 83% of ABC and catch averaged about 81% of TAC. In 8 of those 11 years, TAC equaled ABC exactly. In 2 of those 11 years (1992 and 1996), catch exceeded TAC.

To understand the relationships between ABC, TAC, and catch for the period since 1997, it is important to understand that a substantial fishery for Pacific cod has been conducted during these years inside State of Alaska waters, mostly in the Western and Central Regulatory Areas. To accommodate the State-managed fishery, the Federal TAC was set well below ABC (15-25% lower) in each of those years. Thus, although total (Federal plus State) catch has exceeded the Federal TAC in all but three years since 1997, this is basically an artifact of the bi-jurisdictional nature of the fishery and is not evidence of overfishing. At no time since the separate State waters fishery began in 1997 has total catch exceeded ABC, and total catch has never exceeded OFL.

Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. Assessments conducted prior to 1988 were based on survey biomass alone. From 1988-1993, the assessment was based on stock reduction analysis (Kimura et al. 1984). From 1994-2004, the assessment was conducted using the Stock Synthesis 1 modeling software (Methot 1986, 1990) with length-based data. The assessment was migrated to Stock Synthesis 2 (SS2) in 2005 (Methot 2005b), at which time age-based data began to enter the assessment. Several changes have been made to the model within the SS2 framework (renamed “Stock Synthesis,” or SS3, in 2008) each year since then.

Historically, the majority of the GOA catch has come from the Central regulatory area. To some extent the distribution of effort within the GOA is driven by regulation, as catch limits within this region have been apportioned by area throughout the history of management under the MFCMA. Changes in area-specific allocation between years have usually been traceable to changes in biomass distributions estimated by Alaska Fisheries Science Center trawl surveys or management responses to local concerns. Currently the ABC is derived from the random effects model (which is similar to the Kalman filter approach. The complete history of allocation (in percentage terms) by regulatory area within the GOA is shown in Table 2.3.

The catches shown in Tables 2.1 and 2.2 include estimated discards (Table 2.4).

In addition to area allocations, GOA Pacific cod is also allocated on the basis of processor component (inshore/offshore) and season. The inshore component is allocated 90% of the TAC and the remainder is allocated to the offshore component. Within the Central and Western Regulatory Areas, 60% of each component's portion of the TAC is allocated to the A season (January 1 through June 10) and the remainder is allocated to the B season (June 11 through December 31, although the B season directed fishery does not open until September 1).

NMFS has also published the following rule to implement Amendment 83 to the GOA Groundfish FMP:

> "Amendment 83 allocates the Pacific cod TAC in the Western and Central regulatory areas of the GOA among various gear and operational sectors, and eliminates inshore and offshore allocations in these two regulatory areas. These allocations apply to both annual and seasonal limits of Pacific cod for the applicable sectors. These apportionments are discussed in detail in a subsequent section of this rule. Amendment 83 is intended to reduce competition among sectors and to support stability in the Pacific cod fishery. The final rule implementing Amendment 83 limits access to the Federal Pacific cod TAC fisheries prosecuted in State of Alaska (State) waters adjacent to the Western and Central regulatory areas in the GOA, otherwise known as parallel fisheries. Amendment 83 does not change the existing annual Pacific cod TAC allocation between the inshore and offshore processing components in the Eastern regulatory area of the GOA.
>
> "In the Central GOA, NMFS must allocate the Pacific cod TAC between vessels using jig gear, catcher vessels (CVs) less than 50 feet (15.24 meters) length overall using hook-and-line gear, CVs equal to or greater than 50 feet (15.24 meters) length overall using hook-and-line gear, catcher/processors (C/Ps) using hook-and-line gear, CVs using trawl gear, C/Ps using trawl gear, and vessels using pot gear. In the Western GOA, NMFS must allocate the Pacific cod TAC between vessels using jig gear, CVs using hook-and-line gear, C/Ps using hook-and-line gear, CVs using trawl gear, and vessels using pot gear. Table 3 lists the proposed amounts of these seasonal allowances. For the Pacific cod sector splits and associated management measures to become effective in the GOA at the beginning of the 2012 fishing year, NMFS published a final rule (76 FR 74670, December 1, 2011) and will revise the final 2012 harvest specifications (76 FR 11111, March 1, 2011)."
>
> "NMFS proposes to calculate of the 2012 and 2013 Pacific cod TAC allocations in the following manner. First, the jig sector would receive 1.5 percent of the annual Pacific cod TAC in the Western GOA and 1.0 percent of the annual Pacific cod TAC in the Central GOA, as required by proposed § 679.20(c)(7). The jig sector annual allocation would further be apportioned between the A (60 percent) and B (40 percent) seasons as required by § 679.20(a)(12)(i). Should the jig sector harvest 90 percent or more of its allocation in a given area during the fishing year, then this allocation would increase by one percent in the subsequent fishing year, up to six percent of the annual TAC. NMFS proposes to allocate the remainder of the annual Pacific cod TAC based on gear type, operation type, and vessel length overall in the Western and Central GOA seasonally as required by proposed § 679.20(a)(12)(A) and (B)."

The longline and trawl fisheries are also associated with a Pacific halibut mortality limit which sometimes constrains the magnitude and timing of harvests taken by these two gear types.

Data

This section describes data used in the current assessment model. It does not attempt to summarize all available data pertaining to Pacific cod in the GOA.

Data	Source	Type	Years included
Federal and state fishery catch, by gear type and month	AKFIN	metric tons	1977 – 2014
Federal fishery catch-at-length, by gear type and month	AKFIN / FMA	number, by cm bin	1977 – 2014
State fishery catch-at-length, by gear type and month	ADF&G	number, by cm bin	1997 – 2014
GOA NMFS bottom trawl survey biomass and abundance estimates	AFSC	metric tons, numbers	1984 – 2013
GOA NMFS bottom trawl survey length composition	AFSC	number, by cm bin	1984 – 2013
GOA NMFS bottom trawl survey age composition	AFSC	number, by age	1987 – 2011
GOA NMFS bottom trawl survey mean length-at-age	AFSC	mean value and number	1987 – 2011

Fishery

Catch Biomass

Catches for the period 1991-2014 are shown for the three main gear types in Table 2.7, with the catches for season 5 (Nov – Dec) of 2014 projected. This also shows gear-specific catches by “selectivity seasons,” which are obtained from combinations of “catch seasons.” The catch seasons are defined as January-February, March-April, May-August, September-October, and November-December. Three selectivity seasons are defined by combining catch seasons 1 and 2 into selectivity season 1, equating catch season 3 with selectivity season 2, and combining catch seasons 4 and 5 into selectivity season 3. The catch seasons used were the result of a statistical analysis described in the 2010 assessment (Thompson et al. 2010), and the selectivity seasons were chosen to correspond as closely as possible to the traditional seasons used in previous assessments (given the revised catch seasons). In years for which estimates of the distribution by gear or period were unavailable, proxies based on other years’ distributions were used. Non-commercial catches for 2004 – 2013 are shown in Table 2.8.

Catch Size Composition

Fishery size compositions are presently available, by gear and season, for at least one gear type in every year from 1977 through the first part of 2014. Beginning with the 2010 assessment (Thompson et al. 2010), size composition data are based on 1-cm bins ranging from 4 to 120 cm. As the maximum percent of fish larger than 110 cm over each year-gear type-season is less than 0.5%, the upper limit of the length bins has been changed to 110 cm, with the 110-cm bin accounting for all fish 110 cm and larger.

Survey

Survey Age Composition

Age compositions from each survey except 1984 are available (note that the sample size for the 1987 was very small, however). The age compositions and actual sample sizes are shown in Table 2.9 and Fig. 2.7.

Survey Size Composition

For the last few assessments, the size composition data from the trawl surveys of the GOA conducted by the Alaska Fisheries Science Center have been partitioned into two length categories: fish smaller than 27 cm (the “sub-27” survey) and fish 27 cm and larger (the “27-plus” survey). The relative size compositions from 1984-2013 are shown for the sub-27 and the 27-plus survey in Table 2.10, using the same 1-cm length bins defined above for the fishery catch size compositions. Columns in this table sum to the actual number of fish measured in each year. The full size compositions are shown in Fig. 2.6.

Mean Size at Age

Mean size-at-age data are available for all of the years in which age compositions are available. These are shown in Table 2.11; the sample sizes are shown in Table 2.12.

Abundance Estimates

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.13 and Fig. 2.3, together with their respective coefficients of variation. The abundance estimates by area are shown in Fig. 2.5.

The highest biomass ever observed by the survey was the 2009 estimate of 752,651 t, and the low point was the preceding (2007) estimate of 233,310 t. The 2009 biomass estimate represented a 223% increase over the 2007 estimate. The 2011 biomass estimate was down 33% from 2009, but still 115% above the 2007 estimate. The 2013 biomass estimate is a small increase (1%) from the 2011 estimate (Fig. 2.2). The biomass estimates by area are shown in Fig. 2.4.

In terms of population numbers, the record high was observed in 2009, when the population was estimated to include over 573 million fish. The 2005 estimate of 140 million fish was the low point in the time series. The 2009 abundance estimate represented a 199% increase over the 2007 estimate. The 2011 abundance estimate was a decrease of 39% from 2009, but still 81% above the 2007 estimate.

The 2013 total abundance estimate is a small decrease (3%) from the 2011 estimate, and the 2013 estimate has a lower coefficient of variation (CV), 0.151, than the 2011 estimate. The 2013 abundance estimate for fish 27 cm and above is a decrease of 24% from the 2011 estimate, with a lower CV, 0.139, than in 2011. The 2013 abundance estimate for fish less than 27 cm is an increase of over 800% from the 2011 estimate, with a higher CV, 0.437, than in 2011. The total, 27-plus, and sub-27 abundance estimates for 2013 are a decrease of at least 39% from the 2009 estimates.

Analytic Approach

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

Beginning with the 1994 SAFE report (Thompson and Zenger 1994), a model using the Stock Synthesis 1 (SS1) assessment program (Methot 1986, 1990, 1998, 2000) and based largely on length-structured data formed the primary analytical tool used to assess the GOA Pacific cod stock.

SS1 was a program that used the parameters of a set of equations governing the assumed dynamics of the stock (the “model parameters”) as surrogates for the parameters of statistical distributions from which the data were assumed to be drawn (the “distribution parameters”), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood was the product of the likelihoods for each of the model components. In part because the overall likelihood could be a very small number, SS1 used the logarithm of the likelihood as the objective function. Each likelihood component was associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components were associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey abundance (either biomass or numbers, either relative or absolute).

SS1 permitted each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. In the base model for the GOA Pacific cod assessment, for example, possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries were accommodated by splitting the fishery size composition time series into pre-1987 and post-1986 segments during the era of SS1-based assessments.

Until 2010, each year was been partitioned into three seasons defined as January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants in the EBS fishery). Four fisheries were defined during the era of SS1-based assessments: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

Following a series of modifications from 1993 through 1997, the base model for GOA Pacific cod remained completely unchanged from 1997 through 2001. During the late 1990s, a number of attempts were made to estimate the natural mortality rate *M* and the shelf bottom trawl survey catchability coefficient *Q*, but these were not particularly successful and the Plan Team and SSC always opted to retain the base model in which *M* and *Q* were fixed at traditional values of 0.37 and 1.0, respectively.

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson et al. 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data.

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which made use of the ADMB modeling architecture (Fournier et al. 2012) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to SS2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Technical details of SS2 were described by Methot (2005a, 2007).

The 2006 assessment model (Thompson et al. 2006) was structured similarly to the 2005 assessment model; the primary change being external estimation of growth parameters.

A technical workshop was convened in April, 2007 to consider a wide range of issues pertaining to both the BSAI and GOA Pacific cod assessments (Thompson and Conners 2007).

The 2007 assessment model (Thompson et al. 2007b) for Pacific cod in the GOA was patterned after the model used in that year's assessment of the BSAI Pacific cod stock (Thompson et al. 2007a), with several changes as described in the assessment document. However, the 2007 assessment model was not accepted by the Plan Team or the SSC.

For the 2008 assessment, the recommended model for the GOA was based largely on the recommended model from the 2008 BSAI Pacific cod assessment. Among other things, this model used an explicit algorithm to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity, and another explicit algorithm to determine which selectivity parameters would be allowed to vary periodically in "blocks" of years and to determine the appropriate block length for each such time-varying parameter. One other significant change in the recommended model from the 2008 GOA assessment, which was not shared by the BSAI assessment, was a substantial downweighting of the age composition data. This downweighting was instituted as a means of keeping the root mean squared error of the fit to the survey abundance data close to the sampling variability of those data.

The 2009 assessment (Thompson et al. 2009) featured a total of ten models reflecting a great many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow: 1) input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs;" 2) the standard deviation of length at age was estimated outside the model as a linear function of mean length at age; 3) catchability for the pre-1996 trawl survey was estimated freely while catchability for the post-1993 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.916 obtained by Nichol et al. (2007); 4) potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages

2 and above, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly); 5) weighting of the age composition data was returned to its traditional level; 6) except for the parameter governing selectivity at age 0, all parameters of the selectivity function for the post-1993 years of the 27-plus trawl survey were allowed to vary in each survey year except for the most recent; and 7) cohort-specific growth devs were estimated for all years through 2008.

Many changes were made or considered in the 2010 stock assessment model (Thompson et al. 2010). Five models were presented preliminary assessment, as requested by the Plan Teams in May, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment. Relative to the 2009 assessment, the main changes in the model that was ultimately accepted by the Plan Team and SSC in 2010 were as follow: 1) exclude the single record (each) of fishery age composition and mean length-at-age data, 2) use a finer length bin structure than previous models, and 3) re-evaluate the existing seasonal structure used in the model and revise it as appropriate, and 4) remove cohort-specific growth rates (these were introduced for the first time in the 2009 assessment). The new length bin structure consisted of 1-cm bins, replacing the combination of 3-cm and 5-cm bins used in previous assessments. The new seasonal structure consisted of five catch seasons defined as January-February, March-April, May-August, September-October, and November-December; and three selectivity seasons defined as January-April, May-August, and September-December; with spawning identified as occurring at the beginning of the second catch season (March).

Following a review by the Center for Independent Experts in 2011 that resulted in a total of 128 unique recommendations from the three reviewers, the 2011 stock assessment (Thompson et al. 2011) again considered several possible model changes. Three models were requested by the Plan Teams to be included in the final GOA assessment. The SSC concurred, and added one more model. The model that was ultimately accepted by the Team and SSC differed from the 2010 model in the following respects:

- The age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.3333, to correspond to the age of a 1-year-old fish at the time of the survey, which is when the age data are collected. This change was adopted to prevent mean size at age from going negative (as sometimes happened in previous EBS Pacific cod models), and to facilitate comparison of estimated and observed length at age and variability in length at age.
- The parameters governing variability in length at age were re-tuned. This was necessitated by the change in the age corresponding to the *L1* parameter (above).
- A column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file. Even though there are virtually no age 0 fish represented in these two portions of the data file, unless a column for age 0 is included, SS will interpret age 1 fish as being ages 0 and 1 combined, which can bias the estimates of year class strength.
- Ageing bias was estimated internally. To preserve a large value for the strength of the 1977 year class and to keep the mean recruitment from the pre-1977 environmental regime lower than the mean recruitment from the post-1976 environmental regime, ageing bias was constrained to be positive (this constraint ultimately proved to be binding only at the maximum age).

It should also be noted that, consistent with Plan Team policy adopted in 2010, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the 2010 assessment (with the exception of the parameters governing variability in length at age, for the reason listed above).

Model Structures Considered in This Year's Assessment

Stock Synthesis version 3.24S (Methot and Wetzel 2013; Methot 2013) was used to run all the model configurations in this analysis.

Two of the models in this year's assessment are based on the 2013 final model. The 2013 final model is the 2012 final model, and estimates age-0 recruits for 1977 – 2009 instead of for 1977 – 2011. This model (labeled "2013") is characterized by:

- Three gear types (trawl, longline, and pot), 5 seasons (Jan-Feb, Mar-Apr, May-Aug, Sept-Oct, and Nov-Dec), and three fishery selectivity "seasons" (Jan-Apr, May-Aug, and Sept-Dec);
- Time-varying fishery selectivity-at-length for all gears and seasons (3 – 7 blocks);
- All data for the sub-27 survey omitted;
- Two blocks for catchability for the 27-plus survey, 1984 – 1993 and 1996 – 2013, with the catchability for the latter period set to 1.0;
- Time-varying survey selectivity-at-age for the 27-plus survey (12 blocks); and
- Age-0 recruits estimated through 2009 and recruits for 2010 on set to the average for 1977 – 2009

The adjusted version of the 2013 model (labeled "2013 adj") estimates age-0 recruits through 2011 and uses the recruitment variability multiplier (sigmaR multiplier, value 4.0) for age-0 recruits for 2012, 2013, and 2014.

The additional two models (labeled "S1a" and "S1b") differ significantly from the 2013 final model by:

- Using the GOA NMFS bottom trawl survey as one source of data instead of being split into sub-27 and 27-plus, for the abundance estimates and the length- and age-composition data;
- Using 3 blocks of non-parametric (S1a) or cubic spline-based (S1b) survey selectivity-at-age instead of 12 blocks of double normal selectivity-at-age;
- Including the survey age data as conditional age-at-length data instead of age composition and mean size-at-age data; and
- Using the recruitment variability multiplier (sigmaR multiplier, value 4.0) for age-0 recruits for 2012, 2013, and 2014.

The author's preferred model configuration is Model S1a, with non-parametric survey selectivity-at-age.

Parameters Estimated Outside the Assessment Model

Natural Mortality

In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate *M* was estimated using SS1 at a value of 0.37. All subsequent assessments of the BSAI and GOA Pacific cod stocks (except the 1995 GOA assessment) have used this value for *M*, until the 2007 assessments, at which time the BSAI assessment adopted a value of 0.34 and the GOA assessment adopted a value of 0.38. Both of these were accepted by the respective Plan Teams and the SSC. The new values were based on Equation 7 of Jensen (1996) and ages at 50% maturity reported by (Stark 2007; see "Maturity" subsection below). In response to a request from the SSC, the 2008 BSAI assessment included further discussion and justification for these values.

For historical completeness, other published estimates of *M* for Pacific cod are shown below:

Area	Author	Year	Value
Eastern Bering Sea	Low	1974	0.30-0.45
	Wespestad et al.	1982	0.70
	Bakkala and Wespestad	1985	0.45
	Thompson and Shimada	1990	0.29
	Thompson and Methot	1993	0.37
Gulf of Alaska	Thompson and Zenger	1993	0.27
	Thompson and Zenger	1995	0.50
British Columbia	Ketchen	1964	0.83-0.99
	Fournier	1983	0.65

The model in this assessment sets *M* independently at the SSC-approved value of 0.38.

Catchability

In the 2009 assessment (Thompson et al. 2009), catchability for the post-1993 27-plus trawl survey was estimated iteratively by matching the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.916 obtained by Nichol et al. (2007). The current model configuration has catchability set to 1.0, per Plan Team request.

Variability in Estimated Age

Variability in estimated age in SS is based on the standard deviation of estimated age. Weighted least squares regression has been used in the past several assessments to estimate a linear relationship between standard deviation and age. The regression was recomputed in 2011, yielding an estimated intercept of 0.023 and an estimated slope of 0.072 (i.e, the standard deviation of estimated age was modeled as 0.023 + 0.072 × age), which gives a weighted R^2 of 0.88. This regression was retained in the present assessment.

Variability in Length at Age

The last few assessments have used a regression approach to estimate the parameters of the schedule of variability in length at age, based on the outside-the-model estimates of standard deviation of length at age and mean length at age from the survey age data (Thompson et al. 2009). The best fit was obtained by assuming that the standard deviation is a linear function of length at age. The regression was re-estimated in 2011 after updating with the most recent data, giving an intercept of 2.248 and a slope of 0.044. This regression was retained in the present assessment.

Use of this regression requires an iterative, "quasi-conditional" procedure for specifying the standard deviations of length at ages 0 and 20, because the regression is a function of length at age, and length at age is estimated conditionally (i.e., inside the model).

In the 2011 model, the age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.3333 (to correspond to the age of a 1-year-old fish at the time of the survey, when the age data are collected). This made it necessary to re-do the iterative tuning process for this model.

Weight at Length

Season-specific parameters governing the weight-at-length schedule were estimated in the 2010 assessment (based on data through 2008), giving the following values:

Season:	Jan-Feb	Mar-Apr	May-Aug	Sep-Oct	Nov-Dec
α:	8.799×10^{-6}	8.013×10^{-6}	1.147×10^{-5}	1.791×10^{-5}	7.196×10^{-6}
β:	3.084	3.088	2.990	2.893	3.120
Samples:	36,566	29,753	6,950	9,352	2,957

The above parameters were retained in the present assessment.

Maturity

A detailed history and evaluation of parameter values used to describe the maturity schedule for BSAI Pacific cod was presented in the 2005 assessment (Thompson and Dorn 2005). A length-based maturity schedule was used for many years. The parameter values used for this schedule in the 2005 and 2006 assessments were set on the basis of a study by Stark (2007) at the following values: length at 50% maturity = 50 cm and slope of linearized logistic equation = –0.222. However, in 2007, changes in SS allowed for use of either a length-based or an age-based maturity schedule. Beginning with the 2007 assessment, the accepted model has used an age-based schedule with intercept = 4.3 years and slope = –1.963 (Stark 2007). The use of an age-based rather than a length-based schedule follows a recommendation from the maturity study's author (James Stark, ret., Alaska Fisheries Science Center, personal communication). The age-based parameters were retained in the present assessment.

Parameters Estimated Inside the Assessment Model

Parameters estimated conditionally (i.e., within individual SS runs, based on the data and the parameters estimated independently) in the model include the von Bertalanffy growth parameters, two ageing bias parameters, log mean recruitment before and since the 1976-1977 regime shift, annual recruitment deviations, initial fishing mortality, gear-season-and-block-specific fishery selectivity parameters, survey selectivity parameters, and pre-1996 catchability for the 27-plus or full survey.

The same functional form (pattern 24 for length-based selectivity, pattern 20 for age-based selectivity) used in Stock Synthesis to define the selectivity schedules in last year's assessment was used again this year in the models based on the 2013 final model. This functional form, the double normal, is constructed from two underlying and rescaled normal distributions, with a horizontal line segment joining the two peaks. This form uses the following six parameters (selectivity parameters are referenced by these numbers in several of the tables in this assessment):

1. Beginning of peak region (where the curve first reaches a value of 1.0)
2. Width of peak region (where the curve first departs from a value of 1.0)
3. Ascending "width" (equal to twice the variance of the underlying normal distribution)
4. Descending width
5. Initial selectivity (at minimum length/age)
6. Final selectivity (at maximum length/age)

All but the "beginning of peak region" parameter are transformed: The widths are log-transformed and the other parameters are logit-transformed.

Fishery selectivities are length-based and trawl survey selectivities are age-based in these models.

Uniform prior distributions are used for all parameters, except that *dev* vectors are constrained by input standard deviations ("sigma"), which imply a type of joint prior distribution. These input standard deviations were determined iteratively in the 2009 assessment (Thompson et al. 2009) by matching the standard deviations of the estimated *dev*s. The same input standard deviations were used in this assessment.

For all parameters estimated within individual SS runs, the estimator used is the mode of the logarithm of the joint posterior distribution, which is in turn calculated as the sum of the logarithms of the parameter-specific prior distributions and the logarithm of the likelihood function.

In addition to the above, the full set of year-, season-, and gear-specific fishing mortality rates are also estimated conditionally, but not in the same sense as the above parameters. The fishing mortality rates are determined exactly rather than estimated statistically because SS assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data.

Likelihood Components

The model includes likelihood components for trawl survey relative abundance, fishery and survey size composition, survey age composition, survey mean size at age, recruitment, parameter deviations, and "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), initial (equilibrium) catch, and survey mean size at age.

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, all likelihood components were given an emphasis of 1.0 in the present assessment.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear, and season within the year. In the parameter estimation process, SS weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear, and season) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. For many years, the Pacific cod assessments assumed a multinomial sample size equal to the square root of the true length sample size, rather than the true length sample size itself. Given the true length sample sizes observed in the GOA Pacific cod data, this procedure tended to give values somewhat below 400 while still providing SS with usable information regarding the appropriate effort to devote to fitting individual length samples.

Although the "square root rule" for specifying multinomial sample sizes gave reasonable values, the rule itself was largely *ad hoc*. In an attempt to move toward a more statistically based specification, the 2007 BSAI assessment (Thompson et al. 2007a) used the harmonic means from a bootstrap analysis of the available fishery length data from 1990-2006. The harmonic means were smaller than the actual sample sizes, but still ranged well into the thousands. A multinomial sample size in the thousands would likely overemphasize the size composition data. As a compromise, the harmonic means were rescaled proportionally in the 2007 BSAI assessment so that the average value (across all samples) was 300. However, the question then remained of what to do about years not covered by the bootstrap analysis (2007 and pre-1990) and what to do about the survey samples. The solution adopted in the 2007 BSAI assessment was based on the consistency of the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes. For the years prior to 1999, the ratio was very consistently close to 0.16, and for the years after 1998, the ratio was very consistently close to 0.34.

This consistency was used to specify input sample sizes for size composition data in all GOA assessments since 2007 as follows: For fishery data, the sample sizes for length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for length compositions from 2007 were tentatively set at 34% of the actual sample size. For the trawl survey, sample sizes were tentatively set at 34% of the actual sample size. Then, all sample sizes were adjusted proportionally so that the average was 300. This method was used to adjust the samples sizes used for the size composition data for analyses performed through 2013.

For the models in this analysis, the number of hauls or trips was used as the sample size instead of the adjusted sample size. The sample sizes for the survey length composition data are the number of hauls in that survey year with cod present.

The fishery catch-at-length data did not have distinct haul or trip identifiers for all samples, so the adjusted sample size for each year, gear type, and season was the total number of samples multiplied by a scaling factor for each gear type and season. The scaling factor was calculated using the federal fishery observer catch-at-length data for 1987 – 2014. The scaling factor is the ratio of total number of hauls or trips to the total number of samples for each gear type and season.

Gear type	Season 1	Season 2	Season 3	Season 4	Season 5
Trawl	0.01805	0.01196	0.03219	0.02926	0.03326
Longline	0.03656	0.02212	0.04550	0.05066	0.05207
Pot	0.02901	0.01877	0.02946	0.04009	0.03467
Other	0.02844	0.04201	0.04424	0.04651	0.02402

The average of the new sample sizes for the fishery catch-at-length data is 185.

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular gear, year, and season within the year. Input sample sizes for the multinomial distributions were computed by scaling the actual number of otoliths read in each year proportionally such that the average of the input sample sizes was equal to 300. This method was used to adjust the samples sizes used for the age composition data for analyses performed through 2013.

For the models in this analysis, the number of hauls was used as the sample size instead of the adjusted sample size. For the model configurations with survey age data used as conditional age-at-length data, the sample sizes for a given year sum to the number of hauls in that year.

To avoid double counting of the same data, all models ignore size composition data from each year in which survey age composition data or conditional age-at-length data are available.

Results

Model Evaluation

The 2013 final model and three additional models were evaluated, one of which was based on the 2013 final model, and two others which differed in which and how the survey data were used and the survey selectivity-at-age curves. The model evaluation criteria included the relative sizes of the likelihood components, and how well the model estimates fit to the survey indices, the survey age composition or conditional age-at-length data, reasonable curves for fishery sand survey selectivity, and that the model estimated the variance-covariance matrix.

All of the models fit to the same catch, fishery catch-at-length, and survey length composition data. The 2013 final model (“2013”), with recruits estimated through 2009, and the 2013 final model with recruits estimated through 2011 and the sigmaR multiplier used for recent recruits (“2013 adj”) fit to survey data from the 27-plus portion of the GOA NMFS bottom trawl survey. The two models which fit to the survey data as one source and conditional age-at-length survey data estimated 3 periods of non-parametric (“S1a”) or cubic spline-based (“S1b”) survey selectivity-at-age and used the sigmaR multipler for recent recruits.

Comparing and Contrasting the Models

The four models estimated similar patterns for spawning biomass, although the estimates from Models S1a and S1b were higher than those from the 2013 models (Fig. 2.8). The estimates of age-0 recruits differed between the two sets of models for the first half of the historical period and were similar for the more recent period (Fig. 2.9); however, Models 2013 adj, S1a, and S1b estimated similar values for recent recruitment, as these three models included the sigmaR multiplier on recent recruits. All models fit to the survey indices reasonably well in the middle of the time series, and mediocre fit early and later in the time series, with Models S1a and S1b fitting slightly better to the early and later abundance estimates than the 2013 models (Fig. 2.10).

The two sets of models differed in their fits to their respective sets of survey data with respect to likelihood components (Table 2.14). The 2013 adj model had fewer parameters and a lower total negative log likelihood (NLL) than the 2013 final model. All models had similar fits to the fishery catch-at-length data, although there were differences between the two sets of models for the May-Aug trawl and Sept-Dec trawl data.

The growth parameter estimates also differed between the two sets of models. The 2013 models, which did not include any survey data for fish less than 27 cm, estimated a higher length-at-Amin (age 1.33333) and length-at-A∞ than Models S1a and S1b, with Models S1a and S1b estimating higher values for k than the 2013 models. Models S1a and S1b estimated the CV for length-at-Amin higher than the value used in the 2013 models, 3.13; the estimates of CV for length-at-A∞ for Models S1a and S1b were slightly higher than the value used in the 2013 models, 6.55.

Evaluation Criteria

Models S1a and S1b fit to the full survey abundance index better than the 2013 models fit to the 27-plus survey abundance index. All model configurations had reasonable fishery selectivity-at-length curves; the 2013 models had highly variable survey selectivity-at-age curves. All model configurations converged and produced variance-covariance matrices.

Selection of final model

The two new models, S1a and S1b, are preferred over the 2013 models, as the new models used all of the survey data, instead of data from the 27-plus portion only. The two new models also allowed for the estimation of more flexible survey selectivity-at-age curves and variability in the length-at-age relationship.

Model S1a, the new model with non-parametric survey selectivity-at-age, was selected as the preferred model, as it fit the data better than Model S1b, the new model with cubic spline-based survey selectivity-at-age, although the differences in the NLL components were small.

Final parameter estimates and associated schedules

The fixed and estimated parameters for Model S1a are listed in Table 2.15. Total biomass has decreased from a peak in 1980 to a low in 2008 and is increasing (Fig. 2.11); spawning biomass has a similar pattern with more uncertainty for the recent years (Fig. 2.12). Age-0 recruits had the highest value at the beginning of the time series and has had moderate variability around 290 million since then (Fig. 2.13). The estimates of full survey abundance estimates fit the data reasonably well in the early and middle survey years, and less well in the more recent years, due to the high estimate for 2009 (Fig. 2.14). There does not appear to be a strong relationship between spawning biomass and recruitment (Fig. 2.15). The fits to the survey conditional age-at-length data are good, with moderate variability where there are abundant data (Fig. 2.16). The fits to the survey length composition data are reasonable in most years, with small fish poorly estimated in 2007, 2009, and 2011 (Fig. 2.17); the 1984 survey length composition data were not used in model fitting (Fig. 2.18). The estimated length-at-age relationship is shown in Fig. 2.19.

Survey selectivity-at-age had a maximum at age 4 or 5, with the selectivity at age 1 larger than that of age 2 in most years (Fig. 2.20); fishery selectivity-at-length was more variable, both within and between seasons and gear types (Fig. 2.21). The fits to the fishery catch-at-length data were reasonable in most years, with poor fits to some years in the 1980s for the Jan-Apr trawl fishery (Figs. 2.22 and 2.23).

The seasonal length-at-age and weight-at-age schedules are in Table 2.16. Survey selectivity-at-age by time period is in Table 2.17.

Time Series Results

Definitions

The biomass estimates presented here will be defined in two ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in a given year; and 2) spawning biomass, consisting of the biomass of all spawning females in a given year. The recruitment estimates presented here will be defined as numbers of age-0 fish in a given year.

Biomass

Table 2.18 shows the time series of GOA Pacific cod female spawning biomass for the years 1977-2014 as estimated last year and this year. The estimated spawning biomass time series are accompanied by their respective standard deviations. Total and spawning biomass are shown in Figs. 2.11 and 2.12.

Recruitment and Numbers at Age

Table 2.19 shows the time series of GOA Pacific cod age-0 recruits for the years 1977-2013 as estimated last year and this year. The estimated recruitment time series are accompanied by their respective standard deviations (Fig. 2.13). Table 2.20 shows the numbers-at-age for 1977-2014.

Survey Data

Fig. 2.14 shows the fit to the full survey abundance estimates. Figure 2.16 shows the fit to the full survey conditional age-at-length data, Fig. 2.17 shows the fit to the full survey length composition data, and Fig. 2.18 shows the 1984 survey length composition data, which were not used in model fitting, and the estimated survey length composition.

Fishing Mortality

Table 2.21 shows the "effective" annual fishing mortality by age and year for ages 1-19 and years 1977-2013. The "effective" annual fishing mortality is $-\ln(N_{a+1,y+1}/N_{a,y})-M$.

Retrospective analysis

Estimates of spawning biomass for Model S1a with the 2013 survey age data included with an ending year of 2005 through 2014 are very similar for 1984 through 2000, and have a consistent downward adjustment for the recent years as more data are included (Fig. 2.24). Relative differences in estimates of spawning biomass show the same pattern for the more recent years (Fig. 2.25).

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the GOA have generally been managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points:

$B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $0.05 < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

3c) Stock status: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows, based on this year's model, Model S1a:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	110,700 t	126,600 t	316,500 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on this year's model's estimates of fishing mortality by gear for the five most recent complete years of data (2009-2013). The average fishing mortality rates for those years implied that total fishing mortality was divided among the three main gear types according to the following percentages: trawl 21%, longline 24%, and pot 55%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.626 and 0.502, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2015 is estimated by this year's model to be 155,400 t. This is well above the $B_{40\%}$ value of 126,600 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, the model estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2015 and 2016 as follows (2016 values are predicated on the assumption that 2015 catch will equal 2015 maximum permissible ABC):

Units	Year	Overfishing Level (OFL)	Maximum Permissible ABC
Harvest amount	2015	140,300 t	117,200 t
Harvest amount	2016	133,100 t	110,700 t
Fishing mortality rate	2015	0.626	0.502
Fishing mortality rate	2016	0.626	0.502

The age 0+ biomass projections for 2015 and 2016 from this year's model are 583,800 t and 558,200 t, respectively.

ABC Recommendation

Since 2008 the GOA Plan Team and SSC recommended setting the ABC at the maximum permissible level under Tier 3.

Following this practice, this year's ABC recommendations for 2015 and 2016 are at their respective maximum permissible levels of 117,200 t and 110,700 t.

Area Allocation of Harvests

For the past several years, ABC has been allocated among regulatory areas on the basis of the three most recent surveys. The previous proportions based on the 2009-2013 surveys were 33% Western, 64% Central, and 3% Eastern. In the 2013 assessment, the random effects model was used for the 2014 ABC apportionment. Using this method with the trawl survey biomass estimates through 2013, the area-apportioned ABCs are:

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	37.63	59.61	2.75	100.00
2015 ABC	44,102	69,863	3,223	117,200
2016 ABC	41,656	65,988	3,044	110,700

Standard Harvest and Recruitment Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with a vector of 2014 estimated numbers at age. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TACs for 2015 and 2016, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2015 recommended in the assessment to the *max* F_{ABC} for 2015. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to the 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 4: In all future years, the upper bound on F_{ABC} is set at $F_{60\%}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is 1) above its MSY level in 2014, or 2) above 1/2 of its MSY level in 2014 and expected to be above its MSY level in 2024 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2015 and 2016, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2027 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Projections corresponding to the standard scenarios are shown for this year's model in Table 2.22 (note that Scenarios 1 and 2 are identical in this case, because the recommended ABC is equal to the maximum permissible ABC).

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2015, it does not provide the best estimate of OFL for 2016, because the mean 2016 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2013) is 68,593 t. This is less than the 2013 OFL of 107,300 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2014:

a. If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2014 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2014 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.22). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7 (Table 2.22):

a. If the mean spawning biomass for 2017 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2017 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2017 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2027. If the mean spawning biomass for 2027 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 2.22, the stock is not overfished and is not approaching an overfished condition.

Biological reference points, spawning biomass, and ABC values from the current SAFE document and previous GOA Pacific cod SAFE documents for 2001 – 2014 are listed in Table 2.23.

Ecosystem Considerations

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic "regime shifts," in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Boldt (ed.), 2005). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). In the present assessment, an attempt was made to estimate the change in median recruitment of GOA Pacific cod associated with the 1977 regime shift. According to this year's model, pre-1977 median recruitment was only about 32% of post-1976 median recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson et al. 2004), for example, the correlations between age 1 recruits spawned since 1977 and monthly values of the Pacific Decadal Oscillation (Mantua et al. 1997) were computed and found to be very weak.

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), Lang et al. (2003), Westrheim (1996), and Yang (2004). The composition of Pacific cod prey varies to some extent by time and area. In terms of percent occurrence, some of the most important items in the diet of Pacific cod in the BSAI and GOA have been polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, some of the most important dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, some of the most important dietary items have been walleye pollock, fishery offal, yellowfin sole, and crustaceans. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin. Major trends in the most important prey or predator species could be expected to affect the dynamics of Pacific cod to some extent.

Fishery Effects on the Ecosystem

Potentially, fisheries for Pacific cod can have effects on other species in the ecosystem through a variety of mechanisms, for example by relieving predation pressure on shared prey species (i.e., species which serve as prey for both Pacific cod and other species), by reducing prey availability for predators of Pacific cod, by altering habitat, by imposing bycatch mortality, or by "ghost fishing" caused by lost fishing gear.

Incidental Catch of Nontarget Species

Incidental catches of nontarget species in each year 2005-2014 are shown Table 2.6. In terms of average catch over the time series, only sea stars account for more than 250 t per year.

Steller Sea Lions

Sinclair and Zeppelin (2002) showed that Pacific cod was one of the four most important prey items of Steller sea lions in terms of frequency of occurrence averaged over years, seasons, and sites, and was especially important in winter. Pitcher (1981) and Calkins (1998) also showed Pacific cod to be an important winter prey item in the GOA and BSAI, respectively. Furthermore, the size ranges of Pacific cod harvested by the fisheries and consumed by Steller sea lions overlap, and the fishery operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002).

The Fisheries Interaction Team of the Alaska Fisheries Science Center has been engaged in research to determine the effectiveness of recent management measures designed to mitigate the impacts of the Pacific cod fisheries (among others) on Steller sea lions. Results from studies conducted in 2002-2003 were summarized by Conners et al. (2004). These studies included a tagging feasibility study, which may evolve into an ongoing research effort capable of providing information on the extent and rate to which Pacific cod move in and out of various portions of Steller sea lion critical habitat. Nearly 6,000 cod with spaghetti tags were released, of which approximately 1,000 had been returned as of September 2003.

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.30b and 2.30b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

The following is a summary of information provided by Livingston (ed., 2002): The longline and trawl fisheries for Pacific cod each comprise an important component of the combined fisheries associated with the respective gear type in each of the three major management regions (BS, AI, and GOA). Looking at each gear type in each region as a whole (i.e., aggregating across all target species) during the period 1998-2001, the total number of observed sets was as follows:

Gear	BS	AI	GOA
Trawl	240,347	43,585	68,436
Longline	65,286	13,462	7,139

In the BS, both longline and trawl effort was concentrated north of False Pass (Unimak Island) and along the shelf edge represented by the boundary of areas 513, 517 (in addition, longline effort was concentrated along the shelf edge represented by the boundary of areas 521-533). In the AI, both longline and trawl effort were dispersed over a wide area along the shelf edge. The catcher vessel longline fishery in the AI occurred primarily over mud bottoms. Longline catcher-processors in the AI tended to fish more over rocky bottoms. In the GOA, fishing effort was also dispersed over a wide area along the shelf, though pockets of trawl effort were located near Chirikof, Cape Barnabus, Cape Chiniak and Marmot

Flats. The GOA longline fishery for Pacific cod generally took place over gravel, cobble, mud, sand, and rocky bottoms, in depths of 25 fathoms to 140 fathoms.

Impacts of the Pacific cod fisheries on essential fish habitat were further analyzed in an environmental impact statement by NMFS (2005).

Data Gaps and Research Priorities

Understanding of the above ecosystem considerations would be improved if future research were directed toward closing certain data gaps. Such research would have several foci, including the following: 1) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) behavior of the Pacific cod fishery, including spatial dynamics; 3) determinants of trawl survey catchability and selectivity; 4) age determination; 5) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 6) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

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Literature Cited

Albers, W. D., and P. J. Anderson. 1985. Diet of Pacific cod, *Gadus macrocephalus*, and predation on the northern pink shrimp, *Pandalus borealis*, in Pavlof Bay, Alaska. Fish. Bull., U.S. 83:601-610.

A'mar, T., Thompson, G., Martin, M., and W. Palsson. 2012. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 183-322. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501

Bakkala, R. G., and V. G. Wespestad. 1985. Pacific cod. *In* R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1984, p. 37-49. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-83.

Boldt, J. (editor). 2005. Ecosystem Considerations for 2006. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Calkins, D. G. 1998. Prey of Steller sea lions in the Bering Sea. Biosphere Conservation 1:33-44.

Fournier, D. 1983. An analysis of the Hecate Strait Pacific cod fishery using an age-structured model incorporating density-dependent effects. Can. J. Fish. Aquat. Sci. 40:1233-1243.

Fournier, D., and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 38:1195-1207.

Fournier, D.A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Greer-Walker, M. 1970. Growth and development of the skeletal muscle fibres of the cod (*Gadus morhua L.*). Journal du Conseil 33:228-244.

Gregory, R. S., C. Morris, and B. Newton. In review. Relative strength of the 2007 and 2008 year-classes, from nearshore surveys of demersal age 0 Atlantic cod in Newman Sound, Bonavista Bay. Can. Sci. Advis. Sec. Res. Doc. series./xxx.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47:103-146.

Hiatt, T., R. Felthoven, M. Dalton, B. Garber-Yonts, A. Haynie, K. Herrmann, D. Lew, J. Sepez, C. Seung, L. Sievanen, and the staff of Northern Economics. 2007. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands Area: Economic Status of the Groundfish Fisheries off Alaska, 2006. Economic and Social Sciences Research Program, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, Washington 98115-6349. 353 p.

Jung, S., I. Choi, H. Jin, D.-w. Lee, H.-k. Cha, Y. Kim, and J.-y. Lee. 2009. Size-dependent mortality formulation for isochronal fish species based on their fecundity: an example of Pacific cod (*Gadus macrocephalus*) in the eastern coastal areas of Korea. Fisheries Research 97:77-85.

Ketchen, K.S. 1964. Preliminary results of studies on a growth and mortality of Pacific cod (*Gadus macrocephalus*) in Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada 21:1051-1067.

Lang, G. M., C. W. Derrah, and P. A. Livingston. 2003. Groundfish food habits and predation on commercially important prey species in the Eastern Bering Sea from 1993 through 1996. Alaska Fisheries Science Center Processed Report 2003-04. Alaska Fisheries Science Center, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 351 p.

Livingston, P. A. 1989. Interannual trends in Pacific cod, Gadus macrocephalus, predation on three commercially important crab species in the eastern Bering Sea. Fish. Bull., U.S. 87:807-827.

Livingston, P. A. 1991. Pacific cod. *In* P. A. Livingston (editor), Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986, p. 31-88. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-207.

Livingston, P. A. (editor). 2003. Ecosystem Considerations for 2003. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Low, L. L. 1974. A study of four major groundfish fisheries of the Bering Sea. Ph.D. Thesis, Univ. Washington, Seattle, WA 240 p.

Mantua, N. J., Hare, S. R., Zhang, Y., Wallace, J. M., & Francis, R. C.. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78, 1069-1079.

Methot, R. D. 1986. Synthetic estimates of historical abundance and mortality for northern anchovy, *Engraulis mordax*. NMFS, Southwest Fish. Cent., Admin. Rep. LJ 86-29, La Jolla, CA.

Methot, R. D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. Int. N. Pac. Fish. Comm. Bull. 50:259-277.

Methot, R. D. 1998. Application of stock synthesis to NRC test data sets. *In* V. R. Restrepo (editor), Analyses of simulated data sets in support of the NRC study on stock assessment methods, p. 59-80. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-30.

Methot, R. D. 2000. Technical description of the stock synthesis assessment program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-43, 46 p.

Methot, R. D. 2005a. Technical description of the Stock Synthesis II Assessment Program. Unpubl. manuscr. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 54 p.

Methot, R. D. 2005b. User manual for the assessment program Strock Synthesis 2 (SS2), Model Version 1.19. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

Methot, R. D. 2007. User manual for the integrated analysis program Stock Synthesis 2 (SS2), Model Version 2.00c. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

Methot, R. D. 2013. User Manual for Stock Synthesis, Model Version 3.24q. Unpublished manuscript. 150 p.

Methot, R. D., and Wetzell, C. R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fish. Rsch. 142:86-99.

National Marine Fisheries Service (NMFS). 2005. Final environmental impact statement for essential fish habitat identification and conservation in Alaska. National Marine Fisheries Service, Alaska Region. P.O. Box 21668, Juneau, AK 99802-1668.

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Ona, E., and O. R. Godø. 1990. Fish reaction to trawling noise: the significance for trawl sampling. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 189: 159–166.

Pitcher, K. W. 1981. Prey of Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fishery Bulletin 79:467-472.

Savin, A. B. 2008. Seasonal distribution and Migrations of Pacific cod *Gadus macrocephalus* (Gadidae) in Anadyr Bay and adjacent waters. Journal of Ichythyology 48:610-621.

Shimada, A. M., and D. K. Kimura. 1994. Seasonal movements of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and adjacent waters based on tag-recapture data. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 92:800-816.

Sinclair, E.S. and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83(4).

Spies I. 2012. Landscape genetics reveals population subdivision in Bering Sea and Aleutian Islands Pacific cod. *Transactions of the American Fisheries Society* 141:1557-1573.

Stark, J. W. 2007. Geographic and seasonal variations in maturation and growth of female Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and Bering Sea. Fish. Bull. 105:396–407.

Thompson, G., T. A'mar, and W. Palsson. 2011. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 161-306. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501

Thompson, G. G., and M. E. Conners. 2007. Report of the Pacific cod technical workshop held at the Alaska Fisheries Science Center, April 24-25, 2007. Unpubl. manuscr., Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 56 p.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 155-244. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., M. Dorn, and D. Nichol. 2006. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 147-220. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007a. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2007b. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 169-194. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2009. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 165-352. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2010. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 157-328. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and R. D. Methot. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and A. M. Shimada. 1990. Pacific cod. *In* L. L. Low and R. E. Narita (editors), Condition of groundfish resources of the eastern Bering Sea-Aleutian Islands region as assessed in 1988, p. 44-66. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-178.

Thompson, G. G, and H. H. Zenger. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G, and H. H. Zenger. 1994. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1995, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and H. H. Zenger. 1995. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2002. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 89-167. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2004. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 131-232. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Ueda, Y., Y. Narimatsu, T. Hattori, M. Ito, D. Kitagawa, N. Tomikawa, and T. Matsuishi. 2006. Fishing efficiency estimated based on the abundance from virtual population analysis and bottom-trawl surveys of Pacific cod (Gadus macrocephalus) in the waters off the Pacific coast of northern Honshu, Japan. Nippon Suisan Gakkaishi 72:201-209.

Wespestad, V., R. Bakkala, and J. June. 1982. Current abundance of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and expected abundance in 1982-1986. NOAA Tech. Memo. NMFS F/NWC-25, 26 p.

Westrheim, S. J. 1996. On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). Can. Tech. Rep. Fish. Aquat. Sci. 2092. 390 p.

Yang, M-S. 2004. Diet changes of Pacific cod (Gadus macrocephalus) in Pavlof Bay associated with climate changes in the Gulf of Alaska between 1980 and 1995. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 102:400-405.

Tables

Table 2.1. Catch (t) for 1991 through 2014 by jurisdiction and gear type (as of 2014-10-14)

	Federal					State				
Year	Trawl	Longline	Pot	Other	Subtotal	Longline	Pot	Other	Subtotal	Total
1991	58,093	7,656	10,464	115	76,328	0	0	0	0	76,328
1992	54,593	15,675	10,154	325	80,747	0	0	0	0	80,747
1993	37,806	8,963	9,708	11	56,488	0	0	0	0	56,488
1994	31,447	6,778	9,161	100	47,485	0	0	0	0	47,485
1995	41,875	10,978	16,055	77	68,985	0	0	0	0	68,985
1996	45,991	10,196	12,040	53	68,280	0	0	0	0	68,280
1997	48,406	10,978	9,065	26	68,476	0	7,224	1,319	8,542	77,018
1998	41,570	10,012	10,510	29	62,121	0	9,088	1,316	10,404	72,525
1999	37,167	12,363	19,015	70	68,614	0	12,075	1,096	13,171	81,785
2000	25,443	11,660	17,351	54	54,508	0	10,388	1,643	12,031	66,560
2001	24,383	9,910	7,171	155	41,619	0	7,836	2,084	9,920	51,542
2002	19,810	14,666	7,694	176	42,345	0	10,423	1,714	12,137	54,483
2003	18,885	9,525	12,740	161	41,311	60	7,966	3,242	11,267	52,579
2004	17,513	10,329	14,965	400	43,206	51	10,602	2,765	13,418	56,625
2005	14,549	5,732	14,749	203	35,234	26	9,653	2,673	12,351	47,585
2006	13,131	10,228	14,795	118	38,272	47	8,890	646	9,582	47,854
2007	14,774	11,512	13,477	40	39,803	165	10,886	574	11,625	51,428
2008	20,293	12,125	11,230	62	43,710	233	13,438	1,568	15,239	58,949
2009	13,981	13,879	11,573	199	39,632	503	10,295	2,500	13,298	52,931
2010	21,791	16,463	20,114	427	58,795	583	14,604	4,045	19,231	78,027
2011	16,365	16,377	29,228	721	62,691	857	16,668	4,625	22,150	84,841
2012	20,182	14,477	21,239	722	56,620	852	15,937	4,613	21,402	78,022
2013	21,694	12,975	17,011	476	52,156	980	14,154	1,303	16,437	68,593
2014	24,953	11,224	16,031	1,029	53,237	846	17,453	2,853	21,151	74,388

Table 2.2 History of Pacific cod catch (t, includes catch from State waters), Federal TAC (does not include State guideline harvest level), ABC, and OFL. ABC was not used in management of GOA groundfish prior to 1986. Catch for 2014 is current through 2014-10-14. The values in the column labeled "TAC" correspond to "optimum yield" for the years 1980-1986, "target quota" for the year 1987, and true TAC for the years 1988-present. The ABC value listed for 1987 is the upper bound of the range. Source: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1980	35,345	60,000	-	-
1981	36,131	70,000	-	-
1982	29,465	60,000	-	-
1983	36,540	60,000	-	-
1984	23,898	60,000	-	-
1985	14,428	60,000		-
1986	25,012	75,000	136,000	-
1987	32,939	50,000	125,000	-
1988	33,802	80,000	99,000	-
1989	43,293	71,200	71,200	-
1990	72,517	90,000	90,000	-
1991	76,328	77,900	77,900	-
1992	80,747	63,500	63,500	87,600
1993	56,488	56,700	56,700	78,100
1994	47,485	50,400	50,400	71,100
1995	68,985	69,200	69,200	126,000
1996	68,280	65,000	65,000	88,000
1997	77,018	69,115	81,500	180,000
1998	72,525	66,060	77,900	141,000
1999	81,785	67,835	84,400	134,000
2000	66,560	59,800	76,400	102,000
2001	51,542	52,110	67,800	91,200
2002	54,483	44,230	57,600	77,100
2003	52,579	40,540	52,800	70,100
2004	56,625	48,033	62,810	102,000
2005	47,585	44,433	58,100	86,200
2006	47,854	52,264	68,859	95,500
2007	51,428	52,264	68,859	97,600
2008	58,949	50,269	64,493	88,660
2009	52,931	41,807	55,300	66,000
2010	78,027	59,563	79,100	94,100
2011	84,841	65,100	86,800	102,600
2012	78,022	65,700	87,600	104,000
2013	68,593	60,600	88,500	107,300
2014	74,388	-	117,200	140,300

Table 2.3. History of GOA Pacific cod allocations by regulatory area (in percent)

Year(s)	Western	Central	Eastern
1977-1985	28	56	16
1986	40	44	16
1987	27	56	17
1988-1989	19	73	8
1990	33	66	1
1991	33	62	5
1992	37	61	2
1993-1994	33	62	5
1995-1996	29	66	5
1997-1999	35	63	2
2000-2001	36	57	7
2002	39	55	6
2002	38	56	6
2003	39	55	6
2003	38	56	6
2004	36	57	7
2004	35.3	56.5	8.2
2005	36	57	7
2005	35.3	56.5	8.2
2006	39	55	6
2006	38.54	54.35	7.11
2007	39	55	6
2007	38.54	54.35	7.11
2008	39	57	4
2008	38.69	56.55	4.76
2009	39	57	4
2009	38.69	56.55	4.76
2010	35	62	3
2010	34.86	61.75	3.39
2011	35	62	3
2011	35	62	3
2012	35	62	3
2012	32	65	3
2013	38	60	3
2014	38	60	3

Table 2.4 Estimated retained-and discarded GOA Pacific cod from federal waters (source: AKFIN; as of 2014-11-07)

Year	Discarded	Retained	Grand Total
1991	1,429	74,899	76,328
1992	3,873	76,199	80,073
1993	5,844	49,865	55,709
1994	3,109	43,540	46,649
1995	3,525	64,560	68,085
1996	7,534	60,530	68,064
1997	4,783	63,057	67,840
1998	1,709	59,811	61,520
1999	1,617	66,311	67,928
2000	1,362	52,904	54,266
2001	1,904	39,715	41,619
2002	3,715	38,631	42,345
2003	2,483	50,096	52,579
2004	1,269	55,355	56,625
2005	1,044	46,541	47,585
2006	1,840	46,014	47,854
2007	1,441	49,988	51,428
2008	3,308	55,720	59,027
2009	3,944	49,252	53,196
2010	2,870	75,444	78,314
2011	2,074	83,170	85,244
2012	972	77,050	78,022
2013	4,632	63,961	68,593
2014	4,692	75,166	79,858

Table 2.5 – Groundfish bycatch, discarded and retained, for GOA Pacific cod as target species (AKFIN; as of 2014-10-09)

	2009		2010		2011		2012		2013		2014	
	D	R	D	R	D	R	D	R	D	R	D	R
Arrowtooth Flounder	644.9	109.0	322.0	66.6	310.4	268.8	332.7	498.9	885.3	575.9	816.7	476.4
Atka Mackerel	46.5	0.9	57.1	0.1	16.6	0.2	12.4	1.9	21.4	0.1	1.4	0.0
Flathead Sole	25.3	95.0	41.1	33.2	19.2	149.7	52.3	157.5	249.4	178.5	116.4	175.9
GOA Deep Water Flatfish	1.5	0.4	12.6	1.3	8.5	3.8	0.2	3.1	18.3	5.6	0.8	8.7
GOA Demersal Shelf Rockfish		2.0		1.8		3.0		0.5		1.7		1.4
GOA Dusky Rockfish							23.1	9.4	17.4	6.5	2.8	39.1
GOA Pelagic Shelf Rockfish	32.7	11.2	12.8	14.8	10.0	7.5						
GOA Rex Sole	0.0	66.3	8.9	6.8	8.6	31.6	27.8	109.9	17.5	95.1	11.9	72.5
GOA Rougheye Rockfish	4.0	3.3	4.9	2.6	0.9	5.1	0.4	4.3	0.4	5.0	0.4	4.2
GOA Shallow Water Flatfish	43.5	204.9	161.5	517.3	127.7	816.3	125.1	686.3	173.7	792.0	292.6	511.8
GOA Shortraker Rockfish	3.5	4.0	4.7	3.7	3.8	4.1	2.0	4.0	1.3	4.7	0.4	4.5
GOA Skate, Big	211.0	339.2	333.9	613.6	299.0	662.5	83.3	671.6	227.1	422.7	463.8	179.0
GOA Skate, Longnose	115.9	208.8	175.4	255.0	144.4	230.1	9.3	317.3	114.8	320.4	68.2	223.7
GOA Skate, Other	623.6	65.8	919.1	158.1	605.2	195.0	584.6	119.3	899.1	11.0	669.5	58.7
GOA Thornyhead Rockfish	0.4	7.4	0.6	5.4	0.7	7.0	0.3	2.7	5.0	4.1	0.2	10.5
Halibut									182.5	36.6	136.4	23.7
Northern Rockfish	10.8	13.9	13.9	4.7	8.2	8.2	26.8	24.0	48.1	61.9	2.0	58.7
Octopus					482.1	379.4	135.0	273.1	108.8	211.7	258.0	313.3
Other Rockfish	23.7	11.8	19.8	10.1	20.1	33.5	6.9	38.6	28.7	38.6	9.2	25.2
Other Species	498.1	264.1	596.9	233.4								
Pacific Ocean Perch	4.4	38.2	0.2	8.5	1.3	18.5	7.5	45.8	7.0	5.3	0.3	14.2
Pollock	123.2	353.2	205.5	423.7	47.5	503.7	710.4	970.5	109.6	750.4	82.4	1186.9
Sablefish	25.5	19.1	46.9	72.8	49.4	60.3	0.4	23.1	73.7	16.4	6.4	33.7
Sculpin					332.9	10.3	414.4	42.2	481.1	4.7	368.7	6.1
Shark					90.7	0.7	18.8	0.6	66.1	0.1	66.7	0.2
Squid									0.2			
Total	2,937.8	2,433.4	2,587.1	3,399.3	2,573.7	4,004.8	3,736.5	3,549.7	3,375.1	3,428.4	2,937.8	2,433.4

Table 2.6 - Incidental catch (t) of non-target species groups by GOA Pacific cod fisheries, 2004-2013 (as of 2014-10-09)

Species/group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Benthic urochordata	0.0	0.0	0.0	0.6	3.0	0.0	0.2	0.0	0.0	0.1
Birds	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1
Bivalves	1.3	2.1	1.2	1.7	4.2	2.7	6.2	1.7	2.0	1.4
Brittle star unidentified	0.2	0.1	0.3	0.1	0.0	0.1	2.1	0.0	0.1	0.0
Capelin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corals Bryozoans	0.0	0.1	0.2	0.0	1.7	0.0	0.7	4.0	0.1	0.9
Dark Rockfish	0.0	0.0	0.0	0.3	2.7	12.4	2.5	1.5	1.1	1.8
Eelpouts	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.2	0.1
Eulachon	0.0	2.4	0.0	0.1	0.0	0.6	0.0	0.0	0.0	0.3
Giant Grenadier	0.0	21.9	81.5	31.0	51.3	142.7	60.4	175.8	144.5	142.4
Greenlings	1.5	3.7	0.8	7.1	1.3	0.8	0.8	1.9	1.2	0.4
Grenadier	0.0	0.6	0.0	66.0	6.6	11.3	8.2	0.0	24.1	22.6
Gunnels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hermit crab unidentified	0.4	0.5	1.7	2.9	3.9	2.1	0.8	0.8	1.8	0.4
Invertebrate unidentified	0.0	12.6	1.6	1.3	0.1	1.6	9.1	4.5	0.4	0.5
Misc crabs	1.7	0.7	6.6	2.4	1.5	3.4	2.5	2.2	2.9	2.9
Misc crustaceans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Misc fish	152.5	176.0	539.4	210.5	99.0	89.0	134.2	224.3	91.9	132.6
Misc inverts (worms etc)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other osmerids	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Pacific Sand lance	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Pandalid shrimp	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Polychaete unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scypho jellies	1.1	4.6	0.1	0.4	0.2	11.1	0.8	0.6	1.8	0.9
Sea anemone unidentified	0.7	0.3	5.1	6.0	6.6	7.2	8.8	6.0	7.7	4.0
Sea pens whips	0.0	3.2	1.0	0.0	3.3	3.9	1.4	0.8	2.5	1.7
Sea star	937.7	703.5	299.0	316.5	471.9	871.0	718.0	462.5	553.2	545.9
Snails	4.8	2.9	0.8	0.9	2.5	0.7	1.3	3.7	2.6	25.0
Sponge unidentified	1.0	1.2	0.0	1.1	1.6	0.7	0.5	0.4	0.5	0.4
Stichaeidae	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.1	0.0
Surf smelt	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
urchins dollars cucumbers	1.1	1.0	3.2	0.5	1.3	0.5	2.2	3.6	1.3	1.1

Table 2.7 Catch (t) of Pacific cod by year, gear, and season for the years 1991-2014 as configured in the stock assessment models (as of 2014-10-14) values for 2014 season 5 (Nov – Dec) were estimated given the average fraction of catch in season 5 for 2003 – 2012 (0.0337) and the average fraction of each gear type in season 5 for 2004 – 2013 (0.1089, 0.3490, 0.5421, for trawl, longline, and pot, respectively).

	Trawl				Longline				Pot			
Year	Jan-Apr	May-Aug	Sep-Dec	Total	Jan-Apr	May-Aug	Sep-Dec	Total	Jan-Apr	May-Aug	Sep-Dec	Total
1991	55,862	778	1,493	58,133	7,052	540	72	7,664	9,413	183	934	10,530
1992	51,479	1,828	1,500	54,807	12,545	966	2,243	15,754	9,698	19	470	10,187
1993	33,637	2,625	1,551	37,813	7,999	784	181	8,964	9,384	326	0	9,710
1994	29,150	1,433	877	31,460	6,431	299	52	6,782	8,714	33	496	9,243
1995	38,198	1,117	2,597	41,912	10,553	214	227	10,994	15,410	76	592	16,078
1996	40,506	4,023	1,494	46,023	9,885	215	106	10,206	12,025	27	0	12,052
1997	40,407	1,970	6,044	48,421	10,213	390	379	10,982	13,411	2,356	1,848	17,615
1998	34,372	4,014	3,200	41,586	9,307	444	264	10,015	17,652	2,137	1,136	20,925
1999	30,122	1,520	5,550	37,192	11,808	403	158	12,369	22,793	6,859	2,572	32,224
2000	21,579	3,148	750	25,477	11,401	170	107	11,678	25,768	2,938	699	29,405
2001	14,522	2,753	7,228	24,503	9,644	135	142	9,921	12,275	2,885	1,958	17,118
2002	14,466	4,069	1,309	19,844	11,410	161	3,159	14,730	13,049	2,288	4,573	19,910
2003	10,796	3,780	5,271	19,847	8,932	579	765	10,276	19,399	0	3,057	22,456
2004	9,221	2,429	6,400	18,050	8,259	268	2,046	10,573	23,334	276	4,392	28,002
2005	9,658	2,131	3,159	14,948	3,838	174	1,875	5,887	21,361	250	5,139	26,749
2006	10,028	2,081	1,332	13,441	6,156	251	3,948	10,355	21,417	261	2,381	24,059
2007	9,613	2,357	3,127	15,097	7,094	401	4,262	11,757	20,030	546	3,997	24,574
2008	11,157	4,108	6,118	21,382	9,312	642	2,618	12,572	20,394	0	4,600	24,994
2009	6,877	4,616	3,879	15,372	9,609	1,372	3,954	14,935	19,027	0	3,596	22,624
2010	11,007	5,096	7,728	23,830	11,667	774	5,129	17,571	30,986	1	5,638	36,626
2011	9,570	1,940	5,733	17,244	10,248	1,229	6,301	17,779	36,953	102	12,764	49,819
2012	15,875	1,531	2,789	20,182	11,692	336	3,301	15,328	27,991	0	9,185	39,280
2013	14,646	1,953	5,096	21,694	9,577	2,061	2,318	13,955	24,771	0	6,393	29,044
2014	16,012	5,651	6,157	29,868	10,308	801	4,673	16,318	28,265	101	7,076	36,722

Table 2.8 – Noncommercial fishery catch (in t); total source amounts less than 1 mt were omitted (AFSC for GOA bottom trawl survey values; AKFIN for other values, as of 2014-11-03)

Source	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual Longline Survey	13.88	18.10	17.33	16.71	30.99	33.22	27.07	30.50	22.73
Golden King Crab Pot Survey	0.15	0.43	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Gulf of Alaska Bottom Trawl Survey	20.73	0.00	18.35	0.00	53.11	0.00	29.37	0.00	26.22
IPHC Annual Longline Survey	0.00	0.00	0.00	0.00	0.00	142.30	124.36	85.60	123.20
Large-Mesh Trawl Survey	1.13	0.64	1.03	0.21	0.96	11.70	17.01	20.50	18.58
Sablefish Longline Survey	0.63	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shumigans Acoustic Survey	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	0.00
Small-Mesh Trawl Survey	0.25	0.27	0.11	0.00	0.00	1.89	1.65	2.66	1.68
Sport Fishery	0.00	0.00	0.00	0.00	0.00	113.66	155.53	143.76	131.13

Table 2.9 Age compositions observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2011. Nact = actual sample size (these values get rescaled so that the average across the combined sub-27 and 27-plus age compositions equals 300; the 27-plus age compositions only are rescaled in models omitting the sub-27 data). The record for 1987 is shaded to indicate that these data are ignored in the fitting process due to very low sample size.

Year	Nact	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	28	0.000	0.921	0.078	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	20	0.000	0.995	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	110	0.000	0.981	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	100	0.000	0.951	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	98	0.000	0.971	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	125	0.000	0.919	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	57	0.000	0.895	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	65	0.000	0.870	0.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	93	0.000	0.997	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	83	0.000	0.937	0.053	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	66	0.000	0.981	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Year	Nact	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	110	0.000	0.006	0.248	0.253	0.251	0.157	0.055	0.019	0.009	0.002	0.001	0.000	0.000
1990	473	0.000	0.002	0.078	0.261	0.253	0.200	0.120	0.049	0.025	0.008	0.002	0.000	0.000
1993	750	0.000	0.004	0.102	0.242	0.288	0.202	0.112	0.030	0.016	0.004	0.001	0.000	0.000
1996	671	0.000	0.002	0.064	0.180	0.216	0.222	0.201	0.093	0.016	0.005	0.001	0.001	0.000
1999	584	0.000	0.001	0.052	0.173	0.239	0.278	0.161	0.058	0.026	0.009	0.002	0.001	0.000
2001	626	0.000	0.013	0.115	0.251	0.223	0.168	0.131	0.066	0.023	0.007	0.003	0.000	0.001
2003	654	0.000	0.001	0.032	0.188	0.275	0.285	0.133	0.052	0.027	0.004	0.001	0.001	0.001
2005	471	0.000	0.000	0.075	0.125	0.224	0.289	0.170	0.045	0.034	0.019	0.012	0.003	0.003
2007	378	0.000	0.018	0.279	0.295	0.156	0.110	0.039	0.023	0.014	0.027	0.022	0.002	0.014
2009	463	0.000	0.000	0.100	0.337	0.316	0.174	0.052	0.011	0.007	0.002	0.001	0.000	0.000
2011	753	0.000	0.001	0.106	0.415	0.291	0.148	0.034	0.005	0.001	0.000	0.000	0.000	0.000

Table 2.10 – Relative sub-27 and 27-plus size composition from the 1984 – 2013 bottom trawl surveys (in 1-cm bins from 4 to 110 cm)

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013
N	36	26	16	56	63	25	67	15	26	90	74	24	80
4	0	0	0	0	0	0	1	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	5	0	1	0	1
6	5	0	6	9	0	0	0	1	0	0	1	0	1
7	45	0	18	5	0	0	0	0	0	0	0	1	0
8	100	12	21	1	3	0	0	0	1	0	2	0	2
9	117	25	46	0	0	0	1	0	0	0	0	0	0
10	65	47	21	0	0	0	0	0	0	0	1	0	1
11	26	25	0	0	0	1	4	0	0	2	4	1	2
12	4	17	1	1	6	3	8	0	1	3	16	1	16
13	2	2	0	11	15	2	12	1	3	6	60	6	47
14	1	1	0	17	44	12	29	4	5	33	138	5	47
15	0	4	0	36	77	13	33	3	20	75	151	7	59
16	9	10	3	122	99	22	36	15	27	137	131	33	72
17	5	27	6	218	110	35	48	14	39	191	113	43	115
18	11	52	5	156	132	43	77	14	45	223	139	52	163
19	21	57	17	124	123	50	102	31	59	238	130	53	171
20	26	70	25	62	138	61	117	33	55	194	115	52	134
21	32	54	25	59	106	53	138	39	71	168	116	70	135
22	43	39	23	60	119	64	134	44	65	131	126	45	156
23	37	37	40	61	103	53	174	33	43	127	93	44	138
24	51	34	35	78	95	35	190	24	47	111	75	38	146
25	66	18	23	79	69	31	151	34	33	94	66	31	127
26	69	9	13	49	61	34	138	28	27	119	42	14	121

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013
N	895	946	537	789	519	356	333	422	305	350	783	552	414
27	100	13	20	54	42	28	97	32	33	104	72	13	105
28	101	30	11	51	30	24	91	22	20	81	91	13	93
29	92	47	14	42	20	21	73	21	11	73	163	27	88
30	115	91	19	57	19	37	70	22	23	65	209	18	66
31	134	131	43	68	25	34	70	25	31	65	202	37	61
32	154	168	45	90	47	57	62	37	46	78	211	65	55
33	181	203	62	117	52	75	79	54	51	87	212	76	39
34	176	257	74	120	52	92	74	74	64	89	257	100	48
35	185	277	81	136	64	91	71	93	72	87	283	113	70
36	184	301	67	143	89	101	78	113	87	126	299	120	56
37	196	335	86	144	100	109	71	119	76	128	330	130	76
38	189	371	115	179	127	104	94	149	95	165	302	146	75
39	186	394	106	204	163	114	111	161	82	155	361	157	106
40	214	461	152	274	171	105	106	204	83	195	384	179	132
41	234	403	130	325	193	137	124	198	116	182	393	301	164
42	247	350	172	398	199	142	119	225	87	209	438	336	211
43	277	365	158	404	189	181	133	255	103	226	437	406	214
44	335	332	207	452	209	165	133	312	90	215	474	392	247
45	420	305	213	424	205	179	148	294	104	211	493	423	277
46	492	302	223	405	193	195	140	254	99	227	501	422	241
47	579	359	233	419	194	178	158	234	103	178	488	402	220
48	705	469	328	432	173	209	164	274	115	207	471	356	236
49	786	584	311	373	203	176	176	250	117	179	503	391	241
50	854	680	394	426	193	213	162	266	132	178	503	359	228
51	900	781	344	439	190	169	195	236	138	132	486	337	213
52	886	794	354	538	222	209	172	279	161	140	563	333	212
53	866	818	359	519	222	210	167	260	201	134	539	370	201
54	871	787	386	593	246	238	188	278	246	156	555	439	218
55	835	820	379	623	274	240	178	314	246	166	534	406	295
56	806	744	420	584	272	243	169	277	262	169	564	417	280
57	720	676	471	511	347	284	177	312	253	211	476	432	315
58	705	665	436	559	358	287	194	286	276	225	512	415	343
59	625	644	487	558	353	280	188	307	272	212	411	391	329
60	554	604	472	528	414	262	194	265	257	194	397	373	342
61	482	576	463	490	471	245	214	253	219	228	349	324	344
62	374	529	398	482	458	226	178	212	241	193	337	362	316
63	369	506	361	426	443	191	238	218	185	188	312	291	275

Table 2.10 – Relative sub-27 and 27-plus size composition from the 1984 – 2013 bottom trawl surveys (in 1-cm bins from 4 to 110 cm)

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013
N	36	26	16	56	63	25	67	15	26	90	74	24	80
64	264	488	344	376	418	182	211	181	179	171	294	284	241
65	210	418	315	385	412	171	203	158	146	142	252	211	226
66	185	341	252	388	407	156	167	155	148	144	252	197	189
67	173	302	208	360	350	132	148	120	116	125	189	149	178
68	137	256	173	328	274	128	133	117	114	110	190	150	127
69	127	224	147	280	260	122	122	92	97	106	134	94	112
70	101	190	161	261	238	97	129	89	81	73	114	84	92
71	77	158	114	188	179	75	86	73	71	63	87	61	68
72	83	138	108	179	122	74	94	72	47	77	102	62	60
73	90	104	78	143	113	66	58	67	46	55	70	34	56
74	57	101	57	127	112	51	67	50	34	46	56	24	38
75	76	83	54	89	75	34	50	48	36	56	56	28	28
76	81	72	49	96	71	34	45	39	38	33	52	30	16
77	60	52	43	81	58	31	38	36	23	37	38	18	11
78	69	47	45	53	41	28	26	36	23	26	32	12	10
79	80	86	35	54	52	22	20	36	11	14	16	12	14
80	91	31	26	41	36	10	34	26	22	16	19	15	11
81	48	20	25	41	42	10	24	24	19	10	17	8	7
82	57	26	31	35	30	16	17	27	13	7	21	8	6
83	41	31	23	22	15	11	18	16	12	11	9	4	5
84	32	20	28	21	21	5	12	14	21	5	9	10	7
85	31	26	17	23	21	11	8	11	11	3	7	2	3
86	24	23	20	16	17	3	11	9	5	2	7	4	2
87	28	17	19	12	12	3	6	10	10	6	7	4	1
88	20	16	21	13	12	2	11	4	9	2	4	3	2
89	17	16	28	21	10	8	6	4	10	4	3	3	2
90	22	7	15	6	15	1	5	6	18	3	2	2	1
91	16	9	15	6	19	2	9	6	12	1	0	2	2
92	14	9	5	7	11	0	6	3	12	2	4	1	1
93	10	8	4	10	7	3	6	1	12	4	2	0	1
94	7	6	7	6	3	0	6	0	6	2	5	0	0
95	6	10	3	9	11	1	6	2	13	6	2	1	0
96	4	5	7	4	5	0	6	1	13	1	2	2	0
97	3	3	4	4	5	2	4	1	11	2	1	0	2
98	5	3	4	5	3	2	3	1	12	2	0	0	1
99	1	6	1	4	2	3	2	0	10	0	3	0	0
100	3	2	1	7	5	2	6	0	6	1	1	0	1
101	1	2	3	4	2	0	2	0	7	1	1	0	0
102	1	3	3	3	3	1	2	0	2	1	2	0	1
103	0	1	2	1	2	0	2	0	5	3	0	0	0
104	0	0	0	1	3	0	1	0	6	2	0	0	0
105	0	3	1	1	2	0	1	0	4	0	1	0	0
106	0	0	0	0	0	0	0	0	1	1	0	0	0
107	0	0	0	1	1	0	0	0	0	1	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	1	0
109	0	1	0	0	0	0	0	0	0	1	0	0	0
110+	1	1	0	0	0	0	0	0	0	1	0	0	1

Table 2.11 – Mean size-at-age (in cm) observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2011

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0.000	20.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	21.835	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	20.384	25.652	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	20.440	25.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	20.571	26.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	21.141	25.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	21.131	25.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	18.941	24.493	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.000	17.383	26.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	0.000	19.794	24.898	25.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	0.000	20.829	25.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0.000	0.000	34.251	43.215	52.832	59.235	64.794	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	27.262	35.068	45.917	53.472	59.940	65.134	70.773	77.170	83.949	89.101	98.223	102.518
1993	0.000	27.547	34.306	44.040	52.123	58.893	65.611	70.367	74.692	87.551	94.429	97.411	0.000
1996	0.000	27.101	32.319	41.564	52.395	59.236	64.132	68.530	75.524	82.825	93.850	97.313	85.989
1999	0.000	27.361	32.955	41.050	48.717	58.167	64.406	71.194	71.791	77.824	80.160	83.688	0.000
2001	0.000	27.444	32.840	42.651	52.148	58.807	65.611	70.623	74.937	84.301	86.745	85.000	78.723
2003	0.000	29.298	32.645	43.834	48.972	57.854	64.947	71.741	75.490	84.096	83.477	75.670	75.965
2005	0.000	0.000	33.353	41.202	51.274	57.144	62.322	68.165	78.232	90.879	95.862	95.153	91.745
2007	0.000	27.470	35.212	43.362	55.483	59.665	63.519	70.055	69.838	98.805	103.660	92.826	0.000
2009	0.000	27.000	33.708	44.697	55.494	61.956	65.694	74.054	74.209	84.884	92.512	0.000	0.000
2011	0.000	27.000	35.708	44.863	53.947	62.018	65.501	75.620	83.818	0.000	93.530	0.000	106.283

Table 2.12 – Sample sizes of fish for the mean size-at-age observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2011

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0	28	0	0	0	0	0	0	0	0	0	0	0
1990	0	20	0	0	0	0	0	0	0	0	0	0	0
1993	0	108	2	0	0	0	0	0	0	0	0	0	0
1996	0	92	8	0	0	0	0	0	0	0	0	0	0
1999	0	95	3	0	0	0	0	0	0	0	0	0	0
2001	0	113	8	0	0	0	0	0	0	0	0	0	0
2003	0	52	5	0	0	0	0	0	0	0	0	0	0
2005	0	50	15	0	0	0	0	0	0	0	0	0	0
2007	0	92	1	0	0	0	0	0	0	0	0	0	0
2009	0	77	5	1	0	0	0	0	0	0	0	0	0
2011	0	65	1	0	0	0	0	0	0	0	0	0	0
Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0	0	20	56	22	11	1	0	0	0	0	0	0
1990	0	3	50	95	81	78	59	41	36	20	7	2	1
1993	0	9	90	116	113	113	117	66	53	23	10	2	0
1996	0	2	45	146	123	100	107	92	34	17	3	1	1
1999	0	1	26	76	119	136	103	58	29	11	5	2	0
2001	0	9	87	120	106	81	84	64	34	15	8	3	1
2003	0	2	37	114	134	126	86	60	39	10	1	2	2
2005	0	0	64	87	83	78	84	39	21	6	4	1	1
2007	0	5	47	86	73	65	34	36	25	4	1	2	0
2009	0	1	60	120	105	86	47	19	16	5	4	0	0
2011	0	1	102	189	178	175	76	25	5	0	1	0	1

Table 2.13 Pacific cod abundance measured in biomass (t) and numbers of fish (1000s), as assessed by the GOA bottom trawl survey. Point estimates are shown along with coefficients of variation. The two right-hand sections show the total abundance divided into fish 27 cm or larger and fish smaller than 27 cm (totals are very slightly different in the first four years due to exclusion of tows with no length data from the strata extrapolations).

	All lengths				27-plus		Sub-27cm	
Year	Biomass(t)	CV	Abundance	CV	Abundance	CV	Abundance	CV
1984	550,971	0.145	320,525	0.156	296,057	0.175	19,526	0.596
1987	394,987	0.129	247,020	0.185	238,165	0.234	6,772	0.374
1990	416,788	0.152	212,132	0.208	193,577	0.243	14,739	0.412
1993	409,848	0.178	231,963	0.190	214,244	0.210	17,021	0.372
1996	538,154	0.198	319,068	0.215	234,528	0.172	84,540	0.615
1999	306,413	0.126	166,584	0.112	157,019	0.118	9,565	0.272
2001	257,614	0.202	158,424	0.180	137,041	0.203	21,384	0.270
2003	297,402	0.149	159,749	0.129	153,895	0.134	5,854	0.231
2005	308,091	0.258	139,852	0.208	127,282	0.221	12,570	0.388
2007	233,310	0.138	192,025	0.175	134,261	0.163	57,764	0.425
2009	752,651	0.296	573,509	0.286	422,370	0.239	151,139	0.867
2011	500,975	0.135	348,060	0.177	339,410	0.178	8,650	0.347
2013	506,362	0.148	337,992	0.151	257,315	0.139	80,677	0.437

Table 2.14. Number of parameters, negative log-likelihoods, and growth parameters for all model configurations (smaller indicates better fit to data).

	2013 model	2013 model with adj	Non-parametric srv sel	Splines srv sel
Number of parameters	254	249	230	213
Likelihood components (-ln)				
Survey indices	-1.61	-1.99	-14.01	-12.15
Length compositions	2095.25	2089.93	2202.93	2206.40
Age compositions	56.78	56.48	415.39	418.49
Size-at-age	398.85	396.00	-	-
Recruitment	-21.67	-24.90	-17.52	-17.75
Forecast recruitment	-	4.49	4.22	5.37
27-plus survey indices	-1.61	-1.99	-	-
Full survey indices	-	-	-14.01	-12.14
Total	2527.66	2520.06	2591.09	2600.41
Length composition likelihoods (-ln)				
Jan-Apr Trawl	298.13	294.52	299.84	298.54
Jan-Apr LL	150.88	147.09	140.98	141.14
Jan-Apr Pot	223.57	222.95	212.43	212.96
May-Aug Trawl	452.74	453.65	438.86	438.33
May-Aug LL	136.67	137.26	133.87	134.10
May-Aug Pot	336.42	337.93	334.27	334.10
Sep-Dec Trawl	267.44	267.20	271.28	271.14
Sep-Dec LL	45.78	46.09	45.35	45.41
Sep-Dec Pot	168.59	169.05	168.04	168.86
27-plus survey	15.04	14.18	-	-
Full survey	-	-	158.02	161.83
Age compositions likelihoods (-ln)				
Age 27-plus survey	56.78	56.48	-	-
Age full survey	-	-	415.39	418.49
Mean size-at-age likelihoods (-ln)				
Age 27-plus survey	398.85	396.00	-	-
Growth parameters				
Length-at-Amin	26.32	26.40	23.34	23.37
Length-at-A∞	98.33	98.68	94.28	94.25
k	0.181	0.180	0.201	0.201
CV for L-at-Amin	-	-	4.601	4.590
CV for L-at-A∞	-	-	6.775	6.805
ln(R0)	12.50	12.49	12.64	12.66

Table 2.15 – Parameter values, estimates, and standard deviations from Model S1a

Parameter	Value	Std Dev
M	0.38	_
L_at_Amin	23.3392	0.276908
L_at_Amax	94.283	0.81592
VonBert_K	0.201426	0.004298
CV_young	4.6016	0.134811
CV_old	6.77542	0.217853
Wtlen_1	8.84E-06	_
Wtlen_2	3.07181	_
Mat-at-50%	4.35	_
Mat_slope	-1.9632	_
Eggs/kg	1	_
AgeKeyParm1	1	_
AgeKeyParm2	0.111997	0.046143
AgeKeyParm3	9.50E-09	_
AgeKeyParm4	0	_
AgeKeyParm5	0.096	_
AgeKeyParm6	1.471	_
AgeKeyParm7	0	_
SR_LN(R0)	12.6438	0.06622
SR_BH_steep	1	_
SR_sigmaR	0.41	_
SR_R1_offset	0.069359	0.134755
Early_InitAge_13	-0.15814	0.381102
Early_InitAge_12	-0.19247	0.375512
Early_InitAge_11	-0.21966	0.370966
Early_InitAge_10	-0.23094	0.368343
Early_InitAge_9	-0.19969	0.370475
Early_InitAge_8	-0.09602	0.380637
Early_InitAge_7	0.111669	0.403327
Early_InitAge_6	0.37487	0.424365
Early_InitAge_5	0.502522	0.429912
Early_InitAge_4	1.49303	0.186194
Early_InitAge_3	-0.05908	0.296458
Early_InitAge_2	0.115144	0.191489
Early_InitAge_1	-0.53208	0.233706
Main_RecrDev_1977	1.66695	0.082256
Main_RecrDev_1978	-0.33959	0.221603
Main_RecrDev_1979	0.109951	0.106422
Main_RecrDev_1980	0.148782	0.08298

Main_RecrDev_1981	-0.08276	0.086461
Main_RecrDev_1982	0.066854	0.101395
Main_RecrDev_1983	-0.64218	0.171643
Main_RecrDev_1984	0.347582	0.139732
Main_RecrDev_1985	0.405736	0.119728
Main_RecrDev_1986	-0.44928	0.167252
Main_RecrDev_1987	0.17022	0.092666
Main_RecrDev_1988	0.115401	0.090243
Main_RecrDev_1989	0.117136	0.096423
Main_RecrDev_1990	0.383753	0.081494
Main_RecrDev_1991	0.063184	0.092826
Main_RecrDev_1992	-0.08382	0.101433
Main_RecrDev_1993	0.174726	0.081197
Main_RecrDev_1994	-0.06025	0.092771
Main_RecrDev_1995	0.271541	0.075958
Main_RecrDev_1996	-0.17702	0.090785
Main_RecrDev_1997	-0.29728	0.095106
Main_RecrDev_1998	-0.4744	0.096587
Main_RecrDev_1999	-0.13331	0.0838
Main_RecrDev_2000	-0.05287	0.079195
Main_RecrDev_2001	-0.34987	0.090695
Main_RecrDev_2002	-0.79237	0.113135
Main_RecrDev_2003	-0.42731	0.083729
Main_RecrDev_2004	-0.56617	0.094033
Main_RecrDev_2005	-0.15573	0.081475
Main_RecrDev_2006	0.208225	0.076683
Main_RecrDev_2007	0.119829	0.093486
Main_RecrDev_2008	0.465838	0.095318
Main_RecrDev_2009	0.246061	0.133346
Main_RecrDev_2010	-0.21078	0.16739
Main_RecrDev_2011	0.213214	0.225457
Late_RecrDev_2012	0.595512	0.16214
Late_RecrDev_2013	0.0038	0.203673
Late_RecrDev_2014	0	0.205
ForeRecr_2015	0	0.41
InitF_1Jan-Apr_Trawl_Fishery	0.036569	0.005865
InitF_2May-Aug_Trawl_Fishery	0	_
InitF_3Sep-Dec_Trawl_Fishery	0	_
InitF_4Jan-Apr_Longline_Fishery	0	_
InitF_5May-Aug_Longline_Fishery	0	_
InitF_6Sep-Dec_Longline_Fishery	0	_

InitF_7Jan-Apr_Pot_Fishery	0	_
InitF_8May-Aug_Pot_Fishery	0	_
InitF_9Sep-Dec_Pot_Fishery	0	_
Q_envlink_10_Trawl_Survey	0.356455	0.25064
LnQ_base_10_Trawl_Survey	0	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_2_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_3_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_4_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_5_Jan-Apr_Trawl_Fishery	-10	_
SizeSel_1P_6_Jan-Apr_Trawl_Fishery	10	_
SizeSel_2P_1_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_2_May-Aug_Trawl_Fishery	-7	_
SizeSel_2P_3_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_4_May-Aug_Trawl_Fishery	4.68513	0.314994
SizeSel_2P_5_May-Aug_Trawl_Fishery	-10	_
SizeSel_2P_6_May-Aug_Trawl_Fishery	0	_
SizeSel_3P_1_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_3_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_4_Sep-Dec_Trawl_Fishery	4.37269	0.354623
SizeSel_3P_5_Sep-Dec_Trawl_Fishery	-10	_
SizeSel_3P_6_Sep-Dec_Trawl_Fishery	-1.51788	0.265191
SizeSel_4P_1_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_3_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_4_Jan-Apr_Longline_Fishery	3.96351	0.258395
SizeSel_4P_5_Jan-Apr_Longline_Fishery	-10	_
SizeSel_4P_6_Jan-Apr_Longline_Fishery	0	_
SizeSel_5P_1_May-Aug_Longline_Fishery	0	_
SizeSel_5P_2_May-Aug_Longline_Fishery	-7	_
SizeSel_5P_3_May-Aug_Longline_Fishery	0	_
SizeSel_5P_4_May-Aug_Longline_Fishery	4.82853	0.291221
SizeSel_5P_5_May-Aug_Longline_Fishery	-10	_
SizeSel_5P_6_May-Aug_Longline_Fishery	0	_
SizeSel_6P_1_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_2_Sep-Dec_Longline_Fishery	-7	_
SizeSel_6P_3_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_4_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_5_Sep-Dec_Longline_Fishery	-10	_
SizeSel_6P_6_Sep-Dec_Longline_Fishery	0	_

SizeSel_7P_1_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_2_Jan-Apr_Pot_Fishery	-7	_
SizeSel_7P_3_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_4_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_5_Jan-Apr_Pot_Fishery	-10	_
SizeSel_7P_6_Jan-Apr_Pot_Fishery	0	_
SizeSel_8P_1_May-Aug_Pot_Fishery	0	_
SizeSel_8P_2_May-Aug_Pot_Fishery	-7	_
SizeSel_8P_3_May-Aug_Pot_Fishery	0	_
SizeSel_8P_4_May-Aug_Pot_Fishery	4.76334	0.477814
SizeSel_8P_5_May-Aug_Pot_Fishery	-10	_
SizeSel_8P_6_May-Aug_Pot_Fishery	-1.07732	0.440272
SizeSel_9P_1_Sep-Dec_Pot_Fishery	0	_
SizeSel_9P_2_Sep-Dec_Pot_Fishery	-7	_
SizeSel_9P_3_Sep-Dec_Pot_Fishery	0	_
SizeSel_9P_4_Sep-Dec_Pot_Fishery	4.46758	0.246737
SizeSel_9P_5_Sep-Dec_Pot_Fishery	-10	_
SizeSel_9P_6_Sep-Dec_Pot_Fishery	0	_
AgeSel_10P_1_Trawl_Survey	-2	_
AgeSel_10P_2_Trawl_Survey	3	_
AgeSel_10P_3_Trawl_Survey	-1	_
AgeSel_10P_4_Trawl_Survey	2	_
AgeSel_10P_5_Trawl_Survey	0	_
AgeSel_10P_6_Trawl_Survey	0	_
AgeSel_10P_7_Trawl_Survey	0	_
AgeSel_10P_8_Trawl_Survey	-1	_
AgeSel_10P_9_Trawl_Survey	-1	_
AgeSel_10P_10_Trawl_Survey	-1	_
AgeSel_10P_11_Trawl_Survey	-1	_
AgeSel_10P_12_Trawl_Survey	-1	_
AgeSel_10P_13_Trawl_Survey	-1	_
AgeSel_10P_14_Trawl_Survey	-2	_
AgeSel_10P_15_Trawl_Survey	-999	_
AgeSel_10P_16_Trawl_Survey	-999	_
AgeSel_10P_17_Trawl_Survey	-999	_
AgeSel_10P_18_Trawl_Survey	-999	_
AgeSel_10P_19_Trawl_Survey	-999	_
AgeSel_10P_20_Trawl_Survey	-999	_
AgeSel_10P_21_Trawl_Survey	-999	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_1977	49.7199	3.13875
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_1990	71.8043	1.195

SizeSel_1P_1_Jan-Apr_Trawl_Fishery_1995	74.259	1.07005
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_2000	64.954	2.07086
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_2005	69.3073	2.24715
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_1977	4.16956	0.6253
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_1990	5.82206	0.074596
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_1995	5.87337	0.062162
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_2000	5.6082	0.168419
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_2005	5.84029	0.146064
SizeSel_2P_1_May-Aug_Trawl_Fishery_1977	53.852	1.25039
SizeSel_2P_1_May-Aug_Trawl_Fishery_1985	60.7856	1.21886
SizeSel_2P_1_May-Aug_Trawl_Fishery_1990	65.7192	1.04849
SizeSel_2P_1_May-Aug_Trawl_Fishery_2000	66.538	2.18554
SizeSel_2P_1_May-Aug_Trawl_Fishery_2005	67.8111	1.70648
SizeSel_2P_3_May-Aug_Trawl_Fishery_1977	4.50398	0.216443
SizeSel_2P_3_May-Aug_Trawl_Fishery_1985	5.18616	0.162178
SizeSel_2P_3_May-Aug_Trawl_Fishery_1990	5.10549	0.121318
SizeSel_2P_3_May-Aug_Trawl_Fishery_2000	5.75359	0.197442
SizeSel_2P_3_May-Aug_Trawl_Fishery_2005	5.91311	0.123724
SizeSel_2P_6_May-Aug_Trawl_Fishery_1977	-0.4555	0.285036
SizeSel_2P_6_May-Aug_Trawl_Fishery_1985	-1.44503	0.350824
SizeSel_2P_6_May-Aug_Trawl_Fishery_1990	-2.73456	0.777645
SizeSel_2P_6_May-Aug_Trawl_Fishery_2000	-1.12725	0.856166
SizeSel_2P_6_May-Aug_Trawl_Fishery_2005	-1.75893	1.00035
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1977	46.0044	4.90329
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1980	55.6161	1.64726
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1985	58.5631	1.6486
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1990	58.5454	3.24445
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1995	71.4395	1.41829
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_2000	68.7713	1.59347
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_2005	69.1546	1.27583
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1977	-3.69427	7.32648
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1980	-6	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1985	-7	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1990	-0.10989	0.259243
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1995	-7	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_2000	-7	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_2005	-7	_
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1977	3.79957	0.897482
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1980	5.12747	0.249784
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1985	5.51063	0.199755
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1990	5.11796	0.333539

SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1995	6.16025	0.100253
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_2000	5.88234	0.137355
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_2005	5.7565	0.09604
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1977	54.4347	0.783219
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1985	61.8309	1.33874
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1990	69.3193	0.887452
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1995	72.2259	0.746895
SizeSel_4P_1_Jan-Apr_Longline_Fishery_2000	67.6821	1.03
SizeSel_4P_1_Jan-Apr_Longline_Fishery_2005	68.2574	0.508115
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1977	-0.36988	0.133843
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1985	-0.99007	0.196166
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1990	-7	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1995	-7	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery_2000	-3.73448	2.18653
SizeSel_4P_2_Jan-Apr_Longline_Fishery_2005	-7	_
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1977	4.3904	0.117486
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1985	5.10816	0.118841
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1990	5.2821	0.077346
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1995	5.37007	0.063579
SizeSel_4P_3_Jan-Apr_Longline_Fishery_2000	5.05511	0.09891
SizeSel_4P_3_Jan-Apr_Longline_Fishery_2005	5.04249	0.048854
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1977	-0.223	0.290025
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1985	0.972233	0.329056
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1990	1.41469	0.475192
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1995	0.549834	0.312357
SizeSel_4P_6_Jan-Apr_Longline_Fishery_2000	-0.48297	0.237829
SizeSel_4P_6_Jan-Apr_Longline_Fishery_2005	-0.5524	0.206889
SizeSel_5P_1_May-Aug_Longline_Fishery_1977	54.3418	1.77318
SizeSel_5P_1_May-Aug_Longline_Fishery_1980	55.5032	0.689374
SizeSel_5P_1_May-Aug_Longline_Fishery_1990	69.3543	1.86694
SizeSel_5P_1_May-Aug_Longline_Fishery_2000	69.8589	1.37671
SizeSel_5P_3_May-Aug_Longline_Fishery_1977	4.27944	0.297868
SizeSel_5P_3_May-Aug_Longline_Fishery_1980	4.30932	0.119451
SizeSel_5P_3_May-Aug_Longline_Fishery_1990	4.99503	0.232409
SizeSel_5P_3_May-Aug_Longline_Fishery_2000	4.98389	0.148265
SizeSel_5P_6_May-Aug_Longline_Fishery_1977	0.143932	0.455827
SizeSel_5P_6_May-Aug_Longline_Fishery_1980	-0.96208	0.183823
SizeSel_5P_6_May-Aug_Longline_Fishery_1990	-1.71766	1.03808
SizeSel_5P_6_May-Aug_Longline_Fishery_2000	0.215815	0.657286
SizeSel_6P_1_Sep-Dec_Longline_Fishery_1977	56.1806	1.20256
SizeSel_6P_1_Sep-Dec_Longline_Fishery_1980	55.8547	0.310692

SizeSel_6P_1_Sep-Dec_Longline_Fishery_1990	67.1705	0.502632
SizeSel_6P_3_Sep-Dec_Longline_Fishery_1977	4.41105	0.172616
SizeSel_6P_3_Sep-Dec_Longline_Fishery_1980	4.30241	0.053122
SizeSel_6P_3_Sep-Dec_Longline_Fishery_1990	4.91013	0.052672
SizeSel_6P_4_Sep-Dec_Longline_Fishery_1977	9	_
SizeSel_6P_4_Sep-Dec_Longline_Fishery_1980	4.36572	0.105177
SizeSel_6P_4_Sep-Dec_Longline_Fishery_1990	4.13569	0.265056
SizeSel_6P_6_Sep-Dec_Longline_Fishery_1977	-8.3507	32.9364
SizeSel_6P_6_Sep-Dec_Longline_Fishery_1980	-1.67498	0.093792
SizeSel_6P_6_Sep-Dec_Longline_Fishery_1990	-0.79684	0.196577
SizeSel_7P_1_Jan-Apr_Pot_Fishery_1977	68.1684	0.454695
SizeSel_7P_1_Jan-Apr_Pot_Fishery_1995	70.9519	0.445977
SizeSel_7P_1_Jan-Apr_Pot_Fishery_2000	66.9739	0.597186
SizeSel_7P_1_Jan-Apr_Pot_Fishery_2005	67.0488	0.490147
SizeSel_7P_3_Jan-Apr_Pot_Fishery_1977	4.78643	0.055217
SizeSel_7P_3_Jan-Apr_Pot_Fishery_1995	4.94547	0.046664
SizeSel_7P_3_Jan-Apr_Pot_Fishery_2000	4.89805	0.067174
SizeSel_7P_3_Jan-Apr_Pot_Fishery_2005	4.73899	0.054229
SizeSel_7P_4_Jan-Apr_Pot_Fishery_1977	4.52016	0.185615
SizeSel_7P_4_Jan-Apr_Pot_Fishery_1995	4.20759	0.250571
SizeSel_7P_4_Jan-Apr_Pot_Fishery_2000	4.38012	0.273516
SizeSel_7P_4_Jan-Apr_Pot_Fishery_2005	4.19389	0.259778
SizeSel_7P_6_Jan-Apr_Pot_Fishery_1977	-2.01946	0.259921
SizeSel_7P_6_Jan-Apr_Pot_Fishery_1995	-0.79048	0.200859
SizeSel_7P_6_Jan-Apr_Pot_Fishery_2000	-0.85905	0.212626
SizeSel_7P_6_Jan-Apr_Pot_Fishery_2005	-0.40414	0.202777
SizeSel_8P_1_May-Aug_Pot_Fishery_1977	64.3107	1.61053
SizeSel_8P_1_May-Aug_Pot_Fishery_1995	67.6337	1.07985
SizeSel_8P_1_May-Aug_Pot_Fishery_2000	64.7851	1.28665
SizeSel_8P_3_May-Aug_Pot_Fishery_1977	4.42487	0.274312
SizeSel_8P_3_May-Aug_Pot_Fishery_1995	4.54768	0.165683
SizeSel_8P_3_May-Aug_Pot_Fishery_2000	4.27059	0.249282
SizeSel_9P_1_Sep-Dec_Pot_Fishery_1977	71.1912	0.986786
SizeSel_9P_1_Sep-Dec_Pot_Fishery_1995	71.272	1.12332
SizeSel_9P_1_Sep-Dec_Pot_Fishery_2000	64.9272	0.924086
SizeSel_9P_1_Sep-Dec_Pot_Fishery_2005	65.1577	0.589455
SizeSel_9P_3_Sep-Dec_Pot_Fishery_1977	5.29679	0.097451
SizeSel_9P_3_Sep-Dec_Pot_Fishery_1995	5.34695	0.110862
SizeSel_9P_3_Sep-Dec_Pot_Fishery_2000	4.88804	0.115761
SizeSel_9P_3_Sep-Dec_Pot_Fishery_2005	4.67637	0.075919
SizeSel_9P_6_Sep-Dec_Pot_Fishery_1977	-1.30375	0.414697

SizeSel_9P_6_Sep-Dec_Pot_Fishery_1995	-0.41457	0.464178
SizeSel_9P_6_Sep-Dec_Pot_Fishery_2000	-0.69647	0.304153
SizeSel_9P_6_Sep-Dec_Pot_Fishery_2005	-0.9052	0.253861
AgeSel_10P_1_Trawl_Survey_1977	-1000	_
AgeSel_10P_1_Trawl_Survey_1996	-1000	_
AgeSel_10P_1_Trawl_Survey_2005	-1000	_
AgeSel_10P_2_Trawl_Survey_1977	3.19651	0.997817
AgeSel_10P_2_Trawl_Survey_1996	7.83407	6.30736
AgeSel_10P_2_Trawl_Survey_2005	5.84925	2.36511
AgeSel_10P_3_Trawl_Survey_1977	0.039936	0.352043
AgeSel_10P_3_Trawl_Survey_1996	-0.35766	0.219491
AgeSel_10P_3_Trawl_Survey_2005	-0.1027	0.201135
AgeSel_10P_4_Trawl_Survey_1977	0.949177	0.356349
AgeSel_10P_4_Trawl_Survey_1996	1.29109	0.229264
AgeSel_10P_4_Trawl_Survey_2005	1.37699	0.203529
AgeSel_10P_5_Trawl_Survey_1977	1.02381	0.354691
AgeSel_10P_5_Trawl_Survey_1996	0.446728	0.195477
AgeSel_10P_5_Trawl_Survey_2005	0.132959	0.145057
AgeSel_10P_6_Trawl_Survey_1977	-0.50738	0.446408
AgeSel_10P_6_Trawl_Survey_1996	0.167843	0.163289
AgeSel_10P_6_Trawl_Survey_2005	0	_
AgeSel_10P_7_Trawl_Survey_1977	0.018839	0.436564
AgeSel_10P_7_Trawl_Survey_1996	-0.29082	0.196845
AgeSel_10P_7_Trawl_Survey_2005	-0.57732	0.237381
AgeSel_10P_8_Trawl_Survey_1977	-0.0013	0.044312
AgeSel_10P_8_Trawl_Survey_1996	-0.00561	0.161202
AgeSel_10P_8_Trawl_Survey_2005	-0.00091	0.031864
AgeSel_10P_9_Trawl_Survey_1977	-0.6378	0.536751
AgeSel_10P_9_Trawl_Survey_1996	-0.60489	0.388304
AgeSel_10P_9_Trawl_Survey_2005	-1.08722	0.566615
AgeSel_10P_10_Trawl_Survey_1977	-0.5064	0.706934
AgeSel_10P_10_Trawl_Survey_1996	-0.93429	0.681268
AgeSel_10P_10_Trawl_Survey_2005	-1.23135	0.613485
AgeSel_10P_11_Trawl_Survey_1977	-1.78459	1.8189
AgeSel_10P_11_Trawl_Survey_1996	-0.59196	0.798974
AgeSel_10P_11_Trawl_Survey_2005	-0.0009	0.031727
AgeSel_10P_12_Trawl_Survey_1977	-3.41416	13.21
AgeSel_10P_12_Trawl_Survey_1996	-8.3954	33.212
AgeSel_10P_12_Trawl_Survey_2005	-3.5727	9.30729
AgeSel_10P_13_Trawl_Survey_1977	-0.80874	14.102
AgeSel_10P_13_Trawl_Survey_1996	-5.17895	102.99

AgeSel_10P_13_Trawl_Survey_2005	-0.6585	9.56022
AgeSel_10P_14_Trawl_Survey_1977	-0.76982	3.73773
AgeSel_10P_14_Trawl_Survey_1996	-5.0007	111.757
AgeSel_10P_14_Trawl_Survey_2005	-0.01	_

Table 2.16 – Schedules of estimated population length (cm) and weight (kg) by season and age from Model S1a. Season 1=Jan-Feb, Season 2=Mar-Apr, Season 3=May-Aug, Season 4=Sep-Oct, Season 5=Nov-Dec. Lengths and weights correspond to season mid-points.

	Length, in cm					Mass, in kg				
Age	1	2	3	4	5	1	2	3	4	5
0	0.50	1.93	6.21	10.49	13.35	0.001	0.002	0.007	0.025	0.033
1	16.20	19.06	23.34	26.82	29.05	0.060	0.086	0.158	0.264	0.288
2	31.20	33.29	36.28	39.13	40.95	0.385	0.431	0.560	0.759	0.813
3	42.71	44.41	46.86	49.19	50.68	0.986	1.025	1.182	1.452	1.559
4	52.12	53.51	55.51	57.42	58.64	1.801	1.804	1.946	2.257	2.441
5	59.81	60.95	62.59	64.14	65.14	2.738	2.681	2.774	3.098	3.375
6	66.10	67.03	68.37	69.64	70.46	3.713	3.585	3.603	3.922	4.301
7	71.24	72.00	73.10	74.14	74.80	4.667	4.461	4.392	4.693	5.175
8	75.45	76.07	76.96	77.81	78.36	5.561	5.278	5.117	5.392	5.974
9	78.88	79.39	80.12	80.82	81.26	6.372	6.016	5.766	6.011	6.686
10	81.69	82.11	82.71	83.27	83.64	7.093	6.669	6.335	6.552	7.310
11	83.99	84.33	84.82	85.28	85.58	7.721	7.238	6.828	7.016	7.849
12	85.87	86.14	86.54	86.92	87.17	8.262	7.726	7.249	7.411	8.309
13	87.40	87.63	87.96	88.27	88.47	8.723	8.142	7.606	7.745	8.698
14	88.66	88.84	89.11	89.36	89.53	9.112	8.493	7.906	8.025	9.025
15	89.68	89.84	90.05	90.26	90.39	9.438	8.786	8.157	8.258	9.298
16	90.52	90.65	90.83	91.00	91.10	9.711	9.032	8.366	8.452	9.526
17	91.21	91.31	91.46	91.60	91.68	9.938	9.235	8.539	8.613	9.714
18	91.77	91.85	91.97	92.09	92.16	10.125	9.404	8.682	8.745	9.870
19	92.23	92.30	92.39	92.49	92.55	10.280	9.543	8.801	8.855	9.998
20	92.96	93.00	93.06	93.12	93.16	10.529	9.768	8.991	9.031	10.205

Table 2.17 – Schedule of estimated full survey selectivity-at-age from Model S1a

Age	1984 – 1993	1996 – 2003	2005 – 2013
0	0.005	0.000	0.001
1	0.134	0.213	0.245
2	0.139	0.149	0.221
3	0.359	0.541	0.876
4	1.000	0.845	1.000
5	0.602	1.000	1.000
6	0.614	0.748	0.561
7	0.613	0.743	0.561
8	0.324	0.406	0.189
9	0.195	0.160	0.055
10	0.033	0.088	0.055
11	0.001	0.000	0.002
12	0.000	0.000	0.001
13	0.000	0.000	0.001
14	0.000	0.000	0.001
15	0.000	0.000	0.001
16	0.000	0.000	0.001
17	0.000	0.000	0.001
18	0.000	0.000	0.001
19	0.000	0.000	0.001
20	0.000	0.000	0.001

Table 2.18 – Estimated female spawning biomass (t) from the 2013 assessment and this year's assessment from Model S1a

	Last year		**This year**	
Year	Spawning Biomass	Standard Deviation	Spawning Biomass	Standard Deviation
1977	186,808	22,033	417,262	64,250
1978	227,088	24,465	514,875	74,306
1979	239,480	24,638	528,010	73,382
1980	238,081	23,167	502,250	67,096
1981	252,175	22,457	510,750	64,125
1982	285,659	23,310	561,345	65,805
1983	285,396	22,223	539,730	60,570
1984	262,246	19,764	486,303	53,334
1985	244,848	17,150	438,862	46,804
1986	234,405	14,690	396,007	40,714
1987	226,094	12,560	355,515	35,200
1988	211,026	10,710	319,025	30,626
1989	202,045	9,314	306,546	28,269
1990	192,004	8,352	290,091	26,221
1991	172,390	7,469	260,199	23,940
1992	151,710	6,845	235,414	22,712
1993	144,063	6,517	226,204	22,314
1994	146,202	6,376	229,276	22,529
1995	155,479	6,310	239,934	22,819
1996	150,300	6,055	231,890	22,279
1997	141,547	5,699	220,810	21,694
1998	128,100	5,432	207,654	21,495
1999	122,142	5,347	202,477	21,597
2000	110,458	5,322	192,391	21,775
2001	109,422	5,207	186,894	20,940
2002	102,436	4,930	174,210	19,679
2003	90,860	4,669	158,567	18,548
2004	87,923	4,641	153,702	18,120
2005	87,611	4,751	150,557	17,715
2006	83,399	4,696	140,153	16,594
2007	79,240	4,581	127,838	15,217
2008	73,601	4,632	115,273	14,245
2009	73,230	5,096	109,778	14,049
2010	81,752	6,434	115,966	15,256
2011	95,863	8,938	129,024	17,827
2012	116,606	12,808	147,788	21,528
2013	146,930	18,109	173,781	26,328
2014	*147,000*		183,784	30,013
2015			*175,464*	

Table 2.19 – Estimated age-0 recruits (000's) from the 2013 assessment and this year's assessment from Model S1a

	Last year		This year	
Year	Age-0	Std. Dev	Age-0	Std. Dev
1977	756,157	53,618	1,508,670	166,531
1978	238,560	25,328	202,845	45,570
1979	173,783	14,582	317,978	39,722
1980	209,123	13,140	330,569	36,194
1981	204,331	12,984	262,242	28,787
1982	256,862	17,289	304,565	36,760
1983	182,726	16,137	149,883	27,381
1984	188,096	17,224	403,273	61,991
1985	319,968	17,552	427,420	54,495
1986	175,593	12,358	181,773	31,939
1987	228,726	12,044	337,732	36,908
1988	240,174	11,897	319,716	34,500
1989	230,335	12,418	320,271	37,262
1990	293,018	13,264	418,127	42,785
1991	241,917	11,354	303,450	32,348
1992	204,391	10,644	261,965	31,346
1993	223,157	10,273	339,257	34,955
1994	215,464	9,911	268,213	29,790
1995	227,150	9,706	373,745	38,943
1996	202,627	8,640	238,654	24,452
1997	156,086	7,279	211,612	24,564
1998	127,597	6,645	177,263	20,136
1999	169,207	7,825	249,317	27,191
2000	205,053	9,113	270,200	27,556
2001	156,483	7,441	200,770	20,803
2002	121,066	6,571	128,980	16,534
2003	148,323	7,457	185,809	18,991
2004	143,264	8,123	161,719	18,699
2005	206,195	12,227	243,789	26,509
2006	294,212	19,619	350,814	38,031
2007	298,706	23,992	321,135	37,887
2008	393,735	39,315	453,897	58,116
2009	399,022	47,592	364,342	56,371
2010	246,927	35,982	230,731	42,984
2011	293,917	62,757	352,569	86,650
2012			516,742	92,639
2013			285,954	61,298
Average	239,199	(1977 – 2011)	323,675	(1977 – 2013)

Table 2.20 – Estimated numbers-at-age (millions) at the time of spawning (middle of season 2) from Model S1a

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	1,461,640	118,824	155,222	89,142	286,870	72,442	43,339	22,641	12,504	7,662	5,048	3,470	2,424	1,705	1,477	1,004	682	464	315	214	455
1978	196,522	999,559	81,253	106,009	60,754	195,381	49,344	29,526	15,428	8,522	5,223	3,442	2,367	1,653	1,163	1,007	685	465	316	215	456
1979	308,067	134,394	683,455	55,371	71,820	41,090	132,255	33,431	20,018	10,465	5,784	3,546	2,338	1,608	1,123	790	685	465	316	215	456
1980	320,265	210,675	91,885	465,023	37,341	48,278	27,640	89,061	22,535	13,506	7,067	3,908	2,398	1,581	1,088	760	535	463	315	214	455
1981	254,068	219,017	144,034	62,500	311,065	24,751	32,143	18,515	59,881	15,183	9,111	4,771	2,640	1,621	1,069	736	514	362	313	213	453
1982	295,072	173,747	149,723	97,833	41,613	205,022	16,413	21,481	12,431	40,301	10,232	6,145	3,220	1,783	1,094	722	497	347	244	212	450
1983	145,211	201,788	118,778	101,679	65,112	27,423	135,930	10,964	14,412	8,360	27,140	6,897	4,145	2,173	1,203	739	487	335	235	165	447
1984	390,703	99,304	137,934	80,470	66,937	42,243	17,945	89,921	7,300	9,628	5,595	18,186	4,625	2,781	1,458	808	496	327	225	158	411
1985	414,097	267,186	67,885	93,791	53,864	44,409	28,124	12,009	60,367	4,909	6,481	3,769	12,256	3,118	1,875	983	545	335	221	152	384
1986	176,107	283,185	182,641	46,197	63,141	35,971	29,637	18,811	8,050	40,530	3,299	4,359	2,536	8,250	2,099	1,262	662	367	225	149	361
1987	327,204	120,432	193,546	124,094	30,927	41,824	23,856	19,754	12,586	5,398	27,216	2,217	2,931	1,706	5,550	1,412	849	446	247	152	343
1988	309,750	223,762	82,235	130,280	81,099	19,807	26,840	15,487	12,953	8,305	3,575	18,056	1,473	1,948	1,134	3,690	939	565	296	164	329
1989	310,288	211,826	152,816	55,377	85,561	52,351	12,770	17,429	10,130	8,514	5,475	2,360	11,934	974	1,289	750	2,442	622	374	196	326
1990	405,093	212,190	144,747	103,521	36,273	53,945	32,535	7,970	10,973	6,422	5,421	3,494	1,509	7,634	623	825	481	1,564	398	240	335
1991	293,991	277,018	144,910	97,690	67,130	22,147	31,550	18,827	4,651	6,489	3,840	3,269	2,119	919	4,661	381	506	295	960	245	353
1992	253,799	201,042	189,196	97,927	63,764	41,532	13,113	18,326	10,916	2,709	3,799	2,257	1,926	1,251	543	2,759	226	299	175	569	354
1993	328,682	173,559	137,363	128,283	64,575	40,123	25,118	7,803	10,913	6,543	1,634	2,303	1,373	1,174	764	332	1,687	138	183	107	566
1994	259,853	224,768	118,600	93,246	85,038	41,147	24,737	15,289	4,757	6,693	4,037	1,013	1,431	855	732	477	207	1,054	86	115	421
1995	362,095	177,699	153,597	80,534	61,850	54,161	25,281	14,955	9,235	2,888	4,087	2,476	623	882	528	453	295	128	653	53	332
1996	231,215	247,616	121,410	104,178	53,227	39,061	32,754	14,936	8,791	5,449	1,714	2,436	1,481	374	530	317	272	178	77	393	232
1997	205,016	158,115	169,181	82,326	68,683	33,382	23,395	19,175	8,716	5,157	3,217	1,017	1,451	884	224	317	190	163	107	46	375
1998	171,738	140,199	108,008	114,538	53,922	42,366	19,466	13,278	10,863	4,982	2,978	1,873	596	853	521	132	188	113	97	63	250
1999	241,546	117,442	95,792	73,215	75,168	33,300	24,745	11,097	7,580	6,273	2,911	1,757	1,112	355	510	313	79	113	68	58	189
2000	261,777	165,179	80,191	64,549	47,084	44,979	18,901	13,862	6,293	4,380	3,685	1,730	1,052	670	215	309	190	48	69	41	150
2001	194,512	179,016	112,853	54,307	42,378	29,522	27,388	11,483	8,516	3,914	2,750	2,328	1,097	669	426	137	197	121	31	44	122
2002	124,960	133,016	122,268	76,188	35,235	25,988	17,502	16,227	6,912	5,214	2,427	1,720	1,463	692	423	270	87	125	77	19	105
2003	180,017	85,454	90,879	82,615	49,154	21,156	14,934	10,053	9,512	4,138	3,171	1,491	1,063	908	430	263	168	54	78	48	78
2004	156,678	123,104	58,378	61,353	53,203	29,522	12,196	8,615	5,922	5,728	2,533	1,962	928	665	569	270	166	106	34	49	79
2005	236,190	107,144	84,101	39,490	39,817	32,277	17,154	7,071	5,087	3,567	3,501	1,563	1,218	578	415	356	169	104	66	21	81
2006	339,879	161,517	73,205	56,933	25,636	24,072	18,626	9,871	4,145	3,042	2,165	2,145	963	753	359	258	221	105	64	41	63
2007	311,125	232,424	110,356	49,552	36,923	15,464	13,842	10,674	5,763	2,469	1,839	1,321	1,317	593	465	222	159	137	65	40	65
2008	439,749	212,759	158,755	74,445	31,602	21,386	8,391	7,468	5,904	3,277	1,433	1,082	783	784	355	278	133	96	82	39	63
2009	352,985	300,720	145,348	107,136	47,415	18,192	11,485	4,479	4,100	3,346	1,902	845	644	469	472	214	168	80	58	50	62
2010	223,539	241,385	205,392	97,870	67,426	26,587	9,459	5,943	2,390	2,261	1,891	1,092	490	376	275	277	126	99	47	34	66
2011	341,579	152,865	164,894	138,437	61,669	37,720	13,737	4,862	3,157	1,316	1,279	1,088	635	287	221	162	163	74	59	28	59
2012	500,635	233,584	104,410	111,227	87,940	35,193	20,025	7,255	2,642	1,770	755	744	639	375	170	131	96	97	44	35	52
2013	277,041	342,355	159,588	70,684	72,224	53,052	20,167	11,403	4,205	1,563	1,062	457	454	391	230	104	81	59	60	27	54
2014	275,990	189,451	233,877	107,932	45,762	43,391	30,246	11,413	6,565	2,470	932	640	277	276	238	140	64	49	36	37	50

Table 2.21 – Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,y+1}/N_{a,y})-M$) at age (a) and year (y) from Model S1a

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.000	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1978	0.000	0.002	0.008	0.010	0.010	0.009	0.008	0.008	0.007	0.007	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
1979	0.000	0.002	0.008	0.012	0.012	0.011	0.010	0.009	0.009	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1980	0.000	0.004	0.021	0.033	0.030	0.024	0.020	0.018	0.017	0.016	0.015	0.015	0.014	0.014	0.014	0.013	0.013	0.013	0.013
1981	0.000	0.005	0.024	0.036	0.030	0.023	0.018	0.016	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012
1982	0.000	0.005	0.023	0.034	0.029	0.022	0.018	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012	0.011	0.011	0.011	0.011
1983	0.000	0.006	0.033	0.050	0.042	0.032	0.025	0.022	0.021	0.019	0.019	0.018	0.018	0.017	0.017	0.017	0.017	0.017	0.017
1984	0.000	0.004	0.020	0.031	0.028	0.023	0.020	0.018	0.017	0.016	0.015	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013
1985	0.000	0.002	0.009	0.016	0.018	0.016	0.014	0.013	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.010	0.010
1986	0.000	0.004	0.018	0.033	0.035	0.031	0.027	0.025	0.023	0.022	0.021	0.021	0.020	0.020	0.020	0.020	0.020	0.020	0.020
1987	0.001	0.010	0.036	0.057	0.056	0.045	0.035	0.029	0.026	0.024	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.021	0.021
1988	0.000	0.006	0.029	0.050	0.053	0.047	0.039	0.034	0.031	0.029	0.028	0.027	0.027	0.027	0.027	0.027	0.026	0.026	0.026
1989	0.000	0.005	0.035	0.065	0.071	0.062	0.053	0.046	0.042	0.040	0.039	0.038	0.038	0.037	0.037	0.037	0.037	0.037	0.037
1990	0.000	0.005	0.027	0.072	0.112	0.128	0.125	0.115	0.105	0.098	0.093	0.089	0.087	0.085	0.083	0.082	0.082	0.081	0.080
1991	0.000	0.003	0.019	0.060	0.110	0.140	0.149	0.146	0.141	0.137	0.134	0.132	0.131	0.130	0.129	0.128	0.128	0.128	0.127
1992	0.000	0.003	0.021	0.069	0.127	0.162	0.170	0.165	0.158	0.153	0.149	0.146	0.144	0.143	0.142	0.142	0.141	0.141	0.140
1993	0.000	0.002	0.015	0.050	0.093	0.118	0.123	0.118	0.112	0.107	0.103	0.101	0.099	0.098	0.097	0.097	0.096	0.096	0.095
1994	0.000	0.001	0.011	0.038	0.073	0.094	0.099	0.096	0.091	0.087	0.084	0.082	0.081	0.080	0.080	0.079	0.079	0.079	0.078
1995	0.000	0.002	0.014	0.048	0.097	0.134	0.149	0.148	0.142	0.136	0.131	0.128	0.126	0.124	0.123	0.122	0.122	0.122	0.121
1996	0.000	0.002	0.015	0.051	0.099	0.135	0.148	0.147	0.142	0.136	0.132	0.129	0.127	0.126	0.125	0.124	0.124	0.123	0.123
1997	0.000	0.004	0.020	0.063	0.120	0.161	0.175	0.172	0.163	0.155	0.149	0.145	0.142	0.140	0.139	0.138	0.138	0.137	0.136
1998	0.000	0.003	0.017	0.058	0.117	0.160	0.173	0.168	0.158	0.149	0.142	0.137	0.134	0.132	0.130	0.129	0.128	0.128	0.127
1999	0.000	0.003	0.019	0.068	0.141	0.192	0.207	0.198	0.184	0.170	0.160	0.154	0.149	0.146	0.144	0.142	0.141	0.140	0.139
2000	0.000	0.003	0.021	0.074	0.137	0.164	0.157	0.139	0.123	0.112	0.105	0.100	0.097	0.096	0.095	0.094	0.093	0.093	0.092
2001	0.000	0.005	0.025	0.072	0.120	0.137	0.128	0.112	0.098	0.088	0.082	0.078	0.076	0.074	0.073	0.072	0.072	0.072	0.071
2002	0.000	0.004	0.027	0.084	0.141	0.160	0.150	0.131	0.114	0.104	0.097	0.093	0.090	0.088	0.087	0.086	0.086	0.086	0.085
2003	0.000	0.005	0.027	0.082	0.142	0.165	0.155	0.134	0.115	0.102	0.094	0.089	0.086	0.084	0.083	0.082	0.081	0.081	0.080
2004	0.000	0.005	0.029	0.091	0.158	0.184	0.171	0.146	0.124	0.110	0.100	0.095	0.091	0.089	0.087	0.086	0.085	0.085	0.084

2005	0.000	0.003	0.021	0.073	0.133	0.159	0.150	0.131	0.115	0.104	0.097	0.093	0.090	0.089	0.088	0.087	0.086	0.086	0.085
2006	0.000	0.003	0.021	0.075	0.143	0.172	0.164	0.144	0.127	0.115	0.108	0.103	0.101	0.099	0.098	0.097	0.096	0.096	0.096
2007	0.000	0.004	0.029	0.099	0.180	0.213	0.200	0.174	0.152	0.137	0.128	0.122	0.119	0.116	0.115	0.114	0.113	0.113	0.112
2008	0.000	0.006	0.038	0.121	0.218	0.257	0.243	0.211	0.184	0.165	0.153	0.146	0.142	0.139	0.137	0.136	0.135	0.134	0.133
2009	0.000	0.005	0.030	0.104	0.192	0.231	0.218	0.188	0.163	0.145	0.134	0.128	0.124	0.121	0.119	0.118	0.117	0.117	0.116
2010	0.000	0.006	0.038	0.134	0.250	0.301	0.285	0.248	0.215	0.192	0.178	0.170	0.165	0.161	0.159	0.158	0.156	0.156	0.155
2011	0.000	0.004	0.035	0.129	0.243	0.290	0.273	0.235	0.204	0.183	0.169	0.161	0.157	0.153	0.151	0.150	0.149	0.148	0.148
2012	0.000	0.004	0.028	0.101	0.190	0.229	0.219	0.193	0.171	0.156	0.147	0.141	0.137	0.135	0.134	0.133	0.132	0.132	0.131
2013	0.000	0.004	0.024	0.083	0.151	0.180	0.172	0.152	0.135	0.123	0.115	0.111	0.108	0.106	0.105	0.104	0.104	0.103	0.103

Table 2.22 – Results for the projection scenarios from Model S1a. ABC, OFL, Catch, Female Spawning Stock Biomass (SSB), and Total Biomass (Total Bio) in metric tons. Fishing mortality (F) is also presented.

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	121,847	145,783	82,908	165,670	0.321	585,479
2015	117,211	140,342	117,211	155,441	0.502	583,864
2016	110,799	133,133	110,799	150,466	0.502	558,273
2017	113,542	136,286	113,542	154,334	0.502	545,916
2018	107,605	128,850	107,605	142,594	0.502	516,949
2019	97,622	116,535	97,622	130,872	0.497	493,401
2020	90,869	108,604	90,869	127,701	0.474	485,089
2021	90,930	108,775	90,930	128,959	0.467	485,433
2022	91,674	109,646	91,674	129,976	0.465	485,234
2023	91,378	109,288	91,378	128,612	0.468	482,608
2024	90,661	108,375	90,661	127,268	0.471	481,520
2025	89,887	107,469	89,887	126,837	0.468	482,686
2026	90,288	108,063	90,288	127,418	0.468	486,003
2027	91,585	109,664	91,585	128,947	0.469	490,241
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	65,152	145,783	82,908	165,670	0.321	585,479
2015	62,586	140,342	62,586	160,420	0.246	583,864
2016	67,208	151,830	67,208	176,185	0.246	609,394
2017	74,196	166,971	74,196	194,532	0.246	630,270
2018	75,593	168,756	75,593	193,227	0.246	624,950
2019	72,474	161,933	72,474	185,914	0.246	612,517
2020	70,218	157,473	70,218	182,878	0.246	605,669
2021	69,793	156,572	69,793	182,643	0.246	602,562
2022	69,868	156,580	69,868	182,646	0.246	599,832
2023	69,366	155,247	69,366	180,711	0.246	595,729
2024	68,590	153,503	68,590	178,842	0.246	593,496
2025	68,140	152,575	68,140	177,937	0.246	593,751
2026	68,170	152,640	68,170	178,076	0.246	596,083
2027	68,679	153,577	68,679	179,483	0.246	599,940
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	59,848	145,783	82,908	165,670	0.321	585,479
2015	57,485	140,342	57,485	160,851	0.224	583,864
2016	62,440	153,594	62,440	178,649	0.224	614,200
2017	69,434	170,093	69,434	198,677	0.224	638,827
2018	71,243	173,045	71,243	198,764	0.224	636,581
2019	68,673	166,932	68,673	192,298	0.224	626,112

2020	66,671	162,696	66,671	189,643	0.224	620,177
2021	66,288	161,921	66,288	189,582	0.224	617,476
2022	66,376	161,975	66,376	189,695	0.224	614,989
2023	65,938	160,664	65,938	187,833	0.224	611,047
2024	65,228	158,957	65,228	185,977	0.224	608,858
2025	64,800	158,059	64,800	185,049	0.224	609,069
2026	64,814	158,134	64,814	185,159	0.224	611,340
2027	65,275	159,107	65,275	186,553	0.224	615,166
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	0	145,783	82,908	165,670	0.321	585,479
2015	0	140,342	0	165,375	0.000	583,864
2016	0	173,665	0	207,097	0.000	668,692
2017	0	208,477	0	250,340	0.000	743,768
2018	0	229,102	0	272,490	0.000	789,072
2019	0	236,503	0	283,148	0.000	816,632
2020	0	239,660	0	291,776	0.000	836,146
2021	0	242,768	0	299,007	0.000	849,764
2022	0	245,527	0	304,178	0.000	858,434
2023	0	246,448	0	305,913	0.000	862,427
2024	0	246,110	0	306,279	0.000	865,276
2025	0	245,679	0	306,519	0.000	868,184
2026	0	245,947	0	307,199	0.000	871,783
2027	0	247,228	0	308,986	0.000	876,462
Scenario 6, Whether Pacific cod are overfished – $SB_{35\%}$ = 110,700						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	145,783	145,783	82,908	165,670	0.321	585,479
2015	140,342	140,342	140,342	153,102	0.626	583,864
2016	125,338	125,338	125,338	139,970	0.626	536,837
2017	124,742	124,742	124,742	139,487	0.626	514,014
2018	113,855	113,855	113,855	125,448	0.619	479,282
2019	95,368	95,368	95,368	114,715	0.561	456,071
2020	93,558	93,558	93,558	114,804	0.548	456,282
2021	95,915	95,915	95,915	117,018	0.548	459,204
2022	96,974	96,974	96,974	117,942	0.548	458,862
2023	96,049	96,049	96,049	116,386	0.550	455,714
2024	94,789	94,789	94,789	115,183	0.550	454,814
2025	94,402	94,402	94,402	115,021	0.549	456,659
2026	95,275	95,275	95,275	115,659	0.551	460,170
2027	96,966	96,966	96,966	117,027	0.554	464,097
Scenario 7, Whether Pacific cod is approaching overfished condition						

Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	145,783	145,783	82,908	165,670	0.321	585,479
2015	140,342	140,342	117,211	155,441	0.502	583,864
2016	133,133	133,133	110,799	150,466	0.502	558,273
2017	136,286	136,286	136,286	152,162	0.626	545,916
2018	120,870	120,870	120,870	131,958	0.626	495,491
2019	99,218	99,218	99,218	117,325	0.573	462,674
2020	94,277	94,277	94,277	115,469	0.551	457,825
2021	95,996	95,996	95,996	117,189	0.548	459,566
2022	96,975	96,975	96,975	117,996	0.548	458,972
2023	96,045	96,045	96,045	116,407	0.550	455,756
2024	94,788	94,788	94,788	115,193	0.550	454,833
2025	94,402	94,402	94,402	115,025	0.549	456,667
2026	95,275	95,275	95,275	115,660	0.551	460,173
2027	96,966	96,966	96,966	117,028	0.554	464,098

Table 2.23 – Biological reference points from GOA Pacific cod SAFE documents for years 2001 – 2014

Year	**$SB_{100\%}$**	**$SB_{40\%}$**	**$F_{40\%}$**	**SB_{y+1}**	**ABC_{y+1}**
2001	212,000	85,000	0.41	82,000	57,600
2002	226,000	90,300	0.35	88,300	52,800
2003	222,000	88,900	0.34	103,000	62,810
2004	211,000	84,400	0.31	91,700	58,100
2005	329,000	132,000	0.56	165,000	68,859
2006	259,000	103,000	0.46	136,000	68,859
2007	302,000	121,000	0.49	108,000	66,493
2008	255,500	102,200	0.52	88,000	55,300
2009	291,500	116,600	0.49	117,600	79,100
2010	256,300	102,500	0.42	124,100	86,800
2011	261,000	104,000	0.44	121,000	87,600
2012	234,800	93,900	0.49	111,000	80,800
2013	227,800	91,100	0.54	120,100	88,500
2014	*316,500*	*126,600*	*0.50*	*155,400*	*117,200*

Figures

Fig. 2.1 – Fishery catches by season and gear (AKFIN; as of 2014-10-14)

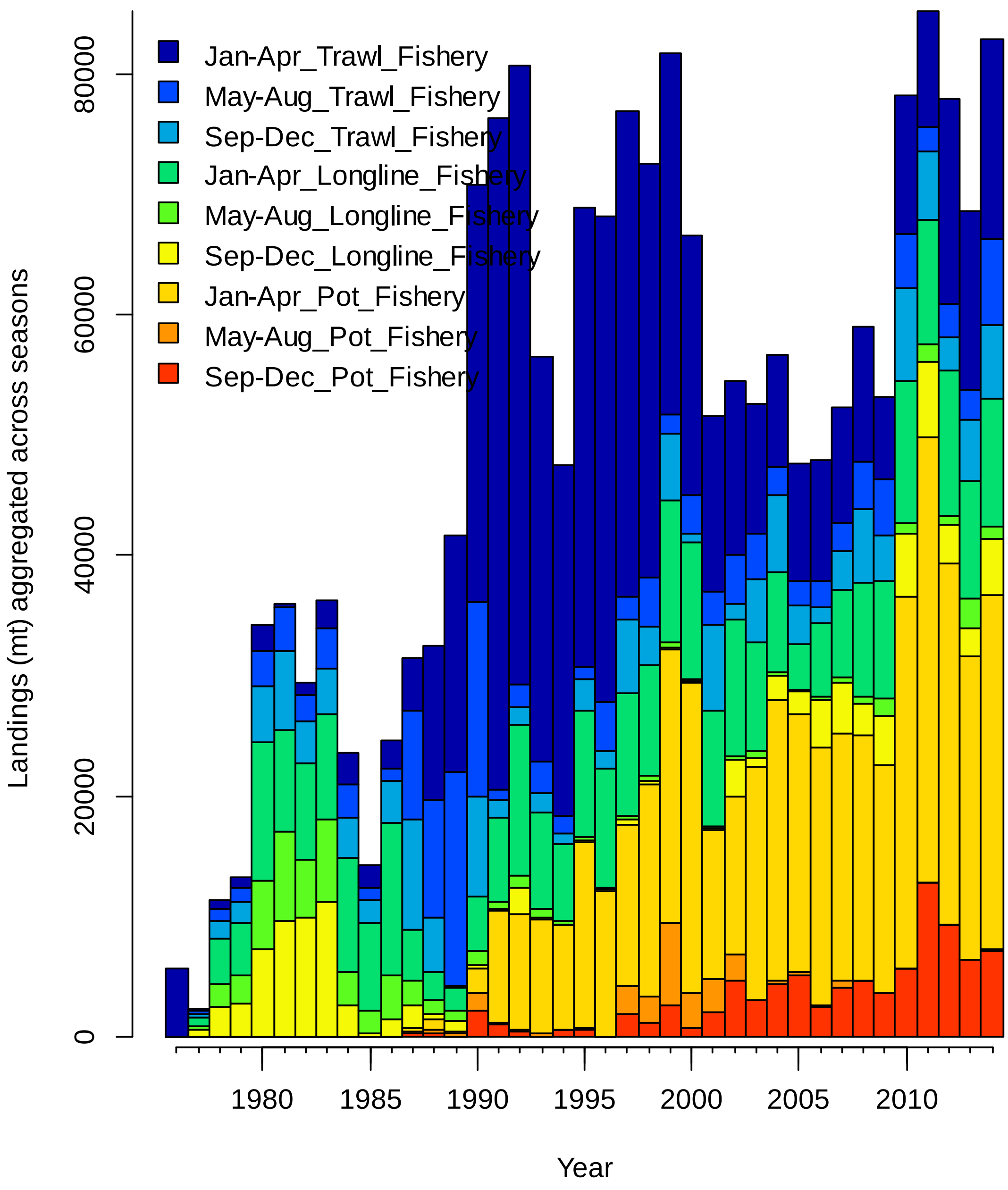


Fig. 2.2 – GOA NMFS bottom trawl survey biomass estimates for Pacific cod, with 95% confidence interval

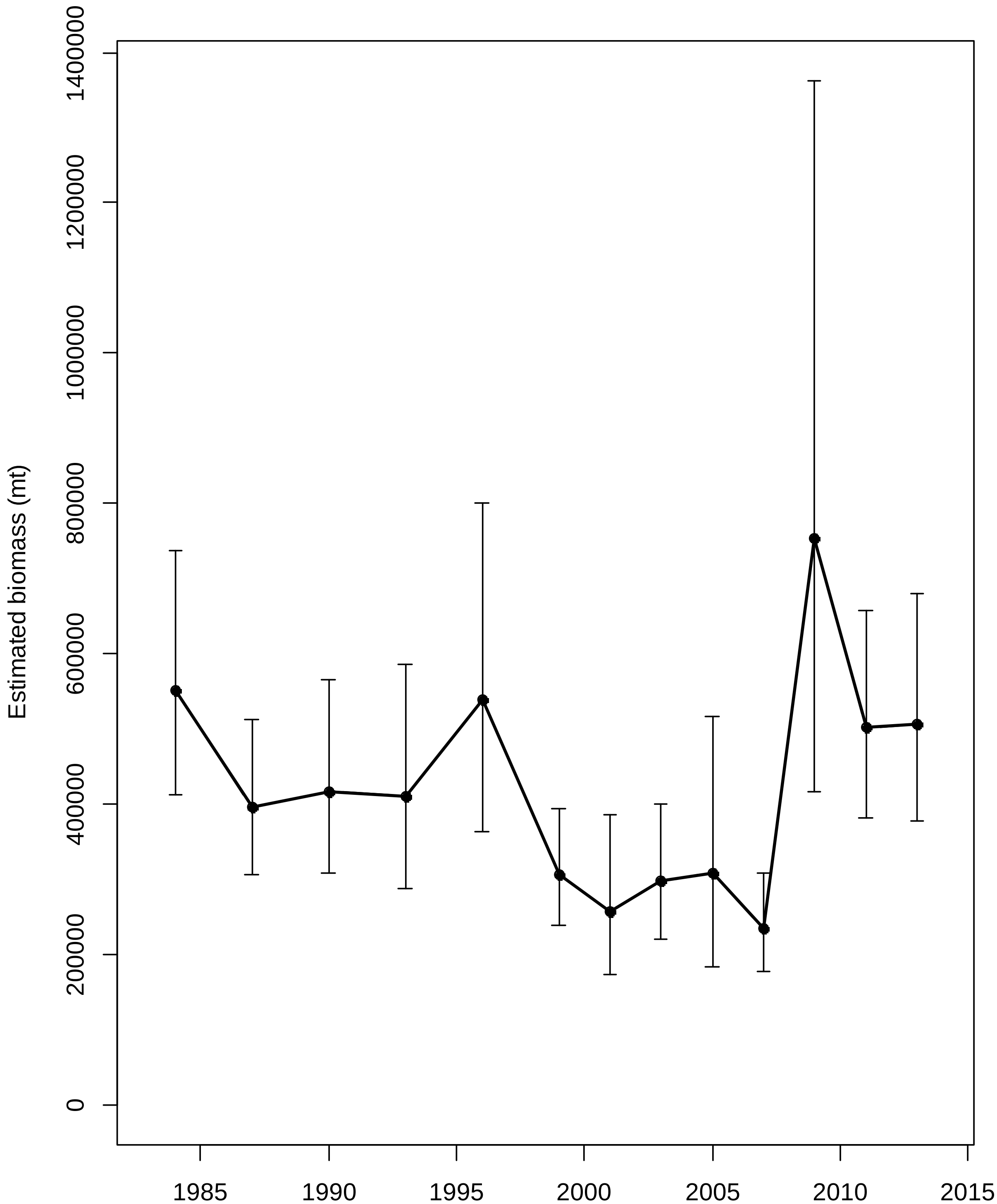


Fig. 2.3 – GOA NMFS survey abundance estimates for Pacific cod, with 95% confidence interval

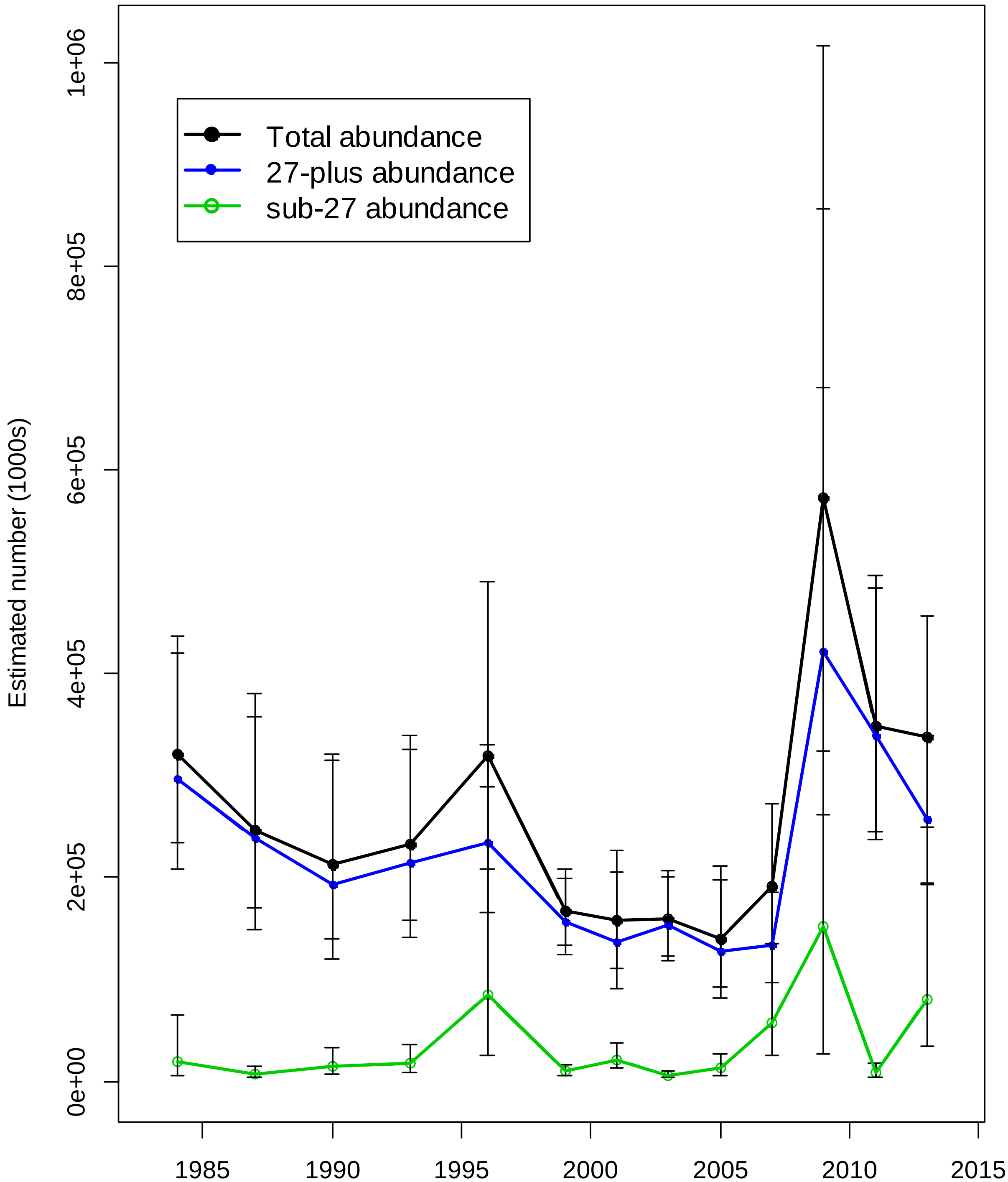


Fig. 2.4 – GOA NMFS bottom trawl survey biomass estimates by area (in t)

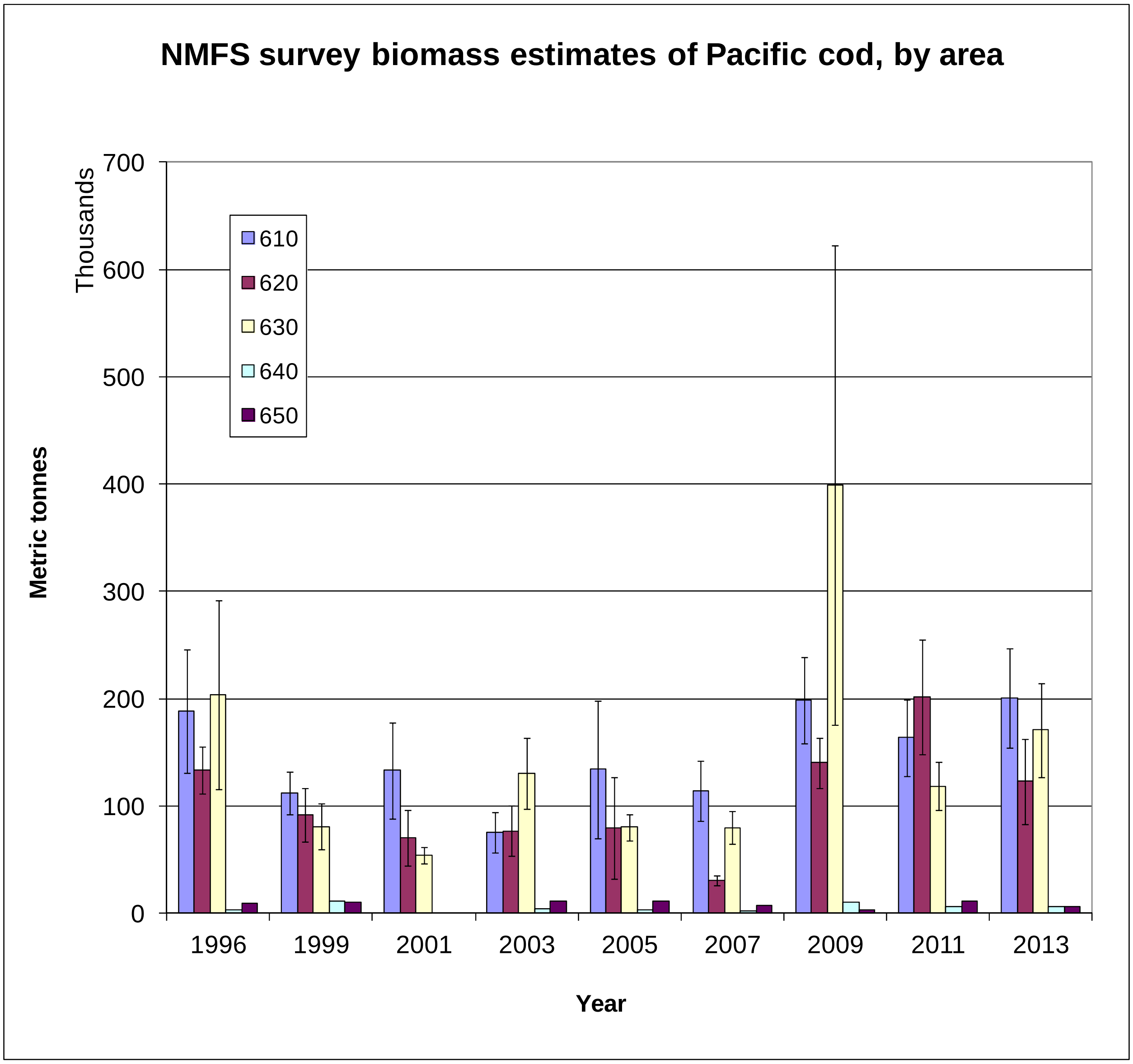


Fig. 2.5 – GOA NMFS bottom trawl survey abundance estimates by area (in numbers)

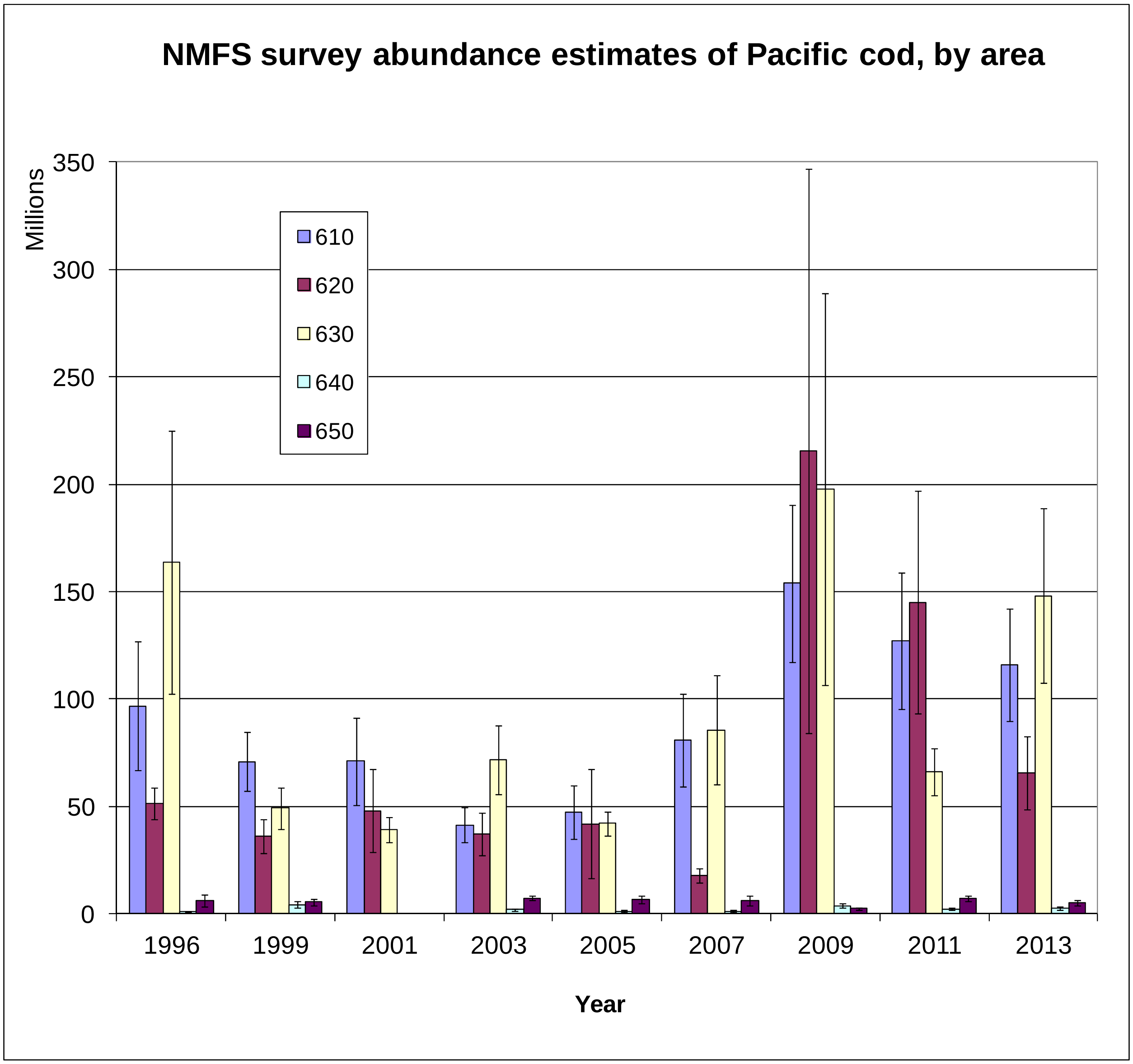


Fig. 2.6 – GOA NMFS bottom trawl population length composition estimates for Pacific cod, by cm

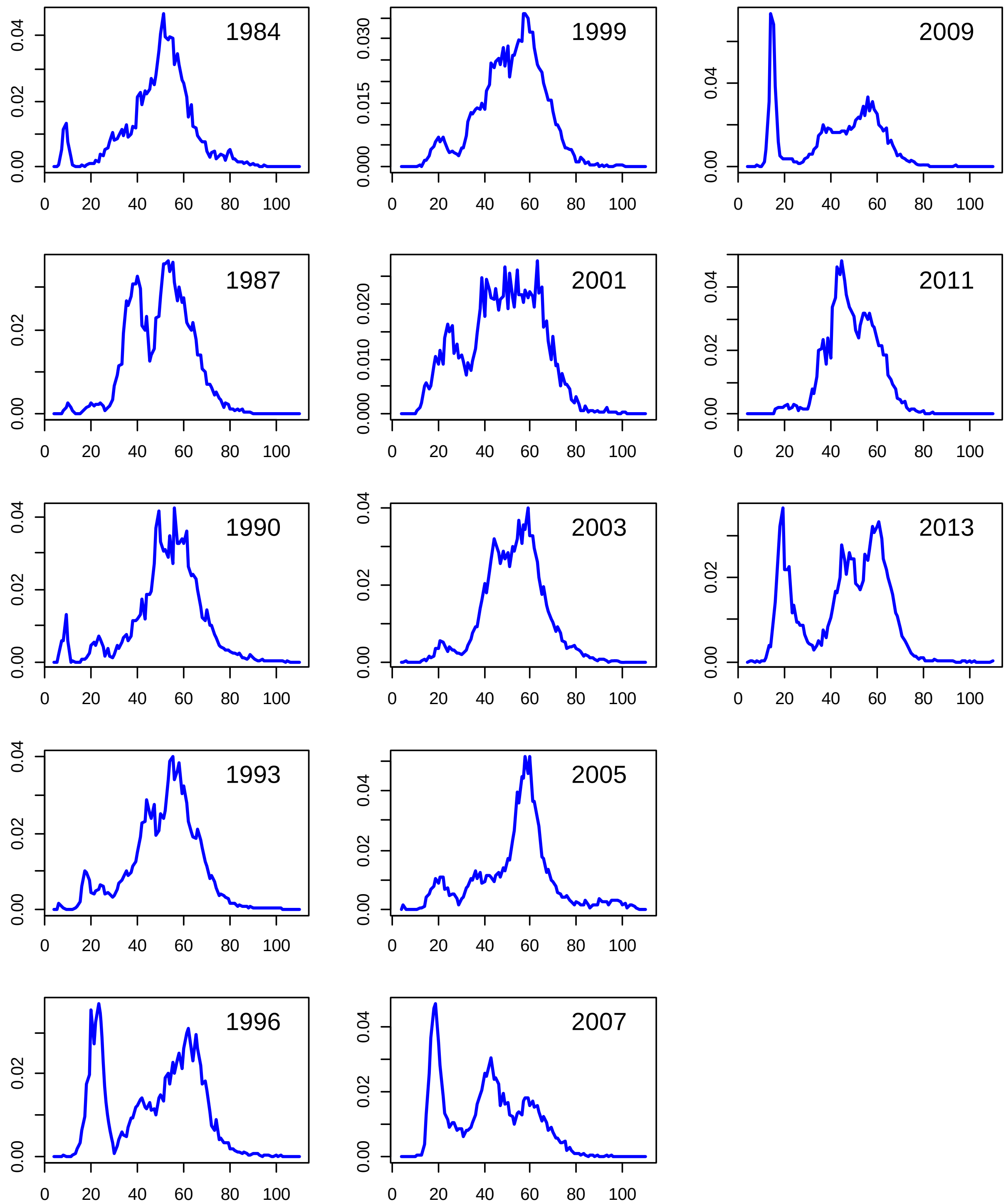


Fig. 2.7 – GOA NMFS bottom trawl population age composition estimates for Pacific cod

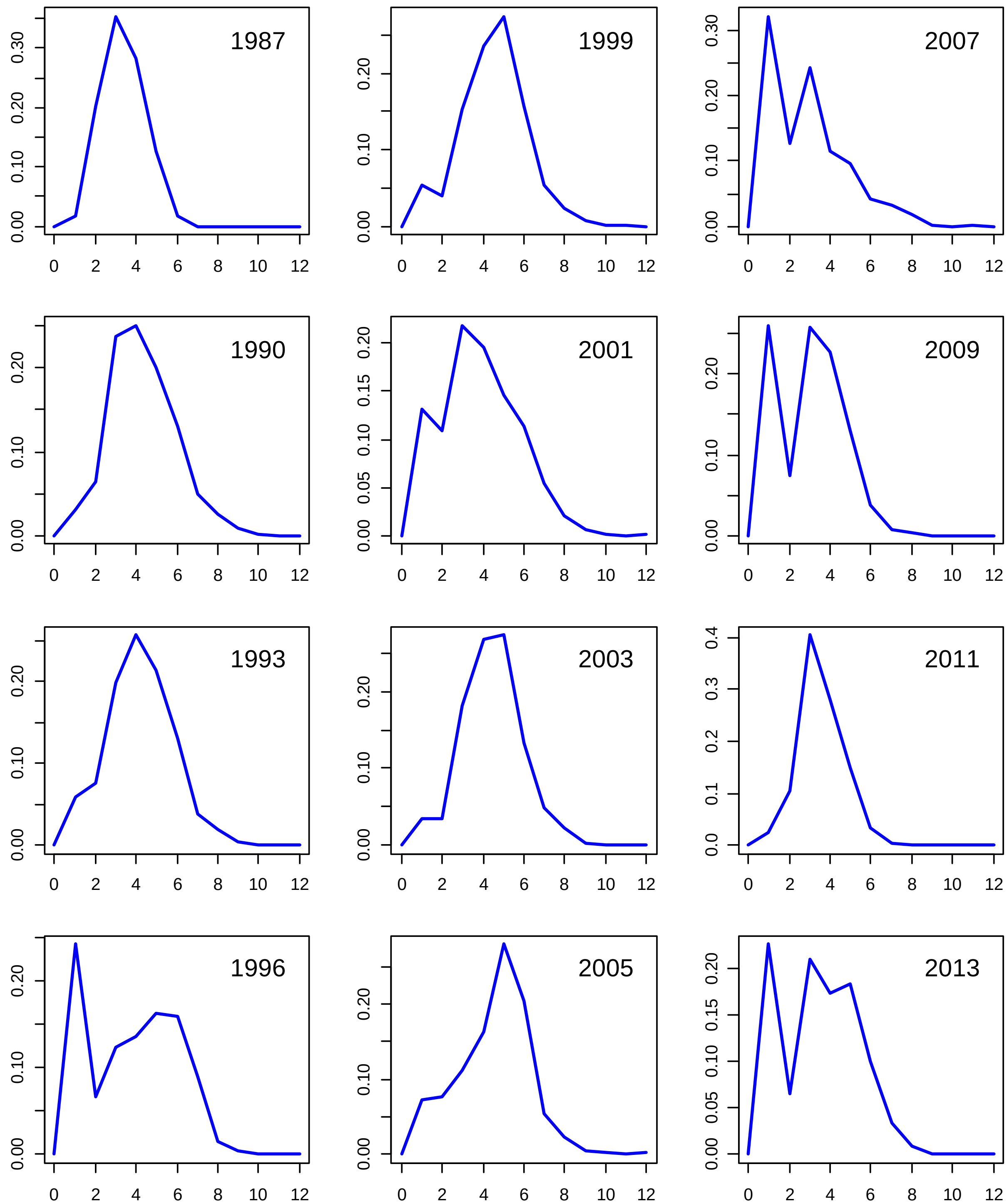


Fig. 2.8 – Estimates of spawning biomass for the 4 models evaluated

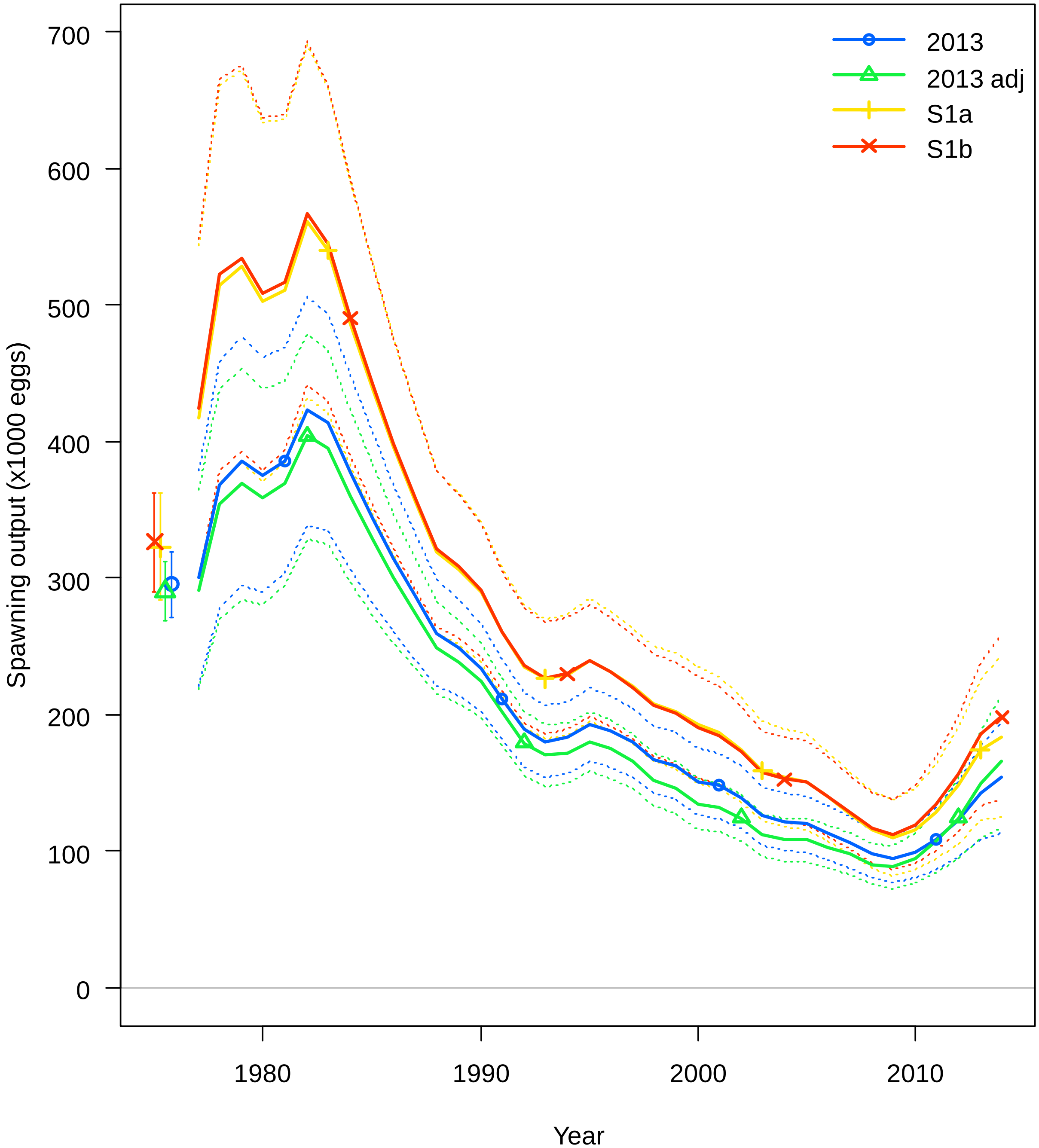


Fig. 2.9 – Estimates of age-0 recruits (billions) for the 4 models evaluated

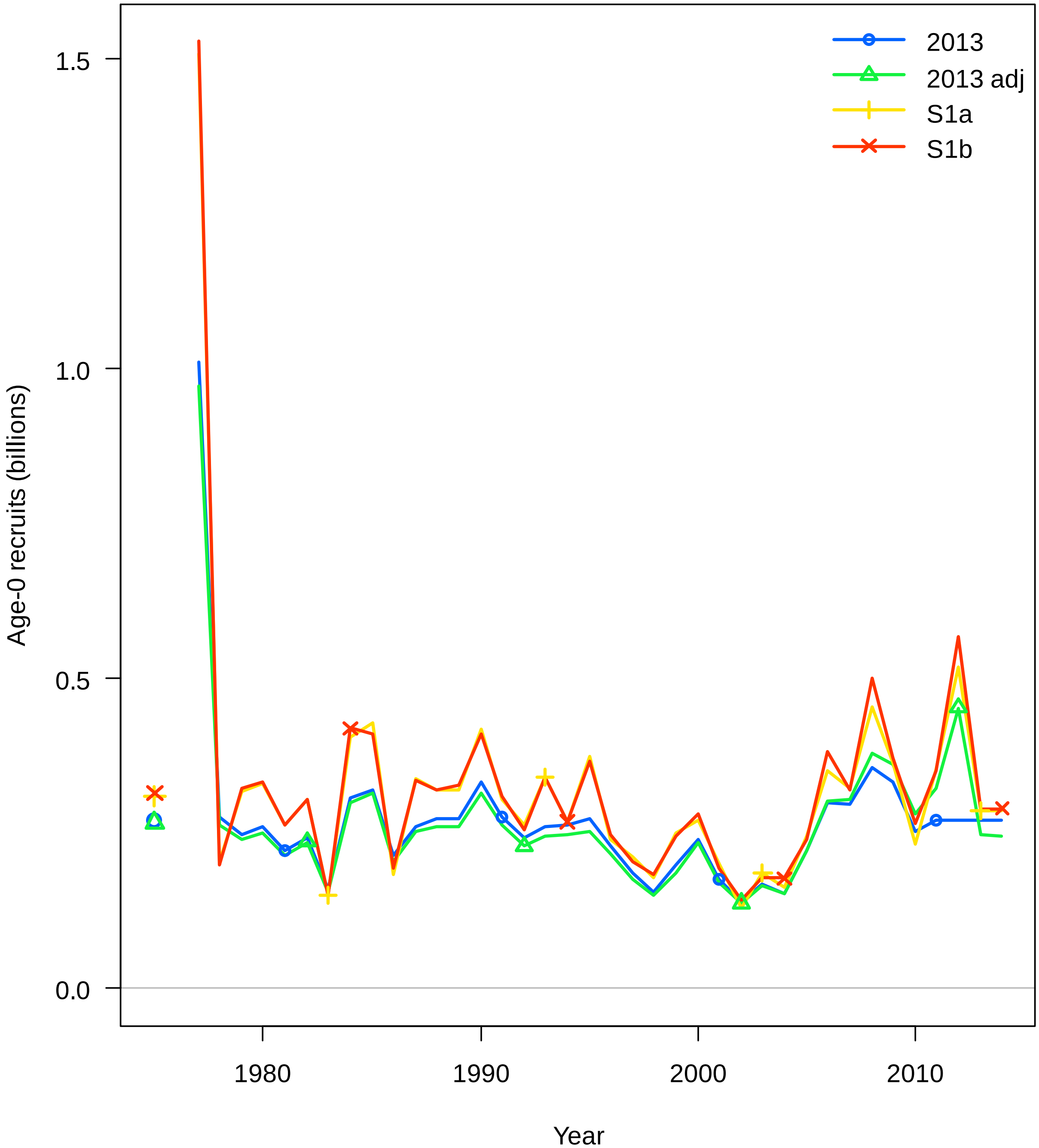


Fig. 2.10 – Fits (solid lines) to the 27-plus survey abundance estimates (solid circles, with 95% confidence intervals) for the 2013 models, and the full survey abundance estimates (solid circles, with 95% confidence intervals) for Models S1a and S1b

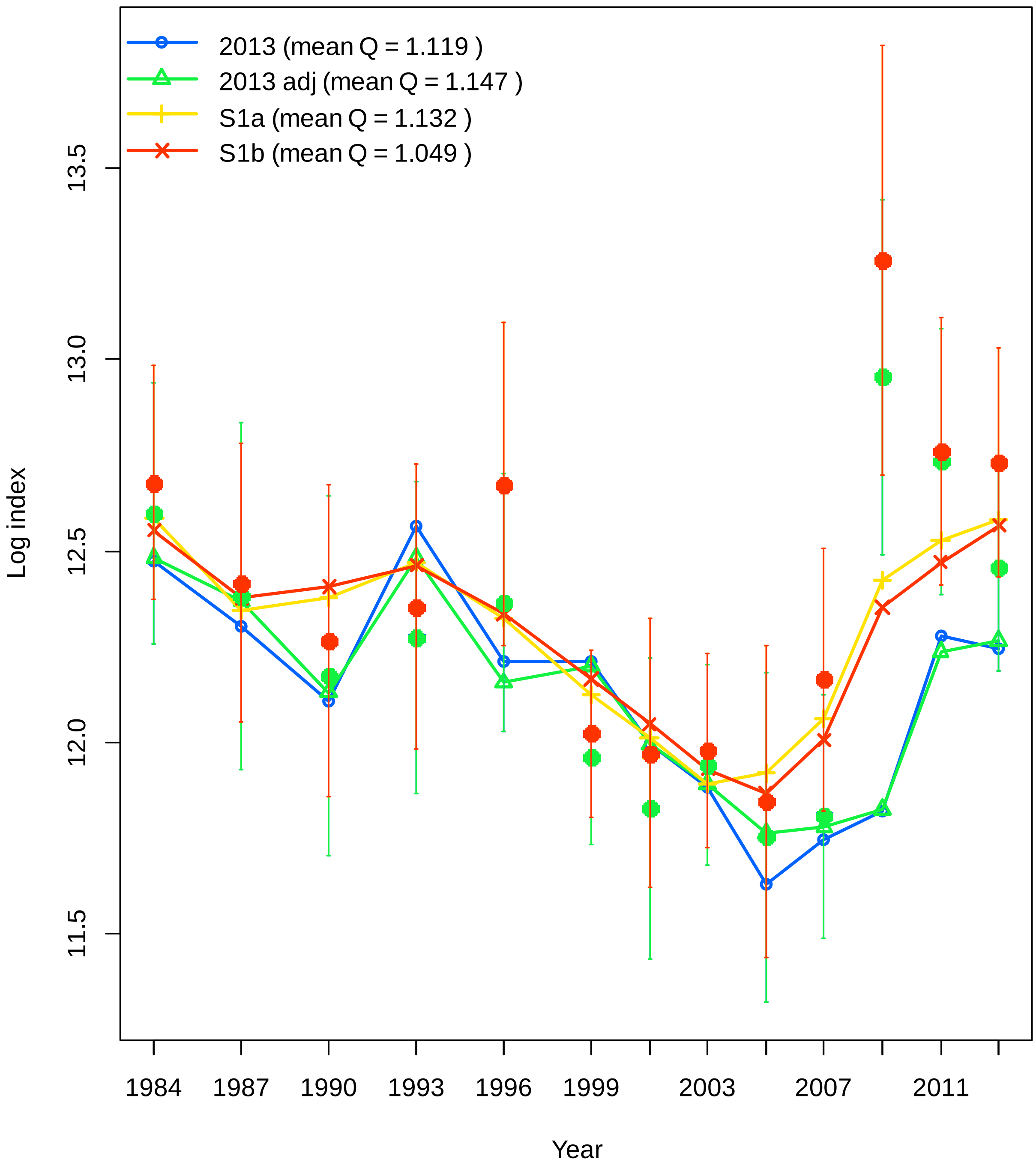


Fig. 2.11 – Estimates of total (age 0+) biomass from Model S1a

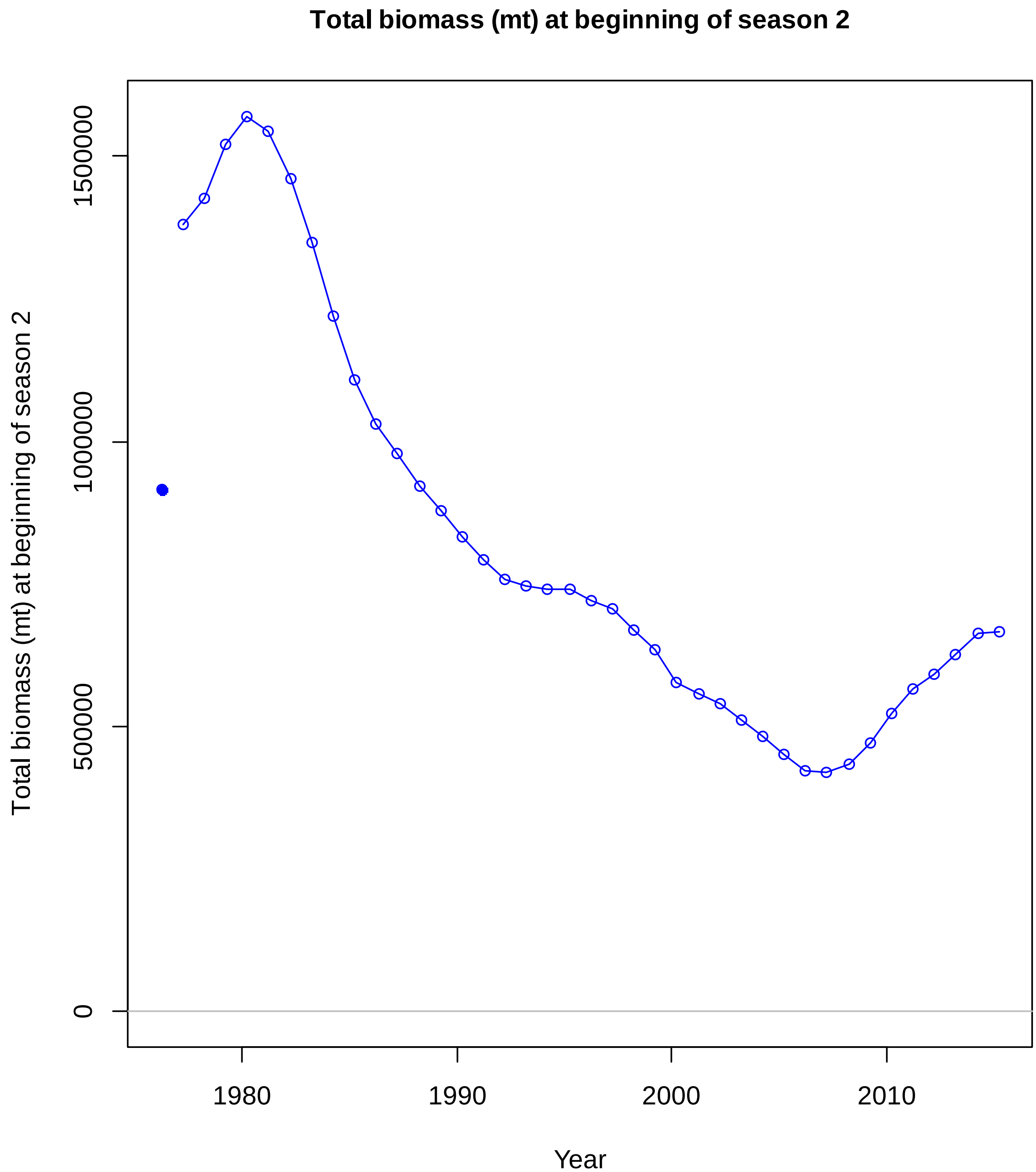


Fig. 2.12 – Estimates of female spawning biomass from Model S1a

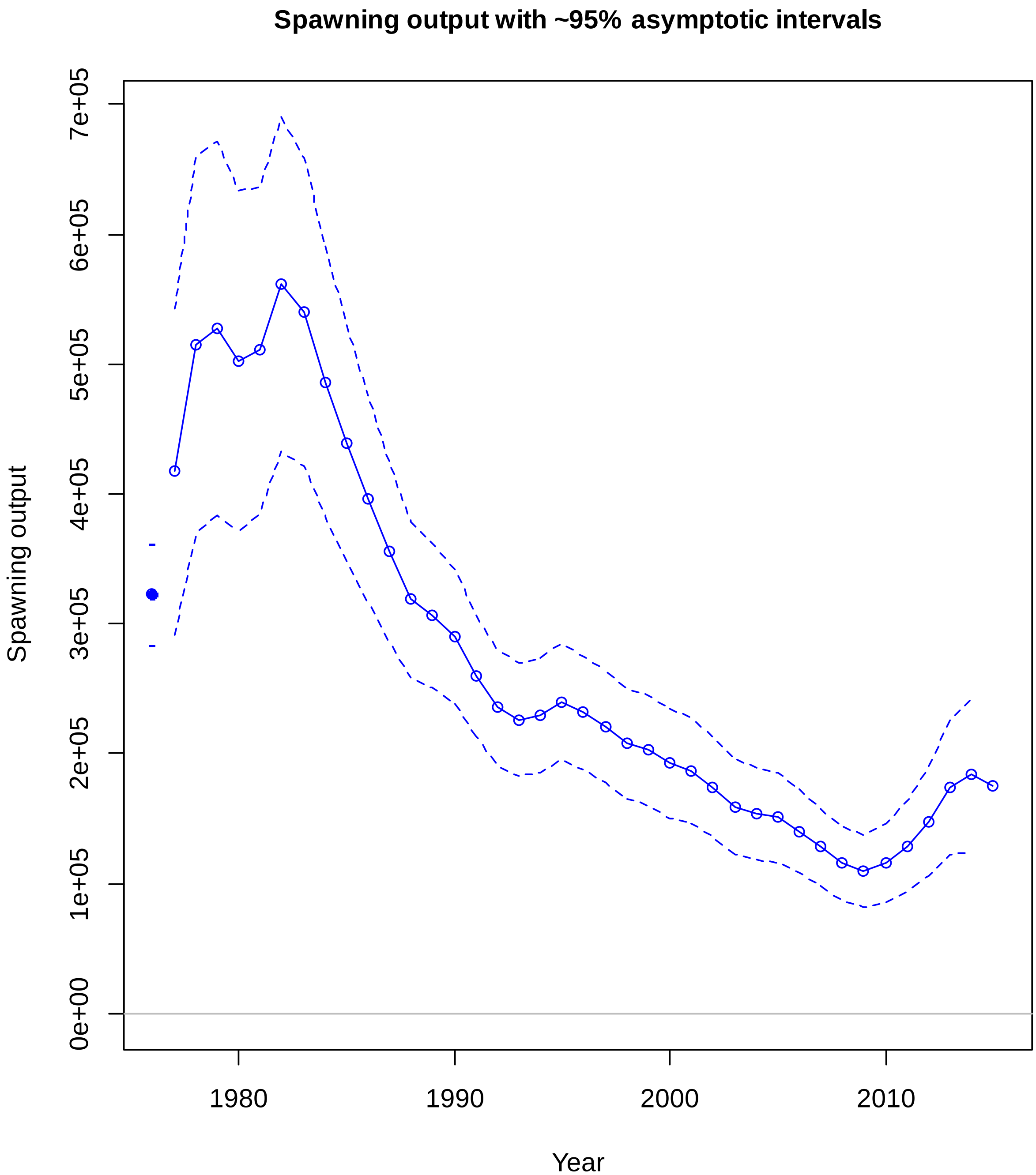


Fig. 2.13 – Estimates of age-0 recruits from Model S1a

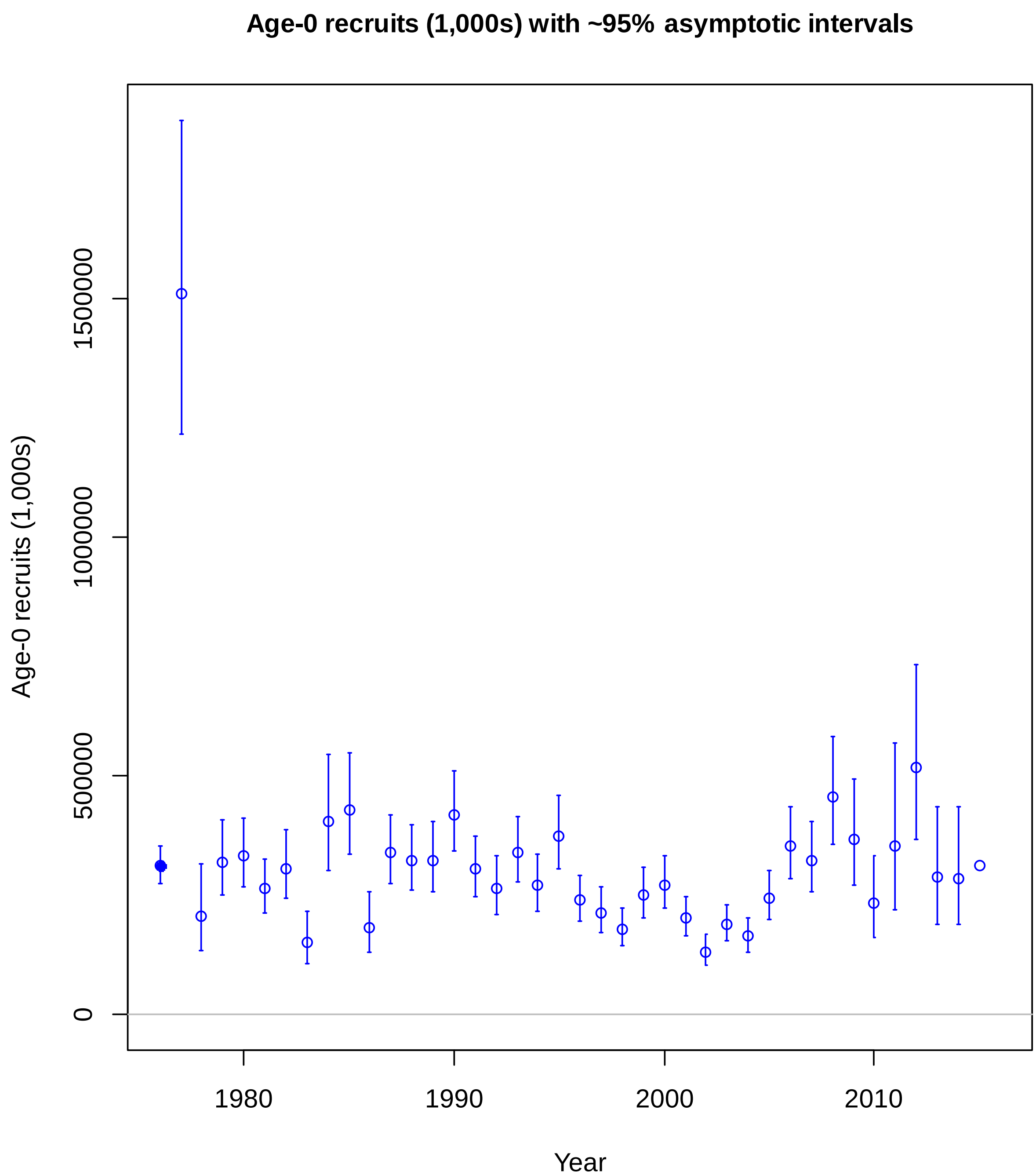
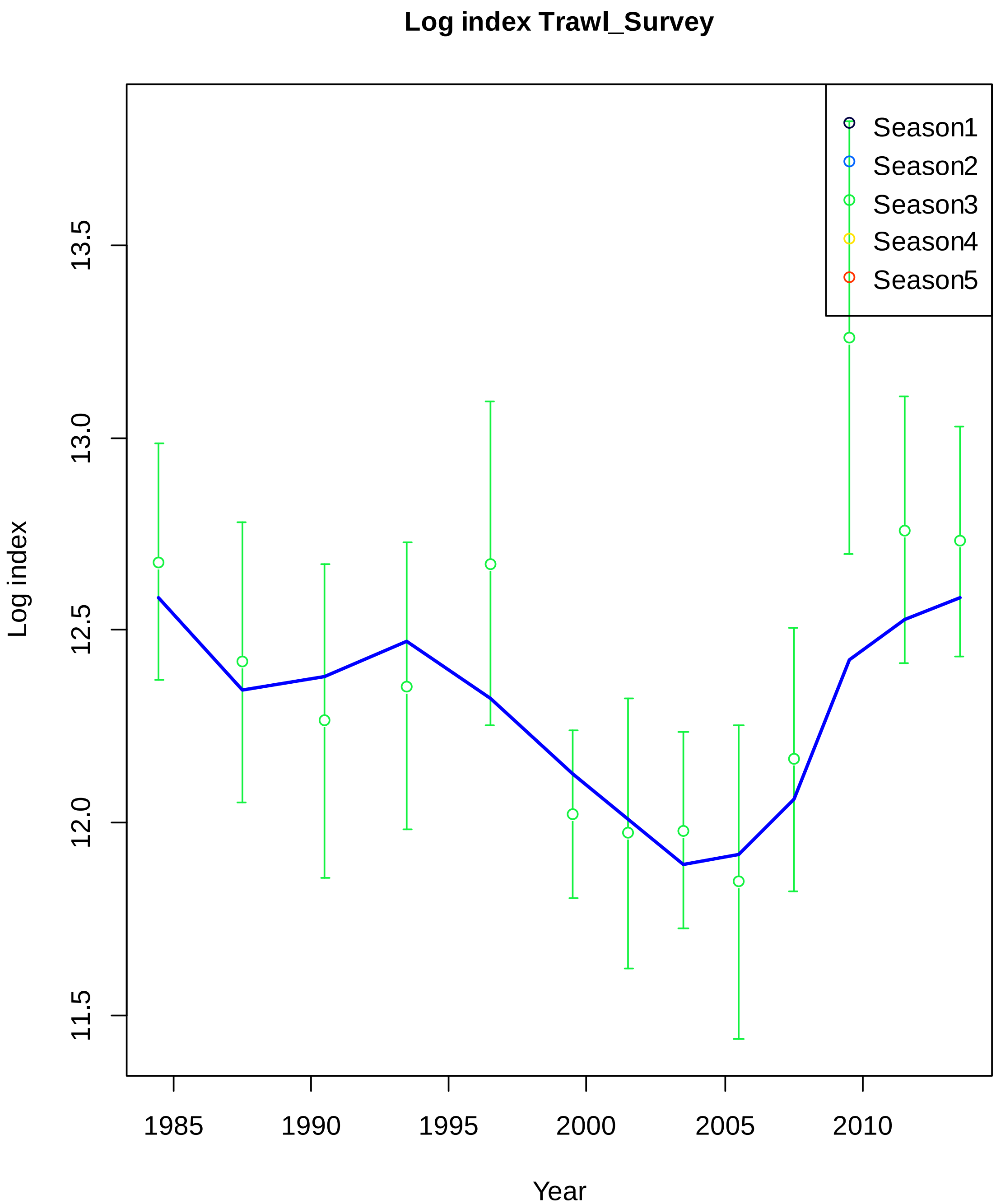


Fig. 2.14 – Fit (solid line) to the abundance estimates (open circles) from the GOA NMFS bottom trawl survey with 95% confidence intervals from Model S1a



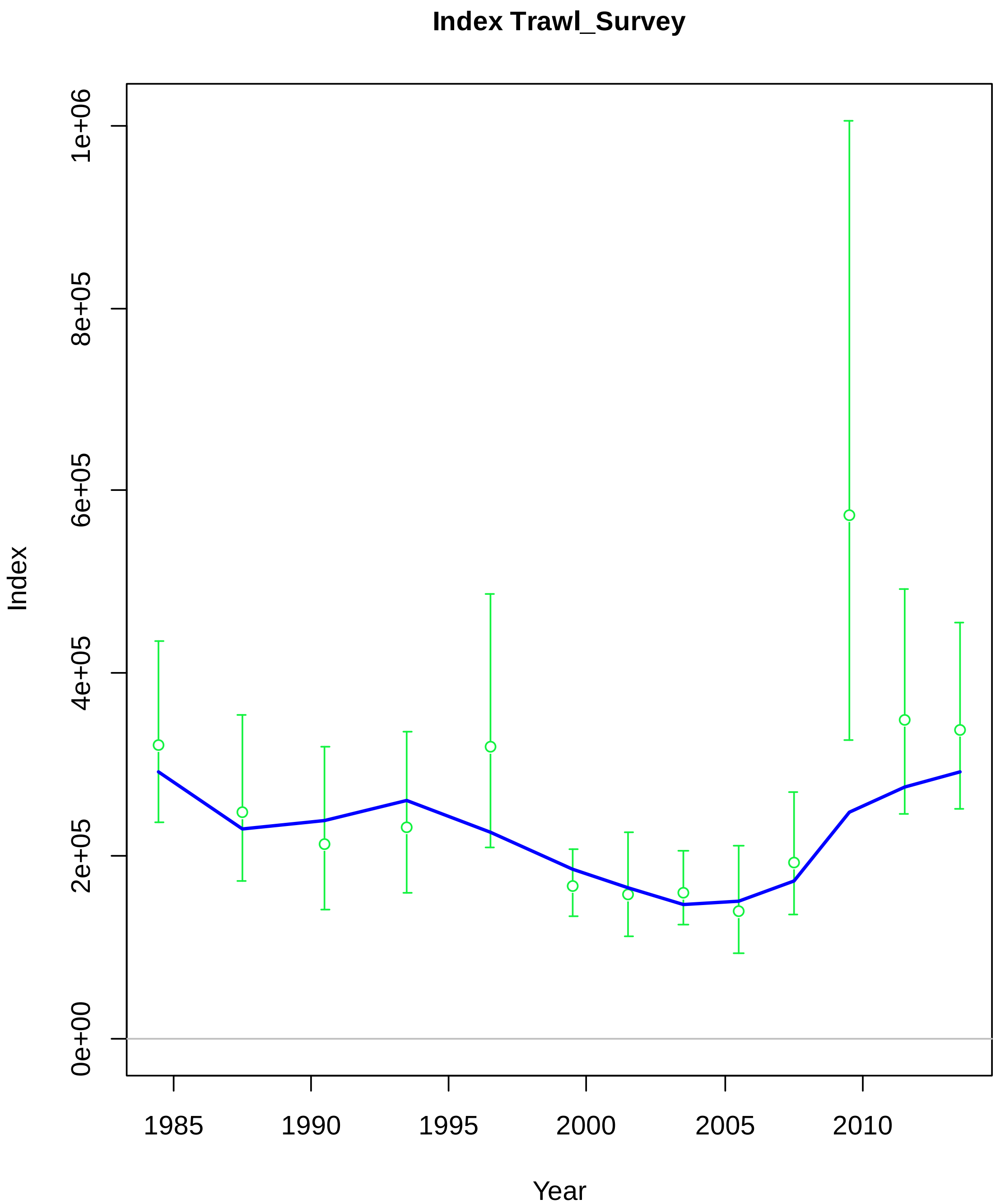

Index Trawl_Survey
Index
0e+00
2e+05
4e+05
6e+05
8e+05
1e+06
1985
1990
1995
2000
2005
2010
Year

Fig. 2.15 – Estimates of spawning biomass (t) and age-0 recruits from Model S1a; the solid black line is the median, and the solid green line is the bias-adjusted median

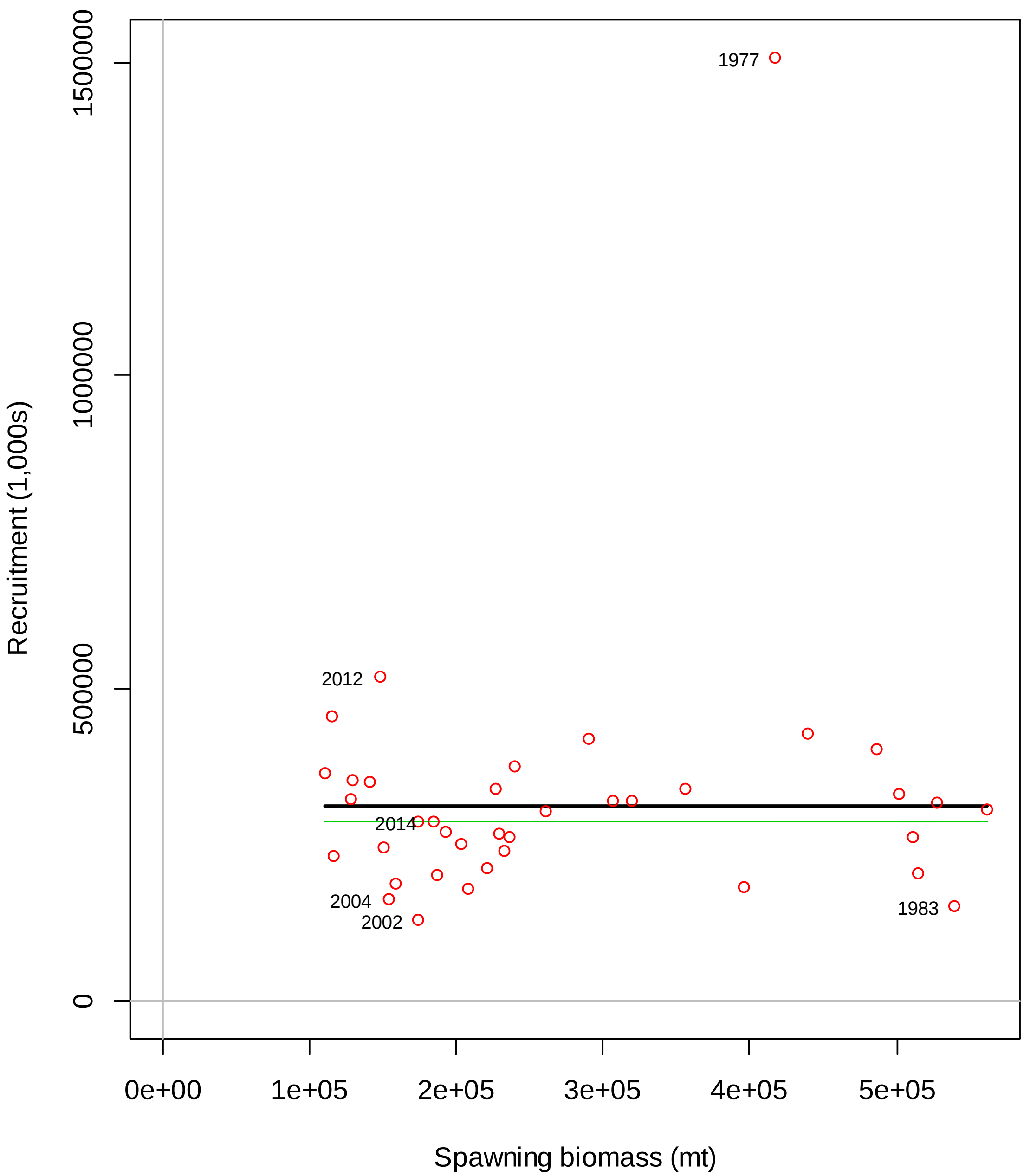
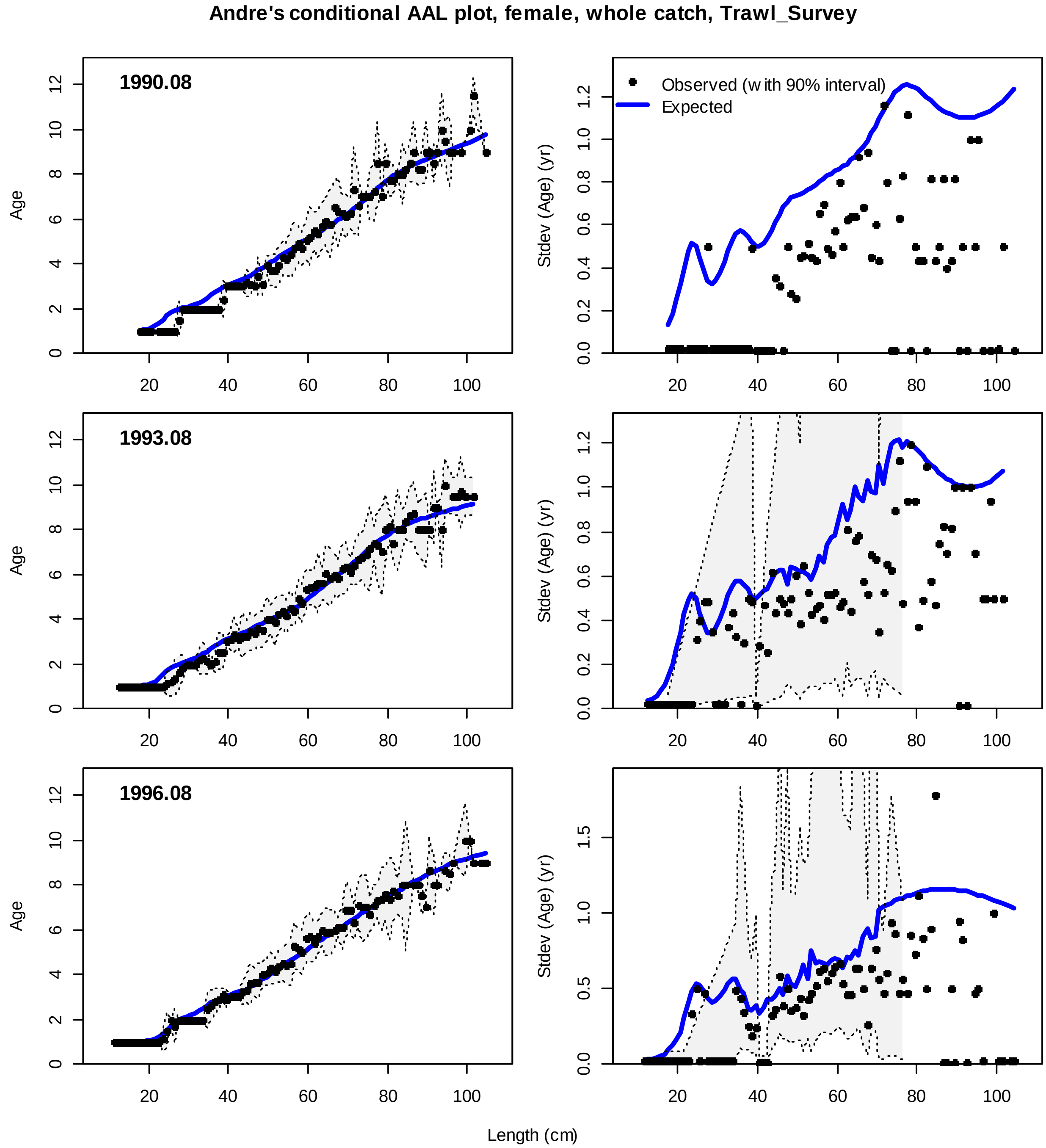
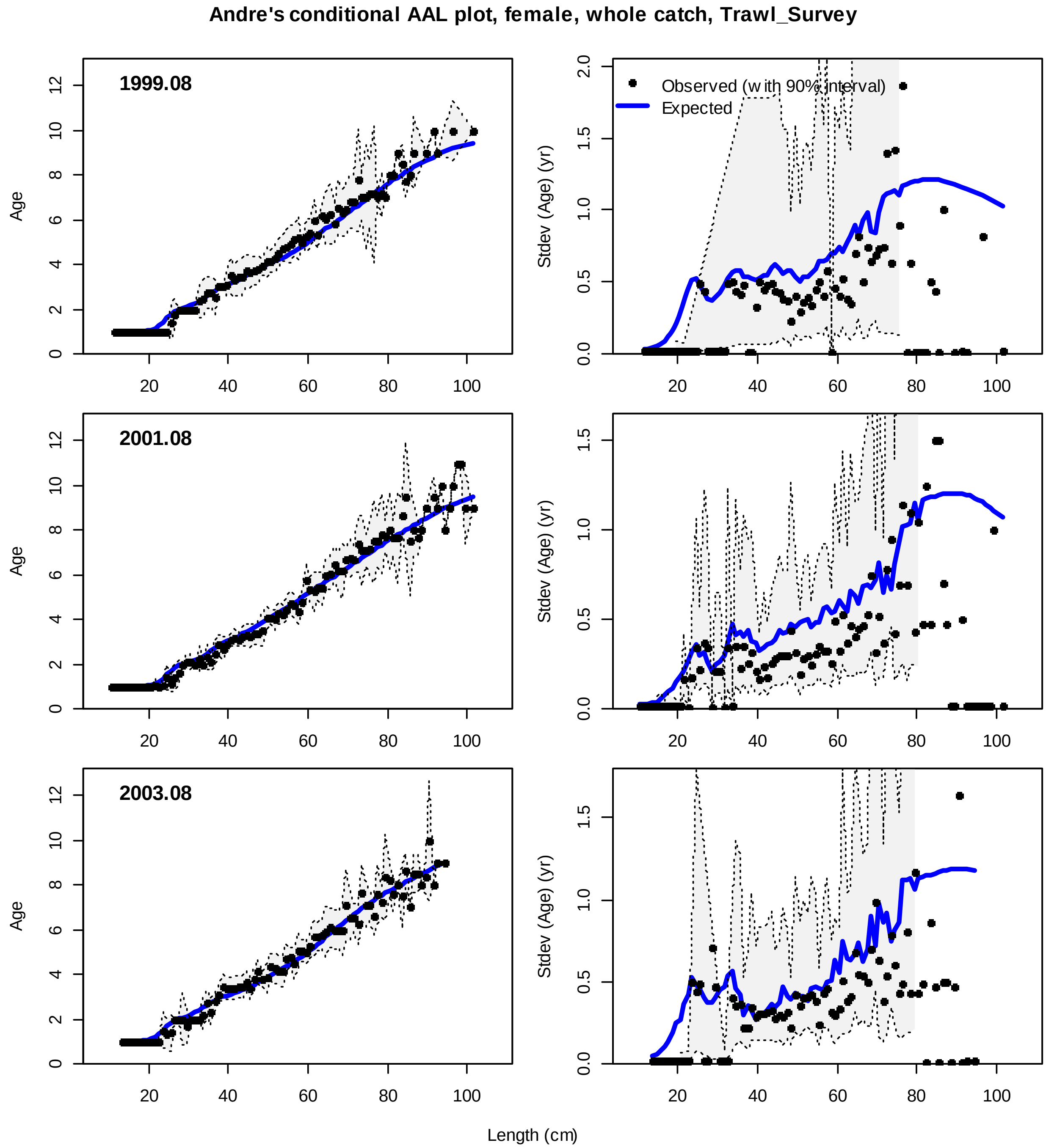
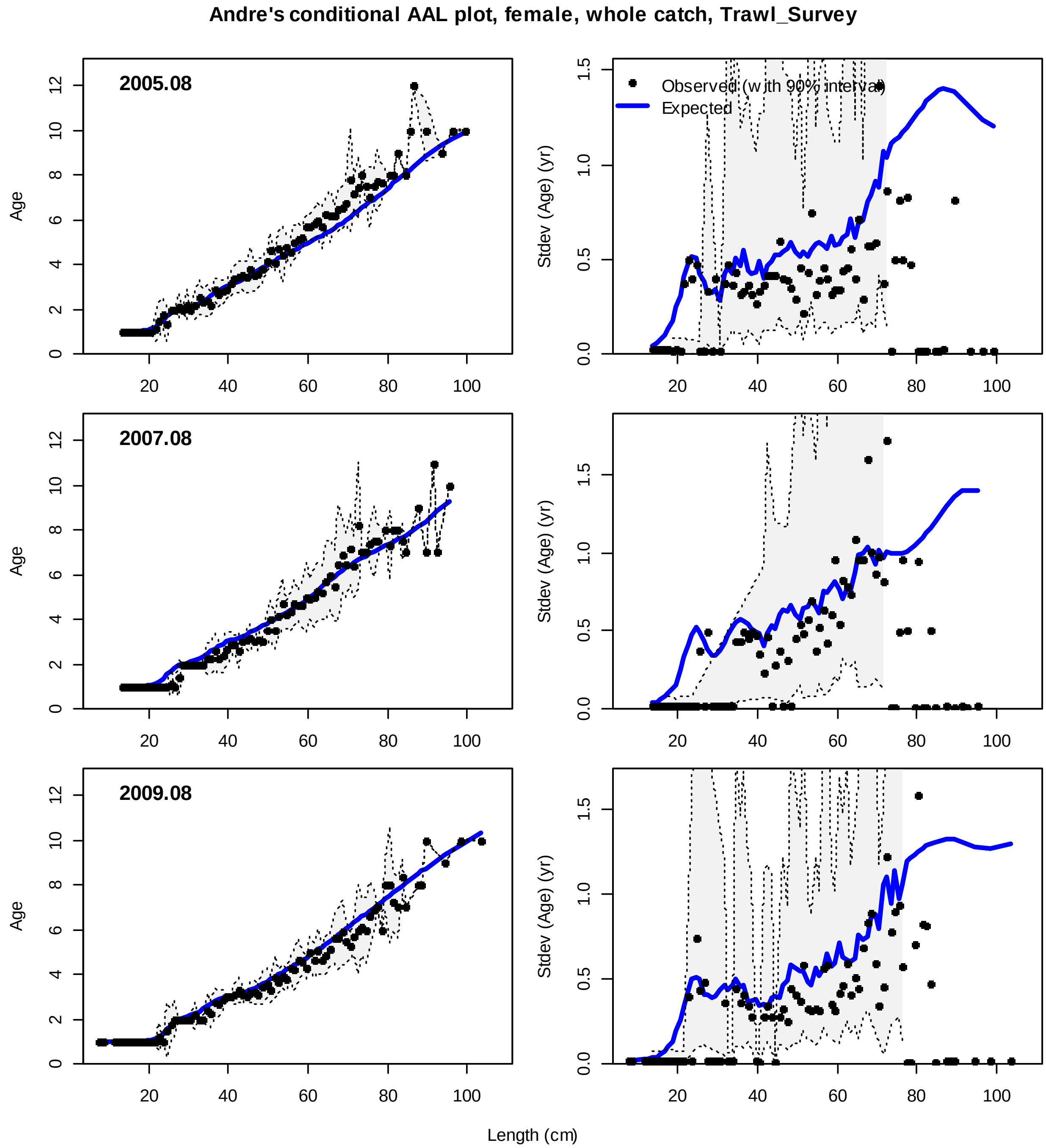


Fig. 2.16 – Fit to the age composition data from the GOA NMFS bottom trawl survey from Model S1a




Andre's conditional AAL plot, female, whole catch, Trawl_Survey
1999.08
2001.08
2003.08
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)


Andre's conditional AAL plot, female, whole catch, Trawl_Survey
2005.08
2007.08
2009.08
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

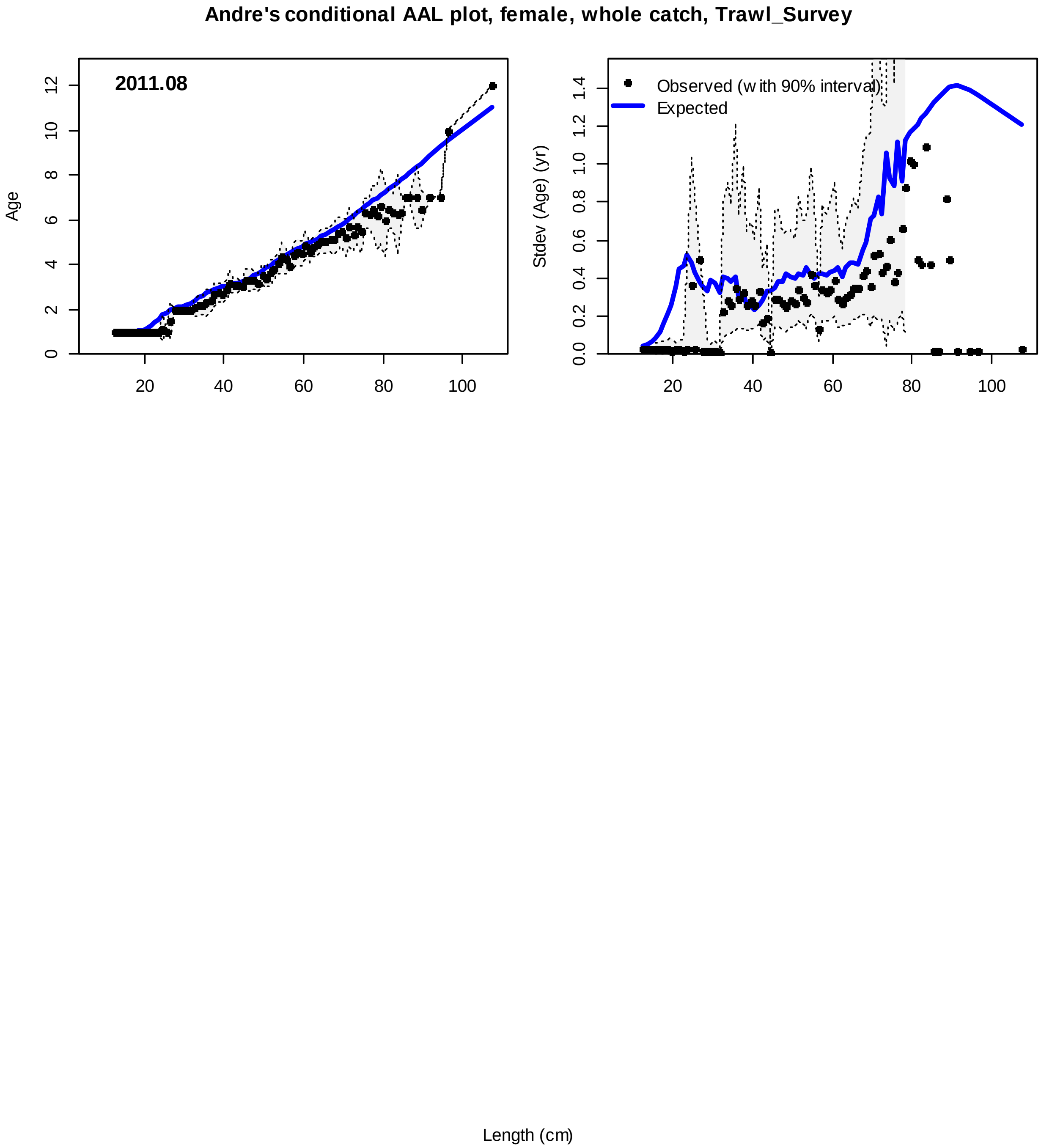

Andre's conditional AAL plot, female, whole catch, Trawl_Survey
2011.08
Age
0
2
4
6
8
10
12
20
40
60
80
100
Stdev (Age) (yr)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Observed (with 90% interval)
Expected
Length (cm)

Fig. 2.17 – Fit (solid line) to the length composition data from the GOA NMFS bottom trawl survey from Model S1a

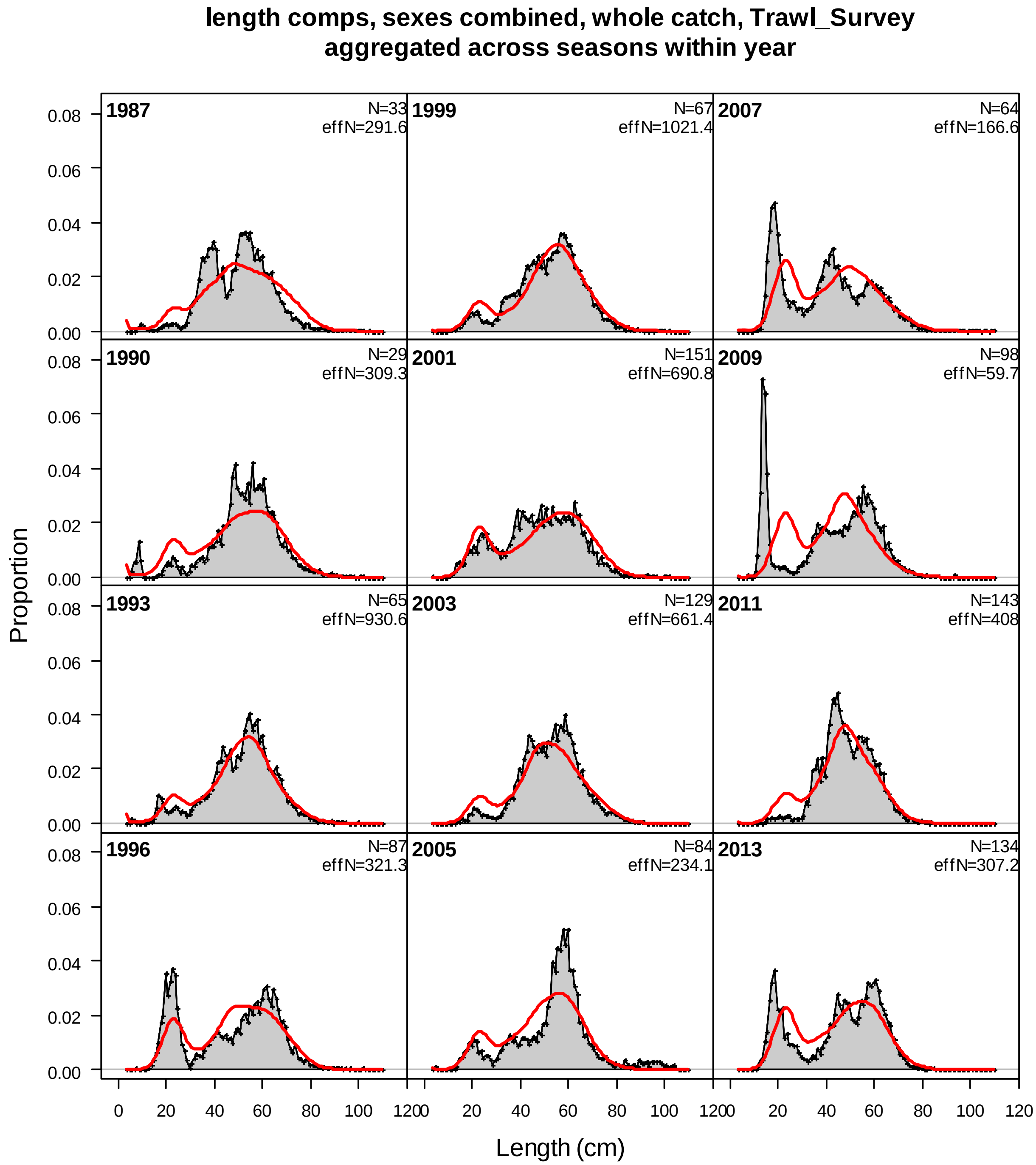


Fig. 2.18 – Estimates of (solid line) and length composition data for the GOA NMFS bottom trawl survey from Model S1a. The 1984 survey length composition data were not used in model fitting, hence "ghost length comps."

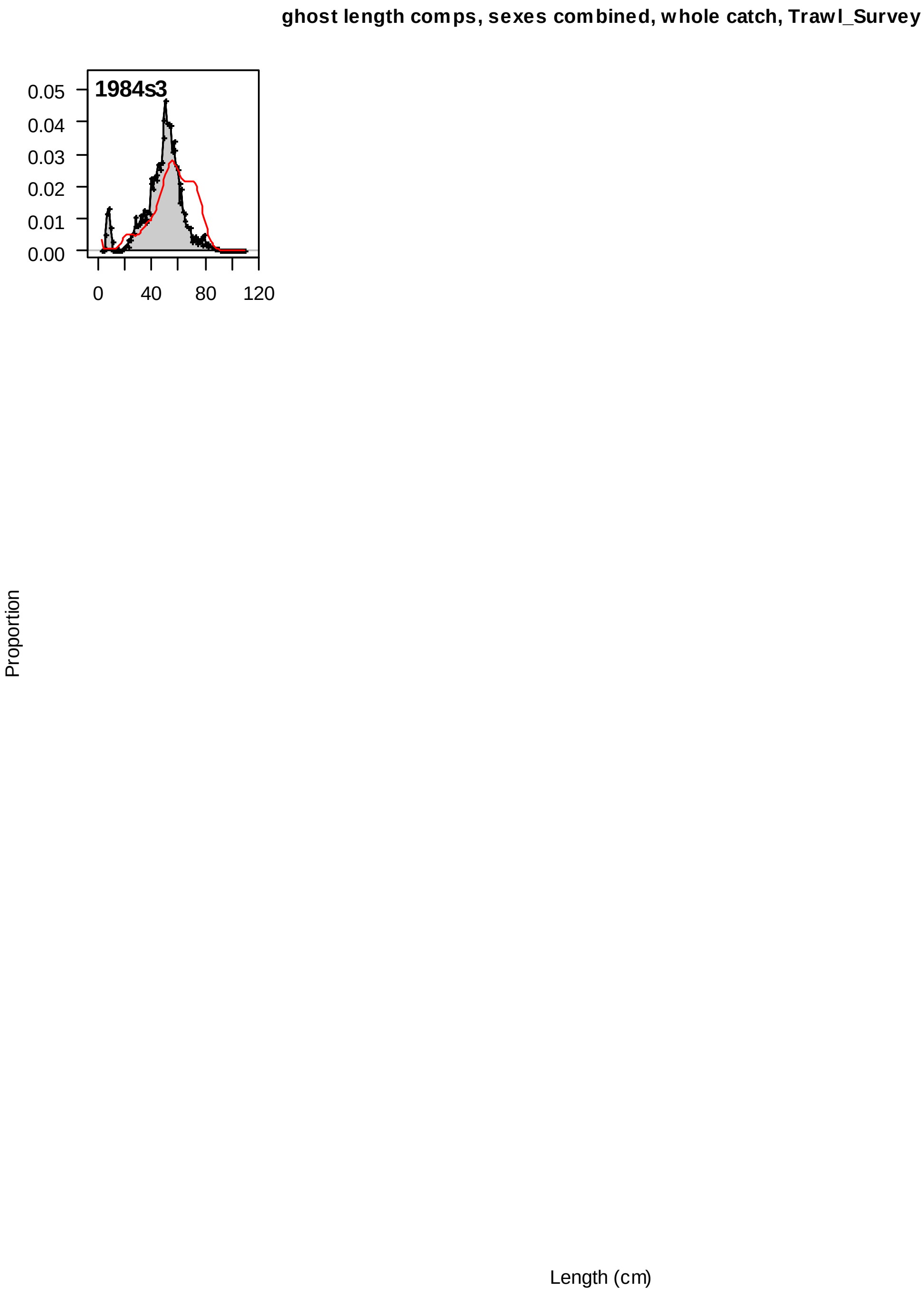


Fig. 2.19 – Estimated length-at-age (cm) from Model S1a

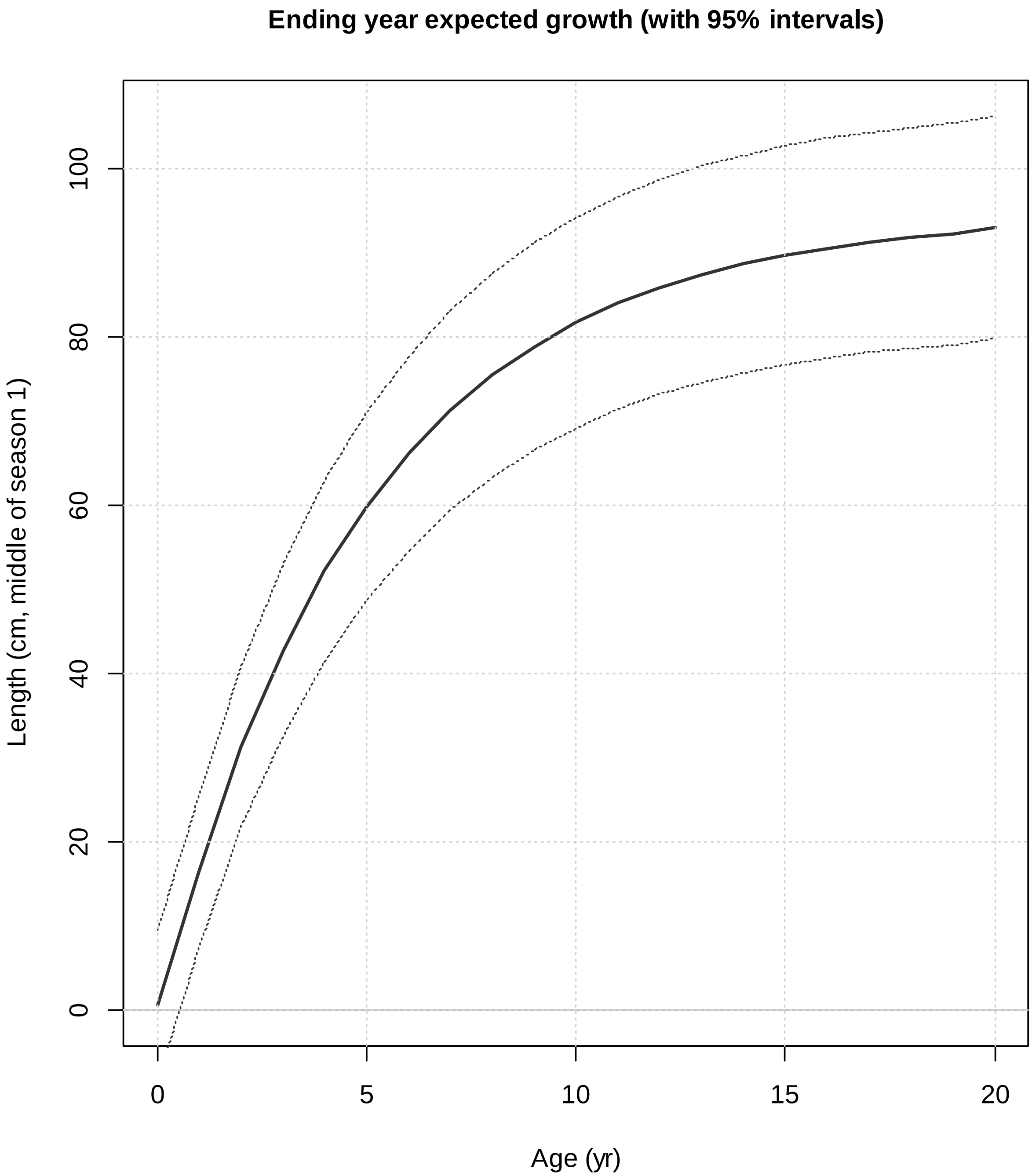


Fig. 2.20 – Estimate trawl survey selectivity-at-age from Model S1a

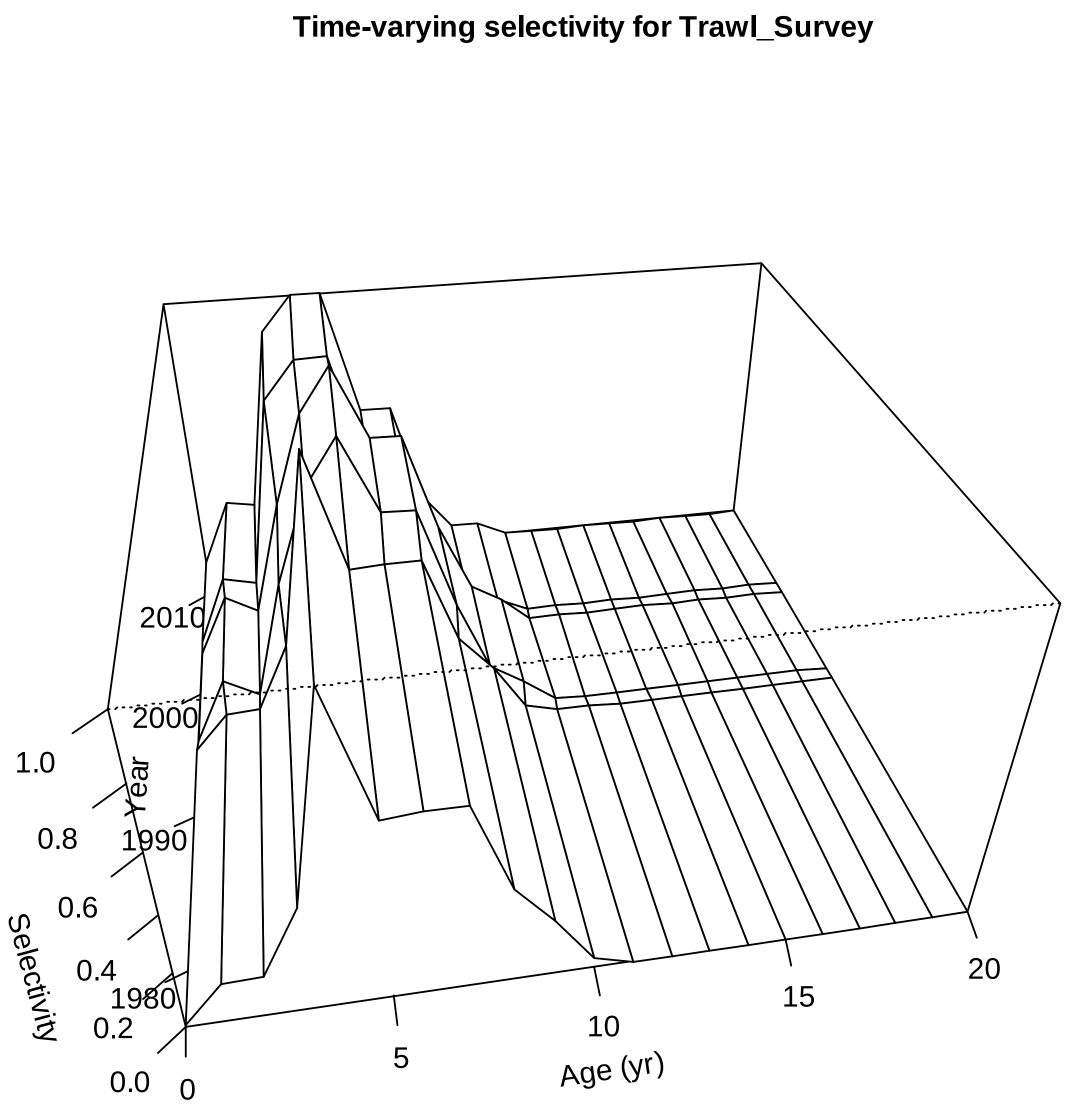
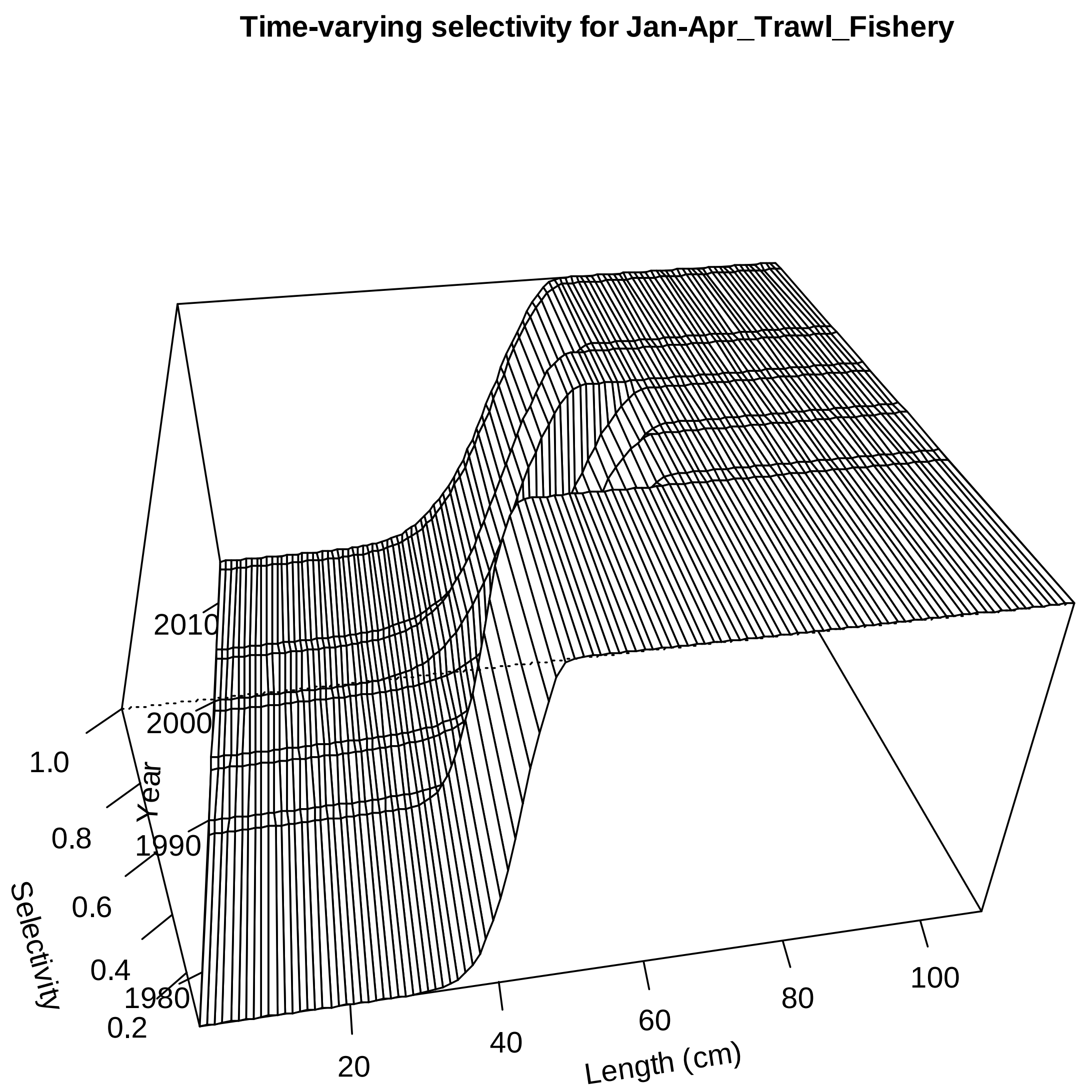
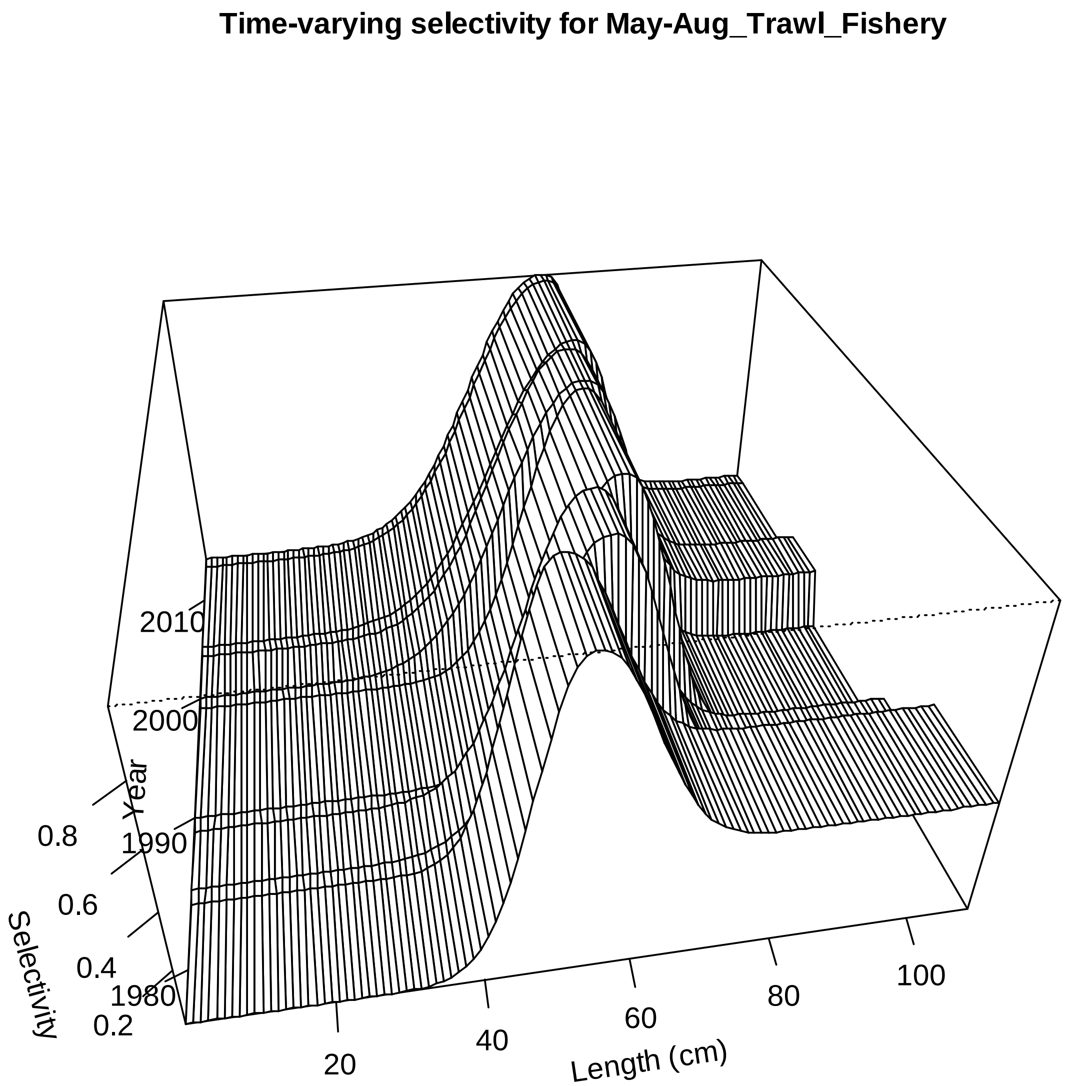
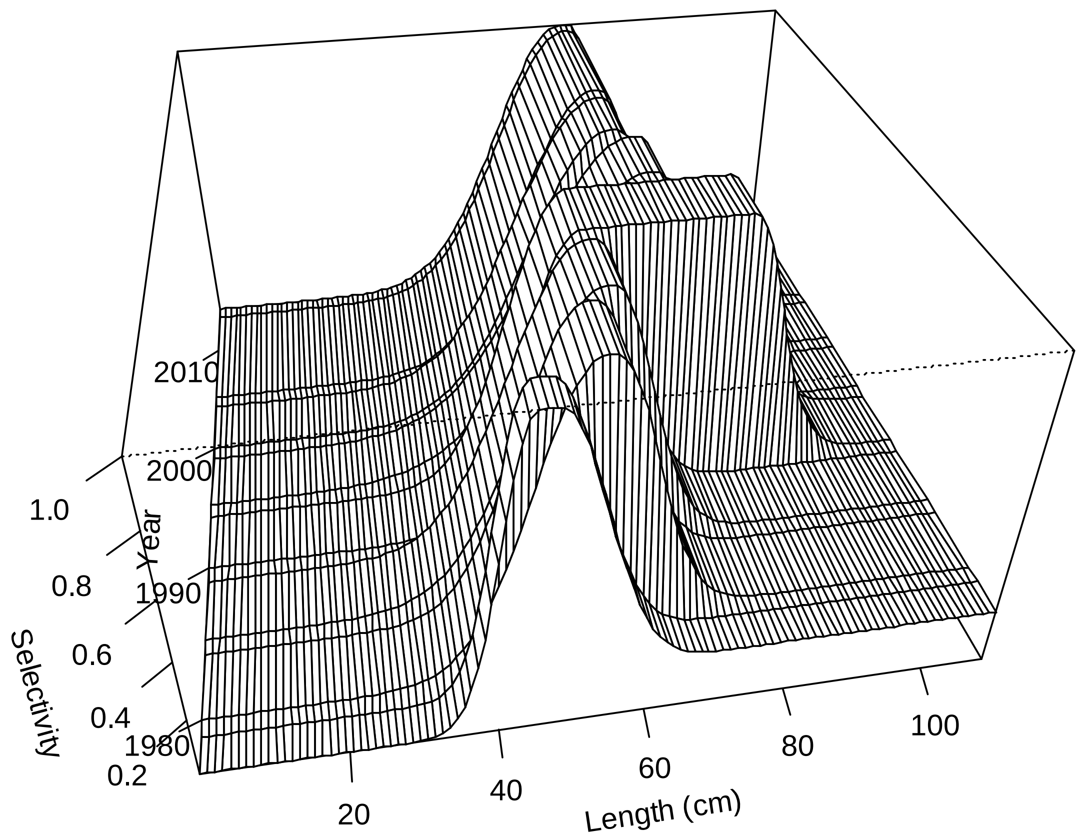


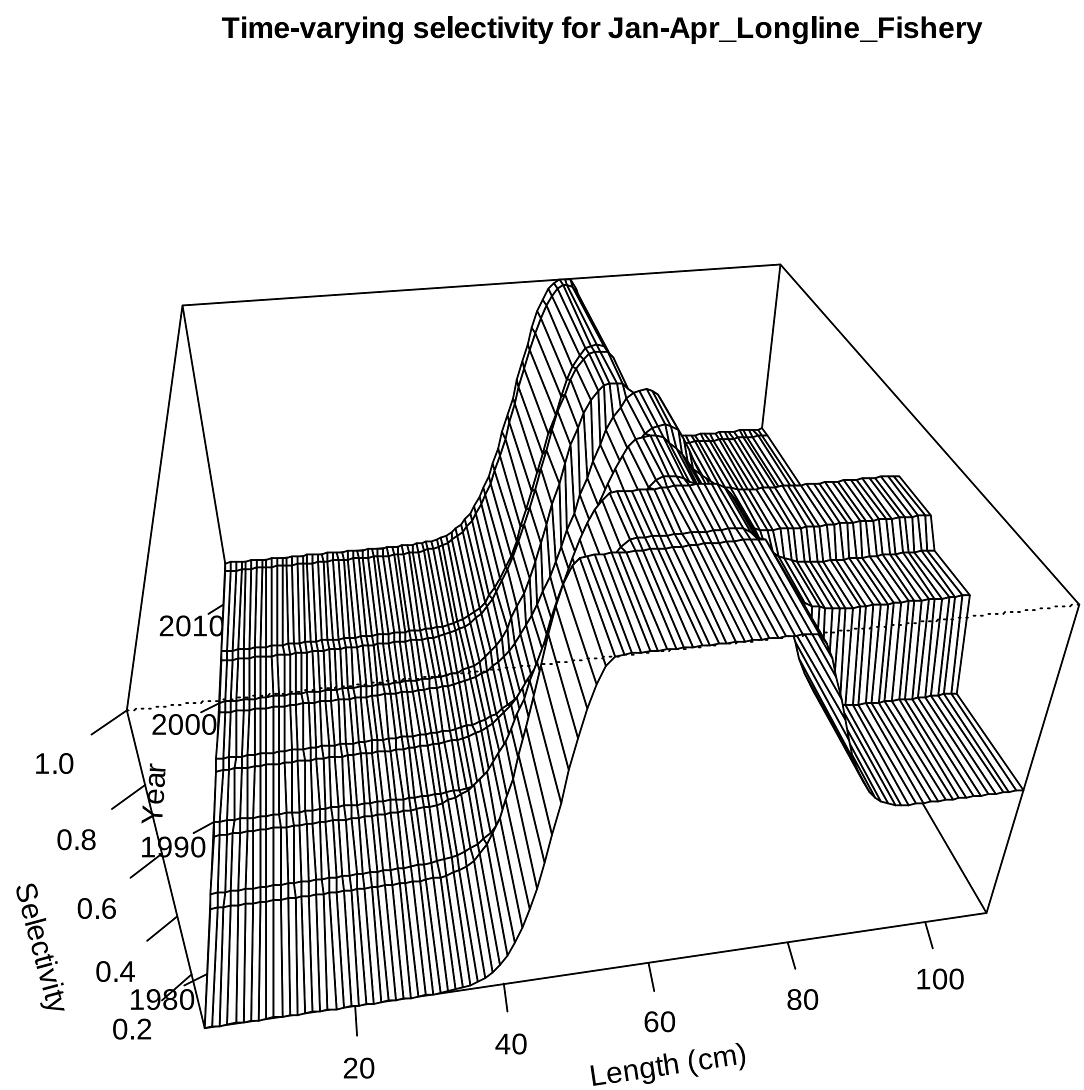
Fig. 2.21 – Fishery selectivity-at-length curves by gear and season from Model S1a

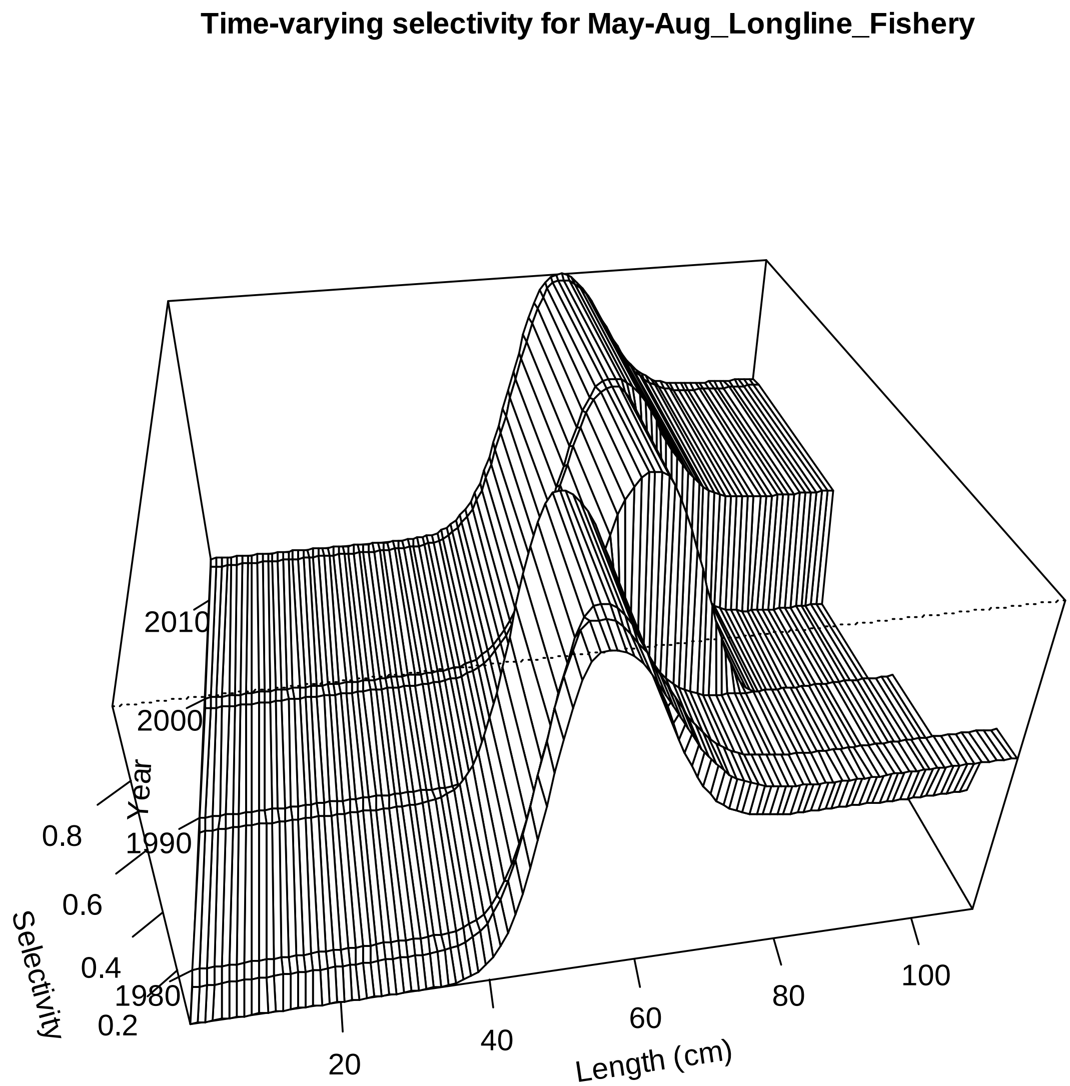


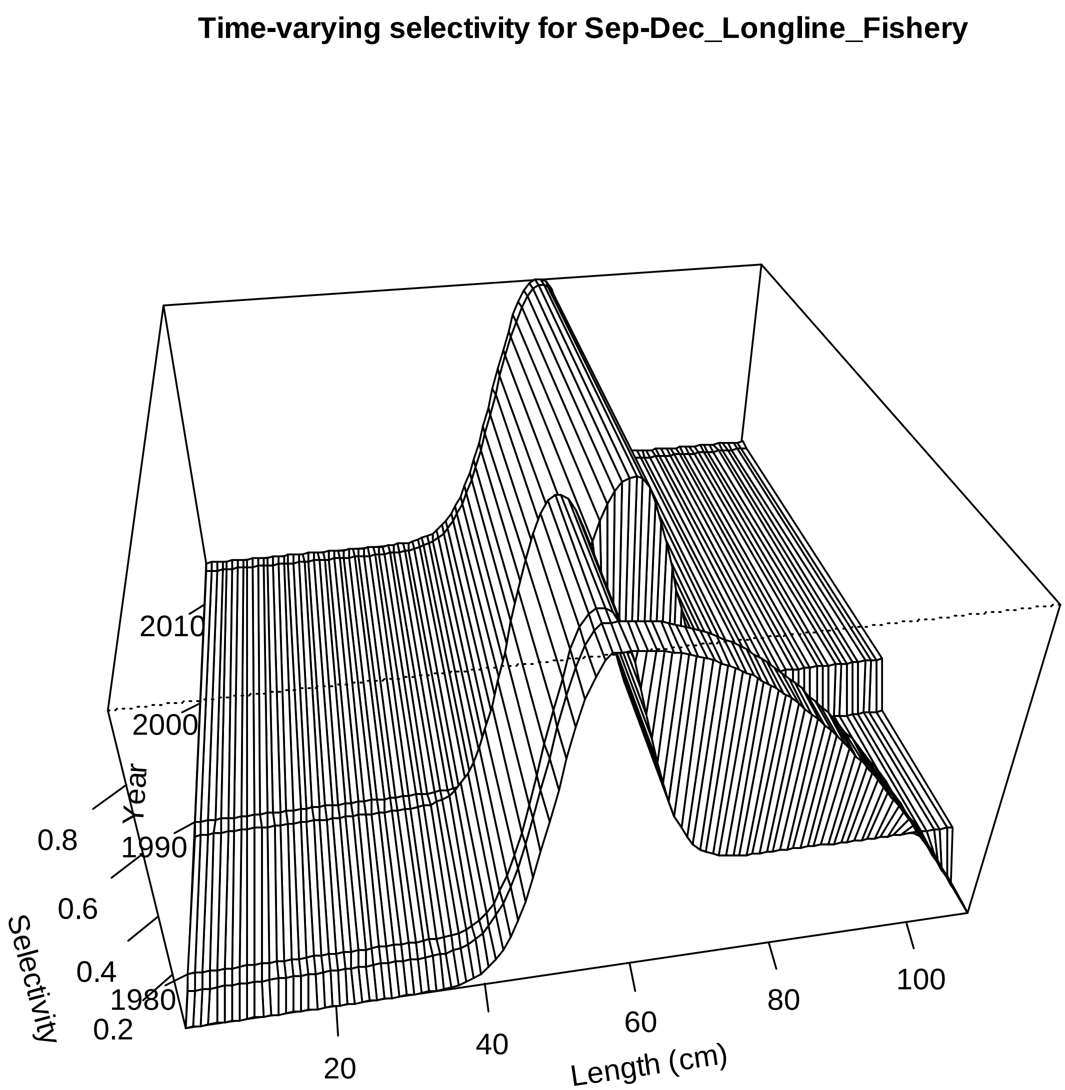

Time-varying selectivity for May-Aug_Trawl_Fishery
2010
2000
Year
1990
1980
0.8
0.6
0.4
0.2
Selectivity
20
40
60
80
100
Length (cm)

Time-varying selectivity for Sep-Dec_Trawl_Fishery

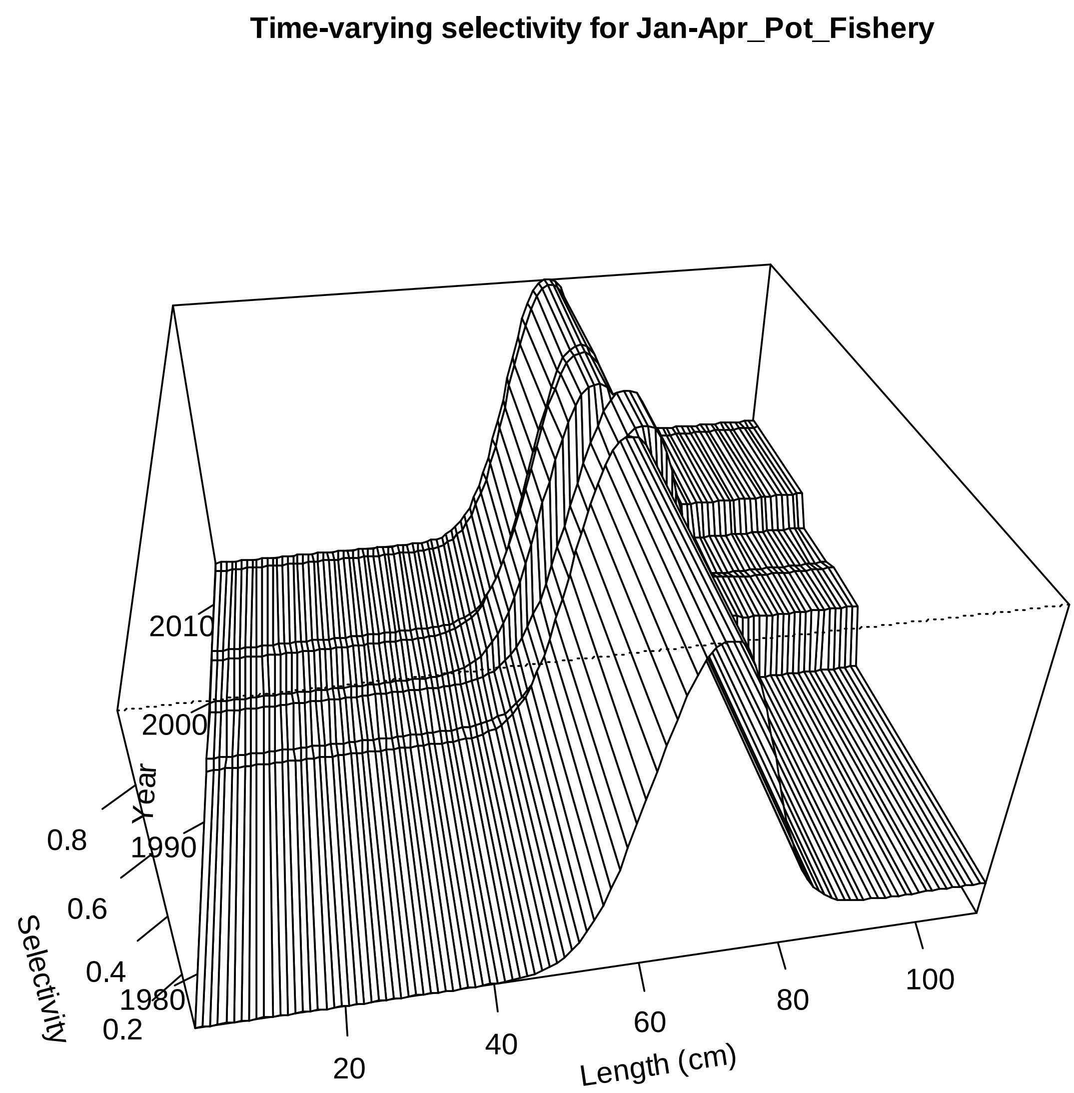


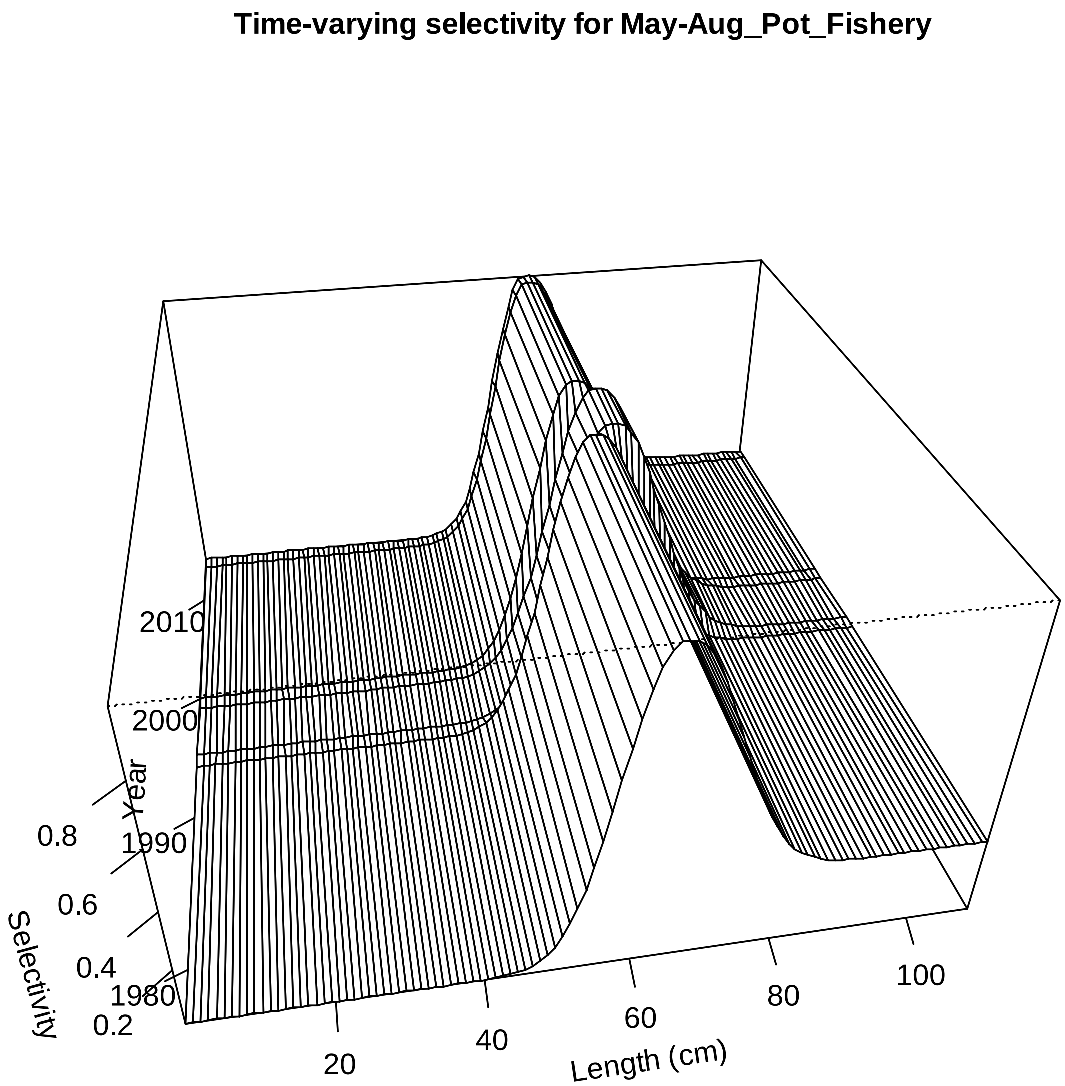

Time-varying selectivity for Jan-Apr_Longline_Fishery
2010
2000
1990
1980
Year
1.0
0.8
0.6
0.4
0.2
Selectivity
20
40
60
80
100
Length (cm)


Time-varying selectivity for May-Aug_Longline_Fishery
Selectivity
0.2
0.4
0.6
0.8
Year
1980
1990
2000
2010
Length (cm)
20
40
60
80
100



Time-varying selectivity for Sep-Dec_Longline_Fishery
Selectivity
0.2
0.4
0.6
0.8
Year
1980
1990
2000
2010
Length (cm)
20
40
60
80
100


Time-varying selectivity for Jan-Apr_Pot_Fishery
2010
2000
Year
1990
1980
0.8
0.6
0.4
0.2
Selectivity
20
40
60
80
100
Length (cm)


Time-varying selectivity for May-Aug_Pot_Fishery
2010
2000
Year
1990
1980
0.8
0.6
0.4
0.2
Selectivity
20
40
60
80
100
Length (cm)

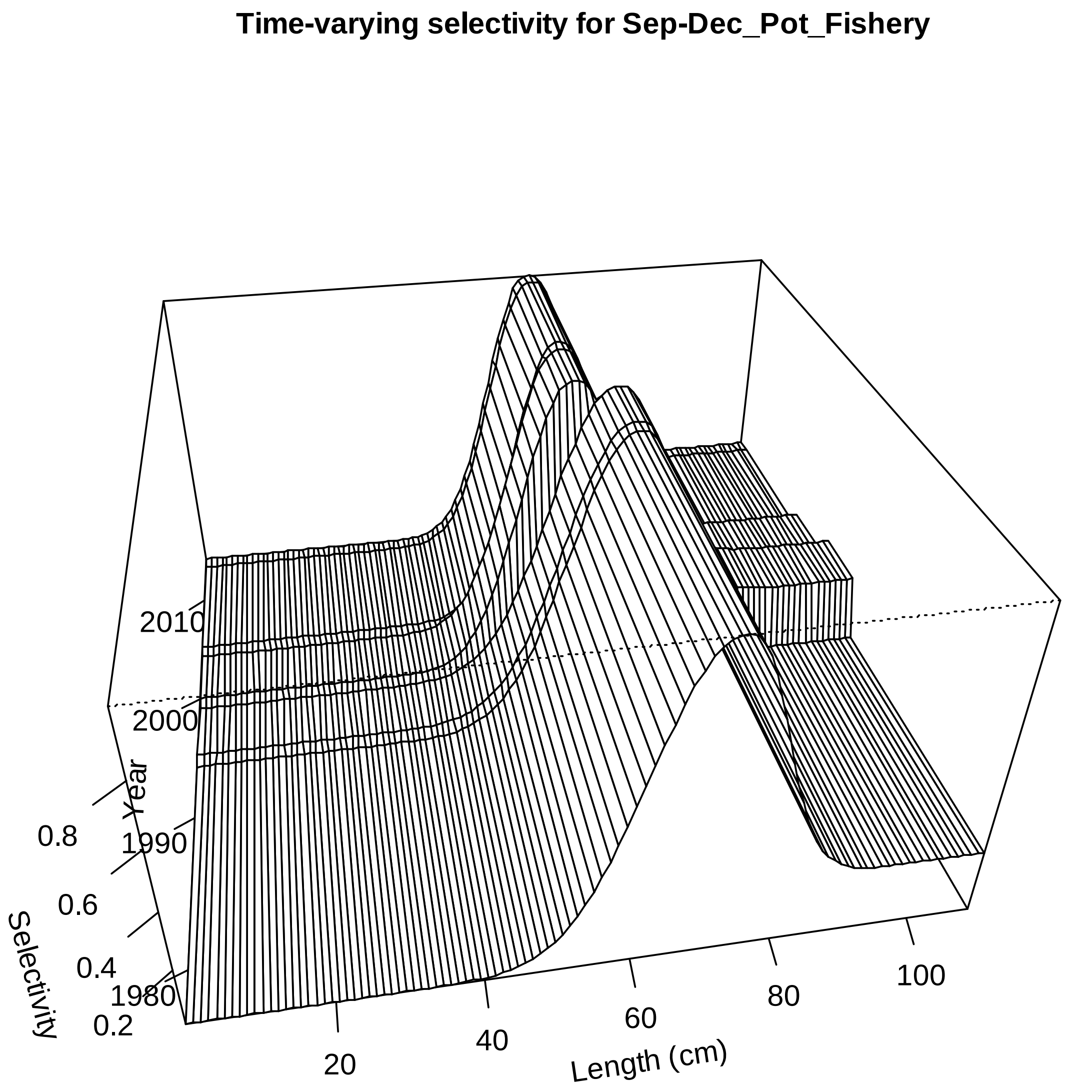

Time-varying selectivity for Sep-Dec_Pot_Fishery
Selectivity
0.2
0.4
0.6
0.8
Year
1980
1990
2000
2010
Length (cm)
20
40
60
80
100

Fig. 2.22 – Summary of fits (solid lines) to fishery and survey length composition data, for season-gear groupings from Model S1a

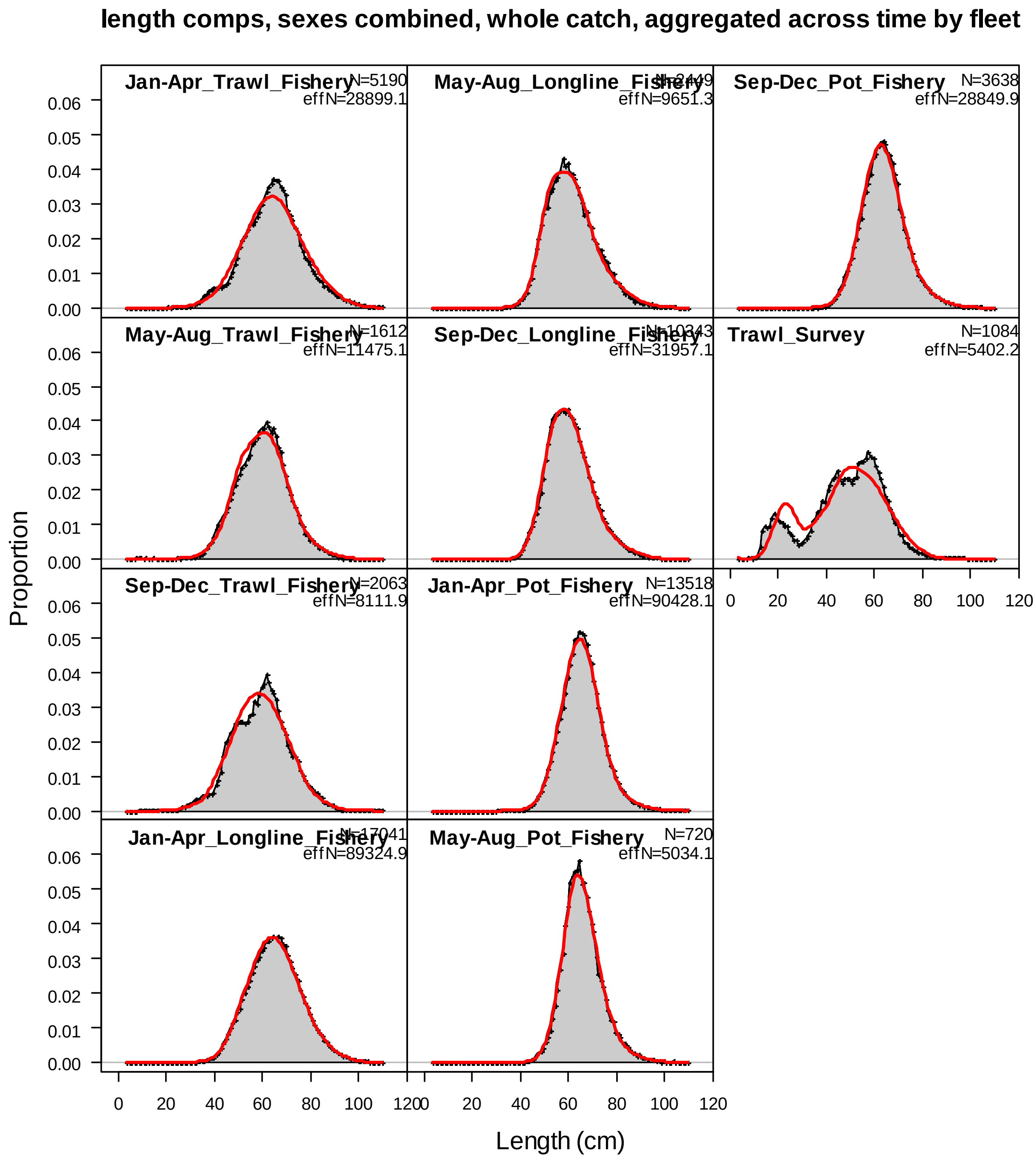
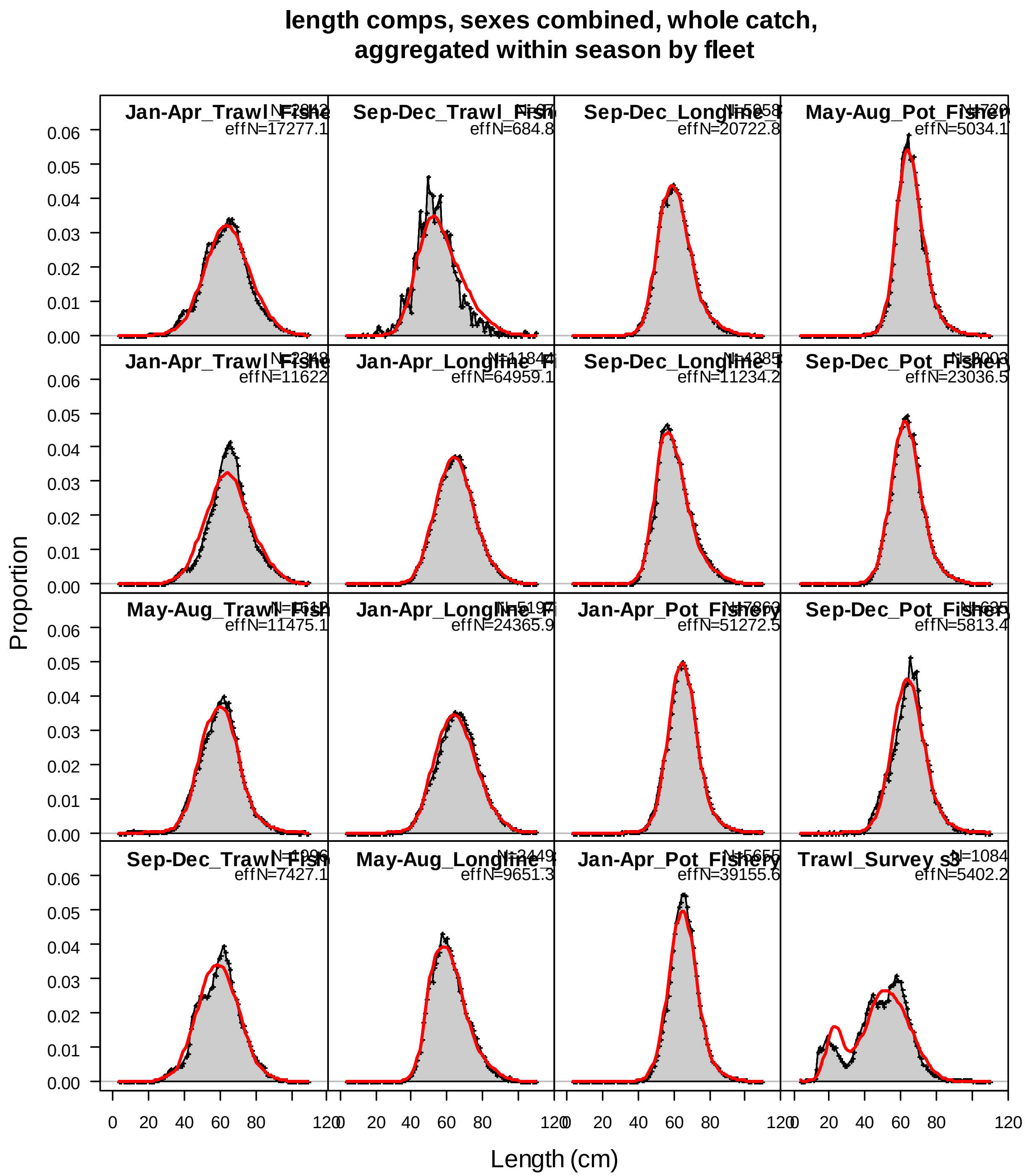
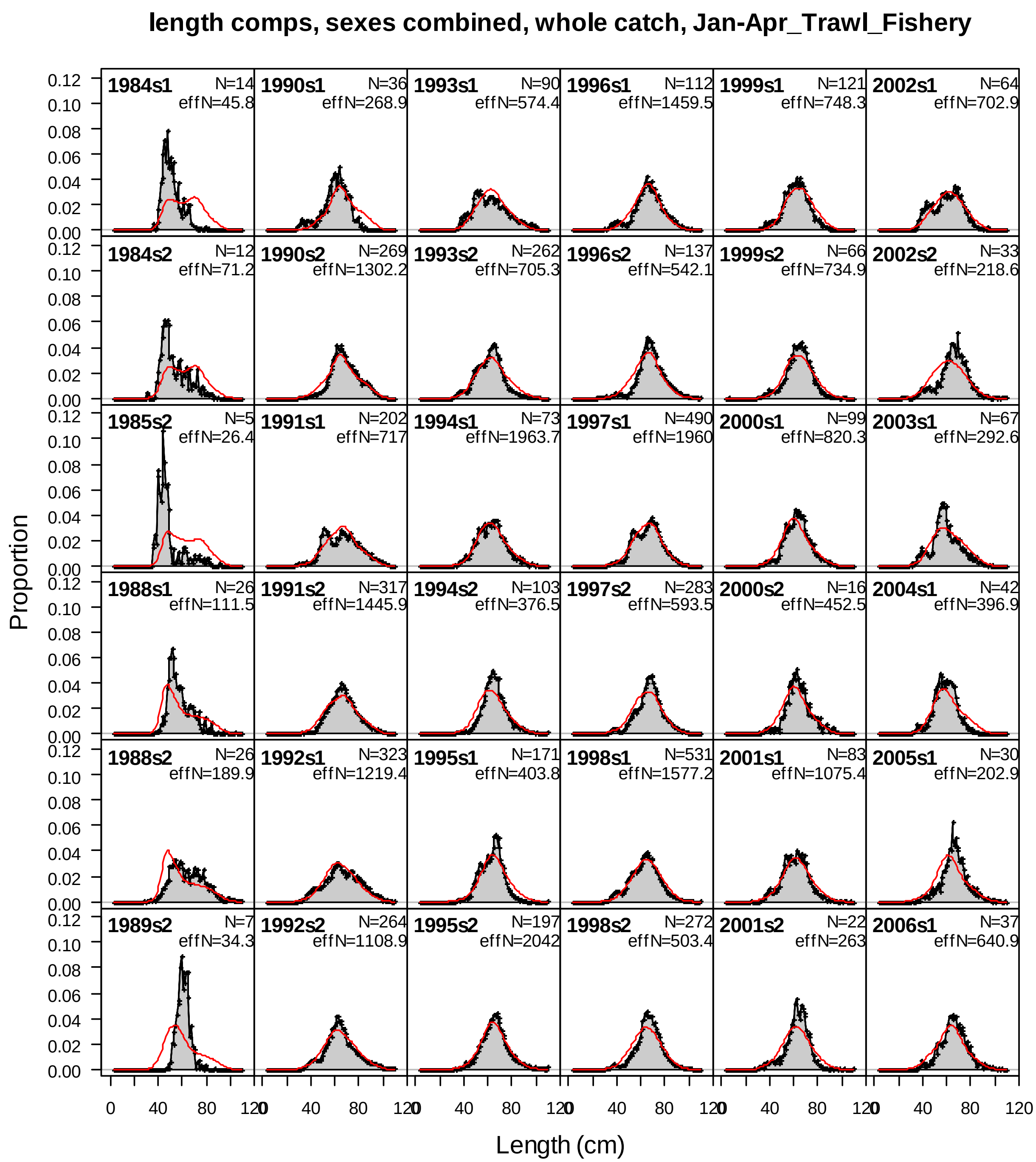


Fig. 2.23 – Fits (solid lines) to fishery length composition data, by season and gear type, from Model S1a




length comps, sexes combined, whole catch, Jan-Apr_Trawl_Fishery
1984s1 N=14 effN=45.8
1990s1 N=36 effN=268.9
1993s1 N=90 effN=574.4
1996s1 N=112 effN=1459.5
1999s1 N=121 effN=748.3
2002s1 N=64 effN=702.9
1984s2 N=12 effN=71.2
1990s2 N=269 effN=1302.2
1993s2 N=262 effN=705.3
1996s2 N=137 effN=542.1
1999s2 N=66 effN=734.9
2002s2 N=33 effN=218.6
1985s2 N=5 effN=26.4
1991s1 N=202 effN=717
1994s1 N=73 effN=1963.7
1997s1 N=490 effN=1960
2000s1 N=99 effN=820.3
2003s1 N=67 effN=292.6
1988s1 N=26 effN=111.5
1991s2 N=317 effN=1445.9
1994s2 N=103 effN=376.5
1997s2 N=283 effN=593.5
2000s2 N=16 effN=452.5
2004s1 N=42 effN=396.9
1988s2 N=26 effN=189.9
1992s1 N=323 effN=1219.4
1995s1 N=171 effN=403.8
1998s1 N=531 effN=1577.2
2001s1 N=83 effN=1075.4
2005s1 N=30 effN=202.9
1989s2 N=7 effN=34.3
1992s2 N=264 effN=1108.9
1995s2 N=197 effN=2042
1998s2 N=272 effN=503.4
2001s2 N=22 effN=263
2006s1 N=37 effN=640.9
Proportion
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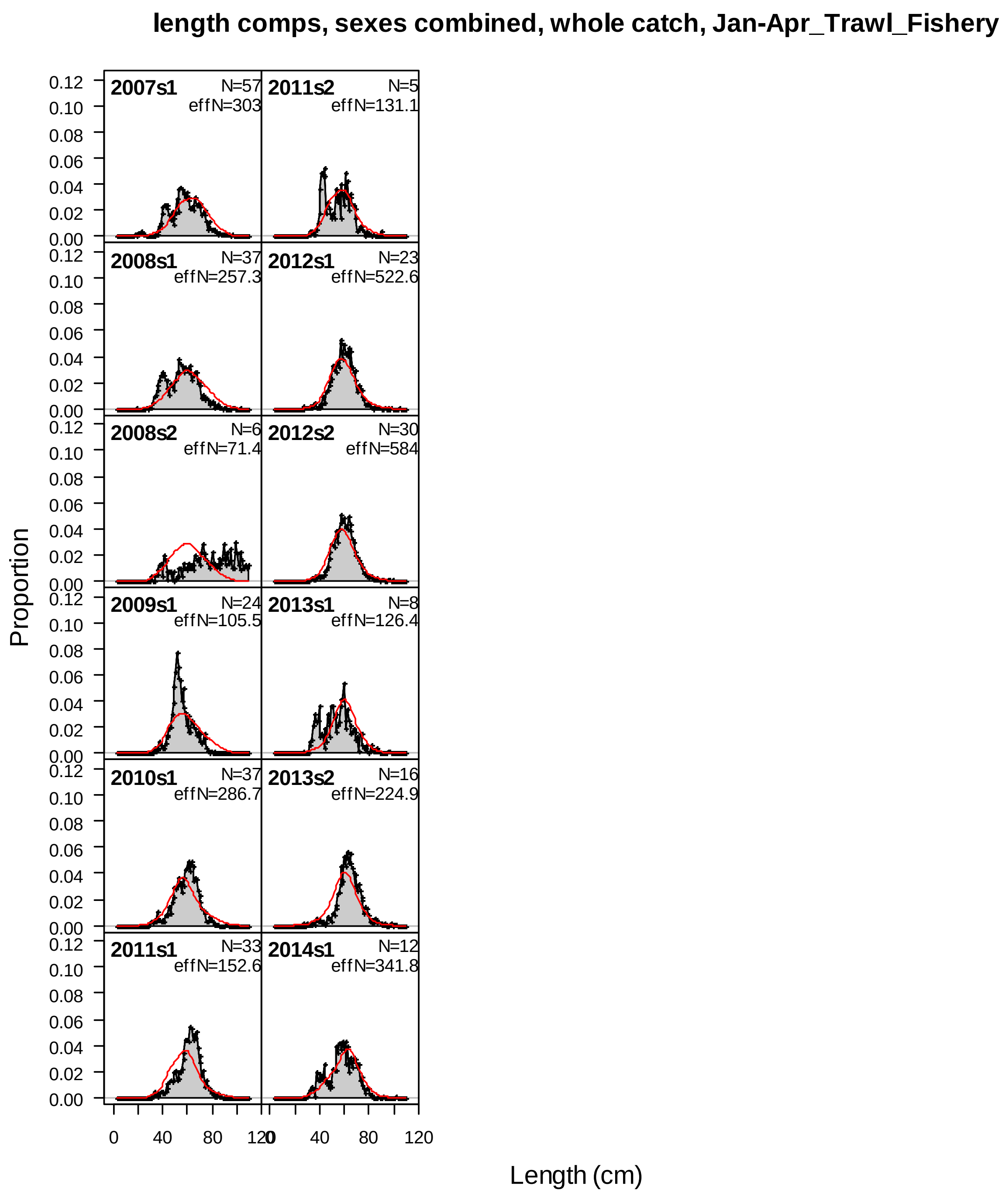
0 40 80 120
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Trawl_Fishery
2007s1 N=57 effN=303
2011s2 N=5 effN=131.1
2008s1 N=37 effN=257.3
2012s1 N=23 effN=522.6
2008s2 N=6 effN=71.4
2012s2 N=30 effN=584
2009s1 N=24 effN=105.5
2013s1 N=8 effN=126.4
2010s1 N=37 effN=286.7
2013s2 N=16 effN=224.9
2011s1 N=33 effN=152.6
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Proportion
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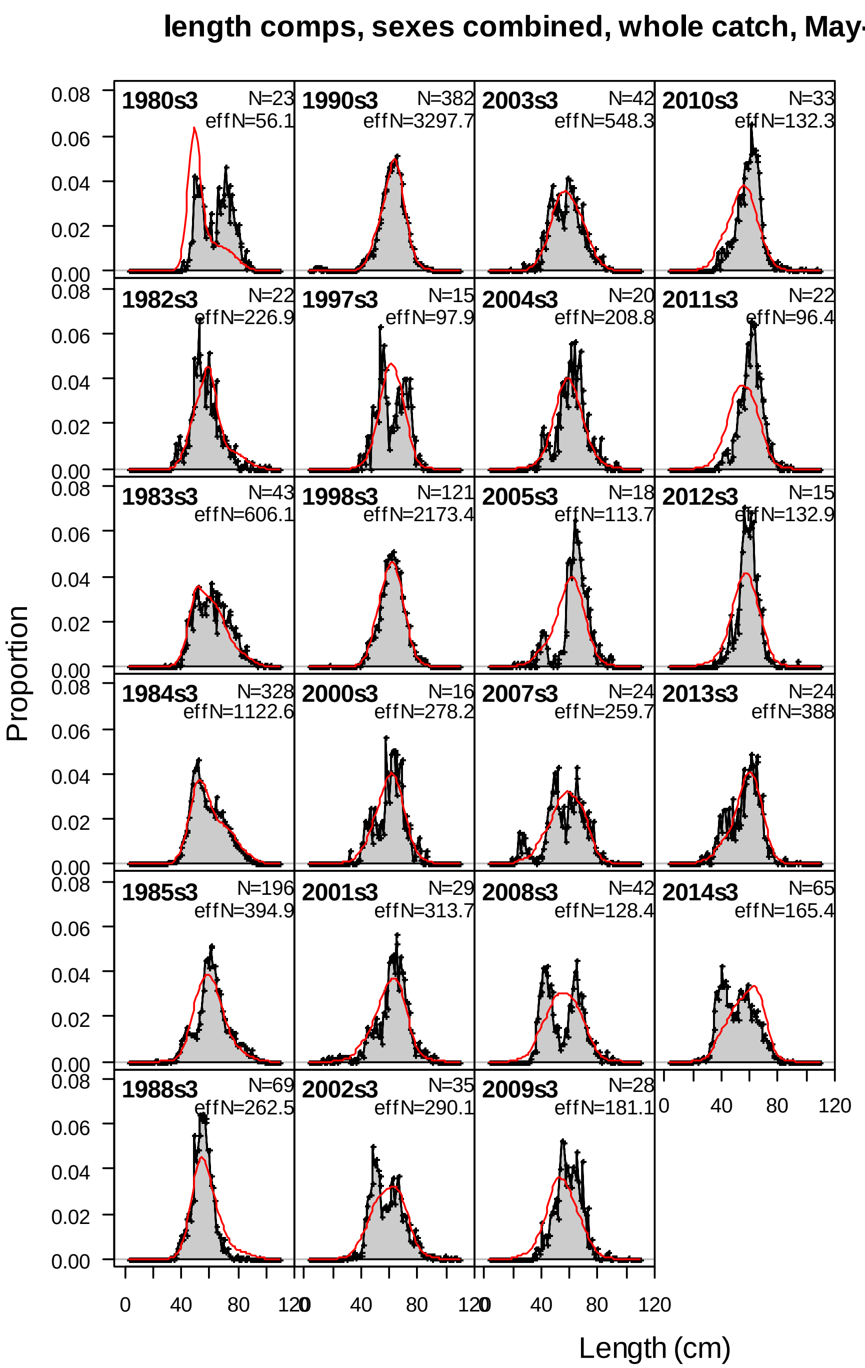
0 40 80 120
Length (cm)


length comps, sexes combined, whole catch, May-Aug_Trawl_Fishery
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1990s3 N=382 effN=3297.7
2003s3 N=42 effN=548.3
2010s3 N=33 effN=132.3
1982s3 N=22 effN=226.9
1997s3 N=15 effN=97.9
2004s3 N=20 effN=208.8
2011s3 N=22 effN=96.4
1983s3 N=43 effN=606.1
1998s3 N=121 effN=2173.4
2005s3 N=18 effN=113.7
2012s3 N=15 effN=132.9
1984s3 N=328 effN=1122.6
2000s3 N=16 effN=278.2
2007s3 N=24 effN=259.7
2013s3 N=24 effN=388
1985s3 N=196 effN=394.9
2001s3 N=29 effN=313.7
2008s3 N=42 effN=128.4
2014s3 N=65 effN=165.4
1988s3 N=69 effN=262.5
2002s3 N=35 effN=290.1
2009s3 N=28 effN=181.1
Proportion
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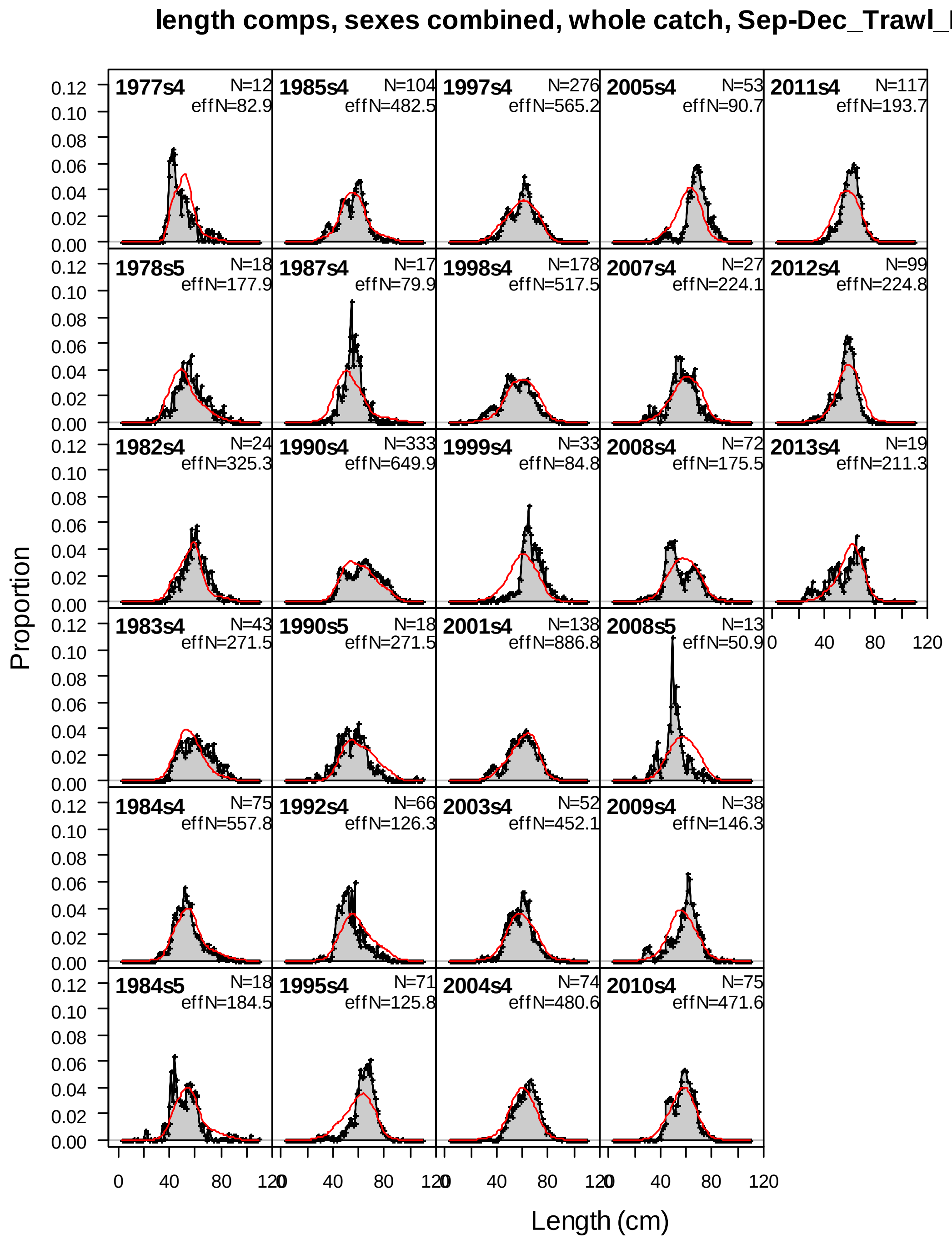
0 40 80 120
Length (cm)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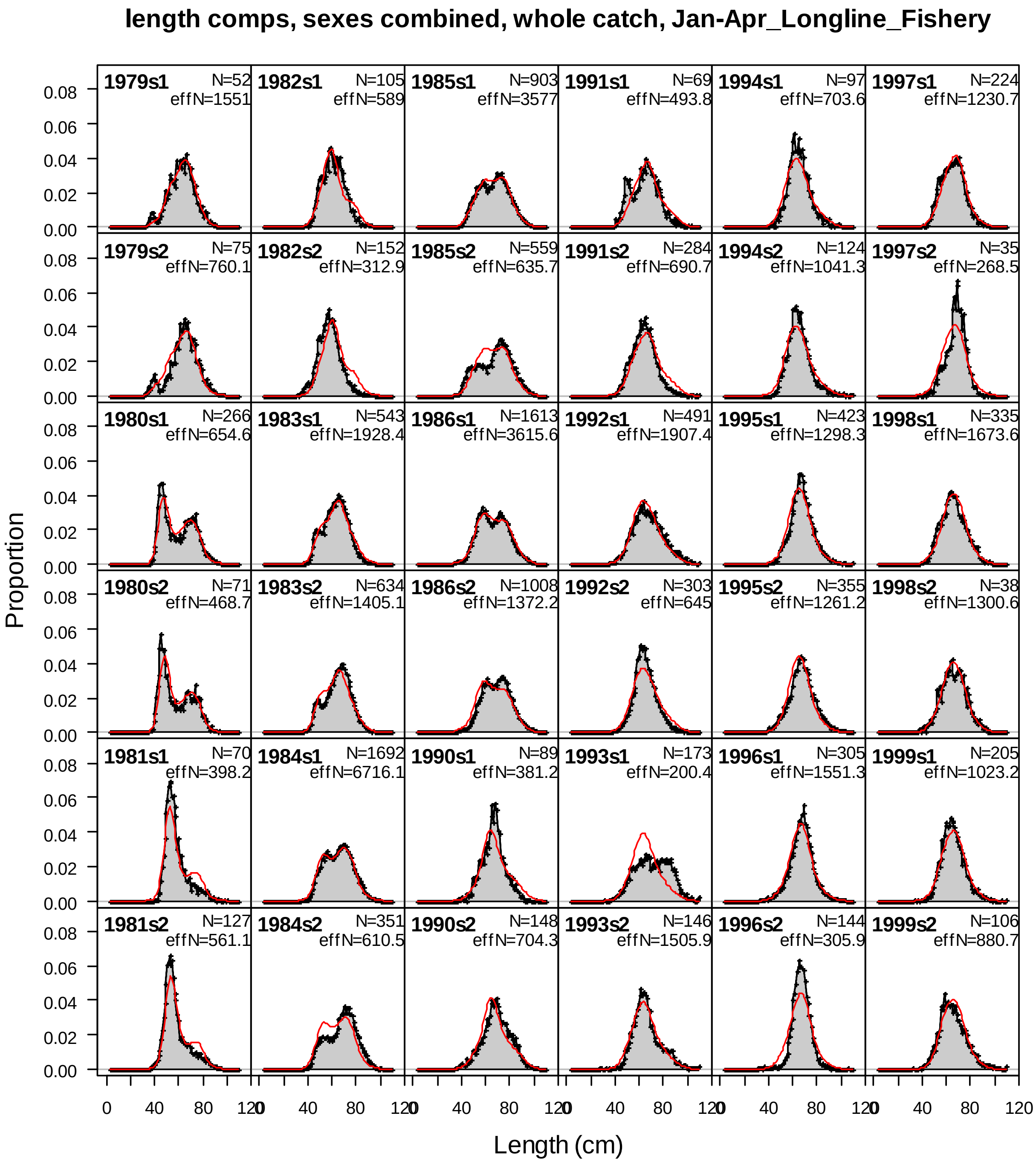
1985s4 N=104 effN=482.5
1997s4 N=276 effN=565.2
2005s4 N=53 effN=90.7
2011s4 N=117 effN=193.7
1978s5 N=18 effN=177.9
1987s4 N=17 effN=79.9
1998s4 N=178 effN=517.5
2007s4 N=27 effN=224.1
2012s4 N=99 effN=224.8
1982s4 N=24 effN=325.3
1990s4 N=333 effN=649.9
1999s4 N=33 effN=84.8
2008s4 N=72 effN=175.5
2013s4 N=19 effN=211.3
1983s4 N=43 effN=271.5
1990s5 N=18 effN=271.5
2001s4 N=138 effN=886.8
2008s5 N=13 effN=50.9
1984s4 N=75 effN=557.8
1992s4 N=66 effN=126.3
2003s4 N=52 effN=452.1
2009s4 N=38 effN=146.3
1984s5 N=18 effN=184.5
1995s4 N=71 effN=125.8
2004s4 N=74 effN=480.6
2010s4 N=75 effN=471.6
Proportion
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Longline_Fishery
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1982s1 N=105 effN=589
1985s1 N=903 effN=3577
1991s1 N=69 effN=493.8
1994s1 N=97 effN=703.6
1997s1 N=224 effN=1230.7
1979s2 N=75 effN=760.1
1982s2 N=152 effN=312.9
1985s2 N=559 effN=635.7
1991s2 N=284 effN=690.7
1994s2 N=124 effN=1041.3
1997s2 N=35 effN=268.5
1980s1 N=266 effN=654.6
1983s1 N=543 effN=1928.4
1986s1 N=1613 effN=3615.6
1992s1 N=491 effN=1907.4
1995s1 N=423 effN=1298.3
1998s1 N=335 effN=1673.6
1980s2 N=71 effN=468.7
1983s2 N=634 effN=1405.1
1986s2 N=1008 effN=1372.2
1992s2 N=303 effN=645
1995s2 N=355 effN=1261.2
1998s2 N=38 effN=1300.6
1981s1 N=70 effN=398.2
1984s1 N=1692 effN=6716.1
1990s1 N=89 effN=381.2
1993s1 N=173 effN=200.4
1996s1 N=305 effN=1551.3
1999s1 N=205 effN=1023.2
1981s2 N=127 effN=561.1
1984s2 N=351 effN=610.5
1990s2 N=148 effN=704.3
1993s2 N=146 effN=1505.9
1996s2 N=144 effN=305.9
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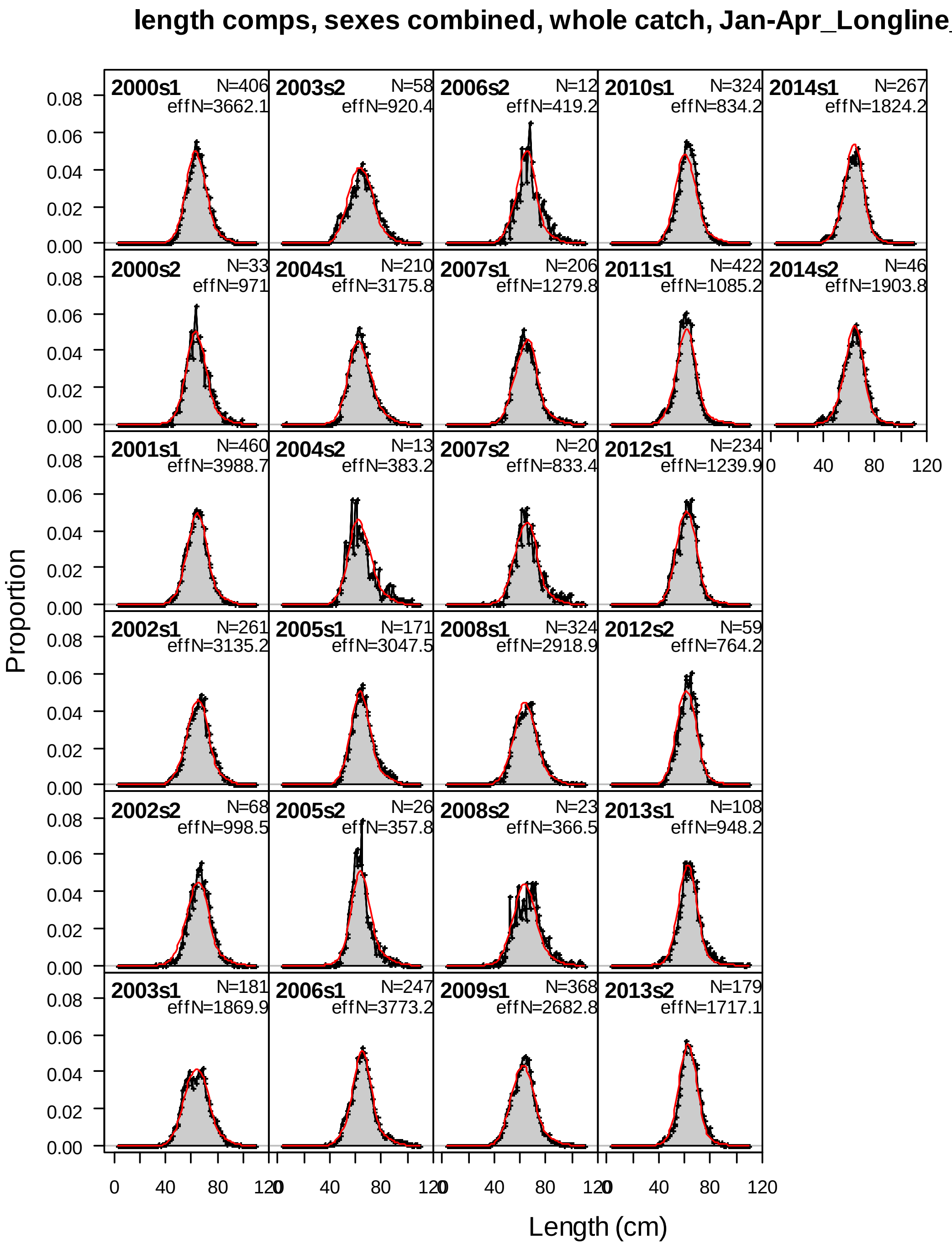
0.06
0.08
0
40
80
120
Length (cm)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Proportion
Length (cm)
2000s1 N=406 effN=3662.1
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2006s2 N=12 effN=419.2
2010s1 N=324 effN=834.2
2014s1 N=267 effN=1824.2
2000s2 N=33 effN=971
2004s1 N=210 effN=3175.8
2007s1 N=206 effN=1279.8
2011s1 N=422 effN=1085.2
2014s2 N=46 effN=1903.8
2001s1 N=460 effN=3988.7
2004s2 N=13 effN=383.2
2007s2 N=20 effN=833.4
2012s1 N=234 effN=1239.9
2002s1 N=261 effN=3135.2
2005s1 N=171 effN=3047.5
2008s1 N=324 effN=2918.9
2012s2 N=59 effN=764.2
2002s2 N=68 effN=998.5
2005s2 N=26 effN=357.8
2008s2 N=23 effN=366.5
2013s1 N=108 effN=948.2
2003s1 N=181 effN=1869.9
2006s1 N=247 effN=3773.2
2009s1 N=368 effN=2682.8
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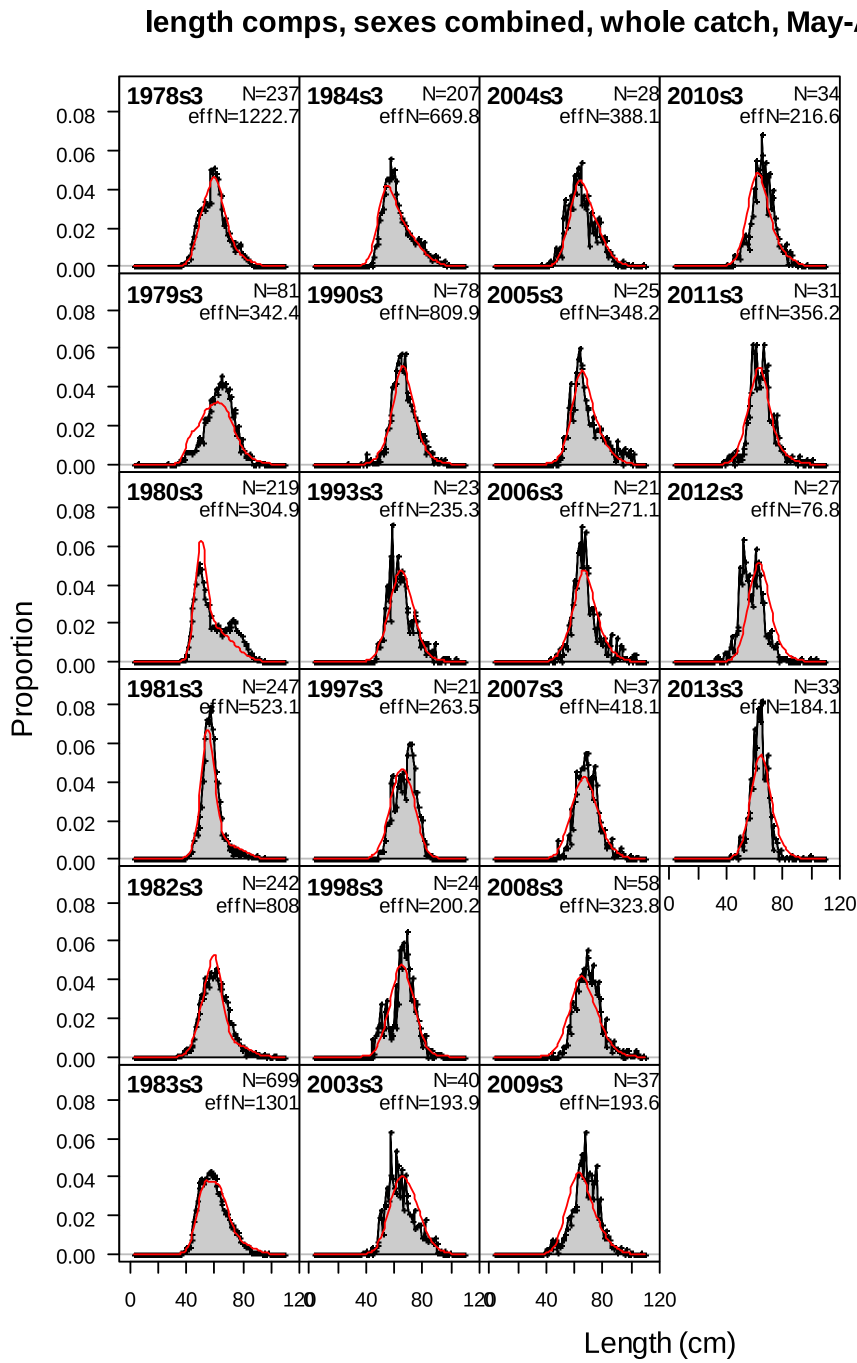
0.00
0.02
0.04
0.06
0.08
0
40
80
120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1978s3 N=237 effN=1222.7
1984s3 N=207 effN=669.8
2004s3 N=28 effN=388.1
2010s3 N=34 effN=216.6
1979s3 N=81 effN=342.4
1990s3 N=78 effN=809.9
2005s3 N=25 effN=348.2
2011s3 N=31 effN=356.2
1980s3 N=219 effN=304.9
1993s3 N=23 effN=235.3
2006s3 N=21 effN=271.1
2012s3 N=27 effN=76.8
1981s3 N=247 effN=523.1
1997s3 N=21 effN=263.5
2007s3 N=37 effN=418.1
2013s3 N=33 effN=184.1
1982s3 N=242 effN=808
1998s3 N=24 effN=200.2
2008s3 N=58 effN=323.8
1983s3 N=699 effN=1301
2003s3 N=40 effN=193.9
2009s3 N=37 effN=193.6
Proportion
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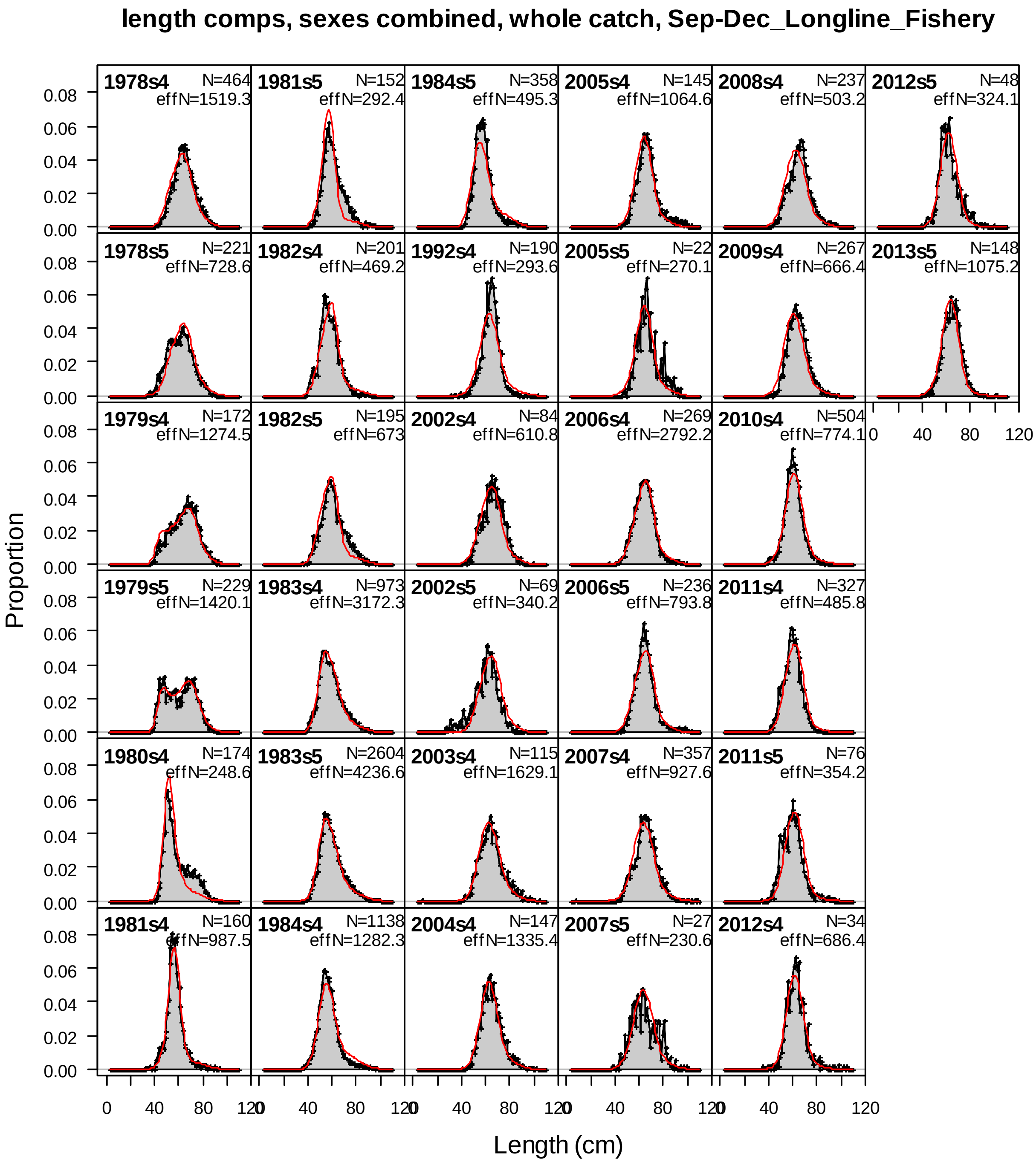
0.04
0.06
0.08
Length (cm)
0
40
80
120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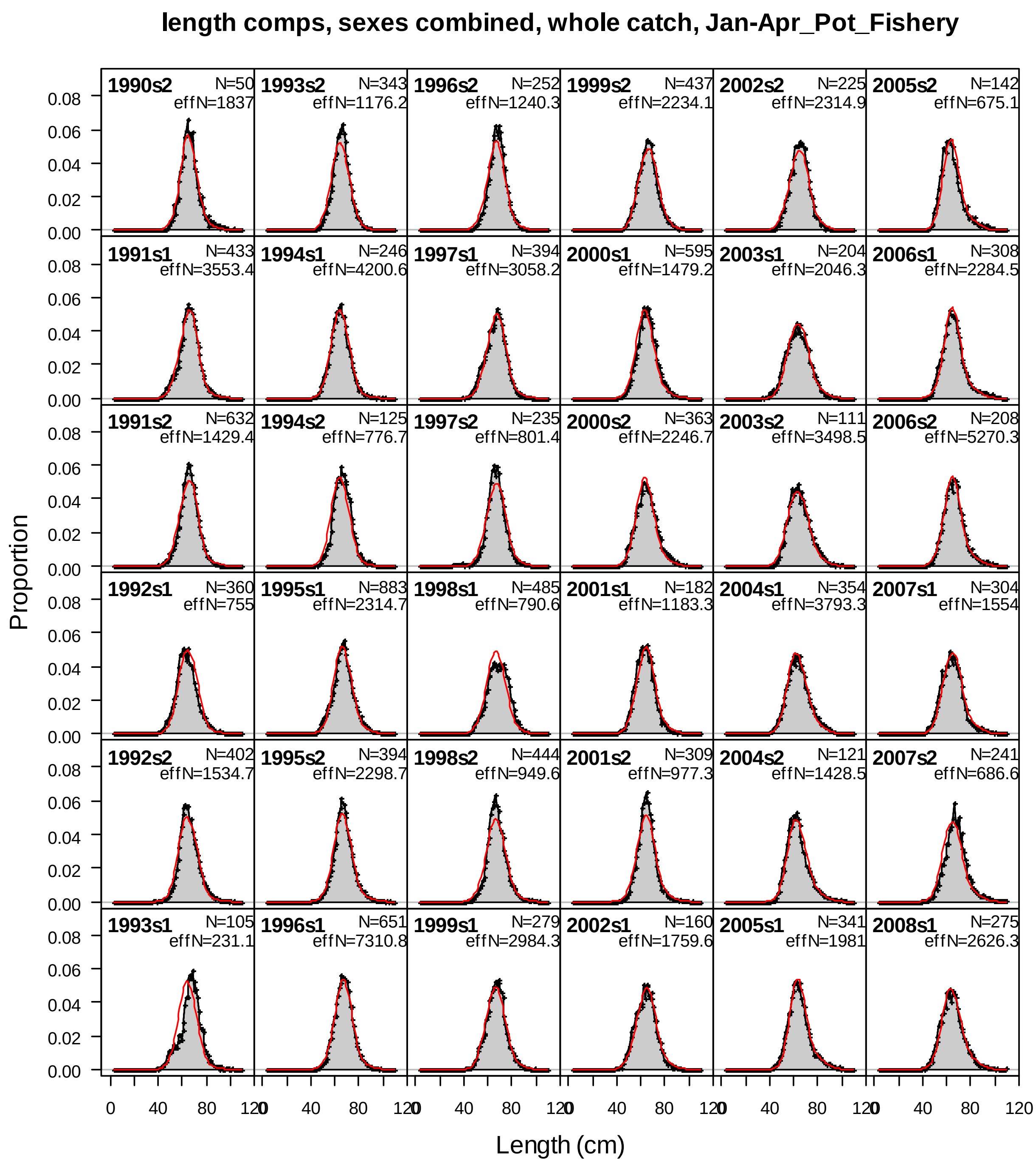
1981s5 N=152 effN=292.4
1984s5 N=358 effN=495.3
2005s4 N=145 effN=1064.6
2008s4 N=237 effN=503.2
2012s5 N=48 effN=324.1
1978s5 N=221 effN=728.6
1982s4 N=201 effN=469.2
1992s4 N=190 effN=293.6
2005s5 N=22 effN=270.1
2009s4 N=267 effN=666.4
2013s5 N=148 effN=1075.2
1979s4 N=172 effN=1274.5
1982s5 N=195 effN=673
2002s4 N=84 effN=610.8
2006s4 N=269 effN=2792.2
2010s4 N=504 effN=774.1
1979s5 N=229 effN=1420.1
1983s4 N=973 effN=3172.3
2002s5 N=69 effN=340.2
2006s5 N=236 effN=793.8
2011s4 N=327 effN=485.8
1980s4 N=174 effN=248.6
1983s5 N=2604 effN=4236.6
2003s4 N=115 effN=1629.1
2007s4 N=357 effN=927.6
2011s5 N=76 effN=354.2
1981s4 N=160 effN=987.5
1984s4 N=1138 effN=1282.3
2004s4 N=147 effN=1335.4
2007s5 N=27 effN=230.6
2012s4 N=34 effN=686.4
Proportion
0.00
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Pot_Fishery
1990s2 N=50 effN=1837
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1996s2 N=252 effN=1240.3
1999s2 N=437 effN=2234.1
2002s2 N=225 effN=2314.9
2005s2 N=142 effN=675.1
1991s1 N=433 effN=3553.4
1994s1 N=246 effN=4200.6
1997s1 N=394 effN=3058.2
2000s1 N=595 effN=1479.2
2003s1 N=204 effN=2046.3
2006s1 N=308 effN=2284.5
1991s2 N=632 effN=1429.4
1994s2 N=125 effN=776.7
1997s2 N=235 effN=801.4
2000s2 N=363 effN=2246.7
2003s2 N=111 effN=3498.5
2006s2 N=208 effN=5270.3
1992s1 N=360 effN=755
1995s1 N=883 effN=2314.7
1998s1 N=485 effN=790.6
2001s1 N=182 effN=1183.3
2004s1 N=354 effN=3793.3
2007s1 N=304 effN=1554
1992s2 N=402 effN=1534.7
1995s2 N=394 effN=2298.7
1998s2 N=444 effN=949.6
2001s2 N=309 effN=977.3
2004s2 N=121 effN=1428.5
2007s2 N=241 effN=686.6
1993s1 N=105 effN=231.1
1996s1 N=651 effN=7310.8
1999s1 N=279 effN=2984.3
2002s1 N=160 effN=1759.6
2005s1 N=341 effN=1981
2008s1 N=275 effN=2626.3
Proportion
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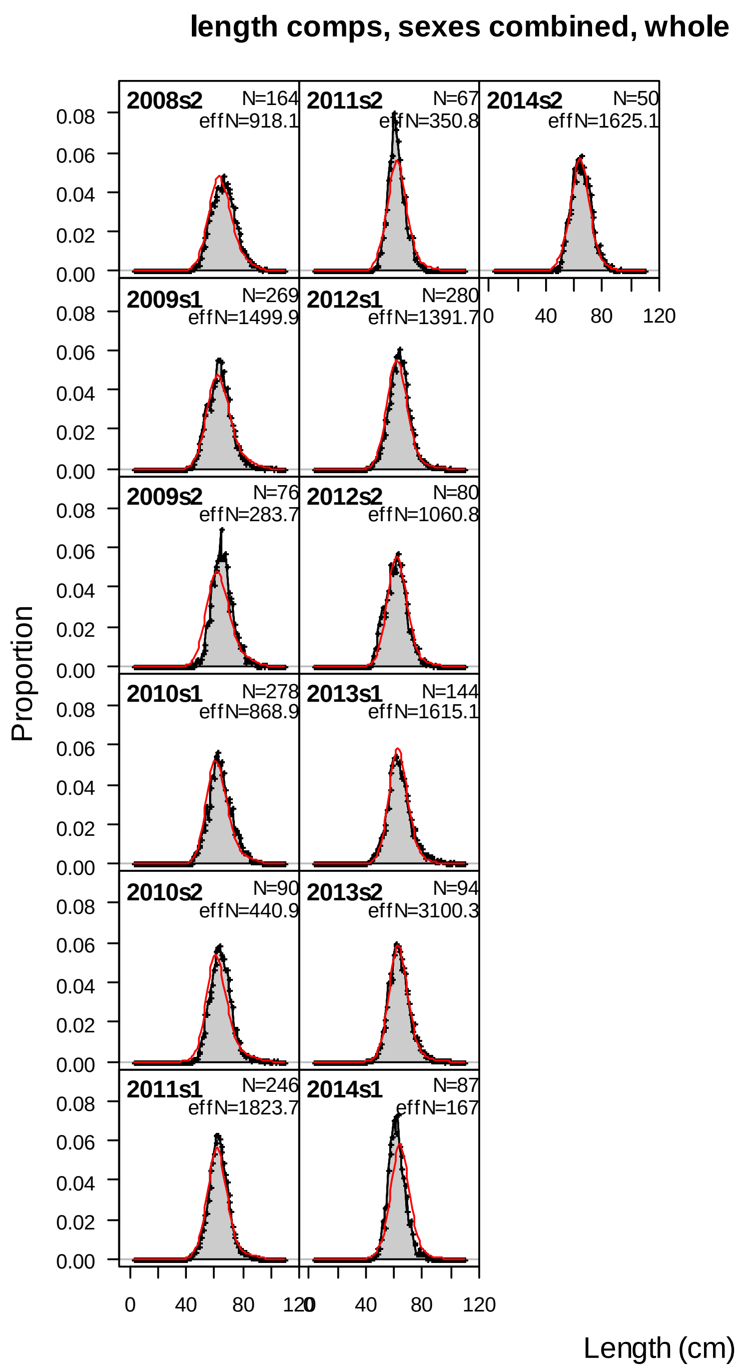
0.04
0.06
0.08
Length (cm)
0
40
80
120


length comps, sexes combined, whole catch, Jan-Apr_Pot_Fishery
2008s2 N=164 effN=918.1
2011s2 N=67 effN=350.8
2014s2 N=50 effN=1625.1
2009s1 N=269 effN=1499.9
2012s1 N=280 effN=1391.7
2009s2 N=76 effN=283.7
2012s2 N=80 effN=1060.8
2010s1 N=278 effN=868.9
2013s1 N=144 effN=1615.1
2010s2 N=90 effN=440.9
2013s2 N=94 effN=3100.3
2011s1 N=246 effN=1823.7
2014s1 N=87 effN=167
Proportion
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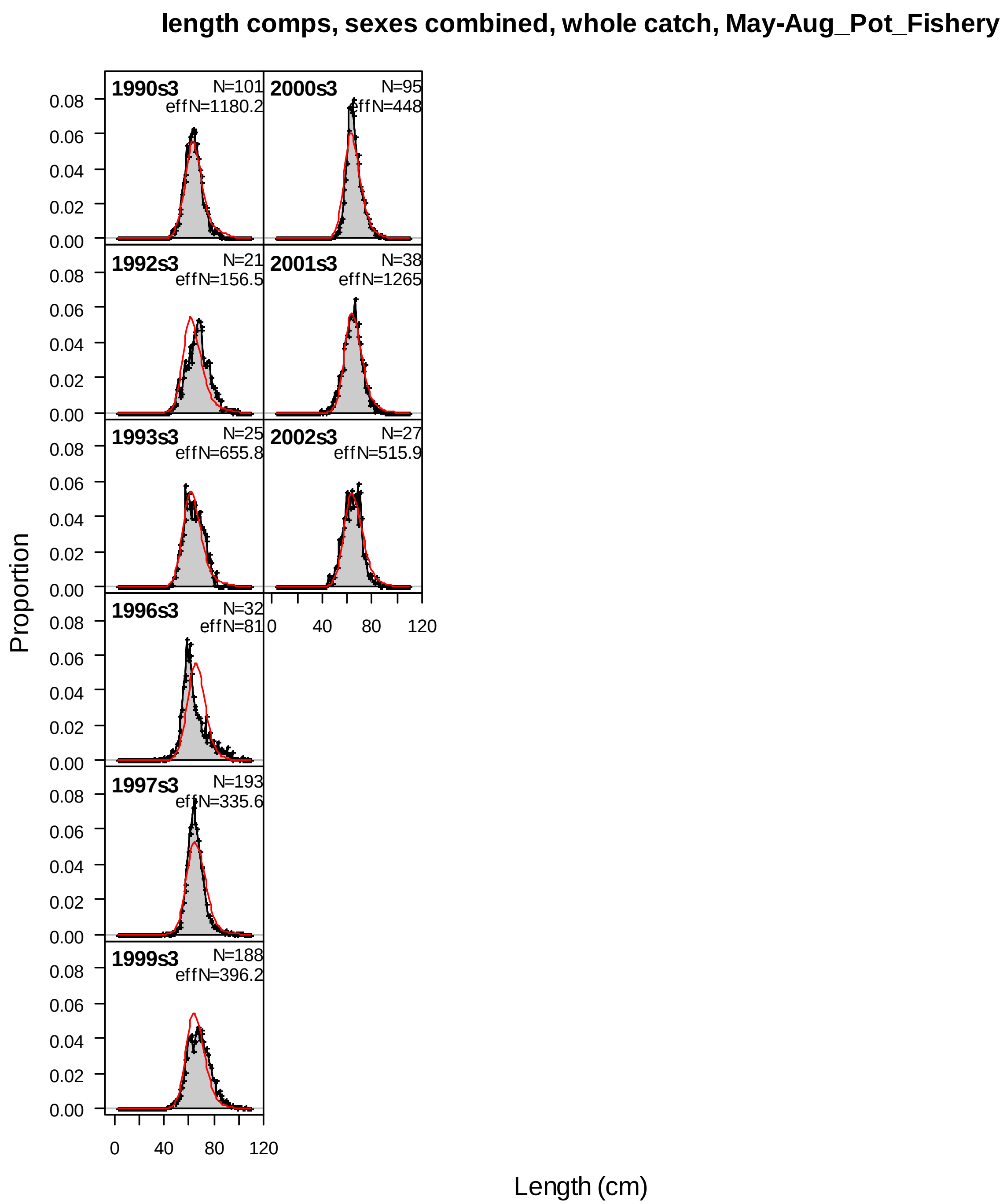
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)


length comps, sexes combined, whole catch, May-Aug_Pot_Fishery
1990s3 N=101 effN=1180.2
2000s3 N=95 effN=448
1992s3 N=21 effN=156.5
2001s3 N=38 effN=1265
1993s3 N=25 effN=655.8
2002s3 N=27 effN=515.9
1996s3 N=32 effN=81
1997s3 N=193 effN=335.6
1999s3 N=188 effN=396.2
Proportion
0.00
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)

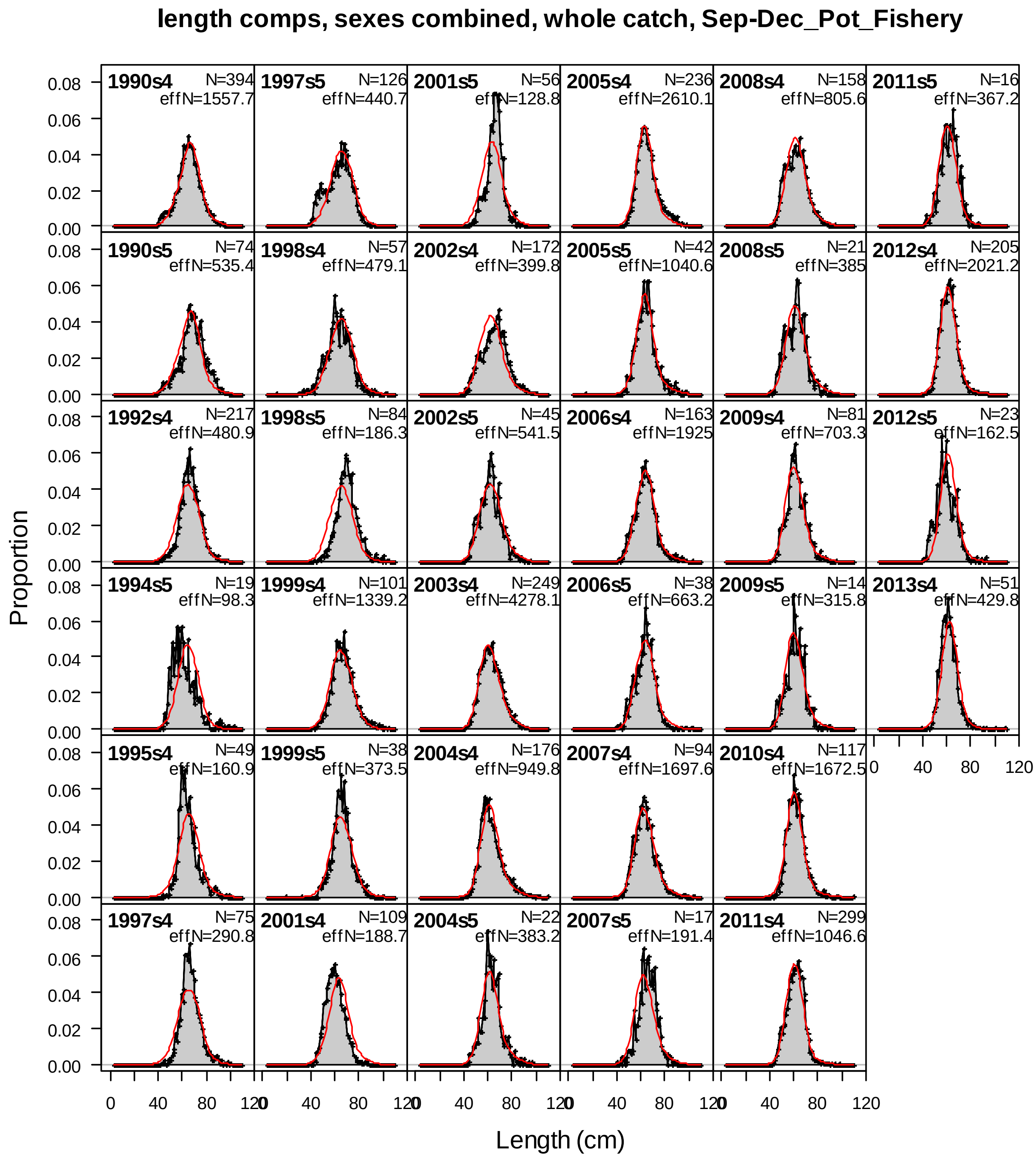

length comps, sexes combined, whole catch, Sep-Dec_Pot_Fishery
Proportion
Length (cm)
1990s4 N=394 effN=1557.7
1997s5 N=126 effN=440.7
2001s5 N=56 effN=128.8
2005s4 N=236 effN=2610.1
2008s4 N=158 effN=805.6
2011s5 N=16 effN=367.2
1990s5 N=74 effN=535.4
1998s4 N=57 effN=479.1
2002s4 N=172 effN=399.8
2005s5 N=42 effN=1040.6
2008s5 N=21 effN=385
2012s4 N=205 effN=2021.2
1992s4 N=217 effN=480.9
1998s5 N=84 effN=186.3
2002s5 N=45 effN=541.5
2006s4 N=163 effN=1925
2009s4 N=81 effN=703.3
2012s5 N=23 effN=162.5
1994s5 N=19 effN=98.3
1999s4 N=101 effN=1339.2
2003s4 N=249 effN=4278.1
2006s5 N=38 effN=663.2
2009s5 N=14 effN=315.8
2013s4 N=51 effN=429.8
1995s4 N=49 effN=160.9
1999s5 N=38 effN=373.5
2004s4 N=176 effN=949.8
2007s4 N=94 effN=1697.6
2010s4 N=117 effN=1672.5
1997s4 N=75 effN=290.8
2001s4 N=109 effN=188.7
2004s5 N=22 effN=383.2
2007s5 N=17 effN=191.4
2011s4 N=299 effN=1046.6

Figure 2.24 – Estimates of spawning biomass with 95% confidence intervals for Model S1a with 2013 survey age data with ending years of 2005 through 2014

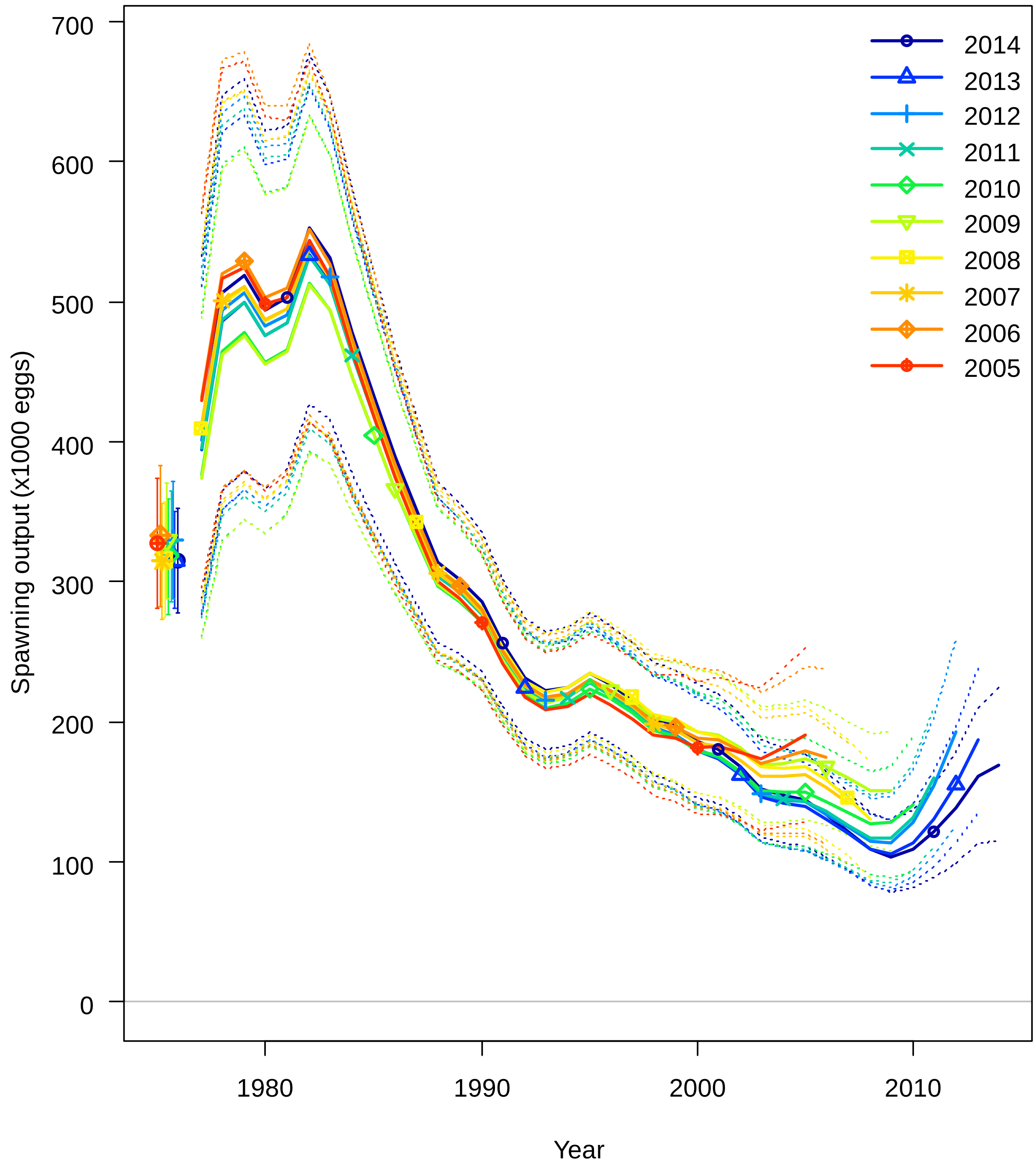


Figure 2.25 – Relative differences in estimates of spawning biomass for Model S1a with 2013 survey age data with ending years of 2005 through 2014

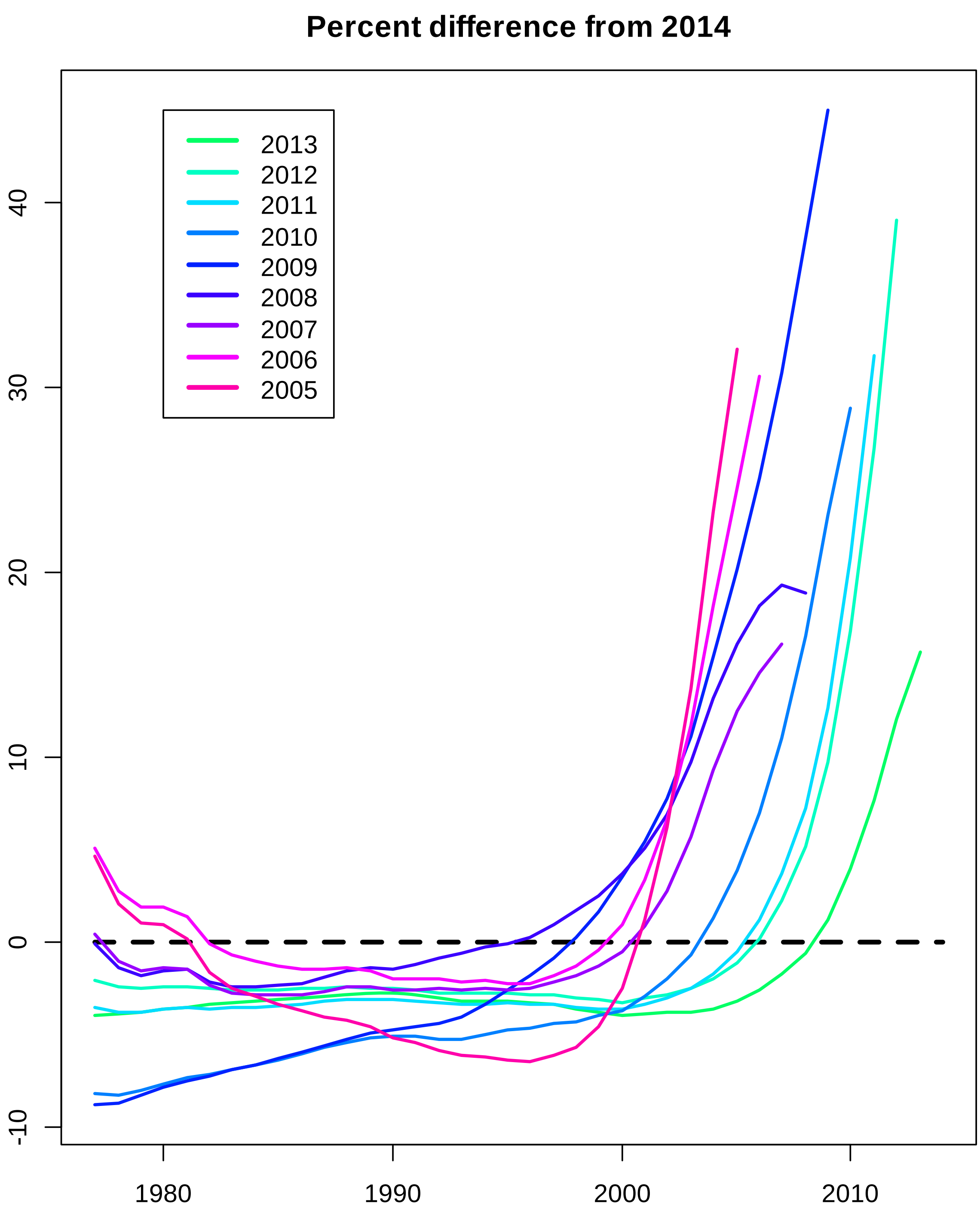


Figure 2.26 - Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model S1a, 1977-2016. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below B20%.

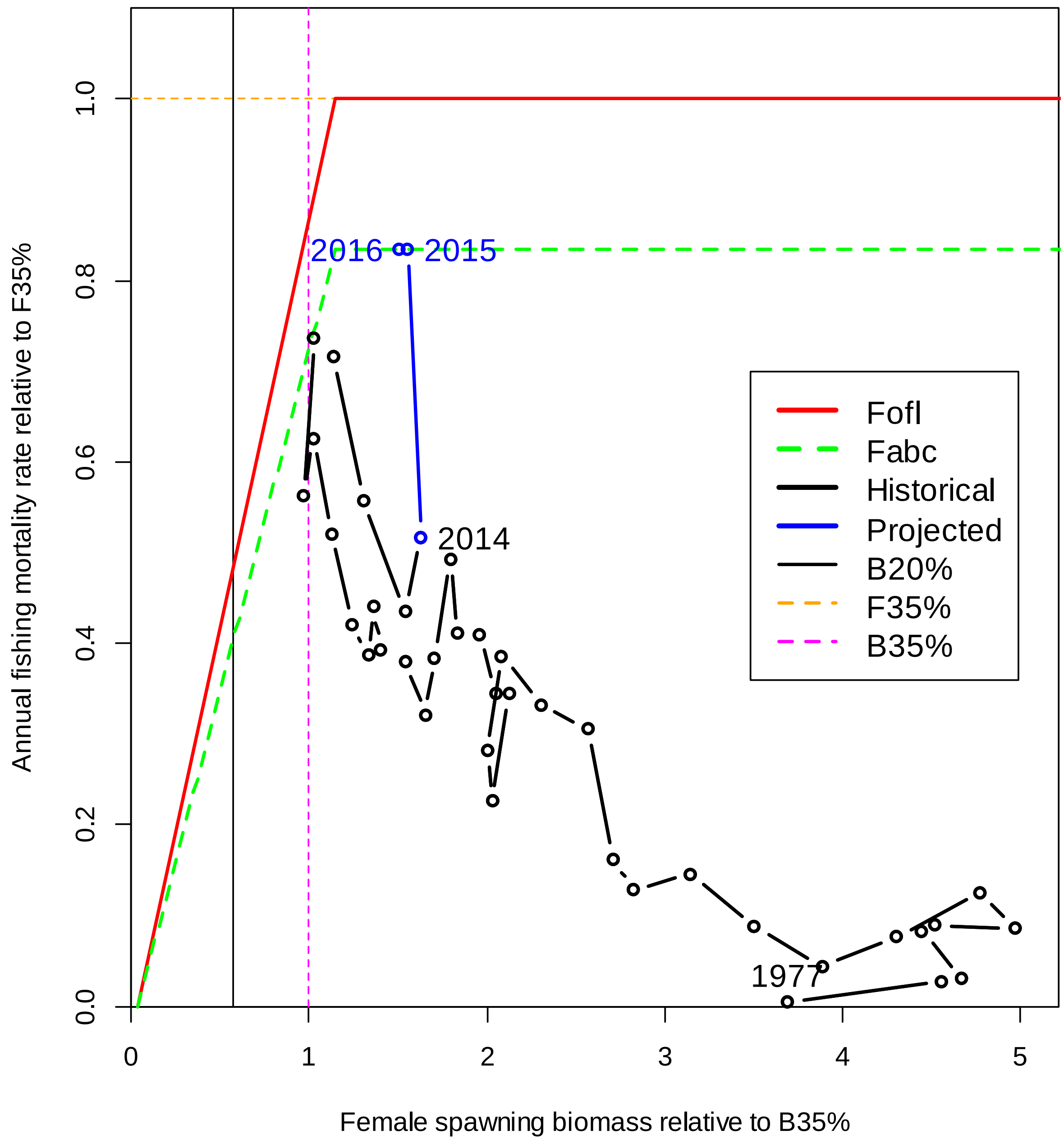
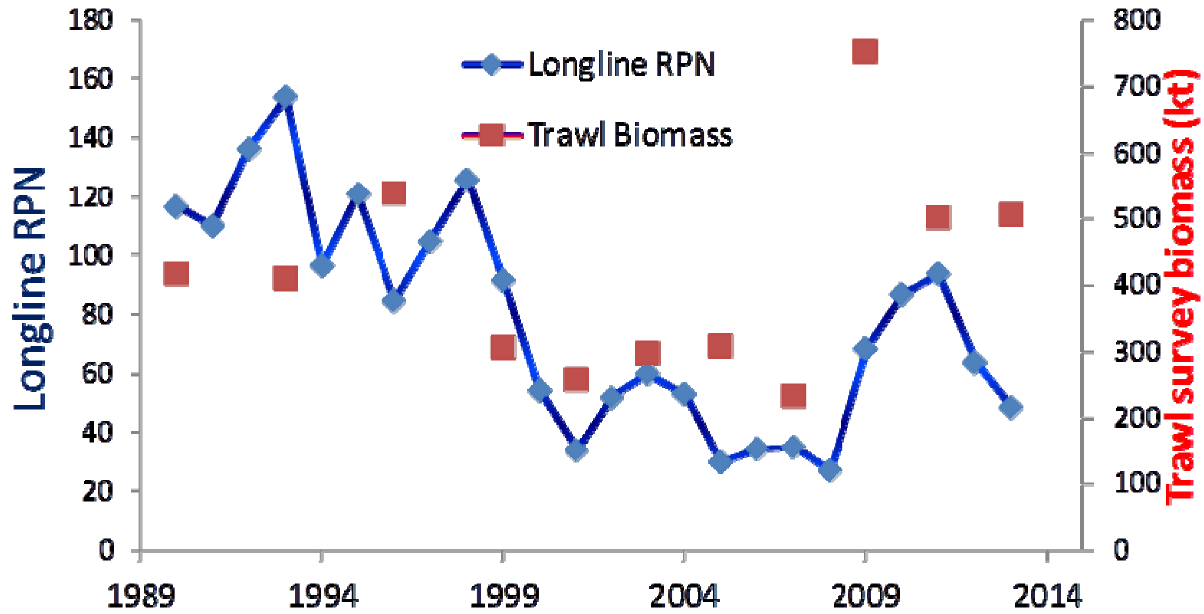


Fig. 2.27 – Comparison of the GOA NMFS bottom trawl survey biomass estimates and the annual longline survey relative population number (RPN) estimates (Dana Hanselman, pers.comm.)



3. Assessment of the sablefish stock in Alaska

by
Dana H. Hanselman, Chris R. Lunsford, and Cara J. Rodgveller

Executive Summary

Summary of changes in assessment inputs

Relative to last year's assessment, we made the following substantive changes in the current assessment.

Changes in the input data: New data included in the assessment model were relative abundance and length data from the 2014 longline survey, relative abundance and length data from the 2013 longline fishery, length data from the 2013 trawl fisheries, age data from the 2013 longline survey and 2013 fixed gear fishery, updated historical catches from 2006 – 2013, and projected 2014- 2016 catches.

Changes in the assessment methodology: There are no model changes.

Summary of results

Quantity/Status	As estimated or specified *last* year for: 2014	2015	As estimated or recommended *this* year for: 2015*	2016*
M (natural mortality rate)	0.10	0.10	0.10	0.10
Tier	3b	3b	3b	3b
Projected total (age 2+) biomass (t)	215,446	221,212	219,997	227,042
Projected female spawning biomass (t)	91,212	88,793	91,183	88,345
$B_{100\%}$	265,903	265,903	262,269	262,269
$B_{40\%}$	106,361	106,361	104,908	104,908
$B_{35\%}$	93,066	93,066	91,794	91,794
F_{OFL}	0.095	0.090	0.098	0.091
$maxF_{ABC}$	0.080	0.077	0.082	0.078
F_{ABC}	0.080	0.077	0.082	0.078
OFL (t)	16,225	14,667	16,128	14,658
max ABC (t)	13,722	12,400	13,657	12,406
ABC (t)	13,722	12,400	**13,657**	12,406
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

* Projections are based on estimated catches of 11,172 t and 9,862 t used in place of maximum permissible ABC for 2015 and 2016. This was done in response to management requests for a more accurate two-year projection.

Assessment results

The fishery abundance index decreased 13% from 2012 to 2013 (the 2014 data are not available yet). The longline survey abundance index increased 15% from 2013 to 2014 following a 25% decrease from 2011 to 2013. Spawning biomass is projected to decrease from 2015 to 2018, and then stabilize.

Sablefish are managed under Tier 3 of NPFMC harvest rules. Reference points are calculated using recruitments from 1979-2012. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 104,908 t (combined across the EBS, AI, and GOA), 0.095, and 0.112, respectively. Projected female spawning biomass (combined areas) for 2015 is 91,183 t (88% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of F_{ABC} under Tier 3b is 0.082, which translates into a 2015 ABC (combined areas) of 13,657 t. The OFL fishing mortality rate is 0.098 which translates into a 2015 OFL (combined areas) of 16,128 t. Model projections indicate that this stock is not subject to overfishing, overfished, nor approaching an overfished condition.

We recommend a 2015 ABC of 13,657 t. The maximum permissible ABC for 2015 from a Tier 3b adjusted $F_{40\%}$ strategy is 13,657 t. The maximum permissible ABC for 2015 is very similar to the 2014 ABC of 13,722 t. The 2013 assessment projected a 10% decrease in ABC for 2015 from 2014. This smaller decrease is supported by a moderate increase in the domestic longline survey index from the all-time low in 2013 that offset the lowest value of the fishery abundance index seen in 2013. The fishery abundance index has been trending down since 2007. The 2013 IPHC GOA sablefish index was not used in the model, but also declined 21% from 2012. The 2008 year class showed potential to be above average in previous assessments based on patterns in the age and length compositions. However the estimate in this year's assessment is only average because it is heavily influenced by the recent large overall decrease in the longline survey and trawl indices. Spawning biomass is projected to decline through 2018, and then is expected to increase; assuming average recruitment is achieved in the future. ABCs are projected to decrease in 2016 to 12,406 t and 12,292 t in 2017 (see Table 3.18).

Projected 2015 spawning biomass is 35% of unfished spawning biomass. Spawning biomass has increased from a low of 32% of unfished biomass in 2002 to 35% of unfished biomass projected for 2015 but is trending downward in projections for the near future. The 1997 year class has been an important contributor to the population; however, it has been reduced and is predicted to comprise less than 7% of the 2015 spawning biomass. The 2000 year class is still the largest contributor, with 16% of the spawning biomass in 2015. The 2008 year class is average and will comprise 10% of spawning biomass in 2015 even though it is only 60% mature.

Apportionment

In December 1999, the Council apportioned the 2000 ABC and OFL based on a 5-year exponential weighting of the survey and fishery abundance indices. We have used the same algorithm to apportion the ABC and OFL since 2000. Following the standard apportionment scheme, we have observed that the objective to reduce variability in apportionment was not being achieved. Since 2007, the average change in apportionment by area has increased annually (Figure 3.36A). While some of these changes may actually reflect interannual changes in regional abundance, they most likely reflect the high movement rates of the population and the high variability of our estimates of abundance in the Bering Sea and Aleutian Islands. For example, the apportionment for the Bering Sea has varied drastically since 2007, attributable to high variability in both survey abundance and fishery CPUE estimates in the Bering Sea (Figure 3.36B). These large annual changes in apportionment result in increased variability of ABCs by area, including areas other than the Bering Sea (Figure 3.36C). Because of the high variability in apportionment seen in recent years, we do not believe the standard method is meeting the goal of reducing the magnitude of interannual changes in the apportionment. Because of these reasons, we recommended fixing the apportionment at the proportions from the 2013 assessment until the apportionment scheme is thoroughly reevaluated and reviewed. A Ph.D. student with the University of Alaska-Fairbanks began a project in 2012 with the objectives of re-examining the apportionment strategy and conducting management strategy evaluations. A spatial sablefish model has been developed, but management strategy evaluations have not begun yet. Meanwhile, it seems imprudent to move to an interim apportionment or return to the former scheme until more satisfactory methods have been identified and evaluated. **Therefore**, **for 2015, we recommend keeping the apportionment fixed at the proportions used in 2014.**

Area	2014 ABC	Standard apportionment for 2015 ABC	Recommended fixed apportionment for 2015 ABC*	Difference from 2014
Total	13,722	13,657	**13,657**	-0.5%
Bering Sea	1,339	2,210	**1,333**	-0.5%
Aleutians	1,811	1,840	**1,802**	-0.5%
Gulf of Alaska (subtotal)	10,572	9,607	**10,522**	-0.5%
Western	1,480	1,445	**1,473**	-0.5%
Central	4,681	3,975	**4,658**	-0.5%
W. Yakutat**	1,574	1,428	**1,567**	-0.5%
E. Yak. / Southeast**	2,837	2,759	**2,823**	-0.5%

* Fixed at the 2012 assessment apportionment proportions (Hanselman et al. 2012). ** Before 95:5 hook and line: trawl split shown below.

Adjusted for 95:5 hook-and-line: trawl split in EGOA	Year	W. Yakutat	E. Yakutat/Southeast
	2015	1,708 t	2,682 t
	2016	1,552 t	2,436 t

Plan team summaries

Area	Year	Biomass (4+)	OFL	ABC	TAC	Catch
GOA	2013	167,000	14,780	12,510	12,510	11,945
	2014	149,000	12,500	10,572	10,572	10,391
	2015	130,000	12,425	10,522		
	2016	127,000	11,293	9,558		
BS	2013	19,000	1,870	1,580	1,580	634
	2014	21,000	1,584	1,339	1,339	328
	2015	34,000	1,575	1,333		
	2016	33,000	1,431	1,211		
AI	2013	28,000	2,530	2,140	2,140	1,062
	2014	28,000	2,141	1,811	1,811	757
	2015	24,000	2,128	1,802		
	2016	23,000	1,934	1,637		

Year	2014				2015		2016	
Region	OFL	ABC	TAC	Catch*	OFL	ABC	OFL	ABC
BS	1,584	1,339	1,339	328	1,575	1,333	1,431	1,211
AI	2,141	1,811	1,811	757	2,128	1,802	1,934	1,637
GOA	12,500	10,572	10,572	10,391	12,425	10,522	11,293	9,558
W	--	1,480	1,480	1,090	--	1,474	--	1,338
C	--	4,681	4,681	4,737	--	4,658	--	4,232
**WYAK	--	1,574	1,574	1,707	--	1,708	--	1,552
SEO	--	2,837	2,837	2,857	--	2,682	--	2,436
Total	16,225	13,722	13,722	11,476	16,128	13,657	14,658	12,406

*Extrapolated from October 1, 2014 Alaska Fisheries Information Network, (www.akfin.org). **After 95:5 trawl split shown above.

Responses to SSC and Plan Team Comments on Assessments in General

The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs. (September 2013, Plan Team)

The Joint Plan Teams in September 2014 examined the compilation of current methods for estimating current year's removals and recognized that the best method was stock specific and encouraged authors to choose the best method for their stocks and document them. We estimated current year's removals by multiplying the official catch as of October 1, 2014, by an expansion factor that represents the average additional catch taken between October 1 and December 31 in the last three complete years (2011-2013). (See *Specified catch estimation* section).

During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment. (December 2013, SSC)

These projections are available in the executive summary table and have been added to the phase-plane plots in this assessment. (See *Figure 3.30*)

Responses to SSC and Plan Team Comments Specific to this Assessment

The Teams recommend establishment of an ecosystem/assessment committee to help set up an example report card that is designed to allow the authors to fill in the blanks as an update rather than develop new conceptual models and to have in-house discussion on this topic before future presentations to the Plan Teams.(November 2012, Plan Team)

In September 2014, a document and presentation was made to the joint Plan Teams by the ecosystem/assessment committee with sablefish as an example species. The Plan Team and SSC encouraged development of stock-specific ecosystem consideration sections that have ecosystem indicators specific to particular stocks. We hope to include sablefish as an example stock as this effort moves forward.

The Teams recommend that the authors investigate time-varying selectivity in relation to some of the issues seen in the retrospective pattern. (November 2012, Plan Team)

Selectivity for the longline survey and longline fishery are currently time-varying, but not annually. The time blocks are related to specific changes in the survey (transition from cooperative to domestic) and the fishery (transition from derby to IFQ). The lack of retrospective trend in recent years (see Figure 3.31) does not warrant a change to fishery selectivity. However, the most recent fishery age data in 2013 show a shift to older fish driven by catches in the Aleutian Islands. These data may warrant exploration of annual varying selectivity for the 2015 assessment.

The SSC continues to encourage the development of a spatial assessment model for research purposes and supports the additional collection and analysis of biological samples needed to support a movement model.(December 2012, SSC)

A study on sablefish movement and mortality has been accepted for publication (Hanselman et al. 2014). Additionally, there is a UAF Ph.D. student working on a spatial assessment model for sablefish. We continue to evaluate and progress towards spatially explicit modeling of sablefish.

The Teams recommended following the authors' approach for apportionment as an interim measure (-15% across all areas). The Teams also recommended that the standard approach (used in previous year's assessments) be presented to the SSC and Council and noted that work is underway to select an improved apportionment approach. (November 2013, Plan Team)

For this year we continue to recommend the interim apportionment approach which is explained in detail in the apportionment Section (See Section *Apportionment*).

The SSC reviewed the recommended alteration to the usual algorithm of spatial apportionment. The SSC approves the alternative apportionment for next year. However, the SSC is concerned about removing a data point (2013) without strong justification. The SSC recommends re-examining the method for spatially allocating the sablefish ABC in the next year. To the extent practicable, the SSC requests that the authors try to include preliminary results of the spatial MSE in the 2014 assessment.(December 2013, SSC)

The spatial MSE is not completed at this time. However, we are working closely with a graduate student who has made significant progress toward a spatial assessment model which will be the foundation of the management strategy evaluations.

The SSC reiterates its concern that the current assessment model exhibits a strong retrospective pattern and encourages further exploration of the factors underlying the slow response of the model to shifts in stock status. (December 2013, SSC)

The sablefish model had a period of retrospective bias between 2004-2008, (see *Retrospective Analysis* section) but that bias appears to have dissipated in the last 5 years. In the Plan Team retrospective investigations group report, sablefish had one of the lowest rankings in terms of retrospective problems (17 out of 20). For 2014, the retrospective pattern has lessened further. In previous examinations of the retrospective pattern for sablefish (Hanselman et al. 2011), it was shown that longline survey catchability had a systematic pattern of change relative to the number of retrospective peels. For 2014, there was a substantial increase in past catch estimates during the period with high retrospective bias (see *Catch* section under ***Data****)*. This increase in catch increased our current estimates of spawning biomass during that historically low period which contributed to the reduction in Mohn's revised rho (see *Retrospective Analysis* section for further details).

Introduction

Distribution

Sablefish (*Anoplopoma fimbria*) inhabit the northeastern Pacific Ocean from northern Mexico to the Gulf of Alaska (GOA), westward to the Aleutian Islands (AI), and into the Bering Sea (BS) (Wolotira et al. 1993). Adult sablefish occur along the continental slope, shelf gullies, and in deep fjords, generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Krieger 1997). In contrast to the adult distribution, juvenile sablefish spend their first two to three years on the continental shelf of the GOA, and occasionally on the shelf of the southeast BS. The BS shelf is utilized significantly in some years and seldom used during other years (Shotwell et al. 2012).

Early life history

Spawning is pelagic at depths of 300-500 m near the edges of the continental slope (Mason et al. 1983, McFarlane and Nagata 1988), with eggs developing at depth and larvae developing near the surface as far offshore as 180 miles (Wing 1997). Along the Canadian coast (Mason et al. 1983) and off Southeast Alaska (Jennifer Stahl, February, 2010, ADF&G, pers. comm.) sablefish spawn from January-April with a peak in February. In a survey near Kodiak Island in December, 2011 that targeted sablefish preparing to spawn, spawning appeared to be imminent, but spent fish were not found. It is likely that they would spawn in January or February (Katy Echave, October 2012, AFSC, pers. comm.). Farther down the coast off of central California sablefish spawn earlier, from October-February (Hunter et al. 1989). An analysis of larval otoliths showed that spawning in the Gulf of Alaska may be a month later than southern sablefish (Sigler et al. 2001). Sablefish in spawning condition were also noted as far west as Kamchatka in November and December (Orlov and Biryukov 2005). In gill nets set at night for several years on the AFSC longline survey, most young-of-the-year sablefish were caught in the central and eastern GOA (Sigler et al. 2001). Near the end of the first summer, pelagic juveniles less than 20 cm move inshore and spend the winter and following summer in inshore waters, reaching 30-40 cm by the end of their second summer (Rutecki and Varosi 1997). After their second summer, they begin moving offshore to deeper water, typically reaching their adult habitat, the upper continental slope at 4 to 5 years. This corresponds to the age range when sablefish start becoming reproductively viable (Mason et al. 1983).

Movement

A movement model for Alaskan sablefish was developed for Alaskan sablefish by Heifetz and Fujioka (1991) based on 10 years of tagging data. The model has been updated by incorporating data from 1979-2009 in an AD Model Builder program, with time-varying reporting rates, and tag recovery data from ADF&G for State inside waters (Southern Southeast Inside and Northern Southeast Inside). In addition, the study estimated mortality rates from the tagging data (Hanselman et al. *in press*). Annual movement probabilities were high, ranging from 10-88% depending on area of occupancy at each time step, and size group. Overall, movement probabilities were very different between areas of occupancy and moderately different between size groups. Estimated annual movement of small sablefish from the central Gulf of Alaska had the reverse pattern of a previous study, with 29% moving westward and 39% moving eastward. Movement probabilities also varied annually with decreasing movement until the late 1990s and increasing movement until 2009. Year specific magnitude in movement probability of large fish was highly negatively correlated with female spawning biomass estimates from the federal stock assessment. Average mortality estimates from time at liberty were similar to the stock assessment.

Stock structure

Sablefish form two populations based on differences in growth rate, size at maturity, and tagging studies (McDevitt 1990, Saunders et al. 1996, Kimura et al. 1998). A northern population inhabits Alaska and northern British Columbia waters and a southern population inhabits southern British Columbia, Washington, Oregon, and California waters, with mixing of the two populations occurring off southwest Vancouver Island and northwest Washington. Significant stock structure among the federal Alaska population is unlikely given extremely high movement rates throughout their lives (Heifetz and Fujioka 1991, Maloney and Heifetz 1997, Kimura et al. 1998).

Fishery

Early U.S. fishery, 1957 and earlier

Sablefish have been exploited since the end of the 19th century by U.S. and Canadian fishermen. The North American fishery on sablefish developed as a secondary activity of the halibut fishery of the United States and Canada. Initial fishing grounds were off Washington and British Columbia and then spread to Oregon, California, and Alaska during the 1920's. Until 1957, the sablefish fishery was exclusively a U.S. and Canadian fishery, ranging from off northern California northward to Kodiak Island in the GOA; catches were relatively small, averaging 1,666 t from 1930 to 1957, and generally limited to areas near fishing ports (Low et al. 1976).

Foreign fisheries, 1958 to 1987

Japanese longliners began operations in the eastern BS in 1958. The fishery expanded rapidly in this area and catches peaked at 25,989 t in 1962 (Table 3.1, Figures 3.1, 3.2). As the fishing grounds in the eastern Bering were preempted by expanding Japanese trawl fisheries, the Japanese longline fleet expanded to the AI region and the GOA. In the GOA, sablefish catches increased rapidly as the Japanese longline fishery expanded, peaking at 36,776 t overall in 1972. Catches in the AI region remained at low levels with Japan harvesting the largest portion of the sablefish catch. Most sablefish harvests were taken from the eastern Being Sea until 1968, and then from the GOA until 1977. Heavy fishing by foreign vessels during the 1970's led to a substantial population decline and fishery regulations in Alaska, which sharply reduced catches. Catch in the late 1970's was restricted to about one-fifth of the peak catch in 1972, due to the passage of the Fishery Conservation and Management Act (FCMA).

Japanese trawlers caught sablefish mostly as bycatch in fisheries targeting other species. In the BS, the trawlers were mainly targeting rockfishes, Greenland turbot, and Pacific cod, and only a few vessels targeted sablefish. In the GOA, sablefish were mainly caught as bycatch in the directed Pacific Ocean perch fishery until 1972, when some vessels started targeting sablefish in 1972 (Sasaki 1985).

Other foreign nations besides Japan also caught sablefish. Substantial Soviet Union catches were reported from 1967-73 in the BS (McDevitt 1986). Substantial Korean catches were reported from 1974-1983 scattered throughout Alaska. Other countries reporting minor sablefish catches were Republic of Poland, Taiwan, Mexico, Bulgaria, Federal Republic of Germany, and Portugal. The Soviet gear was factory-type stern trawl and the Korean gears were longlines and pots (Low et al. 1976).

Recent U.S. fishery, 1977 to present

The U.S. longline fishery began expanding in 1982 in the GOA, and by 1988, the U.S. harvested all sablefish taken in Alaska, except minor joint venture catches. Following domestication of the fishery, the previously year-round season in the GOA began to shorten in 1984 from 12 months in 1983 to 10 days in 1994, warranting the label “derby” fishery.

In 1995, Individual Fishery Quotas (IFQ) were implemented for hook-and-line vessels along with an 8-month season. The IFQ Program is a catch share fishery that issued quota shares to individuals based on sablefish and halibut landings made from 1988-1990. Since the implementation of IFQ’s, the number of longline vessels with sablefish IFQ harvests has experienced a substantial anticipated decline from 616 in 1995 to 362 in 2011 (NOAA 2012). This decrease was expected as shareholders have consolidated their holdings and fish them off fewer vessels to reduce costs (Fina 2011). The sablefish fishery has historically been a small boat fishery; the median vessel length in the 2011 fishery was 56ft. In recent years, approximately 30% of vessels eligible to fish in the IFQ fishery participate in both the halibut and sablefish fisheries and approximately 40% of vessels fish in more than one management area. The season dates have varied by several weeks since 1995, but the monthly pattern has been from March to

November with the majority of landings occurring in May - June. The number of landings fluctuates with quota size, but in 2011 there were 1,726 landings recorded in the Alaska fishery (NOAA 2012).

Pot fishing in the IFQ fishery is not allowed in the GOA but is legal in the BSAI regions. In 2000, the pot fishery accounted for less than ten percent of the fixed gear sablefish catch in these areas but effort has increased substantially in response to killer whale depredation. Pots are longlined with approximately 40-135 pots per set. Since 2004, pot gear has accounted for over 50% of the BS fixed gear IFQ catch and up to 34% of the fixed gear catch in the AI.

Sablefish also are caught incidentally during directed trawl fisheries for other species groups such as rockfish and deepwater flatfish. Allocation of the TAC by gear group varies by management region and influences the amount of catch in each region (Table 3.1, Figures 3.1, 3.2). Five State of Alaska fisheries land sablefish outside the IFQ program; the major State fisheries occur in the Prince William Sound, Chatham Strait, and Clarence Strait and the minor fisheries in the northern GOA and AI. The minor state fisheries were established by the State of Alaska in 1995, the same time as the Federal Government established the IFQ fishery, primarily to provide open-access fisheries to fishermen who could not participate in the IFQ fishery.

IFQ management has increased fishery catch rates and decreased the harvest of immature fish (Sigler and Lunsford 2001). Catching efficiency (the average catch rate per hook for sablefish) increased 1.8 times with the change from an open-access to an IFQ fishery. The change to IFQ also decreased harvest and discard of immature fish which improved the chance that these fish will reproduce at least once. Thus, the stock can provide a greater yield under IFQ at the same target fishing rate because of the selection of older fish (Sigler and Lunsford 2001).

Longline gear in Alaska is fished on-bottom. Since the inception of the IFQ system, average set length in the directed fishery for sablefish has been near 9 km and average hook spacing near1.2 m. The gear is baited by hand or by machine, with smaller boats generally baiting by hand and larger boats generally baiting by machine. Circle hooks are usually used, except for modified J-hooks on some boats with machine baiters. The gear usually is deployed from the vessel stern with the vessel traveling at 5-7 knots. Some vessels attach weights to the longline, especially on rough or steep bottom, so that the longline stays in place on bottom.

Management measures/units

A summary of historical catch and management measures pertinent to sablefish in Alaska are shown in Table 3.7. Influential management actions regarding sablefish include:

Management units

Sablefish are assessed as a single population in Federal waters off Alaska because of their high movement rates. Sablefish are managed by discrete regions to distribute exploitation throughout their wide geographical range. There are four management areas in the GOA: Western, Central, West Yakutat, and East Yakutat/Southeast Outside; and two management areas in the Bering Sea/Aleutian Islands (BSAI): the BS and the AI regions. Amendment 8 to the GOA Fishery Management Plan established the West and East Yakutat management areas for sablefish, effective 1980.

Quota allocation

Amendment 14 to the GOA Fishery Management Plan allocated the sablefish quota by gear type: 80% to fixed gear (including pots) and 20% to trawl in the Western and Central GOA, and 95% to fixed gear and 5% to trawl in the Eastern GOA, effective 1985. Amendment 15 to the BS/AI Fishery Management Plan, allocated the sablefish quota by gear type, 50% to fixed gear and 50% to trawl in the eastern BS, and 75% to fixed gear and 25% to trawl gear in the Aleutians, effective 1990.

IFQ management

Amendment 20 to the GOA Fishery Management Plan and 15 to the BS/AI Fishery Management Plan established IFQ management for sablefish beginning in 1995. These amendments also allocated 20% of the fixed gear allocation of sablefish to a CDQ reserve for the BS and AI.

Maximum retainable allowances

Maximum retainable allowances for sablefish were revised in the GOA by a regulatory amendment, effective April, 1997. The percentage depends on the basis species: 1% for pollock, Pacific cod, Atka mackerel, “other species”, and aggregated amount of non-groundfish species. Fisheries targeting deep flatfish, rex sole, flathead sole, shallow flatfish, Pacific ocean perch, northern rockfish, dusky rockfish, and demersal shelf rockfish in the Southeast Outside district, and thornyheads are allowed 7%. Arrowtooth flounder fisheries are not allowed to retain any sablefish.

Allowable gear

Amendment 14 to the GOA Fishery Management Plan banned the use of pots for fishing for sablefish in the GOA, effective 18 November 1985, starting in the Eastern area in 1986, in the Central area in 1987, and in the Western area in 1989. An earlier regulatory amendment was approved in 1985 for 3 months (27 March - 25 June 1985) until Amendment 14 was effective. A later regulatory amendment in 1992 prohibited longline pot gear in the BS (57 FR 37906). The prohibition on sablefish longline pot gear use was removed for the BS, except from 1 to 30 June to prevent gear conflicts with trawlers during that month, effective 12 September 1996. Sablefish longline pot gear is allowed in the AI.

Catch

Annual catches in Alaska averaged about 1,700 t from 1930 to 1957 and exploitation rates remained low until Japanese vessels began fishing for sablefish in the BS in 1958 and the GOA in 1963. Catches rapidly escalated during the mid-1960s. Annual catches in Alaska reached peaks in 1962, 1972, and 1988 (Table 3.1, Figure 3.2). The 1972 catch was the all-time high, at 53,080 t, and the 1962 and 1988 catches were 50% and 72% of the 1972 catch. Evidence of declining stock abundance and passage of the MSFCMA led to significant fishery restrictions from 1978 to 1985, and total catches were reduced substantially.

Exceptional recruitment fueled increased abundance and increased catches during the late 1980's, which coincided with the domestic fishery expansion. Catches declined during the 1990's, increased in the early 2000s, and have since declined to near 12,000 t (Figure 3.1). TACs in the GOA are nearly fully utilized, while TACs in the BS and AI are rarely fully utilized.

Bycatch and discards

Sablefish discards by target fisheries are available for hook-and-line gear and other gear combined (Table 3.3). From 1994 to 2004 discards averaged 1,357 t for the GOA and BSAI combined (Hanselman et al. 2008). Since then, discards have been lower, averaging 614 t between 2007 and 2013. The highest discard amounts occur in hook-and-line fisheries in the GOA (Table 3.3).

Table 3.4 shows the average bycatch of Fishery Management Plans’ (FMP) groundfish species in the sablefish target fishery from 2009-2013. The largest bycatch group is GOA thornyhead rockfish (520 t/year, 151 t discarded). Arrowtooth flounder and shark are the 2nd and 3rd most caught species at 348 t/year and 331 t/year. Arrowtooth is the only species that has substantial catch in non-longline gear. The next three groups are GOA Shortraker, GOA Other rockfish, and GOA longnose skate which total 435 t/year.

Giant grenadiers, a non-target species that is soon entering both FMPs as an Ecosystem Component, make up the bulk of the nontarget species bycatch, with 2013 the highest in the last five years at 8,083 t (Table

3.5). Other nontarget taxa that have catches over one ton per year are corals, snails, sponges, sea stars, and miscellaneous fishes and crabs.

Prohibited species catches (PSC) in the targeted sablefish fisheries are dominated by halibut (1,224 t/year on average) and golden king crab (66,000 individuals/year on average). Halibut and golden king crab catches are highly variable from year to year, probably as a result of relatively low observer sampling effort in sablefish fisheries (Table 3.6).

Data

The following table summarizes the data used for this assessment:

Source	Data	Years
Fixed gear fisheries	Catch	1960-2014
Trawl fisheries	Catch	1960-2014
Japanese longline fishery	Catch-per-unit-effort (CPUE)	1964-1981
U.S. fixed gear fishery	CPUE, length	1990-2013
	Age	1999-2013
U.S. trawl fisheries	Length	1990,1991,1999, 2005-2013
Japan-U.S. cooperative longline survey	CPUE, length	1979-1994
	Age	1981, 1983, 1985, 1987, 1989, 1991, 1993
Domestic longline survey	CPUE, length	1990-2014
	Age	1996-2013
NMFS GOA trawl survey	Abundance index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013
	Lengths	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013

Fishery

Length, catch, and effort data were historically collected from the Japanese and U.S. longline and trawl fisheries, and are now collected from U.S. longline, trawl, and pot fisheries (Table 3.8). The Japanese data were collected by fishermen trained by Japanese scientists (L. L. Low, August 25, 1999, Alaska Fisheries Science Center, pers. comm.). The U.S. fishery length and age data were collected by at-sea and plant observers. No age data were systematically collected from the fisheries until 1999 because of the difficulty of obtaining representative samples from the fishery and because only a small number of sablefish can be aged each year. The equations used to compile the fishery and survey data used in the assessment are shown in Appendix A of the 2002 SAFE (Sigler et al. 2002).

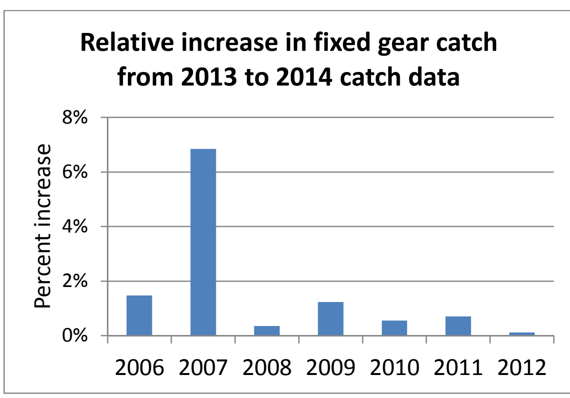
Catch

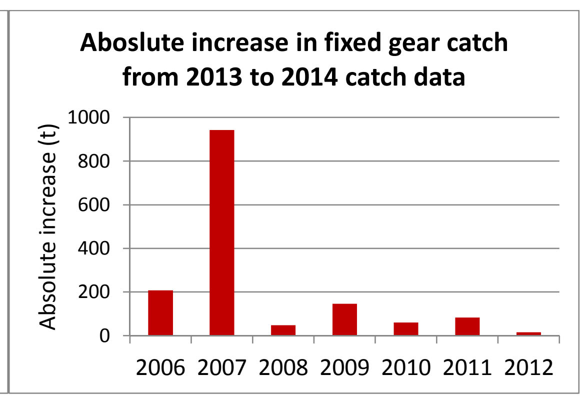
The catches used in this assessment (Table 3.1) include catches from minor State-managed fisheries in the northern GOA and in the AI region because fish caught in these State waters are reported using the area code of the adjacent Federal waters in the Alaska Regional Office catch reporting system (G. Tromble, July 12, 1999, Alaska Regional Office, pers. comm.), the source of the catch data used in this assessment. Minor State fisheries catches averaged 180 t from 1995-1998, about 1% of the average total catch. Most of the catch (80%) is from the AI region. The effect of including these State waters catches in the assessment is to overestimate biomass by about 1%, a negligible error considering statistical variation in other data used in this assessment. Catches from state areas that conduct their own assessments and set Guideline Harvest levels (e.g., Prince William Sound, Chatham Strait, and Clarence Strait), are not included in this assessment.

Some catches probably were not reported during the late 1980's (Kinoshita et al. 1995). Unreported catches could account for the Japan-U.S. cooperative longline survey index's sharp drop from 1989-90 (Table 3.8, Figures 3.3). We tried to estimate the amount of unreported catches by comparing reported catch to another measure of sablefish catch, sablefish imports to Japan, the primary buyer of sablefish. However the trends of reported catch and imports were similar, so we decided to change our approach for catch reporting in the 1999 assessment (Sigler et al. 1999). We assumed that non-reporting is due to at-sea discards, and apply discard estimates from 1994 to 1997 to inflate U.S. reported catches before 1994 (2.9% for hook-and-line and 26.6% for trawl).

In response to Annual Catch Limit (ACL) requirements, assessments now document all removals including catch that are not associated with a directed fishery. Research catches of sablefish have been reported in previous stock assessments (Hanselman et al. 2009). Estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 3B. The sablefish research removals are small relative to the fishery catch, but substantial compared to the research removals for many other species. These research removals support a dedicated longline survey. Additional sources of significant removals are bottom trawl surveys and the International Pacific Halibut Commission's longline survey. Other removals are relatively minor for sablefish but the sport fishery catch has been increasing in recent years, but occurs primarily in State waters. Total removals from activities other than directed fishery have been between 239-359 t since 2006. These catches are not included in the stock assessment model. These removal estimates equate to approximately 2% of the recommended ABC and represent a relatively low risk to the sablefish stock.

For the 2014 assessment, sablefish catches since 2006 have been altered substantively in the Alaska Regional Office Catch Accounting System (CAS) revisions. The years 2006-2009 were particularly different than reported in the 2013 SAFE. These estimates of catch have been updated and corrected to account for selected landings and associated catch that were inadvertently not being counted against the Federal ABC. The missing records were a result of the transition to the eLandings system and the fact that not all processors were using the system in those years. During that time, there were paper fish tickets generated from processors who were not using eLandings. Those data were entered into the eLandings system by Alaska Department of Fish and Game, but were missing federal permit information and thus did not get properly captured by the CAS. Recently, changes were made to CAS to enable accounting of groundfish landings with missing federal permit information and CAS has been re-run for the historical years. This resulted in a net total increase of about 1,500 t to the sablefish catch in since 2005, with the biggest relative increase in 2007 (see figures below).





Lengths

We use length compositions from the U.S. fixed gear (longline and pot) and U.S. trawl fisheries which are both measured by sex. The fixed gear fishery has large sample sizes and has annual data since 1990. The trawl fishery had low levels of observer sampling in much of the 1990s and early 2000s, and has a much smaller sample size than the fixed gear fishery. We only use years for the trawl fishery that have sample sizes of at least 300 per sex. The length compositions are weighted by catch in each FMP management area to obtain a representative estimate of catch-at-length.

Ages

We use age compositions from the U.S. fixed gear fishery since 1999. Sample sizes are similar to the longline survey with about 1,000 otoliths aged every year. The age compositions are weighted by the catch in each area to obtain a representative estimate of catch-at-age.

Longline fishery catch rate index

Fishery information is available from longline sets which target sablefish in the IFQ fishery. Records of catch and effort for these vessels are collected by observers and by vessel captains in voluntary and required logbooks. Fishery data from the Observer Program is available since 1990. Logbooks are required for vessels over 60 feet beginning in 1999. Since 2000, a longline fishery catch rate index has been derived from observed sets and logbook data for use in the model and in apportionment. The mean CPUE is scaled to a relative population weight by the total area size in each area. In the years that logbook and observer CPUEs are available, the average of the two sources is computed by weighting with the inverse of the coefficient of variation.

Longline sample sizes

The total weight of all sets recorded by observers determined to be targeting sablefish represent on average 14% of the annual IFQ hook and line catch; in 2013 they comprised 12% of the catch (1,389 mt). On average, the percent of the IFQ catch observed is lowest in the EY/SE (5%), highest in WY and AI (~22%), and moderate in the BS, CGOA, and WGOA (10-14%). In 2013 coverage in the BS was only 2% and only 10% in WY. The AI had higher coverage than average (35%). This may partially be due to observer restructuring. Low longline fishery sample sizes in the BS are likely a result of poor observer coverage for sablefish directed trips (Table 3.9). Because of confidentiality concerns, the catch rates with less than three vessels cannot be shown.

Killer whales impact sablefish catch rates in the BS, AI and WGOA and these sets are excluded from catch rate analyses. Since 2009, there has been an increase in killer whale depredation in the WGOA (average 6% from 2010-2013); however, this is only 7-18 sets per year. In the AI and BS, killer whale depredation has been variable, ranging from 0-12 sets per year in each area. Sperm whale depredation occurs in the CGOA, EY/SE, WY, and sometimes in the WGOA. The percent of sets in each area depredated by sperm whales varies greatly and determining if sperm whales are depredating can be subjective because whales do not take the great majority of the catch, like killer whales do. Therefore, measures of depredation in the fishery may not be accurate.

Logbook sample sizes are substantially higher than observer samples sizes, especially since 2004, and have continued to rise annually in many management areas (WGOA, WY, CGOA) (Table 3.9). Logbook participation increased sharply in 2004 in all areas primarily because the International Pacific Halibut Commission (IPHC) was used to collect, edit, and enter logbooks electronically. This increasing trend is likely due to the strong working relationship the IPHC has with fishermen, their diligence in collecting logbooks dockside, and because many vessels <60 feet are now participating in the program voluntarily. There were 5% more sets used for catch rate analyses in 2013 than in 2012. Like in 2012, the number of sets submitted by vessels <60 ft was approximately equal to the number from vessels >60 ft. There is a higher proportion of the catch documented by logbooks than by observers; 54% of the catch was documented in logbooks that were used in calculations of catch rates in 2013, compared to 12% for observer data in 2013. Some data is included in both data sets if logbooks are required and an observer was onboard.

Longline catch rates

Killer whale depredation data is excluded for catch rate calculations in observer data, but whale depredation is not documented in logbooks and so no data is excluded. In general, catch rates are highest in the EY/SE and WY areas and are lowest in the BS and AI (Table 3.9, Figures 3.5 and 3.6). Recently, catch rate trends in the observer and logbook data have been similar in the EBS, CGOA, WGOA, and AI. In 2013 catch rates decreased substantially in both fishery data sets in the WGOA and CGOA. The decrease was larger in the logbook data set (30% drop in WGOA and 39% in CGOA in logbook data; 11% drop in WGOA and 31% in CGOA in observer data). Catch rates in the AI have been pretty stable since 2009 in both data sets. In 2013, WY logbook CPUE was down, while the observer data was up from 2012. EY/SE CPUE decreased in both data sets, but more in logbook data than observer data (14% versus 2%).

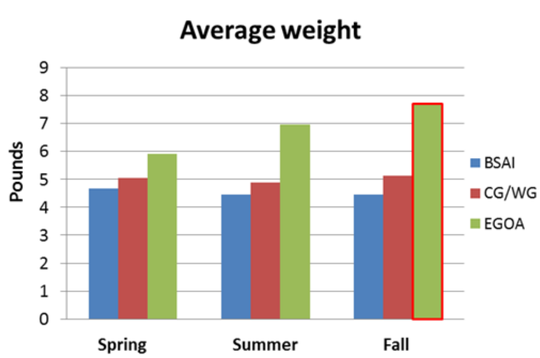
Longline spatial and temporal patterns

Changes in spatial or temporal patterns of the fishery may cause fishery catch rates to be unrepresentative of abundance. For example, fishers sometimes target concentrations of fish, even as geographic distribution shrinks when abundance declines (Crecco and Overholtz 1990). This could lead to an incorrect interpretation of fishery catch rates, which could remain stable while the area occupied by the stock was diminishing (Rose and Kulka 1999).

We examined fishery longline data for seasonal and annual differences in effort and catch rate (CPUE, lbs/hook). Such changes may cause fishery catch rates to be unrepresentative of abundance. In the observed longline data since 2000, the majority of effort occurs in the spring and less in the summer and fall. Since 1998, catch rates are also highest in the spring, moderate in the summer, and variable in the fall (due to lower sample sizes in the fall). No significant spatial or temporal changes have emerged in the logbook or observer data.

Seasonal changes in fish size

In 2012 and 2013 there was an increase in the quantity of logbook data providing estimates of catch in weight and estimated numbers per set. This enables us to examine change in average weight of fish caught by season. Data from 2012 and 2013 were combined to increase sample sizes. To further increase sample size, areas were aggregated into BS/AI, CG/WGOA, and WY/EY/SE (EGOA). Data were included unless there was missing weight or count information. There were very small differences between spring, summer, and fall in all areas except the EGOA (see figure below). However, this may be a sample size issue as there were very few sets available in the fall in EGOA compared to all other areas/seasons (78 sets; highlighted in red below). In EGOA, weight in spring was 5.9 lbs, 7 lbs in summer, and 7.7 lbs in fall. More data is needed to determine if there actually is an increasing trend in weight in the fall in the EGOA.



Count of logbook sets used for calculations of average sablefish weight by area and season.

Area	Spring	Summer	Fall	Total
BS/AI	560	614	157	1,331
CG/WG	1,563	1,409	403	3,375
EGOA	783	297	78	1,158

Pot fishery catch rate analysis

Pot catch rates: Because pot data is sparser than longline data, and in some years is confidential due to fewer than 3 vessels participating, specific annual data is not presented. In addition, it is difficult to discern trends, since pot catch rates have wider confidence intervals than longline data due to smaller sample sizes. Overall, there are more vessels in both the logbook and observer data from the sablefish pot fishery in the BS than the AI.

Since 2006, in the BS there have been from 5 to 9 vessels in logbook data and 5 to 8 vessels in observer data. In the AI, there have been from 1 to 5 vessels in logbooks and 1 to 4 in observer data. In 2013, CPUE remained stable in logbook data but fewer total pots and sets were recorded during the year, especially in the AI. From 2006-2013 the average catch rate in logbook data was 29 lbs/pot in the AI (number sets (n) = 809) and 24 lbs/pot in the BS (n = 6,164). Pot CPUE has been stable in observer data as well. Average catch rate in the observer data from 2006-2013 was 11 lbs/pot (n = 1,156) in the AI and 18 lbs/pot (n = 2,970) in the BS. Effort is approximately equal throughout the fishing season.

The composition of bycatch species caught in observed pots that retained sablefish in the BS and AI is comprised mostly of arrowtooth/Kamchatka flounder, golden king crab, Greenland turbot, Pacific halibut, and giant grenadier. Almost all of the golden king crab is caught in the AI (Hanselman et al. 2010).

Surveys

A number of fishery independent surveys catch sablefish. The survey indices included in the model for this assessment are the AFSC longline survey and the AFSC GOA bottom trawl survey. For other surveys that occur in the same or adjacent geographical areas, but are not included as separate indices in the model, we provide trends and comparative analyses to the AFSC longline survey. Research catch removals including survey removals are documented in Appendix 3B.

AFSC Surveys

Longline survey

Overview: Catch, effort, age, length, weight, and maturity data are collected during sablefish longline surveys. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000). Japan and the United States conducted a cooperative longline survey for sablefish in the GOA annually from 1978 to 1994, adding the AI region in 1980 and the eastern BS in 1982 (Sasaki 1985, Sigler and Fujioka 1988). Since 1987, the Alaska Fisheries Science Center has conducted annual longline surveys of the upper continental slope, referred to as domestic longline surveys, designed to continue the time series of the Japan-U.S. cooperative survey (Sigler and Zenger 1989). The domestic longline survey began annual sampling of the GOA in 1987, biennial sampling of the AI in 1996, and biennial sampling of the eastern BS in 1997 (Rutecki et al. 1997). The domestic survey also samples major gullies of the GOA in addition to sampling the upper continental slope. The order in which areas are surveyed was changed in 1998 to reduce interactions between survey sampling and short, intense fisheries. Before 1998, the order was AI and/or BS, Western Gulf, Central Gulf, Eastern Gulf. Starting in 1998, the Eastern Gulf area was surveyed before the Central Gulf area.

Specimen collections: Sablefish length data were randomly collected for all survey years. Otoliths were collected for age determination for most survey years. From 1979-1994 otolith collections were length-stratified; since 1994 otoliths have been collected randomly. Prior to 1996, otolith collections were aged but not consistently from year to year. Since 1996, a sample of otoliths collected during each survey have been aged in the years they were collected. Approximately one-half of the otoliths collected (~1,000) are aged annually. This sample size for age compositions should be large enough to get a precise age composition for the whole survey area, but may be too small to estimate the age composition in smaller areas by sex (P. Hulson, unpublished manuscript).

Standardization: Kimura and Zenger (1997) compared the performance of the two surveys from 1988 to

1994 in detail, including experiments comparing hook and gangion types used in the two surveys. The abundance index for both longline surveys decreased from 1988 to 1989, the cooperative survey decreased from 1989 to 1990, while the domestic survey increased (Table 3.9). Kimura and Zenger (1997) attributed the difference to the domestic longline survey not being standardized until 1990.

Survey Trends: Relative population abundance indices are computed annually using survey catch rates from stations sampled on the continental slope. Highest sablefish abundance indices occurred during the Japan-U.S. cooperative survey in the mid-1980's, in response to exceptional recruitment in the late 1970's (Figure 3.7). Relative population numbers declined through the 1990's in most areas during the domestic longline survey. Survey catches and abundance estimates trended down through 2009. Three of the lowest overall abundance estimates in the domestic survey occurred from 2007-2009. Survey estimates in the Eastern Gulf increased in 2010 and in 2011 the high Central Gulf estimate increased the entire index. Survey abundance estimates in 2010 and 2011 were unexpectedly high, while the 2012 and 2013 estimates were below expectations.

The 2013 survey estimate of relative abundance in numbers (RPN) was at the lowest point in the domestic time series; however, in 2014 there was an overall increase of 15% from 2013. The individual areas that contributed to the increase were WGOA (67%), WY (21%), and EY/SE (13%). Although there were modest increases, the index is still below average because of recent weak recruitment.

Whale Depredation: Killer whale depredation of the survey's sablefish catches has been a problem in the BS since the beginning of the survey (Sasaki 1987). Killer whale depredation primarily occurs in the BS, AI, WGOA, and to a lesser extent in recent years in the CGOA (Table 3.11). Depredation is easily identified by reduced sablefish catch and the presence of lips or jaws and bent, straightened, or broken hooks. Since 1990, portions of the gear at stations affected by killer whale depredation during the domestic longline survey have been excluded from the analysis of catch rates, RPNs, and RPWs. The AI and the BS were added to the domestic longline survey in 1996 and this is when killer whale depredation increased. In 2009, 10 BS stations were depredated, which significantly impacted catch and biased the abundance index leading to using the 2007 BS RPN estimate to interpolate the 2009 and 2010 BS RPNs (Hanselman et al. 2009). In 2011, depredation levels in the BS were similar to previous years with catches at 7 of 16 stations affected. In 2013, a new high of 11 stations were depredated, although fewer skates were impacted and therefore removed from the analysis in comparison to what occurred in 2009.

In 2014 there were 3 stations depredated by killer whales in the AI, down from the all time high of 5 in 2012 (Table 3.11). There were 4 stations with killer whale depredation in the WGOA. This is within the normal range of 1 to 5 stations. Although there has been some killer whale depredation in the CGOA in the past (1 - 2 stations), this year there was none. Overall the number of skates affected by killer whale depredation was 2/3 of what it was in 2012 (when the AI was last sampled). In total, there were 7 stations in 2014 with killer whale depredation and 10 in 2012.

Sperm whale depredation affects longline catches, but evidence of depredation is not accompanied by obvious decreases in sablefish catch or common occurrence of lips and jaws or bent and broken hooks. Data on sperm whale depredation have been collected since the 1998 longline survey (Table 3.11). Sperm whales are often observed from the survey vessel during haulback but do not appear to be depredating on the catch. Sperm whale depredation and presence is recorded during the longline survey at the station level, not the skate level like killer whales. Depredation is defined as sperm whales being present during haulback with the occurrence of damaged sablefish in the catch.

Sperm whale depredation has been variable since 1998. Whales are most common in the EGOA (WY and EY/SE). There are 65 stations sampled that are used in calculations of population indices in a year when the AI is sampled. In 2014 there were sperm whales depredating at 15 stations (Table 3.11). The number of stations with sperm whale depredation was typical of the range since 2007 (10-19 per year). In 2014, there were whales depredating at 10 stations in the EGOA (out of a total of 25) and 4 in the CGOA (out of 16). Depredation occurred at one station in the AI, which is rare, but has happened in the past. There were no sperm whales depredating in the WGOA in 2014.

Multiple studies have attempted to quantify sperm whale depredation rates. An early study using data collected by fisheries observers in Alaskan waters found no significant effect on the commercial fishery catch (Hill et al. 1999). Another study using data collected from commercial vessels in southeast Alaska, found a small, significant effect comparing longline fishery catches between sets with sperm whales present and sets with sperm whales absent (3% reduction, 95% CI of (0.4 – 5.5%), t-test, $p = 0.02$, Straley et al. 2005).

A general linear model fit to longline survey data from 1998-2004 found neither sperm whale presence ($p = 0.71$) nor depredation rate ($p = 0.78$) increased significantly from 1998 to 2004. Catch rates were about 2% less at locations where depredation occurred, but the effect was not significant ($p = 0.34$). This analysis was updated through 2009 and now shows a significant effect of approximately four kilograms per hundred hooks in the Central and Eastern Gulf regions, which translates into approximately a 2% decrease in overall catch in those areas (J. Liddle, October, 2009, pers. comm.). A retrospective analysis of this data indicates the effect is not significant until the 2009 data is added, indicating the increasing depredation effect has combined with accumulating survey data to give increased power to detect this small reduction in CPUE.

Longline survey catch rates are not adjusted for sperm whale depredation because we do not know when measureable depredation began during the survey time series, because past studies of depredation on the longline survey showed no significant effect, and because sperm whale depredation is difficult to detect (Sigler et al. 2007). Because of recent increases in sperm whale presence and depredation at survey stations, as indicated by whale observations and significant results of recent studies, we evaluated a statistical adjustment to survey catch rates using a general linear modeling approach (Appendix 3C, Hanselman et al. 2010). This approach had promise but had issues with variance estimation and autocorrelation between samples. A new approach has been developed using a generalized linear mixed model (see Appendix 3C).

Gully Stations: In addition to the continental slope stations sampled during the survey, twenty-seven stations are sampled in gullies at the rate of one to two stations per day. The sampled gullies are Shelikof Trough, Amatuli Gully, W-grounds, Yakutat Valley, Spencer Gully, Ommaney Trench, Dixon Entrance, and one station on the continental shelf off Baranof Island. The majority of these stations are located in deep gully entrances to the continental shelf in depths from 150-300 m in areas where the commercial fishery targets sablefish. No gullies are currently sampled in the Western GOA, AI, or BS.

Previous analyses have shown that on average gully stations catch fewer large fish and more small fish than adjacent slope stations (Rutecki et al. 1997, Zenger et al. 1994). Compared with the adjacent regions of the slope, sablefish catch rates for gully stations have been mixed with no significant trend (Zenger et al. 1994). Gully catches may indicate recruitment signals before slope areas because of their shallow depth, where younger, smaller sablefish typically inhabit. Catch rates from these stations have not been included in the historical abundance index calculations because preferred habitat of adult sablefish is on the slope.

These areas do support significant numbers of sablefish, however, and are important areas sampled by the survey. We compared the RPNs of gully stations to the RPNs of slope stations in the GOA to see if catches were comparable, or more importantly, if they portrayed different trends than the RPNs used in this assessment.

To compare trends, we computed Student's-*t* normalized residuals for all GOA gullies and slope stations and plotted them for the time series. If the indices were correlated, then the residuals would track one another over time (Figure 3.8). Overall, gully catches in the GOA from 1990-2014 are moderately correlated with slope catches ($r = 0.51$). There is no evidence of major differences in trends. In regards to gully catches being a recruitment indicator, the increase in the gully RPNs in 1999 and 2001-2002 may be in response to the above average 1997 and 2000 year classes. Both the 2001 and 2002 RPNs for the gully stations are higher than in 1999, which supports the current model estimate that the 2000 year class was larger than 1997. Both gully and slope trends were down in 2012 and 2013, consistent with the overall decrease in survey catch. However, the slope stations increased in 2014, while the gullies continued to decline. In the future, we will continue to explore sablefish catch rates in gullies and explore their usefulness for indicating recruitment; they may also be useful for quantifying depredation, since sperm whales have rarely depredated on catches from gully stations.

Interactions between the fishery and survey are described in Appendix 3A.

Trawl surveys

Trawl surveys of the upper continental slope that adult sablefish inhabit have been conducted biennially or triennially since 1980 in the AI, and 1984 in the GOA, always to 500 m and occasionally to 700-1000 m. Trawl surveys of the BS slope were conducted biennially from 1979-1991 and redesigned and standardized for 2002, 2004, 2008, 2010, and 2012. Trawl surveys of the BS shelf are conducted annually but generally catch no sablefish. Trawl survey abundance indices were not used in the assessment model prior to 2007 in the sablefish assessment because they were not considered good indicators of the sablefish relative abundance. However, there is a long time series of data available and given the trawl survey's ability to sample smaller fish, it may be a better indicator of recruitment than the longline survey. There is some difficulty with combining estimates from the BS and AI with the GOA estimates since they occur on alternating years. A method could be developed to combine these indices, but it leaves the problem of how to use the length data to predict recruitment since the data could give mixed signals on year class strength. At this time we are using only the GOA trawl survey biomass estimates (<500 m depth, Figure 3.4) and length data (<500 m depth) as a recruitment index for the whole population. The largest proportion of sablefish biomass is in the GOA so it should be indicative of the overall population. Biomass estimates used in the assessment for 1984-2013 are shown in Table 3.10. The GOA trawl survey index was at its lowest level of the time series in 2013, down 29% from 2011.

AI and BS Slope survey biomass estimates are not used in the assessment model but are tracked in Figure 3.9. Estimates in the two areas have decreased slowly since 2000.

Other surveys/areas not used in the assessment model

IPHC Longline Surveys

The IPHC conducts a longline survey each year to assess Pacific halibut. This survey differs from the AFSC longline survey in gear configuration and sampling design, but catches substantial numbers of sablefish. More information on this survey can be found in Soderlund et al. (2009). A major difference between the two surveys is that the IPHC survey samples the shelf consistently from ~ 10-500 meters, whereas the AFSC survey samples the slope and select gullies from 200-1000 meters. Because the majority of effort occurs on the shelf in shallower depths, the IPHC survey may catch smaller and younger sablefish than the AFSC survey; however, lengths of sablefish are not taken on the IPHC survey.

For comparison to the AFSC survey, IPHC relative population number's (RPN) were calculated using the same methods as the AFSC survey values, the only difference being the depth stratum increments. First, an average CPUE was calculated by depth stratum for each region. The CPUE was then multiplied by the area size of that stratum. A region RPN was calculated by summing the RPNs for all strata in the region. Area sizes used to calculate biomass in the RACE trawl surveys were utilized for IPHC RPN calculations. Area sizes differ between the IPHC and AFSC longline surveys because the IPHC surveys the shelf while the AFSC survey samples the slope.

We do not obtain IPHC survey estimates for the current year until the following year. We compared the IPHC and the AFSC RPNs for the GOA (Figure 3.10). The two series track well, but the IPHC survey RPN has more variability. This is likely because it surveys shallower water on the shelf where younger sablefish reside and are more patchily distributed. Since the abundance of younger sablefish will be more variable as year classes pass through, the survey should more closely resemble the NMFS GOA trawl survey index described above (Figure 3.4).

While the two surveys have shown consistent patterns for most years, they diverged in 2010 and 2011, but the 2013 estimates both show the lowest point in the time series for each index (Figure 3.10). The IPHC estimate for the Gulf of Alaska for 2013 was a 21% decline from 2012. IPHC trends by region were similar, but IPHC data was more variable for most areas. We will continue to examine trends in each region and at each depth interval for evidence of recruiting year classes and for comparison to the AFSC longline survey. There is some effort in depths shallower than 200 meters on the AFSC longline survey, and we recently have computed RPNs for these depths for future comparisons with the IPHC RPNs.

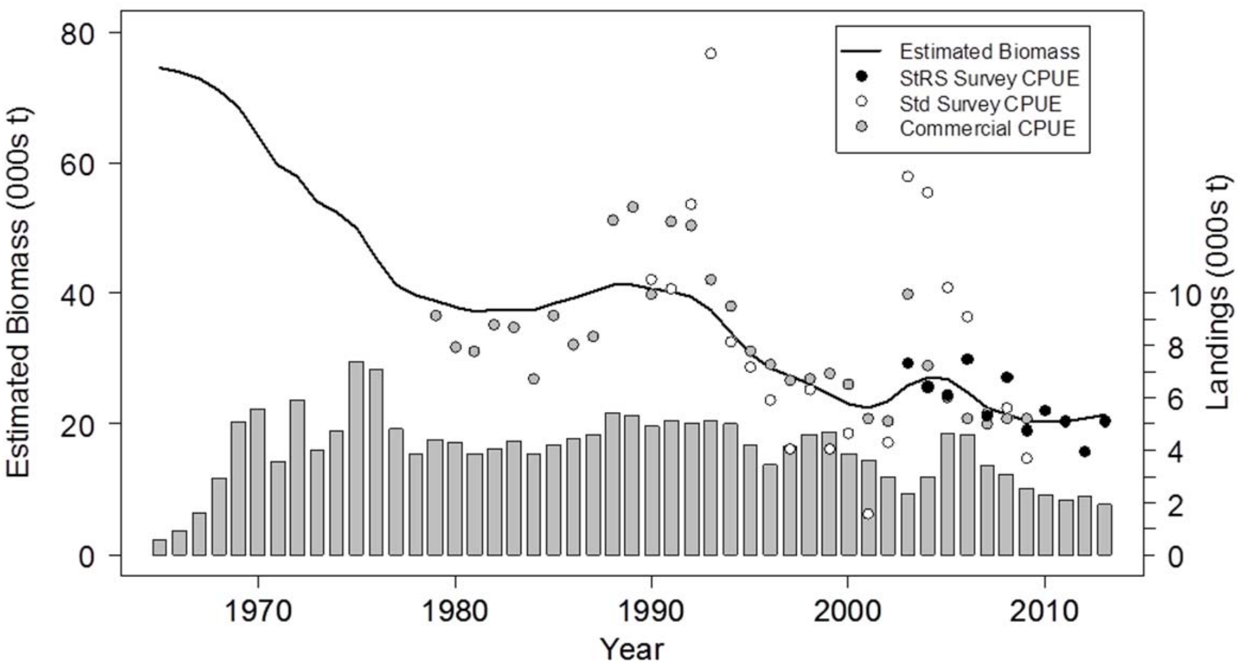
Alaska Department of Fish and Game

The Alaska Department of Fish and Game conducts mark-recapture and a longline survey in Northern Southeast Alaska Inside (NSEI) waters. Sablefish in this area are treated as a separate population, but some migration into and out of Inside waters has been confirmed with tagging studies (Hanselman et al. 2014). Estimates of exploitable population biomass based on mark-recapture estimates show a stable to slightly declining trend. This population seems to be stabilizing from previous steep declines. Their longline survey CPUE estimates (Figure 3.11a) and fishery CPUE estimates (Figure 3.11b) had been slowly increasing since 2000, confirming the lows in 1999/2000 estimated in our assessment. Like the AFSC longline survey, there was a sharp decline in the 2013 longline CPUE estimate for NSEI.

Department of Fish and Oceans of Canada

In a 2011 Science Advisory Report, DFO reported :*"Stock reconstructions suggest that stock status is currently below B_{MSY} for all scenarios, with the stock currently positioned in the mid-Cautious to low-Healthy zones."* Under these scenarios, recent harvest rates on adult sablefish potentially have been between 0.06 – 0.15[1].

The stratified random trap survey was up approximately 29% from 2012 to 2013 after a time series low in 2012. The estimated biomass trend in B.C. is similar to the trend in Alaska (see figure below)[2]. The similarly low abundance south of Alaska concerns us, and points to the need to better understand the contribution to Alaska sablefish productivity from B.C. sablefish. Some potential ideas are to conduct an area-wide study of sablefish tag recoveries, and to attempt to model the population to include B.C. sablefish.



Overall abundance trends

Relative abundance has cycled through three valleys and two peaks near 1970 and 1985 (Table 3.10, Figures 3.3 and 3.4). The post-1970 decrease likely is due to heavy fishing. The 1985 peak likely is due to the exceptionally large late 1970's year classes. Since 1988, relative abundance has decreased substantially. Regionally, abundance decreased faster in the BS, AI, and western GOA and more slowly in the central and eastern GOA (Figure 3.7). The majority of the surveys show that sablefish were at their lowest levels in the early 2000s, with current abundance reaching these lows again.

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[1] Science Advisory Report 2011/25: http://www.dfo-mpo.gc.ca/Csas-sccs/publications/sar-as/2011/2011_025-eng.pdf

[2] DFO. 2014. Performance of a revised management procedure for Sablefish in British Columbia. DFO Can. Sci. Advis. Sec. Sci. Resp. 2014 /025.

Analytic approach

Model Structure

The sablefish population is assessed with an age-structured model. The analysis presented here extends earlier age structured models developed by Kimura (1990) and Sigler (1999), which all stem from the work by Fournier and Archibald (1982). The current model configuration follows a more complex version of the GOA Pacific ocean perch model (Hanselman et al. 2005a); it includes split sexes and many more data sources to attempt to more realistically represent the underlying population dynamics of sablefish. The current configuration was accepted by the Groundfish Plan Team and NPFMC in 2010 (Hanselman et al. 2010). The population dynamics and likelihood equations are described in Box 1. The analysis was completed using AD Model Builder software, a C++ based software for development and fitting of general nonlinear statistical models (Fournier et al. 2012).

Parameters Estimated Outside the Assessment Model

The following table lists the parameters estimated independently:

Parameter name	Value	Value	Source
Time period	1960-1995	1996-current	
Natural mortality	0.1	0.1	Johnson and Quinn (1988)
Female maturity-at-age	$m_a = 1/(1+e^{-0.84(a-6.60)})$		Sasaki (1985)
Length-at-age - females	$\bar{L}_a = 75.6(1-e^{-0.208(a+3.63)})$	$\bar{L}_a = 80.2(1-e^{-0.222(a+1.95)})$	Hanselman et al. (2007)
Length-at-age - males	$\bar{L}_a = 65.3(1-e^{-0.227(a+4.09)})$	$\bar{L}_a = 67.8(1-e^{-0.290(a+2.27)})$	Hanselman et al. (2007)
Weight-at-age - females	$\ln \hat{W}_a = \ln(5.47) + 3.02\ln(1-e^{-0.238(a+1.39)})$		Hanselman et al. (2007)
Weight-at-age - males	$\ln \hat{W}_a = \ln(3.16) + 2.96\ln(1-e^{-0.356(a+1.13)})$		Hanselman et al. (2007)
Ageing error matrix	From known-age tag releases, extrapolated for older ages		Heifetz et al. (1999)
Recruitment variability (σ_r)	1.2	1.2	Sigler et al. (2002)

Age and Size of Recruitment: Juvenile sablefish rear in nearshore and continental shelf waters, moving to the upper continental slope as adults. Fish first appear on the upper continental slope, where the longline survey and longline fishery occur, at age 2, and a fork length of about 45 cm. A higher proportion of young fish are susceptible to trawl gear compared to longline gear because trawl fisheries usually occur on the continental shelf and shelf break inhabited by younger fish, and catching small sablefish may be hindered by the large bait and hooks on longline gear.

Sablefish are difficult to age, especially those older than eight years (Kimura and Lyons 1991). To compensate, we use an ageing error matrix based on known-age otoliths (Heifetz et al. 1999; Hanselman et al. 2012).

Growth and maturity: Sablefish grow rapidly in early life, growing 1.2 mm d^{-1} during their first spring and summer (Sigler et al. 2001). Within 100 days after first increment (first daily otolith mark for larvae) formation, they average 120 mm. Sablefish are currently estimated to reach average maximum lengths and weights of 68 cm and 3.2 kg for males and 80 cm and 5.5 kg for females (Echave et al. 2012).

New growth relationships were estimated in 2007 because many more age data were available (Hanselman et al. 2007); this analysis was accepted by the Plan Team in November 2007 and published in 2012 (Echave et al. 2012). We divided the data into two time periods based on the change in sampling design that occurred in 1995. It appears that sablefish maximum length and weight has increased slightly over time. New age-length conversion matrices were constructed using these curves with normal error fit to the standard deviations of the collected lengths at age (Figure 3.12). These new matrices provided for a superior fit to the data. Therefore, we use a bias-corrected and updated growth curve for the older data (1981-1993) and a new growth curve describing recent randomly collected data (1996-2004).

Fifty percent of females are mature at 65 cm, while 50 percent of males are mature at 57 cm (Sasaki 1985), corresponding to ages 6.6 for females and 5 for males (Table 3.12). Maturity parameters were estimated independently of the assessment model and then incorporated into the assessment model as fixed values. The maturity - length function is $m_l = 1 / (1 + e^{-0.40 (L - 57)})$ for males and $m_l = 1 / (1 + e^{-0.40 (L - 65)})$ for females. Maturity at age was computed using logistic equations fit to the length-maturity relationships shown in Sasaki (1985, Figure 23, GOA). Prior to the 2006 assessment, average male and female maturity was used to compute spawning biomass. Beginning with the 2006 assessment, female-only maturity has been used to compute spawning biomass. Female maturity-at-age from Sasaki (1985) is described by the logistic fit of $m_a = 1/(1+e^{-0.84(a-6.60)})$. In 2011, the AFSC conducted a winter cruise out of Kodiak to sample sablefish when they are preparing to spawn. Ovaries were examined histologically to determine maturity for a study of the age at maturity and fecundity. Skipped spawning was documented for the first time in sablefish. These winter samples provided a similar age at 50% maturity estimate (6.8 years) as the mean of visual observations taken during summer surveys from 1996-2012 (mean = 7.0 years) and the estimate currently used in the assessment (mean =6.6 years), when skipped spawners were classified as mature. Funding for more winter sampling in the same area is being sought for sampling in 2015 to examine the annual variability in skipped spawning rates at age. Future analyses will aim to develop and evaluate methods to incorporate skipped spawning into maturity ogives.

Maximum age and natural mortality: Sablefish are long-lived; ages over 40 years are regularly recorded (Kimura et al. 1993). Reported maximum age for Alaska is 94 years (Kimura et al. 1998). Canadian researchers report age determinations up to 113 years[1]. A natural mortality rate of M=0.10 has been assumed for previous sablefish assessments, compared to M=0.112 assumed by Funk and Bracken (1984). Johnson and Quinn (1988) used values of 0.10 and 0.20 in a catch-at-age analysis and found that estimated abundance trends agreed better with survey results when M=0.10 was used. Natural mortality has been modeled in a variety of ways in previous assessments. For sablefish assessments before 1999, natural mortality was assumed to equal 0.10. For assessments from 1999 to 2003, natural mortality was estimated rather than assumed to equal 0.10; the estimated value was about 0.10 but only with a precise prior imposed. For the 2004 assessment, a more detailed analysis of the posterior probability showed that natural mortality was not well-estimated by the available data (Sigler et al. 2004). Therefore in 2006, we returned to fixing the parameter at 0.10.

Variance and effective sample sizes: Several quantities were computed in order to compare the variance of the residuals to the assumed input variances. The standardized deviation of normalized residuals (SDNR) is closely related to the root mean squared error (RMSE) or effective sample size; values of SDNR of approximately 1 indicate that the model is fitting a data component as well as would be expected for a given specified input variance. The normalized residuals for a given year i of the abundance index was computed as

$$\delta_i = \frac{\ln(I_i) - \ln(\hat{I}_i)}{\sigma_i}$$

[1]Fisheries and Oceans Canada; http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/ground-fond/sable-charbon/bio-eng.htm

where σ_i is the input sampling log standard deviation of the estimated abundance index. For age or length composition data assumed to follow a multinomial distribution, the normalized residuals for age/length group *a* in year *i* were computed as

$$\delta_{i,a} = \frac{(y_{i,a} - \hat{y}_{i,a})}{\sqrt{\hat{y}_{i,a}(1-\hat{y}_{i,a})/n_i}}$$

where *y* and $\hat{y}$ are the observed and estimated proportion, respectively, and *n* is the input assumed sample size for the multinomial distribution. The effective sample size was also computed for the age and length compositions modeled with a multinomial distribution, and for a given year *i* was computed as

$$E_i = \frac{\sum_a \hat{y}_a * (1 - \hat{y}_a)}{\sum_a (\hat{y}_a - y_a)^2}.$$

An effective sample size that is nearly equal to the input sample size can be interpreted as having a model fit that is consistent with the input sample size.

For the 2010 recommended assessment model, we used average SDNR as a criterion to help reweight the age and length compositions. SDNR is a common metric used for goodness of fit in other fisheries, particularly in New Zealand (e.g. Langley and Maunder 2009) and has been recommended for use in fisheries models in Alaska during multiple CIE reviews, such as Atka mackerel and rockfish. We iteratively reweighted the model by setting an objective function penalty to reduce the deviations of average SDNR of a data component from one. Initially, we tried to fit all multinomial components this way, but due to tradeoffs in fit, it was found that the input sample sizes became too large and masked the influence of important data such as abundance indices. Given that we have age and length samples from nearly all years of the longline surveys, we chose to eliminate the attempt to fit the length data well enough to achieve an average SDNR of one, and reweighted all age components and only length components where no age data exists (e.g. domestic trawl fishery). The abundance index SDNRs were calculated, but no attempt was made to adjust their input variance because we have *a priori* knowledge about their sampling variances. This process was completed before the 2010 data were added into the assessment and endorsed by the Plan Teams and SSC in 2010. We continue to use these weightings. The table below shows the input CVs/sample sizes for the data sources and their associated output SDNR for the recommended model. This reweighting is intended to remain fixed for at least several years. The data weights in general continue to do well by these objectives (Table 3.13).

Parameters Estimated Inside the Assessment Model

Below is a summary of the parameters estimated within the recommended assessment model:

Parameter name	Symbol	Number of
Catchability	q	6
Log-mean-recruitment	μ_r	1
Spawners-per-recruit levels	F_{35}, F_{40}, F_{50}	3
Recruitment deviations	τ_y	82
Average fishing mortality	μ_f	2
Fishing mortality deviations	ϕ_y	110
Fishery selectivity	fs_a	8
Survey selectivity	ss_a	7
Total		219

Catchability is separately estimated for the Japanese longline fishery, the cooperative longline survey, the domestic longline survey, U.S. longline derby fishery, U.S. longline IFQ fishery, and the NMFS GOA trawl survey. Information is available to link these estimates of catchability. Kimura and Zenger (1997) analyzed the relationship between the cooperative and domestic longline surveys. For assessments through 2006, we used their results to create a prior distribution which linked catchability estimates for the two surveys. For 2007, we estimated new catchability prior distributions based on the ratio of the various abundance indices to a combined Alaskan trawl index. This resulted in similar mean estimates of catchability to those previously used, but allowed us to estimate a prior variance to be used in the model. This also facilitates linking the relative catchabilities between indices. These priors were used in the recommended model for 2008. This analysis was presented at the September 2007 Plan Team and is presented in its entirety in Hanselman et al. (2007). Lognormal prior distributions were used with the parameters shown below:

Index	U.S. LL Survey	Jap. LL Survey	Fisheries	GOA Trawl
Mean	7.857	4.693	4.967	0.692
CV	33%	24%	33%	30%

Recruitment is not estimated with a stock-recruit relationship, but is estimated with a level of average recruitment with deviations from average recruitment for the years 1933-2013.

Fishing mortality is estimated with two average fishing mortality parameters for the two fisheries (fixed gear and trawl) and deviations from the average for years 1960-2014 for each fishery.

Selectivity is represented using a function and is separately estimated by sex for the longline survey, fixed-gear fishery (pot and longlines combined), and the trawl survey. Selectivity for the longline surveys and fixed-gear fishery is restricted to be asymptotic by using the logistic function. Selectivity for the trawl fishery and trawl survey are dome-shaped (right descending limb) and estimated with a two-parameter gamma-function and a power function respectively (see Box 1 for equations). This right-descending limb is allowed because we do not expect that the trawl survey and fishery will catch older aged fish as frequently because they fish shallower than the fixed-gear fishery. Selectivity for the fixed-gear fishery is estimated separately for the “derby” fishery prior to 1995 and the IFQ fishery from 1995 thereafter. Fishers may choose where they fish in the IFQ fishery, compared to the crowded fishing grounds during the 1985-1994 “derby” fishery, when fishers reportedly often fished in less productive depths due to crowding (Sigler and Lunsford 2001). In choosing their ground, they presumably target bigger, older fish, and depths that produce the most abundant catches.

Bayesian analysis of reference points

Since the 1999 assessment, we have conducted a limited Bayesian analysis of assessment uncertainty. The posterior distribution was computed based on 10 million MCMC simulations drawn from the posterior distribution. A burn-in of 1 million draws was removed from the beginning of the chain and then thinned to 4,000 parameter draws to remove serial correlation between successive draws. This was determined to be sufficient through simple chain plots, and comparing the means and standard deviations of the first half of the chain with the second half.

In previous assessments, we estimated the posterior probability that projected abundance will fall below the decision analysis thresholds based on Mace and Sissenwine (1993). However, in the North Pacific Fishery Management Council setting we have thresholds that are defined in the Council harvest rules. These are when the spawning biomass falls below $B_{40\%}$, $B_{35\%}$, and when the spawning biomass falls below ½ MSY or $B_{17.5\%}$ which calls for a rebuilding plan under the Magnuson-Stevens Act. For the previous analysis based on Mace and Sissenwine (1993), see Hanselman et al. 2005b. To examine the posterior probability, we project spawning biomass into the future with recruitments varied as random draws from a lognormal distribution with the mean and standard deviation of 1979-2012 age-2 recruitments. The fishing mortality used is the current yield ratio described in the *Catch specification* section multiplied by maxABC for each year.

Box 1 Model Description

Y	Year, $y=1, 2,\ldots T$
T	Terminal year of the model
A	Model age class, $a = a_0, a_0+1, \ldots, a_+$
a_0	Age at recruitment to the model
a_+	Plus-group age class (oldest age considered plus all older ages)
L	Length class
Ω	Number of length bins (for length composition data)
G	Gear-type (g = longline surveys, longline fisheries, or trawl fisheries)
X	Index for likelihood component
$w_{a,s}$	Average weight at age a and sex s
φ_a	Proportion of females mature at age a
μ_r	Average log-recruitment
μ_f	Average log-fishing mortality
$\phi_{y,g}$	Annual fishing mortality deviation
τ_y	Annual recruitment deviation ~ $\ln(0, \sigma_r)$
σ_r	Recruitment standard deviation
$N_{y,a,s}$	Numbers of fish at age a in year y of sex s
M	Natural mortality
$F_{y,a,g}$	Fishing mortality for year y, age class a and gear g
$Z_{y,a}$	Total mortality for year y and age class a ($=\sum_g F_{y,a,g} + M$)
R_y	Recruitment in year y
B_y	Spawning biomass in year y
$s^g_{a,s}$	Selectivity at age a for gear type g and sex s
$A_{50\%}, d_{50\%}$	Age at 50% selection for ascending limb, age at 50% deselection for descending limb
δ	Slope/shape parameters for different logistic curves
$\mathbf{A}$	Ageing-error matrix dimensioned $a_+ \times a_+$
$\mathbf{A}_s^{\,l}$	Age to length conversion matrix by sex s dimensioned $a_+ \times \Omega$
q_g	Abundance index catchability coefficient by gear
λ_x	Statistical weight (penalty) for component x
$I_y, \hat{I}_y$	Observed and predicted survey index in year y
$P^g_{y,l,s}, \hat{P}^g_{y,l,s}$	Observed and predicted proportion at length l for gear g in year y and sex s
$P^g_{y,a,s}, \hat{P}^g_{y,a,s}$	Observed and predicted proportion at observed age a for gear g in year y and sex s
ψ^g_y	Sample size assumed for gear g in year y (for multinomial likelihood)
n_g	Number of years that age (or length) composition is available for gear g
$q_{\mu,g}, \sigma_{q,g}$	Prior mean, standard deviation for catchability coefficient for gear g
M_μ, σ_M	Prior mean, standard deviation for natural mortality
$\sigma_{r_\mu}, \sigma_{\sigma_r}$	Prior mean, standard deviation for recruitment variability

Equations describing state dynamics	**Model Description** (continued)
$N_{1,a} = \begin{cases} R_1, & a = a_0 \\ e^{\left(\mu_r + \tau_{a_0 - a + 1}\right)} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ e^{(\mu_r)} e^{-(a-a_0)M} \left(1 - e^{-M}\right)^{-1}, & a = a_+ \end{cases}$	Initial year recruitment and numbers at ages.
$N_{y,a} = \begin{cases} R_y, & a = a_0 \\ N_{y-1,a-1} e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} e^{-Z_{y-1,a-1}} + N_{y-1,a} e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$	Subsequent years recruitment and numbers at ages
$R_y = e^{\left(\mu_r + \tau_y\right)}$	Recruitment
Selectivity equations	
$s^g_{a,s} = \left(1 + e^{(-\delta_{g,s}(a - a_{50\%,g,s}))}\right)^{-1}$	Logistic selectivity
$s^g_{a,s} = \dfrac{a^{\delta_{g,s}}}{\max\left(s^g_{a,s}\right)}$	Inverse power family
$s^g_{a,s} = \left(\dfrac{a}{a_{\max}}\right)^{a_{\max,g,s}/p} e^{(a_{\max,g,s} - a)/p}$ $p = 0.5\left[\sqrt{a_{\max,g,s}{}^2 + 4\delta_{g,s}{}^2} - a_{\max,g,s}\right]$	Reparameterized gamma distribution
$s^g_{a,s} = \left(1 - \varphi^g_s\right)^{-1} \left(\dfrac{\left(1 - \varphi^g_s\right)}{\varphi^g_s}\right)^{\varphi^g_s} \dfrac{\left(e^{(\delta_{g,s}\varphi^g_s(a_{50\%,g,s} - a))}\right)}{\left(1 + e^{(\delta_{g,s}(a_{50\%,g,s} - a))}\right)}$	Exponential-logistic selectivity
Observation equations	
$\hat{C}_{y,g} = \sum_{1}^{g}\sum_{1}^{s} w_{a,s} N_{y,a,g,s} F_{y,a,g,s} \left(1 - e^{-Z_{y,a,g,s}}\right) Z^{-1}_{y,a,g,s}$	Catch biomass in year *y*
$\hat{I}_{y,g} = q^g \sum_{a_0}^{a_+}\sum_{1}^{s} N_{y,a,s} \dfrac{s^g_{a,s}}{\max\left(s^g_{a,s}\right)} w_{a,s}$	Survey biomass index (weight)
$\hat{I}_{y,g} = q^g \sum_{a_0}^{a_+}\sum_{1}^{s} N_{y,a,s} \dfrac{s^g_{a,s}}{\max\left(s^g_{a,s}\right)}$	Survey abundance index (numbers)
$\hat{P}^g_{y,a,s} = N_{y,a,s} s^g \left(\sum_{a_0}^{a_+} N_{y,a,s} s^g_{a,s}\right)^{-1} \mathbf{A}_s$	Vector of fishery or survey predicted proportions at age
$\hat{P}^g_{y,a,s} = N_{y,\cdot,s} s^g_s \left(\sum_{a_0}^{a_+} N_{y,a,s} s^g_{a,s}\right)^{-1} \mathbf{A}^l_s$	Vector of fishery or survey predicted proportions at length

Posterior distribution components	**Model Description** (continued)
$L_C = \lambda_c \sum_1^g \sum_y \left(\ln C_{g,y} - \ln \hat{C}_{g,y}\right)^2 / \left(2\sigma_C^2\right)$	Catch likelihood
$L_I = \lambda_I \sum_1^g \sum_y \left(\ln I_{g,y} - \ln \hat{I}_{g,y}\right)^2 / \left(2\sigma_I^2\right)$	Survey biomass index likelihood
$L_{age} = \lambda_{age} \sum_{i=1}^{n_g} -\psi_y^g \sum_{a_0}^{a_+} \left(P_{i,a}^g + v\right) \ln\left(\hat{P}_{i,a}^g + v\right)$	Age composition likelihood
$L_{length} = \lambda_{length} \sum_1^s \sum_{i=1}^{n_g} -\psi_y^g \sum_{l=1}^{\Omega} \left(P_{i,l,s}^g + v\right) \ln\left(\hat{P}_{i,l,s}^g + v\right)$	Length composition likelihood (ψ_y^g=sample size, n_g = number of years of data for gear *g*, *i* = year of data availability, *v* is a constant set at 0.001)
$L_q = \left(\ln \hat{q}^g - \ln q_\mu^g\right)^2 / 2\sigma_q^2$	Prior on survey catchability coefficient for gear *g*
$L_M = \left(\ln \hat{M} - \ln M_\mu\right)^2 / 2\sigma_M^2$	Prior for natural mortality
$L_{\sigma_r} = \left(\ln \hat{\sigma}_r - \ln \sigma_{r_\mu}\right)^2 / 2\sigma_{\sigma_r}^2$	Prior distribution for σ_r
$L_\tau = 0.1 \sum_{y=1}^{T} \frac{\tau_y^2}{2\hat{\sigma}_r^2} + n \ln \hat{\sigma}_r$	Prior on recruitment deviations
$L_f = \lambda_f \sum_1^g \sum_{y=1}^{T} \phi_{y,g}^2$	Regularity penalty on fishing mortality
$L_{Total} = \sum_x L_x$	Total objective function value

Results

Model Evaluation

For this assessment, we present last year's model updated for 2013 with no model changes. A comparison of the model likelihood components and key parameter estimates from 2013 are compared with the 2014 updated model.

Box 2: Model comparison of the 2013 and 2014 models by contribution to the objective function (negative log-likelihood values) and key parameters.

Model Likelihood Components (Data)	2013	2014
Catch	8	7
Domestic LL survey RPN	46	47
Japanese LL survey RPN	18	18
Domestic LL fishery RPW	7	10
Japanese LL fishery RPW	12	13
NMFS GOA trawl survey	19	19
Domestic LL survey ages	169	180
Domestic LL fishery ages	192	238
Domestic LL survey lengths	55	59
Japanese LL survey ages	144	144
Japanese LL survey lengths	46	46
NMFS trawl survey lengths	290	286
Domestic LL fishery lengths	198	207
Domestic trawl fishery lengths	186	194
Data likelihood	1391	1469
Total objective function value	1415	1489
Key parameters		
Number of parameters	216	219
$B_{next\ year}$ (Female spawning (kt) biomass for next year)	91	92
$B_{40\%}$ (Female spawning biomass (kt))	106	105
B_{1960} (Female spawning biomass (kt))	161	161
$B_{0\%}$ (Female spawning biomass (kt))	266	262
SPR% current	34.3%	35.1%
$F_{40\%}$	0.094	0.094
$F_{40\%}$ (Tier 3b adjusted)	0.080	0.082
ABC(kt)	13.7	13.7
$q_{Domestic\ LL\ survey}$	7.7	7.6
$q_{Japanese\ LL\ survey}$	6.3	6.2
$q_{Domestic\ LL\ fishery}$	4.1	4.0
$q_{Trawl\ Survey}$	1.4	1.3
$a_{50\%}$ (domestic LL survey selectivity)	3.8	3.8
$a_{50\%}$ (LL fishery selectivity)	3.9	3.9
μ_r (average recruitment)	17.8	18.0
σ_r (recruitment variability)	1.20	1.20

The two models are identical in all aspects except for inclusion of new data. Our usual criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony.

Because the models presented have different amounts of data and different data weightings, it is not reasonable to compare their negative log likelihoods so we cannot compare them by the first criterion above. In general we can only evaluate the 2014 model based on changes in results from 2013 and it is unlikely we would reject the model that included the most recent data. The model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. An exception to the generally good fits to the data is the fit to the 2013 fishery age composition, which fits poorly (see further discussion in ***Goodness of fit*** below). The 2014 update shows a slight increase in spawning and total biomass from previous projections. Therefore the 2014 model is utilizing the new information effectively, and we use it to recommend 2015 ABC and OFL.

Time Series Results

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the estimate of all sablefish age-two and greater. Recruitment is measured as the number of age-two sablefish. Fishing mortality is fully-selected F, meaning the mortality at the age the fishery has fully selected the fish.

Abundance trends

Sablefish abundance increased during the mid-1960's (Table 3.15, Figure 3.13) due to strong year classes in the early 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing and relatively low recruitment; catches peaked at 53,080 t in 1972. The population recovered due to a series of strong year classes from the late 1970's (Figure 3.14, Table 3.14) and also recovered at different rates in different areas (Table 3.15); spawning abundance peaked again in 1987. The population then decreased because these strong year classes expired. The model suggested an increasing trend in spawning biomass since the all-time low in 2002, which changed directions again in 2008 (Figure 3.13). The low 2012-2013 longline survey RPN values changed what was a stable trend in 2011 to a downward trajectory in 2014.

Projected 2015 spawning biomass is 35% of unfished spawning biomass. Spawning biomass has increased from a low of 32% of unfished biomass in 2002 to 35% of unfished biomass projected for 2015 but is trending downward in projections for the near future. The 1997 year class has been an important contributor to the population; however, it has been reduced and is predicted to comprise less than 7% of the 2015 spawning biomass. The 2000 year class is still the largest contributor, with 16% of the spawning biomass in 2015. The 2008 year class is average and will comprise 10% of spawning biomass in 2015 even though it is only 60% mature. Figure 3.15 shows the relative contribution of each year class to next year's spawning biomass.

Recruitment trends

Annual estimated recruitment varies widely (Figure 3.14b). The two recent strong year classes in 1997 and 2000 are evident in all data sources. After 2000, few strong year classes are apparent, but the 2008 year class is currently estimated to be the largest since 2000. Few small fish were caught in the 2005 through 2009 trawl surveys, but the 2008 year class appeared in the 2011 trawl survey length composition (Figures 3.16, 3.17). The 2010 and 2011 longline survey age compositions show the 2008 year class appearing relatively strong in all three areas for lightly selected 2 and 3 year old fish (Figures 3.18-3.20). The 2013 survey age composition is dominated by 2005-2008 year classes where the 2005 and 2006 year classes are larger than model predictions. Large year classes often appear in the western areas first and then in subsequent years in the Central and Eastern GOA. While this was true for the 1997 and 2000 year classes, the 2008 year class is appearing in all areas at approximately the same magnitude at the same time (Figure 3.18).

Average recruitment during 1979-2013 was 17.8 million 2-year-old sablefish per year, which is similar to the average recruitment during 1958-2012. Estimates of recruitment strength during the 1960s are less certain because they depend on age data from the 1980s with older aged fish that are subject to more ageing error. In addition the size of the early recruitments is based on an abundance index during the 1960s based only on the Japanese fishery catch rate, which may be a weak measure of abundance. The 2008 year class is being estimated at about average in this year's model. Because of the very low survey abundance indices in 2012 and 2013, the 2008 year class thus far is only just above average. If the 2008 year class is actually strong, the estimate will increase if the survey abundance estimates become stronger in future years.

Juvenile sablefish are pelagic and at least part of the population inhabits shallow near-shore areas for their first one to two years of life (Rutecki and Varosi 1997). In most years, juveniles have been found only in a few places such as Saint John Baptist Bay near Sitka, Alaska. Widespread, abundant age-1 juveniles likely indicate a strong year class. Abundant age-1 juveniles were reported for the 1960 (J. Fujioka & H. Zenger, 1995, NOAA, pers. comm.), 1977 (Bracken 1983), 1980, 1984, and 1998 year classes in southeast Alaska, the 1997 and 1998 year classes in Prince William Sound (W. Bechtol, 2004, ADFG, pers. comm.), the 1998 year class near Kodiak Island (D. Jackson, 2004, ADFG, pers. comm.), and the 2008 year class in Uganik Bay on Kodiak Island (P. Rigby, June, 2009, NOAA, pers. comm.). Numerous reports of young of the year being caught in 2014 have been received including large catches in NOAA surface trawl surveys in the EGOA in the summer (W. Fournier, August, 2014, NOAA, pers. comm.) and in Alaska Department of Fish and Game surveys in Prince William Sound (M. Byerly, 2014, ADFG, pers. comm.). Additionally, salmon fishermen in the EGOA reported large quantities of YOY sablefish in the stomachs of troll caught coho salmon in 2014.

Sablefish recruitment varies greatly from year to year (Figure 3.14b), but shows some relationship to environmental conditions. Sablefish recruitment success is related to winter current direction and water temperature; above average recruitment is more common for years with northerly drift or above average sea surface temperature (Sigler et al. 2001). Sablefish recruitment success is also coincidental with recruitment success of other groundfish species. Strong year classes were synchronous for many northeast Pacific groundfish stocks for the 1961, 1970, 1977, and 1984 year classes (Hollowed and Wooster 1992). For sablefish in Alaska, the 1960-1961 and 1977 year classes also were strong. Some of the largest year classes of sablefish occurred when abundance was near the historic low, the 1977-1978 and 1980-1981 year classes (Figures 3.14, 3.21). These strong year classes followed the 1976/1977 North Pacific regime shift. The 1977 year class was associated with the Pacific Decadal Oscillation (PDO) phase change and the 1977 and 1981 year classes were associated with warm water and unusually strong northeast Pacific pressure index (Hollowed and Wooster 1992). Larger than average year classes were produced again in 1997-2000, when the population was low indicating that recruitment is only weakly related to spawning biomass. Some species such as walleye pollock and sablefish may exhibit increased production at the beginning of a new environmental regime, when bottom up forcing prevails and high turnover species compete for dominance, which later shifts to top down forcing once dominance is established (Bailey 2000, Hunt et al. 2002). The large year classes of sablefish indicate that the population, though low, still was able to take advantage of favorable environmental conditions and produce large year classes. Shotwell et al. (2012) used a two-stage model selection process to examine relevant environmental variables that affect recruitment and included them directly into the assessment model. The best model suggested that colder than average wintertime sea surface temperatures in the central North Pacific represent oceanic conditions that create positive recruitment events for sablefish in their early life history.

Goodness of fit

The model generally fit the data well. Abundance indices generally track through the middle of the confidence intervals of the estimates (Figures 3.3, 3.4), with the exception of the trawl survey, where predictions are typically lower in the early years and higher in later years. This index is given less weight than the other indices based on higher sampling error so it does not fit as well. Like the trawl survey index, the fishery CPUE index is not fit well in 2013, primarily because of the increase in the 2014 longline survey index which is fit more precisely. All age compositions were predicted well, except for not quite reaching the magnitude of the 1997 and 2000 year classes in several years (Figures 3.19, 3.21, 3.24). The length frequencies from the fixed gear fishery are predicted well in most years, but the model appears to not fit the smallest fish that appear in 2011 (Figure 3.22, 3.23). The fits to the trawl survey and trawl fishery length compositions were generally mediocre, because of the small sample sizes relative to the longline survey and fishery length compositions (Figures 3.16, 3.17., 3.25). The model fit the domestic longline survey lengths poorly in the 1990s, then fit well until 2011 and 2012 where the smallest and largest fish were not fit well (Figures 3.26, 3.27). By 2014, the 2008 year class has grown large enough (in length) to be included in the main groups in the length compositions. The 2013 fixed gear fishery age composition is fit poorly, particularly in the plus group. This was due to an exceptionally high proportion of the catch caught in the AI being older than 30 years old. Examination of the origin of these older fish showed that this shift in fishery age composition was caused by a westward shift of the observed fishery into grounds that are not surveyed by the longline survey where there is an apparent abundance of older fish that are unknown to the model. We will explore methods to consider these shifts in future spatial assessment models.

Selectivities

We assume that selectivity is asymptotic for the longline survey and fisheries and dome-shaped (or descending right limb) for the trawl survey and trawl fishery (Figure 3.28). The age-of-50% selection is 3.8 years for females in the longline survey and 3.9 years in the IFQ longline fishery. Females are selected at an older age in the IFQ fishery than in the derby fishery (Figure 3.28). Males were selected at an older age than females in both the derby and IFQ fisheries, likely because they are smaller at the same age. Selection of younger fish during short open-access seasons likely was due to crowding of the fishing grounds, so that some fishers were pushed to fish shallower water that young fish inhabit (Sigler and Lunsford 2001). Relative to the longline survey, small fish are more vulnerable and older fish are less vulnerable to the trawl fishery because trawling often occurs on the continental shelf in shallower waters (< 300 m) where young sablefish reside. The trawl fishery selectivities are similar for males and females (Figure 3.28). The trawl survey selectivity curves differ between males and females, where males stay selected by the trawl survey longer (Figure 3.28). These trawl survey patterns are consistent with the idea that sablefish move out on the shelf at 2 years of age and then gradually become less available to the trawl fishery and survey as they move offshore into deeper waters.

Fishing mortality and management path

Fishing mortality was estimated to be high in the 1970s, relatively low in the early 1980s and then increased and held relatively steady in the 1990s and 2000s (Figure 3.29). Goodman et al. (2002) suggested that stock assessment authors use a “management path” graph as a way to evaluate management and assessment performance over time. In this “management path” we plot estimated fishing mortality relative to the (current) limit value and the estimated spawning biomass relative to limit spawning biomass ($B_{35\%}$). Figure 3.30 shows that recent management has generally constrained fishing mortality below the limit rate, and until recently kept the stock above the $B_{35\%}$ limit. Projected 2015 and 2016 spawning biomass is slightly below $B_{35\%}$.

Uncertainty

We compared a selection of parameter estimates from the Markov-Chain Monte Carlo (MCMC) simulations with the maximum-likelihood estimates, and compared each method’s associated level of uncertainty (Table 3.16). Mean and median catchability estimates were nearly identical. The estimate of $F_{40\%}$ was lower by maximum likelihood and shows some skewness as indicated by the difference between the MCMC mean and median values. Under both methods the variances were similar except for estimation of a large year class (2000) where the uncertainty is higher for MCMC methods. Ending female spawning biomass and the last large recruitment (2000) are estimated precisely by both methods. The more recent 2008 year class is not estimated as precisely, and the MCMC estimates are slightly higher.

Retrospective analysis

Retrospective analysis is the examination of the consistency among successive estimates of the same parameters obtained as new data are added to a model. Retrospective analysis has been applied most commonly to age-structured assessments. Retrospective biases can arise for many reasons, ranging from bias in the data (e.g., catch misreporting, non-random sampling) to different types of model misspecification such as wrong values of natural mortality, or temporal trends in values set to be invariant. Classical retrospective analysis involves starting from some time period earlier in the model and successively adding data and testing if there is a consistent bias in the outputs (NRC 1998).

For this assessment, we show the retrospective trend in spawning biomass and total biomass for ten previous assessment years (2004-2013) compared to estimates from the current preferred model. This analysis is simply removing all new data that have been added for each consecutive year to the preferred model. Each year of the assessment generally adds one year of longline fishery lengths, trawl fishery lengths, longline survey lengths, longline and fishery ages (from one year prior), fishery abundance index, and longline survey index. Every other year, a trawl survey estimate and corresponding length composition are added.

In the first four years of the retrospective plot we see that estimates of spawning biomass were consistently lower for the last few years in the next assessment year (Figure 3.31). In recent years, the retrospective plot of spawning biomass shows only small changes from year to year (e.g., Table 3.17). One common measure of the retrospective bias is Mohn's revised rho which indicates the size and direction of the bias. The revised Mohn's rho of 0.019 is very low (a small positive retrospective bias) relative to most assessments at the AFSC (Hanselman et al. 2013). The retrospective patterns are well within the posterior uncertainty of each assessment (Figure 3.31b). Recruitment estimates appear to have little trend over time with the exception of the 2002 year class which increased from a very low value to near average (Figure 3.31c). Only the 2008 year class started near average indicating low presence of 2 year olds in most of the recent data.

Examining retrospective trends can show potential biases in the model, but may not identify what their source is. Other times a retrospective trend is merely a matter of the model having too much inertia in the age-structure and other historic data to respond to the most recent data. This retrospective pattern likely to be considered mild, but at issue is the "one-way" pattern in the early part of the retrospective time series. It is difficult to isolate the cause of this pattern but several possibilities exist. For example, hypotheses could include environmental changes in catchability, time-varying natural mortality, or changes in selectivity of the fishery or survey. One other issue is that fishery abundance and lengths, and all age compositions are added into the assessment with a one year lag to the current assessment. This estimate of rho is down from 0.089 in 2013, which we attribute to two factors: 1) 2003 was dropped out of the retrospective window which had a relatively large change from the terminal year; and 2) The updated catch data that was used in 2014 added a significant amount of catch in the early part of the retrospective window, which increased the estimate of spawning biomass at the recent low point. We will monitor and explore these patterns in the future.

The 2010 Joint Plan Team requested that we examine what the current model configuration would have recommended for ABCs going back in time to see how much model and author changes has affected management advice. We examined this in the 2011 SAFE and concluded that despite many model changes, including growth updates and a split-gender model, the management advice would have been similar (Hanselman et al. 2011).

Harvest Recommendations

Reference fishing mortality rate

Sablefish are managed under Tier 3 of NPFMC harvest rules. Reference points are calculated using recruitments from 1979-2012. The updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from this assessment are 104,908 t (combined across the EBS, AI, and GOA), 0.095, and 0.112, respectively. Projected female spawning biomass (combined areas) for 2015 is 91,183 t (88% of $B_{40\%}$), placing sablefish in sub-tier "b" of Tier 3. The maximum permissible value of F_{ABC} under Tier 3b is 0.082, which translates into a 2015 ABC (combined areas) of 13,657 t. The OFL fishing mortality rate is 0.098 which translates into a 2015 OFL (combined areas) of 16,128 t. Model projections indicate that this stock is not subject to overfishing, overfished, nor approaching an overfished condition.

Population projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2014 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2014 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2015, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In 2015 and 2016, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2011-2013 to the TAC for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio of F will yield more realistic projections.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2014 or 2) above ½ of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, *F* is set equal to *max* F_{ABC}, and in all subsequent years *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2016 or 2) above 1/2 of its MSY level in 2016 and expected to be above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 3.18). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries (such as sablefish) where the catch is usually less than the ABC. This was suggested to help management with setting more accurate preliminary ABCs and OFLs for 2015 and 2016. The methodology for determining these pre-specified catches is described below in ***Specified catch estimation.***

Status determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2015, it does not provide the best estimate of OFL for 2016, because the mean 2015 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL. A better approach is to estimate catches that are more likely to occur as described below under *Specified Catch Estimation.* The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2013) is 13,582 t. This is less than the 2013 OFL of 20,400 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 (Table 3.18) are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2014:

a. If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2014 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c. If spawning biomass for 2014 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 3.18). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7 (Table 3.18):

a. If the mean spawning biomass for 2016 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2016 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and the results of the seven scenarios in Table 3.18, the stock is not overfished and is not approaching an overfished condition.

Specified catch estimation

In response to GOA Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. We explained the methods and gave examples in the 2011 SAFE (Hanselman et al. 2011). Going forward, for current year catch, we are applying an expansion factor to the official catch on or near October 1 by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2011-2013 for this year).

For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and on the amount of catch taken before spawning in the projection two years out.

Bayesian analysis

The model estimates of projected spawning biomass fall near the center of the posterior distribution of spawning biomass. Most of the probability lies between 80,000 and 100,000 t (Figure 3.32). The probability changes smoothly and exhibits a relatively normal distribution. The posterior distribution clearly indicates the stock is below $B_{40\%}$.

Scatter plots of selected pairs of model parameters were produced to evaluate the shape of the posterior distribution (Figure 3.33). The plots indicate that the parameters are reasonably well defined by the data. As expected, catchabilities, $F_{40\%}$, and ending spawning biomass were confounded. The catchability of the longline survey is most confounded with ending spawning biomass because it has the most influence in the model in recent abundance predictions.

We estimated the posterior probability that projected abundance will fall, or stay below thresholds of 17.5% (MSST), and 35% (MSY), and 40% (B_{target}) of the unfished spawning biomass based on the posterior probability estimates. Abundance was projected for 14 years. For management, it is important to know the risk of falling under these thresholds. The probability that spawning biomass falls below key biological reference points was estimated based on the posterior probability distribution for spawning biomass. The probability that next year's spawning biomass was below $B_{35\%}$ was 0.89. During the next three years, the probability of falling below $B_{17.5\%}$ is near zero, the probability of falling below $B_{35\%}$ is 0.97, and the probability of staying below $B_{40\%}$ is near 100% (Figure 3.34).

Alternative Projection

We also use an alternative projection that considers uncertainty from the whole model by running projections within the model. This projection propagates uncertainty throughout the entire assessment procedure and is based on 10,000,000 MCMC (burnt-in and thinned) using the standard Tier 3 harvest rules. The projection shows wide credible intervals on future spawning biomass (Figure 3.35). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1979-2012 recruitments, and this projection predicts that the mean and median spawning biomass will stay below $B_{35\%}$ until 2020, and then return to $B_{40\%}$ if average recruitment is attained. This projection is run with the same ratio for catch as described in Alternative 2 above, except for all future years instead of the next two.

Acceptable biological catch

We recommend a 2015 ABC of 13,657 t. The maximum permissible ABC for 2015 from a Tier 3b adjusted $F_{40\%}$ strategy is 13,657 t. The maximum permissible ABC for 2015 is very similar to the 2014 ABC of 13,722 t. The 2013 assessment projected a 10% decrease in ABC for 2015 from 2014. This smaller decrease is supported by a moderate increase in the domestic longline survey index from the all-time low in 2013 that offset the lowest value of the fishery abundance index seen in 2013. The fishery abundance index has been trending down since 2007. The 2013 IPHC GOA sablefish index was not used in the model, but also declined 21% from 2012. The 2008 year class showed potential to be above average in previous assessments based on patterns in the age and length compositions. However the estimate in this year's assessment is only average because it is heavily influenced by the recent large overall decrease in the longline survey and trawl indices. Spawning biomass is projected to decline through 2018, and then is expected to increase; assuming average recruitment is achieved in the future. ABCs are projected to decrease in 2016 to 12,406 t and 12,292 t in 2017 (see Table 3.18).

Area allocation of harvests

The combined ABC has been apportioned to regions using weighted moving average methods since 1993; these methods reduce the magnitude of inter-annual changes in the apportionment. Weighted moving average methods are robust to uncertainties about movement rates and measurement error of the biomass distribution, while adapting to current information about the biomass distribution. The 1993 TAC was apportioned using a 5 year running average with emphasis doubled for the current year survey abundance index in weight (relative population weight or RPW). Since 1995, the ABC was apportioned using an exponential weighting of regional RPWs. Exponential weighting is implied under certain conditions by the Kalman filter. The exponential factor is the measurement error variance divided by the prediction error variance (Meinhold and Singpurwalla 1983). Prediction error variance depends on the variances of the previous year's estimate, the process error, and the measurement error. When the ratio of measurement error variance to process error variance is r, the exponential factor is equal to $1-2/(\sqrt{4r+1}+1)$ (Thompson 2004). For sablefish we do not estimate these values, but instead set the exponential factor at ½, so that, except for the first year, the weight of each year's value is ½ the weight of the following year. The weights are year index 5: 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000. A $(1/2)^x$ weighting scheme, where x is the year index, reduced annual fluctuations in regional ABC, while keeping regional fishing rates from exceeding overfishing levels in a stochastic migratory model (J. Heifetz, 1999, NOAA, pers. comm.). Because mixing rates for sablefish are sufficiently high and fishing rates sufficiently low, moderate variations of biomass-based apportionment would not significantly change overall sablefish yield unless there are strong differences in recruitment, growth, and survival by area (Heifetz et al. 1997).

Previously, the Council approved apportionments of the ABC based on survey data alone. Starting with the 2000 ABC, the Council approved an apportionment based on survey and fishery data. The fishery and survey information were combined to apportion ABC using the following method: The RPWs based on the fishery data were weighted with the same exponential weights used to weight the survey data (year index 5: 0.0625; 4: 0.0625; 3: 0.1250; 2: 0.2500; 1: 0.5000). The fishery and survey data were combined by computing a weighted average of the survey and fishery estimates, with the weight inversely proportional to the variability of each data source. The variance for the fishery data has typically been twice that of the survey data, so the survey data was weighted twice as much as the fishery data. Below are area-specific apportionments following the traditional apportionment scheme, which we are **not recommending for 2015:**

Apportionments are based on survey and fishery information	2014 ABC Percent	2014 Survey RPW	2013 Fishery RPW	2015 ABC Percent	2014 ABC	2015 ABC	Change
Total					13,722	**13,657**	0%
Bering Sea	10%	21%	14%	10%	1,339	**2,210**	39%
Aleutians	13%	13%	17%	13%	1,811	**1,840**	2%
Gulf of Alaska	77%	66%	69%	77%	10,572	**9,607**	-10%
Western	14%	19%	12%	14%	1,480	**1,444**	-2%
Central	44%	40%	33%	44%	4,681	**3,975**	-18%
W. Yakutat*	15%	13%	19%	15%	1,574	**1,428**	-10%
E. Yakutat / Southeast*	27%	28%	35%	27%	2,837	**2,759**	-3%

Following the standard apportionment scheme, we have observed that the objective to reduce variability in apportionment was not being achieved. Since 2007, the average change in apportionment by area has increased annually (Figure 3.36A). While some of these changes may actually reflect interannual changes in regional abundance, they most likely reflect the high movement rates of the population and the high variability of our estimates of abundance in the Bering Sea and Aleutian Islands. For example, the apportionment for the Bering Sea has varied drastically since 2007, attributable to high variability in both survey abundance and fishery CPUE estimates in the Bering Sea (Figure 3.36B). These large annual changes in apportionment result in increased variability of ABCs by area, including areas other than the Bering Sea (Figure 3.36C). Because of the high variability in apportionment seen in recent years, we do not believe the standard method is meeting the goal of reducing the magnitude of interannual changes in the apportionment. Because of these reasons, we recommended fixing the apportionment at the proportions from the 2013 assessment until the apportionment scheme is thoroughly reevaluated and reviewed. A Ph.D. student with the University of Alaska-Fairbanks began a project in 2012 with the objectives of re-examining the apportionment strategy and conducting management strategy evaluations. A spatial sablefish model has been developed, but management strategy evaluations have not begun yet. Meanwhile, it seems imprudent to move to an interim apportionment or return to the former scheme until more satisfactory methods have been identified and evaluated. **Therefore**, **for 2015, we recommend keeping the apportionment fixed at the proportions used in 2014.**
These apportionments are shown in the following table:

Area	2014 ABC	Standard apportionment for 2015 ABC	**Recommended fixed apportionment for 2015 ABC***	**Difference from 2014**
Total	13,722	13,657	**13,657**	-0.5%
Bering Sea	1,339	2,210	**1,333**	-0.5%
Aleutians	1,811	1,840	**1,802**	-0.5%
Gulf of Alaska (subtotal)	10,572	9,607	**10,522**	-0.5%
Western	1,480	1,445	**1,473**	-0.5%
Central	4,681	3,975	**4,658**	-0.5%
W. Yakutat**	1,574	1,428	**1,567**	-0.5%
E. Yak. / Southeast**	2,837	2,759	**2,823**	-0.5%

* Fixed at the 2012 assessment apportionment proportions (Hanselman et al. 2012). ** Before 95:5 hook and line: trawl split shown below.

Adjusted for 95:5 hook-and-line: trawl split in EGOA	Year	W. Yakutat	E. Yakutat/Southeast
	2015	1,708 t	2,682 t
	2016	1,552 t	2,436 t

Overfishing level (OFL)

Applying an adjusted $F_{35\%}$ as prescribed for OFL in Tier 3b, results in a value of 16,128 t for the combined stock. The OFL is apportioned by region, Bering Sea (1,575 t), AI (2,128 t), and GOA (12,425 t), by the same method as the ABC apportionment.

Ecosystem considerations

Ecosystem considerations for the Alaska sablefish fishery are summarized in Table 3.19.

Ecosystem effects on the stock

Prey population trends

Young-of-the-year sablefish prey mostly on euphausiids (Sigler et al. 2001) and copepods (Grover and Olla 1990), while juvenile and adult sablefish are opportunistic feeders. Larval sablefish abundance has been linked to copepod abundance and young-of-the-year abundance may be similarly affected by euphausiid abundance because of their apparent dependence on a single species (McFarlane and Beamish 1992). The dependence of larval and young-of-the-year sablefish on a single prey species may be the cause of the observed wide variation in annual sablefish recruitment. No time series is available for copepod and euphausiid abundance, so predictions of sablefish abundance based on this predator-prey relationship are not possible.

Juvenile and adult sablefish feed opportunistically, so diets differ throughout their range. In general, sablefish < 60 cm consume more euphausiids, shrimp, and cephalopods, while sablefish > 60 cm consume more fish (Yang and Nelson 2000). In the GOA, fish constituted 3/4 of the stomach content weight of adult sablefish with the remainder being invertebrates (Yang and Nelson 2000). Of the fish found in the diets of adult sablefish, pollock were the most abundant item while eulachon, capelin, Pacific herring, Pacific cod, Pacific sand lance, and flatfish also were found. Squid were the most important invertebrate and euphausiids and jellyfish were also present. In southeast Alaska, juvenile sablefish also consume juvenile salmon at least during the summer months (Sturdevant et al. 2009). Off the coast of Oregon and California, fish made up 76 percent of the diet (Laidig et al. 1997), while euphausiids dominated the diet off the southwest coast of Vancouver Island (Tanasichuk 1997). Off Vancouver Island, herring and other fish were increasingly important as sablefish size increased; however, the most important prey item was euphausiids. It is unlikely that juvenile and adult sablefish are affected by availability and abundance of individual prey species because they are opportunistic feeders. The only likely way prey could affect growth or survival of juvenile and adult sablefish is by overall changes in ecosystem productivity.

Predators/Competitors: The main juvenile sablefish predators are adult coho and chinook salmon, which prey on young-of-the-year sablefish during their pelagic stage. Sablefish were the fourth most commonly reported prey species in the salmon troll logbook program from 1977 to 1984 (Wing 1985), however the effect of salmon predation on sablefish survival is unknown. The only other fish species reported to prey on sablefish in the GOA is Pacific halibut; however, sablefish comprised less than 1% of their stomach contents (M. Yang, October 14, 1999, NOAA, pers. comm.). Although juvenile sablefish may not be a prominent prey item because of their relatively low and sporadic abundance compared to other prey items, they share residence on the continental shelf with potential predators such as arrowtooth flounder, halibut, Pacific cod, bigmouth sculpin, big skate, and Bering skate, which are the main piscivorous groundfishes in the GOA (Yang et al. 2006). It seems possible that predation of sablefish by other fish is significant to the success of sablefish recruitment even though they are not a common prey item.

Sperm whales are likely a major predator of adult sablefish. Fish are an important part of sperm whale diet in some parts of the world, including the northeastern Pacific Ocean (Kawakami 1980). Fish have appeared in the diets of sperm whales in the eastern AI and GOA. Although fish species were not identified in sperm whale diets in Alaska, sablefish were found in 8.3% of sperm whale stomachs off of California (Kawakami 1980).

Sablefish distribution is typically thought to be on the upper continental slope in deeper waters than most groundfish. However, during the first two to three years of their life sablefish inhabit the continental shelf. Length samples from the NMFS bottom trawl survey suggest that the geographic range of juvenile sablefish on the shelf varies dramatically from year to year. In particular, juveniles utilize the Bering Sea shelf extensively in some years, while not at all in others (Shotwell et al. 2012). Juvenile sablefish (< 60 cm FL) prey items overlap with the diet of small arrowtooth flounder. On the continental shelf of the GOA, both species consumed euphausiids and shrimp predominantly; these prey are prominent in the diet of many other groundfish species as well. This diet overlap may cause competition for resources between small sablefish and other groundfish species.

Changes in the physical environment: Mass water movements and temperature changes appear related to recruitment success. Above-average recruitment was somewhat more likely with northerly winter currents and much less likely for years when the drift was southerly. Recruitment was above average in 61% of the years when temperature was above average, but was above average in only 25% of the years when temperature was below average. Growth rate of young-of-the-year sablefish is higher in years when recruitment is above average (Sigler et al. 2001). Shotwell et al. (2012) showed that colder than average wintertime sea surface temperatures in the central North Pacific may represent oceanic conditions that create positive recruitment events for sablefish in their early life history.

Anthropogenic changes in the physical environment: The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of sablefish is minimal or temporary in the current fishery management regime primarily based on the criterion that sablefish are currently above Minimum Stock Size Threshold (MSST).

Juvenile sablefish are partly dependent on benthic prey (18% of diet by weight) and the availability of benthic prey may be adversely affected by fishing. Little is known about effects of fishing on benthic habitat or the habitat requirements for growth to maturity. Although sablefish do not appear to be directly dependent on physical structure, reduction of living structure is predicted in much of the area where juvenile sablefish reside and this may indirectly reduce juvenile survivorship by reducing prey availability or by altering the abilities of competing species to feed and avoid predation.

Fishery effects on the ecosystem

Fishery-specific contribution to bycatch of prohibited species, forage species, HAPC biota, marine mammals and birds, and other sensitive non-target species: The sablefish fishery catches significant portions of the shark and thornyhead rockfish total catch (Table 3.4). The sablefish fishery catches the majority of grenadier total catch; the annual amount is variable (Table 3.5). The trend in seabird catch is variable, but is substantially low compared to the 1990s, presumably due to widespread use of measures to reduce seabird catch. Prohibited species catches (PSC) in the targeted sablefish fisheries are dominated by halibut (1,224 t/year) and golden king crab (66,000 individuals/year). Halibut catches were low in 2013, while golden king crab catches have dropped precipitously from 210,000 individuals in 2011 to very few in 2013 (Table 3.6).

The shift from an open-access to an IFQ fishery has increased catching efficiency which has reduced the number of hooks deployed (Sigler and Lunsford 2001). Although the effects of longline gear on bottom habitat are poorly known, the reduced number of hooks deployed during the IFQ fishery must reduce the effects on benthic habitat. The IFQ fishery likely has also reduced discards of other species because of the slower pace of the fishery and the incentive to maximize value from the catch.

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The sablefish fishery largely is dispersed in space and time. The longline fishery lasts 8-1/2 months. The quota is apportioned among six regions of Alaska.

Fishery-specific effects on amount of large size target fish: The longline fishery catches mostly medium and large-size fish which are typically mature. Length frequencies from the pot fishery in the BSAI are very similar to the longline fishery. The trawl fishery, which on average accounts for about 10% of the total catch, often catches slightly smaller fish. The trawl fishery typically occurs on the continental shelf where juvenile sablefish sometimes occur. Catching these fish as juveniles reduces the yield available from each recruit.

Fishery-specific contribution to discards and offal production: Discards of sablefish in the longline fishery are small, typically less than 5% of total catch (Table 3.3). The catch of sablefish in the longline fishery typically consists of a high proportion of sablefish, 90% or more. However, at times grenadiers may be a significant catch and they are almost always discarded.

Fishery-specific effects on age-at-maturity and fecundity of the target species: The shift from an open-access to an IFQ fishery has decreased harvest of immature fish and improved the chance that individual fish will reproduce at least once (Sigler and Lunsford 2001).

Fishery-specific effects on EFH non-living substrate: The primary fishery for sablefish is with longline gear. While it is possible that longlines could move small boulders it is unlikely fishing would persist where this would often occur. Relative to trawl gear, a significant effect of longlines on bedrock, cobbles, or sand is unlikely.

Data gaps and research priorities

There is little information on early life history of sablefish and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the sablefish population.

Future sablefish research is going to focus on several directions:

1) Evaluating different apportionment strategies for ABC.
2) Refine survey abundance index model for inclusion in future assessment model that accounts for

whale depredation and potentially includes gully abundance data and other covariates.

3) Refine fishery abundance index to utilize a core fleet, and identify covariates that affect catch rates.
4) Improve knowledge of sperm whale and killer whale depredation in the fishery and begin to quantify depredation effects on fishery catch rates.
5) Continue to explore the use of environmental data to aid in determining recruitment
6) An integrated GOA Ecosystem project funded by the North Pacific Research Board is underway and is looking at recruitment processes of major groundfish including sablefish. We hope to work closely with this project to help understand sablefish recruitment dynamics.
7) We are developing a spatially explicit research assessment model that includes movement, which will help in examining smaller-scale population dynamics while retaining a single stock hypothesis Alaska-wide sablefish model. This is to include management strategy evaluations of apportionment strategies.

Literature Cited

Bailey, K. M. 2000. Shifting control of recruitment of walleye pollock Theragra chalcogramma after a major climatic and ecosystem change. Marine Ecology Progress Series, 198, 215–224.

Bracken, B. 1983. Sablefish migration in the Gulf of Alaska based on tag recoveries. Proceedings of the International Sablefish Symposium. Alaska Sea Grant Report 83-8.

Crecco, V. and W. J. Overholtz. 1990. Causes of density-dependent catchability for Georges Bank haddock *Melanogrammus aeglefinus*. Can. J. Fish. Aquat. Sci. 47: 385-394.

Echave, K. B., D. H. Hanselman, M. D. Adkison, M. F. Sigler. 2012. Inter-decadal changes in sablefish, *Anoplopoma fimbria*, growth in the northeast Pacific Ocean. Fish. Bull. 210:361-374.

Fina, M. 2011. Evolution of Catch Share Management: Lessons from Catch Share Management in the North Pacific. Fisheries. 36(4):164-177.

Fournier, D. and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aq. Sci. 39: 1195-1207.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27, 233-249.

Funk, F. and B. E. Bracken. 1984. Status of the Gulf of Alaska sablefish (*Anoplopoma fimbria*) resource in 1983. Alaska Dept. Fish Game., Info. Leafl. 235, 55 p.

Goodman, D., M. Mangel, G. Parkes, T.J. Quinn II, V. Restrepo, T. Smith, and K. Stokes. 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans. Draft report. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Grover, J. J. and B. L. Olla. 1990. Food habits of larval sablefish Anoplopoma fimbria from the Bering Sea. Fish. Bull. 88: 811-814.

Hanselman, D.H., J. Heifetz, K.B. Echave, and S.C. Dressel. Accepted. Move it or lose it: Movement and mortality of sablefish tagged in Alaska. Canadian Journal of Fish and Aquatic Sciences. http://www.nrcresearchpress.com/doi/abs/10.1139/cjfas-2014-0251

Hanselman, D.H., W. Clark, and M. Sigler. 2013. Retrospective investigations group report. http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/Retrospectives_2013_final3.pdf

Hanselman, D.H., W. Clark, J. Heifetz, and D. Anderl. 2012. Statistical distribution of age readings of known-age sablefish (*Anoplopoma fimbria*). Fish. Res. 131: 1-8.

Hanselman, D.H., C. Lunsford, and C. Rodgveller. 2012. Assessment of the sablefish stock in Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. pp. 323-432.

Hanselman, D.H., C. Lunsford, and C. Rodgveller. 2011. Assessment of the sablefish stock in Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. pp. 307-412.

Hanselman, D. H., C.R. Lunsford, and C. Rodgveller. 2010. Assessment of the sablefish stock in Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2011. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D. H., J. Fujioka, C. Lunsford, and C. Rodgveller. 2009. Assessment of the sablefish stock in Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D. H., C. Lunsford, J. Fujioka, and C. Rodgveller. 2008. Alaskan Sablefish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2008. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D. H., C. Lunsford, J. Fujioka, and C. Rodgveller. 2007. Alaskan Sablefish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2008. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D.H., J. Heifetz, J.T. Fujioka, and J.N. Ianelli. 2005a. Gulf of Alaska Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. pp. 525-578. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Hanselman, D.H., C.R. Lunsford, M.F. Sigler, and J.T. Fujioka. 2005b. Alaska sablefish assessment for 2006. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Heifetz, J., D. Anderl, N.E. Maloney, and T.L. Rutecki. 1999. Age validation and analysis of ageing error from marked and recaptured sablefish, *Anoplopoma fimbria*. Fish. Bull. 97: 256-263

Heifetz, J. and J. T. Fujioka. 1991. Movement dynamics of tagged sablefish in the northeastern Pacific Ocean. Fish. Res., 11: 355-374.

Heifetz, J., J. T. Fujioka, and T. J. Quinn II. 1997. Geographic apportionment of sablefish, *Anoplopoma fimbria*, harvest in the northeastern Pacific Ocean. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 229-238. NOAA Tech. Rep. 130.

Hill, P. S., J. L. Laake, and E. Mitchell. 1999. Results of a pilot program to document interactions between sperm whales and longline vessels in Alaska waters. NOAA Tech. Memo. NMFS-AFSC-108. 42 p.

Hollowed, A.B. and W.S. Wooster. 1992. Variability of winter ocean conditions and strong year classes of Northeast Pacific groundfish. ICES Mar. Sci. Symp. 195, 433-444.

Hunt, G. L., P. Stabeno, G. Walters, E. Sinclair, R.D. Brodeur, J.M. Napp and N. Bond. 2002. Climate change and control of the southeastern Bering Sea pelagic ecosystem. Deep-Sea Res. 49: 5821-5853.

Hunter, J. R., B. J. Macewicz, and C. A. Kimbrell. 1989. Fecundity and other aspects of reproduction in sablefish, Anoplopoma fimbria, in central California waters. CalCOFI Rep. 30: 61-72.

Johnson, S. L., and T. J. Quinn II. 1988. Catch-Age Analysis with Auxiliary Information of sablefish in the Gulf of Alaska. Contract report to National Marine Fisheries Service, Auke Bay, Alaska. 79 pp. Center for Fisheries and Ocean Sciences, University of Alaska, Juneau, Alaska.

Kawakami, T. 1980. A review of sperm whale food. Sci. Rep. Whales Res. Inst. 32: 199-218.

Kimura, D. K. 1990. Approaches to age-structured separable sequential population analysis. Can. J. Fish. Aquat. Sci. 47: 2364-2374.

Kimura, D. K. and J. J. Lyons. 1991. Between-reader bias and variability in the age-determination process. Fish. Bull. 89: 53-60.

Kimura, D. K., A. M. Shimada, and S. A. Lowe. 1993. Estimating von Bertalanffy growth parameters of sablefish, *Anoplopoma fimbria*, and Pacific cod Gadus macrocephalus using tag-recapture data. Fish. Bull. 91: 271-280.

Kimura, D. K., A. M. Shimada, and F. R. Shaw. 1998. Stock structure and movement of tagged sablefish, *Anoplopoma fimbria*, in offshore northeast Pacific waters and the effects of El Niño-Southern Oscillation on migration and growth. Fish. Bull. 96: 462-481.

Kimura, D. K., and H. H. Zenger. 1997. Standardizing sablefish (*Anoplopoma fimbria*) longline survey abundance indices by modeling the log-ratio of paired comparative fishing cpues. ICES J. Mar. Sci. 54:48-59.

Kinoshita, R. K., A. Greig, and J. M. Terry. 1995. Economic status of the groundfish fisheries off Alaska, 1995. Available North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, Alaska 99510.

Krieger, K. J. 1997. Sablefish, *Anoplopoma fimbria*, observed from a manned submersible. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 115-121. NOAA Tech. Rep. 130.

Laidig, T. E., P. B. Adams, and W. M. Samiere. 1997. Feeding habits of sablefish, *Anoplopoma fimbria*, off the coast of Oregon and California. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 65-80. NOAA Tech. Rep. 130.

Langley, A.D. and M. Maunder. 2009. Stock assessment of TRE 7. New Zealand Fisheries Assessment Report 2009/49. 42p.

Low, L. L., G. K. Tanonaka, and H. H. Shippen. 1976. Sablefish of the Northeastern Pacific Ocean and Bering Sea. Northwest Fisheries Science Center Processed Report. 115 p.

Mace, P. M. and M. P. Sissenwine. 1993. How much spawning per recruit is enough? In S. J. Smith, J. J. Hunt, and D. Rivard [ed.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120: 101-118.

Maloney, N. E. and J. Heifetz. 1997. Movements of tagged sablefish, *Anoplopoma fimbria*, released in the eastern Gulf of Alaska. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 115-121. NOAA Tech. Rep. 130.

Mason, J. C. R. J. Beamish, and G. A. McFarlane. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (Anoplopoma fimbria) off the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 40: 2126-2134.

McDevitt, S. A. 1986. A summary of sablefish catches in the Northeast Pacific Ocean, 1956-84. NOAA Tech. Memo. NMFS F/NWC-101. 34 p.

McDevitt, S. A. 1990. Growth analysis of sablefish from mark-recapture data from the northeast Pacific. M.S. University of Washington. 87 p.

McFarlane, G.A. and R.J. Beamish. 1992. Climatic influence linking copepod production with strong year-class in sablefish, Anoplopoma fimbria. Can. J. Fish. Aquat. Sci. 49: 743– 753.

McFarlane, G. A. and W. D. Nagata. 1988. Overview of sablefish mariculture and its potential for industry. Alaska Sea Grant Report 88-4. PP. 105-120. University of Alaska Fairbanks, Fairbanks, Alaska 99775.

Meinhold, R. J. and N. D. Singpurwalla, 1983. Understanding the Kalman Filter. The American Statistician, May 1983, Vol 37, No. 2, pp. 123-127.

NMFS (National Marine Fisheries Service). 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. http://www.fakr.noaa.gov/habitat/seis/efheis.htm.

NOAA (National Oceanic and Atmospheric Administration). 2012. NOAA's National Marine Fisheries Service (NMFS), Alaska Region Restricted Access Management (RAM) Pacific Halibut - Sablefish IFQ Report, Fishing Year 2011. Alaskafisheries.noaa.gov/ram/ifqreports.htm. National Marine Fisheries Service, Juneau, Alaska.

NRC (National Research Council). 1998. Improving fish stock assessments. National Academy Press, Washington, DC, 177 pp

Orlov, A. M., and I. A. Biryukov. 2005. First report of sablefish in spawning condition off the coast of Kamchatka and the Kuril Islands. ICES J. Mar. Sci. 62: 1016-1020.

Rose, G. A. and D. W. Kulka. 1999. Hyperaggregation of fish and fisheries: how catch-per-unit-effort increased as the northern cod (*Gadus morhua*) declined. Can. J. Fish. Aquat. Sci. 56 (Suppl. 1): 118-127.

Rutecki, T. L., M. F. Sigler and H. H. Zenger Jr. 1997. Data report: National Marine Fisheries Service longline surveys, 1991-97.

Rutecki, T.L. and E.R. Varosi. 1997. Distribution, age, and growth of juvenile sablefish, *Anoplopoma* *fimbria*, in Southeast Alaska. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 45-54. NOAA Tech. Rep. 130.

Sasaki, T. 1973. Data on the Japanese blackcod fisheries in the North Pacific--I. Development and history of the Japanese blackcod fisheries through 1972. Unpubl. Rep., 22 p. Far Seas Fish. Res. Lab., Japan Fish Agency, 7-1, Orido 5 chome, Shimizu 424, Japan.

Sasaki, T. 1985. Studies on the sablefish resources in the North Pacific Ocean. Bulletin 22, (1-108), Far Seas Fishery Laboratory. Shimizu, 424, Japan.

Sasaki, T. 1987. Stock assessment of sablefish in the eastern Bering Sea, Aleutian Islands region, and the Gulf of Alaska in 1987. Unpubl. Rep., 33 p. Far Seas Fish. Res. Lab., Japan Fish Agency, 7-1, Orido 5 chome, Shimizu 424, Japan.

Saunders, M. W., B. M. Leaman, V. Haist, R. Hilborn, and G. A. McFarlane. 1996. Sablefish stock assessment for 1996 and recommended yield options for 1997. Unpublished report available Department of Fisheries and Oceans, Biological Sciences Branch, Pacific Biological Station, Nanaimo, British Columbia, V9R 5K6.

Shotwell, S.K., D.H. Hanselman, and I.M. Belkin. 2012. Toward biophysical synergy: Investigating advection along the Polar Front to identify factors influencing Alaska sablefish recruitment. Deep-Sea Res. II, http://dx.doi.org/10.1016/j.dsr2.2012.08.024.

Sigler, M. F. and J. T. Fujioka. 1988. Evaluation of variability in sablefish, *Anoplopoma fimbria*, abundance indices in the Gulf of Alaska using the bootstrap method. Fish. Bull. 86: 445-452.

Sigler, M.F., C.R. Lunsford, and J.T. Fujioka. 2004. Alaska sablefish assessment for 2005. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Sigler, M.F., C.R. Lunsford, J.T. Fujioka, and S.A. Lowe. 2002. Alaska sablefish assessment for 2003. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Bering Sea and Aleutian Islands. pp. 449-514. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Sigler, M. F. and C. R. Lunsford. 2001. Effects of individual quotas on catching efficiency and spawning potential in the Alaska sablefish fishery. Can. J. Fish. Aquat. Sci. 58: 1300-1312.

Sigler, M.F., C.R. Lunsford, J.M. Straley, and J.B. Liddle. 2007. Sperm whale depredation of sablefish longline gear in the northeast Pacific Ocean. Mar. Mammal Sci. doi:10.1111/j.1748-7692.2007.00149.

Sigler, M. F. 2000. Abundance estimation and capture of sablefish, *Anoplopoma fimbria*, by longline gear. Can. J. Fish. Aquat. Sci. 57: 1270-1283.

Sigler, M.F., J.T. Fujioka, and S.A. Lowe. 1999. Alaska sablefish assessment for 2000. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. http://www.afsc.noaa.gov/refm/docs/historic_assess/sable99.pdf. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Sigler, M. F., T. L. Rutecki, D. L. Courtney, J. F. Karinen, and M.-S.Yang. 2001. Young-of-the-year sablefish abundance, growth, and diet. Alaska Fish. Res. Bull. 8(1): 57-70.

Sigler, M. F. and H. H. Zenger. 1989. Assessment of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1987. NOAA Tech. Memo. NMFS F/NWC-169. 54 p.

Soderlund, E., E. Anderson, C. L. Dykstra, T. Geernaert, and A. M. Ranta. 2009. 2008 standardized stock assessment survey. Int. Pac. Comm. Report of Assessment and Research Activities 2008 469-496.

Straley, J., T. O'Connell, S. Mesnick, L. Behnken, and J. Liddle. 2005. Sperm Whale and Longline Fisheries Interactions in the Gulf of Alaska. North Pacific Research Board R0309 Final Report, 15 p.

Sturdevant, M. V., M. F. Sigler, and J. A. Orsi. 2009. Sablefish predation on juvenile Pacific salmon in the coastal marine waters off southeast Alaska in 1999. Trans. Amer. Fish. Soc. 138: 675-691.

Tanasichuk, R. W. 1997. Diet of sablefish, *Anoplopoma fimbria*, from the southwest coast of Vancouver Island. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the

Biology and Management of Sablefish. pp 93-98. NOAA Tech. Rep. 130.
Thompson, G. G. 2004. Estimation of Pacific Cod Biomass Distributions Based on Alternative Weightings of Trawl Survey Estimates. Appendix to Nov. 2004 Pacific Cod Stock Assessment and Fishery Evaluation report.
Wing, B. L. 1985. Salmon stomach contents from the Alaska Troll Logbook Program, 1977-84. NOAA Tech. Memo. NMFS F/NWC-91. 41 p.
Wing, B. L. 1997. Distribution of sablefish, *Anoplopoma fimbria*, larvae in the Eastern Gulf of Alaska. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 13-26. NOAA Tech. Rep. 130.
Wolotira, R. J. J., T. M. Sample, S. F. Noel, and C. R. Iten. 1993. Geographic and bathymetric distributions for many commercially important fishes and shellfishes off the west coast of North America, based on research survey and commercial catch data, 1912-1984. NOAA Tech. Memo. NMFS-AFSC-6. 184 pp.
Yang, M-S. and M. W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. NOAA Tech. Memo. NMFS-AFSC-112. 174 p.
Yang, M-S. K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. NOAA Tech. Memo. NMFS-AFSC-164. 199 p.
Zenger, H. H., Jr., M. F. Sigler, and E. R. Varosi. 1994. Assessment of Gulf of Alaska sablefish and other groundfish species based on the 1988 National Marine Fisheries Service longline survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-39, 55 p.

Tables

Table 3.1. Alaska sablefish catch (t). The values include landed catch and discard estimates. Discards were estimated for U.S. fisheries before 1993 by multiplying reported catch by 2.9% for fixed gear and 26.9% for trawl gear (1994-1997 averages) because discard estimates were unavailable. Eastern includes West Yakutat and East Yakutat / Southeast. 2014 catches are estimated for the full year (www.akfin.org).

		BY AREA								BY GEAR	
Year	Grand total	Bering Sea	Aleu-tians	Western	Central	Eastern	West Yakutat	East Yak/SEO	Un-known	Fixed	Trawl
1960	3,054	1,861	0	0	0	1,193			0	3,054	0
1961	16,078	15,627	0	0	0	451			0	16,078	0
1962	26,379	25,989	0	0	0	390			0	26,379	0
1963	16,901	13,706	664	266	1,324	941			0	10,557	6,344
1964	7,273	3,545	1,541	92	955	1,140			0	3,316	3,957
1965	8,733	4,838	1,249	764	1,449	433			0	925	7,808
1966	15,583	9,505	1,341	1,093	2,632	1,012			0	3,760	11,823
1967	19,196	11,698	1,652	523	1,955	3,368			0	3,852	15,344
1968	30,940	14,374	1,673	297	1,658	12,938			0	11,182	19,758
1969	36,831	16,009	1,673	836	4,214	14,099			0	15,439	21,392
1970	37,858	11,737	1,248	1,566	6,703	16,604			0	22,729	15,129
1971	43,468	15,106	2,936	2,047	6,996	16,382			0	22,905	20,563
1972	53,080	12,758	3,531	3,857	11,599	21,320			15	28,538	24,542
1973	36,926	5,957	2,902	3,962	9,629	14,439			37	23,211	13,715
1974	34,545	4,258	2,477	4,207	7,590	16,006			7	25,466	9,079
1975	29,979	2,766	1,747	4,240	6,566	14,659			1	23,333	6,646
1976	31,684	2,923	1,659	4,837	6,479	15,782			4	25,397	6,287
1977	21,404	2,718	1,897	2,968	4,270	9,543			8	18,859	2,545
1978	10,394	1,193	821	1,419	3,090	3,870			1	9,158	1,236
1979	11,814	1,376	782	999	3,189	5,391			76	10,350	1,463
1980	10,444	2,205	275	1,450	3,027	3,461			26	8,396	2,048
1981	12,604	2,605	533	1,595	3,425	4,425			22	10,994	1,610
1982	12,048	3,238	964	1,489	2,885	3,457			15	10,204	1,844
1983	11,715	2,712	684	1,496	2,970	3,818			35	10,155	1,560
1984	14,109	3,336	1,061	1,326	3,463	4,618			305	10,292	3,817
1985	14,465	2,454	1,551	2,152	4,209	4,098			0	13,007	1,457
1986	28,892	4,184	3,285	4,067	9,105	8,175			75	21,576	7,316
1987	35,163	4,904	4,112	4,141	11,505	10,500			2	27,595	7,568
1988	38,406	4,006	3,616	3,789	14,505	12,473			18	29,282	9,124
1989	34,829	1,516	3,704	4,533	13,224	11,852			0	27,509	7,320
1990	32,115	2,606	2,412	2,251	13,786	11,030			30	26,598	5,518
1991	27,073	1,318	2,168	1,821	11,662	10,014			89	23,124	3,950
1992	24,932	586	1,497	2,401	11,135	9,171			142	21,614	3,318
1993	25,417	669	2,078	740	11,955	9,976	4,620	5,356	0	22,912	2,506
1994	23,577	694	1,725	539	9,376	11,243	4,493	6,750	0	20,639	2,938
1995	20,692	930	1,119	1,747	7,673	9,223	3,872	5,352	0	18,079	2,613
1996	17,275	648	764	1,542	6,773	7,548	2,893	4,655	0	15,088	2,187
1997	14,607	552	781	1,374	6,234	5,666	1,930	3,735	0	12,975	1,632
1998	13,867	563	535	1,432	5,915	5,422	1,956	3,467	0	12,380	1,487
1999	13,585	675	681	1,488	5,874	4,867	1,709	3,159	0	11,601	1,985
2000	15,565	742	1,049	1,582	6,173	6,020	2,066	3,953	0	13,546	2,019
2001	14,064	864	1,074	1,588	5,518	5,021	1,737	3,284	0	12,281	1,783
2002	14,748	1,144	1,119	1,865	6,180	4,441	1,550	2,891	0	12,505	2,243
2003	16,411	1,012	1,118	2,118	6,993	5,170	1,822	3,347	0	14,351	2,060
2004	17,518	1,041	955	2,170	7,310	6,041	2,241	3,801	0	15,861	1,656
2005	16,580	1,070	1,481	1,929	6,701	5,399	1,824	3,575	0	15,024	1,556
2006	15,551	1,079	1,151	2,151	5,921	5,251	1,889	3,362	0	14,305	1,246
2007	15,957	1,182	1,168	2,101	6,003	5,502	2,074	3,429	0	14,721	1,235
2008	14,674	1,141	901	1,679	5,543	5,410	2,056	3,354	0	13,552	1,122
2009	13,128	916	1,100	1,423	5,005	4,684	1,831	2,853	0	12,071	1,057
2010	11,980	755	1,094	1,354	4,508	4,269	1,578	2,690	0	10,976	1,004
2011	12,971	705	1,024	1,402	4,919	4,921	1,896	3,024	0	11,792	1,179
2012	13,868	743	1,205	1,353	5,329	5,238	2,033	3,205	0	12,767	1,102
2013	13,642	634	1,062	1,385	5,207	5,354	2,106	3,247	0	12,604	1,038
2014	11,476	328	757	1,090	4,737	4,564	1,707	2,857	0	10,486	990

Table 3.2. Catch (t) in the Aleutian Islands and the Bering Sea by gear type from 1991-2013. Both CDQ and non-CDQ catches are included. Catches in 1991-1999 are averages. Catch as of October 24, 2014 (www.akfin.org).

Aleutian Islands				
Year	Pot	Trawl	Longline	Total
1991-1999	6	73	1,210	1,289
2000	103	33	913	1049
2001	111	39	925	1074
2002	105	39	975	1119
2003	316	42	760	1118
2004	384	32	539	955
2005	688	115	679	1481
2006	461	60	629	1151
2007	632	40	496	1168
2008	179	76	646	901
2009	78	75	947	1100
2010	59	74	961	1094
2011	141	47	836	1024
2012	77	148	979	1205
2013	87	58	917	1062
Bering Sea				
1991-1999	5	189	539	733
2000	40	283	418	741
2001	106	336	405	847
2002	382	268	467	1117
2003	363	183	417	964
2004	435	276	313	1024
2005	595	262	202	1059
2006	621	76	373	1070
2007	879	80	211	1170
2008	754	181	204	1139
2009	557	91	266	914
2010	452	30	274	755
2011	405	44	256	705
2012	432	93	218	743
2013	352	133	149	634

Table 3.3. Discarded catches of sablefish (amount [t], percent of total catch, total catch [t]) by gear (H&L=hook & line, Other = Pot, trawl, and jig, combined for confidentiality) by FMP area for 2007-2013. Source: NMFS Alaska Regional Office via AKFIN, October 24, 2014.

		BSAI			GOA			Combined		
Year	Gear	Discard	%Discard	Catch	Discard	%Discard	Catch	Discard	%Discard	Catch
2007	Total	66	2.84%	2,338	556	4.11%	13,547	622	3.92%	15,884
	H&L	16	2.25%	707	256	2.07%	12,379	272	2.08%	13,086
	Other	50	3.09%	1,631	300	25.71%	1,168	351	12.53%	2,799
2008	Total	100	4.90%	2,040	755	5.98%	12,623	855	5.83%	14,663
	H&L	93	10.99%	850	674	5.73%	11,760	768	6.09%	12,610
	Other	6	0.54%	1,189	81	9.35%	863	87	4.24%	2,052
2009	Total	24	1.19%	2,014	739	6.65%	11,112	763	5.82%	13,126
	H&L	17	1.39%	1,213	659	6.44%	10,223	675	5.91%	11,436
	Other	7	0.90%	801	499	4.53%	11,016	88	5.21%	1,690
2010	Total	43	2.31%	1,849	371	4.02%	9,231	461	3.85%	11,976
	H&L	36	2.90%	1,234	47	5.22%	896	407	3.89%	10,465
	Other	7	1.12%	614	574	5.12%	11,222	54	3.57%	1,511
2011	Total	25	1.47%	1,729	396	3.90%	10,145	599	4.63%	12,951
	H&L	18	1.63%	1,092	169	15.84%	1,068	413	3.68%	11,237
	Other	8	1.20%	637	327	2.74%	11,917	186	10.86%	1,714
2012	Total	25	1.30%	1,948	253	2.29%	11,060	343	2.48%	13,856
	H&L	13	1.10%	1,197	65	7.62%	848	266	2.17%	12,257
	Other	12	1.63%	750	626	5.24%	11,944	77	4.81%	1,598
2013	Total	30	1.79%	1,697	579	5.21%	11,099	657	4.81%	13,641
	H&L	27	2.51%	1,066	47	5.60%	845	605	4.98%	12,165
	Other	4	0.59%	630	3987	4.83%	82,482	51	3.47%	1,476
2007-2013	Total	45	2.26%	1,945	521	4.59%	11,259	614	4.48%	13,728
Mean	H&L	31	3.25%	1,051	274	6.93%	5,431	487	4.11%	11,894
	Other	13	1.29%	893	913	8.22%	18,659	128	6.38%	1,834

Table 3.4. Bycatch (t) of FMP Groundfish species in the targeted sablefish fishery averaged from 2009-2013. Other = Pot and trawl combined because of confidentiality. Source: AKFIN, October 31, 2014.

	Hook and Line			Other Gear			All Gear		
Species	Discard	Retained	Total	Discard	Retained	Total	Discard	Retained	Total
GOA Thornyhead Rockfish	147	346	493	4	23	27	151	369	520
Arrowtooth Flounder	198	40	238	106	4	110	304	44	348
Shark	330	0	331	1	0	1	331	0	331
GOA Shortraker Rockfish	127	91	219	11	9	20	138	101	239
Other Rockfish	57	95	153	2	1	3	59	96	156
GOA Skate, Longnose	133	7	139	1	0	1	134	7	140
GOA Rougheye Rockfish	55	80	135	2	3	5	57	83	140
GOA Skate, Other	133	2	136	2	0	2	135	2	137
Pacific Cod	40	46	85	1	4	5	41	50	91
Other Species	84	1	85	1	0	1	85	1	86
Greenland Turbot	23	51	74	10	1	10	33	52	85
BSAI Skate	52	0	52	0	-	0	52	0	52
GOA Deep Water Flatfish	8	0	8	16	5	22	24	5	30
Pacific Ocean Perch	1	0	1	2	15	17	2	15	18
BSAI Kamchatka Flounder	12	2	13	3	0	3	15	2	17
BSAI Shortraker Rockfish	5	8	14	0	0	0	6	8	14
BSAI Other Flatfish	11	0	11	1	0	1	12	0	12
GOA Rex Sole	0	-	0	8	4	11	8	4	11
Sculpin	10	-	10	0	0	0	10	0	10
Total	1,315	728	2,046	220	102	322	1,535	830	2,369

Table 3.5. Bycatch of nontarget species and HAPC biota in the targeted sablefish fishery. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN, October 31, 2014.

	Estimated Catch (t)				
Group Name	2009	2010	2011	2012	2013
Benthic urochordata	0.01	0.13	0.13	1.08	0.00
Birds	0.47	0.45	1.46	0.22	0.64
Bivalves	0.04	0.04	0.05	0.01	0.00
Brittle star unidentified	0.45	0.12	0.44	4.52	0.10
Corals Bryozoans	2.21	3.33	5.57	7.57	12.75
Dark Rockfish	0.14	0.00	0.00	0.03	0.07
Eelpouts	1.83	1.38	0.58	0.62	1.11
Giant Grenadier	6,011	4,767	6,973	6,993	8,083
Greenlings	0.07	0.00	0.02	0.00	0.00
Grenadier	1,139	864	843	1,020	1,519
Hermit crab unidentified	0.10	0.19	0.21	0.08	0.09
Invertebrate unidentified	1.53	2.08	2.02	6.81	0.18
Misc crabs	3.29	1.89	1.13	0.31	0.51
Misc crustaceans	2.36	0.00	0.00	0.00	0.00
Misc deep fish	0.00	0.00	0.00	0.00	0.00
Misc fish	5.03	6.20	8.43	10.12	28.81
Scypho jellies	0.08	0.11	0.69	0.00	0.00
Sea anemone unidentified	2.26	1.49	3.29	0.99	0.92
Sea pens whips	0.52	0.35	1.58	0.25	0.28
Sea star	2.97	3.91	3.45	2.99	18.79
Snails	10.79	11.49	20.04	12.08	8.77
Sponge unidentified	2.17	1.05	2.08	0.94	3.31
Urchins, dollars, cucumbers	1.64	0.58	0.26	0.78	0.72

Table 3.6. Prohibited Species Catch (PSC) estimates reported in tons for halibut, thousands of animals for crab, by year, and fisheries management plan (BSAI or GOA) area for the sablefish fishery. Other = Pot and trawl combined because of confidentiality. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN, October 31, 2014.

		2010			2011			2012			2013		Mean
	BSAI	GOA	Total	BSAI	GOA	Total	BSAI	GOA	Total	BSAI	GOA	Total	
Hook and Line													
Bairdi Crab	-	0.06	0.06	-	-	-	-	-	-	-	0.09	0.09	0.04
Golden K. Crab	0.94	-	0.94	0.55	0.13	0.68	0.46	0.02	0.48	0.47	0.11	0.58	0.67
Halibut	341	992	1,333	182	889	1,071	129	1,456	1,585	86	708	794	1,196
Red K. Crab	0.01	-	0.01	0.02	-	0.02	0.01	-	0.01	-	0.03	0.03	0.01
Other													
Bairdi Crab	-	0.06	0.06	0.82	-	0.82	-	-	-	0.22	-	0.22	0.27
Golden K. Crab	32	-	32	210	0	210	17	0	17	1	-	1	65
Halibut	34	4	39	18	6	24	11	5	16	20	12	32	28
Red K. Crab	-	-	-	0.31	-	0.31	-	-	-	-	-	-	0.08

Table 3.7. Summary of management measures with time series of catch, ABC, OFL, and TAC.

Year	Catch(t)	OFL	ABC	TAC	Management measure
1980	10,444			18,000	Amendment 8 to the Gulf of Alaska Fishery Management Plan established the West and East Yakutat management areas for sablefish.
1981	12,604			19,349	
1982	12,048			17,300	
1983	11,715			14,480	
1984	14,109			14,820	
1985	14,465			13,480	Amendment 14 of the GOA FMP allocated sablefish quota by gear type: 80% to fixed gear and 20% to trawl gear in WGOA and CGOA and 95% fixed to 5% trawl in the EGOA.
1986	28,892			21,450	Pot fishing banned in Eastern GOA.
1987	35,163			27,700	Pot fishing banned in Central GOA.
1988	38,406			36,400	
1989	34,829			32,200	Pot fishing banned in Western GOA.
1990	32,115			33,200	Amendment 15 of the BSAI FMP allocated sablefish quota by gear type: 50% to fixed gear in and 50% to trawl in the EBS, and 75% fixed to 25% trawl in the Aleutian Islands.
1991	27,073			28,800	
1992	24,932			25,200	Pot fishing banned in Bering Sea (57 FR 37906).
1993	25,417			25,000	
1994	23,577			28,840	
1995	20,692			25,300	Amendment 20 to the Gulf of Alaska Fishery Management Plan and 15 to the Bering Sea/Aleutian Islands Fishery Management Plan established IFQ management for sablefish beginning in 1995. These amendments also allocated 20% of the fixed gear allocation of sablefish to a CDQ reserve for the Bering Sea and Aleutian Islands.
1996	17,275			19,380	Pot fishing ban repealed in Bering Sea except from June 1-30.
1997	14,607	27,900	19,600	17,200	Maximum retainable allowances for sablefish were revised in the Gulf of Alaska. The percentage depends on the basis species.
1998	13,867	26,500	16,800	16,800	
1999	13,585	24,700	15,900	15,900	
2000	15,565	21,400	17,300	17,300	
2001	14,064	20,700	16,900	16,900	
2002	14,748	26,100	17,300	17,300	
2003	16,411	28,900	18,400	20,900	
2004	17,518	30,800	23,000	23,000	
2005	16,580	25,400	21,000	21,000	
2006	15,551	25,300	21,000	21,000	
2007	15,957	23,750	20,100	20,100	
2008	14,674	21,310	18,030	18,030	Pot fishing ban repealed in Bering Sea for June 1-30 (74 FR 28733).
2009	13,128	19,000	16,080	16,080	
2010	11,980	21,400	15,230	15,230	
2011	12,971	20,700	16,040	16,040	
2012	13,868	20,400	17,240	17,240	
2013	13,642	19,180	16,230	16,230	
2014	11,476	16,160	13,722	13,722	

Table 3.8. Sample sizes for age and length data collected from Alaska sablefish. Japanese fishery data from Sasaki (1985), U.S. fishery data from the observer databases, and longline survey data from longline survey databases. All fish were sexed before measurement, except for the Japanese fishery data.

	LENGTH							AGE		
Year	U.S. NMFS trawl survey (GOA)	Japanese fishery Trawl	Japanese fishery Longline	U.S. fishery Trawl	U.S. fishery Longline	Cooperative longline survey	Domestic longline survey	Cooperative longline survey	Domestic longline survey	U.S. longline fishery
1963			30,562							
1964		3,337	11,377							
1965		6,267	9,631							
1966		27,459	13,802							
1967		31,868	12,700							
1968		17,727								
1969		3,843								
1970		3,456								
1971		5,848	19,653							
1972		1,560	8,217							
1973		1,678	16,332							
1974			3,330							
1975										
1976			7,704							
1977			1,079							
1978			9,985							
1979			1,292			19,349				
1980			1,944			40,949				
1981						34,699		1,146		
1982						65,092				
1983						66,517		889		
1984	12,964					100,029				
1985						125,129		1,294		
1986						128,718				
1987	9,610					102,639		1,057		
1988						114,239				
1989						115,067		655		
1990	4,969			1,229	32,936	78,794	101,530			
1991				721	28,182	69,653	95,364	902		
1992				0	20,929	79,210	104,786			
1993	7,282			468	21,943	80,596	94,699	1,178		
1994				89	11,914	74,153	70,431			
1995				87	17,735		80,826			
1996	4,650			239	14,416		72,247		1,176	
1997				0	20,330		82,783		1,214	
1998				35	8,932		57,773		1,191	
1999	4,408			1,268	28,070		79,451		1,186	1,141
2000				472	32,208		62,513		1,236	1,152
2001	*partial			473	30,315		83,726		1,214	1,003
2002				526	33,719		75,937		1,136	1,059
2003	5,039			503	36,077		77,678		1,128	1,185
2004				694	31,199		82,767		1,185	1,145
2005	4,956			2,306	36,213		74,433		1,074	1,164
2006				721	32,497		78,625		1,178	1,154
2007	3,804			860	29,854		73,480		1,174	1,115
2008				2,018	23,414		71,661		1,184	1,164
2009	3,975			1,837	24,674		67,978		1,197	1,126
2010				1,634	24,530		75,010		1,176	1,159
2011	2,118			1,877	22,659		87,498		1,199	1,190
2012				2,533	22,311		63,116		1,186	1,169
2013	1,561						51,586		1,190	
2014	1,561						52,290			

Table 3.9. Average catch rate (pounds/hook) for fishery data by year and region. SE = standard error, CV = coefficient of variation. C = confidential due to less than three vessels or sets. These data are still used in the combined index.

Observer Fishery Data											
Aleutian Islands-Observer						Bering Sea-Observer					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1990	0.53	0.05	0.10	193	8	1990	0.72	0.11	0.15	42	8
1991	0.50	0.03	0.07	246	8	1991	0.28	0.06	0.20	30	7
1992	0.40	0.06	0.15	131	8	1992	0.25	0.11	0.43	7	4
1993	0.28	0.04	0.14	308	12	1993	0.09	0.03	0.36	4	3
1994	0.29	0.05	0.18	138	13	1994	C	C	C	2	2
1995	0.30	0.04	0.14	208	14	1995	0.41	0.07	0.17	38	10
1996	0.23	0.03	0.12	204	17	1996	0.63	0.19	0.30	35	15
1997	0.35	0.07	0.20	117	9	1997	C	C	C	0	0
1998	0.29	0.05	0.17	75	12	1998	0.17	0.03	0.18	28	9
1999	0.38	0.07	0.17	305	14	1999	0.29	0.09	0.32	27	10
2000	0.29	0.03	0.11	313	15	2000	0.28	0.09	0.31	21	10
2001	0.26	0.04	0.15	162	9	2001	0.31	0.02	0.07	18	10
2002	0.32	0.03	0.11	245	10	2002	0.10	0.02	0.22	8	4
2003	0.26	0.04	0.17	170	10	2003	C	C	C	8	2
2004	0.21	0.04	0.21	138	7	2004	0.17	0.05	0.31	9	4
2005	0.15	0.05	0.34	23	6	2005	0.23	0.02	0.16	9	6
2006	0.23	0.04	0.16	205	11	2006	0.17	0.05	0.21	68	15
2007	0.35	0.10	0.29	198	7	2007	0.28	0.05	0.18	34	8
2008	0.37	0.04	0.10	247	6	2008	0.38	0.22	0.58	12	5
2009	0.29	0.05	0.22	335	10	2009	0.14	0.04	0.21	24	5
2010	0.27	0.04	0.14	459	12	2010	0.17	0.03	0.19	42	8
2011	0.25	0.05	0.19	401	9	2011	0.10	0.01	0.13	12	4
2012	0.25	0.10	0.15	363	8	2012	C	C	C	6	1
2013	0.28	0.06	0.22	613	7	2013	0.21	0.10	0.46	27	5

Table 3.9 (cont.)

Western Gulf-Observer					
Year	CPUE	SE	CV	Sets	Vessels
1990	0.64	0.14	0.22	178	7
1991	0.44	0.06	0.13	193	16
1992	0.38	0.05	0.14	260	12
1993	0.35	0.03	0.09	106	12
1994	0.32	0.03	0.10	52	5
1995	0.51	0.04	0.09	432	22
1996	0.57	0.05	0.10	269	20
1997	0.50	0.05	0.10	349	20
1998	0.50	0.03	0.07	351	18
1999	0.53	0.07	0.12	244	14
2000	0.49	0.06	0.13	185	12
2001	0.50	0.05	0.10	273	16
2002	0.51	0.05	0.09	348	15
2003	0.45	0.04	0.10	387	16
2004	0.47	0.08	0.17	162	10
2005	0.58	0.07	0.13	447	13
2006	0.42	0.04	0.13	306	15
2007	0.37	0.04	0.11	255	12
2008	0.46	0.07	0.16	255	11
2009	0.44	0.09	0.21	208	11
2010	0.42	0.06	0.14	198	10
2011	0.54	0.12	0.22	196	12
2012	0.38	0.04	0.11	147	13
2013	0.34	0.02	0.06	325	18

Central Gulf-Observer					
Year	CPUE	SE	CV	Sets	Vessels
1990	0.54	0.04	0.07	653	32
1991	0.62	0.06	0.09	303	24
1992	0.59	0.05	0.09	335	19
1993	0.60	0.04	0.07	647	32
1994	0.65	0.06	0.09	238	15
1995	0.90	0.07	0.08	457	41
1996	1.04	0.07	0.07	441	45
1997	1.07	0.08	0.08	377	41
1998	0.90	0.06	0.06	345	32
1999	0.87	0.08	0.10	269	28
2000	0.93	0.05	0.06	319	30
2001	0.70	0.04	0.06	347	31
2002	0.84	0.07	0.08	374	29
2003	0.99	0.07	0.07	363	34
2004	1.08	0.10	0.09	327	29
2005	0.89	0.06	0.07	518	32
2006	0.82	0.06	0.08	361	33
2007	0.93	0.06	0.07	289	30
2008	0.84	0.07	0.08	207	27
2009	0.77	0.06	0.07	320	33
2010	0.80	0.05	0.07	286	31
2011	0.85	0.08	0.10	213	28
2012	0.74	0.07	0.09	298	27
2013	0.51	0.05	0.10	419	34

West Yakutat-Observer					
Year	CPUE	SE	CV	Sets	Vessels
1990	0.95	0.24	0.25	75	9
1991	0.65	0.07	0.10	164	12
1992	0.64	0.18	0.27	98	6
1993	0.71	0.07	0.10	241	12
1994	0.65	0.17	0.27	81	8
1995	1.02	0.10	0.10	158	21
1996	0.97	0.07	0.07	223	28
1997	1.16	0.11	0.09	126	20
1998	1.21	0.10	0.08	145	23
1999	1.20	0.15	0.13	110	19
2000	1.28	0.10	0.08	193	32
2001	1.03	0.07	0.07	184	26
2002	1.32	0.13	0.10	155	23
2003	1.36	0.10	0.07	216	27
2004	1.23	0.09	0.08	210	24
2005	1.32	0.09	0.07	352	24
2006	0.96	0.10	0.10	257	30
2007	1.02	0.11	0.11	208	24
2008	1.40	0.12	0.08	173	23
2009	1.34	0.12	0.09	148	23
2010	1.11	0.09	0.08	136	22
2011	1.18	0.09	0.07	186	24
2012	0.97	0.09	0.10	255	24
2013	1.11	0.15	0.13	109	20

East Yakutat/SE-Observer					
Year	CPUE	SE	CV	Sets	Vessels
1990	C	C	C	0	0
1991	C	C	C	17	2
1992	C	C	C	20	1
1993	C	C	C	26	2
1994	C	C	C	5	1
1995	1.45	0.20	0.14	101	19
1996	1.20	0.11	0.09	137	24
1997	1.10	0.14	0.13	84	17
1998	1.27	0.12	0.10	140	25
1999	0.94	0.12	0.13	85	11
2000	0.84	0.13	0.16	81	14
2001	0.84	0.08	0.09	110	14
2002	1.20	0.23	0.19	121	14
2003	1.29	0.13	0.10	113	19
2004	1.08	0.10	0.09	135	17
2005	1.18	0.13	0.11	181	16
2006	0.93	0.11	0.11	104	18
2007	0.92	0.15	0.17	85	16
2008	1.06	0.13	0.12	103	17
2009	0.98	0.12	0.12	94	13
2010	0.97	0.17	0.17	76	12
2011	0.98	0.09	0.10	196	16
2012	0.93	0.11	0.12	104	15
2013	0.91	0.12	0.14	165	22

Table 3.9 (cont.)

Aleutian Islands-Logbook						Bering Sea-Logbook					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1999	0.29	0.04	0.15	167	15	1999	0.56	0.08	0.14	291	43
2000	0.24	0.05	0.21	265	16	2000	0.21	0.05	0.22	169	23
2001	0.38	0.16	0.41	36	5	2001	0.35	0.11	0.33	61	8
2002	0.48	0.19	0.39	33	5	2002	C	C	C	5	2
2003	0.36	0.11	0.30	139	10	2003	0.24	0.13	0.53	25	6
2004	0.45	0.11	0.25	102	7	2004	0.38	0.09	0.24	202	8
2005	0.46	0.15	0.33	109	8	2005	0.36	0.07	0.19	86	10
2006	0.51	0.16	0.31	61	5	2006	0.38	0.07	0.18	106	9
2007	0.38	0.22	0.58	61	3	2007	0.37	0.08	0.21	147	8
2008	0.30	0.03	0.12	119	4	2008	0.52	0.20	0.39	94	7
2009	0.23	0.07	0.06	204	7	2009	0.25	0.04	0.14	325	18
2010	0.25	0.05	0.20	497	9	2010	0.30	0.08	0.27	766	12
2011	0.23	0.07	0.30	609	12	2011	0.22	0.03	0.13	500	24
2012	0.26	0.03	0.14	893	12	2012	0.30	0.04	0.15	721	21
2013	0.26	0.06	0.22	457	7	2013	0.20	0.04	0.18	460	15

Western Gulf-Logbook						Central Gulf-Logbook					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1999	0.64	0.06	0.09	245	27	1999	0.80	0.05	0.06	817	60
2000	0.60	0.05	0.09	301	32	2000	0.79	0.04	0.05	746	64
2001	0.47	0.05	0.10	109	24	2001	0.74	0.06	0.08	395	52
2002	0.60	0.08	0.13	78	14	2002	0.83	0.06	0.07	276	41
2003	0.39	0.04	0.11	202	24	2003	0.87	0.07	0.08	399	45
2004	0.65	0.06	0.09	766	26	2004	1.08	0.05	0.05	1676	80
2005	0.78	0.08	0.11	571	33	2005	0.98	0.07	0.07	1154	63
2006	0.69	0.08	0.11	1067	38	2006	0.87	0.04	0.05	1358	80
2007	0.59	0.06	0.10	891	31	2007	0.83	0.04	0.05	1190	69
2008	0.71	0.06	0.08	516	29	2008	0.88	0.05	0.06	1039	68
2009	0.53	0.06	0.11	824	33	2009	0.95	0.08	0.08	1081	73
2010	0.48	0.04	0.08	1297	46	2010	0.66	0.03	0.05	1171	80
2011	0.50	0.05	0.10	1148	46	2011	0.80	0.06	0.07	1065	71
2012	0.50	0.04	0.08	1142	37	2012	0.79	0.06	0.07	1599	82
2013	0.35	0.03	0.07	1476	32	2013	0.48	0.03	0.07	2102	73

Table 3.9 (cont.)

West Yakutat-Logbook						East Yakutat/SE-Logbook					
Year	CPUE	SE	CV	Sets	Vessels	Year	CPUE	SE	CV	Sets	Vessels
1999	1.08	0.08	0.08	233	36	1999	0.91	0.08	0.08	183	22
2000	1.04	0.06	0.06	270	42	2000	0.98	0.08	0.08	190	26
2001	0.89	0.09	0.11	203	29	2001	0.98	0.09	0.09	109	21
2002	0.99	0.07	0.07	148	28	2002	0.83	0.06	0.07	108	22
2003	1.26	0.10	0.08	104	23	2003	1.13	0.10	0.09	117	22
2004	1.27	0.06	0.05	527	54	2004	1.19	0.05	0.04	427	55
2005	1.13	0.05	0.04	1158	70	2005	1.15	0.05	0.05	446	77
2006	0.97	0.05	0.06	1306	84	2006	1.06	0.04	0.04	860	107
2007	0.97	0.05	0.05	1322	89	2007	1.13	0.04	0.04	972	122
2008	0.97	0.05	0.05	1118	74	2008	1.08	0.05	0.05	686	97
2009	1.23	0.07	0.06	1077	81	2009	1.12	0.05	0.05	620	87
2010	0.98	0.05	0.05	1077	85	2010	1.04	0.05	0.05	744	99
2011	0.95	0.07	0.07	1377	75	2011	1.01	0.04	0.04	877	112
2012	0.89	0.06	0.06	1634	86	2012	1.00	0.05	0.05	972	102
2013	0.74	0.06	0.07	1953	79	2013	0.86	0.05	0.06	865	88

Table 3.10. Sablefish abundance index values (1,000's) for Alaska (200-1,000 m) including deep gully habitat, from the Japan-U.S. Cooperative Longline Survey, Domestic Longline Survey, and Japanese and U.S. longline fisheries. Relative population number equals CPUE in numbers weighted by respective strata areas. Relative population weight equals CPUE measured in weight multiplied by strata areas. Indices were extrapolated for survey areas not sampled every year, including Aleutian Islands 1979, 1995, 1997, 1999, 2001, 2003, 2005, and 2007, 2009, 2011, and 2013, and Bering Sea 1979-1981, 1995, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2009, 2010, 2012, and 2014. NMFS trawl survey biomass estimates (kilotons) are from the Gulf of Alaska at depths <500 m.

	RELATIVE POPULATION NUMBER		RELATIVE POPULATION WEIGHT/BIOMASS				
Year	**Coop. longline survey**	**Dom. longline survey**	**Jap. longline fishery**	**Coop. longline survey**	**Dom. longline survey**	**U.S. fishery**	**NMFS Trawl survey**
1964			1,452				
1965			1,806				
1966			2,462				
1967			2,855				
1968			2,336				
1969			2,443				
1970			2,912				
1971			2,401				
1972			2,247				
1973			2,318				
1974			2,295				
1975			1,953				
1976			1,780				
1977			1,511				
1978			942				
1979	413		809	1,075			
1980	388		1,040	968			
1981	460		1,343	1,153			
1982	613			1,572			
1983	621			1,595			
1984	685			1,822			294
1985	903			2,569			
1986	838			2,456			
1987	667			2,068			271
1988	707			2,088			
1989	661			2,178			
1990	450	649		1,454	2,141	1,201	214
1991	386	593		1,321	2,071	1,066	
1992	402	511		1,390	1,758	908	
1993	395	563		1,318	1,894	904	250
1994	366	489		1,288	1,882	822	
1995		501			1,803	1,243	
1996		520			2,017	1,201	145
1997		491			1,764	1,341	
1998		477			1,662	1,130	
1999		520			1,740	1,316	104
2000		462			1,597	1,139	
2001		535			1,798	1,111	238
2002		561			1,916	1,152	
2003		532			1,759	1,218	189
2004		544			1,738	1,357	
2005		533			1,695	1,304	179
2006		580			1,848	1,206	
2007		500			1,584	1,268	111
2008		472			1,550	1,361	
2009		491			1,580	1,152	107
2010		542			1,778	1,054	
2011		556			1,683	1,048	84
2012		438			1,280	1,023	
2013		416			1,276	893	60
2014		479			1,432		

Table 3.11. Count of stations where sperm (S) or killer whale (K) depredation occurred in the six sablefish management areas. The number of stations sampled that are used for RPN calculations are in parentheses. Areas not surveyed in a given year are left blank. If there were no whale depredation data taken, it is denoted with an "n/a". Killer whale depredation did not always occur on all skates of gear, and only those skates with depredation were cut from calculations of RPNs and RPWs.

	BS (16)		**AI (14)**		**WG (10)**		**CG (16)**		**WY (8)**		**EY/SE (17)**	
Year	**S**	**K**	**S**	**K**	**S**	**K**	**S**	**K**	**S**	**K**	**S**	**K**
1996			n/a	1	n/a	0	n/a	0	n/a	0	n/a	0
1997	n/a	2			n/a	0	n/a	0	n/a	0	n/a	0
1998			0	1	0	0	0	0	4	0		0
1999	0	7			0	0	3	0	6	0	4	0
2000			0	1	0	1	0	0	4	0	2	0
2001	0	5			0	0	3	0	2	0	2	0
2002			0	1	0	4	3	0	4	0	2	0
2003	0	7			0	3	2	0	1	0	2	0
2004			0	0	0	4	3	0	4	0	6	0
2005	0	2			0	4	0	0	2	0	8	0
2006			0	1	0	3	2	1	4	0	2	0
2007	0	7			0	5	1	1	5	0	6	0
2008			0	3	0	2	2	0	8	0	9	0
2009	0	10			0	2	5	1	3	0	2	0
2010			0	3	0	1	2	1	2	0	6	0
2011	0	7			0	5	1	1	4	0	9	0
2012			1	5	1	5	2	0	4	0	3	0
2013	0	11			0	2	2	2	3	0	7	0
2014			1	3	0	4	4	0	6	0	4	0

Table 3.12. Sablefish fork length (cm), weight (kg), and proportion mature by age and sex (weights from 1996-2004 age-length data from the AFSC longline survey).

	Fork length (cm)		**Weight (kg)**		**Fraction mature**	
Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
2	48.1	46.8	1.0	0.9	0.059	0.006
3	53.1	53.4	1.5	1.5	0.165	0.024
4	56.8	58.8	1.9	2.1	0.343	0.077
5	59.5	63.0	2.2	2.6	0.543	0.198
6	61.6	66.4	2.5	3.1	0.704	0.394
7	63.2	69.2	2.7	3.5	0.811	0.604
8	64.3	71.4	2.8	3.9	0.876	0.765
9	65.2	73.1	2.9	4.2	0.915	0.865
10	65.8	74.5	3.0	4.4	0.939	0.921
11	66.3	75.7	3.0	4.6	0.954	0.952
12	66.7	76.6	3.1	4.8	0.964	0.969
13	67.0	77.3	3.1	4.9	0.971	0.979
14	67.2	77.9	3.1	5.1	0.976	0.986
15	67.3	78.3	3.1	5.1	0.979	0.99
16	67.4	78.7	3.1	5.2	0.982	0.992
17	67.5	79.0	3.1	5.3	0.984	0.994
18	67.6	79.3	3.2	5.3	0.985	0.995
19	67.6	79.4	3.2	5.3	0.986	0.996
20	67.7	79.6	3.2	5.4	0.987	0.997
21	67.7	79.7	3.2	5.4	0.988	0.997
22	67.7	79.8	3.2	5.4	0.988	0.998
23	67.7	79.9	3.2	5.4	0.989	0.998
24	67.7	80.0	3.2	5.4	0.989	0.998
25	67.7	80.0	3.2	5.4	0.989	0.998
26	67.8	80.1	3.2	5.4	0.999	0.998
27	67.8	80.1	3.2	5.4	0.999	0.999
28	67.8	80.1	3.2	5.4	0.999	0.999
29	67.8	80.1	3.2	5.5	0.999	0.999
30	67.8	80.2	3.2	5.5	0.999	0.999
31+	67.8	80.2	3.2	5.5	1.000	1.000

Table 3.13. Input and output sample sizes and standard deviation of normalized residuals (SDNR) for data sources in the sablefish assessment model.

Multinomial Compositions	Input N/CV	SDNR	Effective N
Domestic LL Fishery Ages	200	1.10	170
Domestic LL Fishery Lengths	120	0.83	364
Trawl Fishery Lengths	50	0.86	89
LL Survey Ages	160	0.86	199
NMFS Trawl Survey Lengths	140	0.96	149
Domestic LL Survey Lengths	20	0.29	227
Japanese/Coop LL Survey Lengths	20	0.32	197
Lognormal abundance indices			
Domestic RPN	5%	3.84	
Japanese/Coop RPN	5%	2.99	
Domestic Fishery RPW	10%	0.91	
Foreign Fishery RPW	10%	1.29	
NMFS Trawl Survey	10-20%	1.85	

Table 3.14. Sablefish recruits, total biomass (2+), and spawning biomass plus lower and upper lower 95% credible intervals (2.5%, 97.5%) from MCMC. Recruits are in millions, and biomass is in kt.

	Recruits (Age 2)			**Total Biomass**			**Spawning Biomass**		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1960	4.6	0	52	533	468	629	173	133	236
1961	4.5	0	55	546	479	647	179	149	230
1962	90.0	12	145	614	539	710	192	167	235
1963	8.7	0	80	617	542	714	203	178	245
1964	7.4	0	72	615	539	717	218	191	261
1965	26.5	0	118	629	549	734	235	205	278
1966	74.7	0	139	685	606	770	251	220	294
1967	9.4	0	91	689	627	770	262	230	306
1968	15.0	0	57	682	626	752	268	236	311
1969	6.6	0	36	648	597	710	267	237	308
1970	2.7	0	24	595	549	653	264	236	301
1971	2.6	0	29	536	494	593	255	230	289
1972	26.5	0	60	491	446	546	237	215	268
1973	25.5	0	60	445	410	485	209	189	236
1974	2.5	0	22	401	369	436	185	167	210
1975	5.1	0	31	359	333	393	163	146	186
1976	17.9	0	29	333	310	360	147	131	166
1977	1.5	0	11	294	274	318	131	117	148
1978	2.3	0	11	264	245	286	119	108	135
1979	83.5	66	103	322	302	347	114	104	128
1980	27.5	6	48	355	336	379	109	100	122
1981	8.3	0	29	373	351	396	107	99	119
1982	48.5	29	74	417	398	447	111	103	122
1983	22.1	0	39	445	423	467	123	115	134
1984	43.3	34	58	488	468	512	139	131	150
1985	0.4	0	3	491	472	516	154	146	167
1986	23.2	11	33	502	483	524	168	160	181
1987	19.8	13	30	491	475	513	175	166	187
1988	4.0	0	12	457	443	479	174	165	187
1989	4.6	0	11	415	401	433	167	159	180
1990	5.8	3	10	373	360	389	158	150	171
1991	28.6	23	34	356	343	371	147	139	160
1992	0.3	0	2	326	314	340	136	129	148
1993	26.1	22	31	320	308	335	125	118	137
1994	3.1	0	8	297	285	312	115	108	125
1995	6.5	2	11	277	265	291	106	100	116
1996	7.5	5	10	259	247	273	101	95	111
1997	19.2	16	23	254	243	269	98	92	107
1998	1.2	0	4	240	228	253	96	90	104
1999	31.6	27	36	251	239	266	92	86	100
2000	19.6	13	29	260	248	277	89	83	96
2001	11.6	0	20	262	248	277	86	80	93
2002	43.1	36	54	292	278	310	85	80	92
2003	7.8	2	13	299	284	316	88	82	95
2004	14.5	10	19	303	287	321	91	85	98
2005	6.7	4	10	295	280	314	96	90	103
2006	11.1	7	15	289	274	307	102	96	110
2007	8.6	6	12	280	265	298	107	100	115
2008	10.6	7	14	271	256	288	109	102	117
2009	9.8	7	14	262	247	280	108	101	116
2010	17.7	13	23	263	248	281	106	99	114
2011	3.8	0	7	254	239	272	104	97	112
2012	8.4	4	14	246	231	264	101	94	109
2013	0.3	0	1	228	213	246	98	91	106
2014	11.0	4	18	218	196	229	95	88	103
2015	-	-	-	-	-	-	92	85	100
2016	-	-	-	-	-	-	88	79	96

Table 3.15. Regional estimates of sablefish total biomass (Age 2+). Partitioning was done using RPWs from Japanese LL survey from 1979-1989 and domestic LL survey from 1990-2014 using a 2 year moving average. For 1960-1978, a prospective 4:6:9 - year average of forward proportions was used.

Year	Bering Sea	Aleutian Islands	Western GOA	Central GOA	West Yakutat	EYakutat/ Southeast	Alaska
1960	98	118	51	148	46	71	533
1961	101	121	52	152	47	73	546
1962	114	136	59	171	53	82	614
1963	114	136	59	172	54	82	617
1964	114	136	59	171	53	82	615
1965	116	139	60	175	55	84	629
1966	127	151	66	191	60	91	685
1967	127	152	66	192	60	92	689
1968	126	151	65	190	59	91	682
1969	120	143	62	180	56	86	648
1970	110	132	57	166	52	79	595
1971	99	118	51	149	47	71	536
1972	91	108	47	137	43	65	491
1973	82	98	43	124	39	59	445
1974	74	89	38	112	35	53	401
1975	66	79	34	100	31	48	359
1976	62	73	32	93	29	44	333
1977	54	65	28	82	25	39	294
1978	49	60	26	72	23	36	264
1979	61	66	30	95	28	42	322
1980	64	84	34	95	31	47	355
1981	66	93	39	83	35	57	373
1982	76	87	54	101	40	60	417
1983	80	93	69	112	37	54	445
1984	92	113	77	117	35	54	488
1985	101	112	71	122	36	49	491
1986	107	105	68	125	42	53	502
1987	80	107	65	131	49	60	491
1988	48	93	61	147	47	61	457
1989	56	81	48	133	43	54	415
1990	57	61	40	114	43	57	373
1991	39	41	38	112	47	78	356
1992	23	37	25	103	51	86	326
1993	15	35	29	106	54	81	320
1994	18	34	32	98	46	69	297
1995	26	32	28	90	39	62	277
1996	25	27	28	93	33	53	259
1997	24	24	27	99	31	50	254
1998	21	30	27	84	28	50	240
1999	20	41	29	83	27	51	251
2000	20	43	34	87	27	50	260
2001	29	41	41	82	22	46	262
2002	40	45	43	95	24	45	292
2003	40	46	42	101	26	43	299
2004	40	46	38	107	28	43	303
2005	42	45	38	96	26	48	295
2006	45	40	41	87	26	49	289
2007	49	36	30	87	29	49	280
2008	52	34	27	85	26	47	271
2009	50	34	31	82	23	42	262
2010	52	29	28	77	29	49	263
2011	33	26	26	90	33	47	254
2012	14	31	28	98	28	47	246
2013	30	32	23	76	21	46	228
2014	46	27	23	62	19	41	218

Table 3.16. Key parameter estimates and their uncertainty and Bayesian credible intervals (BCI). Recruitment is in millions.

Parameter	μ (MLE)	μ (MCMC)	Median (MCMC)	σ (Hessian)	σ (MCMC)	BCI-Lower	BCI-Upper
$q_{domesticLL}$	7.56	7.55	7.55	0.11	0.22	7.13	7.97
q_{coopLL}	6.22	6.22	6.22	0.11	0.21	5.84	6.65
q_{trawl}	1.34	1.32	1.32	0.32	0.09	1.15	1.52
$F_{40\%}$	0.09	0.11	0.10	0.023	0.029	0.06	0.18
2014 SSB (kt)	95.0	95.2	95.1	3.66	3.86	87.9	103
2000 Year Class	11.6	45.0	44.9	4.26	4.87	35.6	54.5
2008 Year Class	17.7	18.3	18.3	2.30	2.48	13.5	23.1

Table 3.17. Comparison of 2013 results versus 2014 results. Biomass is in kilotons.

Year	2013 SAFE Spawning Biomass	2014 SAFE Spawning Biomass	2013 SAFE Total Biomass	2014 SAFE Total Biomass
1977	129	131	291	294
1978	117	119	261	264
1979	112	114	318	322
1980	107	109	351	355
1981	106	107	367	373
1982	109	111	412	417
1983	121	123	439	445
1984	136	139	481	488
1985	152	154	485	491
1986	165	168	495	502
1987	171	175	484	491
1988	170	174	451	457
1989	164	167	408	415
1990	154	158	367	373
1991	143	147	349	356
1992	132	136	319	326
1993	122	125	313	320
1994	111	115	291	297
1995	103	106	270	277
1996	98	101	252	259
1997	95	98	247	254
1998	92	96	233	240
1999	88	92	244	251
2000	85	89	253	260
2001	82	86	254	262
2002	81	85	284	292
2003	84	88	289	299
2004	87	91	293	303
2005	92	96	285	295
2006	98	102	279	289
2007	103	107	270	280
2008	105	109	261	271
2009	104	108	252	262
2010	102	106	255	263
2011	100	104	247	254
2012	96	101	234	246
2013	93	98	217	228

Table 3.18. Sablefish spawning biomass (kilotons), fishing mortality, and yield (kilotons) for seven harvest scenarios. Abundance projected using 1979-2012 recruitments.

Year	Maximum permissible F	Author's F* (specified catch)	Half max. F	5-year average F	No fishing	Overfished?	Approaching overfished?
			Spawning biomass (kt)				
2014	94.9	94.9	94.9	94.9	94.9	94.9	94.9
2015	92.2	92.2	92.1	92.2	92.2	92.2	92.2
2016	87.1	88.3	90.3	88.4	94.0	85.8	87.1
2017	82.5	84.9	87.8	84.7	95.6	80.4	82.5
2018	80.1	82.1	85.6	82.6	98.4	77.3	79.1
2019	80.6	82.3	84.7	83.4	104.0	77.3	78.8
2020	83.4	84.8	85.5	86.5	112.4	79.6	80.7
2021	87.2	88.3	88.3	90.8	122.3	82.8	83.7
2022	91.1	92.0	91.9	95.5	132.7	86.1	86.8
2023	94.7	95.4	95.9	100.0	143.1	89.1	89.6
2024	97.9	98.4	101.4	104.2	153.1	91.7	92.1
2025	100.6	101.0	106.4	107.9	162.5	93.9	94.2
2026	103.0	103.3	109.8	111.4	171.5	95.7	96.0
2027	105.1	105.3	113.9	114.5	179.9	97.3	97.5
			Fishing mortality				
2014	0.064	0.064	0.064	0.064	0.064	0.064	0.064
2015	0.082	0.067	0.041	0.066	-	0.098	0.098
2016	0.078	0.062	0.040	0.066	-	0.091	0.091
2017	0.073	0.075	0.039	0.066	-	0.085	0.085
2018	0.071	0.073	0.038	0.066	-	0.081	0.081
2019	0.070	0.072	0.038	0.066	-	0.080	0.080
2020	0.071	0.072	0.038	0.066	-	0.081	0.081
2021	0.072	0.072	0.039	0.066	-	0.082	0.082
2022	0.073	0.073	0.041	0.066	-	0.083	0.083
2023	0.074	0.074	0.043	0.066	-	0.084	0.084
2024	0.075	0.075	0.046	0.066	-	0.085	0.085
2025	0.076	0.076	0.047	0.066	-	0.087	0.087
2026	0.077	0.078	0.047	0.066	-	0.088	0.088
2027	0.079	0.079	0.047	0.066	-	0.090	0.090
			Yield (kt)				
2014	11.4	11.4	11.4	11.4	11.4	11.4	11.4
2015	13.7	13.7	7.0	11.0	-	16.1	13.7
2016	12.1	12.4	6.6	10.5	-	13.8	12.1
2017	11.7	12.3	6.8	10.7	-	13.1	13.8
2018	12.3	12.8	7.4	11.4	-	13.6	14.2
2019	13.3	13.7	8.1	12.2	-	14.7	15.1
2020	14.3	14.6	8.9	12.9	-	15.7	16.0
2021	15.3	15.5	9.5	13.5	-	16.8	17.0
2022	16.1	16.2	10.1	14.1	-	17.6	17.8
2023	16.8	16.9	10.7	14.6	-	18.4	18.5
2024	17.5	17.6	11.2	15.0	-	19.0	19.1
2025	18.0	18.1	11.7	15.4	-	19.6	19.7
2026	18.5	18.6	12.1	15.8	-	20.1	20.2
2027	19.1	19.1	12.5	16.1	-	20.7	20.7

* Projections in Author's F (Alternative 2) are based on estimated catches of 11,172 t and 9,862 t used in place of maximum permissible ABC for 2015 and 2016. This was done in response to management requests for a more accurate two-year projection.

Table 3.19. Analysis of ecosystem considerations for the sablefish fishery.

Indicator	***Observation***	***Interpretation***	***Evaluation***
ECOSYSTEM EFFECTS ON STOCK			
Prey availability or abundance trends			
Zooplankton	None	None	Unknown
Predator population trends			
Salmon	Decreasing	Increases the stock	No concern
Changes in habitat quality			
Temperature regime	Warm increases recruitment	Variable recruitment	No concern (can't affect)
Prevailing currents	Northerly increases recruitment	Variable recruitment	No concern (can't affect)
FISHERY EFFECTS ON ECOSYSTEM			
Fishery contribution to bycatch			
Prohibited species	Small catches	Minor contribution to mortality	No concern
Forage species	Small catches	Minor contribution to mortality	No concern
HAPC biota (seapens/whips, corals, sponges, anemones)	Small catches, except long-term reductions predicted	Long-term reductions predicted in hard corals and living structure	Possible concern
Marine mammals and birds	Bird catch about 10% total	Appears to be decreasing	Possible concern
Sensitive non-target species	Grenadier, spiny dogfish, and unidentified shark catch notable	Grenadier catch high but stable, recent shark catch is small	Possible concern for grenadiers
Fishery concentration in space and time	IFQ less concentrated	IFQ improves	No concern
Fishery effects on amount of large size target fish	IFQ reduces catch of immature	IFQ improves	No concern
Fishery contribution to discards and offal production	sablefish <5% in longline fishery, but 30% in trawl fishery	IFQ improves, but notable discards in trawl fishery	Trawl fishery discards definite concern
Fishery effects on age-at-maturity and fecundity	trawl fishery catches smaller fish, but only small part of total catch	slightly decreases	No concern

Figures

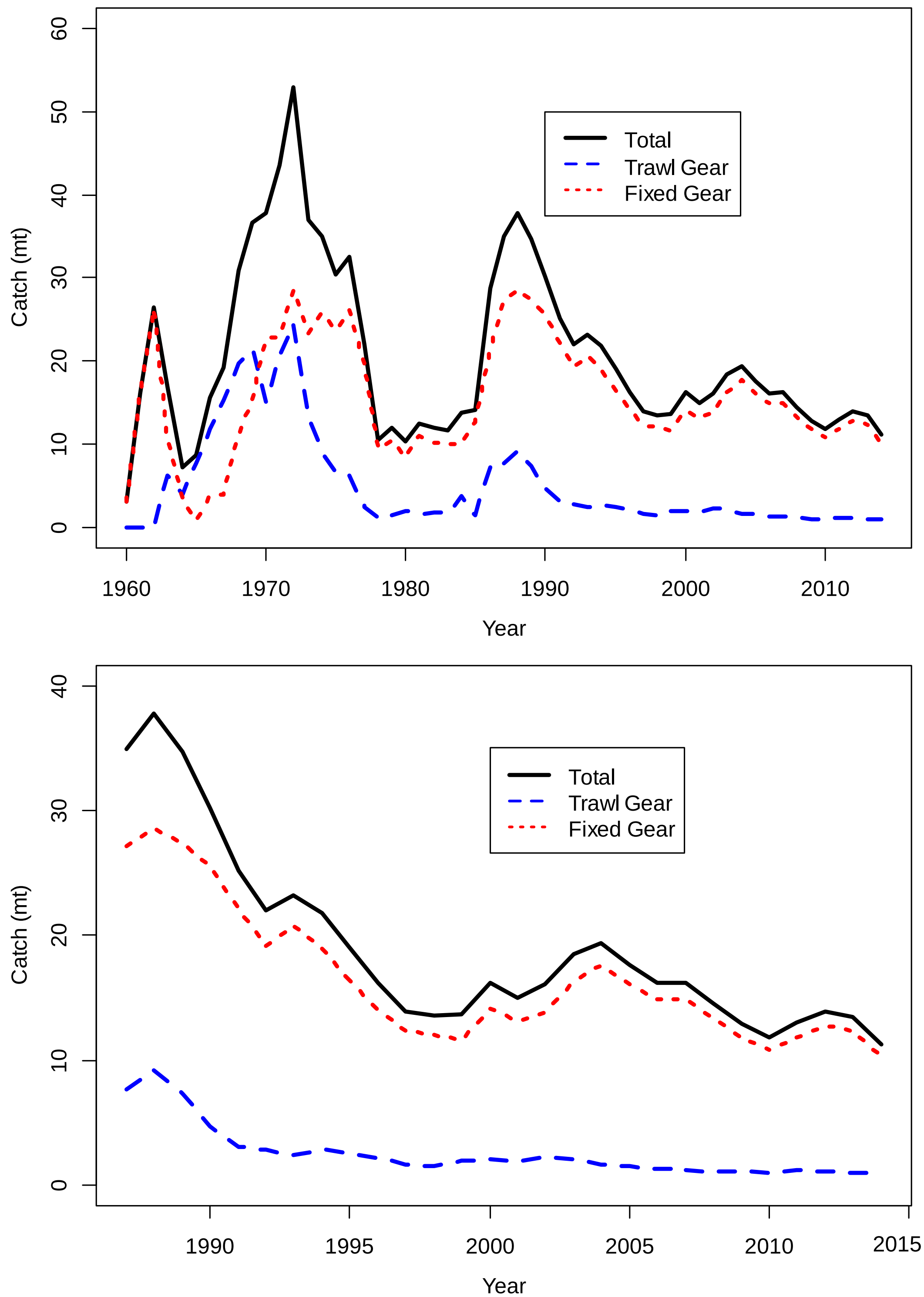

Figure 3.1. Long term and short term sablefish catch by gear type.

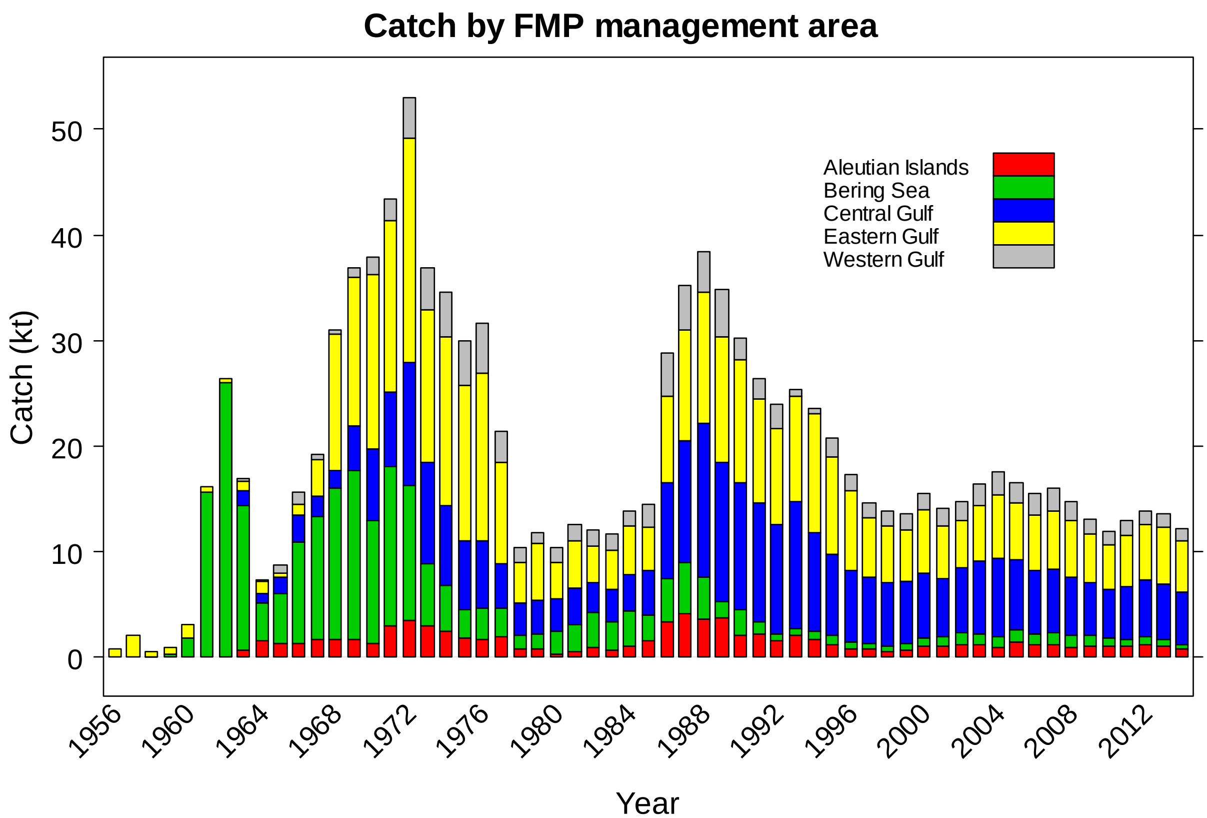

Figure 3.2. Sablefish fishery total reported catch (kt) by North Pacific Fishery Management Council area and year.

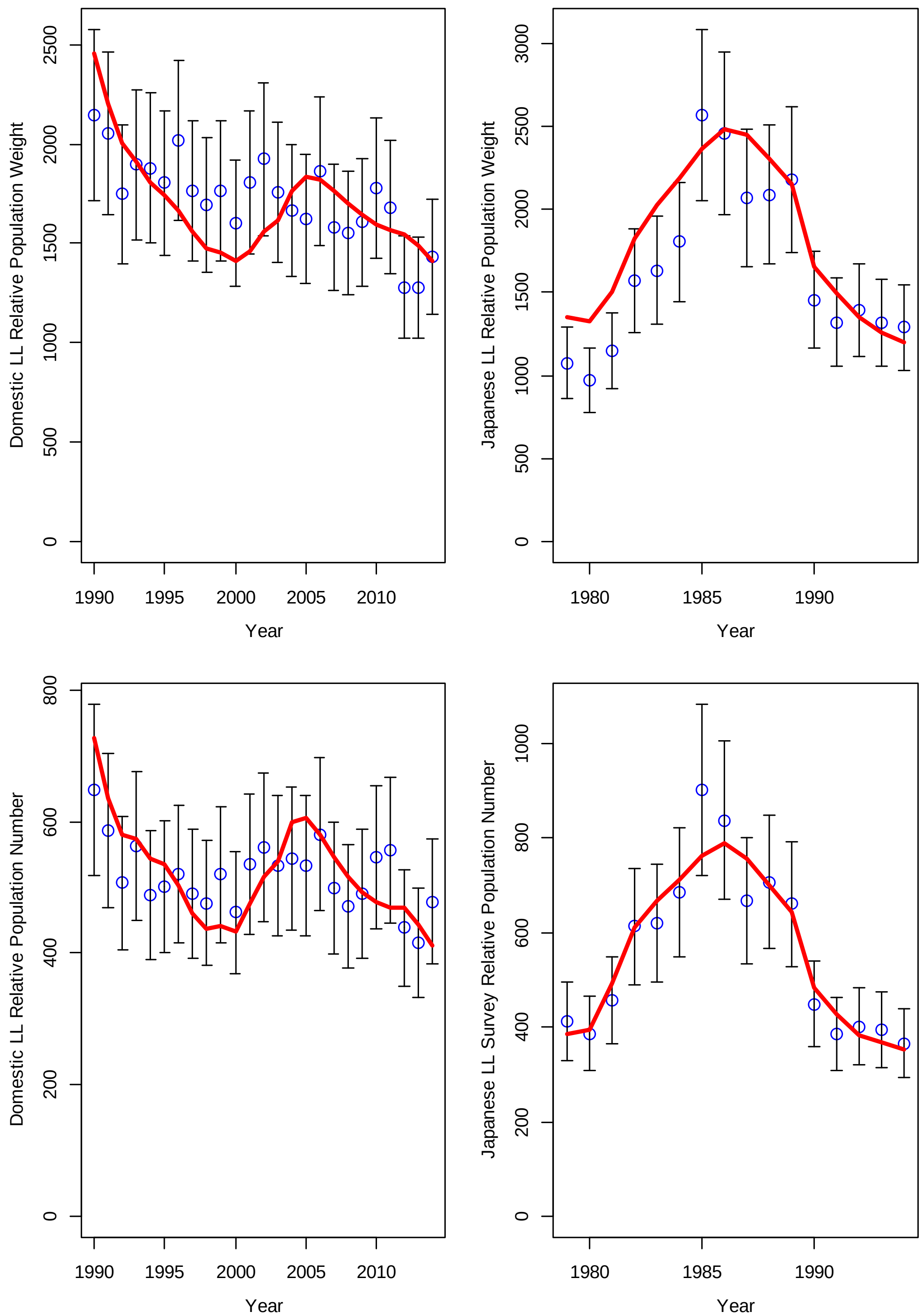

Figure 3.3. Observed and predicted sablefish relative population weight and numbers versus year. Points are observed estimates with approximate 95% confidence intervals, solid red line is model predicted. The relative population weights are not fit in the models, but are presented for comparison.

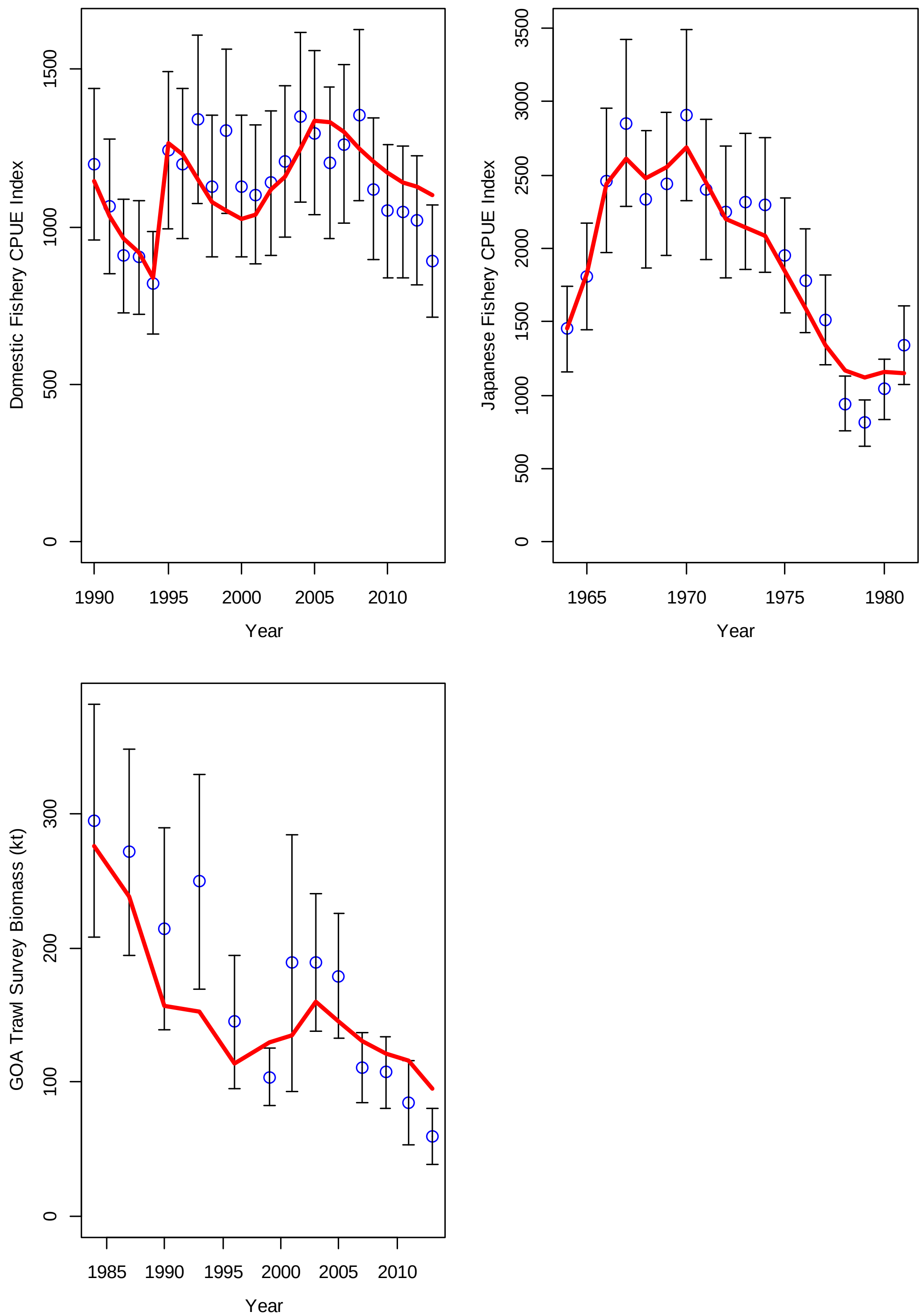

Figure 3.4. Observed and predicted sablefish abundance indices. Fishery indices are on top two panels, GOA trawl survey is on the bottom left panel. Points are observed estimates with approximate 95% confidence intervals while solid red lines are model predictions.

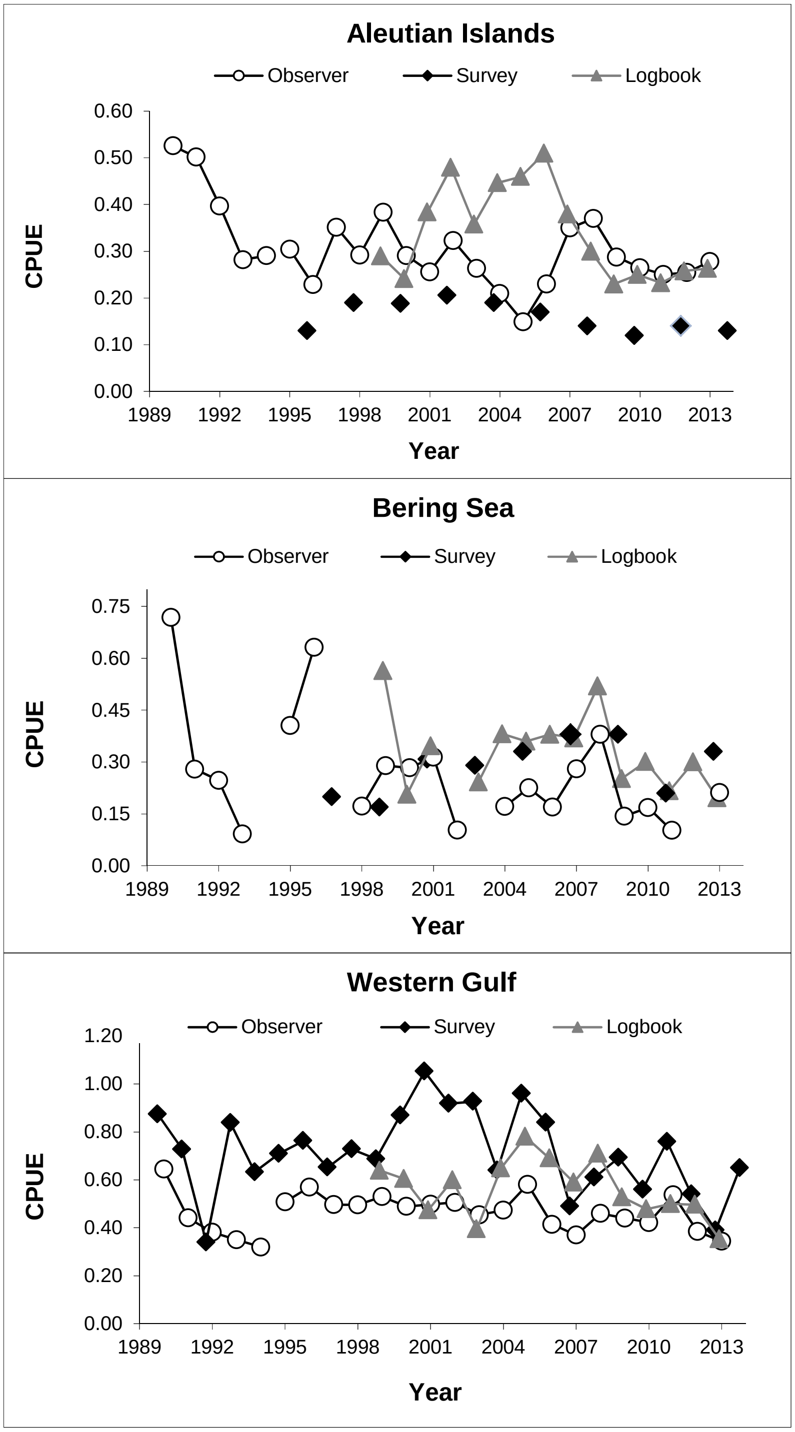

Figure 3.5. Average fishery catch rate (pounds/hook) by region and data source for longline survey and fishery data. The fishery switched from open-access to individual quota management in 1995. Data is not presented for years when there were fewer than three vessels. This occurred in observer data in the Bering Sea in 1994, 1997, 2003, and 2012, in logbook data in the Bering Sea in 2002, and in East Yakutat observer data from 1990-1994.

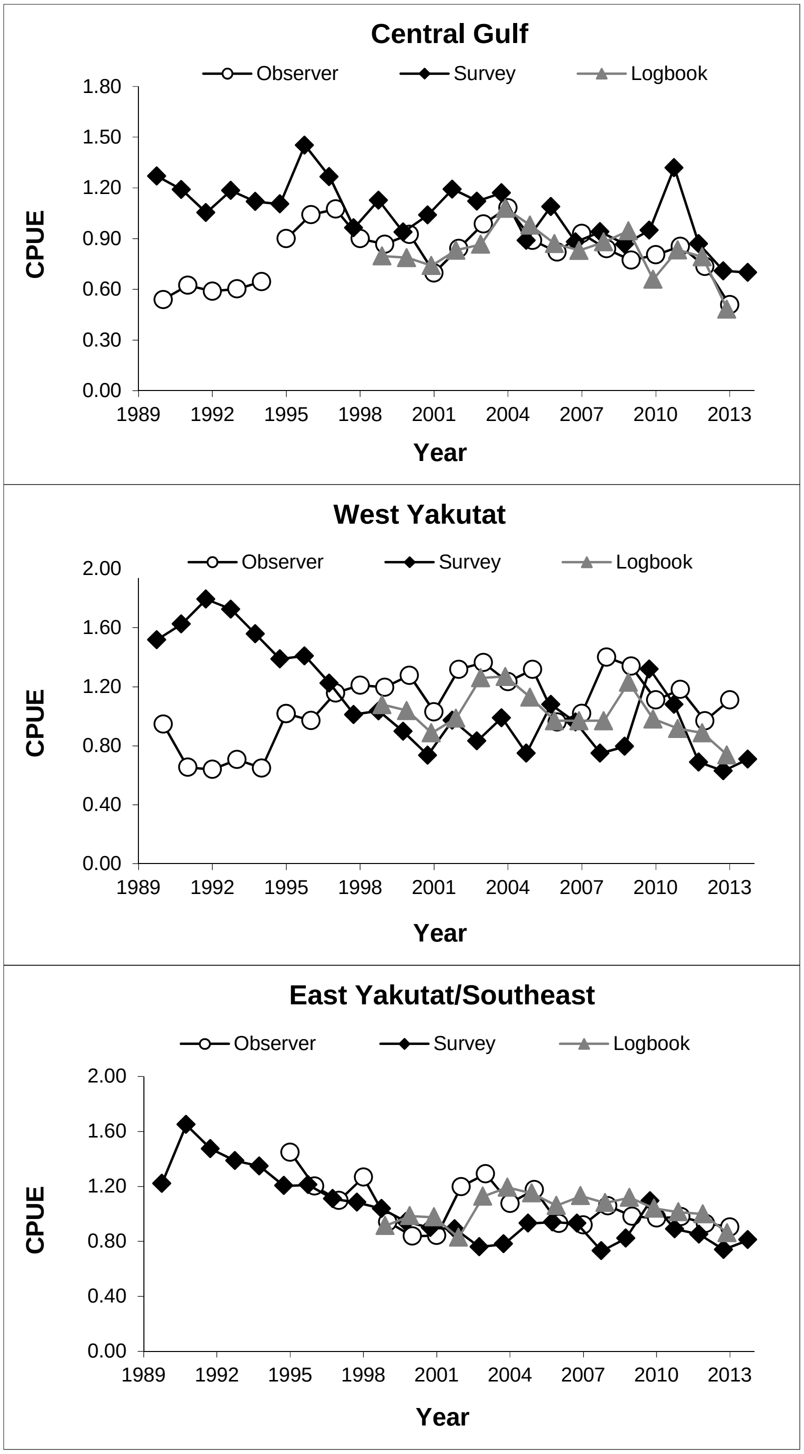

Figure 3.5. (continued)

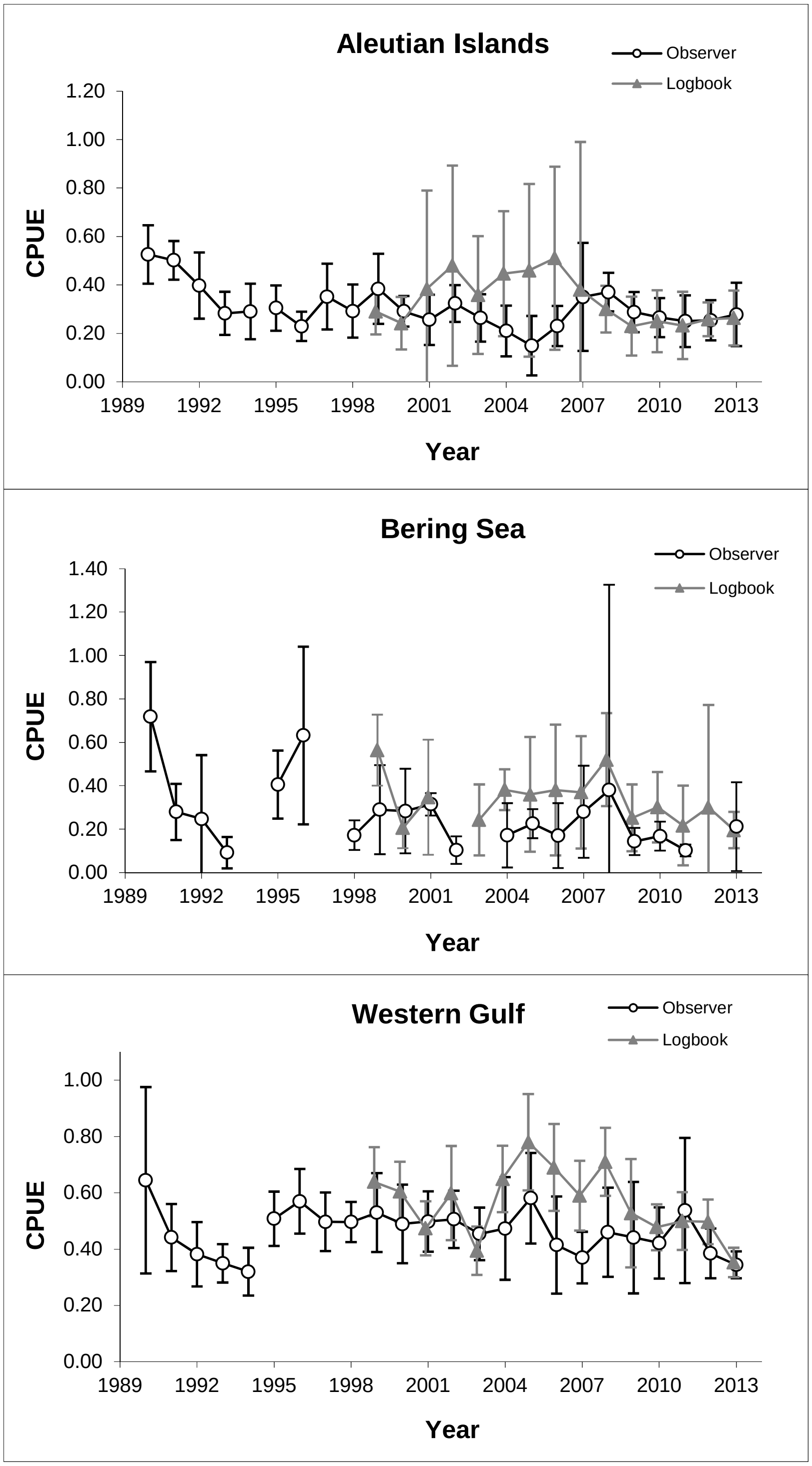

Figure 3.6. Average fishery catch rate (pounds/hook) and associated 95% confidence intervals by region and data source. The fishery switched from open-access to individual quota management in 1995. Data is not presented for years when there were fewer than three vessels. This occurred in observer data in the Bering Sea in 1994, 1997, 2003, and 2012, in logbook data in the Bering Sea in 2002, and in East Yakutat observer data from 1990-1994.

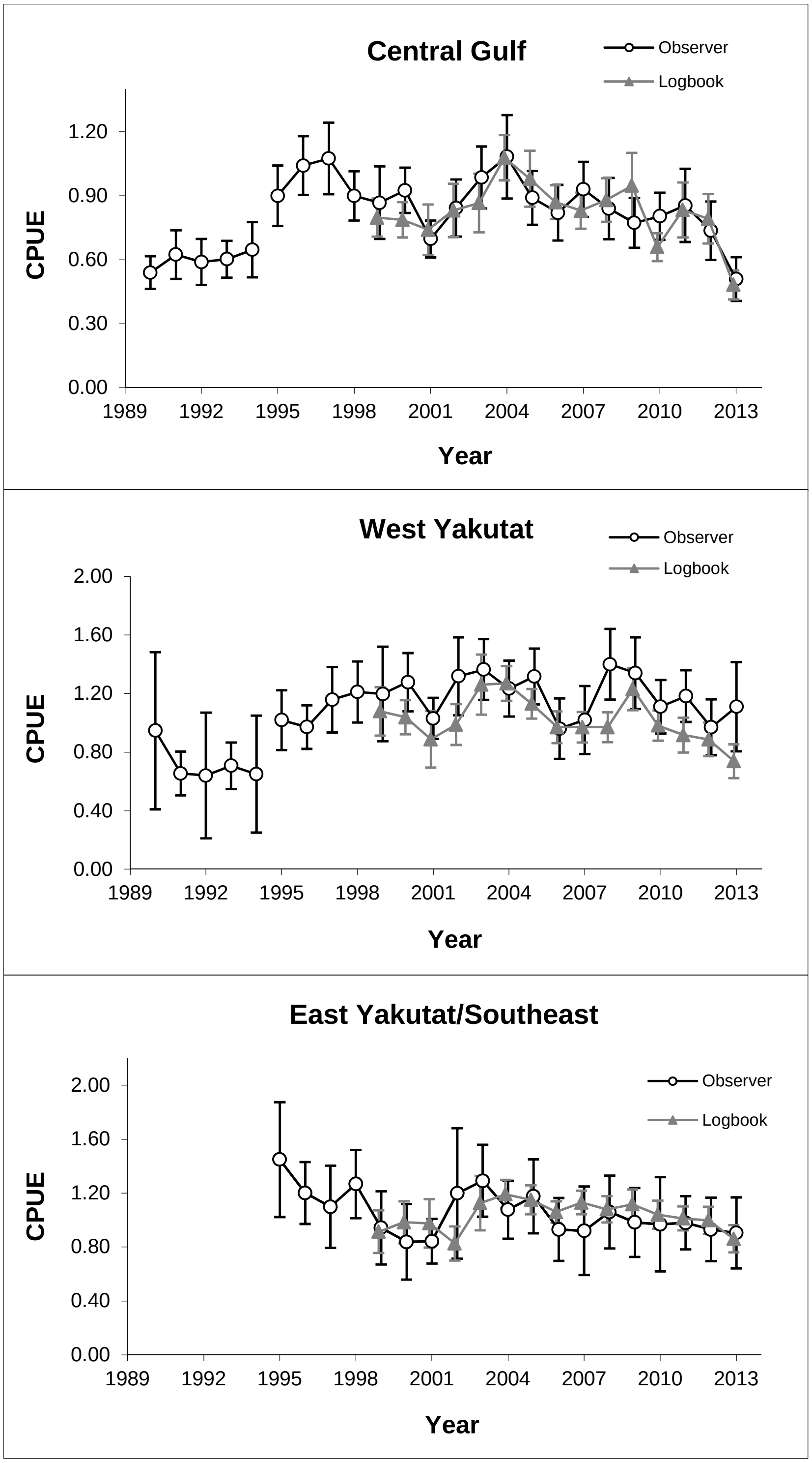

Figure 3.6. (continued)

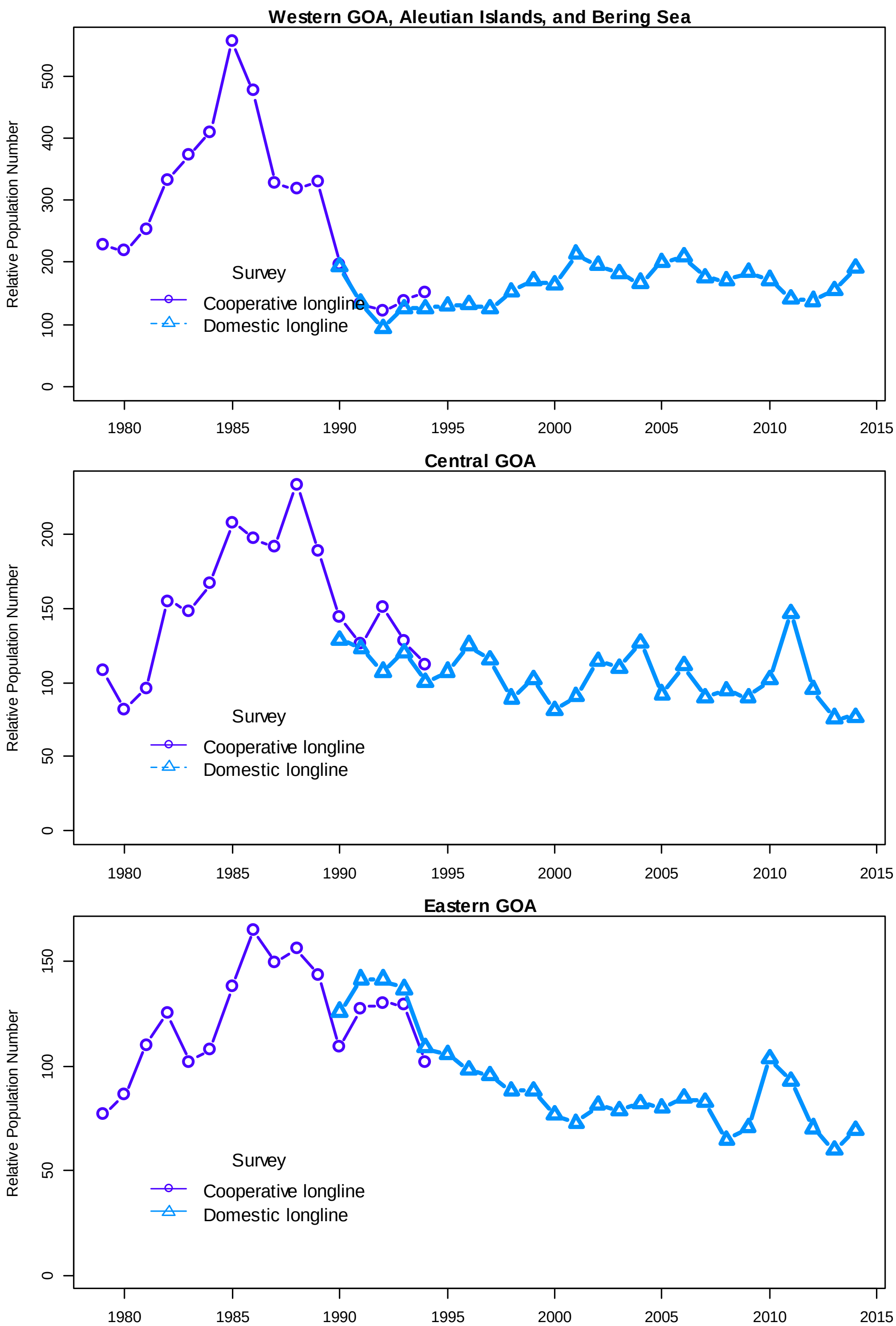

Figure 3.7. Relative abundance (numbers) by region and survey. The regions Bering Sea, Aleutians Islands, and western Gulf of Alaska are combined in the first plot. The two surveys are the Japan-U.S. cooperative longline survey and the domestic (U.S.) longline survey. In this plot, the values for the U.S. survey were adjusted to account for the higher efficiency of the U.S. survey gear.

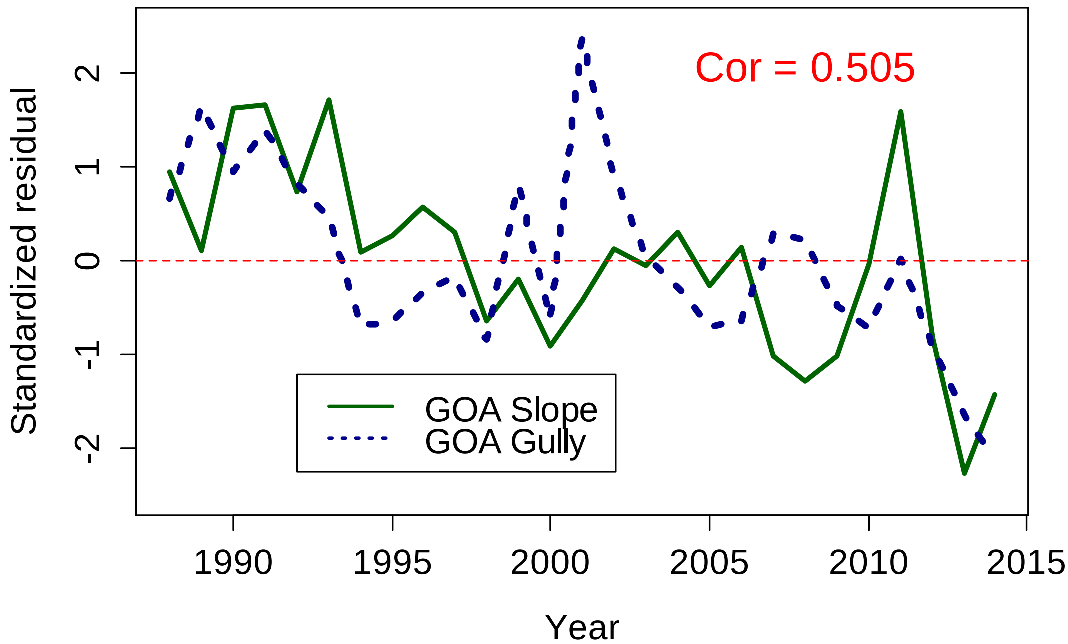

Figure 3.8 Comparison of abundance trends in GOA gully stations versus GOA slope stations.

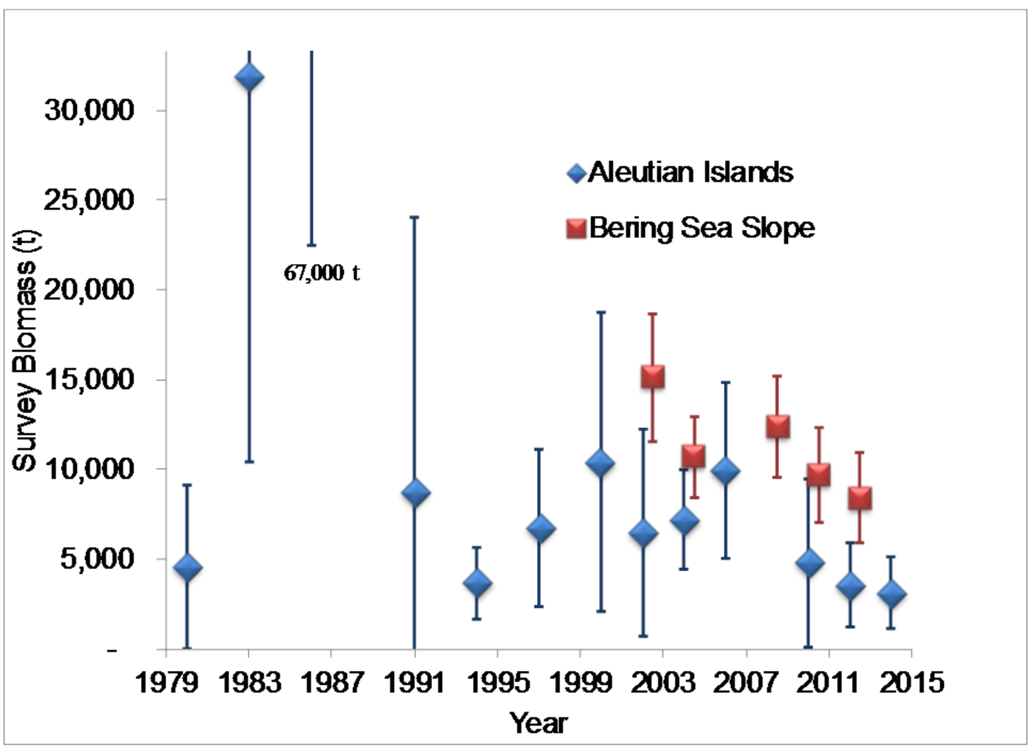

Figure 3.9. NMFS Bering Sea Slope and Aleutian Island trawl survey biomass estimates. Bering Sea Slope years are jittered so that intervals do not overlap.

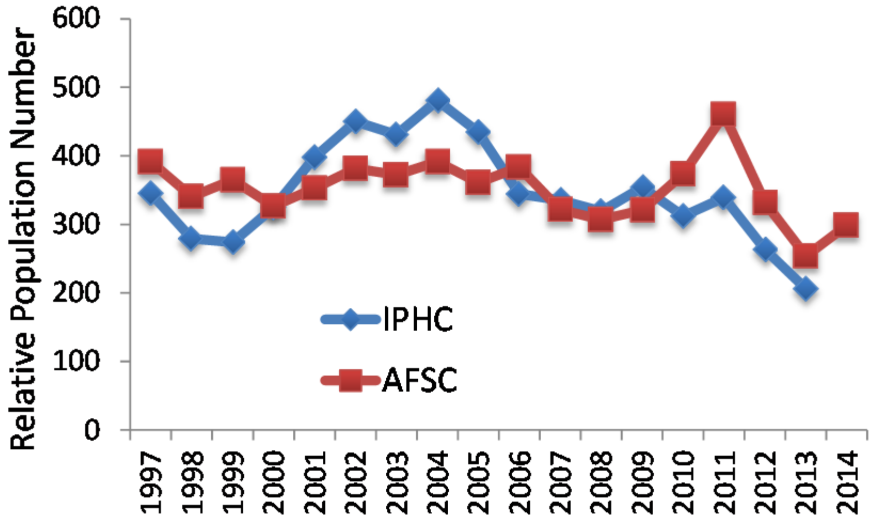

Figure 3.10. Comparisons of IPHC and AFSC longline survey trends in relative population number of sablefish in the Gulf of Alaska.

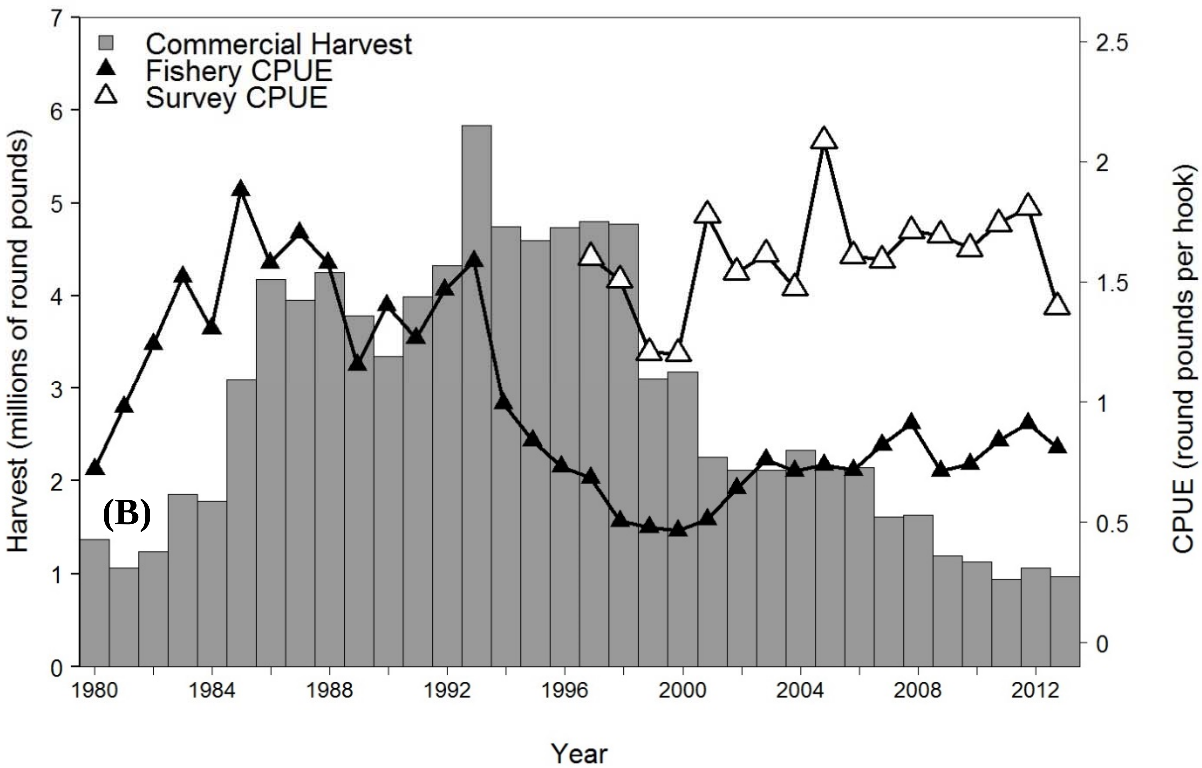

Figure 3.11a. Northern Southeast Inside sablefish long line survey and fishery catch per unit effort (round pounds per hook) and harvest over time (from J. Stahl pers. comm. November, 2014).

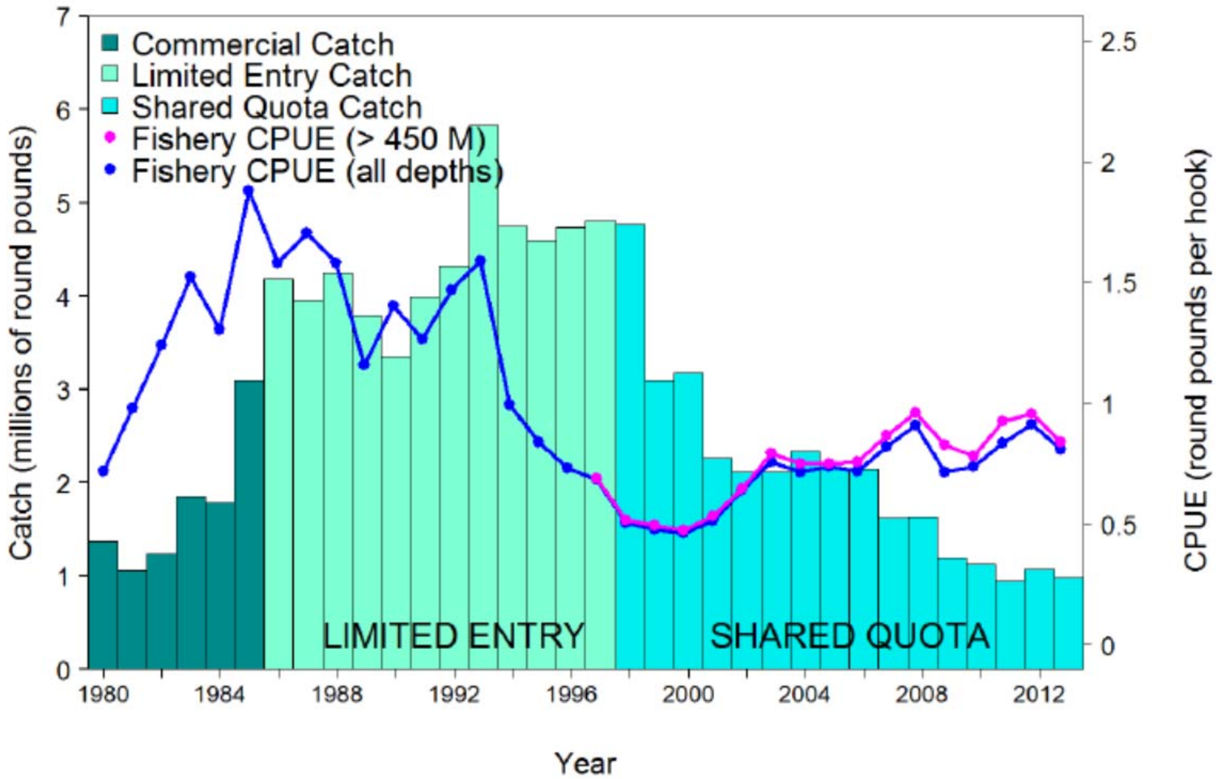

Figure 3.11b. Northern Southeast Inside sablefish long line fishery catch per unit effort (round pounds per hook) and harvest over time (from K. Green pers. comm. September, 2014).

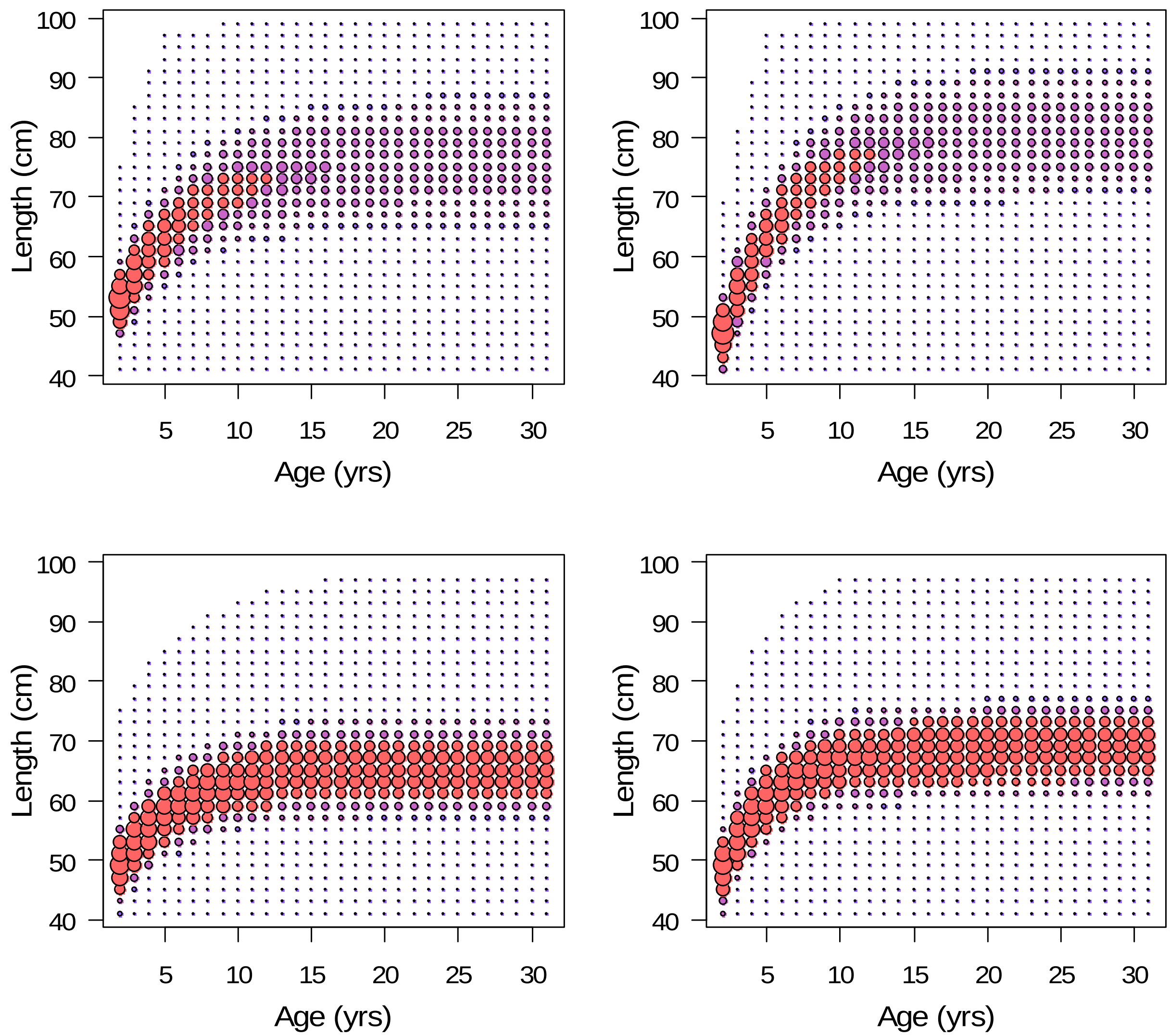

Figure 3.12. Age-length conversion matrices for sablefish. Top panels are female, bottom panel are males, left is 1960-1995, and right is 1996-2014.

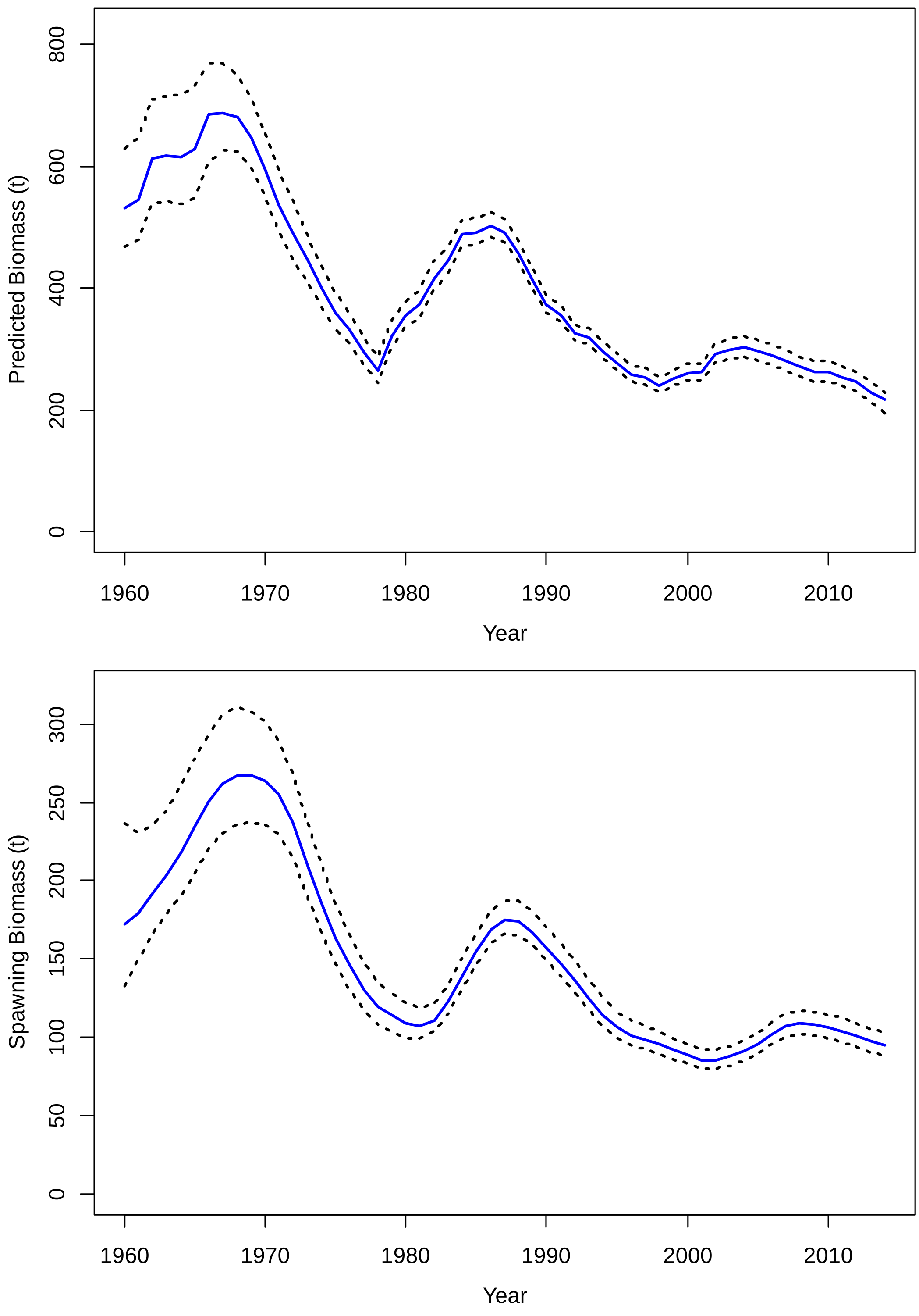

Figure 3.13.--Estimated sablefish total biomass (thousands t) and spawning biomass (bottom) with 95% MCMC credible intervals.

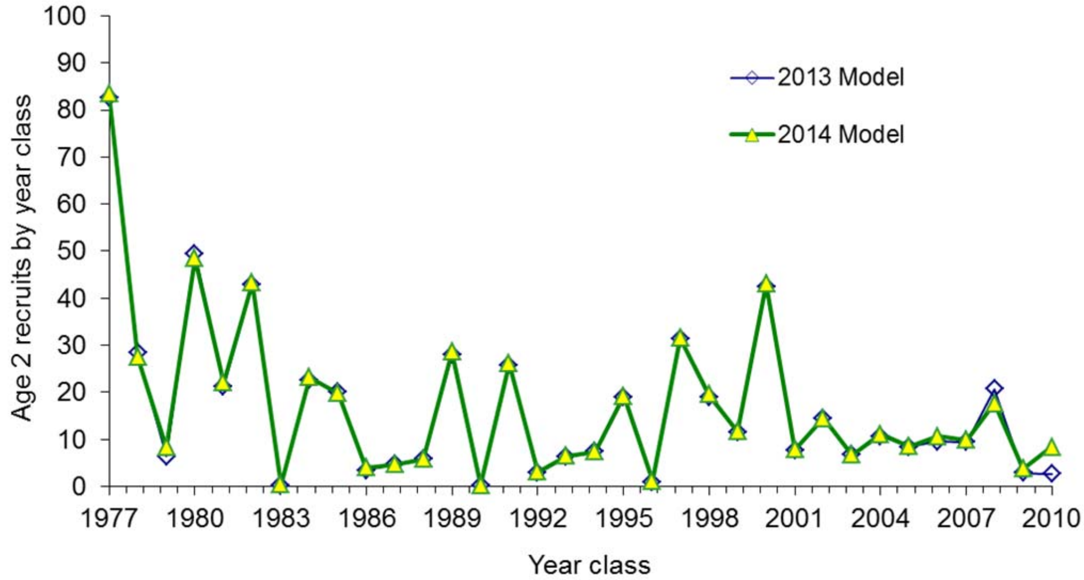

Figure 3.14a. Estimated recruitment by year class 1958-2011 (number at age 2, millions) for 2013 and 2014 models.

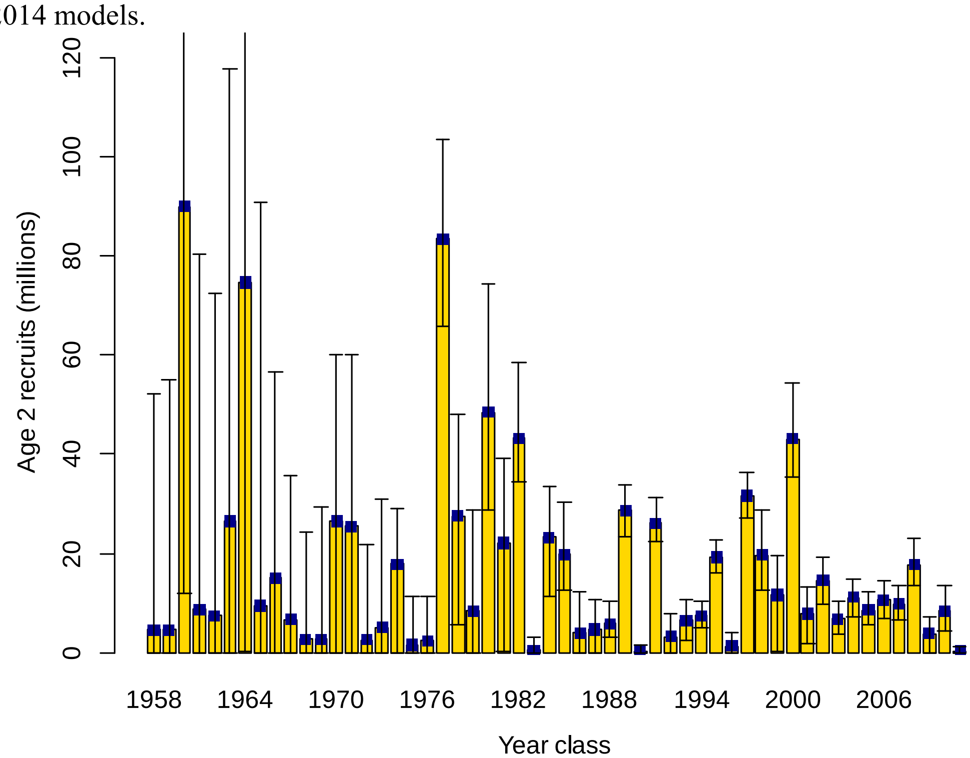

Figure 3.14b. Estimates of the number of age-2 sablefish (millions) with 95% credible intervals by year class. Credible intervals are based on MCMC posterior.

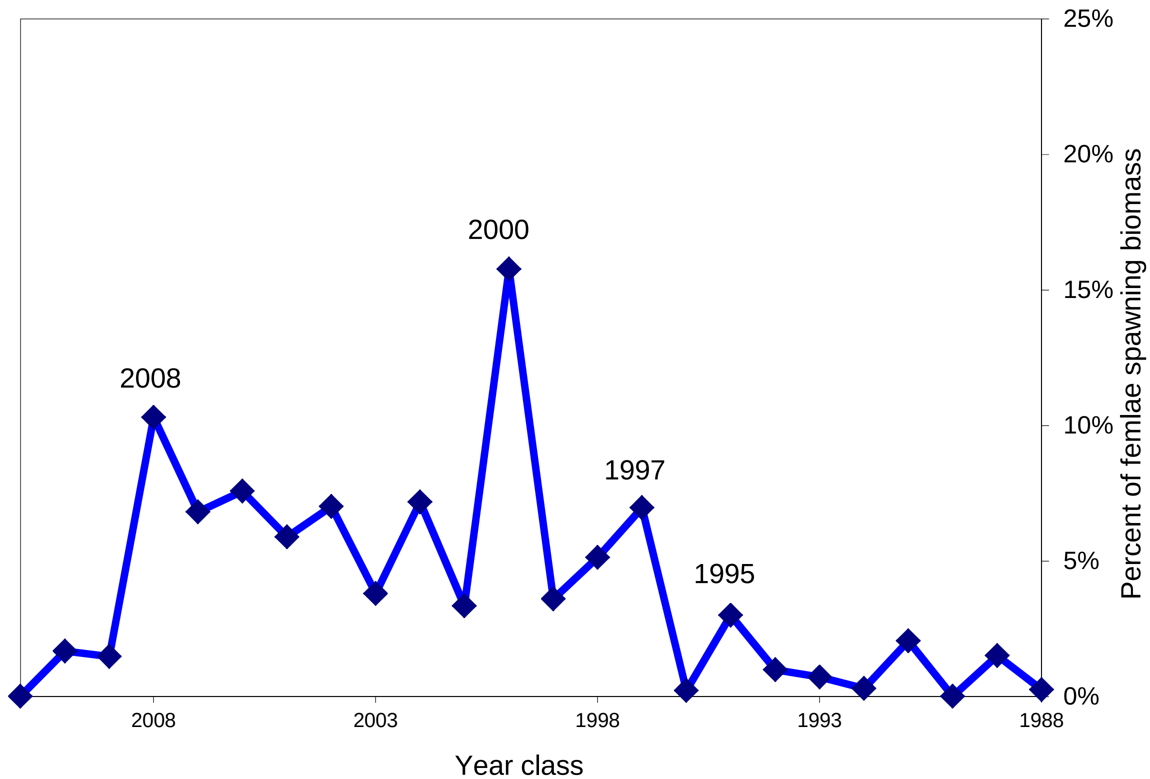

Figure 3.15. Relative contribution of the last 20 year classes to next year's female spawning biomass.

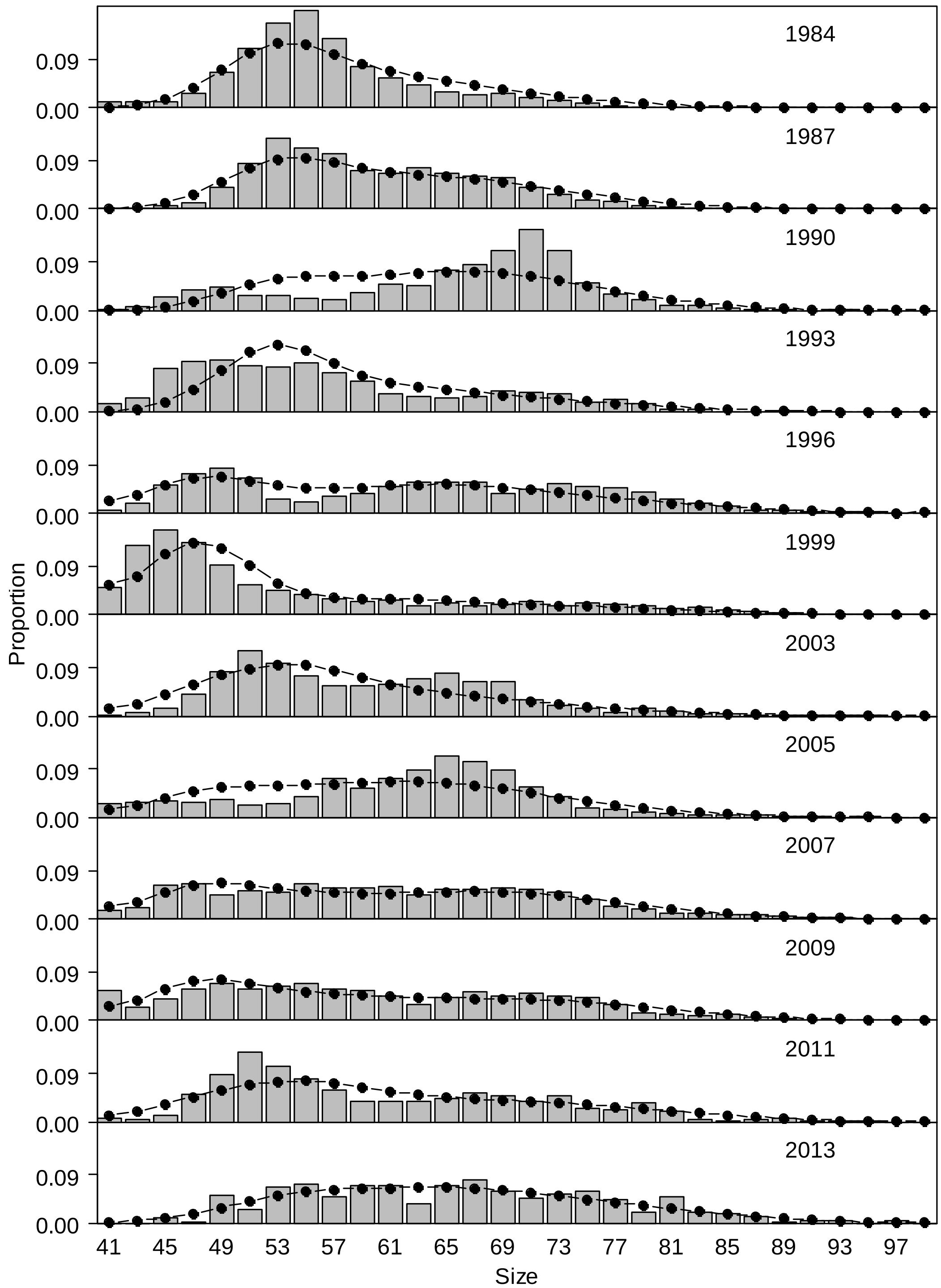

Figure 3.16. Gulf of Alaska bottom trawl survey length (cm) compositions for female sablefish at depths <500 m. Bars are observed frequencies and lines are predicted frequencies.

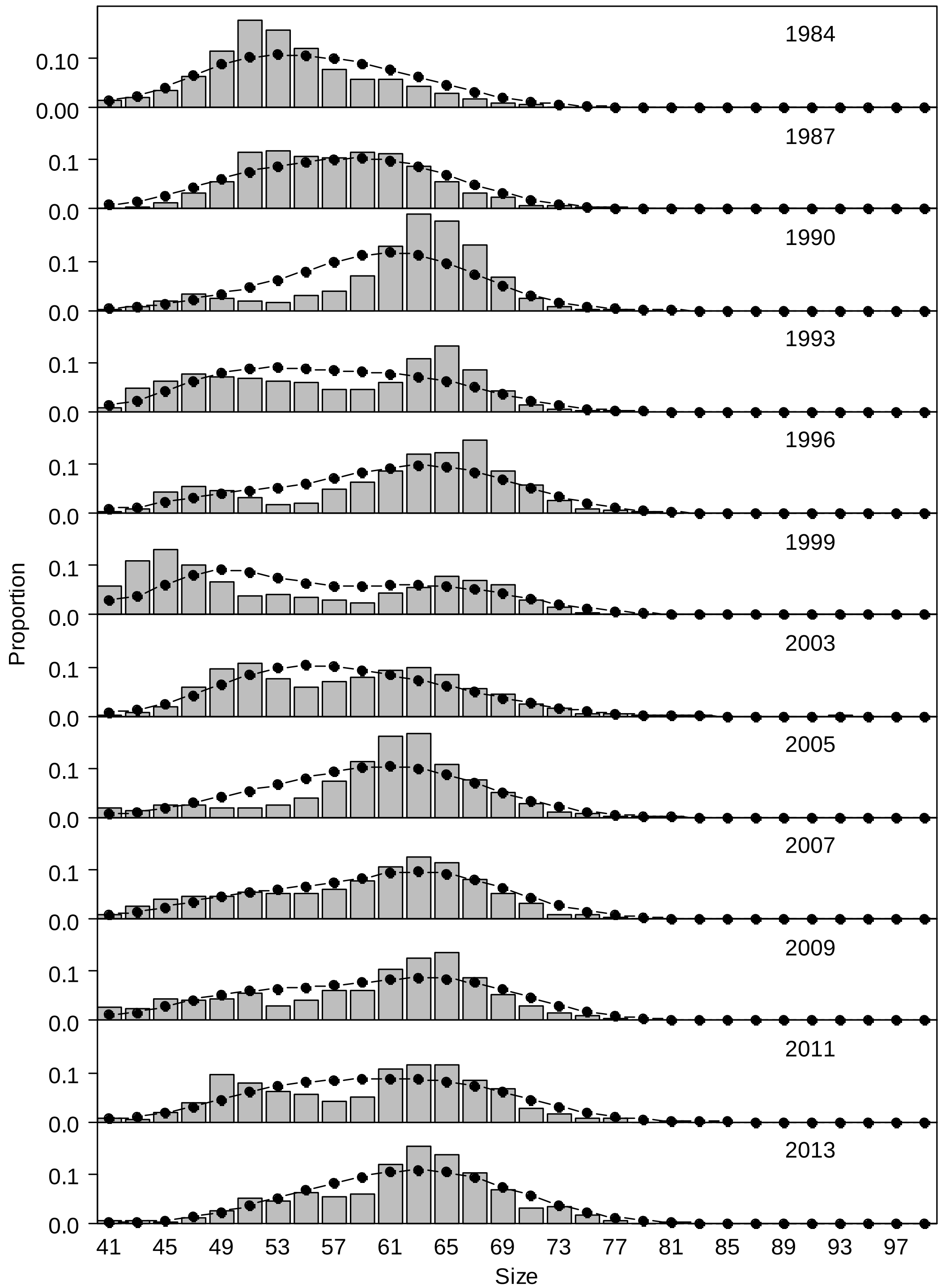

Figure 3.17. Gulf of Alaska bottom trawl survey length (cm) compositions for male sablefish at depths <500 m. Bars are observed frequencies and lines are predicted frequencies.

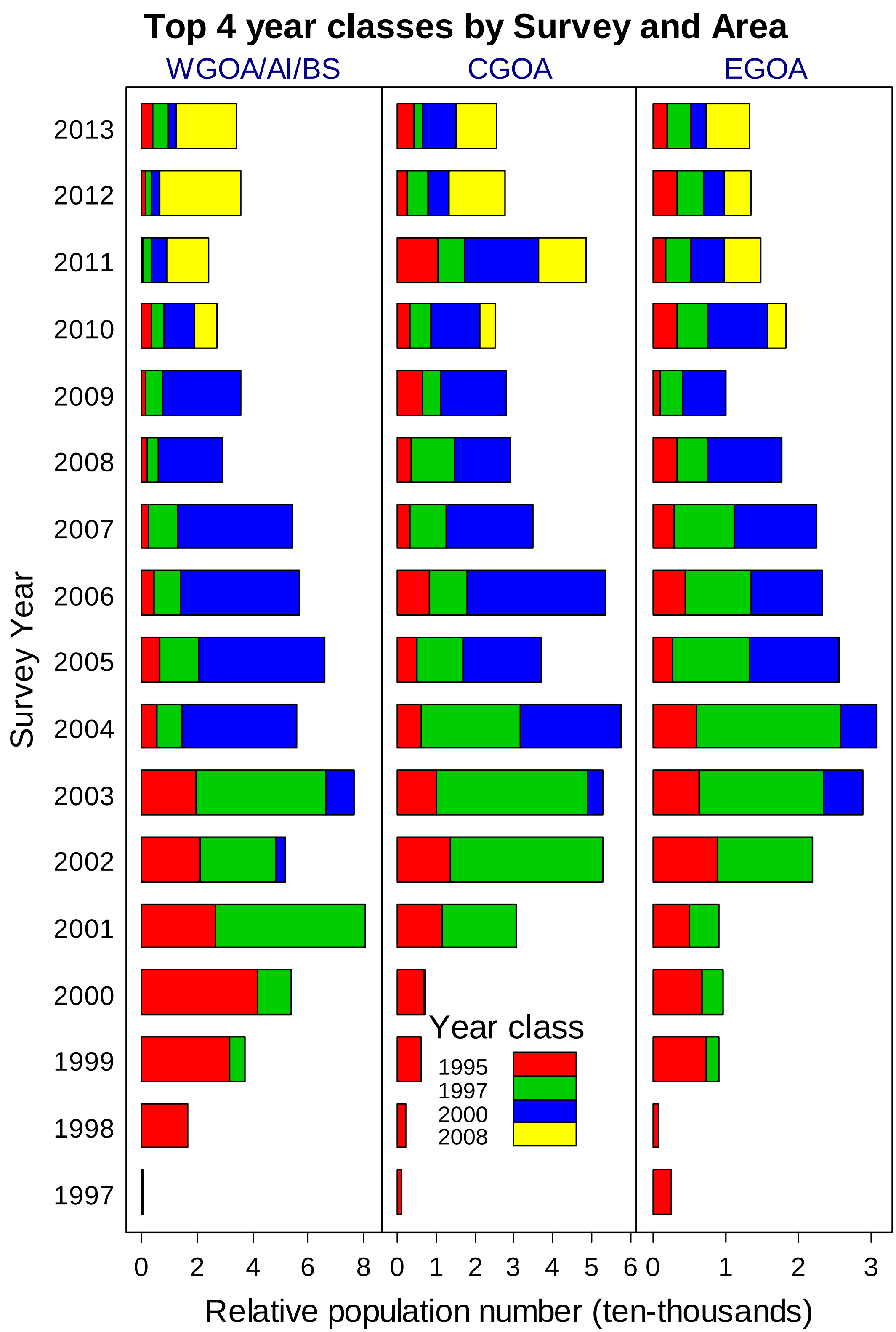

Figure 3.18. Above average 1995, 1997, 2000 and potential above-average 2008 year classes relative population abundance in each survey year and area.

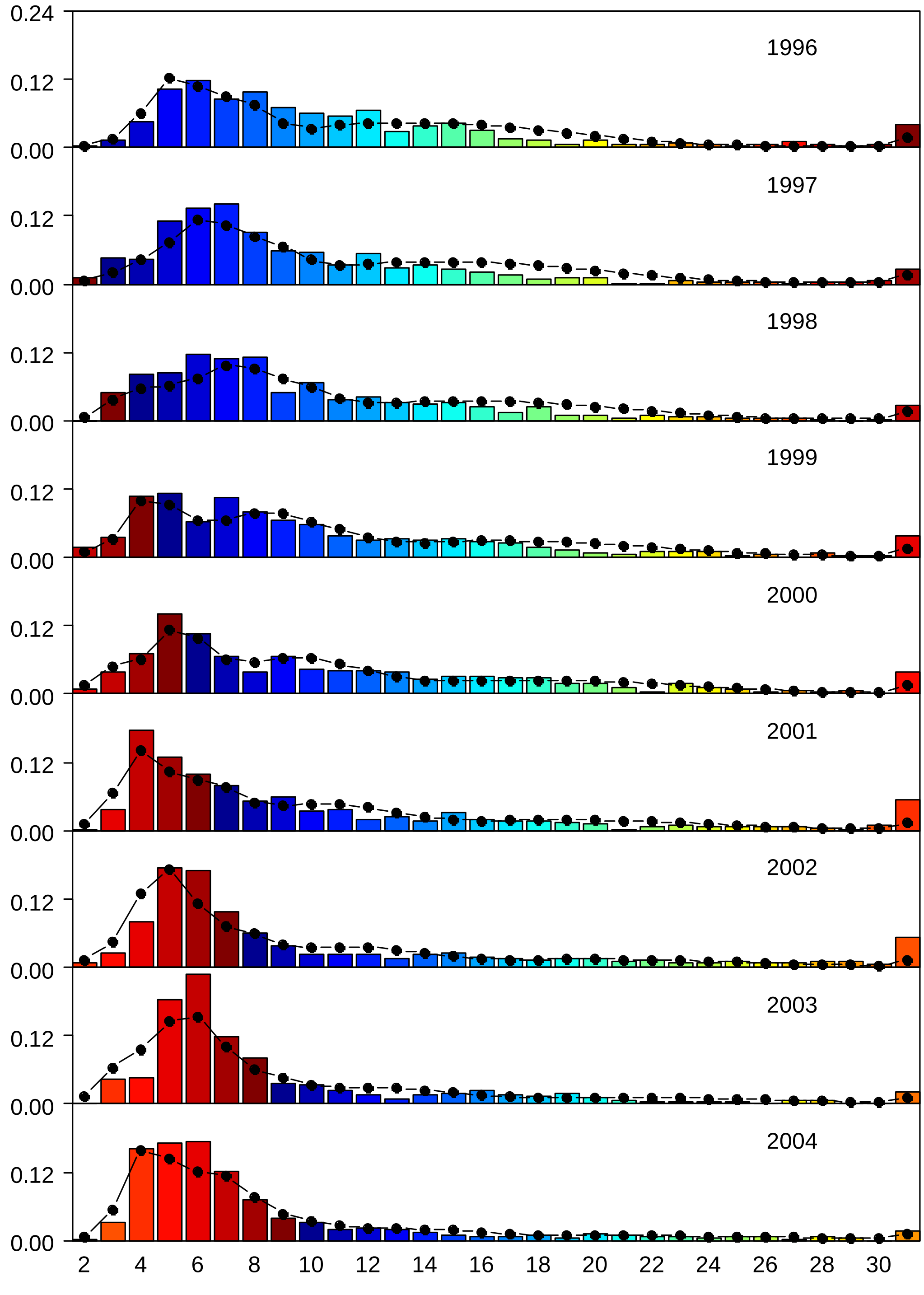

Figure 3.19. Domestic longline survey age compositions. Bars are observed frequencies and lines are predicted frequencies.

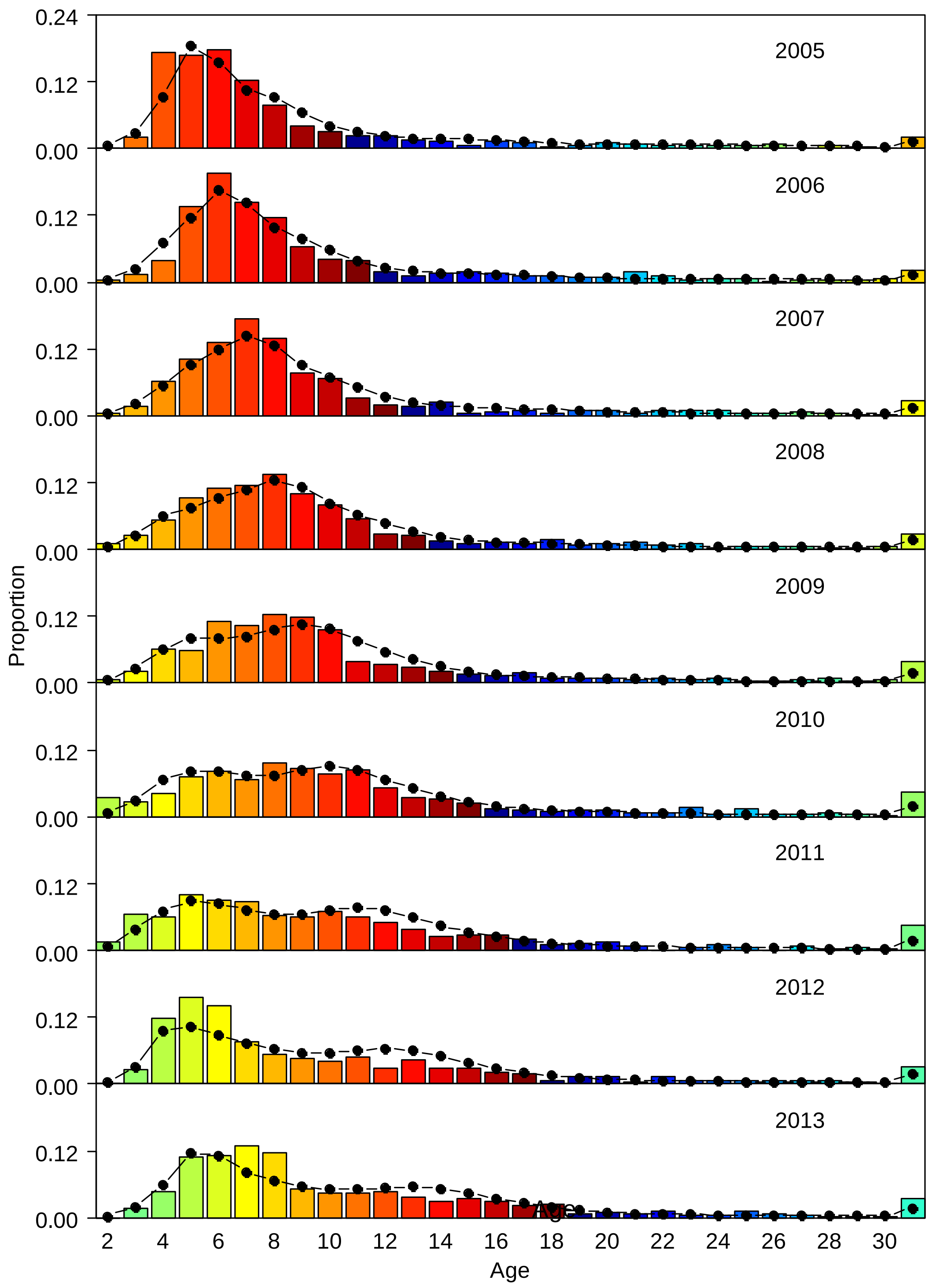

Figure 3.19 (cont.). Domestic longline survey age compositions. Bars are observed frequencies and lines are predicted frequencies.

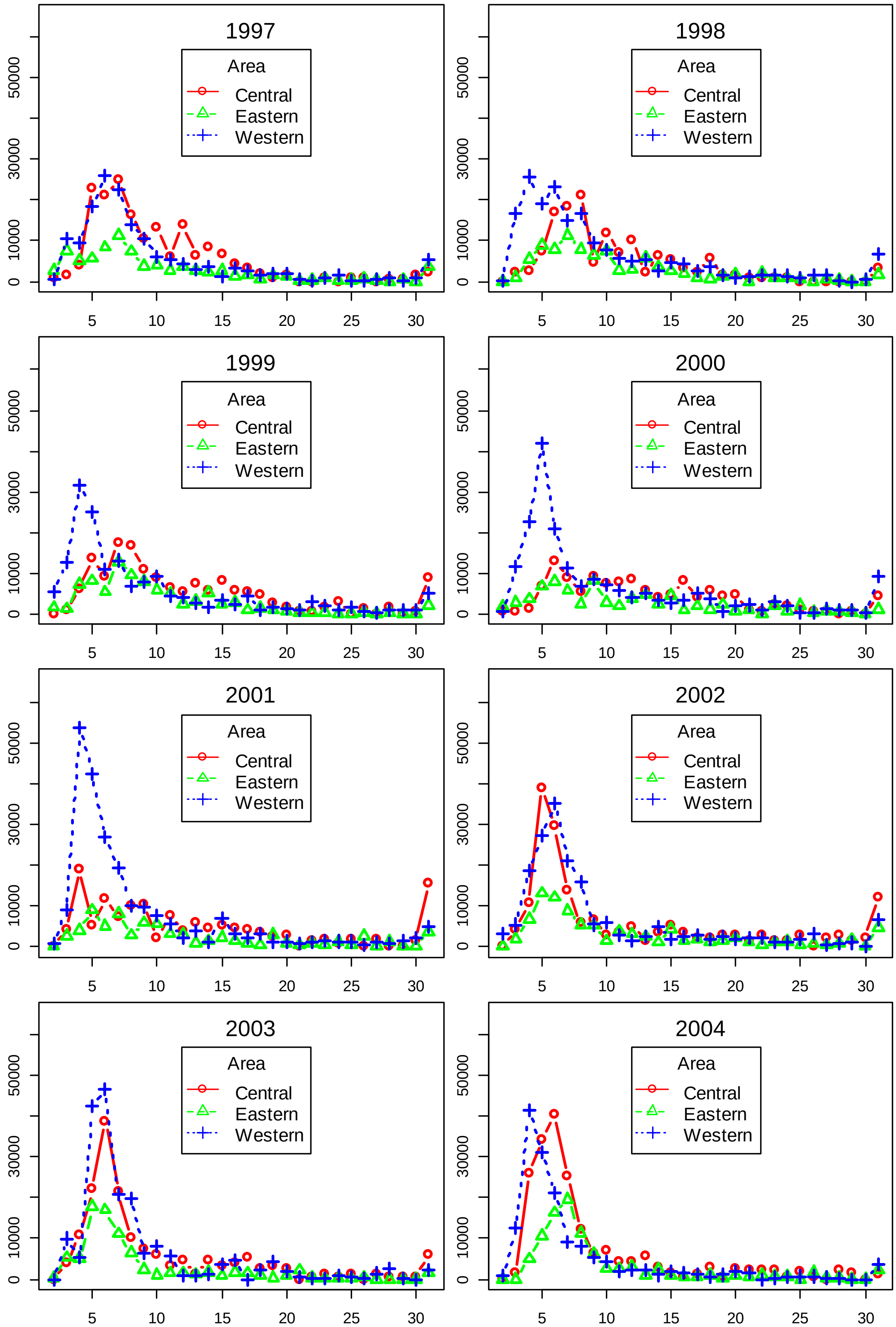

Figure 3.20. Relative abundance (number in thousands) by age and region from the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

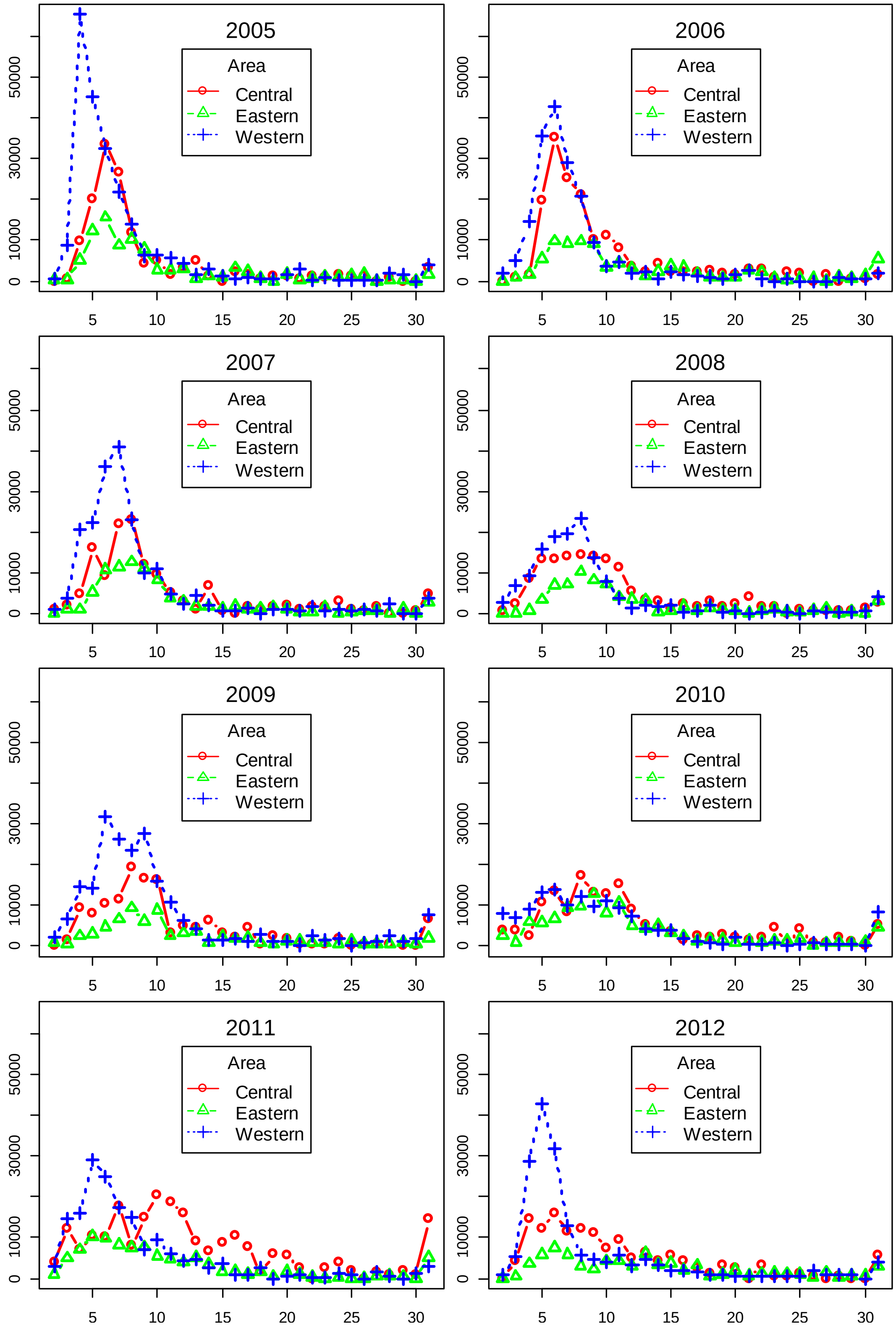

Figure 3.20 (cont.). Relative abundance (number in thousands) by age and region from the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

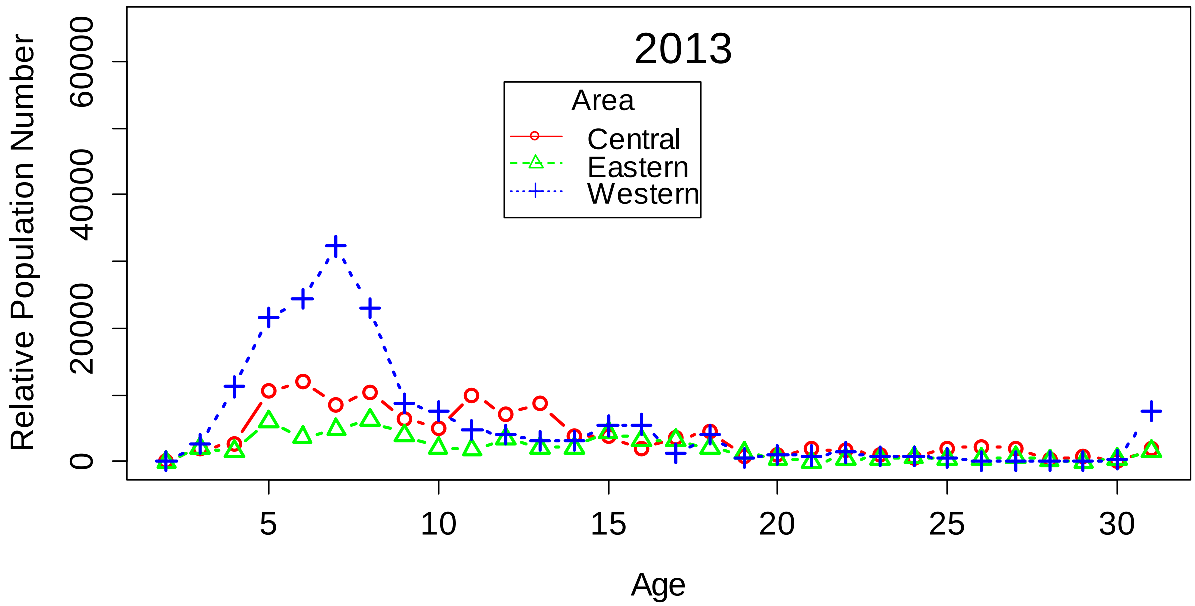

Figure 3.20 (cont.). Relative abundance (number in thousands) by age and region from the domestic (U.S.) longline survey. The regions Bering Sea, Aleutian Islands, and Western Gulf of Alaska are combined.

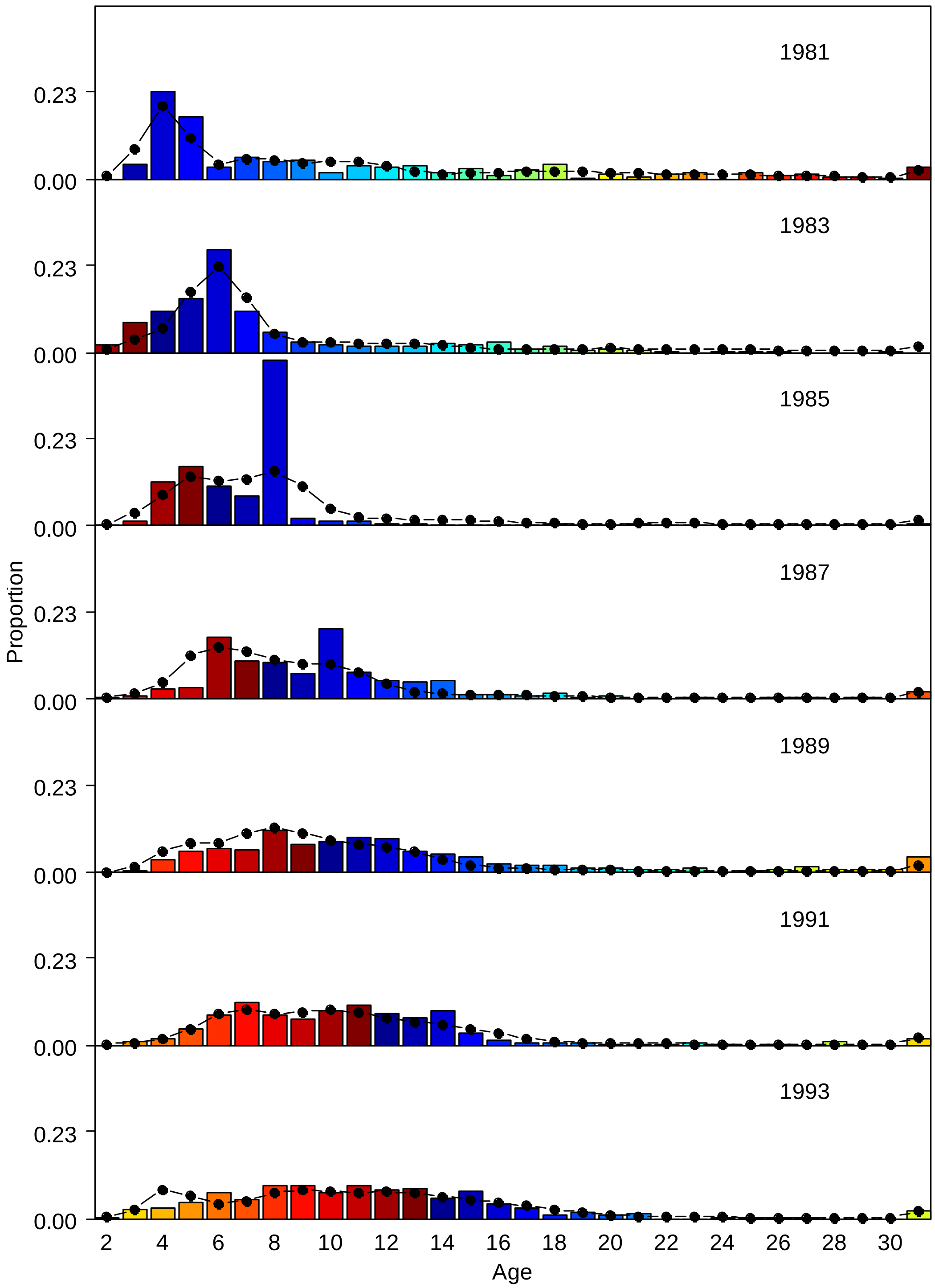

Figure 3.21. Japanese longline survey age compositions. Bars are observed frequencies and line is predicted frequencies.

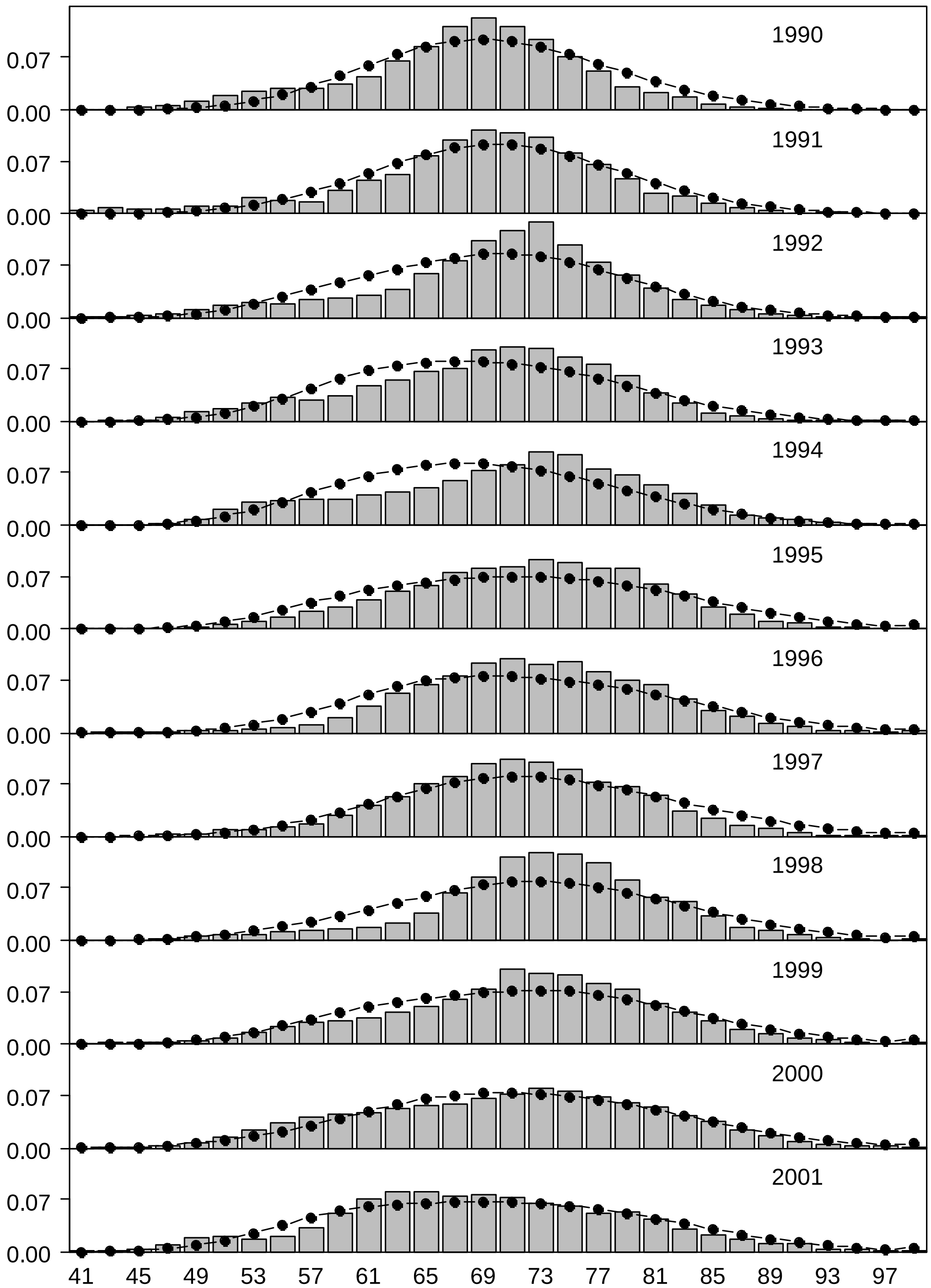

Figure 3.22. Domestic fixed gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

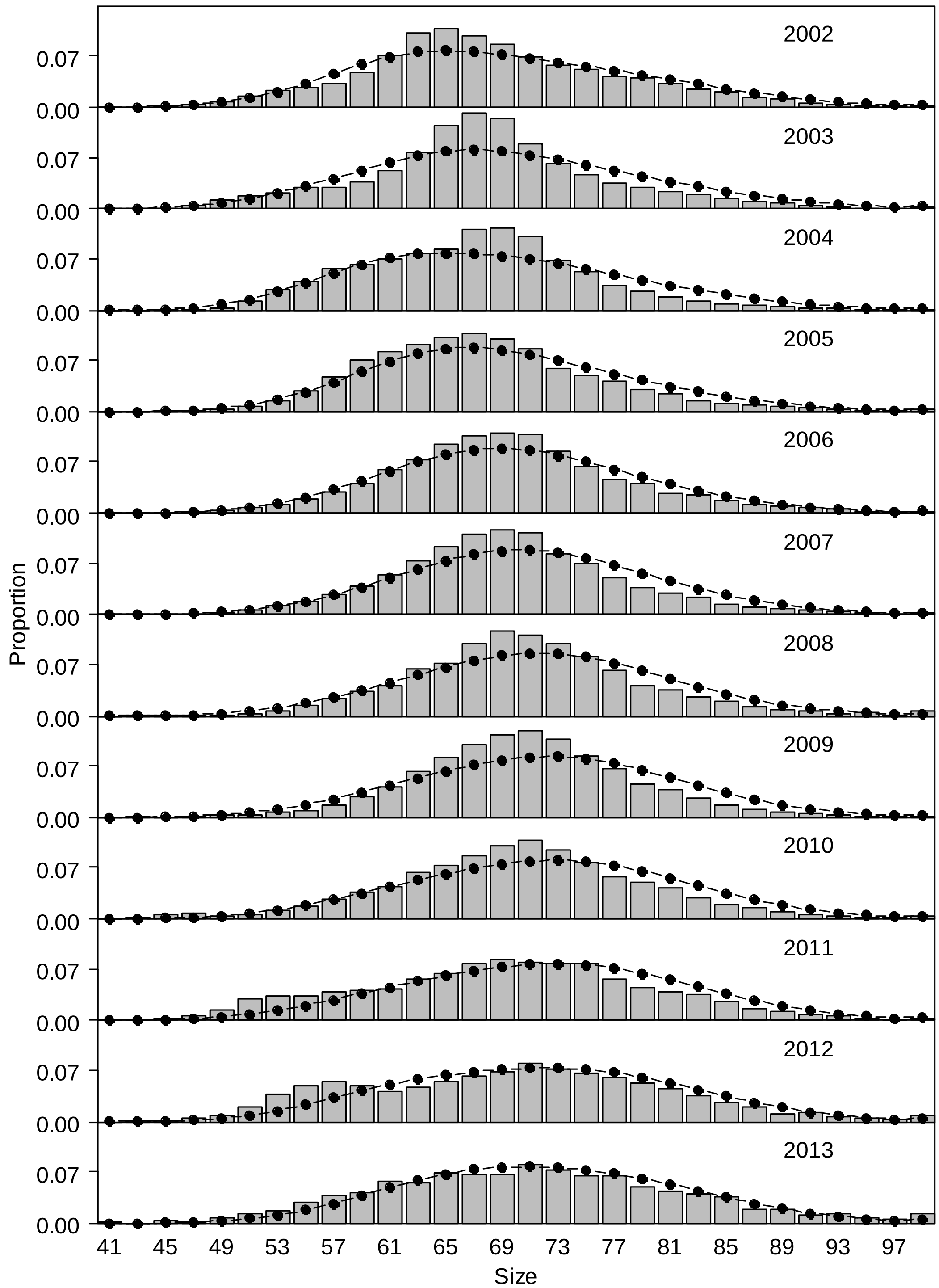

Figure 3.22 (cont.). Domestic fixed gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

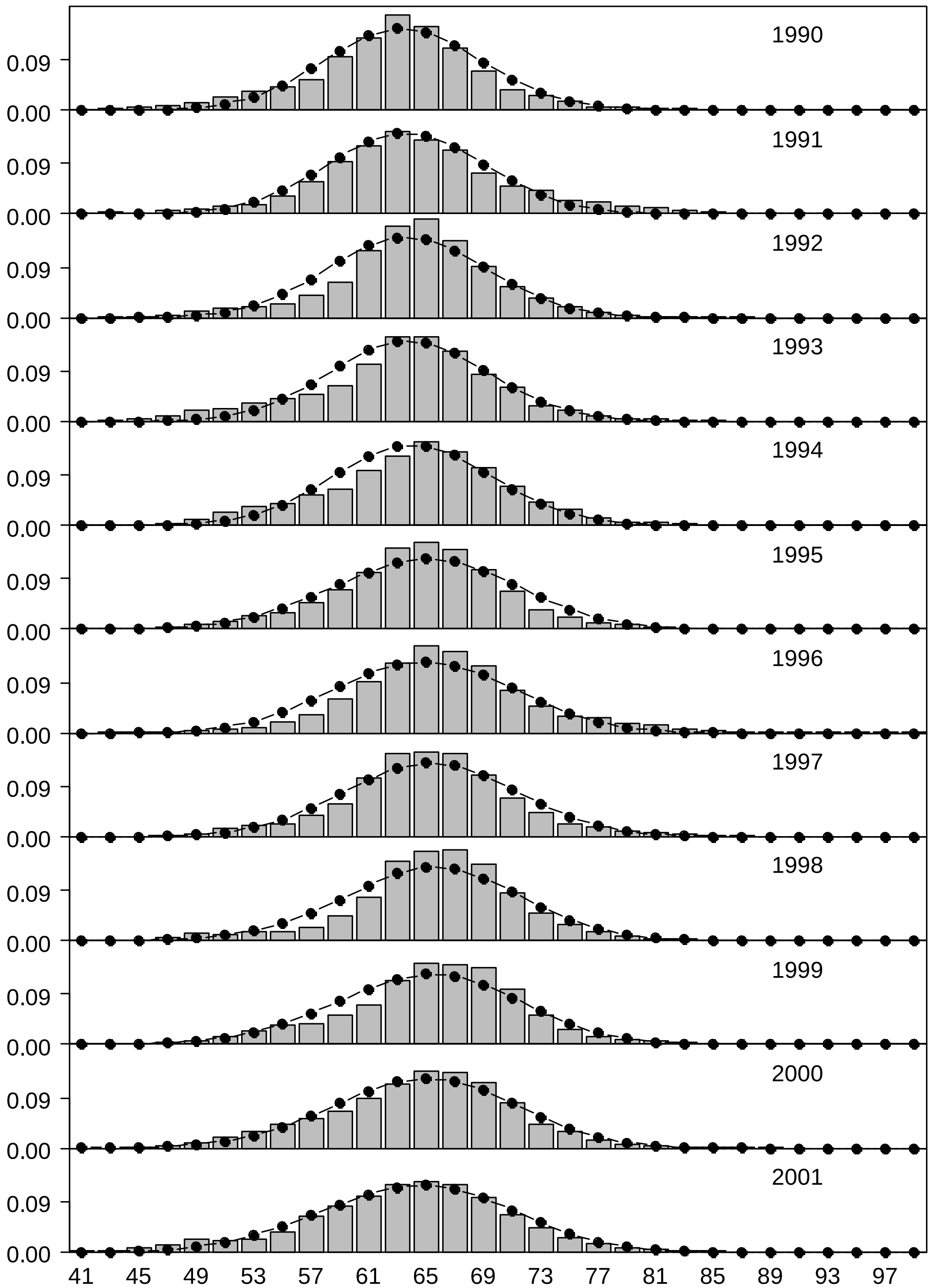

Figure 3.23. Domestic fixed gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

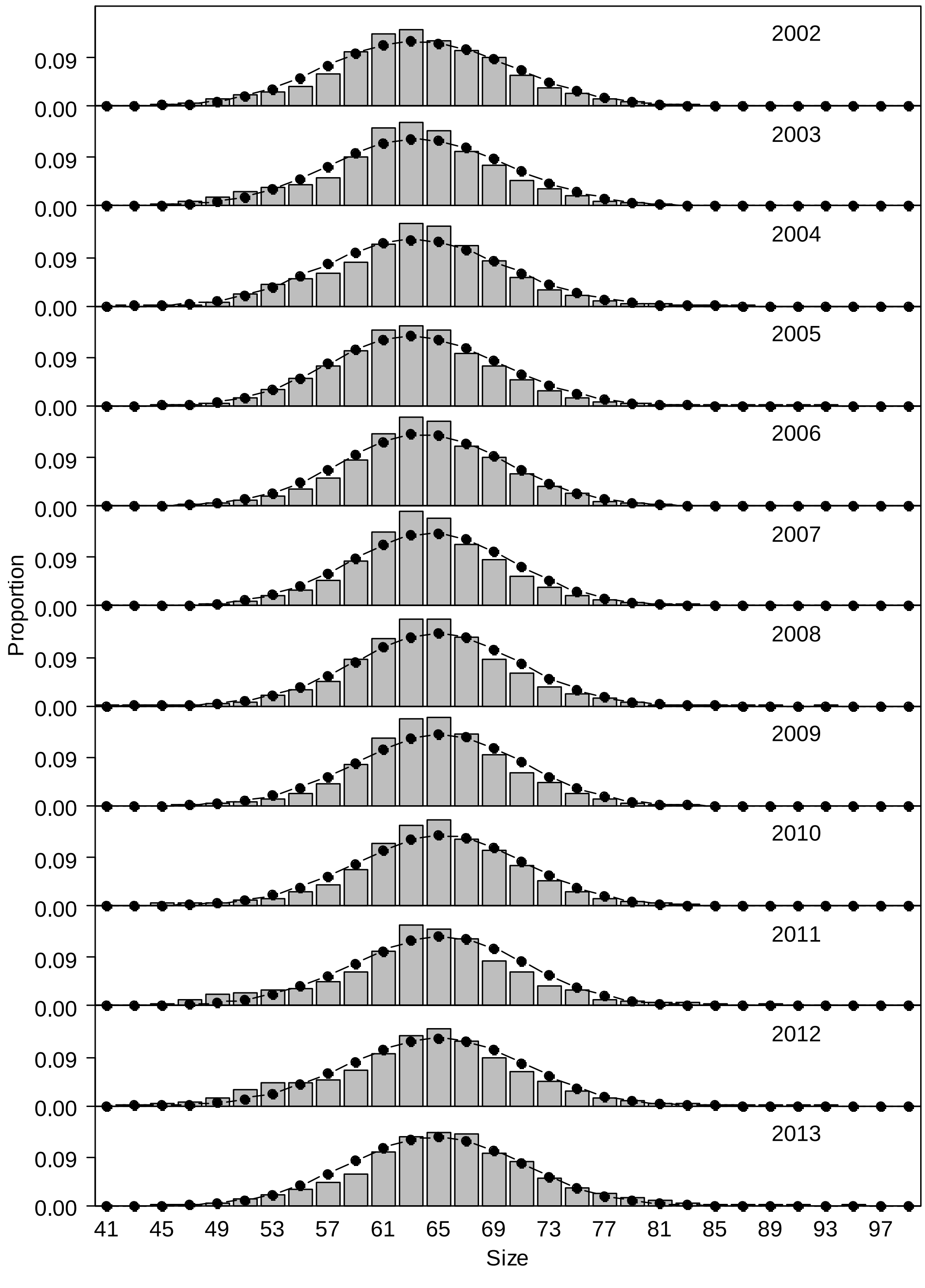

Figure 3.23 (cont.). Domestic fixed gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

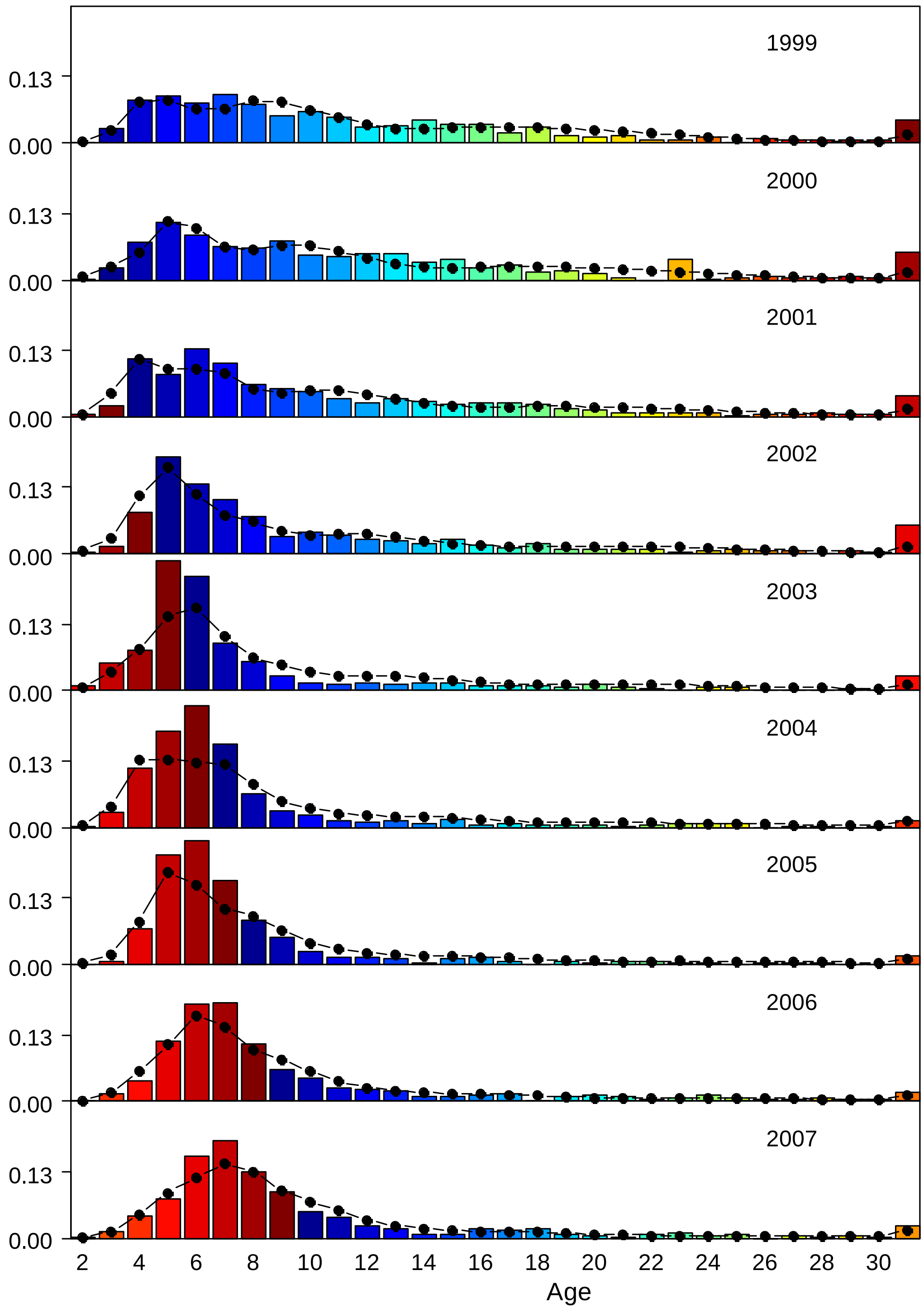

Figure 3.24. Domestic fishery age compositions. Bars are observed frequencies and lines are predicted frequencies.

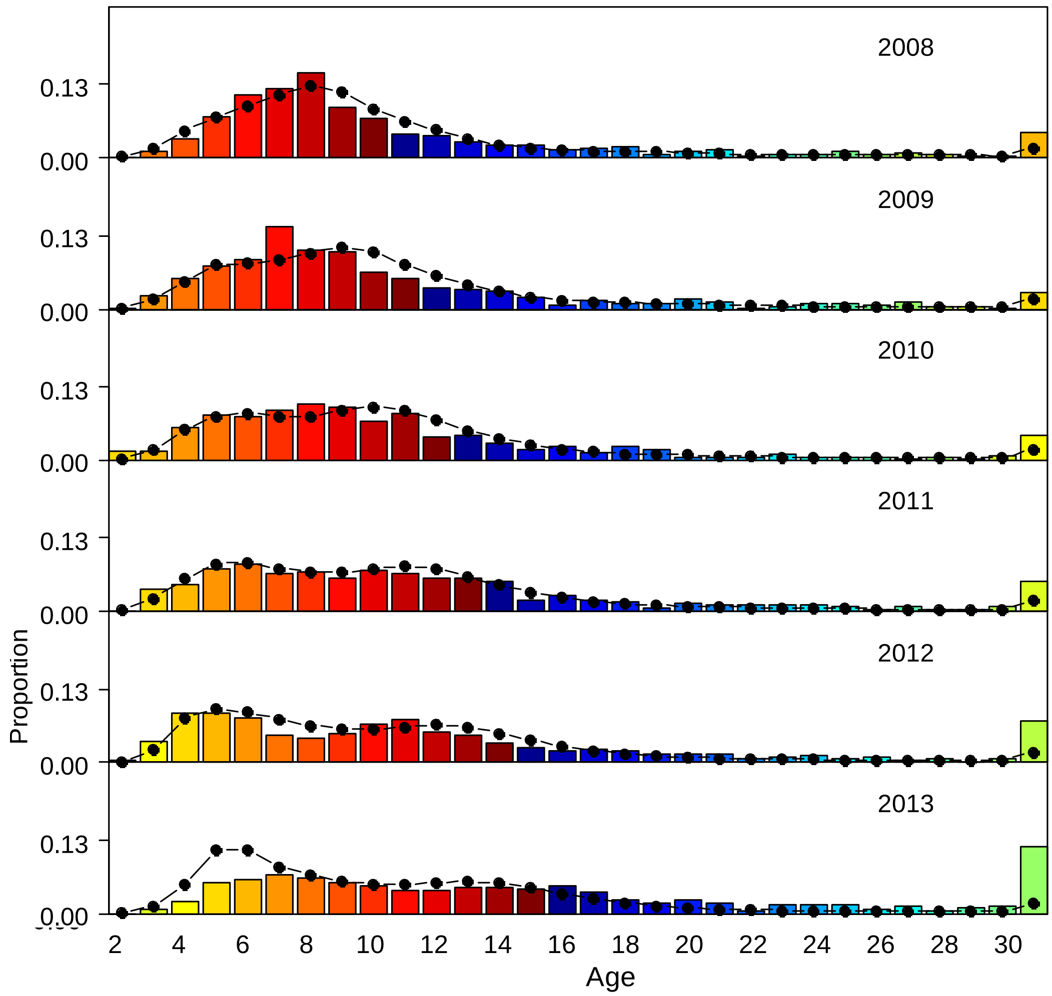

Figure 3.24 (cont.). Domestic fishery age compositions. Bars are observed frequencies and lines are predicted frequencies.

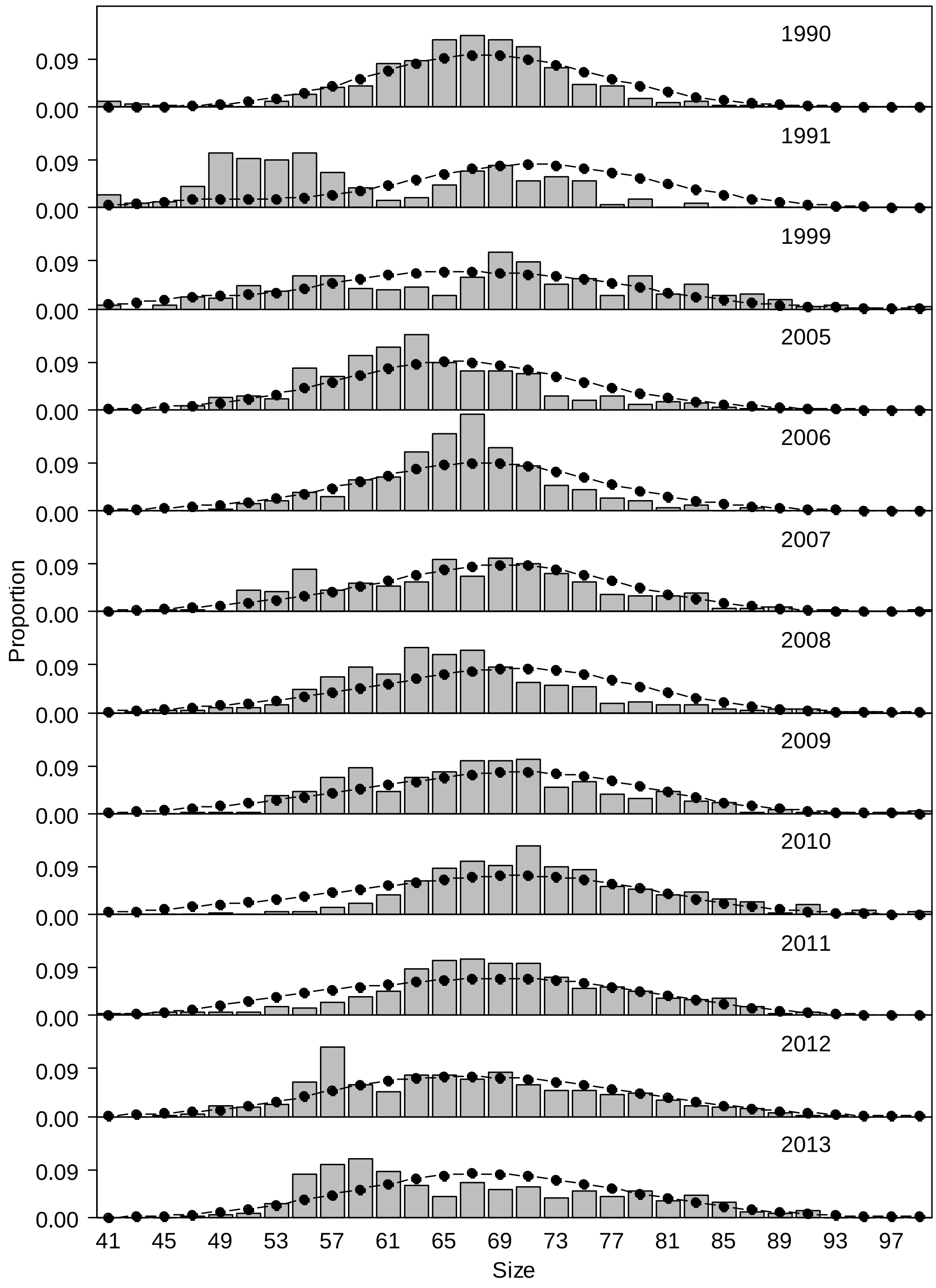

Figure 3.25a. Domestic trawl gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

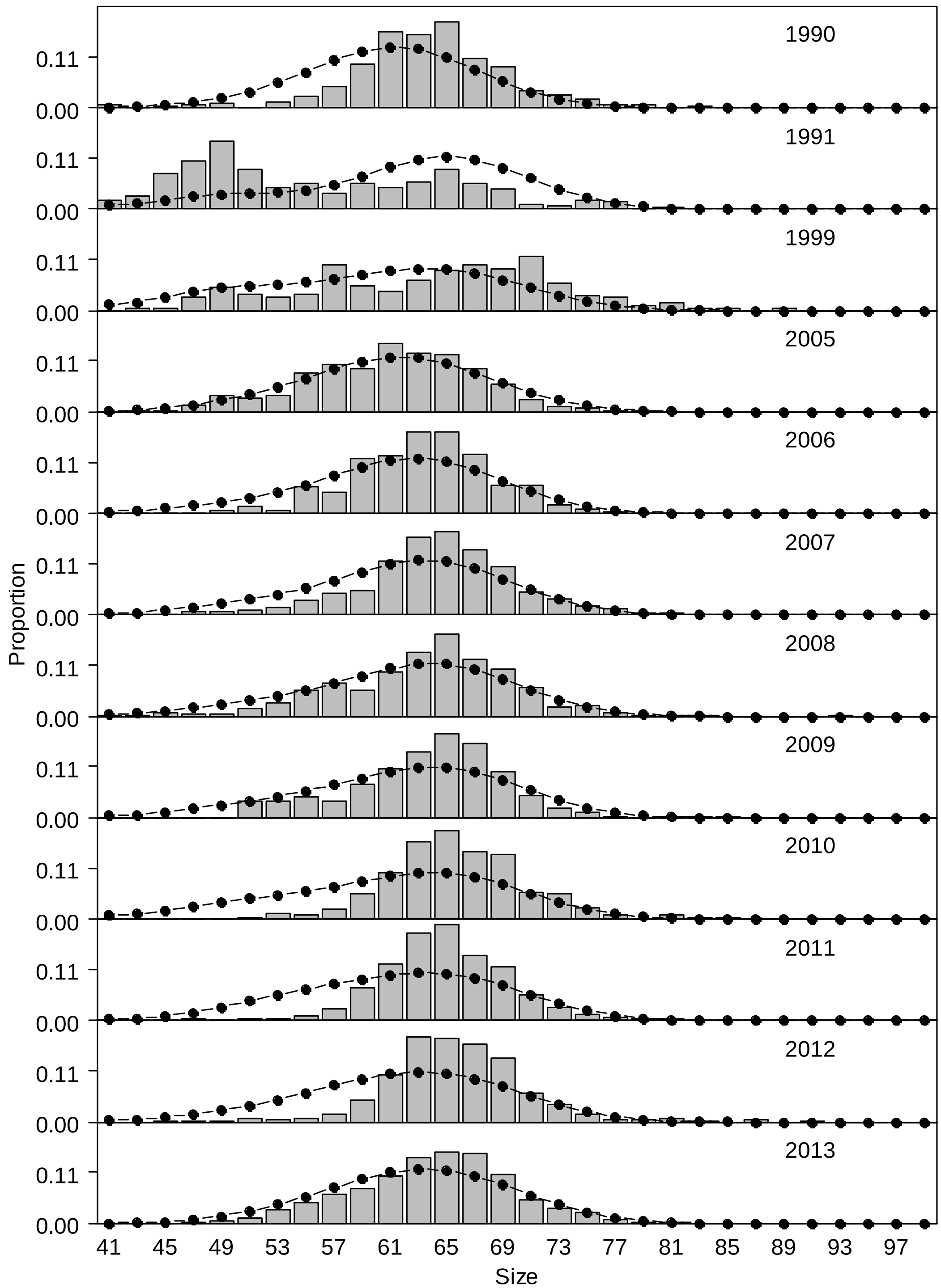

Figure 3.25b. Domestic trawl gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

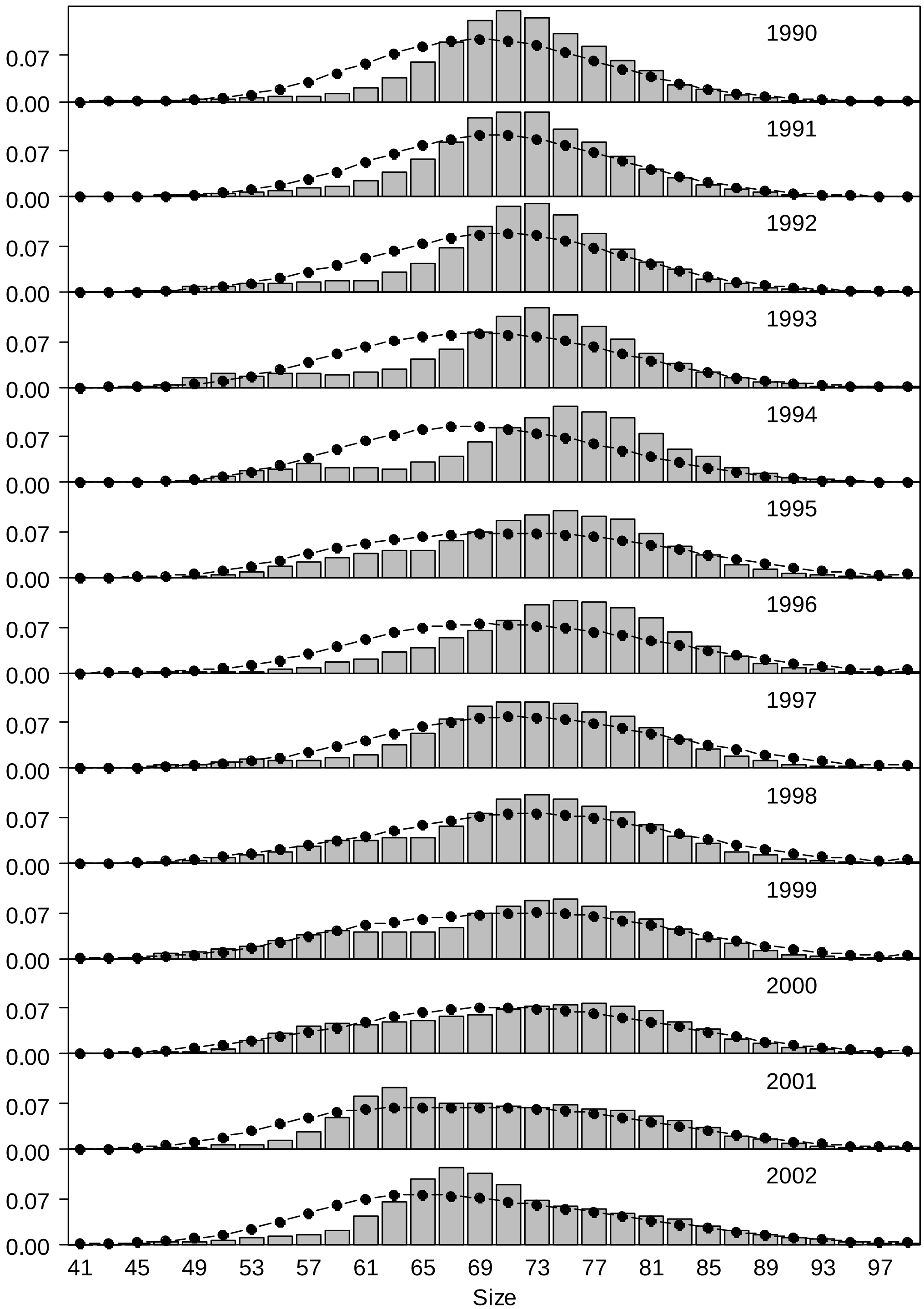

Figure 3.26. Domestic longline survey length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

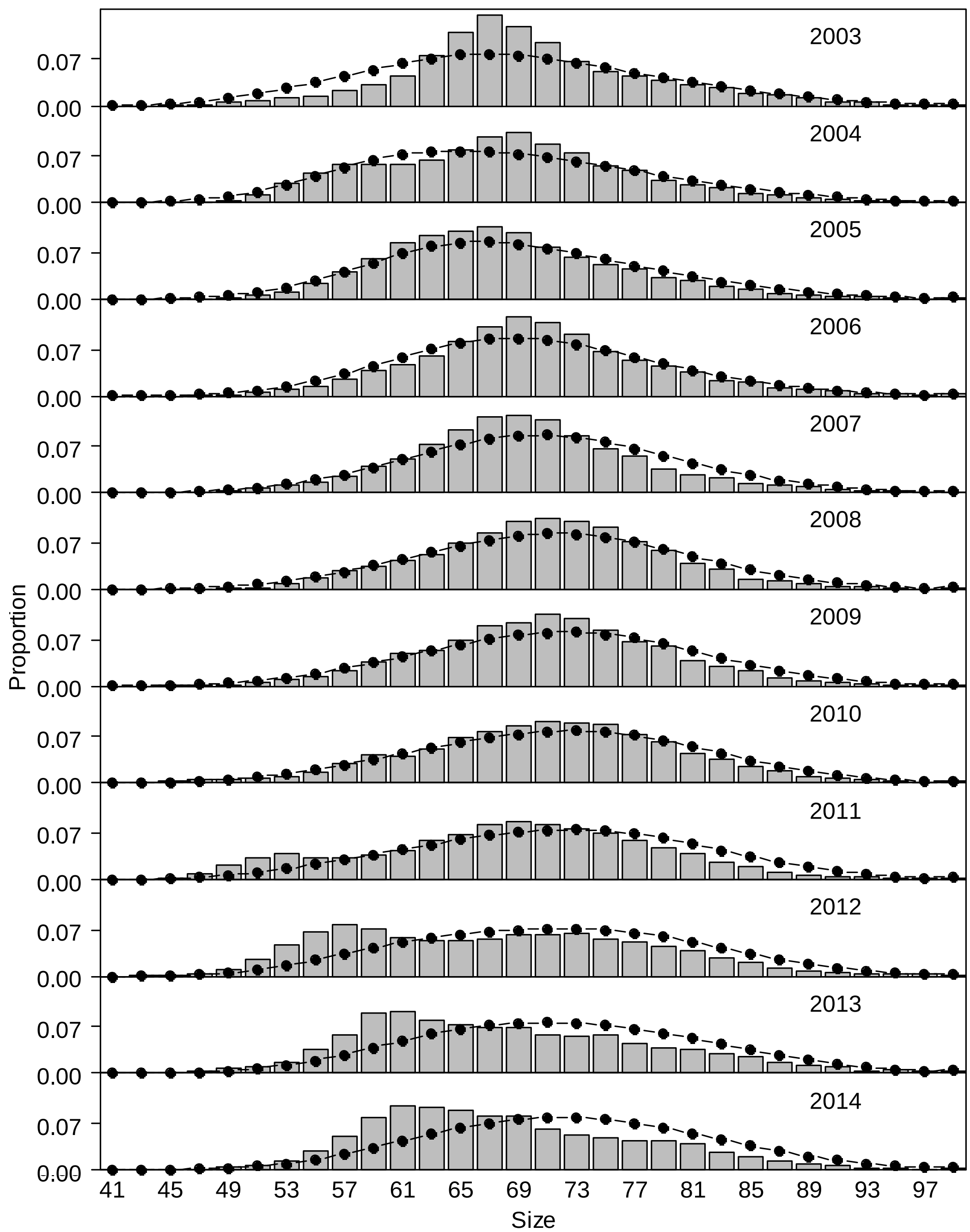

Figure 3.26 (cont.). Domestic longline survey length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

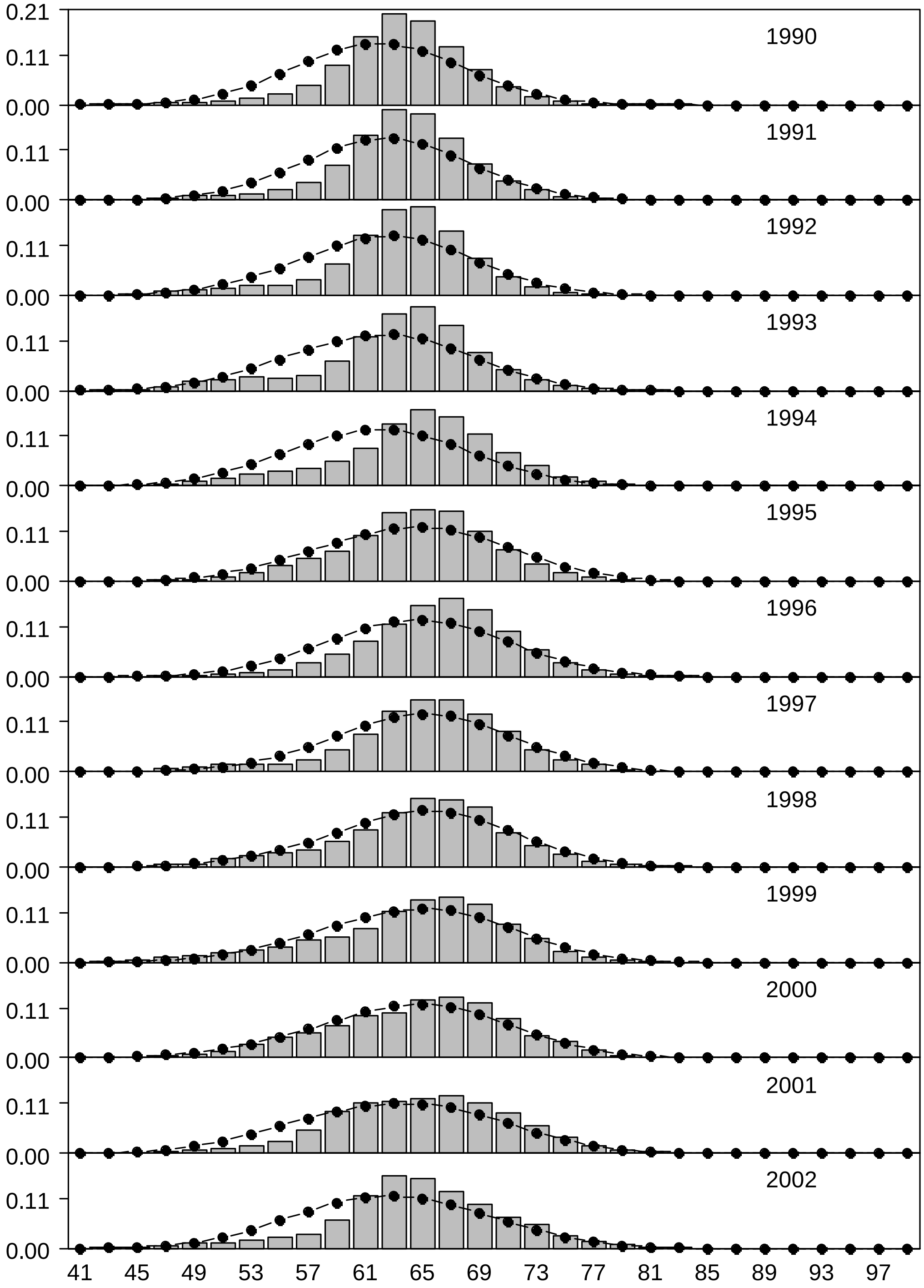

Figure 3.27. Domestic longline survey length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

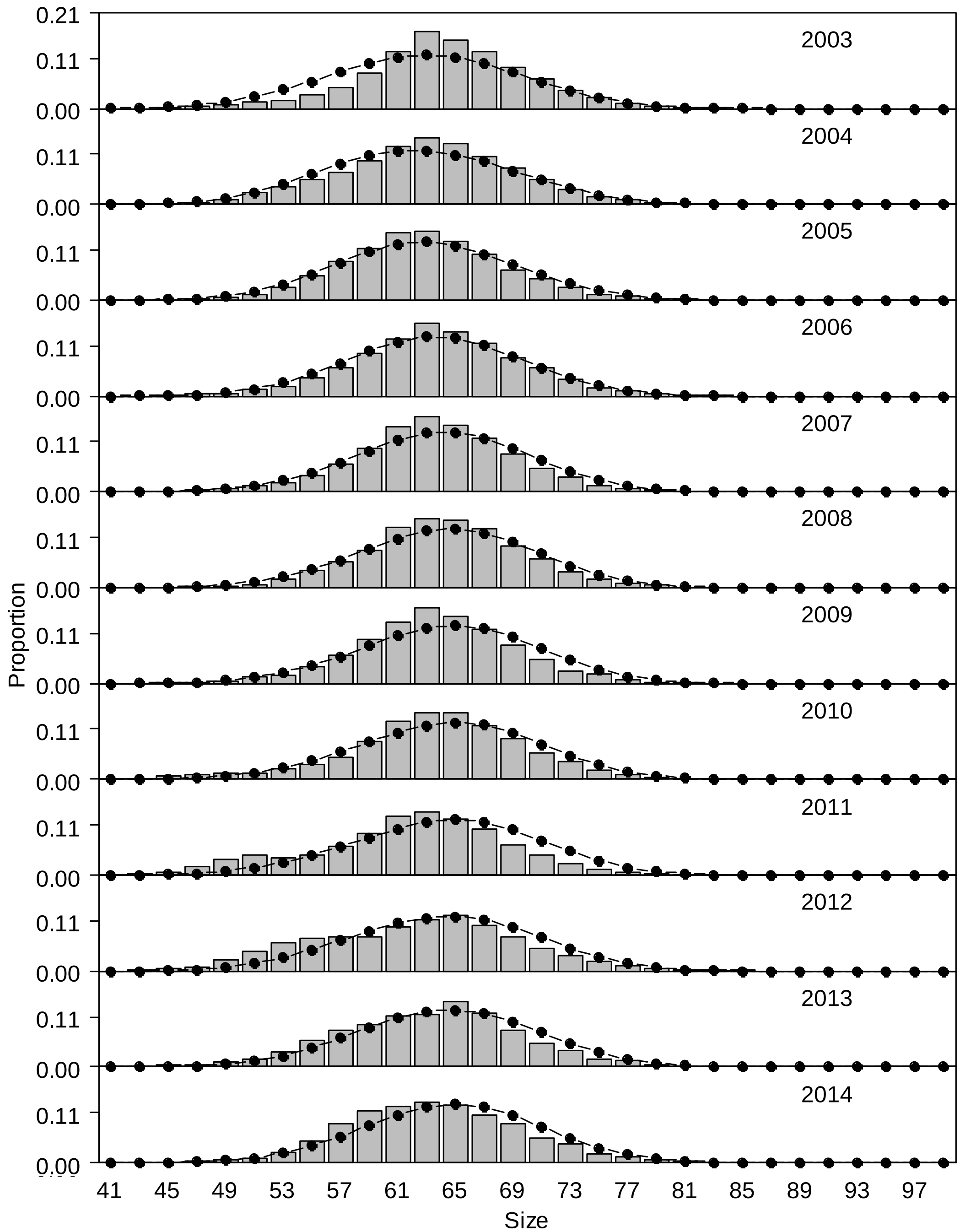

Figure 3.27.(cont.). Domestic longline survey length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

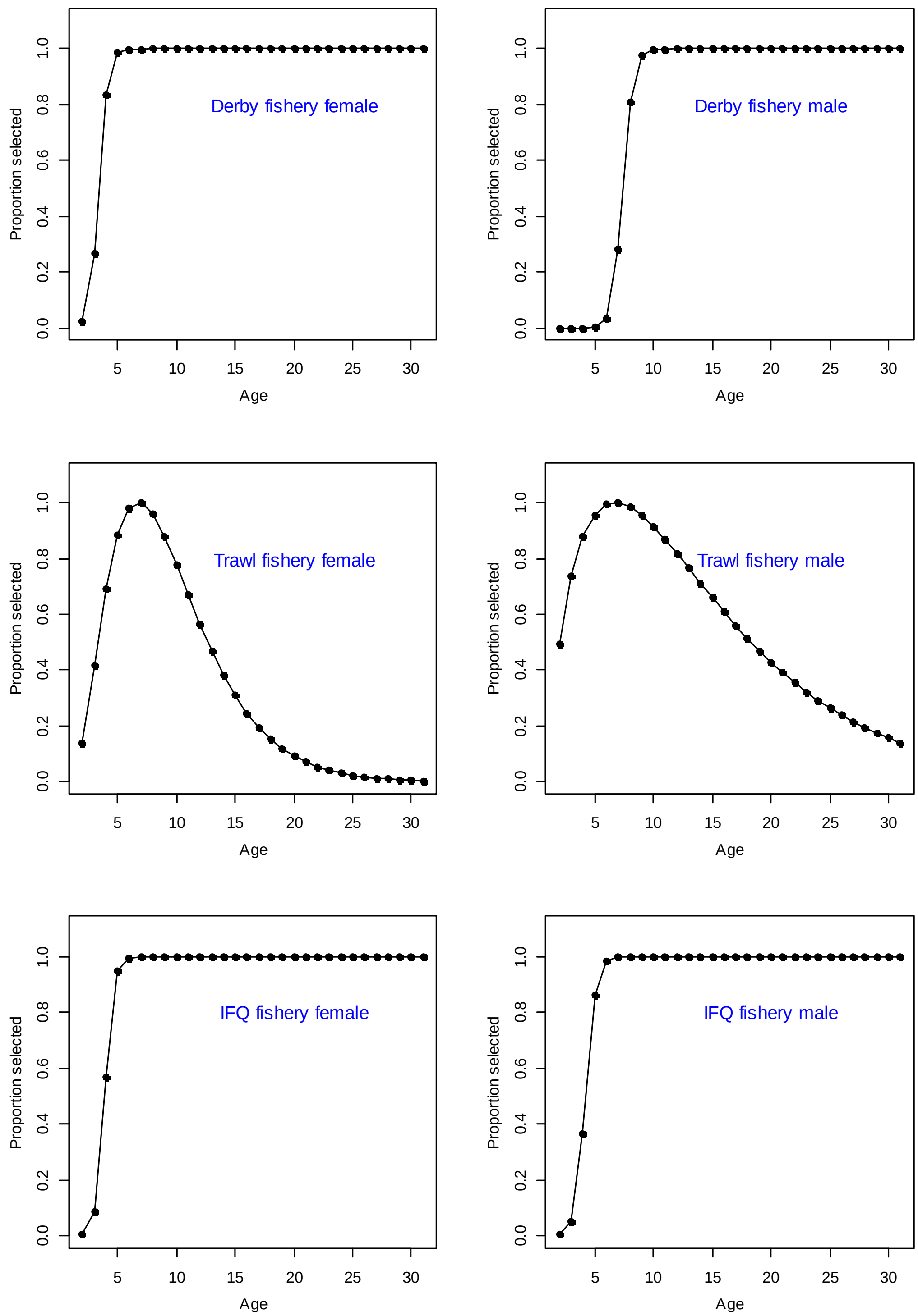

Figure 3.28. Sablefish selectivities for fisheries.

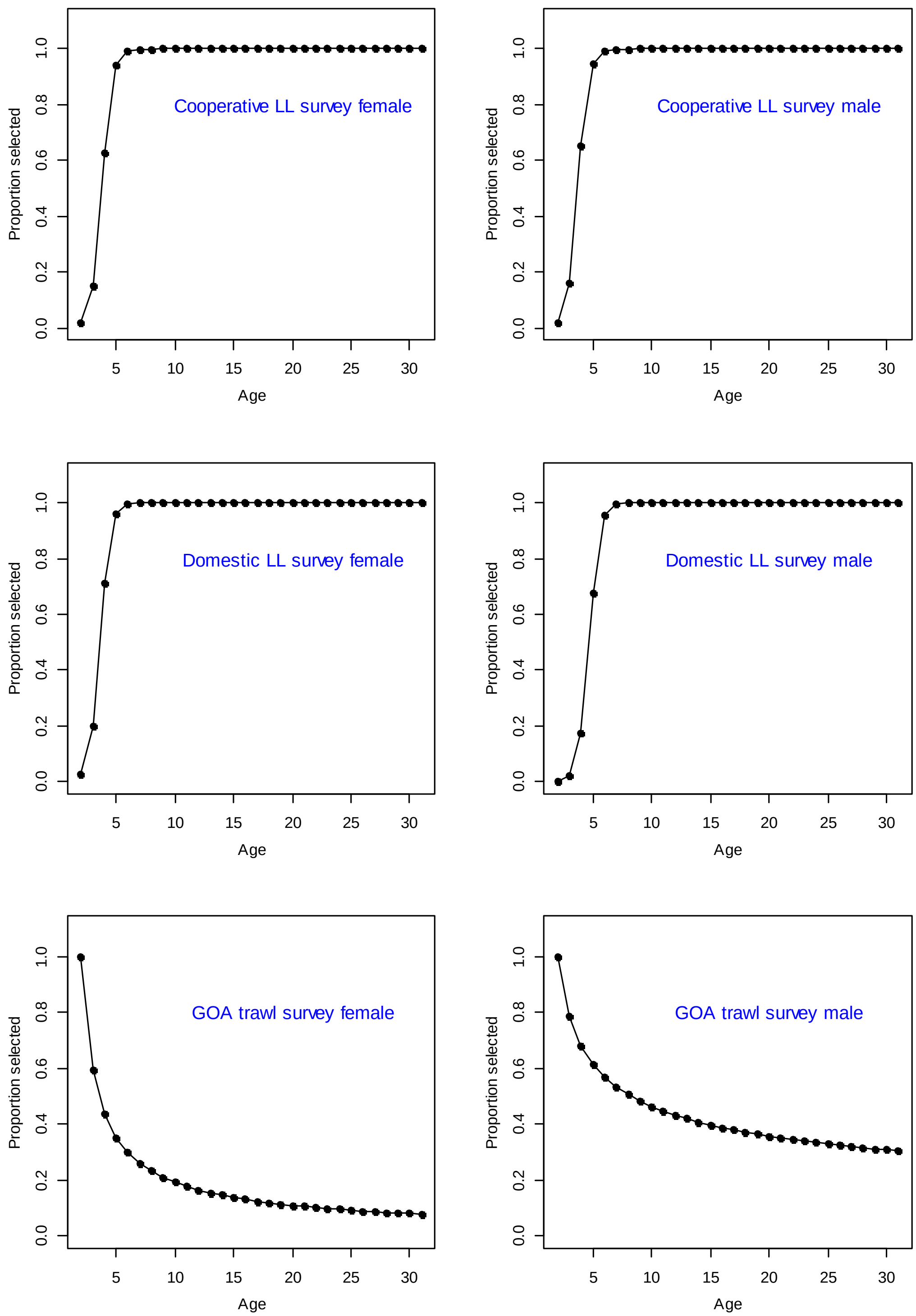

Figure 3.28 (cont.). Sablefish selectivities for surveys.

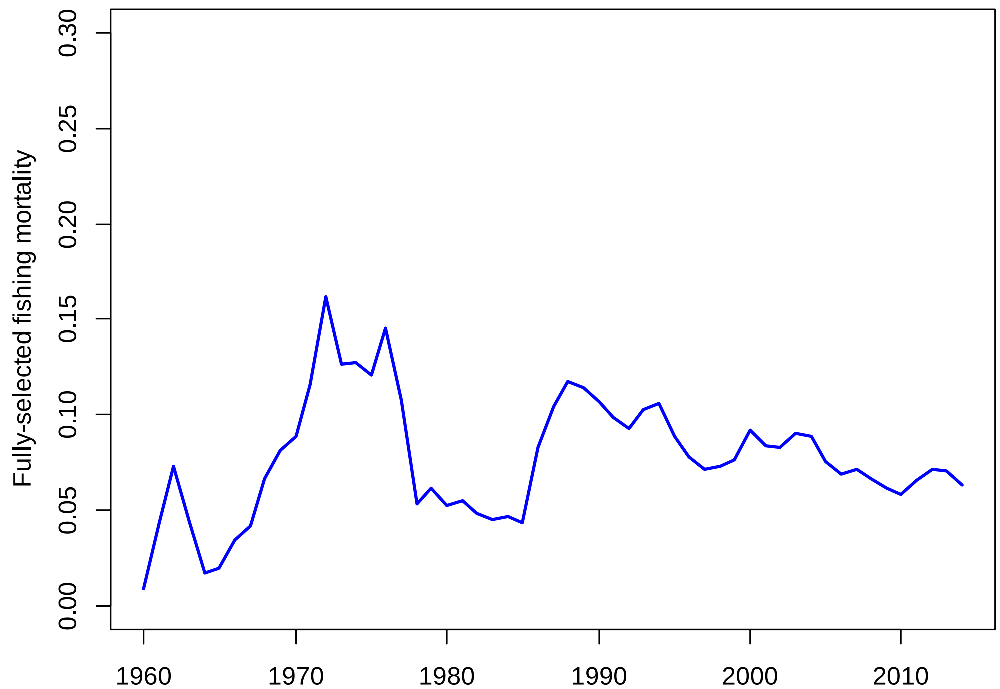

Figure 3.29. Time series of combined fully-selected fishing mortality for fixed and trawl gear for sablefish.

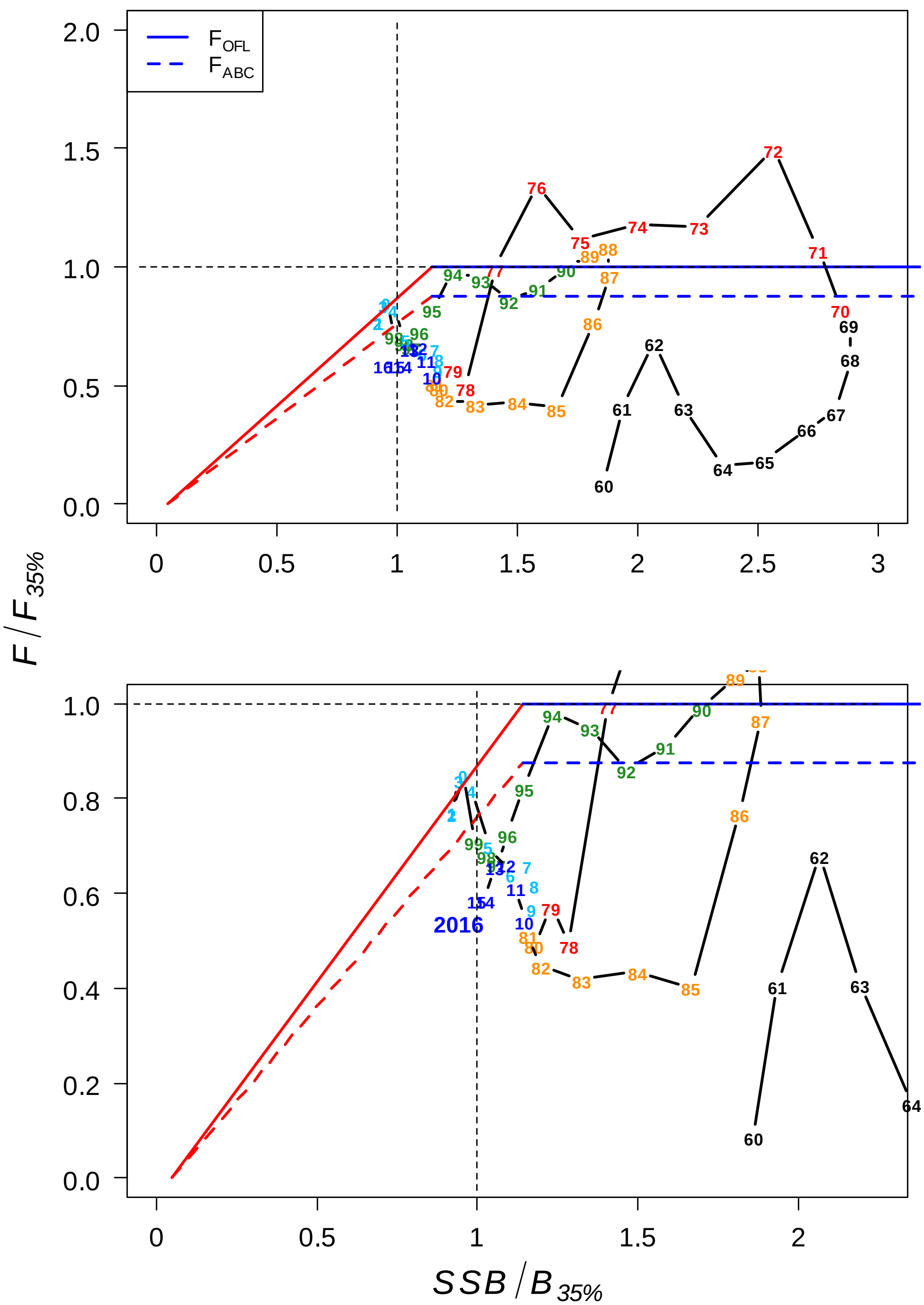

Figure 3.30. Phase-plane diagram of time series of sablefish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model. Bottom is zoomed in to examine more recent years.

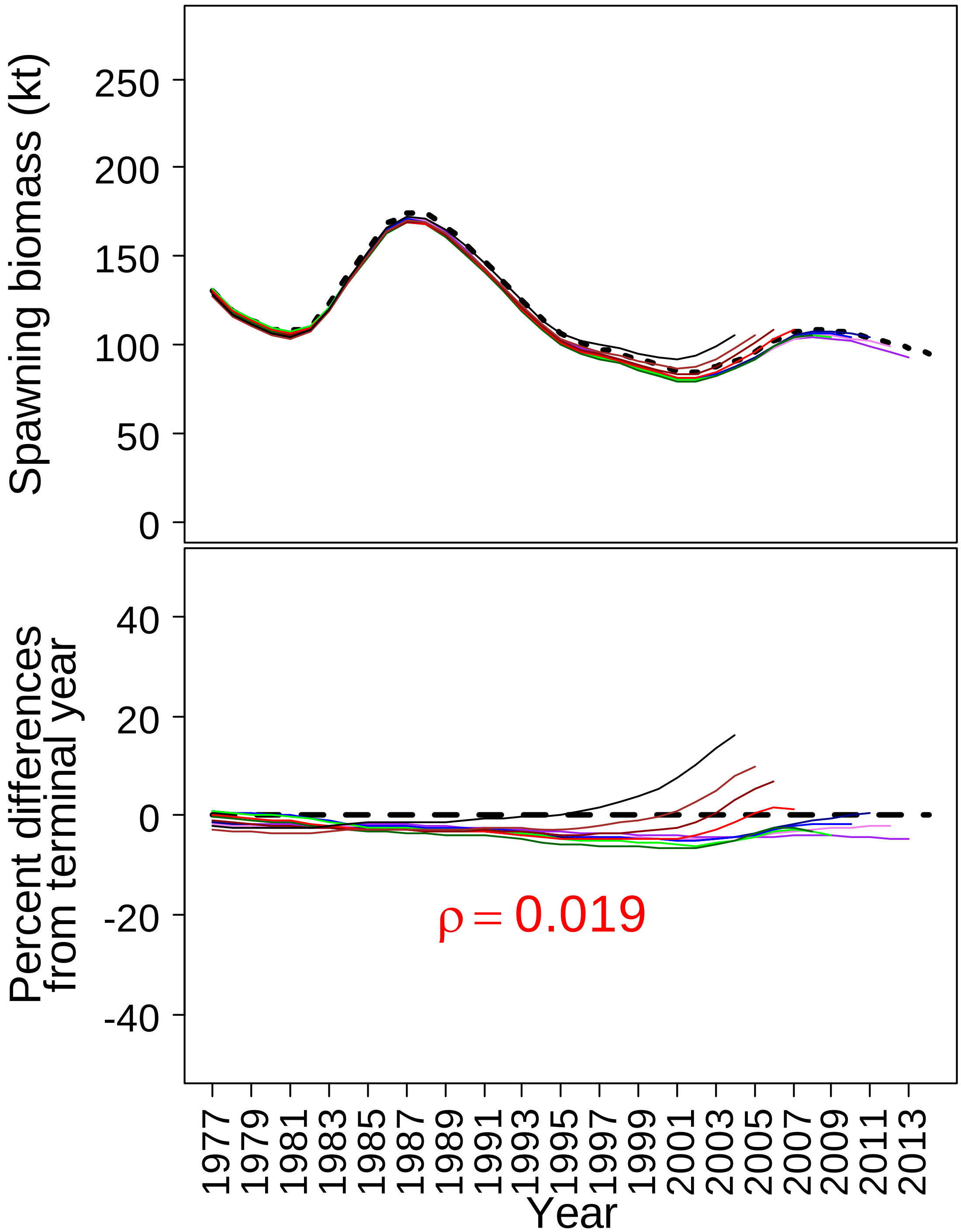

Figure 3.31a. Retrospective trends for spawning biomass (top) and percent difference from terminal year (bottom) from 2004-2014. Mohn's revised ρ = 0.019.

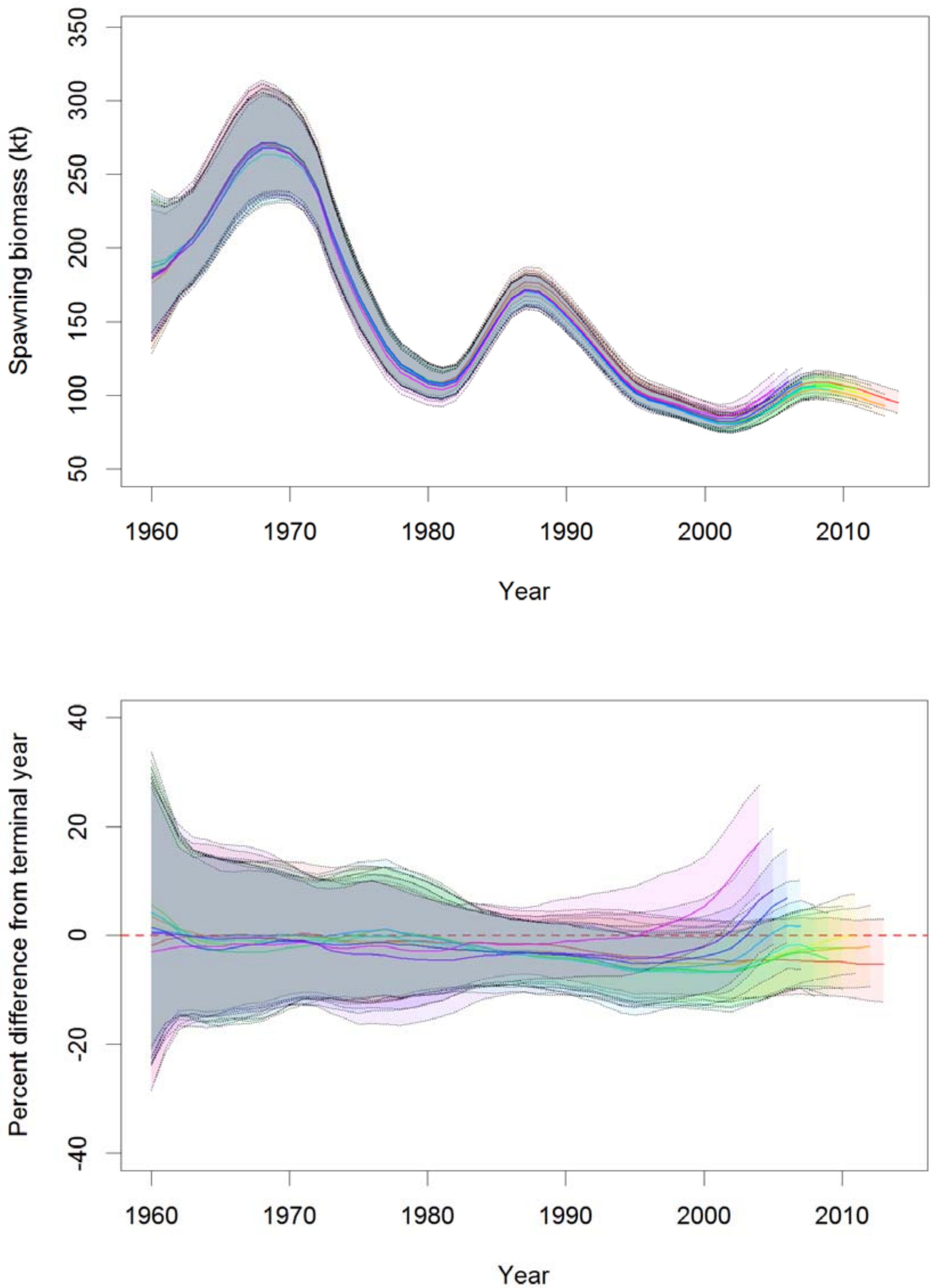

Figure 3.31b. Retrospective trends for spawning biomass (top) and percent difference from terminal year (bottom) from 2004-2014 with MCMC credible intervals per year. Mohn's revised ρ = 0.019.

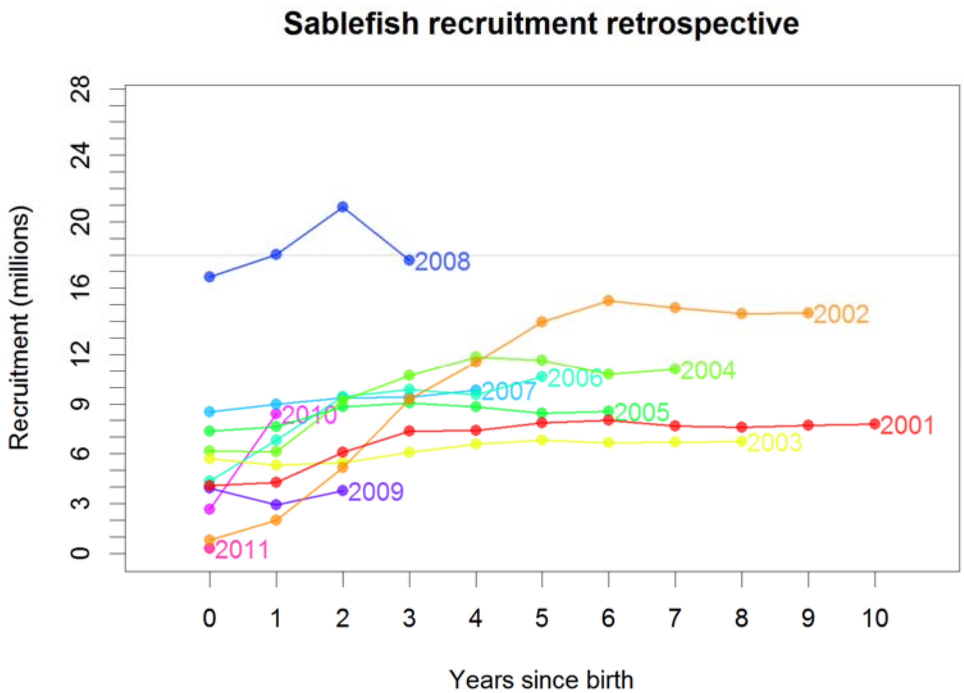

Figure 3.31c. Squid plot of the development of initial estimates of age-2 recruitment since year class 2001 through year class 2011 from retrospective analysis. Number to right of terminal year indicates year class.

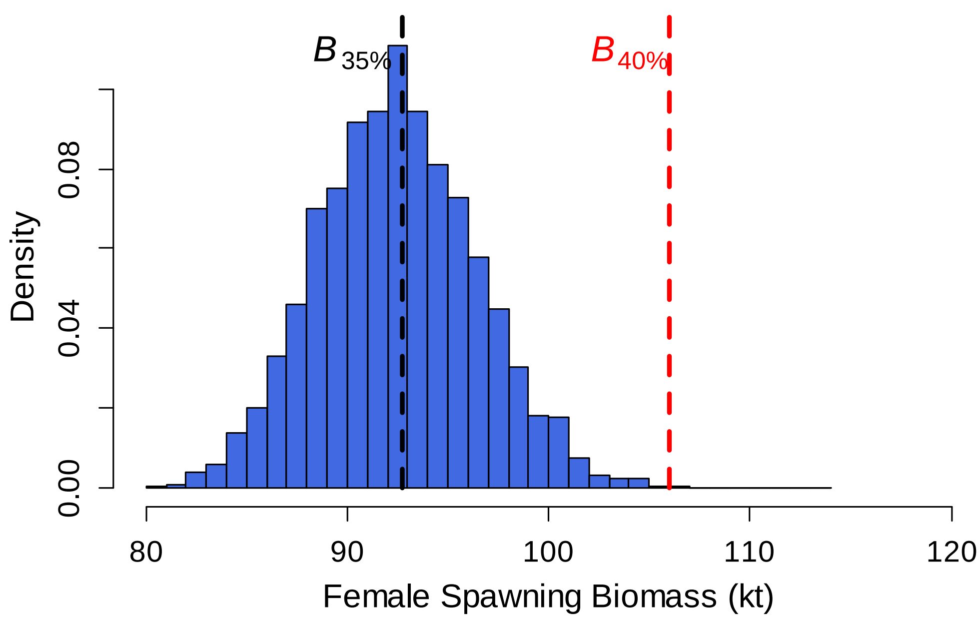

Figure 3.32. Posterior probability distribution for projected spawning biomass (thousands t) in 2014.

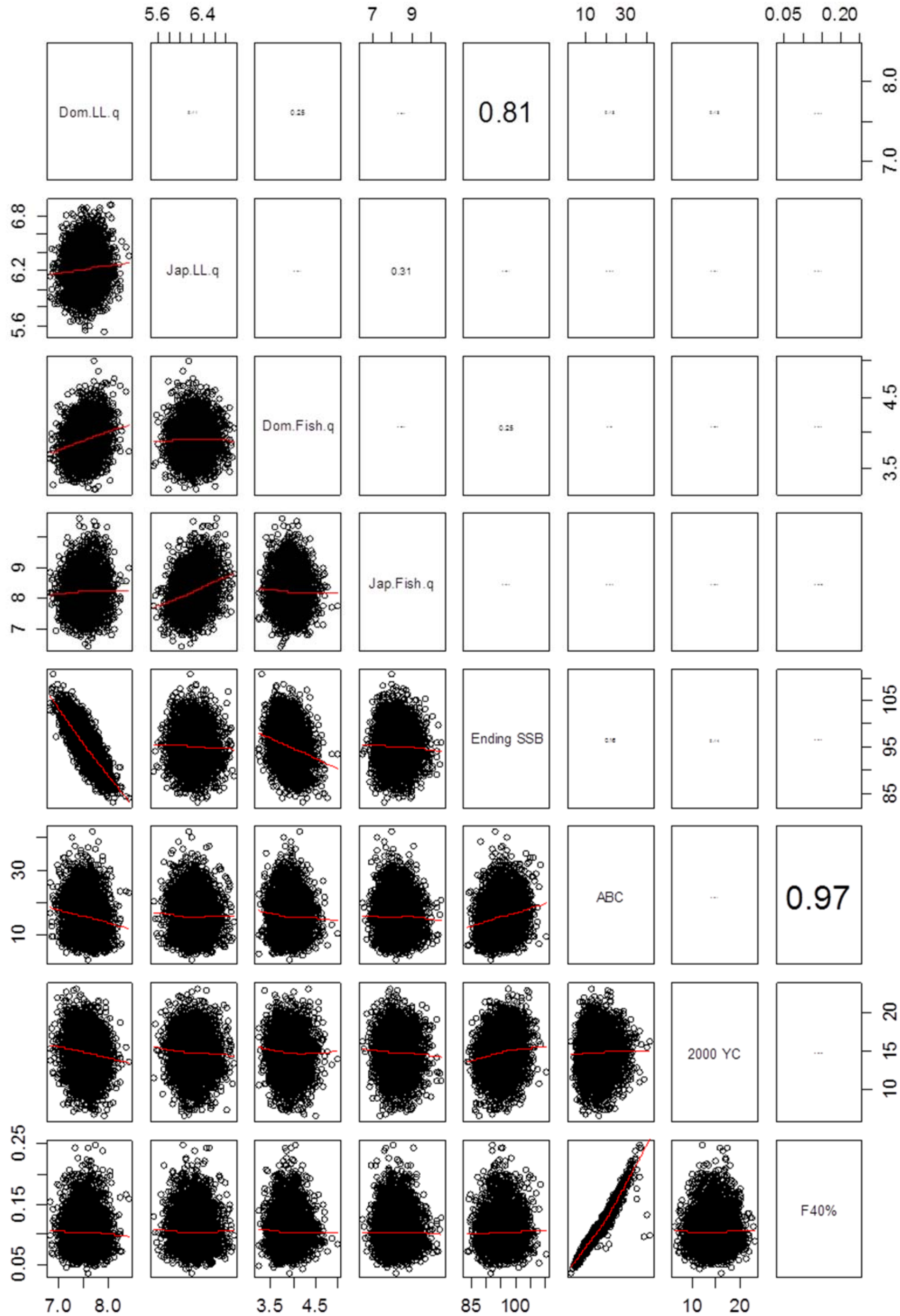

Figure 3.33. Pairwise scatterplots of key parameter MCMC runs. Red curve is loess smooth. Numbers in upper right hand panel are correlation coefficients between parameters.

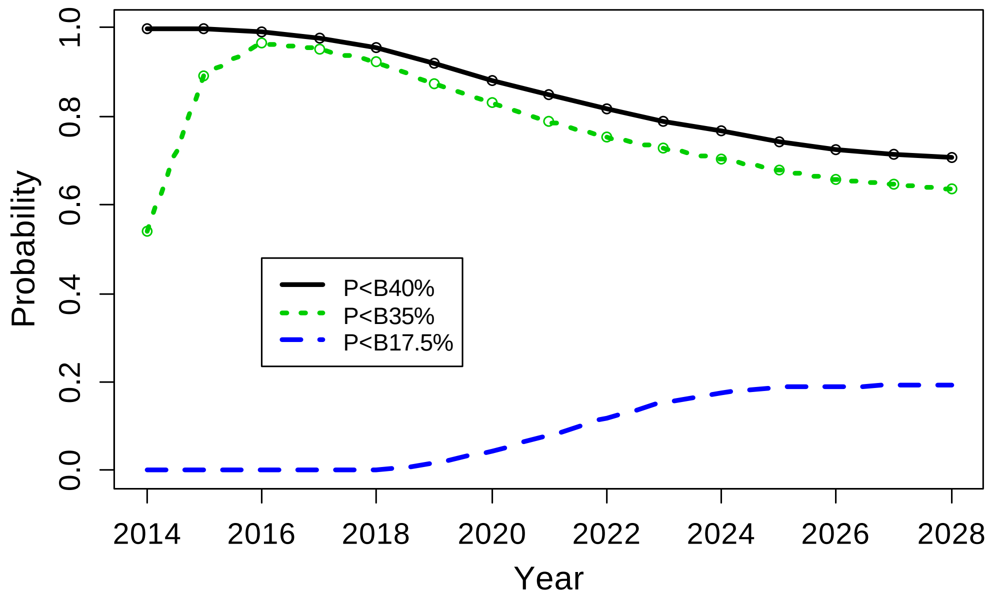

Figure 3.34. Probability that projected spawning biomass (from MCMC) will fall below $B_{40\%}$, $B_{35\%}$ and $B_{17.5\%}$.

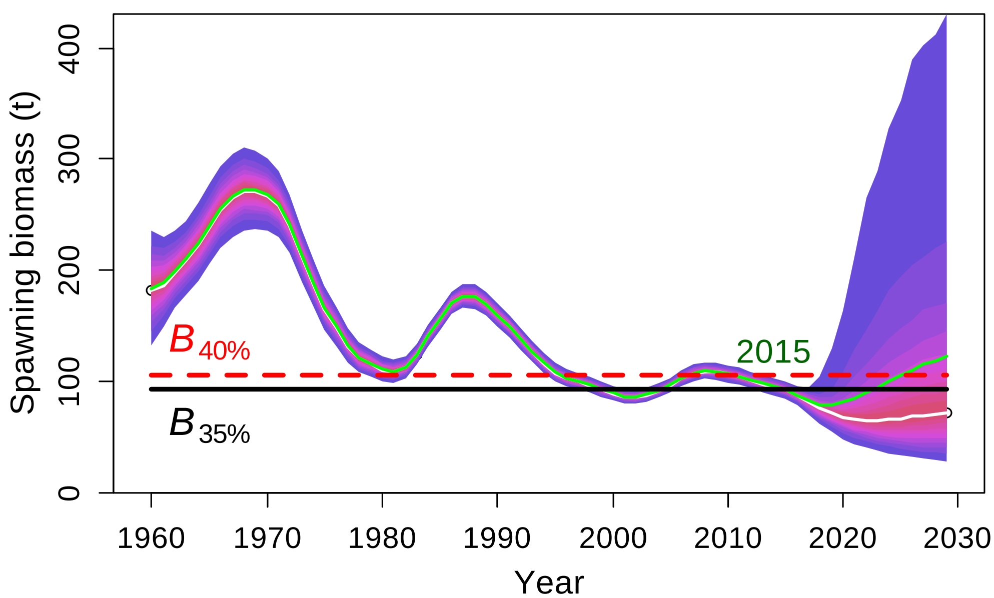

Figure 3.35. Estimates of female spawning biomass (thousands t) and their uncertainty. White line is the median and green line is the mean, shaded fills are 5% increments of the posterior probability distribution of spawning biomass based on 10,000,000 MCMC simulations. Width of shaded area is the 95% credibility interval. Harvest policy is the same as the projections in Scenario 2 (Author's F).

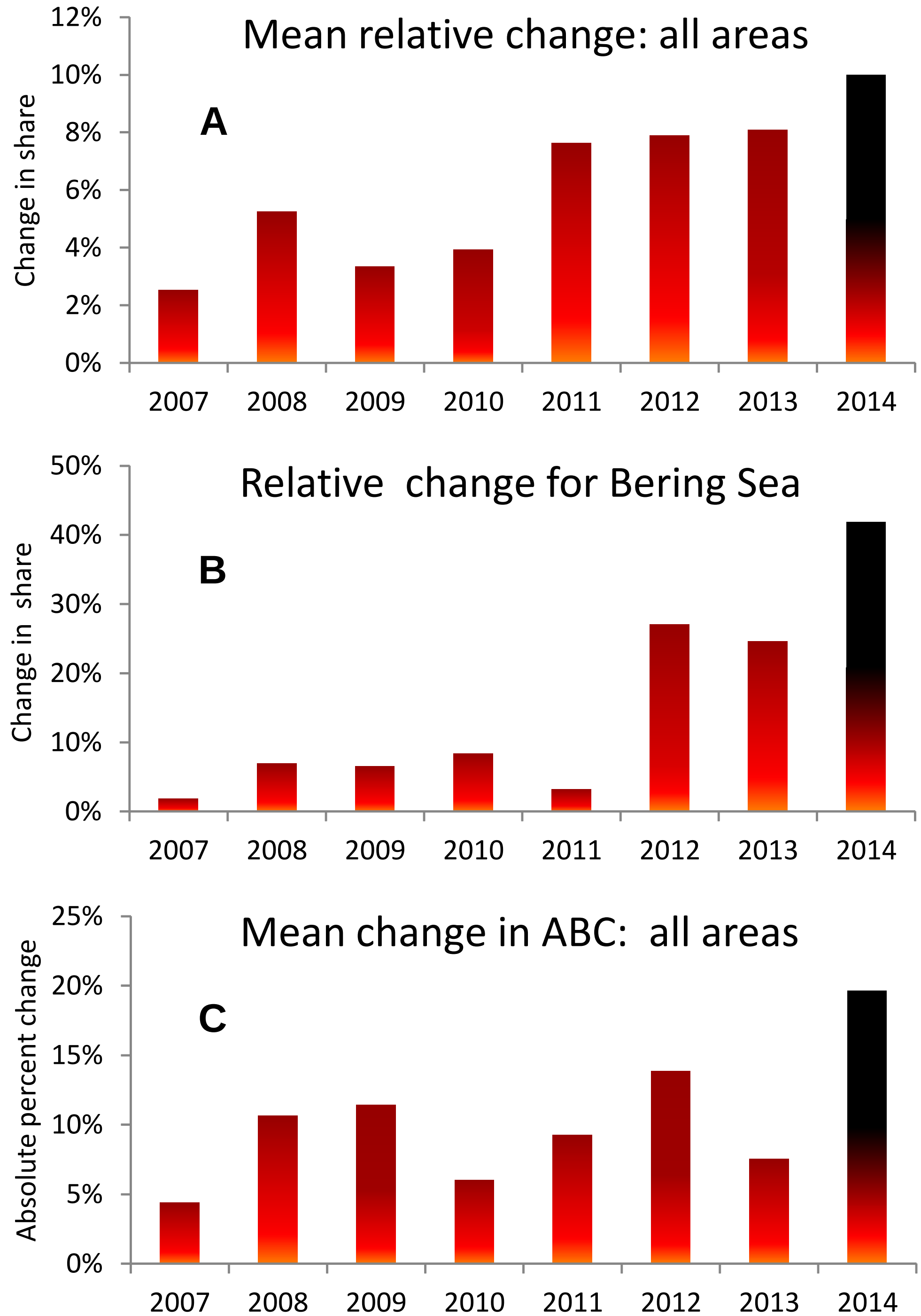

Figure 3.36. (A) The mean relative change in apportionment percentages across areas from 2007-2014. (B) The relative change in the apportionment share for the Bering Sea from 2007-2014. (C) The mean change in ABC for each area from 2007-2014.

Appendix 3A.--Sablefish longline survey - fishery interactions

NMFS has requested the assistance of the fishing fleet to avoid the annual sablefish longline survey since the inception of sablefish IFQ management in 1995. We requested that fishermen stay at least five nautical miles away from each survey station for 7 days before and 3 days after the planned sampling date (3 days allow for survey delays). Beginning in 1998, we also revised the longline survey schedule to avoid the July 1 rockfish trawl fishery opening as well as other short, but less intense fisheries.

History of interactions

Publicity, the revised longline survey schedule, and fishermen cooperation generally have been effective at reducing fishery interactions. Distribution of the survey schedule to all IFQ permit holders, radio announcements from the survey vessel, and the threat of a regulatory rolling closure have had intermittent success at reducing the annual number of longline fishery interactions.
Since 2000, the number of vessels fishing near survey stations has remained relatively low. During the past several surveys, many fishing vessels were contacted by the survey vessel and in most cases fishermen were aware of the survey or willing to help out by fishing other grounds to avoid potential survey interactions.

Longline Survey-Fishery Interactions

	Longline		Trawl		Pot		Total	
Year	Stations	Vessels	Stations	Vessels	Stations	Vessels	Stations	Vessels
1995	8	7	9	15	0	0	17	22
1996	11	18	15	17	0	0	26	35
1997	8	8	8	7	0	0	16	15
1998	10	9	0	0	0	0	10	9
1999	4	4	2	6	0	0	6	10
2000	10	10	0	0	0	0	10	10
2001	1	1	1	1	0	0	2	2
2002	3	3	0	0	0	0	3	3
2003	4	4	2	2	0	0	6	6
2004	5	5	0	0	1	1	6	6
2005	1	1	1	1	0	0	2	2
2006	6	6	1	2	0	0	7	8
2007	8	6	2	2	0	0	10	8
2008	2	2	2	2	0	0	4	4
2009	3	3	0	0	0	0	3	3
2010	2	2	1	1	0	0	3	3
2011	3	3	0	0	0	0	3	3
2012	5	5	0	0	0	0	5	5
2013	5	5	0	0	0	0	5	5
2014	2	2	0	0	0	0	2	2

Recommendation

We have followed several practical measures to alleviate fishery interactions with the survey. Trawl fishery interactions generally have decreased; longline fishery interactions have been low but continue to occur. Discussions with vessels encountered on the survey indicates an increasing level of "hired" skippers who are unaware of the survey schedule. Publicizing the survey schedule to skippers who aren't quota shareholders should be improved. We will continue to work with association representatives and individual fishermen from the longline and trawl fleets to reduce fishery interactions and ensure accurate estimates of sablefish abundance.

Appendix 3B.—Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For sablefish, these estimates can be compared to the research removals reported in previous assessments (Hanselman et al. 2010) (Table 3B.1). The sablefish research removals are substantial relative to the fishery catch and compared to the research removals for many other species. These research removals support a dedicated longline survey. Additional sources of significant removals are bottom trawl surveys and the International Pacific Halibut Commissions longline survey. Recreational removals are relatively minor for sablefish. Total removals from activities other than directed fishery were near 239 tons in 2013. This was 1.7% of the 2014 recommended ABC of 13,722. These removals represent a relatively low risk to the sablefish stock. In 2011, we conducted a model run where these removals were accounted for in the stock assessment model, and it resulted in an increase in ABC of comparable magnitude.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between “retained” or “discarded” catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program.

The HFICE estimates of sablefish catch by the halibut fishery are substantial and represent approximately 10% of the annual sablefish ABC (Table 3B.2). Sablefish and halibut are often caught and landed in association with each other by the IFQ fishery. It is unknown what level of sablefish catch reported here is already accounted for as IFQ harvest in the CAS system because the HFICE estimates do not separate retained and discarded catch. If these were strictly additive removals, 10% would represent a significant amount of additional mortality and a potential risk to the stock, but how much is additive is unknown. The HFICE estimates may represent some valuable discard information for sablefish, but that level is unknown until these estimates are separated from the IFQ landings and CAS system.

Literature Cited

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Hanselman, D. H., C. Lunsford, and C. Rodgveller. 2010. Alaskan Sablefish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.pp.

Tribuzio, C.A., S. Gaichas, J. Gasper, H. Gilroy, T. Kong, O. Ormseth, J. Cahalan, J. DiCosimo, M. Furuness, H. Shen, and K. Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 3B.1 Total removals of sablefish (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, small-mesh, GOA, AI, and BS Slope bottom trawl surveys, and occasional short-term research projects. Other is recreational, personal use, and subsistence harvest.

Year	Source	Trawl	Japan US longline survey	Domestic longline survey	IPHC longline survey*	Other	Total
1977		3					3
1978		14					14
1979		27	104				131
1980		70	114				184
1981		88	150				238
1982		108	240				348
1983		46	236				282
1984		127	284				412
1985		186	390				576
1986		123	396				519
1987		117	349				466
1988		15	389	303			707
1989		4	393	367			763
1990		26	272	366			664
1991	**Assessment of the sablefish stock in Alaska (Hanselman et al. 2010)**	3	255	386			645
1992		0	281	393			674
1993		39	281	408			728
1994		1	271	395			667
1995		0		386			386
1996		13		430			443
1997		1		396			397
1998		26		325	50		401
1999		43		311	49		403
2000		2		290	53		345
2001		11		326	48		386
2002		3		309	58		370
2003		16		280	98		393
2004		2		288	98		387
2005		18		255	92		365
2006		2		287	64		352
2007		17		266	48		331
2008		3		262	46		310
2009		14		242	47		257
2010		3		291	50	15	359
2011	AKRO	9		273	39	16	312
2012		4		203	27	39	273
2013		4		178	22	35	239

* IPHC survey sablefish removals are released and estimates from mark-recapture studies suggest that these removals are expected to produce low mortality. Some state removals are included.

Table 3B.2. Estimates of Alaska sablefish catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. AI = Aleutian Islands, WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Western/Central AI	27	19	34	18	14	11	36	44	17	23
Eastern AI	18	16	46	26	20	6	4	13	6	7
WGOA	10	9	12	22	21	16	7	12	3	12
CGOA-Shumagin	184	27	36	65	60	47	21	38	10	37
CGOA-Kodiak/ PWS*	802	107	96	89	82	49	57	33	69	63
EGOA-Yakutat	110	324	291	258	240	149	175	103	207	195
EGOA-Southeast	339	335	389	315	269	242	230	184	242	262
Southeast Inside*	459	1,018	1,181	917	786	739	701	574	731	805
Total	1,948	2,231	2,346	2,469	2,194	2,476	1,937	1,874	1,921	1,594

*These areas include removals from the state of Alaska.

Appendix 3C: Alaska sablefish research update

Dana Hanselman, Brian Pyper, Chris Lunsford, Cara Rodgveller, and Megan Peterson

Executive Summary

In this appendix we describe some completed and ongoing sablefish research related to stock assessment. New modeling results for estimating the effects of whale depredation are described. In addition, a number of sensitivity model scenarios were conducted that incorporated some of the results of this research. Each section below provides a brief summary of current research and includes model scenarios related to that research. We also provide guidance for future research projects.

Whale depredation and survey modeling

Accounting for whale depredation

Background

Whale depredation has been an ongoing source of uncertainty for the sablefish assessment. Killer whale depredation of the sablefish catch on the longline survey has been a problem in the Bering Sea since the beginning of the survey (Sasaki, 1987). Depredation by killer whales has since been documented commonly in the Aleutian Islands, Bering Sea, and Western Gulf of Alaska. Since 1990, the depredated hachis (skates of 45 hooks), which were identified as depredated by a combination of damaged fish and damaged hooks, were excluded from calculations of abundance indices. At some stations this might result a large number of hachis being removed, or the entire station being removed from abundance calculations. From 1998-2012, the percentage of skates depredated ranged from 12.3 - 55.0% per year in the BS, from 0 - 19% per year in the AI and from 0 - 41% in the WGOA. In management areas like the Bering Sea where there is limited sampling, this can lead to very few stations left to calculate abundance. In addition, if killer whales are non-randomly depredating stations where fish are typically most abundant; this can lead to a downward bias of the index.

Sperm whale depredation has only been documented since 1998. Historically, sperm whale depredation was occurring in the two Eastern Gulf of Alaska (GOA) management areas, but has recently become more common in the Central GOA and occasionally occurs in the Western GOA. Apparent sperm whale depredation on the longline survey is defined as sperm whales being observed and the occurrence of damaged fish. In contrast to killer whale depredation, sperm whale depredation is much more difficult to detect because sperm whales often take only a few fish, and rarely leave behind depredation evidence such as damaged fish or hooks like killer whales. Because actual depredation is difficult to detect, and therefore difficult to document by haul or specific hachis, we use sperm whale presence at a station as a proxy for depredation. Sperm whale presence and evidence of depredation has been variable since 1998 (see figure below).

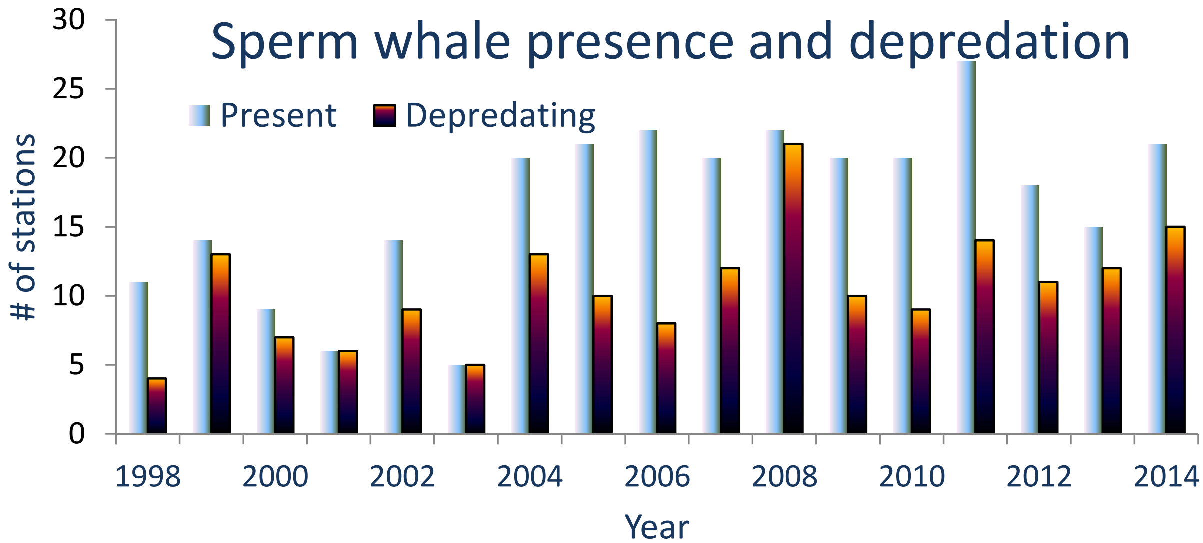

Figure: Sperm whale depredation and presence on the AFSC longline survey since 1998.

A number of studies have examined whale depredation in different ways. An early study using data collected by fisheries observers in Alaskan waters found no significant effect on catch (Hill et al. 1999). In the 2002 SAFE, an analysis was completed using longline survey data from 1998-2001 and found that sablefish catches were significantly less at stations affected by sperm whale depredation. This work was redone in 2006 using additional data from 2002-2004 and general linear models (Sigler et al. 2007). This 2007 study found that neither sperm whale presence ($p = 0.71$) nor depredation rate ($p = 0.78$) increased significantly from 1998 - 2004. Catch rates were about 2% less at locations where depredation occurred, but the effect was not significant ($p = 0.34$). This analysis was updated through 2009 and showed a significant effect of approximately four kilograms per hundred hooks for stations in the CGOA and EGOA, which translates into approximately a 2% decrease in the overall catch rates in those areas (J. Liddle pers. comm.). Another study, using data collected in southeast Alaska, found a small, significant effect comparing longline fishery catches between sets with sperm whales present and sets with sperm whales absent (3% reduction, 95% CI of 0.4 – 5.5%, t-test, $p = 0.02$, Straley et al. 2005).

Hanselman et al. (2010) applied zero-inflated negative binomial models to estimate the effect of sperm whale and killer whale depredation on the longline survey by individual management areas. They estimated that sperm whales decreased the EY/SE area index by 1-10% annually (which we do not correct for), while killer whales affected the Western GOA index by 5-30% annually (which we do correct for). Peterson et al. (2013) used similar methods to estimate depredation effects of killer whales on fishery catch rates of six species including sablefish, Pacific cod, and halibut. They estimated that killer whales when present removed 54-72% of sablefish.

Given perfect data, most of these studies would have provided adequate estimates of the effects of whales. However, the occurrence of whale depredation is sporadic which creates unbalanced data. Analysis of unbalanced designs using fixed-effects models can result in poor estimation and inference compared to mixed-effects models (Zuur et al. 2009). The utility of accounting for depredation effects on survey estimates depends on the precision of model estimates as well as the nature of depredation effects. In particular, if depredation effects are themselves highly variable (e.g., reductions in catch differ appreciably from one event to the next, like for killer whales), then it may not be advisable to “correct” for depredation using a single point estimate derived across numerous depredation events. Other options, such as discarding data from depredated skates, may provide preferable survey estimates.

Since Hanselman et al. (2010), we have conducted simulations and model comparisons to show that a generalized linear mixed effect model (GLMM) performs better than previous modeling methods, in terms of both accuracy and capturing an appropriate amount of uncertainty. Preliminary simulations suggested that a sperm whale correction derived from a GLMM performs well, whereas the benefits of a GLMM model correction for killer whales performed similarly to the current practice of discarding depredated skates. The methods used for estimating sperm and killer whale depredation were similar, but for the purposes of this document we focus on sperm whales. The following section includes a brief description of models compared for sperm whale depredation.

Model structure

The basic structure of the survey data is as follows: year (t), area (i), depth stratum (j), and station (k), where stations are nested within areas. At each station, numerous hachis (skates of 45 hooks) are fished and later assigned to depth strata. Stations are the primary unit of spatial replication, while hachis are essentially pseudo-replicates (subsamples) collected within stations. Modeling data at the hachi level is difficult because of large sample sizes and potential spatial autocorrelation among hachis. Peterson et al. (2013) used a simple and robust alternative, which was to model aggregated data by summing catch and effort (effective hooks fished) across hachis for each year/stratum/station combination. We adopt this approach as well.

A log-linear model of CPUE that accounts for the full structure of the survey data across years (Y_t), areas (A_i), depth strata (D_j), and stations (S_k) is given by:

(1) $$\log(C_{tjk[i]}) = \log(H_{tjk[i]}) + Y_t + A_i + D_j + (YA)_{ti} + (YD)_{tj} + (AD)_{ij} + (YAD)_{tij} + S_{k[i]} + (YS)_{tk[i]} + (DS)_{jk[i]} + (YDS)_{tjk[i]} ,$$

where the subscript $k[i]$ indicates that station k is nested in area i, C denotes aggregated catch (summed across hachis), and H denotes total effective hooks (summed across hachis). The term H is a constant that is specified as an “offset” in model fitting (Venables and Ripley 2002, p. 189). Model (1) is “fully saturated” because it includes all main-level effects (Y_t, A_i, etc.) and two-way and three-way interactions, right up to the level of the aggregate data themselves with $(YDS)_{tjk[i]}$. Thus, the theoretical importance of model (1) is that it contains the full factorial structure at which we expect variation in CPUE, that is, up to and including differences among year/stratum/station combinations, i.e., $(YDS)_{tjk[i]}$. With model (1) in mind, we outline the alternative models used to estimate depredation effects of sperm whales.

Model fitting proceeded in two stages, first with area-specific models and then across-area models. Areas with stations flagged for sperm whale depredation included WGOA, CGOA, WY, and EY/SE. For each area, we compared fits of five models. The first three models had a form similar to that used by Peterson et al. (2013):

(2) $$\log(C_{tjk}) = \log(H_{tjk}) + Y_t + D_j + S_k + (YS)_{tk} + \lambda F_{tk} ,$$

where the coefficient λ denotes the effect of depredation, and F is an indicator (dummy) variable for depredation ($F = 1$ when a station is flagged for depredation and $F = 0$ otherwise). The first model was a quasi-Poisson (QP) model, which is an *ad hoc* approach to account for over-dispersion in count data (Venables and Ripley 2002, p. 208; fit using the `glm` function in R). The second model was a negative binomial (NB) model, as used by Peterson et al. (2013), which assumes that aggregate catches C_{tjk} follow a negative binomial distribution (Venables and Ripley 2002, p. 206; fit using the `glm.nb` function of the MASS library in R). The QP and NB models are generalized linear models (GLMs) that treat all terms as *fixed effects* (Venables and Ripley 2002, p. 271). Both models have been widely used to address over-dispersion in count data, although model results and suitability can differ appreciable between them (Ver Hoef and Boveng 2007).

The third model (denoted ME.1), also based on the structure in equation (2), was a mixed-effects model assuming a Poisson distribution for C_{tjk} (in this context, a generalized linear mixed model or GLMM; Zuur et al. 2009). Specifically, the terms for year (Y_t), station (S_k), and their crossed interactions $(YS)_{tk}$ were treated as *random effects* instead of fixed effects. Each random-effects term was assumed to follow a normal distribution, e.g., $Y_t \sim \mathrm{N}(0,\ \sigma_Y^2)$. With respect to the survey data, the key potential benefit of a mixed model is to obtain robust estimates despite a highly unbalanced design.

The final two models, which were also Poisson mixed models, had a complete factorial structure for the area-specific survey data:

(3) $$\log(C_{tjk}) = \log(H_{tjk}) + Y_t + D_j + S_k + (YD)_{tj} + (YS)_{tk} + (DS)_{jk} + (YDS)_{tjk} + \lambda F_{tk}.$$

In the fourth model (ME.2), all terms were treated as random effects except for depth strata means (D_j) and the depredation effect (λ). The addition of $(YDS)_{tjk}$ in equation (3) saturates the model, providing an individual random effect for each observation of aggregated catch, C_{tjk}. Such an approach is used to account for overdispersion in Poisson mixed models (e.g., Gelman and Hill 2007, p. 326). In our context, the variance of *YDS* will reflect natural variation in mean CPUE among year/strata/station combinations, as well as additional overdispersion accrued via summing catches across hachi.

The last model (ME.3) examined evidence of variation in depredation effects. Up to this point, it has been assumed that depredation effects are essentially constant across events (i.e., year/station combinations), and thus modelled via a single coefficient λ. However, if there was considerable variation in depredation effects, it would be evident in the data. Such variation would be superimposed upon the natural year/station variation in CPUE, which was modelled as $(YS)_{tk} \sim \mathrm{N}(0, \sigma_{YS}^2)$ in ME.2. Suppose the depredation effect followed $\lambda_{tk} \sim \mathrm{N}(\lambda, \sigma_\lambda^2)$. Assuming independence, the variance of year/station effects would equal $\sigma_{YS}^2 + \sigma_\lambda^2$ with depredation ($F = 1$), and σ_{YS}^2 otherwise ($F = 0$). Thus, to estimate potential variation in depredation effects in ME.3 models, we added a random-effects term $(YS)_{tk,F=1}$ for depredation events only (i.e., the variance of this term represents the *additional* variance associated with depredation events). All mixed-effects models were fit using the restricted maximum likelihood method of the `glmer` function in R (R Core Team 2012).

In summary, we fit five models (QP, NB, ME.1, ME.2, ME.3) to each area to test for depredation effects of sperm whales. In addition, we examined two different depredation flags (F) that have been recorded for year/station combinations. The first flag indicated a sperm whales sighting, while the second, less prevalent flag indicated evidence of depredation (damaged fish, hooks, etc.).

Area-specific model results

Across years 1998-2012, a total of 1154 year/station combinations were examined in models of sperm whale depredation (Table 3C.1). Of these, 241 (21%) were flagged for depredation based on presence (Flag 1), while only 149 (13%) were flagged based on evidence (Flag 2). Proportions of flagged units were lowest for the WGOA region and highest for WY (Table 3C.1).

Based on Flag 1, estimates of sperm whale depredation (λ) differed appreciably among areas, and in particular, among models (Table 3C.2). For WGOA, which had limited depredation data (Table 3C.1), the QP and NB models gave nonsensical estimates (with huge standard errors) that implied huge proportional increases in CPUE due to depredation (Table 3C.2). In contrast, the three ME models provided similar and reasonably precise estimates; however, these estimates implied slight positive effects of depredation (e.g., a proportional change of 1.12 or a 12% increase in CPUE) and were not significant (P > 0.2).

Depredation estimates were more consistent for the remaining three regions (Table 3C.2). For CGOA, estimates were generally weak and none were significant (all P > 0.37). Estimates for WY varied widely across models implying proportional changes of 0.96 (a 4% reduction of CPUE) for model QP, 0.44 (56% reduction) for NB, and roughly 0.8 (20% reduction) for the ME models. All ME estimates were significant ($P \leq 0.001$). Likewise, for EY/SE, the QP and NB estimates were quite different and imprecise (high SEs), while ME estimates were consistent (~17% reductions), precise, and significant ($P < 0.001$).

Depredation estimates for Flag 2 showed similar patterns (Table 3C.3). Note that WGOA was excluded because this region had only one flagged unit (Table 3C.1). Across regions, the QP and NB models provided imprecise estimates that often differed strongly from those of the ME models. In general, the ME estimates indicated reductions in CPUE due to sperm whale depredation of roughly 10% for CGOA (all $P > 0.14$), 12 to 18% for WY ($P < 0.015$), and 19% for EY/SE ($P < 0.001$).

The components of variation in CPUE data differed considerably across regions. Variance estimates are reported for ME.3 models using Flag 1, with depth strata (*D*) treated as a random effect (Table 3C.4). For example, differences among depth strata (*D*) accounted for just 10.5% of the variation in CPUE for CGOA, but 50.5% for EY/SE. Our interest lies in the additional year/station variation due to depredation. Without depredation, the standard deviation of year/station random effects (*YS*) ranged from a low of 0.21 for EY/SE to a high of 0.36 for WGOA. There was mixed evidence of additional variation due to depredation events. The largest value of SD($YS_{F=1}$) was 0.24 for CGOA, implying an additional 10.6% variation in CPUE among depredated units due to variability in the effect of depredation. Slightly higher estimates for SD($YS_{F=1}$) were found for Flag 2 data (0.30 for CGOA, 0.23 for WY, and 0.16 for EY/SE). However, as noted below, such values for SD($YS_{F=1}$) are likely to have little consequence for model estimation of depredation effects.

Given the often divergent estimates of whale depredation provided by the QP, NB, and ME models, we conducted detailed simulations to determine the expected accuracy and precision of competing model estimates. These simulations demonstrated that for unbalanced datasets (i.e., sporadic whale depredation events across stations and years), the ME models provided vastly superior estimates of whale depredation compared to the QP and NB models (both in terms of point estimates and standard errors). Despite their structural differences, all three ME models performed similarly well, even when the simulated data included random effects for depredation (e.g., simulated SD($YS_{F=1}$) = 0.2), which is a component only included in the ME.3 model structure.

Across-area models

Based on the simulation results noted above, analysis of across-area models was limited to mixed models with complex structure. For sperm whales, four mixed models were fit to data across all areas. These models started with the structure defined in equation (1), treating area (A_i), depth stratum (D_j), and their interaction $(AD)_{ij}$ as fixed effects and all remaining terms as random effects. The first model (S.1) estimated the mean effect of depredation by including the term F_{tk}. Model S.1 also accounting for potential variation in depredation effects across events by including a random-effects term $(YS)_{tk,F=1}$. Building on S.1, the second model (S.2) tested for differences in depredation effects among areas by including the interaction $(AF)_{itk}$. The third and fourth models examined evidence of a time trend in depredation effects. The third model (S.3) included a random-effects term for depredation by year ($Y_{t,F=1}$). The fourth model (S.4) included explicit linear trends (fixed effects) modelled as $T_t + (TF)_{tk}$, where T denotes year treated as a continuous variable. This formulation provides estimates of the trend in non-depredated CPUE and the difference in trend associated with depredation. The four across-area models were fitted separately to data for the two sperm whale flags (“presence” and “evidence”).

Using Flag1 (presence), the across-area estimate for sperm whale depredation implied a proportional change in CPUE of 0.88 (95% CI: 0.83-0.94), that is, a 12% reduction in CPUE (model S.1, Table 3C.5). However, there was evidence of area differences in the depredation effect. Model S.2, which included area effects, had a lower AIC than S.1 ($\Delta AIC = 8.4$) and a significantly better fit based on the likelihood-ratio test (LRT, $P = 0.002$). Area-specific estimates of proportional change ranged from 0.77 for WY to 1.10 for WGOA (Table 3C.5). Obviously, the estimate for WGOA is not biologically valid (i.e., sperm whale depredation cannot increase CPUE). However, after removing WGOA, estimates for models S.1 and S.2 changed little, and areas differences remained significant (ΔAIC = 6.4; LRT P = 0.006).

In contrast, there was weak evidence of area differences for Flag 2 (evidence). (These analyses excluded the WGOA region because it had only one depredated unit.) The across-area estimate of depredation implied a proportional change in CPUE of 0.84 (a 16% reduction; model S.1, Table 3C.5), while area-specific estimates ranged from 0.80 for EY/SE to 0.94 for CGOA (model S.2). However, the area-specific model (S.2) had a slightly higher AIC and did not significantly improve fit (LRT, P = 0.25). In addition, there was stronger evidence of variation in depredation effects using Flag 2 (SD[$YS_{F=1}$] ~ 0.2) than for Flag 1 (SD < 0.06) (Table 3C.5).

There was little evidence of time trends in the effects of sperm whale depredation. There was no discernable pattern in year-specific random effects for depredation (model S.3) for either Flag 1 or Flag 2 models, and linear trend estimates for depredation (model S.4) were positive and weak in both cases (P = 0.35 for Flag 1 and P = 0.24 for Flag 2).

Summary and applications

We conclude that mixed-effects modelling is the most promising method for estimating the effect of depredation for sperm whales. Our results did not show a time varying trend in the effect of depredation or presence when they occur (however, incidence of depredation and presence have been increasing). We also found that it was difficult to estimate depredation effects for data sparse regions (WGOA and CGOA). We found similar results using either sperm whale presence or evidence of depredation, but we are more confident in the quality of the presence data. Given these results, we recommend when implemented that an area-wide effect of sperm whale presence and variance be estimated and used as a correction to abundance indices. **The CPUE expansion factor from this analysis is 1.14 for stations where sperm whales are present.** This expansion factor should be re-estimated every few years to ensure it is not changing from the applied estimate. We show applications of the estimated sperm whale depredation from these GLMM models in the ***Applications to the stock assessment*** section using model runs OAW, NAW, NAWK, and NAWA). The effect on the overall abundance index (e.g., Figures 3C.1, 3C.2) is an increase of between 2-5% after accounting for sperm whale depredation.

While we believe we have determined a useful correction for sperm whales, and possibly killer whales, it remains questionable when and whether to utilize these corrected indices in the assessment. First, we do not know the extent of sperm whale depredation prior to 1998 in the survey. Considering its apparent increase, we believe historically it may have been a minor impact, but it is an added uncertainty. Second, it may not be prudent to adjust for whale depredation in the survey and increase the estimates of spawning biomass and ABC, while still not accounting for the additional mortality in the fishery that can be attributed to whale depredation. We regard accounting for this additional mortality in the fishery as the second phase of this project, in which we will use similar modeling methods. The data available to estimate mortality in the fishery are sparse and obtaining precise estimates will be challenging. A post-doctoral researcher from the National Research Council will be starting in December 2014 to aid in this project. Finally, adjusting apportionment in relation to the variable whale depredation across areas is also an important consideration. A more detailed document or journal article addressing modeling sperm whale and killer whale depredation and application to the sablefish stock assessment is forthcoming.

Applications to the stock assessment model

We conducted a number of sensitivity models with different potential mechanisms of accounting for mortality by sperm whale depredation on the survey and in the fishery (Table 3C.6). There are a variety of ways one might consider accounting for this mortality. In Table 3C.6 there are 21 model runs that have some scenario that could be related to whales. The major scenario groups are variations on the following five themes with what we consider to be plausible “low” and “high” states of nature:

1) Whale depredation is a source of fishing mortality, and it occurs on longline gear.
2) Whale depredation is an increase in natural mortality, as in the sablefish vulnerability to predators has been increased
3) Whale depredation began in 1998
4) Whale depredation has occurred throughout the modeled time series
5) Whale depredation has reduced survey catch rates

Most scenarios gave reasonably similar predictions for key parameters (Table 3C.7).The lowest ABC projection was for the ICB scenario which added an increasing amount of catch to the fixed gear fleet since 1998. The highest ABC projections occurred for those scenarios where either natural mortality or survey RPNs was monotonically increasing since 1998 (IMB, ISB, Figure 3C.3). As expected, most scenarios showed higher spawning biomass, ABCs, and recruitment from the reference model (BASE, Table 3C.6, and Figure 3C.3). The range of estimates of female spawning biomass appear to be relatively insensitive to these different accounting of whale depredation (Figure 3C.4, Table 3C.8). However, when we look only at the recent series of female spawning biomass estimates in terms of absolute and relative differences (Figures 5, 6), the effects can be more easily perceived and appear more substantial. We believe that this range of scenarios sets reasonable boundaries on how accounting for whale depredation inside the stock assessment would affect model results. Some of the ABCs resulting from these scenarios are considerably larger than the reference case. However, it would be expected that if ABCs are increased by correcting for survey depredation, it would be necessary to somehow decrement those ABCs for the additional mortality caused by depredation in the fishery.

Variance estimation and missing areas

The longline survey index currently uses a fixed CV of 5% for sablefish in the stock assessment model. Some bootstrap analyses were conducted to arrive at this number (Sigler 2000), but it was an approximation because there is covariance between depth strata within a station and between station depth strata combinations. We have since developed more appropriate analytical variance estimates that include covariances and the additional variance introduced by correcting for whale depredation. For the most part, the coefficients of variation (CVs) for the all-area index were not on average much different than the assumed 5%. However, there is some interannual variability, and the method now provides variance estimates for smaller geographic regions, which will be useful for spatial models and other groundfish assessments that utilize the longline survey index. The estimated coefficients of variation for sablefish from 1990-2013 are shown in Figure 3C.7.

The Aleutian Islands (AI) and Bering Sea (BS) are sampled biennially. The abundance index for the unsampled years are filled in using the previous survey of the area scaled by the average change in the Gulf of Alaska areas, which are sampled annually. In this case, the average GOA index is calculated from the four management areas in the GOA. This approach has an obvious drawback if the six areas are relatively uncorrelated in trend. For example, when the observed mean catch/hachi is plotted by area, it is clear that the Bering Sea index is not positively correlated with any of the other areas, and the Aleutian Islands area is significantly negatively correlated with the Central Gulf of Alaska. Therefore, using this approach across all areas may result in a retrospective bias if estimates in unsampled areas do not match the underlying trend for that area. To fill in the missing years, we demonstrated two alternative methods that have been shown to be useful by the Plan Team working group on survey averaging. In our sensitivity results we show the effect of using an ARIMA (0,2,2, local linear smoothing) model and a random effects model to fill in the BS and AI missing years from 1996-2013. The choice of which of these methods is superior is not yet clear, but they have large effects on the overall RPN index in some years (Figure 3C.8). These are shown in models NAWA and NAWK in Table 1.

New survey area sizes

Previous estimates of the size of each geographic area used to estimate RPNs and RPWs were devised before geographic information systems (GIS) and accurate, high resolution bathymetric maps were readily available. Echave et al. (2013) estimated the area sizes currently used in the AFSC longline survey using GIS methods and updated bathymetry. The largest increase in estimated area sizes occurred in Spencer Gully (in the EY/SE management area) and Bering 3 slope areas (Figure 3C.9). The largest negative changes were in the NW Aleutians slope and East Yakutat slope areas. Overall, more areas were calculated to be smaller than the previously used estimates. Only the shallowest depth stratum used in standard RPN/RPW calculations (200-300 meters) increased, while the areas in deeper depths decreased slightly (Figure 3C.10). In addition, Echave et al. (2013) estimated the size of the areas in the depths sampled between 150-200 m which previously were not used in abundance index calculations. The addition of these depths in the RPN/RPW index increases the potential utility of the longline indices for species such as Pacific cod, halibut and rockfish. We show the effect of the area recalculation on the overall sablefish RPN index for the base model (Figures 11, 12) and in model runs beginning with OA, and NA in Table 3C.6.

Maturity research

The first age at maturity and fecundity study of female sablefish sampled in Alaska near their spawning period was undertaken in 2011. Skipped spawning was documented for the first time in sablefish. These winter samples provided a similar age at 50% maturity estimate (6.8 years) as the mean of visual observations taken during summer surveys from 1996-2012 (mean = 7.0 years) and the estimate currently used in the assessment (mean =6.6 years), when skipped spawners were classified as mature. Interestingly, skipped spawning appeared to be occurring for a substantial portion of the older mature population in shallower shelf waters which could have implications for population dynamics. In addition, four female sablefish were fit with pop-off satellite tags during the winter survey. Despite being a highly migratory species throughout their lives, preliminary results of this tagging data suggest that these sablefish exhibited site fidelity during the spawning season. This may be related to whether a fish is spawning in the current season. The paper describing the study is in the process of being submitted for publication.

Movement

A study on sablefish movement and mortality has been accepted for publication. The analysis included over 300,000 tag releases and over 27,000 tag recoveries from 1979-2009. Movement was modeled in three size groups, small (<57 cm), medium (57 – 66 cm), and large (>66 cm) which corresponded approximately to immature, maturing, and mature fish. Annual movement probabilities were high, with annual probabilities ranging from 10-88%, depending on area of occupancy at each time step, and size group. Overall, movement probabilities were very different between areas of occupancy and moderately different between size groups (Figure 3C.13). Estimated annual movement of small sablefish from the Central GOA had the reverse pattern of a previous study using a small subset of these data, with 29% moving westward and 39% moving eastward. The previous study showed movement of small fish to be primarily westward. Movement probabilities in the current study also varied annually with decreasing movement until the late 1990s, and increasing movement until 2009. Year specific magnitude in movement probability of large fish was highly negatively correlated with the total female spawning biomass estimate from the federal stock assessment. This may indicate that slower somatic growth at high population sizes leads to lower movement probabilities. Total average mortality estimates from time at liberty were similar to the values estimated by the stock assessment model. Results do not show an obvious ecologically directed movement pattern. The analysis in this study was conducted using sablefish lengths, but efforts are underway to read ages from a sample of otoliths taken from tag recoveries. These data will aid in estimating age-specific movement and be more useful for conducting management strategy evaluations of spatial stock assessment models.

Fishery abundance index

Estimating abundance from fishery dependent data is a well known challenge. Alaska sablefish is the only model in Alaska that incorporates fishery CPUE data as an index of abundance. Presently, longline CPUE is determined through a targeting algorithm, but not statistically standardized. During a one year National Research Council appointment, Mateo and Hanselman (2014) developed several statistical models that appear to hold promise for modeling fishery CPUE for standardization. Covariates that explained the most variation in the models were CPUE of giant grenadier, depth, longitude, and Pacific halibut CPUE. We wish to extend these models to develop an index for use in the sablefish model, and to potentially estimate whale depredation effects on the fishery. This work will continue as a new postdoctoral researcher from the NRC joins us in December, 2014.

Apportionment

In 2013, we recommended that the apportionment proportions to each area be fixed at 2012 values. We justified this because the apportionment strategy was devised to reduce interannual variability in catch recommendations while still reflecting shifts in abundance. We showed that this variability in catch recommendations by area had been increasing since 2007. While some of these changes may actually reflect interannual changes in regional abundance, they most likely reflect the high movement rates of the population and the high variability of our estimates of abundance in the Bering Sea and Aleutian Islands due to whale depredation and estimating abundance index values in years when these areas are not sampled.

Because of the high variability in apportionment seen in recent years, we suggested that the standard method was not meeting the goal of reducing the magnitude of interannual changes in the apportionment. We, therefore, proposed that the apportionment scheme be reevaluated.

A Ph.D. project with the University of Alaska-Fairbanks was initiated in 2012 to conduct management strategy evaluations to re-examine the apportionment strategy with respect to biological and economic yield. The student involved has been working closely with us and has begun testing spatial sablefish stock assessment models to be used in evaluating apportionment. It will also be important to integrate continuing research into whale depredation effects into analyses regarding the implications of different apportionments. The apportionment strategies being tested will focus on objectives that include but are not limited to:

1) Reduce annual variation in TAC changes
2) Maximizing economic yield by region and for the total fishery
3) Maximizing sustainable yield by region and for the total fishery
4) Maintaining a minimum level of harvest in every region

Some apportionment strategies that may attain these goals may include:

1) Status quo (5 year exponential average of fishery and survey abundance)
2) Apportion from terminal year abundance of a spatially explicit model
3) Apportion based on a longer term (e.g., 10 year) average
4) Equal allocation (Divide TAC by the number of regions)
5) Apportion based on size or numbers (to protect spawning biomass)

Meanwhile, for the same reasons we presented in 2013, until the apportionment scheme has been adequately evaluated it seems prudent to keep the apportionment fixed until there are other viable options to be considered. Therefore, for 2015, we recommend keeping the apportionment fixed from 2014, so that all areas ABCs change equally in accordance with the model results.

Future

There has been much recent research progress on sablefish stock assessment. However, several major challenges remain that include estimating and accounting for whale depredation in the fishery, evaluating the current apportionment strategies, developing a spatial research model of sablefish that includes movement, and determining the ecological basis of year class strength. There is ongoing or planned research for each of these challenges. We are trying to develop a portfolio of complementary model changes before implementing work already accomplished because many changes require other work to balance them. The most obvious example is accounting for whale depredation. We have the potential to correct survey estimates now, but developing estimates for the fishery that account for whale depredation is more difficult. Because it is fishery data, it is noisy, and the observations of depredation are sparse and unbalanced. Thus, we can develop these estimates but they will be less certain than those we can obtain for the survey. In addition, part of our fishery abundance index includes logbook data which do not include whale depredation observations. Until we have both fishery and survey estimates and a good way to use them in concert, it would be unwise to apply one alone. We will be conducting a sablefish CIE review in 2016.This review will provide expert opinion regarding the results of these research projects and provide advice to help integrate the findings into the sablefish stock assessment. We then hope to incorporate this work into the assessment model and bring forward a benchmark assessment.

References

Echave, K., C. Rodgveller, and S.K. Shotwell. 2013. Calculation of the geographic area sizes used to create population indices for the Alaska Fisheries Science Center longline survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-253, 93 p.

Hanselman, D. H., Fujioka, J., Lunsford, C., and Rodgveller, C. 2010. Alaska Sablefish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2011. Appendix C. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Hill, P. S., Laake, J. L., and Mitchell, E. 1999. Results of a pilot program to document interactions between sperm whales and longline vessels in Alaska waters. NOAA Tech. Memo. NMFS-AFSC-108. 42 p.

Mateo, I., and D. H. Hanselman. 2014. A comparison of statistical methods to standardize catch-per-unit-effort of the Alaska longline sablefish fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-269, 71 p.

Peterson, M.J., F. Mueter, D.H. Hanselman, C.R. Lunsford, C. Matkin, and H. Fearnbach. 2013. Killer whale (Orcinus orca) depredation effects on catch rates of six groundfish species: Implications for commercial longline fisheries in Alaska. ICES J. Mar. Sci. doi: 10.1093/icesjms/fst045.

R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/

Sasaki, T. 1987. Stock assessment of sablefish in the eastern Bering Sea, Aleutian Islands region, and the Gulf of Alaska in 1987. Unpubl. Rep., 33 p. Far Seas Fish. Res. Lab., Japan Fish Agency, 7-1, Orido 5 chome, Shimizu 424, Japan.

Sigler, M.F., Lunsford, C.R., Straley, J.M. and Liddle, J.B. 2007. Sperm whale depredation of sablefish longline gear in the northeast Pacific Ocean. Mar. Mammal Sci. doi:10.1111/j.1748-7692.2007.00149.

Straley, J., O'Connell, V., Mesnick, S., Behnken, L. and Liddle, J.B. 2005. Sperm Whale and Longline Fisheries Interactions in the Gulf of Alaska. North Pacific Research Board R0309 Final Report, 15 p.

Venables, W.N and Dichmont, C.M. 2004. GLMS, GAMs and GLMMs: an overview of theory for applications in fisheries research. Fisheries Research 70: 319-337.

Venables, W.N. and Ripley B.D. 2002. Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0

Ver Hoef, J.M. and Boveng, P.L.2007. Quasi-Poisson vs. negative binomial regression: how should we model overdispersed count data? Ecology, 88, 2766–2772.

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A., and Smith, G.M. 2009. Mixed effects models and extensions in ecology with R. Springer, New York. 574 pp.

Table 3C.1. Number of year/station replicates by area used in models of sperm whale depredation. "Flag 1" corresponds to sperm whale presence; "Flag 2" corresponds to evidence of depredation (damaged fish, hooks, etc.). Data from years 1990 through 2012.

Area	Total	Flag 1	Percent	Flag 2	Percent
WGOA	213	15	7.0	1	0.5
CGOA	366	56	15.3	29	7.9
WY	184	71	38.6	56	30.4
EY/SE	391	99	25.3	63	16.1
Total	**1154**	**241**	**20.9**	**149**	**12.9**

Table 3C.2. Estimates of sperm whale depredation (λ) by model and area using Flag 1 (presence). SE = standard error of the estimate. The estimate of proportional change is given by exp(λ) (e.g., a value of 1.0 implies no change; a value of 0.8 implies a 20% reduction in mean CPUE due to depredation).

Area	Model	Estimate	SE	P value	Proportional Change
WGOA	QP	13.4	708	0.985	6.3E+05
	NB	36.9	7.7E+06	1.000	1.0E+16
	ME.1	0.159	0.127	0.211	1.17
	ME.2	0.114	0.131	0.384	1.12
	ME.3	0.113	0.131	0.389	1.12
CGOA	QP	0.161	0.370	0.663	1.17
	NB	-0.015	0.417	0.971	0.99
	ME.1	-0.047	0.053	0.371	0.95
	ME.2	-0.023	0.055	0.674	0.98
	ME.3	-0.026	0.062	0.677	0.97
WY	QP	-0.044	0.388	0.911	0.96
	NB	-0.829	0.547	0.130	0.44
	ME.1	-0.188	0.055	0.001	0.83
	ME.2	-0.259	0.069	<0.001	0.77
	ME.3	-0.257	0.069	<0.001	0.77
EY/SE	QP	-0.193	0.332	0.560	0.82
	NB	0.264	0.515	0.608	1.30
	ME.1	-0.199	0.038	<0.001	0.82
	ME.2	-0.187	0.043	<0.001	0.83
	ME.3	-0.187	0.044	<0.001	0.83

Table 3C.3. Estimates of sperm whale depredation (λ) by model and area using Flag 2 (evidence). SE = standard error of the estimate. The estimate of proportional change is given by exp(λ) (e.g., a value of 1.0 implies no change; a value of 0.8 implies a 20% reduction in mean CPUE due to depredation).

Area	Model	Estimate	SE	P value	Proportional change
CGOA	QP	0.711	0.444	0.110	2.04
	NB	0.751	0.444	0.091	2.12
	ME.1	-0.102	0.069	0.141	0.90
	ME.2	-0.097	0.071	0.173	0.91
	ME.3	-0.096	0.089	0.280	0.91
WY	QP	-0.044	0.388	0.911	0.96
	NB	-0.829	0.547	0.130	0.44
	ME.1	-0.129	0.053	0.015	0.88
	ME.2	-0.195	0.067	0.004	0.82
	ME.3	-0.192	0.071	0.007	0.83
EY/SE	QP	-0.133	0.339	0.695	0.88
	NB	-0.185	0.460	0.688	0.83
	ME.1	-0.208	0.043	<0.001	0.81
	ME.2	-0.218	0.048	<0.001	0.80
	ME.3	-0.216	0.051	<0.001	0.81

Table 3C.4. Estimates of standard deviation and components of variance (%) for random-effects terms in ME.3 models of CPUE with sperm whale depredation using Flag 1 (presence). The shaded row highlights the additional variance due to random depredation effects.

	Standard deviation				Components of variance (%)			
Term	WGOA	CGOA	WY	EY/SE	WGOA	CGOA	WY	EY/SE
Year (Y)	0.19	0.16	0.28	0.21	3.9	4.8	8.3	4.5
Depth (D)	0.59	0.24	0.55	0.72	37.5	10.5	33.2	50.5
Station (S)	0.30	0.14	0.00	0.42	10.0	3.3	0.0	17.2
Y x D	0.24	0.19	0.23	0.09	6.4	6.8	5.5	0.9
Y x S	0.36	0.24	0.24	0.21	13.9	10.6	6.4	4.3
Y x S (F=1)	0.00	0.24	0.07	0.12	0.0	10.6	0.6	1.5
D x S	0.26	0.37	0.47	0.33	7.3	25.0	24.2	10.5
Y x D x S	0.44	0.40	0.45	0.33	20.9	28.3	21.9	10.6
Total					**100.0**	**100.0**	**100.0**	**100.0**

Table 3C.5. Estimates of sperm whale depredation (λ) for across-area models for Flag 1 (presence) and Flag 2 (evidence). SE = standard error of the estimate. Estimates of proportional change are given by exp(λ) with approximate 95% confidence intervals shown (LCI, UCI).

					Proportional change			Random effects	
Flag	Model	Area	Estimate	SE	exp(Est)	LCI	UCI	SD(YS)	$SD(YS_{F=1})$
1	S.1	All	-0.128	0.032	0.88	0.83	0.94	0.264	0.055
	S.2	WGOA	0.096	0.105	1.10	0.90	1.35	0.264	0.000
		CGOA	-0.016	0.055	0.98	0.88	1.10		
		WY	-0.265	0.066	0.77	0.67	0.87		
		EY/SE	-0.199	0.051	0.82	0.74	0.91		
2	S.1	All	-0.173	0.038	0.84	0.78	0.91	0.226	0.209
	S.2	WGOA						0.226	0.203
		CGOA	-0.066	0.075	0.94	0.81	1.09		
		WY	-0.190	0.064	0.83	0.73	0.94		
		EY/SE	-0.223	0.058	0.80	0.71	0.90		

Table 3C.6. List of scenarios with different ways to correct for sperm whale depredation, including new variance estimates for longline survey abundance, and using new area sizes.

Test	***Description***
BASE	Base model
CB	Increase fixed gear catch by 5% in all years
CS	Increase fixed gear catch by 2% in all years
CSB	Increase fixed gear catch and longline RPN by 5% in all years
CSS	Increase fixed gear catch and longline RPN by 2% in all years
EM	Estimate M deviations from 1998
ICB	Increasing trend on fixed gear catch by 1% per year since 1998
ICS	Increasing trend on fixed gear catch by 0.5% per year since 1998
ICSB	Increasing trend of fixed gear catch and longline RPN by 1% since 1998
ICSS	Increasing trend on fixed gear catch and longline RPN by 0.5% since 1998
IMB	Increasing trend of M by 1% per year since 1998
IMS	Increasing trend of M by 0.5% per year since 1998
ISB	Increasing trend on longline RPN by 1% per year since 1998
ISS	Increasing trend on longline RPN by 0.5% per year since 1998
MB	Increase M by 5% in all years
MS	Increase M by 2% in all years
NA	New longline survey area sizes
NAW	New longline survey area sizes with survey sperm whale correction
NAWA	New longline survey area sizes with survey sperm whale correction, and ARIMA area fill
NAWK	New longline survey area sizes with survey sperm whale correction, and random effects area fill
OA	Base model with survey variance estimates
OAW	Base model with survey sperm whale correction
SB	Increase longline RPN by 5% in all years
SS	Increase longline RPN by 2% in all years

Table 3C.7. Key results from various scenarios for accounting for sperm whale depredation, re-estimating survey variance, and new survey areas (see descriptions of scenarios in Table 1).

Test	-lnL	ABC	Catchability	Projected SSB	2008 YC	B40
BASE	1390.54	13.70	7.75	91.14	20.75	106.36
CB	1389.98	13.52	7.66	91.43	21.28	108.97
CS	1390.12	13.62	7.71	91.26	20.95	107.41
CSB	1389.98	13.53	8.04	91.47	21.29	108.99
CSS	1390.19	13.63	7.86	91.26	20.96	107.41
EMS	1390.54	13.70	7.75	91.14	20.75	106.36
ICB	1385.73	13.09	7.67	89.29	21.69	108.13
ICS	1387.98	13.39	7.71	90.22	21.21	107.22
ICSB	1395.85	17.20	7.63	104.24	25.34	112.51
ICSS	1392.21	15.37	7.69	97.52	22.93	109.36
IMB	1385.89	17.57	7.60	88.72	23.14	85.33
IMS	1387.84	15.84	7.67	90.00	21.87	95.35
ISB	1399.85	17.93	7.70	106.23	24.34	110.79
ISS	1394.55	15.70	7.72	98.47	22.46	108.51
MB	1390.88	14.81	7.61	91.81	21.84	103.78
MS	1390.45	14.14	7.69	91.42	21.18	105.28
NA	1398.37	13.88	7.41	91.61	21.58	106.66
NAW	1403.19	14.79	7.40	95.17	22.01	107.72
NAWA	1399.36	15.75	7.38	98.65	22.89	108.76
NAWK	1426.32	16.92	7.32	101.60	25.65	109.45
OA	1399.74	13.84	7.57	91.57	21.30	106.64
OAW	1404.07	14.74	7.56	95.05	21.75	107.69
SB	1390.54	13.71	8.13	91.18	20.75	106.38
SS	1390.54	13.70	7.90	91.16	20.75	106.37

Table 3C.8. Female spawning biomass trajectories from model scenarios for accounting for sperm whale depredation, re-estimating survey variance, and new survey areas (see descriptions of scenarios in Table 1).

Year	BASE	CB	CS	CSB	CSS	EMS	ICB	ICS	ICSB	ICSS	IMB
1977	129	132	130	132	130	129	129	129	129	129	129
1978	117	120	119	120	119	117	117	117	118	118	118
1979	112	115	113	115	113	112	112	112	113	113	112
1980	107	109	108	109	108	107	107	107	108	108	107
1981	106	108	106	108	106	106	106	106	106	106	106
1982	109	111	110	111	110	109	109	109	110	109	109
1983	121	123	122	123	122	121	121	121	122	121	121
1984	136	139	138	139	138	136	137	137	138	137	137
1985	152	155	153	155	153	152	152	152	154	153	153
1986	165	169	167	169	167	165	166	166	168	166	167
1987	171	175	173	175	173	171	172	172	174	173	173
1988	170	174	172	174	172	170	171	171	173	172	172
1989	164	167	165	167	165	164	164	164	166	165	165
1990	154	157	155	157	155	154	155	154	157	155	156
1991	143	146	144	146	144	143	144	144	146	145	145
1992	132	134	133	134	133	132	133	133	135	134	134
1993	122	123	122	123	122	122	123	122	125	123	124
1994	111	112	111	112	111	111	112	111	114	113	113
1995	103	104	103	104	103	103	104	103	106	104	105
1996	98	99	98	99	98	98	99	98	101	100	100
1997	95	96	95	96	95	95	96	95	99	97	97
1998	92	93	92	93	92	92	93	93	96	94	94
1999	88	89	89	89	89	88	90	89	93	91	91
2000	85	86	85	86	85	85	87	86	90	87	88
2001	82	83	82	83	82	82	83	83	87	85	84
2002	82	82	82	82	82	82	83	82	87	84	84
2003	84	85	84	85	84	84	85	84	90	87	86
2004	87	88	87	88	87	87	89	88	95	91	90
2005	92	92	92	92	92	92	93	92	100	96	95
2006	98	98	98	99	98	98	99	98	108	103	101
2007	103	104	103	104	103	103	104	103	114	108	106
2008	105	106	105	106	105	105	106	105	117	111	107
2009	104	105	104	105	104	104	105	104	116	110	106
2010	102	103	102	103	102	102	102	102	115	108	103
2011	100	100	100	100	100	100	100	100	112	106	100
2012	96	97	97	97	97	96	96	96	109	103	96
2013	93	94	93	94	93	93	92	93	106	100	92

Table 3C.8 (cont.). Female spawning biomass trajectories from model scenarios for accounting for sperm whale depredation, re-estimating survey variance, and new survey areas (see descriptions of scenarios in Table 1).

Year	IMS	ISB	ISS	MB	MS	NA	NAW	NAWA	NAWK	OA	OAW	SB	SS
1977	129	129	129	134	131	129	129	129	128	129	129	129	129
1978	118	118	118	122	119	117	118	118	117	117	118	117	117
1979	112	113	113	117	114	112	113	113	112	112	113	112	112
1980	107	108	108	111	109	107	108	108	107	107	107	107	107
1981	106	106	106	109	107	105	106	106	105	105	106	106	106
1982	109	110	109	113	110	109	109	109	109	109	109	109	109
1983	121	122	121	125	122	120	121	121	121	120	121	121	121
1984	137	138	137	141	138	136	137	137	137	136	137	136	136
1985	152	153	152	157	154	151	152	152	152	151	152	152	152
1986	166	167	166	171	167	165	166	166	166	165	166	165	165
1987	172	173	172	177	174	171	172	172	172	171	172	171	171
1988	171	172	171	176	173	170	171	171	171	170	171	170	170
1989	164	166	165	169	166	163	164	164	164	163	164	164	164
1990	155	156	155	159	156	154	154	155	155	154	154	154	154
1991	144	145	144	147	145	143	144	144	144	143	144	143	143
1992	133	134	133	136	134	132	133	133	133	132	133	132	132
1993	123	124	123	125	123	121	122	122	122	121	122	122	122
1994	112	113	112	114	112	111	112	112	112	111	112	111	111
1995	104	105	104	105	104	103	103	104	104	103	104	103	103
1996	99	100	99	100	99	98	99	100	100	98	99	98	98
1997	96	98	96	97	96	96	96	97	97	96	97	95	95
1998	93	95	93	94	93	93	94	95	95	93	94	92	92
1999	90	92	90	90	89	90	91	91	91	90	91	88	88
2000	86	89	87	87	86	86	88	88	88	86	88	85	85
2001	83	86	84	84	83	83	85	85	85	83	85	82	82
2002	83	86	84	83	82	83	84	85	84	83	84	82	82
2003	85	89	86	85	84	85	86	88	86	85	87	84	84
2004	88	93	90	89	88	88	90	91	89	88	90	87	87
2005	93	99	95	94	92	92	95	96	93	92	95	92	92
2006	99	106	102	100	98	98	101	103	100	98	101	98	98
2007	104	113	107	105	103	103	106	108	105	103	106	103	103
2008	106	116	110	107	105	105	108	111	108	105	108	105	105
2009	105	116	110	106	105	104	107	110	108	104	107	104	104
2010	103	115	108	104	103	102	105	108	107	102	105	102	102
2011	100	113	106	101	100	99	103	106	106	99	103	100	100
2012	96	110	103	97	97	96	100	103	104	96	100	96	96
2013	93	108	100	94	94	93	97	100	102	93	97	93	93

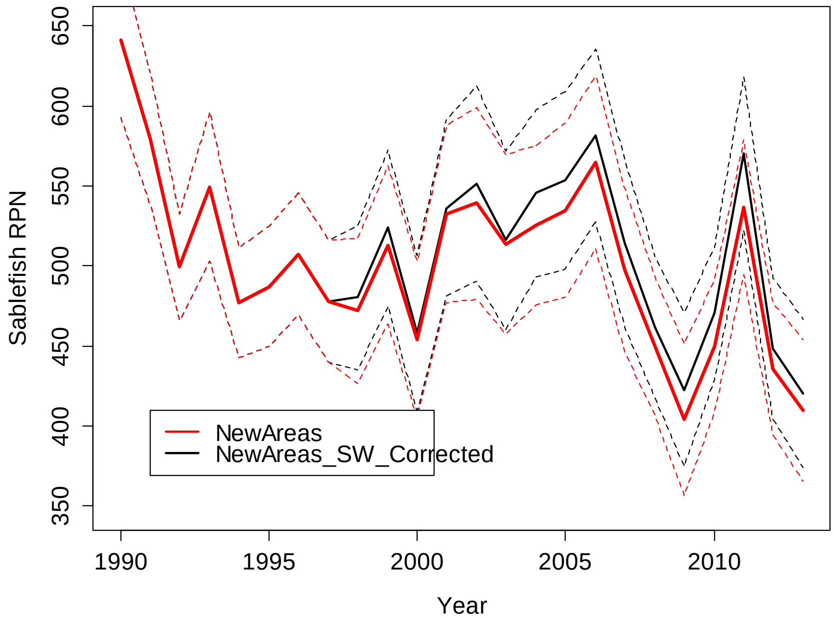

Figure 3C.1. An example of the effect of correcting for sperm whale depredation. Models correspond to NA and NAW in Table 1.

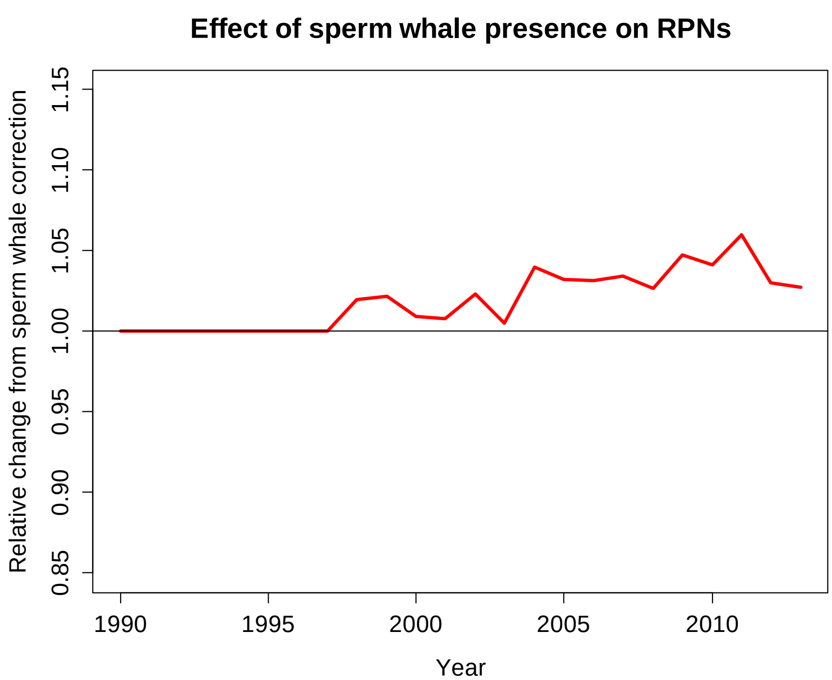

Figure 3C.2. The net increase in the index from the base model after correcting for sperm whale depredation. Black line at 1 corresponds to the NA model, red line is the NAW model in Table 1.

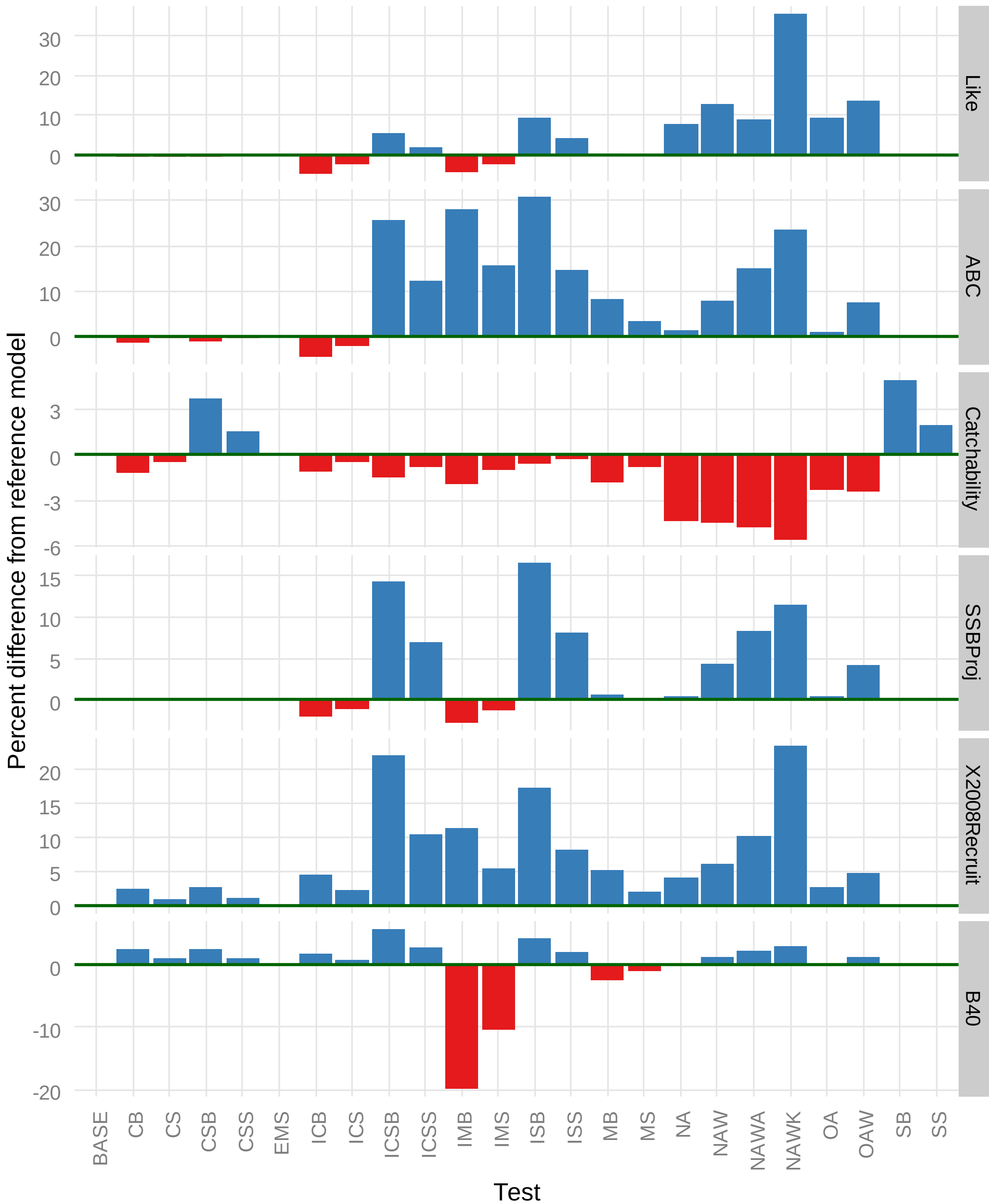

Figure 3C.3. Relative change in key results from sensitivity tests described in Table 1.

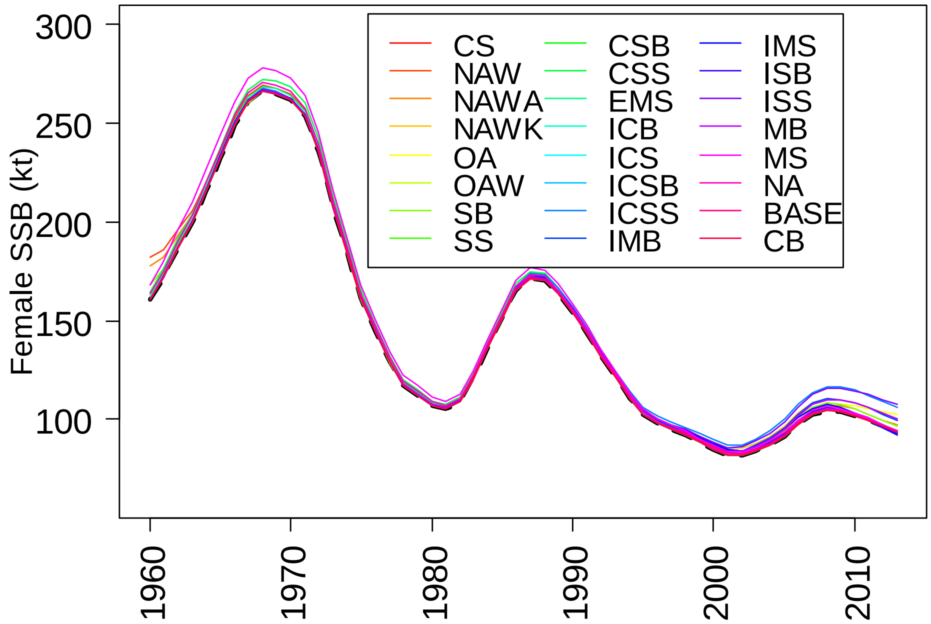

Figure 3C.4. Plots of female spawning biomass for sablefish model sensitivity tests from 1960-2013. Dashed black line is overplotted on the line for BASE model.

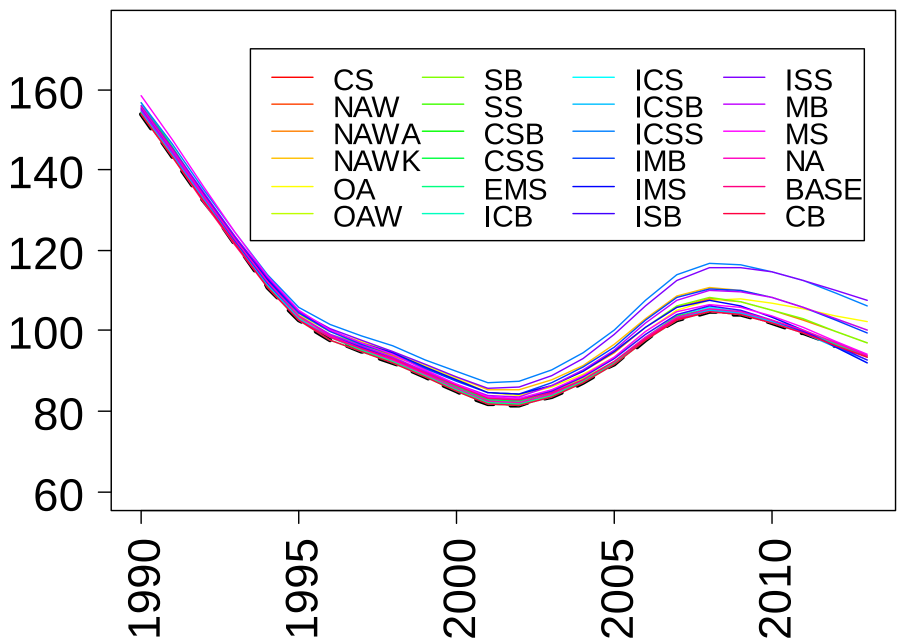

Figure 3C.5. Plots of female spawning biomass for sablefish sensitivity tests from 1990-2013. Dashed black line is overplotted on the line for BASE model.

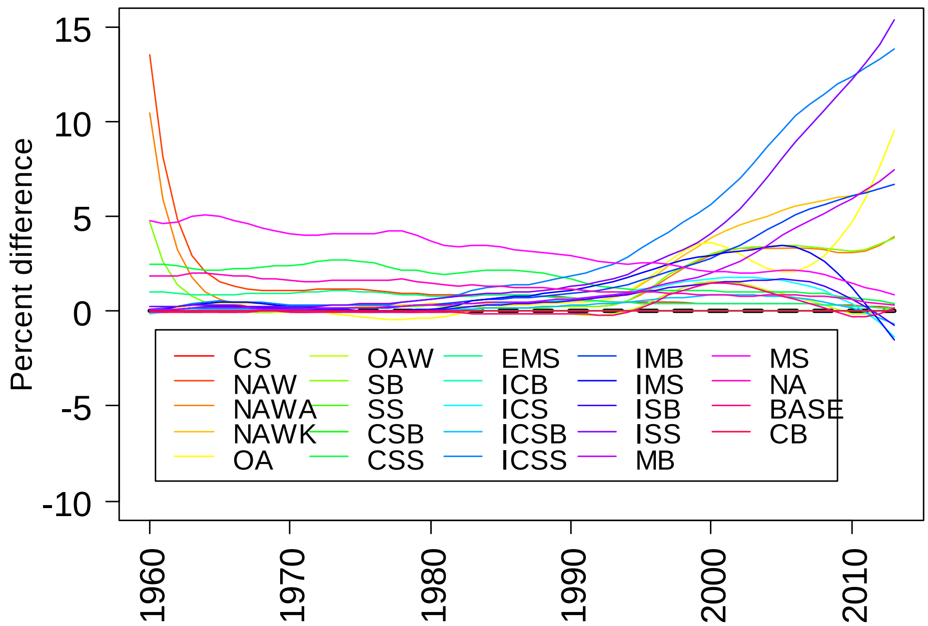

Figure 3C.6. Plots of relative female spawning biomass to reference model for sablefish sensitivity tests from 1990-2013. Dashed black line is overplotted on the line for BASE model.

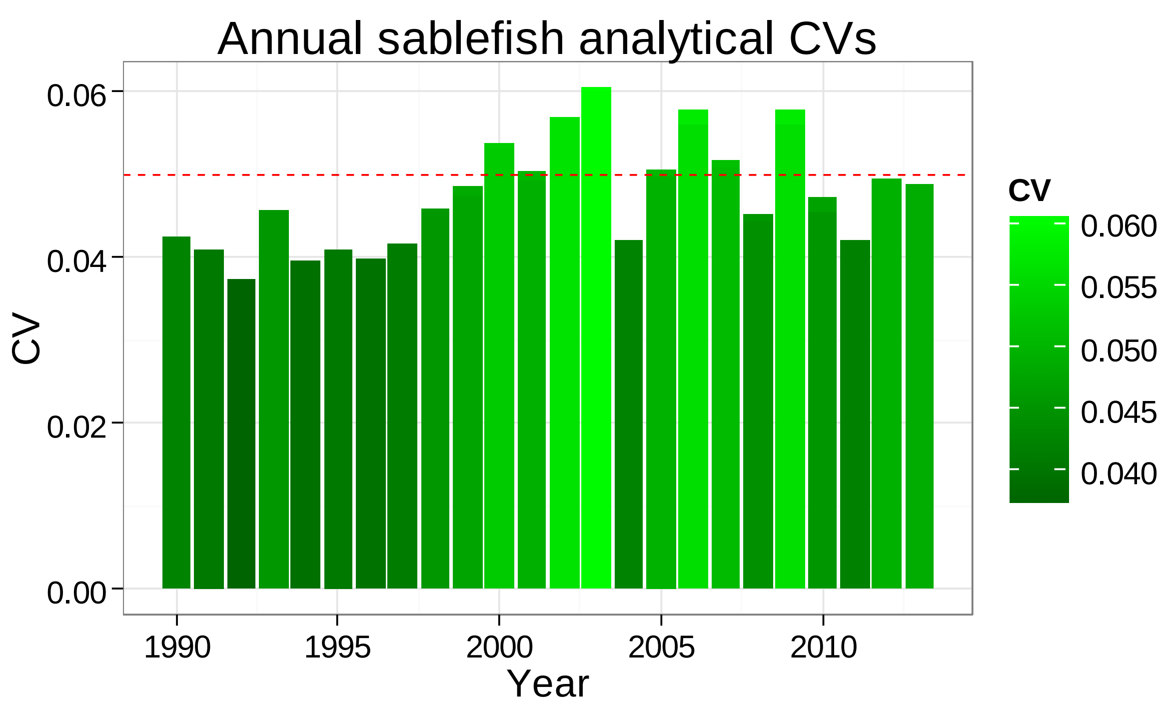

Figure 3C.7. Time series of coefficients of variation (CV) for the all-area sablefish longline RPN index. Five percent CV line is marked as a red dash line.

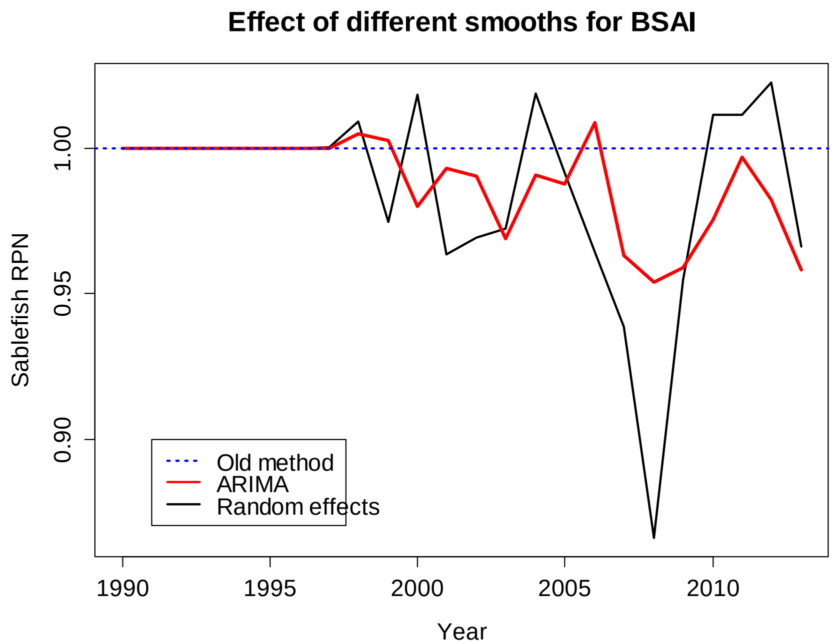

Figure 3C.8. The use of an ARIMA model and a random effects model to fill in missing years for the Bering Sea and Aleutian Islands areas and the effect on the sablefish RPN index.

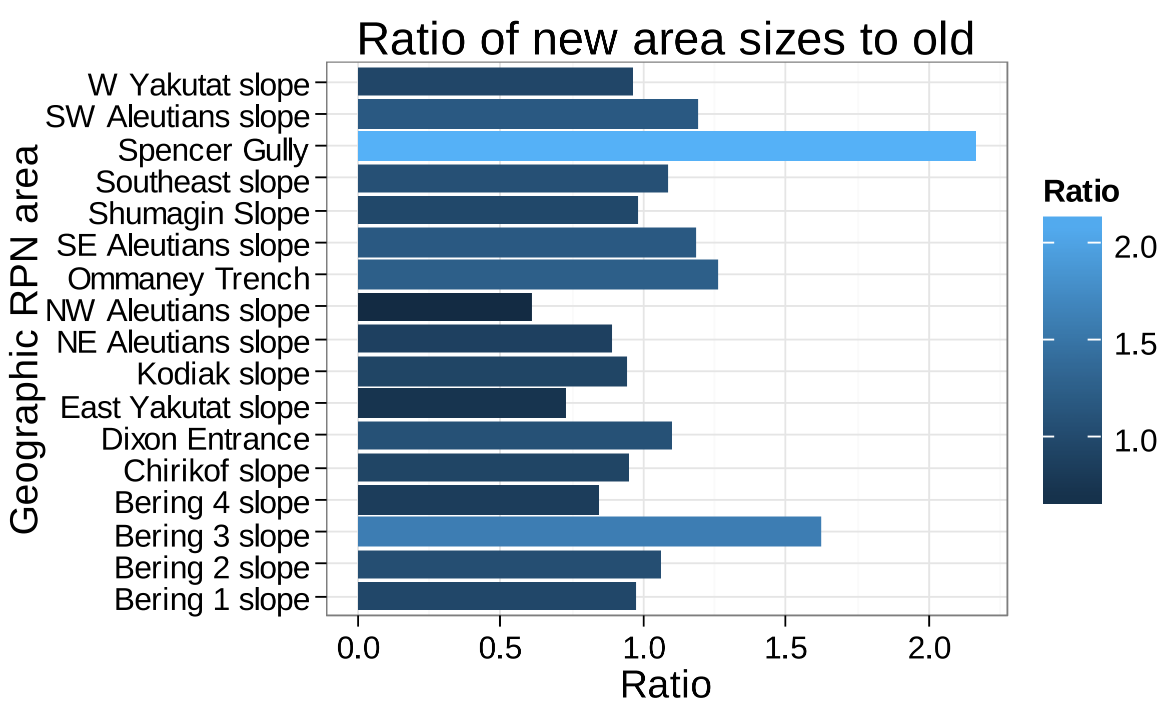

Figure 3C.9. The ratio of new area sizes calculated in Echave et al. (2013) to the area sizes currently used in the sablefish stock assessment by small geographic areas.

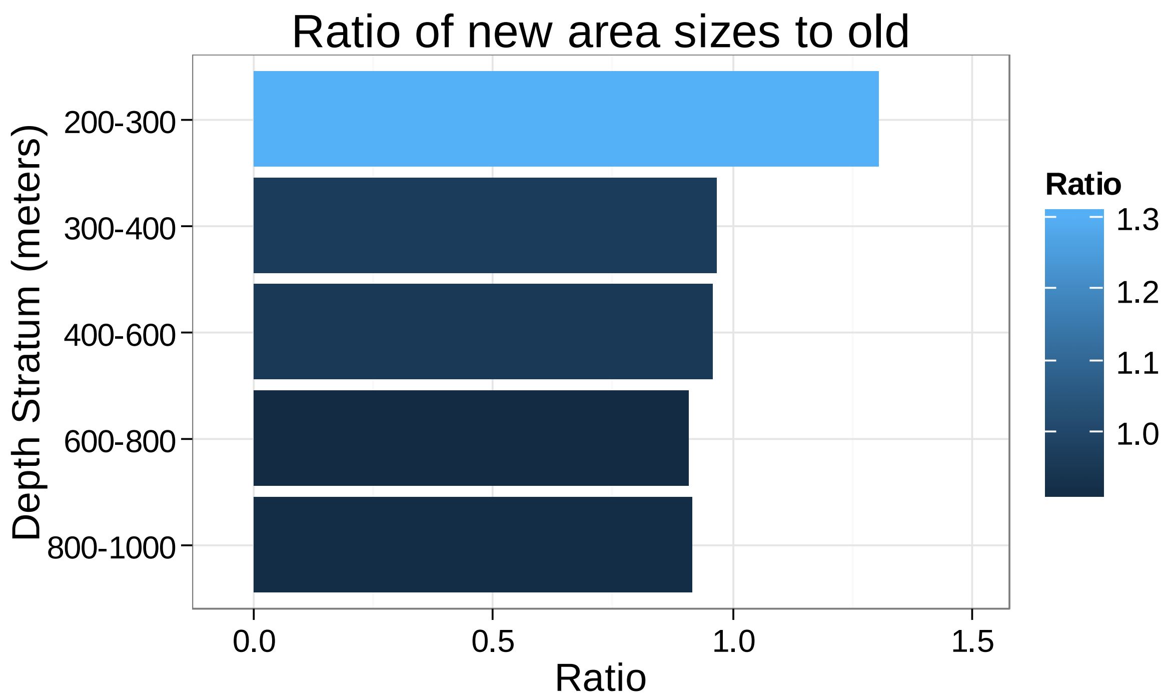

Figure 3C.10. The ratio of new area sizes calculated in Echave et al. (2013) to the area sizes currently used in the sablefish stock assessment by depth strata.

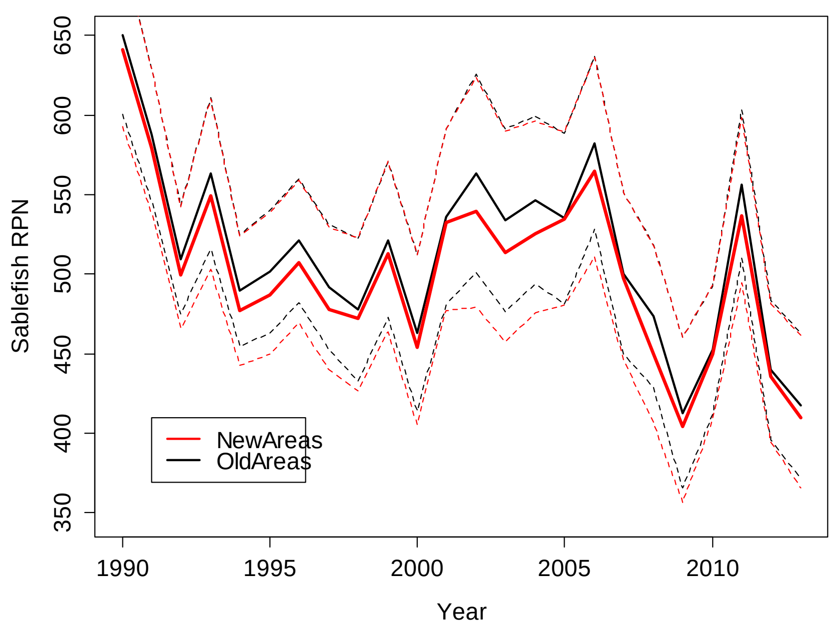

Figure 3C.11. Estimates of sablefish RPNs using new calculated area sizes from Echave et al. (2013) versus using old area sizes used in Hanselman et al. (2013).

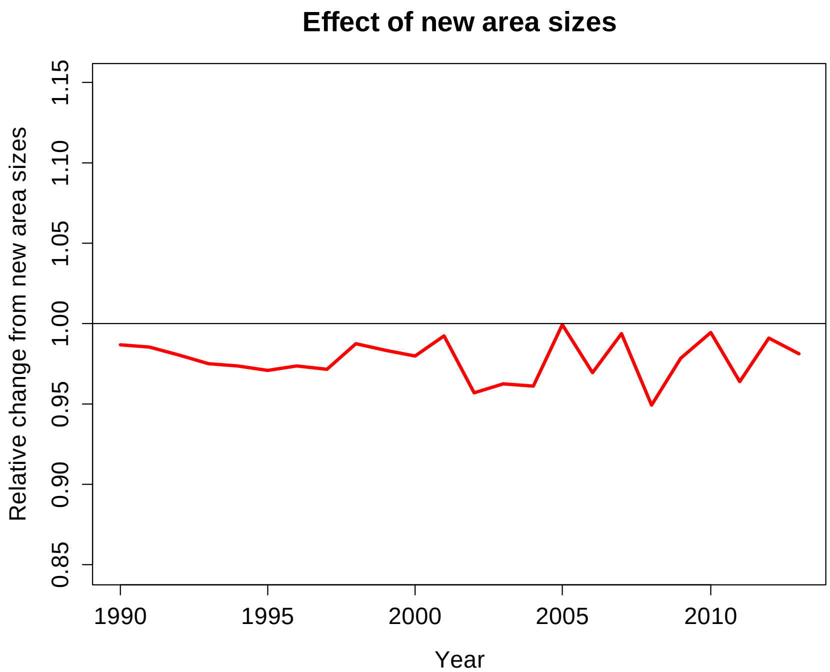

Figure 3C.12. Net effect of new area sizes. Line at 1 is the reference line from the base model in Hanselman et al. (2013).

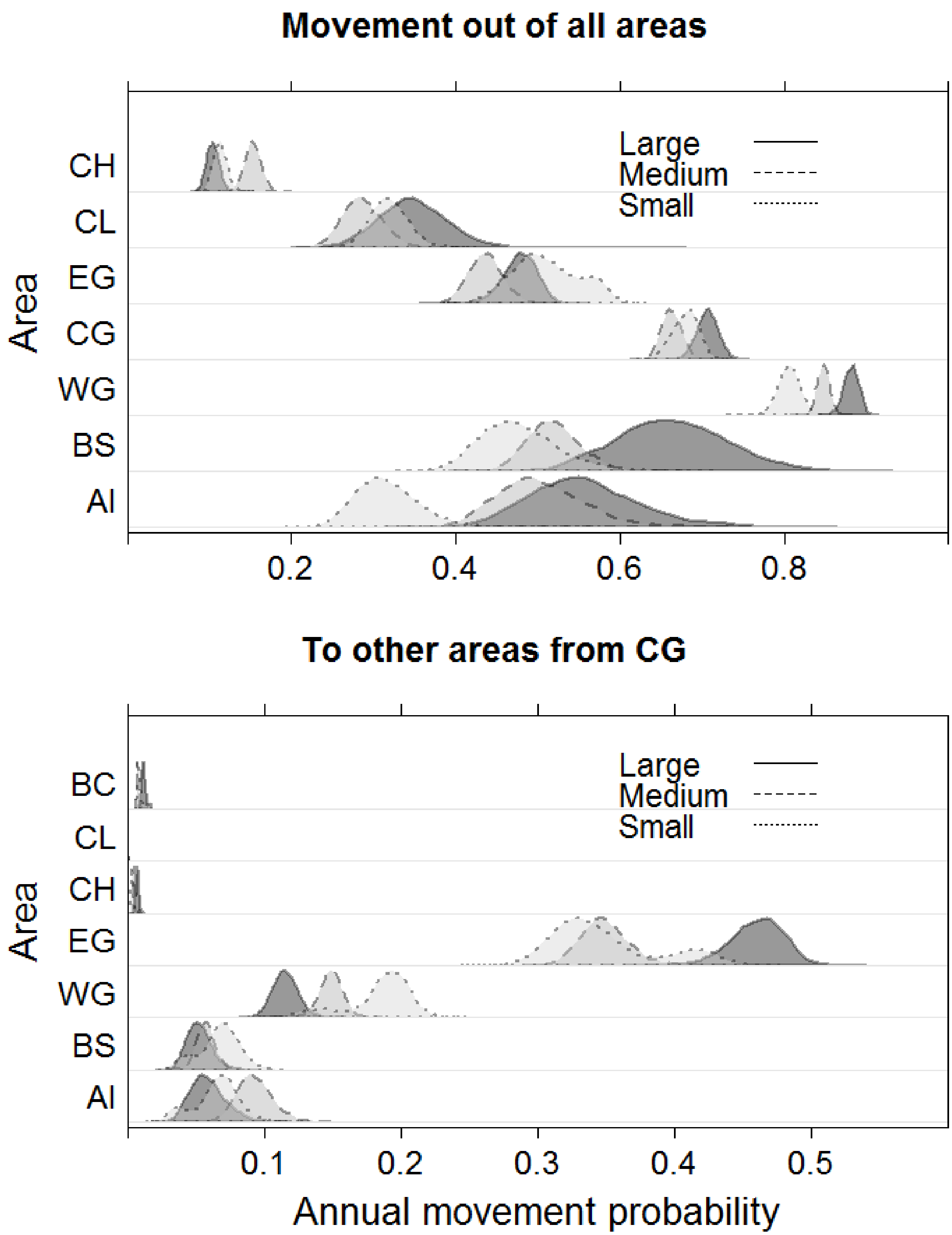

Figure 3C.13. Posterior probability distributions of annual sablefish movement probability by size group and area. Top panel is movement probability out of each area. Bottom panel is movement probability to each area from the central Gulf of Alaska. AI = Aleutian Islands, BS = Bering Sea, WG = western Gulf of Alaska, CG = central Gulf of Alaska, EG = eastern Gulf of Alaska, CH = Chatham Strait, CL = Clarence Strait, Small = <57 cm, Medium = 57-66 cm, Large = >66 cm.

4. Assessment of the Shallow Water Flatfish complex in the Gulf of Alaska (Executive Summary)

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NMFS Alaska Fisheries Science Center
November 6, 2014

Introduction

Assessment for the shallow water flatfish complex has been moved to a biennial schedule to coincide with the expected receipt of new survey data. Usually, on alternate (even) years we will present an executive summary with last year's key assessment parameters and projections for this year. A discussion at the September 2006 Groundfish Plan Team meetings concluded the following two important points for updating information in off-year assessments:

1) Anytime the assessment model is re-run and presented in the SAFE Report, a full assessment document **must** be produced.
2) The single-species projection model **may** be re-run using new catch data without re-running the assessment model.

The shallow water complex is comprised of northern rock sole, southern rock sole, yellowfin sole, butter sole, starry flounder, English sole, sand sole and Alaska plaice. Northern and southern rock sole are in Tier 3a while the other species in the complex are in Tier 5. For further information regarding the shallow water flatfish complex, please see the last full stock assessment (Turnock et al. 2011, http://www.afsc.noaa.gov/refm/docs/2011/GOAshallowflat.pdf).

Summary of changes in the Assessment Inputs

Changes in the input data: The new information available concerning the shallow water flatfish complex are the updated 2013 catch of 5,522 t and the partial 2014 catch of 3,917 t through October 11. Projected catch to the end of 2014 using the same fraction of catch to October 11 that occurred in 2013 (87.6%) would be 4,472 t.

Changes in the assessment methodology: There are no changes to the assessment methodology. The 2013 survey data have been used for the Tier 5 calculations, while northern and southern rock sole are in Tier 3 (See A'mar et al 2014). Biomass, OFL and ABC values for northern and southern rock sole are estimated using projections from the 2014 assessment model with catches updated for 2013 and 2014.

Summary of Results

The 2013 and 2014 catches by species are presented in the following table:

Species		
Shallow-water flatfish	2013 Catch	2014 Catch[1]
Northern rock sole	2,047	2,660
Southern rock sole	2,010	760
Yellowfin sole	2	14
Butter sole	1,237	239
Starry flounder	131	143
English sole	79	91
Sand sole	13	5
Alaska plaice	1	4

Total shallow-water	5,522	3,917

[1]Through Oct. 11, 2014.

Area Apportionment

The recommended apportionment are estimated using the 2013 survey biomass for the shallow water flatfish complex by management areas.

	Western	Central	Yakutat	Southeast
Proportions	0.499	0.437	0.050	0.014
ABC	20,376	17,813	2,039	577

Research Priorities

More aging data is needed to improve estimates of natural mortality for Tier 5 species.

Summaries for Plan Team

Species/Assemblage	Year	Biomass	OFL[1]	ABC[1]	TAC[1]	Catch[2]
Shallow water flatfish	2007	365,766	62,418	51,450	19,972	8,788
	2008	436,591	74,364	60,989	22,256	7,390
	2009	436,591	74,364	60,989	22,256	8,483
	2010	398,961	67,768	56,242	20,062	5,534
	2011	398,961	67,768	56,242	20,062	3,974
	2012	329,217	55,943	45,802	37,029	4,022
	2013	433,869	55,680	45,484	37,077	5,515
	2014	384,134	50,007	40,805	33,679	3,917
	2015	287,534	54,207	44,205		
	2016	260,234	44,205	39,205		

The recommended 2014 and 2015 shallow-water flatfish ABC and OFL levels with tier 3a estimates from projections run with the 2014 model and updated with 2013 and 2014 catches for northern and southern rock sole (see A'mar et al 2014):

Stock/		**2014**				**2015**		**2016**	
Assemblage	**Area**	**OFL[1]**	**ABC[1]**	**TAC[1]**	**Catch[2]**	**OFL**	**ABC**	**OFL**	**ABC**
Shallow water flatfish	W	--	20,376	13,250	232	--	22,074	--	19,577
	C	--	17,813	17,813	3,683	--	19,297	--	17,114
	WYAK	--	2,039	2,039	1	--	2,209	--	1,959
	SEO	--	577	577	1	--	625	--	554
	Total	50,007	40,805	33,679	3,917	54,207	44,205	44,205	39,205

[1]As published in the Federal Register. [2]As of Oct. 11, 2014.

Note: Tables of ABCs, OFLs, and TACs published in the Federal Register are available for:
2013: http://alaskafisheries.noaa.gov/sustainablefisheries/specs13_14/goatable1.pdf
2014: http://alaskafisheries.noaa.gov/sustainablefisheries/specs13_14/goatable2.pdf

The recommended shallow-water flatfish ABC and OFL levels are:

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)[1]	0.2	0.2	0.2	0.2
Tier	3a and 5	3a and 5	3a and 5	3a and 5
Biomass (t)	384,134	362,534	287,534	260,234
F_{OFL}	*	*	*	*
$maxF_{ABC}$	*	*	*	*
F_{ABC}	*	*	*	*
OFL (t)	50,007	46,207	54,207	48,407
maxABC (t)	40,805	37,505	44,205	39,205
ABC (t)	40,805	37,505	44,205	39,205
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	No	No	No	NA

* See following table and A'mar et al 2014 for values by species
[1] Northern rock sole male M=0.251, southern rock sole male M= 0.259, all other M=0.2.

Calculations of the 2015 and 2016 shallow-water flatfish ABC and OFL levels by species including values for Tier 3a for northern and southern rock sole (See A'mar et al 2014) are:

Species					As *specified last* year for: 2014		2015		As *recommended this* year for: 2015		2016	
Shallow-water flatfish	Tier	FABC	FOFL	Biomass[1]	ABC	OFL	ABC	OFL	ABC	OFL	ABC	OFL
Northern rock sole	3a	0.374	0.374	80,000	9,400	11,000	8,300	9,700	14,300	17,000	11,900	14,200
Southern rock sole	3a	0.204	0.243	119,500	18,200	21,400	16,000	18,900	16,700	19,600	14,100	16,600
Yellowfin sole	5	0.15	0.2	23,016	3,452	4,603	3,452	4,603	3,452	4,603	3,452	4,603
Butter sole	5	0.15	0.2	8,122	1,218	1,624	1,218	1,624	1,218	1,624	1,218	1,624
Starry flounder	5	0.15	0.2	30,028	4,504	6,006	4,504	6,006	4,504	6,006	4,504	6,006
English sole	5	0.15	0.2	18,121	2,718	3,624	2,718	3,624	2,718	3,624	2,718	3,624
Sand sole	5	0.15	0.2	703	105	141	105	141	105	141	105	141
Alaska plaice	5	0.15	0.2	8,044	1,207	1,609	1,207	1,609	1,207	1,609	1,207	1,609
Total shallow-water					40,805	50,007	37,505	46,207	44,205	54,207	39,205	48,407

[1] 2013 survey biomass estimates except northern and southern rock sole age 3+ 2015 model estimates from Amar, et al 2014

Responses to SSC and Plan Team Comments specific to this assessment

The Team recommends a full assessment for the Tier 5 contribution to the SWF complex including in-depth consideration of relative catch by fishery and survey biomass estimates by area.

This will be addressed in the next full assessment for SWF in 2015.

4.6 Literature Cited

A'mar, Z.T. and W. Palsson. 2013. Assessment of the northern and southern rock sole (*Lepidopsetta polyxystra and bilineata*) stocks in the Gulf of Alaska for 2014. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

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Chapter 4.1: Assessment of the northern and southern rock sole (*Lepidopsetta polyxystra and bilineata*) stocks in the Gulf of Alaska for 2015

Teresa A'mar and Wayne Palsson

Executive Summary

Summary of Changes in Assessment Inputs

Relative to last year's assessment, the following changes have been made in the current assessment:

New Input data

1. Fishery: 2013 and 2014 total shallow-water flatfish catch, total rock sole catch for 1993 – 2014, and fishery observer undifferentiated (U)/northern (N)/southern (S) rock sole catch-at-length for 1989 – 2014
2. Survey: 2013 N and S rock sole age composition and mean size-at-age from the NMFS GOA bottom trawl survey

Changes in assessment methodology

Stock Synthesis was used for all model configurations in this analysis.

Summary of Results

The biomass estimate from the 2013 GOA NMFS bottom trawl survey for northern rock sole was a slight increase (2.3%) from the estimate from the 2011 survey. The biomass estimate from the 2013 survey for southern rock sole was an increase of 9% from the estimate from the 2011 survey.

Stock Synthesis was used for all model configurations in this analysis; Stock Synthesis models have been presented at the September Groundfish Plan Team meetings in 2013 and 2014. The 2012 final model was a two-species two-sex mixed-fishery statistical catch-at-age population dynamics ADMB (ADMB Project, 2009) model. Due to the government shutdown in October 2013, the results of the 2012 model were used for the projections in the 2013 GOA northern and southern rock sole SAFE document.

Northern Rock Sole

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)	0.2,0.275*	0.2, 0.275*	0.2,0.251*	0.2, 0.251*
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	87,300	79,300	80,000	68,600
Projected Female spawning biomass	40,600	34,400	40,600	32,600
$B_{100\%}$	50,300	50,300	50,400	50,400
$B_{40\%}$	20,100	20,100	20,100	20,100

$B_{35\%}$	17,600	17,600	17,600	17,600
F_{OFL}	0.180	0.180	0.452	0.452
$maxF_{ABC}$	0.152	0.152	0.374	0.374
F_{ABC}	0.152	0.152	0.374	0.374
OFL (t)	11,000	9,700	17,000	14,200
maxABC (t)	9,400	8,300	14,300	11,900
ABC (t)	9,400	8,300	14,300	11,900
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

*Estimated in model for males

Southern Rock Sole

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	2015	2016
M (natural mortality rate)	0.2, 0.267*	0.2, 0.267*	0.2, 0.259*	0.2, 0.259*
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	208,800	195,200	119,500	103,600
Projected Female spawning biomass	81,500	69,300	72,200	65,900
$B_{100\%}$	112,900	112,900	81,500	81,500
$B_{40\%}$	45,100	45,100	32,600	32,600
$B_{35\%}$	39,500	39,500	28,500	28,500
F_{OFL}	0.230	0.230	0.243	0.243
$maxF_{ABC}$	0.193	0.193	0.204	0.204
F_{ABC}	0.193	0.193	0.204	0.204
OFL (t)	21,400	18,900	19,600	16,600
maxABC (t)	18,200	16,000	16,700	14,100
ABC (t)	18,200	16,000	16,700	14,100
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

*Estimated in model for males

Responses to SSC and Plan Team Comments Specific to this Assessment

Plan Team, Sept. 2014: "*Empirical weight-at-age was not feasible, due to a lack of any data for estimating fishery weights-at-age. Instead conditional age-at-length (AAL) was calculated for survey data, allowing growth and growth variability parameters to be estimated internally in the assessment models.* ***The Plan Team recommends using the AAL approach for models to be considered in November.***"
Response: The survey age data were included in all model configurations as conditional age-at-length.

Plan Team, Sept. 2014: "*Investigating the use of length-based selectivity (rather than age-based) might also be helpful in understanding why CVs of length at age were found be quite low (<5%) for age-3 rock sole.*"
Response: Model configurations were run with selectivity-at-age or selectivity-at-length for the survey.

Plan Team, Sept. 2014: "***The Plan Team recommends using the number of hauls as initial values and continuing to explore weighting from there.***"
Response: The number of hauls or trips was used for sample sizes for fishery and survey length composition data, and for the survey conditional age-at-length data.

Plan Team, Sept. 2014: "***The Plan Team recommends estimating male natural mortality in models considered for November***."
Response: Male M was estimated in all model configurations.

Plan Team, Sept. 2014: "*Previous analyses have used 60% and 40% of the total rock sole catches in each of the species-specific assessments in order to recognize the variability in observed ratios.* ***The Plan Team recommends that values of 50:50 be used for the base case.***"
Response: The annual catches for the species-specific models was ½ of the annual total rock sole catch.

Plan Team, Sept. 2014: "***However, the Plan Team is still interested in the relative trends provided by those data, and recommends evaluating ADF&G survey data for model application (time permitting).***"
Response: This analysis is in process.

SSC, Oct. 2014: "*The assessment author responded to all of the recommendations from previous Plan Team meetings and comments from the SSC were addressed in some form. Progress on the stock structure template is underway. Notable changes to the assessment model include the use of conditional age-at-length (AAL) data to jointly estimate growth of male and female northern and southern rock sole. The Plan Team recommends using the AAL approach for models to be considered this November. The Plan Team also recommends down weighting the sample sizes for composition data using the number of hauls as the initial starting values for the iterative re-weighting procedures. Estimating natural mortality for males improved over all fits, and the Plan Team recommends estimating male natural mortality rates for November. The Plan Team also suggests exploring the use of length-based selectivity to investigate if the current age-based selectivity is a source of the low CVs in the estimated length-at-age for age-3 rock sole.* ***The SSC supports all of the above Plan Team recommendations.***"
Response: All of the Plan Team recommendations were addressed.

SSC, Oct. 2014: "*The major axis of uncertainty in this assessment is partitioning catches into species-specific (northern and southern rock sole) values. Catch data in the model date back to 1977, but ratios of northern and southern are only available from 1988 onwards, with no clear trends in the ratios. The Plan Team recommends a 50:50 ratio for splitting the catch in the base model, and if time permits a sensitivity analysis exploring 40:60 ratios in the historical period where ratio information is not available.* ***The SSC also supports this Plan Team recommendation.***"
Response: All of the Plan Team recommendations were addressed.

Introduction

Rock sole are demersal fish and can be found in shelf waters to 600 m (Allen and Smith, 1988). Two species of rock sole are known to occur in the north Pacific Ocean, northern rock sole (*Lepidopsetta polyxystra*) and southern rock sole (*L. bilineata*) (Orr and Matarese, 2000). Adults of the northern rock sole are found from Puget Sound through the Bering Sea and Aleutian Islands to the Kuril Islands, while the southern rock sole is known from the southeast Bering Sea to Baja California (Stark and Somerton, 2002). These species have an overlapping distribution in the Gulf of Alaska (Wilderbuer and Nichol, 2009). Rock sole are most abundant in the Kodiak and Shumagin areas. The northern rock sole spawns in midwinter and spring, and the southern rock sole spawns in summer (Stark and Somerton, 2002). Northern rock sole spawning occurred in areas where bottom temperatures averaged 3°C in January, and Southern rock sole spawning began in areas where bottom temperatures averaged 6°C in June (Stark and Somerton, 2002). Rock soles grow to approximately 60 cm and can live in excess of 20 years (http://www.afsc.noaa.gov/race/behavioral/rocksole_fbe.htm).

Both rock sole species are managed as part of the shallow-water flatfish complex, which also includes yellowfin sole (*Pleuronectes asper*), starry flounder (*Platichthys stellatus*), butter sole (*Pleuronectes isolepis*), English sole (*Pleuronectes vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*), as these species are caught in the shallow-water flatfish fishery (Turnock et al., 2009).

Fishery

Rock sole are caught in the shallow-water flatfish fishery and are not targeted specifically, as they co-occur with several other species. The rock sole species were differentiated in survey data beginning in 1996, and were differentiated in the fishery observer data beginning in 1997. Data for more recent years have the species listed as northern (N), southern (S), or "undifferentiated" (U) rock sole as adult northern and southern rock sole are difficult to differentiate visually (Orr and Matarese, 2000). There is considerable uncertainty about the fraction of annual rock sole catch that is northern or southern rock sole.

See the Chapter 4 for more information on the Gulf of Alaska shallow-water flatfish fishery

Data

This section describes data used in the current assessment model. It does not attempt to summarize all available data pertaining to northern and southern rock sole in the GOA.

Data	Source	Type	Years included
Fishery catch	AKFIN	metric tonnes	1977 – 2014
Fishery catch-at-length[a]	AKFIN / FMA	number, by cm bin	1989 – 2014
GOA NMFS bottom trawl survey biomass and abundance estimates[b]	AFSC	metric tonnes, numbers	1984 – 2013
GOA NMFS bottom trawl survey length composition[b]	AFSC	number, by cm bin	1984 – 2013
GOA NMFS bottom trawl survey age composition[b]	AFSC	number, by age	1984 – 2013
GOA NMFS bottom trawl survey mean length-at-age[b]	AFSC	mean value and number	1984 – 2013

[a]Species-specific fishery observer catch-at-length data are available for 1997 – 2014
[b]Species-specific survey data are available for 1996 – 2013

The survey data for 1984, 1987, 1990, and 1993 are for U rock sole; the survey data for N and S rock sole are specified by species from 1996 on, and the fishery observer length data for N and S rock sole are specified by species from 1997 on. The catch data are for U rock sole.

Fishery:

The fishery data available include total rock sole catch, retained and discarded, by year and area (Table 4.1.1, Figure 4.1.1); fishery observer species-specific extrapolated haul-level data (Table 4.1.2, Figure 4.1.2); and fishery observer catch-at-length data for 1989 through 2014 for U/N/S rock sole. The fishery observer data for N and S rock sole are separated out by species from 1997 on. Data for more recent years have the species listed as N, S, or U rock sole as adult northern and southern rock sole are difficult to differentiate visually (Orr and Matarese, 2000).

See the Chapter 4 for more information on the Gulf of Alaska shallow-water flatfish fishery

Survey:

The survey data available include NMFS GOA bottom trawl survey biomass and population estimates by area for 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, and 2013 (Table 4.1.3, Figures 4.1.3, 4.1.4, 4.1.5, and 4.1.6); survey numbers-at-length for all survey years; survey numbers-at-age for all survey years; survey samples with age and length; and survey estimates of mean length-at-age for all survey years. The survey data for 1984, 1987, 1990, and 1993 are for U rock sole; the survey data for N and S rock sole are separated out by species from 1996 on.

Analytic Approach

Model Structure

Three sets of Stock Synthesis model configurations were developed, for the undifferentiated, northern, and southern rock sole stocks. Stock Synthesis version 3.24S (Methot, 2013) was used. Technical details of Stock Synthesis are described by Methot and Wetzell (2013). All model configurations covered ages 0 to 30, were sex-specific, and estimated male natural mortality; female natural mortality was fixed at 0.2.

For the undifferentiated models configurations, the data were split into 3 groups to account for possible changes in the ratio of northern and southern rock sole. The data from the NMFS GOA bottom trawl survey have been divided into three periods, 1984 – 1993, 1996 – 2004, and 2005 on, with respect to catchability and selectivity. Catchability is set to 1.0 for the latter two survey periods and estimated for the first period, as Thompson et al. (2009) note that “the [NMFS GOA bottom trawl] survey used 30-minute tows during that period [1984-1993], but 15-minute tows thereafter [from 1996 on]”.

All fishery catch-at-length data were used in model fitting; the three fishery selectivity curves correspond to three periods, 1977 – 1996, 1997 – 2005, and 2006 on, so that each period had at least 8 years of data. Survey length composition data for all survey years and survey conditional age-at-length data for 1990 on were used in model fitting. The conditional age-at-length data for 1984 and 1987 were not used, as Boldt and Zador (2009) state that “…the gears used by the Japanese vessels in the [NMFS GOA bottom trawl] surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups.”

For the species-specific model configurations, the species-specific survey data for 1996 on and the fishery length composition data for 1997 on were used as one period in all model configurations. Constant fishery and survey selectivity curves were estimated.

The sample sizes for the fishery and survey length composition data were the number of hauls or trips with U/N/S rock sole. The sample sizes for the survey conditional age-at-length data were the number of samples in that length bin multiplied by the total number of hauls with U/N/S rock sole in that survey year divided by the total number of U/N/S rock sole samples in that survey year. This sample size adjustment results in the sum of the conditional age-at-length sample sizes for each survey year being the number of hauls in that survey year.

Parameters Estimated Outside the Assessment Model

The initial values for the growth and maturity parameters used in the model are from Stark and Somerton, 2002.

Northern rock sole

- Males: L_∞=382 mm, k=0.261, t_0=0.160;
- Females: L_∞=429 mm, k=0.236, t_0=0.387, L_{T50} = 328 mm.

Southern rock sole

- Males: L_∞=387 mm, k=0.182, t_0=-0.962;
- Females: L_∞=520 mm, k=0.120, t_0=-0.715, L_{T50} = 347 mm.

The value for natural mortality for U/N/S females was fixed at 0.2 in all model configurations.

See the Chapter 4 for more information on growth, maturity, and natural mortality for GOA northern and southern rock sole

Parameters Estimated Inside the Assessment Model

Parameters that were estimated in the model configurations included:

- median and initial age-0 recruitment;
- annual recruitment deviations;
- natural mortality for males;
- annual fishing mortality;
- initial fishing mortality;
- fishery selectivity-at-length by period and sex;
- survey catchability for the first survey period for U models;
- survey selectivity-at-age or selectivity-at-length by survey period and sex;
- length-at-age growth parameters by sex; and
- CVs for length-at-age at A_{min} (3.33333), by sex
- CVs for length-at-age at A_{max} (A_∞, corresponding to L_∞)

The stock-recruitment relationship is an average level of recruitment unrelated to stock size in all model configurations. Recruitment variability, σ_R, was fixed at 1.0. Catchability for the survey for 1996 on was fixed at 1.0.

Results

Model Evaluation

The model evaluation criteria included how well the model estimates fit to the survey estimates of biomass, the survey numbers-at-age, the annual U/N/S rock sole catch, the total negative log likelihood (NLL) value and its components, and that the model estimated the variance-covariance matrix.

Two model configurations are presented for each of the U/N/S stocks. The difference between the two configurations was the estimation of survey selectivity-at-age or selectivity-at-length. This difference was shown in model configurations which estimated survey selectivity-at-age fitting to the survey conditional age-at-length data better than to the fishery and survey length composition data relative to model configurations which estimated survey selectivity-at-length, and the reverse for model configurations which estimated survey selectivity-at-length (Table 4.1.4). This difference was also shown in the growth parameter and recruitment estimates, specifically in length-at-A_{min}, k, and R_0 (Tables 4.1.5 and 4.1.6).

The estimates of spawning biomass and age-0 were recruits were moderately higher in model configurations with survey selectivity-at-length than in the model configurations with survey selectivity-at-age for U (Figures 4.1.7 and 4.1.8) and S (Figures 4.1.13 and 4.1.14), and significantly higher for N (Figures 4.1.10 and 4.1.11). However, this difference did not result in significantly different fits to the survey indices (Figures 4.1.9, 4.1.12, and 4.1.15).

The model configurations which estimated survey selectivity-at-age were the preferred models, as the survey age data had more information about the age structure of the stocks than the other included data. The U and N model configurations with survey selectivity-at-age had lower NLL values than the corresponding model configurations with survey selectivity-at-length, although the S model configuration with survey selectivity-at-age had a slightly higher NLL than the corresponding model configuration with survey selectivity-at-length (Table 4.1.4).

Parameter estimates with standard deviations for the N and S model configurations with survey selectivity-at-age are in Table 4.1.12.

Time Series Results

The time series of spawning biomass and age-0 recruits for the U, N, and S model configurations with survey selectivity-at-age are in Figures 4.1.16 and 4.1.17, respectively. The corresponding time series for the U, N, and S model configurations with survey selectivity-at-length are in Figures 4.1.18 and 4.1.19.

The time series of spawning biomass and age-0 recruits, with standard deviations, for the N and S model configurations with survey selectivity-at-age are in Table 4.1.7. The estimates of numbers-at-age for northern rock sole are in Tables 4.1.8 and 4.1.9, and in Tables 4.1.10 and 4.1.11 for southern rock sole. Female maturity-at-age, survey selectivity-at-age and derived fishery selectivity-at-age for the N and S model configurations are in Table 4.1.13.

The time series of annual catches used for the N and S model configurations, which is half of the total annual rock sole catch, is in Figure 4.1.20.

Spawning biomass for N was stable over most of the historical period, with the highest value in 2007 and decreasing moderately through 2014 (Figure 4.1.21). Females are larger than males on average at all ages (Figure 4.1.22). Age-0 recruits are moderately variable for the recent period (Figure 4.1.23), with lower uncertainty on estimates for the 1990s and 2000s (Figure 4.1.24). The fit to the survey index is reasonable, given the uncertainty intervals (Figure 4.1.25). The fishery selectivity-at-length curves for females and males are in Figures 4.1.26 and 4.1.27, respectively; the survey selectivity-at-age curves for females and males are in Figures 4.1.28 and 4.1.29, respectively. The derived fishery selectivity-at-age curves are asymptotic but do not reach full selectivity (Figure 4.1.30). The fits to the fishery and survey length composition data for females and males are in Figures 4.1.31, 4.1.32, 4.1.33, and 4.1.34. The summary fits to the fishery and survey length composition data for females and males are in Figures 4.1.35 and 4.1.36, respectively; the model configurations with survey selectivity-at-age aren't able to match the peak in the female and male survey length composition data as well as the model configurations with survey selectivity-at-length. The survey conditional age-at-length data for females and males and the estimated relationships are in Figures 4.1.37 and 4.1.38.

Spawning biomass for S has been more variable than that for N, with the highest value in 1990 and decreasing moderately through 2014 (Figure 4.1.39). Females are larger than males on average for ages 4 and older (Figure 4.1.40). Age-0 recruits were significantly lower than average in 2006 through 2009, and have increased through 2014 since the lowest level in 2006 (Figure 4.1.41), with lower uncertainty on estimates for the 1990s and 2000s (Figure 4.1.42). The fit to the survey index is reasonable, although few, if any, model configurations were able to estimate the 2009 value well (Figure 4.1.43). The fishery selectivity-at-length curves for males and females are in Figures 4.1.44 and 4.1.45, respectively; the survey selectivity-at-age curves for females and males are in Figures 4.1.46 and 4.1.47, respectively. The derived fishery selectivity-at-age curves are asymptotic, and are almost fully selected by age 30 for females (Figure 4.1.48). The fits to the fishery and survey length composition for females and males are in Figures 4.1.49, 4.1.50, 4.1.51, and 4.1.52; the model configurations with survey selectivity-at-age aren't able to match the peak in the female and male survey length composition data as well as the model configurations with survey selectivity-at-length. The survey conditional age-at-length data for females and males and the estimated relationships are in Figures 4.1.55 and 4.1.56.

Harvest Recommendations

The GOA northern and southern rock sole stocks were moved from Tier 4 to Tier 3 of the NPFMC harvest guidelines in 2011. In Tier 3, reference mortality rates are based on the spawning biomass per recruit (SPR), while biomass reference levels are estimated by multiplying the SPR by average recruitment. Estimates of the FSPR harvest rates were obtained using the life history characteristics. Spawning biomass reference levels were based on average age-0 recruitment for 1977-2013. Spawning was assumed to occur on 1 April and 15 July for northern and southern rock sole, respectively, and female spawning biomass was calculated using the mean weight-at-age at the time of spawning.

	Northern	**Southern**
SB_{2015}	40,600	65,900
$SB_{40\%}$	23,800	37,300
$SB_{35\%}$	20,800	32,600
F_{ABC}	0.374	0.204
ABC	14,300	16,700
F_{OFL}	0.452	0.243
OFL	17,000	19,600

Biomass projections

A standard set of projections is required for stocks managed under Tier 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2014 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total annual catch for 2014. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2015, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2015 recommended in the assessment to the *max* F_{ABC} for 2015. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2014 and above its MSY level in 2027 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2015 and 2016, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished

condition. If the stock is expected to be above its MSY level in 2025 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results indicate the northern (Table 4.1.14) and southern (Table 4.1.15) rock sole are not overfished currently and are not approaching an overfished condition.

The authors' recommendations for F_{ABC} and ABC for northern and southern rock sole for 2015 are 0.374 and 14,300 mt and 0.204 and 16,700 mt, respectively.

Ecosystem Considerations

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks

Ecosystem Effects on the Stock

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks

Fishery Effects on the Ecosystem

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks

Data Gaps and Research Priorities

There is considerable uncertainty about the fractions, by mass, of the shallow-water flatfish catch that is northern or southern rock sole. The fishery observer program samples on average 20% of the shallow-water flatfish catch by mass (A'mar and Palsson, 2013), and U/N/S rock sole is on average 70-80% of the observed shallow-water flatfish catch by mass (A'mar and Palsson, 2013).

The increase in random fishery observer samples throughout the year and across the entire GOA may provide more information about the distribution of northern and southern rock sole during the year. The NMFS bottom trawl survey takes place in the summer, when southern rock sole are spawning, so that the distribution of northern and southern rock sole determined by the survey may not represent the distribution of northern and southern rock sole at different times. The annual shallow-water flatfish catches come primarily from INPFC area 630 (Figure 4.1.1); the fishery observer data for shallow-water flatfish come primarily from INPFC area 630 as well (A'mar and Palsson, 2013). However, the survey data suggest that, in the summer, northern rock sole are located primarily in INPFC area 610 (Figure 4.1.4) and southern rock sole are distributed more widely across the GOA (Figure 4.1.5).

Another research question is how well the northern and southern rock sole animals are differentiated by fishery observers and survey personnel. Future sampling and genetic analysis of tissue samples would provide more information on the rates of misidentification.

Literature Cited

ADMB Project. 2009 AD Model Builder: automatic differentiation model builder. Developed by David Fournier and freely available from http://admb-project.org/.

Allen, M.J., Smith, G.B., 1988. Atlas and Zoogeography of Common Fishes in the Bering Sea and Northeastern Pacific. NOAA Technical Report NMFS 66, 151 pp.

A'mar, T., Palsson, W. 2013. Assessment of the northern and southern rock sole (*Lepidopsetta polyxystra and bilineata*) stocks in the Gulf of Alaska for 2014. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Boldt, J., Zador, S.G. (editors). 2009. Ecosystem Considerations for 2010. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Methot, R. D. 2013. User Manual for Stock Synthesis, Model Version 3.24q. Unpublished manuscript. 150 p.

Methot, R. D., and Wetzell, C. R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fish. Rsch. 142:86-99.

NPFMC. 2010. Fishery Management Plan for Groundfish of the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Orr, J.W., Matarese, A.C. 2000. Revision of the genus *Lepidopsetta* Gill, 1862 (Teleostei: Pleuronectidae) based on larval and adult morphology, with a description of a new species from the North Pacific Ocean and Bering Sea. Fish. Bull. 98(3), 539-582.

Stark, J.W., Somerton, D.A. 2002. Maturation, spawning and growth of rock soles off Kodiak Island in the Gulf of Alaska. J. Fish. Bio., 61: 417 – 431.

Thompson, G.G., Ianelli, J.N., Wilkins, M. 2009. Assessment of the Pacific Cod Stock in the Gulf of Alaska for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Turnock, B.J., A'mar, Z.T., Wilderbuer, T.K. 2009. Assessment of the shallow-water flatfish stock assemblage in the Gulf of Alaska for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Wilderbuer, T.K, Nichol, D.G. 2009. Assessment of northern rock sole in the eastern Bering Sea and Aleutian Islands for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Eastern Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage, AK, USA.

Tables

Table 4.1.1 – Estimated catch (in metric tonnes) for shallow water flatfish (SWFF) and total rock sole catch from the Alaska Fisheries Information Network (AKFIN) (as of 2014-10-24).

Year	SWFF catch (AKFIN)	U/N/S rock sole catch (AKFIN)	% U/N/S rock sole
1991	5,224.6	0.1	-
1992	8,333.8	42.0	-
1993	9,113.7	8,112.1	89.0
1994	3,843.0	3,008.1	78.3
1995	5,436.9	3,923.9	72.2
1996	9,372.4	6,595.3	70.4
1997	7,779.6	5,466.8	70.3
1998	3,567.3	2,532.3	71.0
1999	2,578.4	1,765.4	68.5
2000	6,928.7	5,386.7	77.7
2001	6,163.3	4,771.7	77.4
2002	7,177.3	5,564.3	77.5
2003	4,648.5	3,554.6	76.5
2004	3,094.1	2,216.7	71.6
2005	4,805.1	4,130.5	86.0
2006	7,651.6	5,763.3	75.3
2007	8,692.3	6,727.4	77.4
2008	9,721.0	7,269.1	74.8
2009	8,485.4	6,538.7	77.1
2010	5,533.7	3,285.3	59.4
2011	3,998.2	3,094.4	77.4
2012	4,015.3	2,828.6	70.4
2013	5,521.8	4,057.7	73.5
2014	3,924.4	2,846.5	72.5

Table 4.1.2 – Totals of fishery observer extrapolated haul-level rock sole catch data (in metric tonnes), by species (as of 2014-10-24)

Year	U	N	S	Total		% U	% N	% S
1997	1,057.9	37.9	46.0	1,141.8		92.7	3.3	4.0
1998	135.7	171.7	223.0	530.4		25.6	32.4	42.0
1999	117.9	122.1	122.0	362.1		32.6	33.7	33.7
2000	220.8	359.8	328.8	909.4		24.3	39.6	36.2
2001	179.3	404.4	425.6	1,009.4		17.8	40.1	42.2
2002	247.5	551.0	335.3	1,133.8		21.8	48.6	29.6
2003	112.0	254.3	265.6	632.0		17.7	40.2	42.0
2004	91.6	84.8	225.6	401.9		22.8	21.1	56.1
2005	39.4	209.9	224.3	473.6		8.3	44.3	47.4
2006	79.2	492.3	177.5	748.9		10.6	65.7	23.7
2007	208.3	644.2	429.6	1,282.1		16.2	50.2	33.5
2008	213.2	551.5	610.3	1,374.9		15.5	40.1	44.4
2009	161.1	498.0	441.8	1,100.8		14.6	45.2	40.1
2010	56.8	374.6	368.2	799.6		7.1	46.8	46.0
2011	73.7	149.5	288.4	511.5		14.4	29.2	56.4
2012	115.5	374.0	703.1	1,192.7		9.7	31.4	59.0
2013	116.9	519.1	476.9	1,112.8		10.5	46.6	42.9
2014	27.7	535.2	148.4	711.3		3.9	75.2	20.9

Table 4.1.3 – GOA NMFS bottom trawl survey biomass (in mt) and population estimates

Year	Species	Total biomass	std dev	Total numbers	std dev
1984	U	137,623	12,208	404,285,245	43,401,215
1987	U	123,393	20,329	281,015,223	37,864,353
1990	U	156,032	19,472	329,427,129	40,836,229
1993	U	173,044	14,570	346,198,094	29,291,722
1996	N	78,845	9,930	208,492,467	30,477,247
1999	N	61,543	15,134	151,313,021	34,652,753
2001	N	64,809	9,887	140,508,433	17,513,605
2003	N	79,648	9,514	203,049,571	26,460,258
2005	N	91,459	10,123	216,801,482	23,769,367
2007	N	102,303	12,046	227,003,343	26,624,065
2009	N	95,846	16,068	257,075,774	51,973,203
2011	N	72,875	12,427	148,039,674	24,568,593
2013	N	74,586	13,587	152,326,011	31,004,369
1996	S	127,390	12,580	186,116,865	16,990,673
1999	S	106,235	10,580	154,084,268	15,292,879
2001	S	122,492	14,643	174,732,258	20,118,997
2003	S	126,819	12,480	199,376,622	15,983,336
2005	S	147,665	15,084	240,030,524	25,605,394
2007	S	161,617	11,764	256,910,791	19,144,732
2009	S	191,765	22,591	300,479,225	33,990,620
2011	S	120,573	10,318	174,623,722	15,912,209
2013	S	131,441	13,993	182,199,716	16,748,495

Table 4.1.4 – Negative log likelihood components

	N			S			U	
	sel-at-age	sel-at-length		sel-at-age	sel-at-length		sel-at-age	sel-at-length
Parameters	88	88		88	88		137	137
TOTAL	875.22	890.26		887.63	884.07		1024.65	1045.06
Survey	-14.05	-14.38		-12.05	-14.094		-20.07	-21.612
Fsh length comp	181.66	186.04		157.42	143.42		195.34	198.79
Srv length comp	49.40	29.52		46.90	31.002		51.79	29.96
Srv age comp	674.05	702.73		704.70	733.06		807.00	847.93
Recruitment	-19.22	-19.11		-14.64	-15.83		-13.90	-15.89

Table 4.1.5 – Growth parameter estimates for the northern and southern model configurations

Parameter	Northern rock sole			Southern rock sole	
	sel-at-age	sel-at-length		sel-at-age	sel-at-length
Female L-at-Amin	21.20	15.64		15.93	11.34
Female L-at-Amax	45.36	46.75		49.38	49.53
Female k	0.186	0.212		0.185	0.199
Female CV Amin	3.32	3.03		3.18	3.24
Female CV Amax	6.75	8.06		4.62	4.87
Male M	0.251	0.240		0.259	0.242
Male L-at-Amin	20.98	15.63		17.35	13.12
Male L-at-Amax	40.92	39.28		41.71	41.86
Male k	0.165	0.261		0.186	0.206
Male CV Amin	2.73	2.97		2.37	2.20
Male CV Amax	5.24	5.38		4.15	5.00
Ln(R_0)	11.69	12.08		12.24	12.49

Table 4.1.6 – Growth parameter estimates for the undifferentiated model configuration

Parameter	Early period			Middle period			Later period	
	sel-at-age	sel-at-length		sel-at-age	sel-at-length		sel-at-age	sel-at-length
Female L-at-Amin	19.67	14.45		20.40	15.33		20.20	14.74
Female L-at-Amax	45.12	44.36		49.22	49.87		50.48	50.57
Female k	0.162	0.203		0.168	0.188		0.146	0.170
Female CV Amin	3.35	3.43		-	-		-	-
Female CV Amax	5.32	5.44		-	-		-	-
Male M	0.252	0.241		-	-		-	-
Male L-at-Amin	20.24	15.91		19.56	15.22		19.92	14.69
Male L-at-Amax	40.35	37.75		43.39	42.14		42.13	41.15
Male k	0.133	0.200		0.160	0.210		0.168	0.219
Male CV Amin	2.70	2.92		-	-		-	-
Male CV Amax	4.72	4.72		-	-		-	-
Ln(R_0)	12.75	12.99		-	-		-	-
Q for early period	0.628	0.763		-	-		-	-

Table 4.1.7 – Estimated annual spawning biomass (in metric tonnes) and age-0 recruits (in thousands) with standard deviations by species

Year	Northern rock sole					Southern rock sole			
	Spawning	Std dev	Recruits	Std dev		Spawning	Std dev	Recruits	Std dev
1977	47,048	10,427	102,350	60,857		81,488	15,875	317,989	233,296
1978	46,387	10,495	116,089	70,761		80,717	16,238	315,856	234,054
1979	45,770	10,503	123,678	73,492		79,648	16,321	295,372	207,515
1980	45,094	10,448	105,466	60,207		78,232	16,143	289,087	196,409
1981	44,467	10,331	95,879	51,060		76,887	15,810	283,024	162,037
1982	43,745	10,154	88,141	45,021		75,862	15,413	183,873	102,279
1983	43,995	9,915	80,328	40,297		76,688	15,059	191,596	101,101
1984	44,153	9,593	95,615	46,850		78,622	14,721	241,865	120,305
1985	45,203	9,290	120,481	56,662		82,746	14,434	209,764	99,777
1986	46,634	8,967	120,420	57,565		88,421	14,202	156,658	76,373
1987	47,500	8,540	177,052	58,350		94,307	13,887	243,886	81,142
1988	47,156	8,010	91,379	37,128		98,916	13,365	138,686	55,297
1989	46,666	7,425	79,770	28,290		102,481	12,657	129,649	41,509
1990	45,524	6,821	85,202	25,057		103,579	11,810	113,972	34,666
1991	44,791	6,239	88,645	21,701		102,706	10,858	149,198	35,349
1992	44,950	5,720	71,357	17,387		100,941	9,838	132,177	31,853
1993	45,658	5,252	75,330	17,723		98,354	8,836	197,112	35,864
1994	46,633	4,852	97,506	20,945		95,055	7,880	150,482	30,092
1995	47,068	4,493	126,635	22,503		92,904	6,994	142,916	28,093
1996	46,052	4,115	124,967	21,443		89,963	6,189	182,390	33,524
1997	44,153	3,759	123,899	22,245		85,400	5,484	299,194	43,478
1998	42,529	3,462	182,307	27,374		80,638	4,880	342,941	45,705
1999	41,377	3,216	198,969	27,780		76,975	4,387	178,226	33,879
2000	40,716	3,020	116,889	20,237		74,257	3,997	126,687	27,445
2001	40,232	2,887	61,204	13,393		71,501	3,693	195,607	33,151
2002	41,105	2,828	65,240	14,293		69,701	3,475	184,420	34,622
2003	42,272	2,810	88,541	19,358		68,359	3,328	267,042	41,321
2004	44,679	2,831	168,061	29,507		68,795	3,255	189,328	34,758
2005	49,019	2,926	144,595	26,902		71,675	3,267	157,983	28,916
2006	52,795	3,066	86,407	18,722		75,599	3,345	54,767	14,256
2007	53,254	3,121	56,095	13,486		78,478	3,440	57,404	14,775
2008	50,799	3,072	56,542	14,714		79,062	3,500	80,470	20,736
2009	47,730	3,022	61,223	17,422		78,162	3,540	100,446	30,351
2010	46,383	3,110	90,320	28,781		77,590	3,630	160,540	58,103
2011	48,040	3,408	128,217	50,146		78,372	3,795	173,478	82,970
2012	49,408	3,701	85,851	47,797		78,981	3,993	161,186	93,011
2013	48,767	3,846	99,634	60,016		78,217	4,146	172,577	103,590
2014	46,199	3,867	100,098	60,453		74,865	4,190	173,650	104,608
2015	43,506	3,866	119,839	72,375		70,094	4,135	207,896	125,239

Table 4.1.8 – Numbers-at-age for northern rock sole females

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	51.2	39.5	32.2	26.7	22.2	18.4	15.2	12.4	10.1	8.2	6.7	5.4	4.3	3.5	3.0	2.4	1.9	1.5	1.2	1.0	3.7
1978	58.0	41.9	32.3	26.3	21.8	18.1	14.9	12.3	10.0	8.1	6.6	5.3	4.3	3.4	2.8	2.4	1.9	1.5	1.2	1.0	3.7
1979	61.8	47.5	34.3	26.5	21.5	17.8	14.7	12.1	9.9	8.1	6.5	5.3	4.2	3.4	2.7	2.2	1.9	1.5	1.2	1.0	3.7
1980	52.7	50.6	38.9	28.1	21.6	17.5	14.4	11.9	9.7	8.0	6.5	5.2	4.2	3.4	2.7	2.2	1.7	1.5	1.2	1.0	3.7
1981	47.9	43.2	41.4	31.8	22.9	17.6	14.2	11.7	9.6	7.8	6.4	5.2	4.2	3.3	2.7	2.1	1.7	1.4	1.2	1.0	3.7
1982	44.1	39.2	35.3	33.9	26.0	18.7	14.3	11.5	9.4	7.7	6.3	5.1	4.1	3.3	2.6	2.1	1.7	1.4	1.1	0.9	3.6
1983	40.2	36.1	32.1	28.9	27.7	21.2	15.2	11.7	9.4	7.6	6.2	5.1	4.1	3.3	2.7	2.1	1.7	1.4	1.1	0.9	3.7
1984	47.8	32.9	29.5	26.3	23.6	22.6	17.3	12.4	9.4	7.6	6.2	5.0	4.1	3.3	2.7	2.1	1.7	1.4	1.1	0.9	3.7
1985	60.2	39.1	26.9	24.2	21.5	19.3	18.5	14.1	10.1	7.7	6.1	5.0	4.1	3.3	2.7	2.2	1.7	1.4	1.1	0.9	3.7
1986	60.2	49.3	32.0	22.0	19.8	17.6	15.8	15.1	11.5	8.2	6.3	5.0	4.1	3.3	2.7	2.2	1.8	1.4	1.1	0.9	3.7
1987	88.5	49.3	40.4	26.2	18.0	16.2	14.4	12.9	12.3	9.4	6.7	5.1	4.1	3.3	2.7	2.2	1.8	1.4	1.1	0.9	3.8
1988	45.7	72.5	40.4	33.0	21.4	14.7	13.2	11.7	10.5	10.0	7.6	5.4	4.1	3.3	2.7	2.2	1.8	1.4	1.1	0.9	3.7
1989	39.9	37.4	59.3	33.0	27.0	17.5	12.0	10.8	9.5	8.5	8.1	6.2	4.4	3.3	2.7	2.2	1.8	1.4	1.2	0.9	3.8
1990	42.6	32.7	30.6	48.5	27.0	22.1	14.3	9.8	8.7	7.7	6.9	6.5	4.9	3.5	2.7	2.1	1.7	1.4	1.1	0.9	3.7
1991	44.3	34.9	26.7	25.0	39.7	22.0	17.9	11.6	7.9	7.0	6.2	5.5	5.2	3.9	2.8	2.1	1.7	1.4	1.1	0.9	3.7
1992	35.7	36.3	28.5	21.9	20.5	32.3	17.9	14.5	9.3	6.3	5.6	4.9	4.4	4.1	3.1	2.2	1.7	1.3	1.1	0.9	3.6
1993	37.7	29.2	29.7	23.3	17.8	16.6	26.1	14.4	11.6	7.4	5.0	4.4	3.9	3.4	3.2	2.4	1.7	1.3	1.0	0.8	3.5
1994	48.8	30.8	23.9	24.3	19.0	14.5	13.4	21.0	11.4	9.2	5.8	3.9	3.4	3.0	2.7	2.5	1.9	1.3	1.0	0.8	3.3
1995	63.3	39.9	25.2	19.6	19.8	15.5	11.8	10.9	17.0	9.2	7.4	4.7	3.1	2.8	2.4	2.1	2.0	1.5	1.1	0.8	3.3
1996	62.5	51.8	32.7	20.7	16.0	16.2	12.6	9.6	8.8	13.7	7.4	5.9	3.7	2.5	2.2	1.9	1.7	1.6	1.2	0.8	3.3
1997	61.9	51.2	42.4	26.7	16.9	13.0	13.1	10.2	7.6	7.0	10.8	5.9	4.7	2.9	2.0	1.7	1.5	1.3	1.2	0.9	3.2
1998	91.2	50.7	41.9	34.7	21.8	13.7	10.5	10.6	8.1	6.1	5.6	8.6	4.6	3.7	2.3	1.5	1.4	1.2	1.0	1.0	3.2
1999	99.5	74.6	41.5	34.3	28.4	17.8	11.2	8.6	8.6	6.6	4.9	4.5	6.9	3.7	3.0	1.9	1.2	1.1	0.9	0.8	3.4
2000	58.4	81.5	61.1	34.0	28.0	23.2	14.5	9.1	7.0	6.9	5.3	4.0	3.6	5.6	3.0	2.4	1.5	1.0	0.9	0.8	3.4
2001	30.6	47.9	66.7	50.0	27.7	22.8	18.8	11.7	7.3	5.6	5.5	4.2	3.2	2.9	4.4	2.4	1.9	1.2	0.8	0.7	3.2
2002	32.6	25.1	39.2	54.5	40.8	22.6	18.5	15.2	9.4	5.8	4.4	4.4	3.4	2.5	2.3	3.5	1.9	1.5	0.9	0.6	3.1
2003	44.3	26.7	20.5	32.0	44.5	33.2	18.3	14.9	12.2	7.5	4.6	3.5	3.5	2.7	2.0	1.8	2.7	1.5	1.2	0.7	2.9
2004	84.0	36.2	21.9	16.8	26.2	36.3	27.0	14.8	12.1	9.8	6.0	3.7	2.8	2.8	2.1	1.6	1.4	2.2	1.2	0.9	2.9
2005	72.3	68.8	29.7	17.9	13.7	21.4	29.6	22.0	12.1	9.8	7.9	4.9	3.0	2.3	2.2	1.7	1.3	1.1	1.8	0.9	3.1
2006	43.2	59.2	56.3	24.3	14.6	11.2	17.4	24.0	17.8	9.7	7.9	6.4	3.9	2.4	1.8	1.8	1.4	1.0	0.9	1.4	3.2
2007	28.0	35.4	48.4	46.1	19.8	11.9	9.1	14.0	19.3	14.2	7.8	6.3	5.1	3.1	1.9	1.4	1.4	1.1	0.8	0.7	3.6
2008	28.3	23.0	28.9	39.6	37.6	16.1	9.6	7.3	11.3	15.4	11.3	6.1	4.9	4.0	2.4	1.5	1.1	1.1	0.8	0.6	3.4
2009	30.6	23.1	18.8	23.7	32.3	30.6	13.0	7.8	5.8	9.0	12.2	8.9	4.8	3.9	3.1	1.9	1.2	0.9	0.9	0.7	3.1
2010	45.2	25.1	18.9	15.4	19.3	26.3	24.7	10.5	6.2	4.7	7.1	9.6	7.0	3.8	3.0	2.4	1.5	0.9	0.7	0.7	2.9
2011	64.1	37.0	20.5	15.5	12.6	15.8	21.4	20.1	8.5	5.0	3.8	5.7	7.7	5.6	3.0	2.4	2.0	1.2	0.7	0.5	2.9
2012	42.9	52.5	30.3	16.8	12.7	10.3	12.8	17.4	16.3	6.9	4.0	3.0	4.6	6.2	4.5	2.4	1.9	1.6	1.0	0.6	2.7
2013	49.8	35.1	43.0	24.8	13.7	10.3	8.4	10.4	14.1	13.2	5.6	3.3	2.4	3.7	5.0	3.6	2.0	1.6	1.3	0.8	2.7
2014	50.0	40.8	28.8	35.1	20.2	11.2	8.4	6.8	8.4	11.4	10.6	4.4	2.6	1.9	2.9	4.0	2.9	1.6	1.2	1.0	2.7

Table 4.1.9 – Numbers-at-age for northern rock sole males

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	51.2	37.5	29.0	22.9	18.1	14.2	11.1	8.6	6.7	5.1	3.9	3.0	2.2	1.7	1.4	1.1	0.8	0.6	0.4	0.3	1.0
1978	58.0	39.8	29.2	22.6	17.7	14.0	11.0	8.5	6.6	5.0	3.9	2.9	2.2	1.7	1.3	1.1	0.8	0.6	0.4	0.3	1.0
1979	61.8	45.1	31.0	22.7	17.5	13.7	10.8	8.4	6.5	5.0	3.8	2.9	2.2	1.7	1.3	1.0	0.8	0.6	0.4	0.3	1.0
1980	52.7	48.1	35.1	24.1	17.6	13.5	10.6	8.2	6.4	4.9	3.8	2.9	2.2	1.6	1.2	0.9	0.7	0.6	0.4	0.3	1.0
1981	47.9	41.0	37.4	27.3	18.7	13.6	10.4	8.1	6.3	4.8	3.7	2.8	2.2	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1982	44.1	37.3	31.9	29.1	21.2	14.4	10.5	8.0	6.2	4.7	3.7	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1983	40.2	34.3	29.0	24.8	22.6	16.4	11.2	8.1	6.2	4.7	3.7	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1984	47.8	31.2	26.7	22.5	19.3	17.5	12.7	8.6	6.2	4.7	3.6	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1985	60.2	37.2	24.3	20.7	17.5	14.9	13.6	9.8	6.6	4.8	3.6	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1986	60.2	46.9	28.9	18.9	16.1	13.6	11.6	10.5	7.6	5.1	3.7	2.8	2.1	1.6	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1987	88.5	46.8	36.4	22.5	14.7	12.5	10.6	9.0	8.1	5.9	4.0	2.9	2.2	1.7	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1988	45.7	68.9	36.4	28.3	17.5	11.4	9.7	8.1	6.9	6.2	4.5	3.0	2.2	1.6	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1989	39.9	35.5	53.6	28.3	22.0	13.6	8.8	7.5	6.3	5.3	4.8	3.5	2.3	1.7	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1990	42.6	31.0	27.6	41.6	22.0	17.1	10.5	6.8	5.7	4.8	4.1	3.6	2.6	1.8	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1991	44.3	33.1	24.1	21.5	32.3	17.0	13.1	8.0	5.2	4.4	3.6	3.1	2.7	2.0	1.3	0.9	0.7	0.5	0.4	0.3	1.0
1992	35.7	34.5	25.8	18.8	16.7	25.0	13.1	10.0	6.1	3.9	3.3	2.7	2.3	2.1	1.5	1.0	0.7	0.5	0.4	0.3	1.0
1993	37.7	27.8	26.8	20.0	14.5	12.9	19.1	9.9	7.6	4.6	2.9	2.4	2.0	1.7	1.5	1.1	0.7	0.5	0.4	0.3	0.9
1994	48.8	29.3	21.6	20.8	15.5	11.2	9.8	14.5	7.4	5.6	3.4	2.1	1.8	1.5	1.2	1.1	0.8	0.5	0.4	0.3	0.9
1995	63.3	37.9	22.8	16.8	16.2	12.0	8.6	7.6	11.1	5.7	4.3	2.6	1.6	1.3	1.1	0.9	0.8	0.6	0.4	0.3	0.9
1996	62.5	49.2	29.5	17.7	13.0	12.5	9.3	6.6	5.8	8.4	4.3	3.2	1.9	1.2	1.0	0.8	0.7	0.6	0.4	0.3	0.9
1997	61.9	48.6	38.3	22.9	13.7	10.0	9.6	7.0	5.0	4.3	6.3	3.2	2.4	1.4	0.9	0.7	0.6	0.5	0.5	0.3	0.8
1998	91.2	48.2	37.8	29.8	17.8	10.6	7.7	7.3	5.3	3.8	3.2	4.7	2.4	1.8	1.0	0.7	0.5	0.4	0.4	0.3	0.9
1999	99.5	70.9	37.5	29.4	23.1	13.8	8.2	5.9	5.6	4.1	2.9	2.5	3.6	1.8	1.3	0.8	0.5	0.4	0.3	0.3	0.9
2000	58.4	77.4	55.1	29.1	22.8	17.9	10.7	6.3	4.6	4.3	3.1	2.2	1.9	2.7	1.4	1.0	0.6	0.4	0.3	0.3	0.9
2001	30.6	45.5	60.2	42.9	22.6	17.6	13.8	8.1	4.8	3.4	3.2	2.3	1.6	1.4	2.0	1.0	0.8	0.4	0.3	0.2	0.9
2002	32.6	23.8	35.4	46.8	33.2	17.5	13.5	10.5	6.2	3.6	2.6	2.4	1.7	1.2	1.0	1.5	0.8	0.6	0.3	0.2	0.8
2003	44.3	25.4	18.5	27.5	36.3	25.7	13.4	10.3	8.0	4.6	2.7	1.9	1.8	1.3	0.9	0.8	1.1	0.6	0.4	0.2	0.7
2004	84.0	34.4	19.7	14.4	21.3	28.1	19.8	10.3	7.9	6.1	3.5	2.0	1.5	1.4	1.0	0.7	0.6	0.8	0.4	0.3	0.7
2005	72.3	65.4	26.8	15.3	11.2	16.5	21.7	15.3	7.9	6.1	4.6	2.7	1.6	1.1	1.0	0.7	0.5	0.4	0.6	0.3	0.8
2006	43.2	56.2	50.8	20.8	11.9	8.7	12.8	16.7	11.7	6.0	4.6	3.5	2.0	1.2	0.8	0.8	0.6	0.4	0.3	0.5	0.8
2007	28.0	33.6	43.7	39.5	16.1	9.2	6.7	9.7	12.7	8.8	4.5	3.4	2.6	1.5	0.9	0.6	0.6	0.4	0.3	0.2	1.0
2008	28.3	21.8	26.1	34.0	30.6	12.5	7.1	5.1	7.4	9.5	6.6	3.4	2.6	1.9	1.1	0.6	0.5	0.4	0.3	0.2	0.9
2009	30.6	22.0	17.0	20.3	26.3	23.6	9.5	5.4	3.8	5.5	7.1	4.9	2.5	1.9	1.4	0.8	0.5	0.3	0.3	0.2	0.8
2010	45.2	23.8	17.1	13.2	15.7	20.3	18.1	7.3	4.0	2.9	4.1	5.3	3.6	1.8	1.4	1.0	0.6	0.3	0.2	0.2	0.7
2011	64.1	35.1	18.5	13.3	10.2	12.2	15.7	13.9	5.6	3.1	2.2	3.1	4.0	2.7	1.4	1.0	0.8	0.5	0.3	0.2	0.7
2012	42.9	49.9	27.3	14.4	10.3	7.9	9.4	12.1	10.7	4.3	2.4	1.7	2.4	3.0	2.1	1.1	0.8	0.6	0.3	0.2	0.7
2013	49.8	33.4	38.8	21.2	11.2	8.0	6.1	7.3	9.3	8.2	3.3	1.8	1.3	1.8	2.3	1.6	0.8	0.6	0.5	0.3	0.7
2014	50.0	38.7	26.0	30.1	16.5	8.7	6.2	4.7	5.5	7.1	6.2	2.5	1.4	1.0	1.4	1.7	1.2	0.6	0.4	0.3	0.7

Table 4.1.10 – Numbers-at-age for southern rock sole females

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	159.0	102.2	66.3	50.0	37.2	30.4	25.7	22.2	20.3	16.2	12.6	10.0	8.1	6.6	5.9	4.7	3.8	3.1	2.5	2.0	8.2
1978	157.9	130.2	83.7	54.3	40.9	30.4	24.8	21.0	18.0	16.5	13.1	10.1	8.0	6.5	5.3	4.7	3.8	3.1	2.5	2.0	8.2
1979	147.7	129.3	106.6	68.5	44.4	33.4	24.8	20.2	17.0	14.6	13.3	10.6	8.2	6.5	5.3	4.3	3.8	3.1	2.5	2.0	8.2
1980	144.5	120.9	105.9	87.2	56.1	36.3	27.3	20.2	16.4	13.8	11.8	10.7	8.5	6.6	5.2	4.2	3.4	3.0	2.5	2.0	8.1
1981	141.5	118.3	99.0	86.6	71.4	45.8	29.6	22.2	16.4	13.3	11.2	9.5	8.7	6.9	5.3	4.2	3.4	2.8	2.4	2.0	8.1
1982	91.9	115.9	96.9	81.0	70.9	58.3	37.4	24.1	18.0	13.3	10.7	9.0	7.7	7.0	5.5	4.3	3.4	2.7	2.2	2.0	8.1
1983	95.8	75.3	94.9	79.3	66.3	58.0	47.7	30.5	19.7	14.7	10.8	8.8	7.3	6.3	5.7	4.5	3.5	2.7	2.2	1.8	8.2
1984	120.9	78.4	61.6	77.7	64.9	54.2	47.4	38.9	24.9	16.0	11.9	8.8	7.1	5.9	5.1	4.6	3.6	2.8	2.2	1.8	8.1
1985	104.9	99.0	64.2	50.4	63.6	53.1	44.4	38.7	31.8	20.3	13.0	9.7	7.2	5.8	4.8	4.1	3.7	3.0	2.3	1.8	8.0
1986	78.3	85.9	81.1	52.6	41.3	52.0	43.5	36.3	31.7	26.0	16.6	10.7	7.9	5.8	4.7	3.9	3.4	3.1	2.4	1.9	8.0
1987	121.9	64.1	70.3	66.4	43.0	33.8	42.6	35.6	29.7	25.9	21.2	13.5	8.7	6.5	4.8	3.9	3.2	2.8	2.5	2.0	8.1
1988	69.3	99.8	52.5	57.6	54.3	35.2	27.6	34.8	29.0	24.2	21.1	17.3	11.0	7.1	5.3	3.9	3.1	2.6	2.2	2.0	8.2
1989	64.8	56.8	81.7	43.0	47.1	44.5	28.8	22.6	28.4	23.7	19.7	17.2	14.1	9.0	5.8	4.3	3.2	2.5	2.1	1.8	8.3
1990	57.0	53.1	46.5	66.9	35.2	38.5	36.3	23.5	18.4	23.1	19.2	16.0	13.9	11.4	7.3	4.7	3.5	2.6	2.1	1.7	8.2
1991	74.6	46.7	43.5	38.0	54.8	28.8	31.5	29.6	19.1	15.0	18.7	15.6	13.0	11.3	9.2	5.9	3.8	2.8	2.1	1.7	8.0
1992	66.1	61.1	38.2	35.6	31.1	44.8	23.5	25.6	24.1	15.5	12.1	15.2	12.6	10.5	9.1	7.4	4.7	3.0	2.3	1.7	7.8
1993	98.6	54.1	50.0	31.3	29.1	25.4	36.5	19.1	20.8	19.5	12.5	9.7	12.2	10.1	8.4	7.3	6.0	3.8	2.4	1.8	7.6
1994	75.2	80.7	44.3	40.9	25.6	23.8	20.7	29.6	15.4	16.7	15.6	10.0	7.8	9.7	8.1	6.7	5.8	4.7	3.0	1.9	7.5
1995	71.5	61.6	66.1	36.3	33.5	20.9	19.4	16.9	24.1	12.6	13.6	12.7	8.1	6.3	7.9	6.5	5.4	4.7	3.8	2.4	7.6
1996	91.2	58.5	50.4	54.1	29.7	27.4	17.1	15.8	13.8	19.6	10.2	11.0	10.3	6.6	5.1	6.4	5.3	4.4	3.8	3.1	8.1
1997	149.6	74.7	47.9	41.3	44.2	24.2	22.3	13.9	12.8	11.1	15.8	8.2	8.8	8.2	5.3	4.1	5.1	4.2	3.5	3.0	8.9
1998	171.5	122.5	61.1	39.2	33.8	36.1	19.8	18.1	11.2	10.4	8.9	12.7	6.6	7.1	6.6	4.2	3.3	4.1	3.4	2.8	9.6
1999	89.1	140.4	100.3	50.0	32.1	27.6	29.5	16.1	14.8	9.1	8.4	7.3	10.3	5.3	5.7	5.3	3.4	2.6	3.3	2.7	10.0
2000	63.3	73.0	114.9	82.1	41.0	26.3	22.6	24.1	13.2	12.0	7.5	6.8	5.9	8.4	4.3	4.7	4.3	2.8	2.2	2.7	10.4
2001	97.8	51.9	59.7	94.1	67.2	33.5	21.4	18.3	19.5	10.6	9.7	6.0	5.5	4.7	6.7	3.5	3.7	3.5	2.2	1.7	10.4
2002	92.2	80.1	42.5	48.9	77.0	54.9	27.3	17.4	14.9	15.8	8.6	7.8	4.8	4.4	3.8	5.4	2.8	3.0	2.8	1.8	9.7
2003	133.5	75.5	65.6	34.8	40.0	62.9	44.7	22.2	14.1	12.0	12.7	6.9	6.3	3.9	3.5	3.0	4.3	2.2	2.4	2.2	9.2
2004	94.7	109.3	61.8	53.7	28.4	32.7	51.3	36.4	18.0	11.4	9.7	10.3	5.6	5.1	3.1	2.8	2.4	3.5	1.8	1.9	9.2
2005	79.0	77.5	89.5	50.6	43.9	23.3	26.7	41.9	29.7	14.7	9.3	7.9	8.4	4.5	4.1	2.5	2.3	2.0	2.8	1.4	9.0
2006	27.4	64.7	63.4	73.3	41.4	35.9	19.0	21.8	34.0	24.1	11.9	7.5	6.4	6.7	3.6	3.3	2.0	1.9	1.6	2.3	8.4
2007	28.7	22.4	52.9	51.9	59.9	33.8	29.3	15.4	17.6	27.5	19.4	9.5	6.0	5.1	5.4	2.9	2.6	1.6	1.5	1.3	8.5
2008	40.2	23.5	18.4	43.3	42.5	49.0	27.6	23.8	12.5	14.2	22.1	15.6	7.6	4.8	4.1	4.3	2.3	2.1	1.3	1.2	7.8
2009	50.2	32.9	19.2	15.0	35.4	34.7	39.9	22.3	19.2	10.0	11.4	17.7	12.4	6.1	3.8	3.3	3.4	1.8	1.7	1.0	7.1
2010	80.3	41.1	27.0	15.7	12.3	29.0	28.3	32.4	18.1	15.5	8.1	9.1	14.2	9.9	4.9	3.1	2.6	2.7	1.5	1.3	6.5
2011	86.7	65.7	33.7	22.1	12.9	10.0	23.6	23.0	26.3	14.7	12.6	6.5	7.4	11.5	8.0	3.9	2.5	2.1	2.2	1.2	6.3
2012	80.6	71.0	53.8	27.6	18.1	10.5	8.2	19.3	18.8	21.4	11.9	10.2	5.3	6.0	9.3	6.5	3.2	2.0	1.7	1.8	6.1
2013	86.3	66.0	58.1	44.0	22.6	14.8	8.6	6.7	15.7	15.2	17.4	9.7	8.2	4.3	4.9	7.5	5.3	2.6	1.6	1.4	6.3
2014	86.8	70.6	54.0	47.6	36.0	18.4	12.1	7.0	5.4	12.7	12.3	14.0	7.8	6.6	3.5	3.9	6.0	4.2	2.1	1.3	6.2

Table 4.1.11 – Numbers-at-age for southern rock sole males

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	159.0	96.3	58.9	41.8	29.4	22.6	18.0	14.6	12.6	9.4	6.9	5.1	3.9	3.0	2.5	1.9	1.4	1.1	0.8	0.6	2.0
1978	157.9	122.7	74.3	45.5	32.3	22.6	17.4	13.8	11.1	9.5	7.1	5.2	3.9	3.0	2.3	1.9	1.4	1.1	0.8	0.6	2.0
1979	147.7	121.9	94.7	57.3	35.1	24.8	17.4	13.3	10.5	8.5	7.3	5.4	3.9	2.9	2.2	1.7	1.4	1.1	0.8	0.6	1.9
1980	144.5	114.0	94.0	73.0	44.2	27.0	19.1	13.3	10.1	8.0	6.4	5.5	4.1	3.0	2.2	1.7	1.3	1.1	0.8	0.6	1.9
1981	141.5	111.5	87.9	72.5	56.3	34.0	20.7	14.6	10.1	7.7	6.1	4.9	4.2	3.1	2.3	1.7	1.3	1.0	0.8	0.6	1.9
1982	91.9	109.2	86.1	67.8	55.9	43.3	26.1	15.8	11.1	7.7	5.8	4.6	3.7	3.2	2.4	1.7	1.3	1.0	0.7	0.6	1.9
1983	95.8	70.9	84.3	66.4	52.3	43.1	33.4	20.1	12.2	8.5	5.9	4.5	3.5	2.8	2.4	1.8	1.3	1.0	0.7	0.6	2.0
1984	120.9	73.9	54.7	65.0	51.2	40.3	33.2	25.6	15.4	9.3	6.5	4.5	3.4	2.7	2.2	1.8	1.4	1.0	0.7	0.6	1.9
1985	104.9	93.3	57.0	42.2	50.1	39.5	31.1	25.5	19.7	11.8	7.1	5.0	3.5	2.6	2.1	1.7	1.4	1.1	0.8	0.6	1.9
1986	78.3	80.9	72.0	44.0	32.6	38.7	30.4	23.9	19.6	15.2	9.1	5.5	3.8	2.7	2.0	1.6	1.3	1.1	0.8	0.6	1.9
1987	121.9	60.4	62.4	55.6	34.0	25.1	29.8	23.5	18.4	15.1	11.7	7.0	4.2	3.0	2.0	1.6	1.2	1.0	0.8	0.6	1.9
1988	69.3	94.1	46.6	48.2	42.9	26.2	19.3	22.9	18.0	14.1	11.6	8.9	5.4	3.2	2.3	1.6	1.2	0.9	0.7	0.6	1.9
1989	64.8	53.5	72.6	36.0	37.2	33.0	20.2	14.9	17.6	13.8	10.9	8.9	6.9	4.1	2.5	1.7	1.2	0.9	0.7	0.6	2.0
1990	57.0	50.0	41.3	56.0	27.8	28.6	25.4	15.5	11.4	13.5	10.6	8.3	6.8	5.2	3.1	1.9	1.3	0.9	0.7	0.5	1.9
1991	74.6	44.0	38.6	31.9	43.2	21.4	22.0	19.5	11.8	8.7	10.3	8.1	6.3	5.2	4.0	2.4	1.4	1.0	0.7	0.5	1.9
1992	66.1	57.6	33.9	29.8	24.6	33.3	16.4	16.9	14.9	9.0	6.6	7.8	6.1	4.8	3.9	3.0	1.8	1.1	0.8	0.5	1.8
1993	98.6	51.0	44.4	26.2	23.0	18.9	25.5	12.5	12.8	11.3	6.8	5.0	5.9	4.6	3.6	3.0	2.3	1.4	0.8	0.6	1.8
1994	75.2	76.0	39.3	34.3	20.2	17.7	14.5	19.4	9.5	9.7	8.5	5.1	3.8	4.4	3.5	2.7	2.2	1.7	1.0	0.6	1.8
1995	71.5	58.1	58.7	30.4	26.4	15.5	13.6	11.1	14.9	7.3	7.4	6.5	3.9	2.9	3.4	2.6	2.1	1.7	1.3	0.8	1.8
1996	91.2	55.1	44.8	45.3	23.4	20.4	11.9	10.4	8.5	11.4	5.5	5.6	4.9	3.0	2.2	2.6	2.0	1.6	1.3	1.0	2.0
1997	149.6	70.4	42.5	34.6	34.9	18.0	15.6	9.1	7.9	6.4	8.6	4.2	4.2	3.7	2.2	1.6	1.9	1.5	1.2	1.0	2.2
1998	171.5	115.4	54.3	32.8	26.6	26.9	13.8	11.9	6.9	6.0	4.9	6.5	3.2	3.2	2.8	1.7	1.2	1.5	1.1	0.9	2.4
1999	89.1	132.3	89.1	41.9	25.3	20.5	20.7	10.6	9.1	5.3	4.6	3.7	4.9	2.4	2.4	2.1	1.3	0.9	1.1	0.9	2.5
2000	63.3	68.8	102.1	68.7	32.3	19.5	15.8	15.9	8.1	7.0	4.1	3.5	2.8	3.8	1.8	1.9	1.6	1.0	0.7	0.8	2.6
2001	97.8	48.9	53.1	78.8	53.0	24.9	15.0	12.1	12.1	6.2	5.3	3.1	2.6	2.1	2.8	1.4	1.4	1.2	0.7	0.5	2.6
2002	92.2	75.5	37.7	40.9	60.7	40.8	19.1	11.4	9.2	9.2	4.7	4.0	2.3	2.0	1.6	2.1	1.0	1.1	0.9	0.6	2.3
2003	133.5	71.1	58.2	29.1	31.6	46.7	31.2	14.5	8.7	6.9	6.9	3.5	3.0	1.7	1.5	1.2	1.6	0.8	0.8	0.7	2.2
2004	94.7	103.0	54.9	44.9	22.4	24.3	35.9	23.9	11.1	6.6	5.3	5.3	2.7	2.3	1.3	1.1	0.9	1.2	0.6	0.6	2.2
2005	79.0	73.0	79.5	42.4	34.7	17.3	18.7	27.6	18.4	8.5	5.1	4.0	4.0	2.0	1.7	1.0	0.9	0.7	0.9	0.5	2.1
2006	27.4	61.0	56.4	61.3	32.7	26.7	13.3	14.3	21.0	14.0	6.5	3.8	3.1	3.0	1.5	1.3	0.8	0.7	0.5	0.7	2.0
2007	28.7	21.1	47.0	43.5	47.3	25.1	20.5	10.1	10.9	15.9	10.6	4.9	2.9	2.3	2.3	1.2	1.0	0.6	0.5	0.4	2.0
2008	40.2	22.1	16.3	36.3	33.5	36.4	19.2	15.6	7.7	8.2	12.0	7.9	3.7	2.2	1.7	1.7	0.9	0.7	0.4	0.4	1.8
2009	50.2	31.0	17.1	12.6	28.0	25.8	27.8	14.6	11.8	5.8	6.2	9.0	6.0	2.7	1.6	1.3	1.3	0.7	0.6	0.3	1.6
2010	80.3	38.8	24.0	13.2	9.7	21.5	19.7	21.2	11.1	8.9	4.4	4.7	6.8	4.5	2.1	1.2	1.0	1.0	0.5	0.4	1.5
2011	86.7	61.9	29.9	18.5	10.2	7.5	16.5	15.1	16.2	8.5	6.8	3.3	3.5	5.2	3.4	1.6	0.9	0.7	0.7	0.4	1.4
2012	80.6	66.9	47.8	23.1	14.3	7.8	5.7	12.7	11.6	12.4	6.5	5.2	2.5	2.7	3.9	2.6	1.2	0.7	0.6	0.6	1.4
2013	86.3	62.2	51.6	36.9	17.8	11.0	6.0	4.4	9.7	8.9	9.5	4.9	4.0	1.9	2.1	3.0	2.0	0.9	0.5	0.4	1.5
2014	86.8	66.6	48.0	39.8	28.4	13.7	8.4	4.6	3.4	7.4	6.7	7.2	3.7	3.0	1.5	1.6	2.3	1.5	0.7	0.4	1.4

Table 4.1.12 – Parameter estimates for the northern and southern model configurations

	Northern rock sole			Southern rock sole	
Label	**Value**	**Std Dev**		**Value**	**Std Dev**
NatM females	0.2	-		0.2	-
L_at_Amin females	21.2026	0.684352		15.9336	0.82161
L_at_Amax females	45.3603	1.07436		49.3793	0.616781
VonBert_K females	0.186109	0.01764		0.185096	0.010141
CV_young females	3.31867	0.299856		3.178	0.309287
CV_old females	6.75109	0.304511		4.62328	0.200653
NatM males	0.251293	0.008393		0.259282	0.006388
L_at_Amin males	20.9763	0.534806		17.3469	0.736351
L_at_Amax males	40.9238	1.35756		41.714	0.728567
VonBert_K males	0.164977	0.022107		0.186291	0.016498
CV_young males	2.73327	0.208262		2.37313	0.249195
CV_old males	5.24477	0.286135		4.15062	0.238403
SR_LN(R0)	11.6939	0.068833		12.2448	0.053817
SR_R1_offset	-0.00914	0.131678		0.017224	0.129415
Early_InitAge_13	-0.00017	0.599936		-0.00261	0.599171
Early_InitAge_12	-0.00022	0.599911		-0.00316	0.598988
Early_InitAge_11	-0.00029	0.599875		-0.00382	0.598762
Early_InitAge_10	-0.0005	0.599788		0.022194	0.605992
Early_InitAge_9	-0.00096	0.599606		0.071021	0.616383
Early_InitAge_8	-0.00199	0.599222		0.094955	0.619794
Early_InitAge_7	-0.00439	0.5984		-0.01637	0.589697
Early_InitAge_6	-0.00904	0.596882		-0.06765	0.578779
Early_InitAge_5	-0.01774	0.594217		-0.09709	0.571203
Early_InitAge_4	-0.02881	0.590568		-0.08971	0.569678
Early_InitAge_3	-0.03936	0.58604		0.010438	0.590324
Early_InitAge_2	-0.04593	0.581786		0.100294	0.605002
Early_InitAge_1	-0.03389	0.581493		0.339374	0.663698
Main_RecrDev_1977	0.022255	0.57959		0.604976	0.723463
Main_RecrDev_1978	0.148209	0.597521		0.598245	0.737747
Main_RecrDev_1979	0.21153	0.585849		0.531195	0.700286
Main_RecrDev_1980	0.052239	0.562936		0.509689	0.67803
Main_RecrDev_1981	-0.04306	0.525342		0.488491	0.573372
Main_RecrDev_1982	-0.12721	0.504258		0.057207	0.55077
Main_RecrDev_1983	-0.22002	0.494855		0.098347	0.523972
Main_RecrDev_1984	-0.04582	0.486349		0.331341	0.500312
Main_RecrDev_1985	0.185347	0.47132		0.188941	0.47601
Main_RecrDev_1986	0.18484	0.47534		-0.10298	0.483207
Main_RecrDev_1987	0.570296	0.337145		0.33966	0.340135

Main_RecrDev_1988	-0.09114	0.403107		-0.22483	0.397225
Main_RecrDev_1989	-0.227	0.353601		-0.29221	0.321507
Main_RecrDev_1990	-0.16113	0.295025		-0.42109	0.302582
Main_RecrDev_1991	-0.12151	0.245525		-0.15177	0.236476
Main_RecrDev_1992	-0.33845	0.238648		-0.2729	0.239526
Main_RecrDev_1993	-0.28427	0.2299		0.126734	0.184071
Main_RecrDev_1994	-0.02623	0.213848		-0.1432	0.198327
Main_RecrDev_1995	0.235165	0.174116		-0.19479	0.192673
Main_RecrDev_1996	0.221902	0.167099		0.04911	0.179059
Main_RecrDev_1997	0.213322	0.172528		0.544052	0.143575
Main_RecrDev_1998	0.599544	0.145812		0.680518	0.134949
Main_RecrDev_1999	0.687002	0.135942		0.026012	0.188327
Main_RecrDev_2000	0.155078	0.168614		-0.31532	0.212905
Main_RecrDev_2001	-0.49194	0.21042		0.119069	0.166573
Main_RecrDev_2002	-0.42807	0.209869		0.060176	0.18321
Main_RecrDev_2003	-0.12268	0.208832		0.430365	0.151311
Main_RecrDev_2004	0.51818	0.166364		0.086442	0.179734
Main_RecrDev_2005	0.367787	0.177268		-0.09456	0.177344
Main_RecrDev_2006	-0.14708	0.205159		-1.15395	0.249997
Main_RecrDev_2007	-0.5791	0.224883		-1.10693	0.24409
Main_RecrDev_2008	-0.57116	0.243291		-0.76915	0.242677
Main_RecrDev_2009	-0.49163	0.265215		-0.54742	0.28619
Main_RecrDev_2010	-0.10279	0.298082		-0.0785	0.346107
Main_RecrDev_2011	0.247579	0.374031		-0.00099	0.462219
Late_RecrDev_2012	-0.15354	0.553238		-0.07448	0.575175
Late_RecrDev_2013	-0.00465	0.598423		-0.0062	0.597857
Late_RecrDev_2014	0	0.6		0	0.6
ForeRecr_2015	0	0.6		0	0.6
Initial F	0.044336	0.011291		0.018281	0.003698
P_1_Fishery	54.3191	3.1114		50.7714	2.18457
P_2_Fishery	-1.34075	1.70605		2.21138	30.3393
P_3_Fishery	5.75341	0.158167		5.6192	0.141964
P_4_Fishery	-2.047	32.2319		0.202653	216.869
P_5_Fishery	-10	-		-10	-
P_6_Fishery	1.40235	2.51311		3.56799	97.2086
Male_Peak_Fishery	-12.7845	2.29871		-12.5325	1.86741
Male_Ascend_Fishery	-0.98505	0.155589		-1.0806	0.156653
Male_Descend_Fishery	7.77284	101.784		-0.00144	335.388
Male_Final_Fishery	6.43189	65.3279		0.000425	223.592
Male_Scale_Fishery	1	-		1	-
P_1_Survey	5.3466	0.427369		7.23931	0.476064

P_2_Survey	0.0759	0.574559		1.85494	0.335075
P_3_Survey	1.15328	0.288257		1.78778	0.252216
P_4_Survey	3.21324	1.77916		-4.59863	9.87062
P_5_Survey	-10	-		-10	-
P_6_Survey	-2.71721	3.03098		-8.76529	26.6482
Male_Peak_Survey	-1.00301	0.444775		-1.44857	0.508626
Male_Ascend_Survey	-0.81168	0.360871		-0.83543	0.317157
Male_Descend_Survey	0.222465	2.13557		8.82626	5.2325
Male_Final_Survey	0.748486	5.62296		-0.38918	94.4618
Male_Scale_Survey	1	-		1	-

Table 4.1.13 – Maturity-at-age (fixed), estimated survey selectivity-at-age, and derived fishery selectivity-at-age for males and females for the northern and southern model configurations with survey selectivity-at-age

	Northern						Southern				
Age	Maturity	Srv F	Srv M	Fsh F	Fsh M		Maturity	Srv F	Srv M	Fsh F	Fsh M
0	0	0.000	0.000	0.000	0.000		0	0.000	0.000	0.000	0.000
1	0	0.002	0.000	0.006	0.002		0	0.001	0.000	0.004	0.002
2	0	0.029	0.020	0.017	0.012		0	0.010	0.004	0.010	0.007
3	0	0.176	0.277	0.043	0.047		0	0.049	0.050	0.027	0.031
4	0	0.564	0.920	0.093	0.112		0	0.173	0.290	0.081	0.110
5	0.02	0.963	1.000	0.159	0.205		0.01	0.432	0.786	0.171	0.249
6	0.24	1.000	1.000	0.234	0.311		0.04	0.773	0.999	0.285	0.416
7	0.72	1.000	1.000	0.309	0.416		0.15	0.991	1.000	0.404	0.573
8	0.93	1.000	1.000	0.379	0.510		0.37	1.000	1.000	0.516	0.697
9	0.98	1.000	1.000	0.439	0.589		0.63	1.000	1.000	0.611	0.786
10	0.99	1.000	1.000	0.491	0.652		0.82	1.000	1.000	0.688	0.847
11	1	1.000	1.000	0.534	0.702		0.91	1.000	1.000	0.748	0.888
12	1	1.000	1.000	0.569	0.741		0.96	1.000	1.000	0.793	0.915
13	1	1.000	1.000	0.597	0.772		0.98	1.000	1.000	0.828	0.934
14	1	1.000	1.000	0.620	0.796		0.99	1.000	1.000	0.854	0.946
15	1	1.000	1.000	0.639	0.814		0.99	1.000	1.000	0.874	0.955
16	1	1.000	1.000	0.654	0.829		0.99	1.000	1.000	0.889	0.962
17	1	1.000	1.000	0.666	0.841		1	1.000	1.000	0.901	0.966
18	1	1.000	1.000	0.676	0.851		1	1.000	1.000	0.910	0.970
19	1	0.989	0.971	0.684	0.859		1	1.000	1.000	0.917	0.973
20	1	0.915	0.891	0.691	0.865		1	1.000	1.000	0.922	0.975
21	1	0.785	0.775	0.696	0.871		1	1.000	1.000	0.927	0.976
22	1	0.628	0.641	0.700	0.875		1	1.000	1.000	0.930	0.978
23	1	0.470	0.508	0.704	0.878		1	1.000	1.000	0.933	0.979
24	1	0.332	0.390	0.707	0.881		1	1.000	1.000	0.935	0.979
25	1	0.227	0.296	0.709	0.884		1	1.000	1.000	0.937	0.980
26	1	0.154	0.226	0.711	0.886		1	1.000	1.000	0.939	0.981
27	1	0.108	0.179	0.713	0.888		1	0.049	0.985	0.940	0.981
28	1	0.082	0.149	0.715	0.889		1	0.000	0.818	0.941	0.981
29	1	0.068	0.132	0.716	0.890		1	0.000	0.481	0.942	0.982
30	1	0.062	0.123	0.717	0.892		1	0.000	0.000	0.943	0.982

Table 4.1.14 – Results for the projections scenarios for northern rock sole

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	14,802	17,549	1,600	44,538	0.037	86,708
2015	14,393	17,065	14,393	40,685	0.374	84,233
2016	11,985	14,220	11,985	32,667	0.374	72,279
2017	10,355	12,297	10,355	27,817	0.374	65,151
2018	9,286	11,036	9,286	25,142	0.374	61,207
2019	8,610	10,239	8,610	23,029	0.374	58,390
2020	8,205	9,763	8,205	21,614	0.374	56,577
2021	7,980	9,497	7,980	20,814	0.374	55,520
2022	7,765	9,224	7,765	20,495	0.369	55,032
2023	7,628	9,062	7,628	20,435	0.364	54,869
2024	7,543	8,963	7,543	20,480	0.361	54,877
2025	7,512	8,928	7,512	20,459	0.360	54,886
2026	7,504	8,917	7,504	20,381	0.360	54,875
2027	7,493	8,905	7,493	20,277	0.360	54,836
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	1,850	17,549	1,600	44,538	0.037	86,708
2015	1,798	17,065	1,798	41,917	0.043	84,233
2016	1,757	16,688	1,757	39,757	0.043	82,318
2017	1,731	16,471	1,731	39,028	0.043	82,050
2018	1,720	16,386	1,720	39,376	0.043	82,926
2019	1,721	16,406	1,721	39,413	0.043	83,460
2020	1,730	16,505	1,730	39,513	0.043	83,984
2021	1,745	16,658	1,745	39,817	0.043	84,614
2022	1,762	16,831	1,762	40,341	0.043	85,406
2023	1,780	16,998	1,780	40,905	0.043	86,170
2024	1,795	17,138	1,795	41,430	0.043	86,861
2025	1,807	17,247	1,807	41,769	0.043	87,362
2026	1,816	17,331	1,816	41,961	0.043	87,711
2027	1,823	17,398	1,823	42,056	0.043	87,938
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	7,315	17,549	1,600	44,538	0.037	86,708
2015	7,112	17,065	7,112	41,418	0.176	84,233
2016	6,509	15,641	6,509	36,732	0.176	78,066
2017	6,069	14,608	6,069	34,011	0.176	74,538
2018	5,761	13,890	5,761	32,741	0.176	72,862
2019	5,557	13,419	5,557	31,501	0.176	71,424
2020	5,433	13,134	5,433	30,605	0.176	70,428

2021	5,366	12,983	5,366	30,119	0.176	69,868
2022	5,334	12,913	5,334	29,999	0.176	69,705
2023	5,319	12,880	5,319	30,037	0.176	69,696
2024	5,308	12,856	5,308	30,122	0.176	69,753
2025	5,298	12,830	5,298	30,102	0.176	69,741
2026	5,286	12,803	5,286	30,004	0.176	69,685
2027	5,278	12,782	5,278	29,871	0.176	69,595
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	0	17,549	1,600	44,538	0.037	86,708
2015	0	17,065	0	42,079	0.000	84,233
2016	0	17,044	0	40,791	0.000	83,761
2017	0	17,137	0	40,822	0.000	84,722
2018	0	17,318	0	41,850	0.000	86,661
2019	0	17,568	0	42,477	0.000	88,102
2020	0	17,866	0	43,085	0.000	89,398
2021	0	18,191	0	43,830	0.000	90,690
2022	0	18,515	0	44,739	0.000	92,055
2023	0	18,814	0	45,643	0.000	93,317
2024	0	19,070	0	46,466	0.000	94,440
2025	0	19,280	0	47,065	0.000	95,314
2026	0	19,450	0	47,480	0.000	95,981
2027	0	19,593	0	47,767	0.000	96,476
Scenario 6, Whether N rock sole are overfished – $SB_{35\%}$ = 17,600						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	17,549	17,549	1,600	44,538	0.037	86,708
2015	17,065	17,065	17,065	40,399	0.452	84,233
2016	13,703	13,703	13,703	31,201	0.452	70,167
2017	11,516	11,516	11,516	25,734	0.452	61,960
2018	10,134	10,134	10,134	22,741	0.452	57,483
2019	9,291	9,291	9,291	20,494	0.452	54,438
2020	8,346	8,346	8,346	19,080	0.426	52,553
2021	7,932	7,932	7,932	18,490	0.412	51,836
2022	7,869	7,869	7,869	18,422	0.410	51,797
2023	7,895	7,895	7,895	18,532	0.410	51,926
2024	7,904	7,904	7,904	18,663	0.410	52,065
2025	7,891	7,891	7,891	18,677	0.410	52,112
2026	7,884	7,884	7,884	18,617	0.411	52,116
2027	7,873	7,873	7,873	18,526	0.410	52,085
Scenario 7, Whether N rock sole are approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio

2014	17,549	17,549	1,600	44,538	0.037	86,708
2015	17,065	17,065	14,393	40,685	0.374	84,233
2016	14,220	14,220	11,985	32,667	0.374	72,279
2017	12,297	12,297	12,297	27,629	0.452	65,151
2018	10,679	10,679	10,679	24,111	0.452	59,697
2019	9,667	9,667	9,667	21,467	0.452	55,952
2020	8,873	8,873	8,873	19,734	0.442	53,569
2021	8,192	8,192	8,192	18,830	0.420	52,300
2022	7,979	7,979	7,979	18,582	0.413	51,971
2023	7,933	7,933	7,933	18,595	0.411	51,963
2024	7,911	7,911	7,911	18,677	0.411	52,046
2025	7,885	7,885	7,885	18,671	0.410	52,077
2026	7,875	7,875	7,875	18,605	0.410	52,084
2027	7,864	7,864	7,864	18,514	0.410	52,061

Table 4.1.15 – Results for the projections scenarios for southern rock sole

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	17,597	20,705	1,600	72,243	0.017	127,883
2015	16,727	19,683	16,727	65,942	0.204	123,971
2016	14,177	16,690	14,177	52,717	0.204	107,544
2017	12,500	14,725	12,500	43,009	0.204	96,350
2018	11,471	13,520	11,471	36,712	0.204	89,392
2019	10,895	12,847	10,895	33,111	0.204	85,746
2020	10,183	11,963	10,183	31,257	0.195	84,151
2021	9,934	11,679	9,934	30,529	0.190	83,869
2022	10,036	11,800	10,036	30,476	0.189	84,355
2023	10,258	12,068	10,258	30,812	0.191	85,082
2024	10,418	12,262	10,418	31,346	0.192	85,926
2025	10,505	12,370	10,505	31,901	0.192	86,771
2026	10,589	12,471	10,589	32,306	0.192	87,452
2027	10,698	12,599	10,698	32,511	0.193	87,912
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	1,730	20,705	1,600	72,243	0.017	127,883
2015	1,643	19,683	1,643	67,624	0.019	123,971
2016	1,583	18,988	1,583	62,560	0.019	119,990
2017	1,552	18,649	1,552	58,482	0.019	117,432
2018	1,546	18,605	1,546	56,075	0.019	116,520
2019	1,559	18,787	1,559	55,344	0.019	117,344
2020	1,587	19,133	1,587	55,755	0.019	119,287
2021	1,624	19,592	1,624	56,734	0.019	121,591
2022	1,666	20,103	1,666	58,073	0.019	124,132
2023	1,708	20,609	1,708	59,652	0.019	126,675
2024	1,746	21,067	1,746	61,381	0.019	129,248
2025	1,780	21,462	1,780	63,099	0.019	131,722
2026	1,808	21,801	1,808	64,595	0.019	133,883
2027	1,833	22,098	1,833	65,789	0.019	135,657
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	8,973	20,705	1,600	72,243	0.017	127,883
2015	8,527	19,683	8,527	66,879	0.100	123,971
2016	7,760	17,936	7,760	58,020	0.100	114,293
2017	7,251	16,785	7,251	51,063	0.100	107,414
2018	6,949	16,108	6,949	46,460	0.100	103,189
2019	6,802	15,786	6,802	43,964	0.100	101,363
2020	6,767	15,718	6,767	42,874	0.100	101,083

2021	6,809	15,825	6,809	42,556	0.100	101,482
2022	6,895	16,030	6,895	42,751	0.100	102,353
2023	6,994	16,261	6,994	43,306	0.100	103,418
2024	7,085	16,472	7,085	44,095	0.100	104,656
2025	7,159	16,644	7,159	44,940	0.100	105,923
2026	7,221	16,784	7,221	45,636	0.100	107,004
2027	7,274	16,908	7,274	46,115	0.100	107,830
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	0	20,705	1,600	72,243	0.017	127,883
2015	0	19,683	0	67,796	0.000	123,971
2016	0	19,240	0	63,656	0.000	121,354
2017	0	19,113	0	60,344	0.000	119,924
2018	0	19,248	0	58,579	0.000	119,956
2019	0	19,585	0	58,409	0.000	121,596
2020	0	20,068	0	59,329	0.000	124,270
2021	0	20,648	0	60,772	0.000	127,235
2022	0	21,270	0	62,538	0.000	130,377
2023	0	21,878	0	64,511	0.000	133,472
2024	0	22,431	0	66,608	0.000	136,552
2025	0	22,914	0	68,671	0.000	139,495
2026	0	23,332	0	70,488	0.000	142,084
2027	0	23,701	0	71,977	0.000	144,245
Scenario 6, Whether S rock sole are overfished – $SB_{35\%}$ = 28,500						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	20,705	20,705	1,600	72,243	0.017	127,883
2015	19,683	19,683	19,683	65,589	0.243	123,971
2016	16,242	16,242	16,242	50,835	0.243	105,122
2017	14,024	14,024	14,024	40,309	0.243	92,591
2018	12,682	12,682	12,682	33,616	0.243	84,932
2019	10,955	10,955	10,955	29,903	0.222	80,913
2020	10,201	10,201	10,201	28,356	0.209	79,816
2021	10,109	10,109	10,109	27,914	0.206	80,014
2022	10,349	10,349	10,349	28,069	0.207	80,826
2023	10,732	10,732	10,732	28,537	0.211	81,744
2024	11,070	11,070	11,070	29,114	0.215	82,635
2025	11,229	11,229	11,229	29,620	0.216	83,374
2026	11,305	11,305	11,305	29,927	0.217	83,882
2027	11,394	11,394	11,394	30,032	0.219	84,180
Scenario 7, Whether S rock sole are approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio

2014	20,705	20,705	1,600	72,243	0.017	127,883
2015	19,683	19,683	16,727	65,942	0.204	123,971
2016	16,690	16,690	14,177	52,717	0.204	107,544
2017	14,725	14,725	14,725	42,779	0.243	96,350
2018	13,198	13,198	13,198	35,453	0.243	87,670
2019	11,794	11,794	11,794	31,233	0.232	82,898
2020	10,670	10,670	10,670	29,155	0.216	80,906
2021	10,366	10,366	10,366	28,374	0.210	80,567
2022	10,474	10,474	10,474	28,307	0.209	81,058
2023	10,777	10,777	10,777	28,638	0.212	81,796
2024	11,072	11,072	11,072	29,137	0.215	82,602
2025	11,216	11,216	11,216	29,607	0.216	83,312
2026	11,288	11,288	11,288	29,901	0.217	83,821
2027	11,379	11,379	11,379	30,006	0.218	84,131

Figures

Figure 4.1.1 – Total catch of rock sole by area (as of 2014-10-24)

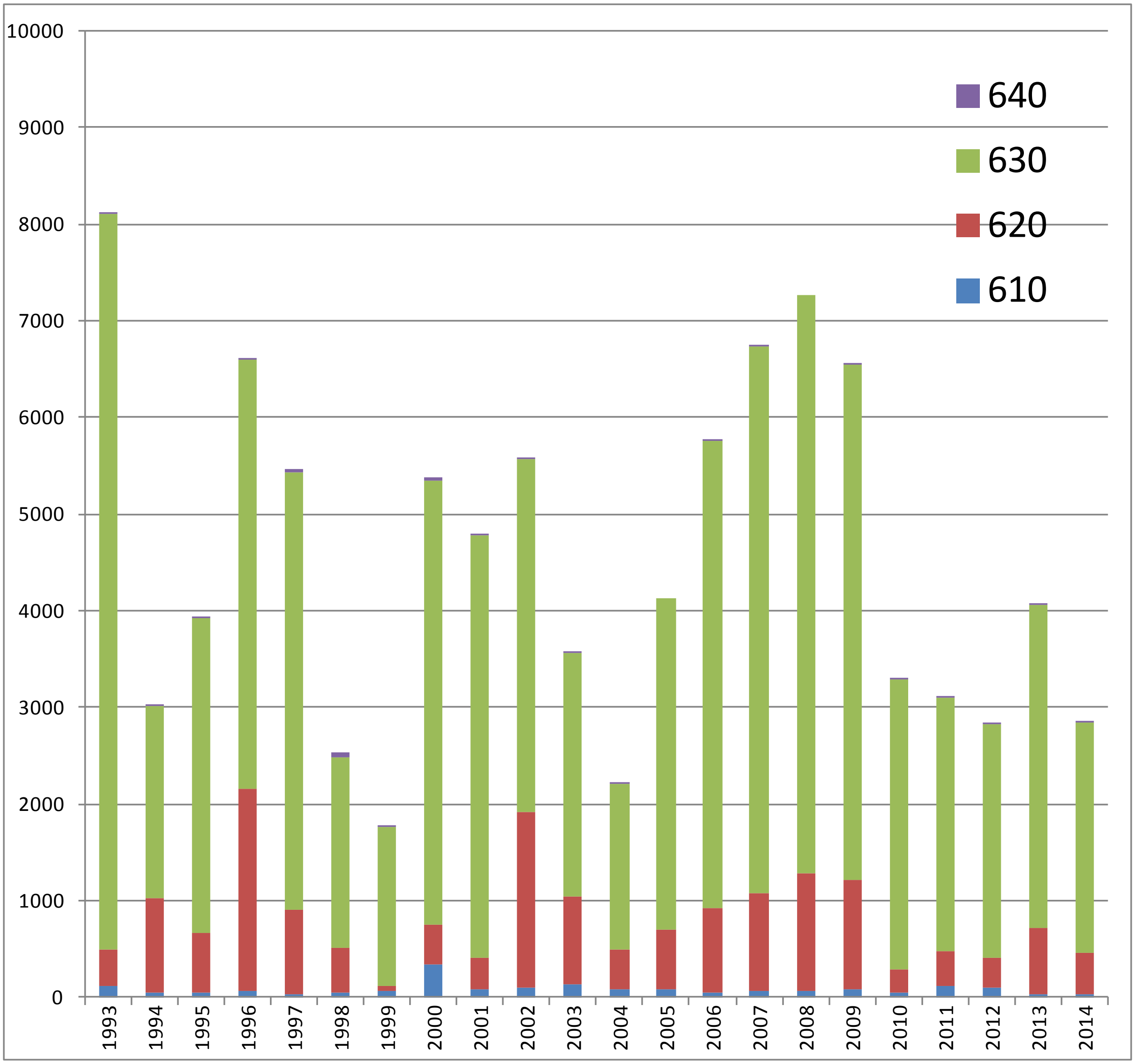


Figure 4.1.2 – Percent of the observed rock sole catch that is U/N/S rock sole (based on fishery observer extrapolated haul-level data; as of 2014-10-24)

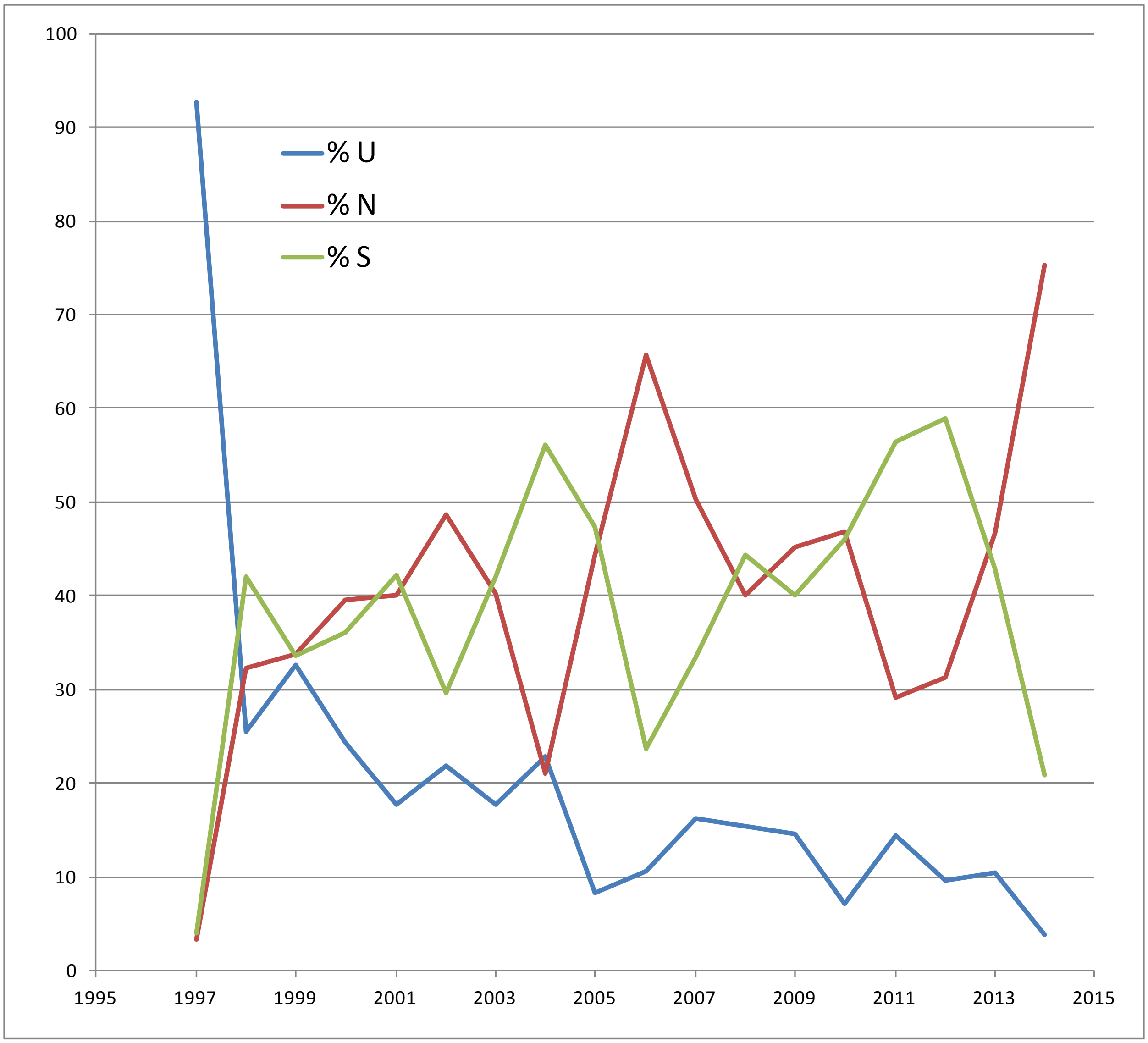


Figure 4.1.3 – GOA NMFS bottom trawl survey estimates for U rock sole by area

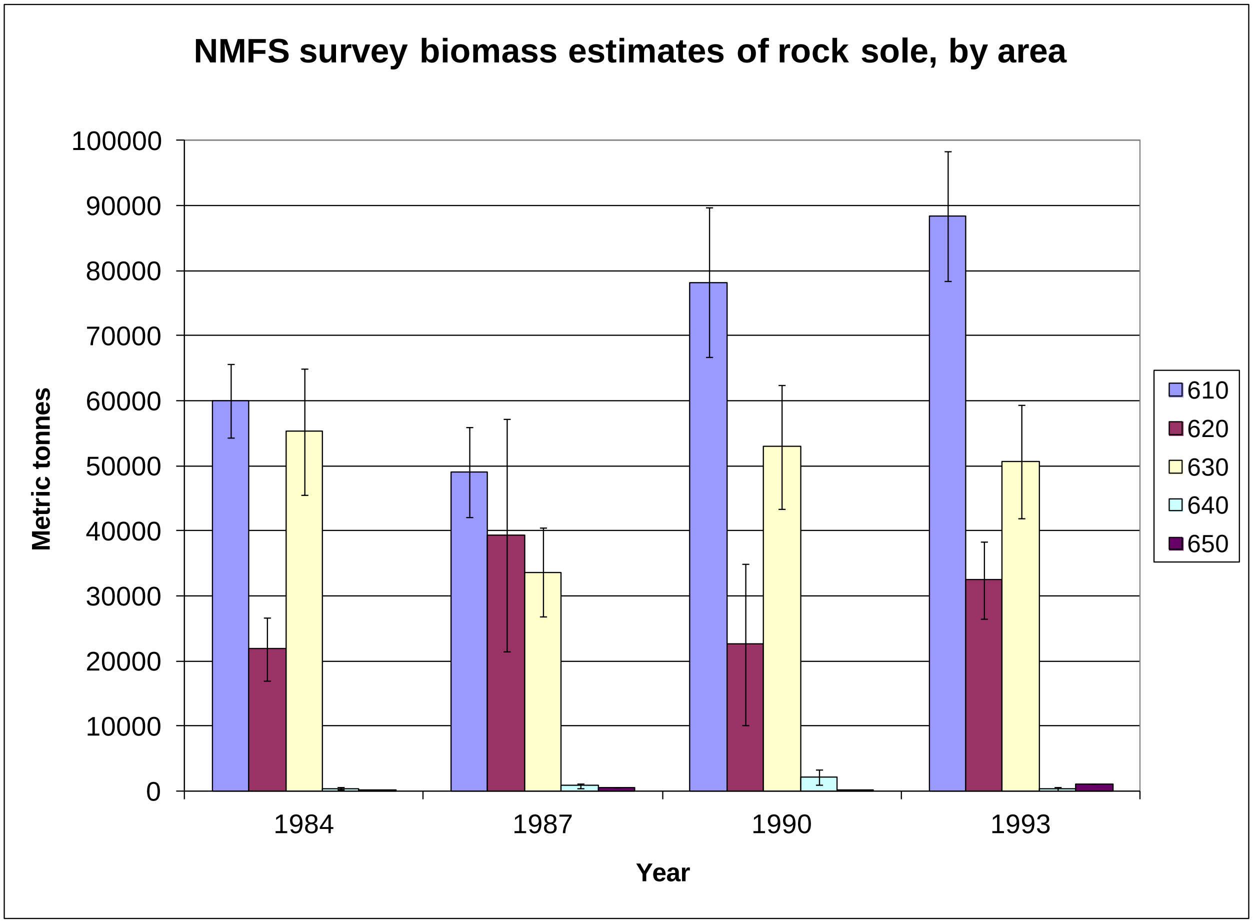


Figure 4.1.4 – GOA NMFS bottom trawl survey estimates for N rock sole by area

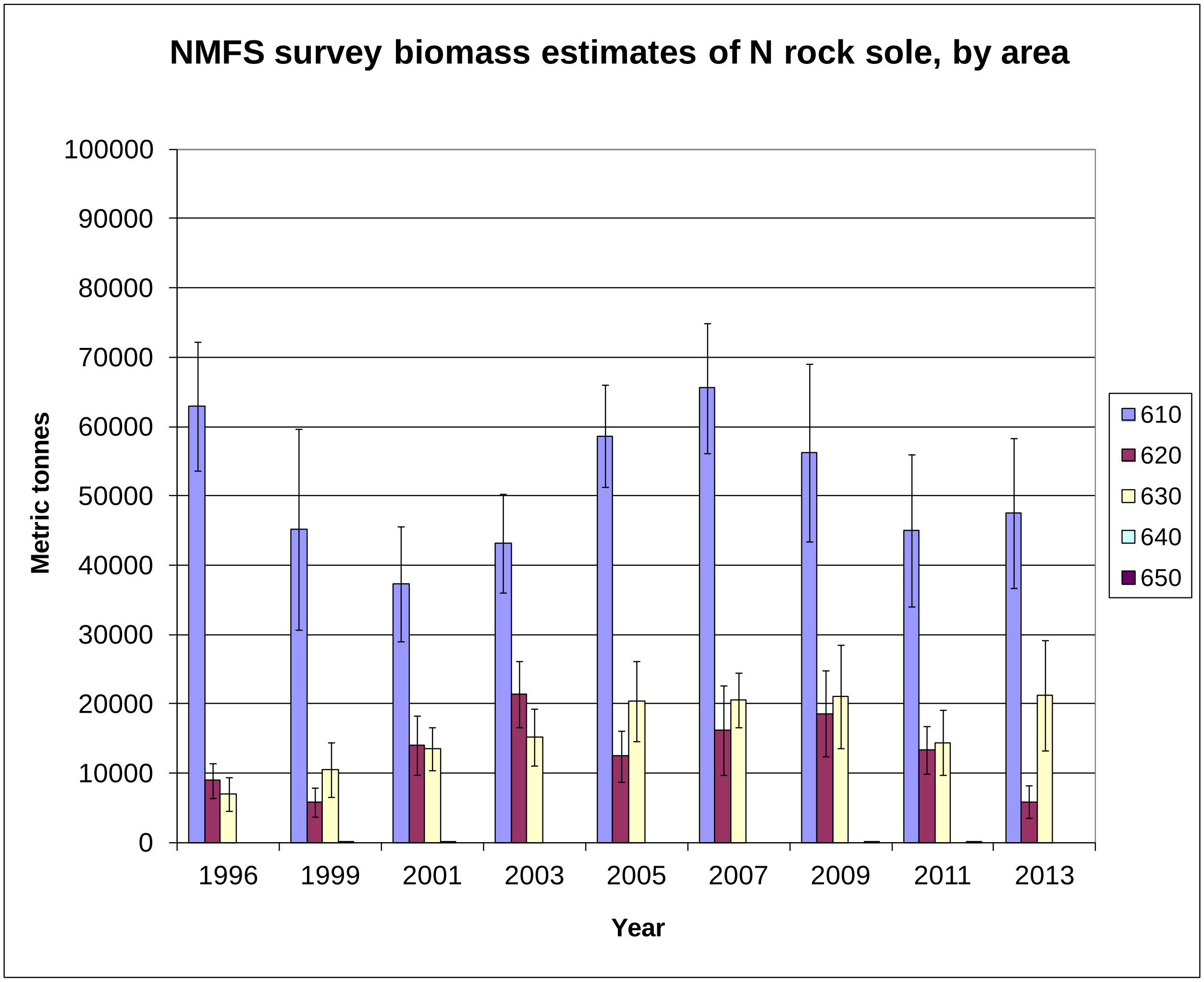


Figure 4.1.5 – GOA NMFS bottom trawl survey estimates for S rock sole by area

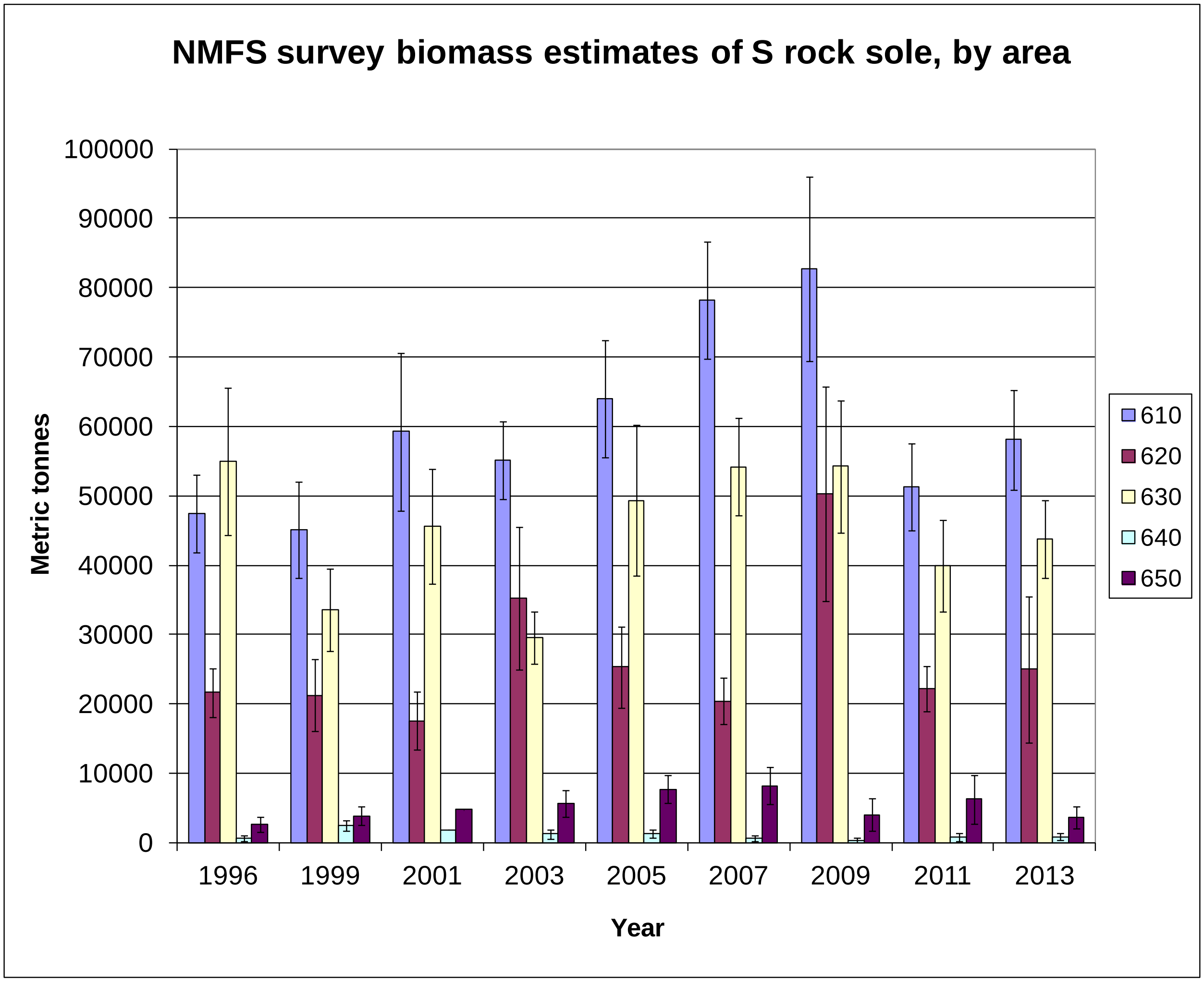


Figure 4.1.6 – GOA NMFS bottom trawl survey estimates for U/N/S rock sole

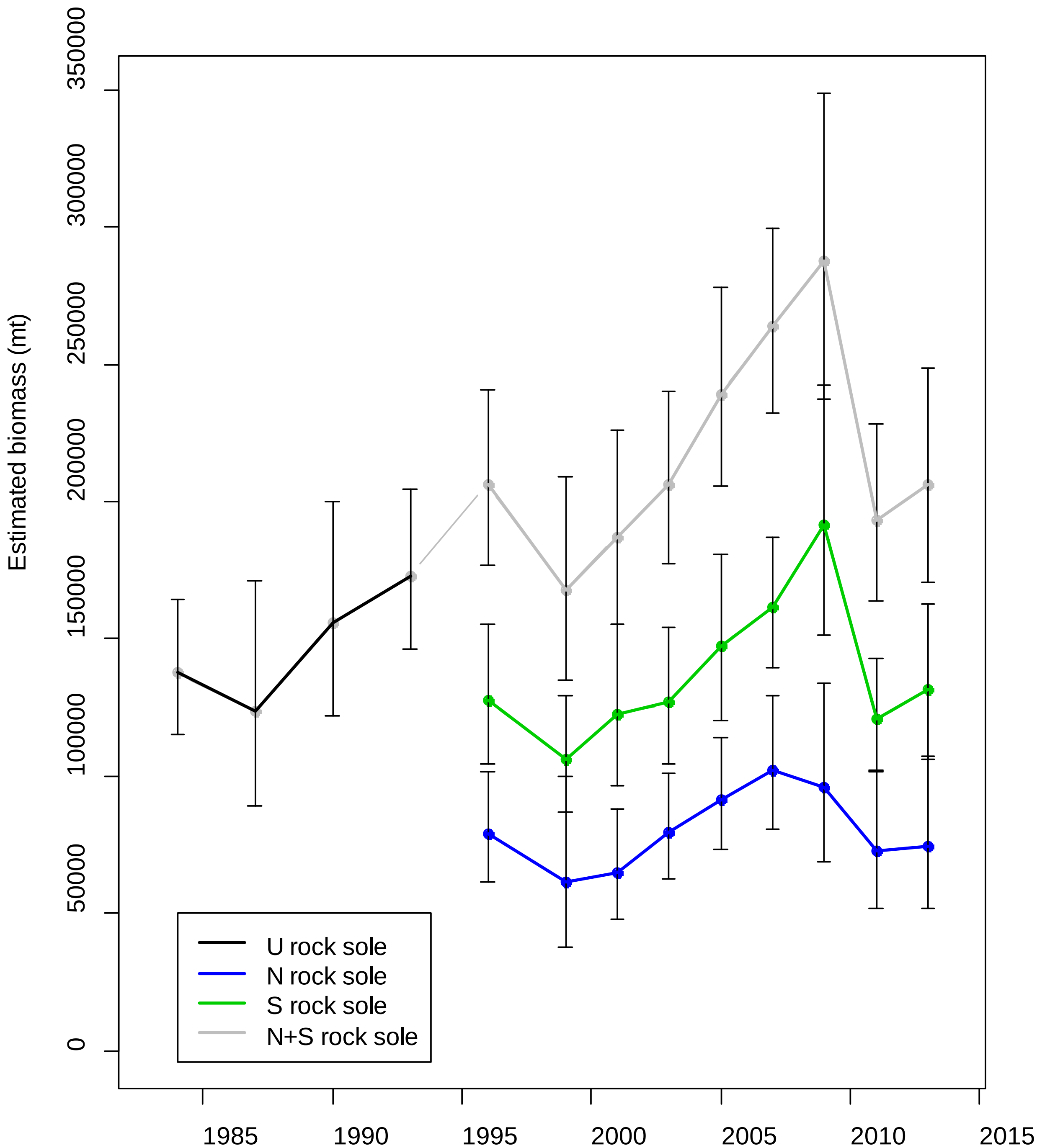


Figure 4.1.7 – Spawning biomass for U model configurations with survey selectivity-at-age and -at-length

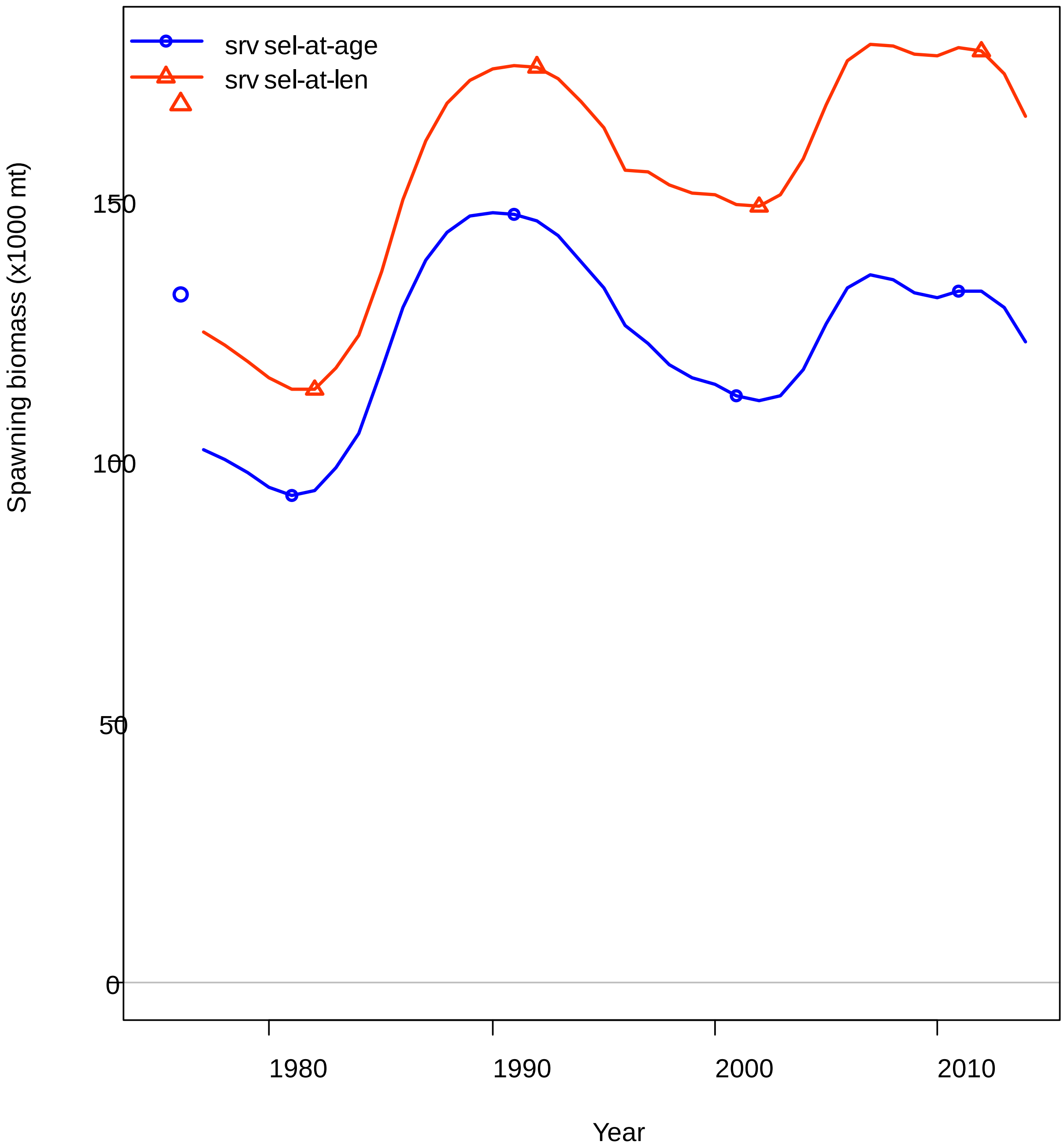


Figure 4.1.8 – Age-0 recruits for U model configurations with survey selectivity-at-age and -at-length

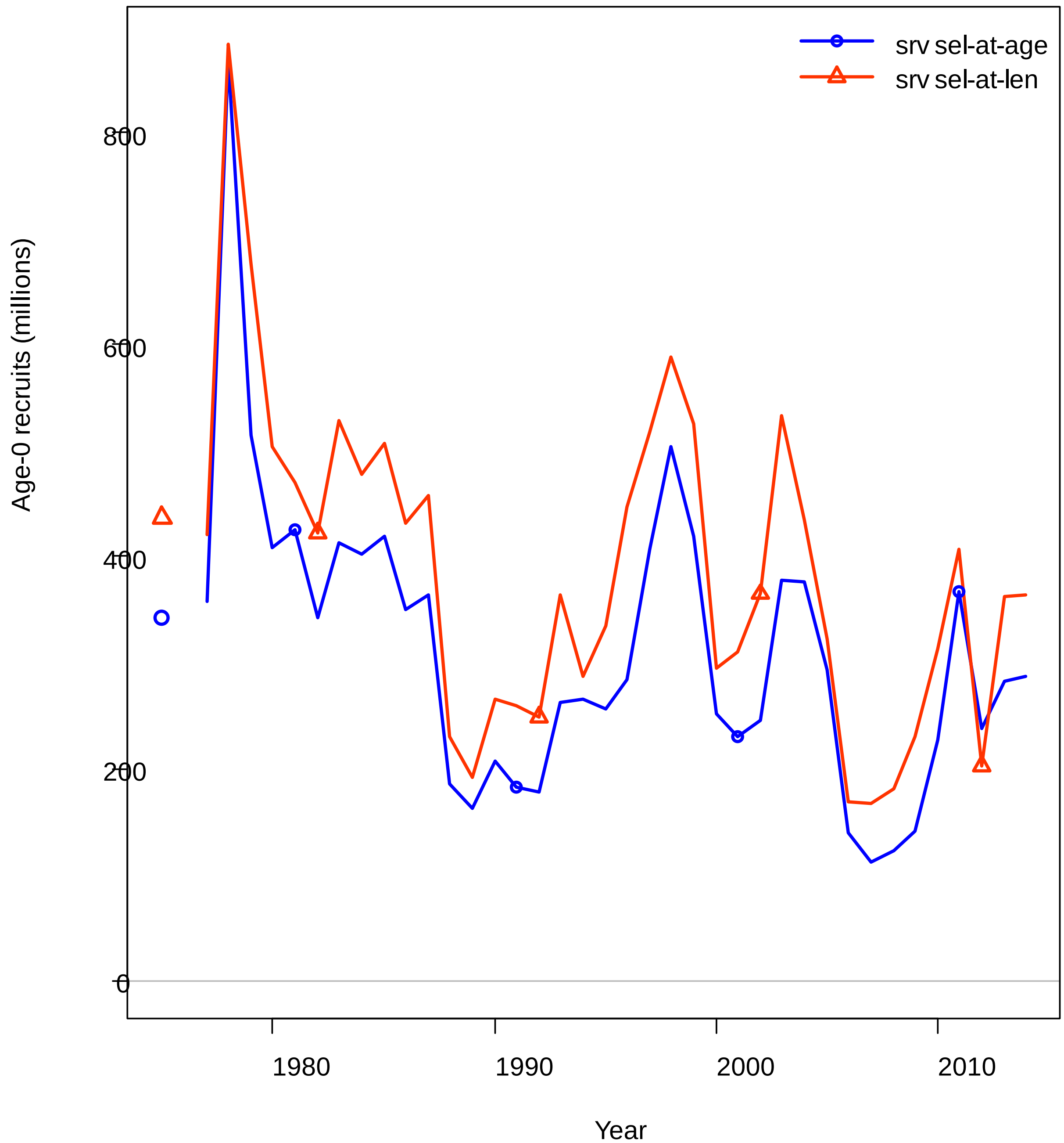


Figure 4.1.9 – Bottom trawl survey index for U model configurations with survey selectivity-at-age and -at-length

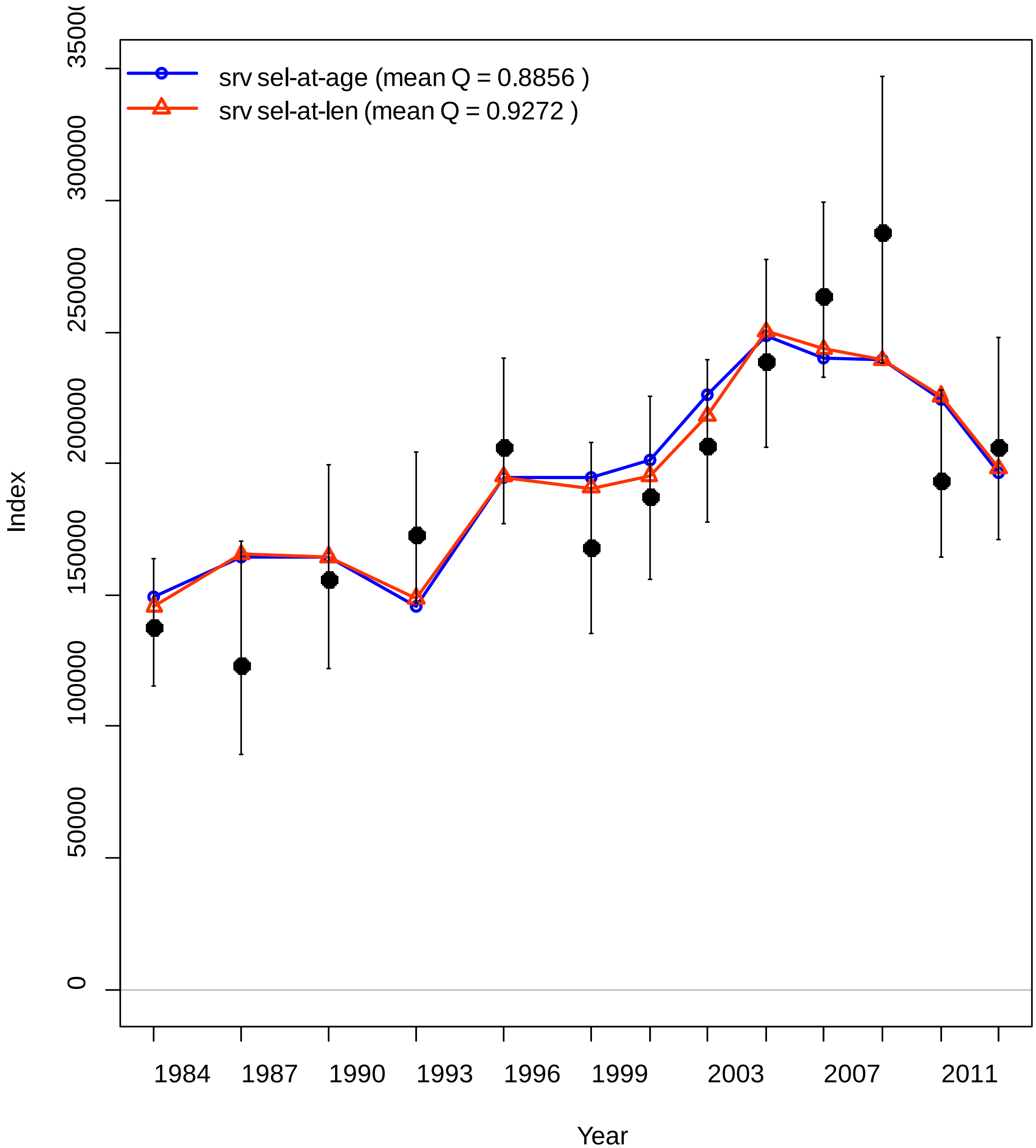


Figure 4.1.10 – Spawning biomass for N model configurations with survey selectivity-at-age and -at-length

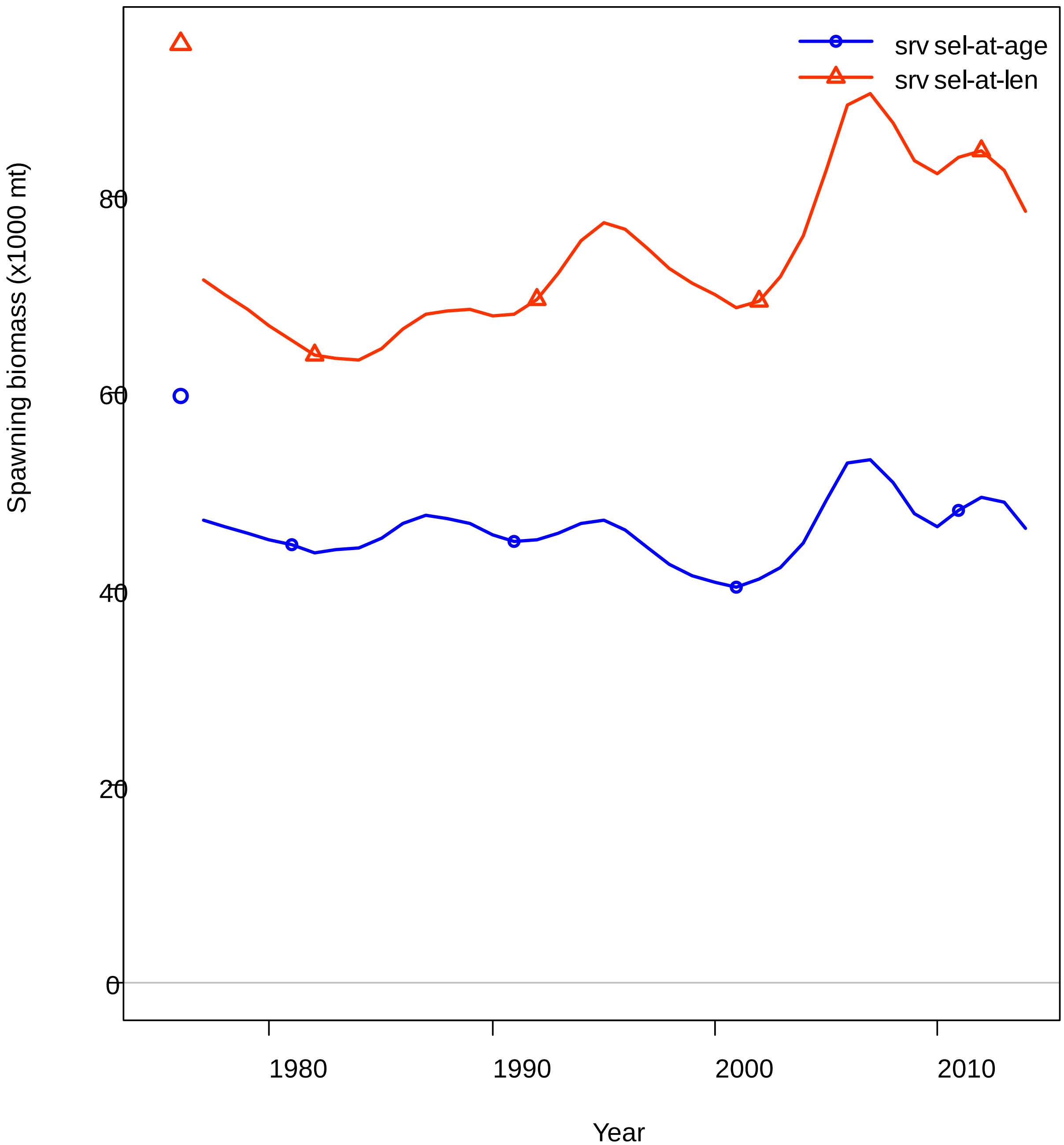


Figure 4.1.11 – Age-0 recruits for N model configurations with survey selectivity-at-age and -at-length

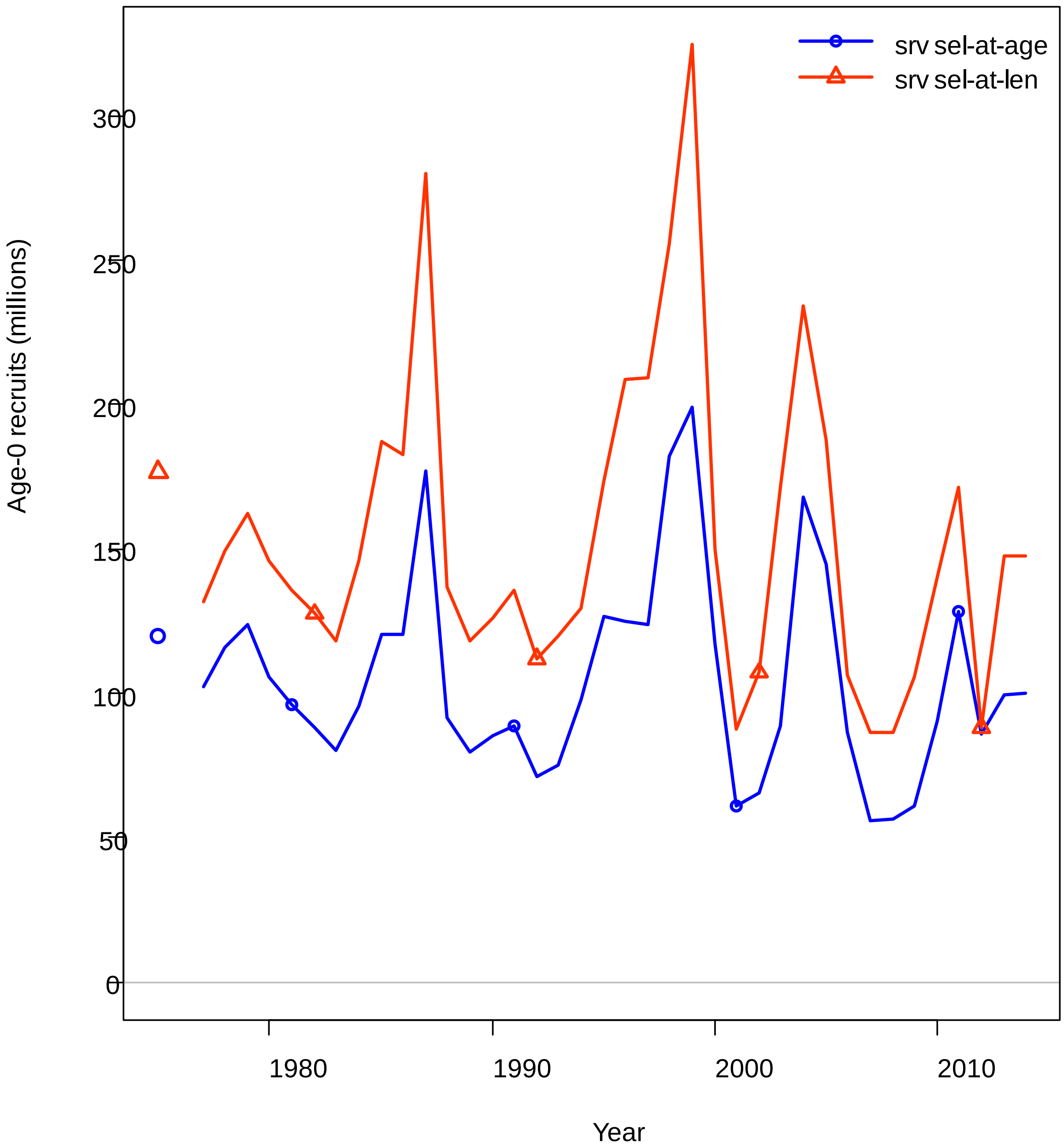


Figure 4.1.12 – Bottom trawl survey index for N model configurations with survey selectivity-at-age and -at-length

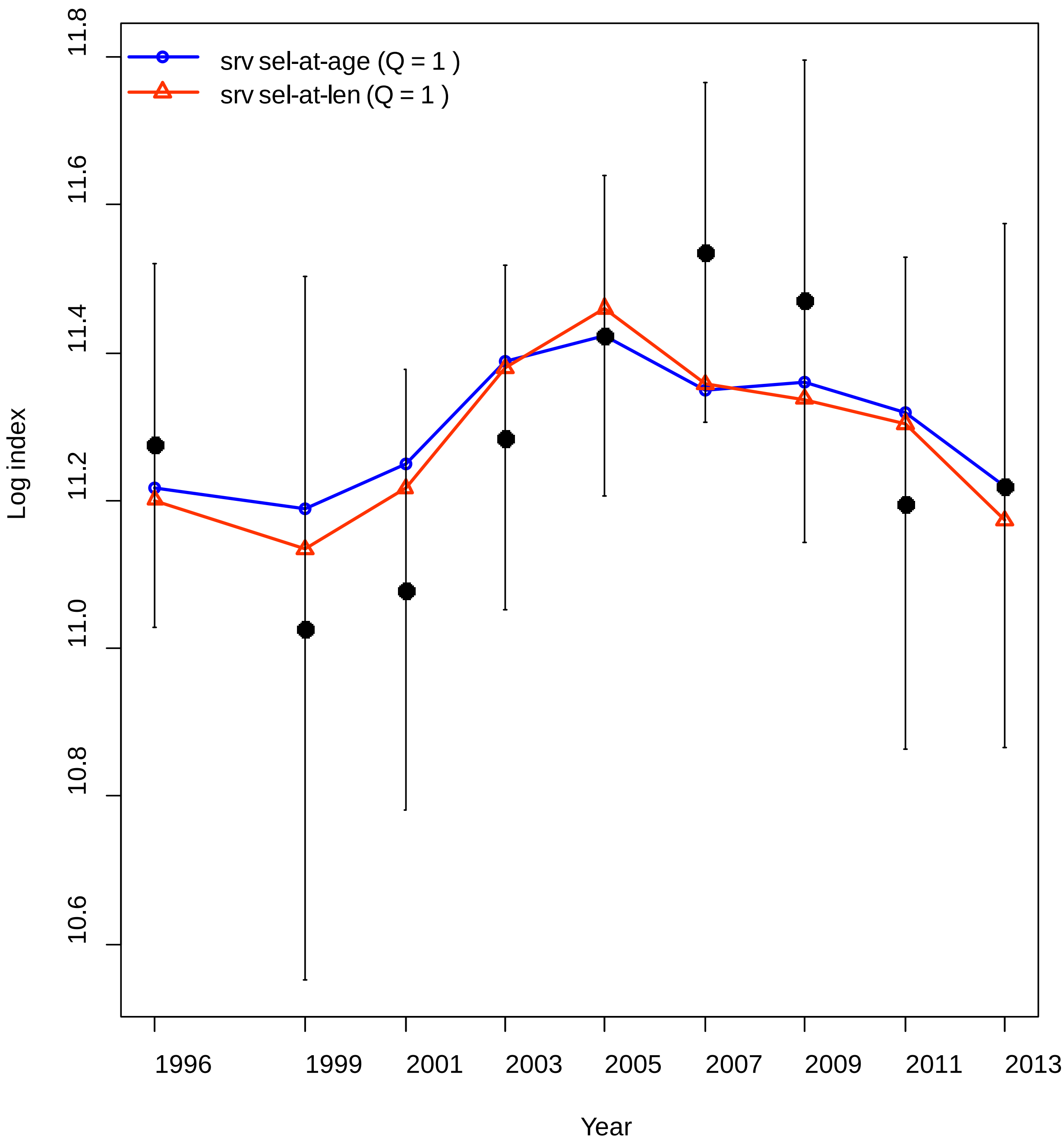


Figure 4.1.13 – Spawning biomass for S model configurations with survey selectivity-at-age and -at-length

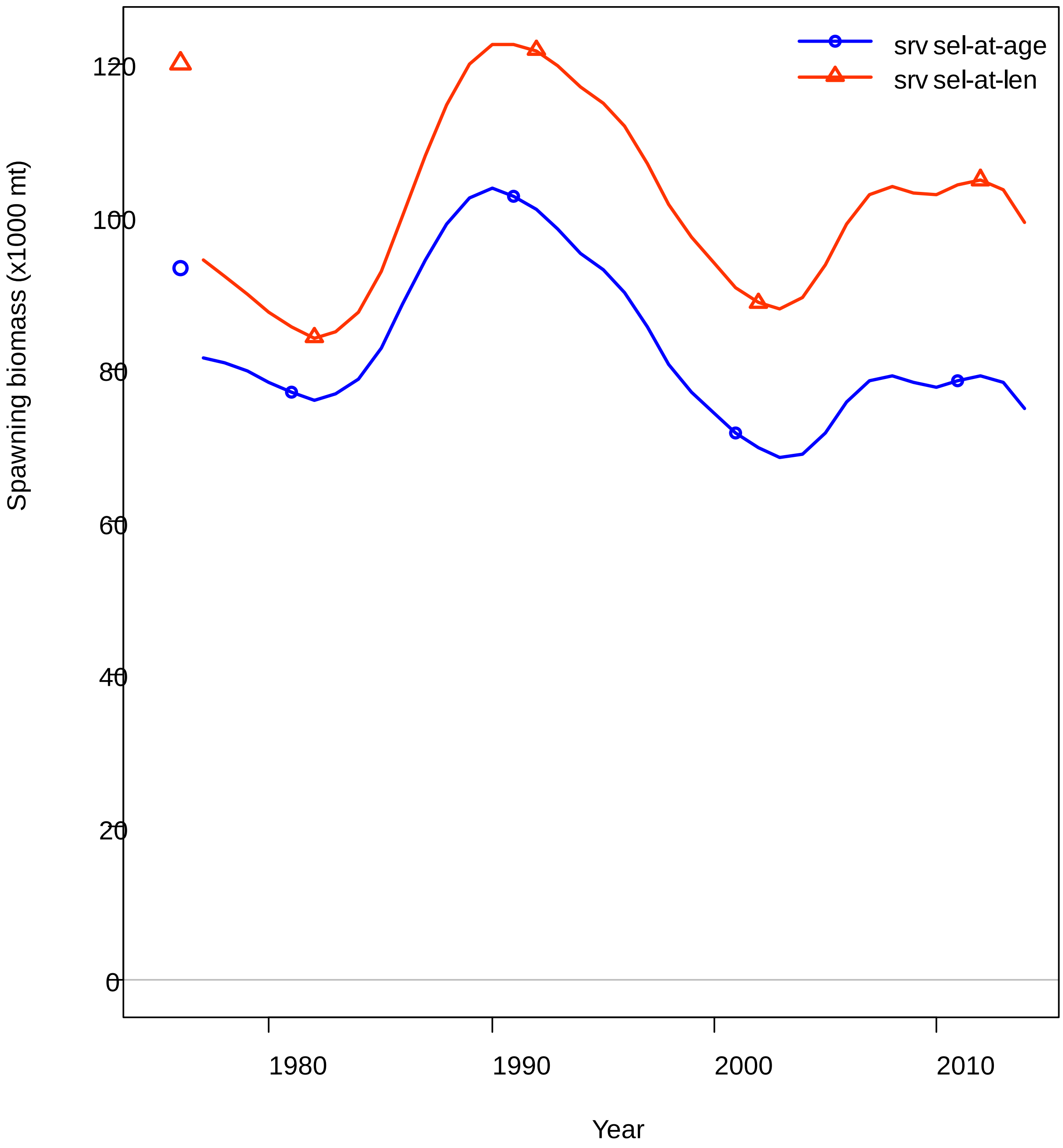


Figure 4.1.14 – Age-0 recruits for S model configurations with survey selectivity-at-age and -at-length

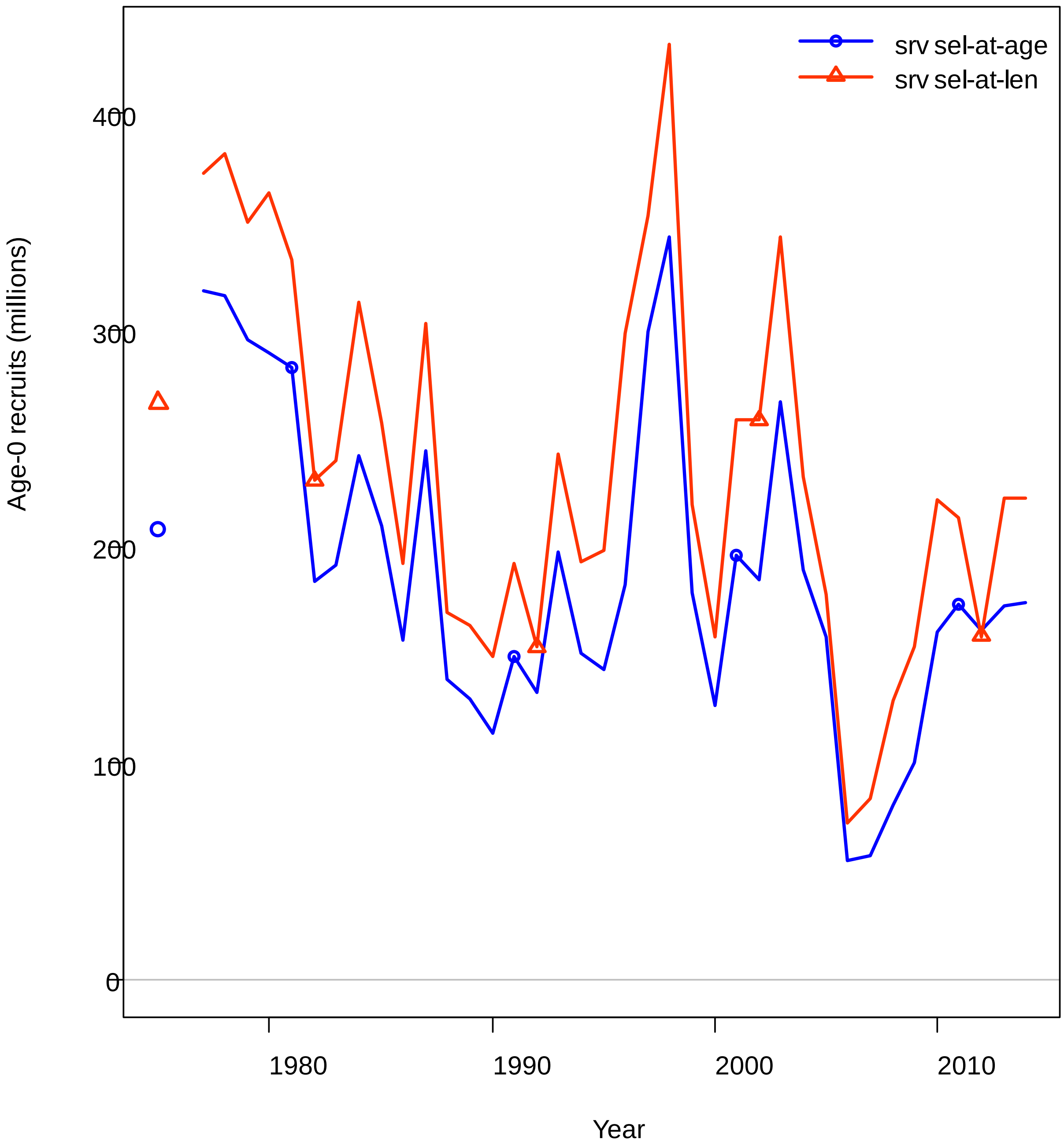


Figure 4.1.15 – Bottom trawl survey index for S model configurations with survey selectivity-at-age and -at-length

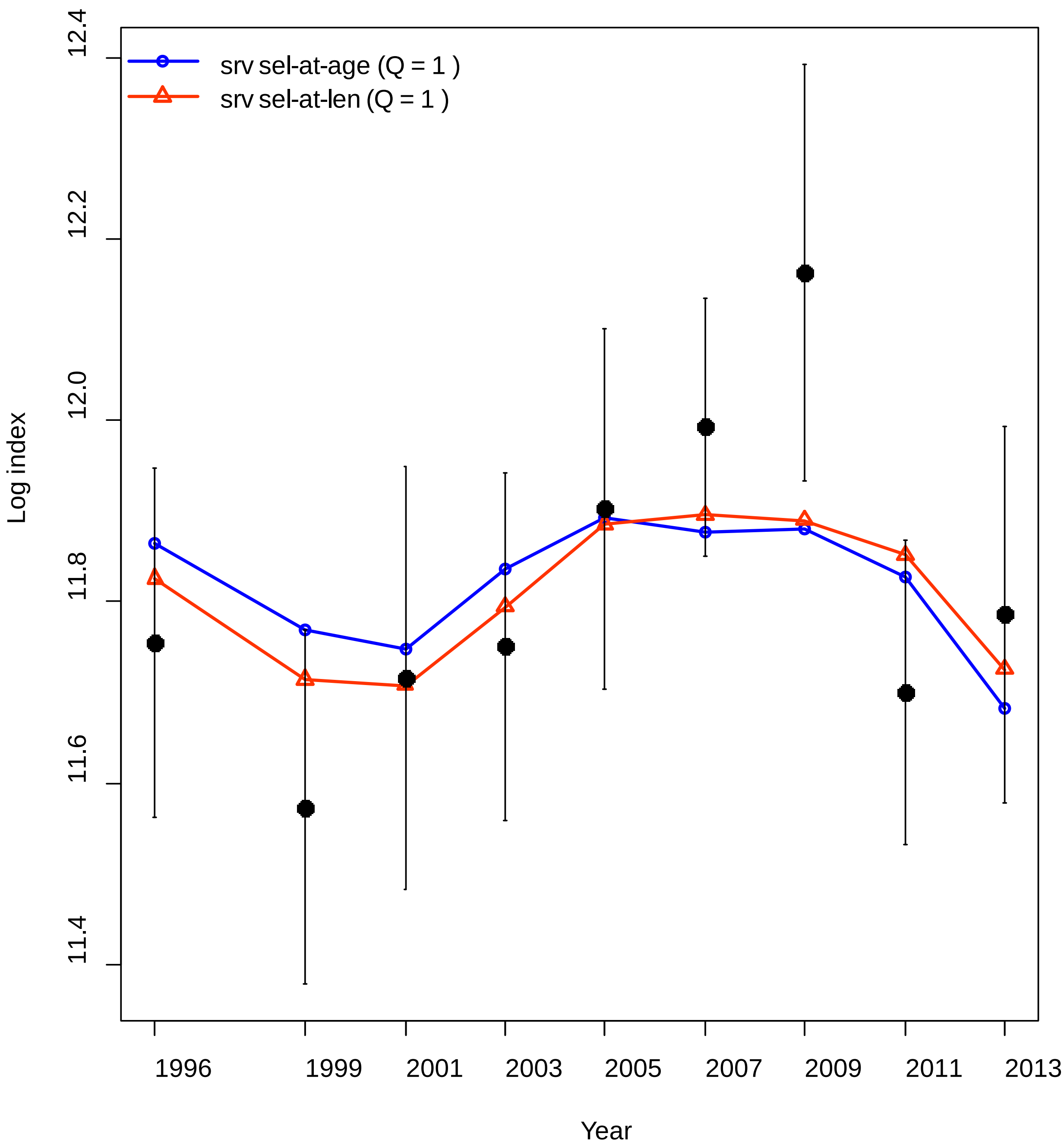


Figure 4.1.16 – Spawning biomass for U, N, and S model configurations with survey selectivity-at-age

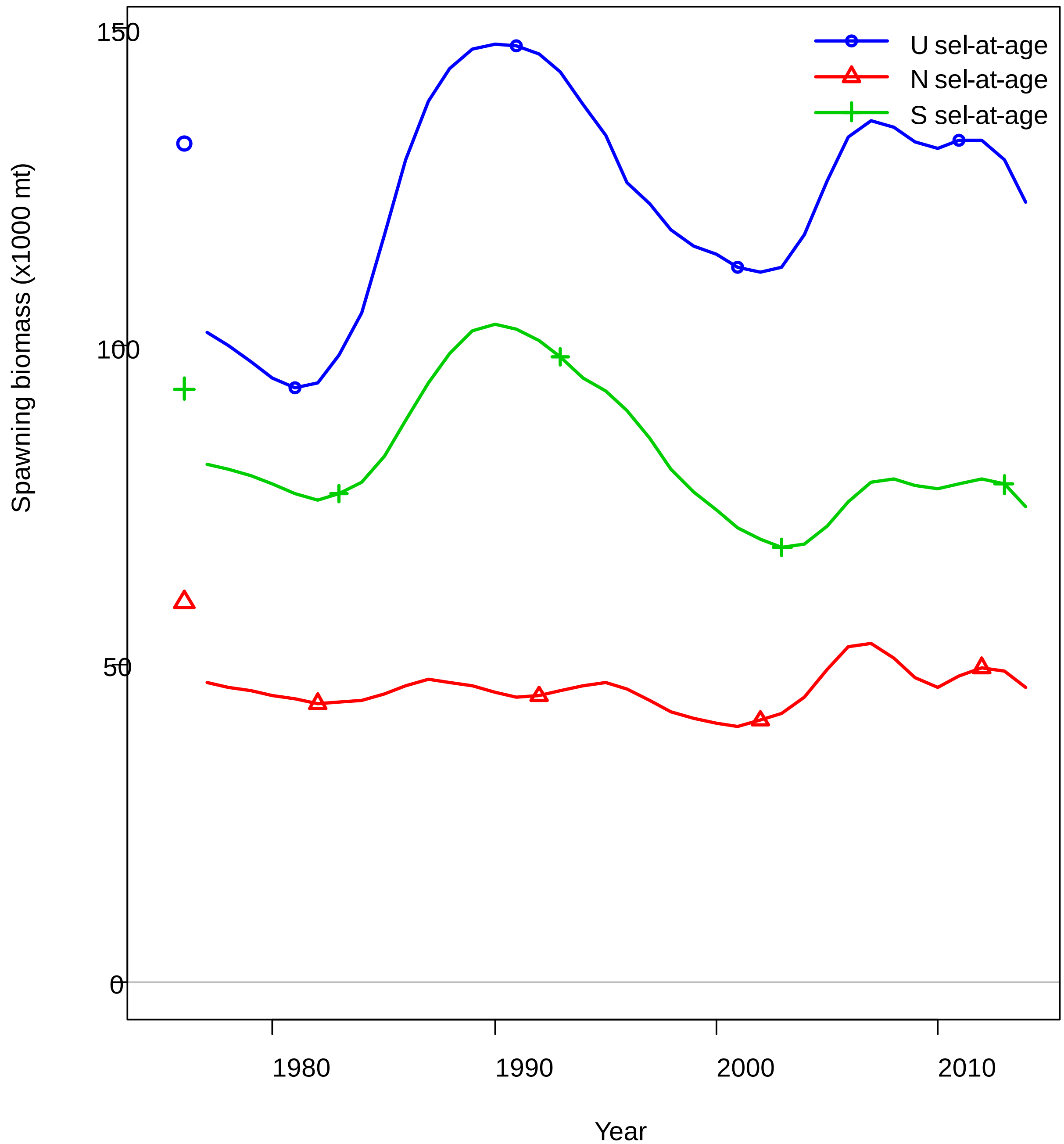


Figure 4.1.17 – Age-0 recruits for U, N, and S model configurations with survey selectivity-at-age

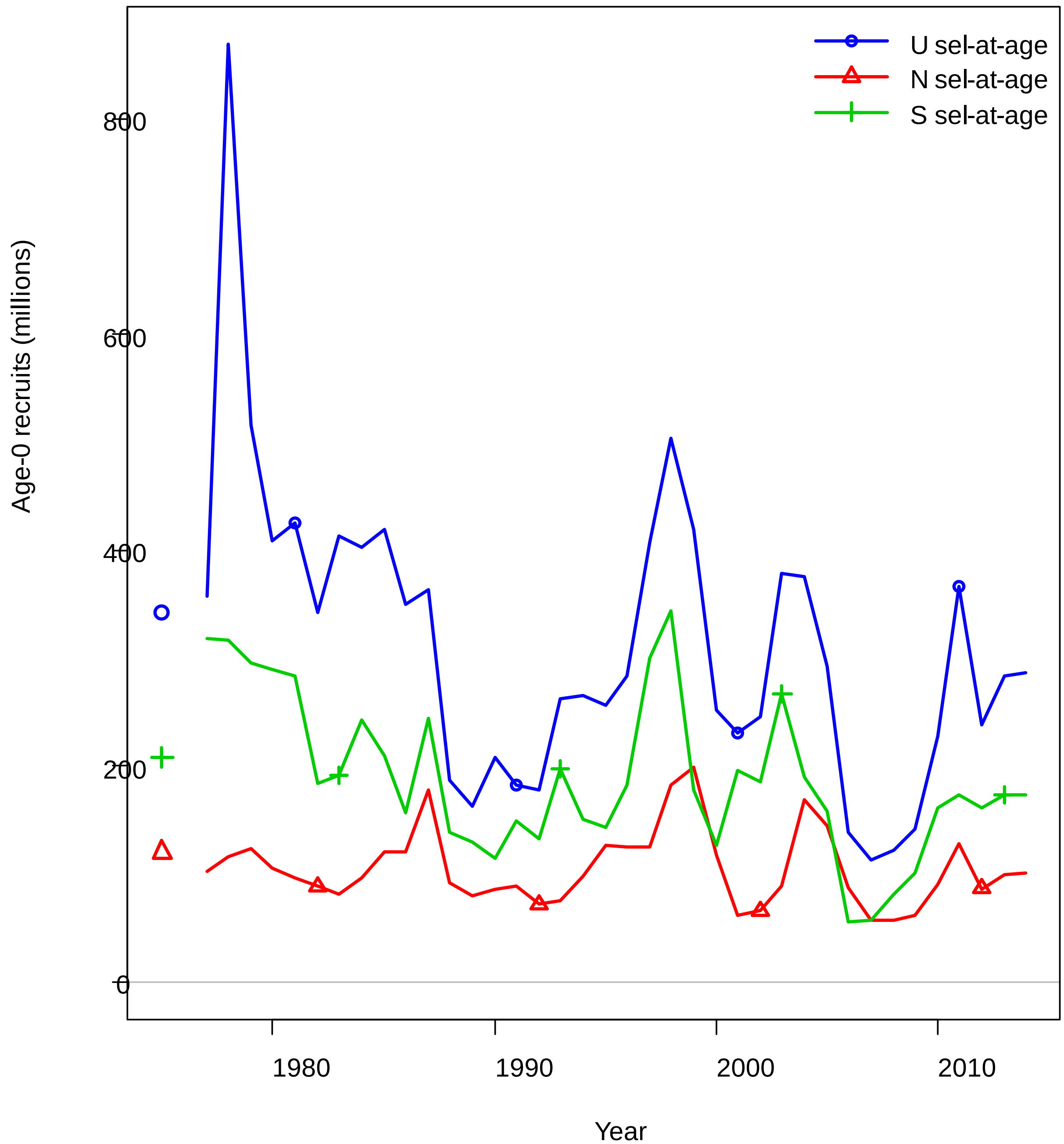


Figure 4.1.18 – Spawning biomass for U, N, and S model configurations with survey selectivity-at-length

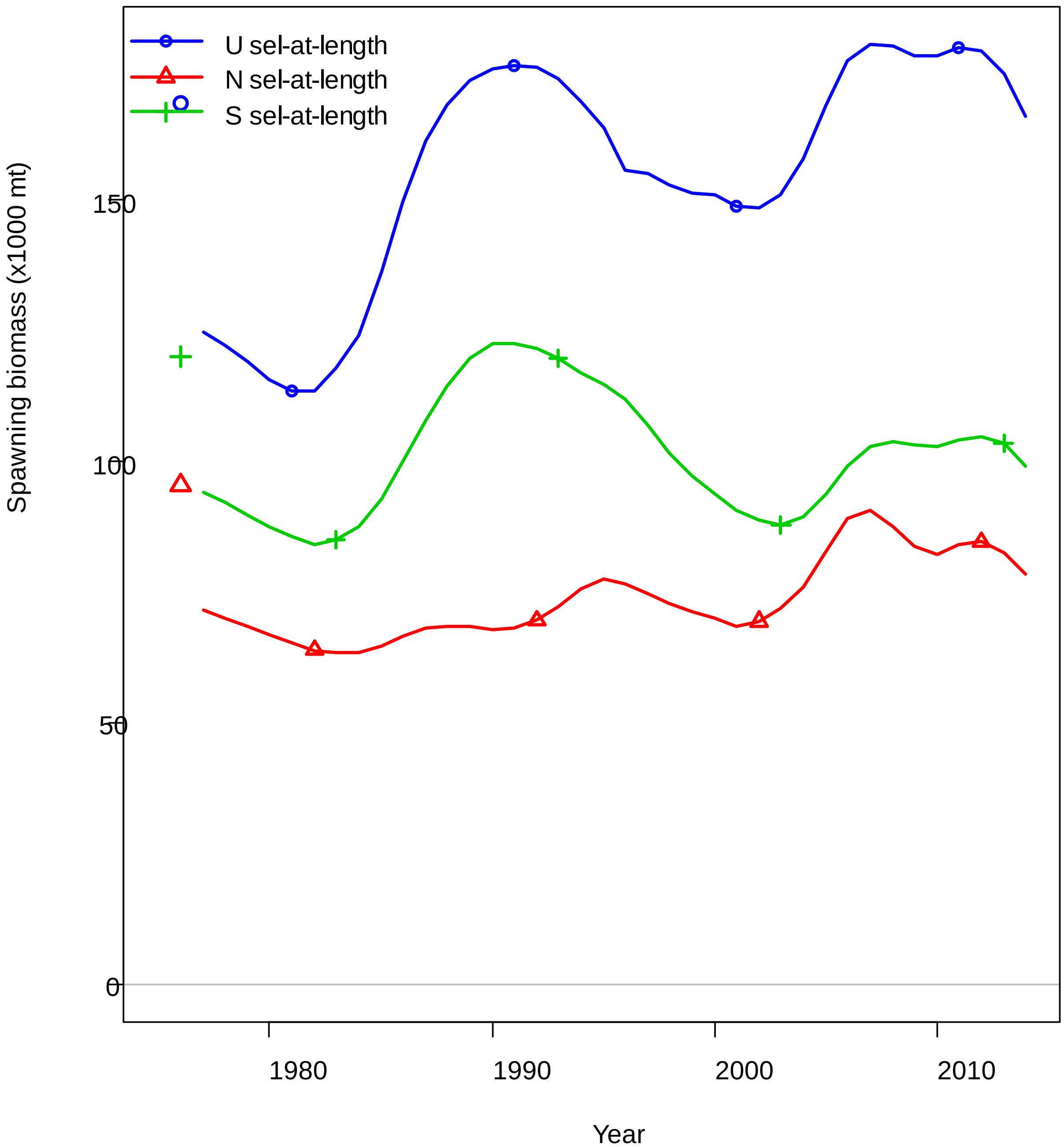


Figure 4.1.19 – Age-0 recruits for U, N, and S model configurations with survey selectivity-at-length

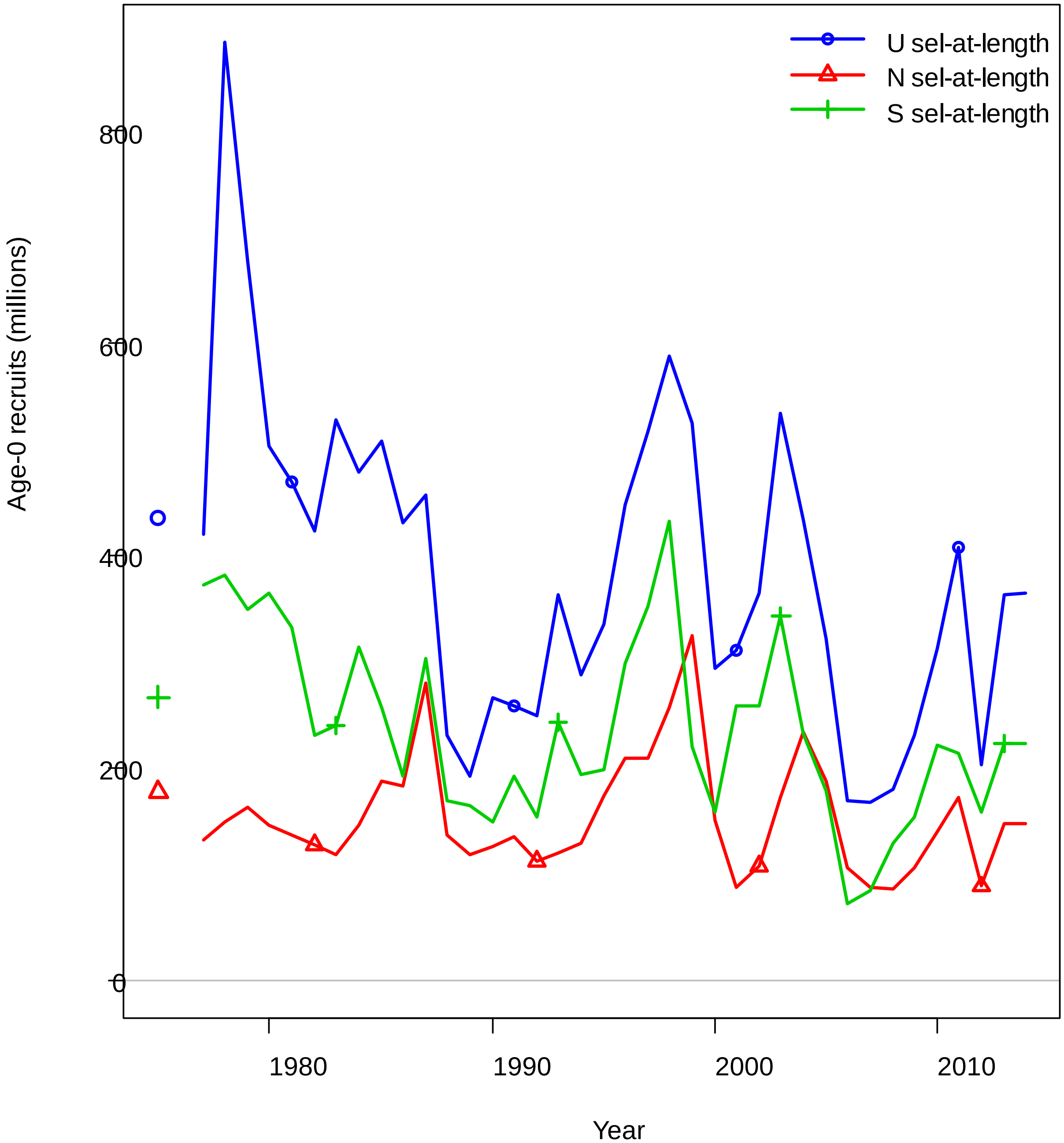


Figure 4.1.20 – Annual catch for northern and southern rock sole (half of total annual rock sole catch)

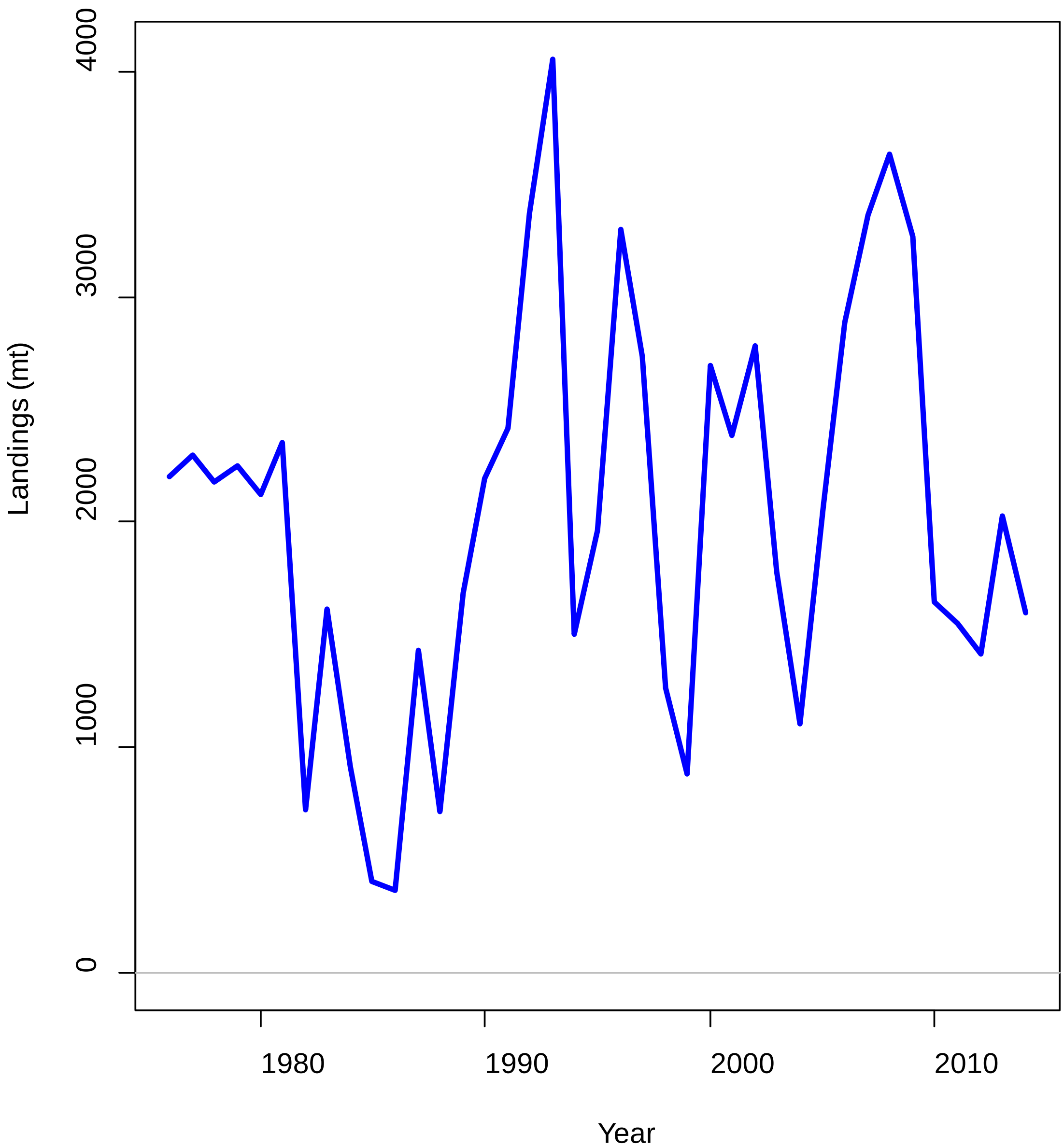


Figure 4.1.21 – Spawning biomass for N model configuration with survey selectivity-at-age

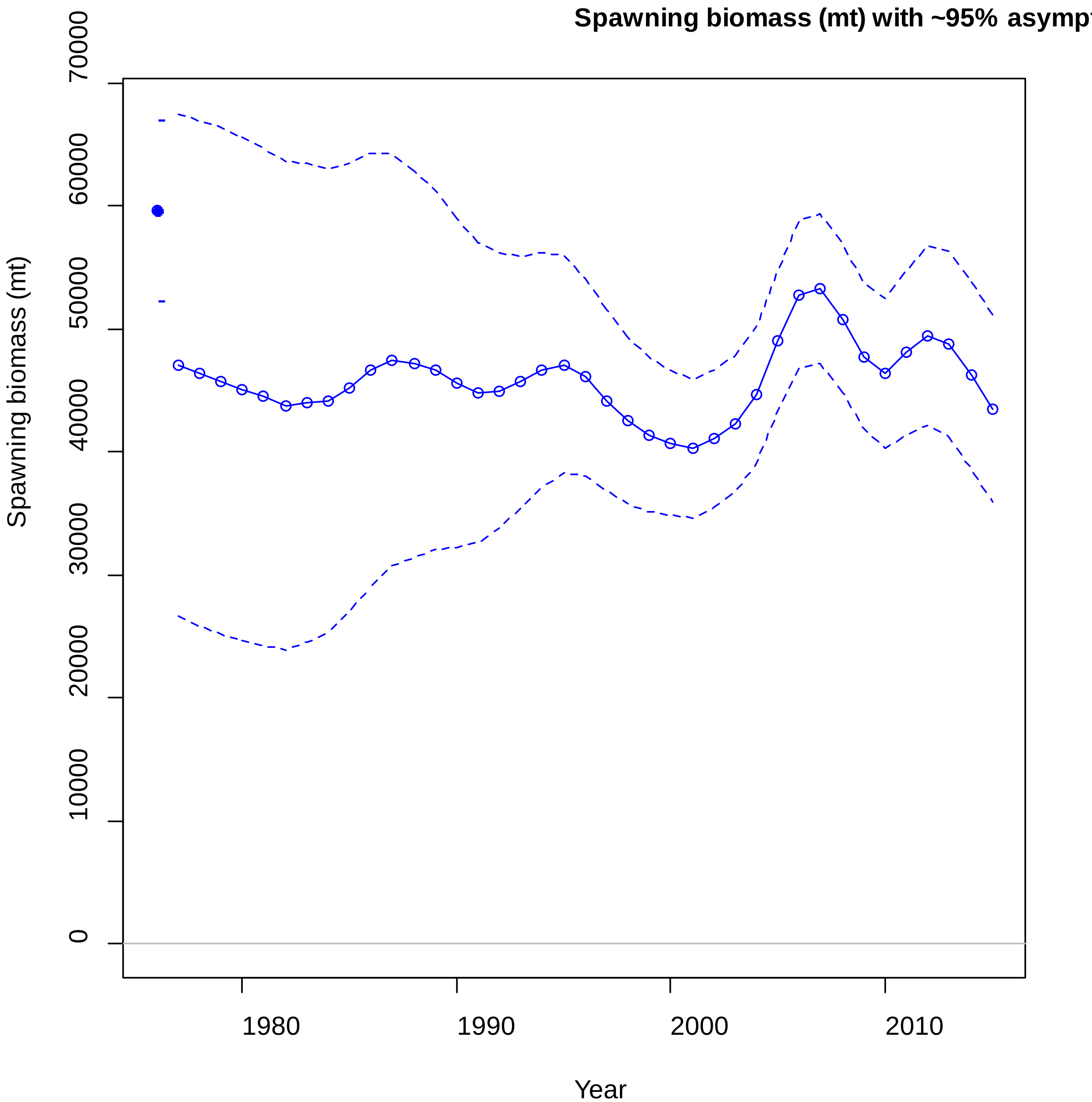


Figure 4.1.22 – Length-at-age for N model configuration with survey selectivity-at-age

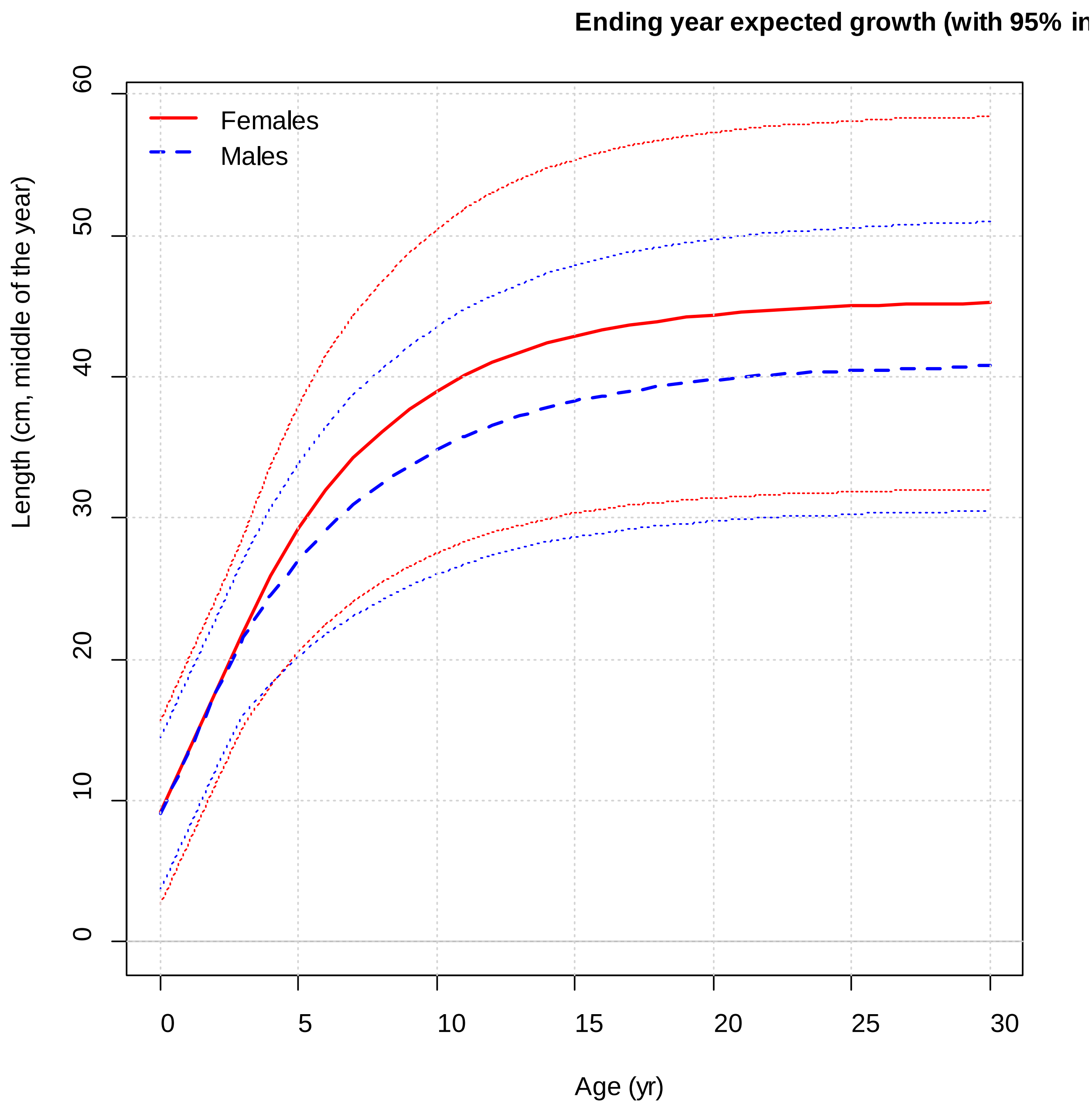


Figure 4.1.23 – Age-0 recruits for N model configuration with survey selectivity-at-age

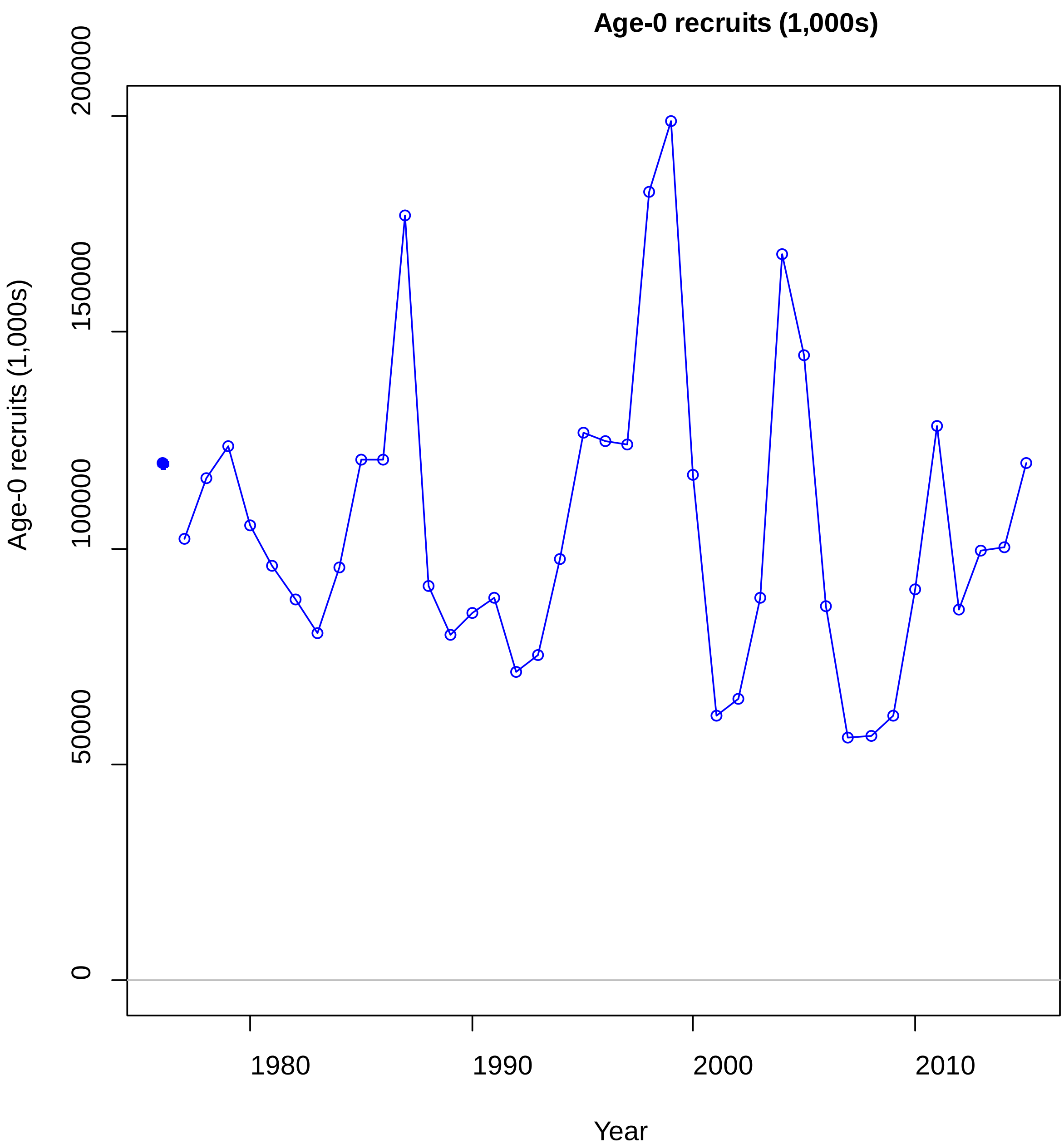


Figure 4.1.24 – Age-0 recruits with uncertainty intervals for N model configuration with survey selectivity-at-age

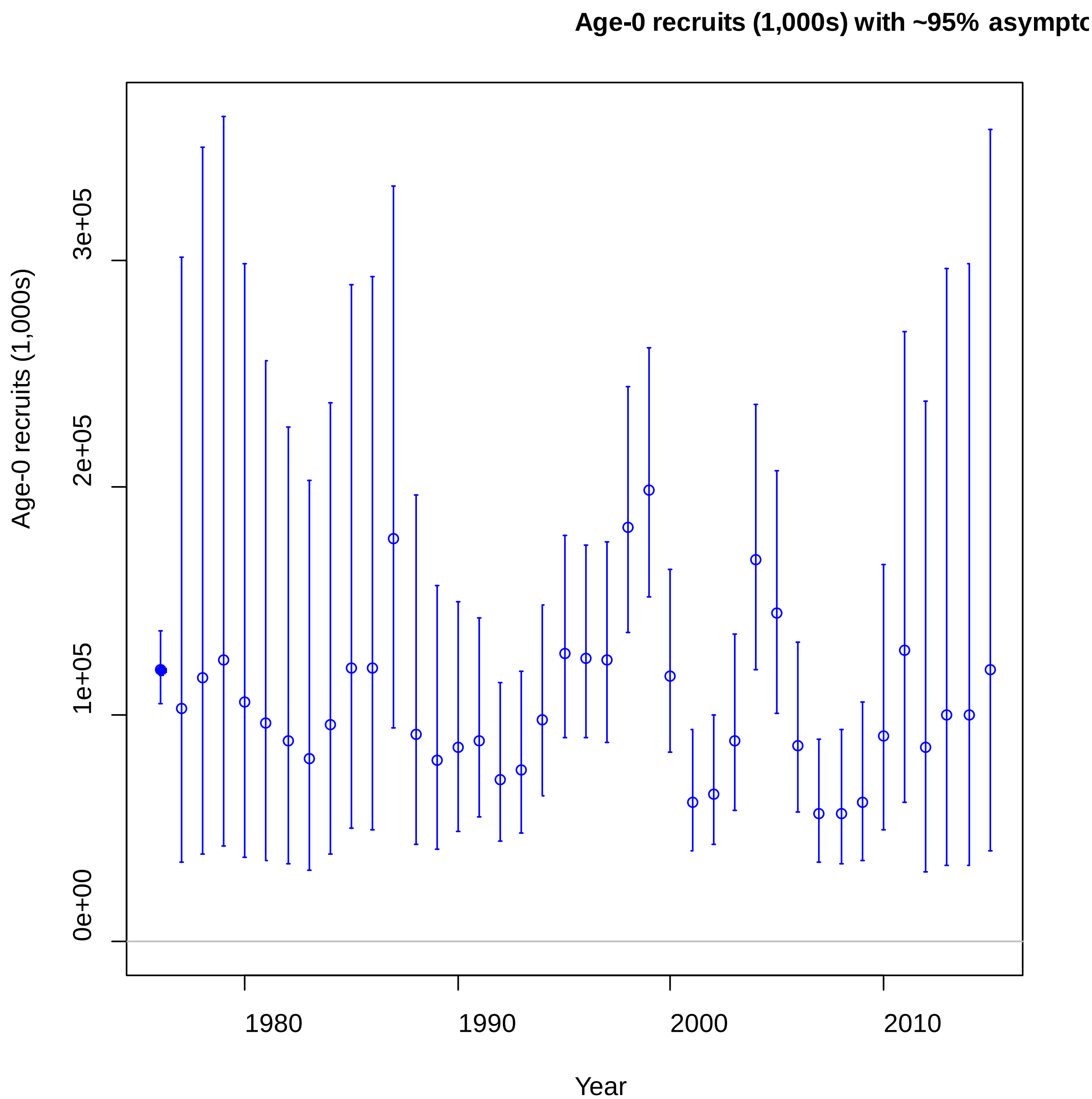


Figure 4.1.25 – Bottom trawl survey index for N model configuration with survey selectivity-at-age

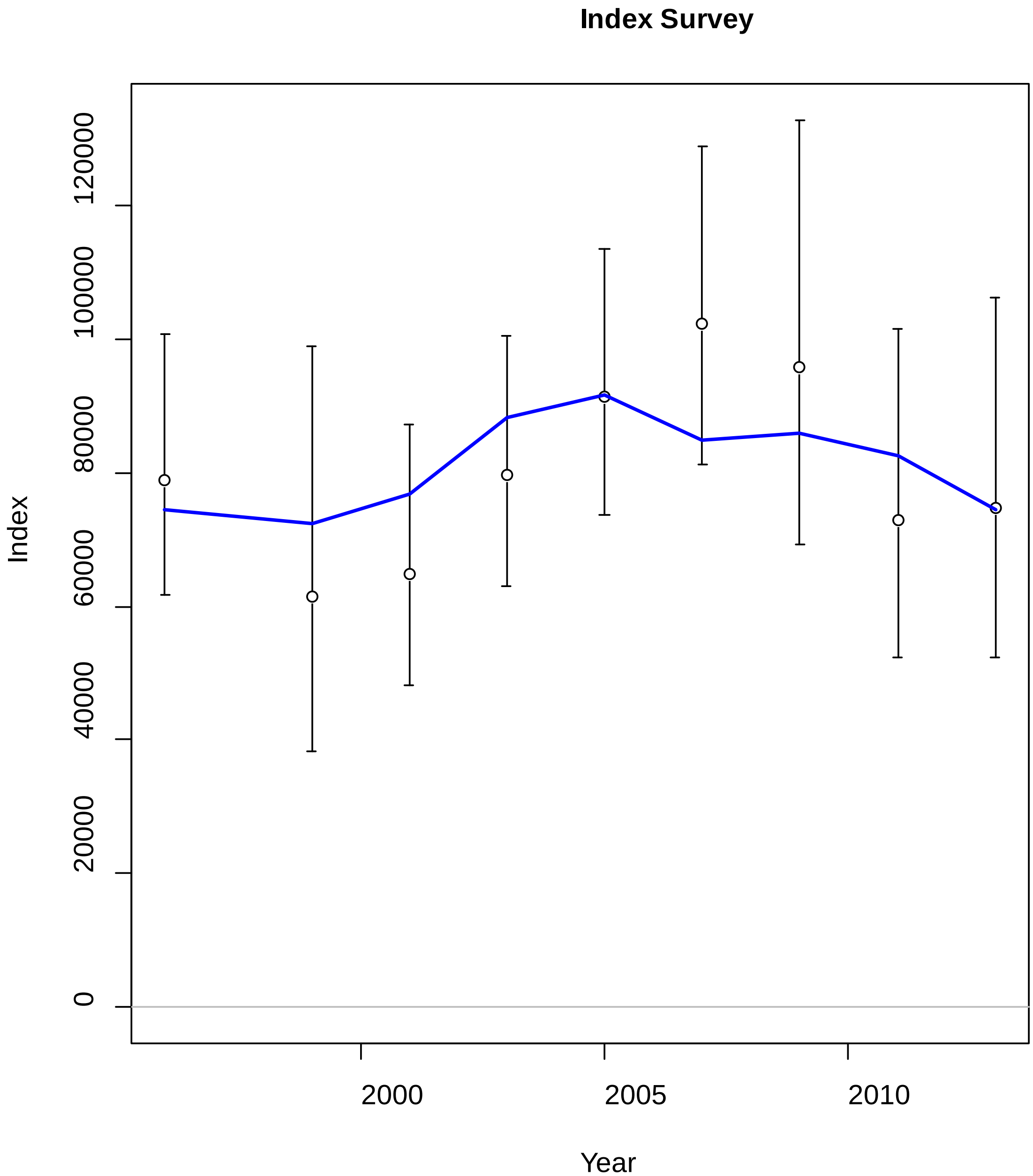


Figure 4.1.26 – Female fishery selectivity-at-length for N model configuration with survey selectivity-at-age

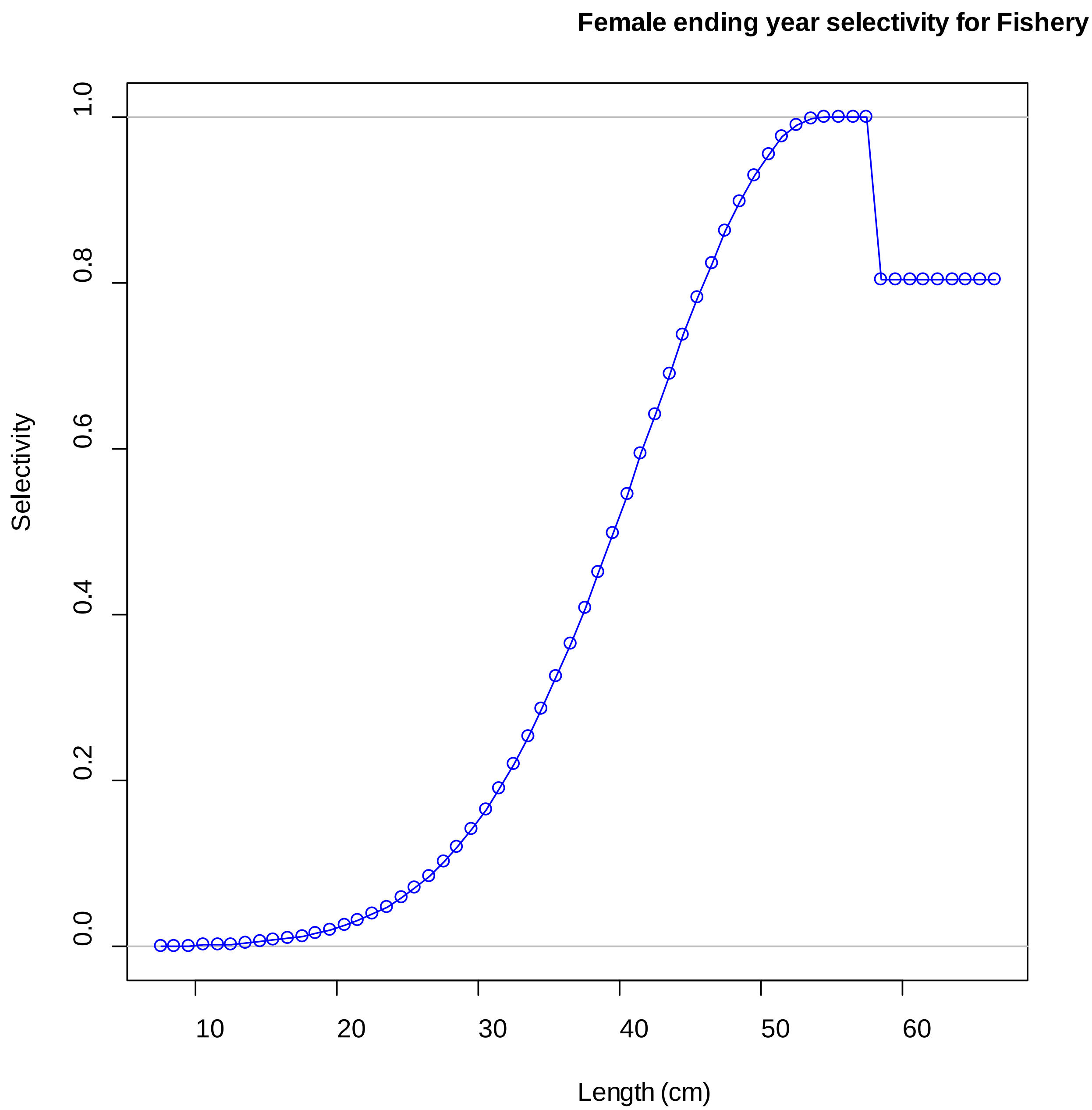


Figure 4.1.27 – Male fishery selectivity-at-length for N model configuration with survey selectivity-at-age

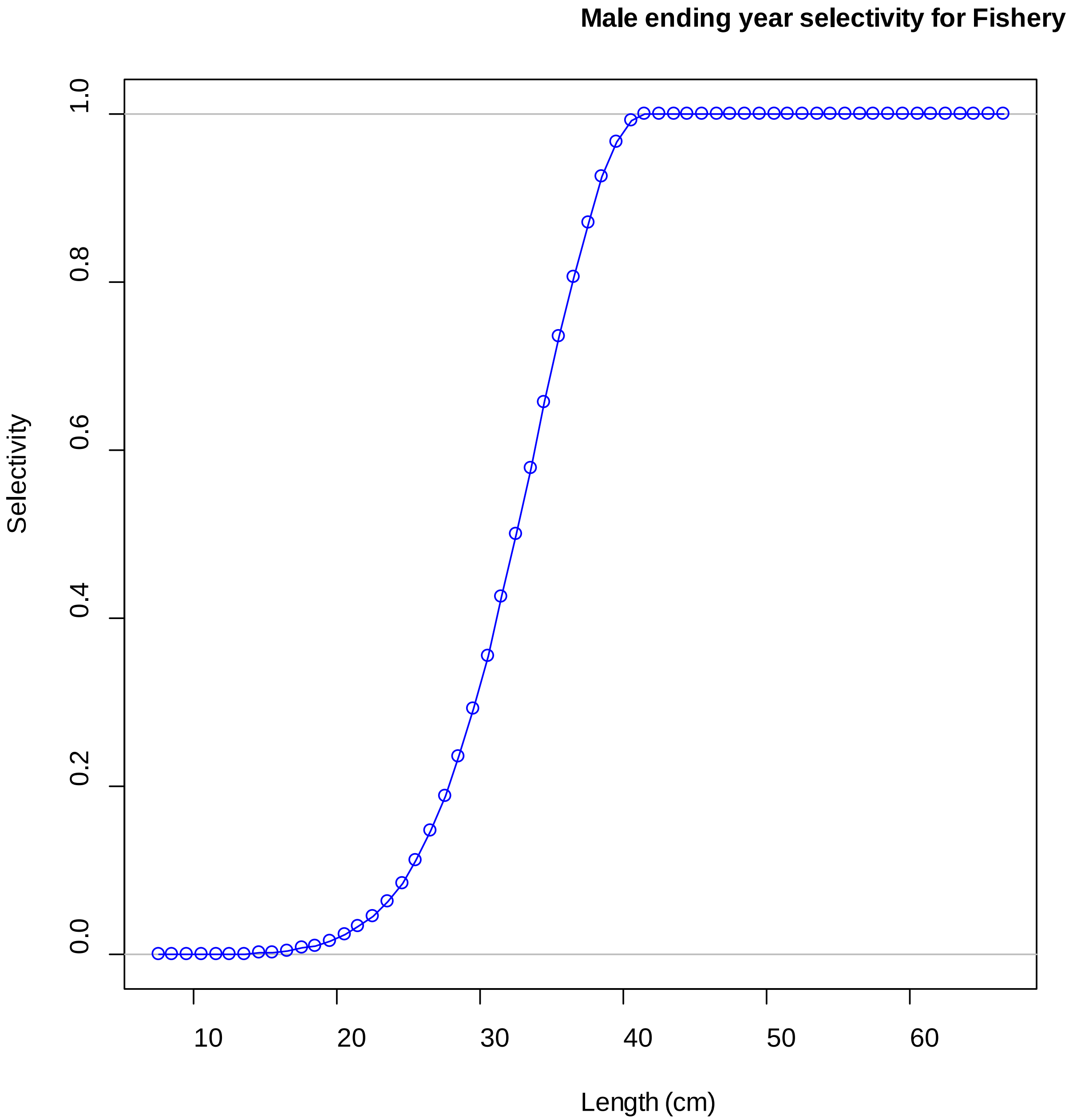


Figure 4.1.28 – Female survey selectivity-at-age for N model configuration with survey selectivity-at-age

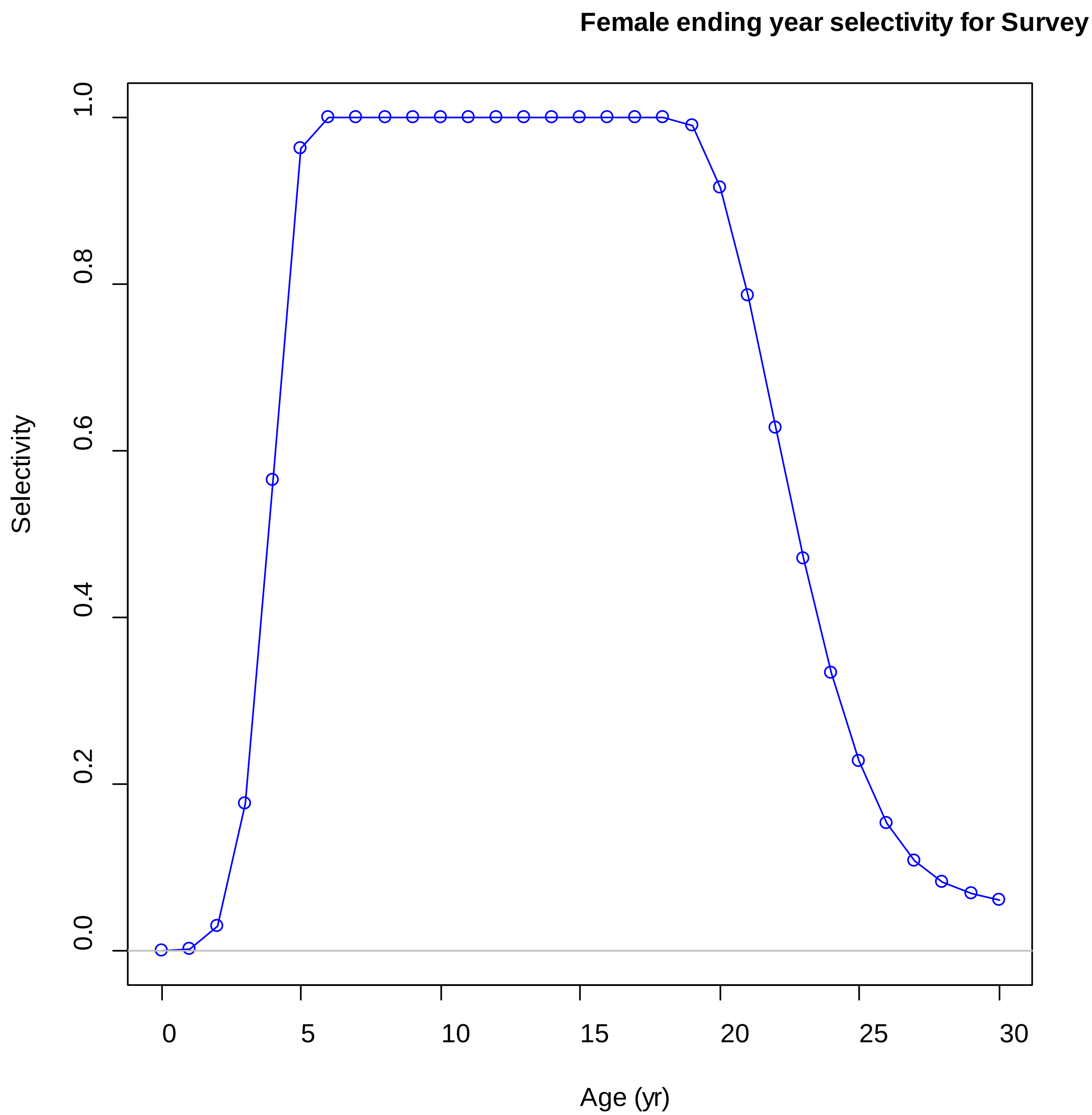


Figure 4.1.29 – Male survey selectivity-at-age for N model configuration with survey selectivity-at-age

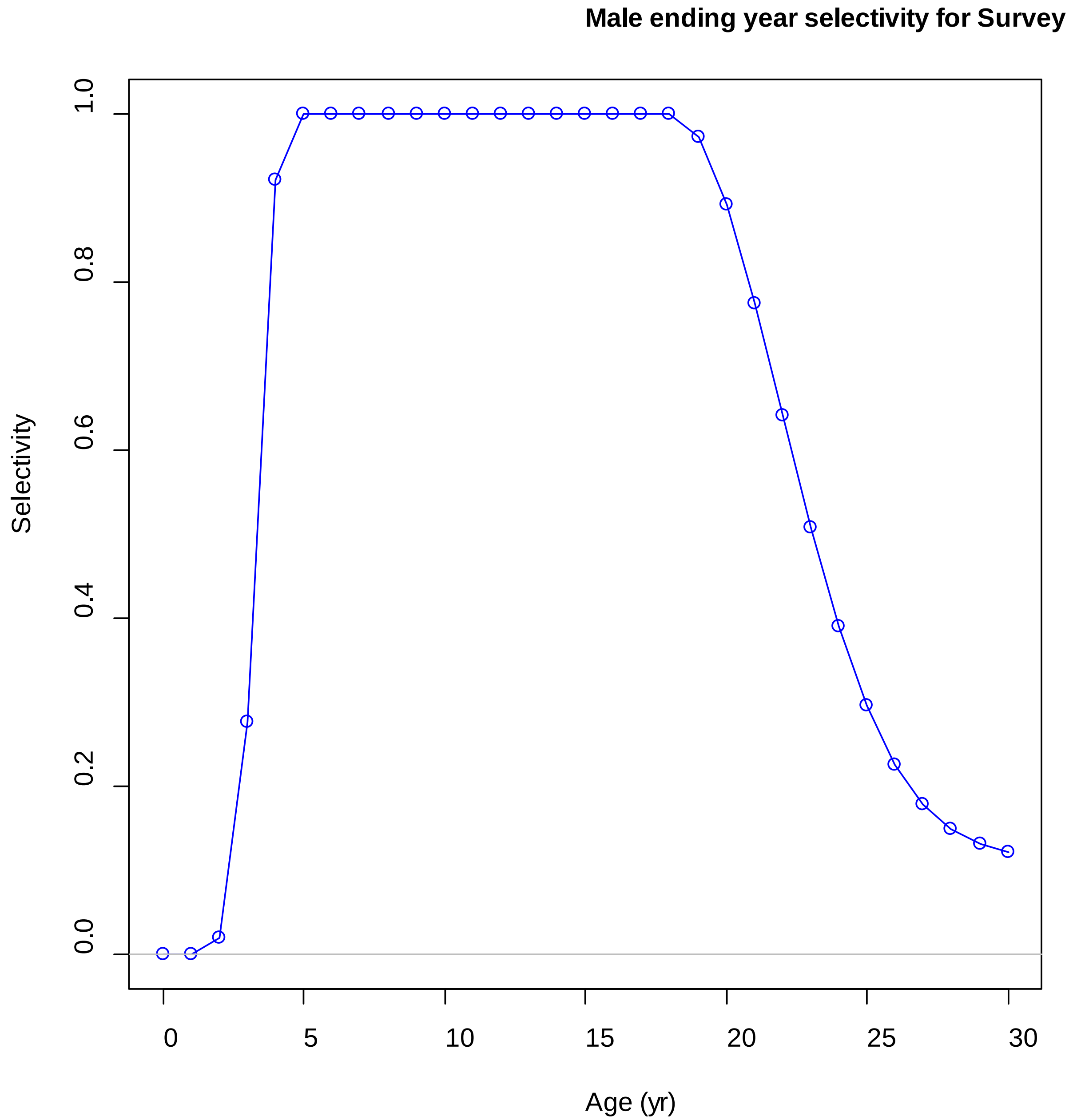


Figure 4.1.30 – Derived female and male fishery selectivity-at-age for N model configuration with survey selectivity-at-age

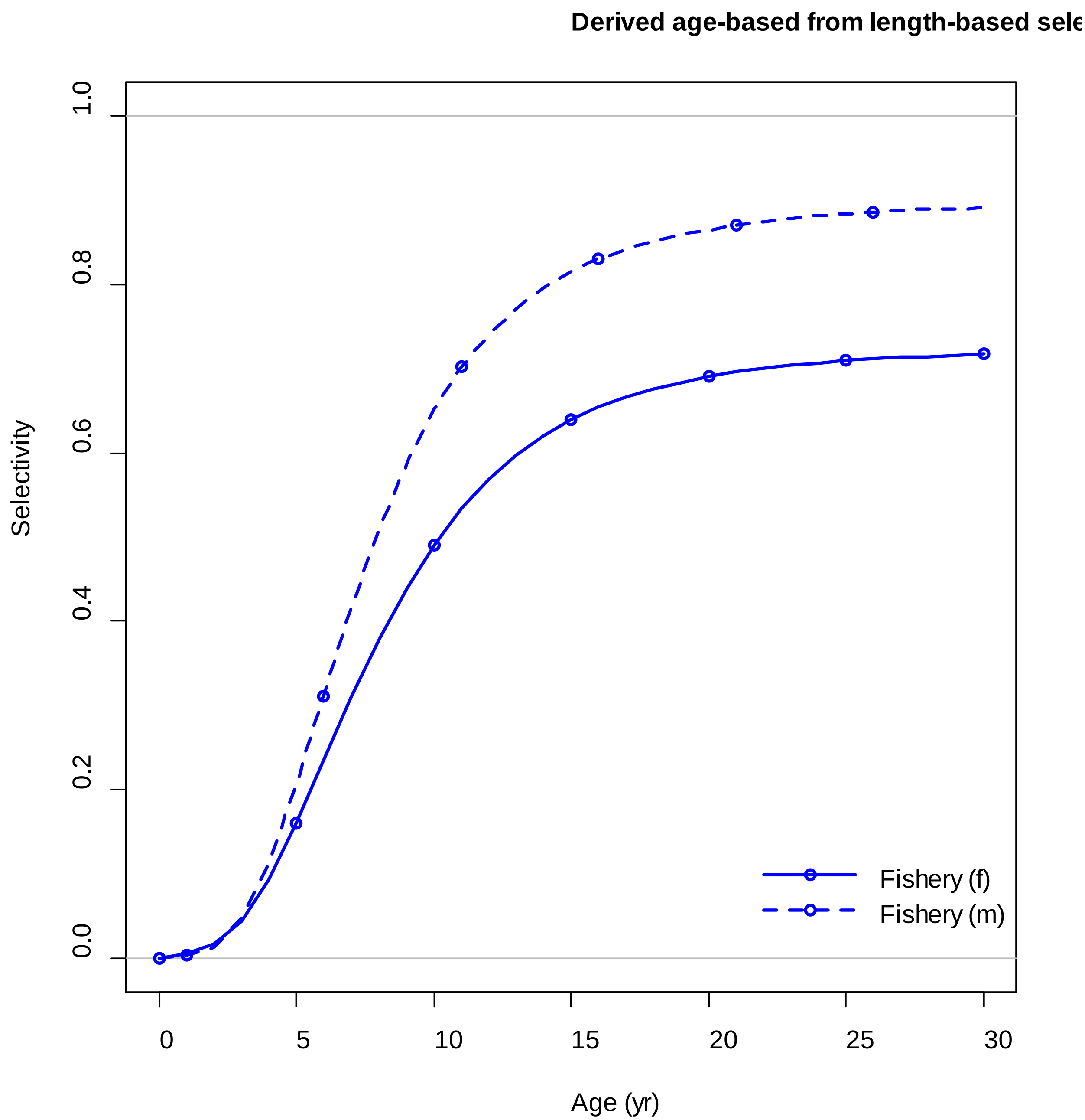


Figure 4.1.31 – Female fishery length compositions for N model configuration with survey selectivity-at-age

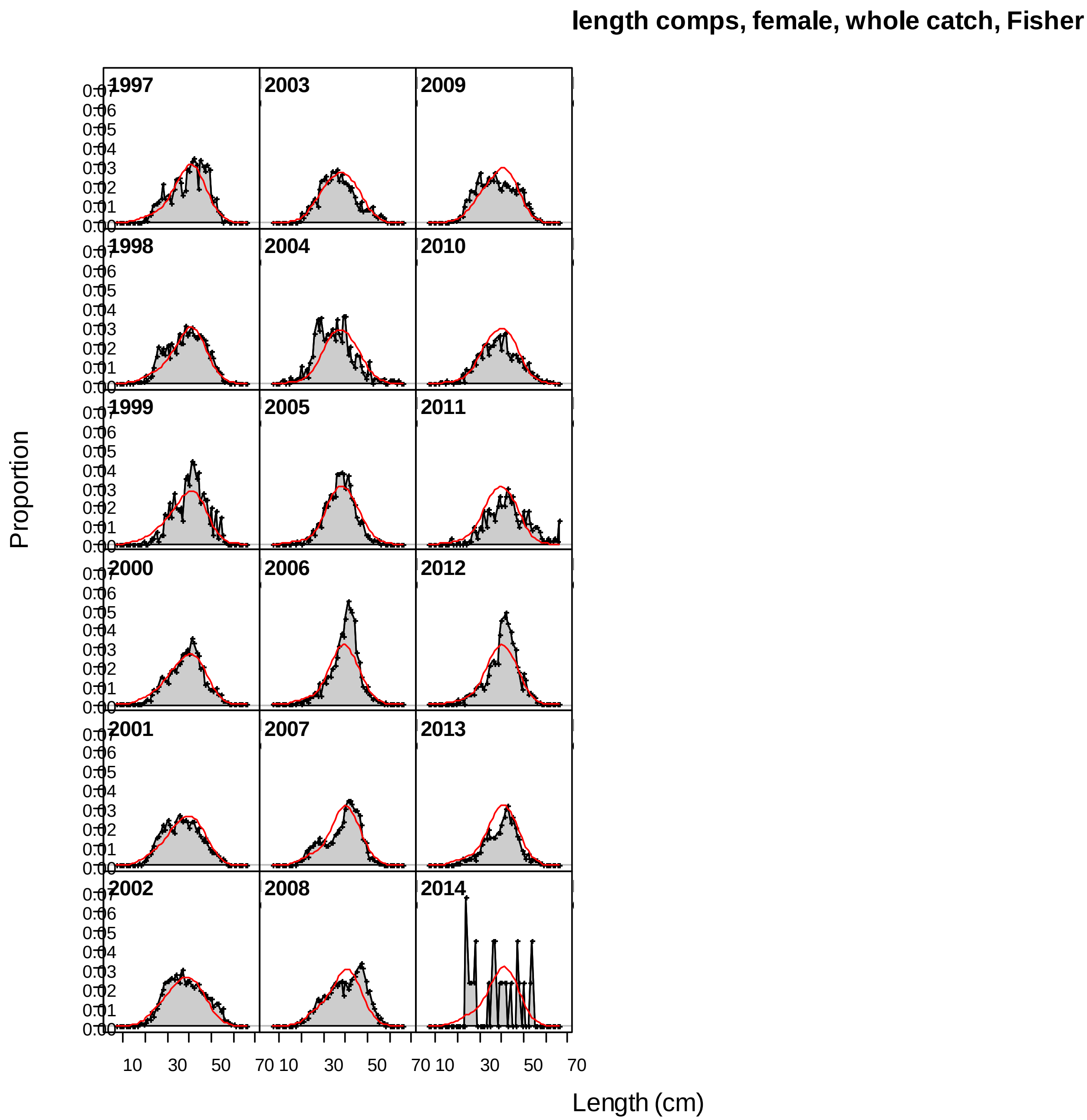


Figure 4.1.32 – Male fishery length compositions for N model configuration with survey selectivity-at-age

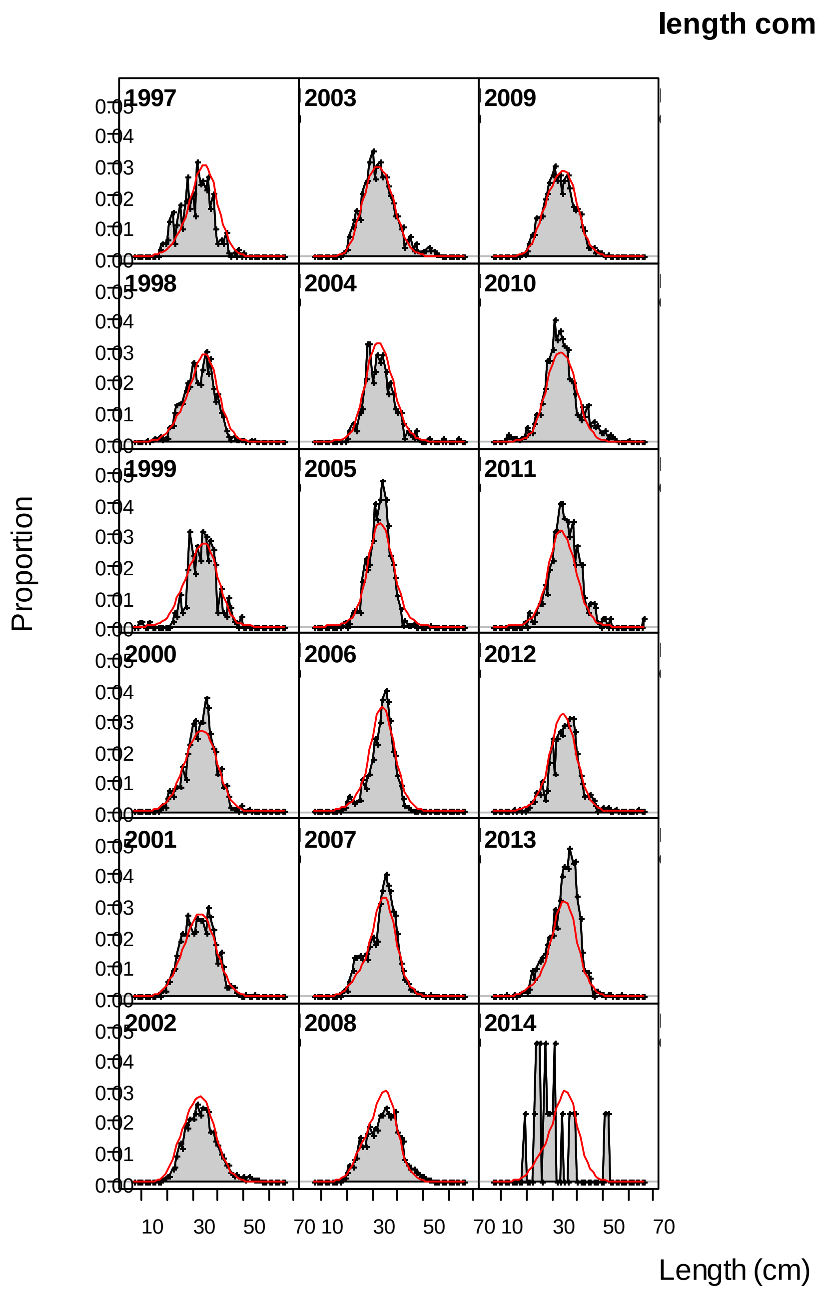


Figure 4.1.33 – Female survey length composition for N model configuration with survey selectivity-at-age

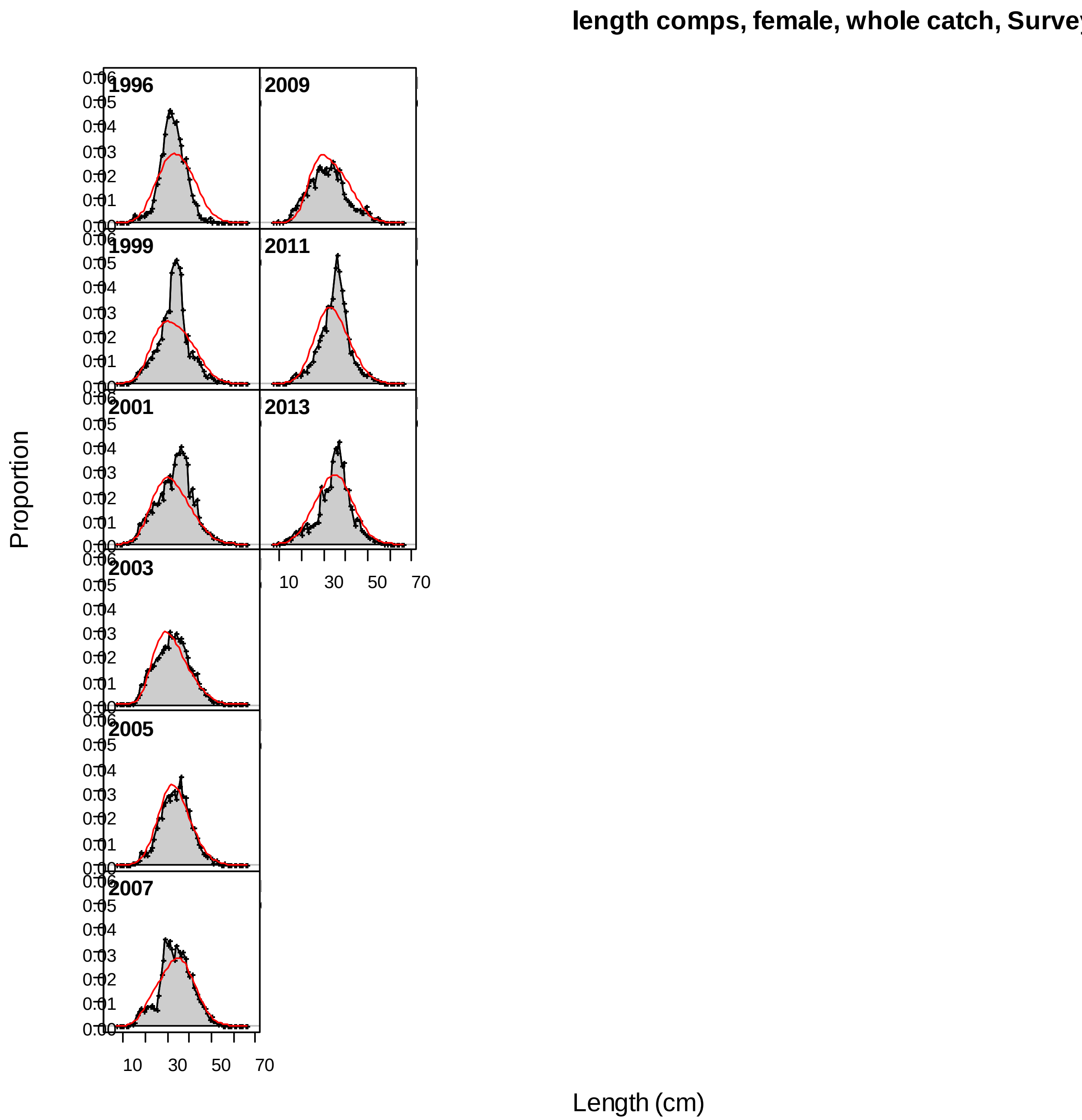


Figure 4.1.34 – Male survey length composition for N model configuration with survey selectivity-at-age

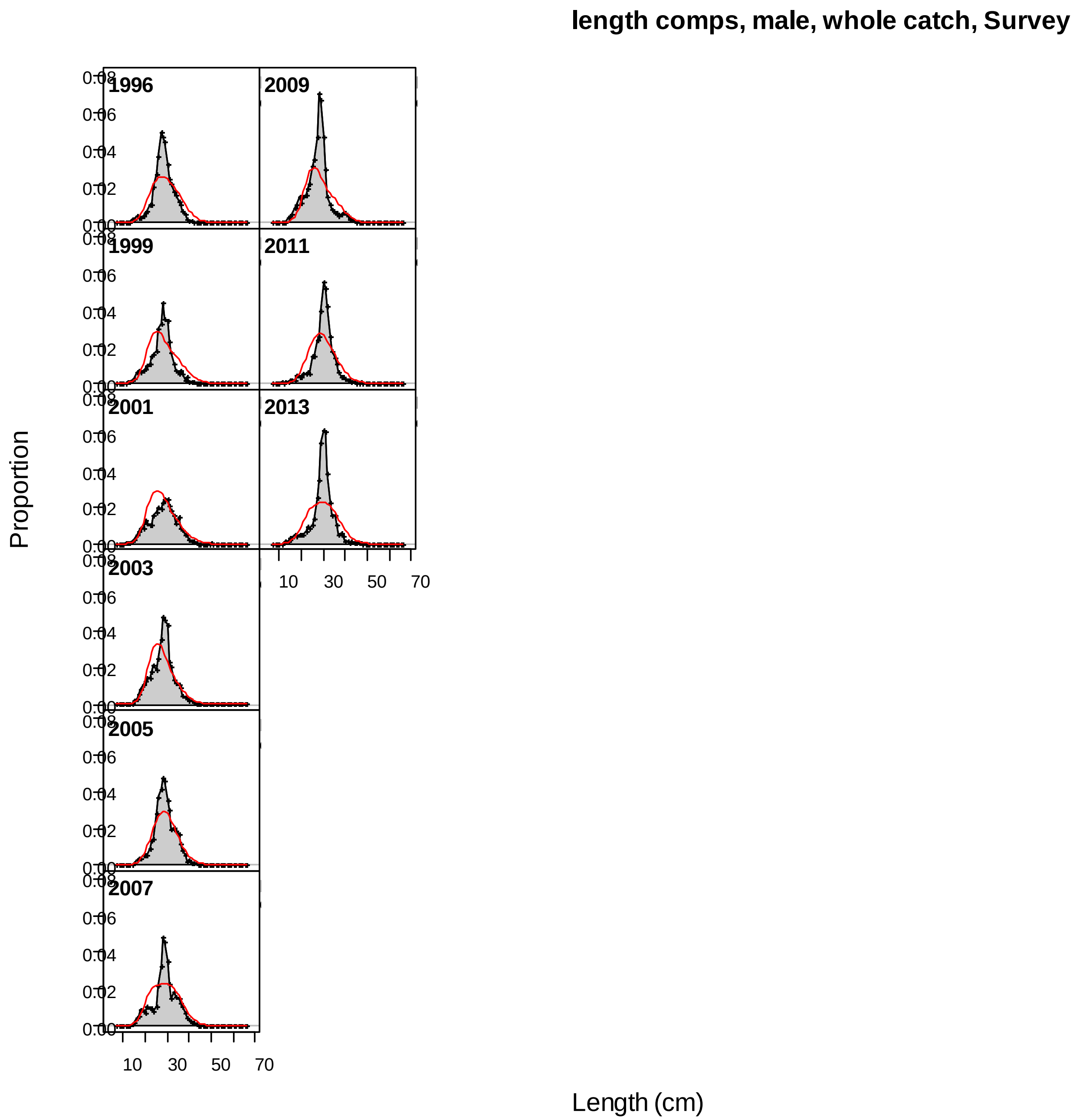


Figure 4.1.35 – Summary female fishery and survey length composition for N model configuration with survey selectivity-at-age

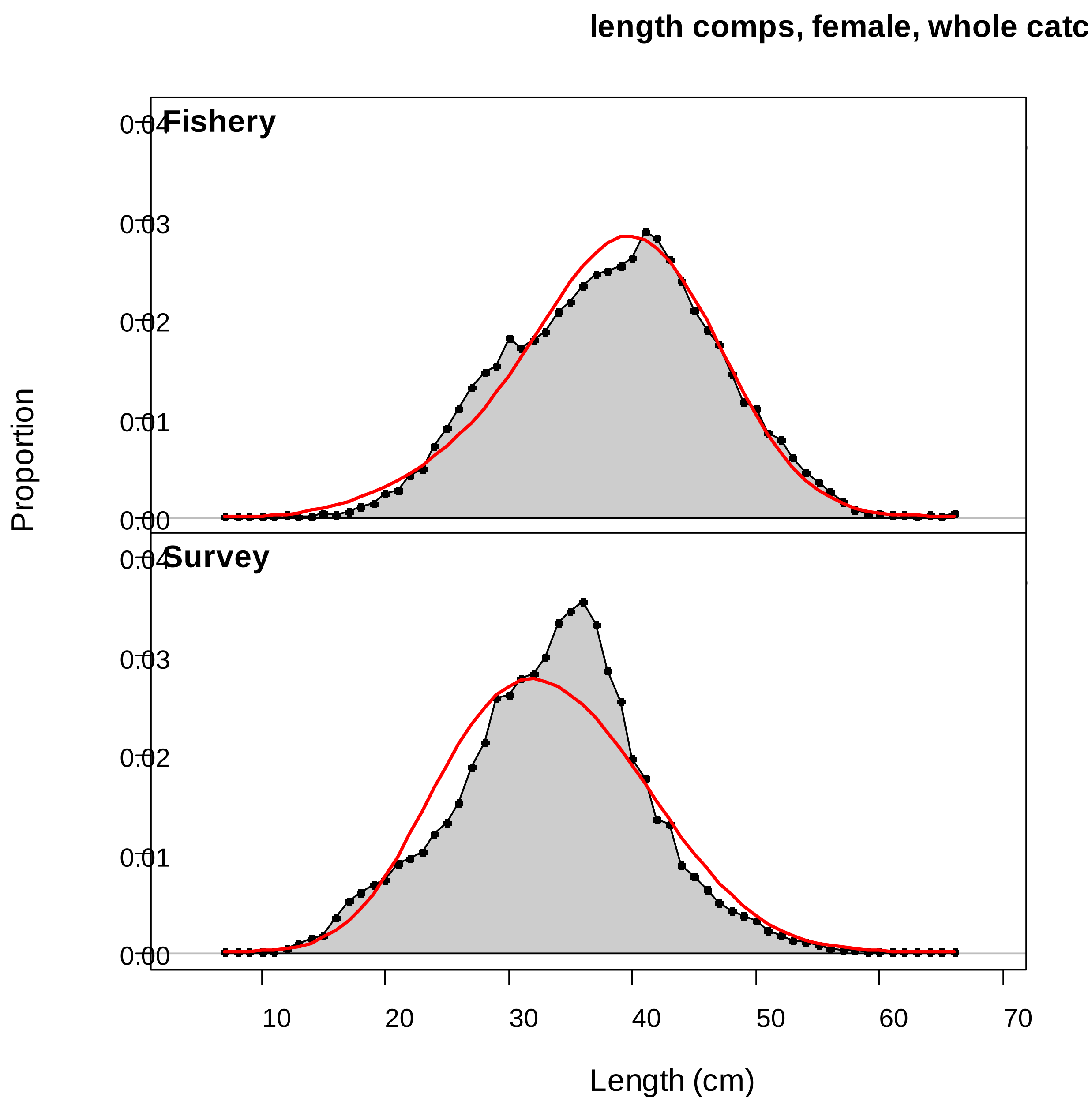


Figure 4.1.36 – Summary male fishery and survey length composition for N model configuration with survey selectivity-at-age

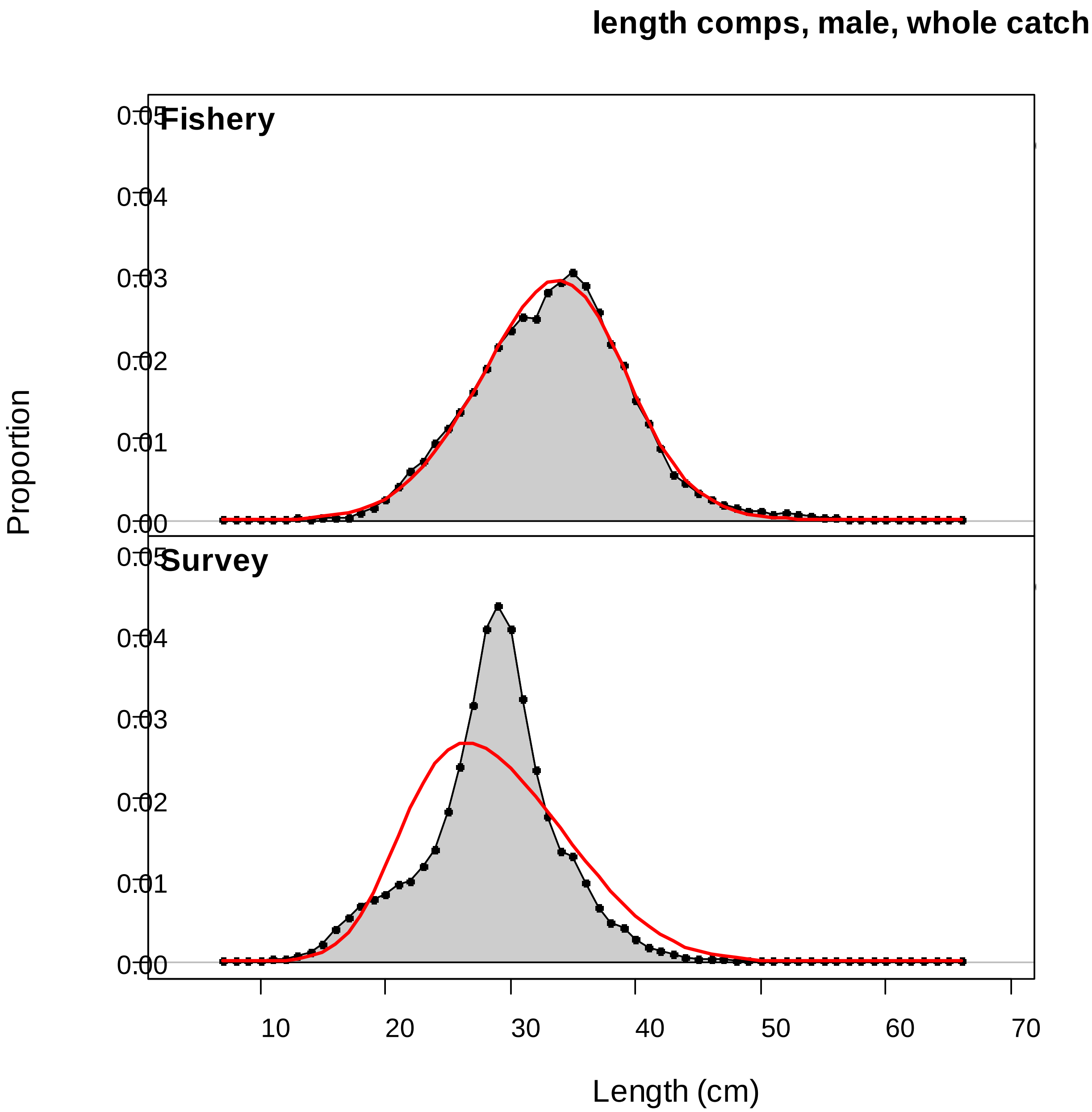
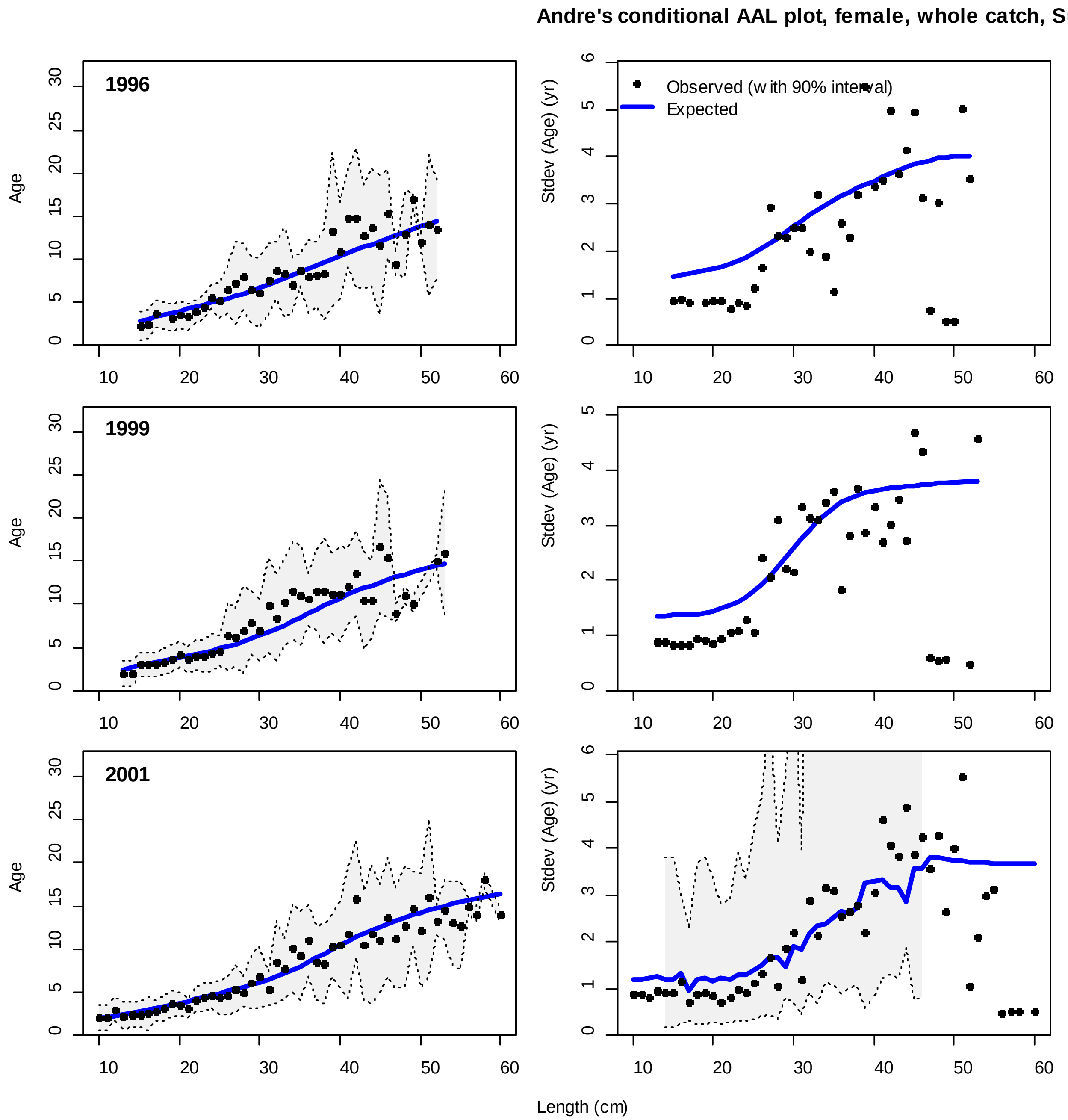
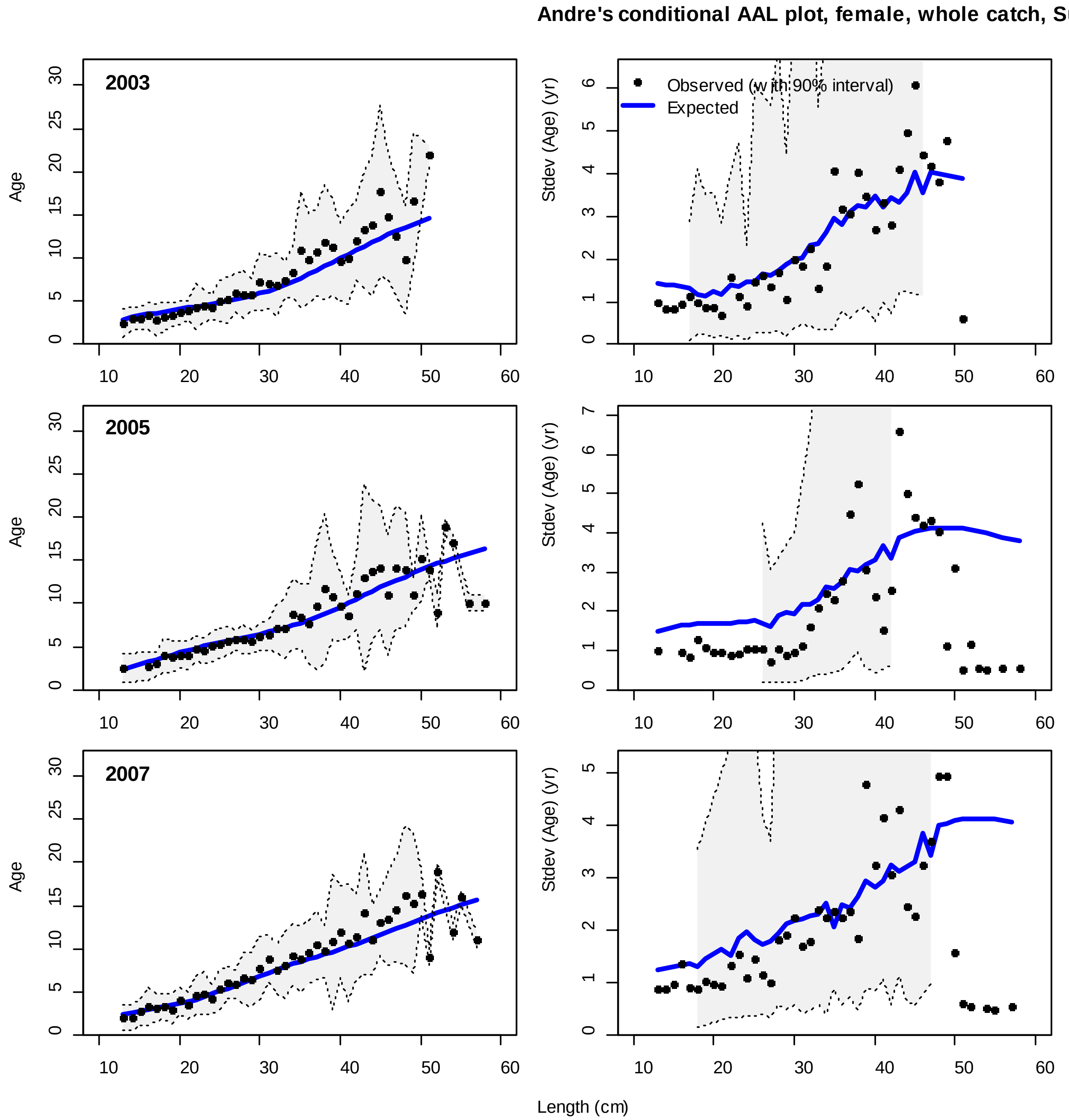


Figure 4.1.37 – Female survey conditional age-at-length for N model configuration with survey selectivity-at-age




Andre's conditional AAL plot, female, whole catch, Su
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

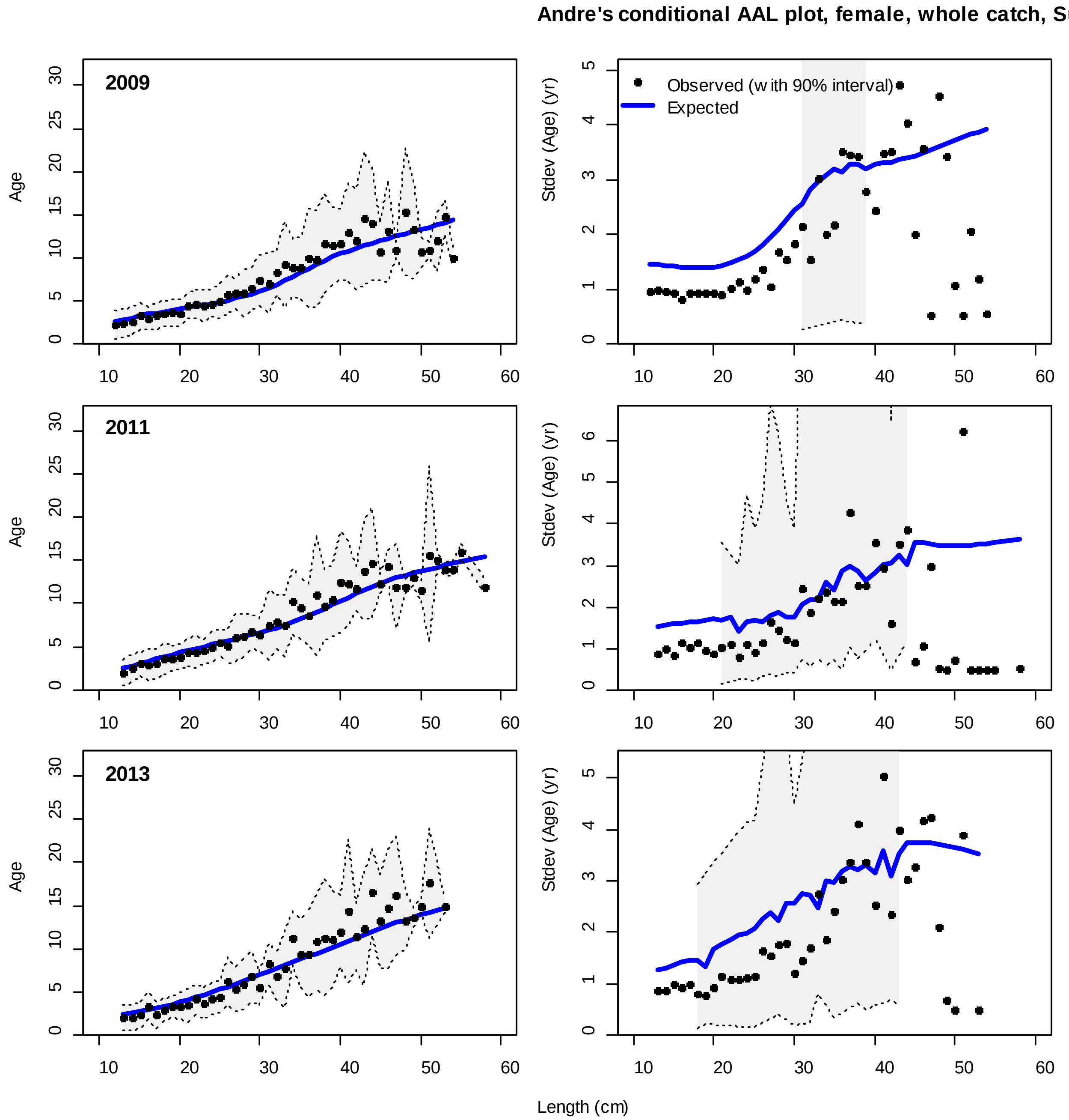
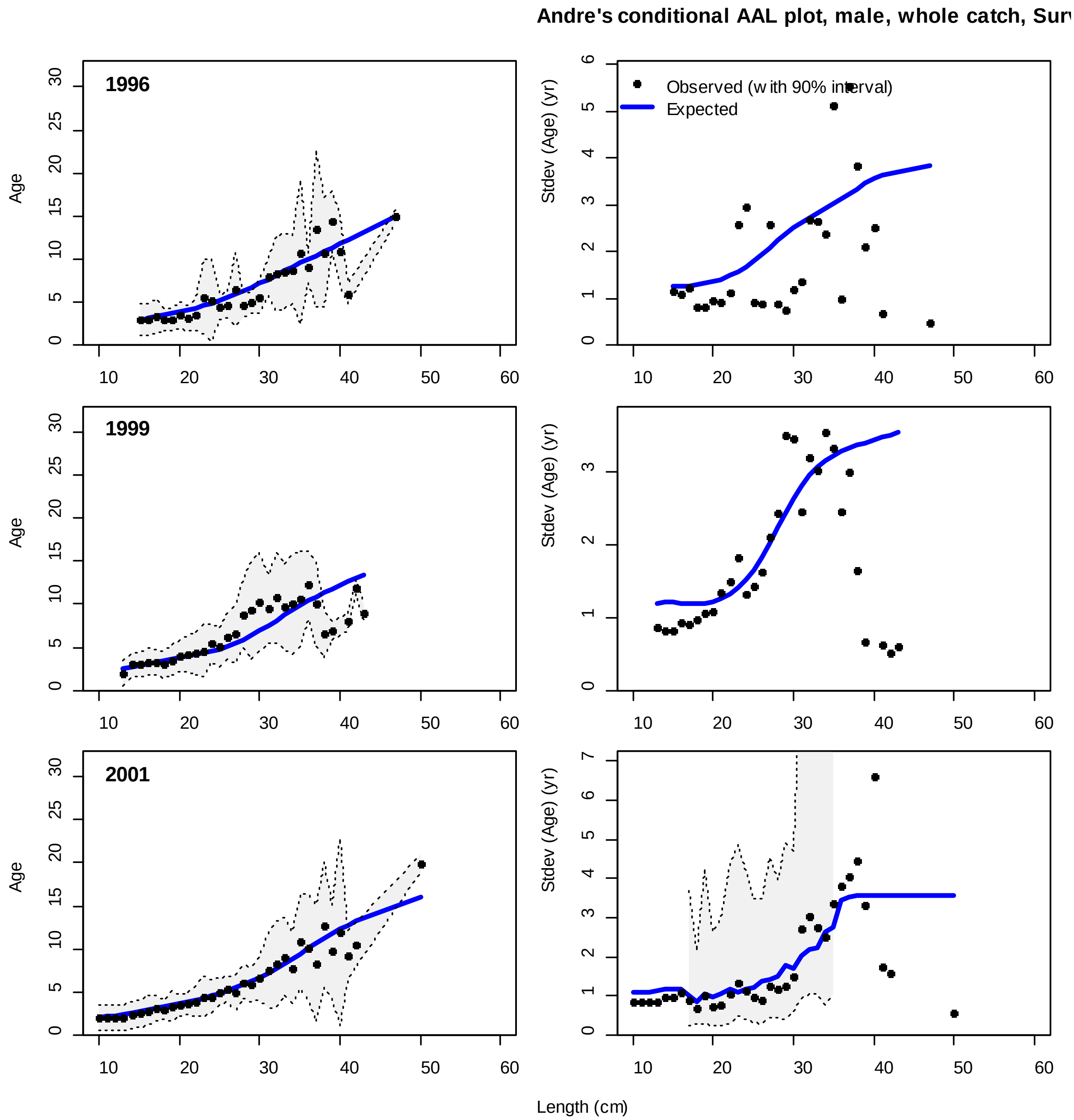
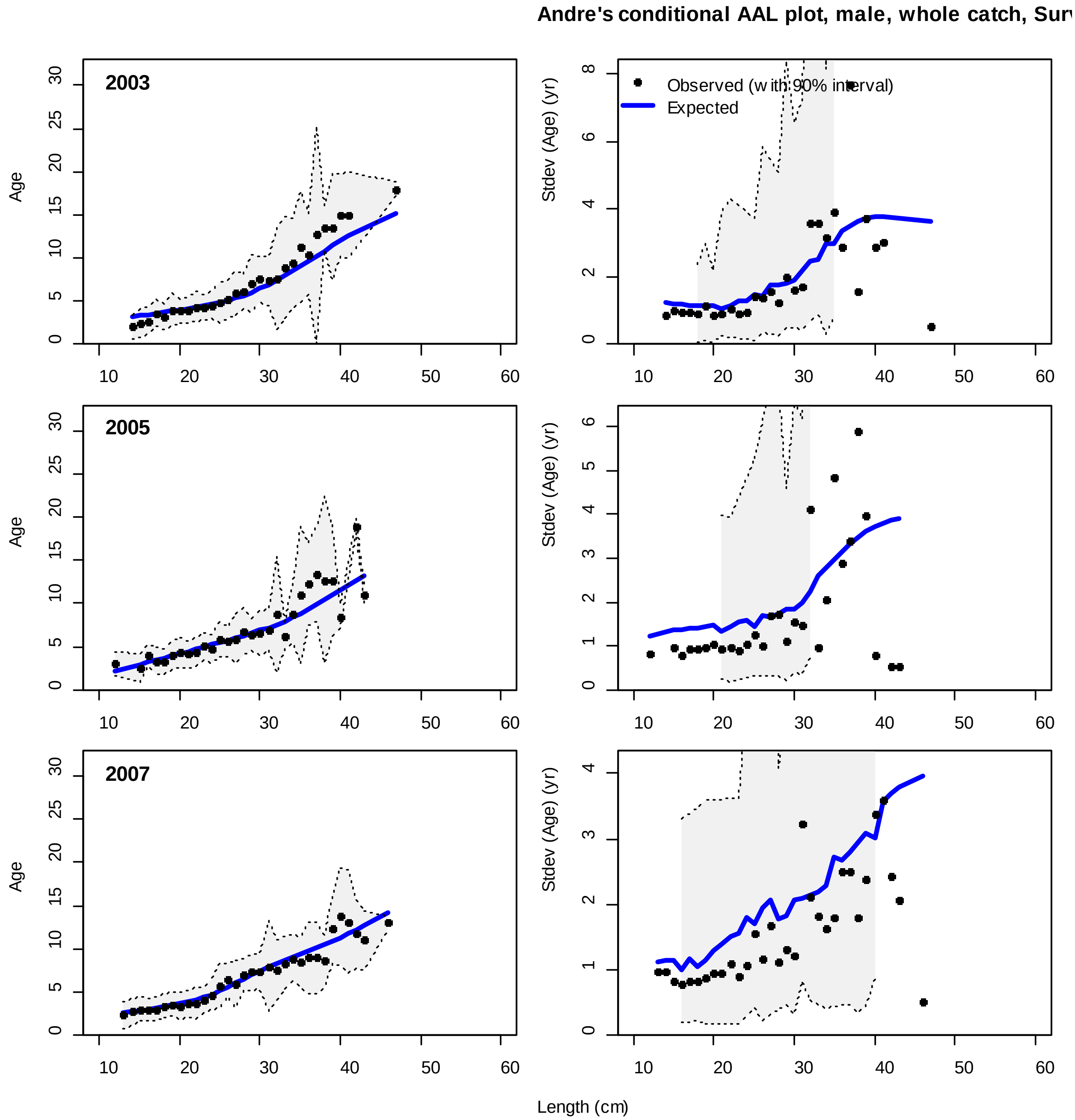

Andre's conditional AAL plot, female, whole catch, Su
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Figure 4.1.38 – Male survey conditional age-at-length for N model configuration with survey selectivity-at-age




Andre's conditional AAL plot, male, whole catch, Surv
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)
0
5
10
15
20
25
30
10
20
30
40
50
60

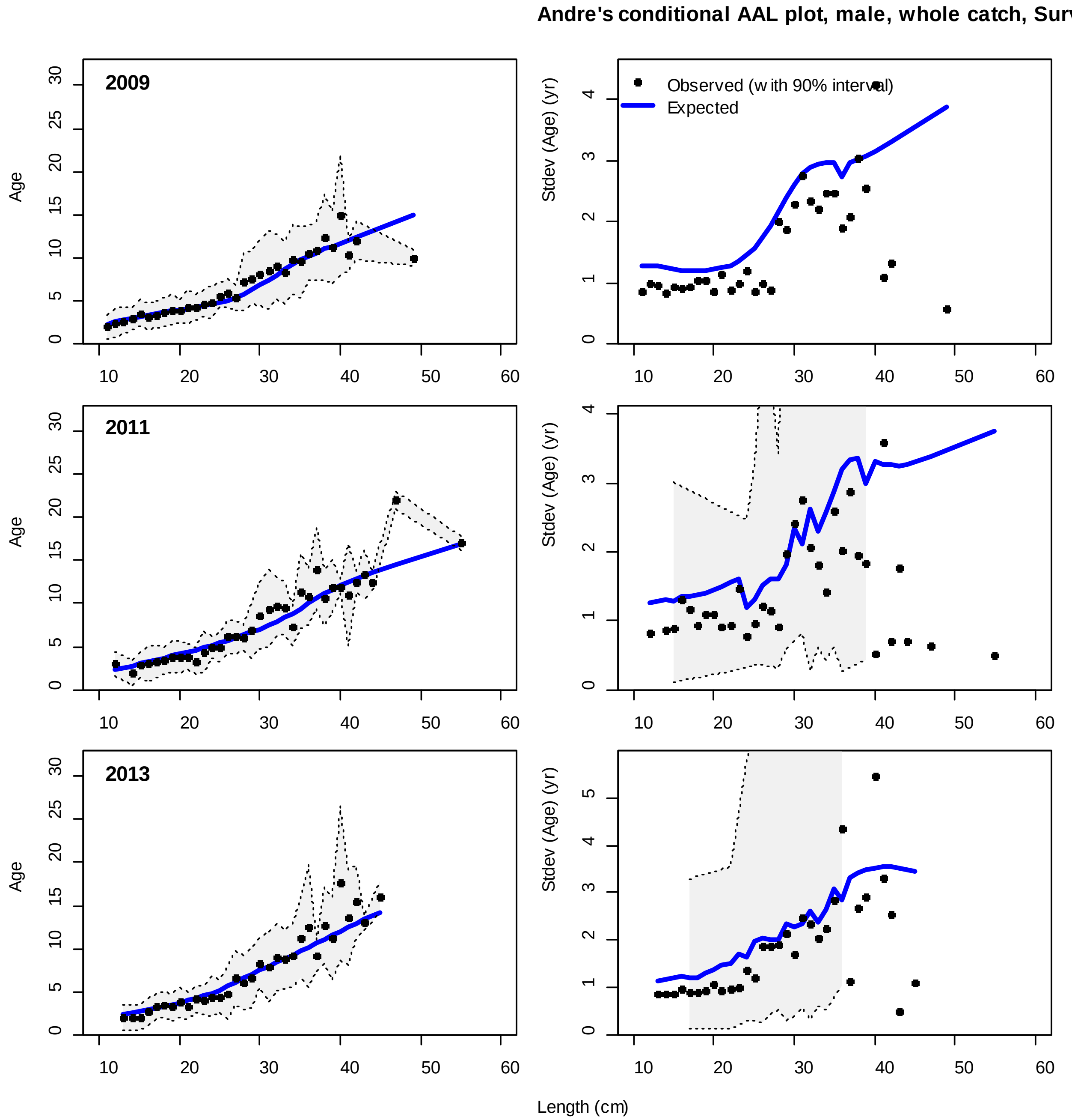

Andre's conditional AAL plot, male, whole catch, Surv
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Figure 4.1.39 – Spawning biomass for S model configuration with survey selectivity-at-age

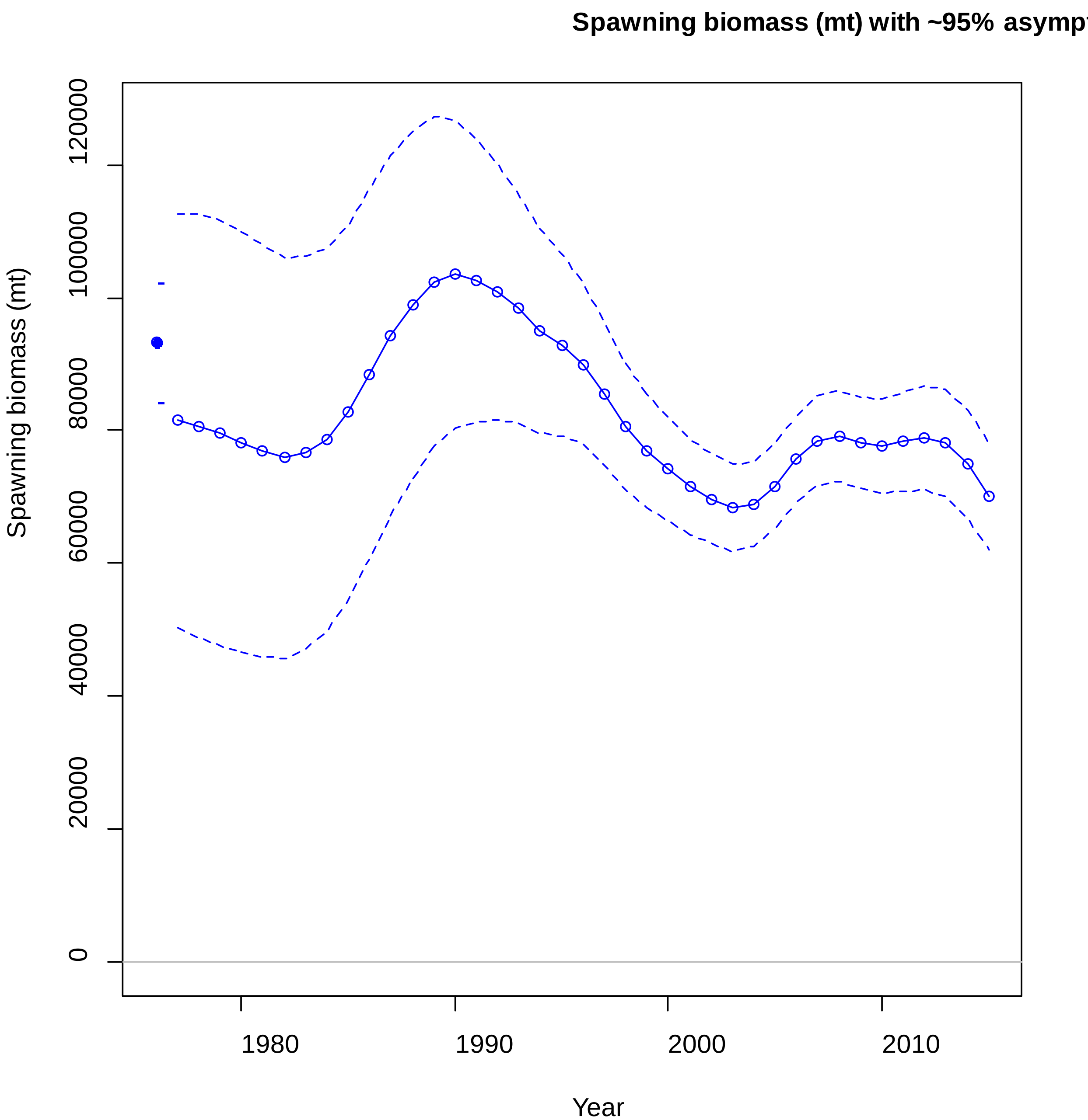


Figure 4.1.40 – Length-at-age for S model configuration with survey selectivity-at-age

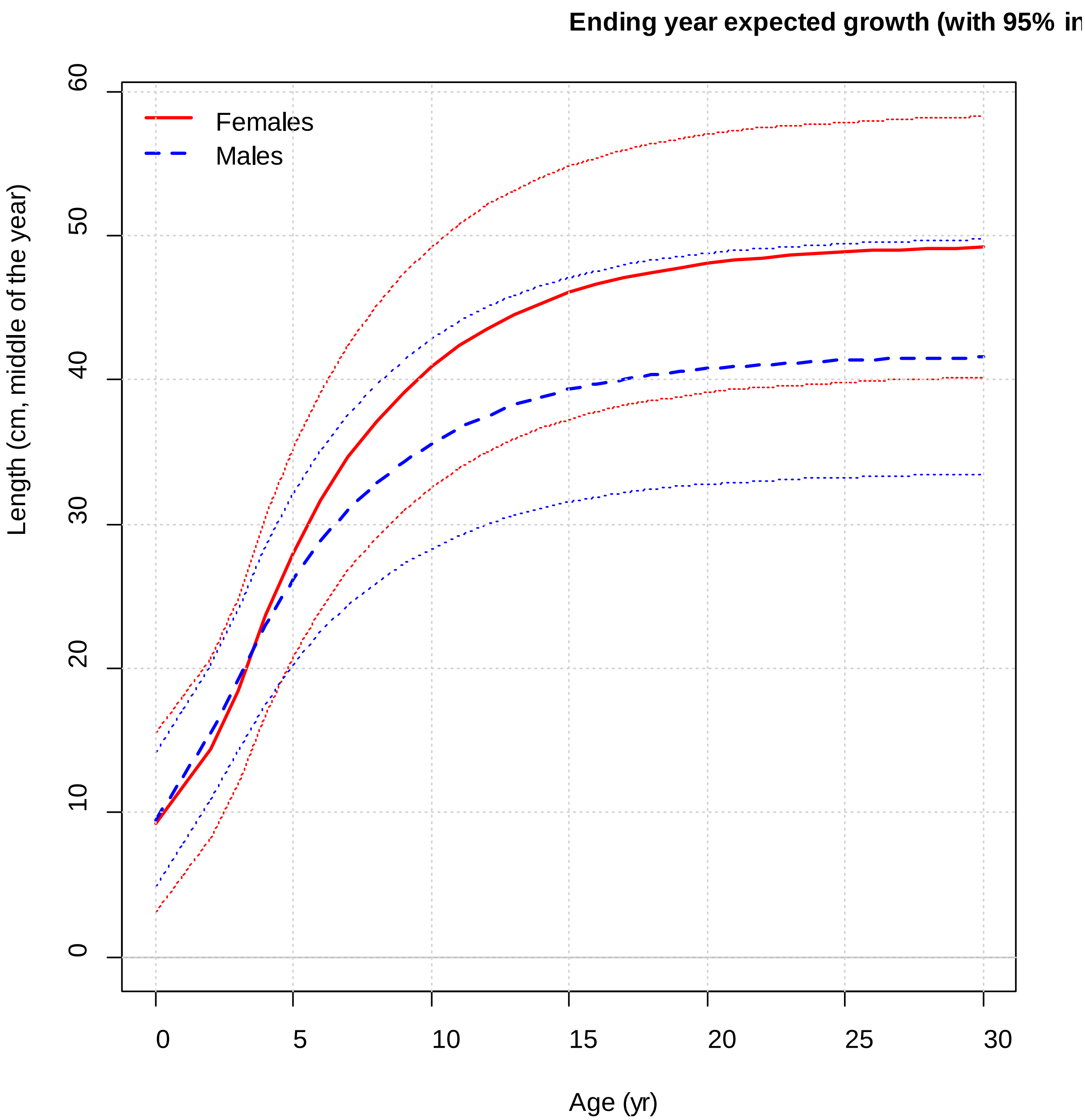


Figure 4.1.41 – Age-0 recruits for S model configuration with survey selectivity-at-age

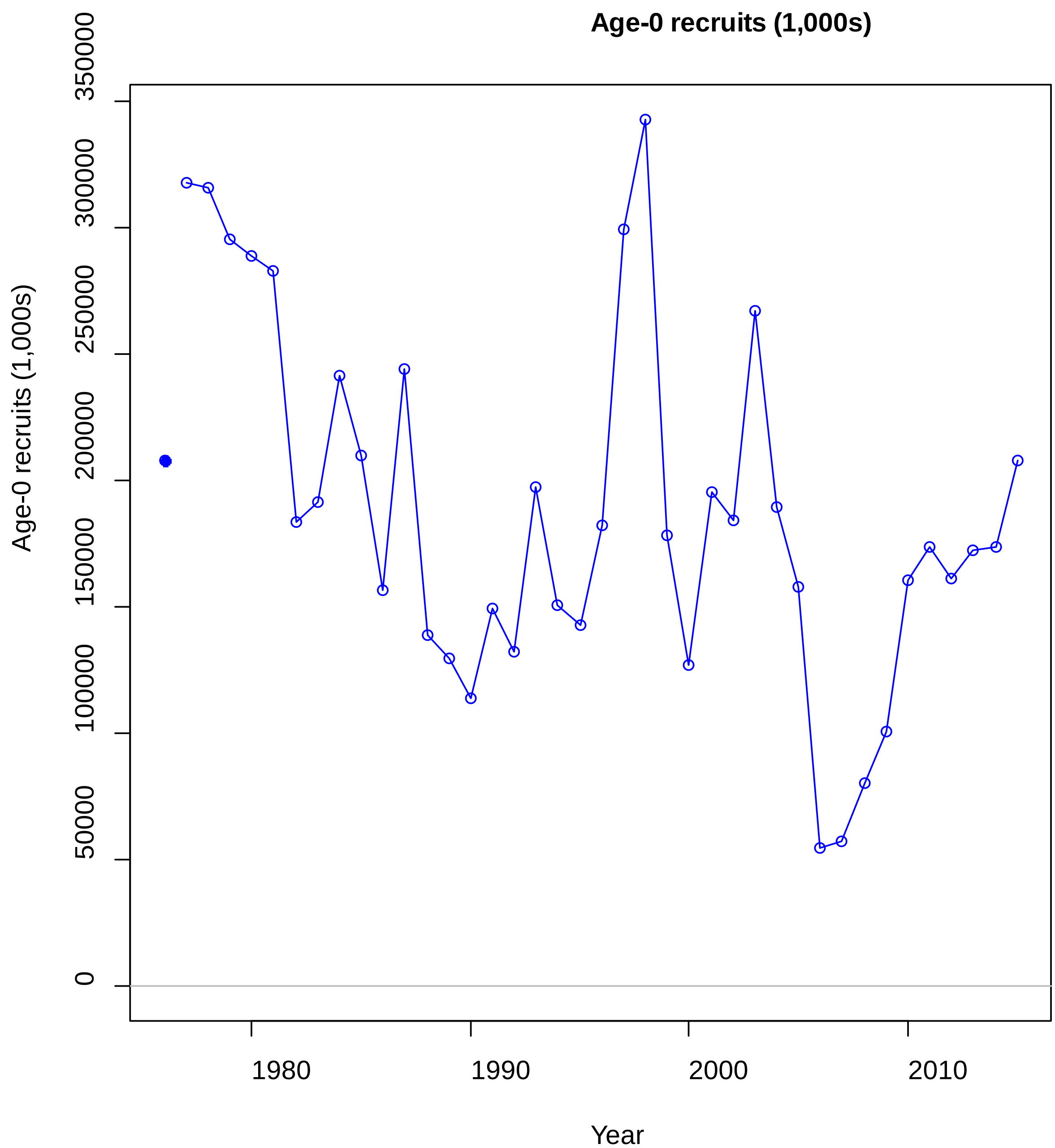


Figure 4.1.42 – Age-0 recruits with uncertainty intervals for S model configuration with survey selectivity-at-age

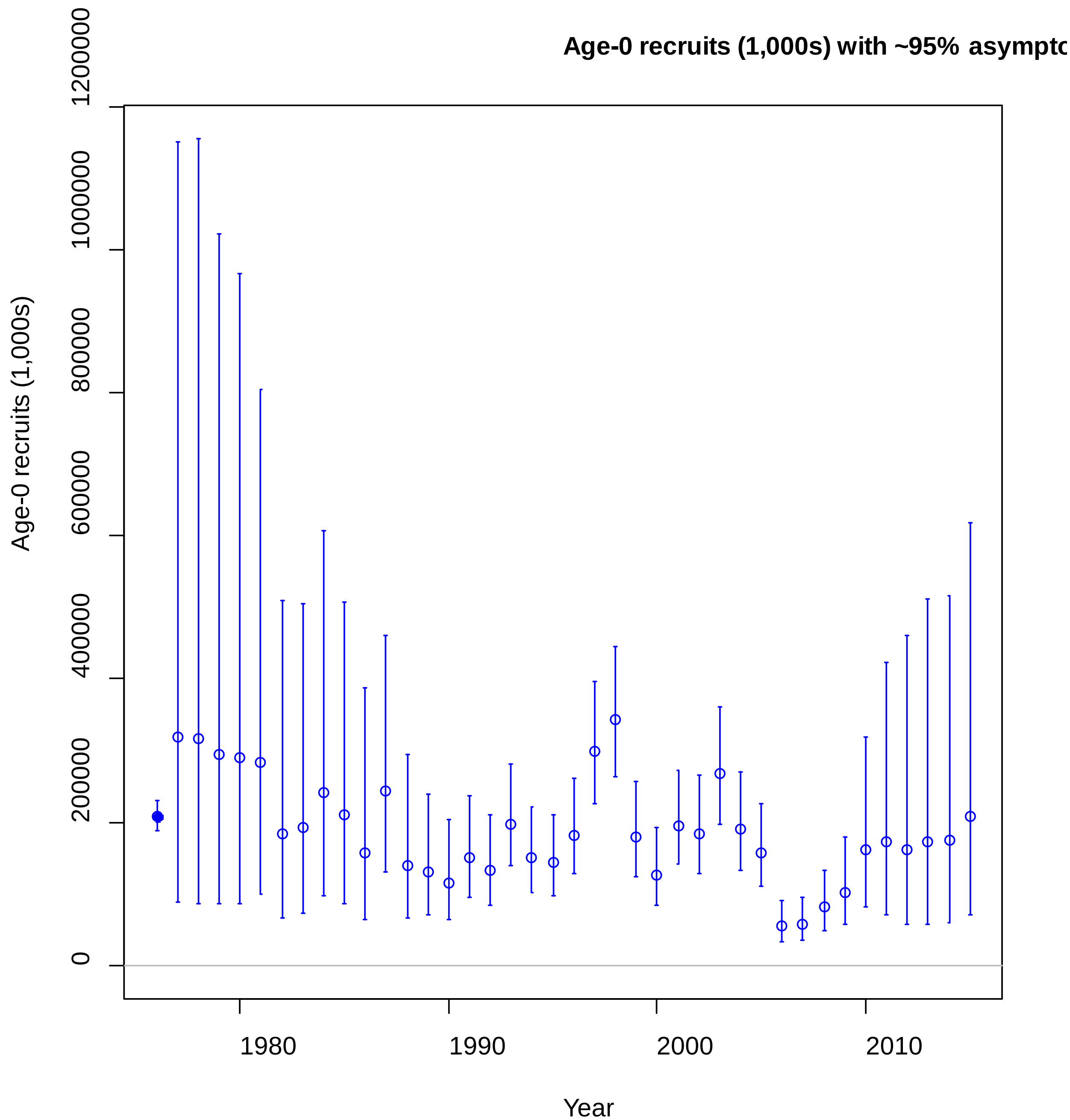


Figure 4.1.43 – Bottom trawl survey index for S model configuration with survey selectivity-at-age

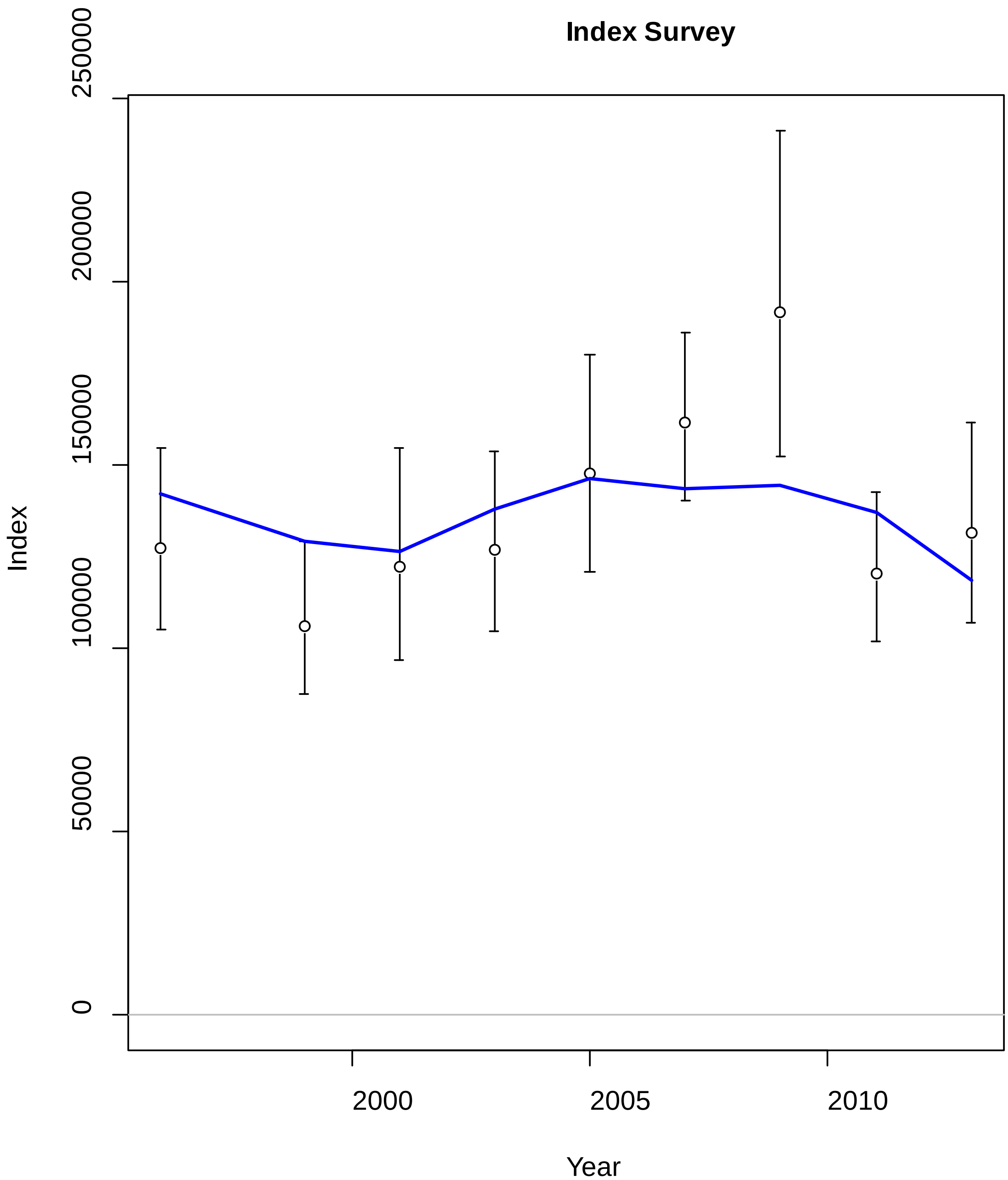


Figure 4.1.44 – Female fishery selectivity-at-length for S model configuration with survey selectivity-at-age

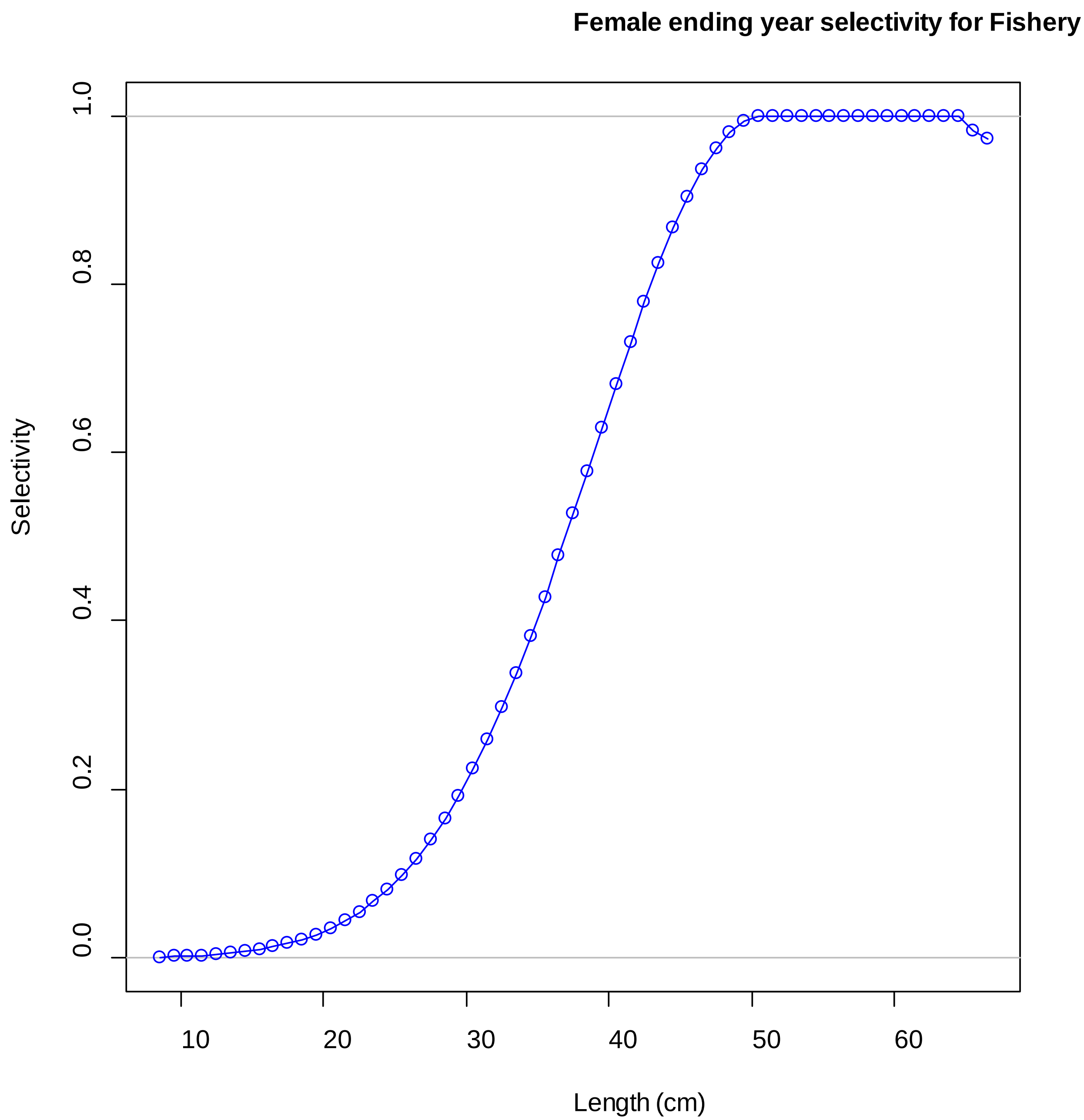


Figure 4.1.45 – Male fishery selectivity-at-length for S model configuration with survey selectivity-at-age

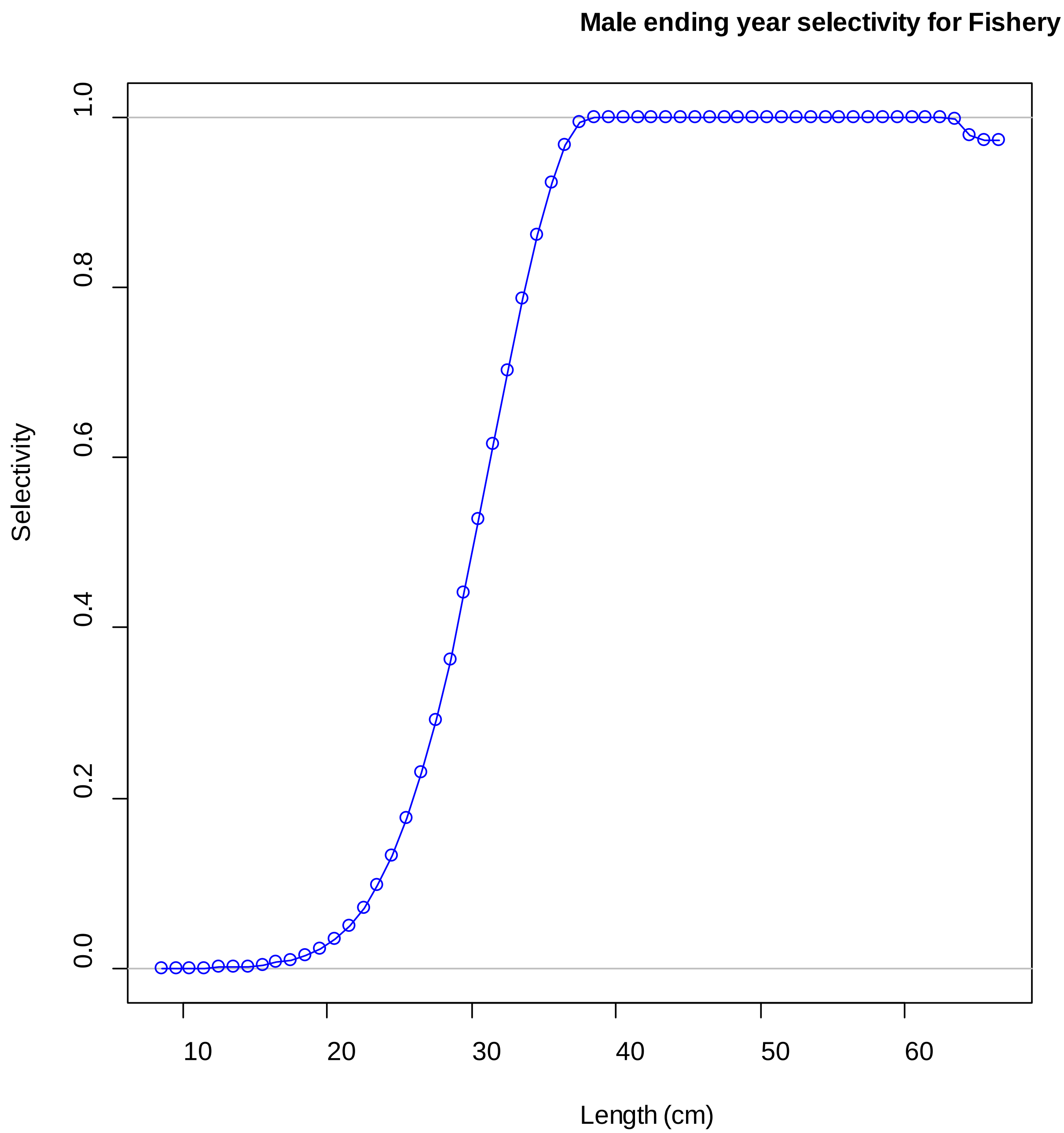


Figure 4.1.46 – Female survey selectivity-at-age for S model configuration with survey selectivity-at-age

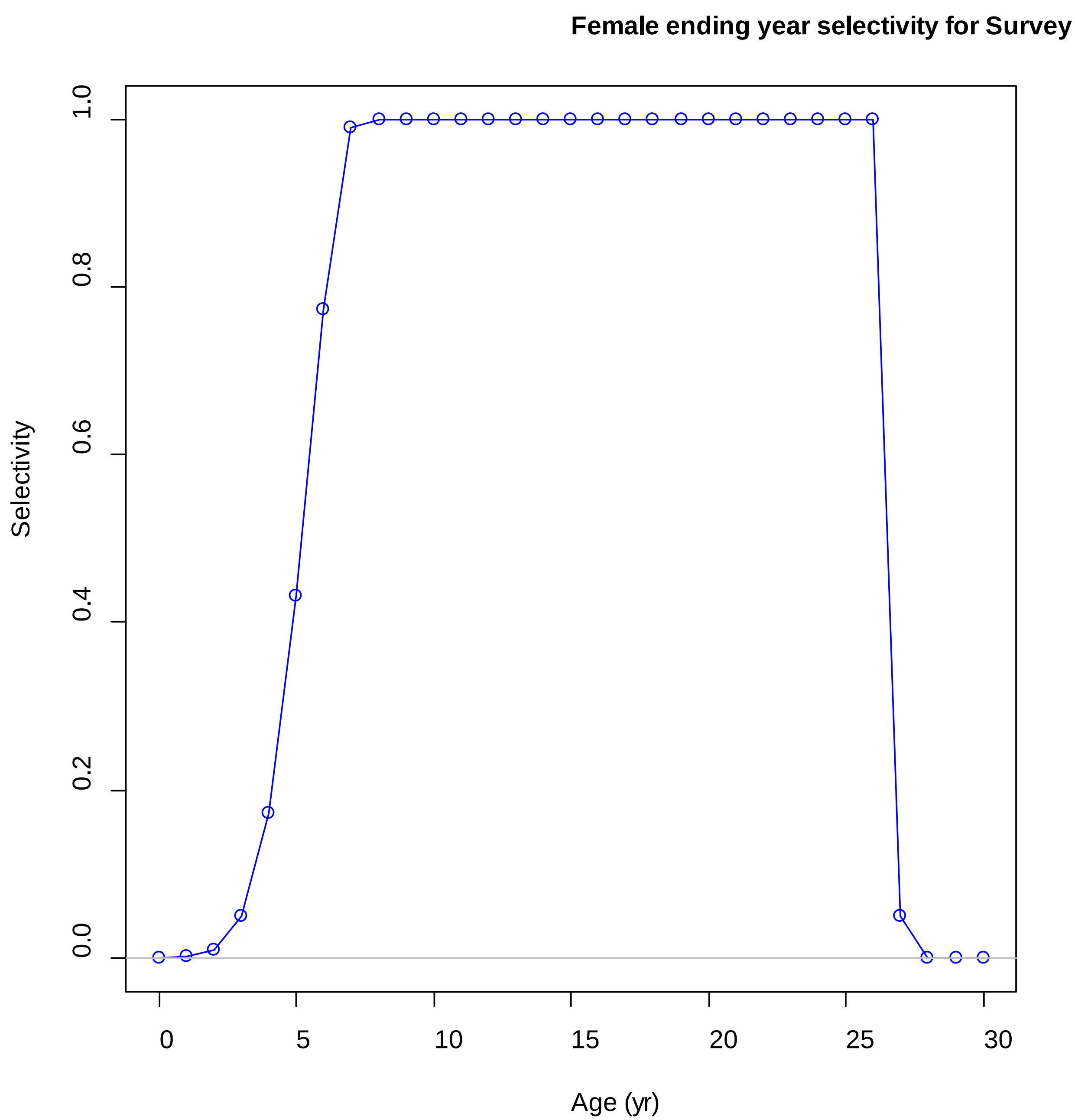


Figure 4.1.47 – Male survey selectivity-at-age for S model configuration with survey selectivity-at-age

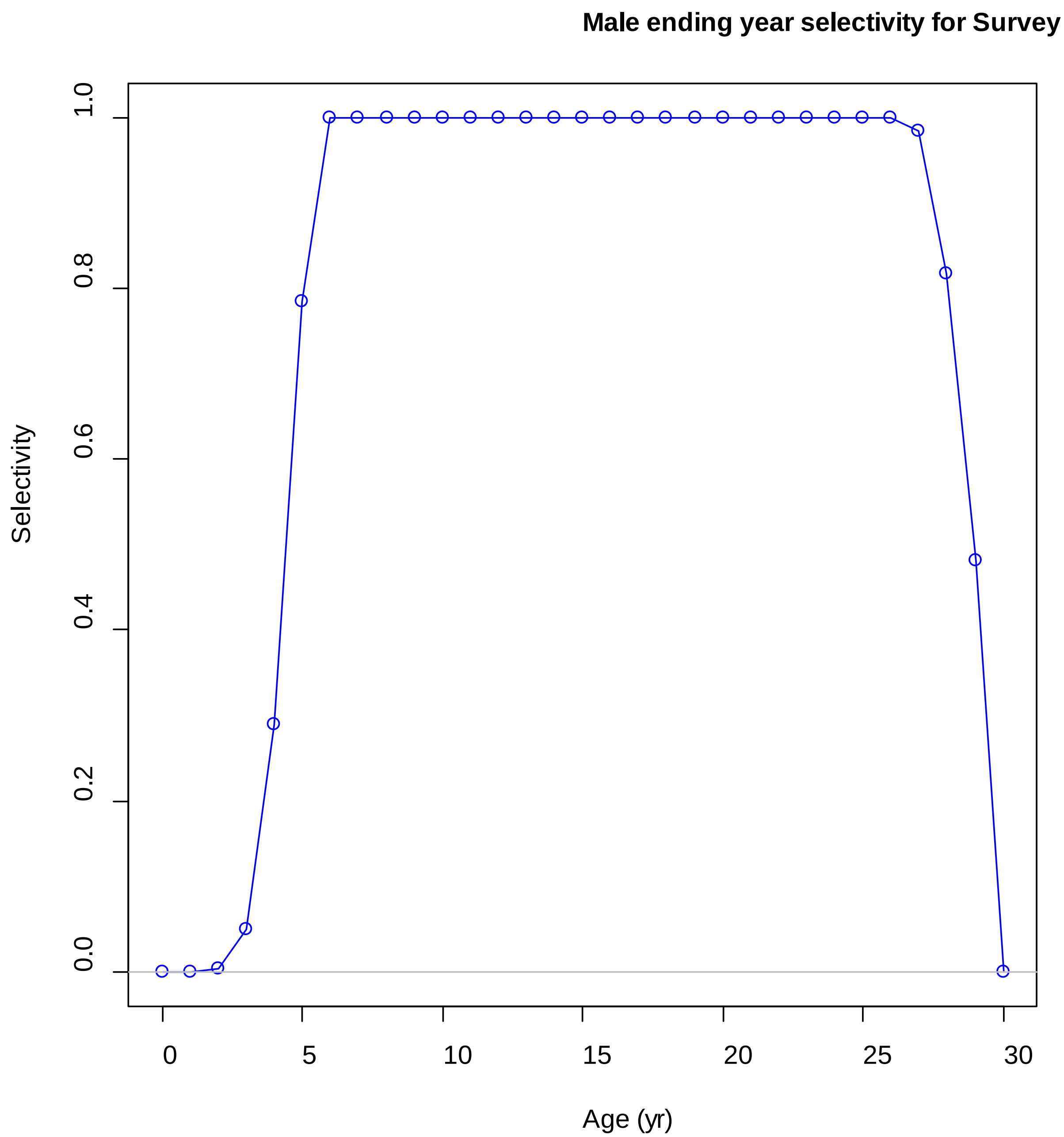


Figure 4.1.48 – Derived female and male fishery selectivity-at-age for S model configuration with survey selectivity-at-age

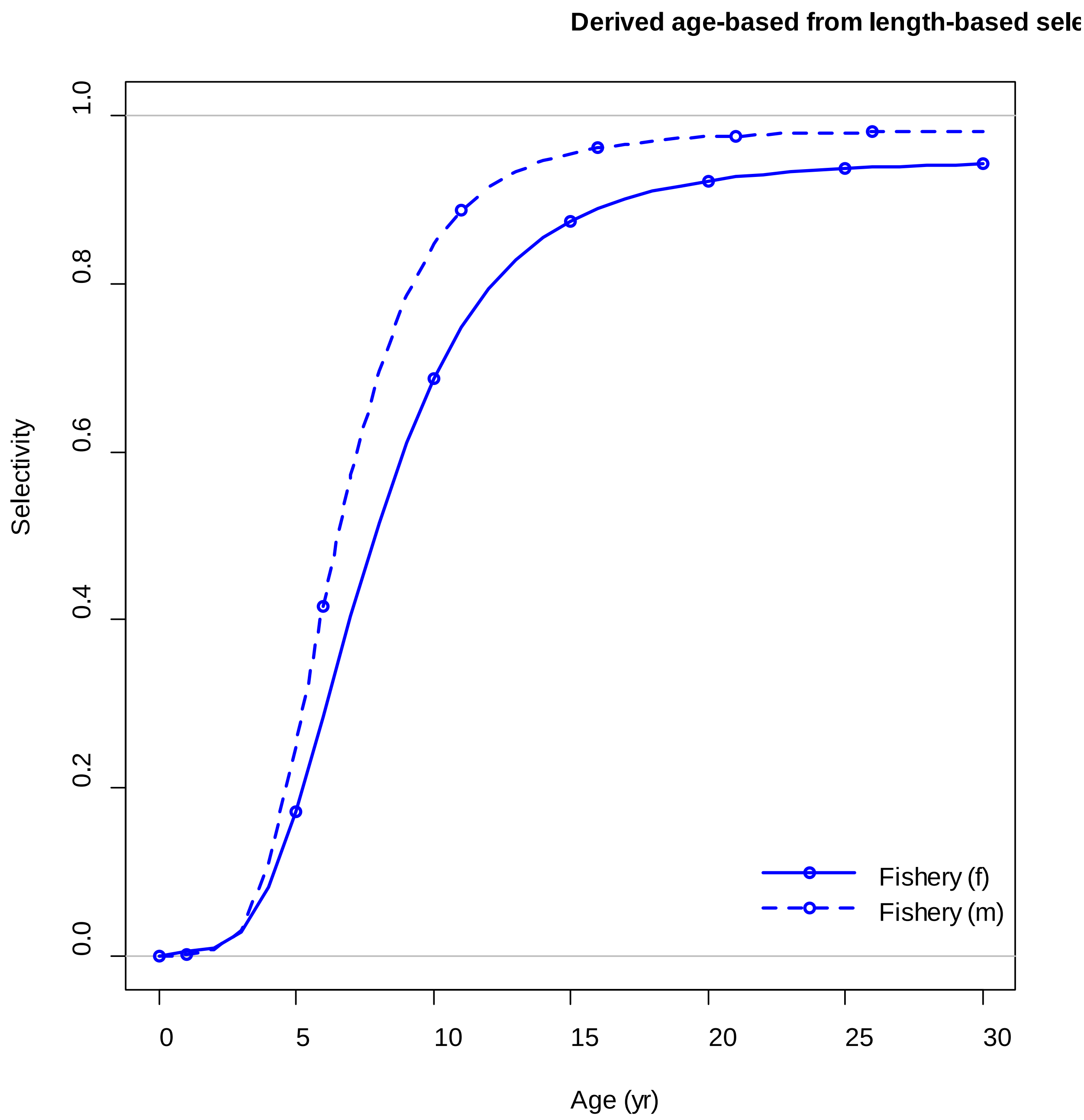


Figure 4.1.49 – Female fishery length composition for S model configuration with survey selectivity-at-age

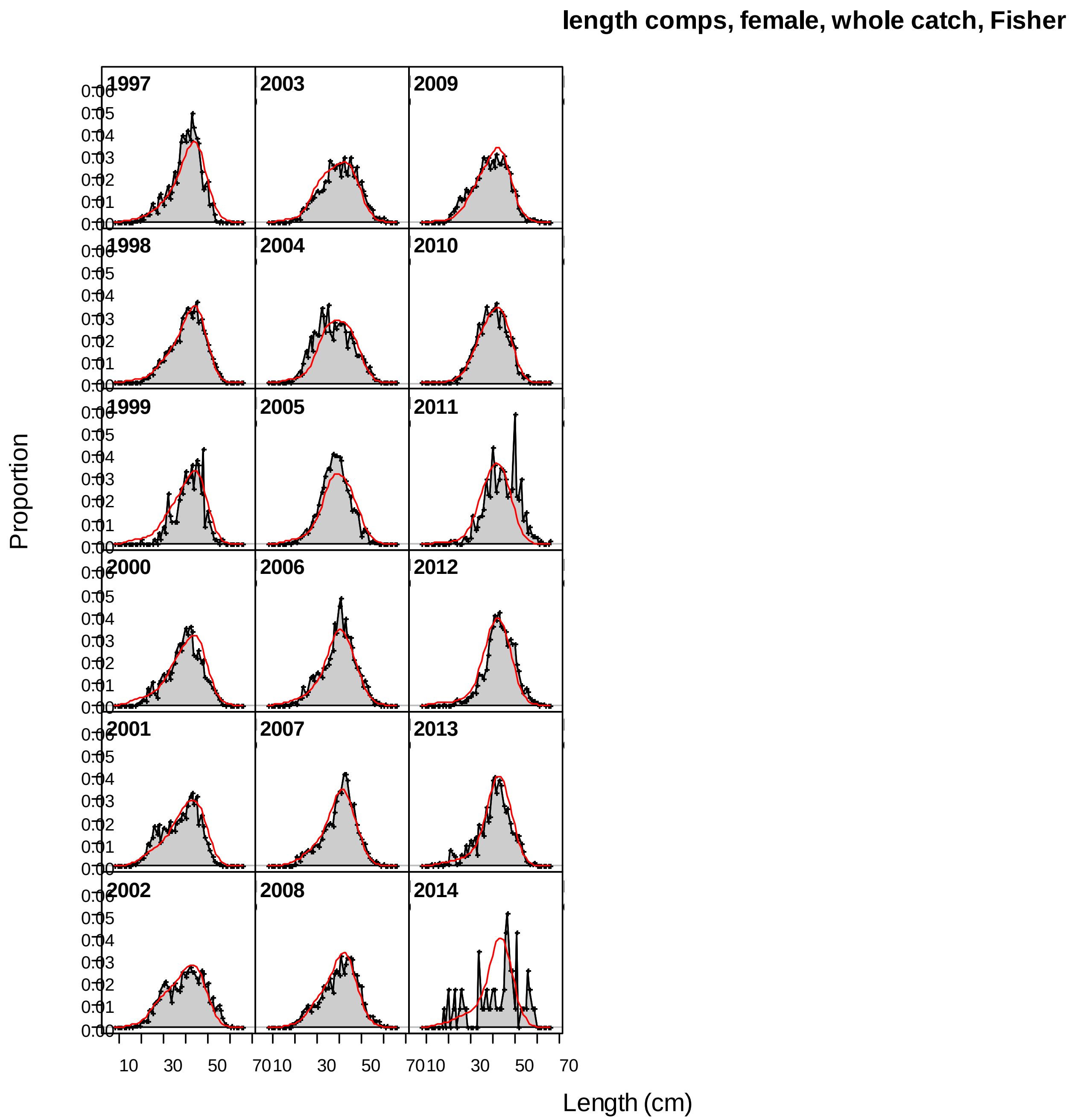


Figure 4.1.50 – Male fishery length composition for S model configuration with survey selectivity-at-age

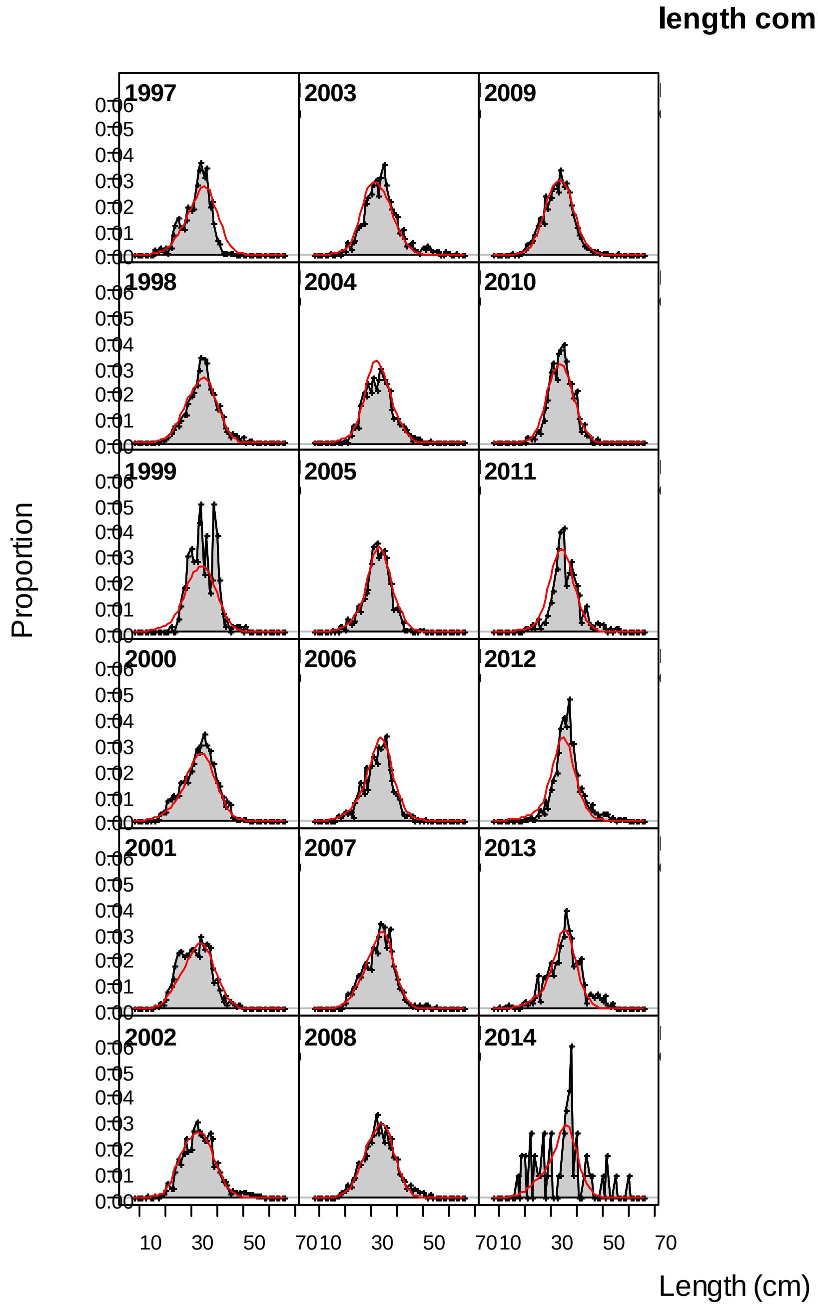


Figure 4.1.51 – Female survey length composition for S model configuration with survey selectivity-at-age

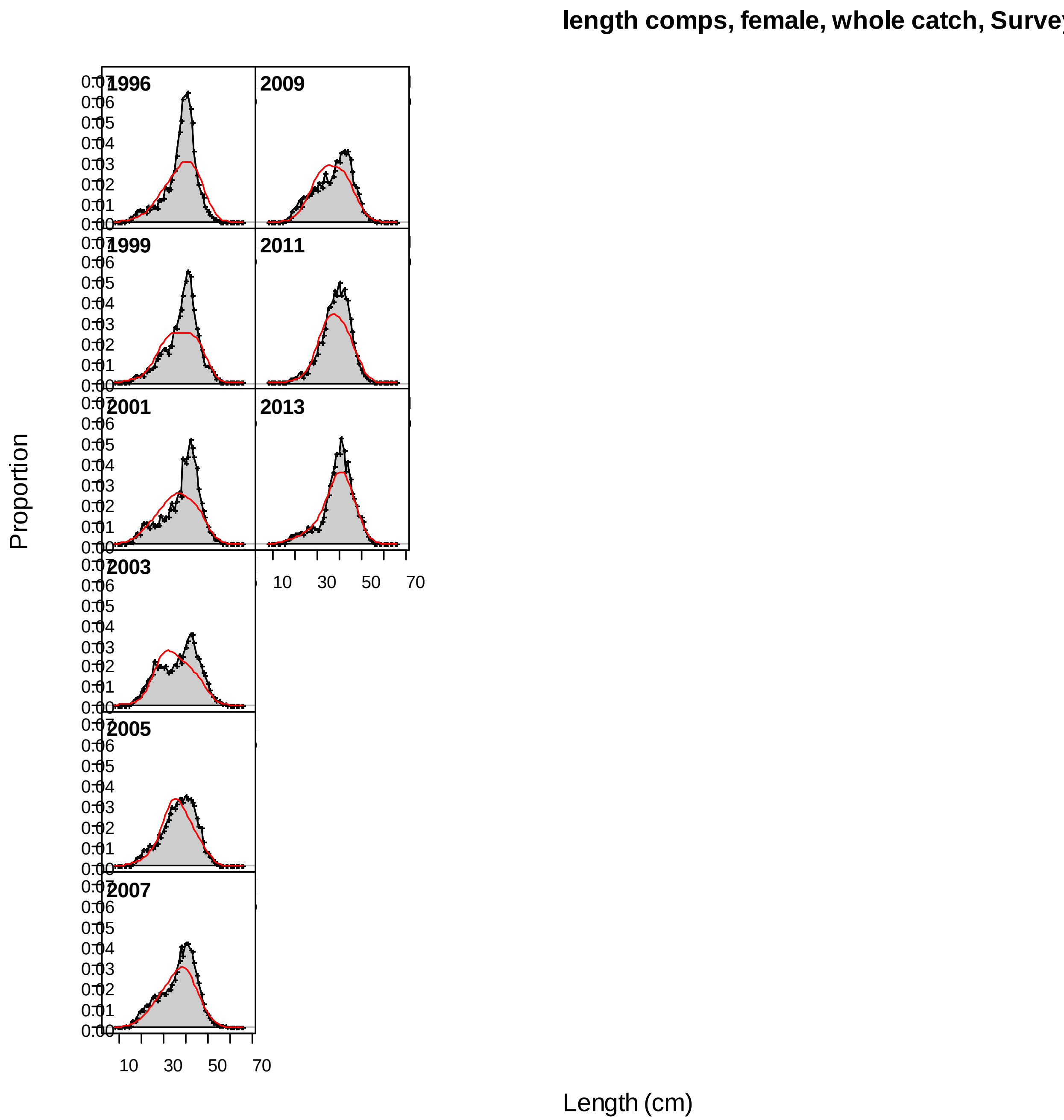


Figure 4.1.52 – Male survey length composition for S model configuration with survey selectivity-at-age

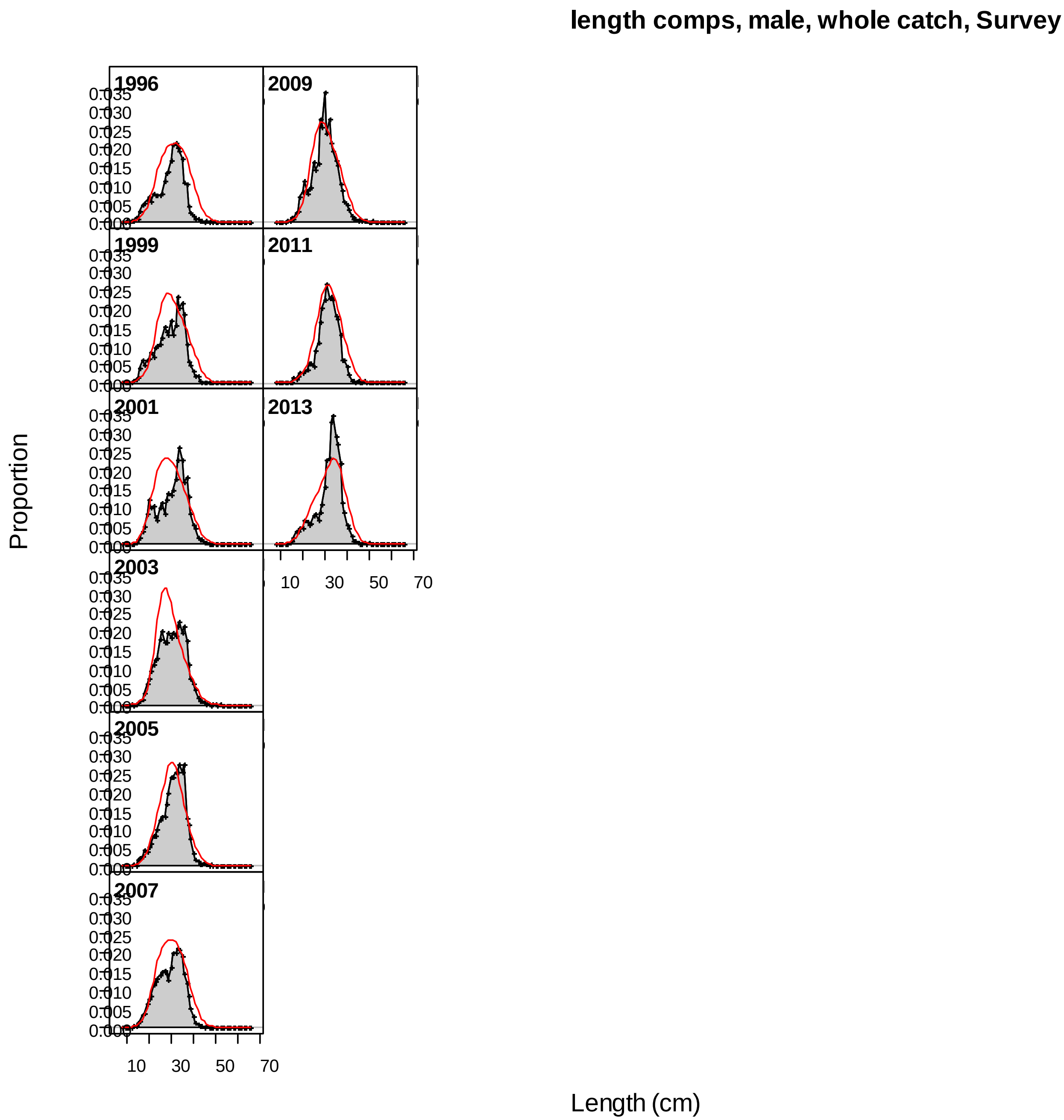


Figure 4.1.53 – Summary female fishery and survey length composition for S model configuration with survey selectivity-at-age

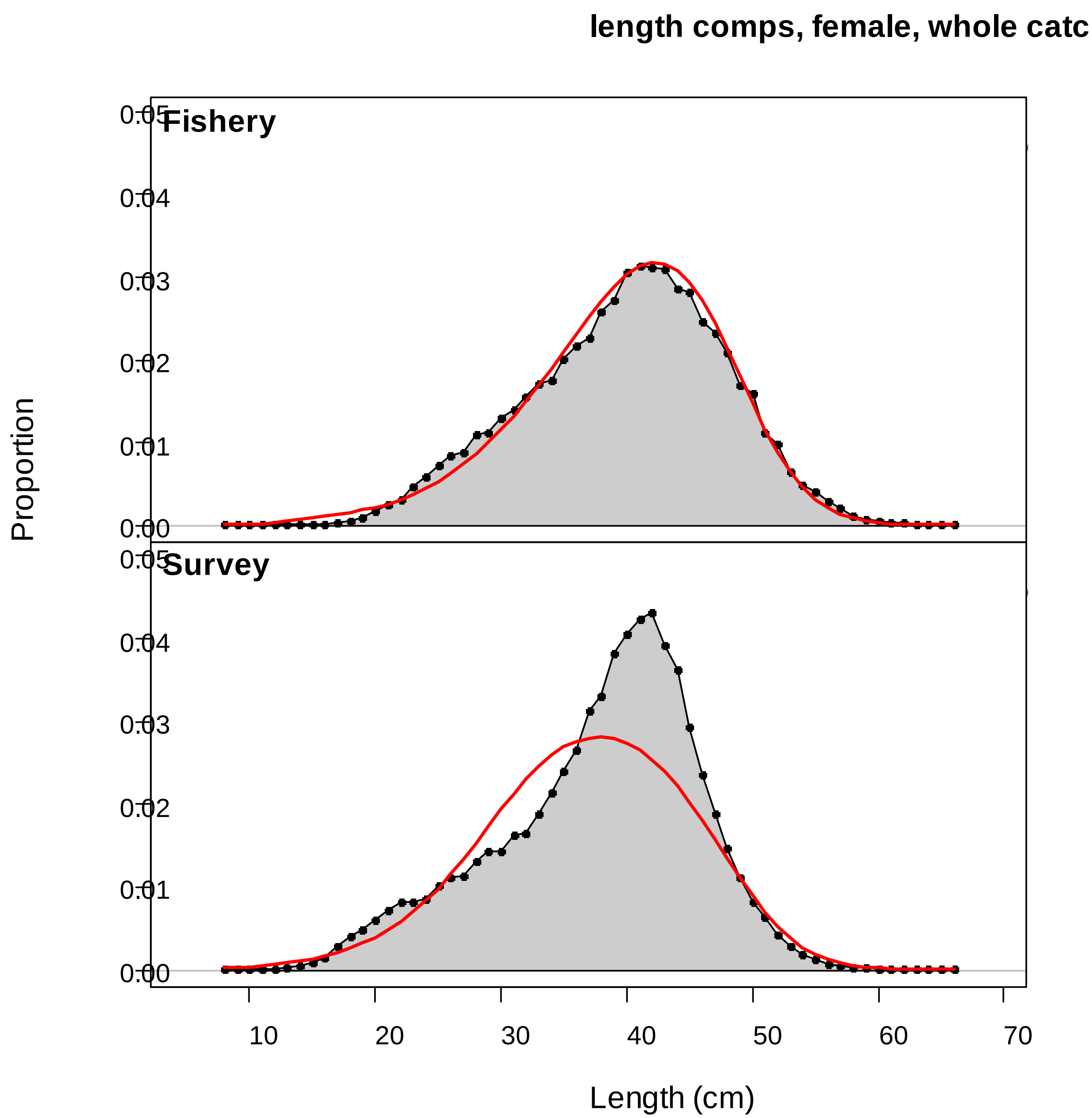


Figure 4.1.54 – Summary male fishery and survey length composition for S model configuration with survey selectivity-at-age

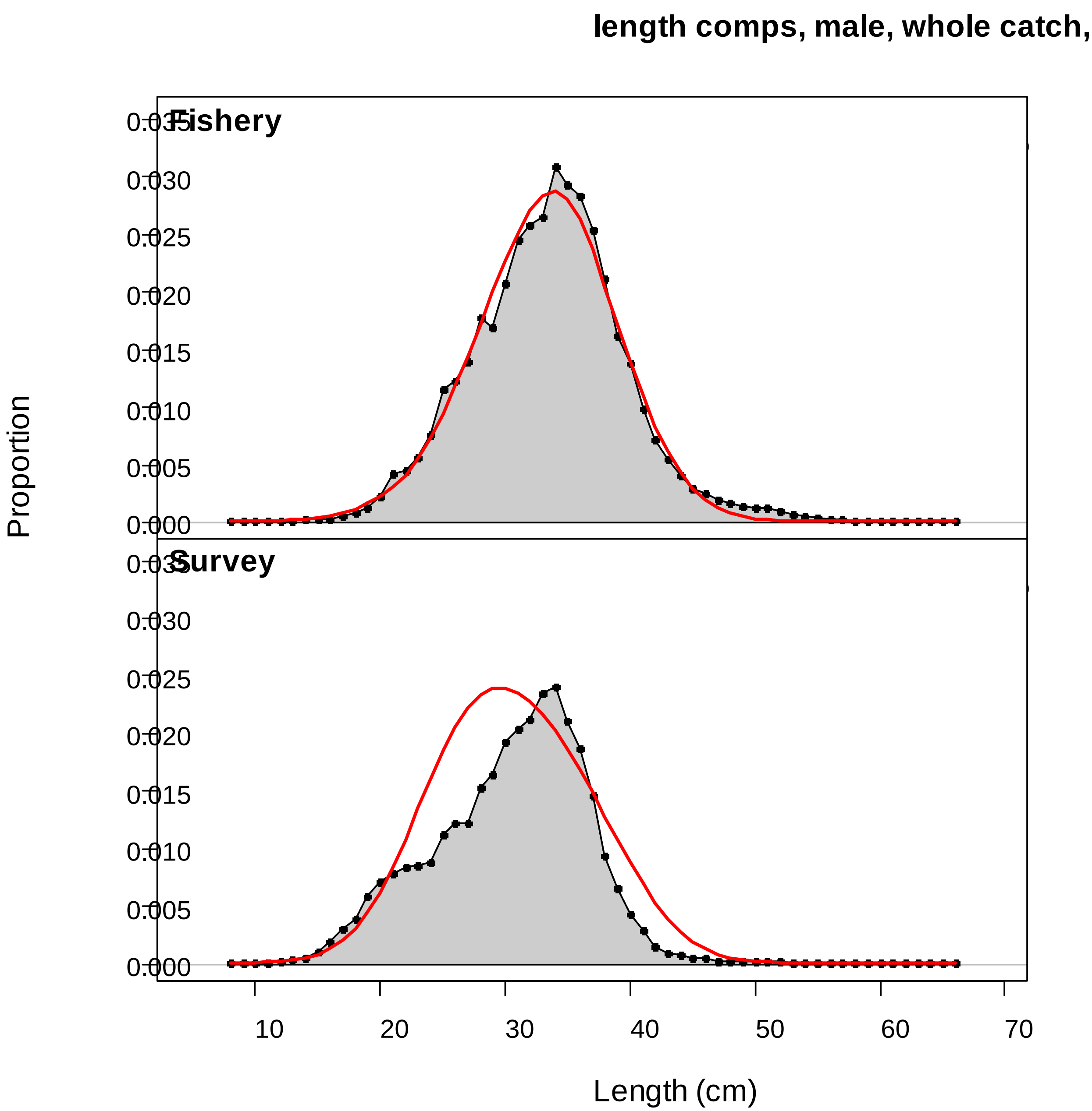
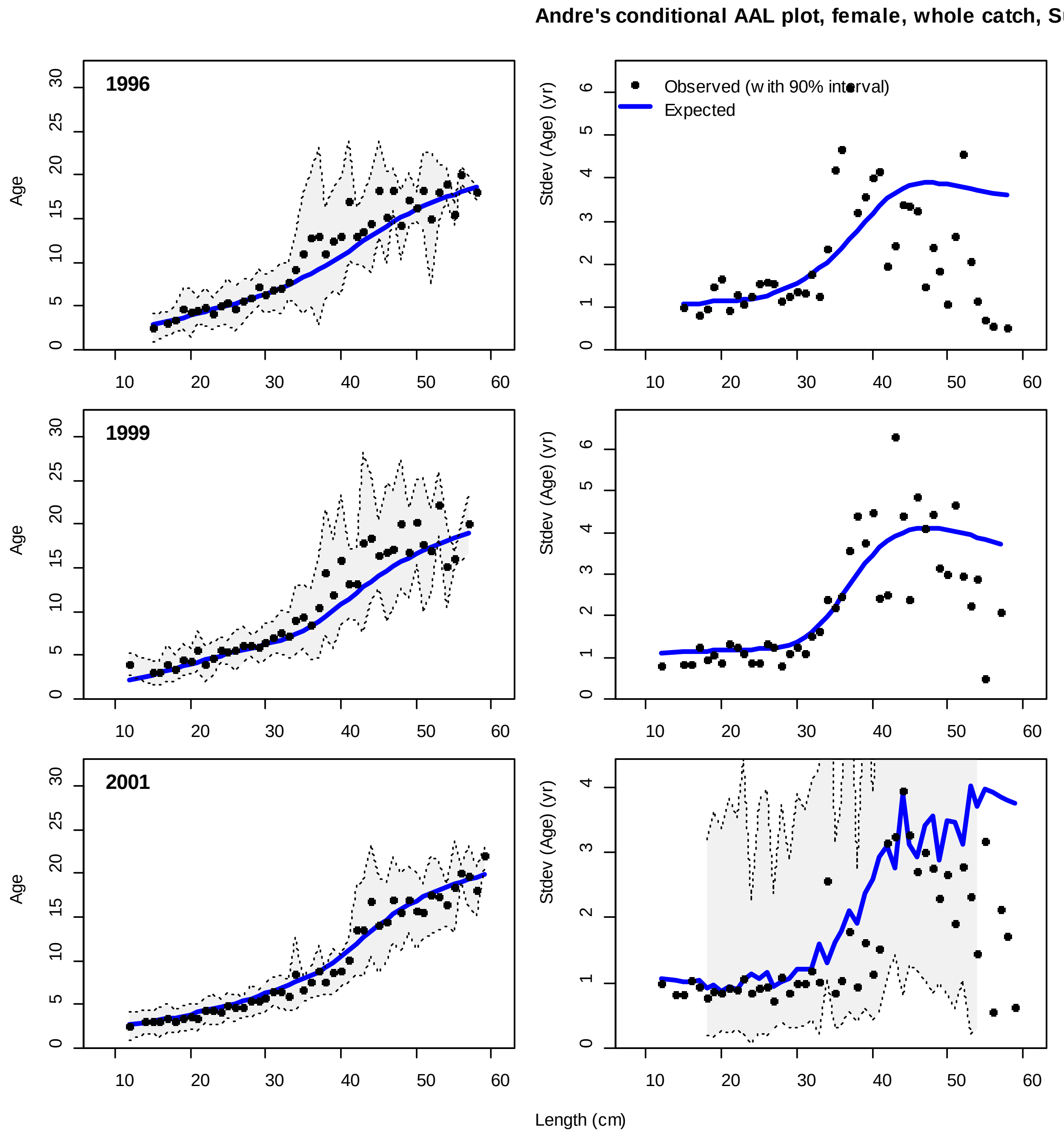
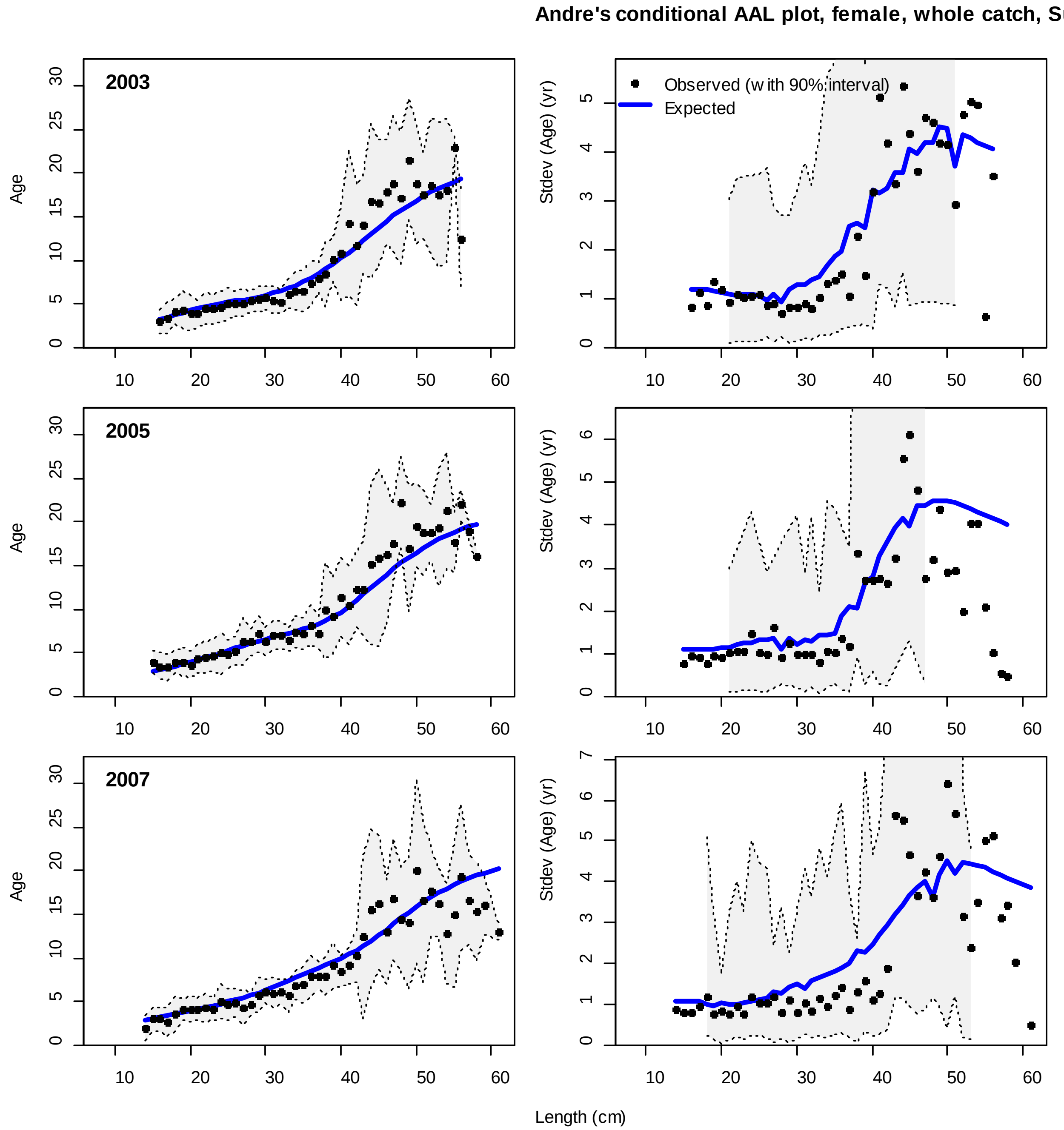


Figure 4.1.55 – Female survey conditional age-at-length for S model configuration with survey selectivity-at-age




Andre's conditional AAL plot, female, whole catch, Su
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

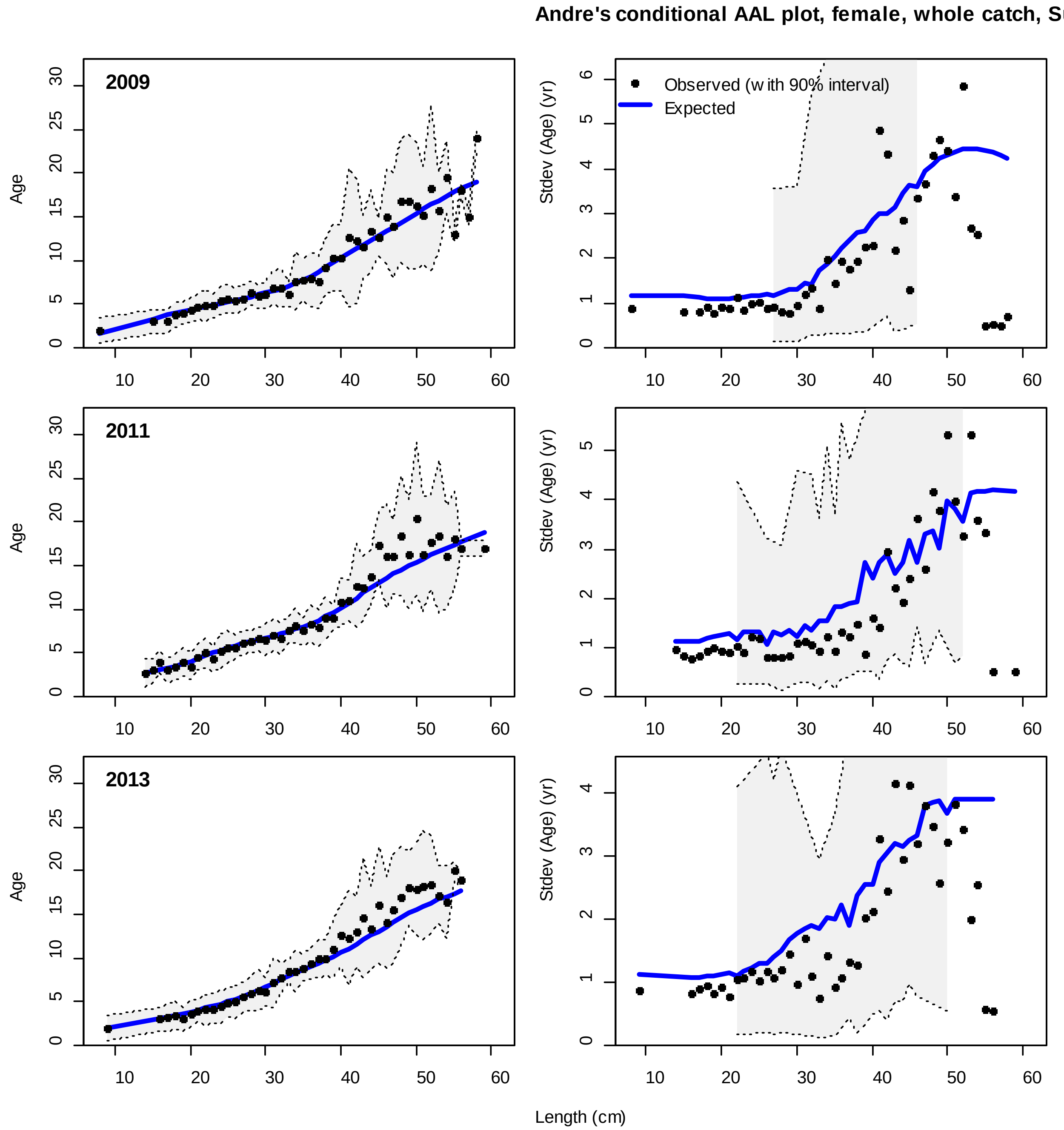
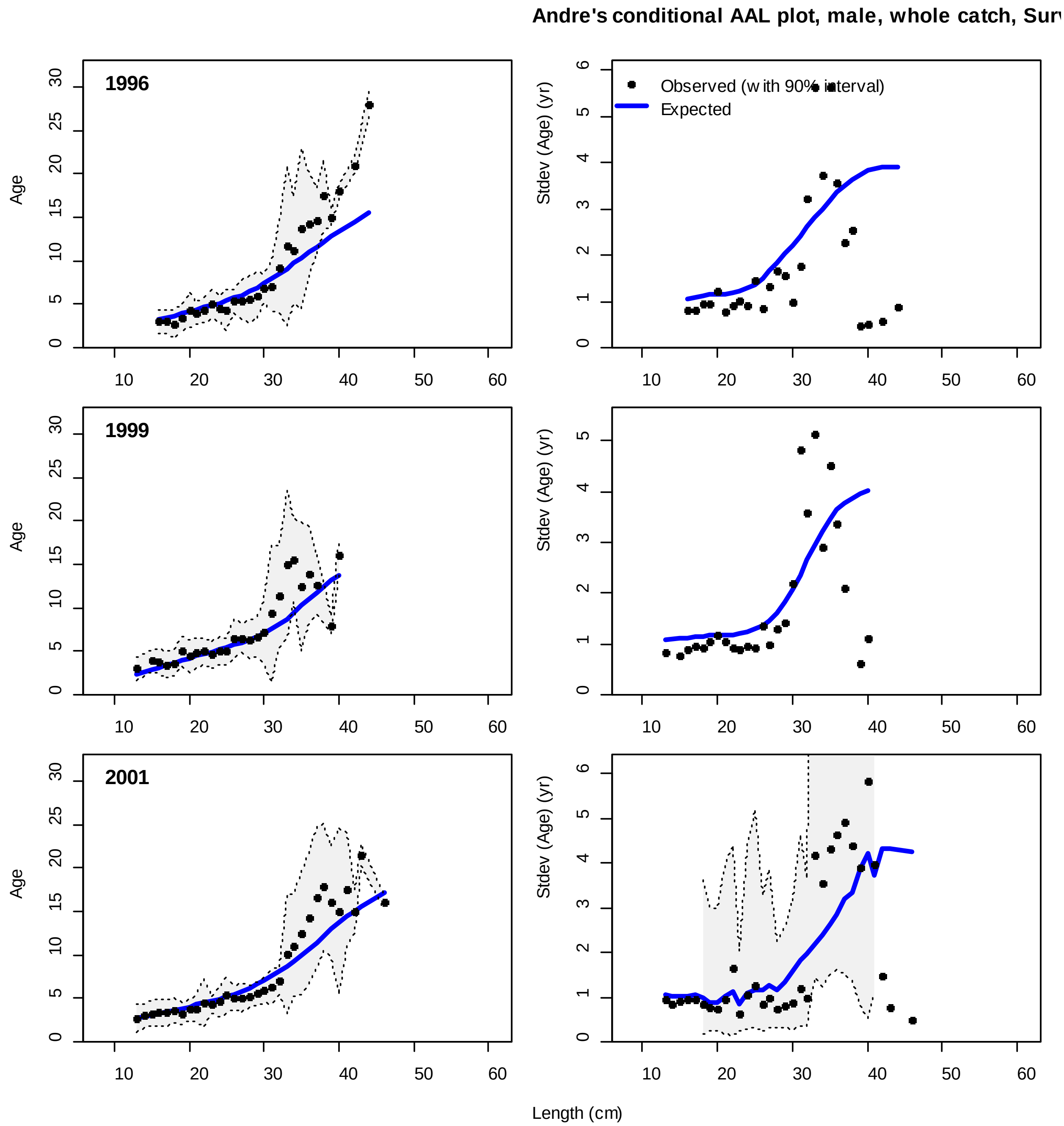
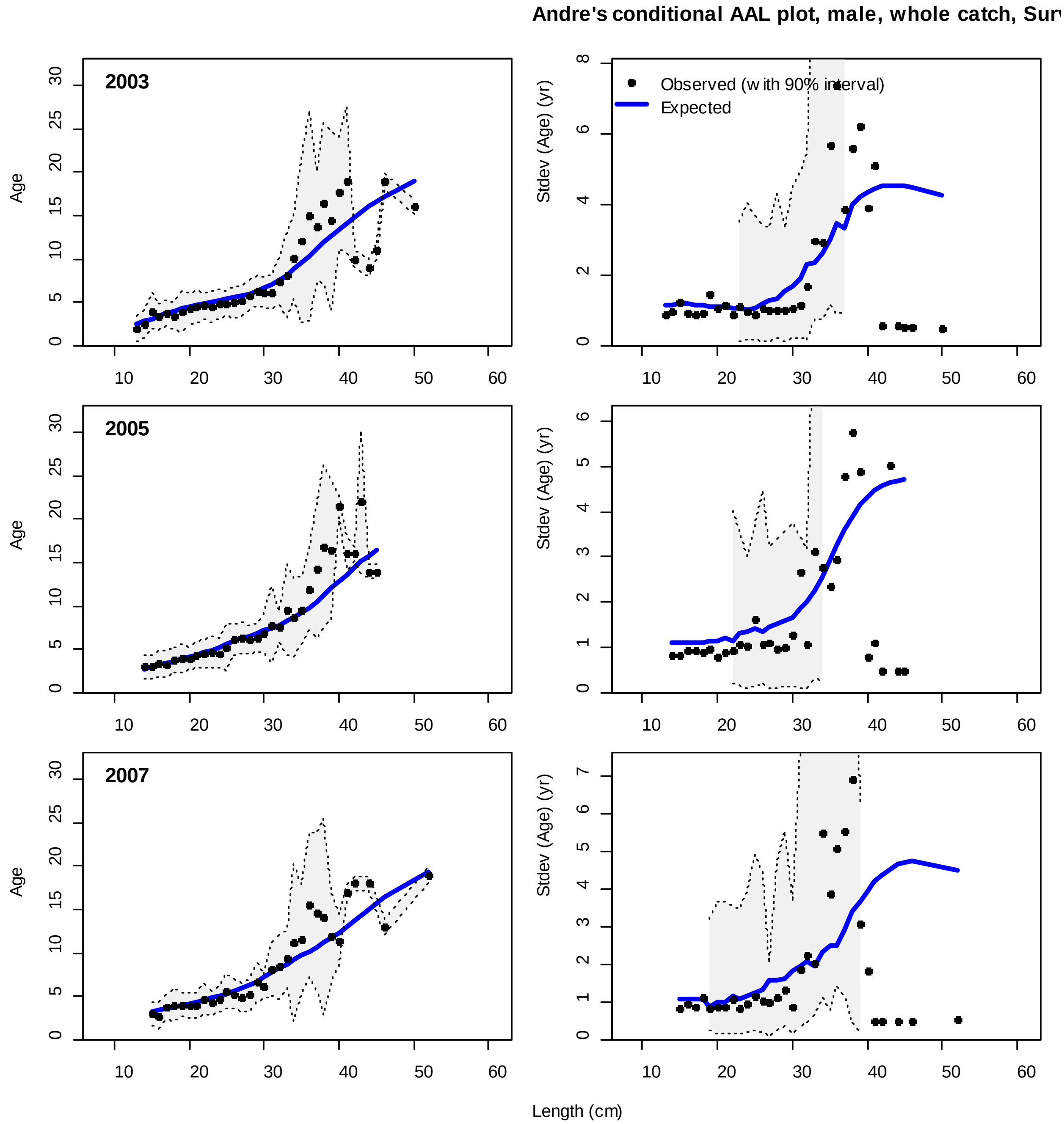
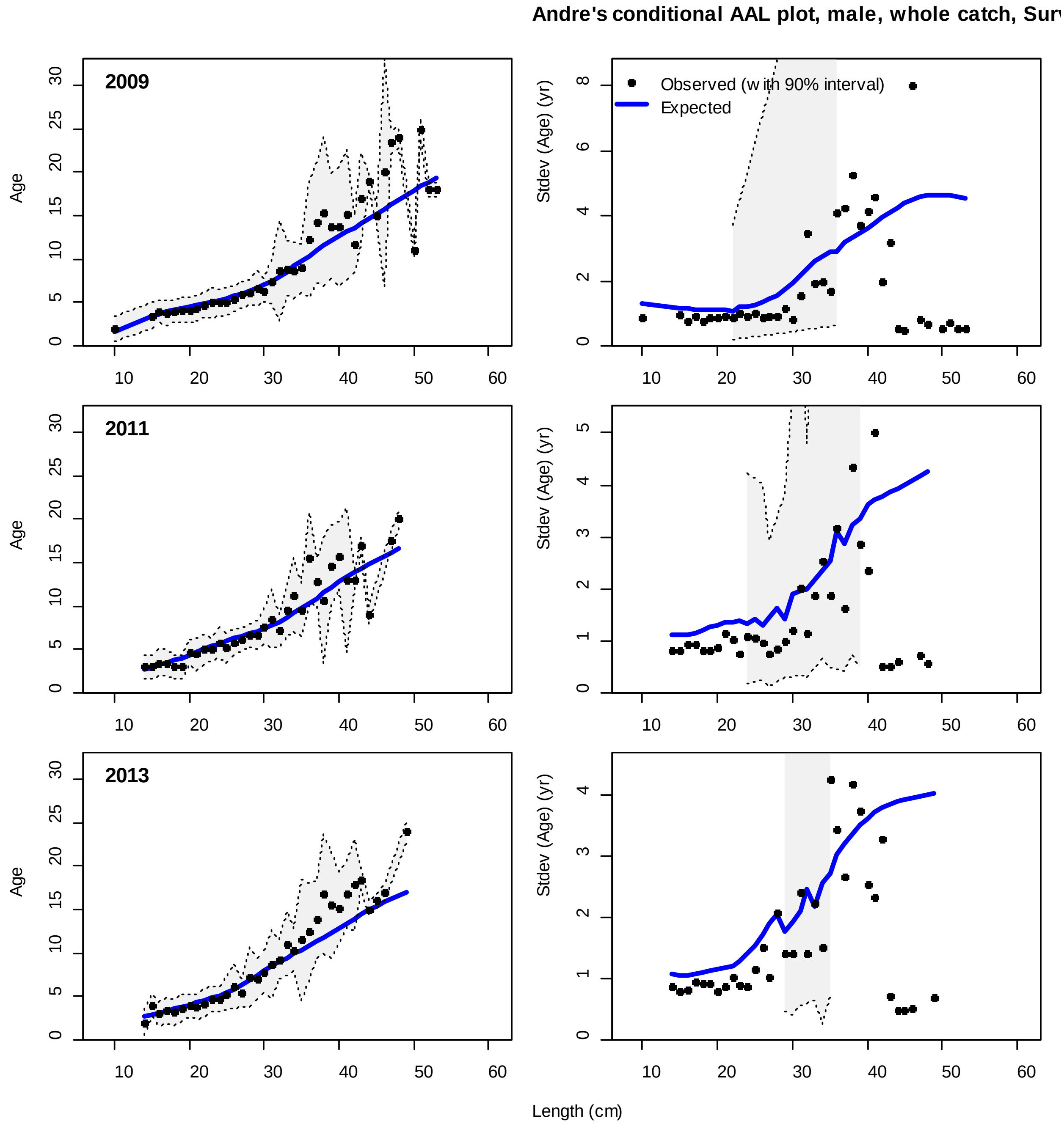

Andre's conditional AAL plot, female, whole catch, Su
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Figure 4.1.56 – Male survey conditional age-at-length for S model configuration with survey selectivity-at-age





Andre's conditional AAL plot, male, whole catch, Surv
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)


Andre's conditional AAL plot, male, whole catch, Surv
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

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5. Assessment of the Deepwater Flatfish Stock Complex in the Gulf of Alaska

Carey R. McGilliard
November 2014

Executive Summary

The Gulf of Alaska deepwater flatfish complex (consisting of Dover sole, Greenland turbot, and deepsea sole) is assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska deepwater flatfish, in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. Please refer to last year's full stock assessment report for further information regarding the assessment model (McGilliard et al., 2013, available online at http://www.afsc.noaa.gov/REFM/Docs/2013/GOAdeepflat.pdf). A full stock assessment document with updated assessment and projection model results will be presented in next year's SAFE report.

Dover sole is assessed using an age-structured model and Tier 3 determination. Thus, the single species projection model was run using parameter values from the accepted 2013 accepted Dover sole assessment model (McGilliard et. al.2013), together with updated catch information for 2013 and 2014, to predict stock status for Dover sole in 2015 and 2016 and to make ABC recommendations for those years. Greenland turbot and deepsea sole fall under Tier 6. ABC's and OFL's for Tier 6 species are based on historical catch levels and therefore these quantities cannot be updated. ABC's and OFL's for the individual species in the deepwater flatfish complex are determined only as an intermediate step for the purpose of calculating complex-level OFL's and ABC's.

Summary of Changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment model inputs since this was an off-cycle year. New information available to update the Dover sole projection model consists of the total catch for 2013 (242 t) and the current catch for 2014 (338 t as of October 19, 2014).). To run the projection model to predict ABC's for 2015 and 2016, estimates are required for the total catches in 2014 and 2015. The final catch for 2014 was estimated by dividing the current catch by the ratio of the catch on the same date in 2013 (October 18, 2014) as the current catch to the final 2013 catch. The estimated final catch for 2014 was 499 t and was also used as an estimate of the 2015 catch.

Changes in assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

As in previous years (McGilliard et al. 2013), the species-level ABC is 179 t for Greenland turbot and the OFL is 238 t for both 2015 and 2016. The species-level ABC for deepsea sole is 4 t and the OFL is 6 t for both 2015 and 2016. The species-level ABC for Dover sole is 13,151 t in 2015 and 12,994 in 2016 and the OFL is 15,749 t in 2015 and 15,559 t in 2016.

Based on the updated projection model results, the recommended complex-level ABC's for 2015 and 2016 are 13,334 t and 13,177 t, and the OFL's are 15,993 t and 15,803 t. The new ABC recommendation and OFL for 2015 are similar to those developed using the 2013 full assessment model (13,303 t and 15,955 t). The principal reference values are shown in the following table:

Species	Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
Dover sole	*M* (natural mortality rate)	0.085	0.085	0.085	0.085
	Tier	3a	3a	3a	3a
	Projected total (3+) biomass (t)	182,727	181,781	182,160	181,691
	Female spawning biomass (t)				
	Projected				
	Upper 95% confidence interval	66,181	67,078	67,233	68,022
	Point estimate	66,147	67,001	67,156	67,868
	Lower 95% confidence interval	66,126	66,945	67,100	67,752
	$B_{100\%}$	70,544	70,544	70,544	70,544
	$B_{40\%}$	28,218	28,218	28,218	28,218
	$B_{35\%}$	24,690	24,690	24,690	24,690
	F_{OFL}	0.12	0.12	0.12	0.12
	$maxF_{ABC}$	0.1	0.1	0.1	0.1
	F_{ABC}	0.1	0.1	0.1	0.1
	OFL (t)	15,915	15,711	15,749	15,559
	maxABC (t)	13,289	13,120	13,151	12,994
	ABC (t)	13,289	13,120	13,151	12,994
Greenland turbot	Tier	6	6	6	6
	OFL (t)	238	238	238	238
	maxABC (t)	179	179	179	179
	ABC (t)	179	179	179	179
Deepsea sole	Tier	6	6	6	6
	OFL (t)	6	6	6	6
	maxABC (t)	4	4	4	4
	ABC (t)	4	4	4	4
Deepwater Flatfish Complex	OFL (t)	16,159	15,955	15,993	15,803
	maxABC (t)	13,472	13,303	13,334	13,177
	ABC (t)	13,472	13,303	13,334	13,177
	Status	As determined in 2013 for: 2012	2013	As determined in 2014 for: 2013	2014
	Overfishing	no	n/a	no	n/a
	Overfished	n/a	no	n/a	no
	Approaching overfished	n/a	no	n/a	no

Area Apportionment

Area apportionment for ABC is currently based on the relative abundance (biomass) of Dover sole found within each management area in the last GOA groundfish survey. The recommended ABC area apportionment percentages are identical to last year because the last GOA groundfish survey was conducted in 2013. The following table shows the recommended area apportionments for 2015 and 2016:

Quantity	Species	Western	Central	West Yakutat	Southeast	Total
Area Apportionment	Dover sole	1.18%	28.02%	41.54%	29.26%	100.00%
	Greenland turbot	81.17%	0.00%	6.40%	12.43%	100.00%
	Deepsea sole	0.00%	100.00%	0.00%	0.00%	100.00%
2015 ABC (t)	Dover sole	156	3,684	5,463	3,848	13,151
	Greenland turbot	145	0	11	22	179
	Deepsea sole	0	4	0	0	4
	Deepwater Flatfish	301	3,688	5,474	3,870	13,334
2016 ABC (t)	Dover sole	154	3,640	5,398	3,802	12,994
	Greenland turbot	145	0	11	22	179
	Deepsea sole	0	4	0	0	4
	Deepwater Flatfish	299	3,644	5,409	3,824	13,177

Responses to SSC and Plan Team Comments on Assessments in General

SSC Dec 2013: "During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment."
An additional two projection years will be included on future phase diagrams for the GOA Dover sole stock.

GPT, Sept 2013: The Teams recommend retaining use of the mean to estimate the central tendency in recruitment, at least for the time being.
The mean is used to estimate the central tendency in recruitment in this assessment.

GPT, Sept. 2013: The Teams recommend that authors choose a method <for catch estimation when doing stock projections> that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2).
The methods for catch estimation used for the projections used in this update are based on the author's best available estimate in the current year and next two years. The methods for catch estimation are documented in the text of this update.

Responses to SSC and Plan Team Comments Specific to this Assessment

GPT, Nov. 2013: The Team recommended that the random effects survey averaging approach be explored for potential application to the apportionment calculations for this stock assessment.
The next full assessment of deepwater flatfish will explore using a survey averaging approach for apportionment calculations.

GPT, Nov. 2013: Based on suggestions from the author, the Team recommended that the next assessment include additional investigation of catchability, and natural mortality (perhaps not assuming a fixed value).

A joint likelihood profile of catchability and natural mortality will be presented in the 2015 Dover sole stock assessment. Estimating catchability or natural mortality with the use of a prior will be considered.

GPT, Nov. 2013: The Team requests the author complete the stock structure template for review in September.
A stock structure template will be completed for the September 2015 Groundfish Plan Team meeting.

GPT, Nov. 2013: The Team also recommended that the items listed for future research by the author be pursued.
The 2015 Dover sole assessment will address these topics.

SSC, Dec. 2013: The SSC looks forward to completion of the stock structure template for this complex next year as well as additional investigation of catchability and natural mortality in the next assessment of Dover sole.
As stated above, these topics will be pursued and presented at the September 2015 Groundfish Plan Team meeting.

Data Gaps and Research Priorities

The 2013 stock assessment incorporated ageing error by using an existing ageing error matrix for West Coast Dover sole. A priority for future assessments is to analyze ageing error data for GOA Dover sole using methods described in Punt et al. (2008) and to incorporate a resulting ageing error matrix into the assessment. In addition, the 2013 assessment adjusted the relative effective sample sizes among years of fishery length composition data to the number of hauls each year; future assessments will investigate changing relative effective sample sizes among years of survey length composition data to the number of survey hauls in each year. Future research should explore potential causes of patterns in early recruitment deviations that were estimated by some alternative models. The assessment would benefit from an exploration of ways to better account for scientific uncertainty, especially uncertainty associated with parameters that are currently fixed in the model.

Summaries for Plan Team

Year	Biomass[1]	OFL[2]	ABC[2]	TAC[2]	Catch[3]
2013	173,853	6,834	5,126	5,126	242
2014	182,727	16,159	13,472	13,472	338
2015	182,160	15,993	13,334		
2016	181,691	15,803	13,177		

1. Age 3+ biomass from the assessment and projection models
2. From http://alaskafisheries.noaa.gov/frules/79fr12890.pdf and http://alaskafisheries.noaa.gov/frules/78fr13162.pdf
3. As of October 18, 2014

Area	2014				2015		2016	
	OFL[1]	ABC[1]	TAC[1]	Catch[3]	OFL[2]	ABC[2]	OFL[2]	ABC[2]
W	--	302	302	67	--	301	--	299
C	--	3,727	3,727	262	--	3,688	--	3,644
WYAK	--	5,532	5,532	5	--	5,474	--	5,409
SE	--	3,911	3,911	4	--	3,870	--	3,824
Total	16,159	13,472	13,472	338		13,334		13,177

1. From http://alaskafisheries.noaa.gov/frules/79fr12890.pdf
2. From assessment and projection model
3. Catch as of October 18, 2014

Literature Cited

McGilliard, C.R. ,Palsson, W., Stockhausen, W., and Ianelli, J. 2013. 5. Gulf of Alaska Deepwater Flatfish. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. pp. 403-536. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage AK 99510.

Punt, A.E., Smith, D.C., Krusic-Golub, K., Robertson, S. 2008.Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia’s southern and eastern scalefish and shark fishery. Can. J. Fish. Aquat. Sci. 65(9): 1991-2005.

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6. Assessment of the Rex Sole Stock in the Gulf of Alaska

Carey R. McGilliard
November 2014

Executive Summary

Rex sole (*Glyptocephalus zachirus)* are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rex sole in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. A new, full assessment was expected in 2013, but an executive summary was presented instead due to the government furlough on Oct. 1-17, 2013. Please refer to the 2011 full stock assessment report for further information regarding the assessment model (Stockhausen et al. 2011), available online at http://www.afsc.noaa.gov/REFM/docs/2011/GOArex.pdf). A full stock assessment document with updated assessment and projection model results will be presented in next year's SAFE report.

GOA rex sole is currently managed as a Tier 5 species because reliable estimates of $F_{35\%}$ and $F_{40\%}$ (required for Tier 3 management) are not available for this stock. However, rather than using biomass estimates from the NMFS bottom trawl survey to calculate ABC and OFL in the standard Tier 5 calculations, the assessment uses a Tier 3-type age-structured assessment model and projection model to estimate total adult biomass for use in the Tier 5 calculations. The single species projection model was run using parameter values from the accepted 2011 accepted assessment model (Stockhausen et. al.2011), together with updated catch information for 2011 - 2014, to predict stock status for rex sole in 2015 and 2016 and to make ABC recommendations for those years. An executive summary was also presented in 2013 due to the government furlough on Oct. 1-17, 2013. A full assessment will be conducted in 2015.

Summary of Changes in Assessment Inputs

There were no changes made to the assessment model inputs since this was an off-cycle year. New data added to the projection model included an updated 2013 catch and new estimated catches for 2014-2016. Additionally, new apportionments were computed based on the 2013 NMFS bottom trawl survey biomass estimates.

Summary of Results

New information available this year to update the projection model consists of the total catch for 2013 (3,707 t) and the current catch for 2014 (3,474 t as of October 18, 2014). The projection model was run to generate estimates of total (age 3+) biomass for 2015-2016. In order to do this, estimates for the total catches to be taken in 2015 and 2016 are required (the 2014 fishery was still underway when this analysis was performed). The total catch for 2014 was estimated by dividing the current catch (as of October 18, 2014) by the ratio of the catch in the same week in 2013 to the final 2013 catch. The estimated final catch for 2014 (3,812 t) was also used as the estimate for the final 2015 catch. The resulting estimates of total biomass in 2015 and 2016 from the projection model were then converted to adult biomass using a conversion factor determined from the 2011 assessment model, because numbers-at-age for 2015 and 2016 were not available from the projection model. The OFLs and maximum permissible ABCs for 2015 (updated from last year's assessment) and 2016 (new this year) were then calculated based on Tier 5 specifications for F_{OFL} (=M) and *max* F_{ABC} (=0.75M) using the estimates of adult biomass at the start of each year, M=0.17, and the Baranov catch equation. The maximum permissible ABCs for 2015 (updated) and 2016 (new) are 9,150 t and 8,979 t, respectively, and the OFLs are 11,957 t for 2015 and 11,733 t for 2016. Not surprisingly, the updated OFL and maximum permissible ABC values for 2015 are quite similar to those proposed last year for 2015 (11,963 t and 9,155 t, respectively).

Although it is not possible to use a Tier 3 approach to making harvest recommendations for rex sole because estimates of $F_{35\%}$ and $F_{40\%}$ are not considered reliable, the SSC has decided that it is possible to use a Tier 3 approach for determining overfished status because the estimate of $B_{35\%}$ (i.e., 35% of the unfished spawning stock biomass) is considered reliable (it does not depend on the fishery selectivity), as is the estimate of current (2014) spawning stock biomass. Because the estimated spawning stock biomass for 2014 (53,164 t) is greater than $B_{35\%}$ (19,434 t), the stock is not considered overfished. Because the 2013 catch was less than the 2013 ABC (i.e. 3,707 t < 9,560 t), overfishing is not occurring.

Because the stock appears to be healthy and is only lightly exploited, the author's recommended ABCs for 2015 and 2016 are the maximum permissible ones. The principal reference values for this update and from last year's assessment are summarized in the following table:

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015*	2016*
M (natural mortality rate)	0.17	0.17	0.17	0.17
Tier	5	5	5	5
Projected total (3+) biomass (t)	84,702	83,012	82,972	81,414
Female spawning biomass (t)	53,164	52,807	49,804	48,554
$B_{100\%}$	55,393	55,393	55,393	55,393
$B_{40\%}$	22,159	22,159	22,159	22,159
$B_{35\%}$	19,434	19,434	19,434	19,434
$F_{OFL}=M$	0.170	0.170	0.17	0.17
$maxF_{ABC}=0.75*M$	0.128	0.128	0.128	0.128
F_{ABC}	0.128	0.128	0.128	0.128
OFL (t)	12,207	11,963	11,957	11,733
maxABC (t)	9,341	9,155	9,150	8,979
ABC (t)	9,341	9,155	9,150	8,979
Status	As determined in 2013 for:		As determined in 2014 for:	
	2012	2013	2013	2014
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no

*Projections are based on estimated catches of 3,812 t used in place of maximum permissible ABC for 2015 and 2016.

Area Apportionment

Area apportionment for ABC is currently based on the relative abundance (biomass) of rex sole found within each management area in the last GOA groundfish survey, which occurred in 2013. The recommended ABC area apportionment percentages differ slightly from those used in 2013 because area apportionment in the 2013 rex sole update assessment was based on the 2011 survey. The following table shows the recommended area apportionments for 2015 and 2016:

Quantity	**Western**	**Central**	**West Yakutat**	**Southeast**	**Total**
Area Apportionment	13.74%	63.57%	8.44%	14.25%	100.00%
2015 ABC (t)	1,258	5,816	772	1,304	9,150
2016 ABC (t)	1,234	5,707	758	1,280	8,979

Responses to SSC and Plan Team Comments on Assessments in General

SSC Dec 2013: "During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment."
An additional two projection years will be included on future phase diagrams for the GOA rex sole stock.

GPT, Sept 2013: The Teams recommend retaining use of the mean to estimate the central tendency in recruitment, at least for the time being.
The mean is used to estimate the central tendency in recruitment in this assessment.

GPT, Sept. 2013: The Teams recommend that authors choose a method <for catch estimation when doing stock projections> that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2).
The methods for catch estimation used for the projections used in this update are based on the author's best available estimate in the current year and next two years. The methods for catch estimation are documented in the text of this update.

Responses to SSC and Plan Team Comments Specific to this Assessment

The SSC and GPT didn't make comments specific to this assessment in 2011-2013.

Data Gaps and Research Priorities

The rex sole fishery is primarily a bycatch fishery that takes mainly older, larger fish. Current estimates of optimum harvest levels based on Tier 3 calculations (e.g., at $F_{40\%}$ harvest rates) are very large but highly uncertain. The rex sole fishery should continue to be monitored to assess whether a directed rex sole fishery has developed; quantities such as $F_{40\%}$ (=F_{ABC} in Tier 3a) will be sensitive to the characteristics of the resulting fishery selectivity curves. More information should be collected on fishery size and age compositions to inform selectivity parameters and potentially improve estimates of harvest rates.

Future plans include constructing a rex sole assessment using Stock Synthesis (SS3), which will allow for exploration of alternative selectivity formulations, stock-recruit curves, time-varying effects, and spatial effects. Inclusion of additional data sources could be explored, such as inclusion of ADF&G small mesh survey data. Alternative data-weighting approaches and inclusion of ageing error could be explored as well.

Lastly, the assessment would benefit from an exploration of ways to better account for scientific uncertainty, especially uncertainty associated with parameters that are currently fixed in the model.

Summaries for Plan Team

Year	Biomass[1]	OFL[2]	ABC[2]	TAC[2]	Catch[3]
2013	86,684	12,492	9,560	9,560	3,707
2014	84,702	12,207	9,341	9,341	3,474
2015	82,972	11,957	9,150		
2016	81,414	11,733	8,979		

1. Age 3+ biomass from the assessment and projection models
2. From http://alaskafisheries.noaa.gov/frules/79fr12890.pdf and http://alaskafisheries.noaa.gov/frules/78fr13162.pdf
3. As of October 18, 2014

Area	2014				2015		2016	
	OFL[1]	ABC[1]	TAC[1]	Catch[3]	OFL[2]	ABC[2]	OFL[2]	ABC[2]
W	--	1,270	1,270	110	--	1,258	--	1,234
C	--	6,231	6,231	3,363	--	5,816	--	5,707
WYAK	--	813	813	1	--	772	--	758
SE	--	1,027	1,027	0	--	1,304	--	1,280
Total	12,207	9,341	9,341	3,474	11,957	9,150	11,733	8,979

1. From http://alaskafisheries.noaa.gov/frules/79fr12890.pdf
2. From assessment and projection model
3. Catch as of October 18, 2014

7. Assessment of the arrowtooth flounder stock in the Gulf of Alaska

Ingrid Spies and Benjamin J. Turnock

Alaska Fisheries Science Center
National Marine Fisheries Service

Executive Summary

Summary of Changes in Assessment Inputs

1. Catch and retention data are updated with partial data for 2014.

The Gulf of Alaska arrowtooth flounder stock is assessed on a biennial basis to coincide with the annual GOA groundfish trawl survey. These surveys occur in odd years, and for these years a full assessment of arrowtooth flounder in the GOA area is conducted. On even years, parameter values from the previous year's assessment model (Spies and Turnock 2013) and total catch information for the current and previous year are used to make projections and to recommend ABC and OFL for the following two years.

Summary of Results

Quantity	As estimated or *specified last* year for: 2014	2015	*As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)	0.2 females, 0.35 males	0.2 females, 0.35 males	0.2 females, 0.35 males	0.2 females, 0.35 males
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	1,978,340	1,949,990	1,957,970	1,915,170
Projected Female spawning biomass	1,205,440	1,176,280	1,189,120	1,147,450
$B_{100\%}$	1,155,170	1,155,170	1,155,170	1,155,170
$B_{40\%}$	462,067	462,067	462,067	462,067
$B_{35\%}$	404,309	404,309	404,309	404,309
F_{OFL}	0.204	0.204	0.204	0.204
$maxF_{ABC}$	0.172	0.172	0.172	0.172
F_{ABC}	0.172	0.172	0.172	0.172
OFL (t)	229,248	222,160	226,390	217,522
maxABC (t)	195,358	189,556	192,921	185,352
ABC (t)	195,358	189,556	192,921	185,352
Status	As determined *last* year for: current year 2012	current year 2013	As determined *this* year for: current year 2013	current year 2014
Overfishing		No		No
Overfished	No		No	
Approaching overfished	No		No	

*Projections are based on estimated catches of 39,744 t used in place of maximum permissible ABC for 2015 and 2016. This value was extrapolated from the proportion of the total 2013 catch caught by October 25 of that year, and the total catch through October 25, 2014.

Responses to SSC and Plan Team Comments on Assessments in General

December 2013 SSC Comments:

The SSC noted that different stock assessment scientists often use different methods for catch estimation to estimate catches between late October and December 31 of the current assessment year, as well as catches to be taken during the following two years for use in the catch specification process. The SSC understands that Dana Hanselman will compile the various methods in use. The SSC looks forward to Plan Team advice on the merits of the various alternatives.

Authors' response:

The catch estimation was based on the total catch in 2013. Justification is discussed in the document under Harvest Recommendations.

Responses to SSC and Plan Team Comments Specific to this Assessment

The November 2013 plan team recommended that the author consider examining how estimating catchability affects the model. In addition, the author is encouraged to examine inclusion of age 1+ fish in the model, versus using only ages 3+. This suggested change would incorporate additional data about size at age for these younger fish. The Team also recommended incorporating new maturity data into the model, following the methodology currently used in the northern and dusky rockfish assessments. The Team recommends completing an executive summary for 2014 rather than a full assessment, unless new maturity data becomes available or if substantial model changes are adopted. The Team also requested the author complete the stock structure template for review in September.

Author's response: The 2014 assessment represents an executive summary, as substantial model changes have not been adopted. The author would like to defer responses to these comments until September, 2015. The author presented work on standardization of the Bering Sea and Aleutian Islands (BSAI) and GOA models in September 2014, and will present recommended changes in 2015. The author completed and presented the stock structure template for arrowtooth flounder in September 2014.

Area Allocation of Harvests

The ABC by management area using $F_{40\%}$ was estimated by calculating the fraction of the survey biomass in each area and applying that fraction to the GOA-wide ABC. The recommended area apportionment percentages are identical to last year because there was no new survey information. The apportionments are estimated using the 2013 percent survey biomass by area.

Arrowtooth ABC by INPFC area

	Western	Central	West Yakutat	East Yakutat/SE	Total
2013 survey biomass percent by area	15.94	59.18	19.06	5.82	100
ABC (based on 2013 proportions and biomass estimates)					
ABC 2014	31,142	115,612	37,232	11,372	195,358
ABC 2015	30,752	114,171	36,771	11,228	192,921
ABC 2016	29,545	109,691	35,328	10,787	185,352

Harvest Recommendations

The projection model was used to estimate the 2015 ABC at 192,921 t, and the 2016 ABC at 185,352 t, using F_{ABC}=0.172. The stock is not overfished, and is not approaching a condition of being overfished. Catch as of October 25, 2014 was available and catch for the remainder of the year was projected for use in the projection model. Catch as of October 25, 2013 was 18,315 t, 85% of the total catch for the year. Therefore, the 2014 catch estimate of 39,744 t is based on the October 25, 2014 catch estimate of 33,782 t scaled up by 15%. The 2015 and 2016 catch estimates are also 39,744 t, based on the assumption that recent fishing trends will continue.

Arrowtooth flounder catch in the current year (2014) is the highest on record. This is partially due to recent changes to regulations (Amendment 95) of the halibut trawl prohibited species catch (PSC) limits. For the Amendment 80 fleet in the GOA, unused halibut PSC limits are now allowed to be rolled from one season to the next, which allows catcher processors to spend more time targeting arrowtooth flounder without constraints due to halibut PSC. In addition, new regulations have moved the deep-water flatfish fishery closure date later in the year for all trawl vessels. These changes will likely result in continued higher arrowtooth flounder catches than previous years, similar to the current year.

Data gaps and research priorities

Otoliths have been aged through the 2009 survey, but continued aging will allow monitoring of growth trends. A population genetic study on arrowtooth flounder would be useful for stock structure in this species.

Summary table for the Plan Team

Year	Age 3+ Biomass (t)[1]	Female spawning biomass (t)[1]	OFL	ABC	TAC	Catch[2]
2013	2,055,560	1,274,290	247,196	210,451	25,000	21,625
2014	1,978,340	1,205,440	229,248	195,358	25,000	33,782
2015	1,957,970	1,189,120	226,390	192,921		
2016	1,915,170	1,147,450	217,522	185,352		

[1] Results from age-structured projection model.
[2] Catch as of October 25, 2014.

Literature cited

Spies, I. and Turnock, J. 2013. Assessment of the arrowtooth flounder stock in the Gulf of Alaska. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, AK 99510.

8. Assessment of the Flathead Sole Stock in the Gulf of Alaska

Carey R. McGilliard
November 2014

Executive Summary

Flathead sole (*Hippoglossoides elassodon*) are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska flathead sole in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. Please refer to last year's full stock assessment report for further information regarding the assessment model (McGilliard et al., 2013, available online at http://www.afsc.noaa.gov/REFM/Docs/2013/GOAflathead.pdf). A full stock assessment document with updated assessment and projection model results will be presented in next year's SAFE report.

GOA Flathead sole is managed in Tier 3a. The single species projection model was run using parameter values from the accepted 2013 accepted assessment model (McGilliard et al. 2013), together with updated catch information for 2013 - 2014, to predict stock status for flathead sole in 2015 and 2016 and to make ABC recommendations for those years.

Summary of Changes in Assessment Inputs

New information available to update the projection model consists of the total catch for 2013 (2,816 t) and the current catch for 2014 (2,317 t as of October 19, 2014).). To run the projection model to predict ABC's for 2015 and 2016, estimates are required for the total catches in 2014 and 2015. The final catch for 2014 was estimated by dividing the current catch by the ratio of the catch on the same date in 2013 (October 19, 2013) as the current catch to the final 2013 catch. The estimated final catch for 2014 was 2,619 t and was also used as an estimate of the 2015 catch.

Summary of Results

Based on the updated projection model results, the recommended ABC's for 2015 and 2016 are 41,349 t and 41,378 t, respectively, and the OFL's are 50,792 t and 50,818 t. The new ABC recommendation and OFL for 2015 are similar to those developed using the 2013 full assessment model (41,007 t and 50,376 t). The principal reference values are shown in the following table:

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015*	2016*
M (natural mortality rate)	0.2	0.2	0.2	0.2
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	252,361	253,418	254,602	256,029
Female spawning biomass (t)				
Projected				
Upper 95% confidence interval	84,076	83,287	83,900	83,606
Point estimate	84,058	83,204	83,818	83,342
Lower 95% confidence interval	84,045	83,141	83,754	83,135
$B_{100\%}$	88,829	88,829	88,829	88,829
$B_{40\%}$	35,532	35,532	35,532	35,532
$B_{35\%}$	31,090	31,090	31,090	31,090
F_{OFL}	0.61	0.61	0.61	0.61
$maxF_{ABC}$	0.47	0.47	0.47	0.47
F_{ABC}	0.47	0.47	0.47	0.47
OFL (t)	50,664	50,376	50,792	50,818
maxABC (t)	41,231	41,007	41,349	41,378
ABC (t)	41,231	41,007	41,349	41,378
Status	As determined in 2012 for:		As determined in 2013 for:	
	2011	2012	2012	2013
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

*Projections are based on estimated catches of 2,619 t used in place of maximum permissible ABC for 2014 and 2015.

Area Apportionment

Area apportionment for ABC is currently based on the relative abundance (biomass) of flathead sole found within each management area in the last GOA groundfish survey. The recommended ABC area apportionment percentages are identical to last year because the last GOA groundfish survey was conducted in 2013. The following table shows the recommended area apportionments for 2015 and 2016 are:

Quantity	Western	Central	West Yakutat	Southeast	Total
Area Apportionment	30.88%	60.16%	8.55%	0.41%	100.00%
2015 ABC (t)	12,767	24,876	3,535	171	41,349
2016 ABC (t)	12,776	24,893	3,538	171	41,378

Responses to SSC and Plan Team Comments on Assessments in General

SSC Dec 2013: "During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment."
An additional two projection years will be included on future phase diagrams for the GOA flathead sole stock.

GPT, Sept 2013: The Teams recommend retaining use of the mean to estimate the central tendency in recruitment, at least for the time being.
The mean is used to estimate the central tendency in recruitment in this assessment.

GPT, Sept. 2013: The Teams recommend that authors choose a method <for catch estimation when doing stock projections> that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2).
The methods for catch estimation used for the projections used in this update are based on the author's best available estimate in the current year and next two years. The methods for catch estimation are documented in the text of this update.

Responses to SSC and Plan Team Comments Specific to this Assessment

GPT, November 2013: The Team agreed with the author and recommends that the next assessment should include exploration of natural mortality and survey catchability. This effort might also include how selectivity is treated, and potentially place a prior on natural mortality based on maximum observed age. Additional model development should include estimation of a stock-specific ageing error matrix and exploration of strong patterns exhibited in early recruitment deviations.
The "Data Gaps and Research Priorities" section of this assessment details plans for investigating each of these issues for the September 2015 Groundfish Plan Team Meeting.

SSC, Dec. 2013: The SSC encourages development of a stock-specific aging error matrix and encourages exploration of the extreme patterns in early recruitment deviations.
A stock-specific ageing error matrix and an exploration of extreme patterns in early recruitment deviations will be investigated for the 2015 flathead sole assessment.

Data Gaps and Research Priorities

The 2013 stock assessment incorporated ageing error by using an existing ageing error matrix for BSAI flathead sole. A priority for future assessments is to analyze ageing error data for GOA flathead sole using methods described in Punt et al. (2008) and to incorporate a resulting ageing error matrix into the assessment. In addition, the 2013 assessment adjusted the relative effective sample sizes among years of fishery length composition data to the number of hauls each year; future assessments will investigate changing relative effective sample sizes among years of survey length composition data to the number of survey hauls in each year. A sensitivity analysis in the 2013 assessment showed that more reasonable estimates of selectivity occurred when natural mortality was estimated; future analyses should explore the relationship between natural mortality and catchability in the model and the effects of these parameters on estimation of selectivity and other parameters. Future research should explore potential causes of patterns in early recruitment deviations that were estimated by some alternative models. The assessment would benefit from an exploration of ways to better account for scientific uncertainty, especially uncertainty associated with parameters that are currently fixed in the model.

Summaries for Plan Team

Year	Biomass[1]	OFL[2]	ABC[2]	TAC[2]	Catch[3]
2013	236,745	61,036	48,738	30,496	2,816
2014	252,361	50,664	41,231	27,746	2,317
2015	254,602	50,792	41,349		
2016	256,029	50,818	41,378		

1. Age 3+ biomass from the assessment and projection models
2. From http://alaskafisheries.noaa.gov/frules/79fr12890.pdf and http://alaskafisheries.noaa.gov/frules/78fr13162.pdf
3. As of October 18, 2014

Area	2014				2015		2016	
	OFL[1]	ABC[1]	TAC[1]	Catch[3]	OFL[2]	ABC[2]	OFL[2]	ABC[2]
W	--	12,730	8,650	202	--	12,767	--	12,776
C	--	24,805	15,400	2,114	--	24,876	--	24,893
WYAK	--	3,525	3,525	1	--	3,535	--	3,538
SE	--	171	171	0	--	171	--	171
Total	50,664	41,231	27,746	2,317	50,792	41,349	50,818	41,378

1. From http://alaskafisheries.noaa.gov/frules/79fr12890.pdf
2. From assessment and projection model
3. Catch as of October 18, 2014

Literature Cited

McGilliard, C.R. ,Palsson, W., Stockhausen, W., and Ianelli, J. 2013. 8. Assessment of the Flathead Sole Stock in the Gulf of Alaska. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. pp. 611-756. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage AK 99510.

Punt, A.E., Smith, D.C., Krusic-Golub, K., Robertson, S. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia’s southern and eastern scalefish and shark fishery. Can. J. Fish. Aquat. Sci. 65(9): 1991-2005.

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9. Assessment of the Pacific ocean perch stock in the Gulf of Alaska

Peter-John F. Hulson, Dana H. Hanselman, S. Kalei Shotwell, Chris R. Lunsford, and James N. Ianelli

November 2014

Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in on-cycle (odd) years, we present a full stock assessment document with updated assessment and projection model results. However, due to the 2013 government shutdown we did not present alternative model configurations in the 2013 assessment. As requested, we are providing a full assessment in 2014 in order to present an alternative model that incorporates new maturity information.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska Pacific ocean perch which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. For this year, we update the 2013 assessment model estimates with new data collected since the last full assessment.

Summary of Changes in Assessment Inputs

Changes in the input data: The new data included are updated weight-at-age and an updated size-at-age transition matrix, a final catch estimate for 2013 and a new catch estimate for 2014-2016 (see *Specified catch estimation* section).

Changes in the assessment methodology: The recommended model incorporates new maturity information and fits the available maturity data within the assessment model to incorporate uncertainty in maturity within uncertainty estimates of other model parameters and estimates.

Summary of Results

For the 2015 fishery, we recommend the maximum allowable ABC of **21,012** t from the updated model. This ABC is a 9% increase from the 2014 ABC of 19,309 t. The increase is attributed to updating weight-at-age and the size-age transition matrix as well as incorporating new maturity information that decreases the age at 50% maturity. This also resulted in a 6% higher ABC than the 2015 ABC projected last year. The corresponding reference values for Pacific ocean perch are summarized in the following table, with the recommended ABC and OFL values in bold. Overfishing is not occurring, the stock is not overfished, and it is not approaching an overfished condition.

Quantity	As estimated or specified *last* year for: 2014	2015	As estimated or recommended *this* year for: 2015	2016[1]
M (natural mortality)	0.061	0.061	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	410,712	408,839	416,140	412,351
Projected Female spawning biomass	120,356	121,939	142,029	144,974
$B_{100\%}$	257,697	257,697	283,315	283,315
$B_{40\%}$	103,079	103,079	113,326	113,326
$B_{35\%}$	90,194	90,194	99,160	99,160
F_{OFL}	0.132	0.132	0.139	0.139
$maxF_{ABC}$	0.113	0.113	0.119	0.119
F_{ABC}	0.113	0.113	0.119	0.119
OFL (t)	**22,319**	22,849	**24,360**	24,849
maxABC (t)	19,309	19,764	**21,012**	21,436
ABC (t)	**19,309**	19,764	**21,012**	21,436
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1]Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 17,716 for 2014, and projected catches of 17,665 t and 17,797 t for 2015 and 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Area Apportionment

We concur with the Plan Team and SSC recommendation to use the random effects model, rather than the weighted survey average approach for apportionment. The apportionment percentages have changed with the use of the random effects model to fit to area-specific survey biomass, in 2013 with the original 4:6:9 weighted average approach the apportionments were 11% for the Western area, 69% for the Central area, and 20% for the Eastern area. The following table shows the recommended apportionment for 2015 and 2016 from the random effects model.

Area Apportionment	Western	Central	Eastern	Total
	11.0%	75.5%	13.5%	100%
2015 Area ABC (t)	**2,302**	**15,873**	**2,837**	**21,012**
2016 Area ABC (t)	**2,358**	**16,184**	**2,894**	**21,436**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is higher than the 2011 assessment at 0.71, a large increase from 0.48. Note that the random effects model was not applied for the WYAK and EYAK/SEO split (explained below in the response to SSC and Pan Team comments) and the weighting method of using upper 95% confidence of the ratio in biomass between these two areas used in previous assessments was continued. This results in the following apportionment of the Eastern Gulf area:

	W. Yakutat	E. Yakutat/Southeast	Total
2015 Area ABC (t)	**2,014**	**823**	**2,837**
2016 Area ABC (t)	**2,055**	**839**	**2,894**

In 2012, the Plan Team and SSC recommended combined OFLs for the Western, Central, and West Yakutat areas (W/C/WYK) because the original rationale of an overfished stock no longer applied. However, because of concerns over stock structure, the OFL for SEO remained separate to ensure this unharvested OFL was not utilized in another area. The Council adopted these recommendations. This results in the following apportionment for the W/C/WYK area:

	Western/Central/W. Yakutat	E. Yakutat/Southeast	Total
2015 Area OFL (t)	**23,406**	**954**	**24,360**
2016 Area OFL (t)	**23,876**	**973**	**24,849**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Pacific ocean perch	2013	345,260	18,919	16,412	16,412	13,183
	2014	410,712	22,319	19,309	19,309	14,863
	2015	416,140	24,360	21,012		
	2016	412,351	24,849	21,436		

[1]Total biomass from the age-structured model

Stock/ Assemblage	Area	2014 OFL	ABC	TAC	Catch[2]	2015 OFL	ABC	2016 OFL	ABC
Pacific ocean perch	W		2,399	2,399	104		2,302		2,349
	C		12,855	12,855	12,887		15,873		16,193
	WYAK		1,931	1,931	1,872		2,014		2,055
	SEO	1,303	2,124	2,124	0	954	823	973	839
	W/C/WYK	21,016				23,406		23,876	
	Total	22,319	19,309	19,309	14,863	24,360	21,012	24,849	21,436

[2]Current as of October 1, 2014, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

SSC and Plan Team Comments on Assessments in General

"The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012

run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years." (Plan Team, September 2012)

In response to both of these comments, this year's assessment includes discussion of a retrospective analysis performed on the recommended model within 'Time series results' section. This retrospective analysis section will become a standard section in future assessments.

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

The degree of overlap between catch-in-areas and the HFICE estimates are negligible for POP, as shown in Table 9A-2 of Appendix 9A.

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)

"The Teams recommend that the whole time series of each category of 'other' catches be made available on the NMFS "dashboard," so that they may be listed in all SAFE chapters." (Plan Team, November 2012)

In response to these two comments, other removals are available on the dashboard. These removals have been included in Table 9A-1 of Appendix 9A and will continue to be included in future assessments.

"The SSC recommends that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL." (SSC, December 2012)

Because *M* is estimated inside the Pacific ocean perch assessment model, *M* is estimated with more than two significant digits.

"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs." (Plan Team, September 2013)

We estimated current year's removals by multiplying the official catch as of October 1, 2014, by an expansion factor, which represents the average additional catch taken after October 1 and through December 31 in the last three complete years (2011-2013). Further description is provided in the 'Specified catch estimation' section below.

"For the GOA age-structured rockfish assessments, if length composition data are withheld, the Team recommends exploratory model runs to test sensitivity. This should include any year of fishery or survey length composition data which could serve as a proxy for the age composition, not simply the most recent survey year." (Plan Team, November 2013)

A sensitivity analysis of including the most recent year's survey length composition has been performed and is included in Appendix 9B. The fishery selectivity in recent years (post-1997) primarily selects ages between around age-9 to age-17 (ages with selectivity greater than 50%). The variability in length-at-age for these ages is such that there is very little distinction in age-at-length in the fishery, thus, little information is contained in the fishery length composition data to inform age. Evaluations of including the fishery length data in years without fishery age data into the assessment model post-1997 has shown that the model is essentially invariant to including the recent fishery length composition data as a proxy for age data. See Appendix 9B for further details regarding the use of the most recent length composition data from the survey.

"For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

Because of the Government shutdown in 2013, comments were not fully addressed in last year's assessment. Full assessment updates for all the GOA rockfish stocks will be completed in 2015 and CIE review comments will be addressed at that time. Please refer to the Summary and response to the 2013 CIE review of the AFSC rockfish document presented to the September 2013 Plan Team (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf).

"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment." (SSC December 2013)

In this year's phase plane diagram the 2-year projections (2015 and 2016) are shown (Figure 9-16). The two year projections will be standard in the phase plan plot's of future assessments.

SSC and Plan Team Comments Specific to this Assessment

"The Team asks the [rockfish] authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities." (Plan Team, November 2011)

The size-age transition matrix and weight-at-age have been updated in this year's assessment. Many of the issues regarding temporal changes in the conversion and error matrices are similar across the age-structured rockfish assessments. In order to properly address this comment we plan to conduct an investigation on developing methods for updating conversion and error matrices for these long-lived species as a group and to perform sensitivity analyses on the timeliness of updates. We anticipate this future investigation to begin next year and will incorporate relevant results into the Pacific ocean perch model following further review. As mentioned above, an analysis evaluating the omission of the most recent year's survey length composition is provided in Appendix 9B.

"Future research will take another look at growth data, and similar to other rockfish assessments, another examination of the age and length bins – particularly in the plus age group. The author also intends to look at fishery spatial patterns. The [GOA Plan] Team supported these activities." (Plan Team, November 2011)

Age and length bins will be investigated for all the GOA rockfish stocks in the 2015 assessments, including new methods for incorporating ageing error, which will have an influence on the results of alternative age and length binning.

"The SSC looks forward to a review of the stock structure template applied to POP in the GOA, as well as an examination of growth data, age and length bins (including the plus group), and fishery spatial patterns during the next assessment cycle." (SSC, December 2011)

In 2012, the POP assessment completed the stock structure template that summarized the body of knowledge on stock structure and spatial management (Hanselman et al. 2012a).

"The Plan Team generally recommends that as part of the CIE review, authors focus on aspects of the assessment model that affect estimates of survey catchability." (Plan Team, November 2012)

During the CIE review estimates of catchability for the BSAI and GOA rockfish stocks were reviewed. Please refer to the Summary and response to the 2013 CIE review of the AFSC rockfish document presented to the September 2013 Plan Team (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf).

"The Plan Team recommends maintaining area specific ABCs but apportioning OFLs across the area currently open to bottom trawling (Western, Central, WYAK) and the area closed to bottom trawling (EYAK/SEO)." (Plan Team, November 2012)

"The SSC also accepts the Plan Team's recommended apportionment of ABCs among Western, Central, West Yakutat, and SEO areas in 2013-2014 with revised OFLs for the fished (W/C/WYAK) and lightly fished (SEO) areas (see table below in metric tons)." (SSC, December 2012)

In response to the previous two comments, since 2012 OFLs have been apportioned between the areas currently open to bottom trawling and the areas closed to bottom trawling.

"The Team recommends additional analyses with the survey length data for 2014 to evaluate effects on the 2006 recruitment estimate. Other contributing factors to the large uncertainty estimate for 2006 recruitment could be related to sample size specified of age data (max at 100)." (Plan Team, November 2013)

At the September 2014 Plan Team meeting analysis of the survey length composition data in relation to the 2006 year class was presented. Alternative input sample sizes for age composition will be investigated for all the GOA rockfish assessments in 2015.

"The survey averaging working group will continue to explore apportionment methods and the authors may consider incorporating their recommendations for apportionment contingent on the findings of this group." (Plan Team, November 2013)

In this year's assessment we are using the random effects model suggested by the survey averaging working group for apportionment among the Western, Central, and Eastern Gulf of Alaska. See the 'Area Apportionment of Harvests' section below for further details.

"The SSC agrees with the authors and Plan Team recommendations for OFL and ABC for 2014 and 2015. However, given concerns raised by the Plan Team on area apportionments, the SSC recommends using the 2011 apportionment to apportion ABCs among GOA areas." (SSC, December 2013)

Apportionment of the 2014 and 2015 ABCs and OFLs in 2013 was changed to use the 2011 apportionment values. In this year's assessment we are using the random effects model for apportionment. See the 'Area Apportionment of Harvests' section below for further details.

"The SSC recommends the following to the assessment authors:

- *Consider incorporating recommendations of the survey averaging working group for apportionment in 2014.*
- *Evaluate the effects of the survey length data on recruitment estimates.*
- *Evaluate the effect of sample size specified for age data.*
- *Bring forward an updated stock structure template for this stock in 2014 to evaluate the merits of continuing to separate OFLs.*
- *Evaluate new maturity data on POP that may be available.*
- *Address past recommendations by the CIE, Plan Team, and SSC."* (SSC, December 2013)

The recommendations of the survey averaging working group have been incorporated into this year's apportionment of ABC and OFL by using the random effects model to estimate the proportion of biomass by area. Appendix 9B contains analysis of the merits of including the most recent survey's length composition, which includes statistics that evaluate the effects on recruitment estimates as well as statistics investigating likelihoods and other model estimates. The effect of sample size specified for age data is an issue that pertains to not just the Pacific ocean perch assessment, but to any age-structured assessment. We plan to perform analyses in the coming year pertaining to the input sample size for the GOA rockfish age-structured assessments and the results of that analysis will be included in the 2015 assessments. However, such analyses should be conducted so that the method of determining input sample sizes are consistent across AFSC assessments, which is perhaps more appropriately evaluated by a Plan Team working group. As stated above, a stock structure template was completed in 2012 and no new information regarding stock structure since 2012 is available for update. The new maturity data available is incorporated into this year's assessment and is estimated conditionally within the model allowing for uncertainty in age-at-maturity to be incorporated into uncertainty for key model results such as ABC. We have addressed several of the past recommendations by the Plan Team and SSC above, and will continue to work on addressing CIE comments for inclusion into future assessments.

"The SSC recommends that this stock assessment be brought forward in the 2014 assessment cycle as a full assessment." (SSC, December 2013)

As per this recommendation by the SSC we are presenting a full assessment this year.

"The Team recommends using the random effects model, rather than the weighted survey average approach to the extent practical for POP and for rockfish in general [for apportionment]." (Plan Team, September 2014)

As stated in several of the previous responses, the random effects model was used in this year's assessment for apportionment of ABC and OFL among the Western, Central, and Eastern Gulf of Alaska.

However, the random effects model was not applied for the WYAK and EYAK/SEO split and the weighting method of using upper 95% confidence of the ratio in biomass between these two areas used in previous assessments was continued. There were two primary reasons for this: (1) uncertainty estimates for WYAK and EYAK/SEO survey biomass are not available at this time, thus, the random effects model cannot be used to fit the time-series of survey biomass in these two regions, and (2) use of the upper 95% confidence interval from WYAK to calculate the ratio between WYAK and EYAK/SEO was a policy decision that allowed for additional harvest of Pacific ocean perch in the WYAK area. Thus, any use of the random effects model to follow a similar method would also be a policy decision that would need to be made by the Plan Team and SSC. We request that the Plan Team and SSC provide a recommendation of how to use the random effects model to incorporate the 95% confidence interval for the WYAK apportionment.

"The Plan Team recommends evaluation of how the data weights given to the various fishery and survey age and length composition data affect the estimates of recruitment and age composition." (Plan Team, September 2014)

We plan to do a more thorough evaluation of weighting age and length data by performing a sensitivity analysis for all of the GOA rockfish assessments rather than just Pacific ocean perch. However, similar to the input sample size evaluation requested by the SSC, this is an issue that would be pertinent to any age-structured assessment performed by AFSC and should be conducted so that any weighting method developed is applicable across assessments. The results of this analysis for GOA rockfish will be presented in the 2015 assessments, although, this analysis may be more appropriately conducted by a Plan Team working group with a broader focus than just the GOA rockfish assessments.

"The Plan Team recommends the following test to evaluate the value of information contained in the survey length data and the transition matrix. Consider model estimates of age structure obtained when survey age composition is included as a standard for comparison. For each survey year, conduct two additional model runs: 1) without either the age or length composition data for that survey year; and 2) with the length composition from that survey year. Finally, evaluate which of these two runs comes closest to producing the age composition estimates obtained when the survey age composition are used. Evaluating this comparison across multiple survey years should provide a more general view of the effect of including survey length data." (Plan Team, September 2014)

This analysis has been provided in Appendix 9B. Overall, the results of this analysis suggest that the utility of using the most recent survey's length composition is case-specific. For Pacific ocean perch, the best case scenario results indicate no improvement to the model occurs by including the most recent year's length composition. At worst, there are unnecessary increases in the variability of modeled estimates when the most recent year's survey length composition is included. Thus, in this year's assessment we continue the convention of not fitting the most recent year of the survey length composition as a proxy for age composition and only fit the survey age composition data.

"Finally, the Plan Team recommends that the author consult with the Age and Growth Lab about the possibility of obtaining the most recent, additional POP age information to incorporate into the model, in order to supplement the survey length data. Additional age at length data for recent year classes would add to the model's accuracy." (Plan Team, September 2014)

We contacted the age and growth lab, but due to other assessment requests they were not able to complete the 2013 survey ages for POP in time to use in this year's assessment.

"The SSC received a presentation on two GOA rockfish species that included Pacific ocean perch (POP) and demersal shelf rockfish (DSR). In 2013, the POP authors conducted a full assessment, but were unable to include updated POP maturity data. At the request of the SSC, the authors will provide a full assessment in 2014 evaluating the effects of new maturity data, survey length data on recruitment estimates, and sample size specified for age data. The assessment author also provided an evaluation of an alternative approach using a random-effects model for area apportionment. The Plan Team recommended using the random effects model, rather than the weighted survey average approach to the extent practical for POP and for rockfish in general and the SSC agrees with this advice." (SSC, October 2014)

As stated in responses above, this year's assessment includes new maturity data, evaluates the utility of survey length composition (Appendix 9B), and uses the random effects model for apportionment. Input sample sizes for ages will be evaluated in the 2015 assessment.

Introduction

Biology and distribution

Pacific ocean perch (*Sebastes alutus*, POP) has a wide distribution in the North Pacific from southern California around the Pacific rim to northern Honshu Is., Japan, including the Bering Sea. The species appears to be most abundant in northern British Columbia, the Gulf of Alaska, and the Aleutian Islands (Allen and Smith 1988). Adults are found primarily offshore on the outer continental shelf and the upper continental slope in depths of 150-420 m. Seasonal differences in depth distribution have been noted by many investigators. In the summer, adults inhabit shallower depths, especially those between 150 and 300 m. In the fall, the fish apparently migrate farther offshore to depths of ~300-420 m. They reside in these deeper depths until about May, when they return to their shallower summer distribution (Love et al. 2002). This seasonal pattern is probably related to summer feeding and winter spawning. Although small numbers of Pacific ocean perch are dispersed throughout their preferred depth range on the continental shelf and slope, most of the population occurs in patchy, localized aggregations (Hanselman et al. 2001). Pacific ocean perch are generally considered to be semi-demersal but there can at times be a significant pelagic component to their distribution. Pacific ocean perch often move off-bottom during the day to feed, apparently following diel euphausiid migrations (Brodeur 2001). Commercial fishing data in the GOA since 1995 show that pelagic trawls fished off-bottom have accounted for as much as 31% of the annual harvest of this species.

There is much uncertainty about the life history of Pacific ocean perch, although generally more is known than for other rockfish species (Kendall and Lenarz 1986). The species appears to be viviparous (the eggs develop internally and receive at least some nourishment from the mother), with internal fertilization and the release of live young. Insemination occurs in the fall, and sperm are retained within the female until fertilization takes place ~2 months later. The eggs hatch internally, and parturition (release of larvae) occurs in April-May. Information on early life history is very sparse, especially for the first year of life. Pacific ocean perch larvae are thought to be pelagic and drift with the current, and oceanic conditions may sometimes cause advection to suboptimal areas (Ainley et al. 1993) resulting in high recruitment variability. However, larval studies of rockfish have been hindered by difficulties in species identification since many larval rockfish species share the same morphological characteristics (Kendall 2000). Genetic techniques using allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Li 2004) are capable of identifying larvae and juveniles to species, but are expensive and time-consuming. Post-larval and early young-of-the-year Pacific ocean perch have been positively identified in offshore, surface waters of the GOA (Gharrett et al. 2002), which suggests this may be the preferred habitat of this life stage. Transformation to a demersal existence may take place within the first year (Carlson and Haight 1976). Small juveniles probably reside inshore in very rocky, high relief areas, and by age 3 begin to migrate to deeper offshore waters of the continental shelf (Carlson and Straty 1981). As they grow, they continue to migrate deeper, eventually reaching the continental slope where they attain adulthood.

Pacific ocean perch are mostly planktivorous (Carlson and Haight 1976; Yang 1993; 1996, Yang and Nelson 2000; Yang 2003; Yang et al. 2006). In a sample of 600 juvenile perch stomachs, Carlson and Haight (1976) found that juveniles fed on an equal mix of calanoid copepods and euphausiids. Larger juveniles and adults fed primarily on euphausiids, and to a lesser degree, copepods, amphipods and mysids (Yang and Nelson 2000). In the Aleutian Islands, myctophids have increasingly comprised a substantial portion of the Pacific ocean perch diet, which also compete for euphausiid prey (Yang 2003). Pacific ocean perch and walleye pollock (*Theragra chalcogramma*) probably compete for the same euphausiid prey as euphausiids make up about 50% of the pollock diet (Yang and Nelson 2000). Consequently, the large removals of Pacific ocean perch by foreign fishermen in the Gulf of Alaska in the 1960s may have allowed walleye pollock stocks to greatly expand in abundance.

Predators of adult Pacific ocean perch are likely sablefish, Pacific halibut, and sperm whales (Major and Shippen 1970). Juveniles are consumed by seabirds (Ainley et al. 1993), other rockfish (Hobson et al. 2001), salmon, lingcod, and other large demersal fish.

Pacific ocean perch is a slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50% maturity (10.5 years for females in the Gulf of Alaska), and a very old maximum age of 98 years in Alaska (84 years maximum age in the Gulf of Alaska) (Hanselman et al. 2003). Age at 50% recruitment to the commercial fishery has been estimated to be between 7 and 8 years in the Gulf of Alaska. Despite their viviparous nature, they are relatively fecund with number of eggs/female in Alaska ranging from 10,000-300,000, depending upon size of the fish (Leaman 1991) Rockfish in general were found to be about half as fecund as warm water snappers with similar body shapes (Haldorson and Love 1991).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-compression could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Research on black rockfish (*Sebastes melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. de Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for Pacific ocean perch or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. Spencer et al. (2007) showed that the effects of enhanced larval survival from older mothers decreased estimated F_{msy} (the fishing rate that produces maximum sustainable yield) by 3% to 9%, and larger decreases in stock productivity were associated at higher fishing mortality rates that produced reduced age compositions. Preliminary work at Oregon State University examined Pacific ocean perch of adult size by extruding larvae from harvested fish near Kodiak, and found no relationship between spawner age and larval quality (Heppell et al. 2009). However, older spawners tended to undergo parturition earlier in the spawning season than younger fish. These data are currently still being analyzed.

Evidence of stock structure

A few studies have been conducted on the stock structure of Pacific ocean perch. Based on allozyme variation, Seeb and Gunderson (1988) concluded that Pacific ocean perch are genetically quite similar throughout their range, and genetic exchange may be the result of dispersion at early life stages. In contrast, analysis using mitochondrial DNA techniques indicates that genetically distinct populations of Pacific ocean perch exist (Palof 2008). Palof et al. (2011) report that there is low, but significant genetic divergence (FST = 0.0123) and there is a significant isolation by distance pattern. They also suggest that there is a population break near the Yakutat area from conducting a principle component analysis. Withler et al. (2001) found distinct genetic populations on a small scale in British Columbia. Kamin et al (2013) examined genetic stock structure of young of the year Pacific ocean perch. The geographic genetic pattern they found was nearly identical to that observed in the adults by Palof et al. (2011). Currently, genetic studies are underway that should clarify the genetic stock structure of Pacific ocean perch and its relationship to population dynamics.

In a study on localized depletion of Alaskan rockfish, Hanselman et al. (2007) showed that Pacific ocean perch are sometimes highly depleted in areas 5,000-10,000 km^2 in size, but a similar amount of fish return in the following year. This result suggests that there is enough movement on an annual basis to prevent serial depletion and deleterious effects on stock structure.

In 2012, the POP assessment completed the stock structure template that summarized the body of knowledge on stock structure and spatial management (Hanselman et al. 2012a).

Fishery

Historical Background

A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960s. This fishery developed rapidly, with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965, when a total of nearly 350,000 metric tons (t) was caught. This apparent overfishing resulted in a precipitous decline in catches in the late 1960s. Catches continued to decline in the 1970s, and by 1978 catches were only 8,000 t (Figure 9-1). Foreign fishing dominated the fishery from 1977 to 1984, and catches generally declined during this period. Most of the catch was taken by Japan (Carlson et al. 1986). Catches reached a minimum in 1985, after foreign trawling in the Gulf of Alaska was prohibited.

The domestic fishery first became important in 1985 and expanded each year until 1991 (Figure 9-1b). Much of the expansion of the domestic fishery was apparently related to increasing annual quotas; quotas increased from 3,702 t in 1986 to 20,000 t in 1989. In the years 1991-95, overall catches of slope rockfish diminished as a result of the more restrictive management policies enacted during this period. The restrictions included: (1) establishment of the management subgroups, which limited harvest of the more desired species; (2) reduction of total allowable catch (TAC) to promote rebuilding of Pacific ocean perch stocks; and (3) conservative in-season management practices in which fisheries were sometimes closed even though substantial unharvested TAC remained. These closures were necessary because, given the large fishing power of the rockfish trawl fleet, there was substantial risk of exceeding the TAC if the fishery were to remain open. Since 1996, catches of Pacific ocean perch have increased again, as good recruitment and increasing biomass for this species have resulted in larger TAC's. In recent years, the TAC's for Pacific ocean perch have usually been fully taken (or nearly so) in each management area except Southeast Outside. (The prohibition of trawling in Southeast Outside during these years has resulted in almost no catch of Pacific ocean perch in this area). In 2013, approximately 21% of the TAC was taken in the Western GOA. NMFS did not open directed fishing for Pacific ocean perch in this area because the catch potential from the expected l effort (15 catcher/processors) for a one day fishery (shortest allowed) exceeded the available TAC. Depending on management measures adopted in this area, future harvest levels are uncertain.

Detailed catch information for Pacific ocean perch in the years since 1977 is listed in Table 9-2. The reader is cautioned that actual catches of Pacific ocean perch in the commercial fishery are only shown for 1988-2012; for previous years, the catches listed are for the Pacific ocean perch complex (a former management grouping consisting of Pacific ocean perch and four other rockfish species), Pacific ocean perch alone, or all *Sebastes* rockfish, depending upon the year (see Footnote in Table 9-2). Pacific ocean perch make up the majority of catches from this complex. The acceptable biological catches and quotas in Table 9-2 are Gulf-wide values, but in actual practice the NPFMC has divided these into separate, annual apportionments for each of the three regulatory areas of the Gulf of Alaska.

Historically, bottom trawls have accounted for nearly all the commercial harvest of Pacific ocean perch. In recent years, however, a sizable portion of the Pacific ocean perch catch has been taken by pelagic trawls. The percentage of the Pacific ocean perch Gulf-wide catch taken in pelagic trawls increased from 2-8% during 1990-95 to 14-20% during 1996-98. By 2008, the amount caught in pelagic trawls was even higher at 31%.

Before 1996, most of the Pacific ocean perch trawl catch (>90%) was taken by large factory-trawlers that processed the fish at sea. A significant change occurred in 1996, however, when smaller shore-based trawlers began taking a sizeable portion of the catch in the Central area for delivery to processing plants in Kodiak. These vessels averaged about 50% of the catch in the Central Gulf area since 1998. By 2008, catcher vessels were taking 60% of the catch in the Central Gulf area and 35% in the West Yakutat area. Factory trawlers continue to take nearly all the catch in the Western Gulf area.

In 2007, the Central Gulf of Alaska Rockfish Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This rationalization program establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish management groups. The primary rockfish management groups are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Potential effects of this program on Pacific ocean perch include: 1) extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA (e.g. Figure 9-21), 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, 4) and a higher potential to harvest 100% of the TAC in the Central GOA region. Recent data show that the Pilot project has resulted in much higher observer coverage of catch in the Central Gulf.

Hanselman et al. (2009) showed evidence that the fishery has changed over time and is more focused on younger fish and smaller boats. In response to this evidence it was suggested that we examine fishery age compositions by year, depth, and vessel size. We examine both the mean and the median because the presence of very old fish has consequences to modeling the plus group selectivity. Mean age has declined substantially from the first few years of fishery ages collected, while the median has remained steady because fewer very old fish are showing up in the catch (Figure 9-2a). This was also true in the bottom trawl survey age composition (Figure 9-2b). There is a clear cline toward older fish starting with NMFS area 620 (Chirikof) toward NMFS area 650 (Southeast Alaska) which has been closed to trawling since 1998 (Figure 9-2c). In the trawl survey data, this cline is not apparent in mean age from west to east (Figure 9-2d). A small increase in mean age with depth resulted in both the fishery and trawl survey age composition data (Figure 9-2e and f).

Overall, it would appear that there are trends in the data to support that the fishery is more focused on middle-aged fish, rather than older fish in recent years. Also as described in 2009, the fishery is focusing on shallower depths where younger fish are. As mean fishery age has declined, the mean survey age has steadily been increasing (Figure 9-2f, using 25+ group). The hypothesis that moving to smaller boats has caused a change in selectivity is not supported by this analysis, and we do not have age data far enough back to examine the very large catches of the foreign fleet. Further analysis would be to do some comparisons of the catch-at-age of other slope rockfish and to further examine length compositions from the foreign fleet.

Nominal catch rates (kg/minutes) have increased substantially since 1991 in the Gulf of Alaska. However, when compared to a measure of exploitable biomass (Age 6+), the increases in catch rate are coincident with a tripling of biomass during the same period. Increases in catch rates appear to be leveling off along with biomass estimates in recent years (Figure 9-3a). We also compared exploitation rate with CPUE and it shows that exploitation rate has slowly risen since the 1994 and is now leveling off near around 4 or 5% (Figure 9-3b).

Management measures/units

In 1991, the NPFMC divided the slope assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. In 1993, a fourth management subgroup, northern rockfish, was also created. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC (acceptable biological catch) and TAC (total allowable catch), whereas prior to 1991, an ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on distribution of survey biomass.

Amendment 32, which took effect in 1994, established a rebuilding plan for POP. The amendment stated that "*stocks will be considered to be rebuilt when the total biomass of mature females is equal to or greater than* B_{MSY}" (Federal Register: April 15, 1994, http://alaskafisheries.noaa.gov/prules/noa_18103.pdf). Prior to Amendment 32, overfishing levels had been defined GOA-wide. Under Amendment 32, "*the overfishing level would be distributed among the eastern, central, and western areas in the same proportions as POP biomass occurs in those areas. This measure would avoid localized depletion of POP and would rebuild POP at equal rates in all regulatory areas of the GOA.*" This measure established management area OFLs for Pacific ocean perch.

Amendment 41, which took effect in 2000, prohibited trawling in the Eastern area east of 140 degrees W. longitude. Since most slope rockfish, especially Pacific ocean perch, are caught exclusively with trawl gear, this amendment could have concentrated fishing effort for slope rockfish in the Eastern area in the relatively small area between 140 degrees and 147 degrees W. longitude that remained open to trawling. To ensure that such a geographic over-concentration of harvest would not occur, since 1999 the NPFMC has divided the Eastern area into two smaller management areas: West Yakutat (area between 147 and 140 degrees W. longitude) and East Yakutat/Southeast Outside (area east of 140 degrees W. longitude). Separate ABC's and TAC's are now assigned to each of these smaller areas for Pacific ocean perch, while separate OFLs have remained for the Western, Central, and Eastern GOA management areas.

In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action implemented the Central GOA Rockfish Program (formerly the Rockfish Pilot Program or RPP). The intention of this program is to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. This should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. In a comparison of catches in the four years before the program to the four years after, it appears some effort has shifted to area 620 (Chirikof) from area 630 (Kodiak) (Figure 9-21). The authors will pay close attention to the benefits and consequences of this action.

Since the original establishment of separate OFLs by management areas for POP in the rebuilding plan (Amendment 32) in 1994, the spawning stock biomass has tripled. The rebuilding plan required that female spawning biomass be greater than B_{msy} and the stock is now 35% higher than B_{msy}. Management has prosecuted harvest accurately within major management areas using ABC apportionments. While evidence of stock structure exists in the Gulf of Alaska, it does appear to be along an isolation by distance cline, not sympatric groups (Palof et al. 2011; Kamin et al. 2013)). Palof et al. (2011) also suggest that the Eastern GOA might be distinct genetically, but this area is already its own management unit, and has additional protection with the no trawl zone. Hanselman et al. (2007) showed that POP are reasonably resilient to serial localized depletions (areas replenish on an annual basis). The NPFMC stock structure template was completed for Gulf of Alaska POP in 2012 (Hanselman et al. (2012a). Recommendations from this exercise were to continue to allocate ABCs by management area or smaller. However, the original rationale for area-specific OFLs from the rebuilding plan no longer exists because the overall population is above target levels and is less vulnerable to occasional overages. Therefore, in terms of rebuilding the stock, management area OFLs are no longer a necessity for the Gulf of Alaska POP stock.

Management measures since the break out of Pacific ocean perch from slope rockfish are summarized in Table 9-1.

Bycatch and discards

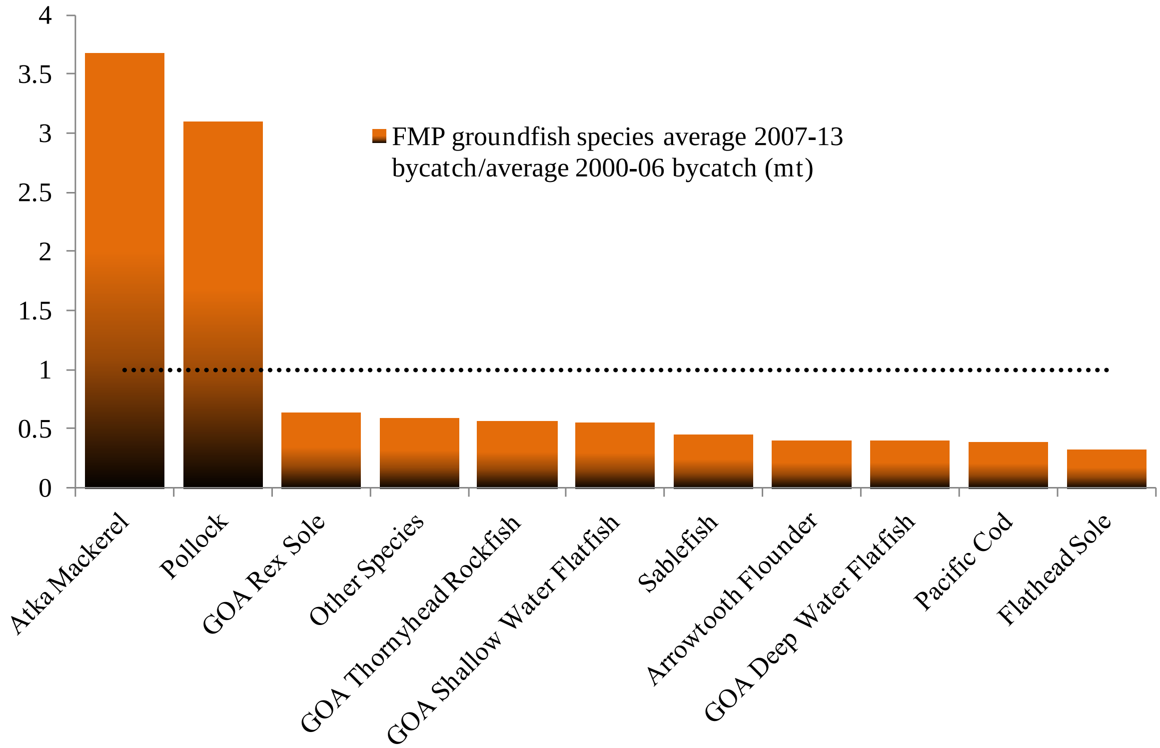
Gulf-wide discard rates[2] (% discarded) for Pacific ocean perch in the commercial fishery for 2000-2013 are listed as follows:

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Discard	11.3	8.6	7.3	15.1	8.2	5.7	7.8	3.7	4.1	6.8	4.2

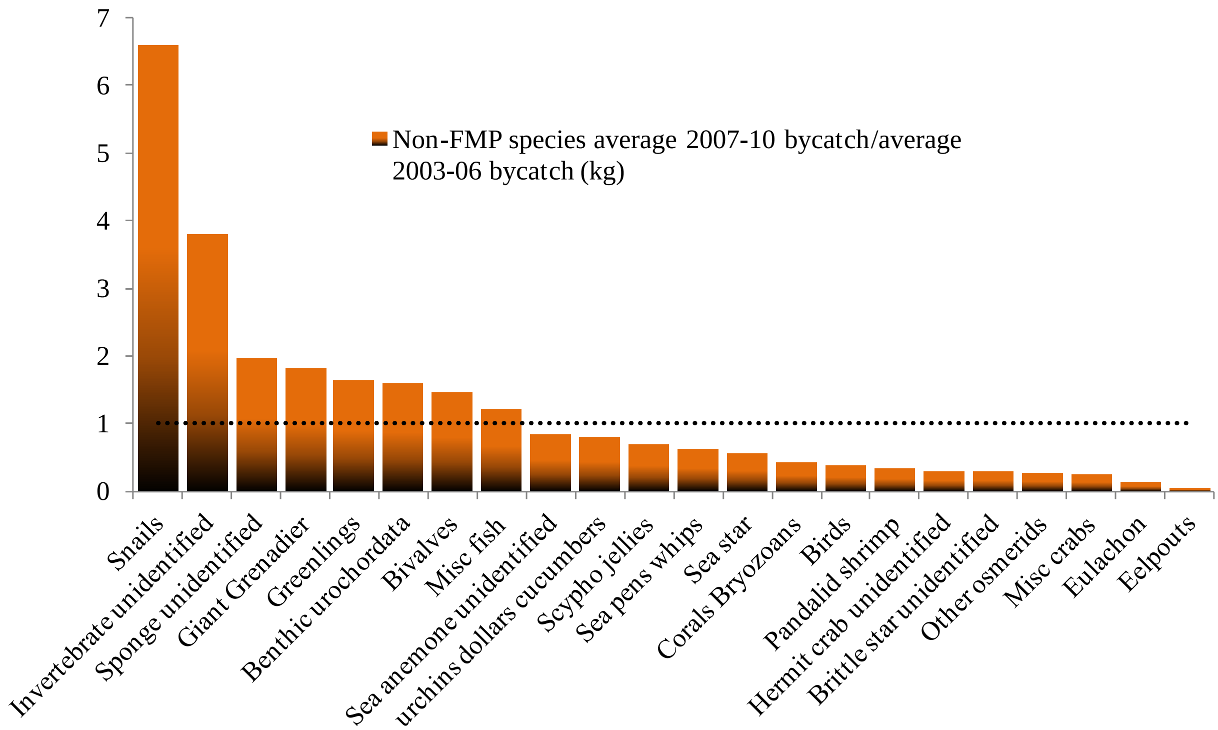
Year	2011	2012	2013
% Discard	6.5	4.8	7.6

Total FMP groundfish catch estimates in the GOA rockfish targeted fisheries from 2008-2013 are shown in Table 9-3. For the GOA rockfish fishery during 2008-2013, the largest non-rockfish bycatch groups are Atka mackerel (1,591 t/year), pollock (818 t/year), arrowtooth flounder (581 t/year), and Pacific cod (558 t/year). Catch of Pacific ocean perch in other Gulf of Alaska fisheries is mainly in the rex sole (326 t/year average) and arrowtooth (272 t/year) targeted fishing (Table 9-4).

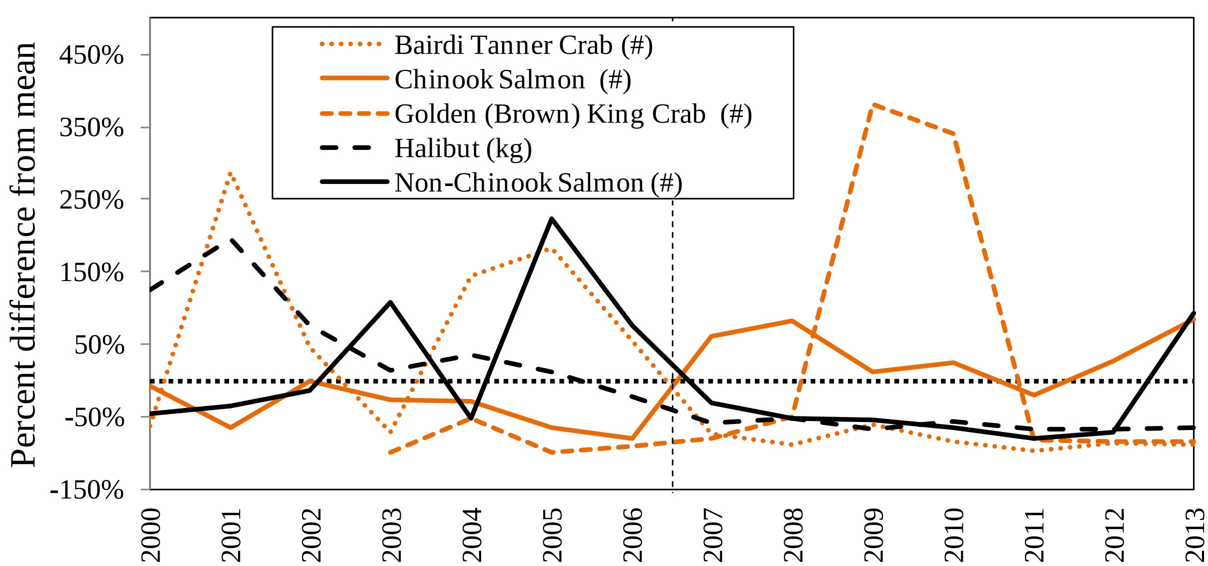
We compared bycatch from pre-2006 and post-2007 in the central GOA for the combined rockfish fisheries to determine impact of the Central GOA Rockfish Program implementation. We divided the average post-2006 bycatch (2007-2013) by the average pre-2007 bycatch (2000-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species, bycatch in the central GOA has been reduced since 2007, with the exception of Atka mackerel (414 t/year pre-2006 compared to 1,520 t/year post-2007) and walleye pollock (234 t/year pre-2006 compared to 722 t/year post-2007, see figure below):



Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier, miscellaneous fish, and ocassionally dark rockfish (recently removed from FMP to state management) (Table 9-5). 8 of 22 nontarget species resulted in an increase in bycatch post-2007 compared to pre-2006 (see figure below):



Prohibited species catch in the GOA rockfish fishery has been lower than average since 2011 for most major species. In 2013 only chinook and non-chinook salmon bycatch was larger than average. The catch of golden king crab drecreased dramatically from over 3,000 animals in 2009 and 2010, to just over 100 in 2011 – 2013. (Table 9-6). Catch of prohibited species in the combined rockfish trawl fisheries has decreased, on average, since 2006 for most groups, with the exception of chinook salmon:



Data

The following table summarizes the data used for this assessment:

Source	Data	Years
NMFS Groundfish survey	Survey biomass	1984-1999 (triennial), 2001-2013 (biennial)
	Age Composition	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011
U.S. trawl fisheries	Catch	1961-2014
	Age Composition	1990,1998-2002, 2004, 2005, 2006, 2008, 2010, 2012
	Length Composition	1963-1977, 1991-1997

Fishery

Catch

Catches range from 2,500 t to 350,000 t from 1961 to 2014. Detailed catch information for Pacific ocean perch is listed in Table 9-2 and shown graphically in Figure 9-1. This is the commercial catch history used in the assessment model. In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery. Research catches of Pacific ocean perch have been reported in previous stock assessments (Hanselman et al. 2009). Estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 9-A. In summary, research removals have typically been less than 100 t and very little is taken in recreational or halibut fisheries. These levels likely do not pose a significant risk to the Pacific ocean perch stock in the GOA.

Age and Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age composition of the commercial catch of Pacific ocean perch. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Table 9-7 summarizes the length compositions from 1995-2012. Table 9-8 summarizes age compositions from 1990, 1998-2002, 2004-2006, 2008, 2010, and 2012 for the fishery. Figures 9-4 and 9-5 show the distributions graphically. The age compositions in all years of the fishery data show strong 1986 and 1987 year classes. These year classes were also strong in age compositions from the 1990-1999 trawl surveys. The 2004-2006 fishery data show the presence of strong 1994 and 1995 year classes. These two year classes are also the highest proportion of the 2003 survey age composition. The 2012 fishery age composition shows a relatively high number of older fish in the plus group (25 years and older).

Survey

Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and a biennial survey schedule has been used since the 1999 survey. The surveys provide much information on Pacific ocean perch, including an abundance index, age composition, and growth characteristics. The surveys are theoretically an estimate of absolute biomass, but we treat them as an index in the stock assessment. The surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 1,000 m), but the 2001 survey did not sample the eastern Gulf of Alaska. Summaries of biomass estimates from 1984 to 2013 surveys are provided in Table 9-9.

Comparison of Trawl Surveys in 1984-2013

Gulf-wide biomass estimates for Pacific ocean perch are shown in Table 9-9. Gulf-wide biomass estimates for 1984-2013 and 95% confidence intervals are shown in Figure 9-6. The 1984 survey results should be treated with some caution, as a different survey design was used in the eastern Gulf of Alaska. In addition, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed here, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 does introduce an element of uncertainty as to the standardization of these two surveys.

The biomass estimates for Pacific ocean perch were generally more imprecise between 1996-2001 than after 2003 (Figure 9-6). Although more precise, a fluctuation in biomass of 60% in two surveys (e.g. 2003 to 2005) does not seem reasonable given the slow growth and low natural mortality rates of Pacific ocean perch. Large catches of an aggregated species like Pacific ocean perch in just a few individual hauls can greatly influence biomass estimates and may be a source of much variability. Anomalously large catches have especially affected the biomass estimates for Pacific ocean perch in the 1999 and 2001 surveys. While there are still several large catches, the distribution of Pacific ocean perch is becoming more uniform with more medium-sized catches in more places compared to previous surveys (for example compare 2009 and 2011 with 1999 Figures 9-7a, b). In past SAFE reports, we have speculated that a change in availability of rockfish to the survey, caused by unknown behavioral or environmental factors, may explain some of the observed variation in biomass. We repeat this speculation here and acknowledge that until more is known about rockfish behavior, the actual cause of changes in biomass estimates will remain the subject of conjecture. Previous research has focused on improving rockfish survey biomass estimates using alternate sampling designs (Quinn et al. 1999, Hanselman et al. 2001, Hanselman et al. 2003). Research on the utility of hydroacoustics in gaining survey precision was completed in 2011 (Hanselman et al. 2012b, Spencer et al. 2012) which confirmed again that there are ways to improve the precision, but all of them require more sampling effort in high POP density strata. In addition, there is a study underway exploring the density of fish in untrawlable grounds that are currently assumed to have an equal density of fish compared to trawlable grounds.

Biomass estimates of Pacific ocean perch were relatively low in 1984 to 1990, increased markedly in both 1993 and 1996, and became substantially higher in 1999 and 2001 with much uncertainty. Biomass estimates in 2003 have less sampling error with a total similar to the 1993 estimate indicating that the large estimates from 1996-2001 may have been a result of a few anomalous catches. However, in 2005 the estimate was similar to 1996-2001, but was more precise. To examine these changes in more detail, the biomass estimates for Pacific ocean perch in each statistical area, along with Gulf-wide 95% confidence intervals, are presented in Table 9-9. The large rise in 1993, which the confidence intervals indicate was statistically significant compared with 1990, was primarily the result of big increases in biomass in the Central and Western Gulf of Alaska. The Kodiak area increased greater than ten-fold, from 15,765 t in 1990 to 153,262 t in 1993. The 1996 survey showed continued biomass increases in all areas, especially Kodiak, which more than doubled compared with 1993. In 1999, there was a substantial decline in biomass in all areas except Chirikof, where a single large catch resulted in a very large biomass estimate (Figure 9-7a). In 2001, the biomass estimates in both the Shumagin and Kodiak areas were the highest of all the surveys. In particular, the biomass in Shumagin was much greater than in previous years; as discussed previously, the increased biomass here can be attributed to very large catches in two hauls. In 2003 the estimated biomass in all areas except for Chirikof decreased, where Chirikof returned from a decade low to a more average value. The rise in biomass in 2005 can be attributed to large increases in the Shumagin and Kodiak areas. In 2007, the biomass dropped about 10% from 2005, with the bulk of that drop in the Shumagin area. Pacific ocean perch continued to be more uniformly distributed than in the past (Figure 9-7b). In 2009, total biomass was similar to 2007, and is the fourth survey in a row with relatively high precision. The biomass in the Western Gulf dropped severely, while the Chirikof and Eastern Gulf areas increased. It also appeared some of the biomass was consolidating around Kodiak Island (Figure 9-7b). In 2011, total biomass increased from 2009, but was quite similar to the mean of the last decade. The biomass estimate for 2013 was an all-time high and is one of the most precise of the survey time series. The 2013 survey design consisted of fewer stations than average, but the effect of this reduction in effort on POP survey catch was not apparent. The 2013 survey biomass increased in the Western, Central, and Easter Gulf. The Eastern gulf biomass had large uncertainty associated with it in comparison to the Western and Central Gulf.

Age Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2011 surveys showed that although the fish ranged in age up to 84 years, most of the population was relatively young; mean survey age was 10.2 years in 1996 and 11.4 years in 2009 (Table 9-10). The first four surveys identified a relatively strong 1976 year class and also showed a period of very weak year classes prior to 1976 (Figure 9-8). The weak year classes of the early 1970's may have delayed recovery of Pacific ocean perch populations after they were depleted by the foreign fishery. The survey age data from 1990-1999 suggested that there was a period of large year classes from 1986-1989. In 1990-1993, the 1986 year class looked very strong. Beginning in 1996 and continuing in 1999 survey ages, the 1987 and 1988 year classes also became prominent. Rockfish are difficult to age, especially as they grow older, and perhaps some of the fish have been categorized into adjacent age classes between surveys. Alternately, these year classes were not available to the survey until much later than the 1986 year class. Recruitment of the stronger year classes from the late 1980s probably has accounted for much of the increase in the estimated biomass for Pacific ocean perch in recent surveys. The 2003 survey age data indicate that 1994-1995 may also have been strong year classes. The 2005 and 2007 survey age compositions suggest that 1998 is a large year class. Indications from the 2009 and 2011 survey and the 2010 fishery age compositions suggest that the 2006 year class may be particularly strong.

Survey Size Compositions

Gulf-wide population size compositions for Pacific ocean perch are shown in Figure 9-9. The size composition for Pacific ocean perch in 2001 was bimodal, which differed from the unimodal compositions in 1993, 1996, and 1999. The 2001 survey showed a large number of relatively small fish, ~32 cm fork length which may indicate recruitment in the early 1990s, together with another mode at ~38 cm. Compared to the previous survey years, both 2001 and 2003 show a much higher proportion of small fish compared to the amount of fish in the pooled class of 39+ cm. This could be from good recruitment or from fishing down of larger fish. Survey size data are used in constructing the age-length transition matrix, but not used as data to be fitted in the stock assessment model. Size compositions from 2005-2007 returned to the same patterns as the 1996-1999 surveys, where the biomass was mainly adults. In 2009, there is indication of an incoming recent year class with an increase in the 18-20 cm range. In 2011, there are two modes of smaller fish at 20 and 25 cm likely showing potentially above-average 2006 and 2004 year classes, respectively. In 2013, these modes are less evident indicating the majority of the population is greater than 24cm.

In response to the groundfish Plan Team's request we performed analysis of the utility of including the most recent year's survey length composition into the assessment model (Appendix 9B). We recommend that the Pacific ocean perch assessment continue to not fit the most recent survey length composition as there was no improvement for most statistics evaluated, and for others, using the most recent year's length composition induced unnecessary variability in model estimates.

Maturity

In previous assessments female age and size at 50% maturity were estimated for Pacific ocean perch from a study in the Gulf of Alaska that is based on the currently accepted break-and-burn method of determining age from otoliths (Lunsford 1999). A recent study of Pacific ocean perch maturity was undertaken by Conrath and Knoth (2013) which indicated a younger age at 50% maturity than the previous study. Using the same method as Hulson et al. (2011), in this year's assessment, we fit the data for both studies simultaneously within the assessment model so that uncertainty in maturity is reflected in the uncertainty of other model estimates.

Analytic Approach

Model Structure

We present results for Pacific ocean perch based on an age-structured model using AD Model Builder software (Fournier et al. 2012). Prior to 2001, the stock assessment was based on an age-structured model using stock synthesis (Methot 1990). The assessment model used for Pacific ocean perch is based on a generic rockfish model described in Courtney et al. (2007).

The parameters, population dynamics, and equations of the model are described in Box 1. Since its initial adaptation in 2001, the models' attributes have been explored and changes have been made to the template to adapt to Pacific ocean perch and other species. For 2009, further modifications were made to accommodate MCMC projections that use a pre-specified proportion of ABC for annual catch. Additionally in 2009, a change in selectivity curves was accepted to allow for time blocks and the dome-shaped gamma selectivity function.

Parameters Estimated Outside the Assessment Model

In previous assessments a von Bertalanffy growth curve was fitted to survey size at age data from 1984-1999 (Malecha et al. 2007). A second size to age transition matrix was adopted in 2003 to represent a lower density-dependent growth rate in the 1960s and 1970s (Hanselman et al. 2003), thus, there are two size to age transition matrices used in the model (pre- and post-1980). In this year's assessment the size at age data was updated through the 2011 survey. Sexes were combined. The size to age transition matrix for the recent period was then constructed by adding normal error with a standard deviation equal to the survey data for the probability of different ages for each size class. The estimated parameters for the growth curve are shown below:

L_∞=41.3 cm κ=0.19 t_0=-0.40 n=12,305

The previous assessments growth curve parameters were:

L_∞=41.4 cm κ=0.19 t_0=-0.47 n=9,336

Weight-at-age was constructed with weight at age data from the same data set as the length at age. The estimated growth parameters are shown below. A correction of $(W_\infty\text{-}W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

W_∞=1023 g a=0.00001 b=3.05 n=7,673

The previous assessments weight-at-age parameters were:

W_∞=984 g a=0.0004 b=2.45 n=3,592

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age based on percent agreement tests conducted at the AFSC Age and Growth lab.

Parameters Estimated Inside the Assessment Model

The estimates of natural mortality (*M*), catchability (*q*) and recruitment deviations (σ_r) are estimated with the use of prior distributions as penalties. The prior mean for natural mortality is based on catch curve analysis to determine *Z*. Estimates of *Z* could be considered as an upper bound for *M*. Estimates of *Z* for Pacific ocean perch from Archibald et al. (1981) were from populations considered to be lightly exploited and thus are considered reasonable estimates of *M*, yielding a value of ~0.05. Natural mortality is a notoriously difficult parameter to estimate within the model so we assign a relatively precise prior CV of 10% (Figure 9-10). Catchability is a parameter that is somewhat unknown for rockfish, so while we assign it a prior mean of 1 (assuming all fish in the area swept are captured and there is no herding of fish from outside the area swept, and that there is no effect of untrawlable grounds), we assign it a less precise CV of 45% (Figure 9-11). This allows the parameter more freedom than that allowed to natural mortality. Recruitment deviation is the amount of variability that the model allows for recruitment estimates. Rockfish are thought to have highly variable recruitment, so we assign a high prior mean to this parameter of 1.7 with a CV of 20% (Figure 9-11).

Selectivity

In 2009, we presented empirical evidence that the fishery has changed its fishing practices over the time period (Hanselman et al. 2009). We noted that the fishery selectivity, which at that time was a nonparametric selectivity by age was drifting toward a dome shape. The fishery was catching a much higher proportion of older fish than the survey in the “eighties,” whereas in the “noughties” the fishery was catching a lower proportion of older fish than that found in the survey. Older POP generally are in the deepest water (Figure 9.2), and the trend since 1995 has been about a 50 meter decrease in catch-weighted average fishing depth (see figure below). This evidence led us to recommend allowing the fishery selectivity to become more dome-shaped and blocking fishery selectivity into three time periods:

1) 1961-1976: This period represented the massive catches and overexploitation by the foreign fisheries which slowed considerably by 1976. We do not have age data from this period to examine, but we can assume the near pristine age-structure was much older than now, and that at the high rate of exploitation, all vulnerable age-classes were being harvested. For these reasons we chose to only consider asymptotic (logistic) selectivity.
2) 1977-1995: This period represents the change-over from the foreign fleet to a domestic fleet, but was still dominated by large factory trawlers, which generally would tow deeper and further from port.
3) 1996-Present: During this period we have noted the emergence of smaller catcher-boats, semi-pelagic trawling and fishing cooperatives. The length of the fishing season has also been recently greatly expanded.

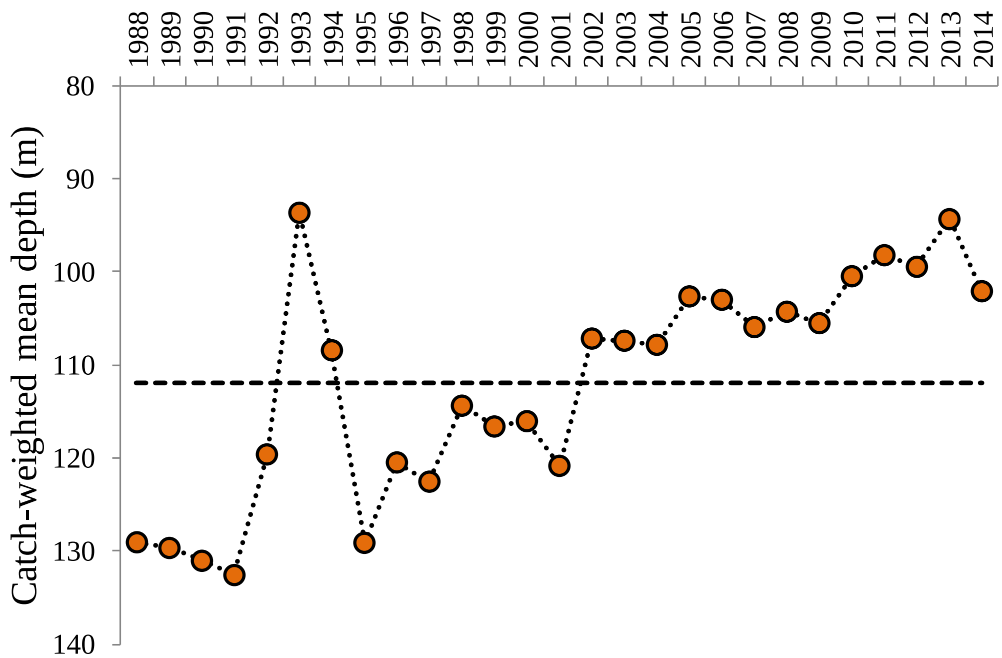
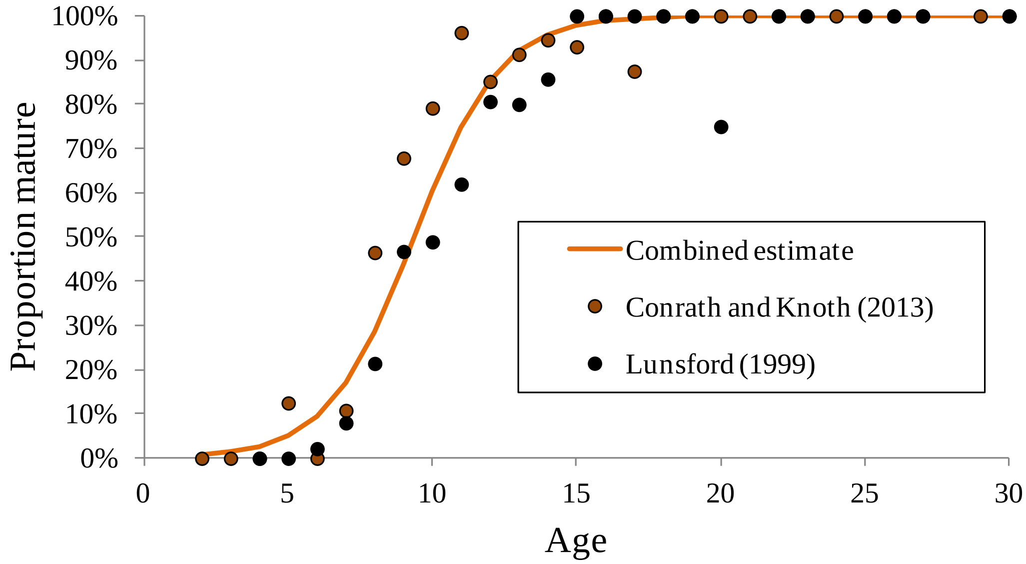


Figure. Change in catch-weighted mean depth of the Gulf of Alaska POP fishery over time (horizontal dashed line is average from 1988-2014).

We continue to recommend a model that transitions into dome-shaped selectivity for the fishery in the three time blocks described previously. We fitted a logistic curve for the first block, an averaged logistic-gamma in the 2nd block, and a gamma function for the 3rd block. In 2009 we also switched to fitting survey selectivity with the logistic curve (it was already very similar to the logistic) to be consistent. This accomplished a reduction of nine parameters that were used in the original non-parametric selectivities used between 2001-2007.

Maturity

Maturity-at-age is modeled with the logistic function, similar to selectivity-at-age for the survey and early-period fishery. In this year's assessment the recommended model estimates logistic parameters for maturity-at-age conditionally following the method presented in Hulson et al. (2011). Parameter estimates for maturity-at-age are obtained by fitting both datasets collected on female Pacific ocean perch maturity from Lunsford (1999) and Conrath and Knoth (2013). The binomial likelihood is used in the assessment model as an additional component to the joint likelihood function to fit the combined observations of female Pacific ocean perch maturity (e.g., Quinn and Deriso 1999). Parameters for the logistic function describing maturity-at-age are estimated conditionally in the model so that uncertainty in model results (e.g., ABC) can be linked to uncertainty in maturity parameter estimates through the Markov Chain Monte Carlo (MCMC) procedure described below in the *Uncertainty approach* section. The fit to the combined observations of maturity-at-age obtained in the recommended assessment model is shown below.



Identical maturity-at-age parameter estimates are obtained whether fitting the maturity data independently or conditionally, this is also true for the all the other parameters estimated in the model. Estimating maturity-at-age parameters conditionally influences the model only through the evaluation of uncertainty, as the MCMC procedure includes variability in the maturity parameters in conjunction with variability in all other parameters, rather than assuming the maturity parameters are fixed.

Other parameters estimated conditionally include, but are not limited to: mean recruitment, fishing mortality, and spawners per recruit levels. The numbers of estimated parameters for the recommended model are shown below. Other derived parameters are described in Box 1.

Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	1
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Spawners-per-recruit levels	F_{35}, F_{40}, F_{50}	3
Recruitment deviations	τ_y	76
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	54
Fishery selectivity coefficients	fs_a	4
Survey selectivity coefficients	ss_a	2
Maturity-at-age coefficients	m_a	2
Total		146

Uncertainty approach

Evaluation of model uncertainty has recently become an integral part of the “precautionary approach” in fisheries management (Hilborn et al. 2001). In complex stock assessment models, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the

Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the model presented in this SAFE report, the number of parameters estimated is 142. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, it will converge. The "burn-in" is a set of iterations removed at the beginning of the chain. In our simulations we removed the first 1,000,000 iterations out of 10,000,000 and "thinned" the chain to one value out of every two thousand, leaving a sample distribution of 4,500. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters.

BOX 1. AD Model Builder POP Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition matrix
q	Survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
M_{prior}	Prior mean for natural mortality
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment variance
σ_M^2	Prior CV for natural mortality
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_y = q \;* \sum_a N_{y,a} * \frac{ss_a}{\max\left(ss_a\right)} * w_a$$

Survey biomass index (t)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * ss_a}{\sum_a N_{y,a} * ss_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * ss_a}{\sum_a N_{y,a} * ss_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{\left(\mu_r\right)} e^{-(a-a_0)M}}{\left(1 - e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components **<u>BOX 1 (Continued)</u>**

$L_1 = \lambda_1 \sum_y \left(\ln\left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y\right)^2}{2 * \hat{\sigma}^2 \left(I_y\right)}$	Survey biomass index likelihood
$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Fishery age composition likelihood ($n^*{}_y$ =sample size, standardized to maximum of 100)
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Survey size composition likelihood
$L_7 = \frac{1}{2\sigma_M^2} \left(\ln\left(M / M_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_8 = \frac{1}{2\sigma_q^2} \left(\ln\left(q / q_{prior} \right) \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_9 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln\left(\sigma_r / \sigma_{r(prior)} \right) \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{10} = \lambda_{10} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln\left(\sigma_r\right) \right]$	Penalty on recruitment deviations
$L_{11} = \lambda_{11} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty

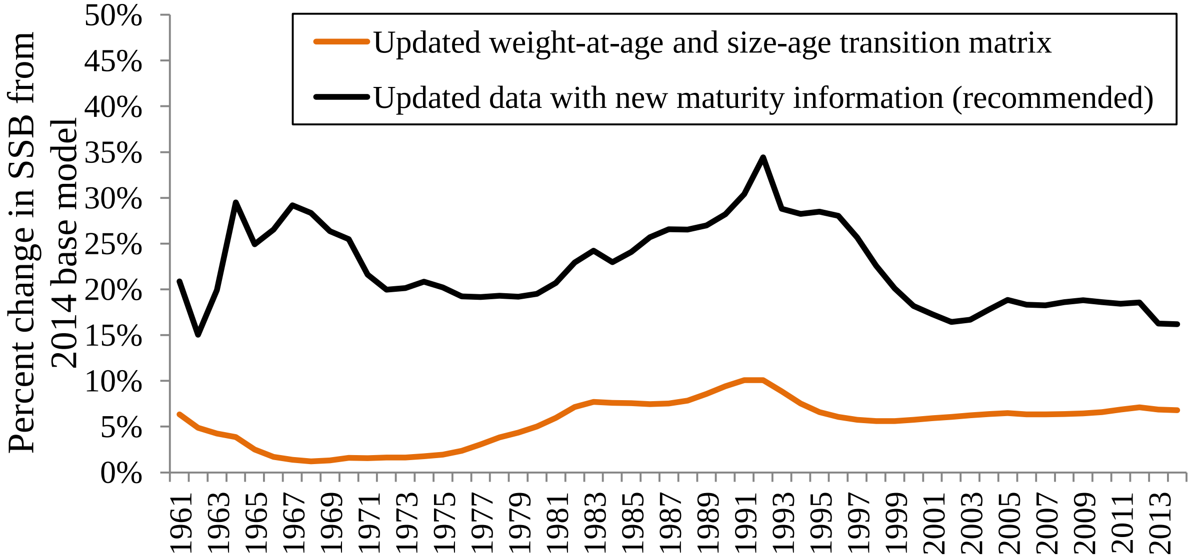
Selectivity equations

$s_{a,s}^g = \left(1 + e^{\left(-\delta_{g,s}\left(a - a_{50\%,g,s}\right)\right)}\right)^{-1}$	Logistic selectivity
$s_{a,s}^g = \left(\frac{a}{a_{\max}} \right)^{a_{\max,g,s}/p} e^{\left(a_{\max,g,s} - a\right)/p}$ $p = 0.5\left[\sqrt{{a_{\max,g,s}}^2 + 4{\delta_{g,s}}^2} - a_{\max,g,s} \right]$	Reparameterized gamma distribution

Results

Model Evaluation

This model is identical in all aspects to the model accepted in 2013 except for inclusion of updated weight-at-age, an updated size-at-age transition matrix, and new maturity data. When we present alternative model configurations, our usual criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony. In the following figure the percent change in spawning biomass from the 2014 base model (the same model as 2013 with only catch updated in 2014) compared to a model that updated growth data and the 2014 recommended model that updated both growth data and included new maturity information is shown.



Overall, including the updated growth data resulted in a 5% increase in spawning biomass on average compared to the base model. Including updated growth data with new maturity data resulted in a larger increase in spawning biomass, on average about 22%, which is expected given the decrease in the age at 50% maturity when including the new maturity information. The parameter estimates and likelihoods are also similar between the three models and are shown in Table 9-12.

The 2014 recommended model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. This model does not fit the 2013 survey estimate well, likely due to the large increase in this estimate compared to previous years that is difficult to explain in a long-lived species with our current model configuration. The 2014 recommended model update shows recent recruitment stabilizing and an increase in spawning and total biomass from previous projections. Therefore the, 2014 recommended model is utilizing the new information effectively, and we use it to recommend 2015 ABC and OFL.

Time Series Results

Key results have been summarized in Tables 9-12 to 9-15. Model predictions generally fitted the data well (Figures 9-1, 9-4, 9-5, 9-6, and 9-8) and most parameter estimates have remained similar to the last several years using this model.

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all Pacific ocean perch age two and greater. Recruitment is measured as the number of age two Pacific ocean perch. Fishing mortality is the mortality at the age the fishery has fully selected the fish.

Biomass and exploitation trends

Estimated total biomass gradually increased from a low near 85,000 t in 1980 to over 400,000 t for 2014 (Figure 9-12). MCMC credible intervals indicate that the historic low is reasonably certain while recent increases are not quite as certain. These intervals also suggest that current biomass is likely between around 270,000 and 780,000 t. Spawning biomass shows a similar trend, but is not as smooth as the estimates of total biomass (Figure 9-13). This is likely due to large year classes crossing a steep maturity curve. Spawning biomass estimates show a rapid increase between 1992 and 2000, and a slower increase (with considerable uncertainty) thereafter. Age of 50% selection is 5 and between 7 and 9 years for the survey and fishery, respectively (Figure 9-14). Fish are fully selected by both fishery and survey between 10 and 12. Current fishery selectivity is dome-shaped and matches well with the ages caught by the fishery. Catchability is slightly smaller (2.00) than that estimated in 2013 (2.09). The high catchability for POP is supported by several empirical studies using line transect densities counted from a submersible compared to trawl survey densities (Krieger 1993 [q=2.1], Krieger and Sigler 1996 [q=1.3], Hanselman et al. 2006[1] [q=2.1]).

Fully-selected fishing mortality shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 9-15). Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. We chose to plot a phase plane plot of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to unfished spawning biomass ($B_{100\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The management path for Pacific ocean perch has been above the $F_{35\%}$ adjusted limit for most of the historical time series (Figure 9-16). In addition, since 1999, Pacific ocean perch SSB has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

Recruitment (as measured by age 2 fish) for Pacific ocean perch is highly variable and large recruitments comprise much of the biomass for future years (Figure 9-17). Recruitment has increased since the early 1970s, with the 1986 year class and potentially the 2006 year classes being the highest in recent history. The 1990s and 2000s are starting to show some steady higher than average recruitments. The addition of new survey age data and the large increase in 2013 survey biomass suggests that the 2006 year class may be above average (Figure 9-18). However, these recent recruitments are still highly uncertain as indicated by the MCMC credible intervals in Figure 9-17. Pacific ocean perch do not seem to exhibit much of a stock-recruitment relationship because large recruitments have occurred during periods of high and low biomass (Figure 9-17).

Uncertainty results

From the MCMC chains described in *Uncertainty approach*, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 9-19) and credible intervals (Table 9-13 and 9-15). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass, and recruitment (e.g. Figures 9-12, 9-13, 9-17, and 9-20).

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[1] Hanselman, D.H., S.K. Shotwell, J. Heifetz, and M. Wilkins. 2006. Catchability: Surveys, submarines and stock assessment. 2006 Western Groundfish Conference. Newport, OR. Presentation.

Table 9-13 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC, mean, median, standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The Hessian and MCMC standard deviations are similar for *q*, *M*, and $F_{40\%}$, but the MCMC standard deviations are larger for the estimates of female spawning biomass and ABC. These larger standard deviations indicate that these parameters are more uncertain than indicated by the Hessian approximation. The distributions of these parameters with the exception of natural mortality are slightly skewed with higher means than medians for spawning biomass and ABC, indicating possibilities of higher biomass estimates (also see Figure 9-19).

Retrospective analysis

A within-model retrospective analysis of the recommended model was conducted for the last 10 years of the time-series by dropping data one year at a time. The revised Mohn's "rho" statistic (Hanselman et al. 2013) in female spawning biomass was -0.095, indicating that the model increases the estimate of female spawning biomass in recent years as data is added to the assessment. The retrospective female spawning biomass and the relative difference in female spawning biomass from the model in the terminal year are shown in Figure 9-22 (with 95% credible intervals from MCMC). In general the relative difference in female spawning biomass ranges from around -30% to 30%, with the largest differences occurring in the mid- to late-1970s, and early 1990's.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific ocean perch in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$,,equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age-2 recruitments between 1979 and 2012 (i.e., the 1977 – 2010 year classes). Because of uncertainty in very recent recruitment estimates, we lag 2 years behind model estimates in our projection. Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2014 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
283,315	113,326	99,160	0.119	0.139

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2015 is estimated at 142,029 t. This is above the $B_{40\%}$ value of 113,326 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2015, yields the following ABC and OFL:

$F_{40\%}$	0.119
ABC	**21,012**
$F_{35\%}$	0.139
OFL	**24,360**

Since 2009, our estimate of $F_{40\%}$ has been higher than past assessments and quite a bit higher than natural mortality. While it means that fishing will be taking place at a higher rate for a section of the population, fishing mortality is much lower in the older ages of the population due to the dome-shaped nature of the selectivity curve.

Projections and Status Determination

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2014 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2014 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2015, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, *F* is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In 2015 and 2016, *F* is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2011-2013 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio catch to ABC will yield more realistic projections.)

Scenario 3: In all future years, *F* is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, *F* is set equal to the 2009-2013 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of F_{TAC}

than F_{ABC}.)

Scenario 5: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2014 or 2) above ½ of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, *F* is set equal to *max* F_{ABC}, and in all subsequent years *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2016 or 2) above 1/2 of its MSY level in 2016 and expected to be above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 9-16). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries (such as POP) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for two year ahead specifications. The methodology for determining these pre-specified catches is described below in ***Specified catch estimation.***

Status determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2015, it does not provide the best estimate of OFL for 2016, because the mean 2015 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2013) is 13,183 t. This is less than the 2013 OFL of 18,919 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2014:
a. If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2014 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2014 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 9-16). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2016 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2016 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 9-16, the stock is not overfished and is not approaching an overfished condition.

Specified catch estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the Gulf of Alaska rockfish assessments, for current year catch, we are applying an expansion factor to the official catch on or near October 1 by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2011-2013 for this year). For Pacific ocean perch, the expansion factor for 2014 catch is 1.06. Since the 2014 rockfish directed fishery did not occur in the Western Gulf until October 15 and those catches are not available at this time, an estimated 2,000 t of total catch in the Western Gulf was added to the 2014 total catch in the Central and Eastern Gulf to better reflect the 2014 estimated catch. The value of 2,000 t is based on the average recent catch in this area.

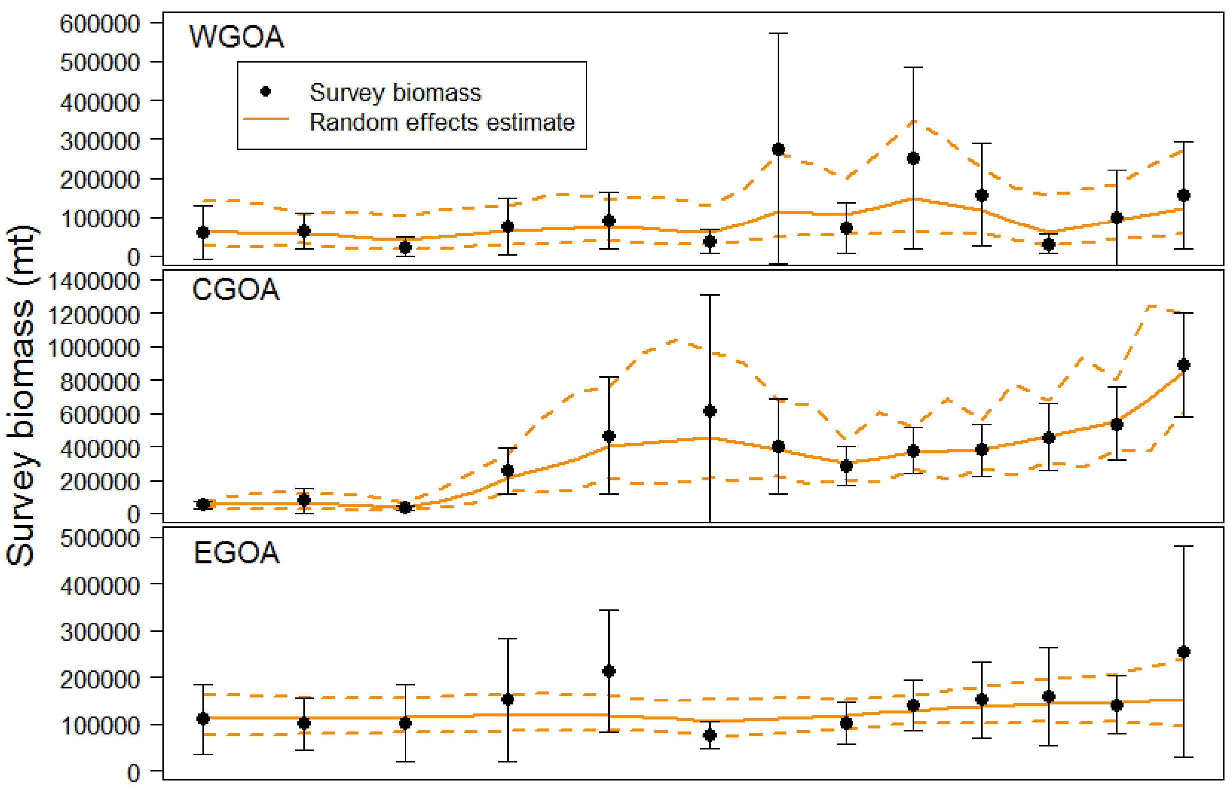
For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out. To estimate future catches, we updated the yield ratio (0.84), which was the average of the ratio of catch to ABC for the last three complete catch years (2011-2013). This yield ratio was multiplied by the projected ABCs for 2015 and 2016 from the assessment model to generate catches for those years.

Alternate Projection

During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at maxABC (Alternative 1). This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 9-20). The $B_{35\%}$ and $B_{40\%}$ reference points and future recruitments are based on the 1979-2012 age-2 recruitments, and this projection predicts that the median spawning biomass will eventually tend toward these reference points while at harvesting at $F_{40\%}$.

Area Apportionment of Harvests

Since 1996, apportionment of ABC and OFL among regulatory areas has been based on a method of weighting the prior 3 trawl survey biomass estimates. For this assessment the Plan Team and SSC requested that the random effects model proposed by the survey averaging working group be utilized for apportionment. The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern Gulf of Alaska. The random effects model estimates a process error parameter (constraining the variability of the modeled estimates among years) and random effects parameters in each year modeled. The fit of the random effects model to survey biomass in each area is shown in the following figure. For illustration the 95% confidence intervals are shown for the survey biomass (error bars) and the random effects estimates of survey biomass (dashed lines).



In general the random effects model fits the area-specific survey biomass reasonably well. In the most recent survey, the random effects model fit the increases in biomass well within the Western and Central GOA, but did not fit the increase in the Eastern GOA well due to its large uncertainty. The previous weighting method resulted in apportionments of 11% for the Western area, 69% for the Central area, and 20% for the Eastern area. Using the random effects model estimates of survey biomass the apportionment results in 11.0% for the Western area, 75.5% for the Central area, and 13.5% for the Eastern area. This results in recommended ABC's of **2,302** t for the Western area, **15,873** t for the Central area, and **2,837** t for the Eastern area.

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. In the past, the Plan Team has calculated an apportionment for the West Yakutat area that is still open to trawling (between 147°W and 140°W). We calculated this apportionment using the ratio of estimated biomass in the closed area and open area. This calculation was based on the team's previous recommendation that we use the weighted average of the upper 95% confidence interval for the W. Yakutat. We computed this interval this year using the weighted average of the ratio for 2009, 2011, and 2013. We calculated the approximate upper 95% confidence interval using the variance of a weighted mean for the 2009-2013 weighed mean ratio. This resulted in higher ratio of 0.71, up from 0.48 in 2011. This results in an ABC apportionment of **2,014** t to the W. Yakutat area which would leave **823** t unharvested in the Southeast/Outside area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.139), overfishing is set equal to 24,360 t for Pacific ocean perch. The overfishing level is apportioned by area for Pacific ocean perch and historically used the apportionment described above for setting area specific OFLs. However, in 2012, area OFLs were combined for the Western, Central, and West Yakutat (W/C/WYK) areas, while East Yakutat/Southeast (SEO) was separated to allow for concerns over stock structure. This results in overfishing levels for W/C/WYK area of **23,406** t and **954** t in the SEO area.

Ecosystem Considerations

In general, a determination of ecosystem considerations for Pacific ocean perch is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 9-17.

Ecosystem Effects on the Stock

Prey availability/abundance trends: Similar to many other rockfish species, stock condition of Pacific ocean perch appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval Pacific ocean perch may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval slope rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval slope rockfish (Gharrett et. al 2001). Some juvenile rockfish found in inshore habitat feed on shrimp, amphipods, and other crustaceans, as well as some mollusk and fish (Byerly 2001). Adult Pacific ocean perch feed primarily on euphausiids. Little if anything is known about abundance trends of likely rockfish prey items. Euphausiids are also a major item in the diet of walleye pollock. Recent declines in the biomass of walleye pollock, could lead to a corollary change in the availability of euphausiids, which would then have a positive impact on Pacific ocean perch abundance.

Predator population trends: Pacific ocean perch are preyed upon by a variety of other fish at all life stages, and to some extent marine mammals during late juvenile and adult stages. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile slope rockfish, but information on these life stages and their predators is scarce.

Changes in physical environment: Stronger year classes corresponding to the period around 1977 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including slope rockfish. Pacific ocean perch appeared to have strong 1986-88 year classes, and these may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could affect prey abundance and the survival of rockfish from the pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents. Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions. Carlson and Straty (1981), Pearcy et al (1989), and Love et al (1991) have noted associations of juvenile rockfish with biotic and abiotic structure. Recent research by Rooper and Boldt (2005) found juvenile POP were positively correlated with sponge and coral.

The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish is minimal or temporary. The continuing upward trend in abundance of Pacific ocean perch suggests that at current abundance and exploitation levels, habitat effects from fishing is not limiting this stock.

Effects of Pacific ocean perch Fishery on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for pollock, deepwater flatfish, and Pacific ocean perch account for most of the observed bycatch of coral, while rockfish fisheries account for little of the bycatch of sea anemones or of sea whips and sea pens. The bottom trawl fisheries for Pacific ocean perch and Pacific cod and the pot fishery for Pacific cod accounts for most of the observed bycatch of sponges (Table 9-5).

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The directed slope rockfish trawl fisheries used to begin in July concentrated in known areas of abundance and typically lasted only a few weeks. The Rockfish Pilot project has spread the harvest throughout the year in the Central Gulf of Alaska. The recent annual exploitation rates on rockfish are thought to be quite low. Insemination is likely in the fall or winter, and parturition is likely mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery. There is momentum for extending the rockfish fishery over a longer period, which could have minor effects on reproductive output.

Fishery-specific effects on amount of large size target fish: The proportion of older fish has declined since 1984, although it is unclear whether this is a result of fishing or large year-classes of younger fish coming into the population.

Fishery contribution to discards and offal production: Fishery discard rates for the whole rockfish trawl fishery has declined from 35% in 1997 to 25% in 2004. Arrowtooth flounder comprised 22-46% of these discards. Non-target discards are summarized in Table 9-5, with grenadiers (*Macrouridae sp.*) dominating the non-target discards.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Research is under way to examine whether the loss of older fish is detrimental to spawning potential.

Fishery-specific effects on EFH non-living substrate: Effects on non-living substrate are unknown, but the heavy-duty “rockhopper” trawl gear commonly used in the fishery is suspected to move around rocks and boulders on the bottom. Table 9-5 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries. The average bycatch of corals/bryozoans (0.78 t), and sponges (2.98 t) by rockfish fisheries are a large proportion of the catch of those species taken by all Gulf-wide fisheries.

Data Gaps and Research Priorities

There is little information on early life history of Pacific ocean perch and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the POP population. Studies to improve our understanding of POP density between trawlable and untrawlable grounds and other habitat associations would help in our determination of catchability parameters. Future assessment priorities include:

1) Respond to the various Plan Team and SSC requests that were not addressed in this year's assessment
2) Incorporate changes recommended by the 2013 CIE review (please refer to the Summary and response to the 2013 CIE review of AFSC rockfish document presented to the September 2013 Plan Team for further details)
3) Synthesize previous studies on rockfish catchability with submersibles into informative prior distributions on catchability in the model
4) Increase analysis of fishery spatial patterns and behavior

Summary

A summary of biomass levels, exploitation rates and recommended ABCs and OFLs for Pacific ocean perch is in the following table:

	As estimated or specified *last* year for:		As estimated or recommended *this* year for:	
Quantity	2014	2015	2015	2016[1]
M (natural mortality)	0.061	0.061	0.061	0.061
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	410,712	408,839	416,140	412,351
Projected Female spawning biomass	120,356	121,939	142,029	144,974
$B_{100\%}$	257,697	257,697	283,315	283,315
$B_{40\%}$	103,079	103,079	113,326	113,326
$B_{35\%}$	90,194	90,194	99,160	99,160
F_{OFL}	0.132	0.132	0.139	0.139
$maxF_{ABC}$	0.113	0.113	0.119	0.119
F_{ABC}	0.113	0.113	0.119	0.119
OFL (t)	**22,319**	22,849	**24,360**	24,849
maxABC (t)	19,309	19,764	**21,012**	21,436
ABC (t)	**19,309**	19,764	**21,012**	21,436
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1]Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 17,716 for 2014, and projected catches of 17,665 t and 17,797 t for 2015 and 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Literature Cited

Ainley, D.G., Sydeman, W.J., Parrish, R.H., and Lenarz, W.H. 1993. Oceanic factors influencing distribution of young rockfish (Sebastes) in central California: A predator's perspective. CalCOFI Report 34: 133-139.

Allen, M .J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.

Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-1979. Can. Tech. Rep. Fish. Aquat. Sci. 1048: iv +57 p.

Berkeley, S. A., C. Chapman, and S. M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85(5):1258-1264.

Bobko, S.J. and S.A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish (Sebastes melanops). Fisheries Bulletin 102:418-429.

Brodeur, R. D. 2001. Habitat-specific distribution of Pacific ocean perch (Sebastes alutus) in Pribilof Canyon, Bering Sea. Continent. Shelf Res., 21:207-224.

Byerly, Michael M. 2001. The ecology of age-1 Copper Rockfish (Sebastes caurinus) in vegetated habitats of Sitka sound, Alaska. M.S. thesis. University of Alaska, Fairbanks. Fisheries Division, 11120 Glacier Hwy, Juneau, AK 99801.

Carlson, H. R., and R. E. Haight. 1976. Juvenile life of Pacific ocean perch, *Sebastes alutus*, in coastal fiords of southeastern Alaska: their environment, growth, food habits, and schooling behavior. Trans. Am. Fish. Soc. 105:191-201.

Carlson, H. R., and R. R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.

Carlson, H.R., D.H. Ito, R.E. Haight, T.L. Rutecki, and J.F. Karinen. 1986. Pacific ocean perch. In R.L. Major (editor), Condition of groundfish resources of the Gulf of Alaska region as assessed in 1985, p. 155-209. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-106.

Chilton, D.E. and R.J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Can. Spec. Pub. Fish. Aquat. Sci. 60.

Conrath, C. L. and B. Knoth. 2013. Reproductive biology of Pacific ocean perch in the Gulf of Alaska. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 5: 21-27.

Courtney, D.L., J. Heifetz, M. F. Sigler, and D. M. Clausen. 1999. An age structured model of northern rockfish, *Sebastes polyspinis*, recruitment and biomass in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2000. Pp. 361-404. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Courtney, D.L., J. N. Ianelli, D. Hanselman, and J. Heifetz. 2007. Extending statistical age-structured assessment approaches to Gulf of Alaska rockfish (Sebastes spp.). In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 429–449.

de Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, sebastes aleutianus and S. alutus. Biol. Reprod. 71: 1036-1042.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall, London. 526 pp.

Gharrett, A. J., A.K. Gray, and J. Heifetz. 2001. Identification of rockfish (*Sebastes* spp.) from restriction site analysis of the mitochondrial NM-3/ND-4 and 12S/16S rRNA gene regions. Fish. Bull. 99:49-62.

Gharrett, A. J., Z. Li, C. M. Kondzela, and A. W. Kendall. 2002. Final report: species of rockfish (*Sebastes* spp.) collected during ABL-OCC cruises in the Gulf of Alaska in 1998-2002. (Unpubl. manuscr. available from the NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801.)

Goodman, D., M. Mangel, G. Parkes, T.J. Quinn II, V. Restrepo, T. Smith, and K. Stokes. 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans. Draft report. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Haldorson, L, and M. Love. 1991. Maturity and fecundity in the rockfishes, Sebastes spp., a review. Mar. Fish. Rev. 53(2):25–31.

Hanselman, D.H., S.K. Shotwell, P.J.F. Hulson, J. Heifetz, and J.N. Ianelli. 2012a. Assessment of the Pacific ocean perch stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. pp. 563-592.

Hanselman, D.H., P.D. Spencer, D. McKelvey, and M. Martin. 2012b. Application of an acoustic-trawl survey design to improve rockfish biomass estimates. Fish. Bull. 110: 379-396.

Hanselman, D.H., S.K. Shotwell, P.J.F. Hulson, J. Heifetz, and J.N. Ianelli. 2011. Assessment of the Pacific ocean perch stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. pp. 821-892.

Hanselman, D. H., J. Heifetz, J. Fujioka, and J. N. Ianelli. 2003. Gulf of Alaska Pacific ocean perch. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2004. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D.H., Shotwell, S.K., Hulson, P.J.F., Heifetz, J. and Ianelli, J.N. 2012. Assessment of the Pacific ocean perch stock in the Gulf of Alaska. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. Anchorage, AK, North Pacific Fishery Management Council: 563-592.

Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D.M. Clausen. 2001. Spatial implications of adaptive cluster sampling on Gulf of Alaska rockfish. In Proceedings of the 17th Lowell-Wakefield Symposium: Spatial Processes and Management of Marine Populations, pp. 303-325. Univ. Alaska Sea Grant Program, Fairbanks, AK.

Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D.M. Clausen. 2003. Applications in adaptive cluster sampling of Gulf of Alaska rockfish. Fish. Bull. 101(3): 501-512.

Hanselman, D., P. Spencer, K. Shotwell,and R. Reuter. 2007. Localized depletion of three Alaska rockfish species. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and

Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 493 – 511.

Hanselman, D.H., B. Clark, and M. Sigler. 2013. Report of the groundfish plan team retrospective investigations group, part II: the compilation. Presented at September 2013 Plan Team, 12 pp. http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/Retrospectives_2013_final3.pdf

Heppell, S.S., S.A. Heppell, P. Spencer, W.D. Smith, and L. Arnold. 2009. Assessment of female reproductive effort and maternal effects in Pacific Ocean Perch *Sebastes alutus*: do big old females matter? Project 629 Final Report to the North Pacific Research Board.

Heifetz, J., D. M. Clausen, and J. N. Ianelli. 1994. Slope rockfish. In Stock assessment and fishery evaluation report for the 1995 Gulf of Alaska groundfish fishery, p. 5-1 - 5-24. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Heifetz, J., J. N. Ianelli, D. M. Clausen, D. L. Courtney, and J. T. Fujioka. 2000. Slope rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2001. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hilborn, R., J. Maguire, A. Parma, and A. Rosenberg, A. 2001. The Precautionary Approach and risk management: can they increase the probability of successes in fishery management? Can. J. Fish. Aquat. Sci. 58: 99-107.

Hobson, E.S., J.R. Chess, D.F. Howard. 2001. Interannual variation in predation on first-year Sebastes spp. by three northern California predators. Fish. Bull. 99: 292-302.

Kamin, L. M., K. J. Palof, J. Heifetz, and A.J. Gharrett, A. J. 2013. Interannual and spatial variation in the population genetic composition of young-of-the-year Pacific ocean perch (Sebastes alutus) in the Gulf of Alaska. Fisheries Oceanography. doi: 10.1111/fog.12038.

Karinen, J. F., and B. L. Wing. 1987. Pacific ocean perch. In R. L. Major (editor), Condition of groundfish resources of the Gulf of Alaska region as assessed in 1986, p. 149-157. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-119.

Kendall, A. W., and W. H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. Proc. Int. Rockfish Symp. Oct. 1986, Anchorage Alaska; p. 99-117.

Kendall, A.W., Jr. 2000. An historical review of Sebastes taxonomy and systematics. Mar. Fish. Rev. 62: 1-16.

Krieger, K.J., 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull. 91, 87-96.

Krieger, K.J., and M.F. Sigler. 1996. Catchability coefficient for rockfish estimated from trawl and submersible surveys. Fish. Bull. 94, 282-288.

Leaman, B. M. 1991. Reproductive styles and life history variables relative to exploitation and management of Sebastes stocks. Environmental Biology of Fishes 30: 253-271.

Leaman, B.M. and R.J. Beamish. 1984. Ecological and management implications of longevity in some Northeast Pacific groundfishes. Int. North Pac. Fish. Comm. Bull. 42:85-97.

Li, Z. 2004. Phylogenetic relationships and identification of juveniles of the genus Sebastes. University of Alaska-Fairbanks, School of Fisheries and Ocean Sciences. M.S. thesis.

Longhurst, A., 2002. Murphy's law revisited: longevity as a factor in recruitment to fish populations.. Fish. Res. 56:125-131.

Love, M.S., M.H. Carr, and L.J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus Sebastes. Environmental Biology of Fishes 30:225-243.

Love M.S, M.M. Yoklavich, and L. Thorsteinson 2002. The Rockfishes of the Northeast Pacific. University of California Press, Los Angeles.

Lunsford, C. 1999. Distribution patterns and reproductive aspects of Pacific ocean perch (*Sebastes alutus*) in the Gulf of Alaska. M.S. thesis. University of Alaska Fairbanks, Juneau Center, School of Fisheries and Ocean Sciences.

Malecha, P. W., D. H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfish (Scorpaenidae) from Alaskan waters. NOAA Tech. Memo. NMFS-AFSC-172. 61 p.

Major, R. L., and H. H. Shippen. 1970. Synopsis of biological data on Pacific ocean perch, *Sebastodes alutus*. FAO Fisheries Synopsis No. 79, NOAA Circular 347, 38 p.

Methot, R.D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. INPFC Bull. 50: 259-289.

National Marine Fisheries Service. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. http://www.fakr.noaa.gov/habitat/seis/efheis.htm.

Palof, K.J. 2008. Population genetic structure of Alaskan Pacific ocean perch (*Sebastes alutus*). M.S. thesis, University of Alaska Fairbanks, Fairbanks, Alaska. 65 pp.

Palof, K. J., J. Heifetz, and A. J. Gharrett. 2011. Geographic structure in Alaskan Pacific Ocean perch (*Sebastes alutus*) indicates limited life-time dispersal.Marine Biology 158:779–792.

Pearcy, W. G., D. L. Stein, M. A. Hixon, E. K. Pikitch, W. H. Barss, and R. M. Starr. 1989. Submersible observations of deep-reef fishes of Heceta Bank, Oregon. Fishery Bulletin 87:955-965.

Quinn II, T.J., D. Hanselman, D.M. Clausen, J. Heifetz, and C. Lunsford. 1999. Adaptive cluster sampling of rockfish populations. Proceedings of the American Statistical Association 1999 Joint Statistical Meetings, Biometrics Section, 11-20.

Rooper, C.N. and J.L. Boldt. 2005. Distribution of juvenile Pacific ocean perch *Sebastes alutus* in the Aleutian Islands in Relation to Benthic Habitat. Alaska Fishery Research Bulletin 11(2):102-112.

Schnute, J.T., R. Haigh, B.A. Krishka, and P. Starr. 2001. Pacific ocean perch assessment for the west coast of Canada in 2001. Canadian research document 2001/138. 90 pp.

Seeb, L. W. and D.R. Gunderson. 1988. Genetic variation and population structure of Pacific ocean perch (*Sebastes alutus*). Can. J. Fish. Aquat. Sci. 45:78-88.

Seeb, L. W., and A. W. Kendall, Jr. 1991. Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus Sebastes. Environmental Biology of Fishes 30:191-201.

Spencer, P., Hanselman, D. and Dorn, M. 2007. The effect of maternal age of spawning on estimation of Fmsy for Alaska Pacific ocean perch. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 513 – 533.

Spencer, P., D.H. Hanselman, and D. McKelvey. 2012. Simulation modeling of a trawl-acoustic survey design for patchily distributed species. Fish. Res. 126: 289-299.

Withler, R.E., T.D. Beacham, A.D. Schulze, L.J. Richards, and K.M. Miller. 2001. Co-existing populations of Pacific ocean perch, *Sebastes alutus*, in Queen Charlotte Sound, British Columbia. Mar. Bio. 139: 1-12.

Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60, 105 p.

Yang, M.S. 2003. Food habits of the important groundfishes of the Aleutian Islands in 1994 and 1997. National Marine Fisheries Service. AFSC Processed report 2003-07: 233 pp.

Yang, M.-S., and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

Tables

Table 9-1. Management measures since the break out of Pacific ocean perch from slope rockfish are outlined in the following table:

Year	Catch (t)	ABC	TAC	OFL	Management Measures
1988	1,621	16,800	16,800		The slope rockfish assemblage, including POP, was one of three management groups for *Sebastes* implemented by the North Pacific Management Council. Previously, *Sebastes* in Alaska were managed as "Pacific ocean perch complex" or "other rockfish"
1989	19,003	20,000	20,000		
1990	21,140	17,700	17,700		
1991	6,542	5,800			Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992	6,538	5,730	5,200		
1993	2,060	3,378	2,560		
1994	1,841	3,030	2,550	3,940	Amendment 32 establishes rebuilding plan Assessment done with an age structured model using stock synthesis
1995	5,741	6,530	5,630	8,232	
1996	8,378	8,060	6,959	10,165	
1997	9,519	12,990	9,190	19,760	
1998	8,908	12,820	10,776	18,090	
1999	10,473	13,120	12,590	18,490	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	10,146	13,020	13,020	15,390	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	10,817	13,510	13,510	15,960	Assessment is now done using an age structured model constructed with AD Model Builder software
2002	11,734	13,190	13,190	15,670	
2003	10,847	13,663	13,660	16,240	
2004	11,640	13,336	13,340	15,840	
2005	11,248	13,575	13,575	16,266	
2006	13,595	14,261	14,261	16,927	
2007	12,954	14,636	14,636	17,158	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	12,461	14,999	14,999	17,807	
2009	12,736	15,111	15,111	17,940	
2010	15,616	17,584	17,584	20,243	
2011	14,213	16,997	16,997	19,566	
2012	14,912	16,918	16,918	19,498	
2013	13,183	16,412	16,412	18,919	Area OFL for W/C/WYK combined, SEO separate
2014	14,863	19,309	19,309	22,319	

Table 9-2. Commercial catch[a] (t) of fish of Pacific ocean perch in the Gulf of Alaska, with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1977-2013.

		Regulatory Area		Gulf-wide		Gulf-wide value	
Year	Fishery	Western	Central	Eastern	Total	ABC	Quota
1977	Foreign	6,282	6,166	10,993	23,441		
	U.S.	0	0	12	12		
	JV	-	-	-	-		
	Total	6,282	6,166	11,005	23,453	50,000	30,000
1978	Foreign	3,643	2,024	2,504	8,171		
	U.S.	0	0	5	5		
	JV	-	-	-	-		
	Total	3,643	2,024	2,509	8,176	50,000	25,000
1979	Foreign	944	2,371	6,434	9,749		
	U.S.	0	99	6	105		
	JV	1	31	35	67		
	Total	945	2,501	6,475	9,921	50,000	25,000
1980	Foreign	841	3,990	7,616	12,447		
	U.S.	0	2	2	4		
	JV	0	20	0	20		
	Total	841	4,012	7,618	12,471	50,000	25,000
1981	Foreign	1,233	4,268	6,675	12,176		
	U.S.	0	7	0	7		
	JV	1	0	0	1		
	Total	1,234	4,275	6,675	12,184	50,000	25,000
1982	Foreign	1,746	6,223	17	7,986		
	U.S.	0	2	0	2		
	JV	0	3	0	3		
	Total	1,746	6,228	17	7,991	50,000	11,475
1983	Foreign	671	4,726	18	5,415		
	U.S.	7	8	0	15		
	JV	1,934	41	0	1,975		
	Total	2,612	4,775	18	7,405	50,000	11,475
1984	Foreign	214	2,385	0	2,599		
	U.S.	116	0	3	119		
	JV	1,441	293	0	1,734		
	Total	1,771	2,678	3	4,452	50,000	11,475
1985	Foreign	6	2	0	8		
	U.S.	631	13	181	825		
	JV	211	43	0	254		
	Total	848	58	181	1,087	11,474	6,083
1986	Foreign	Tr	Tr	0	Tr		
	U.S.	642	394	1,908	2,944		
	JV	35	2	0	37		
	Total	677	396	1,908	2,981	10,500	3,702
1987	Foreign	0	0	0	0		
	U.S.	1,347	1,434	2,088	4,869		
	JV	108	4	0	112		
	Total	1,455	1,438	2,088	4,981	10,500	5,000
1988	Foreign	0	0	0	0		
	U.S.	2,586	6,467	4,718	13,771		
	JV	4	5	0	8		
	Total	2,590	6,471	4,718	13,779	16,800	16,800

Table 9-2. (continued)

		Regulatory Area				Gulf-wide value	
Year	Fishery	Western	Central	Eastern[1]	Total	ABC	Quota
1989	U.S.	4,339	8,315	6,348	19,003	20,000	20,000
1990	U.S.	5,203	9,973	5,938	21,140	17,700	17,700
1991	U.S.	1,758	2,638	2,147	6,542	5,800	5,800
1992	U.S.	1,316	2,994	2,228	6,538	5,730	5,200
1993	U.S.	477	1,140	443	2,060	3,378	2,560
1994	U.S.	166	909	767	1,841	3,030	2,550
1995	U.S.	1,422	2,597	1,721	5,741	6,530	5,630
1996	U.S.	987	5,145	2,247	8,378	8,060	6,959
1997	U.S.	1,832	6,709	978	9,519	12,990	9,190
1998	U.S.	846	8,062	Conf.	8,908	12,820	10,776
1999	U.S.	1,935	7,911	627	10,473	13,120	12,590
2000	U.S.	1,160	8,986	Conf.	10,146	13,020	13,020
2001	U.S.	945	9,872	Conf.	10,817	13,510	13,510
2002	U.S.	2,723	9,011	Conf.	11,734	13,190	13,190
2003	U.S.	2,124	8,117	606	10,847	13,663	13,660
2004	U.S.	2,196	8,567	877	11,640	13,336	13,340
2005	U.S.	2,338	8,064	846	11,248	13,575	13,580
2006	U.S.	4,051	8,285	1,259	13,595	14,261	14,261
2007	U.S.	4,430	7,282	1,242	12,954	14,636	14,635
2008	U.S.	3,679	7,682	1,100	12,461	14,999	14,999
2009	U.S.	3,141	10,550	1,926	12,736	15,111	15,111
2010	U.S.	3,682	7,677	1,040	15,616	17,584	17,584
2011	U.S.	1,819	10,523	1,871	14,213	16,997	16,997
2012	U.S.	2,452	10,777	1,683	14,912	16,918	16,918
2013	U.S.	447	11,199	1,537	13,183	16,412	16,412

Note: There were no foreign or joint venture catches after 1988. Catches prior to 1989 are landed catches only. Catches in 1989 and 1990 also include fish reported in weekly production reports as discarded by processors. Catches in 1991-2013 also include discarded fish, as determined through a "blend" of weekly production reports and information from the domestic observer program.

Definitions of terms: JV = Joint venture; Tr = Trace catches;

[a]Catch defined as follows: 1977, all Sebastes rockfish for Japanese catch, and Pacific ocean perch for catches of other nations; 1978, Pacific ocean perch only; 1979-87, the 5 species comprising the Pacific ocean perch complex; 1988-2013, Pacific ocean perch.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2013 total allowable catch.

Sources: Catch: 1977-84, Carlson et al. (1986); 1985-88, Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 S.W. 5th Avenue, Portland, OR 97201; 1989-2005, National Marine Fisheries Service, Alaska Region, P.O. Box 21668, Juneau, AK 99802. ABC and Quota: 1977-1986 Karinen and Wing (1987); 1987-1990, Heifetz et al. (2000); 1991-2013, NMFS AKRO BLEND/Catch Accounting System via AKFIN database.

Table 9-3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2008-2014. Conf. = Confidential because of less than three vessels or processors. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/28/2014.

	Estimated Catch (t)						
Group Name	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Pacific Ocean Perch	12135	12397	14974	13120	13953	11555	12972
Northern Rockfish	3805	3855	3833	3163	4883	4527	2784
Dusky Rockfish	-	-	-	-	3642	2870	2606
Pelagic Shelf Rockfish	3521	2956	2966	2324	-	-	-
Arrowtooth Flounder	517	497	706	340	764	766	1255
Pollock	390	1280	1046	813	574	829	856
Other Rockfish	632	736	737	657	889	488	626
Sablefish	503	404	388	440	470	495	484
Pacific Cod	445	631	734	560	404	584	441
Rougheye/Blackspotted Rockfish	104	97	180	286	219	274	348
Atka Mackerel	1744	1913	2148	1404	1173	1162	257
Shortraker Rockfish	231	247	133	239	303	290	198
Thornyhead Rockfish	248	177	106	161	130	104	187
Rex Sole	67	83	93	51	72	89	69
Deep Water Flatfish	29	30	48	57	54	37	68
Demersal Shelf Rockfish	45	77	34	27	111	136	38
Sculpin	-	-	-	39	55	70	28
Skate, Other	10	13	28	14	20	18	23
Skate, Longnose	12	17	12	25	23	23	21
Shallow Water Flatfish	71	53	47	48	65	27	17
Flathead Sole	19	32	24	13	16	26	16
Squid	-	-	-	12	15	10	16
Octopus	-	-	-	1	1	2	5
Skate, Big	4	4	14	8	13	2	3
Shark	-	-	-	5	5	93	1

Table 9-4 . Catch (t) of GOA Pacific ocean perch as bycatch in other fisheries from 2008-2014. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/28/2014.

Target	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Average**
Arrowtooth Flounder	163	76	83	566	496	424	1318	447
Rex Sole	79	420	359	291	92	714	423	340
Pollock - midwater	37	4	24	48	224	133	285	108
Pollock - bottom	13	16	72	124	70	294	121	102
Pacific Cod	17	43	9	20	53	12	15	24
Shallow Water Flatfish	2	3	0	2	3	20	11	6
Flathead Sole	2	2	74	2	2	19	6	15
Sablefish	13	26	19	17	17	8	2	15
Deep Water Flatfish	-	-	-	-	-	1	1	1

Table 9-5. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2008 - 2014. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/28/2014.

Species Group Name	2008	2009	2010	2011	2012	2013	2014
Giant Grenadier	160.97	224.36	476.28	418.90	347.85	968.44	601.55
Misc fish	195.62	134.75	167.10	133.25	156.73	163.97	124.27
Dark Rockfish	17.86	46.98	112.04	12.82	59.03	42.16	13.35
Grenadier	2.82	3.11	34.94	110.49	89.67	39.11	6.33
Scypho jellies	0.11	0.70	1.87	0.00	0.16	0.50	6.05
Greenlings	14.73	8.10	9.52	7.91	9.05	7.25	2.96
Sea star	1.15	1.78	1.38	1.53	0.98	0.97	1.42
Sea anemone unidentified	0.69	3.24	1.56	4.10	6.33	4.20	1.11
Sponge unidentified	2.97	6.65	3.66	4.41	1.39	1.34	1.04
urchins dollars cucumbers	0.26	0.49	0.22	0.44	0.31	0.30	0.18
Corals Bryozoans	0.47	0.32	0.42	0.38	0.59	0.20	0.13
Pandalid shrimp	0.11	0.09	0.22	0.06	0.06	0.06	0.10
Eelpouts	0.35	0.00	0.05	Conf.	0.30	0.04	0.10
Sea pens whips	Conf.	0.01	0.01	0.04	-	0.05	0.07
Benthic urochordata	0.27	Conf.	0.08	Conf.	Conf.	Conf.	0.07
Snails	0.18	10.63	0.20	0.23	1.26	0.20	0.07
Brittle star unidentified	0.04	0.03	0.02	0.01	0.03	0.03	0.05
Hermit crab unidentified	0.01	0.01	0.01	0.02	Conf.	0.03	0.04
Misc crabs	0.07	0.10	0.07	0.04	0.05	0.01	0.04
Stichaeidae	-	0.01	-	-	-	Conf.	0.00
Invertebrate unidentified	0.23	0.30	5.05	0.36	3.86	0.18	0.00
Bivalves	0.00	Conf.	0.01	0.01	0.01	Conf.	Conf.
Eulachon	0.01	0.03	0.00	0.00	0.01	0.10	Conf.
Misc crustaceans	-	0.10	0.02	Conf.	-	Conf.	Conf.
Other osmerids	Conf.	0.16	0.00	-	Conf.	0.02	Conf.
Birds	Conf.	-	-	Conf.	Conf.	-	-
Capelin	-	0.00	-	-	-	0.02	-
Lanternfishes (myctophidae)	-	0.00	Conf.	-	-	Conf.	-
Misc deep fish	0.00	-	-	-	-	Conf.	-
Misc inverts (worms etc)	0.01	Conf.	-	Conf.	-	-	-
Pacific Sand lance	-	-	-	Conf.	-	-	-
Polychaete unidentified	-	-	-	-	-	Conf.	-

Table 9-6. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN 10/28/2014.

Species Group Name	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**Average**
Halibut	159	109	141	108	109	113	123
Chinook Salmon	2.28	1.39	1.57	1.02	1.60	2.32	1.70
Non-Chinook Salmon	0.50	0.47	0.37	0.21	0.31	2.02	0.65
Golden (Brown) King Crab	0.34	3.28	3.00	0.13	0.11	0.10	1.16
Bairdi Tanner Crab	0.06	0.24	0.10	0.03	0.09	0.07	0.10
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Herring	0.04	0.00	0.15	0.00	0.00	0.00	0.03
Opilio Tanner (Snow) Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 9-7. Fishery length frequency data for Pacific ocean perch in the Gulf of Alaska.

Length (cm)	Year 1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
12	0	0	0	0	0	0	0	0	0	0
13-15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0.001	0	0.001	0	0	0	0.001	0.001	0.001
21	0	0	0.001	0.001	0.001	0.001	0	0.001	0.001	0.001
22	0	0	0	0.002	0.001	0.001	0.001	0.002	0.001	0.002
23	0	0.001	0.001	0.001	0.002	0.001	0.001	0.003	0.001	0.003
24	0.001	0.003	0.001	0.001	0.002	0.001	0.002	0.002	0.003	0.004
25	0.002	0.003	0.002	0.002	0.006	0.002	0.003	0.004	0.003	0.004
26	0.003	0.004	0.004	0.002	0.006	0.002	0.004	0.006	0.005	0.006
27	0.002	0.004	0.007	0.003	0.006	0.004	0.003	0.005	0.007	0.009
28	0.003	0.004	0.007	0.005	0.007	0.007	0.006	0.01	0.01	0.009
29	0.005	0.008	0.01	0.007	0.008	0.008	0.014	0.011	0.015	0.014
30	0.005	0.006	0.009	0.01	0.009	0.008	0.018	0.018	0.022	0.015
31	0.008	0.009	0.014	0.012	0.011	0.012	0.013	0.026	0.03	0.026
32	0.012	0.015	0.014	0.018	0.019	0.015	0.018	0.035	0.057	0.041
33	0.021	0.032	0.023	0.033	0.038	0.024	0.026	0.045	0.075	0.068
34	0.053	0.068	0.057	0.052	0.067	0.057	0.042	0.063	0.091	0.099
35-38	0.64	0.583	0.581	0.556	0.503	0.519	0.514	0.495	0.425	0.475
>38	0.24	0.257	0.268	0.292	0.315	0.337	0.333	0.273	0.255	0.226
Total	18,724	5,126	7,027	5,750	6,156	7,112	6,140	5,563	6,094	9,784

Length (cm)	Year 2008	2009	2010	2011	2012	2013	2014
12	0	0	0	0	0	0	0
13-15	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0.001	0	0	0
19	0	0.001	0	0.001	0	0	0.001
20	0	0	0.002	0.001	0.001	0.001	0.001
21	0	0	0.001	0.001	0.003	0	0.002
22	0.001	0.001	0.003	0.001	0.005	0.001	0.003
23	0.002	0	0.005	0.002	0.008	0.003	0.003
24	0.002	0.001	0.004	0.002	0.008	0.004	0.003
25	0.003	0.002	0.003	0.003	0.010	0.008	0.002
26	0.003	0.003	0.003	0.003	0.015	0.013	0.002
27	0.003	0.005	0.004	0.003	0.014	0.014	0.003
28	0.008	0.006	0.005	0.005	0.010	0.015	0.004
29	0.012	0.008	0.006	0.007	0.009	0.019	0.007
30	0.016	0.013	0.008	0.010	0.009	0.020	0.011
31	0.025	0.023	0.014	0.012	0.012	0.022	0.015
32	0.04	0.042	0.025	0.020	0.021	0.014	0.019
33	0.063	0.071	0.042	0.033	0.031	0.017	0.024
34	0.093	0.099	0.074	0.060	0.051	0.032	0.043
35-38	0.473	0.498	0.551	0.551	0.521	0.328	0.343
>38	0.255	0.227	0.248	0.284	0.271	0.487	0.513
Total	8,154	8,898	11,174	9,800	12,882	10,767	10,427

Table 9-8. Fishery age compositions for GOA Pacific ocean perch 1999-2012.

Age Class	1999	2000	2001	2002	2004	2005	2006	2008	2010	2012
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000
4	0.000	0.005	0.004	0.003	0.002	0.001	0.001	0.005	0.013	0.018
5	0.003	0.015	0.002	0.014	0.007	0.012	0.003	0.005	0.005	0.026
6	0.016	0.037	0.017	0.016	0.051	0.021	0.045	0.021	0.013	0.020
7	0.024	0.026	0.040	0.035	0.040	0.085	0.089	0.031	0.019	0.023
8	0.029	0.056	0.029	0.097	0.049	0.085	0.114	0.102	0.070	0.028
9	0.043	0.064	0.058	0.078	0.166	0.103	0.108	0.103	0.071	0.046
10	0.051	0.057	0.060	0.108	0.177	0.142	0.084	0.161	0.120	0.092
11	0.178	0.054	0.060	0.105	0.067	0.114	0.106	0.108	0.149	0.105
12	0.191	0.132	0.063	0.051	0.075	0.074	0.087	0.048	0.122	0.116
13	0.130	0.127	0.131	0.070	0.069	0.047	0.061	0.090	0.074	0.093
14	0.088	0.110	0.146	0.108	0.036	0.044	0.037	0.051	0.057	0.093
15	0.120	0.104	0.084	0.086	0.036	0.021	0.035	0.043	0.051	0.051
16	0.061	0.060	0.092	0.065	0.049	0.032	0.026	0.023	0.041	0.045
17	0.021	0.052	0.061	0.054	0.050	0.050	0.027	0.026	0.040	0.049
18	0.019	0.031	0.071	0.038	0.041	0.041	0.035	0.011	0.021	0.033
19	0.003	0.025	0.040	0.035	0.030	0.032	0.038	0.026	0.014	0.025
20	0.003	0.008	0.015	0.011	0.021	0.026	0.027	0.028	0.014	0.021
21	0.000	0.010	0.012	0.003	0.009	0.028	0.025	0.026	0.016	0.015
22	0.008	0.011	0.002	0.005	0.007	0.011	0.010	0.026	0.032	0.016
23	0.003	0.004	0.006	0.003	0.005	0.008	0.015	0.020	0.011	0.011
24	0.000	0.001	0.000	0.003	0.006	0.007	0.010	0.015	0.006	0.006
25+	0.011	0.011	0.006	0.011	0.006	0.015	0.016	0.030	0.041	0.068
Sample size	376	734	521	370	802	727	734	609	631	1024

Table 9-9. Biomass estimates (t) and Gulf-wide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984-2013 trawl surveys. (Biomass estimates and confidence intervals have been slightly revised from those listed in previous SAFE reports for Pacific ocean perch.)

	Western	**Central**		**Eastern**		**95 % Conf. Intervals**			
Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total	Lower CI	Upper CI	CV
1984	60,666	9,584	39,766	76,601	34,055	220,672	110,732	330,613	25%
1987	64,403	19,440	56,820	47,269	53,274	241,206	133,712	348,699	23%
1990	24,543	15,309	15,765	53,337	48,341	157,295	64,922	249,669	30%
1993	75,416	103,224	153,262	50,048	101,532	483,482	270,548	696,416	22%
1996	92,618	140,479	326,281	50,394	161,641	771,413	372,447	1,170,378	26%
1999	37,980	402,293	209,675	32,749	44,367	727,064	-	1,488,653	53%
2001*	275,211	39,819	358,126	44,397	102,514	820,066	364,576	1,275,556	27%
2003	72,851	116,278	166,795	27,762	73,737	457,422	316,273	598,570	16%
2005	250,912	75,433	300,153	77,682	62,239	766,418	479,078	1,053,758	19%
2007	158,100	77,002	301,712	52,569	98,798	688,180	464,402	911,957	17%
2009	31,739	209,756	247,737	97,188	63,029	649,449	418,638	880,260	18%
2011	99,406	197,357	340,881	68,339	72,687	778,670	513,078	1,044,262	17%
2013	157,457	291,763	594,675	179,862	74,686	1,298,443	879,952	1,716,934	16%

*The 2001 survey did not sample the eastern Gulf of Alaska (the Yakutat and Southeastern areas). Substitute estimates of biomass for the Yakutat and Southeastern areas were obtained by averaging the biomass estimates for Pacific ocean perch in these areas in the 1993, 1996, and 1999 surveys, that portion of the variance was obtained by using a weighted average of the three prior surveys' variance.

Table 9-10. Survey age composition (% frequency) data for Pacific ocean perch in the Gulf of Alaska. Age compositions for are based on "break and burn" reading of otoliths.

Age	1984	1987	1990	1993	1996	1999	2003	2005	2007	2009	2011
2	0.003	0.019	0.005	0.006	0.006	0.006	0.016	0.001	0.003	0.005	0.001
3	0.002	0.101	0.043	0.018	0.016	0.020	0.057	0.034	0.020	0.087	0.030
4	0.058	0.092	0.155	0.021	0.036	0.045	0.053	0.050	0.018	0.044	0.046
5	0.029	0.066	0.124	0.044	0.043	0.052	0.071	0.077	0.044	0.049	0.124
6	0.079	0.091	0.117	0.088	0.063	0.026	0.040	0.073	0.041	0.025	0.042
7	0.151	0.146	0.089	0.125	0.038	0.041	0.054	0.119	0.056	0.096	0.036
8	0.399	0.056	0.065	0.129	0.088	0.059	0.107	0.069	0.089	0.065	0.024
9	0.050	0.061	0.054	0.166	0.145	0.095	0.115	0.087	0.125	0.106	0.071
10	0.026	0.087	0.055	0.092	0.185	0.054	0.057	0.092	0.094	0.047	0.073
11	0.010	0.096	0.036	0.045	0.110	0.114	0.053	0.063	0.063	0.053	0.105
12	0.016	0.018	0.024	0.052	0.080	0.144	0.044	0.035	0.064	0.079	0.073
13	0.015	0.011	0.028	0.038	0.034	0.086	0.036	0.027	0.050	0.035	0.065
14	0.019	0.011	0.072	0.025	0.036	0.067	0.057	0.031	0.030	0.039	0.047
15	0.005	0.009	0.017	0.026	0.028	0.046	0.048	0.039	0.026	0.047	0.037
16	0.003	0.011	0.011	0.011	0.006	0.040	0.042	0.022	0.013	0.013	0.024
17	0.008	0.013	0.005	0.036	0.013	0.023	0.032	0.027	0.018	0.006	0.015
18	0.004	0.007	0.008	0.007	0.009	0.013	0.029	0.036	0.039	0.015	0.024
19	0.002	0.005	0.004	0.003	0.014	0.003	0.016	0.024	0.028	0.005	0.024
20	0.000	0.005	0.006	0.002	0.013	0.012	0.015	0.021	0.043	0.012	0.023
21	0.003	0.004	0.004	0.002	0.003	0.007	0.010	0.013	0.024	0.032	0.018
22	0.003	0.003	0.002	0.004	0.004	0.008	0.005	0.018	0.022	0.062	0.009
23	0.002	0.002	0.002	0.002	0.003	0.012	0.006	0.004	0.016	0.013	0.018
24	0.003	0.002	0.006	0.004	0.000	0.004	0.007	0.008	0.018	0.022	0.019
25+	0.110	0.083	0.070	0.054	0.027	0.025	0.031	0.030	0.055	0.043	0.053
Total	1428	1824	1754	1378	641	898	985	1009	1177	418	794

Table 9-11. Estimated numbers (thousands) in 2014, fishery selectivity, and survey selectivity of Pacific ocean perch in the Gulf of Alaska. Also shown are schedules of age specific weight and female maturity.

Age	Numbers in 2014 (1000's)	Maturity (%)	Weight (g)	Fishery selectivity (%)	Survey selectivity (%)
2	49,318	0.7	42	0.0	4.5
3	46,456	1.3	91	0.0	11.0
4	43,995	2.5	155	0.2	24.6
5	39,662	4.7	227	1.6	46.3
6	41,681	8.8	304	6.1	69.5
7	43,845	15.8	381	15.3	85.8
8	168,021	26.9	455	29.9	94.1
9	33,210	41.8	525	48.3	97.7
10	24,581	58.4	589	67.4	99.1
11	20,181	73.3	647	83.9	99.7
12	21,428	84.3	698	95.2	99.9
13	21,620	91.3	744	100.0	100.0
14	24,033	95.3	784	98.5	100.0
15	45,394	97.6	818	91.9	100.0
16	20,517	98.7	849	81.8	100.0
17	12,546	99.3	875	69.9	100.0
18	13,329	99.7	897	57.6	100.0
19	18,836	99.8	916	46.0	100.0
20	9,330	99.9	932	35.6	100.0
21	6,336	100.0	946	27.0	100.0
22	5,348	100.0	958	19.9	100.0
23	4,838	100.0	968	14.4	100.0
24	4,809	100.0	977	10.2	100.0
25+	71,910	100.0	1004	7.1	100.0

Table 9-12. Summary of results from 2014 compared with 2013 results

	2013	**2014 base**	**2014 recommended**
Likelihoods			
Catch	0.12	0.12	0.12
Survey Biomass	10.06	10.09	10.26
Fishery Ages	26.99	27.02	27.06
Survey Ages	47.59	47.68	47.67
Fishery Sizes	55.71	55.76	54.28
Maturity	n/a	n/a	103.52
Data-Likelihood	140.5	140.7	242.91
Penalties/Priors			
Recruitment Devs	23.28	22.77	22.18
F Regularity	4.15	4.16	4.25
σ_r prior	4.76	4.93	5.03
q prior	1.36	1.34	1.21
M prior	2.00	2.05	2.15
Objective Fun Total	176.0	175.9	277.7
Parameter Ests.			
Active parameters	142	144	146
q	2.09	2.08	2.00
M	0.061	0.061	0.062
σ_r	0.92	0.91	0.90
Mean Recruitment (millions)	46.36	46.75	49.32
$F_{40\%}$	0.113	0.113	0.119
Total Biomass	410,712	406,112	416,140
$B_{CURRENT}$	120,356	121,599	142,029
$B_{100\%}$	257,697	255,708	283,315
$\mathbf{B_{40\%}}$	103,079	102,283	113,326
maxABC	19,309	19,661	**21,012**
$F_{35\%}$	0.132	0.132	0.139
$OFL_{F35\%}$	19,764	22,730	**24,360**

Table 9-13. Estimates of key parameters with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ(MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations.

Parameter	μ	μ (MCMC)	Median (MCMC)	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	2.003	1.903	1.860	0.483	0.482	1.096	2.949
M	0.062	0.063	0.062	0.006	0.006	0.052	0.075
$F_{40\%}$	0.119	0.132	0.128	0.028	0.033	0.081	0.209
2014 SSB	142,029	161,723	155,085	39,749	47,604	88,395	270,182
2014 ABC	21,012	25,849	24,131	7,725	10,561	10,060	51,295

Table 9-14. Estimated time series of female spawning biomass, 6+ biomass (age 6 and greater), catch/6 + biomass, and number of age two recruits for Pacific ocean perch in the Gulf of Alaska. Estimates are shown for the current assessment and from the previous SAFE.

	Spawning biomass (t)		6+ Biomass (t)		Catch/6+ biomass		Age 2 recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	27,585	32,872	93,797	94,879	0.229	0.227	17,282	18,820
1978	22,980	27,427	76,923	78,461	0.104	0.102	30,977	33,426
1979	22,669	27,039	73,310	75,301	0.114	0.111	54,603	59,379
1980	21,908	26,220	69,205	71,618	0.157	0.152	22,095	24,265
1981	19,829	23,990	63,185	65,909	0.168	0.161	18,347	20,104
1982	17,598	21,720	61,212	64,013	0.089	0.085	23,382	25,623
1983	17,493	21,849	71,566	74,359	0.040	0.038	26,625	29,303
1984	19,036	23,542	77,350	80,652	0.036	0.034	28,600	31,205
1985	20,815	25,991	81,946	85,860	0.010	0.009	45,072	47,698
1986	23,636	29,892	89,474	94,025	0.025	0.024	58,464	62,204
1987	26,450	33,679	96,154	101,375	0.047	0.045	44,613	49,982
1988	28,738	36,581	100,851	106,678	0.085	0.081	217,676	235,995
1989	29,459	37,647	105,712	111,647	0.113	0.107	66,294	58,052
1990	28,935	37,360	111,364	117,233	0.118	0.112	45,787	44,411
1991	28,305	37,196	113,157	119,805	0.058	0.055	40,462	43,268
1992	30,252	40,989	168,157	173,688	0.039	0.038	36,239	39,043
1993	36,055	46,788	189,965	193,393	0.011	0.011	34,717	37,125
1994	43,817	56,578	210,155	213,498	0.009	0.009	35,966	38,478
1995	53,077	68,622	227,268	231,740	0.025	0.025	39,240	42,353
1996	62,238	80,151	237,113	242,963	0.035	0.035	54,634	57,344
1997	70,871	89,560	241,798	248,970	0.039	0.038	99,952	105,296
1998	78,071	96,239	243,937	252,321	0.037	0.035	62,162	67,019
1999	83,542	100,883	246,287	255,829	0.043	0.041	52,189	56,122
2000	86,781	103,137	250,293	260,333	0.041	0.039	75,574	80,845
2001	88,792	104,702	266,813	276,525	0.041	0.039	149,929	156,280
2002	90,508	105,956	274,475	284,964	0.043	0.041	67,591	71,913
2003	91,575	107,436	278,379	289,777	0.039	0.037	53,094	56,160
2004	93,242	110,457	288,908	300,885	0.040	0.039	45,761	48,503
2005	95,623	114,271	318,916	329,585	0.035	0.034	37,571	40,164
2006	100,183	119,152	330,581	342,081	0.041	0.040	40,587	43,583
2007	104,120	123,774	334,968	347,558	0.039	0.037	49,172	53,275
2008	108,366	129,172	336,454	350,298	0.037	0.036	249,793	247,509
2009	112,814	134,664	334,567	349,807	0.039	0.037	56,816	60,006
2010	116,586	138,931	331,212	347,682	0.047	0.045	50,656	53,389
2011	118,372	140,821	326,607	344,277	0.043	0.041	44,992	47,712
2012	119,111	141,890	376,194	387,212	0.040	0.038	46,839	49,756
2013	118,145	142,586	381,472	392,662	0.032	0.034	46,457	49,404
2014		139,765		396,767		0.045		49,318

Table 9-15. Estimated time series of recruitment, female spawning biomass, and total biomass (2+) for Pacific ocean perch in the Gulf of Alaska. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC estimated posterior distribution.

	Recruits (age-2)			Total Biomass			Spawning Biomass		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	18,820	4,232	56,040	102,090	84,508	144,602	32,872	25,660	48,701
1978	33,426	6,878	101,406	86,393	68,985	129,994	27,427	20,160	43,438
1979	59,379	10,983	140,510	86,105	67,999	131,556	27,039	19,699	43,515
1980	24,265	5,232	76,617	85,829	67,164	135,468	26,220	18,888	43,208
1981	20,104	4,582	59,751	83,249	63,345	136,825	23,990	16,620	41,658
1982	25,623	5,243	69,829	81,327	59,771	139,671	21,720	14,392	39,888
1983	29,303	6,024	81,314	85,103	62,111	146,923	21,849	14,390	40,920
1984	31,205	6,497	91,829	91,759	67,082	157,964	23,542	15,762	43,658
1985	47,698	8,384	137,261	99,365	73,133	170,917	25,991	17,763	47,534
1986	62,204	10,235	173,681	110,501	82,235	188,276	29,892	20,918	53,523
1987	49,982	8,084	232,746	121,195	90,784	207,281	33,679	23,923	59,548
1988	235,990	18,398	470,276	138,309	103,104	236,262	36,581	25,996	64,558
1989	58,052	9,607	271,567	152,824	112,081	265,408	37,647	26,238	67,660
1990	44,411	7,145	145,902	165,744	119,389	293,239	37,360	25,284	69,597
1991	43,268	6,728	131,593	177,913	125,639	321,707	37,196	23,986	72,422
1992	39,043	6,773	116,890	196,054	138,847	352,623	40,989	26,251	79,881
1993	37,125	6,777	113,788	212,585	150,212	381,576	46,788	30,248	90,374
1994	38,478	6,554	123,838	231,793	165,167	410,222	56,578	37,884	106,571
1995	42,353	6,956	141,835	249,251	178,772	436,839	68,622	46,873	125,708
1996	57,344	8,509	196,514	261,252	187,539	456,576	80,151	55,195	145,893
1997	105,300	12,555	275,306	271,325	193,261	475,559	89,560	61,597	162,539
1998	67,019	9,185	252,806	279,961	198,862	493,102	96,239	65,940	174,708
1999	56,122	8,331	217,527	289,132	204,661	510,361	100,883	68,725	182,529
2000	80,845	9,018	308,661	297,568	211,055	527,237	103,137	69,808	188,071
2001	156,280	13,766	393,803	310,294	218,476	550,964	104,702	70,516	191,770
2002	71,913	10,367	294,507	322,981	227,249	577,693	105,956	71,073	194,363
2003	56,160	8,336	193,431	334,912	235,052	602,041	107,436	71,311	197,598
2004	48,503	7,865	164,266	347,081	243,619	625,294	110,457	73,045	203,847
2005	40,163	6,302	143,141	356,677	249,114	644,380	114,271	75,390	212,180
2006	43,583	7,435	163,654	364,579	253,408	658,493	119,152	78,532	220,310
2007	53,275	8,380	267,197	368,164	254,892	666,771	123,774	81,126	231,273
2008	247,510	15,288	667,117	378,723	259,080	684,123	129,172	84,678	242,200
2009	60,006	8,925	387,495	388,987	265,588	700,981	134,664	88,197	252,172
2010	53,389	7,655	270,694	398,943	271,512	715,009	138,931	90,786	260,028
2011	47,712	6,882	223,097	405,820	274,250	732,783	140,821	90,349	266,214
2012	49,756	7,112	271,787	412,006	277,798	752,097	141,890	90,715	268,729
2013	49,404	6,626	256,720	415,589	277,488	767,744	142,586	90,654	271,659
2014	49,318	6,987	260,266	418,867	278,973	781,772	139,765	87,682	267,460
2015	61,430	7,228	292,041	416,140	272,721	789,332	142,029	88,395	270,182
2016	61,430	6,822	305,980	412,351			144,974	91,310	270,084

Table 9-16. Set of projections of spawning biomass and yield for Pacific ocean perch in the Gulf of Alaska. This set of projections encompasses six harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see ***Projections and Harvest Alternatives***. All units in t. $B_{40\%}$ = 113,326 t, $B_{35\%}$ = 99,160 t, $F_{40\%}$ = 0.119, and $F_{35\%}$ = 0.139.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2014	139,766	139,766	139,766	139,766	139,766	139,766	139,766
2015	141,569	142,029	142,972	142,360	144,396	141,105	141,569
2016	143,096	144,974	148,806	146,287	154,846	141,259	143,096
2017	143,592	146,442	153,772	149,230	164,985	140,403	143,110
2018	142,223	144,956	156,858	150,255	173,655	137,762	140,322
2019	139,335	141,893	158,112	149,545	180,577	133,767	136,131
2020	135,825	138,183	158,222	147,893	186,131	129,359	131,512
2021	132,386	134,541	157,823	145,976	190,753	125,223	127,169
2022	129,542	131,507	157,511	144,370	194,981	121,838	123,596
2023	127,476	129,273	157,601	143,343	199,163	119,331	120,926
2024	126,123	127,775	158,175	142,915	203,482	117,600	119,051
2025	125,104	126,626	158,907	142,735	207,646	116,272	117,581
2026	124,330	125,736	159,784	142,754	211,740	115,243	116,423
2027	123,710	125,011	160,733	142,888	215,736	114,407	115,470
			Fishing mortality				
2014	0.101	0.101	0.101	0.101	0.101	0.101	0.101
2015	0.119	0.099	0.060	0.085	-	0.139	0.139
2016	0.119	0.098	0.060	0.085	-	0.139	0.139
2017	0.119	0.119	0.060	0.085	-	0.139	0.139
2018	0.119	0.119	0.060	0.085	-	0.139	0.139
2019	0.119	0.119	0.060	0.085	-	0.139	0.139
2020	0.119	0.119	0.060	0.085	-	0.139	0.139
2021	0.119	0.119	0.060	0.085	-	0.139	0.139
2022	0.119	0.119	0.060	0.085	-	0.139	0.139
2023	0.119	0.119	0.060	0.085	-	0.139	0.139
2024	0.119	0.119	0.060	0.085	-	0.138	0.138
2025	0.119	0.119	0.060	0.085	-	0.137	0.137
2026	0.119	0.119	0.060	0.085	-	0.136	0.136
2027	0.119	0.119	0.060	0.085	-	0.135	0.135
			Yield (t)				
2014	17,716	17,716	17,716	17,716	17,716	17,716	17,716
2015	17,665	17,665	10,717	15,239	-	24,360	17,665
2016	21,169	17,797	11,221	15,690	-	24,232	21,169
2017	21,097	21,641	11,614	15,974	-	23,850	24,449
2018	20,586	21,076	11,770	15,922	-	22,986	23,517
2019	19,676	20,097	11,662	15,527	-	21,717	22,167
2020	18,575	18,922	11,358	14,913	-	20,305	20,670
2021	17,526	17,802	10,969	14,250	-	19,027	19,313
2022	16,679	16,892	10,591	13,665	-	18,039	18,257
2023	16,095	16,255	10,288	13,229	-	17,382	17,547
2024	15,763	15,881	10,087	12,959	-	16,957	17,116
2025	15,630	15,719	9,991	12,841	-	16,722	16,867
2026	15,601	15,672	9,965	12,814	-	16,633	16,752
2027	15,625	15,686	9,985	12,844	-	16,630	16,729

*Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 17,716 for 2014, and projected catches of 17,665 t and 17,797 t for 2015 and 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Table 9-17. Summary of ecosystem considerations for Gulf of Alaska Pacific ocean perch.

Ecosystem effects on *GOA Pacific ocean perch*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Primary contents of stomach	Important for all life stages, no time series	Unknown
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, ling cod, rockfish, arrowtooth)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment
***GOA POP* fishery effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several month starting 2007
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-targets rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies initiated in 2005 and ongoing

Figures

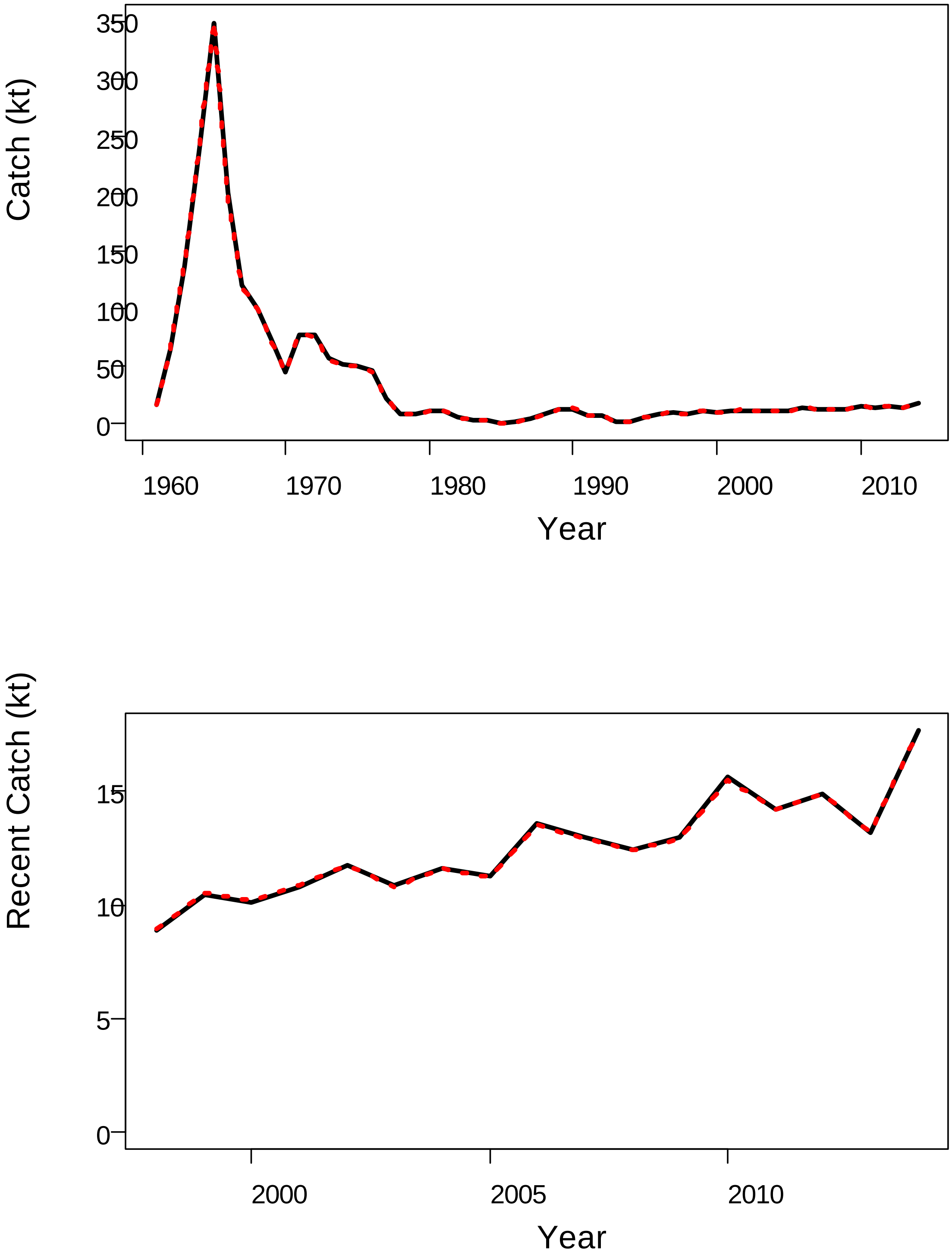


Figure 9-1. Estimated and observed long-term (top figure) and short-term (bottom figure) catch history for Gulf of Alaska Pacific ocean perch.

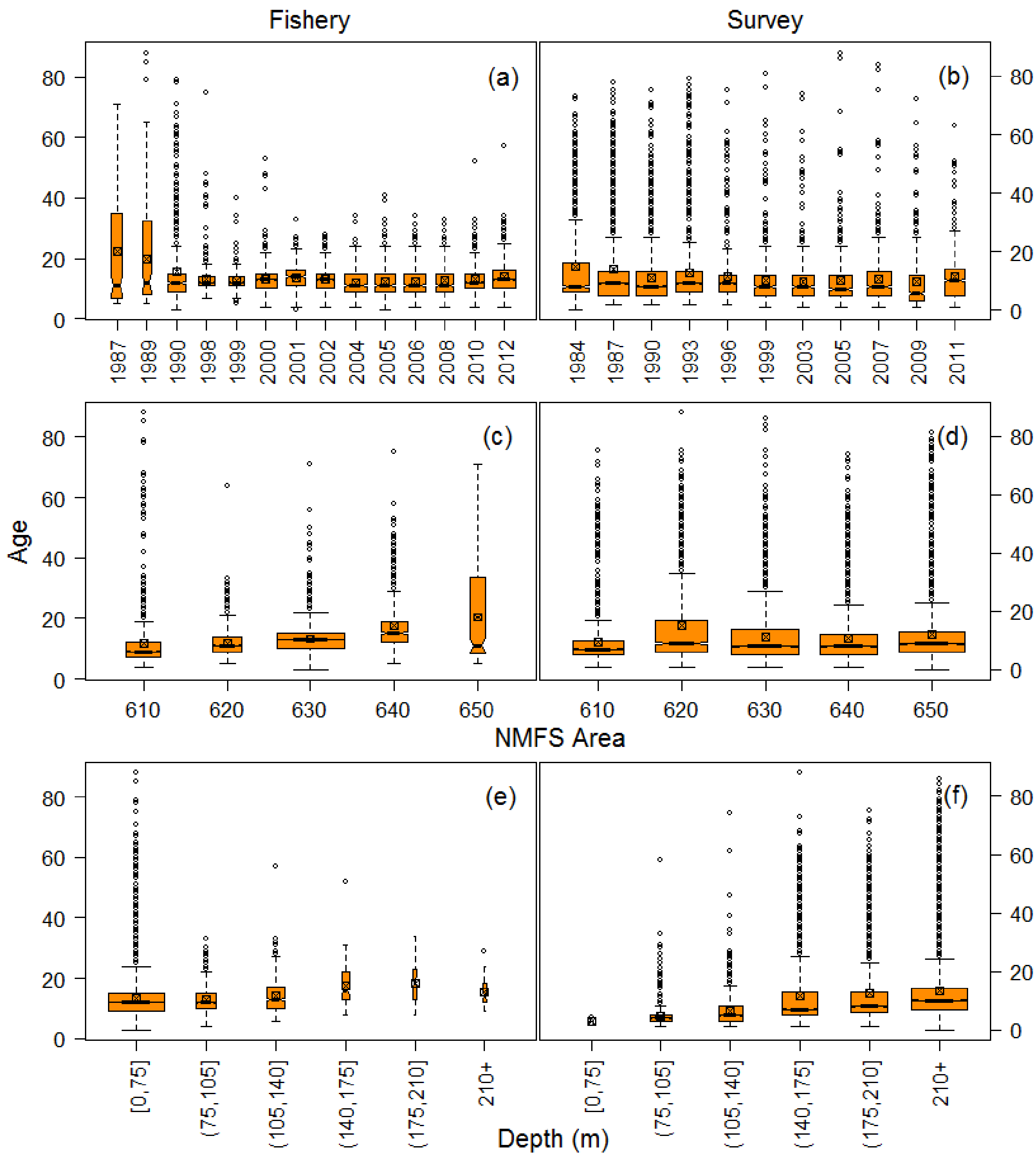


Figure 9-2. Comparisons of fishery and survey age compositions across time, depth, and NMFS area.

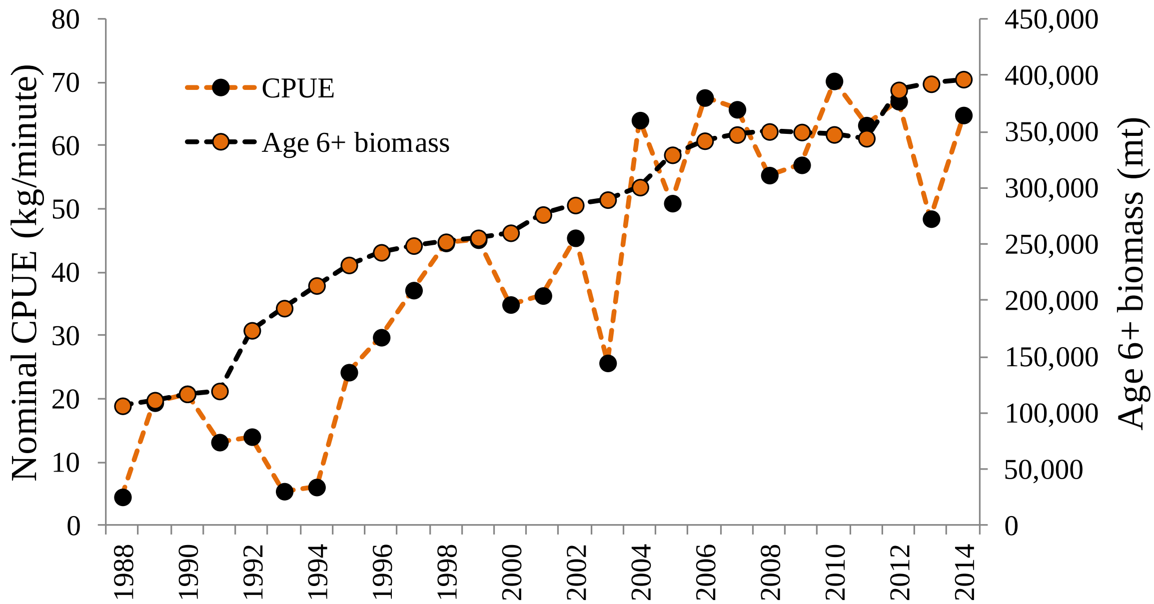


Figure 9-3a. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and biomass (age 6+) in the Gulf of Alaska Pacific ocean perch fishery.

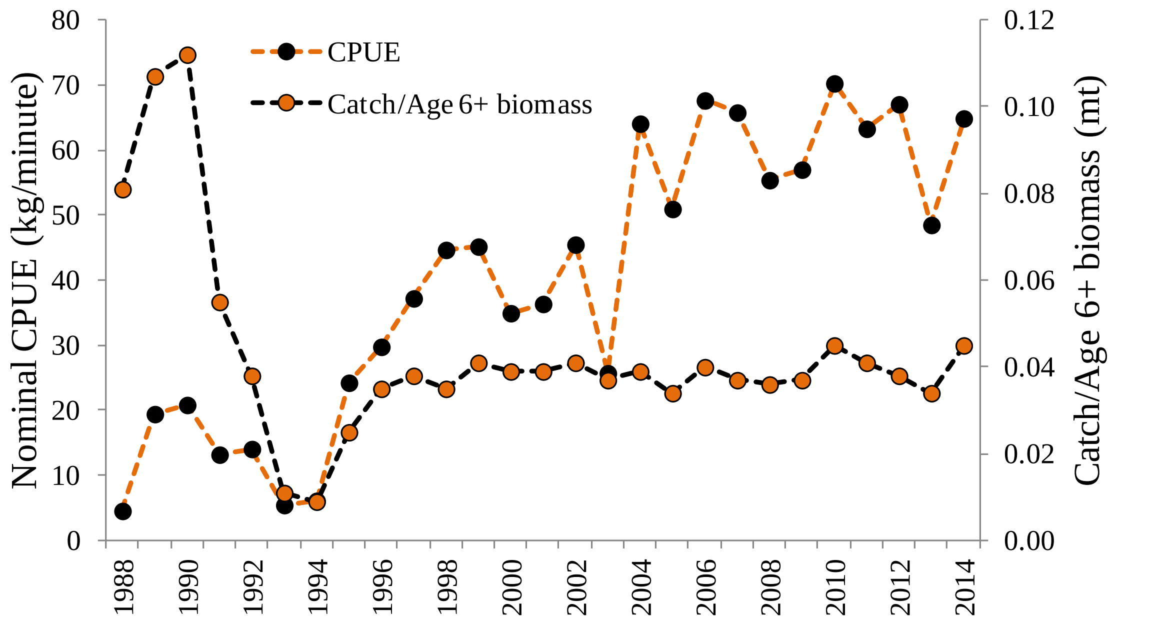


Figure 9-3b. Comparison of nominal catch-per-unit-effort (CPUE, kg/minute) and a proxy for exploitation rate (Catch/Age 6+ Biomass) for the Gulf of Alaska Pacific ocean perch fishery.

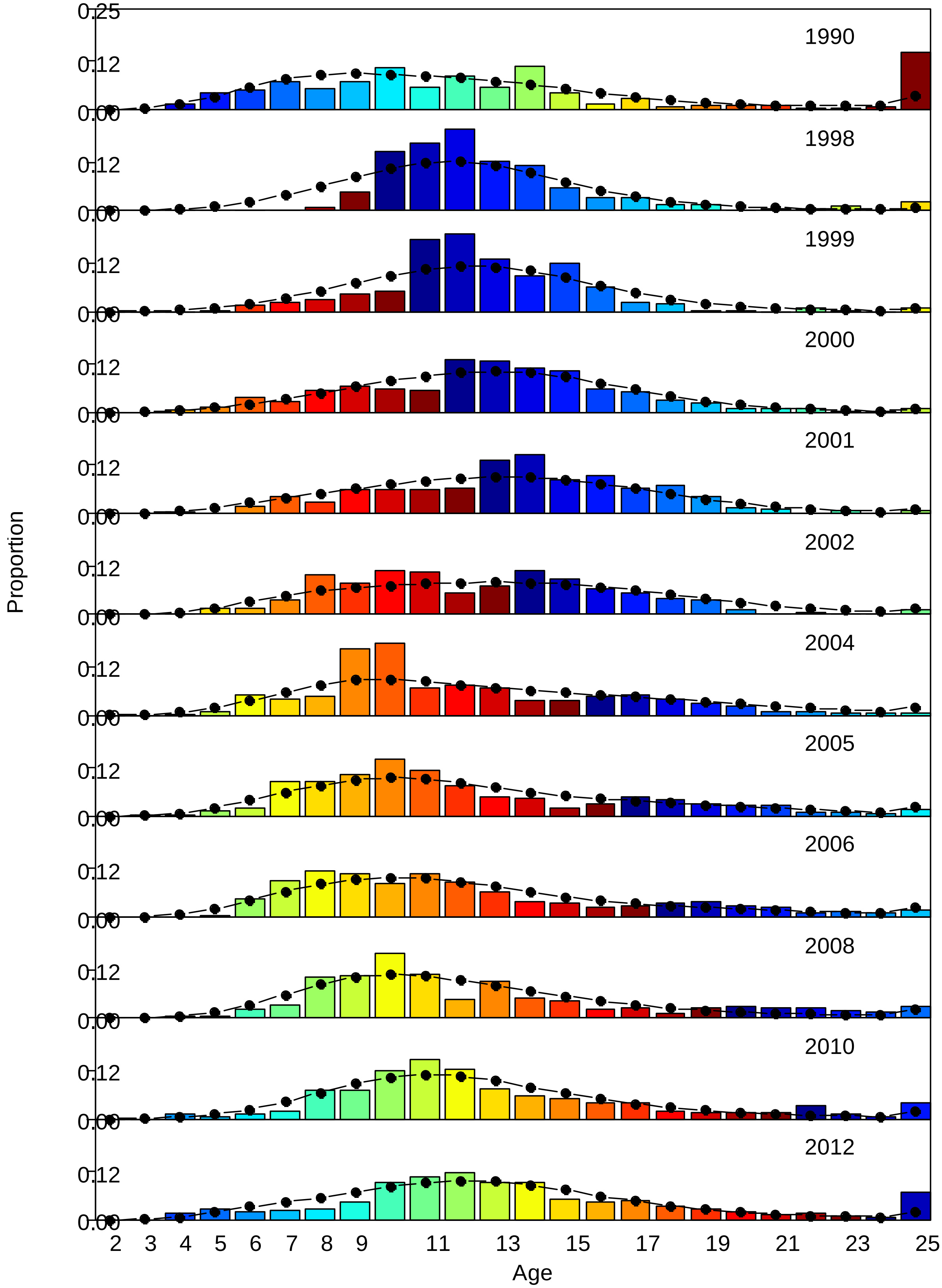


Figure 9-4. Fishery age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles. Colors follow cohorts.

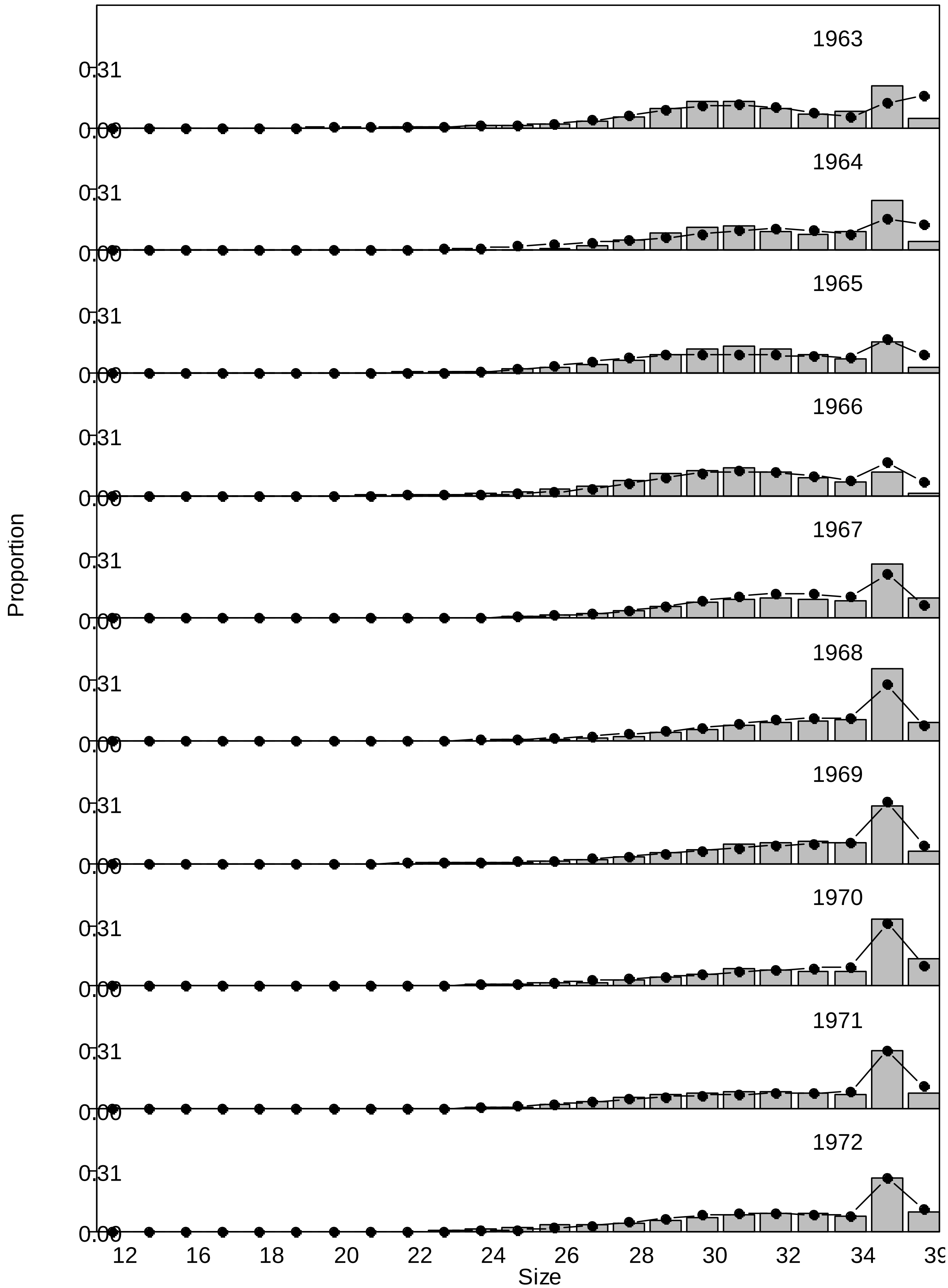


Figure 9-5. Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

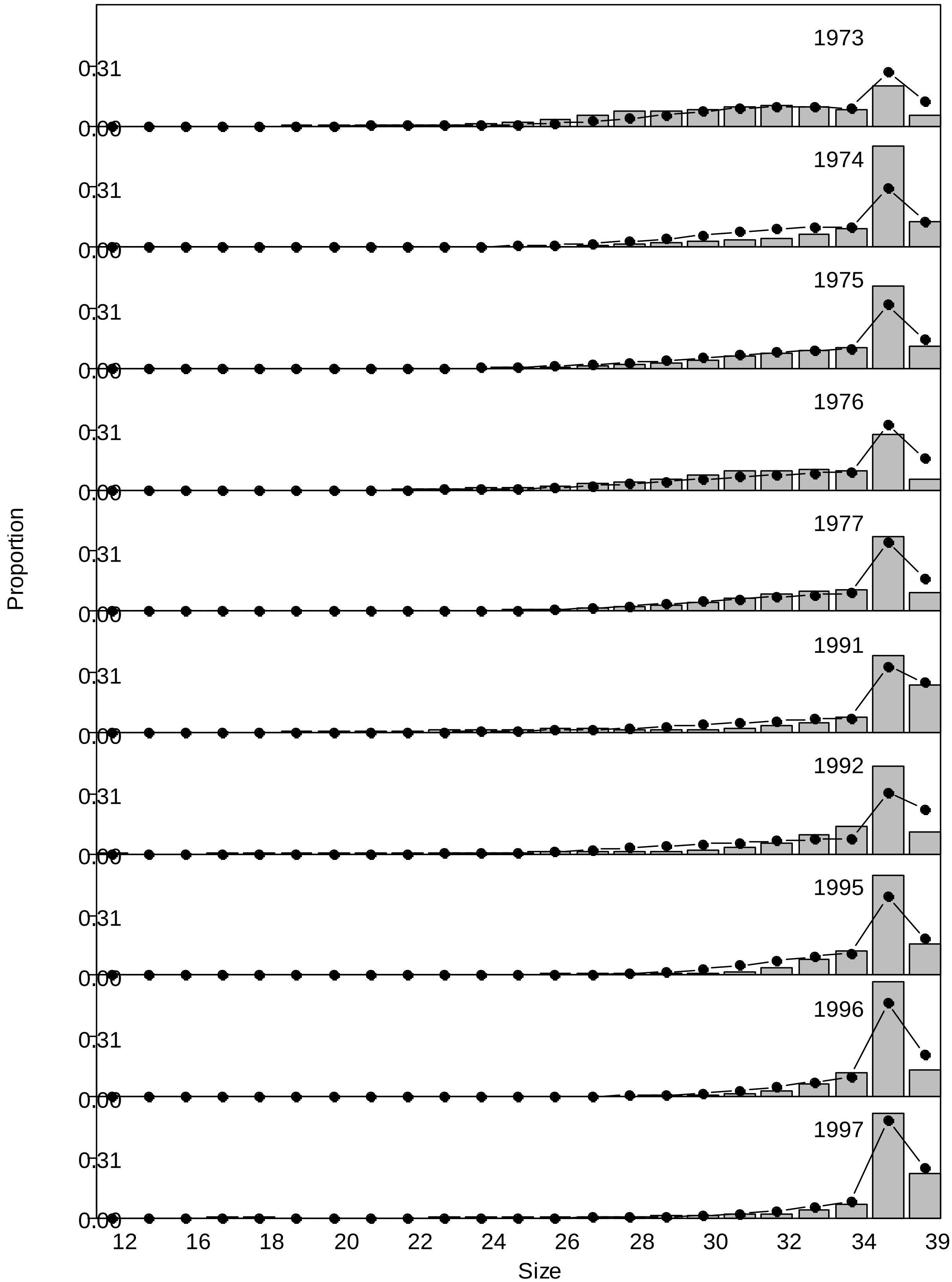


Figure 9-5. (continued) Fishery length (cm) compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

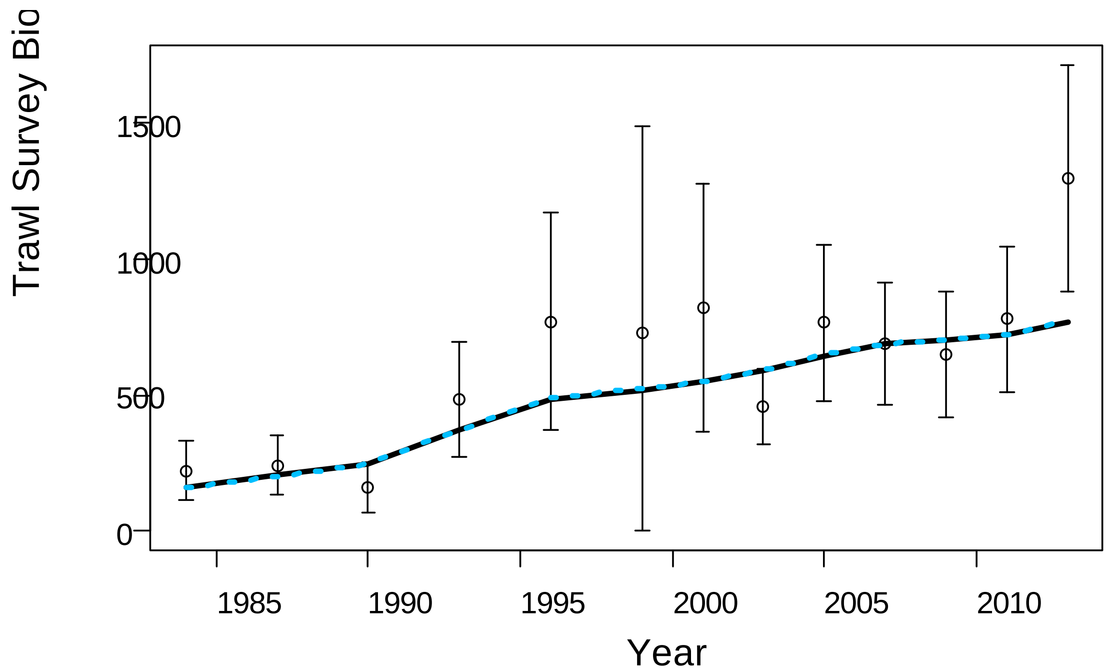


Figure 9-6. NMFS Groundfish Survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for Gulf of Alaska Pacific ocean perch. Predicted estimates from the recommended model (black dashed line) compared with last year's model fit (blue dotted line).

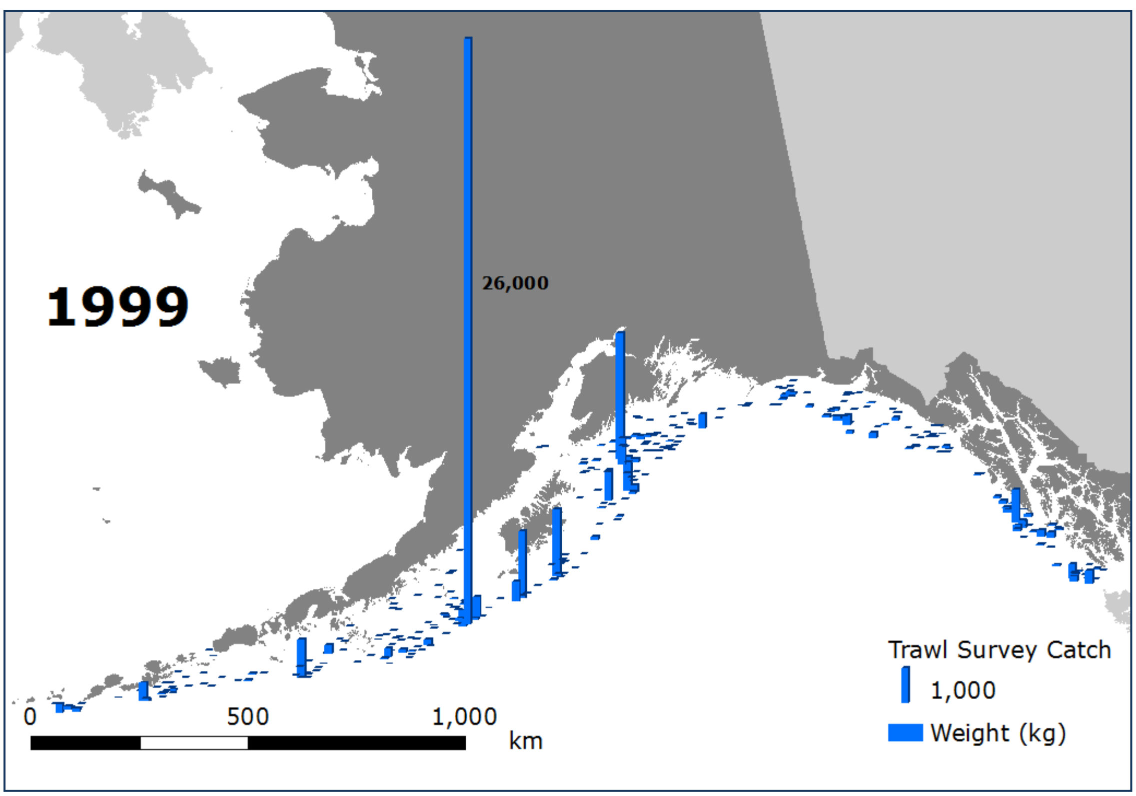


Figure 9-7a. Distribution of Gulf of Alaska Pacific ocean perch catches in the 1999 Gulf of Alaska groundfish survey.

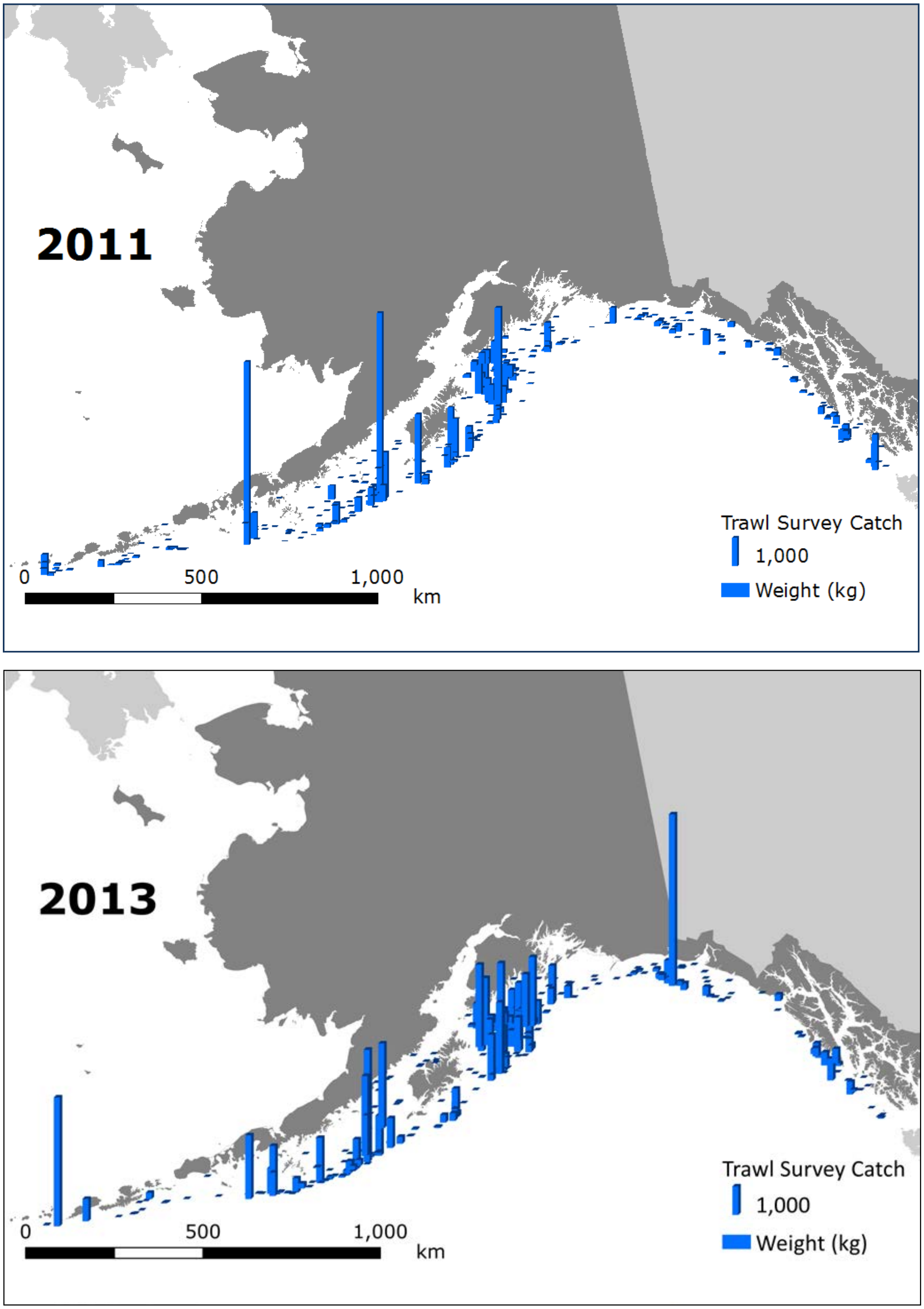


Figure 9-7b. Distribution of Gulf of Alaska Pacific ocean perch catches in the 2011 and 2013 Gulf of Alaska groundfish surveys.

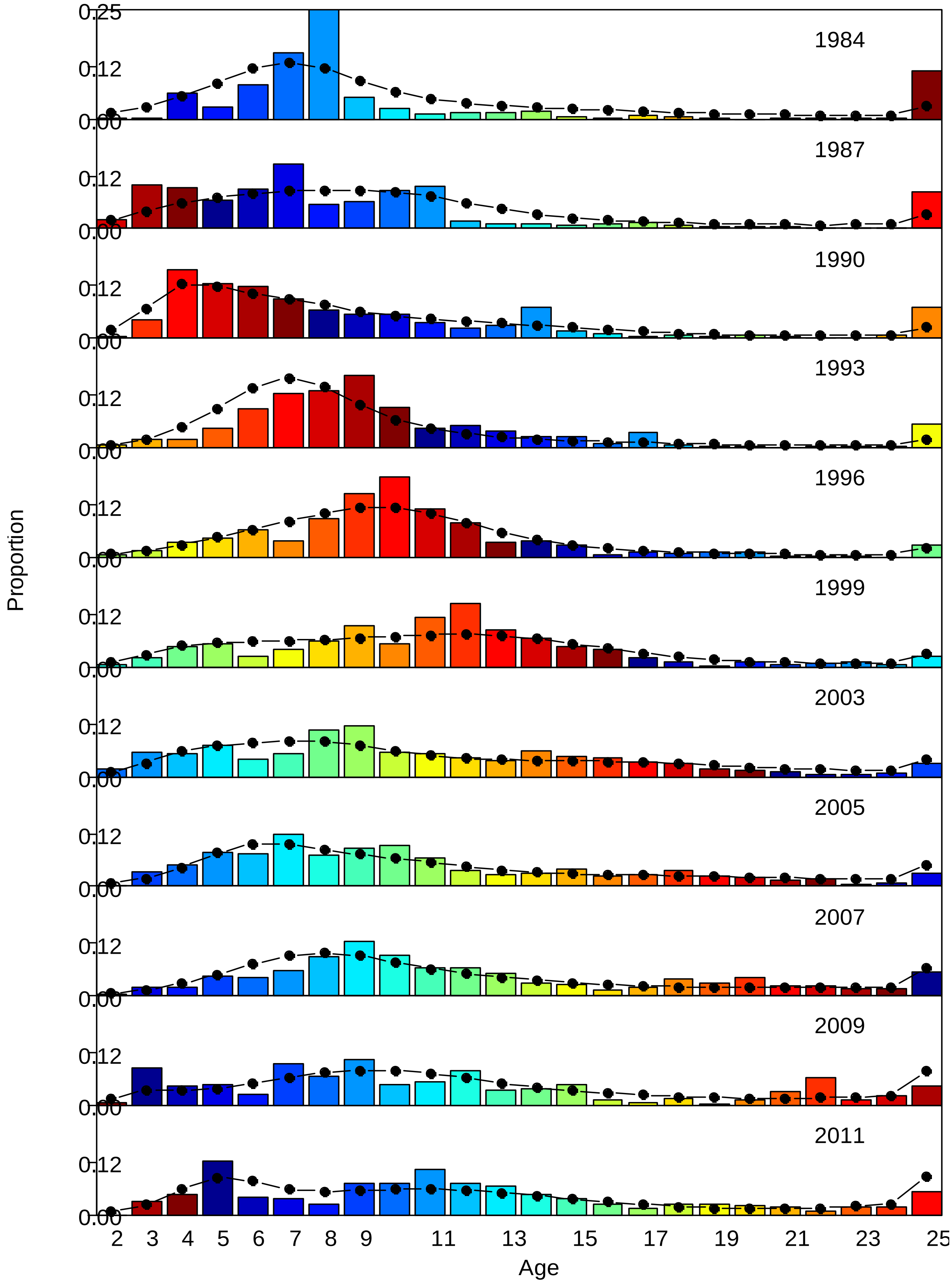


Figure 9-8. Groundfish survey age compositions for GOA Pacific ocean perch. Observed = bars, predicted from author recommended model = line with circles.

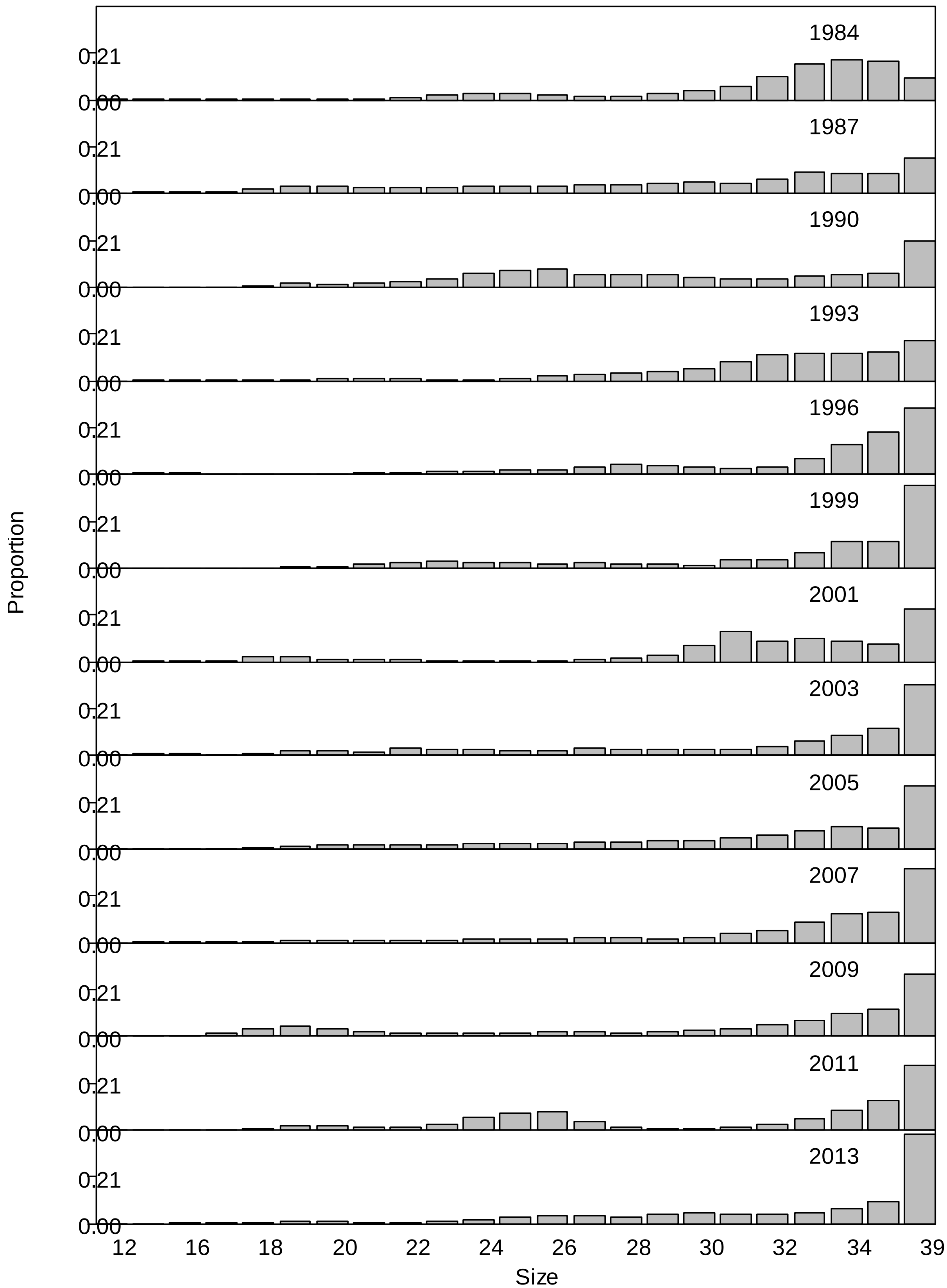


Figure 9-9. Groundfish survey length compositions for GOA Pacific ocean perch. Observed = bars. Survey size not used in Pacific ocean perch model because survey ages are available for these years.

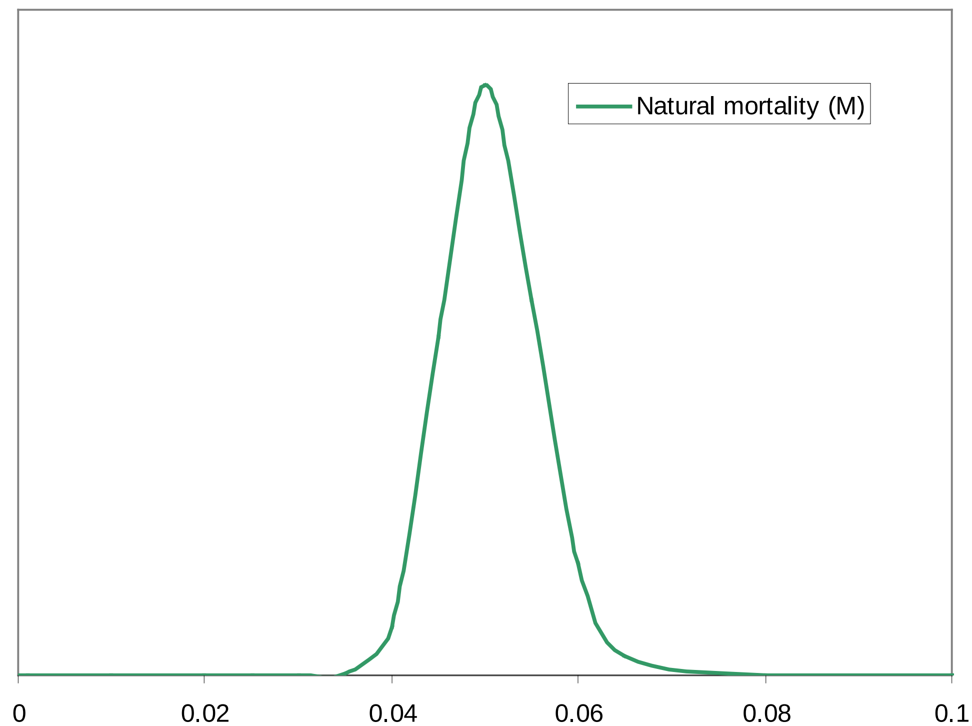


Figure 9-10. Prior distribution for natural mortality (*M*) of Pacific ocean perch, μ=0.05, CV=10%.

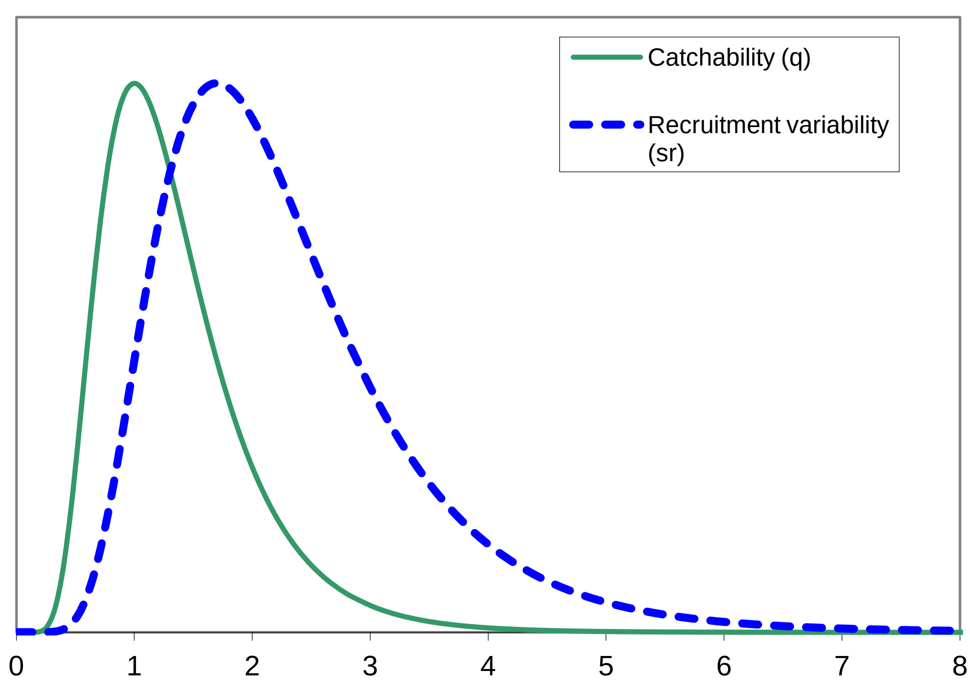


Figure 9-11. Lognormal prior distributions for catchability (*q*, μ=1, CV=45%) and recruitment variability (σ_r, μ=1.7, CV=20%) of Pacific ocean perch.

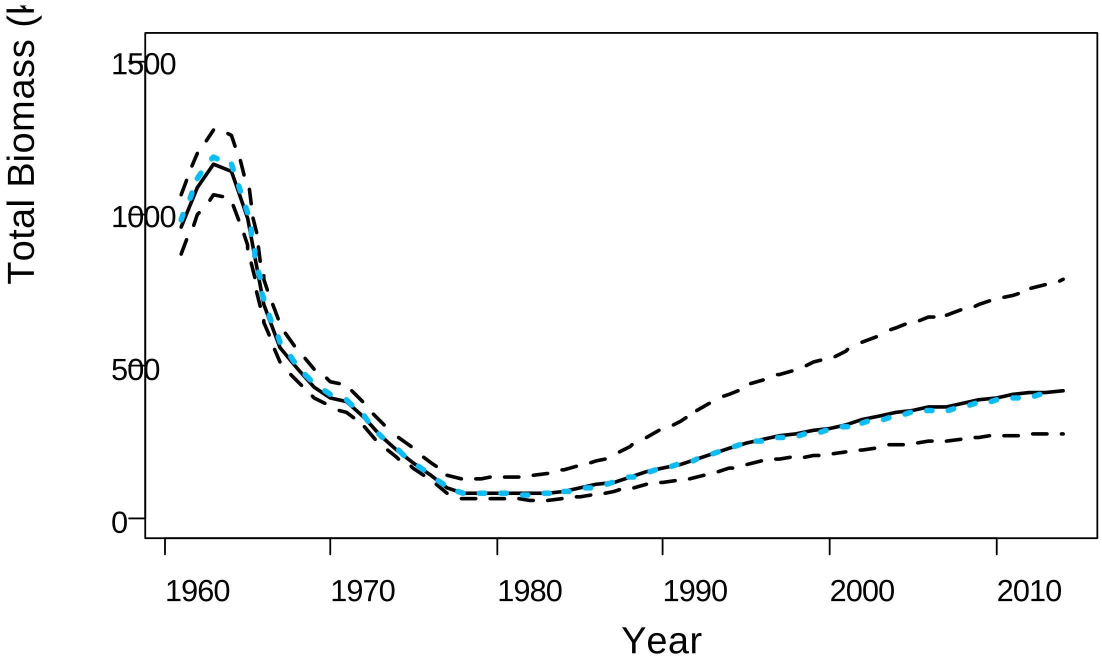


Figure 9-12. Model estimated total biomass (solid black line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch. Last year's model estimates included for comparison (dotted blue line).

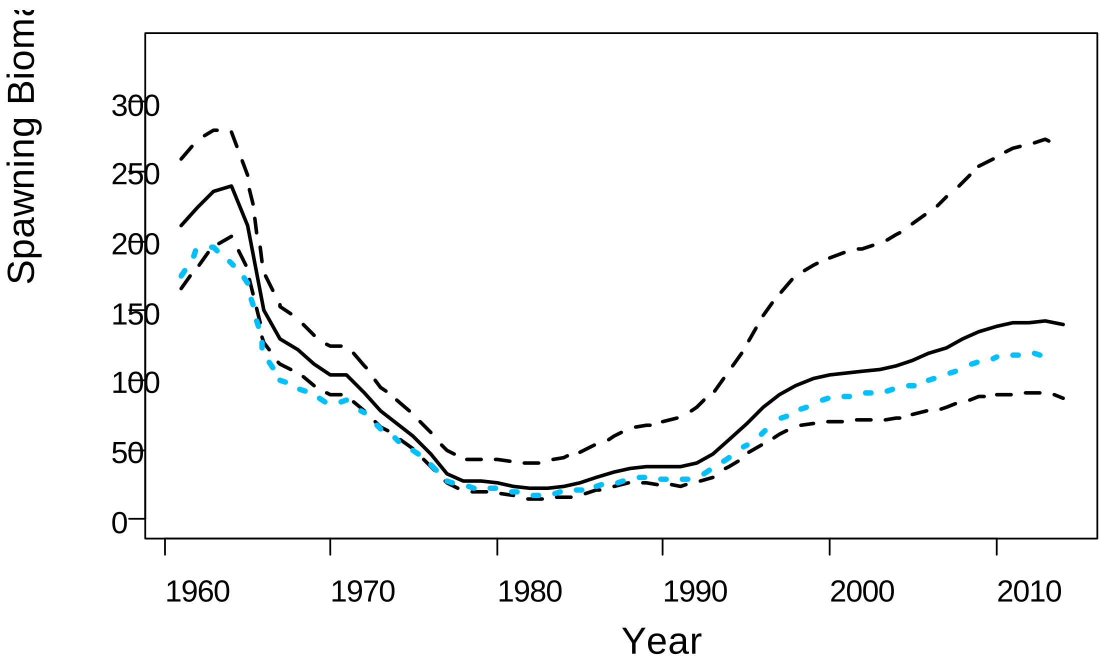


Figure 9-13. Model estimated spawning biomass (solid line) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska Pacific ocean perch. Last year's model estimates included for comparison (dotted blue line).

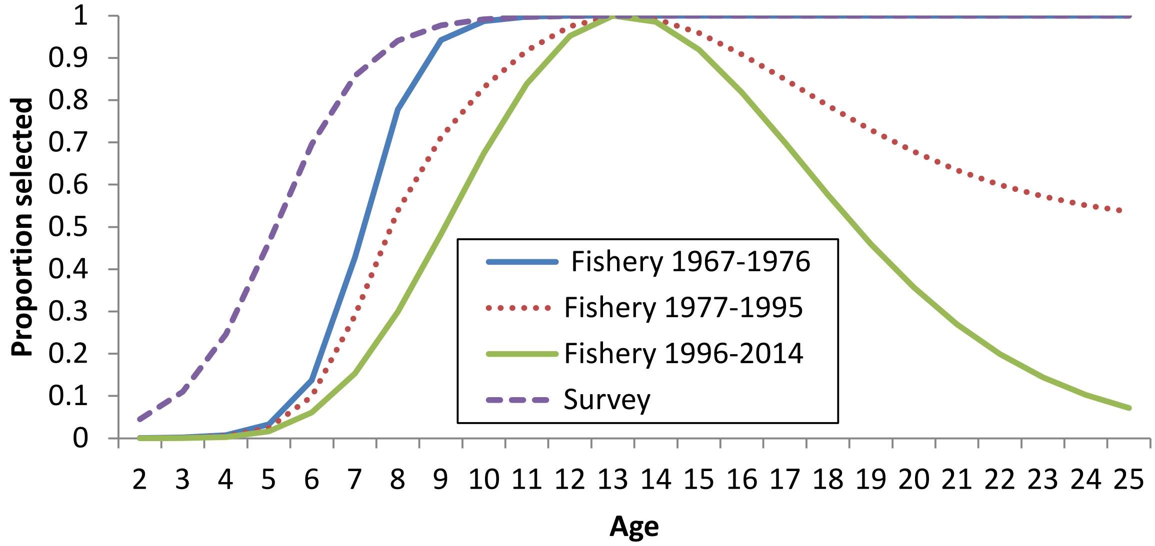


Figure 9-14. Estimated selectivities for the fishery for three periods and groundfish survey for Gulf of Alaska Pacific ocean perch.

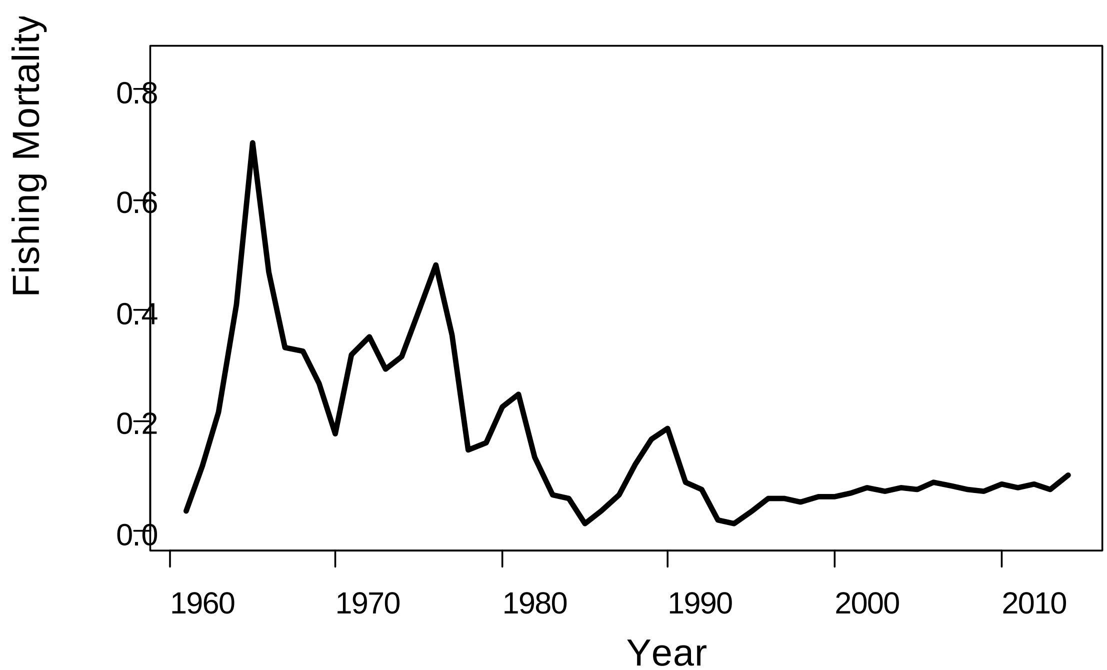


Figure 9-15. Estimated fully selected fishing mortality over time for GOA Pacific ocean perch.

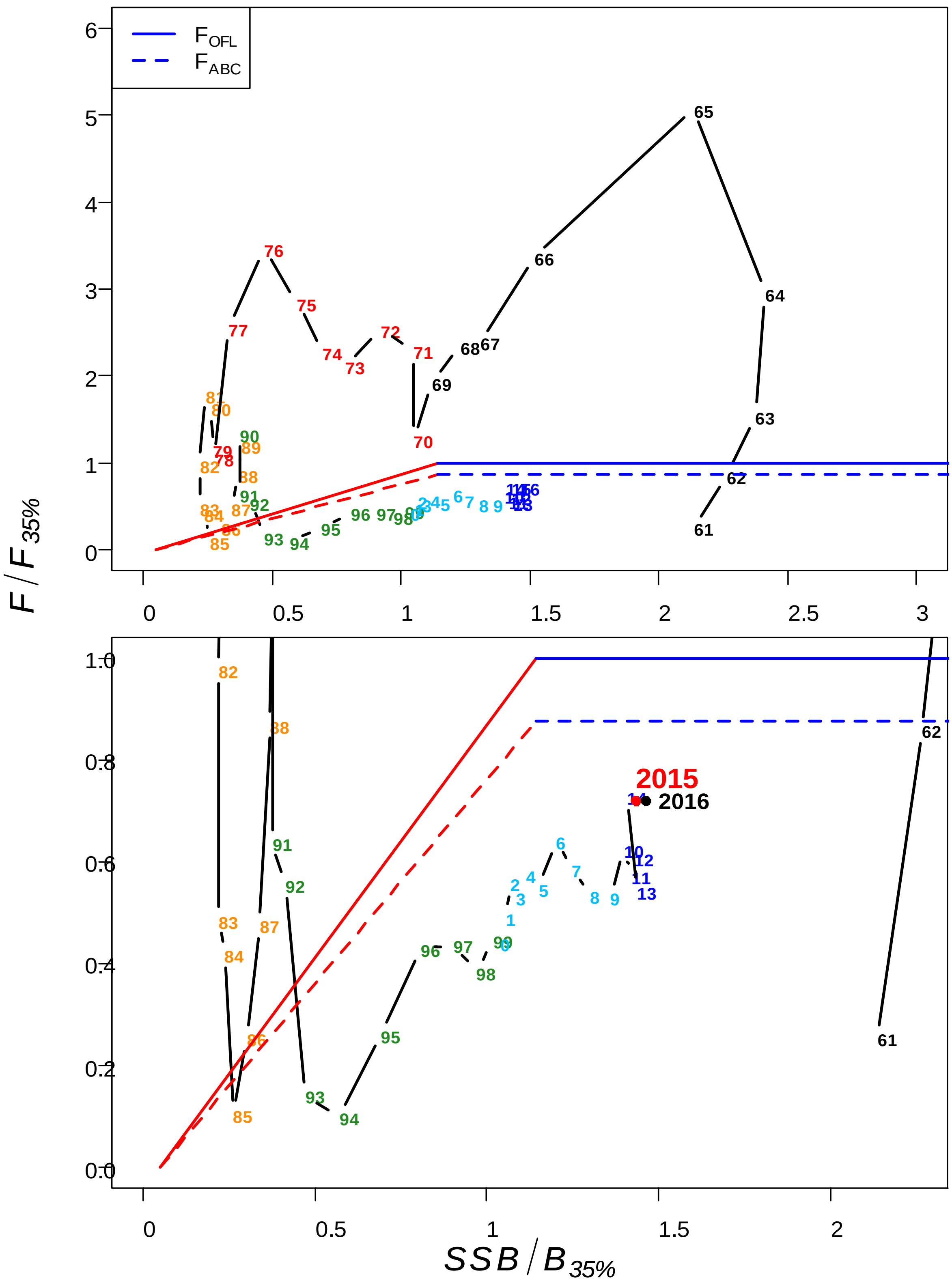


Figure 9-16. Time series of Pacific ocean perch estimated spawning biomass relative to the target level $B_{35\%}$ level and fishing mortality relative to $F_{35\%}$ for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.

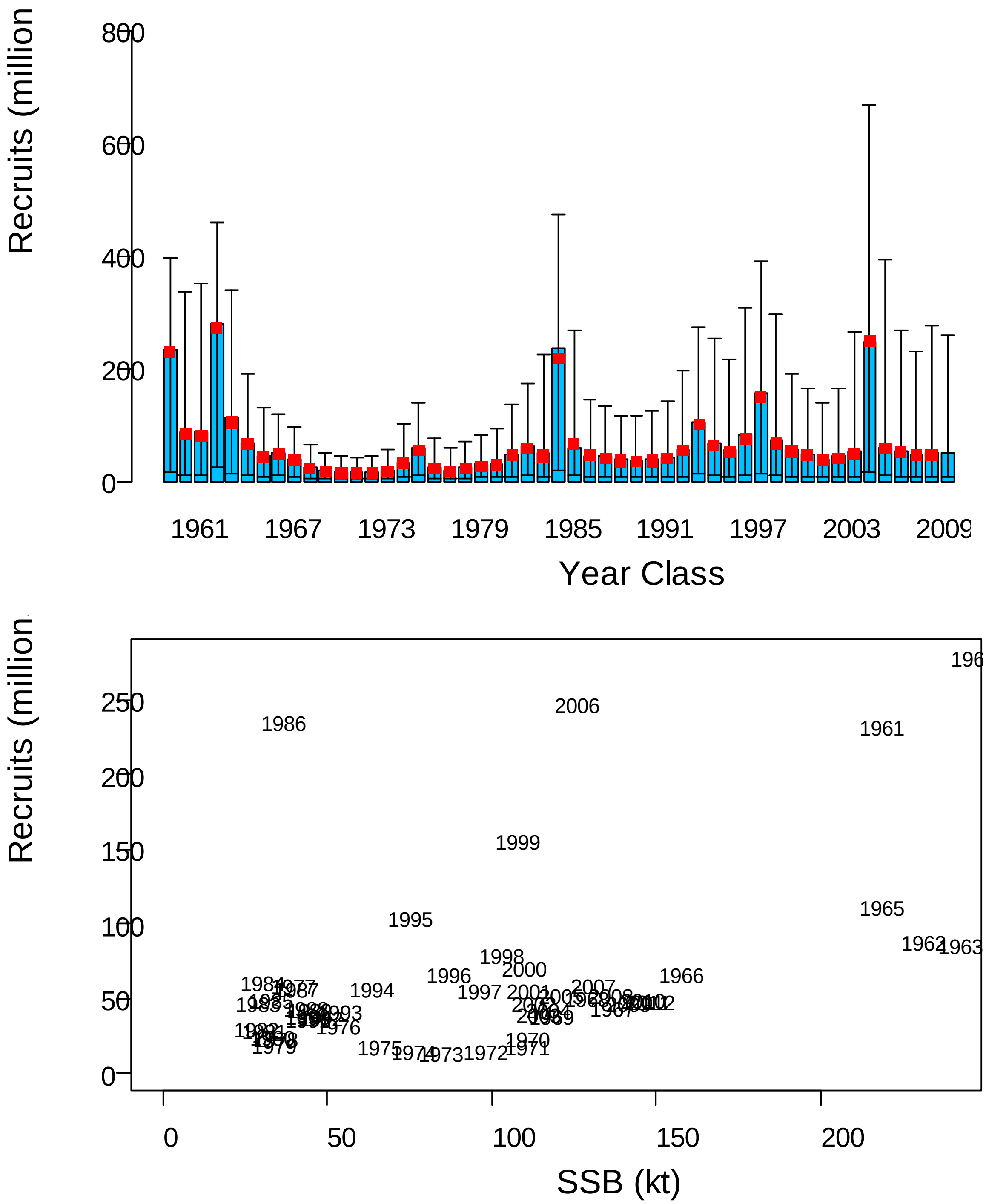


Figure 9-17. Estimated recruitment of Gulf of Alaska Pacific ocean perch (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimated recruits per spawning stock biomass (bottom). Red square in top graph are last year's estimates for comparison.

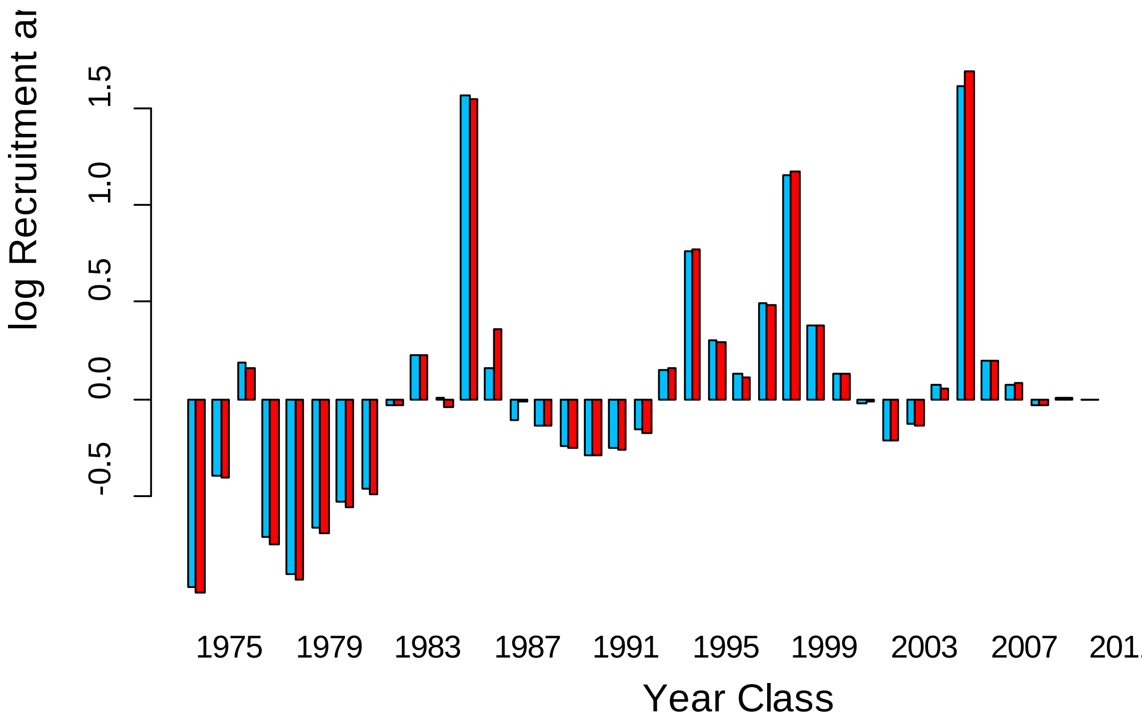


Figure 9-18. Recruitment deviations from average on the log-scale comparing last cycle's model (red) to current year recommended model (blue) for Gulf of Alaska Pacific ocean perch.

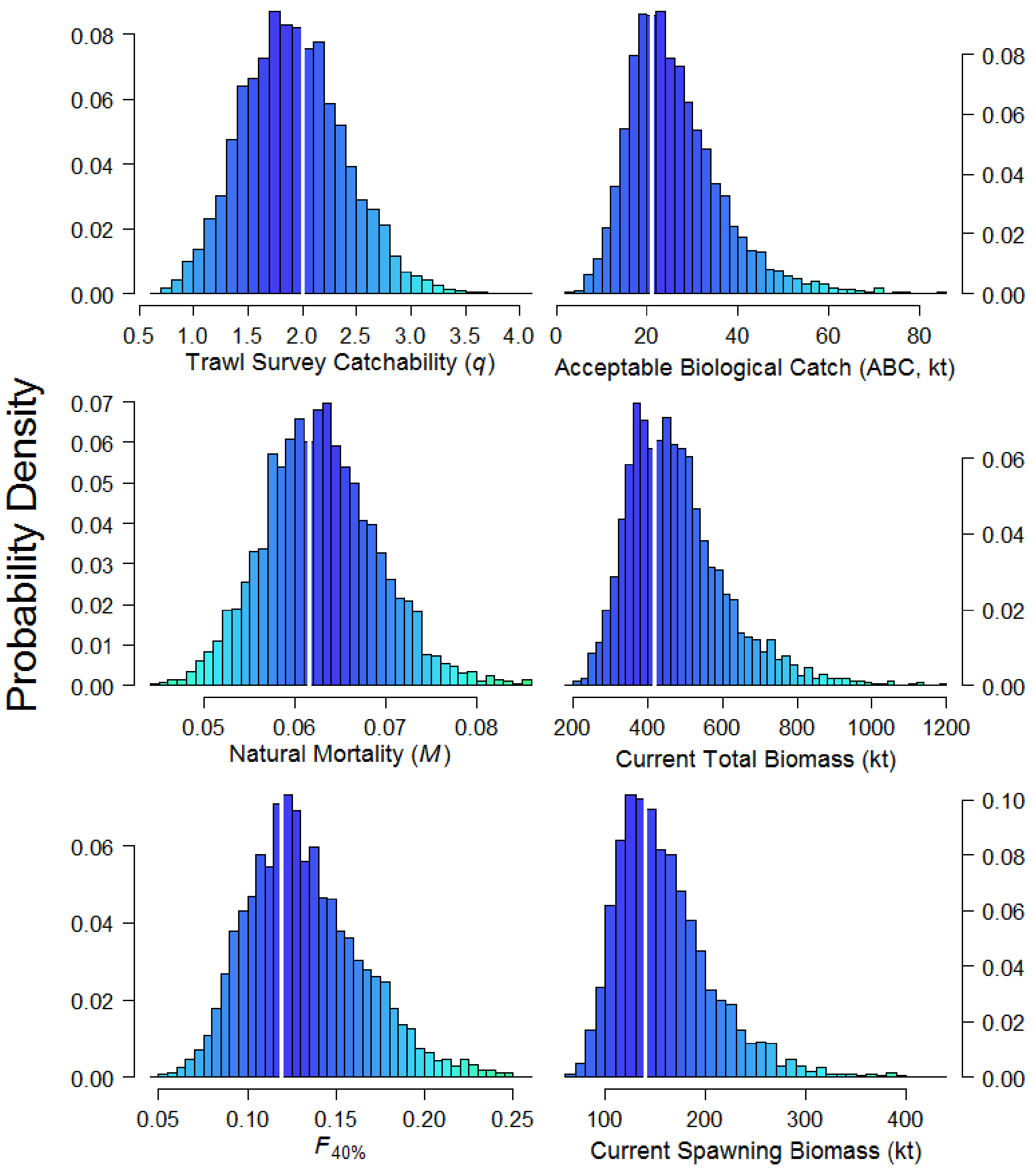


Figure 9-19. Histograms of estimated posterior distributions of key parameters derived from MCMC for Gulf of Alaska Pacific ocean perch. The vertical white lines are the recommended model estimates.

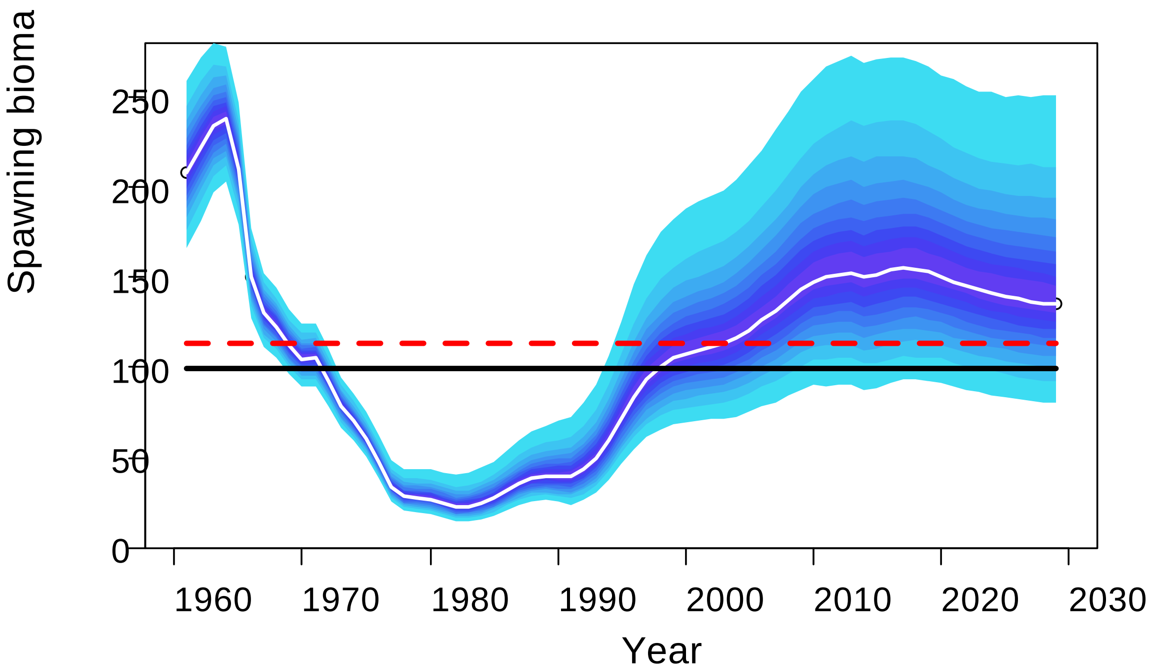


Figure 9-20. Bayesian credible intervals for entire spawning stock biomass series including projections through 2029. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2012. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

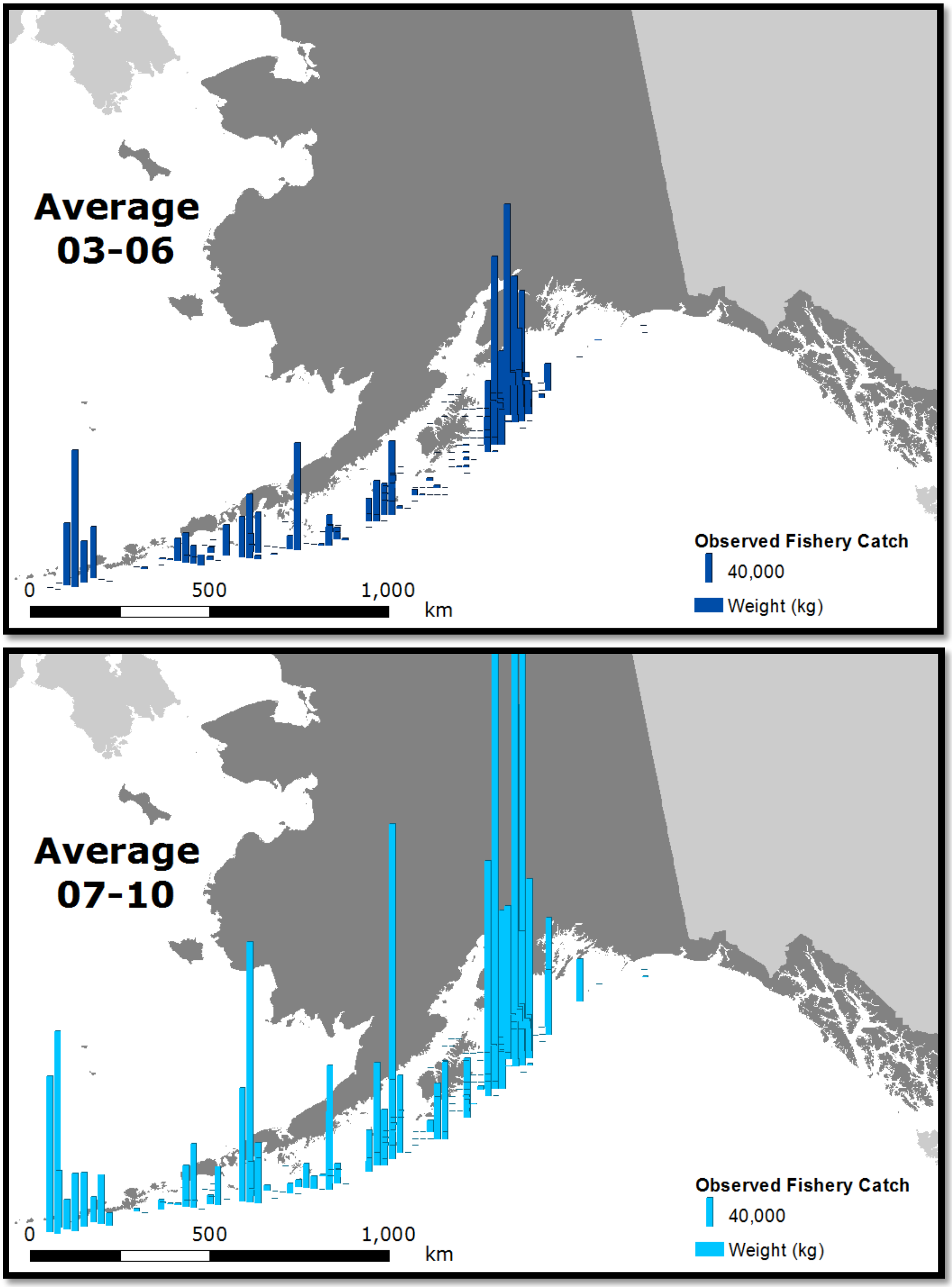


Figure 9-21. Maps of fishery catch based on observer data by 100 km^2 blocks for Pacific ocean perch from four years before and after the Rockfish Pilot Program.

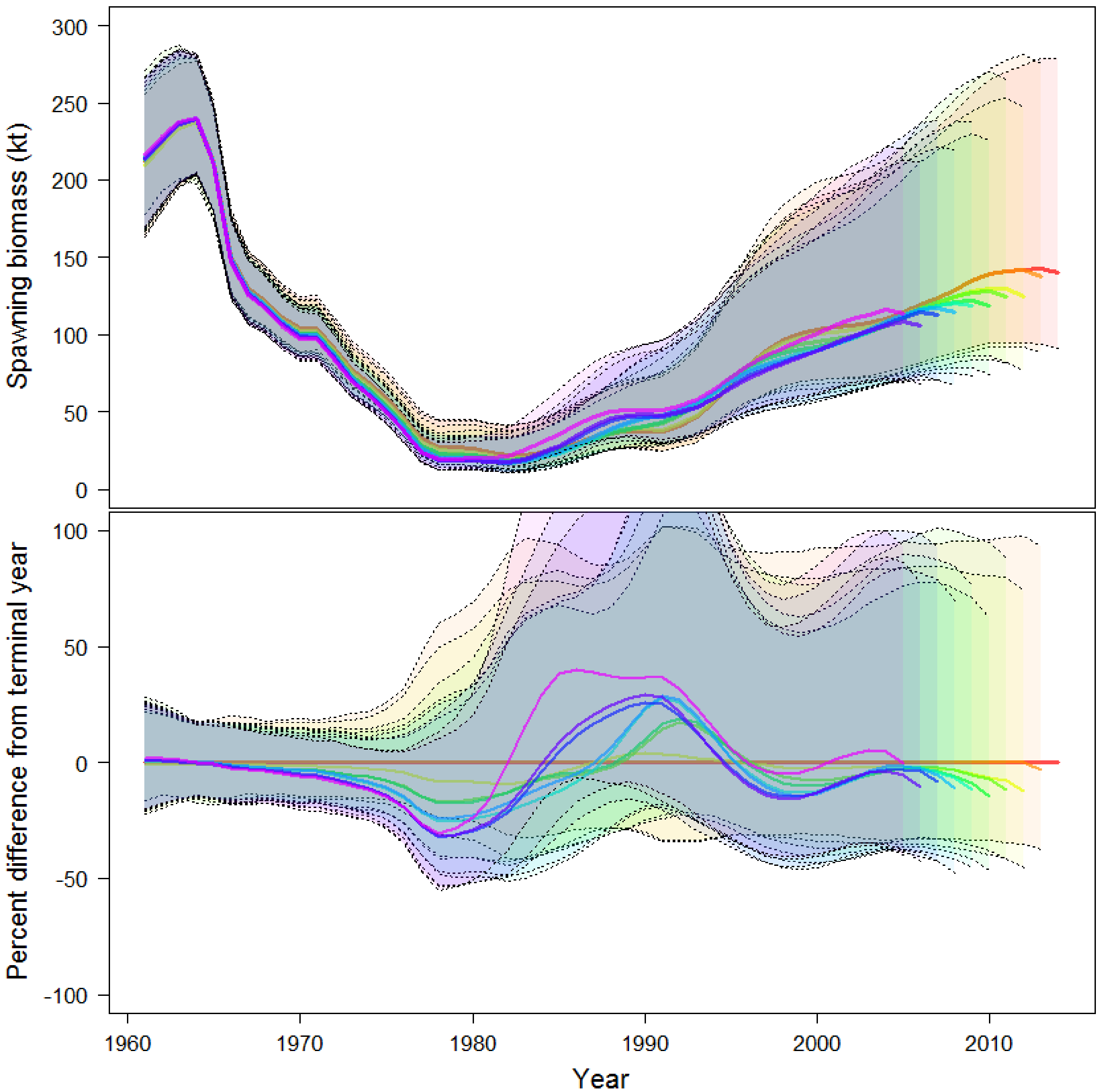


Figure 9-22. Retrospective peels of estimated female spawning biomass for the past 10 years from the recommended model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the recommended model in the terminal year with 95% credible intervals from MCMC.

Appendix 9A.—Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For Gulf of Alaska (GOA) Pacific ocean perch, these estimates can be compared to the research removals reported in previous assessments (Hanselman et al. 2010) (Table 9A.1). Pacific ocean perch research removals are minimal relative to the fishery catch and compared to the research removals for many other species. The majority of removals are taken by the Alaska Fisheries Science Center's biennial bottom trawl survey which is the primary research survey used for assessing the population status of Pacific ocean perch in the GOA. Other research conducted using trawl gear catch minimal amounts of Pacific ocean perch. No reported recreational or subsistence catch of Pacific ocean perch occurs in the GOA. Total removals from activities other than directed fishery were near 3 tons in 2010. This is less than 0.02% of the 2011 recommended ABC of 19,309 t and represents a very low risk to the Pacific ocean perch stock. The removals for 2010 are lower than many other years. This is due to the biennial cycle of the bottom trawl survey in the GOA. However, since 2000 removals have been less than 100 t, and do not pose significant risk to the stock. For example, if these removals were accounted for in the stock assessment model, it would result in an increase in ABC 0f 0.1% for 2012.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between "retained" or "discarded" catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program in 2013.

The HFICE estimates of GOA Pacific ocean perch catch are zero indicating the halibut fishery rarely if ever encounter Pacific ocean perch. (Table 9A.2). This is not unexpected as Pacific ocean perch are rarely encountered using hook and line gear and are primarily harvested using trawl gear. Therefore, due to the lack of Pacific ocean perch catch in the HFICE estimates, the impact of the halibut fishery on Pacific ocean perch stocks is negligible.

References:

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Hanselman, D. H, S. K. Shotwell, J. Heifetz, and J. N. Ianelli. 2010. Assessment of the Pacific ocean perch stock in the Gulf of Alaska (executive summary). In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 543-546. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 9A-1 Total removals of Gulf of Alaska Pacific ocean perch (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, small-mesh, and GOA bottom trawl surveys, and occasional short-term research projects. Other is recreational, personal use, and subsistence harvest.

Year	Source	Trawl	Other	Total
1977		13		13
1978		6		6
1979		12		12
1980		13		13
1981		57		57
1982		15		15
1983		2		2
1984		77		77
1985		35		35
1986		14		14
1987		69		69
1988		0		0
1989		1		1
1990		26		26
1991	**Assessment of Pacific ocean perch in the Gulf of Alaska (Hanselman et al. 2010)**	0		0
1992		0		0
1993		59		59
1994		0		0
1995		0		0
1996		81		81
1997		1		1
1998		305		305
1999		330		330
2000		0		0
2001		43		43
2002		60		60
2003		43		43
2004		0		0
2005		84		84
2006		0		0
2007		93		93
2008		0		0
2009		69		69
2010		3	<1	3
2011	AKRO	64	<1	64
2012		<1	<1	1
2013		87	<1	87

Table 9A-2. Estimates of Gulf of Alaska Pacific ocean perch catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WGOA	0	0	0	0	0	0	0	0	0	0
CGOA-Shumagin	0	0	0	0	0	0	0	0	0	0
CGOA-Kodiak/ PWS*	0	0	0	0	0	0	0	0	0	0
EGOA-Yakutat	0	0	0	0	0	0	0	0	0	0
EGOA-Southeast	0	0	0	0	0	0	0	0	0	0
Southeast Inside*	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0

*These areas include removals from the state of Alaska waters.

Appendix 9B.—Bottom Trawl Survey Length Composition Analysis

Introduction and Methods

An analysis of including the most recent year of the bottom trawl survey length composition data into the GOA POP assessment model was conducted in order to respond to the GOA Groundfish Plan Team's request from the September 2014 meeting. The primary issue investigated is that in any given full-assessment year the most recent bottom trawl survey age composition is unavailable, as the age and growth lab do not have time to process the otoliths prior to when assessments are conducted. In the absence of the most recent age composition, some assessments use the bottom trawl survey length composition (e.g., Spencer and Ianelli 2012, Dorn et al. 2013). The primary reason for including the length composition in the most recent year of the survey is that the assessment results would then reflect the most recent demographic information available. Alternatively, it has been argued that a reason for excluding the most recent length composition from the bottom trawl survey is that the potential benefits are offset by greater variability caused by sequentially adding and removing a single observation type (e.g. Hanselman et al. 2013, Hulson et al. 2013). It may also induce retrospective patterns. In either case, both methods replace the survey length data when age data becomes available. Consequently, a sensitivity analysis was designed to compare an 'ideal' case in which all years of the bottom trawl survey age composition data were included with the status quo and alternative cases:

Model case	Description
C0	Base case: all years of bottom trawl survey age composition are available and fitted by model
C1	Status quo: most recent bottom trawl survey age composition unavailable in the assessment year, survey length composition data excluded
C2	Alternative: most recent bottom trawl survey age composition unavailable in the assessment year, assessment year survey length composition *included*

Cases were evaluated across multiple years and the model was fit to data with ending years that coincided with bottom trawl surveys in the GOA between 2003 and 2011 (e.g., model comparison was made every 2 years from 2003 to 2011). The analysis was conducted for GOA POP, northern rockfish, and dusky rockfish providing results for three separate stock assessment models.

For case C2, several sub-cases were investigated that evaluated the input sample size used for the bottom trawl survey length composition fitted. These sub-cases included:

Model C2 sub-case	Description
C2a	Mean input sample size for bottom trawl survey age composition (square root of age sample size)
C2b	Square root of survey length sample size, scaled to 100
C2c	Square root of survey length sample size, scaled to 200
C2d	Square root of number of hauls from which survey lengths were sampled
C2e	Square root of survey length sample size * hauls, scaled to 100

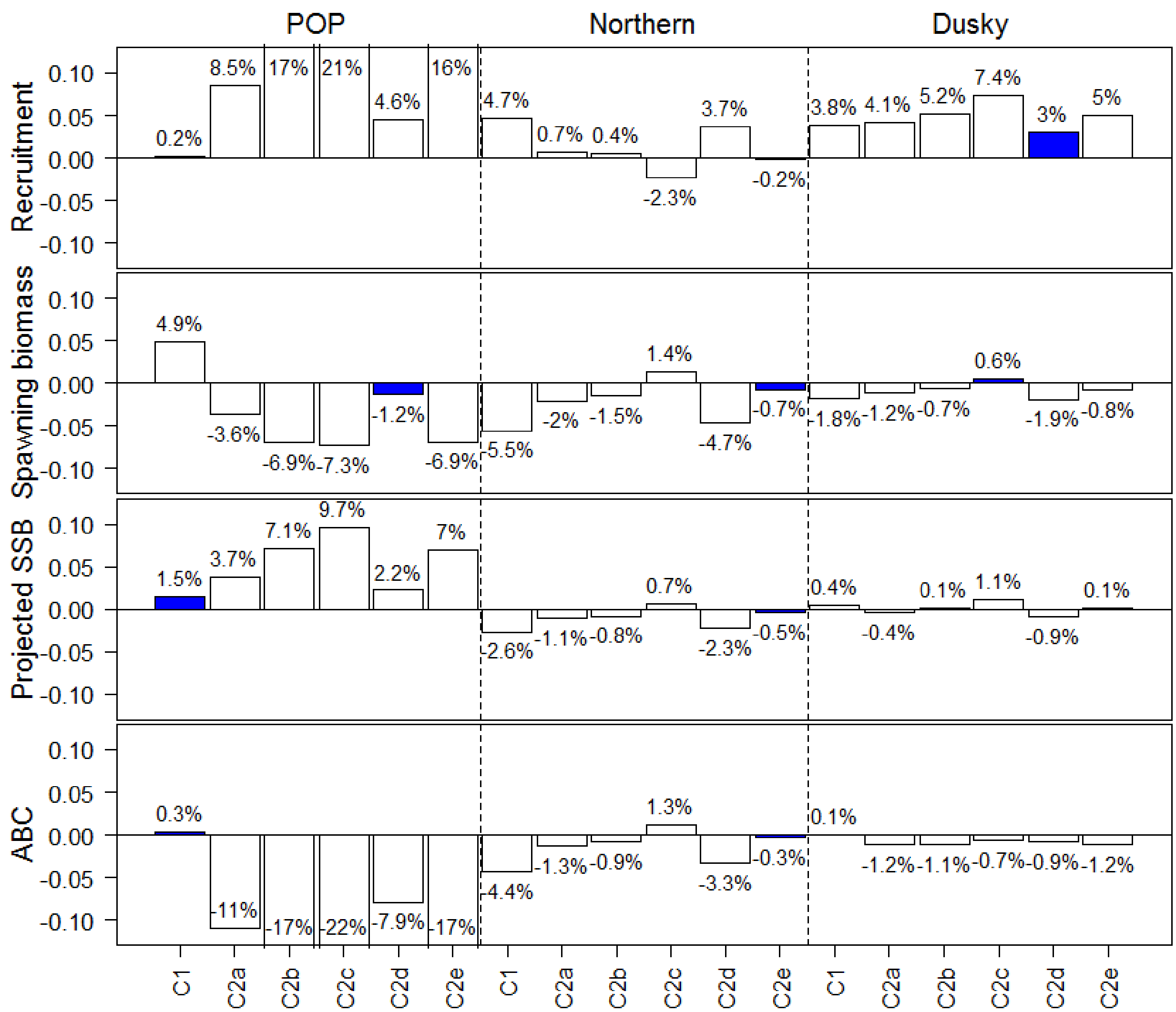
Each of these sub-cases reflect input sample sizes that were related to either the number of samples and/or number of hauls from which samples were taken, which have been shown to be related to the effective sample size of age/length composition data (Pennington et al. 2002, Hulson et al. 2011). These cases were also representative of several of the methods used for defining input sample sizes in AFSC groundfish assessments.

Several performance statistics were developed. These included:

1. The mean percent change in the model estimates relative to case C0. Specifically, the model estimates evaluated included:
    a. the most recent 15 years of estimated recruitment,
    b. the most recent 15 years of estimated spawning biomass,
    c. the 15-year projected spawning biomass, and
    d. the estimated ABC.
2. Likelihoods of fitted data (bottom trawl survey biomass and age composition, fishery age and length composition) and the recruitment deviations penalty from the model cases were investigated. The likelihood performance measures can highlight similarities among model cases. The survey age composition likelihood was calculated for years that cases C1 – C2e were overlapped with C0 as well as the final year likelihood (i.e., as cases C1 – C2e had one less year than case C0 the final year's survey age composition was estimated for models C1 – C2e and the likelihood was computed with the final year's observed age composition and added to the model's likelihood).
3. Retrospective statistics for spawning biomass were calculated (to see if any of the retrospective patterns in model scenarios C1 – C2e were an improvement over C0):
    a. the revised Mohn's ρ (Retrospective Working Group),
    b. Wood's Hole ρ (Legault 2009), and
    c. the root-mean-squared error (RMSE, Parma 1993).

Results and Discussion

In the following figure the percent difference in the most recent 15 years of estimated recruitment, the most recent 15 years of estimated spawning biomass, the 15-year projected spawning biomass, and the estimated ABC between model cases C1 – C2e and C0 are shown, with the closest estimate to case C0 highlighted in blue. The percent difference between model cases C1 – C2e and C0 are shown in text above each bar.

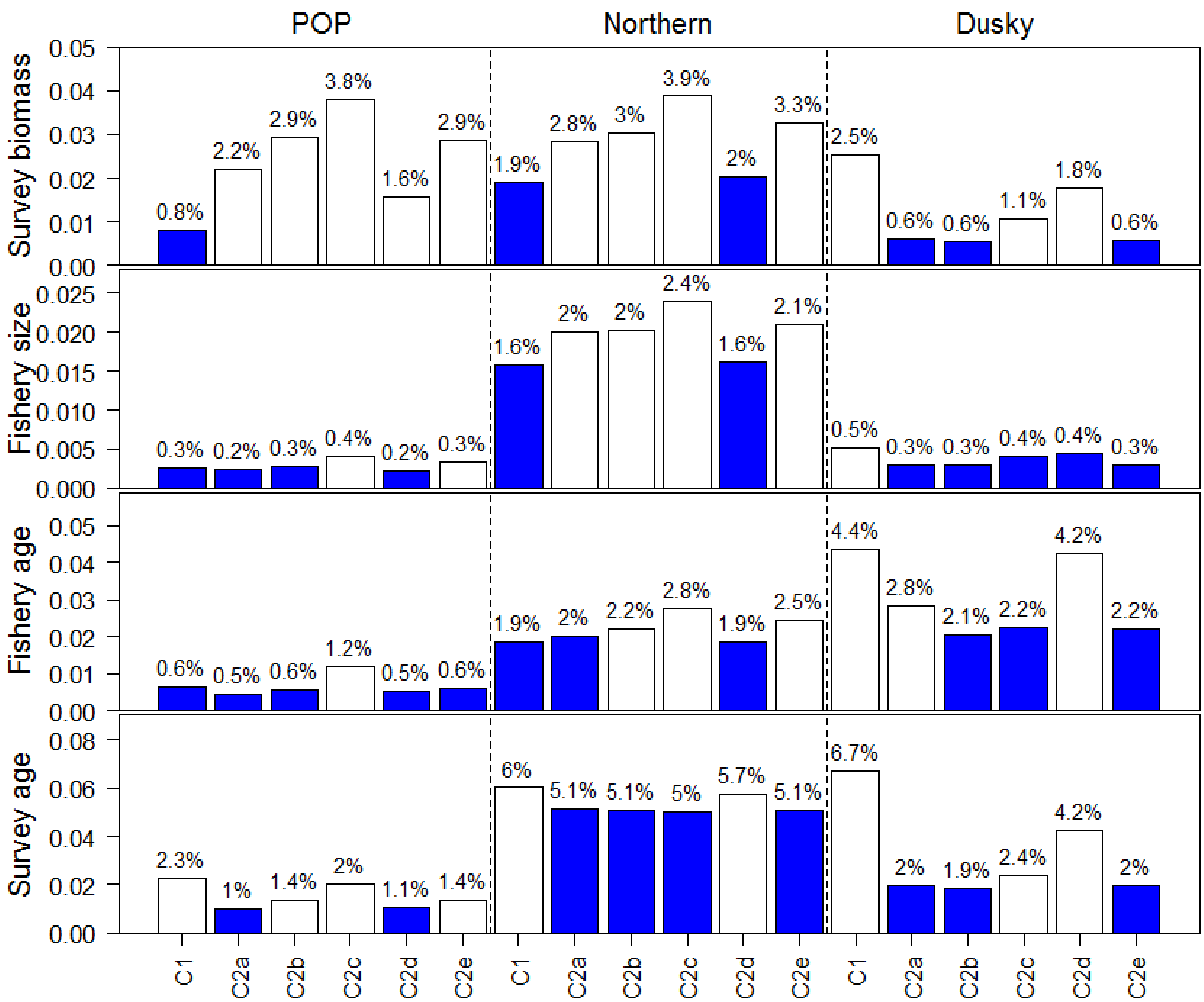


For POP, model case C1 resulted in the most similar estimates to C0 for 3 of the 4 model estimates evaluated (recruitment, projected spawning biomass, and ABC). Only for the estimates of spawning biomass over the final 15 years of the model was C1 not the closest model to case C0. The general results for POP when the survey length composition in the most recent survey was included in cases C2a – C2e was that recruitment in the final 15 years and projected spawning biomass were overestimated, and spawning biomass in the final15 years and ABC were underestimated. In these cases the most recent recruitments were greatly overestimated when the survey length data was used, which resulted in an overestimate of the projected spawning biomass once these year-classes reached full maturity compared to case C0. Alternatively, for northern and dusky rockfish the model cases that were the most similar to case C0 were one of the sub-cases of case C2, with the exception of ABC for dusky rockfish, in which C1 was the most similar. For northern rockfish the most similar case to C0 was C2e, whereas for dusky the most similar cases varied by the model estimate evaluated. For each of these model estimates for northern and dusky rockfish, however, the changes compared to model case C0 were relatively small, with a maximum difference of 7.4%. The following table includes the absolute percent differences in these four model estimates compared to case C0, with the smallest difference highlighted in bold.

Species	Model case	Recruitment	Spawning biomass	Projected SSB	ABC
POP	C1	**1.7%**	5.5%	**1.7%**	**3.1%**
	C2a	8.5%	3.6%	3.9%	11.0%
	C2b	16.7%	6.9%	7.1%	17.4%
	C2c	21.2%	7.3%	9.7%	21.8%
	C2d	4.6%	**2.9%**	2.4%	7.9%
	C2e	16.4%	6.9%	7.0%	17.3%
Northern	C1	5.0%	6.3%	2.7%	5.8%
	C2a	**1.0%**	2.6%	1.1%	2.0%
	C2b	1.2%	2.2%	0.8%	1.4%
	C2c	2.3%	**1.6%**	0.7%	1.4%
	C2d	4.0%	5.4%	2.3%	4.6%
	C2e	1.6%	1.9%	**0.5%**	**0.9%**
Dusky	C1	6.4%	2.6%	7.1%	3.3%
	C2a	**4.2%**	2.0%	2.1%	2.2%
	C2b	5.5%	1.6%	1.3%	2.1%
	C2c	8.5%	**1.5%**	2.9%	**1.4%**
	C2d	4.4%	2.6%	5.5%	2.5%
	C2e	5.3%	1.7%	**1.2%**	2.1%

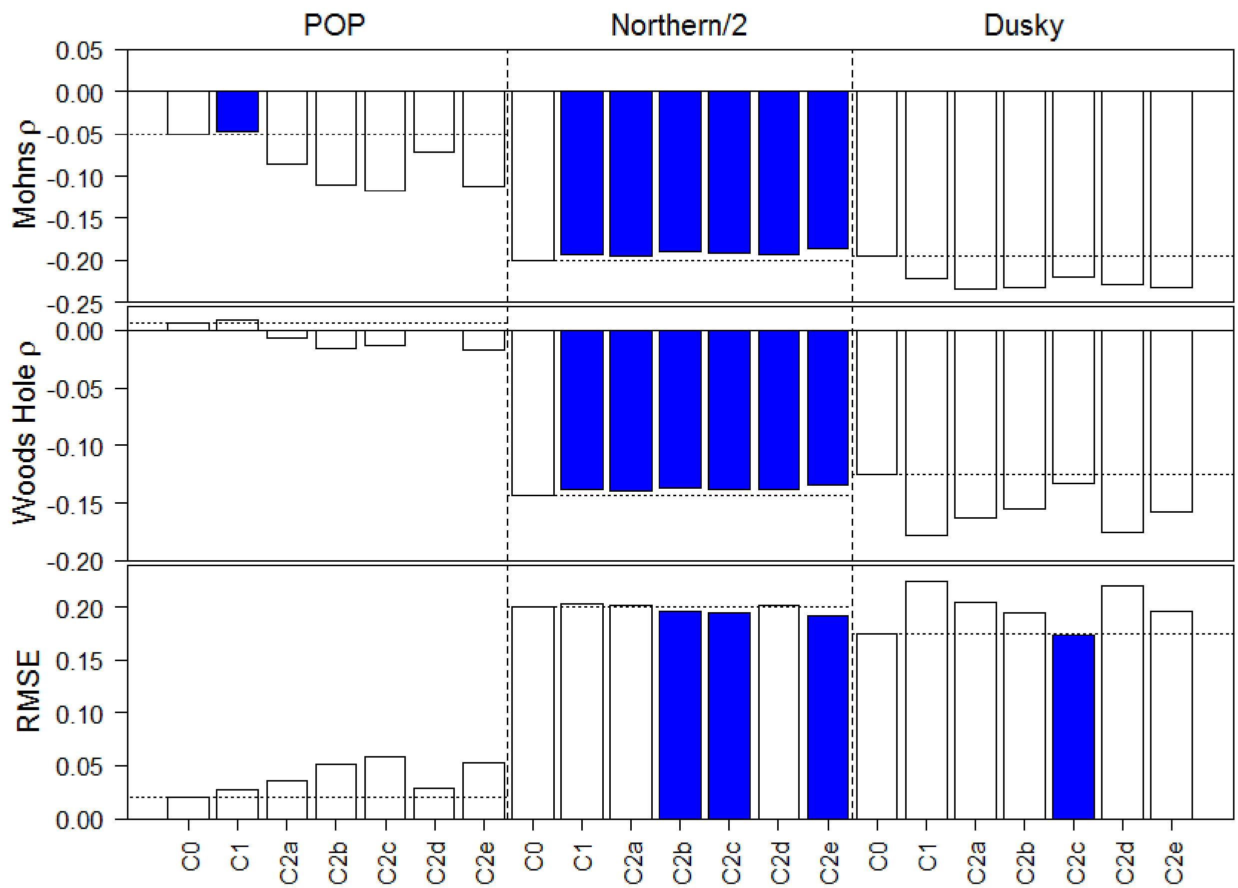
For POP, the absolute percent difference resulted in the same general trend as the standard percent difference, with case C1 resulting in the smallest value for 3 of 4 model estimates. However, for northern rockfish, rather than case C2e being consistently smaller in only 2 of 4 model estimates was this case the smallest. For dusky rockfish, case C2c was smaller than case C1 for ABC, which was the only estimate for which case C1 was the smallest in terms of standard percent difference.

The percent difference of the likelihoods for cases C1 – C2e compared to C0 are shown in the following figure. The smallest model case (i.e., the case with likelihoods most similar to C0) and model cases that were within 0.1% of the smallest case (i.e., cases that were essentially the same as the smallest case) are highlighted in blue. The percent difference between model cases C1 – C2e and C0 are shown in text above each bar.



For each of the species investigated there did not seem to be any single case among model cases C1 – C2e where the likelihood components were consistently closest to the base case C0. Indeed, across the species and likelihood components, with only a single exception, there were at least two model cases that were the closest to the base case (or within 0.1% of the closest case). The only exception to this was in the survey biomass likelihood for POP, in which case C1 was the closest to C0 and none of the C2 sub-cases were within 0.1% of C1. For both POP and northern rockfish, case C1 was one of the closest cases to C0 for 3 of 4 likelihood components, including the fit to the survey biomass. Thus, there did not seem to be a case that included the survey length composition in the final year of the model (C2a – C2e) that provided a marked improvement to the model over not including the final year's length data (C1). However, for dusky rockfish there did seem to be an improvement to the likelihood components when the survey length composition was included in the most recent year, as C1 was not within 0.1% of the smallest case for any of the likelihood components. Although, for dusky there was not a single C2 sub-case that was consistently closer than any other sub-case to the likelihoods of C0.

In the figure below the retrospective statistics investigated for POP, northern rockfish, and dusky rockfish are shown. The horizontal dashed line is the value for model case C0 and model cases that are an improvement over C0 are highlighted in blue (note for northern rockfish the values are divided by 2 so the statistics can be seen more easily).



For POP the best model scenario in terms of retrospective patterns for Mohn's ρ was case C1 and for Woods Hole ρ was C2d. In terms of RMSE model scenario C0 had the smallest RMSE, followed by model cases C1 and C2d. For northern rockfish, which has a strong retrospective pattern, any of the cases C1 – C2e was an improvement over case C0 for both Mohn's ρ and Woods Hole ρ. In terms of RMSE, only cases C2b, C2c, and C2e were smaller than C0 for northern rockfish. For dusky rockfish none of the scenarios C1 – C2e was better than case C0 for either Mohn's ρ or Woods Hole ρ. The RMSE for model case C2c was slightly smaller than C0 for dusky rockfish. In general, the retrospective statistics investigated were consistent across different models and no single approach appeared to be favored.

Conclusion

Overall, the results of this analysis suggest that the usefulness of including the most recent year's bottom trawl survey length composition is case specific. For example, in the evaluation of likelihoods compared to the base case it seemed that including the most recent year's length composition consistently performed better than excluding those data for dusky rockfish. However, the results for POP and northern rockfish suggest that it was better to exclude the most recent length information. Indeed, there were several likelihoods for which the case that excluded the most recent survey's length composition performed better than the cases that included the data for POP and northern rockfish. Statistics comparing the estimation differences for northern and dusky rockfish performed well when the most recent survey's length composition was used. In contrast, for POP case C1 (excludes the most recent survey's length composition) results were most similar to the base case for the majority of model estimates, including ABC. Specifically for POP, the results of using the most recent year's survey length composition failed to provide a consistent improvement over the status quo model for any of the statistics evaluated, and in some cases induced greater variability in model estimates. Additionally, in many cases recent recruitments were overestimated resulting in incorrect perceptions regarding population size.

In the interest of model stability and consistency we recommend that the status quo assessment model that does not include the most recent year's survey length composition continue to be used for POP. However, we recommend that the northern and dusky rockfish assessment authors consider using the most recent year's survey length composition, as it provided improvements relative to case C1. Further analyses of additional assessment models with species that exhibit a range of life histories may be warranted to help guide appropriate used of length composition data prior to having age composition data available. For the species evaluated here, POP ages are sampled at higher levels than northern and dusky rockfish, which could influence the usefulness of survey length data.

References

Dorn, M., K. Aydin, D. Jones, W. Palsson, and K. Spalinger, 2013. Assessment of the Walleye Pollock Stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, pp. 53 – 158. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 206, Anchorage, AK 99501.

Hanselman, D.H., S.K. Shotwell, P.J.F. Hulson, C.R. Lunsford, and J.N. Ianelli, 2013. Assessment of the Pacific ocean perch stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, pp. 757 – 832. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 206, Anchorage, AK 99501.

Hulson, P.-J.F., J. Heifetz, D.H. Hanselman, S.K. Shotwell, and J.N. Ianelli, 2013. Assessment of the northern rockfish stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, pp. 833 – 904. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 206, Anchorage, AK 99501.

Hulson, P.-J. F., D. H. Hanselman, and T. J. Quinn II, 2011. Effects of process and observation errors on effective sample size of fishery and survey age and length composition using variance ratio and likelihood methods. ICES J. Mar. Sci. 68(7): 1548-1557.

Legault, C.M., Chair, 2009. Report of the retrospective working group, January 14-16, 2008, Woods Hole, Massachusetts. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-01; 30 p.

Mohn, R., 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES J. Mar. Sci. 56: 473 – 488.

Parma, A.N., 1993. Retrospective catch-at-age analysis of pacific halibut: implications on assessment of harvesting policies. *In* Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations, pp. 247 – 265. *Ed.* G. Kruse, D.M. Eggers, C. Pautske, R.J. Marasco, and T.J. Quinn II. Alaska Sea Grant College Program.

Pennington, M., L.M. Burmeister, and V. Hjellvik, 2002. Assessing the precision of frequency distributions estimated from trawl-survey samples. Fish. Bull., 100: 74-80.

Spencer, P.D., and J.N. Ianelli, 2012. Assessment of the Pacific ocean perch stock in the Bering Sea/Aleutian Islands. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region, pp. 1291 – 1348. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 206, Anchorage, AK 99501.

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10. Assessment of the Northern Rockfish stock in the Gulf of Alaska

Peter-John F. Hulson, Chris R. Lunsford, Jonathan Heifetz, Dana H. Hanselman, S. Kalei Shotwell, and James N. Ianelli
November 2014

Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. Please refer to last year's full stock assessment report for further information regarding the assessment model (Hulson et al., 2013, available online at http://www.afsc.noaa.gov/REFM/docs/2013/GOAnorthern.pdf). A full stock assessment document with updated assessment and projection model results will be presented in next year's SAFE report.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska northern rockfish stock which qualifies as a Tier 3 stock. For an off-cycle year, we do not re-run the assessment model, but do update the projection model with new catch information. This incorporates the most current catch information without re-estimating model parameters and biological reference points.

Summary of changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment model inputs since this was an off-cycle year. New data added to the projection model included an updated 2013 catch and new estimated catches for 2014-2016. New estimates for this year's projection model are an updated 2013 catch at 4,879 t, and new estimated 2014-2016 catches. The 2014 catch was estimated by increasing the official catch as of October 1, 2014, by an expansion factor of 3%, which represents the average percentage of catch taken after October 1 in the last three complete years (2011-2013). Since the 2014 rockfish directed fishery did not occur in the Western Gulf until October 15 and those catches are not available at this time, an estimated 1000 t (maximum estimated catch by in-season management) was added to the corrected 2014 total catch to better reflect the 2014 estimated catch. To estimate future catches, we updated the yield ratio to 0.86, which was the average of the ratio of catch to ABC for the last three complete catch years (2011-2013). This yield ratio was multiplied by the projected ABCs for 2015 and 2016 from the updated projection model to generate catches for those years. The yield ratio was lower than last year's ratio of 0.95 whereas the expansion factor was the same as last year's expansion factor.

Changes in assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

For the 2015 fishery, we recommend the maximum allowable ABC of **4,999** t from the updated projection model. This ABC is 6% less than last year's ABC of 5,324 t but only slightly less than last year's 2015 projected ABC of 5,012 t. Recommended area apportionments of ABC are 1,226 t for the Western area, 3,772 t for the Central area, and 1 t for the Eastern area. The 2015 Gulf-wide OFL for northern rockfish is **5,961** t.

Reference values for northern rockfish are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not being subjected to overfishing last year, is not currently overfished, nor is it approaching a condition of being overfished.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015	2016
M (natural mortality rate)	0.06	0.06	0.06	0.06
Tier	3a	3a	3a	3a
Projected total (ages 2+) biomass (t)	102,893	98,572	98,409	94,820
Projected Female spawning biomass (t)	42,960	40,004	39,838	37,084
$B_{100\%}$	75,183	75,183	75,183	75,183
$B_{40\%}$	30,073	30,073	30,073	30,073
$B_{35\%}$	26,314	26,314	26,314	26,314
F_{OFL}	0.073	0.073	0.073	0.073
$maxF_{ABC}$	0.061	0.061	0.061	0.061
F_{ABC}	0.061	0.061	0.061	0.061
OFL (t)	6,349	5,978	**5,961**	5,631
maxABC (t)	5,324	5,012	4,999	4,722
ABC (t)	5,324	5,012	**4,999**	4,722
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1] Projections are based on estimated catches of 4,333 t and 4,111 t used in place of maximum permissible ABC for 2015 and 2016.

Updated catch data (t) for northern rockfish in the Gulf of Alaska as of October 1, 2014 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org) are summarized in the following table.

Year	Western	Central	Eastern	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
2013	2,174	2,705		4,879	5,130	5,130
2014	60	3,297		3,357	5,322	5,322

Area Apportionment

The apportionment percentages are the same as in the 2013 full assessment. The following table shows the recommended apportionment of ABC for 2015 and 2016. Please refer to last year's full stock assessment report for information regarding the apportionment rationale for northern rockfish.

	Western	Central	Eastern*	Total
Area Apportionment	24.52%	75.45%	0.03%	100%
2015 Area ABC (t)	**1,226**	**3,772**	**1**	**4,999**
2016 Area ABC (t)	**1,158**	**3,563**	**1**	**4,722**

*For management purposes the small ABC in the Eastern area is combined with other rockfish.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC[3]	TAC[3]	Catch[2]
Northern rockfish	2013	99,089	6,124	5,130	5,130	4,879
	2014	102,893	6,349	5,322	5,322	3,357
	2015	98,409	5,961	4,999		
	2016	94,820	5,631	4,722		

Stock/		2014				2015		2016	
Assemblage	Area	OFL	ABC[3]	TAC[3]	Catch[2]	OFL	ABC	OFL	ABC
Northern rockfish	W		1,305	1,305	60		1,226		1,158
	C		4,017	4,017	3,297		3,772		3,563
	E						1		1
	Total	6,349	5,322	5,322	3,357	5,961	4,999	5,631	4,722

[1]Total biomass (ages 2+) from the age-structured model
[2]Current as of October 1, 2014. Source: NMFS Alaska Regional Office Catch Accounting System via the AKFIN database (http://www.akfin.org).
[3]For management purposes, the small ABC for northern rockfish in the Eastern Gulf of Alaska is combined with other rockfish. Thus, for 2014 the Eastern Gulf ABC (and associated TAC) is not reported in these tables, but the Eastern Gulf ABC for 2015 and 2016 are included as future recommendations.

SSC and Plan Team Comments on Assessments in General

"The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years." (Plan Team, September 2012)

In response to both of these comments, retrospective analyses for the author's recommended model were included in the retrospective investigation group's Plan Team report. We will include further examination of retrospective analysis in next year's full assessment.

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

The degree of overlap between catch-in-areas and the HFICE estimates are negligible for northern rockfish (see Table 10A.2 in the 2013 SAFE report).

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)
"The Teams recommend that the whole time series of each category of 'other' catches be made available on the NMFS "dashboard," so that they may be listed in all SAFE chapters." (Plan Team, November 2012)

In response to these two comments, other removals are available on the dashboard. These removals were included the 2013 SAFE report and will continue to be included in future full-assessments.

"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs." (Plan Team, September 2013)

We estimated current year's removals by multiplying the official catch as of October 1, 2014, by an expansion factor, which represents the average additional catch taken after October 1 and through December 31 in the last three complete years (2011-2013). Further description is provided in the 'Specified catch estimation' section in the 2013 SAFE report.

"For the GOA age-structured rockfish assessments, if length composition data are withheld, the Team recommends exploratory model runs to test sensitivity. This should include any year of fishery or survey length composition data which could serve as a proxy for the age composition, not simply the most recent survey year." (Plan Team, November 2013)

A sensitivity analysis of including the most recent year's survey length composition has been performed for northern rockfish and is included in Appendix 9B of the Pacific ocean perch SAFE. The results of that analysis suggests that in some cases using the most recent year's survey length composition in the northern rockfish assessment improves results. We will further investigate this results in the full assessment provided in 2015. Fishery length compositions are utilized in the northern rockfish assessment in years for which fishery age data is not available.

"For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

Because of the Government shutdown in 2013, comments were not fully addressed in last year's assessment. Full assessment updates for all the GOA rockfish stocks will be completed in 2015 and CIE review comments will be addressed at that time. Please refer to the Summary and response to the 2013 CIE review of the AFSC rockfish document presented to the September 2013 Plan Team (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf).

"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment." (SSC December 2013)

These projections are available in the executive summary table and will be added to the phase-plane plots in future full assessments.

SSC and Plan Team Comments Specific to this Assessment

"The Team asks the [rockfish] *authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities."* (Plan Team, November 2011)

The conversion matrix and all growth information were updated in the 2011 assessment. Many of the issues regarding temporal changes in the conversion and error matrices are similar across the age-structured rockfish assessments. In order to properly address this comment we plan to conduct an investigation on developing methods for updating conversion and error matrices for these long-lived species as a group and to perform sensitivity analyses on the timeliness of updates. We anticipate this future investigation to begin next year and will incorporate relevant results into the northern rockfish model following further review. Analysis of including the survey length data into the northern rockfish model is included in the Pacific ocean perch assessment, and recommendations from which will be taken into account in next year's full assessment.

"The SSC also looks forward to an update of weight-at-age, length and age transition matrices, ageing error matrix, and length bins for fishery length compositions during the next assessment cycle." (SSC, December 2011)

An alternative method to incorporate ageing error was presented at the November 2013 Plan Team meeting. This method will be further explored and incorporated into the 2015 rockfish assessments. Upon implementation of the new ageing error method the age and length bins will be further investigated and any changes suggested by these analyses will be implemented in the 2015 assessments.

"The SSC supports the inclusion of the maturity data within the model to estimate an intermediate maturity schedule as an interim solution to dealing with two conflicting studies. However, we encourage the authors to further explore the reasons for differences seen between the two studies of maturity that formed the basis of the estimated maturity schedule in the model." (SSC, December 2011)

We agree with the SSC that the reasons for such differences found in maturity should be explored to refine the method of incorporating maturity into the assessment model. However, additional studies for northern rockfish must be conducted to make any such analysis fruitful, as it is unclear whether the change seen in northern rockfish maturity between these two studies was due to maturity changing over time, observation error in maturity observations, or a combination of both. Additional studies would help to clarify the reasons behind changing maturity.

"The SSC recommends that the authors explore and evaluate alternative approaches to constructing the trawl survey biomass and consider recommendations from the survey averaging work group for apportionment. The SSC recommends including work on maturity for northern rockfish as a research priority." (SSC, December 2013)

We hope to explore and present alternative approaches to constructing trawl survey biomass for the 2015 full assessment. In the 2015 assessment we will explore using the random effects model for apportionment similar to the approach used for this year's POP assessment. We also agree that additional information on northern rockfish maturity would be useful.

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11. Assessment of the Shortraker Rockfish stock in the Gulf of Alaska

Katy B. Echave and S. Kalei Shotwell
November 2014

Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska (GOA) rockfish in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. Please refer to the last full stock assessment report presented in 2011 for further information regarding the assessment calculations (Clausen and Echave 2011, http://www.afsc.noaa.gov/refm/docs/2011/GOAshortraker.pdf). A full stock assessment document with updated assessment results will be presented in next year's SAFE report.

We average the biomass estimates from the three most recent GOA trawl surveys to estimate exploitable biomass and determine the recommended ABC for the shortraker rockfish stock. This stock is classified as a Tier 5 stock. For an off-cycle year, there is no new survey information for the shortraker rockfish stock; therefore, the 2013 estimates (Echave and Shotwell 2013, http://www.afsc.noaa.gov/REFM/Docs/2013/GOAshortraker.pdf) are rolled over for the next year.

Summary of Changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment inputs since this was an off-cycle year.

Changes in assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

For the 2015 fishery, we recommend the maximum allowable ABC of 1,323 t for shortraker rockfish. Reference values for shortraker rockfish are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not being subjected to overfishing last year.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015	2016
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	58,797	58,797	58,797	58,797
F_{OFL}	0.03	0.03	0.03	0.03
$maxF_{ABC}$	0.0225	0.0225	0.0225	0.0225
F_{ABC}	0.0225	0.0225	0.0225	0.0225
OFL (t)	1,764	1,764	**1,764**	1,764
maxABC (t)	1,323	1,323	1,323	1,323
ABC (t)	1,323	1,323	**1,323**	1,323
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a

Updated catch data (t) for shortraker rockfish in the Gulf of Alaska as of October 1, 2014 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org) are summarized in the following table.

Year	Western	Central	Eastern	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
2013	37	449	244	730	1,081	1,081
2014	27	297	235	559	1,323	1,323

Area Apportionment

The following table shows the recommended apportionment for 2015. The apportionment percentages are the same as in the 2013 assessment (for the 2014 fishery). Please refer to the last full stock assessment report for information regarding the apportionment rationale for the shortraker rockfish stock.

	Western	Central	Eastern	Total
Area Apportionment	6.98%	29.94%	63.08%	100%
Area ABC (t)	**92**	**397**	**834**	**1,323**
OFL (t)				**1,764**

Summaries for Plan Team

Species	**Year**	**Biomass[1]**	**OFL**	**ABC**	**TAC**	**Catch[2]**
Shortraker Rockfish	2013	48,048	1,441	1,081	1,081	730
	2014	58,797	1,764	1,323	1,323	559
	2015	58,797	1,764	1,323		
	2016		1,764	1,323		

Stock/ Assemblage	**Area**	**2014**				**2015**		**2016**	
		OFL	**ABC**	**TAC**	**Catch[2]**	**OFL**	**ABC**	**OFL**	**ABC**
Shortraker rockfish	W		92	92	27		92		92
	C		397	397	297		397		397
	E		834	834	235		834		834
	Total	1,764	1,323	1,323	559	1,764	1,323	1,764	1,323

[1]Total biomass from trawl survey estimates.

[2]Current as of October 1, 2014. Source: NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org).

Responses to SSC and Plan Team Comments on Assessments in General

Because of the government shutdown in 2013, there was only sufficient time to compile SSC and Plan Team comments in last year's assessment. Since this is an "off" year and only an executive summary is presented, we respond here to priority comments. For comments that are relevant to or require a full assessment, we will present responses in next year's full assessment.

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)
The authors of HFICE were unable to delineate the overlap between CAS and HFICE (Tribuzio et al. 2014). The HFICE authors recommended waiting for more years of the restructured observer program data so that a comparison between the two procedures can be made. The SSC reviewed that recommendation again with regards to the GOA shark assessment at its October 2014 meeting and agreed with the authors that waiting for more data was appropriate (see Appendix 20.A of the 2014 BSAI or GOA shark assessments).

"The SSC encourages assessment authors of stocks managed in Tier 5 to consider the recommendations found in the draft survey averaging workgroup report." (SSC, December 2012)
Efforts are underway to determine the most appropriate approach for this species and will be presented in the next full assessment.

"The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC." (Plan Team, September 2013)
An appendix of "other" removals will be included in the next full assessment.

"The Teams recommend that stock assessment authors calculate biomass for Tier 5 stocks based on the random effects model and compare these values to status quo. In addition, the Teams recommend that the working group examine autocorrelation in subarea recruitment when conducting spatial simulations for evaluating apportionment." (Plan Team, September 2014)
Various approaches to calculated biomass based on the random effects model were presented to the Plan Team in September 2013. Continued efforts are underway to determine the most appropriate approach for this species, and this method will be presented in the next full assessment.

SSC and Plan Team Comments Specific to this Assessment

"The Plan Team recommends this species be included in the review of area apportionments [to be presented] *in September 2012."* (Plan Team, November 2011)
Authors continue to use status quo methods of area apportionments. Currently the Plan Team's working group on survey averaging is evaluating alternative methods for area apportionments.

"The assessment authors note that the trawl survey can only sample a limited proportion of the likely range of shortraker, and that the longline survey may be providing a better abundance index. The SSC encourages the authors to continue to look at ways the longline survey data can be incorporated into the assessment." (SSC, December 2011)
Authors agree that the longline survey may provide a better abundance index for several rockfish species, shortrakers included. Work continues to be done addressing this problem and will be included in the next full assessment.

"The Plan Team recommends that in addition to the current assessment methodology, authors use the Kalman filter method to estimate survey biomass and summarize the results for comparison at the September 2013 meeting. The Plan Team did not make other recommendations for changes to the

assessment model but noted that recommendations may occur as a result of the March 2013 CIE review. The Plan Team also supports ongoing efforts to validate current ageing methodology." (Plan Team, November 2012)
Various approaches to calculated biomass based on the random effects model were presented to the Plan Team in September 2013. Continued efforts are underway to determine the most appropriate approach for this species and will be presented in the next full assessment. Ongoing efforts to validate current aging methodology continue, but no method has yet been approved.

"The Team recommends that the random effects survey averaging approach be explored for future apportionment calculations. The Team also recommends the author provide an executive summary for the 2014 assessment as no new data will be available, to include any outstanding Team or SSC recommendations with the summary." (Plan Team, November 2013)
Various approaches to calculated biomass based on the random effects model were presented to the Plan Team in September 2013. Continued efforts are underway to determine the most appropriate approach for this species, and this method will be presented in the next full assessment.

Literature Cited

Clausen, D. M. and K.B. Echave. 2011. Assessment of shortraker rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 971-1008. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501. Available online: http://www.afsc.noaa.gov/refm/docs/2011/GOAshortraker.pdf

Echave, K. B. and S.K. Shotwell. 2013. Assessment of shortraker rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 905-908. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501. Availableonline: http://www.afsc.noaa.gov/REFM/Docs/2013/GOAshortraker.pdf

Tribuzio, C. A., J. R. Gasper, and S. K. Gaichas. 2014. Estimation of bycatch in the unobserved Pacific halibut fishery off Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-265, 506 p.

12. Assessment of the Dusky Rockfish stock in the Gulf of Alaska

Chris R. Lunsford, S. Kalei Shotwell, Peter-John F. Hulson, and Dana H. Hanselman
November 2014

Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. Please refer to last year's full stock assessment report for further information regarding the assessment model (Lunsford et al., 2013, available online at http://www.afsc.noaa.gov/REFM/docs/2013/GOAdusky.pdf). A full stock assessment document with updated assessment and projection model results will be presented in next year's SAFE report.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska dusky rockfish which qualifies as a Tier 3 stock. For an off-cycle year, we do not re-run the assessment model, but do update the projection model with new catch information. This incorporates the most current catch information without re-estimating model parameters and biological reference points.

Summary of changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment model inputs since this was an off-cycle year. New data added to the projection model included an updated 2013 catch and new estimated catches for 2014-2016. New catch estimates for this year's projection model are an updated 2013 catch of 3,158 t, and estimated 2014-2016 catches of 3,106 t, 3,379 t, and 3,124 t, respectively. The 2014 catch was estimated by multiplying the official catch as of October 1, 2014, by an expansion factor of 1.03, which represents the average fraction of catch taken between October 1 and December 31 in the last three complete years (2011-2013). Since the 2014 rockfish directed fishery did not occur in the Western Gulf until October 15 and those catches aren't available at this time, an estimated 200 t (maximum estimated catch by in-season management) was added to the corrected 2014 total catch to better reflect the 2014 estimated catch. To estimate future catches, we updated the yield ratio (0.67), which was the average of the ratio of catch to ABC for the last three complete catch years (2011-2013). This yield ratio was multiplied by the projected ABCs for 2015 and 2016 from the 2013 assessment model to generate catches for those years. The yield ratio was higher than last year's ratio of 0.63 whereas the expansion factor was the same as last year's expansion factor.

Changes in assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

For the 2015 fishery, we recommend the maximum allowable ABC of **5,109** t from the updated projection model. This ABC is 7% lower than the 2014 ABC of 5,486 t but similar to the ABC of 5,081 t projected for 2015 in the 2014 assessment. Recommended area apportionments of ABC are 296 t for the Western area, 3,336 t for the Central area, 1,288 t for the West Yakutat area, and 189 t for the Southeast/Outside area. The 2015 Gulf-wide OFL for dusky rockfish is **6,246 t**.

Reference values for dusky rockfish are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not being subjected to overfishing last year, is not currently overfished, nor is it approaching a condition of being overfished.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015[1]	2016[1]
M (natural mortality rate)	0.07	0.07	0.07	0.07
Tier	3a	3a	3a	3a
Projected total (ages 4+) biomass (t)	69,371	66,104	66,629	64,295
Projected female spawning biomass (t)	29,256	27,200	27,345	25,344
$B_{100\%}$	52,264	52,264	52,264	52,264
$B_{40\%}$	20,906	20,906	20,906	20,906
$B_{35\%}$	18,292	18,292	18,292	18,292
F_{OFL}	0.122	0.122	0.122	0.122
$maxF_{ABC}$	0.098	0.098	0.098	0.098
F_{ABC}	0.098	0.098	0.098	0.098
OFL (t)	6,708	6,213	**6,246**	5,759
maxABC (t)	5,486	5,081	5,109	4,711
ABC (t)	5,486	5,081	**5,109**	4,711
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1] Projections are based on estimated catches of 3,379 t and 3,124 t used in place of maximum permissible ABC for 2015 and 2016.

Updated catch data (t) for dusky rockfish in the Gulf of Alaska as of October 1, 2014 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org) are summarized in the following table. The 2014 dusky rockfish catch as of October 1 was lower in the Western Gulf than previous years because in 2014 the rockfish trawl fishery in this region was not opened to directed fishing until October 15. Final catch estimates will likely be similar to previous years when the directed fishery catch from this region is included.

Year	Western	Central	Eastern	West Yakutat	E. Yakutat/ Southeast	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
2013	217	2,929		4	8	3,158	4,700	4,700
2014	22	2,718		86	4	2,830	5,486	5,486

Area Apportionment

The apportionment percentages are the same as in the 2013 full assessment. The following table shows the recommended apportionment for 2015. Please refer to last year's full stock assessment report for information regarding the apportionment rationale for dusky rockfish.

	Western	Central	West Yakutat[1]	E Yakutat / Southeast[1]	Total
Area Apportionment	5.8%	65.3%	25.2%	3.7%	100%
Area ABC (t)	**296**	**3,336**	**1,288**	**189**	**5,109**
OFL (t)					**6,246**

[1]Amendment 41 prohibited trawling in the eastern area east of 140° W longitude. To account for the portion of the dusky rockfish biomass in the West Yakutat area that is still open to trawling a ratio is calculated to apportion the eastern area into West Yakutat and East Yakutat/Southeast Outside. This ratio is the same as last year (0.87).

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Dusky Rockfish	2013	63,515	5,746	4,700	4,700	3,158
	2014	69,371	6,708	5,486	5,486	2,830
	2015	66,629	6,246	5,109		
	2016	64,295	5,759	4,711		

Stock/ Assemblage	Area	2014				2015		2016	
		OFL	ABC	TAC	Catch[2]	OFL	ABC	OFL	ABC
Dusky Rockfish	W		317	317	22		296		273
	C		3,584	3,584	2,718		3,336		3,077
	WYAK		1,384	1,384	86		1,288		1,187
	EYAK/SEO		201	201	4		189		174
	E		--	--	--				
	Total	6,708	5,486	5,486	2,830	6,246	5,109	5,759	4,711

[1]Total biomass (ages 4+) from the age-structured model

[2]Current as of October 1, 2014. Source: NMFS Alaska Regional Office Catch Accounting System via the AKFIN database (http://www.akfin.org).

Responses to SSC and Plan Team Comments on Assessments in General

Because of the government shutdown in 2013, there was only sufficient time to compile SSC and Plan Team comments in last year's assessment. Since this is an "off" year and only an executive summary is presented, we respond here to priority comments. For comments relevant to or require a full assessment and/or model run, we will present responses in next year's full assessment.

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years."
(Plan Team, September 2012)

Retrospective analyses for the author's recommended model were included in the retrospective investigation group's Plan Team report in September, 2013 (Hanselman et al., 2013.

http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/Retrospectives_2013_final3.pdf). We will include further examination of retrospective analysis in next year's full assessment.

"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs." (Plan Team, September 2013)

We estimated current year's removals by multiplying the official catch as of October 1, 2014, by an expansion factor of 1.03, which represents the average additional catch taken between October 1 and December 31 in the last three complete years (2011-2013). (*Section: Executive Summary: Summary of Results*).

"For the GOA age-structured rockfish assessments, if length composition data are withheld, the Team recommends exploratory model runs to test sensitivity. This should include any year of fishery or survey length composition data which could serve as a proxy for the age composition, not simply the most recent survey year." (Plan Team, November 2013)

Preliminary analysis of including length composition data in the model has been conducted for GOA POP and was presented September, 2014. Additional analyses for three rockfish species including dusky are presented as an appendix in this year's POP assessment. Following Plan Team and SSC review on this, we plan to explore similar sensitivity analyses for the 2015 dusky rockfish assessment.

"For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

Because of the Government shutdown in 2013, comments were not fully addressed in last year's assessment. Full assessment updates for GOA rockfish will be completed in 2015 and CIE review comments will be addressed at that time. Additionally, an AFSC response to the rockfish CIE review was prepared that addresses some of their concerns. Please refer to the "Summary and response to the 2013 CIE review of the AFSC rockfish" document presented to the September 2013 Plan Team for further details (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf).

"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment." (SSC December 2013)

These projections are available in the executive summary table and will be added to the phase-plane plots in future full assessments.

SSC and Plan Team Comments Specific to this Assessment

"The Team asks the [rockfish] *authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be*

based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities." (Plan Team, November 2011)

For the 2013 dusky rockfish assessment we used the same weight-at-age estimates, age-length transition matrix, and aging error conversion matrix as the 2011 assessment which used survey data from 1984-2007. This was an update from previous assessments (2001-2009) which used values from the 2001 Pelagic Shelf Rockfish SAFE document (Clausen and Heifetz, 2001). We hope to update with the most recent data for the 2015 full assessment. Many of the issues regarding temporal changes in the conversion and error matrices are similar across the age-structured rockfish assessments. In order to properly address this comment we plan to conduct an investigation on developing methods for updating conversion and error matrices for these long-lived species as a group and to perform sensitivity analyses on the timeliness of updates. We anticipate this to begin next year and will incorporate relevant results into the dusky rockfish model following further review. An analysis of including the survey length data into the dusky rockfish model is included in this year's Pacific ocean perch assessment, and we plan to take the forthcoming recommendations into account in next year's full assessment.

"The Team noted the low recruitment estimates (with high uncertainty) for recent year classes, and requests a retrospective analysis to evaluate how changes in available data affect estimated year-class strength." (Plan Team, November 2011)

A retrospective analysis is planned for next year and year class strength changes will be evaluated at that time.

"Results from model 3 showed the age at 50% maturity from model 3 was approximately 10 years, a decline from the value of approximately 11 years used in previous assessments. This resulted in an increase in the recommended F_{OFL} and F_{ABC}. The SSC asks the author to consider whether this downward adjustment in the age at 50% maturity is warranted." (SSC, December 2011)

In 2011 a new age at maturity value was presented. The previous value was from opportunistic sampling of sixty-four female dusky rockfish. The proposed maturity-at-age was modeled with the logistic function and parameter estimates were obtained by combining the data from the sixty-four specimens with the results of a newly published study on dusky rockfish in the GOA. This approach utilized the best available information combining data from the two studies. Additionally, these parameter estimates were estimated conditionally within the model allowing for uncertainty in age-at-maturity to be incorporated into uncertainty for key model results such as ABC. This approach has also been adopted for GOA and BSAI POP and GOA northern rockfish where multiple age-at-maturity estimates from different studies were available.

"The authors noted that if area specific OFLs were in place they would have been exceeded in the western GOA. The SSC encourages the authors to continue to track this in future years." (SSC, December 2012)

The western GOA catch did not exceed TAC in 2013 and is not expected to exceed TAC in 2014. In-season management has worked with the rockfish fleet to ensure overages do not occur in the western GOA rockfish fishery. We will continue to monitor and report if these catches exceed TAC.

"The Team recommends exploration of extending the modeled ages beyond the plus group in the data in order to improve the fits to the age composition data." (Plan Team, November 2013)

The GOA rockfish stock assessment authors hope to address these comments as a whole for all of the rockfish species that have age-structured assessments. We expect to present an analysis in September, 2015 for inclusion in next year's stock assessments.

"In order to evaluate the relative precision of area-specific biomass estimates, the Team recommends that the authors include the survey CVs by region when presenting apportionment estimates." (Plan Team, November 2013)

For 2015, when apportionments are re-calculated, we will include survey CVs by region.

"The SSC concurs with the Plan Team that exploration of the impacts of extending the plus-group in the assessment, and trying the random effects models for spatial allocation, would be potentially useful enhancements to the assessment. The SSC notes that the CIE reviewers provided comments on the use of survey data in stock assessments and encourages the author to evaluate comments relevant to the dusky assessment." (SSC, December 2013)

We hope to have a rockfish analysis on the plus-group issue in September, 2015. We plan to include the random effects model in apportionment calculations for 2015, per the September 2014 SSC recommendation for GOA POP. We will also address CIE review comments in next year's assessment.

13. Assessment of the Rougheye and Blackspotted Rockfish stock complex in the Gulf of Alaska

S. Kalei Shotwell, Dana H. Hanselman, Peter F. Hulson, and Jonathan Heifetz
November 2014

Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska (GOA) rockfish in off-cycle (even) years, we typically present an executive summary to recommend harvest levels for the next two years. However, last year during an on-cycle (odd) year, we presented an executive summary similar to an off-cycle year for GOA rougheye and blackspotted (RE/BS) rockfish due to the 2013 government shutdown and extensive data updates that were needed. The GOA Plan Team (November 2013) subsequently recommended a full stock assessment be presented in 2014. We, therefore, present a full stock assessment document with updated assessment and projection model results to recommend harvest levels for the next two years.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska rougheye and blackspotted rockfish (RE/BS complex) which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels.

The data sets used in this assessment include total catch biomass, fishery age and size compositions, trawl and longline survey abundance estimates, trawl survey age compositions, and longline survey size compositions. For this assessment year, there are three models presented in the assessment. Model 0 is the last full assessment base model from 2011. Model 1 is an intermediate model which uses all the new and updated data but keeps the previous longline survey abundance index based on weights and the old conversion matrices. Finally, Model 2 is the author preferred model which uses all the new and updated data, the longline survey abundance index based on numbers, and the updated conversion matrices.

Summary of Changes in Assessment Inputs

Changes in the input data: New and updated data added to this model include updated catch estimates for 2011-2013, new catch estimates for 2014-2016 (see *Specified Catch Estimation* subsection in **Harvest Recommendations** section), new fishery ages for 2009 and 2012, new fishery lengths for 2011, a new trawl survey estimate for 2013, updated trawl survey ages for 2009, new trawl survey ages for 2011, and fully revised longline survey abundance estimates and length frequencies. We now use the time series of relative population numbers (RPNs) rather than relative population weights (RPWs) to represent the longline survey abundance (see *AFSC Longline Abundance Index* section). Use of the RPNs follows what is done for the sablefish assessment model. New biological data on growth and aging error were used to update the weight-at-age estimates, the size-at-age conversion matrix, and the aging error matrix.

Changes in the assessment methodology: For the preferred model (Model 2), the longline survey abundance index is fit in number instead of weight.

Summary of Results

Reference values for RE/BS rockfish are summarized in the following table, with the recommended ABC and OFL values for 2015 in bold. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:*	
	2014	2015	2015	2016
M (natural mortality rate)	0.034	0.034	0.034	0.034
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	42,810	43,337	36,584	36,610
Projected female spawning biomass (t)	12,897	13,325	12,480	12,595
$B_{100\%}$	24,329	24,329	22,449	22,449
$B_{40\%}$	9,732	9,732	8,980	8,980
$B_{35\%}$	8,515	8,515	7,857	7,857
F_{OFL}	0.047	0.047	0.045	0.045
$maxF_{ABC}$	0.039	0.039	0.038	0.038
F_{ABC}	0.039	0.039	0.038	0.038
OFL (t)	1,497	1,518	**1,345**	1,370
maxABC (t)	1,244	1,262	1,122	1,142
ABC (t)	1,244	1,262	**1,122**	1,142
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 736 t for 2014 and projected catches of 502 t for 2015 and 501 t for 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

The 2013 trawl survey estimate was the lowest of the time series at 40% below average. The 2012 and 2013 longline survey abundance estimates (RPNs) were about 6% and then 16% below average. However, the 2014 longline RPN increased substantially from 2013 to be 17% above average.

Parameter estimates for all three models are provided for comparison purposes. The updated Models 1 and 2 are somewhat similar with higher trawl and longline survey catchability than the base Model 0. However, Model 1 (intermediate model) has lower mean recruitment and lower estimates of spawning biomass. Other estimates are similar between all three models.

For the 2015 fishery, we recommend the maximum allowable ABC of 1,122 t from the author preferred model (Model 2). This is a 10% decrease from last year's ABC of 1,244 t. Recent recruitments are steady and near the median of the recruitment time series. This is evident in the ages for the trawl survey with more young fish over time. Female spawning biomass is well above $B_{40\%}$, and projected to be stable.

Area Allocation of Harvests

The apportionment percentages have changed with the addition of the 2013 trawl survey biomass. In past assessments, we determine apportionment using a 4:6:9 weighted average of the proportion of biomass in each area from the three most recent bottom trawl surveys. This exponential moving average was used to smooth the estimates but weight the most recent observation most heavily. As an alternative to this, both the Plan Team and SSC have requested that the random effects model proposed by the Survey Averaging Working Group be considered for apportionment and provided alongside the current apportionment for comparison purposes.

The following table shows the apportionment for the 2015 and 2016 fishery using the three survey weighted average and random effects methods.

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Average			10.3%	56.3%	33.4%	100%
	2015	Area ABC (t)	**115**	**632**	**375**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**117**	**643**	**382**	**1,142**
		OFL (t)				**1,370**
Random Effects			10.6%	57.3%	32.1%	100%
	2015	Area ABC (t)	**119**	**643**	**360**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**122**	**654**	**366**	**1,142**
		OFL (t)				**1,370**

We recommend continuing with the standard three survey weighted average apportionment for RE/BS rockfish. The random effects model fit the area-specific biomass reasonably well but was sensitive to starting values for the Central GOA (see *Area Allocation of Harvests* subsection in **Harvest Recommendations** section). We will consider the random effects model for RE/BS rockfish when recommendations on estimation uncertainty and inclusion of other survey biomass estimates (e.g. AFSC longline survey) are provided by the Survey Averaging Working Group.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2013	42,883	1,482	1,232	1,232	574
	2014	42,810	1,497	1,244	1,244	704
	2015	36,584	1,345	1,122		
	2016	36,610	1,370	1,142		

Stock/ Assemblage	Area	2014 OFL	2014 ABC	2014 TAC	2014 Catch[2]	2015 OFL	2015 ABC	2016 OFL	2016 ABC
RE/BS complex	W		82	82	10		115		117
	C		864	864	528		632		643
	E		298	298	166		375		382
	Total	1,497	1,244	1,244	704	1,345	1,122	1,370	1,142

[1]Total biomass (ages 3+) from the age-structured model

[2]Current as of October 1, 2014. Source: NMFS Alaska Regional Office Catch Accounting System via the AKFIN database (http://www.akfin.org).

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)
"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years."
(Plan Team, September 2012)

In September 2013, the Retrospective Investigations Group responded to both of these comments with a report on retrospective analyses conducted on Alaska FMP groundfish species (Hanselman et al. 2013). We updated this analysis to the current author recommended model and include results and discussion within the **Time Series Results** section. This *Retrospective Analysis* section will be included as a standard section in the future.

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal."
(Plan Team, September 2012)
"The Teams recommend that the whole time series of each category of 'other' catches be made available on the NMFS "dashboard," so that they may be listed in all SAFE chapters."
(Plan Team, November 2012)

A report for generating the time series of other removals is available on the AKFIN stock assessment dashboard entitled "Non-Commercial Catch" (http://www.akfin.org). We use this report to update the appendix of total removals and present in Table 13A-1 of Appendix 13A in this assessment. We will continue to include this appendix in the future.

"The SSC recommends that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL."
(SSC, December 2012)

M is estimated inside the RE/BS rockfish assessment model and is, therefore, estimated with more than two significant digits.

"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs." (Plan Team, September 2013)
"The Teams recommend that authors choose a method that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also

document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2)." (Plan Team, September 2013).

We estimated current year's removals by multiplying the official catch as of October 1, 2014, by an expansion factor of 1.045, which represents the average fraction of the catch taken between October 1 and December 31 in the last three complete years (2011-2013). The catch was lower in the Western GOA than in previous years because the 2014 rockfish trawl fishery in this region was not opened to directed fishing until October 15. Final catch estimates for this region will likely be similar to previous years when the directed fishery catch is included and preliminary estimates suggest this to be the case (23 t as of November 3). The expanded estimate of the 2014 catch used in the preferred assessment model (736 t) is very close to the current total catch as of November 3, 2014 (730 t). Therefore, we did not apply any correction factor to the expanded estimate for the late fishing in the Western GOA. Further description of the catch estimation method is provided in the *Specified Catch Estimation* subsection under the **Harvest Recommendations** section.

"For the GOA age-structured rockfish assessments, if length composition data are withheld, the Team recommends exploratory model runs to test sensitivity. This should include any year of fishery or survey length composition data which could serve as a proxy for the age composition, not simply the most recent survey year." (Plan Team, November 2013)

Preliminary analysis of including length composition data in the model had been conducted for GOA Pacific ocean perch (POP) and was presented to the Plan Team in September, 2014. For GOA RE/BS rockfish, the fishery primarily selects for older aged fish (16 + for ages with selectivity greater than 50%) where the variability in length-at-age provides very little distinction in age-at-length and therefore little information is contained in the length composition data to inform recent recruitment. An evaluation for GOA POP (where the ages with fishery selectivity greater than 50% is around ages 9 to 17) found that the model was essentially invariant to including the recent fishery length composition data as a proxy for age data (see GOA POP November 2014 assessment). Additional sensitivity analyses for GOA POP, northern rockfish, and dusky rockfish on including the bottom trawl survey length composition from the most recent year are presented in Appendix 9B of the GOA POP November 2014 assessment. Following Plan Team and SSC review on this sensitivity analysis, we plan to explore similar analyses for the 2015 RE/BS rockfish stock assessment.

"For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

Full assessment updates for all GOA rockfish will be completed in 2015 and CIE review comments will be addressed at that time since many of the issues in the CIE review are similar across the age-structured rockfish assessments. An AFSC response to the rockfish CIE review was prepared that addresses some of their concerns. Please refer to the "Summary and response to the 2013 CIE review of the AFSC rockfish" document presented to the September 2013 Plan Team for further details regarding this response:

http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf

"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment." (SSC December 2013)

These projections are available in the executive summary table and are now added to the phase-plane plots (Figure 13-18). The two year projections will be standard in the phase diagrams in the future.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The Team asks the [rockfish] *authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities."* (Plan Team, November 2011)

In the author preferred model of this assessment (Model 2) we update the size-at-age conversion matrix and weight-at-age estimates with the full time series of age data. Sample sizes for determining these estimates have increased by an order of magnitude. We also updated the aging error matrix with newly available age agreement tests, which now cover a range of years from 1984 – 2009. Please see the **Parameters Estimates Outside the Assessment Model** section for more details. Many of the issues regarding temporal changes in the conversion and error matrices are similar across the age-structured rockfish assessments. In order to properly address this comment we plan to conduct an investigation on developing methods for updating conversion and error matrices for these long-lived species as a group and to perform sensitivity analyses on the timeliness of updates. We anticipate this future investigation to begin next year and will incorporate relevant results into the RE/BS model following further review. Analyses of including survey length data into the Pacific ocean perch, northern rockfish, and dusky rockfish models are included in Appendix 9B of the GOA POP November 2014 assessment, and recommendations from this will be taken into account in next year's full assessment.

"The Team supports the author's suggestion to conduct sensitivity analysis on optimum plus group for age comps. The Team also supports the author's interest to explore selectivity patterns. The Team also encouraged the author to continue to investigate difference in the longline and trawl survey to help understand the different trends." (Plan Team, November 2011)

We plan to address the concerns over the optimum plus group for age compositions along with the conversion and error matrices investigation (see comment above on conversion matrix) as the two concepts are ultimately connected within the modeling procedures. This will further the concept of consistency among the age-structured rockfish assessments, and hopefully lead to agreement on best practices regarding updating this information.

"SSC supports the Plan Team recommendation for the author to continue to investigate difference in the longline and trawl survey to help understand the different trends." (SSC, December 2011)

We continue to use both surveys for this full assessment because we consider that the two surveys adequately sample different parts of the RE/BS population. Much of the prime habitat area for RE/BS rockfish is in 300-500 m depths on the upper continental slope. This area is often not trawlable by the bottom trawl survey's gear because of its steep and rocky bottom; therefore, trawl survey biomass estimates for RE/BS rockfish may not indicate a complete picture of the abundance trends. Conversely, the longline survey can sample a large variety of habitats. One drawback, however, is that juvenile fish are not as susceptible to longline gear. Subsequently, the longline survey does not provide much information on recruitment. The trawl survey may be limited in sampling particular habitats, but does capture juveniles. We therefore utilize both the trawl and longline (which can sample where survey trawls cannot) abundance indices within the RE/BS model to alleviate some of these concerns.

Because of the different habitats sampled and gear selectivity, we do anticipate some differences between the two survey biomass estimates and size compositions. Additionally, several recent investigations are in progress to consider the effects of untrawlable/trawlable habitat on the trawl survey estimates, and whale depredation on the longline survey estimates. We await the final results of these studies prior to conducting sensitivity analyses on trawl versus longline survey indices so that the most appropriate trawl or longline survey index is used in that comparison.

"In response to SSC comments the authors commented on the veracity of model based estimates of trawl survey catchability. The authors reported that the model based estimate of survey catchability is 1.42 compared with a submersible observations in a 2006 analysis and yielded a catchability of 0.85. The SSC encourages the author to report on the evidence to support the current model based estimate given the discrepancy between experimental and model based estimates of catchability." (SSC, December 2011)

We anticipate continuing to use the current model based estimate for catchability rather than incorporating the 2006 estimate based on submersible observations. The study that yielded the catchability of 0.85 was based on a very small region in the central GOA at depths that could not cover the entire potential habitat for RE/BS rockfish due to diving safety limitations on the submersible. Rather than a direct comparison we plan to investigate how to use this submersible based estimate as a contextual lower bound for developing the prior on RE/BS catchability. The multiple surveys and large amount of age and size data in the model allows for a more appropriate estimate of catchability that takes into account the full distribution on the RE/BS population for the GOA. In the future, we plan to conduct a synthesis of previous studies on rockfish catchability using submersibles and develop recommendations for generating informative prior distributions on catchability. This study may also incorporate the results from recent trawlable/untrawlable studies to include habitat information in the priors.

"The Team recommends a full stock assessment with updated assessment and projection model results for 2014. The Team also recommends further exploration into the effects of reduced trawl survey effort in relation to the all-time low biomass recorded in 2013." (Plan Team, November 2013)

As per this recommendation by the Plan Team, we are presenting a full assessment this year. Several current research efforts are in progress investigating issues regarding bottom trawl survey catchability and survey biomass estimation. The continued reduction in survey effort over the past several surveys should be considered in these initiatives as there was a 30% drop in stations sampled on the 2013 survey compared to the long-term average. Precision and accuracy of biomass estimates are particularly vulnerable for deep-water species like RE/BS rockfish due to the already low number of stations sampled in the deep strata. We will incorporate results of these studies when they become available to consider the effects of reduced trawl survey effort on RE/BS rockfish trawl survey biomass estimates.

"The Team recommends using the random effects model, rather than the weighted survey average approach to the extent practical for POP and for rockfish in general [for apportionment]*."* (Plan Team, September 2014)

We include both the weighted survey average and the random effects model approach for estimating apportionment in this assessment. Please see the *Area Allocation of Harvests* subsection in **Harvest Recommendations** section for further details.

Introduction

Life History and Distribution

Rougheye (*Sebastes aleutianus*) and blackspotted (*S. melanostictus*) rockfish inhabit the outer continental shelf and upper continental slope of the northeastern Pacific. Their distribution extends around the arc of the North Pacific from Japan to Point Conception, California and includes the Bering Sea (Kramer and O'Connell 1988). The two species occur in sympatric distribution, with rougheye extending farther south along the Pacific Rim and blackspotted extending into the western Aleutian Islands (Orr and Hawkins 2008). The overlap of the two species is quite extensive, ranging primarily from southeast Alaska through the Alaska Peninsula (Gharrett et al. 2005, Orr and Hawkins 2008). The center of abundance for both species appears to be Alaskan waters, particularly the eastern Gulf of Alaska (GOA). Adults in the GOA inhabit a narrow band along the upper continental slope at depths of 300-500 m; outside of this depth interval, abundance decreases considerably (Ito, 1999). These species often co-occur with shortraker rockfish (*Sebastes borealis*).

Though relatively little is known about their biology and life history, rougheye and blackspotted (RE/BS) rockfish appear to be K-selected with late maturation, slow growth, extreme longevity, and low natural mortality. As with other *Sebastes* species, RE/BS rockfish are ovoviviparous, where fertilization and incubation of eggs is internal and embryos receive at least some maternal nourishment. There have been no studies on fecundity of RE/BS in Alaska. One study on their reproductive biology indicated that rougheye had protracted reproductive periods, and that parturition (larval release) may take place in December through April (McDermott 1994). There is no information as to when males inseminate females or if migrations for spawning/breeding occur. The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is labor-intensive. The post-larvae and early young-of-the-year stages also appear to be pelagic (Matarese et al. 1989, Gharrett et al. 2002). Genetic techniques have been used recently to identify post-larval RE/BS rockfish from opportunistically collected samples in epipelagic waters far offshore in the Gulf of Alaska, which is the only documentation of habitat preference for this life stage.

There is no information on when juvenile RE/BS rockfish become demersal. Juvenile rougheye and blackspotted rockfish (15- to 30-cm fork length) are frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates. They are generally found at shallower, more inshore areas than adults and have been taken in variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye or blackspotted rockfish, it is reasonable to suspect that juvenile RE/BS rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Adult rougheye and blackspotted rockfish are demersal and are known to inhabit particularly steep, rocky areas of the continental slope, with highest catch rates generally at depths of 300 to 400 m in longline surveys (Zenger and Sigler 1992) and at depths of 300 to 500 m in bottom trawl surveys and in the commercial trawl fishery (Ito 1999). Observations from a manned submersible in this habitat indicate that these species prefer steep slopes and are often associated with boulders and sometimes with *Primnoa* spp. coral (Krieger and Ito 1999, Krieger and Wing 2002). Within this habitat, rougheye rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of other rockfish such as Pacific ocean perch (*Sebastes alutus*) (Clausen and Fujioka, 2007).

Food habit studies in Alaska indicate that the diet of adult rougheye and blackspotted rockfish is primarily shrimp (especially pandalids) and that fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). However, juvenile RE/BS rockfish (less than 30-cm fork length) in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Recent food studies show the most common prey of RE/BS as pandalid shrimp, euphausiids, and tanner crab (Chionoecetes bairdi). Other prey include octopi and copepods (Yang et al. 2006). Predators of RE/BS rockfish likely include halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may dramatically increase with the age of the mother (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. Pacific ocean perch (*S. alutus*) and rougheye/blackspotted rockfish were examined by de Bruin et al. (2004) for senescence in reproductive activity of older fish and they found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for rougheye and blackspotted rockfish or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. However, in a recent study on Pacific ocean perch, Spencer et al. (2007) showed that the effects of enhanced larval survival from older mothers decreased estimated F_{msy} (the fishing rate that produces maximum sustainable yield) by 3% to 9%, and larger decreases in stock productivity were associated at higher fishing mortality rates that produced reduced age compositions.

Evidence of Stock Structure

Since 2007, we have responded to requests regarding the difficulty identifying rougheye and blackspotted rockfish and the development of a rationale for assessment decisions regarding this mixed stock. Reports have included summaries of recent studies on the genetic and phenotypic differences between rougheye and blackspotted rockfish, discussion of the current research regarding at-sea misidentification rates, and new projects developed to understand species specific life history characteristics (Shotwell et al. 2008, 2009). We completed a full stock structure evaluation of rougheye and blackspotted rockfish following the template provided by the Stock Structure Working Group (SSWG, Spencer et al. 2010) and provided this evaluation in **Appendix A** of the 2010 GOA rougheye and blackspotted rockfish executive summary SAFE report (Shotwell et. al 2010). Brief summaries of rougheye and blackspotted rockfish speciation, the stock structure template, and current research are provided below.

Rougheye and Blackspotted Speciation

Several studies on the genetic differences between the observed types of rougheye rockfish indicate two distinct species (Gharrett et al. 2005, Hawkins et al. 2005, Orr and Hawkins 2006, summarized in Shotwell et al. 2009). The proposed speciation was initiated by Tsuyuki and Westrheim (1970) after electrophoretic studies of hemoglobin resolved distinct banding patterns in rougheye rockfish. Subsequent allozyme-based studies demonstrated clear isolation between samples (Seeb 1986) and five distinguishable loci for the two types of rougheye (Hawkins et al. 1997). A later extended allozyme study found the two types occurred in sympatry (overlapping distribution without interbreeding), and samples with depth information demonstrated a significantly deeper depth for what was later described as blackspotted rockfish (Hawkins et al. 2005). Another study analyzed the variation in mitochondrial DNA and microsatellite loci and determined the two distinct types of rougheye with relatively little hybridization (Gharrett et al. 2005).

In 2008, the presence of the two species was formally verified (Orr and Hawkins 2008). Rougheye rockfish is typically pale with spots absent from the spinous dorsal fin and possibly has mottling on the body. Blackspotted rockfish is darker with spotting almost always present on the dorsal fin and body. However, the distributions of these phenotypic parameters tend to overlap with only slight differences in gill rakers, body depth, and coloration (Gharrett et al. 2006). Spatially, rougheye rockfish has been defined as the southern species extending farther south along the Pacific Rim, while blackspotted rockfish was considered the northern species extending farther into the western Aleutian Islands and Bering Sea (Orr and Hawkins 2008).

Stock Structure Template Summary

We summarize the available information on stock structure for the GOA rougheye and blackspotted rockfish complex in Table 13-1. Since the formal verification of the two species has only recently occurred, most data on rougheye and blackspotted rockfish is for both species combined. We follow the example framework recommended by the SSWG for defining spatial management units (Spencer et al. 2010) and elaborate on each category within this template to evaluate stock structure for rougheye and blackspotted rockfish. Please refer to Shotwell et al. (2010) for the complete stock structure evaluation.

Non-genetic information suggests population structure by large management areas of eastern, central, and western GOA. This is evident in opposite trajectories for population trends by area, significantly different age, length, and growth parameters by area, and significant differences in parasite prevalence and intensity by area. Genetic studies have generally been focused on the speciation of the RE/BS complex; however, consistencies between the two species also suggest population structure by management area. One such study showed genetic structure consistent with a neighborhood model of dispersion and significant isolation by distance for blackspotted rockfish (Gharrett et al. 2007). However, these data have been reanalyzed with a much larger sample size, and no longer exhibit a significant isolation by distance pattern in the Aleutian Islands and Bering Sea (see Spencer et al. 2014 BSAI blackspotted/rougheye assessment for more details).

Currently, GOA RE/BS rockfish is managed as a Tier 3a species with area-specific Acceptable Biological Catch (ABC) and gulf-wide Overfishing Level (OFL). Given the multiple layers of precaution instituted with relatively low Maximum Retained Allowance (MRA) percentages, a bycatch only fishery status, and the generally low area-specific harvest rates, we continue to recommend the current management specifications for RE/BS rockfish.

Current Research

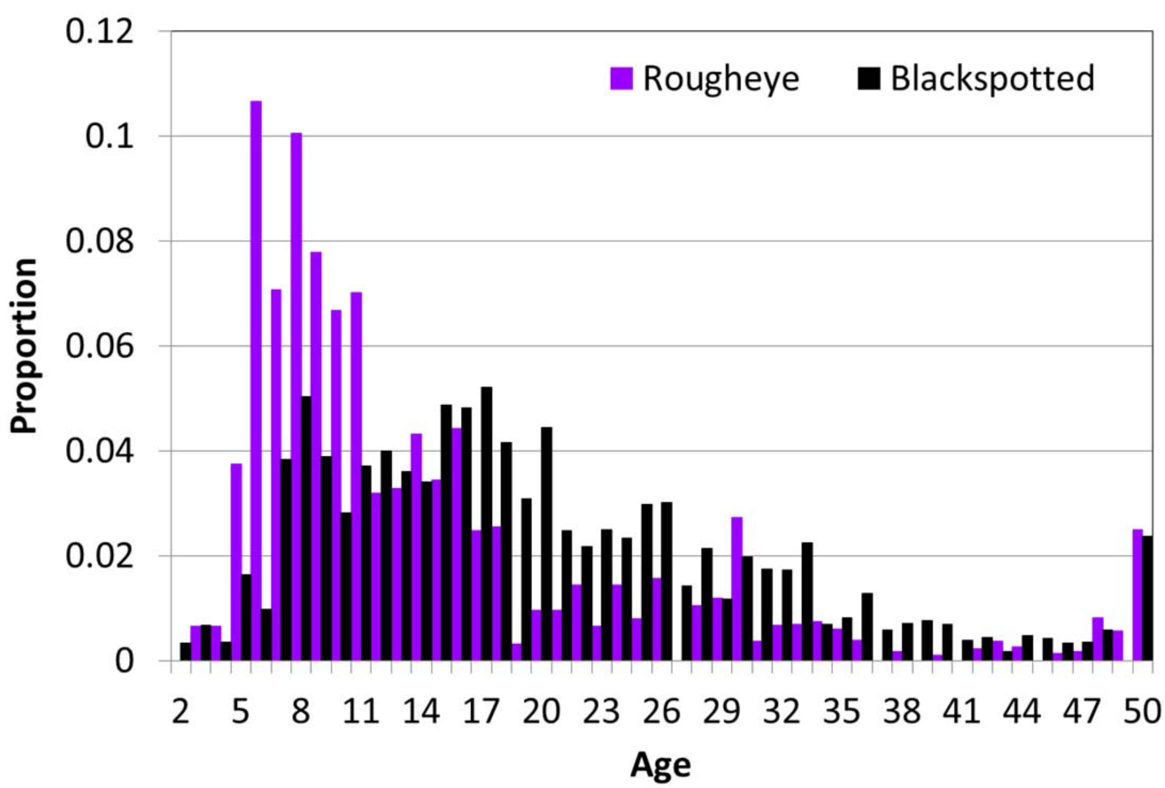
There is difficulty in accurate at-sea field identification between the two species. Previous studies have found that on average, when compared to genetic identifications, field scientists had a misidentification rate of approximately 46% (samples in eastern GOA near Yakutat), while the expert (Jay Orr) had misidentification rates of 9% (Shotwell et al. 2009). In addition, if differences in growth and maturity exist, one species may be at greater risk to overfishing than the other. This may be particularly true in areas where the two species are caught together in the same haul such as in central and eastern GOA (Gharrett et al. 2005).

In response to these concerns, special projects were initiated during the 2009 and 2013 Alaska Fisheries Science Center (AFSC) GOA bottom trawl survey. The goals of these projects were to collect relevant biological and genetic data to improve at-sea identification, adjust the species-specific biomass estimates based on misidentification rates, and examine differences in life history characteristics between the two species. Field scientists collected length, weight, and muscle tissue (2009) or fin clips (2013) from most rougheye and blackspotted rockfish sampled for otoliths. Additionally, most of the unidentified rougheye/blackspotted specimens were sampled for otoliths.

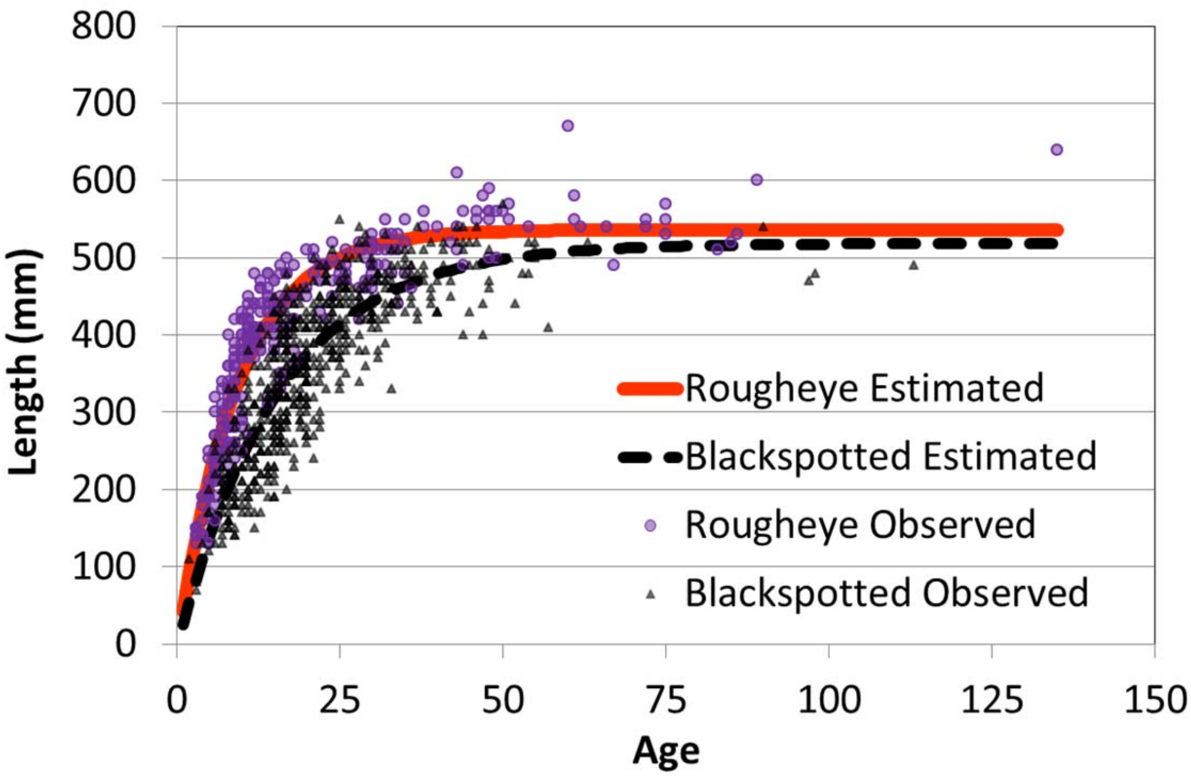
For the 2009 survey, 895 fish were genetically identified in the lab. Overall (not including hybrids or fish unidentified in the field) these results show a 23% misidentification rate. This is a substantial improvement over previous studies. Of the genetically identified rougheye rockfish (n=307), only 6% were incorrectly identified in the field as blackspotted rockfish and 1% were unidentified. Of the genetically identified blackspotted rockfish (n=577), 31% were incorrectly identified in the field as rougheye rockfish and 3% were unidentified. Hybrids existed between the two species (n=11). These hybrids were mostly identified as rougheye rockfish in the field (82 %).

Trawl survey data were adjusted for species misidentification rates to compute species specific biomass estimates and age compositions. For the 2009 survey the adjusted data indicated that 47%, 51%, and 2% of the estimated biomass was comprised of rougheye, blackspotted, and hybrids, respectively. Prior to this adjustment the estimated biomass was 63% rougheye and 37% blackspotted rockfish.

Trawl survey age compositions based on samples taken in 2009 indicate that the average age of blackspotted rockfish was 20 years and 15 years in rougheye rockfish (see figure below). The majority of the trawl survey age composition for rougheye rockfish was less than 20 years old whereas blackspotted rockfish had a more uniform age composition. Data from the 2013 trawl survey have been analyzed for species misidentification rates, but ages have not been determined. Preliminary analysis of the 2013 survey data show that there have been continued improvements in species identification with overall misidentification rates of 13% compared to 23% from the 2009 survey.



A preliminary study on the 2009 genetically identified and aged otoliths (n=879, hybrids=11) found differences in growth between the two species. Rougheye rockfish grow faster and typically attain a greater maximum size than blackspotted rockfish (see figure below).



The estimated Von Bertalanffy growth parameters for the two species based on the samples taken in the 2009 bottom trawl survey were as follows:

	Rougheye	Blackspotted
Sample Size	298	570
L_∞ (mm)	536	519
κ	0.109	0.065
t_0	0.250	0.250

Scientists and observers are currently evaluating new techniques to determine whether rapid and accurate field identification can occur; however, until reliable identification of both species exists, we will continue to model rougheye and blackspotted rockfish as if they are a single species. The special projects in the 2009 and 2013 GOA trawl surveys will enhance training and field identification guides, accurately specify misidentification rates, and estimate biological parameters such as growth and distribution by species. Additionally, recently developed techniques utilizing diagnostic single-nucleotide polymorphisms (SNPs) for rougheye and blackspotted rockfish may reduce the cost and processing time for genetic identification of large sample sizes (Garvin et al. 2011).

In the future, we would like to extend this sampling to commercial fisheries as a special project requested of the Observer Program. When combined with accurate species-specific catch and survey data, such information will help determine the utility of a split-species complex model or separate species models for examining if one species may be at greater risk to overfishing. At present, the area-specific harvest rates for RE/BS rockfish have been on average low and catches have consisted of approximately half the ABC in recent years. We consider current management specifications for this two species, non-targeted complex to be sufficiently precautionary.

Fishery

History

Rougheye and blackspotted rockfish have been managed as a “bycatch” only species complex since the creation of the shortraker/rougheye rockfish management subgroup in the Gulf of Alaska in 1991. Since 1977, gulf-wide catches of the rougheye and blackspotted rockfish have been between 130-2,418 t (Table 13-2). Catches peaked in the late 80s and early 90s, declined rapidly in the mid-90s and have been relatively stable, with recent increases since 2009. RE/BS rockfish are generally caught in either bottom trawls or with longline gear and the majority of the recent catch increase was in the Central GOA bottom trawl fishery. In 2014, 70% of the catch was from bottom trawls, 27% from longline, and 3% from pelagic trawls. Approximately 70% of this bottom trawl catch was taken in the rockfish fishery while, 30% was taken in the flatfish fisheries. The amount of catch taken in the rockfish fishery has more than doubled in the past two years, probably due to increased Pacific ocean perch ABC allocated to the central GOA. For longline gear, nearly all the RE/BS catch appears to come as “true” bycatch in the sablefish or halibut longline fisheries, with 83% of the 2014 catch taken in the sablefish fishery and 16% in the halibut fishery. Since catch accounting was established separately for RE/BS rockfish in 2005, the TACs for RE/BS rockfish are not fully taken, and are generally between 30-50% of potential quota (Table 13-2).

In 2013, restructuring of the AFSC Fisheries Monitoring and Analysis (FMA) Observer Program began and the extent that this program affected perceived catches of RE/BS rockfish in the small-boat fishery (due to improved coverage) is uncertain. Understanding the potential for catch accounting biases due to shifts in observer coverage will require further study.

Management Measures

In 1991, the North Pacific Fishery Management Council (NPFMC) divided the slope assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. Although each management subgroup was assigned its own value of ABC (acceptable biological catch) and TAC (total allowable catch), shortraker/rougheye rockfish and other slope rockfish were discussed in the same SAFE chapter because all species in these groups were classified into tiers 4 or lower in the overfishing definitions. This resulted in an assessment approach based primarily on survey biomass estimates rather than age-structured modeling. In 1993, a fourth management subgroup, northern rockfish (*Sebastes polyspinis*), was also created. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC and TAC, whereas prior to 1991, one ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on the distribution of survey biomass.

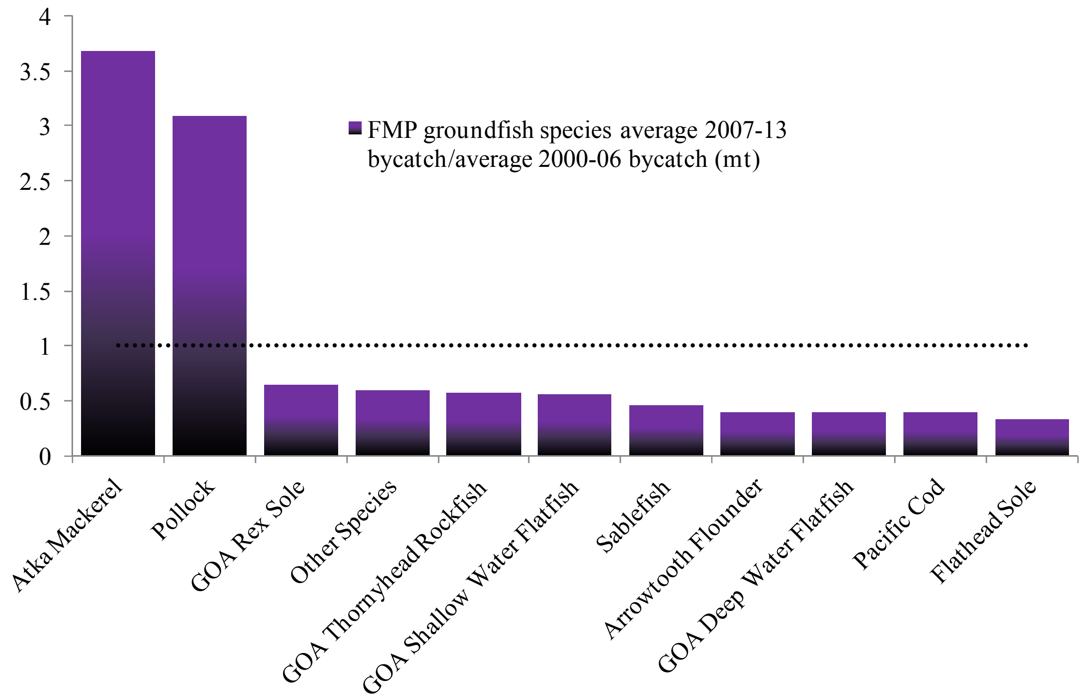
In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action initiated the Central Gulf of Alaska Rockfish Program (formerly the Rockfish Pilot Program) which was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This rationalization program establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish species. This implementation impacts primary rockfish management groups but will also affect secondary rockfish groups with a maximum retained allowance (MRA). The primary rockfish management groups are Pacific ocean perch, northern rockfish, and pelagic shelf rockfish (changed to dusky rockfish only in 2012), while the secondary species include rougheye, blackspotted, and shortraker rockfish. The program should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. Potential effects of this program to rougheye and blackspotted rockfish include: 1) an extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and 4) a higher potential to harvest 100% of the TAC in the Central GOA region. Recent data show that the Rockfish Program has resulted in much higher observer coverage of catch in the Central GOA (Figure 13-1). There does not seem to be a major shift in the spatial distribution of RE/BS catch and it is difficult to discern whether the increases in catch levels are due to increases in the observer coverage or actual increases in fishing pressure. We will continue to monitor available fishery data to help understand potential effects the Rockfish Program may have on the RE/BS rockfish stock in the Central GOA.

A summary of key management measures since the creation of the slope rockfish assemblage in 1988 and a time series of catch, OFL, ABC, and TAC are shown in Table 13-3.

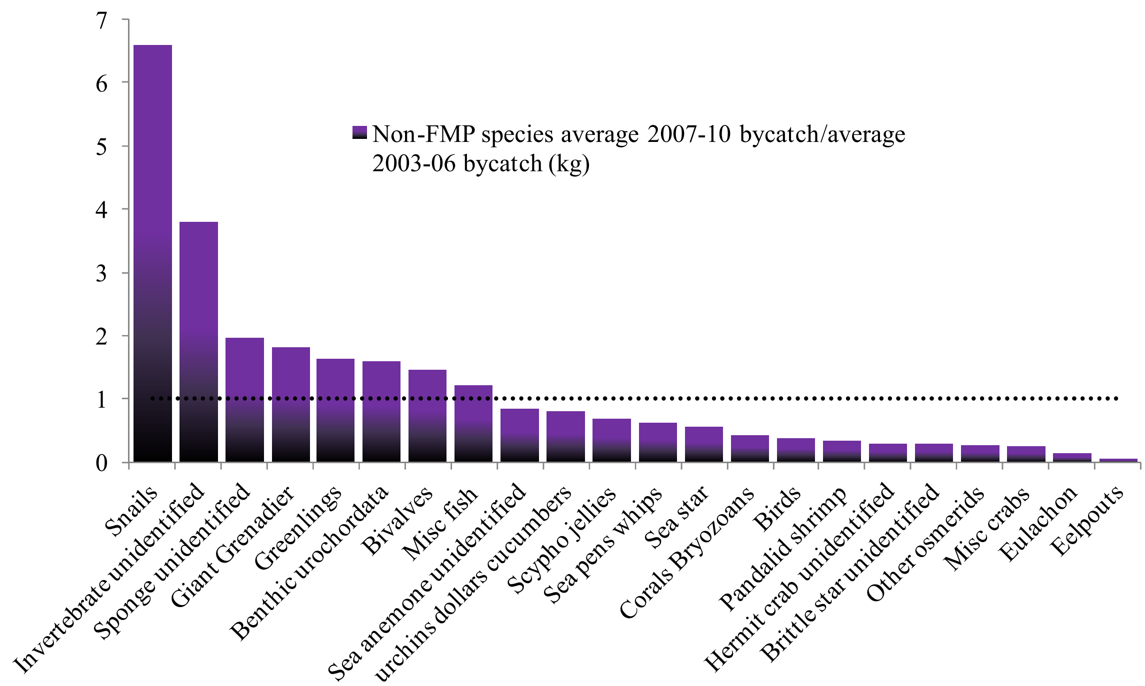
Bycatch

The only analysis of bycatch for rougheye rockfish is that of Ackley and Heifetz (2001) from 1994-1996 on hauls they identified as targeted on shortraker/rougheye rockfish. The major bycatch species were arrowtooth flounder (*Atheresthes stomias*), sablefish, and shortspine thornyhead (*Sebastolobus alascanus*), in descending order. The primary fisheries that catch rougheye and blackspotted rockfish as bycatch are the targeted rockfish and sablefish fisheries with occasional surges from the flatfish fishery (Table 13-4). For the combined GOA rockfish trawl fisheries during 1991-2014, the largest non-rockfish bycatch groups are on average arrowtooth flounder (1,413 t/year), sablefish (869 t/year), Pacific cod (762 t/year), Atka mackerel (657 t/year) and walleye pollock (421 t/year). Total FMP groundfish species catch estimates targeted in the rockfish fishery from 2007-2014 are shown in Table 13-5. Non-FMP species catch in the rockfish target fisheries is generally dominated by giant grenadier (127 – 968 t), other grenadier (3 – 111 t), miscellaneous fish (124 – 195 t), and occasionally dark rockfish (recently removed from FMP to state management, 0 – 112 t) (Table 13-6). Prohibited species catch in the GOA rockfish fishery has been relatively steady over time. Halibut catch during rockfish targeted hauls has declined since 2007 from 136 t to 60 t in 2014. The catch of golden king crab decreased dramatically from over 3,000 animals in 2009 and 2010, to just over 100 in 2011 – 2013 (Table 13-7).

We compared bycatch from pre-2006 and post-2007 in the central GOA for the combined rockfish fisheries to determine impact of the Central GOA Rockfish Program implementation. We divided the average post-2006 bycatch (2007-2013) by the average pre-2007 bycatch (2000-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species, bycatch in the central GOA has been reduced since 2007, with the exception of Atka mackerel (414 t/year pre-2006 compared to 1,520 t/year post-2007) and walleye pollock (234 t/year pre-2006 compared to 722 t/year post-2007, see figure below):



Currently 8 of 22 nontarget species for which bycatch data were available for the two time periods resulted in an increase in bycatch post-2006 compared to pre-2007 (see figure below).



We will continue to monitor the bycatch of the combined rockfish fisheries to understand potential effects of the Rockfish Program.

Discards

Gulf-wide discard rates (percent of the total catch discarded within management categories) of fish in the shortraker/rougheye subgroup were available for the years 1991-2004, and are listed in the following table[1]. Beginning in 2005, discards for rougheye and blackspotted rockfish were reported separately.

	Shortraker / Rougheye / Blackspotted Complex													
Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
% Discards	42.0	10.4	26.8	44.8	30.7	22.2	22.0	27.9	30.6	21.2	29.1	20.8	28.3	27.6

	Rougheye / Blackspotted Complex									
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
% Discards	19.5	27.4	36.7	27.6	18.6	19.2	16.3	15.5	22.8	17.0

The above table indicates that discards of rougheye and blackspotted rockfish have ranged from approximately 15% to 38% with an average of 22%. These values are relatively high when compared to other *Sebastes* species in the Gulf of Alaska.

Data

The following table summarizes the data used for this assessment (bold denotes new or updated data for this assessment):

Source	Data	Years
Fisheries	Catch	1977-**2011, 2012, 2013, 2014**
	Age	1990, 2004, 2006, 2008, **2009**, **2012**
	Length	1991-1992, 2002-2003, 2005, 2007, **2010**, **2011**
AFSC bottom trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, **2013**
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, **2009**, **2011**
AFSC longline survey	Relative Population Number (RPN)	**1993-2014**
	Length	**1993-2014**

Fishery:

Catch

Catches of rougheye and blackspotted rockfish have ranged between 130 t to 2,418 t from 1977 to 2014. The catches from 1977-1992 were from Soh (1998). Catches from 1993-2004 were available as the shortraker/rougheye subgroup from the NMFS Alaska Regional Office. Originally we used information from a document presented to the NPFMC in 2003 to determine the proportion of rougheye rockfish in this catch (Ianelli 2003). This proportion was based on the NMFS Regional Office catch accounting system ("blend estimates"). The SSC recommended using the average of the values provided in the document, 0.43. In 2004 another method was developed for determining the proportion of rougheye/blackspotted in the catch based on data from the FMA Observer Program (Clausen et al. 2004, Appendix A). Observed catches were available from the FMA database by area, gear, and species for

[1] Data from 1991-2004 from NMFS, AKRO, Juneau, AK weekly production and observer reports. Data from 2005 through present are from NMFS, AKRO, Catch Accounting System via Alaska Fisheries Information Network (AKFIN). Most recent estimate is current as of October 1, 2014 (http://www.akfin.org)

hauls sampled by observers. This information was used to calculate proportions of RE/BS catch by gear type. These proportions were then applied to the combined shortraker/rougheye catch from the NMFS Alaska Regional Office to yield estimates of total catch for RE/BS rockfish (Figure 13-2, Table 13-2).

One caveat of the observer catch data is that these data are based only on trips that had observers on board. Consequently, they may be biased toward larger vessels, which had more complete observer coverage. This bias may be a particular problem for rougheye and blackspotted rockfish that were caught by longliners. Much of the longline catch is taken by small vessels that have no observer coverage. Hence, the observer catch data probably reflects more what the trawl fishery catches. However, this data may provide a more accurate estimate of the true proportion of RE/BS catch than the proportion based on the blend estimates. The blend estimates are derived from a combination of data turned in by fishermen, processors, and observers. In the case of fishermen and processors, prior to 2004 there was no requirement to report catches of shortraker/rougheye rockfish by species, and fishermen and processors were free to report their catch as either shortraker, rougheye, or shortraker/rougheye combined. Shortraker and rougheye rockfish are often difficult for an untrained person to separate taxonomically, and fishermen and processors had no particular incentive to accurately identify the fish to species. In contrast, all observers in the FMA Observer Program are trained in identification of Alaska groundfish, and they are instructed as to the importance of accurate identifications. Consequently, the catch data based on information from the FMA Observer Program may be more reliable than those based on the blend estimate. We use the observer estimates of catch from 1993-2004. Catches are reported separately for RE/BS and shortraker since 2005.

Age composition

Rougheye and blackspotted rockfish appear to be among the longest-lived of all *Sebastes* species (Chilton and Beamish 1982, Munk 2001). Interpretation of annuli on otoliths is extremely difficult; however, recently NMFS age readers determined that aging of RE/BS rockfish could be moved into a production mode. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Rougheye and blackspotted rockfish otolith samples from onshore processing facilities have recently been aged. The sample sizes from onshore processing facilities are generally low and the distribution of ages is quite different from the at-sea samples. Therefore, we do not use these samples in calculating the fishery age compositions. The FMA Observer Program began in 1990 and although this first year was considered preliminary, the 1990 ages are the only age compositions we have from the fishery prior to 2004. We, therefore, utilize this data in the model since it is considered important for estimating catch at age in the early 1990s. Table 13-8 summarizes the available fishery age compositions from 1990, 2004, 2006, 2008, 2009, and 2012.

New fishery ages since the last full assessment are available for 2009 and 2012. We generally request fishery ages only for years that do not overlap with an AFSC bottom trawl survey since analyzing otoliths for long-lived rockfish such as RE/BS rockfish is time-consuming. In this case the 2009 fishery ages were requested and completed rather than the 2010 ages. We have subsequently requested that the 2010 fishery ages be completed as soon as possible and will incorporate the data as soon as that information is available. Sample sizes from the fishery are typically between 300 and 400 otoliths (Table 13-8). The mean ages for a given year range between 28-35 years and are relatively old when compared to other aged rockfish species. Ages 25 and greater are pooled into a plus (+) group that is quite substantial in all years (Table 13-8). This may imply that our age bins are somewhat restrictive for this extremely long-lived species. We anticipate a future investigation on furthering methods for determining the plus group for rockfish species, including RE/BS, to begin next year and will incorporate relevant results into the RE/BS model. This study will likely consider the potential for increasing the number of age bins to include several older age groups following analyses completed for other rockfish (Hulson et al. 2011, Spencer and Ianelli, 2012).

Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size composition of the commercial catch of rougheye and blackspotted rockfish. Table 13-9 summarizes the available size compositions from 1991-2011. Sample sizes from 1993-2001 were limited for RE/BS rockfish and in other years range from 300 to 2500 (Table 13-9). In general, we do not use size compositions in the model when age compositions are available because we consider age data to be a more reliable measure of population structure for these long-lived species. Since we anticipate fishery ages for non-trawl survey years, we do not include the size compositions for off-cycle years in the model. Additionally, in long-lived rockfish species the fish are selected late to the fishery and size compositions tend to be relatively uninformative as year classes will blend together. In the case of the 2010 fishery size compositions, we utilize that information in this model since this year was not available in the fishery ages at this time. Therefore, fishery size compositions from 1991-1992, 2002-2003, 2005, 2007, 2010 and 2011 are included in this full assessment.

Length samples from onshore processing facilities also exist for RE/BS rockfish; however, the distribution between onshore and at-sea lengths differ dramatically and the samples sizes are quite low. Therefore, as with age samples, we do not use these onshore length samples in calculating the fishery size compositions. Lengths were binned into 2 cm categories to obtain better sample sizes per bin from 20-60+ with the (+) group containing all the fish 60 cm and larger. On average, approximately 34% of the lengths are taken from the trawl fishery and 66% from the longline fishery for at-sea samples. This percentage is consistent for the data used in the model with 38% of lengths from the trawl fishery and 62% from the longline fishery. The mode of lengths for the 1991-1992 samples is approximately 45 cm and from 2002-2011 has remained relatively steady between 45 to 48 cm. Moderate presence of fish smaller than 40 cm is present in most years, particularly 1991 and 1992.

Survey:

AFSC Bottom Trawl Biomass Estimates

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999. These surveys became biennial starting in 2001. The surveys provide much information on rougheye and blackspotted rockfish, including an abundance index, age composition, and growth characteristics. The surveys are theoretically an estimate of absolute biomass, but we treat them as an index in the stock assessment model. The triennial surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 700 m or 1,000 m), but the 2001 biennial survey did not sample the eastern Gulf of Alaska. Because the 2001 survey did not cover the entire Gulf of Alaska, we omitted this survey from our analysis for RE/BS rockfish.

Summaries of biomass estimates from the 1984-2013 surveys are provided in Table 13-10. Trawl survey biomass estimates are shown in Figure 13-3. Historically estimates by region indicate that the western and eastern GOA time series of biomass tended to be in opposite phase (Table 13-10). From 2003-2007, the central and eastern GOA estimates increased, while the western GOA decreased. In 2009, all regions decreased and in 2011 both the eastern and central GOA decreased while the western GOA slightly increased. The 2013 biomass estimate was an all-time low for this time series. The decrease was 37% below the 2011 estimate and 40% below the mean biomass estimate for the time series. The estimates by area were not consistently down as there was a 66% decrease in the central GOA with increases in the western and eastern GOA by 19% and 51%, respectively. Given that the regional patterns are quite different and that the 2001 survey did not sample the eastern GOA, omitting this survey estimate from the model is reasonable. Additionally, data for 2001 are available from the longline survey.

The 1984 and 1987 survey results should be treated with some caution. A different survey design was used in the eastern GOA in 1984; furthermore, much of the survey effort in the western and central GOA in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this latter problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates discussed here, and the estimates are believed to be the best available. Even so, the reader should be aware that an element of uncertainty exists as to the standardization of the 1984 and 1987 surveys.

The biomass estimates for rougheye and blackspotted rockfish have been relatively constant among the surveys, with the exception of 1993, 2007, and 2013. Generally, inter-survey changes in biomass are not statistically significant from each other (Table 13-10; Figure 13-3). Compared with other species of *Sebastes*, the biomass estimates for rougheye and blackspotted rockfish show relatively tight confidence intervals and low coefficients of variations (CV), ranging between 11% and 23%. The low CVs are an indication of the rather uniform distribution for this species compared with other slope rockfish (discussed previously in *Life History and Distribution* section). Despite this precision, however, trawl surveys are believed to do a relatively poor job of assessing abundance of adult RE/BS rockfish on the upper continental slope. Nearly all the catch of these fish is found at depths of 300-500 m. Much of this area is not trawlable by the survey's gear because of its steep and rocky bottom, except for gully entrances where the bottom is not as steep. If RE/BS rockfish are located disproportionately on rough, untrawlable bottom, then the trawl survey may underestimate their abundance. Conversely, if the bulk of their biomass is on smoother, trawlable bottom, then we could be overestimating their abundance with the trawl survey estimates. Consequently, trawl survey biomass estimates for RE/BS rockfish are mostly based on the relatively few hauls in gully entrances, and they may not indicate a true picture of the abundance trends. However, the utilization of both the trawl and longline (which can sample where survey trawls cannot) biomass estimates should alleviate some of this concern.

In 2007, the trawl survey began separating rougheye rockfish from blackspotted rockfish using a species key developed by J. Orr (Orr and Hawkins, 2008). Biomass estimates by region of the two species somewhat support the broad southern and northern distribution of rougheye versus blackspotted rockfish in that blackspotted estimates were higher in the western GOA and rougheye estimates were higher in the eastern GOA (discussed previously in *Evidence of Stock Structure* section). However, both species were identified in all regions, implying some overlap throughout the GOA. Over all areas, more blackspotted rockfish were identified than rougheye in 2007 (56% versus 44%), while in 2009, 2011, and 2013 the reverse occurred (36%, 35%, and 37% versus 64%, 65%, and 63%, respectively). This shift may be due to the decreases in misidentification rates at-sea between the two species as new identification keys and more training have been incorporated. Despite this improvement, given the lack of species-specific catch we will continue to combine all survey data for both species until more information regarding species' specific life history characteristics is determined.

AFSC Bottom Trawl Age Compositions

Increased age samples for 2009 and new ages for 2011 were added this year resulting in a total of eleven years of survey age compositions with a total sample size of 5,681 ages. Survey age sample sizes are comparable to fishery age sample sizes, ranging from 200 to 900. Although rougheye and blackspotted rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected over these survey years was 135 (AFSC 2010). The average age ranged from 15 to 23 over all survey years available (Table 13-11). Compositions from 1984, 1987, 1990, 1996, 1999 showed especially prominent modes in the younger ages, suggesting periods of large year classes from the mid to late 1970s, early 1980s and then again in the late 1980s early 1990s. Since 2003 compositions were spread more evenly across age groups 3-15 corresponding to the strong year classes of the early 1990s and another period of increased recruitment in the early 2000s that is tracked through each survey year. In 2011, a higher proportion of five year old fish suggests another period of increased recruitment in the mid-2000s.

Since 2007, when the survey began identifying by individual species of rougheye and blackspotted rockfish, rougheye compositions tend to be spread evenly across ages, while blackspotted tend to be much older. Mean age of rougheye range from 13 - 18, while mean age for blackspotted range from 22 - 24. We combine these two age compositions for 2007, 2009, and 2011 in the stock assessment model. The mean age for the combined compositions ranged from 15 - 19. Ages 25 and greater are pooled into a plus (+) group that is fairly substantial in nearly all years, but is much smaller than the fishery age composition. As with the fishery ages, this may imply that our age bins are somewhat restrictive for this extremely long-lived species.

AFSC Bottom Trawl Size Compositions

Gulf-wide population size compositions for RE/BS rockfish are in Table 13-12 and sample sizes range from 1,700 to 5,600. The size composition of RE/BS rockfish in the 1984 survey indicated that a sizeable portion of the population was >40 cm in length. This is consistent with the presence of a large plus group in the age composition of this survey. In the 1996 through 2011 surveys there is a substantial increase in compositions of fish <30 cm in length suggesting that at least a moderate level of recruitment has been occurring throughout these years or there are fewer larger fish in the population. Compositions from all surveys (with the possible exception of 1990) were all skewed to the right, with a mode of about 43-45 cm. The 1990 size composition appears somewhat bimodal. The average length steadily decreased from 1984-1999, ranging from 41 to 35 cm. After this the mean length remained relatively steady between 36-38 cm. Since 2007, survey rougheye and blackspotted rockfish lengths were split. Rougheye have an average length of 36 cm while blackspotted have an average of 40 cm. Rougheye have a much broader range of lengths from 15-53 cm, while blackspotted tend to be more confined to the 35-50 cm range. However, in the 2013 survey, a larger composition of small blackspotted rockfish (< 25cm) were sampled. Again, this may be indicative of misidentification or a true difference in size distribution between species. Future analysis of the 2009 and 2013 trawl survey experiment will aid in understanding some of these differences. Trawl survey size data are used in constructing the size-age conversion matrix, but are not used as data to be fit in the stock assessment model since survey ages for most years were available. Investigations into including the most recent survey's length composition as a proxy for unavailable age composition were presented in this Appendix 9B of the GOA POP November 2014 assessment. The results of that analysis suggest that the utility of the most recent survey's length composition is case specific. We will investigate whether including the most recent survey's length composition in this assessment is useful in next year's full assessment.

AFSC Longline Abundance Index

Catch, effort, and length data were collected for rougheye and blackspotted rockfish during longline surveys. Data were collected separately for RE/BS rockfish and shortraker since 1990. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000) and may also provide a reasonable index for rougheye and blackspotted rockfish in addition to the AFSC bottom trawl survey (Rodgveller et al. 2011). Relative population abundance indices are computed annually using survey catch per unit of effort (CPUE) rates that are multiplied by the area size of the stratum within each geographic area. These relative population indices are available by numbers (RPN) and weights (RPW) for a given species (Rodgveller et al.2011). In previous assessments, the longline abundance index for RE/BS rockfish was expressed as an RPW and used as a second biomass index in the model.

There have been several updates to the longline survey database since the 2011 assessment. These include updated growth parameters for all species except sablefish, updated species coding for shortraker and rougheye rockfish, and new area estimates for all strata including the shallow stratum from 150-200 m

(Echave et. al. 2013). These updates result a full revision of longline survey estimates for RE/BS rockfish. Due to the updated data checks on the length codes for shortraker and rougheye rockfish, it was determined that the time series for RE/BS should start in 1993. The new area estimates for the shallow stratum now allow the catch data from 150 to 200 m to be included in the survey index. Since RE/BS rockfish are often caught in this stratum (Shotwell et al. 2014), we include this information in the RE/BS longline survey index.

The updated relative population weight (RPW) index for RE/BS rockfish now uses the trawl survey information to generate the weight conversion parameters for this complex. During the 2009 CIE for sablefish the use of both relative population number (RPN) and weight (RPW) survey indices in the model was discussed. The CIE recommendation was to use only the RPN index to avoid the added uncertainty that results from converting lengths to weight, estimating numbers at age and then converting back to weight for the ultimate ABC recommendation. We follow this recommendation for RE/BS and now use the RPN index since the weight conversion data is already incorporated into the assessment model. The final longline survey RPN index for RE/BS rockfish runs from 1993-2014 with all available strata updated with new area estimates (Table 13-13).

In addition to recalculating RPN values, variance estimates were computed for RE/BS rockfish (Figure 13-4). These estimates were derived by assuming that the mean CPUE of a station in a depth stratum were a representative sample, but recognizing that there is covariance between hachis and between depth stratum since hachis and stratum means are not independent among stations. Previously, the variance of the RPW index was assumed to have a CV of 20% across all years based on the interannual variance. New estimates of CVs range from 14-22% (Table 13-13).

The RPN estimates for RE/BS rockfish have been relatively constant since 1993, with the exception of large increases in 1997 and again in 2000. A sharp decline occurred in 2005 and estimates generally increased until 2011 when the survey reached an all-time high for this time series. Another sharp decline occurred in 2012 with an additional decrease in 2013. However, the current 2014 survey increased by 40% from 2013 and is 17% above the average for the time series (Figure 13-4). The agreement between the trawl and longline surveys in 2013 may be indicative of a decrease in the RE/BS rockfish biomass; however, the 2014 longline estimates suggest that the decline may not be so dramatic. As mentioned in the previous section, the trawl survey is not typically capable of sampling the deeper depths and high relief habitat of rougheye and blackspotted rockfish. This is not the case with the longline survey which can sample a large variety of habitats. One drawback, however, is that juvenile fish are not susceptible to longline gear. Subsequently, the longline survey does not provide much information on recruitment because most fish are similar in size once they have reached full selection of the longline gear. The trawl survey may be limited in sampling particular habitats, but does capture juveniles. Another potential concern is the unknown effect due to competition between larger predators for hooks (Rodgveller et al. 2008). However, Shotwell et al. (2014) investigated the potential for hook competition in the longline survey and found that it was very unlikely to be large, and if it occurs it happens only in occasional specific year and station combinations. In the future, if competition is deemed more important, it will be straightforward to include a competition parameter into the RPN index rather than the RPW index. Incorporating both longline and trawl survey estimates in the model should remedy some of these issues and offset the variable pattern in both surveys that may be an artifact of sampling issues.

AFSC Longline Size Compositions

Large samples of lengths were collected gulf-wide of RE/BS rockfish from 1990 - 2005. Efficiency has improved in recent surveys and lengths are now collected for nearly all RE/BS rockfish caught ranging from 3,500 to 7,000 (Table 13-14). The influence of such large sample sizes in the stock assessment model are somewhat remedied by taking the square root of sample size relative to the max of the series and scaling to 100 to determine the weight for each year. However, the implications of these assumptions toward weighting of samples sizes should be addressed and is a likely area for future research.

Since the longline survey does not sample in proportion to area, we used area weighted longline survey size compositions instead of compositions based on raw sample size. Updated longline survey size compositions are also now available from 1993-2014 using all strata information and are calculated using the same length bins as the fishery and AFSC bottom trawl data. The longline survey size compositions show that small fish were rarely caught in the longline survey and that the length distribution was fairly stable through time (Table 13-14). Compositions for all years were normally distributed with a mode between 45 and 47 cm in length. An unusually large amount of fish appeared in the 26 cm length bin in 2014 and we are currently investigating this data point. However, setting this composition to average had a negligible effect on the assessment results so we retain this data until further information is available.

Comparison of AFSC Bottom Trawl and Longline Surveys

The spatial distribution of numbers of rougheye and blackspotted rockfish caught in the 2009, 2011, and 2013 trawl and longline surveys is depicted in Figure 13-5a. The trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. However, the trawl survey tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This can be seen in the 2009 and 2011 surveys, particularly in the eastern GOA. In 2013, both estimates decreased from the previous surveys. The spatial distribution of hauls that encountered RE/BS rockfish seemed to be the opposite of the 2011 survey with many small catches throughout the central GOA and a few relatively large catches in the eastern GOA. There was also a reduction in survey effort in 2013. Similar to 2011, only 2 boats were chartered for the survey (usually 3 boats are used). This resulted in even fewer stations sampled compared to previous surveys: 550 stations in 2013 compared to 670 in 2011 and 823 in 2009. The 2013 sampling level (based on number of stations) is 30% lower than the long-term mean for this survey. We will continue to monitor the number of stations sampled in the trawl survey to better understand the potential effects on estimates in the future.

Rougheye and blackspotted rockfish were identified separately since 2007 in the trawl surveys. The spatial distribution of the two species somewhat reflects the area differences seen in the trawl survey biomass estimates (discussed previously in *AFSC Bottom Trawl Biomass Estimates* section); however, the difference seems to be more slope versus continental shelf oriented (Figure 13-5b). In general, more rougheye are identified in the shallower depths than blackspotted, particularly in the central GOA. The changes in spatial distribution of the two species over time may be an area of future research when determining differences in life history characteristics.

Sensitivity Analysis of AFSC Bottom Trawl and Longline Surveys

In response to comments by the SSC in December 2005, a preliminary sensitivity analysis was conducted in the 2006 RE/BS rockfish assessment on the relative influence of the trawl and longline survey estimates. Data for the RE/BS model substantially increased for the 2007 assessment; therefore, we included a more thorough sensitivity analysis that also included the relative influence of the trawl survey age and longline survey length compositions. The trajectory of female spawning biomass (SSB) was relatively similar over all model runs; however, the magnitude of SSB depended on the specification of precision of input data. We altered the specified precision by changing the assumed CV for each data source. In general, model estimates were robust to only altering the precision on the trawl survey biomass estimates or the longline survey length compositions. Estimates of SSB increased with a moderately high precision on the trawl survey biomass coupled with decreased precision on the longline survey biomass or a decrease in weight on the trawl survey age compositions. Model estimates decreased with high precision on only the longline survey or high precision on the trawl survey age compositions.

In two scenarios, B_{2008} fell below $B_{40\%}$. The first scenario was very high precision on only the longline survey. In this case, the relatively low weight of the catch index allowed the model to predict highly anomalous values resulting in fairly low fit to the catch data. The second scenario was very high precision on the trawl survey biomass combined with very high weight on the trawl survey age compositions. In this second case, trawl survey selectivity shifts to the right and catchability increased dramatically, resulting in reduced overall biomass trajectory. Results of this sensitivity analysis suggest increasing the weight on the catch index to increase robustness of the model to the assumed specification of precision. We may also explore the effects of increasing the age bins as we update the size-at-age matrix and weight-at-age vector when considering model assumptions. At this time, we do not feel that any particular increase or decrease of the current precision or weighting scheme on the trawl or longline biomass estimates or compositions is warranted, given that they all provide information on different aspects of the rougheye and blackspotted rockfish population.

International Pacific Halibut Commission (IPHC) Longline Estimates

The IPHC conducts a longline survey each year to assess Pacific halibut. This survey differs from the AFSC longline survey in gear configuration and sampling design, but also catches rougheye and blackspotted rockfish. More information on this survey can be found in Soderlund et al. (2009). A major difference between the two surveys is that the IPHC survey samples the shelf consistently from 1-500 meters, whereas the AFSC longline survey samples the slope and select gullies from 200 to 1000 meters. Because the majority of effort occurs on the shelf in shallower depths, the IPHC survey may catch smaller and younger rougheye and blackspotted rockfish than the AFSC longline survey; however, lengths of RE/BS rockfish are not taken on the IPHC survey.

We conducted a preliminary comparison between the three surveys from 1998-2008 in Shotwell et al. (2011). IPHC relative population numbers (RPN) were calculated similar to the AFSC survey, the only difference being the depth stratum increments. Area sizes used to calculate biomass in the AFSC bottom trawl surveys were utilized for IPHC RPN calculations. A Student’s t normalized residuals was used to compare between the IPHC longline, AFSC longline, and AFSC bottom trawl surveys. The IPHC and AFSC longline surveys track well until about 2004 and then have somewhat diverging trends. The consistently shallower IPHC survey may better capture variability of younger RE/BS rockfish. Since the abundance of younger RE/BS rockfish will be more variable as year classes pass through, the IPHC survey should more closely resemble the AFSC bottom trawl survey. We plan to revisit this analysis in the 2015 assessment using the newly computed RPNs for all strata on the AFSC longline survey.

Analytic Approach

Model Structure

We present model results for the RE/BS rockfish complex based on an age-structured model using AD Model Builder software (Fournier et al. 2012). This consists of an assessment model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model which uses result from the assessment model to predict future population estimates and recommended harvest levels. The GOA RE/BS model closely follows the GOA Pacific ocean perch model which was built from the northern rockfish model (Courtney et al. 1999; Hanselman et al. 2003, Courtney et al. 2007). As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there little contrast in the spawner/recruits data (Figure 13-6). The main difference between the RE/BS model and the Pacific ocean perch model is the addition of data from the AFSC longline survey. Unlike the Pacific ocean perch model, the starting point for the RE/BS model is 1977, so the population at the starting point has already sustained fishing pressure. The parameters, population dynamics and equations of the model are described in Box 1 (below). The model has been in its current configuration since 2005. In 2009, further modifications were made to accommodate MCMC projections that use a pre-specified proportion of ABC for annual catch. This year a modification was made to allow for a numbers index rather than a weight index in the model following the configuration used in the sablefish assessment model (Hanselman et al. 2013).

Parameters Estimated Outside the Assessment Model

Size at 50% maturity has been determined for 430 specimens of rougheye rockfish (McDermott 1994). This was converted to 50% maturity-at-age using the size-age matrix from this stock assessment. These data are summarized below (size is in cm fork length and age is in years).

Sample size	Size at 50% maturity (cm)	Age at 50% maturity
430	43.9	19

New information on growth is available due to the large number of aged specimens for RE/BS rockfish from the AFSC bottom trawl survey. Previous growth estimates were based on data from only 1990 and 1999. We calculated an updated size-at-age conversion matrix and mean weight-at-age using the same methods as the previous growth estimates. A von Bertalanffy growth curve was fit to size and age data from 1990 to 2011. Sexes were combined and the size-at-age conversion matrix was constructed by adding normal error with a standard deviation equal to the standard deviation of the survey ages for each size class. The new estimated parameters for the growth curve are:

L_∞=51.4 cm κ=0.08 t_0=-1.27 n=5,681

And, for comparison, the old growth parameters were:

L_∞=51.2 cm κ=0.08 t_0=-1.15 n=866

The mean weight-at-age was constructed from the same data set as the size-at-age matrix and a correction of $(W_\infty - W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001). The new estimated growth parameters are:

W_∞=2,171 g κ=0.08 t_0=-1.27 β=3.077 n=4,749

And, for comparison, the old growth parameters were:

W_∞=2,311 g κ=0.05 t_0=1.68 β=1.712 n=735

When this information was applied to produce the size-at-age conversion matrix and mean weight-at-age, the differences from the old growth parameters were minor and on average the new mean weight-at-age was about 36% lower than previous. Size-at-age differences were negligible.

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age. Originally we used the error structure of the Pacific ocean perch model because we used approximately the same age bins for the RE/BS assessment. Newly available age samples allowed for an update of the 2011 age-error matrix. Age agreement tests have now been run on samples from 1984, 1987, 1990, 1993, 1996, 1999, 2003-2007, and 2009 for RE/BS rockfish for a total of 1,589 specimens. We estimated a new age error structure based on the percent agreement for each age from these tests.

New Research

A new maturity study on RE/BS rockfish species was recently initiated through the RACE Division (C. Conrath and B. Knoth). Samples were collected throughout the year on a variety of scientific surveys and observed fishery vessels. Preliminary results suggest slightly lower age at 50% maturity; however, substantial number of adults appeared to be skip spawning. More samples from a larger variety of areas and during different years and/or seasons are needed to adequately assess the spawning state (C. Conrath, pers. comm.). We plan to use this new maturity information as it becomes available and will follow the method that was recently developed to incorporate estimated maturity within the assessment model (Hulson et al. 2011, Lunsford et al. 2011, Spencer and Ianelli, 2012).

Parameters Estimated Inside the Assessment Model

The estimates of natural mortality (*M*), catchability (*q*), and recruitment deviations (σ_r) are estimated with the use of prior distributions as penalties. The prior for RE/BS rockfish natural mortality estimate is 0.03 which is based on McDermott (1994). She used the gonadosomatic index (GSI) following the methodology described by Gunderson and Dygert (1988) to estimate a range of natural mortalities specifically for rougheye/blackspotted (0.03 – 0.04). In general, natural mortality is a notoriously difficult parameter to estimate within the model so we assign a precise prior CV of 10% (Figure 13-7).

Several other alternatives to estimating natural mortality for rockfish are available such as catch-curve analysis, empirical life history relationships, and simplified maximum age equations (Malecha et al. 2007). Each of these methodologies was detailed in the draft response of the Rockfish Working Group to the center of independent expert's review of Alaskan Rockfish Harvest Strategies and Stock Assessment Methods (ftp://ftp.afsc.noaa.gov/afsc/public/rockfish/RWG response to CIE review.pdf). We applied the various methods to data from RE/BS rockfish and used a maximum age of 132 (AFSC 2006). Values are shown below.

Method	***M***
Current stock assessment prior	0.030
Catch Curve Analysis	0.072
Empirical Life-History: Growth	0.004
Empirical Life-History: Longevity	0.035
Rule of Thumb: Maximum Age	0.035

The Hoenig (1983) methods based on longevity and the "rule-of-thumb" approach both produce natural mortality estimates similar to McDermott (1994). Catch-curve analysis produced an estimate of Z=0.094 and average fishing mortality (0.022) is subtracted to yield a natural mortality 0.072 which is the highest estimate. The Alverson and Carney (1975) estimate was much lower. Several assumptions of catch-curve analysis must be met before this method can be considered viable, and there is a likely time trend in recruitment for GOA rockfish. The method described by Alverson and Carney (1975) for developing an estimate of critical age is based on a regression of 63 other population estimates and may not be representative of extremely long-lived fish such as rougheye and blackspotted rockfish (Malecha et al. 2007). McDermott (1994) collected 430 samples of rougheye/blackspotted rockfish from across the Pacific Northwest to the Bering Sea, providing a representative sample of RE/BS rockfish distribution. Since the value of 0.03 estimated by McDermott (1994) is within the range of most other estimates of natural mortality and designed specifically for RE/BS rockfish, we feel that this is the most suitable estimate for a prior mean.

Catchability is a parameter that is somewhat uncertain for rockfish. We assign a prior mean of 1 for both the trawl and longline survey. For the trawl survey, a value of 1 assumes all fish in the area swept are captured, there is no herding of fish from outside the area swept, and there is no effect of untrawlable grounds. This area-swept concept does not apply to the longline survey; however, since the RPNs for rougheye and blackspotted rockfish are of the same magnitude as the trawl survey estimates we deemed this a logical starting point. We also assume a lognormal distribution to bind the minimum at zero. Without utilizing empirical data to assign a CV to the catchability prior we assign it a relatively imprecise prior CV of 45% to allow the data to influence the catchability estimate. This is a better assumption than fixing the trawl survey catchability at 1 or an arbitrary value near 1. In the future, we will consider using more informative priors for the trawl survey that are based on empirical observations from submersibles and the untrawlable/trawlable work currently underway. For the longline survey, we assign a very broad CV of 100% which essentially mimics a uniform prior with a lower bound of zero (Figure 13-8). These prior distributions allow the catchability parameters more freedom than that allowed to natural mortality.

Recruitment deviation is the amount of variability that the model assigns recruitment estimates. Rougheye and blackspotted rockfish are likely the longest-lived rockfish and information on recruitment is quite limited, but is expected to be episodic similar to Pacific ocean perch. Therefore, we assign a relatively high prior mean to this parameter of 1.1 with a precise CV of 6% to allow recruitments to be potentially variable (Figure 13-8).

Other parameters estimated conditionally include, but are not limited to: selectivity (up to full selectivity) for surveys and fishery, mean recruitment, fishing mortality, and reference fishing morality rates. The numbers of estimated parameters as determined by ADMB are shown below. Other derived parameters are described in Box 1.

Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	2
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Fishing mortality rates	$F_{35\%}$, $F_{40\%}$, $F_{50\%}$	3
Recruitment deviations	τ_v	59
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_v	38
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	25
Total		145

Uncertainty

Evaluation of model uncertainty has recently become an integral part of the "precautionary approach" in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the models presented in this SAFE report, the number of parameters estimated is 145. In a low-dimensional model, an analytical solution for the uncertainty might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The "burn-in" is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 4,000,000 iterations out of 20,000,000 and "thinned" the chain to one value out of every 4,000, leaving a sample distribution of 4,000. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters.

BOX 1. AD Model Builder Rougheye Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length conversion matrix
q_1	Trawl survey catchability coefficient
q_2	Longline survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
M_{prior}	Prior mean for natural mortality
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment variance
σ^2_M	Prior CV for natural mortality
σ^2_q	Prior CV for catchability coefficient
$\sigma^2_{\sigma_r}$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_{1y} = q_1 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$$

Trawl survey biomass index (t)

$$\hat{I}_{2y} = q_2 \sum_a N_{y,a} * \frac{s_a}{\max(s_a)}$$

Longline survey abundance index (RPN)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr - a_0 - a - 1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr - a_0 - a - 1}\right)} e^{-(a - a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{(\mu_r)} e^{-(a - a_0)M}}{\left(1 - e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment
Number at ages between recruitment and pooled age class
Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln \left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \left(\ln I_{1y} - \ln \hat{I}_{1y} \right)^2 / \left(2\sigma_{I_1}^2 \right)$	Trawl survey biomass index likelihood
$L_3 = \lambda_3 \sum_y \left(\ln I_{2y} - \ln \hat{I}_{2y} \right)^2 / \left(2\sigma_{I_2}^2 \right)$	Longline survey abundance index (RPN) likelihood
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_{l}^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_{a}^{a+} \left(P_{y,a} + 0.001 \right) * \ln \left(\hat{P}_{y,a} + 0.001 \right)$	Trawl survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_{l}^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Trawl survey size composition likelihood
$L_7 = \lambda_7 \sum_{styr}^{endyr} -n^*{}_y \sum_{l}^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Longline survey size composition likelihood
$L_8 = \frac{1}{2\sigma_M^2} \left(\ln M / M_{prior} \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_9 = \frac{1}{2\sigma_{q_1}^2} \left(\ln q_1 / q_{1\,prior} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for trawl survey
$L_{10} = \frac{1}{2\sigma_{q_2}^2} \left(\ln q_2 / q_{2\,prior} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for longline survey
$L_{11} = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \sigma_r / \sigma_{r(prior)} \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{12} = \lambda_{12} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln \left(\sigma_r \right) \right]$	Penalty on recruitment deviations
$L_{13} = \lambda_{13} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{14} = \lambda_{14} \bar{s}^2$	Average selectivity penalty (attempts to keep average selectivity near 1)
$L_{15} = \lambda_{15} \sum_{a_0}^{a_+} \left(s_i - s_{i+1} \right)^2$	Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)
$L_{16} = \lambda_{16} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1}) \right)^2$	Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences)
$L_{total} = \sum_{i=1}^{16} L_i$	Total objective function value

Results

Model Evaluation

We present three models in this assessment as described in the following table:

Model Number	Model Description
Model 0 (Base)	Model from Shotwell et al. (2011)
Model 1 (Intermediate)	Incorporates all new and updated data, longline RPW index, 2011 conversion matrices
Model 2 (Full update)	Same as Model 1 but uses longline RPN index and all new conversion matrices

Model 0 is the last full assessment base model from Shotwell et al. (2011). Model 1 is an intermediate model which uses all the new and updated data but keeps the previous longline RPW index for the longline survey and the mean weight-at-age, size-at-age conversion matrix, and ageing error matrix from the 2011 model. This model was run for comparison purposes only given the large amount of new data available for this assessment. Model 2 uses all the new and updated data, the RPN longline survey index, and the updated growth data to estimate new mean weight-at-age, size-at-age conversion matrix, and aging error conversion matrix.

At minimum, there is improved overall fit to the data (in terms of negative log-likelihood) with the full update Model 2, particularly in the size composition data from the intermediate Model 1 (Table 13-15). Given this information and the recommendation from the 2009 sablefish CIE to use the RPN index for the longline survey, we prefer the Model 2 full update to estimate management quantities for 2015 and discuss results of this model in the following section. Estimated numbers in 2014, fishery selectivity, trawl and longline survey selectivity and schedules of age specific weight and female maturity are provided in Table 13-16 for reference.

Time Series Results

Table 13-15 provides parameter estimates for all three models for comparison purposes. Tables 13-16 through 13-19 summarize other results for the 2014 author preferred model. Model predictions fit the age and size data relatively well (Figures 13-9, 13-10, 13-11 and 13-13), with the exception of the plus age group in some years, particularly in the fishery ages. AFSC bottom trawl survey size compositions are provided for reference (Figure 13-12).

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all rougheye/blackspotted rockfish age three and greater. Recruitment is measured as number of age three RE/BS rockfish. Fishing mortality is fully-selected F, meaning the mortality at the age the fishery has fully selected the fish.

Parameter estimates for the preferred Model 2 are somewhat similar to the base Model 0 (2011) estimates, except for higher catchability in the bottom trawl and longline surveys. Natural mortality, recruitment variability, and mean recruitment estimates were all similar to Model 0 estimates (Table 13-15). The intermediate Model 1 had much higher catchability estimates, lower mean recruitment, and substantially lower spawning biomass. Spawning biomass for the preferred Model 2 compared to base Model 0 was higher overall (except in the most recent years); while total biomass was lower overall with the difference becoming more prominent in recent years. Recruitment was generally similar between the preferred Model 2 and the base Model 0 except in 1997 and slightly different in recent years (Table 13-18). This is likely due to the differences between the two survey trajectories and in using RPN versus RPW estimates. Projected total and spawning biomass decreased, while recruitment increases slightly. Estimates continue to track the influx of new recruits from the early 2000s. Catchability, selectivity, and recruitment are all somewhat confounded within the model. As the surveys estimate fewer fish, and age compositions suggest less recruitment, catchability estimates tend to increase so that large swings in biomass do not occur. This seems reasonable for long-lived fish such as rougheye and blackspotted rockfish.

Preferred Model 2 predictions fit the data relatively well. Model fits to bottom trawl survey biomass and longline survey relative population numbers (RPN) were fairly consistent over time with a steady value for the trawl survey estimate (more so than in the base Model 0) and a slight increase in the most recent longline survey estimates (Figures 13-3, 13-4). Predicted values for the trawl survey do not capture the recent low 2013 estimate and predicted values for the longline survey do not capture the fluctuating high and low spikes since 1997. Average longline RPNs surrounding these years combined with corresponding average trawl survey biomass estimates likely restrict the model from large swings in predictions for the longline RPNs. Fit to the fishery age compositions is marginal but likely hindered by an extremely large plus group which has increased since the bin structure was originally imposed (Figure 13-9). This may be improved by increasing the age bins or allowing selectivity for older aged fish more flexibility. Fit to the fishery size compositions are slightly flattened (Figure 13-10) particularly in 1991. This may be due to the slight right or left skew in most years. Fit to the bottom trawl survey age compositions are generally very good with some over- or underestimation of the plus group in all years except 1987, 1990, 1996, and 2011 (Figure 13-11). Fit to the longline survey size compositions are similar to the fishery size compositions with slightly flattened peaks in most years (Figure 13-13). The model does not fit the relatively large composition of size 26 cm fish in 2014.

The consistent patterns of positive residuals in the fishery and survey size compositions could be due to a variety of confounding issues between selectivity, growth, and ageing. In the future we may consider applying different shaped selectivity curves or explore separate selectivity curves for trawl and longline fisheries. Additionally, we may experiment with increasing the age bins to reduce the influence of the large plus group during estimation.

Biomass and Exploitation Trends

Estimates of total biomass are relatively steady, decreasing slightly from the beginning of the time series until 1991 and increasing slightly to the most current estimate (Figure 13-14). These estimates are slightly lower than the 2011 model estimates but not until after 1991. Spawning biomass estimates are very similar to total biomass with a slightly steeper decreasing slope to 1991 and slightly steeper increasing slope to present (Figure 13-15). In this case, the spawning biomass is slightly higher than the 2011 estimates up until the most recent years. Fairly wide credible intervals result from the MCMC simulation for biomass estimates, with decreasing certainty in the more recent estimates, particularly the upper credible intervals. Estimated selectivity curves were similar to expected (Figure 13-16). The commercial fishery should target larger and subsequently older fish and the trawl survey should sample a larger range of ages. The longline survey samples deeper depths and small fish are not susceptible to the gear. The fishery selectivity curve is similar to the longline selectivity curve with a steeper knife-edge at about 15 years. This is expected as the fish caught in the fishery are slightly larger on average than the fish caught on the longline survey. The trawl survey is somewhat dome-shaped for older fish since adult habitat is typically in rocky areas along the shelf break where the trawl survey gear may have difficulty sampling.

Fully selected fishing mortality increased in the late 1980s and early 1990s due to the high levels of estimated catch and returned to relatively low levels from 1993 to present (Figure 13-17). The spike may be due to the management of rougheye/blackspotted rockfish in the slope rockfish complex prior to 1991 and the disproportionate harvest on shortraker due to their high value. Rougheye would also be caught as they often co-occur with shortraker. In general, fishing mortality is relatively low because historically most of the available TAC has not been caught. There is a slight increase in the most recent years.

Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. We present a similar graph termed a phase plane which plots the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to $B_{35\%}$. Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The phase for RE/BS rockfish has been above the F_{OFL} adjusted limit for only three years in the late 1980s and 1990 (Figure 13-18). Since 1990, spawning biomass of RE/BS rockfish has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

MCMC credible intervals (CI) for recruitment have continued to narrow with the addition of more age data (Figure 13-19). This is particularly true for the 1990 year class, which exists as a large proportion in the age compositions. In general, though recruitment is highly variable, particularly in the most recent years where very little information exists on this part of the population. There also does not seem to be a clear spawner-recruit relationship for rougheye and blackspotted rockfish as recruitment is apparently unrelated to spawning stock biomass and there is little contrast in spawning stock biomass (Figure 13-6).

Uncertainty

From the MCMC chains described previously, we summarize the posterior densities of key parameters for the author recommended model using histograms (Figure 13-20) and credible intervals (Table 13-17). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 13-14, 13-15, 13-19, Table 13-19).

Table 13-17 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The MLE and MCMC standard deviations are similar for q_1 (trawl survey catchability), q_2 (longline survey catchability), and M, but the MCMC standard deviations are larger for the estimates of projected female spawning biomass, and ABC, and σ_r (recruitment deviation). The larger standard deviations indicate that these parameters are more uncertain than indicated by the standard modeling, especially in the case of σ_r in which the MLE estimate is slightly out of the Bayesian credible intervals. This highlights a concern that σ_r requires a fairly informative prior distribution since it is confounded with available data on recruitment variability. To illustrate this problem, imagine a stock that truly has variable recruitment. If this stock lacks age data (or the data are very noisy), then the modal estimate of σ_r is near zero. As an alternative, we could run sensitivity analyses to determine an optimum value for σ_r and fix it at that value instead of estimating it within the model. In contrast the Hessian standard deviation was larger for the estimate of q_2 (longline survey catchability), which may imply that this parameter is well estimated in the model. This is possibly due to the large amount of longline survey data in the model relative to the trawl survey index. The MCMC distribution of ABC, current total biomass, and current spawning biomass are skewed (Figure 13-20) indicating potential for higher biomass estimates (see also Figure 13-14 and Figure 13-15).

Retrospective Analysis

A within-model retrospective analysis of the preferred model was conducted for the last 10 years of the time-series by dropping data one year at a time. The revised Mohn's "rho" statistic (Hanselman et al.

2013) in female spawning biomass was 0.353, indicating that the model decreases the estimate of female spawning biomass in the retrospective model's terminal year as data is added to the assessment. The retrospective female spawning biomass and the relative difference in female spawning biomass from the 2014 model are shown in Figure 13-21 (with 95% credible intervals from MCMC).

The RE/BS model is exhibiting a relatively strong retrospective pattern. The 2014 value of the revised Mohn's "rho" statistic was similar to the value of 0.34 in Hanselman et al. (2013) which ranked GOA RE/BS rockfish as the 5th strongest retrospective of the 20 stocks investigated. We examined natural mortality and catchability because of the scale changes between retrospective peels for serial retrospective trends, but did not find any obvious shifts. We plan to further examine potential retrospective causes when we update bin structures and effective sample sizes in the 2015 full assessment.

Harvest Recommendations

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, rougheye and blackspotted rockfish in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age 3 recruits from 1980-2012 (i.e. the 1977-2009 year classes). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2014 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
22,449 (t)	8,980 (t)	7,857 (t)	0.038	0.045

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2015 is 12,480 t. This is above the $B_{40\%}$ value of 8,980 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for *ABC* is $F_{40\%}$ and fishing mortality for *OFL* is $F_{35\%}$. Applying these fishing mortality rates for 2015 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.038
ABC (t)	1,122
$F_{35\%}$	0.045
OFL (t)	1,345

Population Projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of

Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2014 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2014 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2015, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In 2015 and 2016, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2011-2013 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio of F will yield more realistic projections.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2014 or 2) above ½ of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, F is set equal to max F_{ABC}, and in all subsequent years F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2016 or 2) above ½ of its MSY level in 2016 and expected to be above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 13-20). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries (such as rougheye and blackspotted) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for two year ahead specifications. The methodology for determining these pre-specified catches is described below in *Specified Catch Estimation*.

Status Determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2015, it does not provide the best estimate of OFL for 2016, because the mean 2015 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2013) is 574 t. This is less than the 2013 OFL of 1,482 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2014:

a) If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2014 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2014 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 13-20). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

a) If the mean spawning biomass for 2016 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2016 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 13-20, the stock is not overfished and is not approaching an overfished condition.

Specified Catch Estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the Gulf of Alaska rockfish assessments, for current year catch, we are using an expansion factor to the catch in early October by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2011-2013 for this year, see example figures below). For rougheye and blackspotted rockfish, the expansion factor for 2014 catch is 1.045.

For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out. To estimate future catches, we updated the yield ratio (0.45), which was the average of the ratio of catch to ABC for the last three complete catch years (2011-2013). This yield ratio was multiplied by the projected ABCs for 2015 and 2016 from the assessment model to generate catches for those years.

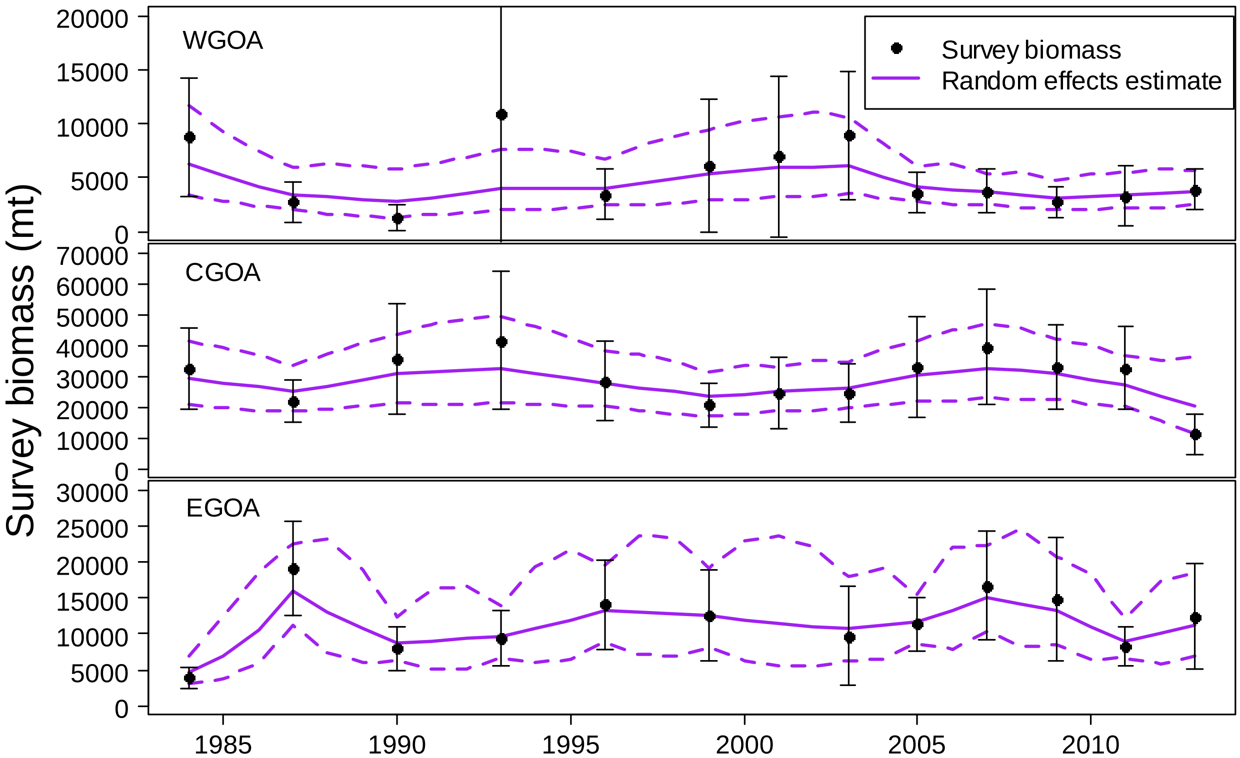
Alternative Projection

During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at author's F (0.3 maximum permissible based on recent ratios of catch to ABC). This is conservative relative to a max ABC or alternative 1 projection scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 20,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 13-22). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1980-2012 age-3 recruitments, and this projection predicts that the median spawning biomass is well above these reference points for the entire time series and will steadily increase as average recruitment is consistently applied and the very low proportion of ABC is taken (0.45).

Area Allocation of Harvests

We determine apportionment of ABC among areas utilizing a method that was recommended by the Plan Team and accepted by the Council in 1996. This method weights prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3rd of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3rd the weight of the preceding survey. This resulted in weights of 4:6:9 for the 2009, 2011, and 2013 surveys, respectively and apportionments for rougheye and blackspotted rockfish of 10.3% for the western area, 56.3% for the central area, and 33.4% for the eastern area (Table 13-21). This represents a shift from the central area to an approximate 4% increase in the western and a 10% increase in the eastern areas from the 2011 apportionments (6.60% for the Western area, 69.46% for the Central area, and 23.94% for the Eastern area).

The Plan Team and SSC requested that the random effects model proposed by the Survey Averaging Working Group be evaluated for apportionment. The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern Gulf of Alaska. The random effects model estimates a process error parameter (constraining the variability of the modeled estimates among years) and random effects parameters in each year modeled. The fit of the random effects model to survey biomass in each area is shown in the figure below. For illustration purposes the 95% confidence intervals are shown for the survey biomass (error bars) and the random effects estimates of survey biomass (dashed lines).



In general the random effects model fits the area-specific survey biomass reasonably well. However, there did seem to be some sensitivity to starting values in which case the model had difficulty estimating process error. This occurred in the Central GOA which contains the bulk of the RE/BS biomass and has the smallest sampling error. When the random effects model did converge, we used the random effects estimates of ending year biomass to determine the apportionment results as 10.6% for the Western area, 57.3% for the Central area, and 32.1% for the Eastern area. This is very similar to the results from the updated 4:6:9 survey average weighting method.

We recommend continuing with the standard three survey weighted average apportionment for RE/BS rockfish given the sensitivity of the random effects model to converging in the Central GOA. We will consider the random effects model for RE/BS rockfish when recommendations on model estimation procedure and potential inclusion of other survey biomass estimates (e.g. AFSC longline survey) are provided by the Survey Averaging Working Group.

The following table shows the apportionment for the 2015 and 2016 fishery when applying the percentages using the three survey weighted average and random effects methods to the ABC for RE/BS rockfish (1,122 t):

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Average			10.3%	56.3%	33.4%	100%
	2015	Area ABC (t)	**115**	**632**	**375**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**117**	**643**	**382**	**1,142**
		OFL (t)				**1,370**
Random Effects			10.6%	57.3%	32.1%	100%
	2015	Area ABC (t)	**119**	**643**	**360**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**122**	**654**	**366**	**1,142**
		OFL (t)				**1,370**

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.045), overfishing is set equal to 1,345 t in 2015 and 1,370 t in 2016 for rougheye and blackspotted rockfish.

Ecosystem Considerations

In general, a determination of ecosystem considerations for the rougheye/blackspotted rockfish complex is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 13-22.

Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of rougheye/blackspotted rockfish appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval rockfish may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval RE/BS rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval RE/BS rockfish (Gharrett et. al 2001). Food habit studies in Alaska indicate that the diet of RE/BS rockfish is primarily shrimp (especially pandalids) and that various fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). Juvenile RE/BS rockfish in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Recent food studies show the most common prey of RE/BS as pandalid shrimp, euphausiids, and tanner crab (*Chionoecetes bairdi*). Other prey include octopi and copepods (Yang et al. 2006). Little if anything is known about abundance trends of likely rockfish prey items.

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages and to some extent marine mammals during late juvenile and adult stages. Likely predators of RE/BS rockfish likely include halibut, Pacific cod, and sablefish. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile rockfish, but information on these life stages and their predators is unknown.

Changes in physical environment: Strong year classes corresponding to the period around 1976-77 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including RE/BS rockfish. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have effect on prey item abundance and success of transition of rockfish from pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents.

Anthropogenic causes of changes in physical environment: Bottom habitat changes from effect of various fisheries could alter survival rates by altering available shelter, prey, or other functions. The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish are minimal or temporary. The steady trend in abundance of rougheye and blackspotted rockfish suggests that at current abundance and exploitation levels, habitat effects from fishing are not limiting this stock.

There is little information on when juvenile fish become demersal. Juvenile RE/BS rockfish 6 to 16 inches (15 to 40 cm) fork length have been frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates (Clausen et al. 2003). They are generally found at shallower, more inshore areas than adults and have been taken in a variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye or blackspotted rockfish, it is reasonable to suspect that juvenile rougheye and blackspotted rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for RE/BS rockfish account for very little bycatch of HAPC biota. This low bycatch may be explained by the fact that these fish are taken as bycatch or topping off in fisheries classified as targeting other species, thus any bycatch is attributed to other target species.

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: Unknown

Fishery-specific effects on amount of large size target fish: Unknown

Fishery contribution to discards and offal production: Fishery discard rates during 2005-2014 have been 15-36% for the RE/BS rockfish stock complex.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Unknown.
Fishery-specific effects on EFH living and non-living substrate: unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can move around rocks and boulders on the bottom. Table 13-6 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries.

Data Gaps and Research Priorities

Future assessment priorities include 1) a synthesis of previous studies on rockfish catchability using submersibles to develop informative prior distributions on catchability, 2) assessment of RE/BS rockfish density between trawlable and untrawlable grounds, 3) analyses of fishery spatial patterns and behavior given the observer restructuring, 4) sensitivity analyses with respect to the optimum plus groups for rockfish species, and 5) examining potential age and growth differences between RE/BS rockfish to help develop a rationale for a two-species model.

There is little information on early life history of rougheye and blackspotted rockfish. Recruitment processes influencing the early life stages or habitat requirements for all stages are mostly unknown. A better understanding of early life stage distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the RE/BS population.

We also hope to collect and age subsamples of rougheye otoliths from the longline survey for future use in the stock assessment model. Additional analyses may then include implications of sampling methodology and comparisons between trawl and longline survey age and length compositions.

Many of the comments specific to the RE/BS rockfish assessment during the 2013 Center for Independent Experts (CIE) Alaska rockfish scientific peer review may also be incorporated in this year’s full assessment. Please refer to the Summary and response to the 2013 CIE review of AFSC rockfish document presented to the September 2013 Plan Team for further details.

A summary of the primary reference values (i.e. biomass levels, exploitation rates, recommended ABCs and OFLs) for RE/BS rockfish are provided in the following table. Recommended values are in bold.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015	2016[*]
M (natural mortality rate)	0.034	0.034	0.034	0.034
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	42,810	43,337	36,584	36,610
Projected female spawning biomass (t)	12,897	13,325	12,480	12,595
$B_{100\%}$	24,329	24,329	22,449	22,449
$B_{40\%}$	9,732	9,732	8,980	8,980
$B_{35\%}$	8,515	8,515	7,857	7,857
F_{OFL}	0.047	0.047	0.045	0.045
$maxF_{ABC}$	0.039	0.039	0.038	0.038
F_{ABC}	0.039	0.039	0.038	0.038
OFL (t)	1,497	1,518	**1,345**	1,370
maxABC (t)	1,244	1,262	1,122	1,142
ABC (t)	1,244	1,262	**1,122**	1,142
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[*]Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 736 t for 2014 and projected catches of 502 t for 2015 and 501 t for 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Literature Cited

Alaska Fisheries Science Center. 2010. Age and Growth Program maximum age encountered statistics page. http://www.afsc.noaa.gov/REFM/Age/Stats/max_age.htm

Ackley, D. R. and J. Heifetz. 2001. Fishing practices under maximum retainable bycatch rates in Alaska's groundfish fisheries. Alaska Fish. Res. Bull. 8:22-44.

Berkeley, S. A., C. Chapman, and S. M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish*, Sebastes melanops*. Ecology 85(5):1258-1264.

Bobko, S.J. and S.A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish (*Sebastes melanops*). Fisheries Bulletin 102:418-429.

Byerly, Michael M. 2001. The ecology of age 1 copper rockfish (Sebastes caurinus) in vegetated habitats of Sitka sound, Alaska. M.S. Thesis University of Alaska, Fairbanks.

Carlson, H.R. and R.R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of southeastern Alaska. Marine Fisheries Review 43(7):13-19.

Chilton, D.E. and R.J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Can. Spec. Pub. Fish. Aquat. Sci. 60.

Clausen, D.M., J.T. Fujioka, and J. Heifetz. 2003. Shortraker/rougheye and other slope rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA, p. 531-572. Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Clausen, D. M., D.H. Hanselman, J.T. Fujioka, and J. Heifetz. 2004. Gulf of Alaska shortraker/rougheye and other slope rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 413 – 463. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Clausen, D. M., and J. T. Fujioka. 2007. Variability in trawl survey catches of Pacific ocean perch, shortraker rockfish, and rougheye rockfish in the Gulf of Alaska. *In* J. Heifetz, J. Dicosimo, A. J. Gharrett, M. S. Love, V. M. O'Connell, and R. D. Stanley (editors), Biology, assessment, and management of North Pacific rockfishes, p. 411-428. Alaska Sea Grant, Univ. of Alaska Fairbanks.

Courtney, D.L., J. Heifetz, M. F. Sigler, and D. M. Clausen. 1999. An age structured model of northern rockfish, *Sebastes polyspinis*, recruitment and biomass in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2000. Pg. 361-404. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Courtney, D.L., J. N. Ianelli, D. Hanselman, and J. Heifetz. 2007. Extending statistical age-structured assessment approaches to Gulf of Alaska rockfish (*Sebastes* spp.). *In*: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 429–449.

De Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, *Sebastes aleutianus* and *S. alutus*. Biol. Reprod. 71:1036-1042.

Echave, K., C. Rodgveller, and S.K. Shotwell. 2013. Calculation of the geographic area sizes used to create population indices for the Alaska Fisheries Science Center longline survey. NOAA Technical Memorandum NMFS-AFSC-253. Pp. 107

Freese, J.F., B.L. Wing. 2004. Juvenile red rockfish, *Sebastes* spp., associations with sponges in the Gulf of Alaska. Mar. Fish. Rev. 65(3):38-42.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Software 27 (2), 233-249.

Garvin, M.R., R.W. Marcotte, K.J. Palof, R.J. Riley, L.M. Kamin, and A.J. Gharrett. 2011. Diagnostic Single-Nucleotide Polymorphisms Identify Pacific Ocean Perch and Delineate Blackspotted and Rougheye Rockfish. Transactions of the American Fisheries Society, 140:4, 984-988.

Gelman, A., J.B. Carlin, H.S. Stern and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall, London. 526 pp.

Gharrett, A. J., A. K. Gray, and J. Heifetz. 2001. Identification of rockfish *(Sebastes* spp.) from restriction site analysis of the mitochondrial NM-3/ND-4 and 12S/16S rRNA gene regions. Fish. Bull. Fish. Bull. 99:49-62.

Gharrett, A.J., Z. Li, C.M. Kondzela, and A.W. Kendall. 2002. Final report: species of rockfish (*Sebastes* spp.) collected during ABL-OCC cruises in the GOA in 1998-2002. (Unpubl. manuscr. available from the NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801).

Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray, Z. Li, and J. Heifetz. 2005. Two genetically distinct forms of rougheye rockfish are different species. Trans. Am. Fish. Soc. 132:242-260.

Gharrett, A.J., C.W. Mecklenburg, L.W. Seeb, L. Li, A.P. Matala, A.K. Gray, and J. Heifetz. 2006. Do genetically distinct rougheye rockfish sibling species differ phenotypically? Trans. Am. Fish. Soc. 135:792-800.

Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray, Z. Li, and J. Heifetz. 2007. Distribution and population genetic structure of sibling rougheye rockfish species. Pages 121-140 *In* J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell, and R.D. Stanley (eds.) 2007. Biology, assessment, and management of North Pacific rockfishes. Alaska Sea Grant College Publication AK-SG-07-01, University of Alaska Fairbanks.

Goodman, D., M. Mangel, G. Parkes, T.J. Quinn II, V. Restrepo, T. Smith, and K. Stokes. 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans. Draft report. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D., J. Heifetz, J. Fujioka, and J. Ianelli. 2003. Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 289-308. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Hanselman, D.H., C.R. Lunsford, and C.J. Rodgveller. 2013. Assessment of the sablefish stock in Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea, Aleutian Islands and Gulf of Alaska, p. 267-376. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Hanselman, D.H., B. Clark, and M. Sigler. 2013. Report of the groundfish plan team retrospective investigations group, part II: the compilation. Presented at September 2013 Plan Team, 12 pp. http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/Retrospectives_2013_final3.pdf

Hawkins, S., J. Heifetz, J. Pohl, and R. Wilmot. 1997. Genetic population structure of rougheye rockfish (*Sebastes aleutianus*) inferred from allozyme variation. In Quarterly Report, July - August - September 1997, p. 1-10. Alaska Fisheries Science Center, 7600 Sandpoint Way, Seattle WA 98115.

Hawkins, S.L, J.H. Heifetz, C.M. Kondzela, J.E. Pohl, R.L. Wilmot, O.N. Katugin, V.N. Tuponogov. 2005. Genetic variation of rougheye rockfish (*Sebastes aleutianus*) and shortraker rockfish (*S. borealis*) inferred from allozymes. Fishery Bulletin. 103:524-535.

Heifetz, J., D. M. Clausen, and J. N. Ianelli. 1994. Slope rockfish. In Stock assessment and fishery evaluation report for the 1995 Gulf of Alaska groundfish fishery, p. 5-1 - 5-24. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hulson, P.J.F., J. Heifetz, D.H. Hanselman, S. K. Shotwell, and J. Ianelli. 2011. Assessment of the northern rockfish stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. Chapter 10. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 9950-2252.

Ianelli, J. 2003. An examination of GOA SR/RE species composition available from the NMFS catch-accounting database. Presented at North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Ito, D. H. 1999. Assessing shortraker and rougheye rockfishes in the GOA: addressing a problem of habitat specificity and sampling capability. Ph.D. Dissertation, Univ. Washington, Seattle. 205 pp.

Jones, G.J. and J.P. Hobert. 2001. Honest exploration of intractable probability distributions via Markov Chain Monte Carlo. Stat. Sci. 16(4): 312-334.

Jordan, D.S., and B.W. Evermann. 1898. The fishes of North and Middle America: a descriptive catalogue of the species of fish-like vertebrates found in the waters of North America, north of the Isthmus of Panama, Part III. Bull. U.S. Natl. Mus. 47:2183-3136.

Kramer, D.E., and V.M. O'Connell. 1988. A Guide to Northeast Pacific Rockfishes: Genera *Sebastes* and *Sebastolobus*. In: Alaska Sea Grant Advisory Bulletin, 25. In National Marine Fisheries Service 2001(a).

Krieger, K. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fishery Bulletin 91(1):87-96.

Krieger, K.J. and D.H. Ito. 1999. Distribution and abundance of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *S. aleutianus*, determined from a manned submersible. Fish. Bull. 97:264-272.

Krieger, K.J. and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the GOA. Hydrobiologia 471: 83-90.

Leaman, B. M. 1991. Reproductive styles and life history variables relative to exploitation and management of *Sebastes* stocks. Environmental Biology of Fishes 30: 253-271.

Leaman, B.M. and R.J. Beamish. 1984. Ecological and management implications of longevity in some Northeast Pacific groundfishes. Int. North Pac. Fish. Comm. Bull. 42:85-97.

Longhurst, A., 2002. Murphy's law revisited: longevity as a factor in recruitment to fish populations. Fish. Res. 56:125-131.

Lunsford, C.R., S. K. Shotwell, P.J.F. Hulson, and D.H. Hanselman. 2011. Assessment of the northern rockfish stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. Chapter 12. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 9950-2252.

Malecha, P.W., D.H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfishes (Scorpaenidae) from Alaska Waters. NOAA Tech. Memo. NMFS-AFSC-172. 61 p.

Matarese, A.C., A.W. Kendall, Jr., D.M. Blood, and B.M. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. NOAA Tech. Rep. NMFS 80, 652 p.

Matsubara, K. 1934. Studies on the scorpaenoid fishes of Japan, I. Descriptions of one new genus and five new species. Journal of the Imperial Fisheries Institute of Tokoyo 30: 199-210. (In Japanese).

McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. Master's thesis. University of Washington, Seattle 76 pp.

Moles. A., J. Heifetz, and D.C. Love. 1998. Metazoan parasites as potential markers for selected Gulf of Alaska rockfishes. Fish. Bull 96: 912-916.

Munk, K.M. 2001. Maximum ages of groundfishes in waters off Alaska and British Columbia and considerations of age determination. Alaska Fish. Res. Bull. 8(1): 12-21.

National Marine Fisheries Service. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. http://www.fakr.noaa.gov/habitat/seis/efheis.htm.

Orr, J.W. and S. Hawkins. 2008. Species of the rougheye rockfish complex: resurrection of *Sebastes melanostictus* (Matsubara, 1934) and a redescription of *Sebastes aleutianus* (Jordan and Evermann, 1898) (Teleostei: Scorpaeniformes). Fisheries Bulletin. 106: 111-134.

Rodgveller, C. J., C. R. Lunsford, and J. T. Fujioka. 2008. Evidence of hook competition in longline surveys. Fish. Bull. 106: 364-374.

Rodgveller, C.J., M.F. Sigler, D.H. Hanselman, and D.H. Ito. 2011. Sampling Efficiency of Longlines for Shortraker and Rougheye Rockfish Using Observations from a Manned Submersible, Marine and Coastal Fisheries, 3:1, 1-9.

Rodgveller, C.J., C. Lunsford, P. Malecha, and D. Hanselman. 2011. Calculations of indices of abundance from the Alaska Fishery Science Center's Longline Survey. Unpublished report. 7 pp. Available online: https://akfinbi.psmfc.org/analyticsRes/Documentation/RPN_HowTo_2011.pdf

Schnute, J.T., R. Haigh, B.A. Krishka, and P. Starr. 2001. Pacific ocean perch assessment for the west coast of Canada in 2001. Canadian research document 2001/138. 90 pp.

Seeb, L. W. 1986. Biochemical systematics and evolution of the Scorpaenid genus *Sebastes*. Ph.D. Thesis, Univ. Washington, Seattle, WA. 177 p.

Shotwell, S.K., D. Hanselman, and D. Clausen. 2008. Assessment of rougheye and blackspotted rockfish in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. p. 453-462. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 9950-2252.

Shotwell, S.K., D. Hanselman, and D. Clausen. 2009. Assessment of rougheye and blackspotted rockfish in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. p. 993-1066. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 9950-2252.

Shotwell, S.K., D. Hanselman, and D. Clausen. 2010. Assessment of rougheye and blackspotted rockfish stock in the Gulf of Alaska (Executive Summary). *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska. p. 563-588. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 9950-2252.

Shotwell, S.K., D.H. Hanselman, P.F. Hulson, and J. Heifetz. 2014. Summary of assessment inputs for the rougheye and blackspotted rockfish stock complex in the Gulf of Alaska. Report to the Plan Team, September 2014. 7 pp.

Sigler, M. F. 2000. Abundance estimation and capture of sablefish, Anoplopoma fimbria, by longline gear. Can. J. Fish. Aquat. Sci. 57: 1270-1283.

Soderlund, E., E. Anderson, C. L. Dykstra, T. Geernaert, and A. M. Ranta. 2009. 2008 standardized stock assessment survey. Int. Pac. Comm. Report of Assessment and Research Activities 2008 469-496.

Soh, Sung Kwon. 1998. The use of harvest refugia in the management of shortraker and rougheye rockfish (*Sebastes borealis/Sebastes aleutianus*) in the Gulf of Alaska. Ph.D. Thesis – U. Wash. 194 pp.

Spencer, P., Hanselman, D. and Dorn, M. 2007. The effect of maternal age of spawning on estimation of F_{msy} for Alaska Pacific ocean perch. *In*: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 513 – 533.

Spencer, P., M. Canino, J. DiCosimo, M. Dorn, A.J. Gharrett, D. Hanselman, K. Palof, and M. Sigler. 2010. Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans. 40pp.

Specncer, P., and J. Ianelli. 2012. Assessment of the Pacific ocean perch stock in the Bering Sea/Aleutian Islands. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Bering Sea/Aleutian Islands. p. 1291-1348. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 9950-2252.

Straty, R.R. 1987. Habitat and behavior of juvenile Pacific rockfish (*Sebastes* spp. and *Sebastolobus alascanus*) off southeastern Alaska. NOAA Symp. Ser. Undersea Res. 2(2):109-123.

Tsuyuki, H., and S.J. Westrheim. 1970. Analyses of the *Sebastes aleutianus – S. melanostomus* complex, and description of a new scorpaenid species, *Sebastes caenaematicus*, in the northeast Pacific Ocean. J. Fish. Res. Board Can. 27: 2233-2254.

Yang, M.S. 2003. Food habits of the important groundfishes in the AI in 1994 and 1997. AFSC Proc.Rep 2003-07. 233 p. (Available from NMFS, AFSC, 7600 Sand Point Way NE, Seattle WA 98115).

Yang, M.S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the GOA in 1990, 1993, and 1996. NOAA Tech. Memo. NMFS-AFSC-112. 174 p.

Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

Zenger, H.H., Jr. and M.F. Sigler. 1992. Relative abundance of GOA sablefish and other groundfish based on National Marine Fisheries Service longline surveys, 1988-90. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-216, 103 pp.

Table 13-1: Summary of available data on stock structure for GOA RE/BS rockfish.

Factor and criterion	Available information
Harvest and trends	
Fishing mortality (5-year average percent of F_{ABC})	Recent catch in the Western GOA are near F_{ABC}, and far below F_{ABC} in the Central and Eastern GOA
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Catches are distributed similarly to survey abundance, except for a potential nursery area in Amatuli Gully region
Population trends (Different areas show different trend directions)	Population trend is stable for overall Gulf of Alaska, declining toward the Western GOA, and increasing toward the Eastern GOA
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	The generation time is > 19 years
Physical limitations (Clear physical inhibitors to movement)	No known physical barriers; predominant current patterns move from east to west, potential restriction in gullies and canyons
Growth differences (Significantly different LAA, WAA, or LW parameters)	Significantly different growth curves and length-at-age relationships between the Western GOA, Central GOA, and Eastern GOA.
Age/size-structure (Significantly different size/age compositions)	Mean length is significantly higher in WGOA, mean age is significantly higher in WGOA
Spawning time differences (Significantly different mean time of spawning)	Unknown
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Unknown
Morphometrics (Field identifiable characters)	Unknown within species, hypothesized pigmentation differences between species (Gharrett et al. 2006, Orr and Hawkins 2008)
Meristics (Minimally overlapping differences in counts)	Unknown within species, significantly different means of dorsal spines and gill rakers (Gharrett et al. 2006)
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data not available, but potential to reduce barotrauma with new pressure tanks
Natural tags (Acquired tags may show movement smaller than management areas)	Parasite analysis shows structure by INPFC management area and between species (Moles et al. 1998, Hawkins et al. 2005)
Genetics	
Isolation by distance (Significant regression)	No significant isolation by distance for Type I or Type II rougheye (likely blackspotted and rougheye, respectively) (Gharrett et al. 2007)
Dispersal distance (<<Management areas)	Low, but significant F_{st} for both types indicates some limits to dispersal (Gharrett et al. 2007)
Pairwise genetic differences (Significant differences between geographically distinct collections)	Adjacency analysis suggests genetic structure on scale of INPFC management areas for Type I (blackspotted) and potentially finer scale structure for Type II (rougheye) (Gharrett et al. 2007)

Table 13-2. Estimated commercial catch[a] (t) for GOA RE/BS rockfish (1977-2013), with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1991-2013. Catch is provided through the most recent full year estimate.

Year	Catch (t)				OFL	ABC	TAC
	Commercial	Western GOA	Central GOA	Eastern GOA			
1977	1443						
1978	568						
1979	645						
1980	1353						
1981	719						
1982	569						
1983	628						
1984	760						
1985	130						
1986	438						
1987	525						
1988	1621						
1989	2185						
1990	2418						
1991	350					2,000	2,000
1992	1127					1,960	1,960
1993	583					1,960	1,764
1994	579					1,960	1,960
1995	704					1,910	1,910
1996	558					1,910	1,910
1997	545					1,590	1,590
1998	665					1,590	1,590
1999	320					1,590	1,590
2000	530					1,730	1,730
2001	591					1,730	1,730
2002	273					1,620	1,620
2003	394					1,620	1,620
2004	301					1,318	1,318
2005	293	53	126	115	1,531	1,007	1,007
2006	358	58	138	162	1,180	983	983
2007	422	71	194	157	1,148	988	988
2008	392	78	193	121	1,548	1,286	1,286
2009	282	80	101	101	1,545	1,284	1,284
2010	450	91	219	139	1,568	1,302	1,302
2011	541	26	368	148	1,579	1,312	1,312
2012	568	28	371	169	1,472	1,223	1,223
2013	574	15	384	175	1,482	1,232	1,232

[a]Catch defined as follows: 1977-1992 from Soh (1998), 1993-2004 from observer program, 2005-present from NMFS AKRO Catch Accounting System via Alaska Fisheries Information Network (AKFIN, www.akfin.org).

[b]ABC and TAC were available for the shortraker/rougheye rockfish complex from 1991-2004 (gray shade). Separate catch accounting were established for GOA RE/BS rockfish since 2005.

Table 13-3. History of management measures with associated time series of catch, ABC, and TAC for GOA RE/BS rockfish.

Year	Catch (t)*	ABC	TAC	Management Measures
1988	1,621	16,800	16,800	The slope rockfish assemblage, including rougheye, is one of three management groups for Sebastes implemented by the North Pacific Management Council. Previously, Sebastes in Alaska were managed as "Pacific ocean perch complex" (rougheye included) or "other rockfish"
1989	2,185	20,000	20,000	
1990	2,418	17,700	17,700	
1991	350	2,000	2,000	Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992	1,127	1,960	1,960	
1993	583	1,960	1,764	
1994	579	1,960	1,960	
1995	704	1,910	1,910	
1996	558	1,910	1,910	
1997	545	1,590	1,590	
1998	665	1,590	1,590	
1999	320	1,590	1,590	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	530	1,730	1,730	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	591	1,730	1,730	
2002	273	1,620	1,620	
2003	394	1,620	1,620	
2004	301	1,318	1,318	Shortraker and rougheye rockfish divided into separate subgroups and assigned individual ABCs and TACs
2005	293	1,007	1,007	Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status
2006	358	983	983	
2007	422	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	392	1,286	1,286	Rougheye and blackspotted formally verified as separate species so assessment now called the rougheye/blackspotted rockfish complex
2009	282	1,284	1,284	
2010	450	1,302	1,302	
2011	541	1,312	1,312	Rockfish Program continues from pilot initiative
2012	568	1,223	1,223	
2013	574	1,232	1,232	

*Catch since 2005 of RE/BS rockfish is provided through the most recent full year estimate. Source: NMFS Alaska Region (AKRO) Catch Accounting System via Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org/).

Table 13-4. Catch (t) of RE/BS rockfish as bycatch in other fisheries from 2005 - present. Other fisheries category not included due to confidentiality (# vessels or # processors is fewer than or equal to 2). Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2014.

Year	Flatfish	Halibut	P. Cod	Pollock	Rockfish	Sablefish
2005	15	36	1	16	106	119
2006	40	46	2	23	83	170
2007	90	64	1	28	114	140
2008	57	55	9	41	104	115
2009	34	40	6	11	97	86
2010	64	42	6	30	180	103
2011	64	33	2	34	286	122
2012	122	26	4	21	219	177
2013	49	32	1	6	274	211
2014	149	30	3	19	346	158
Average	68	40	4	23	181	140

Table 13-5. Incidental catch of FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2007 - present. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2014.

	Estimated Catch (t)							
Group Name	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Atka Mackerel	1,094	1,744	1,913	2,148	1,404	1,173	1,162	232
Pacific Cod	251	445	631	734	560	404	584	425
Pollock	124	390	1,280	1,046	813	574	829	750
Sablefish	641	503	404	388	440	470	495	468
Arrowtooth Flounder	688	517	497	706	340	764	766	1,173
Flathead Sole	18	19	32	24	13	16	26	16
Rex Sole	52	67	83	93	51	72	89	68
Deep Water Flatfish	45	29	30	48	57	54	37	68
Shallow Water Flatfish	22	71	53	47	48	65	27	17
Pacific Ocean Perch	12,641	12,135	12,397	14,974	13,120	13,953	11,555	12,814
Northern Rockfish	3,957	3,805	3,855	3,833	3,163	4,883	4,527	2,762
Dusky Rockfish						3,642	2,870	2,582
Pelagic Shelf Rockfish	3,119	3,521	2,956	2,966	2,324			
Rougheye Rockfish	114	104	97	180	286	219	274	346
Shortraker Rockfish	291	231	247	133	239	303	290	195
Other Rockfish	494	632	736	737	657	889	488	617
Demersal Shelf Rockfish	3	45	77	34	27	111	136	38
Thornyhead Rockfish	300	248	177	106	161	130	104	153
Skate, Big	0	4	4	14	8	13	2	3
Skate, Longnose	17	12	17	12	25	23	23	21
Skate, Other	20	10	13	28	14	20	18	23
Other Species	42	39	57	74				
Octopus					1	1	2	4
Sculpin					39	55	70	27
Shark					5	5	93	1
Squid					12	15	10	15

Table 13-6. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2007 - present. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2014.

	Estimated Catch (t)							
Group Name	2007	2008	2009	2010	2011	2012	2013	2014
Benthic urochordata	0.03	0.27	Conf.	0.08	Conf.	Conf.	Conf.	0.07
Birds	Conf.	Conf.	-	-	Conf.	Conf.	-	-
Bivalves	-	0.00	Conf.	0.01	0.01	0.01	Conf.	Conf.
Brittle star unid.	0.01	0.04	0.03	0.02	0.01	0.03	0.03	0.04
Capelin	-	-	0.00	-	-	-	0.02	-
Corals Bryozoans	2.27	0.47	0.32	0.42	0.38	0.59	0.20	0.13
Dark Rockfish	-	17.86	46.98	112.04	12.82	59.03	42.16	13.35
Eelpouts	0.12	0.35	0.00	0.05	Conf.	0.30	0.04	0.10
Eulachon	0.05	0.01	0.03	0.00	0.00	0.01	0.10	Conf.
Giant Grenadier	127.14	160.97	224.36	476.28	418.90	347.85	968.44	599.37
Greenlings	7.74	14.73	8.10	9.52	7.91	9.05	7.25	2.80
Grenadier	70.61	2.82	3.11	34.94	110.49	89.67	39.11	6.33
Hermit crab unid.	Conf.	0.01	0.01	0.01	0.02	Conf.	0.03	0.04
Invertebrate unid.	0.01	0.23	0.30	5.05	0.36	3.86	0.18	0.00
Lanternfishes	0.00	-	0.00	Conf.	-	-	Conf.	-
Misc crabs	0.13	0.07	0.10	0.07	0.04	0.05	0.01	0.04
Misc crustaceans	-	-	0.10	0.02	Conf.	-	Conf.	Conf.
Misc deep fish	-	0.00	-	-	-	-	Conf.	-
Misc fish	186.08	195.62	134.75	167.10	133.25	156.73	163.97	124.25
Misc inverts (worms etc)	-	0.01	Conf.	-	Conf.	-	-	-
Other osmerids	0.09	Conf.	0.16	0.00	-	Conf.	0.02	Conf.
Pacific Sand lance	-	-	-	-	Conf.	-	-	-
Pandalid shrimp	0.11	0.11	0.09	0.22	0.06	0.06	0.06	0.10
Polychaete unid.	-	-	-	-	-	-	Conf.	-
Scypho jellies	0.21	0.11	0.70	1.87	0.00	0.16	0.50	6.05
Sea anemone unid.	0.20	0.69	3.24	1.56	4.10	6.33	4.20	1.11
Sea pens whips	-	Conf.	0.01	0.01	0.04	-	0.05	0.07
Sea star	0.66	1.15	1.78	1.38	1.53	0.98	0.97	1.42
Snails	0.07	0.18	10.63	0.20	0.23	1.26	0.20	0.07
Sponge unid.	0.65	2.97	6.65	3.66	4.41	1.39	1.34	0.98
Stichaeidae	-	-	0.01	-	-	-	Conf.	0.00
Urchins, dollars, cucumbers	0.17	0.26	0.49	0.22	0.44	0.31	0.30	0.18

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, for the GOA rockfish fishery 2007 - present. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2014.

Group Name	2007	2008	2009	2010	2011	2012	2013	2014
Bairdi Tanner Crab	0.16	0.06	0.24	0.10	0.03	0.09	0.07	0.00
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	2.03	2.28	1.39	1.57	1.02	1.60	2.32	0.00
Golden King Crab	0.13	0.34	3.28	3.00	0.13	0.11	0.10	0.00
Halibut	136.88	158.80	108.67	141.45	108.14	109.37	113.39	59.40
Herring	0.02	0.04	0.00	0.15	0.00	0.00	0.00	0.00
Other Salmon	0.72	0.50	0.47	0.37	0.21	0.31	2.02	0.00
Opilio Tanner Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 13-8. Fishery age compositions for GOA RE/BS rockfish and sample sizes by year. Pooled age 25+ includes all fish 25 and older.

Age (years)	1990	2004	2006	2008	2009	2012
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0033	0.0000	0.0000	0.0034	0.0000	0.0000
9	0.0266	0.0000	0.0028	0.0103	0.0000	0.0000
10	0.0498	0.0049	0.0000	0.0103	0.0097	0.0000
11	0.0332	0.0000	0.0000	0.0069	0.0032	0.0000
12	0.0266	0.0000	0.0083	0.0069	0.0000	0.0061
13	0.0166	0.0049	0.0055	0.0172	0.0162	0.0030
14	0.0365	0.0049	0.0083	0.0172	0.0032	0.0182
15	0.0100	0.0171	0.0193	0.0137	0.0097	0.0030
16	0.0066	0.0098	0.0193	0.0241	0.0325	0.0121
17	0.0166	0.0122	0.0138	0.0412	0.0195	0.0121
18	0.0033	0.0073	0.0055	0.0344	0.0162	0.0182
19	0.0166	0.0196	0.0110	0.0515	0.0325	0.0030
20	0.0133	0.0416	0.0110	0.0928	0.0552	0.0152
21	0.0133	0.0391	0.0138	0.0275	0.0260	0.0212
22	0.0133	0.0440	0.0303	0.0412	0.0325	0.0091
23	0.0100	0.0465	0.0331	0.0206	0.0260	0.0364
24	0.0199	0.0367	0.0441	0.0206	0.0162	0.0242
25+	0.6811	0.7115	0.7741	0.5601	0.7013	0.8182
Sample size	301	409	363	291	308	330

Table 13-9. Fishery size compositions for GOA RE/BS rockfish and sample size by year and pooled pairs of adjacent lengths.

Length (cm)	1991	1992	2002	2003	2005	2007	2010	2011
20	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0045	0.0000
22	0.0000	0.0056	0.0087	0.0000	0.0007	0.0007	0.0011	0.0010
24	0.0010	0.0065	0.0058	0.0012	0.0013	0.0007	0.0056	0.0010
26	0.0021	0.0084	0.0087	0.0020	0.0013	0.0048	0.0100	0.0020
28	0.0063	0.0130	0.0029	0.0040	0.0047	0.0054	0.0134	0.0061
30	0.0042	0.0297	0.0058	0.0032	0.0074	0.0122	0.0111	0.0081
32	0.0094	0.0270	0.0058	0.0064	0.0067	0.0115	0.0290	0.0304
34	0.0125	0.0362	0.0145	0.0095	0.0134	0.0258	0.0323	0.0314
36	0.0104	0.0455	0.0174	0.0139	0.0315	0.0326	0.0390	0.0354
38	0.0261	0.0660	0.0378	0.0382	0.0308	0.0605	0.0568	0.0354
40	0.0396	0.1004	0.0494	0.0545	0.0455	0.0713	0.0757	0.0840
42	0.1585	0.1087	0.1453	0.1010	0.0717	0.0965	0.0980	0.1083
44	0.2857	0.1645	0.1657	0.1427	0.1165	0.1209	0.1236	0.1235
46	0.2221	0.1292	0.1948	0.1924	0.1514	0.1461	0.1347	0.1306
48	0.1512	0.0790	0.1395	0.1717	0.1541	0.1352	0.1526	0.1407
50	0.0448	0.0465	0.1134	0.1125	0.1306	0.1175	0.0724	0.1113
52	0.0136	0.0344	0.0465	0.0719	0.0884	0.0822	0.0624	0.0577
54	0.0042	0.0362	0.0145	0.0322	0.0583	0.0299	0.0367	0.0425
56	0.0063	0.0251	0.0116	0.0199	0.0275	0.0190	0.0134	0.0202
58	0.0010	0.0167	0.0058	0.0079	0.0221	0.0129	0.0100	0.0162
60+	0.0010	0.0214	0.0058	0.0147	0.0362	0.0143	0.0178	0.0142
Sample size	959	1077	344	2516	1493	1472	899	988

Table 13-10. GOA RE/BS rockfish biomass estimates from NMFS triennial/biennial trawl surveys in the Gulf of Alaska. We excluded the 2001 survey because no sampling was performed in the Eastern Gulf. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively, and CV is the coefficient of variation expressed as a percent.

Year	Western	Central	Eastern	Biomass	SE	LCI	UCI	CV (%)
1984	8,779	32,416	3,896	45,091	7,313	30,758	59,425	16.2
1987	2,737	21,881	19,063	43,681	4,897	34,083	53,278	11.2
1990	1,329	35,467	8,041	44,837	9,296	26,617	63,057	20.7
1993	10,889	41,616	9,358	61,863	14,415	33,610	90,115	23.3
1996	3,449	28,396	14,067	45,913	7,432	31,346	60,481	16.2
1999	6,156	20,781	12,622	39,560	5,793	28,206	50,913	14.6
2003	8,921	24,610	9,670	43,202	6,724	30,024	56,380	15.6
2005	3,621	32,898	11,343	47,862	8,618	30,971	64,754	18.0
2007	3,773	39,410	16,697	59,880	10,380	39,536	80,225	17.3
2009	2,765	33,154	14,855	50,774	8,297	34,512	67,035	16.3
2011	3,305	32,583	8,228	44,115	7,126	30,149	58,082	16.2
2013	3,922	11,207	12,452	27,581	5,078	17,627	37,534	18.4

Table 13-11. AFSC bottom trawl survey relative age compositions for GOA RE/BS rockfish since 1984. Pooled age 25+ includes all fish 25 and older.

Age (yr)	1984	1987	1990	1993	1996	1999	2003	2005	2007
3	0.0000	0.0000	0.0011	0.0342	0.0023	0.0000	0.0285	0.0375	0.0065
4	0.0005	0.0006	0.0025	0.0122	0.0003	0.0247	0.0184	0.0468	0.0093
5	0.0000	0.0061	0.0058	0.0108	0.0204	0.0518	0.0669	0.0844	0.0331
6	0.0000	0.0652	0.0105	0.0237	0.1446	0.0251	0.0466	0.0385	0.0794
7	0.0035	0.0460	0.0395	0.0155	0.0173	0.0327	0.0275	0.0652	0.0429
8	0.0892	0.0249	0.0503	0.0211	0.0201	0.0587	0.0554	0.0510	0.0130
9	0.0338	0.0401	0.1100	0.0492	0.0321	0.1376	0.0509	0.0532	0.0465
10	0.0215	0.0533	0.1684	0.0727	0.0232	0.0505	0.0233	0.0791	0.0331
11	0.0075	0.1381	0.0918	0.0665	0.0246	0.0434	0.0203	0.0339	0.0220
12	0.0255	0.0959	0.0231	0.0898	0.0458	0.0186	0.0376	0.0504	0.0318
13	0.0100	0.0474	0.0548	0.0755	0.0410	0.0433	0.0387	0.0178	0.0480
14	0.0310	0.0445	0.0876	0.0571	0.0710	0.0442	0.0427	0.0403	0.0150
15	0.0747	0.0445	0.0285	0.0486	0.0698	0.0451	0.0136	0.0513	0.0273
16	0.0938	0.0156	0.0132	0.0633	0.0682	0.0546	0.0309	0.0327	0.0362
17	0.0400	0.0171	0.0075	0.0457	0.0517	0.0463	0.0254	0.0339	0.0411
18	0.0280	0.0149	0.0036	0.0229	0.0277	0.0565	0.0169	0.0226	0.0349
19	0.0120	0.0078	0.0206	0.0244	0.0353	0.0298	0.0195	0.0205	0.0315
20	0.0036	0.0038	0.0073	0.0242	0.0387	0.0362	0.0466	0.0315	0.0282
21	0.0094	0.0257	0.0088	0.0235	0.0212	0.0188	0.0312	0.0108	0.0308
22	0.0083	0.0070	0.0074	0.0114	0.0200	0.0192	0.0396	0.0179	0.0572
23	0.0113	0.0246	0.0098	0.0221	0.0187	0.0175	0.0396	0.0117	0.0344
24	0.0160	0.0117	0.0211	0.0098	0.0116	0.0130	0.0246	0.0116	0.0107
25+	0.4803	0.2652	0.2267	0.1758	0.1944	0.1326	0.2554	0.1574	0.2870
Sample size	369	348	194	775	701	617	488	424	435

Table 13-11 (continued). AFSC bottom trawl survey relative age compositions for GOA RE/BS rockfish since 1984. Pooled age 25+ includes all fish 25 and older.

Age (yr)	2009	2011
3	0.0113	0.0124
4	0.0099	0.0096
5	0.0191	0.0575
6	0.0497	0.0322
7	0.0348	0.0491
8	0.0607	0.0427
9	0.0437	0.0978
10	0.0389	0.0436
11	0.0560	0.0762
12	0.0377	0.0764
13	0.0378	0.0559
14	0.0369	0.0407
15	0.0506	0.0543
16	0.0441	0.0273
17	0.0374	0.0257
18	0.0309	0.0152
19	0.0250	0.0260
20	0.0414	0.0090
21	0.0199	0.0176
22	0.0240	0.0232
23	0.0182	0.0095
24	0.0202	0.0253
25+	0.2519	0.1726
Sample size	928	402

Table 13-12. AFSC bottom trawl survey length compositions for GOA RE/BS rockfish. Data are not explicitly used in the model because trawl survey ages were available for most years.

Length (cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
20	0.0068	0.0143	0.0133	0.0158	0.0380	0.0751	0.0223	0.0602	0.0481	0.0399
22	0.0162	0.0328	0.0173	0.0176	0.0509	0.0625	0.0360	0.0579	0.0523	0.0393
24	0.0258	0.0314	0.0244	0.0236	0.0540	0.0501	0.0421	0.0437	0.0548	0.0488
26	0.0236	0.0294	0.0271	0.0288	0.0485	0.0416	0.0498	0.0423	0.0636	0.0443
28	0.0190	0.0286	0.0428	0.0341	0.0382	0.0552	0.0594	0.0484	0.0667	0.0420
30	0.0331	0.0404	0.0626	0.0472	0.0511	0.0699	0.0517	0.0570	0.0652	0.0470
32	0.0369	0.0515	0.0854	0.0519	0.0509	0.0642	0.0448	0.0579	0.0589	0.0462
34	0.0449	0.0572	0.1022	0.0692	0.0463	0.0685	0.0614	0.0473	0.0659	0.0469
36	0.0562	0.0727	0.1201	0.0772	0.0623	0.0621	0.0706	0.0418	0.0603	0.0558
38	0.0578	0.0721	0.0869	0.1069	0.0639	0.0720	0.0884	0.0525	0.0701	0.0804
40	0.0841	0.0817	0.0695	0.1240	0.0858	0.0788	0.0970	0.0680	0.0781	0.0874
42	0.1448	0.0858	0.0622	0.1337	0.1158	0.0821	0.1341	0.1003	0.0835	0.1063
44	0.1660	0.1147	0.0938	0.1259	0.1117	0.0802	0.0965	0.1146	0.0791	0.1160
46	0.1200	0.1120	0.0820	0.0764	0.0816	0.0614	0.0668	0.0963	0.0480	0.0794
48	0.0773	0.0872	0.0464	0.0323	0.0464	0.0369	0.0410	0.0598	0.0319	0.0520
50	0.0398	0.0418	0.0225	0.0116	0.0236	0.0220	0.0164	0.0261	0.0272	0.0332
52	0.0191	0.0223	0.0101	0.0067	0.0149	0.0076	0.0085	0.0099	0.0140	0.0167
54	0.0094	0.0080	0.0094	0.0036	0.0053	0.0033	0.0028	0.0069	0.0087	0.0096
56	0.0057	0.0054	0.0073	0.0034	0.0061	0.0017	0.0052	0.0029	0.0070	0.0036
58	0.0044	0.0034	0.0052	0.0031	0.0025	0.0023	0.0018	0.0022	0.0045	0.0022
60+	0.0090	0.0073	0.0096	0.0070	0.0024	0.0027	0.0034	0.0040	0.0121	0.0031
Sample size	4,701	3,994	3,522	5,639	3,943	3,758	1,959	2,924	4,089	4,252

Table 13-12 (continued). AFSC bottom trawl survey length compositions for GOA RE/BS rockfish. Data are not explicitly used in model because trawl survey ages were available for most years.

Length (cm)	2009	2011	2013
20	0.0402	0.0364	0.0637
22	0.0545	0.0507	0.0516
24	0.0593	0.0522	0.0526
26	0.0690	0.0596	0.0516
28	0.0552	0.0569	0.0598
30	0.0598	0.0704	0.0450
32	0.0440	0.0543	0.0489
34	0.0425	0.0627	0.0562
36	0.0466	0.0602	0.0724
38	0.0527	0.0638	0.0857
40	0.0691	0.0825	0.0872
42	0.0798	0.0992	0.0844
44	0.0904	0.0867	0.0595
46	0.0880	0.0603	0.0627
48	0.0662	0.0480	0.0449
50	0.0406	0.0251	0.0383
52	0.0240	0.0111	0.0183
54	0.0090	0.0098	0.0078
56	0.0041	0.0034	0.0046
58	0.0026	0.0017	0.0020
60+	0.0024	0.0049	0.0026
Sample size	4,155	2,475	1,692

Table 13-13. GOA RE/BS rockfish relative population weights (RPW) and relative population numbers (RPN) estimated from the AFSC longline survey 1993-2014. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively and CV is the coefficient of variation expressed as a percent. S.E., LCI, UCI, and CV are respective to the RPNs.

Year	RPW	RPN	SE	LCI	UCI	CV%
1993	37,694	23,269	4,336	14,597	31,942	18.6
1994	38,010	22,622	3,885	14,852	30,391	17.2
1995	44,044	27,472	4,875	17,722	37,222	17.7
1996	41,896	25,624	4,122	17,381	33,868	16.1
1997	61,150	37,070	7,578	21,913	52,227	20.4
1998	42,190	24,570	3,284	18,003	31,137	13.4
1999	46,297	27,254	4,238	18,778	35,729	15.5
2000	65,507	37,894	5,860	26,174	49,614	15.5
2001	46,163	29,523	5,056	19,411	39,634	17.1
2002	44,004	27,517	4,581	18,354	36,679	16.6
2003	43,893	24,389	3,883	16,623	32,156	15.9
2004	41,067	27,913	5,222	17,469	38,358	18.7
2005	29,288	18,863	3,657	11,549	26,177	19.4
2006	33,673	20,478	3,262	13,954	27,001	15.9
2007	50,123	33,663	5,570	22,524	44,802	16.5
2008	49,173	30,960	4,700	21,559	40,361	15.2
2009	40,747	29,751	5,398	18,956	40,547	18.1
2010	51,501	35,288	5,549	24,190	46,387	15.7
2011	57,553	39,783	8,164	23,454	56,111	20.5
2012	43,283	26,962	5,016	16,929	36,995	18.6
2013	35,197	23,939	4,960	14,019	33,860	20.7
2014	51,763	33,464	5,629	22,205	44,723	16.8

Table 13-14. AFSC longline survey size compositions for GOA RE/BS rockfish. Lengths are area-weighted by all available strata and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0006	0.0002
24	0.0011	0.0005	0.0000	0.0000	0.0015	0.0000	0.0006	0.0005	0.0025	0.0012
26	0.0061	0.0004	0.0027	0.0001	0.0007	0.0005	0.0034	0.0013	0.0037	0.0024
28	0.0057	0.0041	0.0055	0.0022	0.0016	0.0023	0.0061	0.0028	0.0052	0.0058
30	0.0111	0.0073	0.0087	0.0102	0.0103	0.0203	0.0116	0.0084	0.0181	0.0153
32	0.0284	0.0136	0.0196	0.0159	0.0100	0.0234	0.0159	0.0167	0.0196	0.0208
34	0.0504	0.0303	0.0294	0.0338	0.0165	0.0369	0.0378	0.0311	0.0431	0.0305
36	0.0529	0.0371	0.0432	0.0476	0.0440	0.0468	0.0541	0.0610	0.0503	0.0515
38	0.0653	0.0548	0.0742	0.0760	0.0769	0.0607	0.0704	0.0820	0.0707	0.0738
40	0.0856	0.0839	0.1123	0.1010	0.0889	0.0762	0.0943	0.0931	0.0999	0.0945
42	0.1443	0.0863	0.1192	0.1287	0.1207	0.0992	0.1085	0.1040	0.1007	0.1282
44	0.1453	0.1492	0.1379	0.1518	0.1331	0.1366	0.1484	0.1354	0.1257	0.1473
46	0.1346	0.1507	0.1308	0.1482	0.1569	0.1587	0.1616	0.1312	0.1348	0.1333
48	0.0872	0.1303	0.1101	0.1192	0.1280	0.1383	0.1248	0.1362	0.1245	0.1207
50	0.0807	0.0880	0.0920	0.0754	0.0859	0.0888	0.0808	0.0829	0.0905	0.0699
52	0.0439	0.0689	0.0428	0.0363	0.0462	0.0504	0.0435	0.0501	0.0460	0.0432
54	0.0196	0.0333	0.0334	0.0242	0.0243	0.0205	0.0153	0.0263	0.0225	0.0237
56	0.0158	0.0186	0.0175	0.0120	0.0116	0.0153	0.0051	0.0132	0.0101	0.0108
58	0.0057	0.0142	0.0093	0.0058	0.0089	0.0100	0.0034	0.0054	0.0058	0.0119
60+	0.0166	0.0286	0.0113	0.0114	0.0339	0.0153	0.0143	0.0185	0.0256	0.0153
Sample size	3,996	3,560	5,090	4,636	5,696	4,508	5,938	7,084	4,767	4,768

Table 13-14 (continued). AFSC longline survey size compositions for GOA RE/BS rockfish.

Length (cm)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
20	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0005	0.0004	0.0005	0.0000
24	0.0007	0.0001	0.0013	0.0001	0.0008	0.0005	0.0015	0.0007	0.0022	0.0001
26	0.0023	0.0029	0.0036	0.0025	0.0032	0.0023	0.0027	0.0079	0.0076	0.0024
28	0.0086	0.0160	0.0130	0.0230	0.0013	0.0068	0.0118	0.0185	0.0129	0.0097
30	0.0132	0.0238	0.0265	0.0098	0.0120	0.0207	0.0469	0.0324	0.0301	0.0165
32	0.0185	0.0217	0.0341	0.0192	0.0330	0.0341	0.0272	0.0561	0.0404	0.0272
34	0.0166	0.0348	0.0334	0.0273	0.0465	0.0540	0.0421	0.0614	0.0585	0.0431
36	0.0278	0.0553	0.0508	0.0383	0.0840	0.0671	0.0555	0.0746	0.0763	0.0616
38	0.0617	0.0973	0.0535	0.0493	0.0657	0.0701	0.0844	0.0834	0.0938	0.0852
40	0.0885	0.0976	0.0704	0.0823	0.0998	0.0766	0.1038	0.0931	0.1037	0.1061
42	0.1135	0.1152	0.1166	0.1160	0.1140	0.1042	0.1222	0.1098	0.1160	0.1069
44	0.1387	0.1378	0.1430	0.1384	0.1466	0.1204	0.1148	0.1197	0.1157	0.1335
46	0.1610	0.1443	0.1452	0.1475	0.1341	0.1231	0.1092	0.1110	0.0931	0.1162
48	0.1451	0.1082	0.1363	0.1415	0.1084	0.1143	0.1046	0.0832	0.0921	0.1025
50	0.0830	0.0703	0.0687	0.0783	0.0614	0.0946	0.0703	0.0565	0.0562	0.0698
52	0.0430	0.0338	0.0350	0.0478	0.0385	0.0514	0.0488	0.0259	0.0333	0.0496
54	0.0163	0.0146	0.0224	0.0283	0.0150	0.0259	0.0223	0.0135	0.0156	0.0239
56	0.0150	0.0111	0.0108	0.0141	0.0159	0.0111	0.0147	0.0118	0.0137	0.0120
58	0.0103	0.0065	0.0101	0.0150	0.0050	0.0106	0.0047	0.0085	0.0064	0.0050
60+	0.0361	0.0084	0.0254	0.0207	0.0148	0.0116	0.0121	0.0317	0.0320	0.0287
Sample size	4,596	4,834	4,095	4,305	6,575	5,683	4,642	5,949	5,778	5,095

Table 13-14 (continued). AFSC longline survey size compositions for GOA RE/BS rockfish.

Length (cm)	2013	2014
20	0.0000	0.0000
22	0.0000	0.0000
24	0.0001	0.0001
26	0.0033	0.0515
28	0.0074	0.0035
30	0.0270	0.0155
32	0.0404	0.0213
34	0.0573	0.0401
36	0.0956	0.0596
38	0.0860	0.0730
40	0.0961	0.1019
42	0.1026	0.1145
44	0.1207	0.1131
46	0.1206	0.1104
48	0.1016	0.1038
50	0.0628	0.0766
52	0.0290	0.0432
54	0.0181	0.0238
56	0.0102	0.0162
58	0.0132	0.0099
60+	0.0081	0.0221
Sample size	3,744	6,820

Table 13-15. Likelihoods and MLE estimates of key parameters with estimates of standard error (σ) derived from the Hessian matrix for GOA RE/BS rockfish models.

	Model 0		***Model 1***		***Model 2***	
Likelihoods	Value	Weight	Value	Weight	Value	Weight
Catch	0.074	5/50*	0.077	5/50*	0.037	5/50*
Trawl Biomass	2.738	1	8.427	1	8.933	1
Longline Biomass	8.160	1	9.565	1	11.922	1
Fishery Ages	25.090	1	38.115	1	37.270	1
Trawl Survey Ages	35.247	1	38.766	1	39.300	1
Fishery Sizes	50.104	1	53.651	1	51.364	1
Trawl Survey Sizes	0	0	0	0	0	0
Longline Survey Sizes	104.519	1	101.469	1	97.708	1
Data-Likelihood	225.932		250.071		246.532	
Penalties/Priors						
Recruit Deviations	2.534	1	-1.031	1	-0.090	1
Fishery Selectivity	2.433	1	2.456	1	2.587	1
Trawl Selectivity	0.272	1	0.456	1	0.503	1
Longline Selectivity	0.586	1	0.542	1	0.401	1
Fish-Sel Domeshape	0	1	0	1	0.000	1
Survey-Sel Domeshp	0.038	1	0.080	1	0.103	1
LL-Sel Domeshape	0	1	0	1	0.001	1
Average Selectivity	0	0.1	0.000	0.1	0.000	0.1
F Regularity	1.193	0.1	1.110	0.1	1.146	0.1
σ_r prior	3.620		4.826		4.578	
q-trawl	0.310		0.756		0.632	
q-longline	0.013		0.174		0.056	
M	0.767		0.645		0.649	
Total penalties/priors	11.765		10.015		10.567	
Objective Fun. Total	237.697		260.085		257.099	

Parameter Estimates	Value	σ	Value	σ	Value	σ
q-trawl	1.422	0.431	1.733	0.475	1.654	0.511
q-longline	1.173	0.348	1.803	0.522	1.399	0.516
M	0.034	0.003	0.034	0.003	0.034	0.003
σ_r	0.928	0.058	0.904	0.056	0.908	0.057
Mean Recruitment (mil)	1.523		1.157		1.565	
$F_{40\%}$	0.039	0.011	0.039	0.011	0.038	0.010
Total Biomass (t)	42,856	12,143	32,046	8,962	36,583	11,588
Spawning Biomass (t)	12,610	3,791	9,856	2,971	12,479	4,140
$B_{100\%}$ (t)	24,329		18,348		22,449	
$B_{40\%}$ (t)	9,732	2,731	7,339	1,920	8,980	2,570
$\boldsymbol{ABC_{F40\%}}$ ***(t)***	1,223	511	927	390	1,122	496

*Values are weights on the catch series before the catch reliability penalty (1977-1992) and after (1993-2014).

Table 13-16. Estimated GOA RE/BS rockfish population numbers (thousands) in 2014, fishery selectivity, trawl and longline (LL) survey selectivity of GOA RE/BS rockfish from the author preferred model. Also shown are schedules of age specific weight and female maturity estimated outside the assessment model.

Age	Numbers in 2014 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
3	1,262	0	48	0	16	0
4	1,211	0	82	0	26	0
5	1,156	0	125	0	49	0
6	1,139	0	176	0	73	0
7	984	0	234	1	72	0
8	1,316	0	298	1	78	0
9	985	0	367	3	97	0
10	894	1	440	3	100	0
11	990	2	515	3	96	1
12	1,254	5	591	3	70	4
13	1,550	8	668	4	70	13
14	1,738	14	745	9	70	35
15	889	22	821	25	70	71
16	1,570	31	895	100	70	100
17	1,131	40	968	100	70	98
18	720	50	1038	100	70	98
19	1,239	59	1107	100	70	98
20	1,765	66	1172	100	70	98
21	587	72	1235	100	70	98
22	538	77	1295	100	70	98
23	516	81	1352	100	70	98
24	1,551	84	1406	100	70	98
25+	10,577	92	1814	100	70	98

Table 13-17. Estimates of key parameters from the author preferred model (μ) with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ (MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations for GOA RE/BS. q is catchability, M is natural mortality, $F_{40\%}$ is a fishing mortality rate (see **Harvest Recommendations** for complete definition), SSB is spawning stock biomass for the current year (2014), ABC is acceptable biological catch, and σ_r is the recruitment standard deviation parameter.

	μ		σ		MCMC		
Parameter	Hessian	MCMC	Hessian	MCMC	Median	BCI-Lower	BCI-Upper
q_1, trawl survey	1.6536	1.7266	0.5110	0.5332	1.6612	0.8589	2.9078
q_2, longline survey	1.3993	1.3743	0.5160	0.4452	1.3334	0.6320	2.3345
M	0.0336	0.0341	0.0030	0.0032	0.0339	0.0283	0.0406
$F_{40\%}$	0.0376	0.0435	0.0101	0.0136	0.0413	0.0238	0.0760
SSB (2014)	12,479	16,130	4,140	6,581	14,698	8,121	33,075
ABC	1,122	1,689	496	921	1,478	594	4,103
σ_r	0.9084	1.0717	0.0567	0.0655	1.0703	0.9504	1.2045

Table 13-18. Estimated time series of female spawning biomass, 6+ biomass (ages 6 and greater), catch divided by 6 + biomass, and number of age 3 recruits for GOA RE/BS rockfish, 1977-2014. Estimates are shown for the author preferred model (Model 2) and from the previous assessment in 2011 (Model 0).

	Spawning Biomass (t)		6+ Biomass (t)		Catch/6+ Biomass		Age 3 Recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	16,232	17,470	43,850	44,123	0.033	0.033	729	968
1978	15,522	16,792	42,367	42,625	0.013	0.013	882	1,074
1979	15,203	16,496	41,706	42,002	0.015	0.015	3,952	4,637
1980	14,860	16,172	40,941	41,304	0.033	0.033	900	1,137
1981	14,223	15,548	39,523	39,927	0.018	0.018	885	914
1982	13,891	15,215	40,084	39,770	0.014	0.014	986	955
1983	13,651	14,964	39,714	39,379	0.016	0.016	3,070	3,589
1984	13,413	14,704	39,260	38,913	0.019	0.020	1,647	1,640
1985	13,138	14,398	38,693	38,316	0.003	0.003	1,353	1,203
1986	13,147	14,375	39,644	38,768	0.011	0.011	1,371	1,347
1987	13,039	14,231	39,808	38,712	0.013	0.014	900	1,014
1988	12,905	14,063	39,788	38,537	0.041	0.042	737	802
1989	12,336	13,458	38,714	37,337	0.056	0.059	635	682
1990	11,558	12,650	36,919	35,579	0.065	0.068	709	633
1991	10,787	11,801	34,991	33,631	0.010	0.010	869	732
1992	10,850	11,844	34,898	33,659	0.032	0.033	765	834
1993	10,697	11,628	34,140	32,925	0.017	0.018	3,963	3,585
1994	10,789	11,656	33,971	32,719	0.017	0.018	1,106	1,139
1995	10,817	11,655	33,606	32,422	0.021	0.022	1,172	1,131
1996	10,805	11,608	34,456	32,401	0.016	0.017	1,358	1,176
1997	10,865	11,631	34,441	32,243	0.016	0.017	4,970	3,382
1998	10,913	11,648	34,429	32,084	0.019	0.021	1,635	2,264
1999	10,893	11,601	34,364	31,814	0.009	0.010	1,091	1,251
2000	11,007	11,690	36,221	32,265	0.015	0.016	1,604	1,864
2001	11,236	11,938	37,075	32,909	0.016	0.018	2,121	2,454
2002	11,154	11,812	37,188	32,824	0.007	0.008	1,098	1,338
2003	11,208	11,800	37,793	33,137	0.010	0.012	2,320	2,524
2004	11,238	11,746	38,501	33,462	0.008	0.009	2,285	2,176
2005	11,500	11,962	39,170	34,141	0.007	0.009	1,679	1,701
2006	11,666	12,008	40,093	34,682	0.009	0.010	1,125	1,298
2007	11,825	12,014	40,926	35,077	0.010	0.012	1,046	1,132
2008	12,001	12,036	41,465	35,382	0.009	0.011	1,043	1,206
2009	12,188	12,082	41,713	35,638	0.007	0.008	1,160	1,557
2010	12,444	12,191	41,965	35,938	0.011	0.012	1,076	1,126
2011	12,653	12,263	41,984	36,065	0.013	0.015	1,082	1,260
2012		12,314		36,112		0.016		1,237
2013		12,385		36,081		0.016		1,253
2014		12,480		36,062		0.020		1,262

Table 13-19. Estimated time series of recruitment, total biomass (3+), and female spawning biomass for RE/BS rockfish in the Gulf of Alaska, 1977-2015. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC posterior distribution.

	Recruits (Age 3, 1000s)			Total Biomass (3+)			Spawning biomass (t)		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	968	134	3,666	44,379	31,718	85,210	17,470	11,772	31,950
1978	1,074	142	5,280	42,870	30,409	84,417	16,792	11,275	31,774
1979	4,637	721	10,242	42,424	30,369	85,292	16,496	11,164	31,890
1980	1,137	145	5,368	41,853	29,944	85,015	16,172	11,036	31,762
1981	914	127	3,620	40,603	28,988	84,373	15,548	10,535	31,310
1982	955	137	4,010	40,021	28,651	84,434	15,215	10,386	31,236
1983	3,589	429	8,603	39,735	28,549	84,800	14,964	10,289	31,385
1984	1,640	207	6,403	39,389	28,324	85,152	14,704	10,136	31,234
1985	1,203	157	4,309	38,923	28,009	85,005	14,398	10,012	31,162
1986	1,347	171	4,176	39,120	28,307	85,777	14,375	10,123	31,104
1987	1,014	162	3,376	39,009	28,226	86,127	14,231	10,097	31,092
1988	802	122	2,613	38,814	28,008	86,030	14,063	9,964	31,119
1989	682	121	2,206	37,552	26,886	85,125	13,458	9,365	30,616
1990	633	113	1,898	35,758	25,116	83,441	12,650	8,644	29,668
1991	732	125	2,256	33,796	23,262	81,570	11,801	7,890	28,829
1992	834	131	3,121	33,832	23,346	81,566	11,844	7,925	29,027
1993	3,585	1,289	8,275	33,250	22,707	80,990	11,628	7,721	28,915
1994	1,139	148	4,463	33,156	22,630	80,858	11,656	7,750	29,326
1995	1,131	146	3,994	32,986	22,483	81,065	11,655	7,751	29,409
1996	1,176	161	4,757	32,680	22,173	81,057	11,608	7,655	29,667
1997	3,382	464	8,787	32,631	22,037	81,038	11,631	7,670	29,785
1998	2,264	250	7,408	32,599	21,981	81,526	11,648	7,650	29,973
1999	1,251	155	5,459	32,450	21,760	81,957	11,601	7,611	29,933
2000	1,864	224	7,178	32,719	21,938	82,608	11,690	7,702	30,181
2001	2,454	327	6,985	33,321	22,268	84,688	11,938	7,816	31,005
2002	1,338	177	5,554	33,301	22,290	84,961	11,812	7,705	30,821
2003	2,524	406	7,543	33,651	22,556	85,307	11,800	7,718	30,658
2004	2,176	300	7,664	33,923	22,711	85,726	11,746	7,672	30,508
2005	1,701	231	5,898	34,691	23,299	87,714	11,962	7,797	31,120
2006	1,298	178	4,665	35,133	23,663	88,760	12,008	7,872	31,118
2007	1,132	156	4,447	35,433	23,864	90,074	12,014	7,877	31,245
2008	1,206	165	5,357	35,682	24,018	90,555	12,036	7,877	31,456
2009	1,557	214	6,540	35,941	24,236	91,341	12,082	7,929	31,469
2010	1,126	135	6,058	36,257	24,463	91,791	12,191	7,999	31,554
2011	1,260	162	6,799	36,397	24,546	92,661	12,263	8,035	31,996
2012	1,237	145	9,783	36,403	24,529	92,916	12,314	8,047	32,185
2013	1,253	149	9,430	36,386	24,477	93,290	12,385	8,087	32,422
2014	1,262	150	10,427	36,367	24,435	93,562	12,480	8,119	32,760
2015	1,627	---	---	36,583	---	---	12,480	8,146	32,859

Table 13-20. Set of projections of spawning biomass (SB) and yield for GOA RE/BS rockfish. Seven harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see *Harvest Recommendations* section. Spawning biomass and yield are in t. $B_{40\%}$ = 8,980 t, $B_{35\%}$ = 7,857 t, $F_{40\%}$ = 0.038 and $F_{35\%}$ = 0.045.

Year	Maximum permissible F	Author's F*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2014	12,182	12,182	12,182	12,182	12,182	12,182	12,182
2015	12,373	12,480	12,469	12,466	12,565	12,334	12,373
2016	12,234	12,595	12,556	12,545	12,886	12,105	12,234
2017	12,095	12,598	12,639	12,621	13,209	11,880	12,057
2018	11,954	12,443	12,717	12,691	13,530	11,656	11,827
2019	11,959	12,439	12,948	12,915	14,022	11,578	11,744
2020	11,832	12,296	13,034	12,993	14,362	11,375	11,535
2021	11,611	12,055	13,007	12,960	14,578	11,087	11,239
2022	11,430	11,854	13,016	12,961	14,833	10,842	10,986
2023	11,277	11,683	13,049	12,988	15,115	10,628	10,765
2024	11,037	11,422	12,970	12,902	15,262	10,338	10,466
2025	10,885	11,250	12,982	12,908	15,511	10,136	10,257
2026	10,708	11,048	12,949	12,870	15,698	9,916	10,028
2027	10,508	10,826	12,875	12,790	15,826	9,681	9,785
			Fishing Mortality				
2014	0.025	0.025	0.025	0.025	0.025	0.025	0.025
2015	0.038	0.017	0.019	0.019	-	0.045	0.045
2016	0.038	0.016	0.019	0.019	-	0.045	0.045
2017	0.038	0.038	0.019	0.019	-	0.045	0.045
2018	0.038	0.038	0.019	0.019	-	0.045	0.045
2019	0.038	0.038	0.019	0.019	-	0.045	0.045
2020	0.038	0.038	0.019	0.019	-	0.045	0.045
2021	0.038	0.038	0.019	0.019	-	0.045	0.045
2022	0.038	0.038	0.019	0.019	-	0.045	0.045
2023	0.038	0.038	0.019	0.019	-	0.045	0.045
2024	0.038	0.038	0.019	0.019	-	0.045	0.045
2025	0.038	0.038	0.019	0.019	-	0.045	0.045
2026	0.038	0.038	0.019	0.019	-	0.045	0.045
2027	0.038	0.038	0.019	0.019	-	0.045	0.045
			Yield (t)				
2014	736	736	736	736	736	736	736
2015	502	502	566	584	-	1,345	502
2016	1,119	501	575	593	-	1,333	1,119
2017	1,111	1,156	581	599	-	1,313	1,332
2018	1,094	1,137	582	599	-	1,285	1,303
2019	1,082	1,123	585	603	-	1,262	1,279
2020	1,061	1,100	583	600	-	1,228	1,245
2021	1,037	1,074	579	596	-	1,193	1,208
2022	1,020	1,056	579	595	-	1,167	1,182
2023	1,001	1,035	577	593	-	1,138	1,152
2024	979	1,011	572	588	-	1,107	1,120
2025	963	993	571	586	-	1,083	1,095
2026	946	974	568	583	-	1,059	1,070
2027	930	956	565	579	-	1,035	1,045

*Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 736 t for 2014 and projected catch of 502 t for 2015 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Table 13-21. Recommended allocation of ABC and OFL for 2015 and 2016 GOA RE/BS rockfish based on the preferred weighted survey average method.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
2009	4	6%	65%	29%	100%
2011	6	7%	74%	19%	100%
2013	9	14%	41%	45%	100%
Weighted Mean	19				
Area Allocation		10.3%	56.3%	33.4%	100%
2015	Area ABC (t)	**115**	**632**	**375**	**1,122**
	OFL (t)				**1,345**
2016	Area ABC (t)	**117**	**643**	**382**	**1,142**
	OFL (t)				**1,370**

Table 13-22: Analysis of ecosystem considerations for GOA RE/BS rockfish.

Ecosystem effects on *GOA rougheye rockfish*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Important for larval and post-larval survival but no information known	May help determine year class strength, no time series	Possible concern if some information available
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, arrowtooth, lingcod)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment

GOA rougheye rockfish fishery effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several month starting 2006
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-target rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies being initiated in 2005

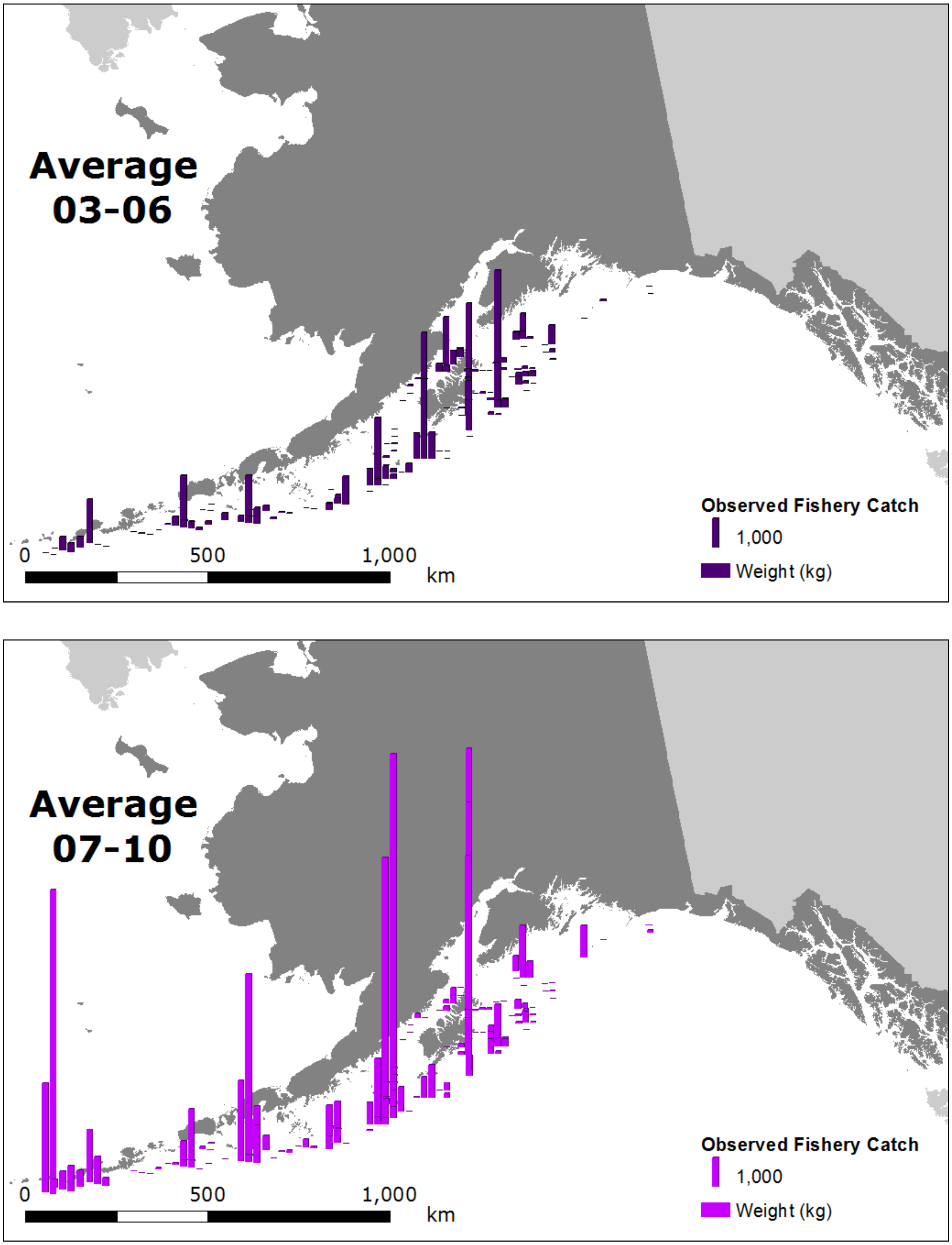


Figure 13-1. Spatial distribution of observed rougheye and blackspotted rockfish trawl fishery catch in the Gulf of Alaska (GOA) based on observer data aggregated by 400 km^2 blocks and averaged by four years prior to central GOA Rockfish Pilot Program, 2003-2006 (upper panel), and four years after implementation of program, 2007-2010 (lower panel). Source: Observer Program (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

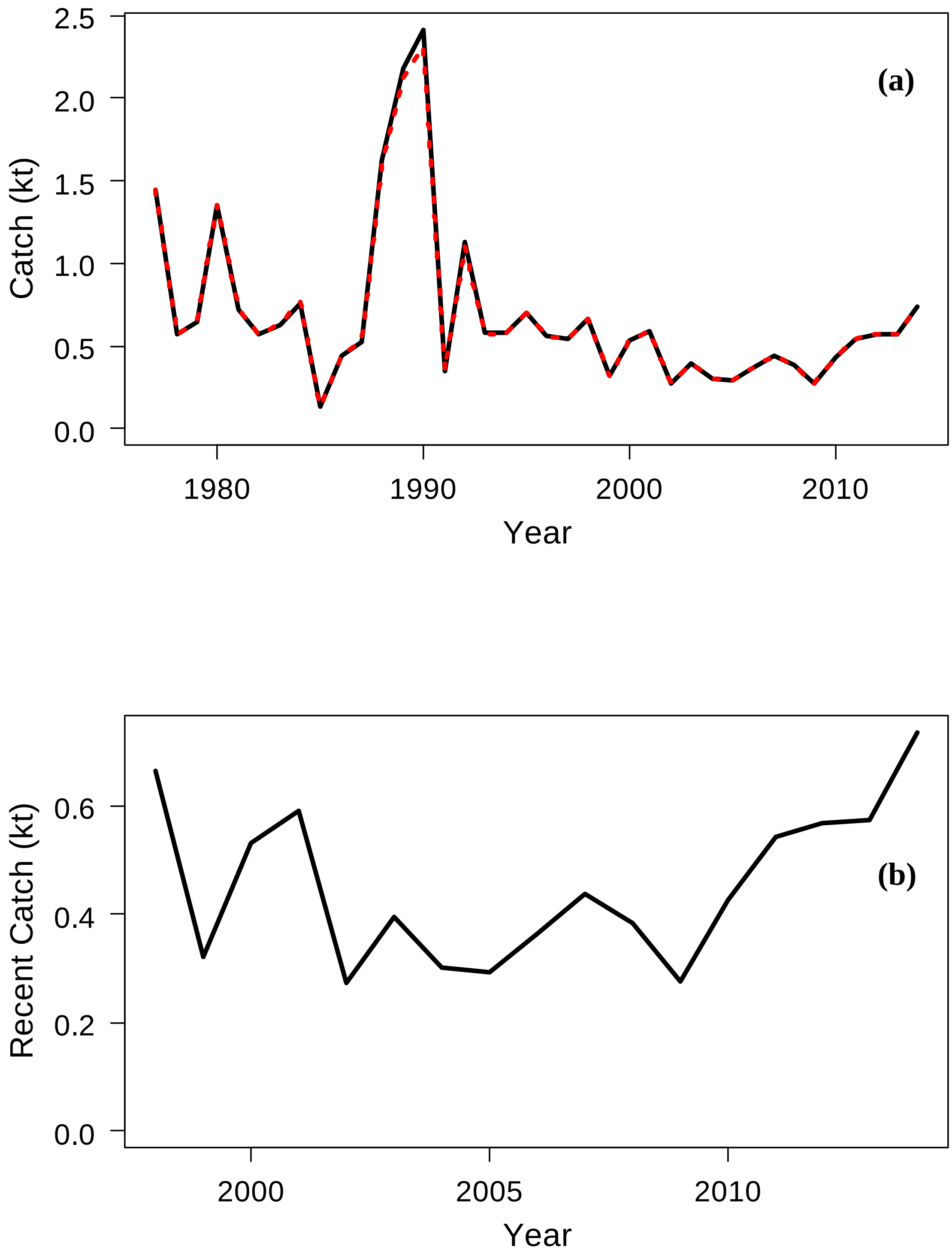


Figure 13-2. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed line (in a only) is predicted catch from the author preferred model.

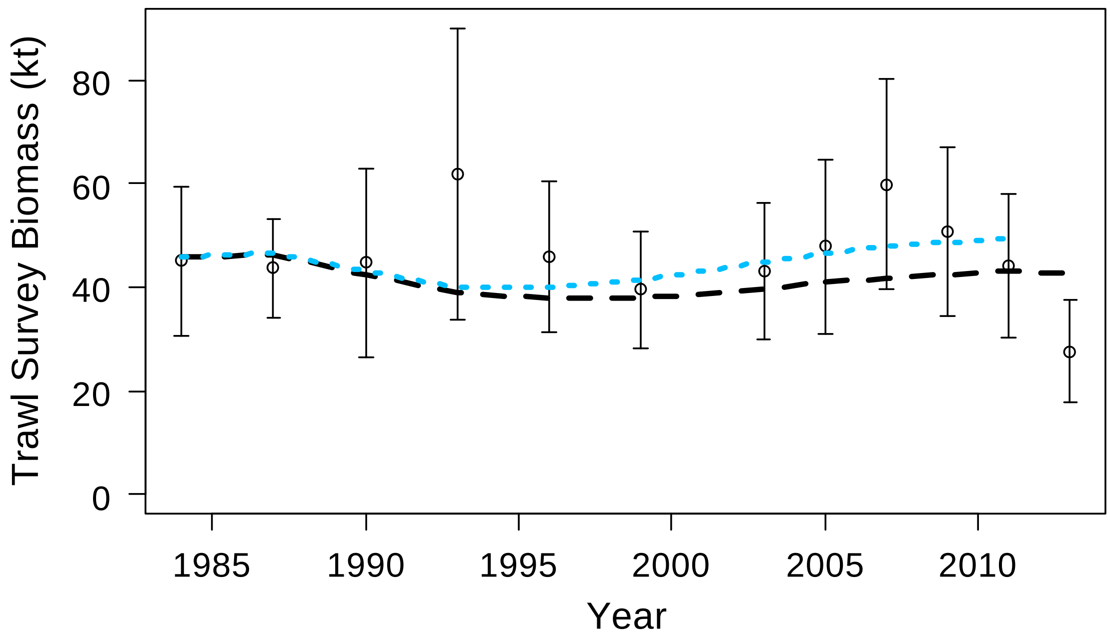


Figure 13-3. AFSC bottom trawl survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue line).

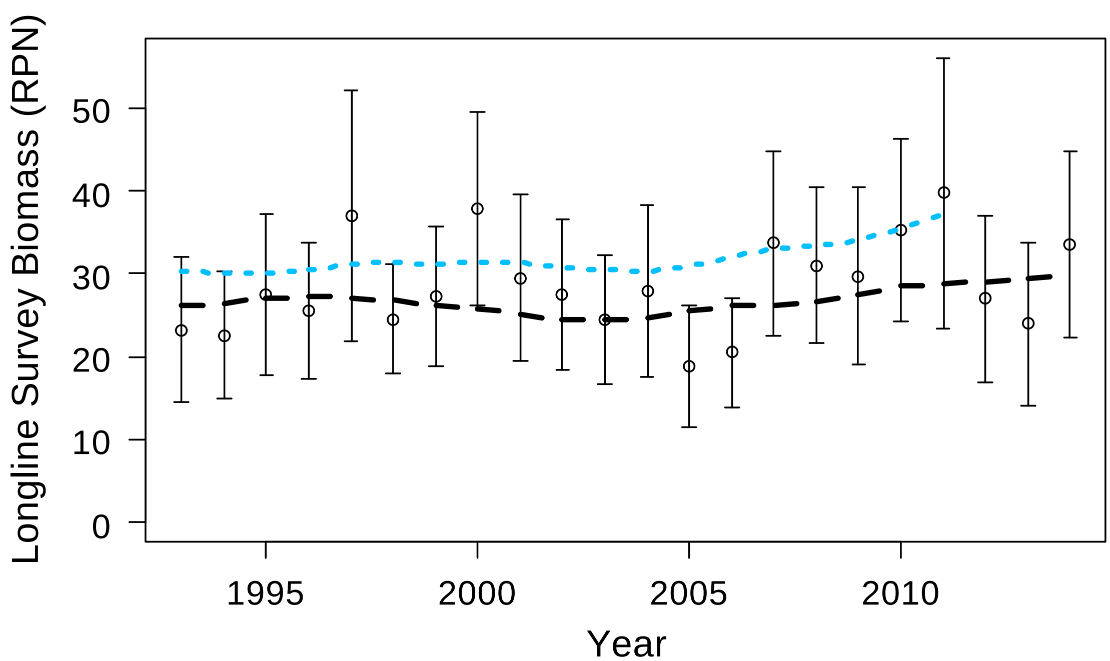


Figure 13-4. AFSC longline survey relative population numbers (RPN in thousands, open circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue line) which was based on relative population weights (RPW).

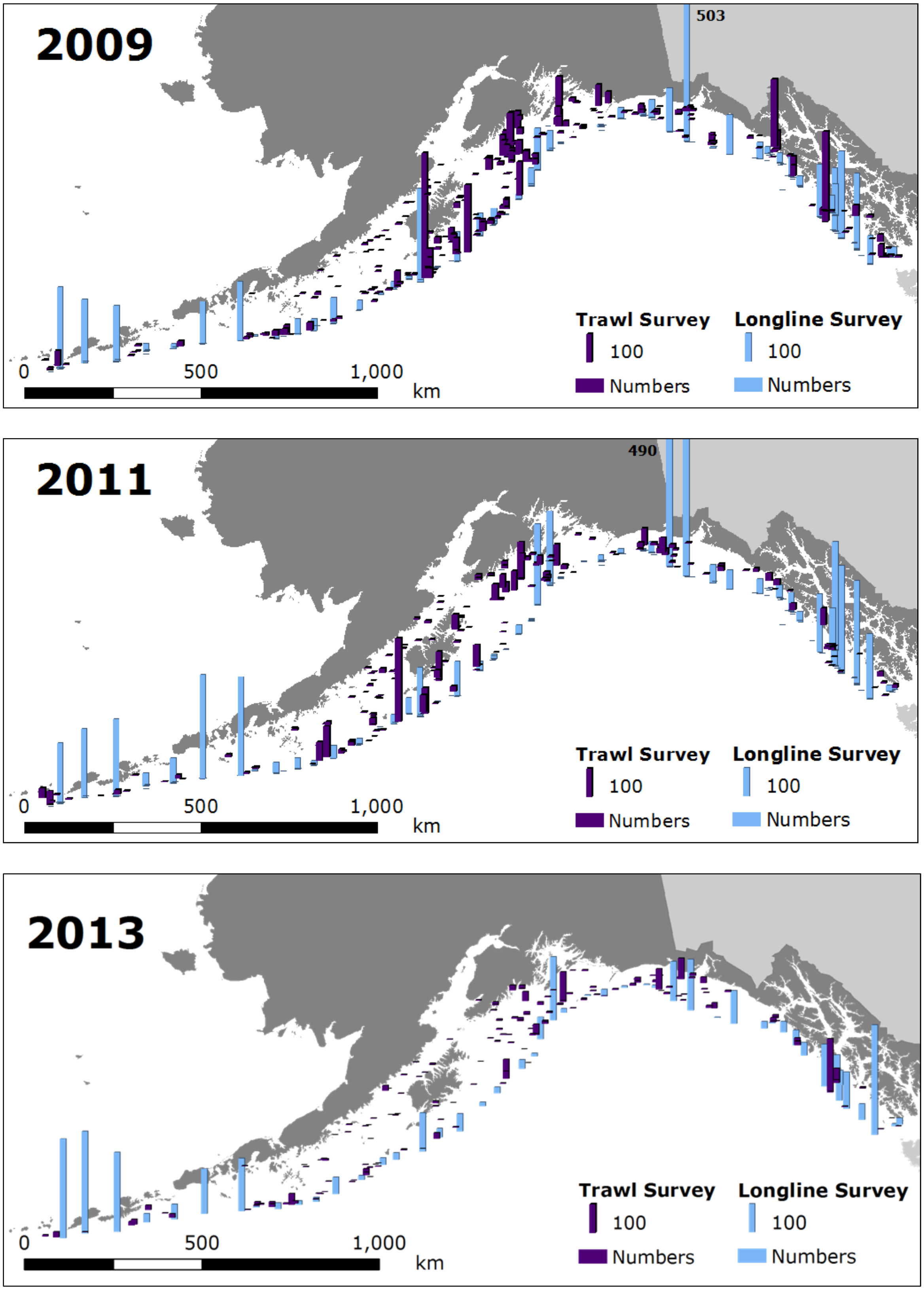


Figure 13-5a. Spatial distribution of rougheye and blackspotted rockfish in the Gulf of Alaska during the 2009, 2011, and 2013 AFSC trawl (dark purple) and AFSC longline (blue) surveys.

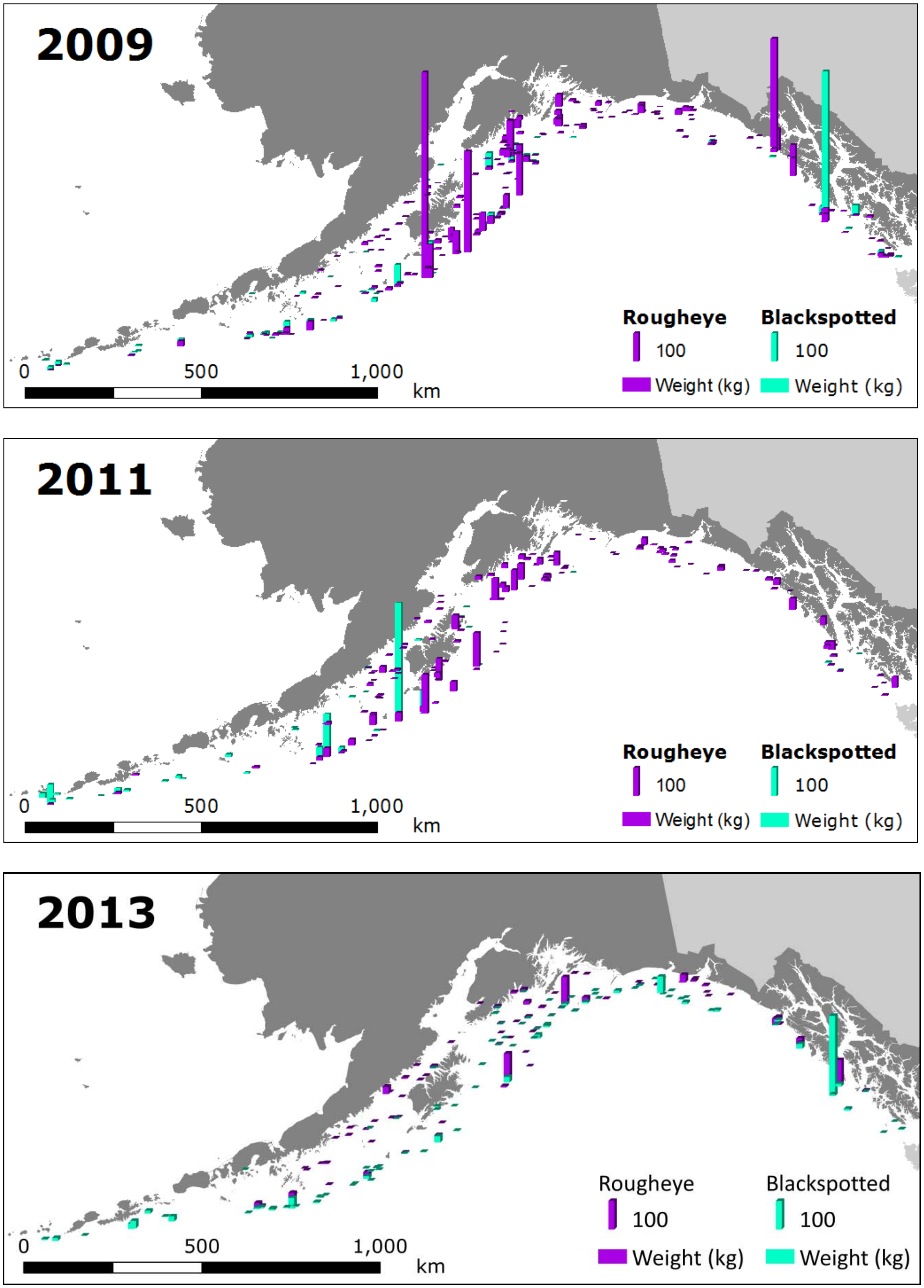


Figure 13-5b. Comparison of the spatial distribution between at-sea identified rougheye (purple) and blackspotted (green) rockfish in the Gulf of Alaska during the 2009, 2011, 2013 AFSC trawl surveys.

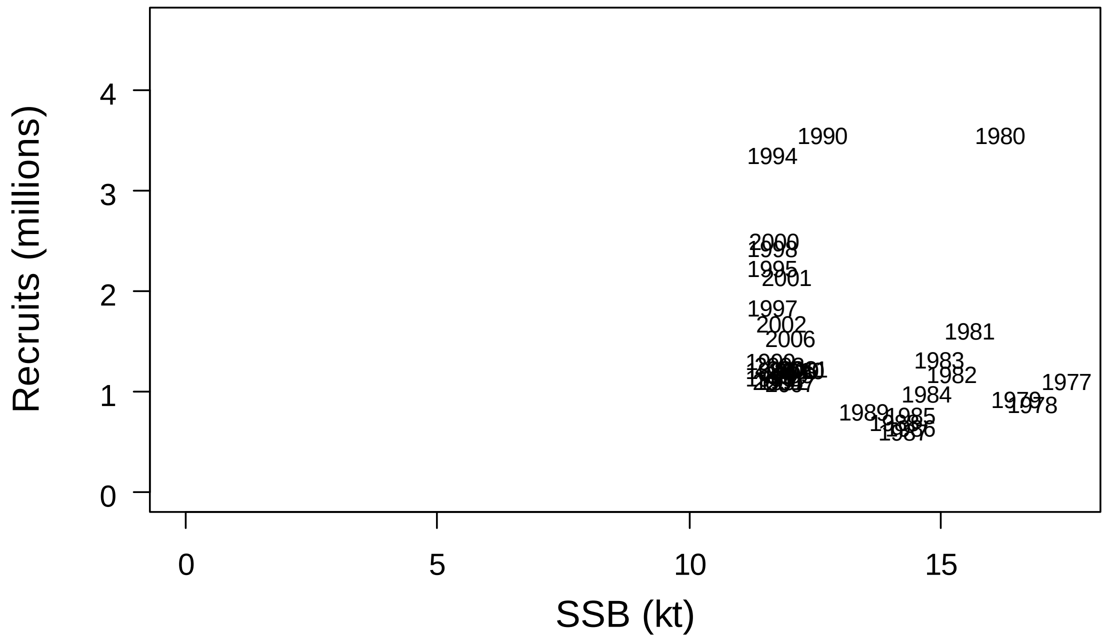


Figure 13-6. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author preferred model. Label is year class of age 3 recruits. Recruits are in millions and SSB = Spawning stock biomass in tons.

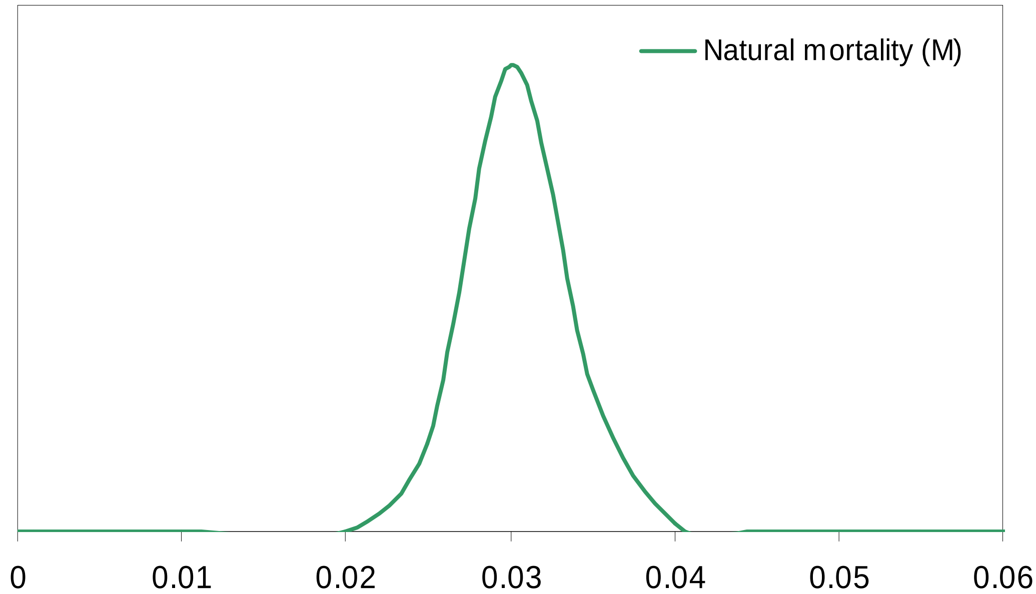


Figure 13-7. Prior distribution for natural mortality (*M*, μ=0.03, CV=10%) of GOA RE/BS rockfish.

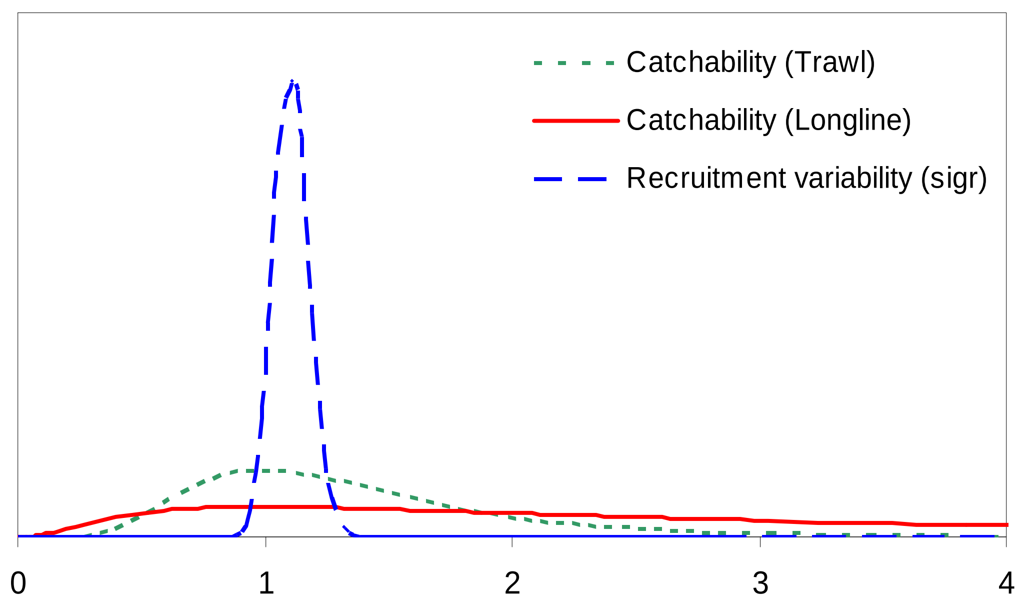


Figure 13-8. Prior distributions for NMFS trawl survey catchability ($q1$, μ=1, CV=45%), AFSC longline survey catchability ($q2$, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA RE/BS rockfish.

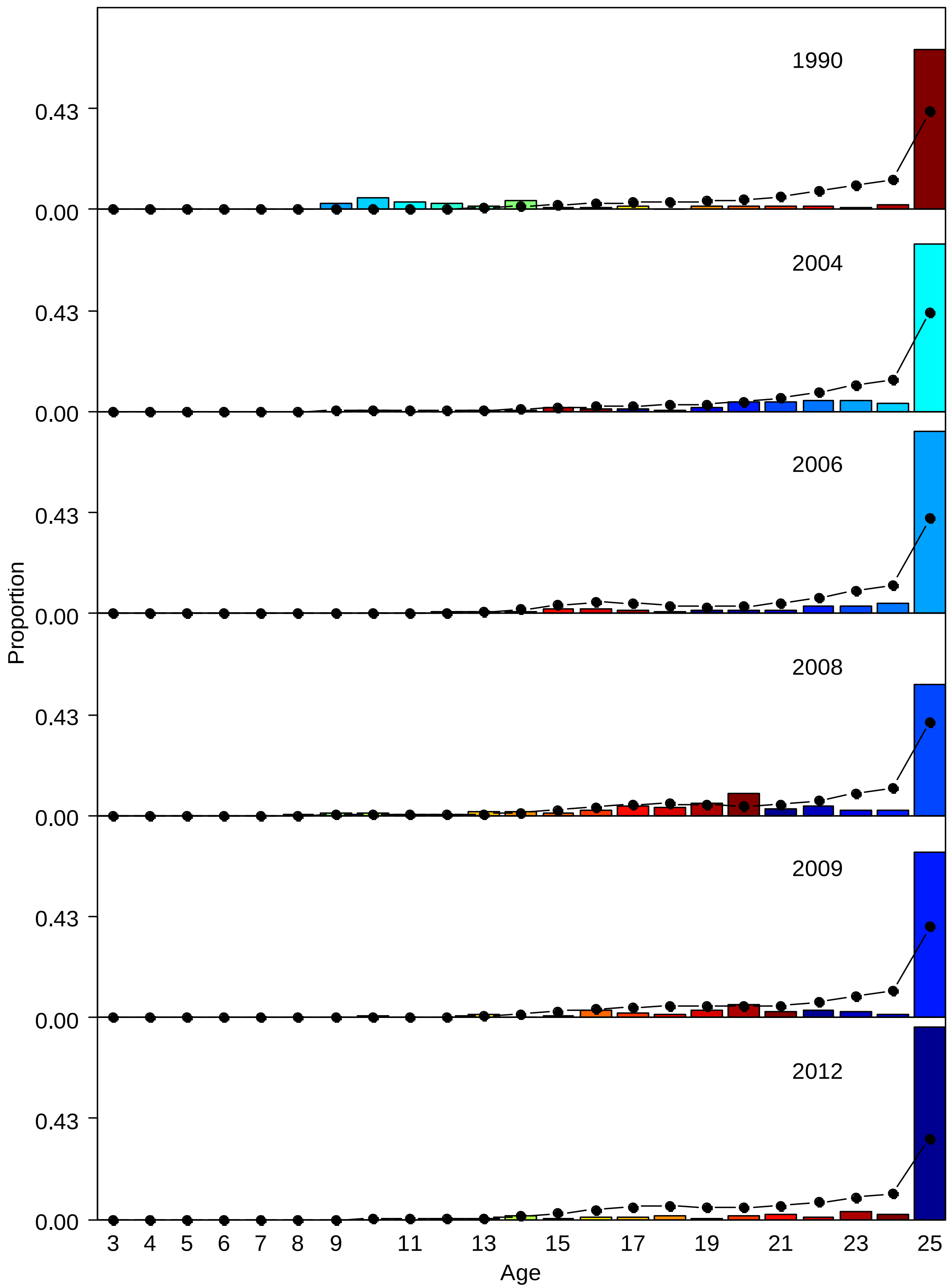


Figure 13-9. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

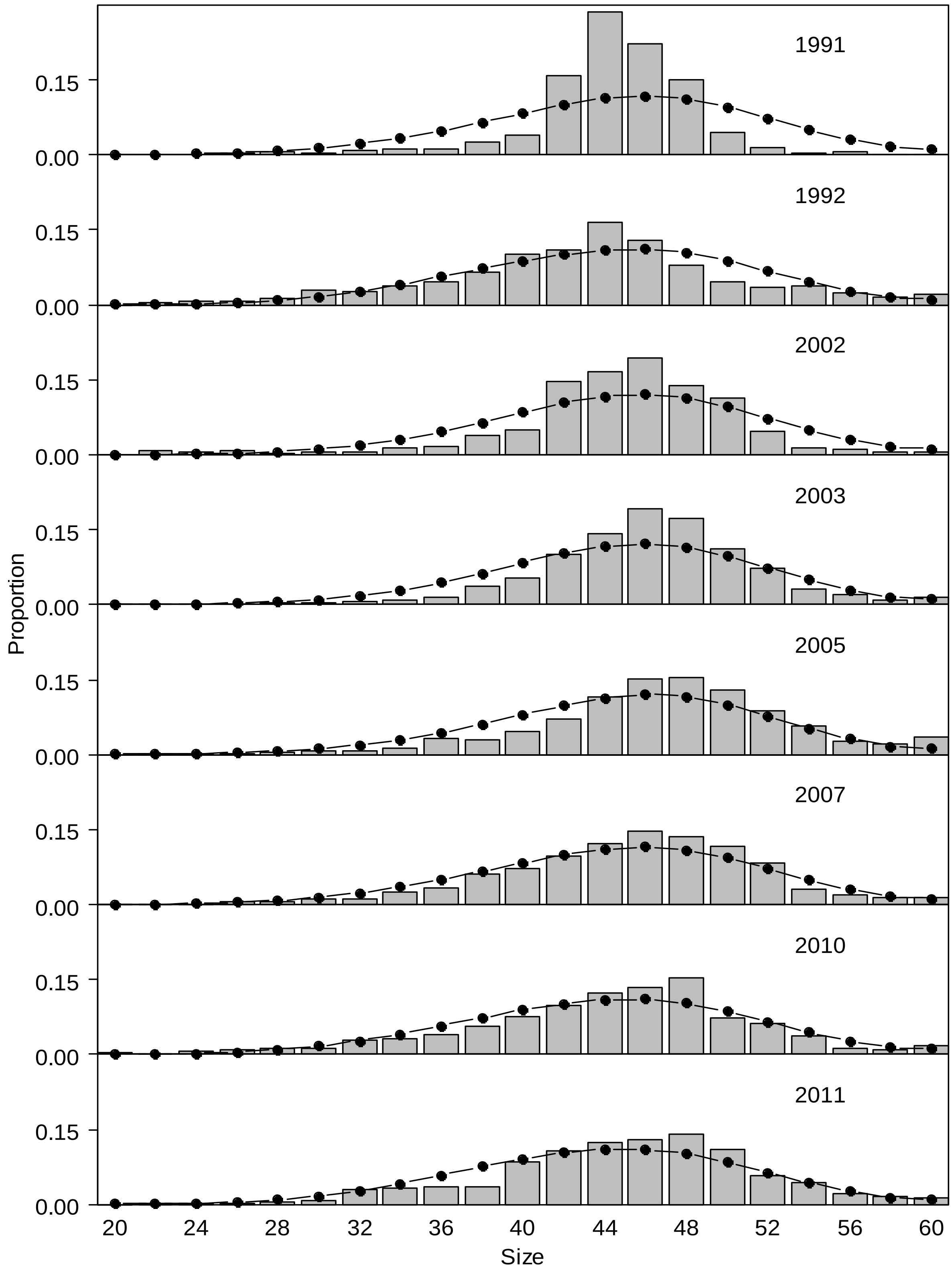


Figure 13-10. Fishery length compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

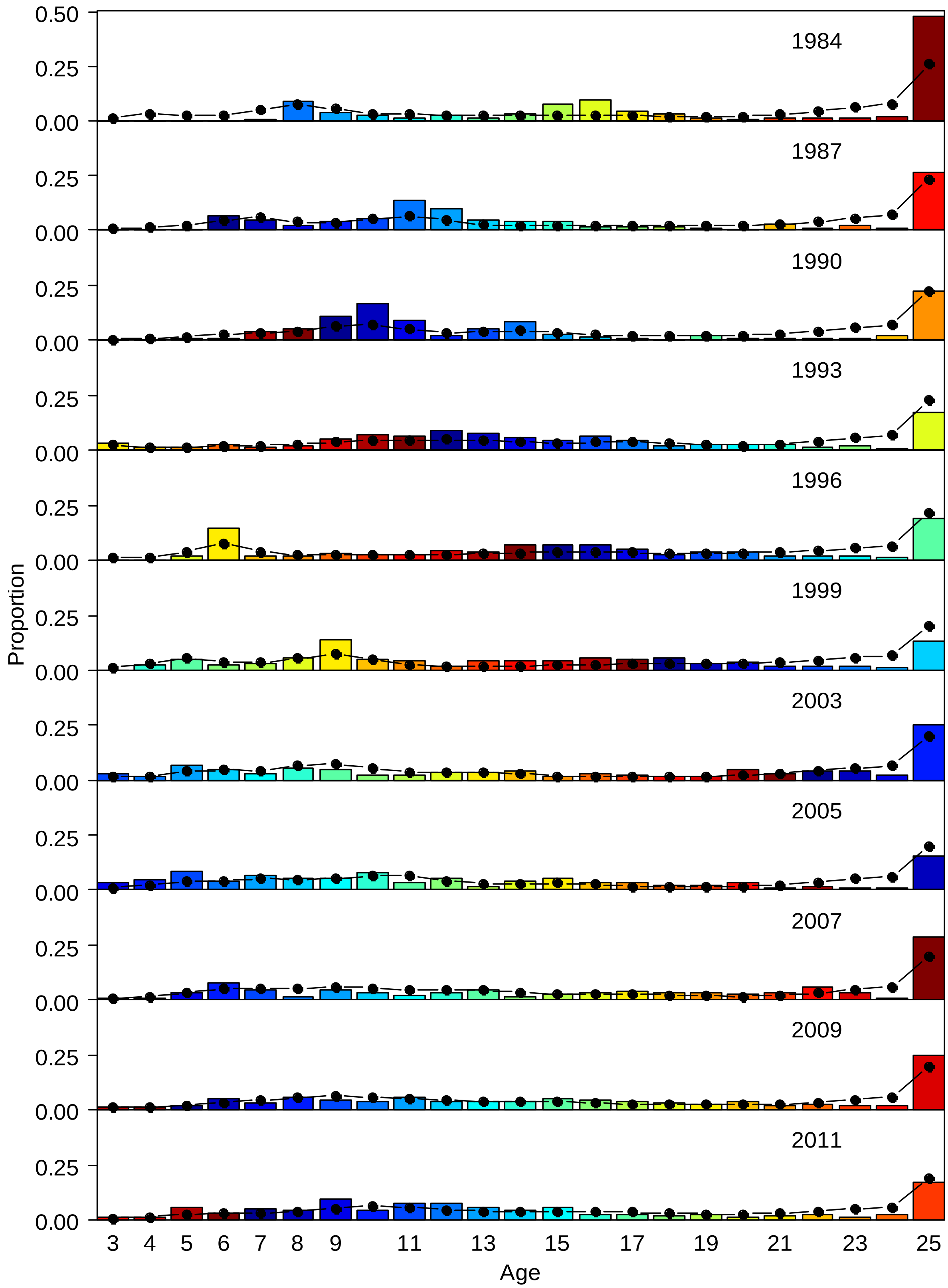


Figure 13-11. AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish**.** Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

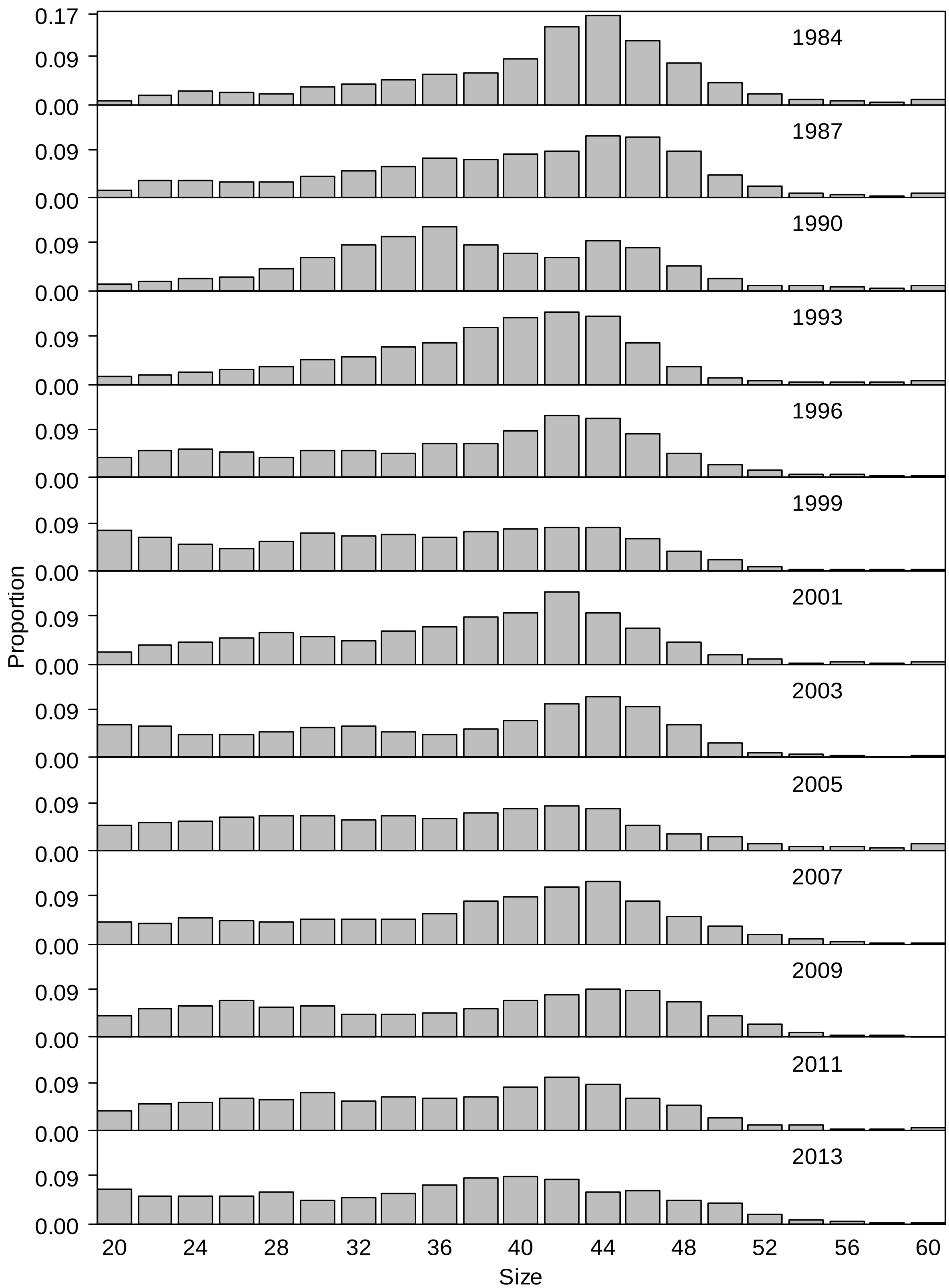


Figure 13-12. AFSC bottom trawl survey length composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

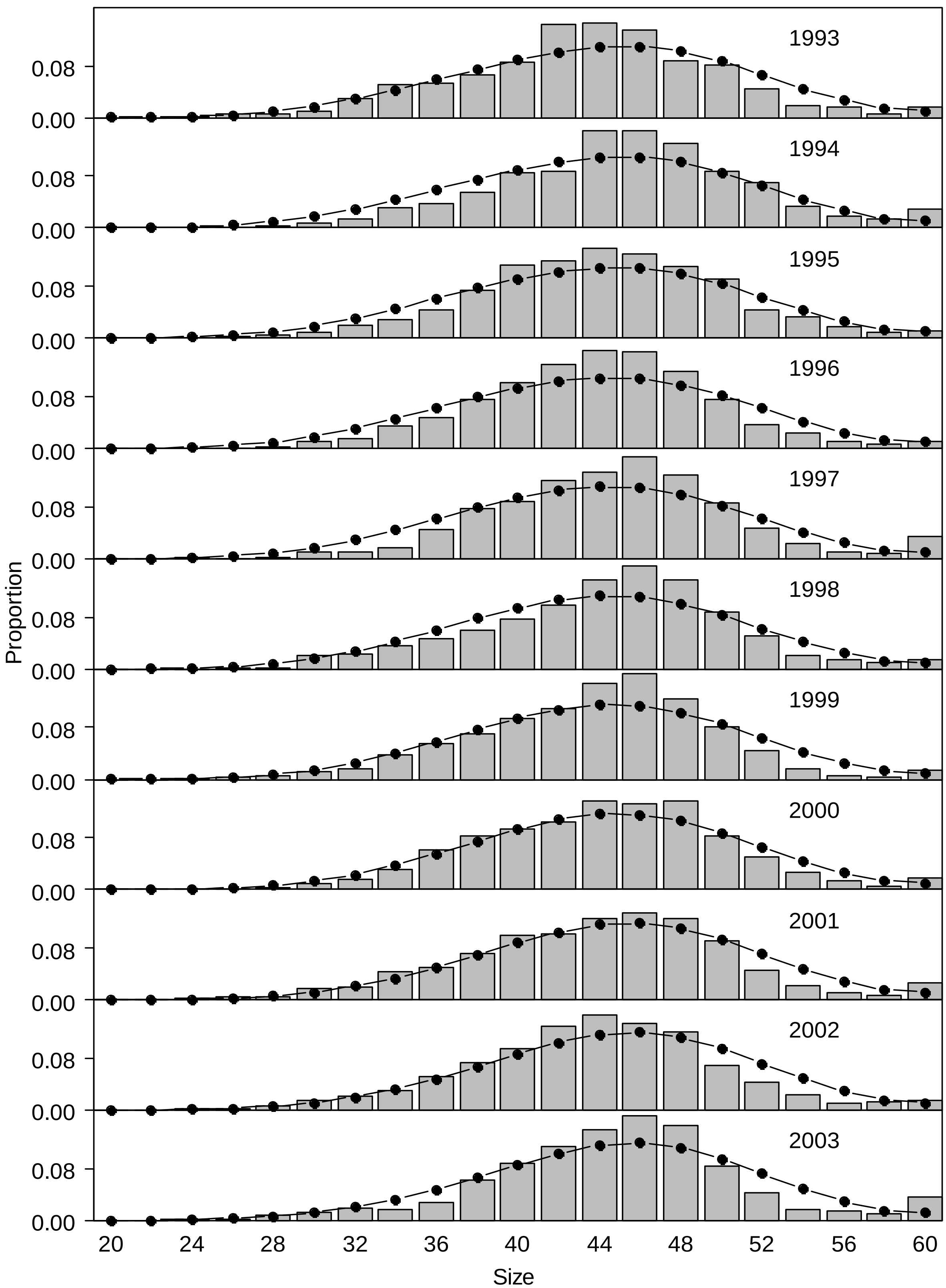


Figure 13-13. AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

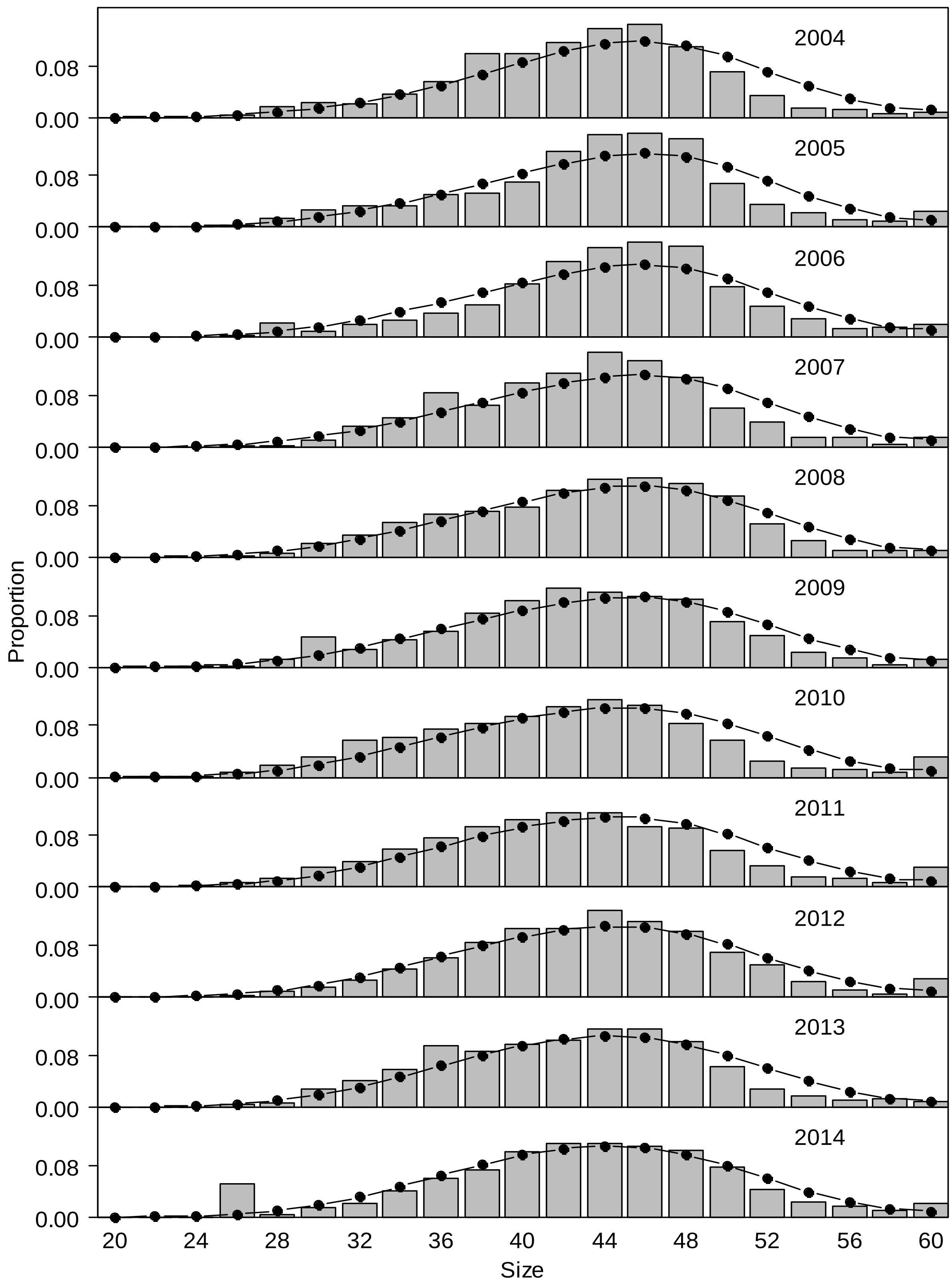


Figure 13-13 (continued). AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

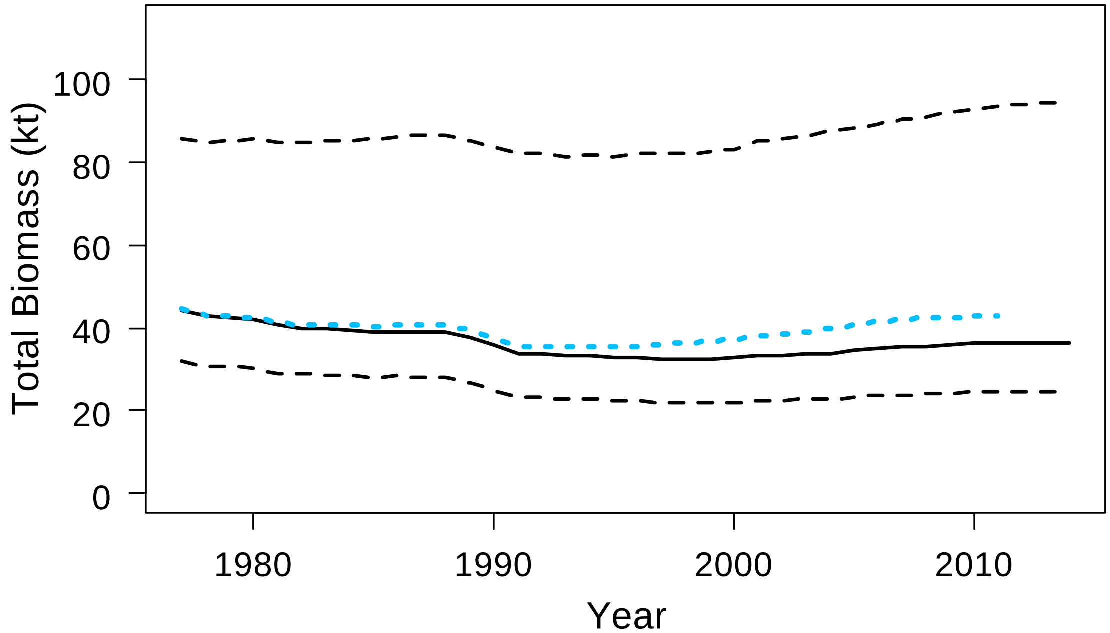


Figure 13-14. Time series of predicted total biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (dotted blue line).

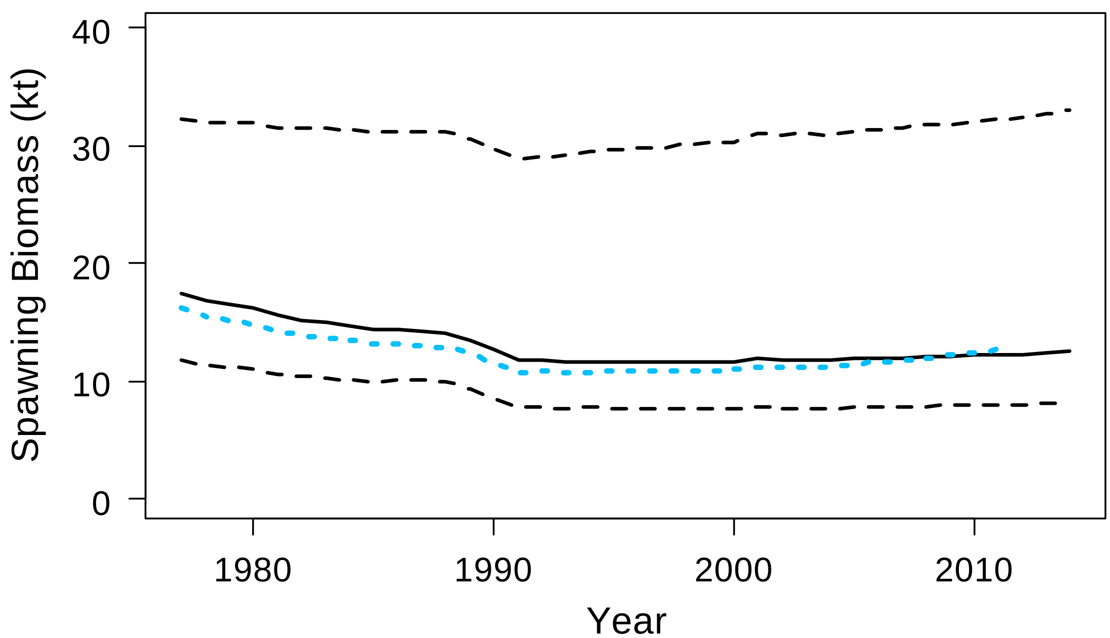


Figure 13-15. Time series of predicted spawning biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (dotted blue line).

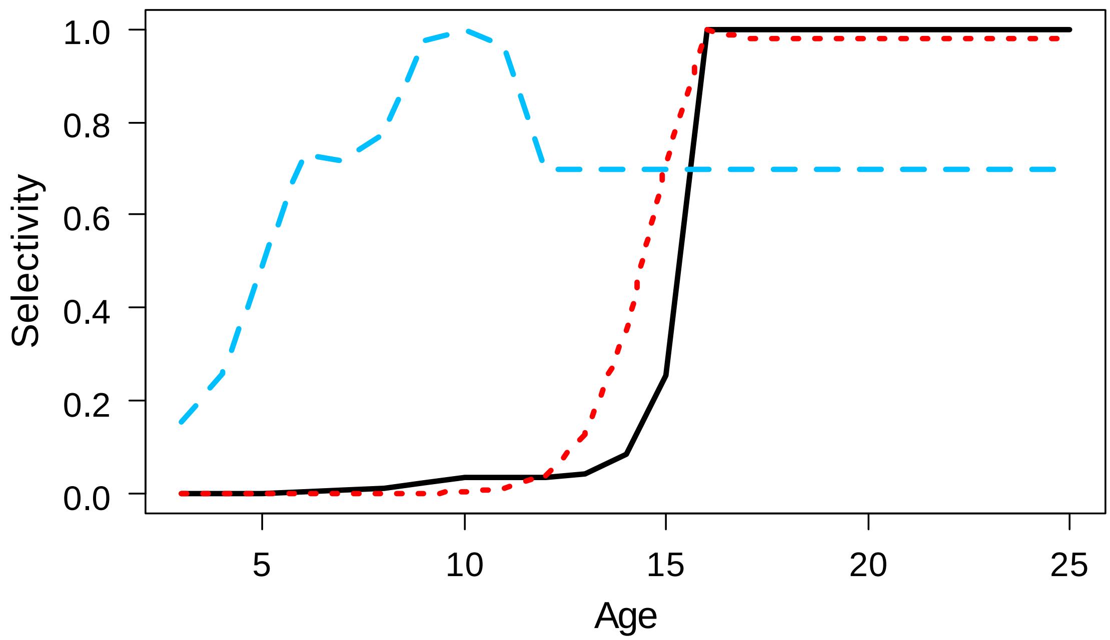


Figure 13-16. Estimated selectivity curves for GOA RE/BS rockfish from author preferred model. Dashed blue line = AFSC bottom trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

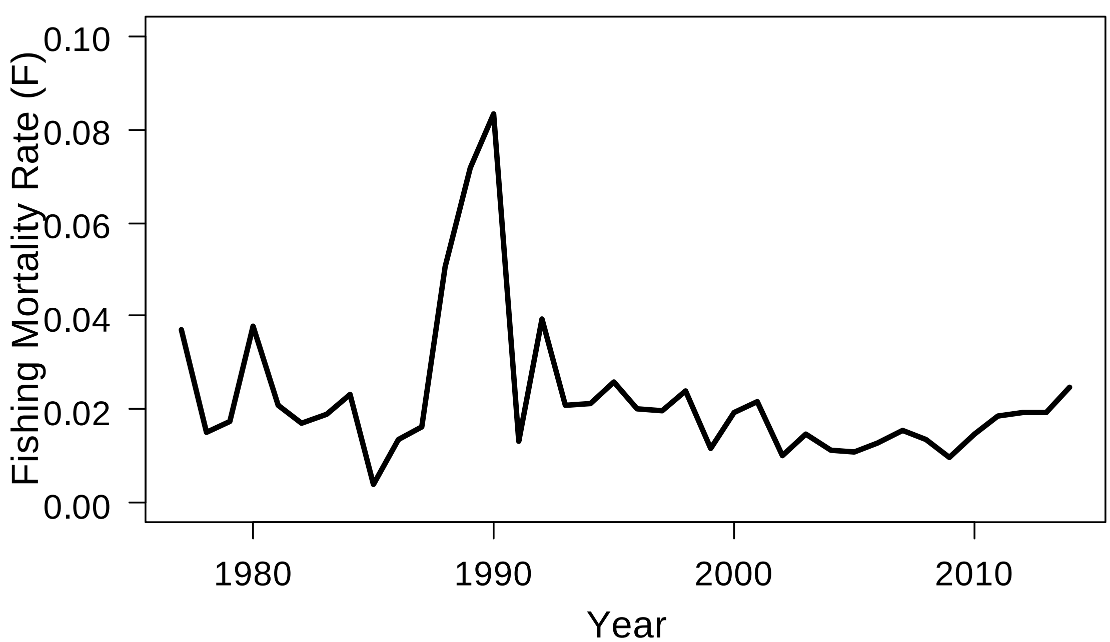


Figure 13-17. Time series of estimated fully selected fishing mortality for GOA RE/BS rockfish from author preferred model.

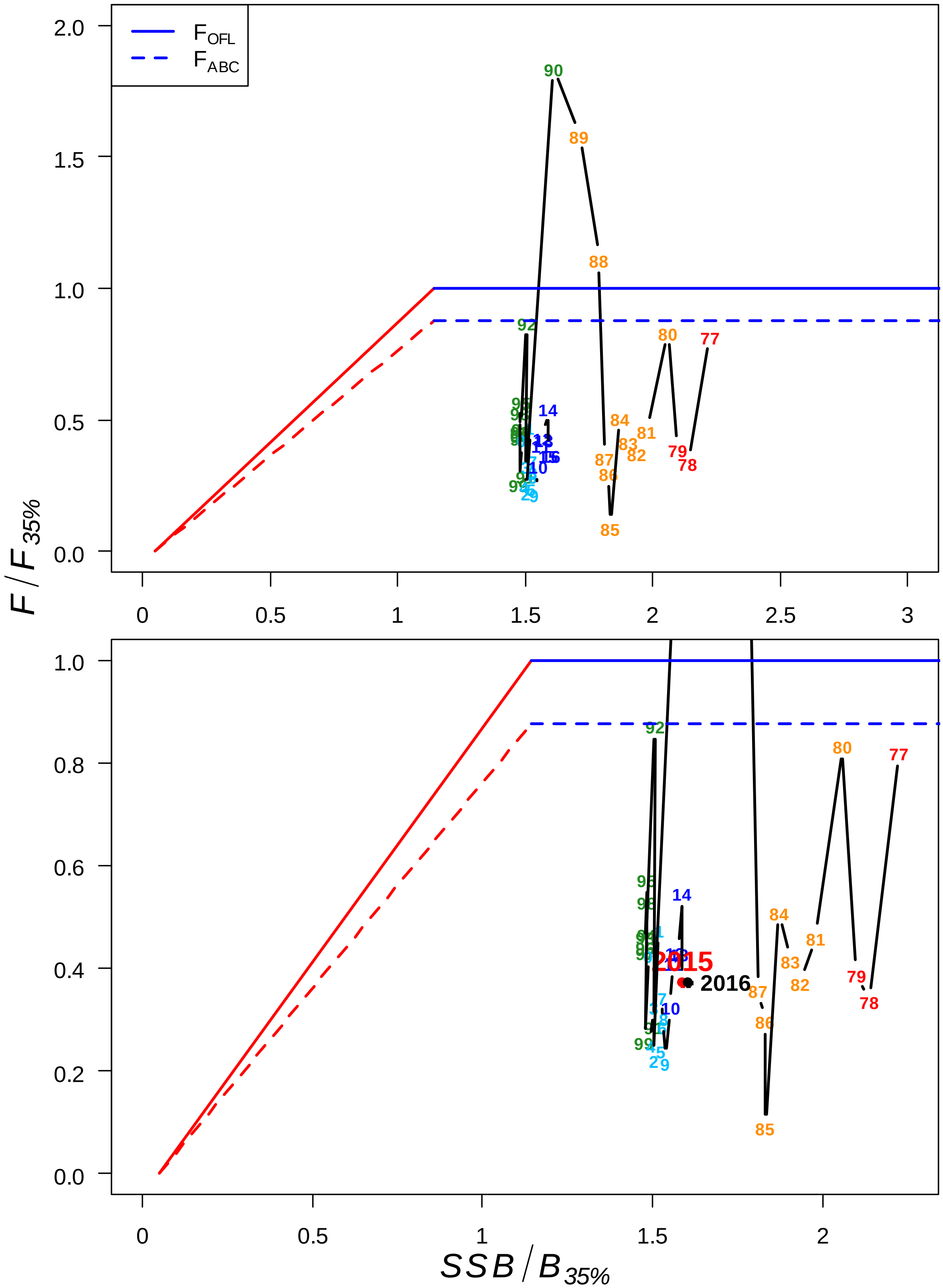


Figure 13-18. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the target $B_{35\%}$ level and fishing mortality relative to F_{OFL} for author preferred model. The upper panel provides the entire time series while bottom panel presents the more recent management path.

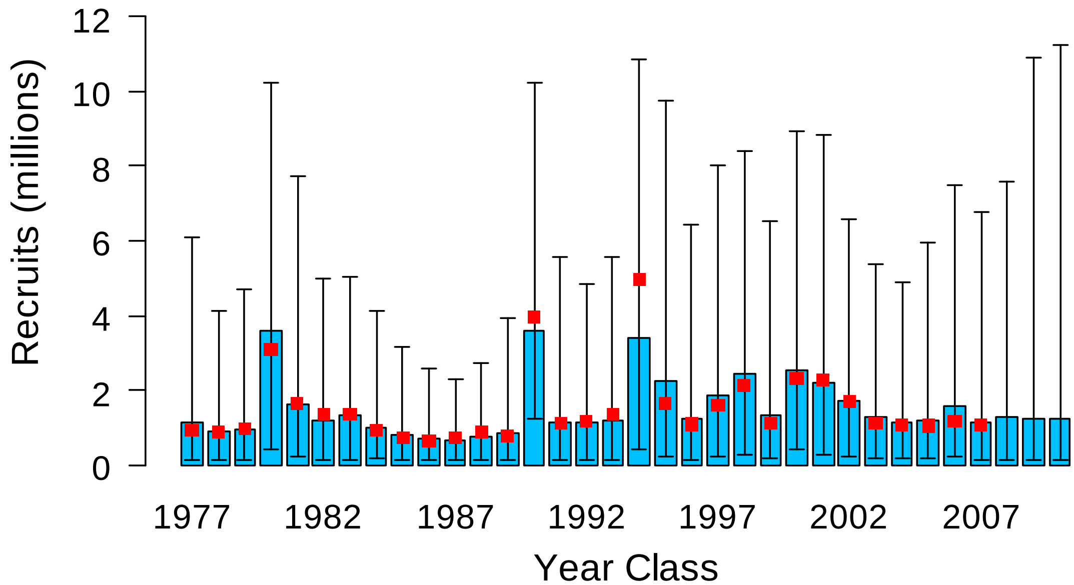


Figure 13-19. Estimated recruitments (age 3) of GOA RE/BS rockfish from author preferred model by year class with 95% credible intervals derived from MCMC. Red square in top graph presents last year's recruitment estimates for comparison.

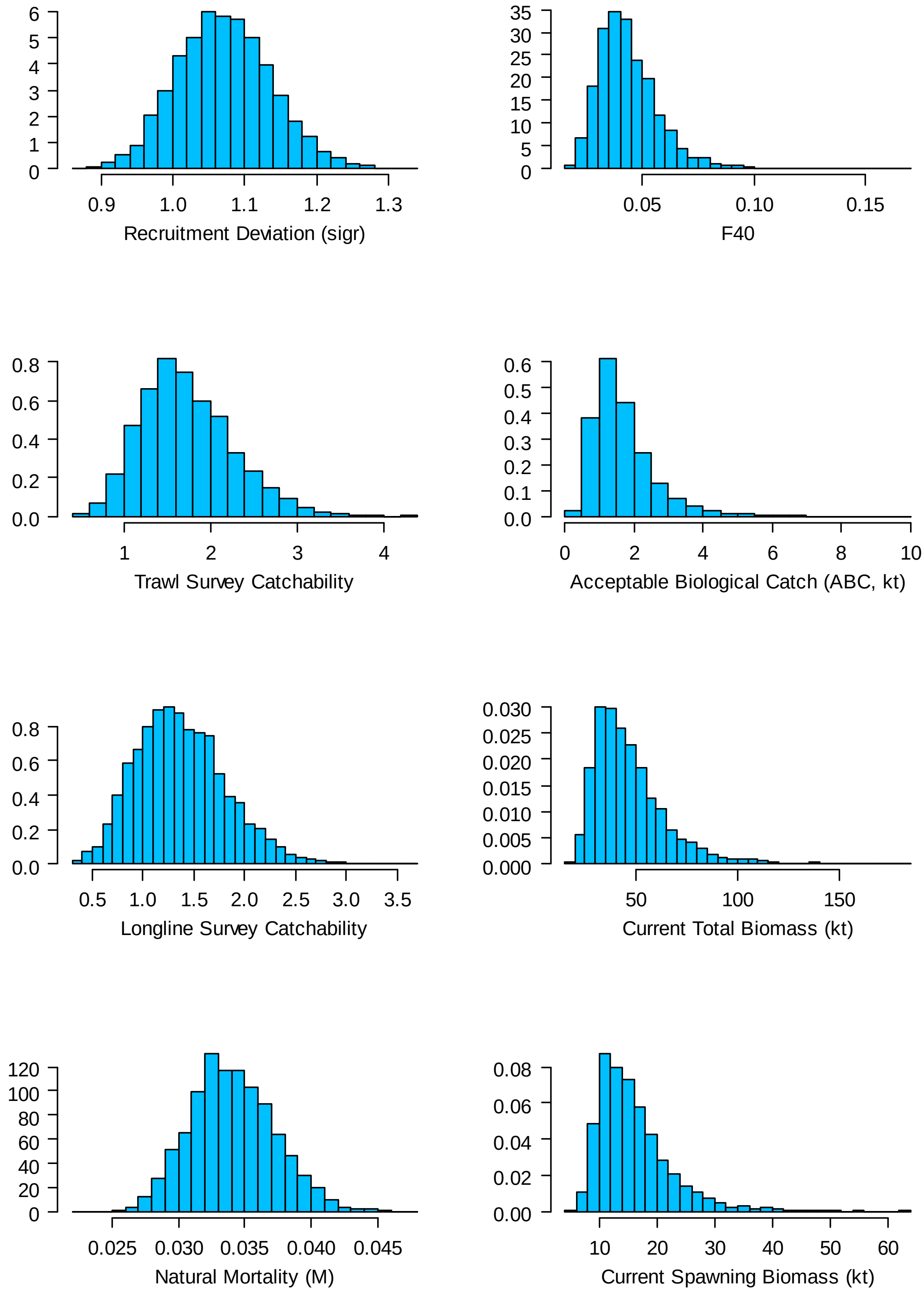


Figure 13-20: Histograms of estimated posterior distributions for key parameters derived from MCMC for GOA RE/BS rockfish.

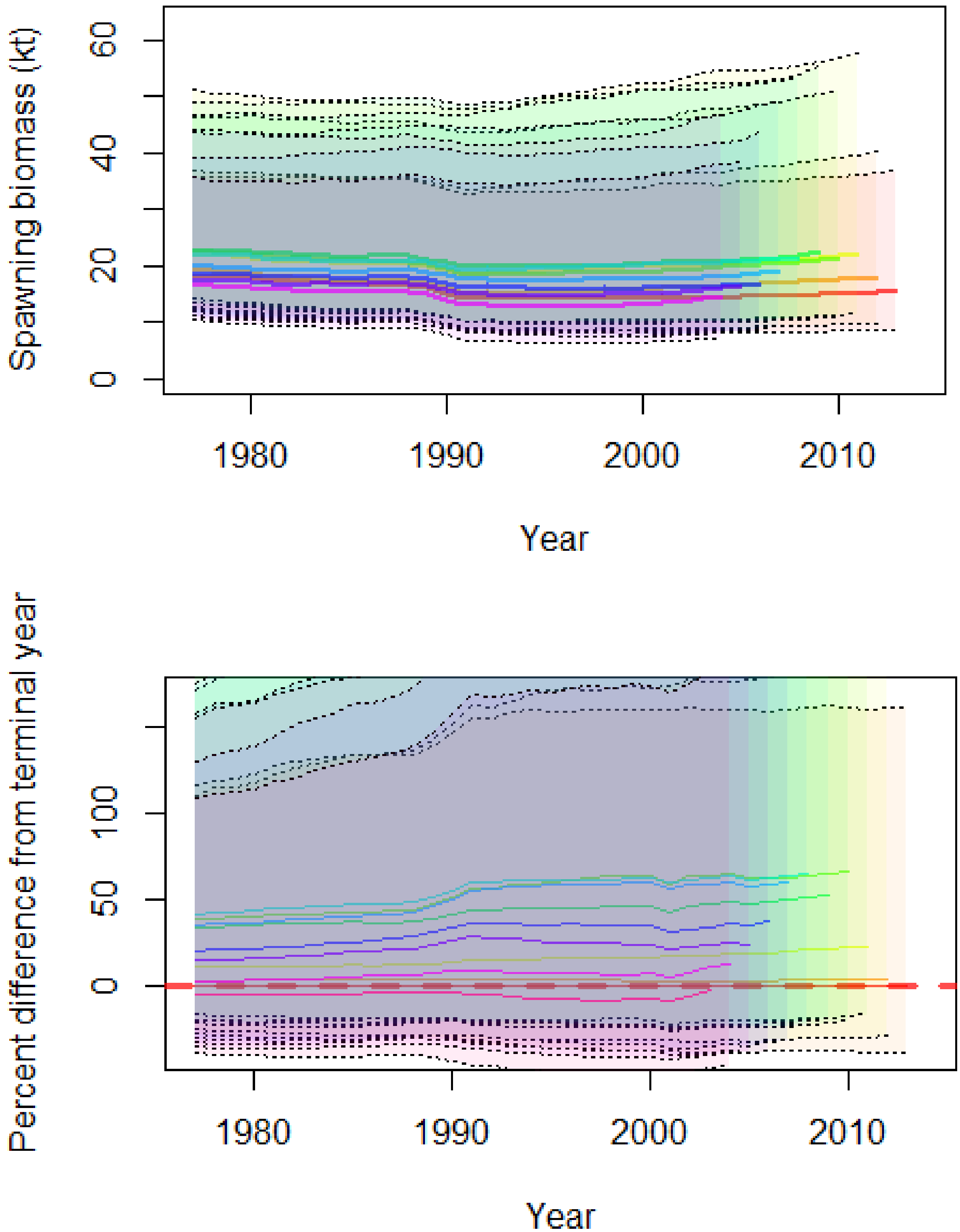


Figure 13-21: Retrospective peels of estimated female spawning biomass for the past 10 years from the preferred model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the preferred model in the terminal year with 95% credible intervals from MCMC (bottom).

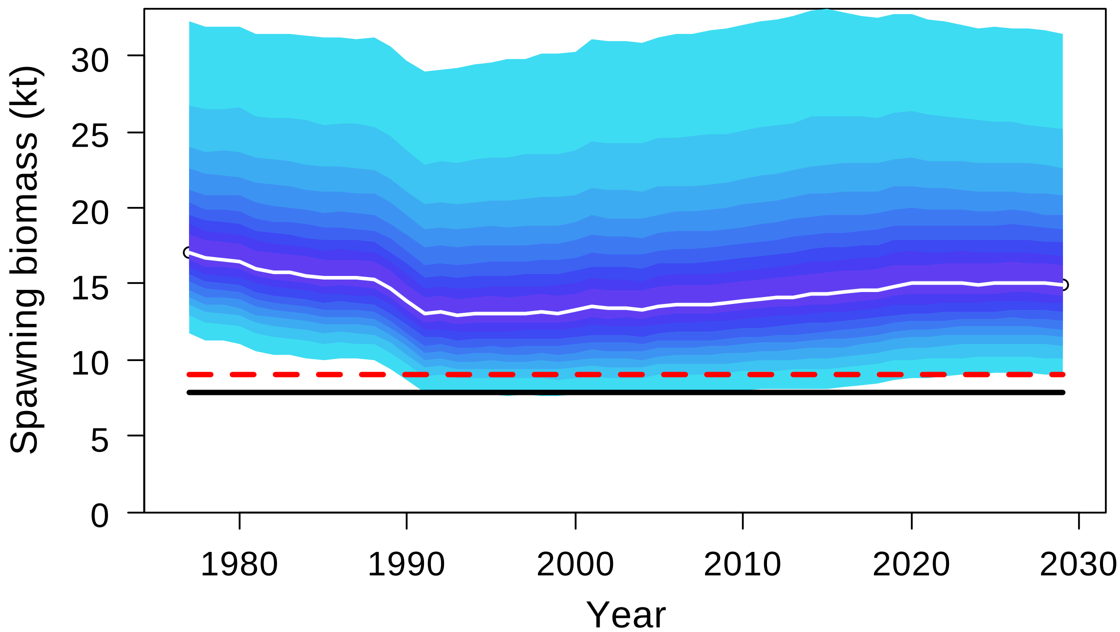


Figure 13-22: Bayesian credible intervals for entire spawning stock biomass series including projections through 2029. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1980-2012. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

Appendix 13A. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities (Table 13A-1). This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For Gulf of Alaska (GOA) rougheye and blackspotted (RE/BS) rockfish stock, these estimates can be compared to the research removals reported in previous assessments (Shotwell et al. 2009, Shotwell et al. 2011). The majority of research removals are taken by the Alaska Fisheries Science Center's (AFSC) biennial bottom trawl survey and by the AFSC's longline survey and International Pacific Halibut Commission's (IPHC) longline survey. Other research activities that harvest RE/BS rockfish are minor but include other trawl research activities, scallop dredge, and recreational harvests.

Although data are not available for a complete accounting of all research catches, the values in Table 13A-1 indicate that generally RE/BS stock research removals have been modest relative to the fishery catch and compared to the research removals for many other species. The exceptions are in 1998 and 1999 where a total of 52 and 36 t, respectively were taken, mostly by research trawling. However, because commercial catches for the shortraker/rougheye rockfish complex during these years were below ABC (please refer to Table 13-3 in the main document) this relatively large catch was not a conservation concern. Total removals from activities other than a directed fishery were 6 t in 2013. This is 0.5% of the 2013 recommended ABC of 1,232 t and represents a low risk to the RE/BS stock. Research harvests dominate this with three major surveys taking significant amounts of RE/BS rockfish. Even research catches of this magnitude, however, do not pose a significant risk to the RE/BS stock in the GOA.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between "retained" or "discarded" catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery will become available following restructuring of the FMA Program in 2013. At this time all vessels greater than 25 ft will be monitored for groundfish catch.

The HFICE estimates of GOA RE/BS stock catch are highly variable but also significant ranging from 28 – 78 t per year (Table 13A-2). The majority of catch occurs in the Southeast and Southeast Inside waters. It should be noted that Southeast Inside waters are managed by the State of Alaska and catches from these areas are generally not included in groundfish assessments in the Gulf of Alaska Federal Management Plan. It is unknown what level of RE/BS catch is double-counted in these estimates and the Catch Accounting System. Regardless, the estimated catch from the unobserved halibut fishery is substantial and improved catch estimates from this fishery are warranted.

Literature Cited

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Shotwell, S.K., D. Hanselman, and D. Clausen. 2009. Gulf of Alaska rougheye rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. pp. 993-1066.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 13A-1. Total removals of Gulf of Alaska rougheye/blackspotted rockfish (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, large-mesh, GOA bottom trawl surveys, and occasional short-term research projects. Longline is the IPHC and AFSC longline surveys. Other includes personal use, recreational, scallop dredge, and subsistence harvest.

Year	Source	Trawl	Longline	Other	Total
1977		1			1
1978		2			2
1979		1			1
1980		1			1
1981		6			6
1982		3			3
1983		3			3
1984		17			17
1985		7			7
1986		2			2
1987		13			13
1988		0			0
1989		1			1
1990		5			5
1991		0			0
1992		0			0
1993	**Assessment of RE/BS stock complex in the Gulf of Alaska (Shotwell et al. 2009)**	10			10
1994		0			0
1995		0			0
1996		5	8		13
1997		0	16		16
1998		45	7		52
1999		28	8		36
2000		0	10		10
2001		2	7		9
2002		0	6		6
2003		3	6		9
2004		0	6		6
2005		5	4		9
2006		0	5		5
2007		8	7		15
2008		0	11		11
2009		6	9		15
2010	AKRO	<1	7	<1	7
2011	AKRO	<1	6	<1	8
2012	AKRO	2	5	<1	6
2013	AKRO	2	4	<1	6

Table 13A-2. Estimates of Gulf of Alaska RE/BS stock catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WGOA	<1	4	7	1	5	3	2	5	3	<1
CGOA-Shumagin	<1	2	1	<1	3	<1	<1	<1	6	1
CGOA-Kodiak	4	<1	6	8	1	9	<1	7	28	22
EGOA-Yakutat/PWS*	<1	<1	<1	4	2	5	3	5	7	12
EGOA-Southeast	2	18	9	14	15	8	11	9	6	7
Southeast Inside*	21	29	31	24	51	19	31	11	7	4
Total	28	53	54	51	78	44	46	37	56	46

*These areas include removals from the state of Alaska waters.

14: ASSESSMENT OF THE DEMERSAL SHELF ROCKFISH STOCK COMPLEX IN THE SOUTHEAST OUTSIDE DISTRICT OF THE GULF OF ALASKA

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Executive Summary

The demersal shelf rockfish (DSR) complex (yelloweye, quillback, copper, rosethorn, canary, China, and tiger rockfish) (Table 1) is assessed on a biennial cycle, with full stock assessments typically conducted in odd calendar years, however we are presenting a full stock assessment this year to coincide with new survey data and the development of a new model. Historically, the stock assessment was based on relative abundance estimates from a manned submersible (*Delta*), however as of 2010, the submersible was retired from use. No surveys were conducted in 2010 and 2011 while an alternate vehicle was sought. In 2012, we transitioned the survey from a submersible to a remote operated vehicle (ROV), and conducted stock assessment surveys in 2012 and 2013. In 2014, we planned to conduct a survey but had to cancel due to weather. The acceptable biological catch (ABC) and overfishing level (OFL) for this year's SAFE (Table 2) are based on the most recent ROV and submersible density estimates of yelloweye rockfish in each management area using our historical methodology (Brylinsky et al. 2009). However, the results of a preliminary statistical age-structured model, which incorporates submersible and ROV yelloweye rockfish density estimates, commercial, sport, and subsistence fishery data, and International Pacific Halibut Commission (IPHC) survey data, are presented in Appendix B.

Summary of Changes in Assessment Inputs

Changes in the input data:

Catch information and average weights for yelloweye rockfish catch from the commercial fishery were updated for 2014. Average weight of yelloweye rockfish changed from 4.06 kg to 3.69 kg in East Yakutat (EYKT), from 3.19 kg to 3.34 kg in Central Southeast Outside (CSEO), and 3.24 to 3.68 kg in Northern Southeast Outside (NSEO). There was not a directed fishery in Southern Southeast Outside (SSEO) and no samples were taken from bycatch in the halibut fishery in this area so average weight from 2013 was used (3.53 kg).

Yelloweye rockfish density was derived from the most recent survey data for all management areas (Table 3) with the exception of NSEO. The 2012 CSEO density estimate was used as a proxy for the NSEO area, as the last time it was surveyed with a sufficient sample size was in 1994. NSEO is a small management area directly adjacent to CSEO, and should have similar habitat attributes, and yelloweye rockfish recruitment potential as CSEO. Fishing pressure in NSEO is likely slightly less than in CSEO as there has not been a directed fishery since 1995, however, like the other management areas, incidental catch of DSR in the halibut fishery is the primary source of commercial mortality. Yelloweye rockfish density was also updated in this stock assessment for SSEO using the 2013 survey data (ROV-derived). DSR habitat area was updated for this stock assessment based on the best available information from fishery logbooks, side scan, and multibeam data.

Changes in the assessment methodology:

There are no changes to the assessment methodology data from the previous habitat-based assessment using submersible and ROV density estimates as the primary survey data.

However, a preliminary area-specific age-structured assessment model is presented in Appendix B. The data used in the age-structured assessment model consist of total annual catch (tons) from the directed DSR commercial fishery in the four SEO management areas through 2014 (Table 1; Appendix B), age composition data from the commercial fisheries (directed and incidental from the halibut fishery) through 2013 and projected catch for 2014, total annual catch from the commercial longline halibut fishery through 2013 (Appendix B), estimates of yelloweye density (individuals per square kilometer) derived from submersible and ROV surveys through 2013 (Table 3; Appendix B), updated estimates of total rockfish habitat per management area in square kilometers derived from sonar, sounding, and fishery data (Table 4; Appendix B), recreational harvest, IPHC survey relative abundance through 2013, and historical estimates of length, weight, and maturity composition derived from commercial fisheries data.

Summary of Results

DSR are managed under Tier 4 of North Pacific Fishery Management Council (NPFMC) harvest rules, where maximum allowable $F_{ABC} \leq F_{40\%}$ and $F_{OFL}=F_{35\%}$. The maximum allowable ABC for 2015 is 293 t based on Tier 4 status for DSR. DSR are particularly vulnerable to overfishing given their longevity, late maturation, and habitat-specific residency. As in previous years, we recommend a harvest rate lower than the maximum allowed under Tier 4; F=M=0.02. This results in an author's recommended ABC of 225 t for 2015, a decrease from the 2014 ABC of 274 t. The overfishing level (OFL) is set using $F_{35\%}=0.032$; which is 361 t for 2015. The ABC and OFL are calculated after adjusting for the non-yelloweye rockfish species landed in the complex.

Per the 2009 Board of Fisheries (BOF) decision, subsistence DSR removals are deducted off the ABC prior to the allocation of the total allowable catch (TAC) between the commercial and sport fisheries. In the current assessment, 8 t was deducted from the ABC for DSR caught in the subsistence fisheries, for a TAC of 217 t. In 2006 the BOF allocated the SEO DSR TAC in the following manner: 84% to the commercial fishery and 16% to the sport fishery. Thus 182 t is allocated to commercial fisheries, and 35 t is allocated to sport fisheries for 2015.

Reference values for DSR are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not subjected to overfishing last year.

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)	0.02	0.02	0.02	0.02
Tier	4	4	4	4
Yelloweye Biomass (t)	13,274		10,933	
$F_{OFL}=F_{35\%}$	0.032	0.032	0.032	0.032
$maxF_{ABC}$	0.026	0.026	0.026	0.026
Specified/recommended F_{ABC}	**0.020**	**0.020**	**0.020**	**0.020**
Total DSR ABC (Yelloweye ABC/0.97) (t) [1]	274		225	
Total DSR OFL (Yelloweye OFL/0.97) (t) [1]	438		361	
Total DSR max ABC (t)	**356**		**293**	
Status	As determined last year for: 2012	2013	As determined this year for: 2013	2014
Is the stock being subjected to overfishing?	No	n/a	No	n/a

[1] The DSR ABC and OFL were increased by 3% as the previous year's commercial catch is used to determine the percentage of non-yelloweye DSR.

Updated catch data (t) for DSR in the Gulf of Alaska as of October 19, 2014 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org are summarized in the following table.

Year	EGOA Catch Total[1]	EGOA ABC	EGOA TAC[1]
2013	212	303	224
2014	93	274	182

[1] TAC and Catch are for the commercial fishery only. The recreational harvest for the SEO (16% of the ABC after the subsistence harvest removal, or 35 mt) was 34 t in 2014 and is projected to be 34 t in 2015.

Area Apportionment

The ABC and OFL for DSR are for the SEO Subdistrict. The State of Alaska manages DSR in the Eastern regulatory area with Council oversight and any further apportionment within the SEO Subdistrict is at the discretion of the State.

Summaries for Plan Team

Species	Year	Biomass	OFL	ABC	TAC[1]	Catch[2]
	2012	14,307	467	293	240	180
	2013	14,588	487	303	249	212
	2014	13,274	438	274	224	93[2]
	2015	10,933	361	225	182	

[1] TAC and Catch are for the commercial fishery only. The TAC is calculated after the subsistence projected catch is deducted from the ABC. The estimated recreational catch was 34 t for 2014.

[2]Updated commercial catch data (t) for demersal shelf rockfish in the Southern Outside District as of October 19, 2014.

Responses to SSC and Plan Team Comments on Assessments in General

The SSC supports the GOA Plan Team recommendation that there should be an investigation into the use of different survey averaging methods, particularly with respect to estimates for species complexes. The SSC requests that both Plan Teams note when area ABCs have been exceeded in the prior year. For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014.

The SSC noted that different stock assessment scientists often use different methods for catch estimation to estimate catches between late October and December 31 of the current assessment year, as well as catches to be taken during the following two years for use in the catch specification process. The SSC understands that Dana Hanselman will compile the various methods in use. The SSC looks forward to Plan Team advice on the merits of the various alternatives.

We also look forward to these data. Currently, since the directed DSR fisheries are completed by March, and the DSR bycatch in the halibut fishery is usually completed by early November, we have been simply running the final catch numbers in early November and assuming that is the final catch for the calendar year. Very little (<2 t) DSR catch is reported after early November.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The SSC looks forward to preliminary results of the age-structured model next year and asks that the authors evaluate and include IPHC survey data as one of the data inputs. The SSC also looks forward to seeing the results of the final report by Yoklavich et al. comparing fish abundances derived from an ROV versus a submersible. The SSC shares the Plan Team's concern regarding the decreasing biomass trend in CSEO and agrees that the evaluation of catch trends in CSEO compared to other areas may be helpful."

We present the preliminary ASA model in this document in Appendix B, including the IPHC survey data for the Plan Team and SSC's review. We also present the commercial catch per unit effort (CPUE) to compare catch trends in CSEO compared to other areas. There have not been any new published results from the ROV/submersible comparison work done by Yoklavich et al. (2013) but we will continue to keep appraised of the latest ROV and submersible research.

"For September, the Team recommends the authors present preliminary results of the age structured model if available. Contingent on the working group's efforts on the random effects model, the authors may consider including the results of the random effects model incorporating the new recommendations. The Team also recommends that recreational harvest (16% of the allocation) be footnoted in the catch table of the assessment to reflect the total DSR catch and to help clarify apportionments."

We present the preliminary ASA model in this document, including the IPHC survey data for the Plan Team and SSC's review. The random effects model has not, at this time, been incorporated into the stock assessment for 2015, but we await the Plan Team review in September. We added the recreational harvest to the catch table in a footnote per the Plan Team's request.

Introduction

Biology and Distribution

Rockfishes of the genus *Sebastes* are found in temperate waters of the continental shelf off North America. At least thirty-two species of *Sebastes* occur in the Gulf of Alaska. The DSR assemblage is comprised of the seven species of nearshore, bottom-dwelling rockfishes (Table 1). These fish are located on the continental shelf, reside on or near the bottom, and are generally associated with rugged, rocky habitat. For purposes of this report, emphasis is placed on yelloweye rockfish, as it is the dominant species in the DSR fishery (O'Connell and Brylinsky 2003).

All DSR are considered highly K-selective, exhibiting slow growth and extreme longevity (Adams 1980, Gunderson 1980, Archibald et al. 1981). Estimates of natural mortality are very low. These types of fishes are very susceptible to over-exploitation and are slow to recover once driven below the level of sustainable yield (Leaman and Beamish 1984, Francis 1985). An acceptable exploitation rate is assumed to be very low (Dorn 2000).

Management Units

Prior to 1992, DSR was recognized as a Fishery Management Plan (FMP) assemblage only in the waters east of 137^o W. longitude. In 1992, DSR was recognized in EYKT, and management of DSR extended westward to 140^o W. longitude. This area is referred to as the Southeast Outside (SEO) Subdistrict and is comprised of four management sections: EYKT, NSEO, CSEO, and SSEO. In the SEO, the State of Alaska and the National Marine Fisheries Service (NMFS) manage DSR jointly. The two internal state water Subdistricts, Northern Southeast Inside (NSEI) and Southern Southeast Inside (SSEI) are managed entirely by the State of Alaska and are not included in this stock assessment (Figure 1). Please see Appendix A for a more complete description of historical DSR management changes.

Stock structure

Siegle et al. 2013 detected subtle population genetic structure in yelloweye rockfish from the outer British Columbia coast and inner waters, but a lack of genetic structure on the outer coast (between the Bowie Seamount and other coastal locations in British Columbia). These data suggest that due to the long pelagic larval duration for *Sebastes* spp. (several months to one year) there is not significant genetic stock structure for the DSR complex in the SEO management area. However, additional life history data analyses at finer spatial scales are needed to evaluate DSR stock structure in the Eastern GOA. In addition, the limited movements of yelloweye rockfish can lead to serial depletion of localized areas if overharvest occurs.

Life History

Rockfishes are considered viviparous although different species have different maternal contribution (Boehlert and Yoklavich 1984, Boehlert et al. 1986, Love et al. 2002). Rockfishes have internal fertilization with several months separating copulation, fertilization, and parturition. Within the DSR species complex, parturition occurs from February through September with the majority of species extruding larvae in spring. Yelloweye rockfish extrude larvae over an extended time period, with the peak period of parturition occurring in April and May in Southeast Alaska (O'Connell 1987). Although some species of *Sebastes* have been reported to spawn more than once per year in other areas (Love et al. 1990), no incidence of multiple brooding has been noted in Southeast Alaska (O'Connell 1987).

Rockfishes have a closed swim bladder that makes them susceptible to embolism mortality when brought to the surface from depth. Full retention regulations for the commercial fleet have been in place since 2005. Full retention of DSR had been required for the recreational fleet, but beginning in the 2013 season, all charter operators in Southeast Alaska were required to possess and utilize deep-water release devices for releasing non-pelagic (i.e. DSR) rockfish. Historically, release mortality biomass has been estimated using the assumption that released rockfish experience 100% mortality (Green et al. 2013).

Fishery

Description of directed fishery

The directed fishery for DSR began in 1979 as a small, shore-based, hook and line fishery in Southeast Alaska. This fishery targeted the nearshore, bottom-dwelling component of the rockfish complex, with fishing occurring primarily inside the 110 m contour. The early directed fishery targeted the entire DSR complex (Table 1), which at that time also included silvergray, bocaccio, and redstripe rockfish (Appendix A). In more recent years the fishery has targeted yelloweye rockfish and fished primarily between the 90 m and the 200 m contours. Over the past five years, yelloweye rockfish accounted for 96 to 98% (by weight) of the total DSR catch (Table 5). Quillback rockfish are the next most common species landed in the complex, accounting for approximately 2% of the landed catch between 2009 and 2013 (Table 5). The directed fishery is prosecuted almost exclusively by longline gear. Although snap-on longline gear was originally used in this fishery, most vessels now use conventional (fixed-hook) longline gear. Markets for this product are domestic fresh markets and fish are generally brought in whole, bled, and iced. Processors will not accept fish delivered more than three days after being caught.

In SEO, regulations stipulate one season only for directed fishing for DSR opening January 5th (unless closed by emergency order) and continuing until the allocation is landed or until the day before the start of the IFQ halibut season (to prevent over-harvest of DSR), whichever comes first. The directed DSR fleet requested a winter fishery, as the ex-vessel price is highest at that time. Directed fisheries are opened by management area if there is sufficient commercial TAC remaining after subtracting the estimated DSR incidental catch in other fisheries.

Description of Effort and CPUE

Figure 14 in Appendix B discusses the CPUE for each of three of the four management areas since 1997, when the commercial logbook program became mandatory. There has not been directed fishery in the

NSEO area since 2001; thus it is not shown. Prior to the logbook requirement, the department did not have access to location and effort by set from the commercial fishery. Some fishermen kept logbooks voluntarily, but this was not required.

Catch History

Although the DSR fishery has been active since the late 1970s, catch reconstruction for DSR prior to 1992 is problematic due to changes in the species assemblage as well as the lack of a directed fishery harvest card prior to 1990 for CSEO, SSEO, and NSEO, and 1992 for EYKT (Appendix A). Thus, the history of domestic landings of DSR from SEO is shown from 1992–2014 in Table 2. The directed DSR catch in SEO was above 350 mt in the mid-1990s. Since 1998, landings have been below 250 mt, and since 2005, directed landings have typically been less than 100 mt. During the reported years (1992 to 2014), total catches peaked at 604 mt in 1994, and directed catch peaked at 381 mt in 1994. Although directed landings were higher in the 1990s, since 2000, most of the DSR total reported catch is from incidental catch of DSR in the halibut fishery. It should be emphasized, however, that prior to 2005, unreported mortality from incidental catch of DSR associated with the halibut and other non-directed fisheries is unknown and may have been as great as a few hundred tons annually. Directed commercial fishery landings have often been constrained by other fishery management actions. In 1992, the directed DSR fishery was allotted a separate halibut prohibited species cap (PSC) and is therefore no longer affected when the PSC is met for other longline fisheries in the GOA. In 1993, the fall directed fishery was closed early due to an unanticipated increase in DSR incidental catch during the fall halibut fishery.

Directed fisheries are held in the four management areas (EYKT, NSEO, SSEO, and CSEO) if there is sufficient quota available after the DSR mortality in other commercial fisheries (primarily the IFQ halibut fishery) is estimated. The directed fishery in NSEO has been closed since 1995; the total allocation for this management area has not been sufficient to prosecute an orderly fishery. The directed commercial DSR fisheries in the CSEO and SSEO management areas were not opened in 2005 because it was estimated that total mortality in the sport fishery was significant and combined with the directed commercial fishery would likely result in exceeding the TAC. No directed fisheries occurred in 2006 or 2007 in the SEO district as ADFG took action in two areas; one was to enact management measures to keep the catch of DSR in the sport fishery to the levels mandated by the BOF, and the other was to further compare the estimations of incidental catch in the halibut fishery to the actual landings from full retention regulations in the commercial fishery in those years to see how closely our predicted incidental catch matched the landed catch. Between 2006 and 2013, there was sufficient quota to hold directed commercial fisheries in at least two of the four SEO management areas. In 2014, only the EYKT area was opened to directed fishing.

DSR mortality in other fisheries

DSR have been taken as incidental catch in domestic longline fisheries, particularly the halibut fishery, for over 100 years. Some incidental catch was also landed by foreign longline and trawl vessels targeting slope rockfish in the EGOA from the late 1960s through the mid-1970s. Other sources of DSR incidental commercial catch are the lingcod, Pacific cod, and sablefish fisheries; however the halibut longline fishery is the most significant contributor to the commercial mortality of DSR.

In 1998 the NPFMC passed an amendment to require full retention of DSR in federal waters. Seven years later, in mid-season 2005, the final rule was published and fishermen must now retain and report all DSR caught in federal waters; any poundage above the 10% incidental catch allowance may be donated or kept for personal use but may not enter commerce. In July of 2000, the State of Alaska enacted a parallel regulation requiring DSR landed in state waters of Southeast Alaska to be retained and reported on fish tickets. Proceeds from the sale of DSR in excess of legal sale limits are forfeited to the State of Alaska.

Since the implementation of the state and federal full retention regulations for DSR, over 95% of the landed overages of DSR in the state and federal waters are now retained for personal use rather than being donated or sold. There appears to be increasing compliance with the full retention. In addition, the Alaska Longline Fishermen's Association has developed a database of rockfish "hotspots" so that halibut and sablefish longline fishermen can avoid making sets in these areas in an effort to reduce rockfish incidental catch.

The DSR mortality anticipated in the halibut fishery needs to be deducted from the total commercial TAC before a directed fishery can be prosecuted. From 2006 to 2011, we estimated the amount of DSR incidental catch in the halibut fishery using the IPHC stock assessment survey data to determine the weight ratio of yelloweye rockfish to halibut by depth and area. The yelloweye/halibut weight ratio by strata was applied to the IPHC halibut catch limit by strata. For a complete description of estimating the incidental catch of DSR in the halibut fishery prior to 2011, please see Brylinsky et al. (2009). Since 2012, we have used full retention data to calculate the ratio of DSR to halibut landed in the halibut fishery, by management area, and applied this to the estimated halibut quota, to project DSR incidental mortality. The results of this analysis showed that on an annual basis, the commercial fleet incidental catch rate was consistent (8 to 10%) over a five year period, while the IPHC survey incidental catch rate was highly variable by strata and year (ranging from 3 to 20%). An additional 10% is added to the estimation preseason for unreported incidental catch. Our modeled estimates using the full retention data are accurate when compared to actual catch.

Discards in the directed DSR Fishery

Discards in the directed DSR fishery include lingcod, Pacific cod, spiny dogfish, skates, and other rockfishes (Table 6). The magnitude of at-sea discard in the directed DSR fishery is difficult to quantify, as the fleet was unobserved until 2013, when the observer program was expanded to the small boat fleet in Southeast Alaska. Logbook data indicate that the primary discards were halibut and small numbers of lingcod and skates when fishermen reached their incidental catch allowance for those species.

Other removals

Other removals (subsistence, recreational, and research catch) are documented in Table 2. In July 2009, the ADF&G Division of Subsistence published the results of a study done to estimate the subsistence harvest of rockfish near four Alaskan communities, one of which was Sitka (Turek et al. 2009). ADF&G Subsistence Division conducted a call-out survey of "high harvesting households" to obtain additional information on the species composition of subsistence-caught rockfish. This survey revealed that 50% of the rockfish harvested are DSR species, predominantly quillback rockfish. These "high harvesting households" fished predominantly in the Sitka Local Area Management Plan (LAMP) area. The DSR subsistence harvest is reported in numbers of fish by location (northern southeast, southern southeast, and the Sitka LAMP area); these data are converted to biomass using the average weights provided from creel sampled recreational harvest. For 2015 estimates, the voluntary mail survey indicated 9,116 rockfish (not defined by species) had been taken in the EGOA subsistence fisheries.[1] Applying the data methodology described above to make a prediction about what might be taken in the subsistence fishery in 2015, the total anticipated harvest is 8 t.

Small research catches of yelloweye rockfish occur during the annual IPHC longline survey (Table 2). Research catch data are based on yelloweye rockfish reported on fish tickets from the IPHC survey. These are deducted, by management area, from the TAC prior to the opening of the directed commercial fishery.

Sport Fishery Removals

The Alaska Board of Fisheries currently allocates 16% of the DSR TAC for the Southeast Outside District to the recreational fishery after deduction of the estimated subsistence harvest. The sport fishery allocation includes estimated harvest and release mortality. Prior to 2006, the daily bag limit in the Southeast Alaska sport fishery for nonpelagic (DSR and slope/other) rockfish was 3 to 5 fish, depending upon the area fished, and there were no annual limits on any rockfish species. Since then, the board has established management provisions that may be implemented by the department on an annual basis to manage the sport fishery within the allocation. Sport fishery regulations for the Southeast outside waters in 2013 and 2014 were as follows:

1. For resident anglers, the daily bag limit was two nonpelagic rockfish, only one of which could be a yelloweye rockfish; the possession limit was four nonpelagic rockfish, only two of which could be yelloweye.
2. For nonresident anglers, the daily bag limit was two nonpelagic rockfish, only one of which could be a yelloweye; the possession limit was four nonpelagic rockfish, only one of which could be a yelloweye. In addition, nonresidents were restricted to one yelloweye per year. Immediately upon harvesting a yelloweye, the angler was required to log the harvest in ink on the back of their fishing license or on a nontransferable harvest record.
3. All nonpelagic rockfish caught were required to be retained until the angler's daily bag limit was reached.
4. Guides and crew members were not allowed to retain nonpelagic rockfish when clients were on board the vessel.

In addition, effective January 1, 2013, all nonpelagic rockfish released from a charter vessel are required to be released with a deepwater release device at the depth of capture or at a depth of at least 100 feet. All charter vessels are required to have at least one functional deepwater release device on board, have it readily available for use while anglers are fishing, and present it for inspection upon request by department or enforcement personnel.

Data sources for the recreational fishery include the ADF&G statewide harvest survey (SWHS), mandatory charter logbooks, and interview and biological sampling data from dockside surveys in major ports throughout Southeast Alaska. The SWHS is an annual mail survey sent to a stratified random sample of approximately 45,000 households containing resident and nonresident licensed anglers. The survey provides estimates of harvest and catch (kept plus released) in numbers of fish, for all rockfish species combined. Up to three questionnaires may be mailed to unresponsive households. Responses are

[1] With the exception of the fish reported from the Sitka LAMP area, it cannot be determined how many of DSR were caught in the SEO Subdistrict versus internal state waters.

coded by mailing, which allows adjustments for nonresponse bias. Estimates are provided for SWHS reporting areas, which closely mirror ADF&G Sport Fish management areas.

Logbooks have been mandatory for the charter fishery since 1998. Before 2006, charter logbook data were reported for pelagic and non-pelagic rockfish assemblages. Since 2006 logbooks have required reporting of the numbers of pelagic rockfish, yelloweye rockfish, and all other non-pelagic species kept and released by each individual angler. Charter operators are also required to report the primary ADF&G statistical area for each boat trip.

Creel survey sampling is conducted at public access sites in major ports throughout Southeast Alaska. There is also some sampling of fish landed at private docks and lodges. Prior to 2006, there were no biological data collected by creel samplers beyond species composition of sport-caught rockfish. Length and weight data were collected in 2006 and 2007 to estimate length-weight functions for each species. Only species composition and length have been collected since 2008. The numbers of rockfish kept and released per boat-trip have been collected by DSR species since 2006. The creel survey interviews also include reporting of the primary statistical area fished for each boat trip.

Final estimates of recreational fishery removals used a combination of data from the SWHS, creel survey, and charter logbook. The total removals were estimated as the sum of the mass of the harvest (retained catch) and release mortality. Harvest biomass *HB* was estimated for the outside waters portion of SWHS areas B, D, G, and H, which correspond roughly with the SSEO, CSEO, NSEO, and EYKT groundfish management districts, and summed:

$$HB = \sum_a \sum_c \sum_s \hat{H}_{ac}\, \hat{p}_{ac} \hat{\imath}_{acs} \hat{\hat{w}}_{acs}$$

where:

- $\hat{H}_{ac}$ = the SWHS estimate of the number of rockfish (all species combined) harvested in SWHS area *a* by class *c* (charter or noncharter),
- $\hat{p}_{ac}$ = the estimated proportion of harvest by class *c* from outside waters portion of area *a*,
- $\hat{\imath}_{acs}$ = the estimated proportion of species *s* in the sport harvest of all rockfish by class *c* from the outside waters of area *a*, and
- $\hat{\hat{w}}_{acs}$ = the estimated average round weight of species *s* in the sport harvest by class *c* from outside waters of area *a*.

Because the SWHS areas include inside waters, harvest estimates must be apportioned to obtain the outside waters harvest using $\hat{p}_{ac}$. Neither SWHS estimates nor creel survey interviews are adequate for this apportionment. SWHS reporting locations are not precise enough to identify outside waters, and many survey respondents are too unfamiliar with where they were fishing to report accurately. Creel survey data are precise, but surveys are only conducted in major ports and interviewed anglers may not accurately represent the spatial distribution of total harvest. Logbook data are mandatory and presumably represent a complete census of the charter harvest. Therefore, logbook data were used to apportion both charter and noncharter harvest to outside waters. This proportion is treated as a constant in calculation of variance.

Average weight was estimated for each species by applying species-specific length-weight relationships to length measurements of all harvested fish from outside waters in each SWHS area (Brylinsky et al. 2009).

Release mortality biomass (RB) was estimated by area and species for each class using different methods. For the noncharter sector, the mortality rate of all species of rockfish released was assumed to be 100 percent, and the average weight of released rockfish was assumed to equal the average weight of harvested rockfish for each species. Therefore, release mortality was estimated as a function of harvest biomass and the release rate by SWHS area for the noncharter sector:

$$RB_{Noncharter} = \sum_{a}\sum_{s}\left(\frac{\widehat{HB}_{as}}{1-r_{as}} - \widehat{HB}_{as}\right)$$

where:

$\widehat{HB}_{as}$ = the estimated harvest biomass of species s in SWHS area a by noncharter anglers, and

r_{as} = the proportion of the catch of rockfish species s that was released in area a.

The release rate r_{as} for the noncharter and charter sectors was obtained using charter logbook data from outside waters. Logbook data were used for noncharter sector estimates because SWHS estimates are for all species combined and could not be apportioned to species for the noncharter sector. Creel survey interview data on noncharter fishery releases were spotty and incomplete. Given the similarity in resident (mostly noncharter) and nonresident (mostly charter) bag limits, logbook data were felt to provide a reasonable proxy for release rates in the noncharter fishery.

Starting in 2013, release biomass was estimated for the charter sector taking into account a higher survival rate due to mandatory use of deepwater release devices. There is now substantial evidence that survival of benthic rockfish species is dramatically increased when fish are released at depth (Jarvis and Lowe 2008, Hochhalter and Reed 2011, Hannah et al. 2012, GMT 2014). Point estimates of survival for yelloweye rockfish and other DSR species held in cages for two days ranged from 0.90 to 1.00 (Hannah et al. 2012, Hannah et al. 2014). Hochhalter and Reed (2011) estimated 17-day survival of fish caught and released in the wild at 0.988. The Pacific Fishery Management Council has adopted depth-specific mortality rates for yelloweye, canary rockfish, and cowcod. The mortality rates for yelloweye rockfish are based on 90% confidence limits and range from 0.22 to 0.27 for depths shallower than 50 fathoms, and 0.57 for depths of 50-75 fathoms (GMT 2014). Hochhalter and Reed (2011) captured yelloweye at depths of 18-72 m but were unable to discern an effect of depth of capture on survival.

Based on the above studies, we assumed a mortality rate of 20% for estimation of 2013 and 2014 charter release mortality for DSR species. This rate is higher than most scientific study results for yelloweye rockfish, but is precautionary in order to take into account the lack of depth information for sport-caught fish, expected variation in types of gear used, less than ideal handling, and potential noncompliance with the release requirement. The choice of 20% is somewhat arbitrary and will be adjusted if better information becomes available.

Release mortality biomass RB was estimated for the charter sector as:

$$RB_{Charter} = \sum_{a} \sum_{s} \hat{R}_{as} \widehat{MR} \hat{\bar{w}}_{as}$$

where:

$\hat{R}_{as}$ = the estimated number of rockfish of species *s* released in the outside waters of SWHS area a by charter anglers,

$\widehat{MR}$ = the assumed short-term mortality rate due to capture, handling, and release of demersal shelf rockfish (all species, all depths), and

$\hat{\bar{w}}_{as}$ = the estimated average round weight of species *s* released by charter anglers from outside waters of area a.

As noted above, the assumed mortality rate was 0.20, with a standard error of 0.03. The assumed standard error was "borrowed" from the Pacific Council adopted mortality rates for yelloweye rockfish (GMT 2014). The average weight of harvested rockfish was used as a proxy for the average weight of released rockfish because there are no size data available for rockfish released in the charter fishery. This is not an unreasonable proxy given the requirement that anglers must retain all rockfish until their bag limit is reached.

The number of rockfish released in each area in the equation above (R_{acs}) was estimated as:

$$\hat{R}_{as} = r_{as} \frac{\hat{H}_{as}}{(1 - r_{as})}$$

where $\hat{H}_{as}$ is the estimated charter harvest in SWHS area a of species s, and r_{as} is proportion of rockfish catch by charter anglers that was released, as described above.

As noted previously, SWHS estimates were used to calculate final estimates of the biomass of harvest and release mortality. However, SWHS estimates are not available until September of the year following harvest. In order to produce a preliminary harvest estimate for the current year, the number of rockfish of all species harvested in each SWHS was projected. Charter harvest estimates were projected using regressions of SWHS estimates on partial-year logbook data (through July 31). Regression through the origin was used because some SWHS areas had very little contrast in the harvest estimates, producing insignificant slopes and illogical intercepts. Harvest projections for the noncharter sector were obtained from time series forecasts of SWHS estimates. The Box-Jenkins procedure was used to identify suitable ARIMA models (Box and Jenkins 1976). All models were evaluated using Akaike's Information Criteria corrected for small sample sizes (AICc). For most SWHS areas, no autoregressive or moving average components were identified, leaving the naïve forecast, or the previous year's harvest, as the best model. However, for 2014, a simple exponential smoother (SAS 2011: Proc ESM) produced superior forecasts for all areas. For SWHS Area G (Glacier Bay), rockfish harvest has increased dramatically in the last two years, departing from the previous trend. Therefore, even though the exponential forecast has the lowest AICc, the previous year's harvest was higher and was used for the preliminary estimate in order to be precautionary.

Final estimates of 2013 sport fishery removals and preliminary estimate of 2014 removals (in mt) are as follows:

Type of Estimate		***2013***	***2014***
Retained Harvest	Estimate	31.4	32.8
	StdErr	1.4	1.7
	95% CI[a]	28.6-34.2	29.4-36.2
Release Mortality	Estimate	2.3	1.5
	StdErr	0.2	0.1
	95% CI[a]	1.8-2.7	1.2-1.8
Total	**Estimate**	**33.6**	**34.3**
	StdErr	1.6	1.8
	95% CI[a]	30.5-36.8	30.8-37.8

Data

Submersible and ROV surveys

ADF&G began conducting a fishery-independent, habitat-based stock assessment for DSR using visual survey techniques to record yelloweye rockfish observations on line transects in rock habitat in 1988. The DSR stock assessment surveys have historically rotated among management areas on a biannual basis; it would be time and cost-prohibitive to survey the entire SEO in one field season due to the large size of the area (Figure 1). Instead, the most recent abundance estimate from a management area is used to update the annual stock assessment for SEO, but four to six years may elapse between surveys (Brylinsky et al. 2009). Between 1988 and 2010, density estimates derived from yelloweye rockfish counts from submersible video observations were extrapolated over the total yelloweye rockfish habitat. Average weight for yelloweye rockfish landed in the halibut and directed commercial fisheries was applied to the density estimate to obtain a biomass estimate for each management area (O'Connell and Carlile 1993, Brylinsky et al. 2009).

In 2012, ADF&G transitioned to using an ROV for visual surveys given the unavailability of a cost-effective and appropriate submersible. ROVs are a low-cost and versatile tool that have been increasingly used to study marine habitats and organisms (e.g. Pacunski et al. 2008). Although the survey vehicle has changed, the basic methodology to perform the stock assessment for the DSR complex remains unchanged. We use a Phantom ROV (HD 2+2) "*Buttercup*" that is owned and operated by ADF&G Central Region. The ROV is outfitted with a pair of high definition machine-vision stereo cameras that are used to record video data from line transects. Two additional cameras are mounted to the ROV, the "main" camera, which is a wide-angle, color camera that the pilot uses to drive the ROV, and a "forward-facing" camera. Two scaling lasers, mounted 10 cm apart and in line with the camera housing, are used as a measurement reference for objects viewed in the non-stereo cameras. However, objects viewed in the stereo cameras are most accurately measured during video review in the stereo camera software viewing package. All stereo camera video data are reviewed and analyzed using SeaGIS software (SeaGIS Pty Ltd., EventMeasure version 3.50). The SeaGIS software is a measurement science software used to log and archive events in digital imagery (Seager 2012).

The initial ROV survey was conducted in 2012 in the CSEO management area. Forty-six transects were conducted, and the resulting yelloweye rockfish density estimate was 752 fish/km^2 with a coefficient of variation (CV) of 13% (Table 3; Figure 2). Ralston et al. (2011) examined stock assessments for 17 data-rich groundfish and coastal pelagic species, and found the mean CV for biomass estimates to be 18%. In this context, a CV of 13% was considered a high level of precision, a view supported by Robson and Regier (1964) and Seber (1982). Although we were not able to compare the ROV results directly with the submersible or account for natural changes in the yelloweye rockfish population between years, the ROV yelloweye rockfish density estimate for 2012 was comparable to previous submersible estimates with a similar magnitude (Figure 3). The ROV was successfully deployed in most weather conditions and able to navigate the seafloor and currents in the preferred direction and orientation for the majority of the planned dive transects. In 2013, 31 transects were successfully surveyed in the SSEO; the density estimate was 986 fish/km^2 (CV=22%). In 2014, we planned to survey EYKT, but had to cancel the survey due to poor weather. Plans are pending to reschedule the survey for May 2015.

Habitat

Visual surveys are conducted only in yelloweye rockfish habitat; which is defined as rock habitat inshore of the 100-fathom depth contour. Seafloor is designated as "rock" based on information from sonar surveys, directed commercial fishery logbook data, and substrate information from NOAA charts. Substrate information obtained from sonar surveys is considered the best information available on rock habitat. In the absence of sonar data, directed commercial fishery logbook data are considered a proxy for rocky habitat (O'Connell and Carlile 1993, Brylinsky et al. 2009). In NSEO management area, where no sonar surveys have been performed and commercial fishery logbook data are limited, yelloweye rockfish habitat was delineated by buffering locations designated as coral, rock, or hard seafloor on NOAA charts by 0.5 miles. Locations were only considered preferred yelloweye rockfish habitat if <100 and ≥35 fm; this criterion was based on observations from the submersible that indicated that 90% of yelloweye rockfish were recorded between those depths.

Seafloor mapping has been performed across 3,058 km^2 of SEO (Figure 3). Backscatter data have been collected during side scan and multibeam surveys and comprehensive bathymetry data during multibeam surveys with some limited bathymetric soundings collected during side scan surveys. Seafloor has been classified into habitat type by Moss Landings Marine Laboratories' Center for Habitat Studies using bathymetry, backscatter, and direct observations from the *Delta* submersible and reduced to substrate induration of soft, mixed, or hard (Greene et al. 1999). Seafloor identified as hard substrate is considered yelloweye rockfish habitat.

In CSEO management area, 832 km^2 have been surveyed with 442 km^2 of this area considered rocky habitat (Table 4). A side scan survey covering 538 km^2 was performed west of Cape Edgecumbe (located on Kruzof Island) in 1996 (Figure 3), and in 2005, a high resolution 8 km^2 multibeam survey, which encompasses the Pinnacles Marine Reserve, was performed within the southern portion of the area originally side scanned. In 2001, a 294 km^2 area west of Cape Ommaney (located on the southern tip of Baranof Island) was surveyed.

In EYKT management area, 1,072 km^2 have been surveyed on the Fairweather grounds with 500 km^2 of this area composed of rocky habitat. A total of 784 km^2 were side scanned on the west bank in 1998 and 288 km^2 multibeamed on the east bank in 2002 and 2004 (Table 4).

In SSEO management area, 1,154 km^2 have been multibeamed, with 322 km^2 considered rocky habitat. Multibeam surveys have been performed around the Hazy Islands west of Coronation Island in 2001 (400 km^2), west of Cape Addington on Noyes Island in 2006 (84 km^2), at Learmonth Bank in Dixon Entrance in 2008 (530 km^2), and south of Cape Felix on Suemez Island in 2010 (140 km^2) (Table 4; Figure 3).

For areas without seafloor mapping information, we delineate rocky habitat using directed commercial fishery logbook data. Locations where catch per unit effort is $\geq$ 0.04 yelloweye rockfish per hook are considered preferred yelloweye rockfish habitat. Longline sets with only start positions are buffered by 0.5 miles (this established buffer size was retained for consistency). Starting in 2003, fishermen were required to include both start and end set positions; sets with both locations are buffered 0.5 km around the entire track. This buffering criterion was based on the minimum range of travel of four yelloweye rockfish tagged with transmitters in Oregon (P. Rankin, Oregon Department of Fish and Wildlife, personal communication). Buffered logbook sets were merged, and segments were included in the delineated habitat if $\geq$2,300 m in length (to ensure rocky segments were large enough for two non-overlapping submersible transects). To consider habitat segments as "continuous", no gaps > 0.5 nautical miles were allowed.

Total yelloweye rockfish habitat is estimated for SEO at 3,892 km^2. The Fairweather grounds in EYKT management area composes 739 km^2 of rocky habitat with 68% derived from sonar; CSEO management area is composed of 1,661 km^2 rocky habitat with 27% from sonar; SSEO composed of 1,056 km^2 of rock with 30% from sonar; and NSEO with 436 km^2 rock with no sonar surveys performed in this area (Table 4). Rock habitat not derived from sonar is defined based on fishery logbook data.

Analytic approach

Distance sampling methodology is used to estimate yelloweye rockfish density from ROV and submersible surveys. Density estimates are limited to adult and subadult yelloweye rockfish, the principal species targeted and caught in the directed DSR fishery, and our ABC recommendations for the entire assemblage are based on adult yelloweye biomass. Biomass of adult yelloweye rockfish is derived as the product of estimated density, the estimate of rocky habitat within the 200 m contour, and average weight of fish for each management area. Variances are estimated for the density and weight parameters but not for area. Estimation of both transect line lengths and total area of rocky habitat are difficult and contribute to the uncertainty in the biomass estimates. As a result of this uncertainty in the habitat area estimation, the lower 90% confidence interval of the biomass estimate is used to calculate the ABC.

Yelloweye Rockfish Density Estimates from Submersible Surveys (1988-2009)
In a typical submersible dive, two transects were completed per dive with each transect lasting 30 minutes. During each transect, the submersible pilot attempted to maintain a constant speed of 0.5 km and to remain within 1 m of the bottom, terrain permitting. A predetermined compass heading was used to orient each transect line. Line transect sampling entails counting objects on both sides of a transect line. Due to the configuration of the submersible, with primary view ports and imaging equipment on the starboard side, we only counted fish on the right side of the line. All fish observed from the starboard port were individually counted and their perpendicular distance from the transect line recorded (Buckland et al. 1993). An externally mounted video camera was used on the starboard side to record both habitat and audio observations. In 1995, a second video camera was mounted in a forward-facing position. This camera was used to ensure 100% detectability of yelloweye rockfish on the transect line, a critical assumption when using line transect sampling to estimate density. The forward camera also enabled counts of fish that avoided the sub as the sub approached and removals of fish that swam into the transect from the left side because of interaction with the submersible. Yelloweye rockfish have distinct coloration differences between juveniles, subadults, and adults, so these observations were recorded separately.

Hand-held sonar guns were used to calibrate observer estimates of perpendicular distances. It was not practical to make a sonar gun confirmation for every fish. Observers calibrated their eye to making visual estimates of distance using the sonar gun to measure the distance to stationary objects (e.g. rocks) at the beginning of each dive prior to running the transect and between transects.

Yelloweye Rockfish Density Estimates from ROV Surveys (2012-present)
Random dive locations for line transects (Figure 4) are selected in preferred yelloweye rockfish habitat using ArcGIS. Random locations were removed from the survey design if they were in depths ≥200 m, which is the maximum operating depth for the ROV. Transects of 1-km length were mapped at each suitable random point with four possible orientations along the cardinal directions and crossing through the random point (Figure 5). A transect length of 1-km was selected after consideration of visual surveys conducted by other agencies (personal communication, Robert Pacunski, WDFW, Mike Byerly, ADF&G), the encounter rate of yelloweye rockfish based on our previous surveys, and ROV pilot fatigue. The number of planned transects was based on yelloweye rockfish encounter rates from previous surveys and our targeted precision (CVs of less than 15%).

Transect Line Lengths – Submersible
Beginning in 1997, we positioned the support ship directly over the submersible at five-minute time intervals and used the corresponding Differential Global Positioning System (DGPS) fixes to determine line length. In 2003 the submersible tracking system was equipped with a gyro compass, enabling more accurate tracking of the submersible without positioning the vessel over the submersible. In 2007 and 2009, in addition to collecting the position of the submersible using five minute time intervals, we also collected position data every 2 seconds using the WinFrog tracking software provided by *Delta*. Outliers were identified in the WinFrog data by calculating the rate of travel between submersible locations. The destination record was removed if the rate of travel was greater than 2 meters per second. In 2007, a 9-

point running average was used to smooth the edited WinFrog data and then smoothed data were visually examined in ArcGIS. If any additional irregularities in data were observed, such as loops or back tracks, then these anomalies were removed and the data resmoothed. After a 27-point smoother was applied to the data, these smoothed line transects were examined in ArcGIS. If any irregularities still existed in the line transects that were thought to be misrepresentations of the actual submersible movements, then these anomalies were edited out of the line transect and the line transect data were resmoothed.

Transect Line Lengths - ROV

Transect line length is estimated by editing ROV tracking data generated from Hypack software. Tracking data are filtered for outliers using Hypack® singlebeam editor (positioning errors are removed and data are filled in to one second intervals using linear interpolation). Video data are "pre-reviewed" to remove any video segments where poor visbility would obscure yelloweye rockfish observations or when the ROV was not moving forward (i.e. stalled, or stopped due to some logistical problem). Navigation data are mapped in ArcGIS after treatment with a smoothing spline and video quality segments are overlaid navigation data using linear referencing. The total line length for each transect is estimated using the good quality video segments only.

Video Review-Submersible

The side facing and forward facing video from the submersible dives were reviewed post-dive while listening to the verbal recording made by the scientist-observer in the submersible. The audio transcript includes the scientist's observations of the species observed, and each individual fish's distance away from the submersible. These data are recorded in the database, as well as any additional yelloweye rockfish seen in either video camera that the observer may have missed while underwater. The observer is able to see farther out the window than the camera field of view, thus the verbal transcript is critical for data collection.

Video Review-ROV

Fish are recorded on the right and left side of the "center line" of the line transect when reviewing video within the SeaGIS Event Measure software (Figure 6). The video reviewer will identify and enumerate yelloweye rockfish for density estimation, and other DSR, lingcod, halibut and other large-bodied fish, as time allows, for species composition. Fish total length will be recorded for individual yelloweye rockfish, lingcod, and halibut. Fish behavior and maturity stage are recorded for yelloweye rockfish only.

For each fish, a perpendicular distance from the origin of the transect line to the fish will be obtained through the SeaGIS software. The precision of a 3D point is a geometric function of the camera resolution, camera focal length, camera separation, camera distance from object (close is better precision) and object distance from center of field of view (center of field of view is more precise than at the edges). Fish will be marked in both the left and right stereo cameras to obtain a 3D point measurement with coordinates of x, y, and z; the perpendicular distance to the fish corresponds to "x" (Figure 7). Fish that swim into the field of view more than once will not be double counted (this behavior is obvious, and based on our observations, rare for yelloweye rockfish).

Fish total length is recorded from the tip of the snout to the tip of the caudal fin. Length measurements are most accurate when fish are close, straight (i.e. not curled), and parallel, relative to the cameras; the video reviewer will measure each fish in the best possible orientation and position. The best possible horizontal direction will be obtained; the horizontal direction is the angle between the horizontal component of the measured length and the camera base and represents the degree to which a fish is turned away from the camera. For example, if a fish is parallel to the camera then it has a horizontal direction of 0° and if a fish is facing directly toward or away from the camera, the horizontal direction is 90°. As the horizontal direction increases, the precision of a length measurement decreases because the Δz (the difference in the z coordinate between the snout and tail) becomes larger (Δz=0 when fish parallel) as

$$\sigma_d = \frac{1}{d}\sqrt{2(\Delta x^2\sigma_x^2 + \Delta y^2\sigma_y^2 + \Delta z^2\sigma_z^2)} \qquad (4)$$

for which σ_d = the standard deviation of a given length measurement (Seager 2012). Precision is expressed in terms of the difference between the x, y, and z coordinates for each endpoint of the length measurement (Δx, Δy, Δz), the standard deviation (precision) of x, y, and z (σ_x, σ_y, σ_z), and the length of the fish (d). The standard deviation of x and y is equivalent and small compared to the standard deviation of z. When a fish is parallel $\Delta z = 0$ and there is no contribution to the error from Δz, but as a fish turns away from the camera, Δz increases resulting in a decrease in precision (σ_d).

Density and Biomass Estimates

Yelloweye rockfish density is estimated using DISTANCE 6.0 software (Thomas et al. 2010) which utilizes the following equations to estimate density with the principal function to estimate the probability of detection evaluated at the origin of the transect line ($\hat{f}(0)$):

$$\hat{D} = \frac{n\hat{f}(0)}{2L} \qquad (5)$$

$$\hat{f}(0) = \frac{1}{\mu} = \frac{1}{wP_a} \qquad (6)$$

where:

n = total number yelloweye rockfish included in the density estimate

$\hat{f}(0)$ = the probability density function evaluated at the origin of the transect line

L = total line length

μ = the effective width

w = width of line transect

P_a = probability of observing an object in the defined area

Yelloweye rockfish lengths are examined to determine whether to exclude any small yelloweye rockfish identified as adults or subadults from the density model data. The best probability detection model is selected in order to obtain a valid density estimate. Models are explored with and without binning and truncation (i.e. at some predefined maximum distance) of distance data and with different key model functions and adjustment terms. The best model is selected based on visual fit of model, the Akaike information criterion (AIC) value, X^2 goodness of fit test, and the CV for the density estimate ($cv_t(\hat{D})$). Probability detection functions are visually examined to determine if the model fits the data well; it is most important to have a good fit at the origin. In addition, the model is examined to determine if the shape is biologically realistic, and if the model has the preferred "shoulder" at the origin of the transect line (Burnham et al. 1980). The probability detection functions for the most recent survey (ROV and submersible) in each management area are shown in Figure 8a-8c.

The average weight of yelloweye rockfish sampled from the directed commercial fishery and from the halibut fishery has been used to expand density estimates to biomass for each management area.

Evaluation of Distance Sampling Assumptions
Distance sampling (Buckland et al. 1993) requires that three major assumptions are met to achieve reliable estimates of density from line transect sampling: (1) objects on the line must be detected with certainty (i.e. every object on the line must be detected); (2) objects must be detected at their initial location, (i.e. animals do not move toward or away from the transect line in response to the observer before distances are measured); (3) distances from the transect line to each object are measured accurately. Failure to satisfy these assumptions may result in biased density estimates. All assumptions were carefully evaluated and met during the ROV and submersible surveys.

To ensure that (1) all objects on the transect line are detected with certainty, the probability detection function and histograms of the distance data are examined. If the detectability at the transect line is close to 100%, then the probability detection function will have a broad shoulder at the line that will drop off at some distance from the line (Buckland et al. 1993). In the past submersible surveys, the observer looked out the side window for fish identification, and fish under or in close proximity to the submersible were sometimes missed by the observer and the main camera prior to installing a "forward-facing" camera in 1995 to record fish on or close to the transect line. The ROV stereo cameras are already oriented forward, so the video reviewer can easily detect fish on the transect line.

The second assumption (2) that yelloweye rockfish are detected at their initial location and are not moving in response to the vehicle (submersible or ROV) prior to detection in the video is evaluated by examining the probability detection function and the behavioral response of yelloweye rockfish to the vehicle. The shape of the probability detection function may indicate if there is yelloweye rockfish movement response to the vehicle. If the probability detection function has a high peak near the origin line, this may indicate an attraction. Whereas, if there are lower detections near the line and an increase in detection at some distance away from the origin of the line this may indicate avoidance behavior. Yelloweye rockfish behaviors during the 2012 survey indicate that yelloweye rockfish are not moving in response to the ROV; generally yelloweye rockfish moved very little or slowly (85%), with the majority (76%) not indicating any directional movement (i.e. milling, resting on the bottom). These results are consistent with those observed in other ROV and submersible surveys and indicate that yelloweye rockfish move slowly relative to the speed of the survey vehicle. If undetected movements are random and slow relative to the speed of the vehicle then this assumption will not be violated (Buckland et al. 1993). Byerly et al. (2005) found that yelloweye rockfish movement prior to detection by the ROV cameras was random.

The third assumption of distance sampling: (3) distances from the transect line to the fish are recorded accurately is met through the use of the stereo cameras in conjunction with the SeaGIS software (Seager 2012). In the submersible surveys, the observer visually estimated the perpendicular distance from the submersible to a fish, which is subject to measurement error despite observer calibration before a dive using a hand-held sonar gun.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set the OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set the ABC (F_{ABC}) may be less than this maximum permissible level but not greater. DSR are managed under Tier 4 because reliable estimates of spawning biomass and recruitment are not available. Demersal shelf rockfish are particularly vulnerable to overfishing given their longevity, late maturation, and habitat-specific residency. We recommend and use a harvest rate lower than the maximum allowed under Tier 4; F=M=0.02. This rate is more conservative than would be obtained by using Tier 4 definitions for setting the maximum permissible F_{ABC} is $F_{40\%}$ ($F_{40\%}$=0.026). Continued conservatism in managing this fishery is warranted given the life history of the species and the uncertainty of the biomass estimates.

Specification of F_{OFL} and the maximum permissible ABC

Under tier 4 projections of harvest scenarios for future years is not possible.

Yields for 2014 are computed for scenarios 1-5 as follows:

Scenario 1: F equals the maximum permissible F_{ABC} as specified in the ABC/OFL definitions. For tier 4 species, the maximum permissible F_{ABC} is $F_{40\%}$. $F_{40\%}$ equals 0.026 corresponding to a yield of 293 t (including 3% for other DSR).

Scenario 2: F equals the stock assessment author's recommended F_{ABC}. In this assessment, the recommended F_{ABC} is F=M=0.02, and the corresponding yield is 225 t (including 3% for other DSR).

Scenario 3: F equals the 5-year average F from 2010 to 2014. The true past catch is not known for this species assemblage so the 5-year average is estimated at F=0.02 (the proposed F in all 5 years), and the corresponding yield is 225 t (including the 3% other DSR).

Scenario 4: F equals 50% of the maximum permissible F_{ABC} as specified in the ABC/OFL definitions. 50% of $F_{40\%}$ is 0.013, and the corresponding yield is 147 t (including 3% other DSR).

Scenario 5: F equals 0. The corresponding yield is 0 t.

Ecosystem Considerations

In general, ecosystem considerations for the DSR complex are limited. Table 7 consolidates information regarding ecosystem effects on the stock and the stocks effect on the ecosystem. Specific data to evaluate these effects are mostly lacking

Ecosystem Effects on the Stock

Prey availability

Like many rockfishes, the DSR complex is highly influenced by periodic abundant year classes. Zooplankton prey availability and favorable environmental conditions may affect the survivability of larval rockfishes. Yelloweye rockfish consume rockfishes, herring, sandlance, shrimps, and crabs and seasonally lingcod eggs, and changes in the abundance of these food sources could impact yelloweye rockfish abundance (Love et al. 2002).

Predator population trends

Many predators, including other rockfishes consume larval and juvenile yelloweye rockfish. Adult yelloweye rockfish have been found in the stomachs of longline caught lingcod and halibut but this may be opportunistic feeding as the yelloweye rockfish were caught on the fishing gear. A yelloweye rockfish was also found in the stomach of an orca whale (Love et al. 1990). Yelloweye rockfish are considered mid to high in trophic level (Kline et al. 2007). Predator effects, or an increase in predation on any one of the life stages of the DSR complex could have negative effects on the stock.

Changes in physical environment:

Strong year classes for many species of fish correlate with good environmental conditions. Black et al. (2011) documented seasonal (winter and summer modes) upwelling as an index for predicting rockfish productivity. For yelloweye rockfish, increased growth was associated with the winter upwelling mode but not summer upwelling in the California Current Ecosystem. Thorson et al. (2013) found that a multi-species approach to estimating recruitment may be promising for some species (e.g. for yelloweye rockfish, a shared index of cohort strength decreased coefficient of variation for recruitment for the modeled year by 40%). Thus, recruitment estimates for data poor species such as yelloweye rockfish may be improved by using multispecies recruitment indices.

Availability of physical bottom habitat would impact yelloweye rockfish at many different stages of life. Both juveniles and adults are associated with high relief rock habitat, as well as corals and sponges (O'Connell and Carlile 1993). Bottom trawling is not a legal gear type in the Eastern Gulf of Alaska so the effects of commercial fishing on the bottom habitat are minimal, although there is some removal of coral and sponges from non-trawl gear that comes in contact with the bottom (e.g. hook and line, dinglebar gear.)

Fishery Effects on the Ecosystem

Fishery specific contribution to HAPC biota

HAPC biota such as corals and sponges are associated with some of the same habitats that yelloweye and other demersal shelf rockfish inhabit. On ROV and submersible dives, we have recorded many observations of yelloweye rockfish in close association with corals and sponges. However, as described above, bottom trawling is prohibited in the EGOA, so contact with the bottom and therefore biogenic habitat removal is limited to primarily hook and line and dinglebar gear. The expanded observer program should provide additional data on invertebrate incidental catch in the DSR directed and halibut fisheries.

Fishery specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components

Insufficient research exists to determine yelloweye rockfish catch relative to predator needs in time and space. Yelloweye rockfish are winter/spring spawners, with a peak period of parturition in April and May in Southeast Alaska (O'Connell 1987). The directed fishery, if opened, occurs between late January and early March, but the bulk of the mortality for the DSR complex is taken as incidental catch in the halibut longline fishery. Reproductive activities do overlap with the fishery, but since parturition takes place over a protracted period, there should be sufficient spawning potential relative to fishery mortality.

Fishery-specific effects on amount of large size target fish

Full retention of the DSR complex is required in the EGOA, therefore high grading should be minimized in the reported catch and lengths sampled in port should be representative of lengths composition of yelloweye rockfish captured on the gear. The commercial directed fisheries landing data show that most fish are captured between 450 and 650 mm (Figure 9). There are some differences in the length compositions of yelloweye rockfish from the commercial fishery compared with the measurements of yelloweye rockfish derived from the ROV survey, however we are still exploring those differences.

Fishery contribution to discards and offal production

Full retention requirements of the DSR complex became regulation in 2000 in state waters and 2005 in federal waters of the EGOA, thus making discard at sea of DSR illegal. There may be some unreported discard in the fishery. Data from the observer restructuring program may shed additional light on the magnitude of unreported catch.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery

Fishery effects on age-at-maturity and fecundity are unknown. Age composition of the fishery, by management area, is shown in Figure 10. The age at 50% maturity used in this stock assessment for yelloweye rockfish in Southeast Alaska is 17.6 years. This age is based on a maturity-at-age curve for males and females combined and was derived from directed DSR commercial fishery data from 1992 – 2013 from all four management areas (Figure 13 in Appendix B). Most yelloweye rockfish are captured at ages greater than the length at 50% maturity (Figure 10).

Fishery-specific effects on EFH living and non-living substrate:

Effects of the DSR fishery on non-living substrates are minimal since no trawl gear is used in the fishery. Occasionally fishing gear is lost in the fishery, so longline and anchors may end up on the bottom. There is likely minimal damage to EFH living substrate as the gear used in the fishery is set on the bottom but does not drag along the bottom.

Data Gaps and Research Priorities

There is a need for better estimation of rockfish habitat through more complete geophysical surveys (NSEO, SSEO areas in particular) and validation of the technique of using commercial fishery logbook data as a proxy for rock habitat in areas without geophysical surveys.

We also plan to explore the conversion of yelloweye rockfish lengths collected from the ROV video observations to weight using length-weight relationships for yelloweye rockfish. We will determine if weights derived from length-weight relationships are appropriate for estimating biomass while considering the sample size of the length data obtained from the ROV.

There is limited information on yelloweye rockfish fecundity; a fecundity study specific to southeast Alaska would be useful. Little is known about the timing of parturition for yelloweye rockfish recruitment or post larval survival. A recruitment index for yelloweye rockfish would improve modeling estimates for total yelloweye rockfish biomass.

Literature Cited

Adams, P. B. 1980. Life history patterns in marine fishes and their consequences for fisheries management. Fish Bull. 78(1):1-12.

Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfish (Scorpaenidae) from B. C. coastal waters. 1977-1979. Can. Tech. Rep. Fish. Aquat. Sc. No. 1048. 57 p.

Boehlert, G. W. and M. M. Yoklavich. 1984. Reproduction, embryonic energetics, and the maternal-fetal relationship in the viviparous genus Sebastes. Biol. Bull. 167:354-370.

Black, B.A.; I.D. Schroeder, W.J. Sydeman, S.J Bograd, B.K. Wells, F.B. Schwing. 2011. Winter and summer upwelling modes and their biological importance in the California Current Ecosystem. *Publications, Agencies and Staff of the U.S. Department of Commerce.* Paper 242.

Boehlert, G. W., M. Kusakari, M. Shimizu, and J. Yamada. 1986. Energetics during embryonic development in kurosoi, *Sebastes schlegeli* Hilgendorf. J. Exp. Mar. Biol. Ecol. 101:239-256.

Box, G.E.P. and G. M. Jenkins. 1976. Time series analysis: forecasting and control. Holden-Day, San Francisco.

Buckland, S. T., D. R. Anderson, K. P Burnham, and J. L. Laake. 1993. Distance sampling: estimating abundance of biological populations. Chapman & Hall. London. 446 p.

Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs. Vol. 72. 202 p.

Brylinksy, C., J. Stahl, D. Carlile, and M. Jaenicke. 2009. Assessment of the demersal shelf rockfish stock for 2010 in the southeast outside district of the Gulf of Alaska. In: Stock assessment and fishery evaluation report for the groundfish resources for the Gulf of Alaska, North Pacific Fisheries Management Council, Anchorage, Alaska pp. 1067 – 1110.

Dorn, M. 2000. Advice on west coast rockfish harvest rates from Bayesian meta-analysis of *Sebastes* stock-recruit relationships. Proceedings of the 11th Western Groundfish Conference, Alaska Department of Fish and Game, Sitka, Alaska.

Francis, R. C. 1985. Fisheries research and its application to west coast groundfish management. In T. Frady (ed.). Proceedings of the Conference on Fisheries Management: Issues and Options. p. 285-304. Alaska Sea Grant Report 85-2.

GMT 2014. Groundfish Management Team report on proposed discard mortality for cowcod, canary rockfish, and yelloweye rockfish released using descending devices in the recreational fishery. Pacific Fishery Management Council, Agenda Item D.3.b, Supplemental GMT Report 2, March 2014.

Gunderson, D. R. 1980. Using r-K selection theory to predict natural mortality. Can J. Fish. Aquat. Sci. 37:1522-1530.

Green, K., D. Carlile, M. Jaenicke, and S. Meyer. 2013. Assessment of the demersal shelf rockfish stock for 2014 in the southeast outside district of the Gulf of Alaska. Chapter 14 IN 2013 Stock Assessment and Fishery Evaluation Report for 2014. North Pacific Fishery Management Council, Anchorage, AK.

Greene, H. G., Yoklavich, M. M., Starr, R., O'Connell, V. M., Wakefield, W. W., Sullivan, D. L., MacRea, J. E., and Cailliet, G. M. 1999. A classification scheme for deep-water seafloor habitats: Oceanographica Acta 22: 663–678.

Hannah, R. H., P. S. Rankin, and M. T. O. Blume. 2012. Use of a novel cage system to measure postrecompression survival of northeast Pacific rockfish. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4:46-56.

Hannah, R. H., P. S. Rankin, and M. T. O. Blume. 2014. The divergent effect of capture depth and associated barotrauma on post-recompression survival of canary (*Sebastes pinniger*) and yelloweye rockfish (*S. ruberrimus*). Fisheries Research 157:106-112.

Hochhalter, S. J. and D. J. Reed. 2011. The effectiveness of deepwater release at improving the survival of discarded yelloweye rockfish. North. Amer. J. Fish. Mgmt. 31:852-860.

Jarvis, E. T. and C. G. Lowe. 2008. The effects of barotrauma on the catch-and-release survival of southern California nearshore and shelf rockfish (Scorpaenidae, Sebastes spp.). Can. J. Fish. Aquat. Sci. 65:1286-1296.

Kline Jr., T.C. 2007. Rockfish Trophic Relationships in Prince William Sound, Alaska, Based on Natural Abundances of Stable Isotopes. In: J. Heifetz, J. Dicosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell, and R.D. Stanley (eds.), Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant College Program, Fairbanks, pp. 21-37. doi:10.4027/bamnpr.2007.02

Leaman, B. M. and R. J. Beamish. 1984. Ecological and management implications of longevity in some northeast Pacific groundfishes. Int. North Pac. Fish. Comm. Bull. 42:85-97.

Love, M. S., P. Morris, M. McCrae, and R. Collins. 1990. Life History Aspects of 19 rockfish species (Scorpaenidae: Sebastes) from the southern California Bight. NOAA Tech. Rpt. NMFS 87: 38pp.

Love, M. S., M. Yoklavich, and L. Thorsteinson. 2002. The Rockfishes of the Northeast Pacific.University of California Press. Berkeley, CA.

O'Connell, V.M. 1987. Reproductive seasons for some Sebastes species in Southeastern Alaska. Alaska Department of Fish and Game Information Leaflet 263: 21 p.

O'Connell, V.M. 2003. The Southeast Alaska Demersal Shelf Rockfish Fishery With 2003 Season Outlook. Alaska Department of Fish and Game Regional Information Report No. IJ03-10. Juneau, AK. 49p.

O'Connell, V.M. and D.W. Carlile. 1993. Habitat-specific density of adult yelloweye rockfish *Sebastes ruberrimus* in the eastern Gulf of Alaska. Fish Bull 91:304-309.

Pacunski, R. Palsson, W. Greene, G. Water and D. Gunderson. 2008. Conducting Visual Surveys with a Small ROV in Shallow Water. Alaska Sea Grant. University of Alaska Fairbanks

Ralston, S., Punt, E., Hamel, O., DeVore, J., and R. Conser. 2011. A meta-analytic approach to quantifying scientific uncertainty in stock assessments. Fish. Bull. 109:217 – 231

SAS institute Inc. 2011. SAS/ETS® User's Guide. SAS Institute Inc, Cary, NC.

Seager, James 2012. EventMeasure User Guide. SeaGIS Pty Ltd. February 2012 (version 3.32)

Seber, G.A.F. 1982. A review of estimating animal abundance. Biometrics: 42. 267-292.

Siegle M.R., E.B. Taylor, K.M. Miller, R.E. Withler, K.L. Yamanaka .2013. Subtle Population Genetic Structure in Yelloweye Rockfish (*Sebastes ruberrimus*) Is Consistent with a Major Oceanographic Division in British Columbia, Canada. PLoS ONE 8(8): e71083.

Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

Thorson J.T., I.J. Stewart, I.G. Taylor, A.E. Punt. 2013. Using a recruitment-linked multispecies stock assessment model to estimate common trends in recruitment for US West Coast groundfishes. Mar Ecol Prog Ser 483:245-256

Turek, M., N. Ratner, W.E. Simeone, and D.L. Holen. 2009. Subsistence harvests and local knowledge of rockfish *Sebastes* in four Alaskan communities; Final report to the North Pacific Research Board. Alaska Department of Fish and Game, Division of Subsistence Technical Paper No. 337, Juneau.

O'Connell, V.M. and C.K. Brylinksy. 2003. The Southeast Alaska demersal shelf rockfish fishery with 2004 season outlook. Alaska Department of Fish and Game Regional Information Report No. 1J03-43.

Yoklavich, M., T. Laidig, D. Watters, and M. Love. 2013. Understanding the capabilities of new technologies and methods to survey west coast groundfishes: Results from a visual survey conducted in 2011 using the Dual Deepworker manned submersible at Footprint and Piggy banks off Southern California. [Final report to NMFS Science Advisor for Stock Assessments.] U.S. National Marine Fisheries Service, Santa Cruz, California. 28 p.

Table 1. Species included in the demersal shelf rockfish assemblage.

Common name	Scientific Name
canary rockfish	*S. pinniger*
China rockfish	*S. nebulosus*
copper rockfish	*S. caurinus*
quillback rockfish	*S. maliger*
rosethorn rockfish	*S. helvomaculatus*
tiger rockfish	*S. nigrocinctus*
yelloweye rockfish	*S. ruberrimus*

Table 2. Reported landings of demersal shelf rockfish (t) from research, incidental commercial, directed commercial, recreational and subsistence fisheries in the Southeast Outside Subdistrict (SEO), 1988–2014[a], acceptable biological catch (ABC), Overfishing Level (OFL) and total allowable catch (TAC) for commercial and recreational sectors combined.

YEAR	Research	Directed	Incidental	Recreational[b]	Subsistence[c]	Total[d]	ABC[e]	OFL	TAC
1988							660		660
1989							420		420
1990							470		470
1991							425		425
1992		359	119			478	550		550
1993	13	334	188			535	800		800
1994	4	381	219			604	960		960
1995	13	155	103			271	580		580
1996	11	344	81			436	945		945
1997	16	267	97			380	945		945
1998	2	241	118			361	560		560
1999	2	241	125			368	560		560
2000	8	183	104			295	340		340
2001	7	173	144			324	330		330
2002	2	136	147			285	350	480	350
2003	6	102	167			275	390	540	390
2004	2	174	153			329	450	560	450
2005	4	42	191			237	410	650	410
2006	2	0	203	64		269	410	650	410
2007	3	0	196	74		273	410	650	410
2008	1	42	152	51		246	382	611	382
2009	2	76	139	33		250	362	580	362
2010	7	30	131	41	8	217	295	472	287
2011	5	22	87	24	6	144	300	479	294
2012	4	105	76	31	7	223	293	467	286
2013	4	129	83	24	7	247	303	487	296
2014		33	60		7	100	274	438	267
2015					8		225	361	217

[a]Landings from ADF&G Southeast Region fish ticket database and NMFS weekly catch reports through October 19, 2014.
[b]Sport fish catch from 2006 to 2008 includes EYKT and IBS. These data are not available prior to 2006.
[c]Projected subsistence catch for the fishery year, i.e. 2010 is for the 2010 fishery. These data were not available or deducted from the ABC prior to 2009.
[d]Prior to full retention regulations in 2005, DSR mortality associated with halibut fishery was unknown.
[e]No ABC prior to 1988, 1988–1993 ABC for CSEO, NSEO, and SSEO only (not EYKT).

Table 3. Submersible (1994–1995, 1997, 1999, 2003, 2005, 2007, 2009) and ROV (2012–2013) yelloweye rockfish density estimates with 95% confidence intervals (CI) and coefficient of variations (CV) by year and management area. The number of transects, yelloweye rockfish (YE), and meters surveyed included in each model are shown, along with the encounter rate of yelloweye rockfish. Values in bold were used for this stock assessment. The 2012 CSEO density estimate was used as a proxy for the NSEO management area yelloweye rockfish density estimate. The NSEO area was surveyed in 2001, but too few yelloweye rockfish were observed to be used for a density estimate.

Area	Year	# transects	# YE[b]	Meters surveyed	Encounter rate (YE/m)	Density (YE/km^2)	Lower CI (YE/km^2)	Upper CI (YE/km^2)	CV
EYKT[a]	1995	17	330	22,896	0.014	2,711	1,776	4,141	0.20
	1997	20	350	19,240	0.018	2,576	1,459	4,549	0.28
	1999	20	236	25,198	0.009	1,584	1,092	2,298	0.18
	2003	20	335	17,878	0.019	3,825	2,702	5,415	0.17
	2009	**37**	**215**	**29,890**	**0.007**	**1,930**	**1,389**	**2,682**	**0.17**
CSEO	1994[c]					1,683			0.10
	1995	24	235	39,368	0.006	2,929			0.19
	1997	32	260	29,273	0.009	1,631	1,224	2,173	0.14
	2003	101	726	91,285	0.008	1,853	1,516	2,264	0.10
	2007	60	301	55,640	0.005	1,050	830	1,327	0.12
	2012	**46**	**118**	**38,590**	**0.003**	**752**	**586**	**966**	**0.13**
SSEO	1994[c]	13	99	18,991	0.005	1,173			0.29
	1999	41	360	41,333	0.009	2,376	1,615	3,494	0.20
	2005	32	276	28,931	0.010	2,357	1,634	3,401	0.18
	2013	31	118	30,439	0.004	986	641	1,517	0.22
NSEO	**1994[c]**	**13**	**62**	**17,622**	**0.004**	**765**	**383**	**1,527**	**0.33**

[a] Estimates for EYKT management area include only the Fairweather grounds, which is composed of a west and an east bank. In 1997, only 2 of 20 transects and in 1999, no transects were performed on the east bank that were used in the model. In other years, transects performed on both the east and west bank were used in the model.

[b] Subadult and adult yelloweye rockfish were included in the analyses to estimate density. A few small subadult yelloweye rockfish were excluded from the 2012 model based on size; length data were only available for the ROV surveys (not submersible surveys). Data were truncated at large distances for some models; as a consequence, the number of yelloweye rockfish included in the model does not necessarily equal the total number of yelloweye rockfish observed on the transects.

[c] Only a side-facing camera was used in 1994 and earlier years to video fish. The forward-facing camera was added after 1994, which ensures that fish are observed on the transect line.

Table 4. Area estimates for sonar locations and rocky habitat by management area in Southeast Alaska.

	Sonar location	Sonared area (km^2)	Area rocky habitat (km^2)
EYKT	Fairweather West Bank	784	402
	Fairweather East Bank	288	98
Total Sonar		1,072	500
Total rock (Sonar & fishery)			739
Percentage rocky habitat from sonar			68%
CSEO	Cape Edgecumbe	538	328
	Cape Ommaney	294	114
Total Sonar		832	442
Total rock (Sonar & fishery)			1,661
Percentage rocky habitat from sonar			27%
SSEO	Hazy Islands	400	120
	Addington	84	47
	Cape Felix	140	78
	Learmonth Bank	530	77
Total Sonar		1,154	322
Total rock (Sonar & fishery)			1,056
Percentage rocky habitat from sonar			30%
NSEO			
NOAA chart			364
Total rock (NOAA chart & fishery)			436

Table 5. Commercial landings (t) of demersal shelf rockfish species in Southeast Outside Subdistrict between 2008 and 2014. Discards (Harvest Code 98 (Discard at sea) included.

Species	2008	2009	2010	2011	2012	2013	2014	Sum (t)
Canary rockfish	0.67	0.86	0.87	0.34	2.87	2.88	0.26	8.75
China rockfish	0.01	0.04	0.03	0.02	0.02	0.05	0.02	0.19
Copper rockfish	0.01	0.04	0.01	0.01	0.03	0.03	0.01	0.13
Quillback rockfish	2.88	3.82	4.08	1.68	3.79	3.72	1.80	21.76
Rosethorn rockfish	0.09	0.01	0.00	0.00	0.02	0.04	0.00	0.17
Tiger rockfish	0.26	0.50	0.28	0.11	0.41	0.31	0.25	2.12
Yelloweye rockfish	189.71	209.34	155.62	106.16	172.83	205.37	90.46	1130.44
Sum (t)	193.63	214.61	160.89	108.32	179.97	211.86	75.09	1163.57
% yelloweye rockfish of total	98.0%	97.5%	96.7%	98.0%	96.0%	96.9%	97.8%	97.2%

Table 6. Other Fishery Management Plan (FMP) groundfish species landed (t) in DSR directed commercial fisheries in the Southeast Outside Subdistrict.

Species	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Black rockfish					0.3	0.8
Bocaccio rockfish	0.1					0.1
Pacific cod	0.5	0.4	0.9	1.0	2.3	5.1
Redbanded rockfish	0.2	0.1		0.1	1.1	1.7
Dark rockfish		0.1				
Dusky rockfish	2.1	2.0	0.5	0.3	3.8	5.3
Rougheye rockfish	0.1					
Shortraker rockfish	0.1					
Silvergray rockfish	0.7	0.5	0.4	0.3	0.7	1.9
Skate, general		1.7			0.2	
Spiny dogfish shark					0.2	
Yellowtail rockfish					0.1	0.1
Total	**3.8**	**4.8**	**1.8**	**1.7**	**8.7**	**15**

Table 7. Ecosystem effects on GOA DSR

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Important for larval and post larval survival but no information known	May help determine recruitment strength, no time series.	Possible concern if more information known
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Pollock, Pacific cod, halibut)	Stable	No effect	No concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift		No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different Phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings nutrients to the Gulf	Some years highly variable, i.e. El Nino 1998	Probably no concern, contributes to high variability in rockfish recruitment

GOA DSR fishery effects on the ecosystem			
Prohibited species	Halibut are taken as incidental catch but released	Minor contribution to mortality, soak times are short for DSR gear, separate PSC cap for DSR	Little concern
Forage (including herring, Atka mackerel, cod, and pollock)	A small amount of cod incidental catch is taken in this fishery	Incidental catch levels small relative to forage biomass	No concern
HAPC biota	Low incidental catch levels of Primnoa coral, hard coral, and sponges.	Longline gear has some incidental catch but levels small relative to HAPC biota	Little concern
Marine mammals and birds	Minor take associated with longline gear, little impact	Data limited for discards, fishery has been largely unobserved until recently.	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be harvested in proportion to their abundance.	No concern
Fishery concentration in space and time	Majority of catch is harvested during halibut IFQ season (March to November), the directed fishery is concentrated during the winter	Fishery does not hinder reproduction	Little concern
Fishery effects on amount of large size target fish	Fishery is catching primarily adults but difficult to target largest individuals over others	Large and small fish both occur in population	Little concern
Fishery contribution to discards and offal production	Discard rates low for DSR fishery but can include dogfish and skates	Data limited for discards, fishery has been largely unobserved until recently	Possible concern
Fishery effects on age-at-maturity and fecundity	Fishery is catching some immature fish but small proportion of total catch. Larger fish likely contribute more to spawning output via exponentially greater and higher quality larvae.	If increased could reduce spawning potential and yield	Possible concern

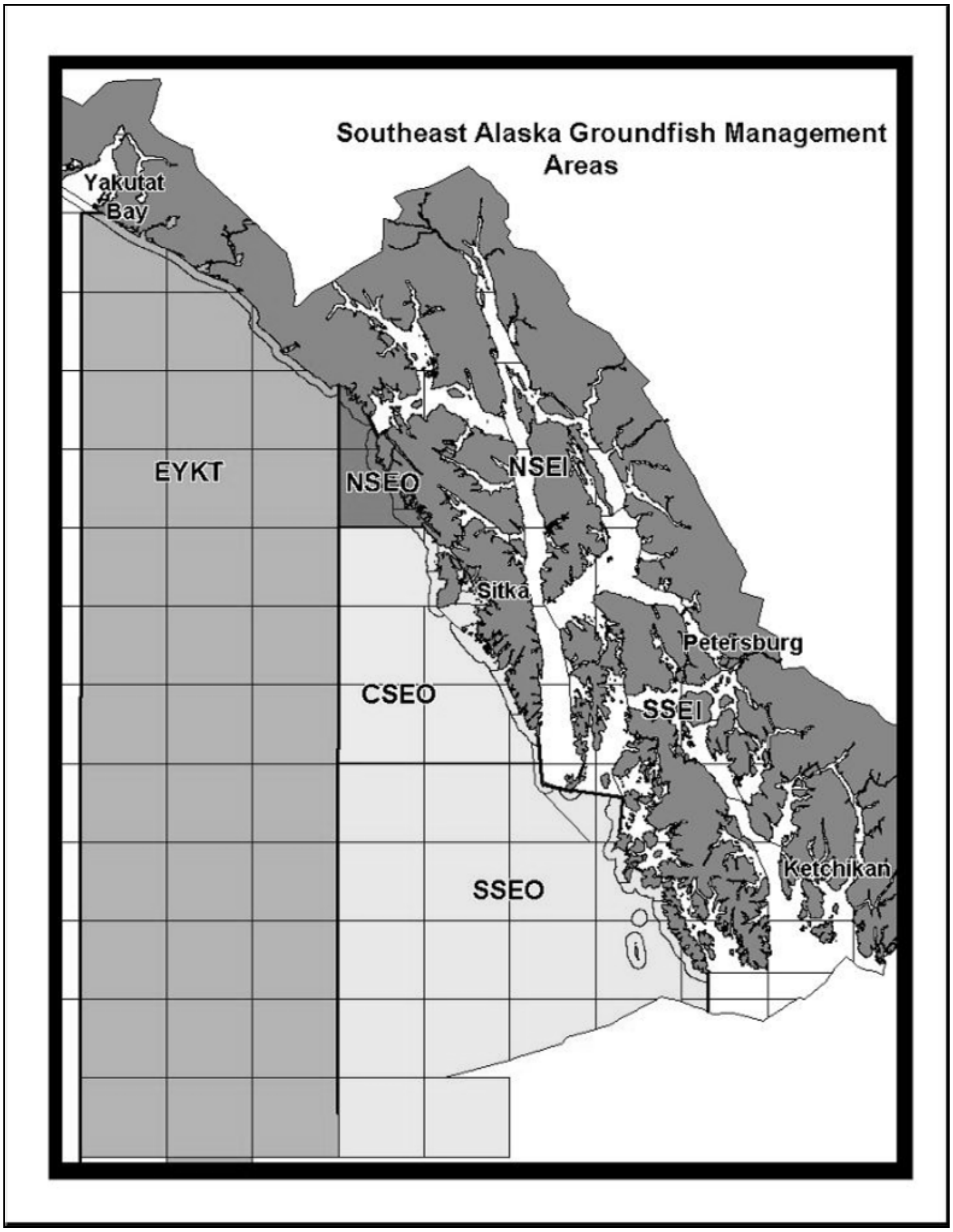


Figure 1. Southeast Alaska Outside Waters (SEO), or Eastern Gulf of Alaska (EGOA) with the Alaska Department of Fish and Game groundfish management areas; East Yakutat (EYKT), Central Southeast Outside (CSEO), Northern Southeast Outside (NSEO), and Southern Southeast Outside (SSEO).

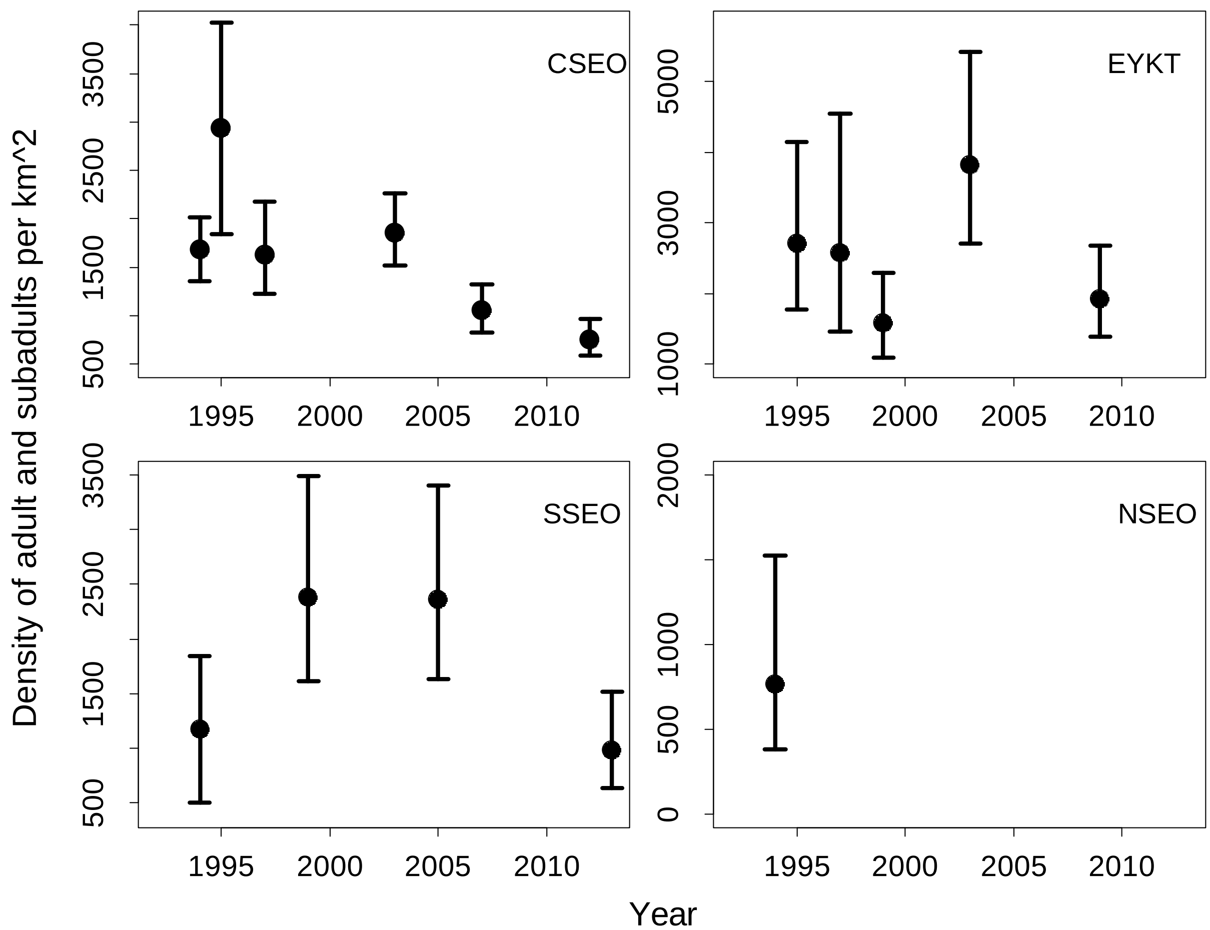


Figure 2. Density (adults and sub-adults per square kilometer) predicted by DISTANCE (circles) +/- two standard deviations in each management area (Central Southeast Outside (CSEO), East Yakutat (EYKT), , Southern Southeast Outside (SSEO), Northern Southeast Outside (NSEO).

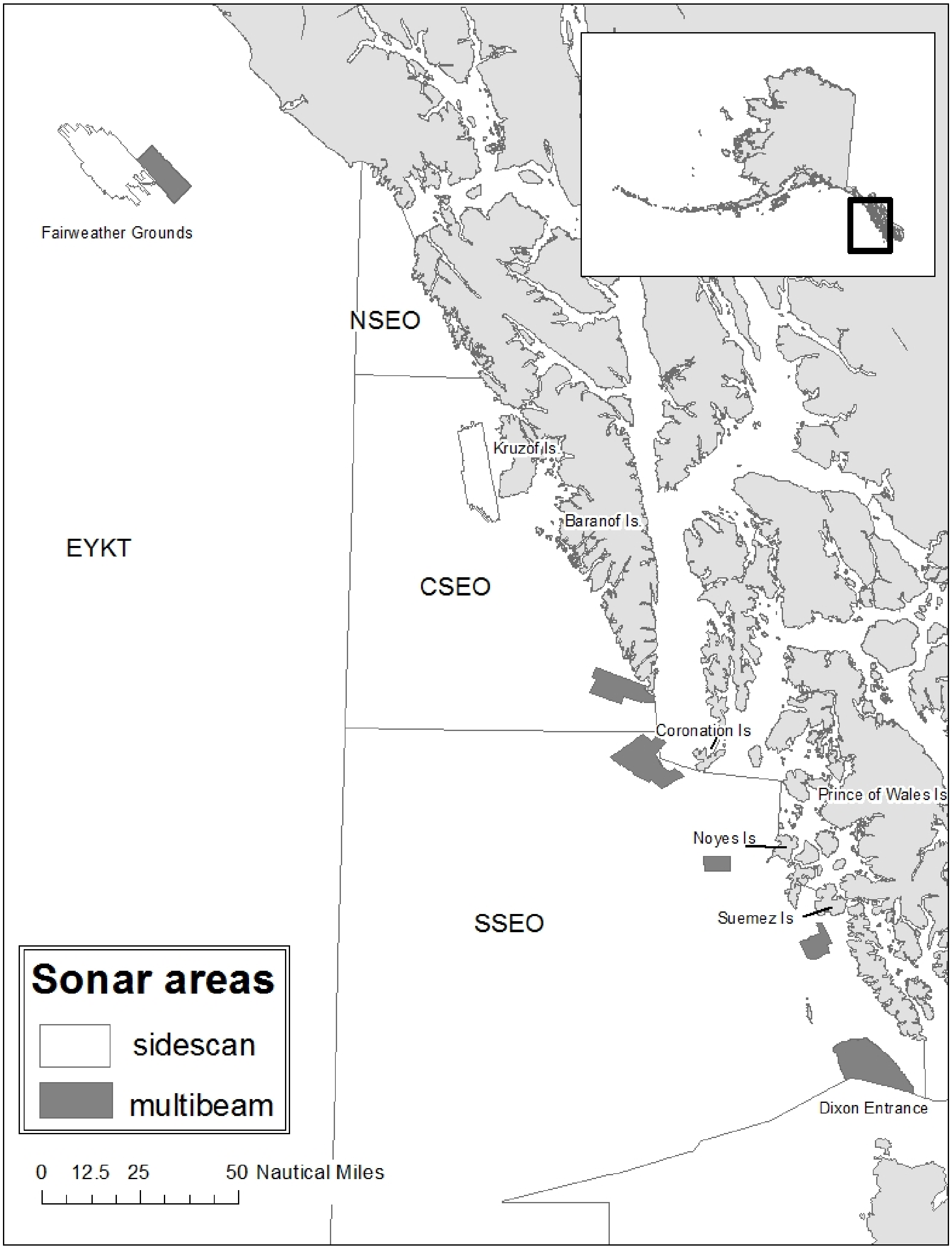


Figure 3. Sonar surveys performed in southeast Alaska and used in yelloweye rockfish habitat delineation.

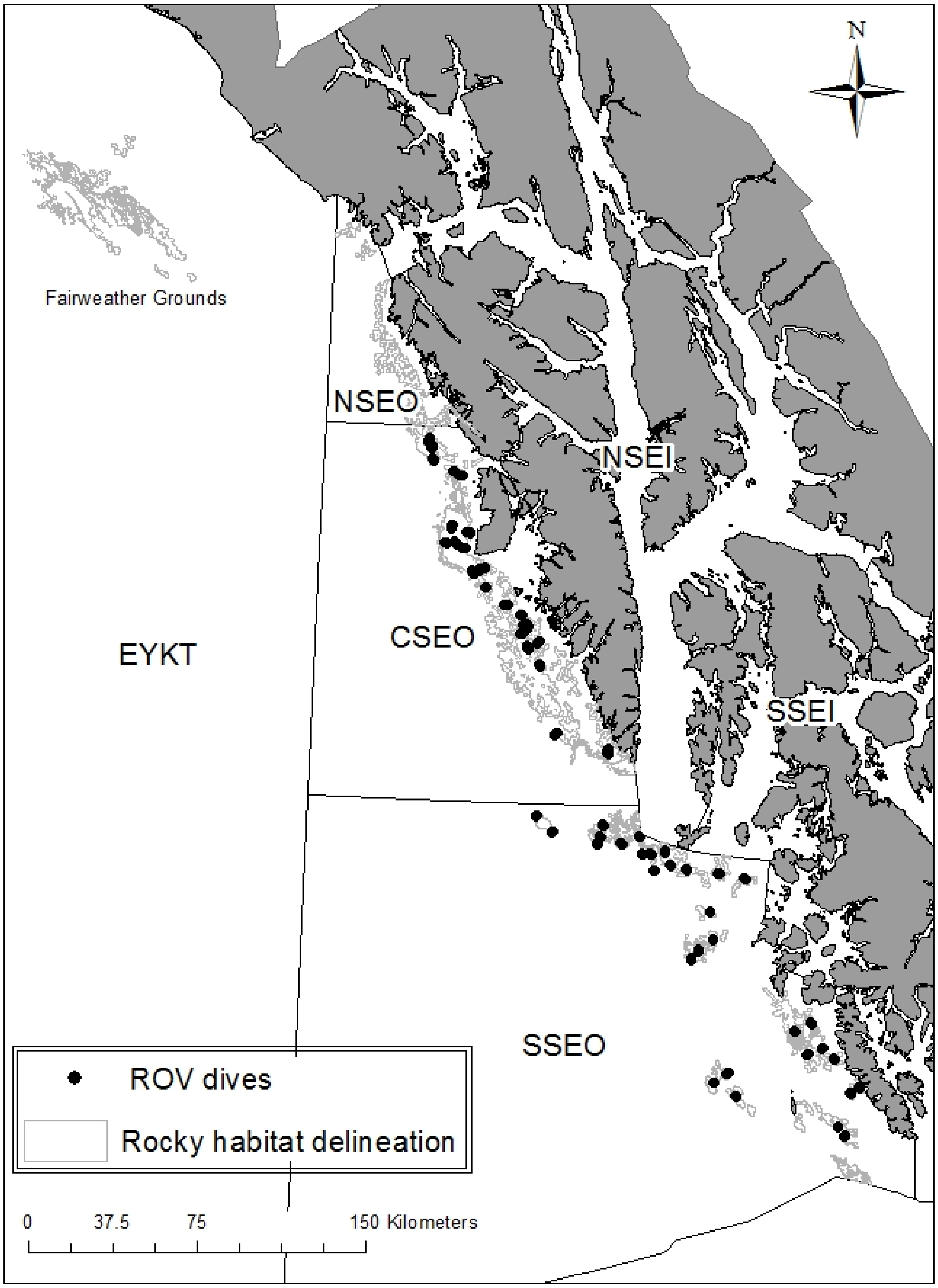


Figure 4. ROV transects conducted in Central Southeast Outside (CSEO) in 2012 and Southern Southeast Outside (SSEO) in 2013.

Figure 5. Example of 1-km transect plan lines for remote operated vehicle (ROV) dives. Plan lines have been adjusted in some cases to remain within the delineation of rocky habitat (solid gray).

Figure 6. Yelloweye rockfish with a 3D point (circle with black outline) and a total length (white line) measured in the stereo camera overlapping field of view in the SeaGIS Event Measure software.

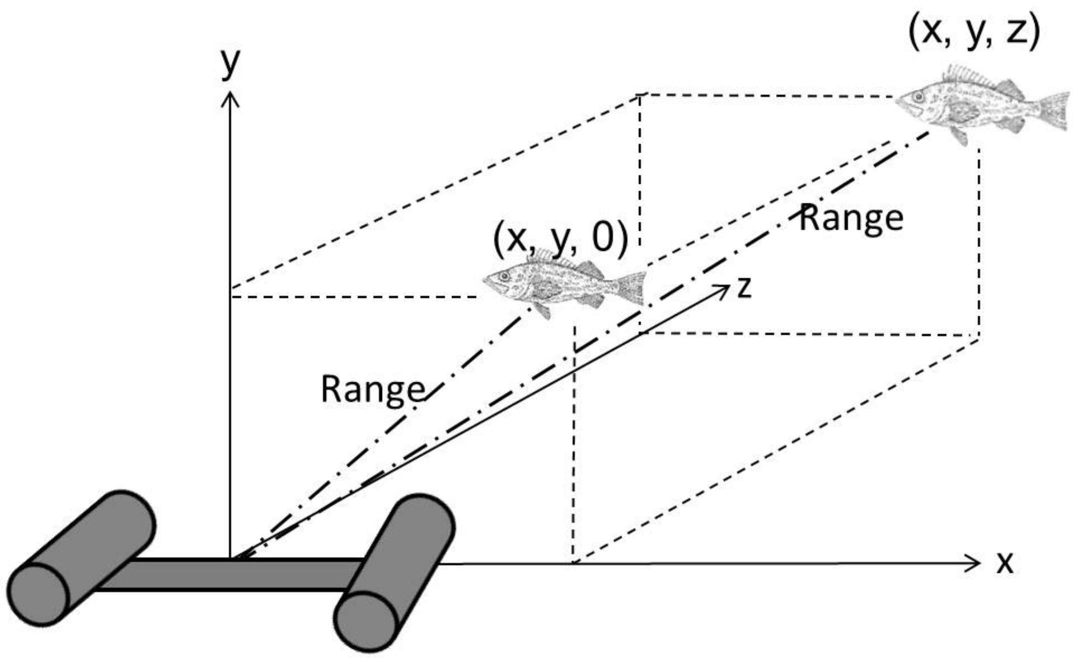


Figure 7. The components of a 3D point measurement.

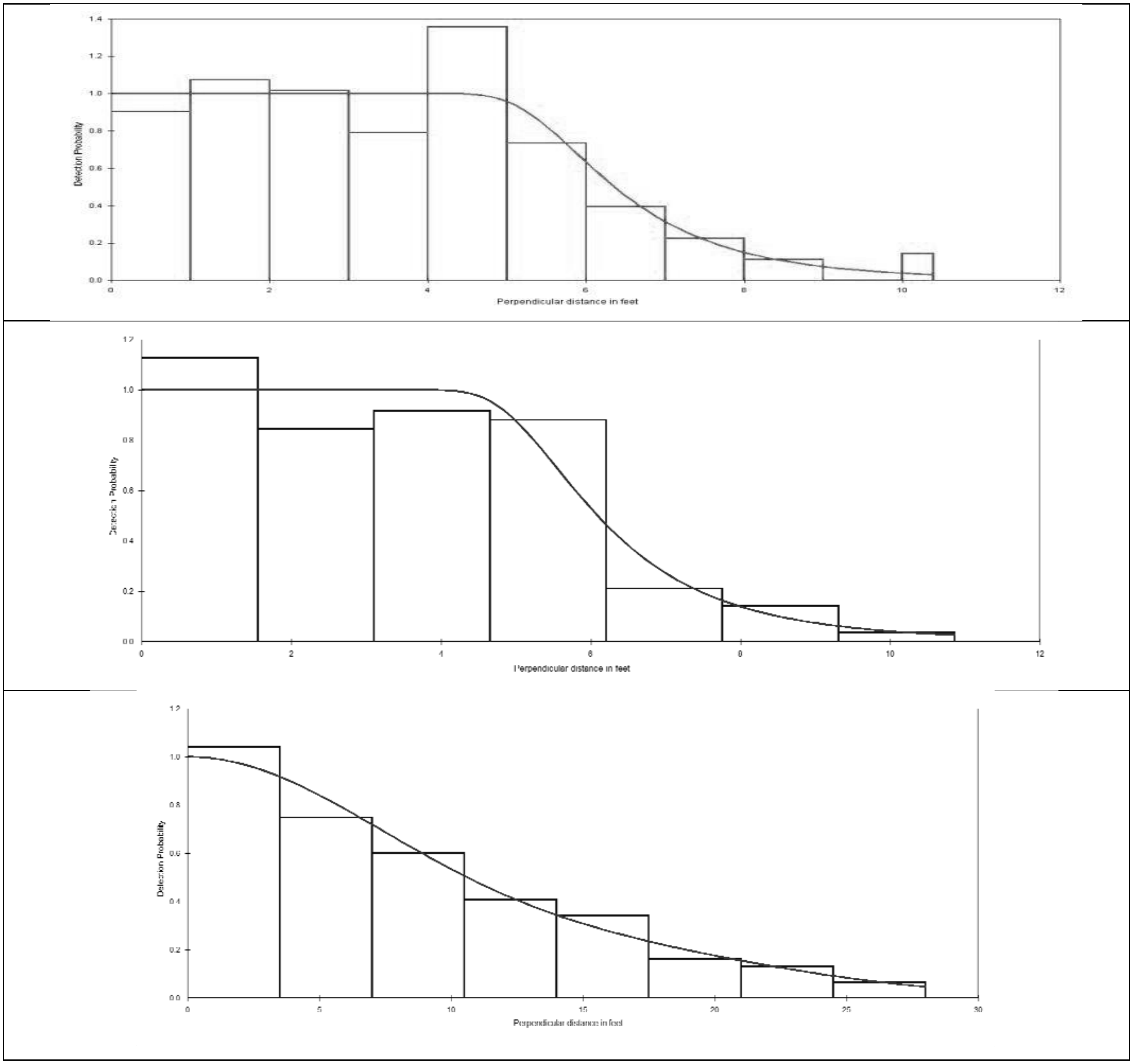


Figure 8a. The selected probability detection function for yelloweye rockfish from the 2012 ROV survey in Central Southeast Outside (CSEO) shown with expected data bins at 1-ft intervals. Data were not binned to estimate density in the CSEO selected model. The CSEO data were used as a proxy for the Northern Southeast Outside (NSEO) management area in this stock assessment since over 13 years have elapsed since the last usable NSEO survey.

Figure 8b. The selected probability detection function for yelloweye rockfish from the 2013 ROV survey in Southern Southeast Outside (SSEO) shown with expected data bins at 1.55 ft intervals. Data were not binned to estimate density with the selected model.

Figure 8c. The selected probability detection function for East Yakutat (EYKT) in 2009 shown with with 3.5 ft bins and truncation at 28 ft. This is ahalf normal cosine model.

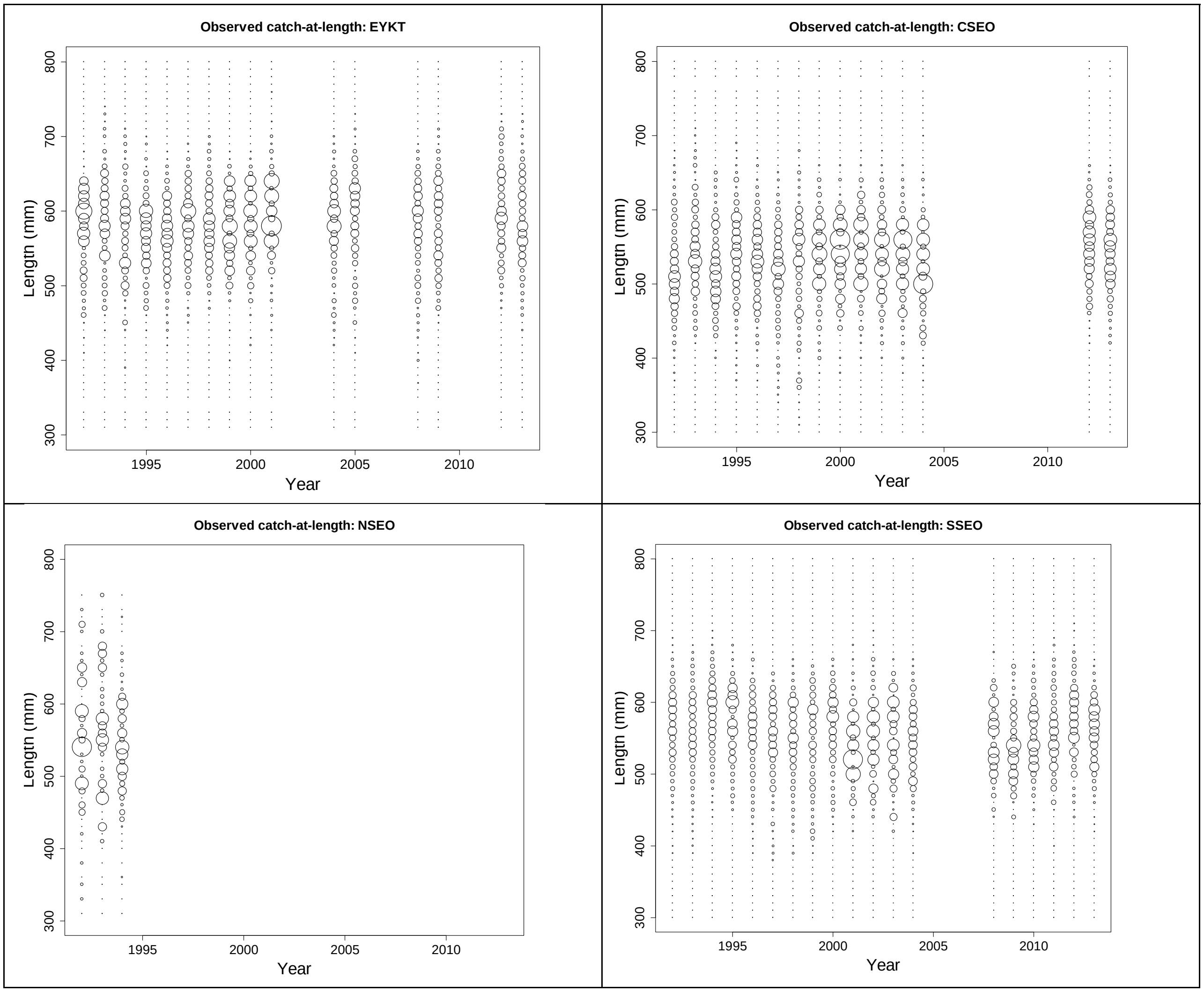


Figure 9. Length compositions from DSR captured in the directed fishery in East Yakutat (EYKT), Central Southeast Outside (CSEO), Northern Southeast Outside (NSEO), and Southern Southeast Outside (SSEO).

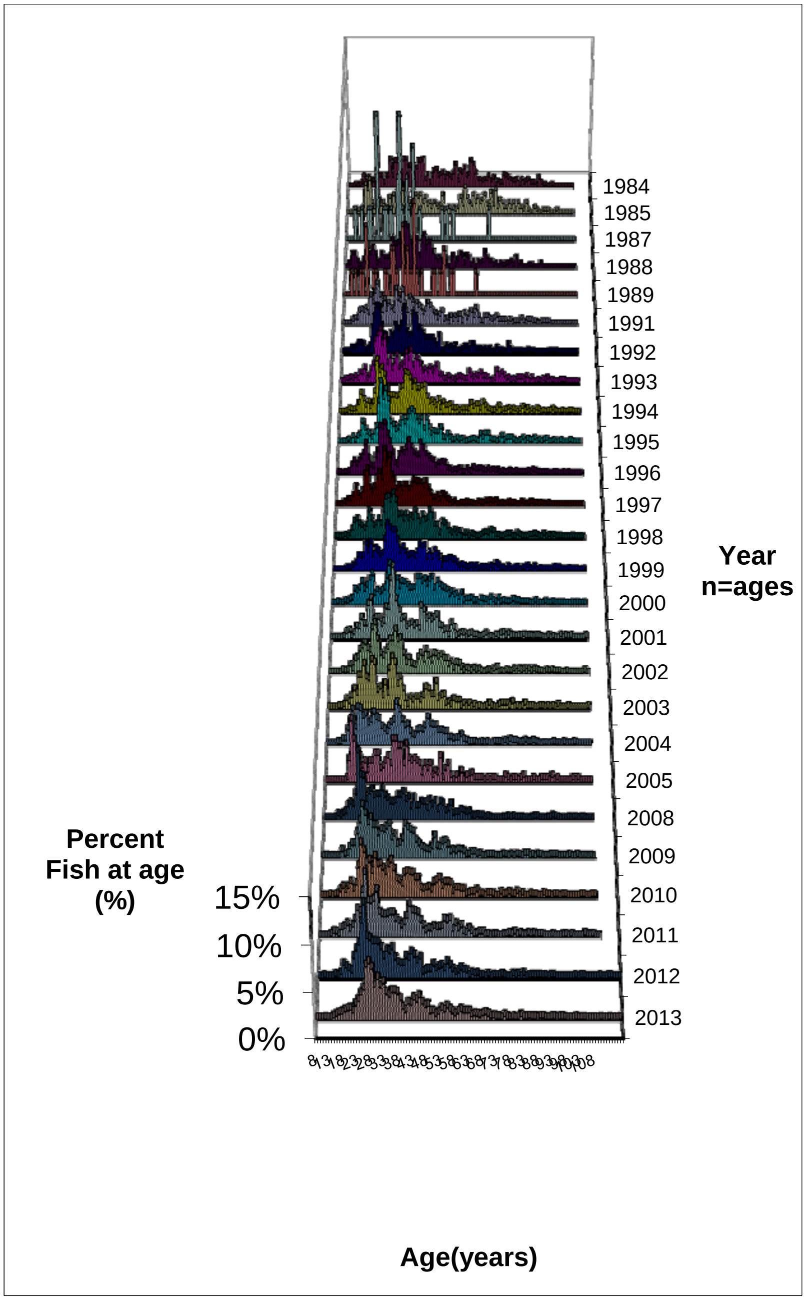


Figure 10. Age (year) frequency histogram from yelloweye rockfish landed in both the commercial directed and as incidental catch in the halibut fishery from 1984 through 2013.

Appendix A. History of DSR management action, Board of Fisheries (BOF), North Pacific Management Council (NPFMC) and Alaska Department of Fish and Game (ADF&G).

YEAR	ACTION
1984	Marine reserves recommended to BOF by ADF&G – rejected 600 t Guideline harvest limit for 10 species of DSR in CSEO directed fishery NPFMC defines 10 species assemblage as DSR (yelloweye, quillback, china, copper, canary, rosethorn, tiger, silvergrey, bocaccio, redstripe) October 1-Sept 30 accounting year
1986	ADF&G restricts gear for rockfish in the Southeast Region to hook and line only NPFMC gives ADF&G management authority for DSR to 137^0 W long. (Southeast Outside SEO) Guideline harvest limit (GHL) for directed fishery reduced to 300 t (CSEO) GHL for directed fishery set for SSEO (250 t), SSEI (225 t), NSEO (75 t), and NSEI (90 t)
1987	Sitka Sound closed to commercial fishing for DSR
1988	NPFMC implements 660 t total allowable catch for all fisheries (TAC) for SEO
1989	NPFMC imposes TAC of 470 t (catch history average) Industry working group discusses ITQ options with NPMFC (rejected) IWG recommends 7,500 lb trip limits, mandatory logbooks, and seasonal allocations (10/1-11/31 43%, 12/1-5/15 42%, 7/1-9/30 15%). Ketchikan area closure implemented GHL for directed fishery reduced in all areas (CSEO 150 t, SSEO 170 t, NSEO 50 t).
1990	Directed permit card required for CSEO, SSEO, NSEO, NPFMC TAC of 470 t
1991	NPFMC TAC of 425 t. Change in assemblage to 8 species (removed silvergrey, bocaccio, redstripe added redbanded). Craig and Klawock closures implemented
1992	East Yakutat area included in SEO (NPFMC extends ADF&G mgt authority to 140^0) NPFMC TAC of 550 t. Directed fishery permit card required in EYKT. Submersible line transect data used to set ABC in EYKT
1993	BOF changes seasonal allocation to calendar year: 1/1-5/15 (43%), 7/1-9/30 15%, and 10/1-12/31 (42%), DSR opened for 24 hour halibut opening 6/10 (full retention) NPFMC TAC of 800, yelloweye line transect data used to set TAC NPFMC institutes a separate halibut prohibited species cap (PSC) for DSR
1994	Trip limits reduced to 6,000 in SE and 12,000 lb trip limit implemented in EYKT NPFMC TAC 960 t line transect yelloweye plus 12% for other species. Last time a directed fishery in NSEO was held.
1995	NPFMC TAC 580 t
1996	NPFMC TAC 945 t
1997	NPFMC TAC 945 t, redbanded removed from assemblage definition
1998	NPFMC TAC 560 t, revised estimates of rock habitat in EYKT, 10% included for other species, Directed fishery season changed to prevent overlap with IFQ fishery 1/1-3/14 (67%), 11/16-12/31 (33%)
1999	NPFMC TAC 560 t

2000 NPFMC TAC 340 t, revised estimates of rock habitat in SEO. Regulation to require full retention for all DSR landed incidentally in the commercial halibut fishery was adopted for state waters.
2001 NPFMC TAC 330 t , Fall directed fishery season initially 24 hours in CSEO and SSEO due to small quota then re-opened 11/26 until quotas taken, no directed fishery NSEO
2002 NPFMC TAC 350 t, no directed fishery in EYKT due to changes in estimated incidental mortality in that area, no directed fishery in NSEO.
2003 NPFMC TAC 390 t, no directed fishery in EYKT or NSEO, protocol for classifying habitat revised resulting in changes in TAC. Registration required before participating in directed fishery.
2004 NPFMC TAC 460 t, directed fishery reopened in EYKT, no directed fishery in NSEO.
2005 NPFMC Final rule to require full retention for all DSR landed incidentally in the commercial halibut fishery for federal waters.
2006 DSR TAC is allocated as follows: 84% to the commercial fleet, 16% to the recreational fleet. SEO DSR restricted to winter fishery only and must close before the start of the halibut fishery. All directed fisheries closed.
2007 All directed fisheries closed.
2008 SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2009 Subsistence catch to be deducted from the ABC before allocation of the TAC to the commercial and recreational sectors. SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2010 SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2011 SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2012 Rockfish release devices required on recreational charter vessels. SSEO, CSEO and EYKT directed fisheries opened. NSEO closed.
2013 SSEO, CSEO and EYKT directed fisheries opened. NSEO closed.
2014 EYKT directed fishery opened. SSEO, CSEO, and NSEO remain closed.

Appendix B: An initial exploration of an age-structured model for yelloweye rockfish (*Sebastes rubberimus*) in Southeast Alaska Outside Waters

Introduction

This appendix to the 2014 Demersal Shelf Rockfish SAFE represents an effort to develop an age-structured assessment (ASA) model for yelloweye rockfish in Southeast Alaska outside waters (Fig. 1). This model is in response to previous commentary from both the Gulf of Alaska Plan Team and the Sciences and Statistical Committee to develop such an assessment. Model data, structure, assumptions and results are presented below.

Changes in model structure and data following September Plan Team meeting

1. *Model years*

Model years now run from 1985 – 2013 instead of 1992 – 2013.

2. *Mortality division*

Estimates of recruitment and natural mortality *M* begin in 1896 to populate the first model year (1985) with estimates of cohort abundance, conditioned on age-composition data. Prior to 1985, however, *M* = *Z*, as no fisheries data are available despite the existence of commercial fisheries. The revised model structure therefore separates *Z* into two estimates, one applied to 1896 – 1984, the other to 1985 – 2013, for each management area to prevent higher estimates of *Z* from earlier years from affecting estimates for *Z* for the period 1985 - 2013.

3. *Catch-curve estimate of total mortality Z set as model prior*

Model estimate of mean natural mortality *M*, averaged over all management areas, was 0.0716 in the original version. Comments from the Plan Team indicated this was high for yelloweye and efforts should be made to reduce it. Yelloweye are managed as a Tier 4 species, with the assumption $F = M = 0.02$. Rather than implement a high penalty on model deviation from a prior for *M* set to 0.02, which is a management criteria independent of data, a prior for total mortality *Z* for 1985 – 2013 was taken from catch-curve analysis and implemented with a very large penalty for model deviation.

4. *Assumptions regarding morphology and maturity*

The submarine and ROV survey estimates of density are conditioned on yelloweye morphology-only adult and subadults are counted. It was initially assumed that changes in morphology-at-age were equivalent to changes in maturity-at-age; this assumption has been shown to be wrong. Scaling model estimates of total abundance to density estimates of adult/subadult abundance is now a function of a morphology-at-age curve, made possible by the length-morphology data gathered by the recent ROV surveys.

5. *Submarine survey data*

Submarine survey data from 1994 were removed from model data sets. The 1994 submarine survey lacked the forward-facing camera standard on all subsequent submarine surveys. Analysis of fish counts showed a significant reduction of fish detected on the transect line in 1994 relative to all other submarine survey years, producing artificially low estimates of yelloweye density for 1994.

6. Management areas

Removal of the 1994 submarine survey data left no survey data points for NSEO. Without survey data, model estimates of abundance cannot be scaled, and NSEO was removed from the list of management areas for which an age-structured assessment was prepared.

7. IPHC survey CPUE

CPUE data from the IPHC were initially conditioned on the assumption that survey skates with no yelloweye present were deployed over habitat suitable for halibut but not yelloweye, and removed from CPUE calculations. This approach has been discarded. IPHC survey skate locations have been compared to rocky habitat suitable for yelloweye and only those skates deployed on rockfish habitat selected for calculation of IPHC survey CPUE.

8. *CPUE (directed commercial fisheries and IPHC*)

Efforts to find normal distributions for CPUE data from the directed commercial longline fishery initially merged data from all management areas to increase sample size; the same was done with IPHC longline survey data. This has been changed so that CPUE data for each management area are analyzed separately, allowing for different transformations to normality for each area.

9. Halibut longline bycatch age-composition and selectivity

Age-composition data from yelloweye caught as bycatch in the commercial longline halibut fishery were available for a small number of years for CSEO and EYKT. These data are now included along with estimates of selectivity-at-age curve separate from the curves derived from directed commercial yelloweye fisheries age composition data.

Executive Summary of Results

- Estimates of abundance, natural mortality *M,* and full-recruitment fishing mortality *F* were improved following revisions to model structure. Mean *M* dropped from 0.0716 to 0.0307, and estimates of F_{OFL} and F_{ABC} were more reasonable (Summary Table);
- Population trends showeddeclines in SSEO but remained relatively steady for CSEO and EYKT, which is different from the original model output which showed declines in all areas. Averaged over all areas, however, biomass estimates show a gradual decline (Summary Table);
- The revised model was able to estimate reasonable values for unfished spawning biomass, which suggest that current biomass levels range between $SB_{40\%}$ to $SB_{55\%}$;
- Models were highly sensitive to both density surveys and age data; efforts to continue surveys and improve ageing methods should be supported;

Summary Table					
Quantity	**Current assessment**		**ASA structure**		
	2014	**2015**	**2013**	**2014**	**2015**
M (natural mortality, ages 8+)	0.02		0.0307[1]		
Tier	4		4		
Biomass - total (metric tons)[3]	13,274	10,933	10,512[2]	10,467[2]	10,277[2]
Female spawning biomass (metric tons)			4,751[2]	4,662[2]	4,543[2]
$F_{OFL} = F_{35\%}$	0.032		$F_{35\%}$ = 0.0487[1]		
Max F_{ABC} (maximum = $F_{40\%}$)	0.026		$F_{40\%}$ = 0.0393[1]		
F_{ABC} (*recommended* = $F_{45\%}$)	0.02		$F_{45\%}$ = 0.032[1]		

[1]Mean over all management areas scaled by relative area (km^2)
[2]Summed over all management areas

Model Data

Data used in the age-structured model:

1. total annual catch (metric tons) from the directed DSR commercial fishery in the three SEO management areas (Southern Southeast Outside Waters (SSEO), Central Southeast Outside Waters (CSEO), and East Yakutat (EYKT)) (Table 1);
2. total annual incidental bycatch (metric tons) from the commercial halibut longline fishery (Table 2);
3. total annual catch (metric tons) from the sport fishery from 1996 – present (Table 3);
4. estimates of yelloweye density (individuals per square kilometer) derived from ADF&G submarine and remote operated vehicle (ROV) bottom surveys (Table 4);
5. estimates of total rockfish habitat per management area in square kilometers derived from sonar and other bathymetric surveys (Table 4);
6. age composition data from the commercial fishery;
7. age composition data from the commercial longline halibut fishery bycatch;
8. commercial fishery catch-per-unit effort (CPUE) derived from logbooks and fish tickets;
9. International Pacific Halibut Commission (IPHC) longline survey bycatch CPUE from IPHC survey logs;
10. estimates of length, weight, age, and maturity composition derived from commercial fisheries data from 1985 - 2013.

Total Annual Catch

Estimates of total annual catch were obtained through analyses of fisheries logbook data and fish tickets for each year in which a commercial fishery for yelloweye was implemented in the three management areas. Fisheries data from the early 1990's and prior are characterized by varied record-keeping methods in addition to changes in management areas and harvest regulations. Logbook data were re-assessed in construction of model data sets, and the numbers presented in Table 1 may differ somewhat from previous DSR stock assessments (Table 1, Fig. 2)

Halibut fishery incidental catch

In contrast to the directed commercial fishery for yelloweye, which has not been opened in every management area for every year included in the assessment model, incidental catch removals in the commercial longline halibut fishery have occurred every modeled year (Fig. 2). These incidental catch data stabilize model performance and compensate for years in which no commercial catch data exist. For years prior to 2006, yelloweye rockfish incidental catch data from the commercial halibut longline fishery were taken from halibut processor fish tickets; after 2006 these data were taken from the Interagency Electronic Reporting System (IERS), a joint effort between ADF&G, the IPHC, and the National Marine Fisheries Service (NMFS) to consolidate landing, IFQ, and logbook reporting (Table 2, Fig. 2).

Sport and Subsistence Catch

Sport catch refers to total removal from subsistence and recreational efforts, with an assumption of 100% mortality for any fish released. Total tonnage is calculated as the product of total number and the estimated mean weight over all ages for a given year. Data are available from 2006 – present (Table 3, Fig. 2). The assumption of 100% mortality may be relaxed in future assessment with the implementation of mechanisms designed to reduce mortality of released fish.

Density - Submarine and ROV *surveys*

ADF&G utilized a manned submersible to conduct line-transect surveys with direct observations of yelloweye abundance from 1990 - 2009. Survey locations were selected randomly but constrained to fall within rocky habitat considered appropriate for rockfish (a detailed description of ADF&G submarine and ROV survey methods is found in Green et al. 2014). After 2009, the submersible became unavailable, and was replaced by a ROV controlled directly from the survey ship. Surveys utilizing the ROV were conducted from 2012 onward. Line transect methods implemented in the software package DISTANCE 6.0 (Thomas et al. 2010) were used to calculate density of adult and sub-adult yelloweye from count data from both submarine and ROV surveys along with estimates of variance (Table 4). For the purposes of the ASA model, density and variance estimates from the submarine and ROV are assumed equivalent.

Fishery Age Composition

Estimates of fishery age composition for each management area were derived from data collected through port sampling of catch from the directed commercial fishery and bycatch taken in the commercial halibut longline fishery. Sampled otoliths were sent to the ADF&G Age Determination Unit for aging and the results used to construct length-age relationships. Age-composition was estimated from the catches specific to each area to potentially identify region-specific differences in age composition and recruitment. Years in which sample size was less than 50 were omitted.

CPUE

IPHC survey

The IPHC standardizes survey effort into “effective skates” relative to hook spacing and hook type as

$$effskt = noskt * 1.52 * (1 - e^{-0.06*hkspc}) * nohk / 100 * hkadj$$

where *noskt* = the number of skates hauled, *hkspc* = the mean spacing between hooks on a given skate, *nohk* = mean number of hooks per skate, and *hkadj* = hook type. If no hook type is available, a circle hook is assumed. Prior to 2009, yelloweye were counted for the first 20 hooks of each skate; total skate counted were extrapolated. From 2009 onward, yelloweye have been counted in full for each skate.
For model fitting, skates for which no yelloweye were retained were discarded from CPUE consideration under the assumption that they were set over halibut habitat unsuitable for rockfish. Catch-per-unit data were expressed as individual rockfish caught relative to hooks deployed.

Commercial fisheries

Catch-per-effort data for the directed commercial fishery, expressed as total pounds of rockfish retained relative to hooks deployed, were taken from logbook entries and fish tickets. Catch was determined sensitive to hook spacing, average depth fished, and the number of boats entered into the permitted fishery by year and management area (Fig. 3). A generalized linear model assuming a Poisson error distribution was used to fit the pounds of yelloweye rockfish caught to hook spacing, average depth fished, and number of boats participating in the fishery, factored by year, management area, and specific vessel (to account for relative experience levels).

CPUE for both the directed fishery and the IPHC survey was initially calculated as the ratio of catch to standardized effort for each reported set for a given vessel, for each management area in a given year. The results were not normally distributed and were problematic to model fitting. Following Quinn and Deriso (1999), catch for the commercial fishery and bycatch from the IPHC survey were transformed by implementation of the Box-Cox transformation

$$T(U) = \frac{U^{\alpha} - 1}{\alpha}$$

to describe an underlying normal distribution where U = the untransformed catch values, T = the transformed values, and α = the transformation parameter. For the commercial fishery, α was set to 0.33 for all management areas to obtain a cube root transform (Fig. 3). For the IPHC longline survey, it was necessary to assign different α values to each area to obtain normality (CSEO = 0.33; EYKT = 0.2; SSEO = 0.5) (Fig. 3). Median catch C for each year y and management area a was calculated and back transformed as

$$C_{y,a} = S(T) = (\alpha\hat{\mu}_{y,a} + 1)^{(1/\alpha)}$$

where $\hat{\mu}$ is the median of the transformed values.

Model years and management areas

The model covers the years from 1985 – 2013.

Data set		*Years available*
Directed DSR total annual fishery catch:	CSEO	1985-2004, 2012, 2013
	SSEO	1985- 2004, 2008 – 2012, 2013
	EYKT	1985, 1987-2001, 2004-2005, 2008-2009, 2012, 2013
Directed DSR fishery age composition:	CSEO	1988, 1992 – 2004, 2012, 2013
	SSEO	1991 – 2005, 2009 – 2013
	EYKT	1992 – 2001, 2004 – 2005, 2008 – 2009, 2012, 2013
Halibut longline fishery total annual bycatch		1985 – 2013 for all management areas
Halibut bycatch fishery age composition:	CSEO	2008 - 2011
	SSEO	None
	EYKT	2010 - 2011
Directed DSR fishery CPUE		As for total annual catch
IPHC survey CPUE		1998 – 2013 for all management areas
Sport fishery total annual catch		2006 - 2013

Submarine/ROV survey density:	CSEO	1995, 1997, 2003, 2007, 2012
	SSEO	1999, 2005, 2013
	EYKT	1995,1997, 1999, 2003, 2009

Each management area (EYKT, CSEO, SSEO) was considered a distinct population, with recruitment, mortality, fishery removals, halibut longline fishery incidental catch, survey density estimates, and estimates of suitable rockfish habitat specific to each area. Length-weight-age keys and maturity-at-age were assumed the same for all areas, estimated external to the model, and input. Natural mortality and selectivity-at-age were estimated for each area. Males and females were not separated except in the calculation of female spawning biomass and female maturity-at-age.

Analytic approach

Model structure

Standard age-structured population dynamics equations (Quinn and Deriso 1999) were used to model yelloweye rockfish in SEO waters from 1985 – 2013 using AD Model Builder (Fournier et al. 2011) (BOX 1). Modeled age classes ran from 8 – 97, with 8 being the age of recruitment (the youngest age observed in commercial fisheries data), and 97 being a plus class. Recruitment was estimated from 1903 – 2013 to populate the first year of the age-structured (1992). Model estimates included spawning biomass, recruitment, natural mortality, abundance-at-age, commercial catch, incidental catch in the commercial longline halibut fishery, sport catch, CPUE for both the commercial fishery and the IPHC halibut longline survey, and density (number of individual per square kilometer) for each management area.

Density

Although the line transect surveys count all observed yelloweye, density calculations are completed in DISTANCE 6.0 only for adults and sub-adults, omitting juveniles. The distinction between juvenile and sub-adult classification is based on assessment of changes in coloring and morphology that occur as a fish ages. The ROV surveys in 2012 and 2013 provided length-classification data, allowing for construction of a classification-at-age curve which was used to scale model estimates of total abundance to model estimates of adult and sub-adult density. Estimates of maturity-at-age and suitable rockfish habitat for each management area in square kilometers were assumed known without error.

As survey density scales model estimates of absolute abundance, catchability for the submarine and ROV line transects was set to 1.

Catch-at-age

Catch-at-age for each management area was a function of the Baranov catch equation, with fishing mortality-at-age a in year y $F_{y,a}$ the product of an asymptotically increasing selectivity-at-age f_a and a full-recruitment fishing mortality term F_y (BOX 1). Both the sport fishery and bycatch in the halibut longline fishery were modeled as separate fisheries, but selectivity-at-age f_a was assumed the same as for the yelloweye directed fishery.

Spawning biomass

For each management area, female spawning biomass for a given year y was estimated under the assumption of equal male/female proportions (BOX 2). Yelloweye have internal fertilization and potentially extended periods of parturition; for convenience, it was assumed that parturition occurs in May, following O'Connell (1987).

CPUE

For each year y and management area, median catch C was modeled as

$$C_y = q_{iphc} E_y^{\alpha+1} N_y^{\beta+1} \qquad \text{IPHC survey}$$
$$C_y = q E_y^{\alpha+1} B_y^{\beta+1} \qquad \text{Directed fishery}$$

where C = median catch (pounds for the directed fishery, numbers for the IPHC survey), q = catchability for the commercial fishery, q_{iphc} = catchability for the IPHC longline survey, E = median effort (total hooks), N = abundance (millions of individuals), B = biomass (metric tons), and α and β are model parameters defining the relationship between catch and abundance.

Selectivity-at-age

Within SSEO, selectivity-at-age f_a is assumed the same for the directed yelloweye commercial longline fishery, the commercial halibut longline fishery, and the sport fishery. CSEO and EYKT contain age-composition data for halibut longline fishery bycatch, and a separate selectivity-at-age vector for bycatch was estimated. Selectivity vectors were estimated for each management area to potentially aid in identifying differences in age-structure. Selectivity-at-age was estimated as

$$f_a = \frac{1}{1 + \exp(-slope * (age - sel_{50\%}))}$$

for which $sel_{50\%}$ is the age at which 50% of the population is selected into the fishery, *slope* is the slope of the sigmoid curve at the $sel_{50\%}$ point.

Parameter estimation

Model parameters were estimated by minimizing a penalized negative log-likelihood objective function (BOX 3). Log-normal likelihoods were assumed for total annual catch, total annual halibut longline fishery incidental catch, sport catch, and density for each management area. Multinomial likelihoods were assumed for age composition data. Penalties were implemented in the objective function to facilitate scaling and parameter estimation. Natural mortality Z, full-recruitment fishing mortality F, catchability in the directed commercial fishery q, catchability in the IPHC longline survey q_{iphc}, and recruitment variability σ_r were constrained by minimizing deviations from assumed log-normal prior probability distributions. Fishing mortality-at-age for both the commercial DSR fishery and incidental catch in the halibut longline fishery was constrained by minimizing annual fluctuations (BOX 3). Irregularities in recruitment were also constrained (BOX 3).

Yelloweye are managed as a Tier 4 species, with the assumption $F = M = 0.02$. The prior for F was set to 0.02 as per the Tier 4 management criteria, but with a variance sufficiently large to allow for parameter flexibility. The prior for total mortality Z (for years prior to 1985) was similarly set to 0.02 primarily for stability in the estimation process. The prior for total mortality Z (1985 – 2013) was set to the catch-curve estimate of Z and heavily weighted.

Priors, starting values, and assumed variances

Parameter	Prior value	Variance	Estimation phase
Z (pre-1985)	0.02	0.4	4
Z (1985 – 2013)	0.0564	0.1	4
Mean *F*	0.02	0.4	1
Recruitment deviations σ_r	0.5	0.5	5
Commercial catchability *q*	1	0.5	1
IPHC survey catchability *q*	1	0.5	1

Objective components and weights for each management area

Component	Weight		
	CSEO	EYKT	SSEO
Density	30	30	30
Commercial annual catch	70	70	70
IFQ halibut annual bycatch	50	50	50
Total annual sport catch	25	25	25
Commercial catch-age composition	5	5	5
Halibut bycatch age-composition	20	20	n/a
Commercial CPUE	0.5	0.5	0.5
IPHC bycatch CPUE	0.5	0.5	0.5
F regularity	0.01	0.01	0.01
PRIORS			
Z (1985 – 2013)	50,000	50,000	50,000
Z (pre-1985)	1	1	1
Mean *F*	1	1	1
Recruitment deviations σ_r	1	1	1
Commercial catchability *q*	1	1	1
IPHC survey catchability *q*	1	1	1

Total estimated parameters for each management area

Parameter	Number
1) mean full-recruitment fishing mortality *F*	1
2) mean recruitment	1
3) natural mortality (pre-1985, post-1984)	2
4) annual fishing mortality deviations for yelloweye fishery	29
5) annual fishing mortality deviations for IFQ halibut bycatch	29
6) annual fishing mortality deviations for sport catch	8
7) annual recruitment deviation	118
8) recruitment variability	1
9) Selectivity and CPUE parameters (CSEO, EYKT / SSEO)[1]	10 / 8
Total (CSEO, EYKT / SSEO)	197 / 195

[1]As there are no halibut bycatch age-composition data for SSEO, no selectivity-at-age curve is estimated for SSEO for that fishery.

Externally estimated parameters

Life history attributes were estimated externally from data collected through port sampling of commercial fisheries catches from 1992 - 2013. These were assumed constant over all areas and years, and include:

- Weight-at-age
- Maturity-at-age
- Age-error matrix

Weight-at-age (kilograms)

Mean weight-at-age W was estimated by fitting observed weights-at-age to the equation

$$W_t = W_\infty[1 - e^{-k(t-t_0)}]$$

for which W_t = weight at time t (age), W_∞ = asymptotic weight, t_0 = the time (age) at which an individual is considered to have weight 0, and k = growth rate. Mean weight-at-age was assumed consistent across all management areas and equivalent between males and females (Fig. 4).

W_∞	***k***	$\boldsymbol{t_0}$
6.027	0.039	-10.13

Maturity-at-age

Proportions mature-at-age m_a were calculated for females only, fitting observed maturity-at-age to the equation:

$$m_a = \frac{mat_\infty}{1 + \exp(-slope * (age - mat_{50\%}))}$$

for which $mat_{50\%}$ is the age at which 50% of the population is reproductively mature, *slope* is the slope of the sigmoid curve at the $mat_{50\%}$ point, and mat_∞ = asymptotic maturity.

slope	$\boldsymbol{mat_{50\%}}$
-0.341	17.634

Age-error matrix

An age-error matrix, defining the probability of correctly aging a fish based on otolith analysis, was constructed by Dana Hanselman (Auke Bay Lab, National Marine Fisheries Service) for earlier model work in 2010. This matrix is preserved in the current model iteration. The matrix is implemented in the calculation of predicted catch-at-age proportions for the directed yelloweye commercial fishery (BOX 1 & 2). This matrix, however, reflects the uncertainty of age readers for NMFS, not the age readers from the ADF&G Age Determination Unit. An age-error matrix was constructed from ADU data but improvements in the analysis of ADU data are needed before it is considered sufficiently robust for model integration.

Model Results

Objective function values are presented in Table 5.

Model fits to DISTANCE 6.0 estimates of region-specific yelloweye rockfish per square kilometer are presented in Fig. 5. Following Plan Team comments, these data points scale model estimates of abundance and provide general population trends, as opposed to requiring a precise fit to each point.

Fits to directed commercial total annual catch (Fig. 6), commercial halibut longline fishery annual bycatch (Fig. 7) and annual sport catch (Fig. 8) were good. Estimates of full-recruitment fishing mortality *F* for the directed commercial fishery were generally below the Tier 4 assumption that $F = 0.02$ (Fig. 9, Table 7), although when combined with IFQ halibut bycatch fishing mortality, total *F* levels often exceeded 0.02.

Estimates of natural mortality *M* (1985 – 2013) exceeded the Tier 4 assumption that $M = 0.02$ for all areas, but only slightly (Table 6). Total mortality *Z* (1985 – 2013) exceeded the Tier 4 assumption that $Z = 0.04$ for all management areas, and estimates for each area fell within 10% of the specified prior for *Z* derived from the catch-curve analysis (Fig. 10).

Annual recruitment is presented in Fig. 11 along with period-specific estimates of *Z* (1896 – 1984) and *M* (1985 – 2013). Estimates of total mortality for 1896 – 1984 were roughly twice that of natural mortality for 1985 – 2013.

Spawning biomass in CSEO and EYKT appeared relatively steady, while spawning biomass in SSEO declined over model years. Projected spawning biomass (2014 – 2018) for all areas showed a decrease (Fig 12).

Selectivity-at-age curves for all areas were similar (Fig. 13), with age at 50% selectivity ranging from 20.6 to 23.9. Maturity-at-age, calculated external to the model, appears to occur prior to recruitment into the commercial fishery for all areas.

Fits to CPUE data were variable (Figs. 14 and 15). Catchability values for commercial CPUE remained close to 1, while catchability for the IPHC longline survey varied markedly between management areas.

	CSEO	EYKT	SSEO
Q (commercial fisheries)	1.1262	1.0744	0.7823
Q (iphc survey)	0.9942	0.4156	0.8670

Age-composition fits to observed commercial fisheries age data are presented in Figs. 16 -18. EYKT shows strong recruitment events in recent years, which may account for the relative stability of abundance, while both CSEO and SSEO have weaker recruitments. All three areas show decline of older cohorts over time.

Mean recruitment was estimated as the average recruitment from 1987 – 2005 (Table 7). Estimates of female spawning biomass in the terminal model year (2013) for each area fell between $F_{spr\ 40\%}$ and $F_{spr\ 55\%}$. A comparison of the current management F levels with model estimates of fishing mortality (Table 8) suggests that F_{ABC} lies closer to $F_{55\%}$ than $F_{45\%}$.

Discussion

Density

It can be seen in Fig. 5 that while density data scale model estimates of absolute abundance, fitting to individual estimates was often poor. As discussed above, model estimates of density are not fitted directly to observed survey data, but to estimates of density derived from survey data by the DISTANCE software package (Thomas et al. 2006) as

$$\hat{D}_{distance} = \frac{nf(0)}{L}$$

for which n = number of adult and sub-adult yelloweye observed, *f(0)* probability of detection as a function of distance from the transect line, and L = total line length (meters). The probability detection function assumes that detection on the line = 1 (Burnham et al. 1980).

Model estimates of density assume the following:

- Estimates of rockfish habitat (km^2) are without error;
- The physical appearance of adults and sub-adults counted in the survey can be represented by the maturity-at-age curve without error;
- Estimates of density and variance from DISTANCE 6.0 are correct, including the assumption that detection on the line = 1.

If assumptions #1 and/or #2 above are relaxed, the model would likely require extremely tight constraints on parameter estimation to allow model convergence. The author is also uncomfortable with an arbitrary *ad hoc* approach to weighting density objective function components, especially when it results in different weights for different areas based on the number of years for which surveys were completed. Although it is logical to change weights relative to available data, the current structure implements the same weight for density estimates over all management areas because a formal approach for weighting density objective function components relative to the years of available data has not yet been developed.

CPUE

Estimates of CPUE and the model functions for fitting to these data remain problematic, and additional work is needed to improve the signal to noise ratio in the data.

Mortality and Fishing Pressure

Use of catch-curve-derived total mortality Z as a prior for model estimates of Z to obtain reasonable values for M appeared to work well, although the statistical implications of using catch-age data both within the model and to calculate the prior for Z are unclear to the author. O'Connell and Brylinksy (2003) applied catch-curve analysis to "lightly fished" 1984 SSEO commercial longline data and estimated M = 0.017 (under the assumption that Z was roughly equal to M under conditions of little fishing pressure), while alternative methods produced estimates ranging from 0.02 to 0.056 (O'Connell and Brylinksy 2003, Table 3). The estimate from O'Connel and Brylinksy (2003) of $Z = 0.056$ was from commercial fisheries data in CSEO from 2000 – 2002, which is virtually identical to the current catch-curve estimate for CSEO of 0.0564 (Fig. 10).

While slight modifications to the assumption that $F_{ABC} = 0.02$ may move towards sustainable fisheries removals, model outputs suggest that 0.02 should be understood as representing a somewhat smaller reduction of unfished spawning biomass than the commonly assumed $F_{ABC} = F_{45\%}$ (Table 8). Relative F levels were calculated ranging from $F_{30\%}$ to $F_{70\%}$ for each region, suggesting that F_{OFL} begins roughly at $F_{45\%}$ instead of $F_{35\%}$, and F_{ABC} lies closer to $F_{55\%}$ instead of $F_{45\%}$. If accurate, the implication is that yelloweye are highly sensitive to fisheries removals. The current management assessment set an ABC of 274 metric tons for 2014 (Green et al. 2014). When compared with projected catch levels for 2014 under varying F levels from the ASA model, 274 metric tons represented a removal at roughly $F_{45\%}$. This corresponds to an F level of 0.032, which under current management regulations is classified as the OFL threshold (Table 8).

Biological reference points and unfished spawning biomass

Model estimates of unfished spawning biomass appear reasonable in that current spawning biomass levels are all below $SB_{100\%}$, and the current stock levels fall between $SB_{40\%}$ and $SB_{55\%}$. The implication is that while the Tier 4 assumptions regarding F levels will likely need some minor adjustments to adequately ensure sustainable stock numbers and catch levels, they have, up to the present, been largely adequate for management of yelloweye populations. The author is very interested in comments from the Plan Team and the SSC as to whether the current model structure is considered sufficiently robust to move yelloweye from Tier 4 to a Tier 3 species.

Predation mortality is generally disproportionately higher for younger ages in non-apex species (Gaichas et al. 2010, Van Kirk et al. 2012). One approach to improving estimates of recruitment, natural mortality, and SPR rates might be to construct predation profiles for yelloweye rockfish predators in the Gulf of Alaska, and either actively model predation mortality for younger ages or, alternatively, estimate a separate natural mortality for each age below a given limit, depending on available predation data. Increased mortality for younger ages through predation produces increased recruitment but at the same time prevents the increased biomass from being passed into older cohorts and then requiring unrealistic levels of natural mortality to maintain cohort structure. This, in turn, may aid in estimating realistic values for unfished spawning biomass.

Unified model

The current model estimates the population dynamics of each management area separately, but there may be an advantage to modeling the entire geography of the Southeast Outside water as a single population. Following parturition, yelloweye larvae experience dispersal through passive transport until capable of independent mobility, eventually settling into benthic habitat and thereafter exhibiting only local movement. This early dispersal is unlikely to follow management divisions, may account for differences in relative abundance and natural mortality for each area, and would serve to link adult populations that are largely sedentary and isolated but are treated as a single stock for management purposes.

Data Gaps and Research Priorities

1. Aging methods and data from the ADFG Age Determination Unit need to be better analyzed to allow for construction of a valid age-error matrix that reflects the uncertainty of the ADFG age data instead of using the NMFS age-error matrix. This is of critical importance, as the age-structure of the model has a large effect on estimates of *M* and *F* as well as selectivity-at-age;
2. Alternate methods of estimating recruitment should be explored in the hopes of moving yelloweye rockfish from Tier 4 to Tier 3 management status;
3. CPUE data should be further examined to determine whether the information contained there is able to be extracted with a better signal-to-noise ratio.

The author looks forward to comments and suggestions from the Plan Team and SSC regarding these points and any other suggestions or recommendations for improving model performance.

References

Brylinksy, C., J. Stahl, D. Carlile, and M. Jaenicke. 2009. Assessment of the demersal shelf rockfish stock for 2010 in the southeast outside district of the Gulf of Alaska. In: Stock assessment and fishery evaluation report for the groundfish resources for the Gulf of Alaska, North Pacific Fisheries Management Council, Anchorage, Alaska pp. 1067 – 1110.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2011. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Taylor and Francis Online.

Gaichas, S.K., K.Y. Aydin, and R.C. Francis. 2010. Using food web model results to inform stock assessment estimates of mortality and production for ecosystem-based fisheries management. Can. J. Fish. Aquat. Sci. **67**, 1490-1506.

McAllister, M.K., and J.N. Ianelli. 1997. Bayesian stock assessment using catchage data and the sampling – importance resampling algorithm. Can. J. Fish. Aquat. Sci. **54**(2): 284–300.

O’Connell, V.M. 1987. Reproductive seasons for some Sebastes species in Southeast Alaska. Alaska Department of Fish and Game Information Leafelt 263: 21 p.

O’Connell and Brylinksy. 2003. The Southeast Alaska demersal shelf rockfish fishery with 2004 season outlook. Alaska Department of Fish and Game Regional Information Report No. 1J03-43

Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology **47**: 5-14.

Quinn, T.J. II and R.B. Deriso. 1999. *Quantitative Fish Dynamics*, Oxford, New York.

Van Kirk, K.F., T.J.Quinn II, J.S. Collie, and Z.T. A'mar. 2012. Multispecies age-structured assessment for groundfish and sea lions in Alaska, in G.H. Kruse, H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, P.A. Livingston, D. Woodby, and C.I. Zhang (eds.), *Global Progress in Ecosystem-based Fisheries Management*, Alaska Sea Grant, University of Alaska, Fairbanks. pp. 147-168.

Table 1. Total annual directed commercial yelloweye catch (t) for each management district for all modeled years

Year	CSEO	SSEO	EYKT	Total
1985	215.38	26.85	5.15	247.38
1986	204.82	77.74	0.00	282.56
1987	171.75	288.66	64.79	525.2
1988	127.19	211.13	39.17	377.49
1989	118.65	112.16	35.56	266.37
1990	70.22	86.02	15.69	171.93
1991	76.61	87.31	173.08	337
1992	101.11	131.41	46.92	279.44
1993	122.17	62.72	87.48	272.37
1994	128.32	72.57	110.38	311.27
1995	73.61	22.69	46.12	142.42
1996	162.25	62.94	95.86	321.05
1997	136.15	49.62	63.51	249.28
1998	110.44	50.17	64.44	225.05
1999	97.78	57.46	72.55	227.79
2000	58.74	58.94	55.59	173.27
2001	58.94	56.52	48.91	164.37
2002	70.89	57.02	0.00	127.91
2003	57.99	36.33	0.00	94.32
2004	55.51	23.71	86.88	166.1
2005	0.00	0.00	41.90	41.9
2006	0.00	0.00	0.00	0
2007	0.00	0.00	0.00	0
2008	0.00	19.70	21.72	41.42
2009	0.00	29.28	44.40	73.68
2010	0.00	28.49	0.00	28.49
2011	0.00	21.39	0.00	21.39
2012	31.05	31.99	35.99	99.03
2013	35.69	5.27	36.64	77.6

Table 2. Total annual yelloweye incidental catch (t) in the commercial longline halibut fishery for each management district for all modeled years

Year	CSEO	SSEO	EYKT	Total
1985	7.61	0.67	1.49	9.77
1986	4.28	0.92	0.27	5.47
1987	4.52	2.14	1.33	7.99
1988	1.57	3.09	0.11	4.77
1989	22.65	23.59	5.73	51.97
1990	13.01	29.97	5.08	48.06
1991	24.65	11.97	17.59	54.21
1992	43.81	22.30	16.48	82.59
1993	73.91	36.19	11.21	121.31
1994	103.13	44.80	14.61	162.54
1995	34.32	6.68	11.03	52.03
1996	28.18	8.63	14.09	50.9
1997	45.95	6.86	22.79	75.6
1998	49.54	10.20	35.26	95
1999	44.97	13.97	33.40	92.34
2000	40.20	14.37	24.61	79.18
2001	55.73	23.92	34.00	113.65
2002	56.06	23.10	34.97	114.13
2003	56.61	27.09	47.12	130.82
2004	47.17	32.72	45.76	125.65
2005	59.02	47.42	53.14	159.58
2006	67.03	54.17	39.16	160.36
2007	66.42	43.05	54.39	163.86
2008	48.61	26.08	46.73	121.42
2009	41.08	27.08	52.82	120.98
2010	32.54	23.32	57.02	112.88
2011	24.86	7.34	44.24	76.44
2012	20.18	9.96	33.69	63.83
2013	26.23	10.09	33.56	69.88

Table 3. Total annual yelloweye sport and subsistence catch (t) for each management district for 2006 - present

Year	CSEO	SSEO	EYKT	Total
2006	36.973	21.859	0.804	59.636
2007	50.687	18.484	0.270	69.441
2008	34.829	12.313	0.399	47.541
2009	7.825	7.406	0.002	15.233
2010	28.605	9.666	0.004	38.275
2011	16.160	5.820	0.004	21.984
2012	20.665	7.707	0.011	28.383
2013	14.147	7.135	0.001	21.283

Table 4. Submersible (1995, 1997, 1999, 2003, 2005, 2007, 2009) and ROV (2012–2013) yelloweye rockfish density estimates with 95% confidence intervals (CI) and coefficient of variations (CV) by year and management area. The number of transects, yelloweye rockfish (YE), and meters surveyed included in each model are shown, along with the encounter rate of yelloweye rockfish. Values in bold were used for this stock assessment. (Table adapted from Green at al. 2014)

Area	Year	Area (km^2)	# YE[b]	Meters surveyed	Encounter rate (YE/m)	Density (YE/km^2)	Lower CI (YE/km^2)	Upper CI (YE/km^2)	CV
EYKT[a]	1995	744	330	22,896	0.014	2711	1776	4141	0.20
	1997		350	19,240	0.018	2576	1459	4549	0.28
	1999		236	25,198	0.009	1584	1092	2298	0.18
	2003		335	17,878	0.019	3825	2702	5415	0.17
	2009		**215**	**29,890**	**0.007**	**1930**	**1389**	**2682**	**0.17**
CSEO	1995	1404	235	39,368	0.006	2929			0.19
	1997		260	29,273	0.009	1631	1224	2173	0.14
	2003		726	91,285	0.008	1853	1516	2264	0.10
	2007		301	55,640	0.005	1050	830	1327	0.12
	2012		**118**	**38,590**	**0.003**	**752**	**586**	**966**	**0.13**
SSEO	1999	732	360	41,333	0.009	2376	1615	3494	0.20
	2005		276	28,931	0.010	2357	1634	3401	0.18
	2013		118	30,439	0.004	986	641	1517	0.22

[a] Estimates for EYKT management area include only the Fairweather grounds, which is composed of a west and an east bank. In 1997, only 2 of 20 transects and in 1999, no transects were performed on the east bank that were used in the model. In other years, transects performed on both the east and west bank were used in the model.

[b] Subadult and adult yelloweye rockfish were included in the analyses to estimate density. A few small subadult yelloweye rockfish were excluded from the 2012 model based on size; length data were only available for the ROV surveys. Data were truncated at large distances for some models; as a consequence, the number of yelloweye rockfish included in the model does not necessarily equal the total number of yelloweye rockfish observed on the transects.

Table 5. Objective function values

Component	Objective function values		
	CSEO	EYKT	SSEO
Density	246.37	211.54	71.45
Annual commercial catch	10.22	5.36	6.22
Annual commercial longline halibut bycatch	1.84	0.14	0.18
Annual sport catch	0.44	0.00	0.03
Directed commercial catch age composition	4988.49	5157.63	10,428.5
Commercial longline halibut bycatch age composition	3986.83	1529.65	n/a
Directed commercial fishery CPUE	13.17	13.69	29.06
IPHC survey bycatch CPUE	2.65	1705.76	6.02
F regularity	28.26	25.63	14.47
PRIORS			
Z (1985 – 2013)	18.78	0.26	2.04
Z (pre-1985)	0.003	0.002	0.001
Mean *F*	16.33	13.34	11.49
Recruitment deviations σ_r	1.64	1.01	1.12
Commercial catchability *q*	0.02	0.005	0.02
IPHC survey catchability *q*	0.00	0.81	0.06

Table 6. Natural mortality *M,* mean full-recruitment fishing mortality *F*, mean total mortality *Z,* (1985 – 2013)

	CSEO	EYKT	SSEO	Mean
Nat. mortality *M*	0.0299	0.0287	0.0342	0.0307[1]
F commercial	0.0481	0.0273	0.0215	0.0359[1]
F IFQ hal. bycatch	0.0187	0.0125	0.0074	0.0142[1]
F sport	0.0132	0.0000	0.0044	0.0075[1]
Tot. mortality *Z*	0.0601[2]	0.0559[2]	0.0575[2]	0.0583[1,2]

[1]Mean over all management areas scaled by relative area (km^2)

[2]Mean over all age classes, including unfished cohorts

Table 7. Mean recruitment, F_{spr} values, and model female spawning biomass

	CSEO	EYKT	SSEO
Avg. Recr. (1000s) (1987 – 2005)	74.99	68.61	57.25
Area (km^2)	1,404	744	732
Female spawning biomass under F_{spr} rates			
$F_{spr\ 100\%}$	2,609	3,437	2,234
$F_{spr\ 45\%}$	1,677	1,547	1,005
$F_{spr\ 40\%}$	1,491	1,375	894
$F_{spr\ 35\%}$	1,305	1,203	782
Female spawning biomass, terminal year (2013)	1,944	1,422	1,385

Table 8. ASA model F levels and ASA model projected catch for all management areas, compared with F levels and 2014 allowable catch from current management approach.

	CSEO	EYKT	SSEO		Current management levels
Estimated commercial F levels				Mean[1]	
$F_{70\%}$	0.0108	0.0112	0.0127	0.0114	
$F_{65\%}$	0.0135	0.0141	0.0159	0.0143	
$F_{60\%}$	0.0167	0.0174	0.0197	0.0176	
$F_{55\%}$	0.0203	0.0214	0.0241	0.0216	$F_{ABC} = 0.02$
$F_{50\%}$	0.0247	0.0262	0.0294	0.0263	Max F_{ABC} (max = $F_{40\%}$) = 0.026
$F_{45\%}$	0.0300	0.0321	0.0359	0.0320	$F_{OFL} = F_{35\%} = 0.032$
$F_{40\%}$	0.0366	0.0396	0.0440	0.0393	
$F_{35\%}$	0.0452	0.0495	0.0546	0.0487	
$F_{30\%}$	0.0566	0.0633	0.0689	0.0615	
Projected commercial catch for 2014 (m. tons)				Total	TAC for 2014
Catch - $F_{70\%}$	39	26	32	97	
Catch - $F_{65\%}$	49	33	40	121	
Catch - $F_{60\%}$	60	40	49	149	
Catch - $F_{55\%}$	73	49	60	182	182 metric tons
Catch - $F_{50\%}$	88	60	73	222	
Catch - $F_{45\%}$	107	74	89	270	274 metric tons
Catch - $F_{40\%}$	130	91	108	330	
Catch - $F_{35\%}$	160	113	134	407	
Catch - $F_{30\%}$	200	144	168	511	

[1] Calculated as a weighted mean relative to the km2 of rockfish habitat per management area.

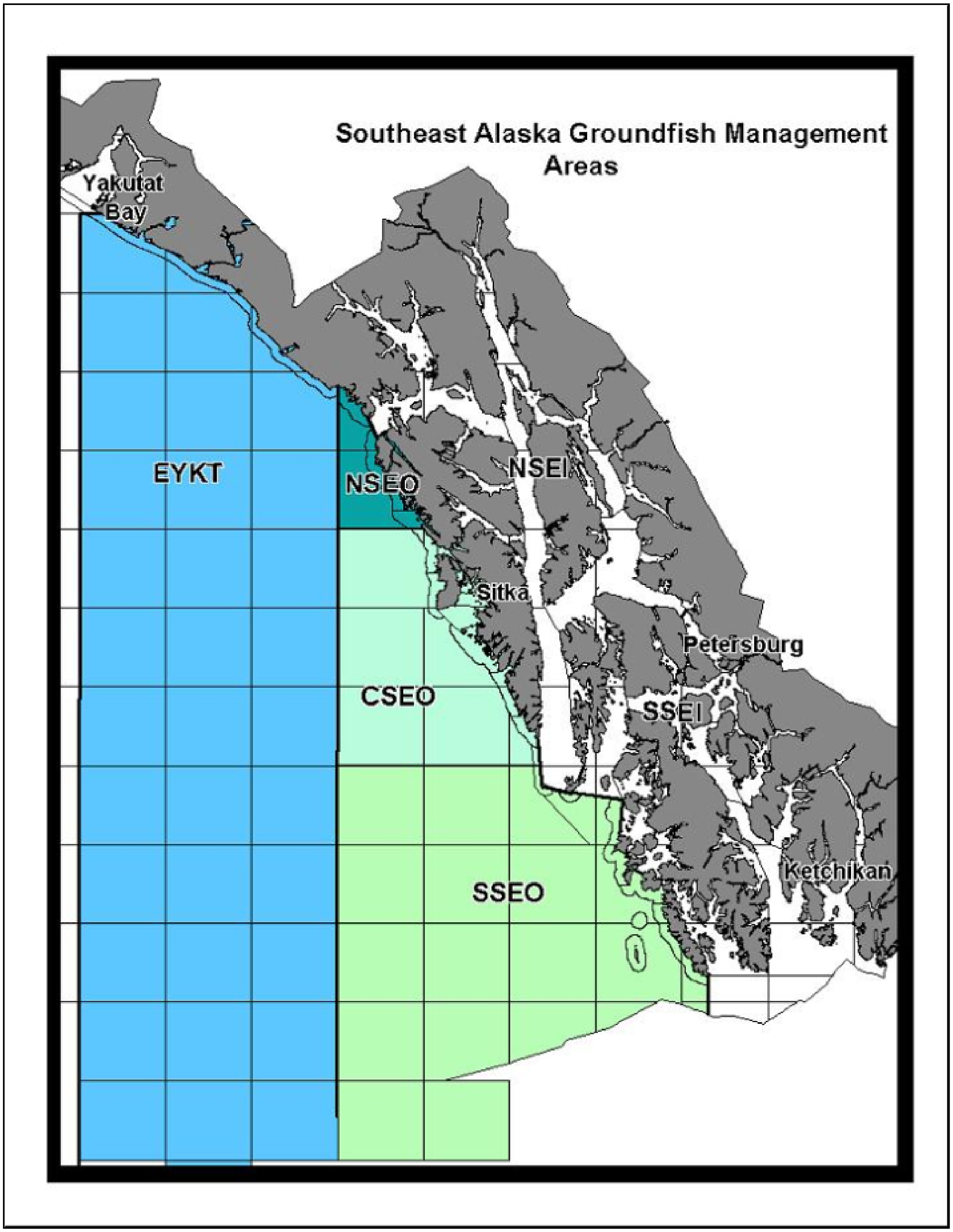


Figure 1. Southeast Alaska Outside Waters (Eastern Gulf of Alaska) with the Alaska Department of Fish and Game groundfish management areas; EYKT, CSEO, NSEO, and SSEO.

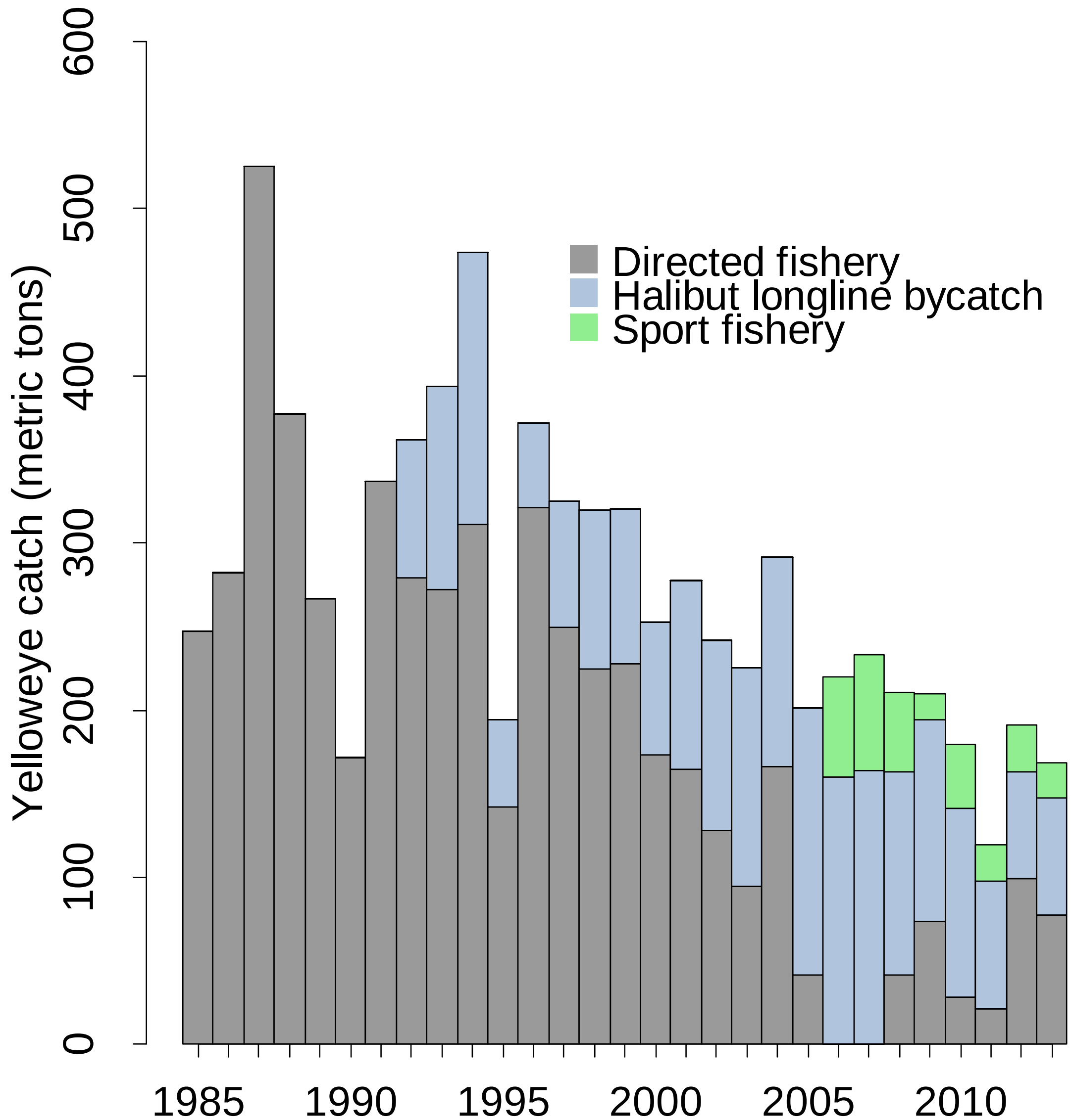


Figure 2. Total annual catch from SEO (CSEO,EYKT,SSEO) waters from the directed DSR commercial fishery, the commercial longline halibut fishery, and sport removals as used in the ASA model.

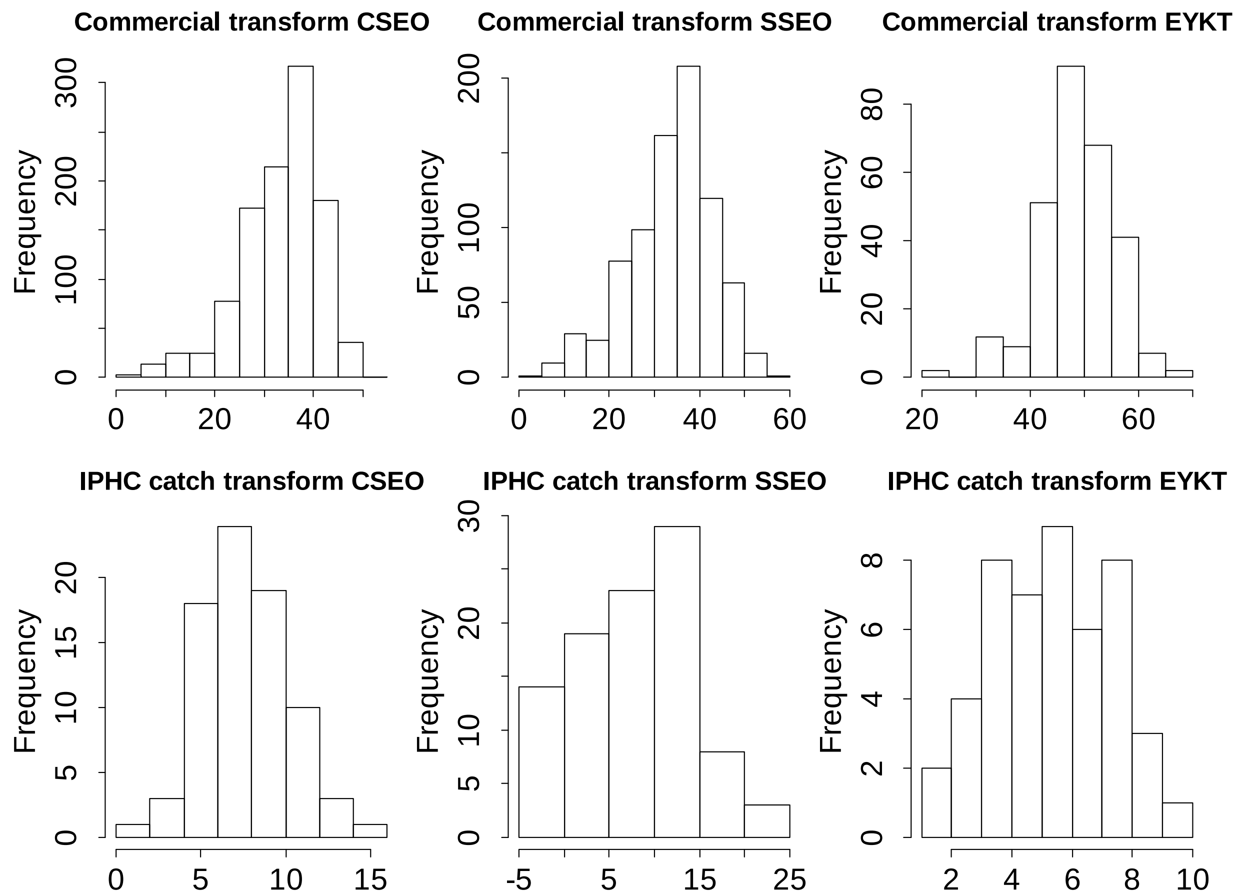
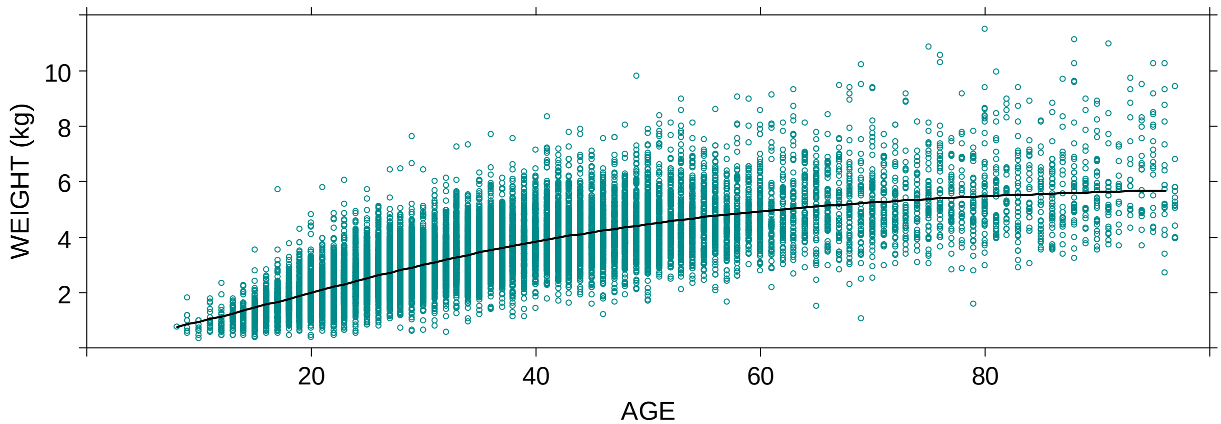


Figure 3. Transformed catch data and transformed catch data from the directed commercial fishery (top row), and the IPHC longline survey (bottom row) for estimating CPUE.



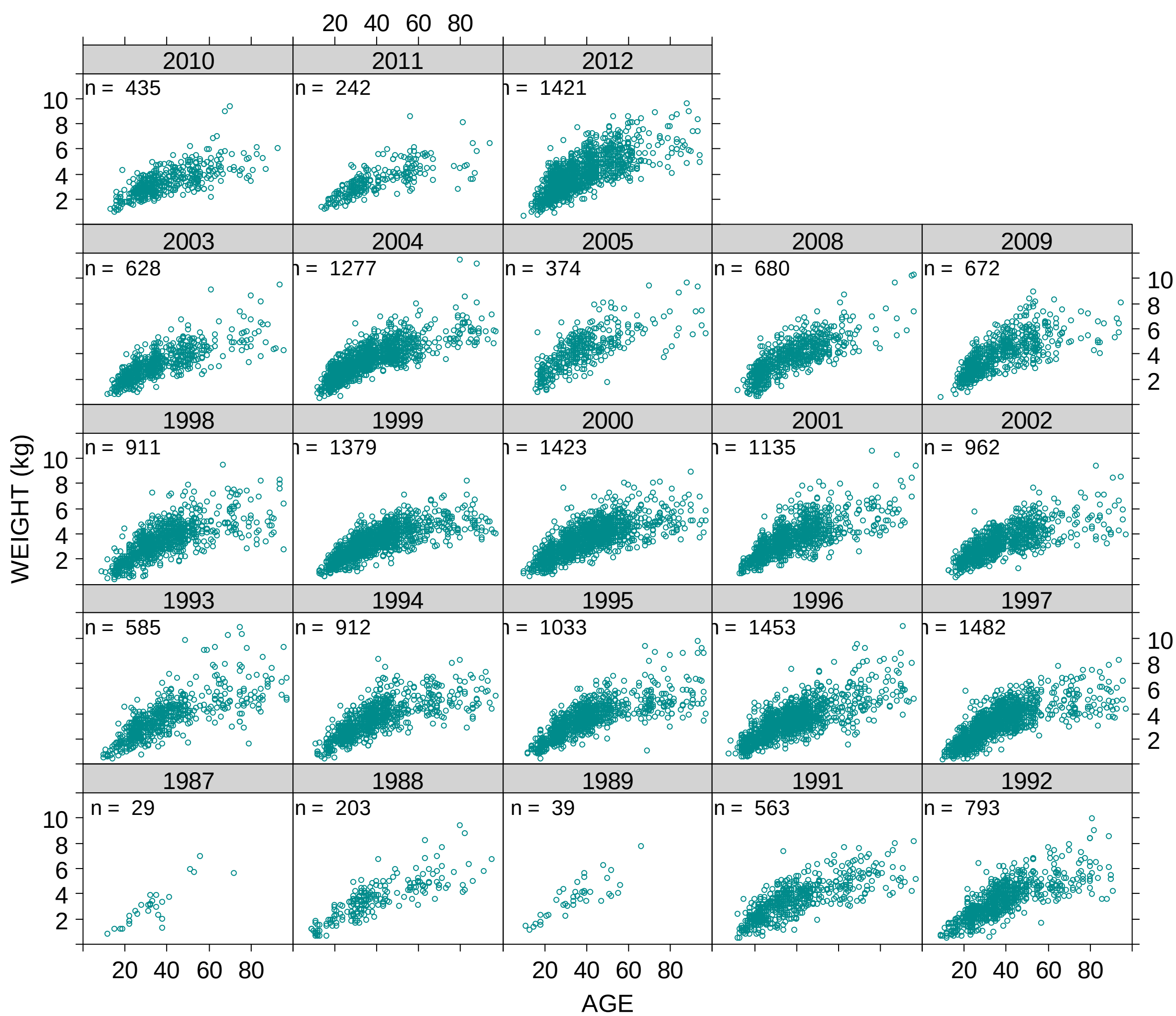


Figure 4. Mean weight-at-age (top) fit to aged samples from 1985 – 2013, with relative distributions and sample size per year (bottom)

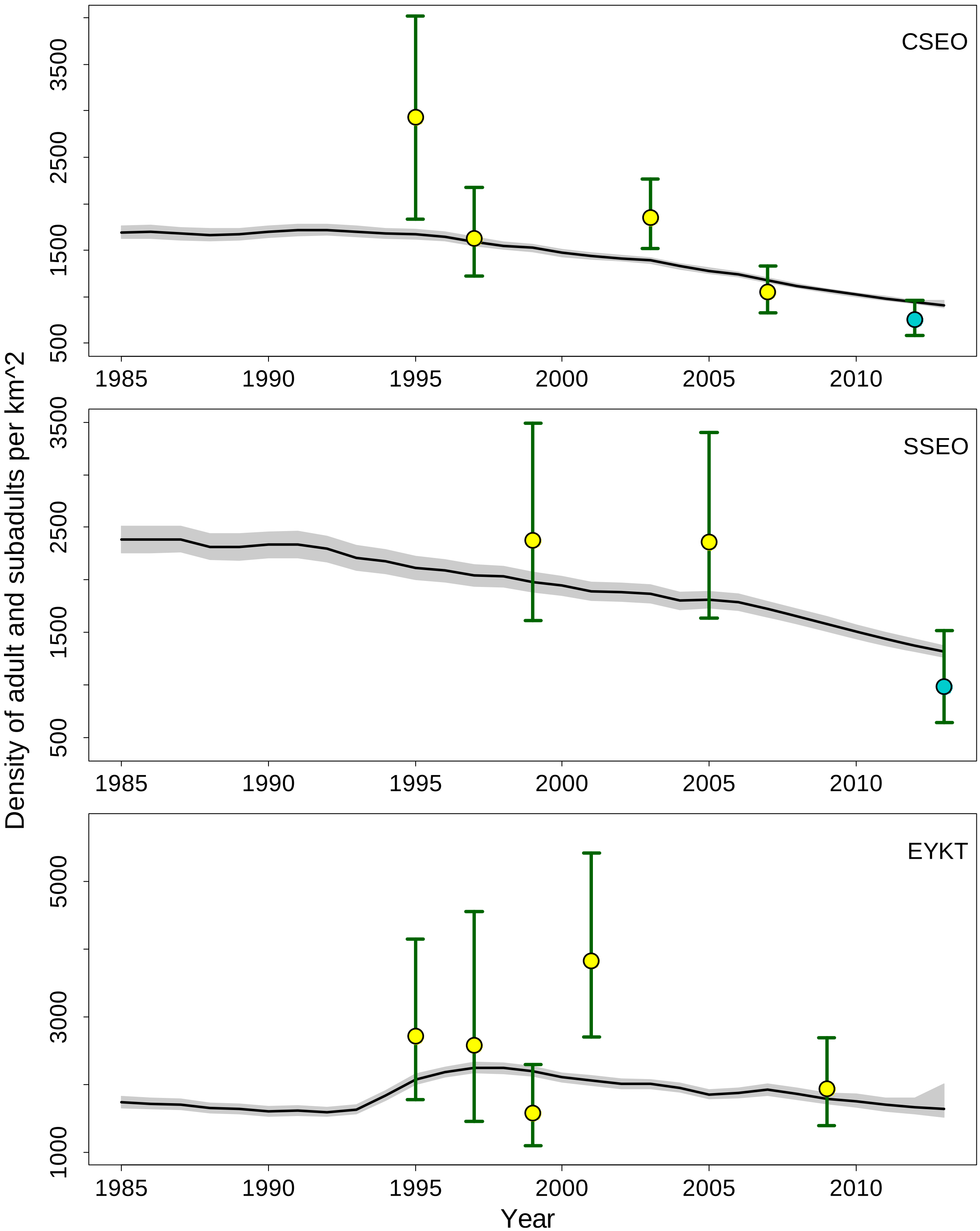


Figure 5. Estimates of yelloweye adult and sub-adult density from ADF&G submarine/ROV surveys +/- two standard deviations and model estimates of density with 95% credible intervals from 2,000,000 MCMC iterations.

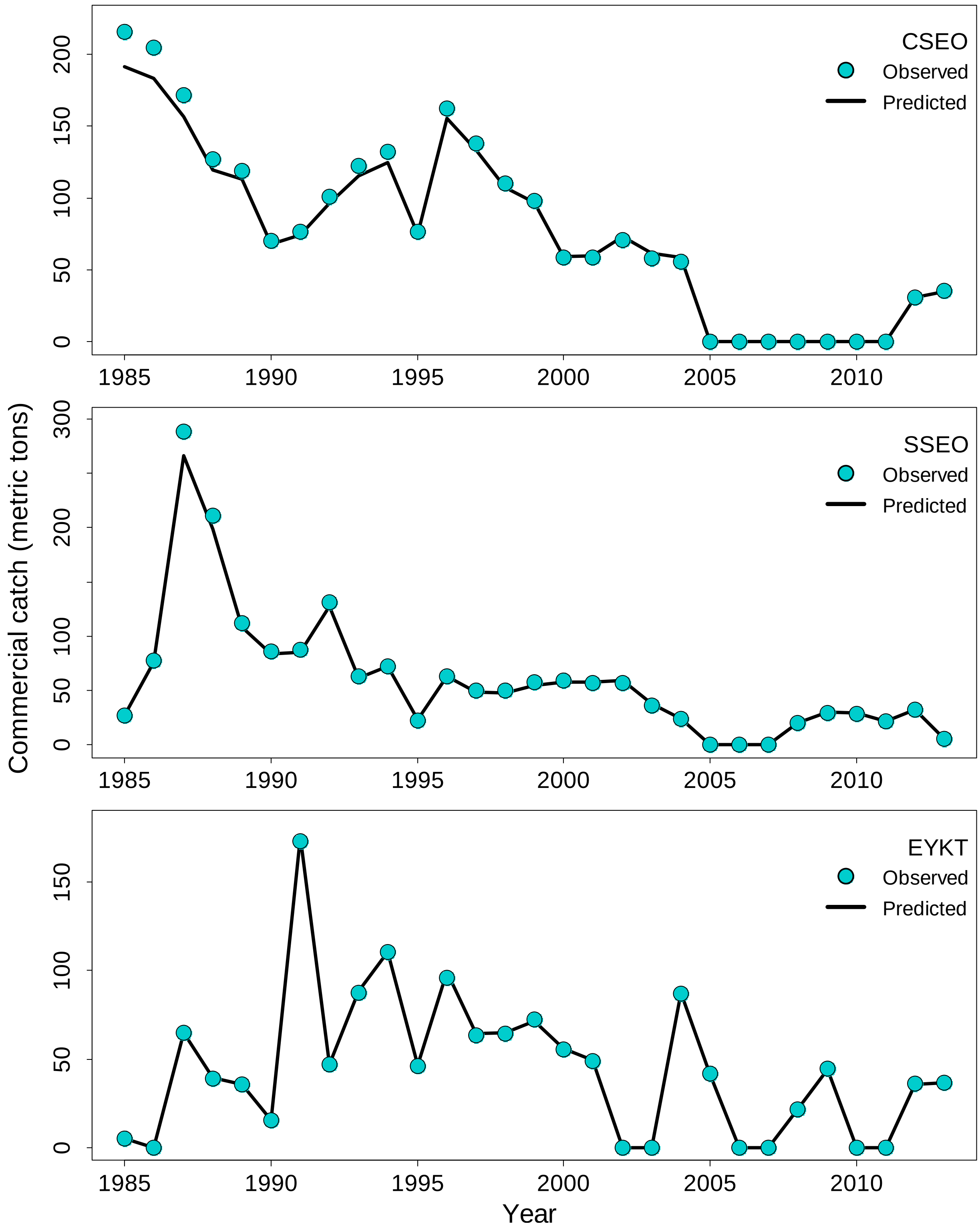


Figure 6. Observed and predicted total annual yelloweye catch from the directed DSR commercial fishery, 1992 - 2013

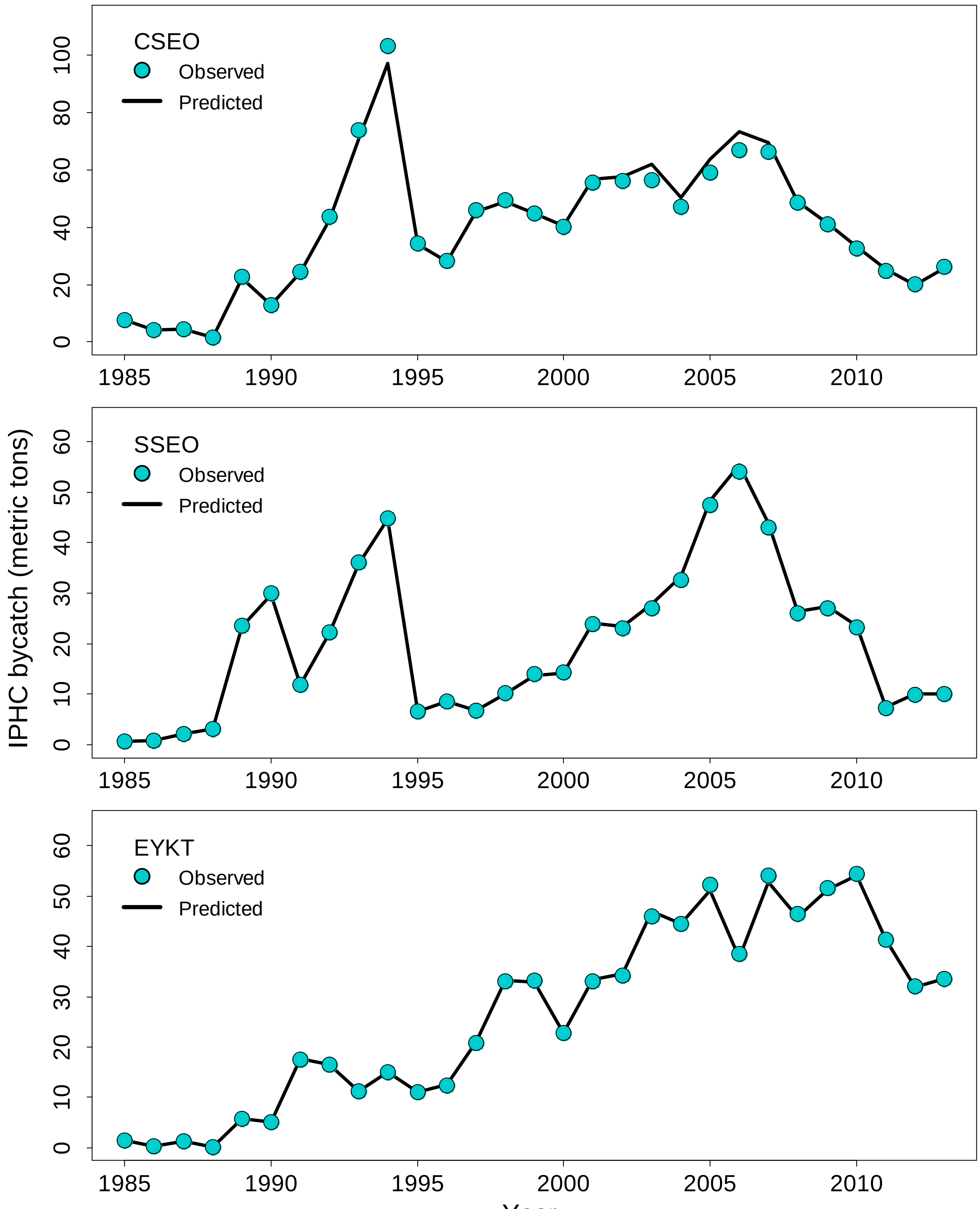


Figure 7. Observed and predicted total annual yelloweye incidental bycatch from the commercial longline halibut fishery, 1992 - 2013

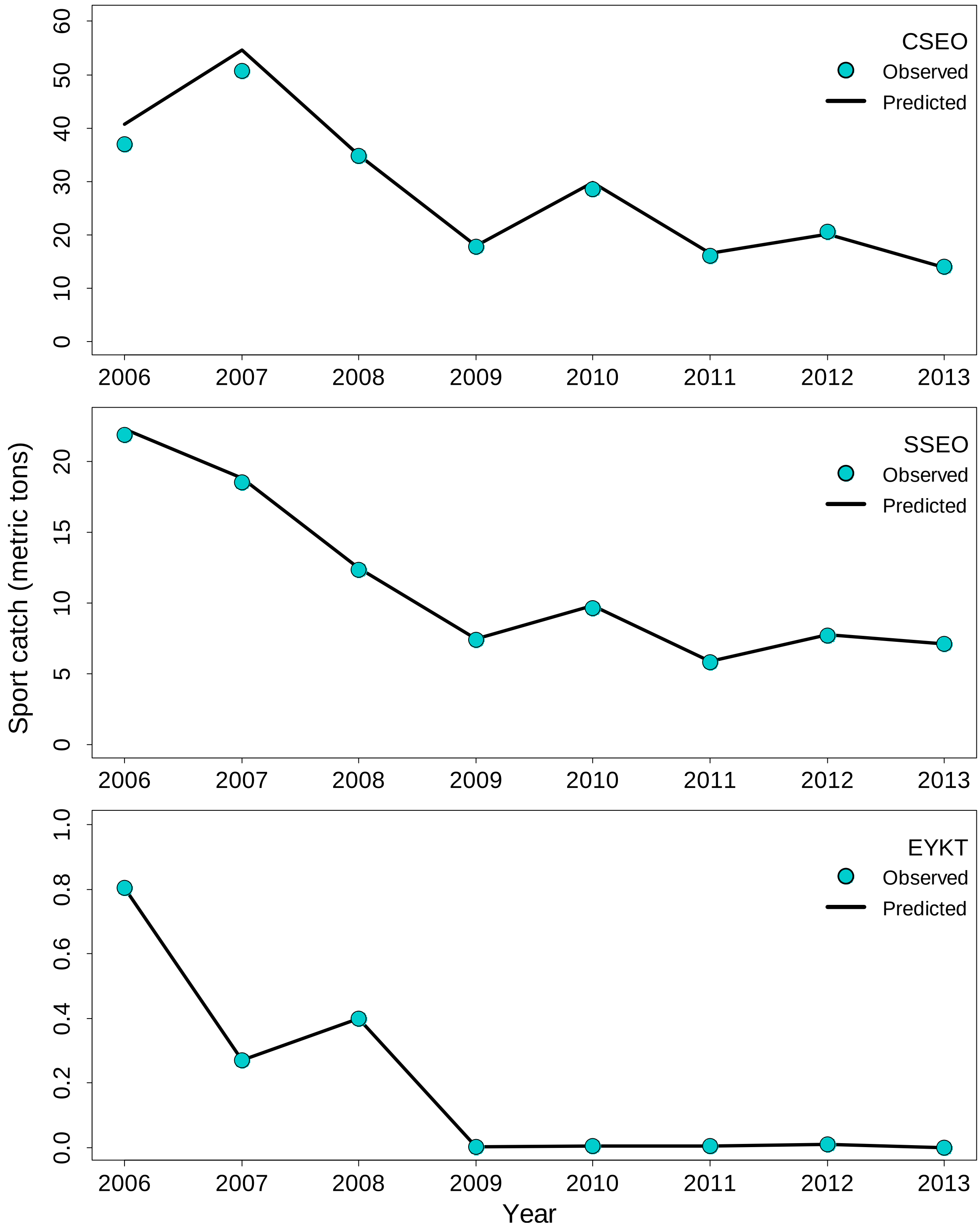


Figure 8. Observed and predicted total annual yelloweye catch from the sport fishery, 1992 - 2013

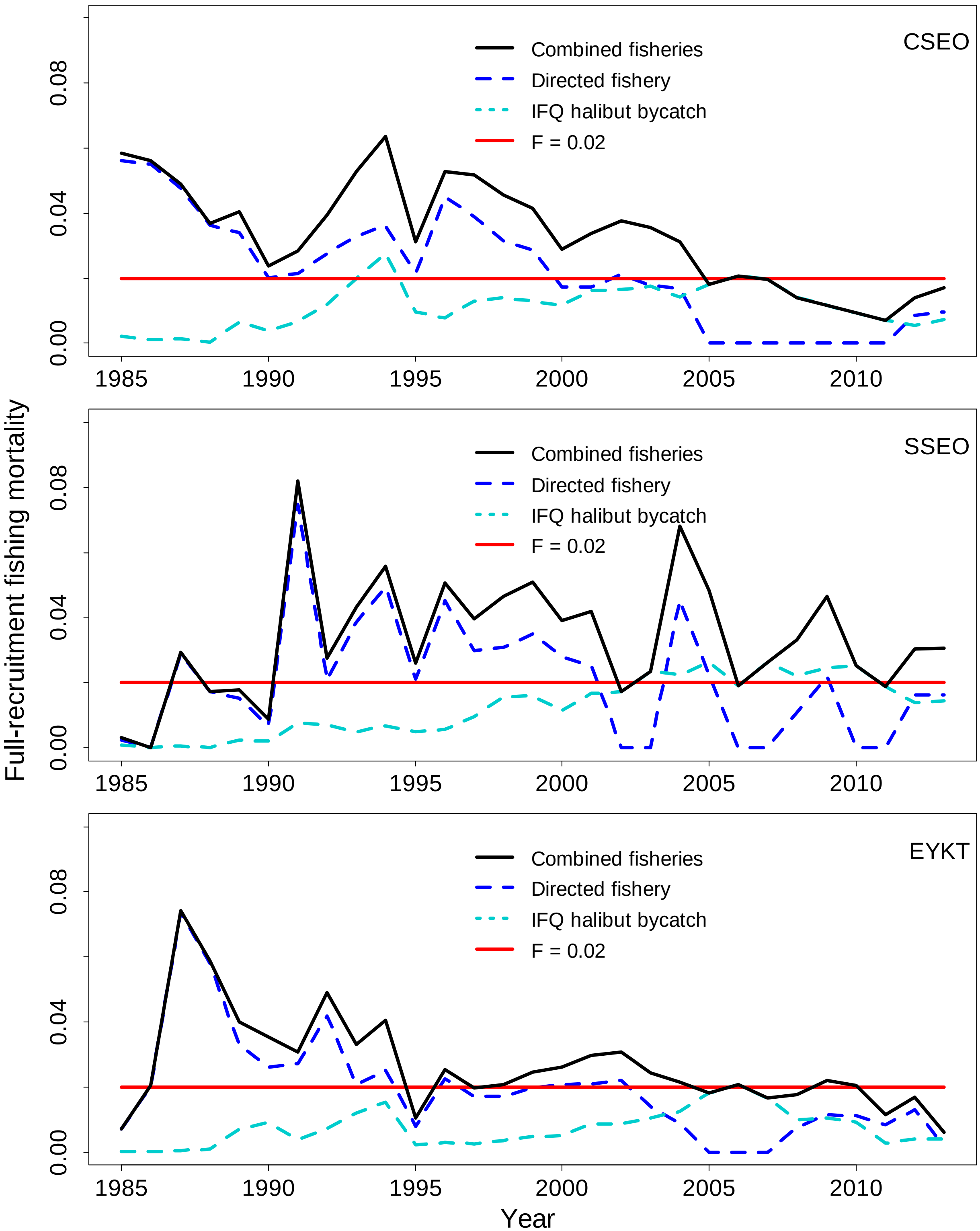


Figure 9. Relative full-recruitment fishing mortality *F* levels from the directed DSR fishery, the commercial halibut longline fishery, combined *F* levels, and a reference *F* = 0.02 value from Tier 4 management guidelines.

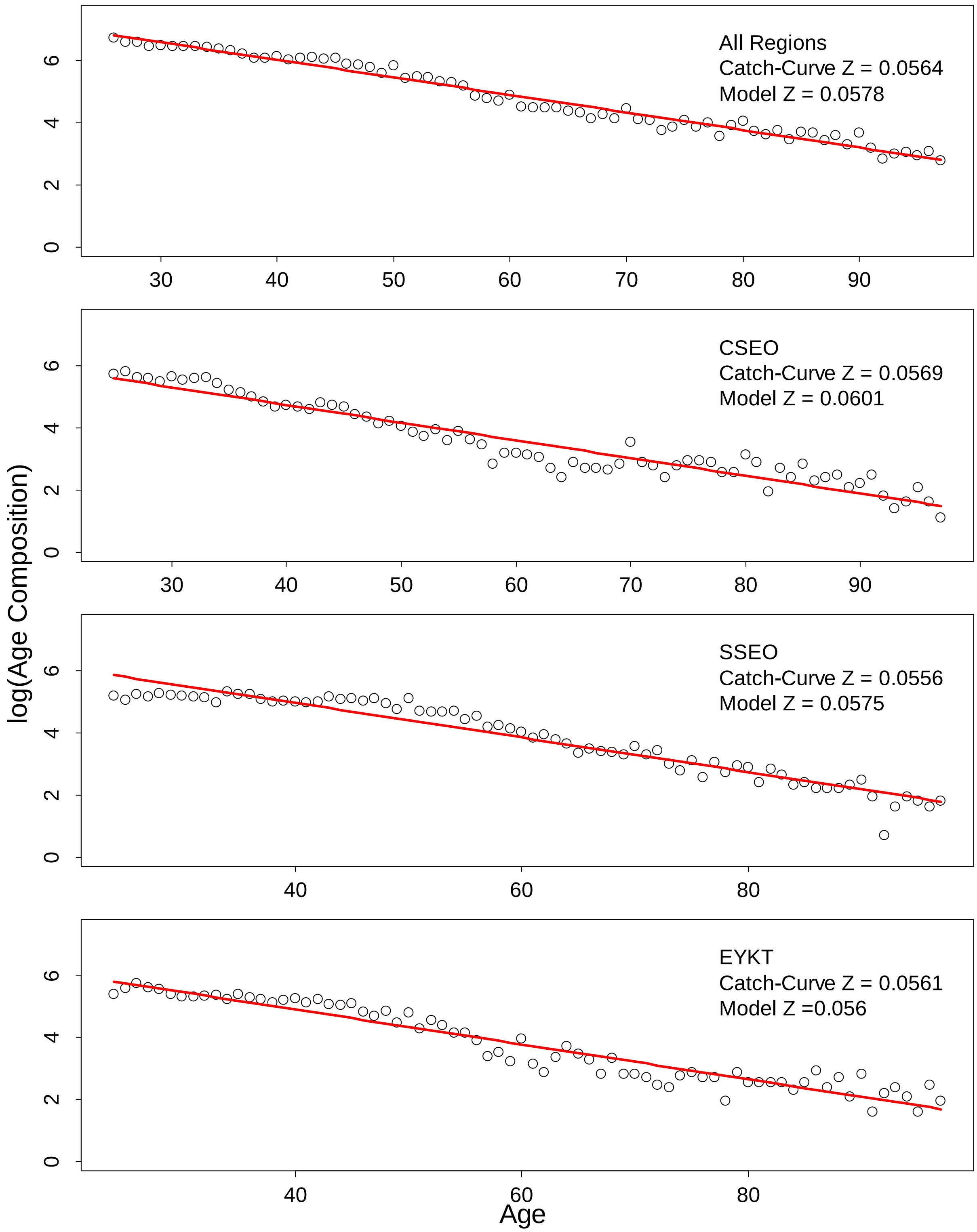


Figure 10. Catch-curve calculations of total mortality *Z* (ages 26 – 90+) compared to model-estimates of total mortality *Z* over all ages for all management areas combined (top panel) and each area individually (lower panels)

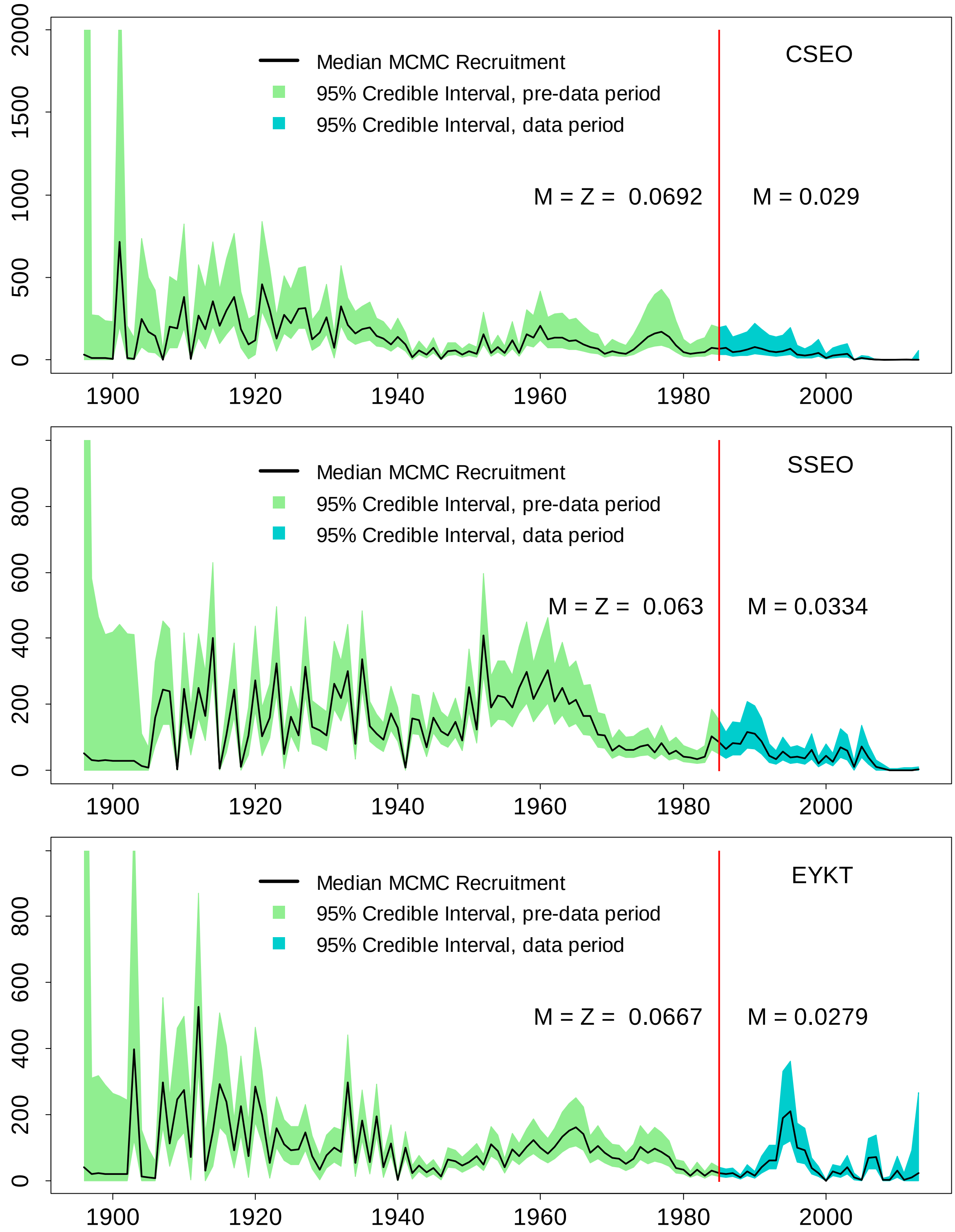


Figure 11. Median recruitment from 1903 – 2013 from 2,000,000 MCMC iterations with 95% credible intervals.

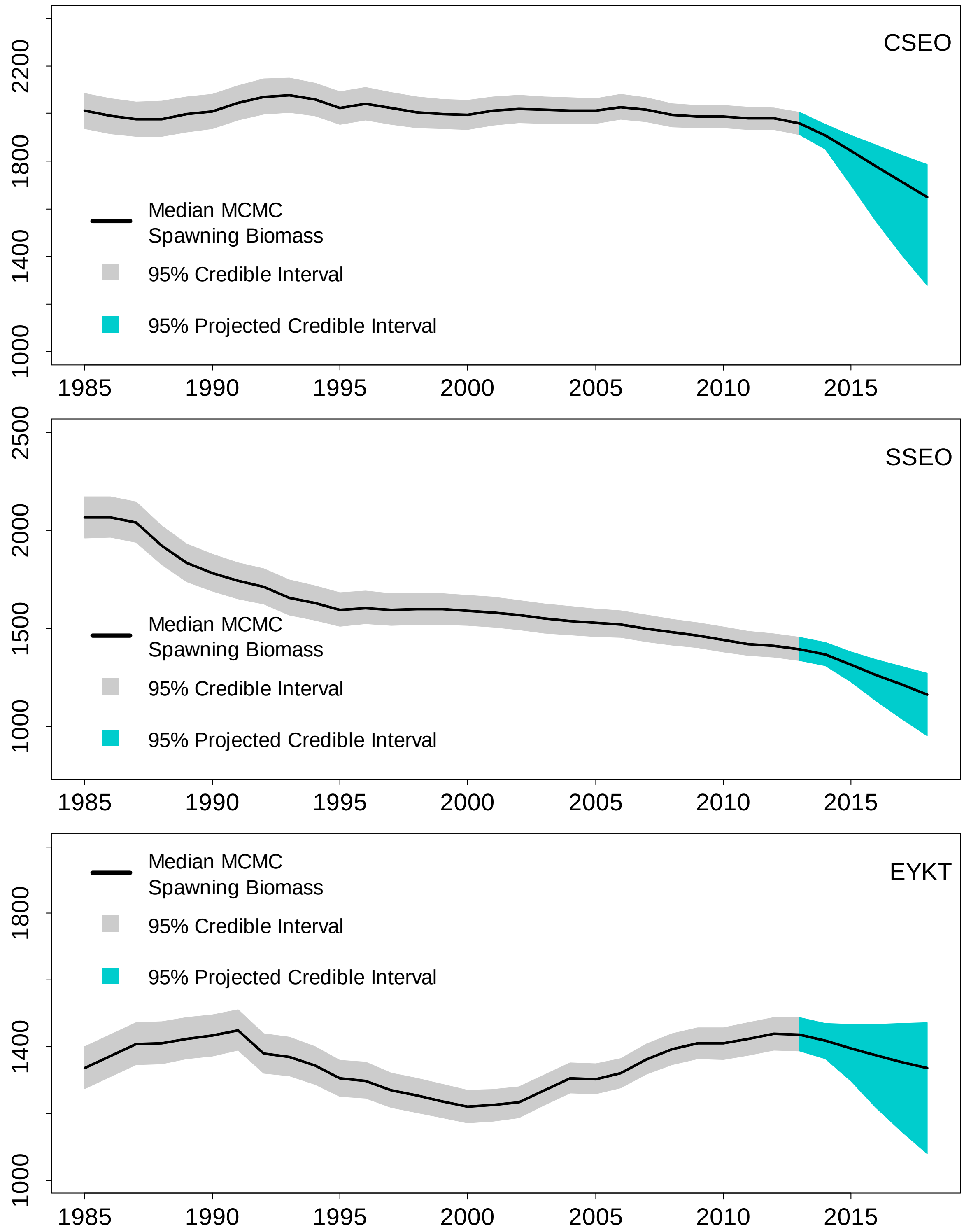


Figure 12. Median spawning biomass 1992 – 2013 and projected to 2018 from 2,000,000 MCMC iterations with 95% credible intervals.

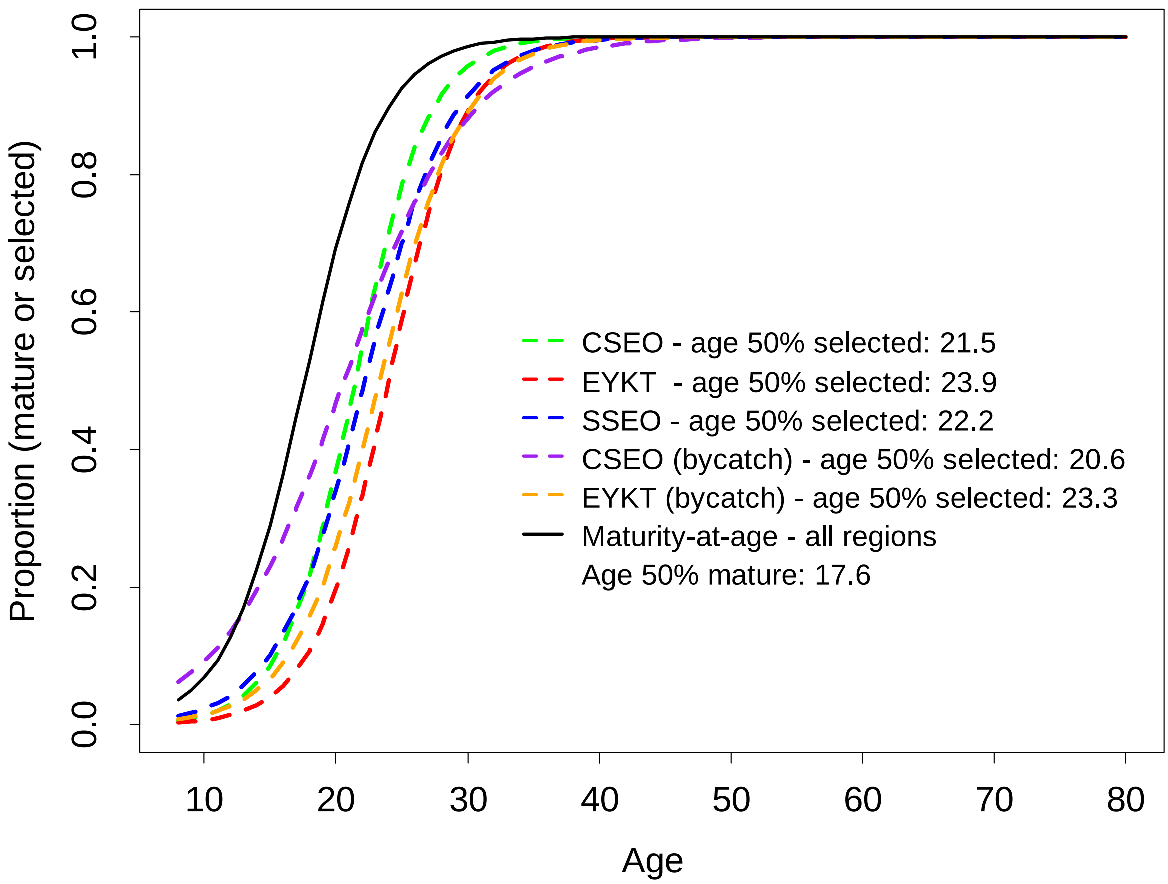


Figure 13. Maturity-at-age relative to selectivity-at-age for all management regions.

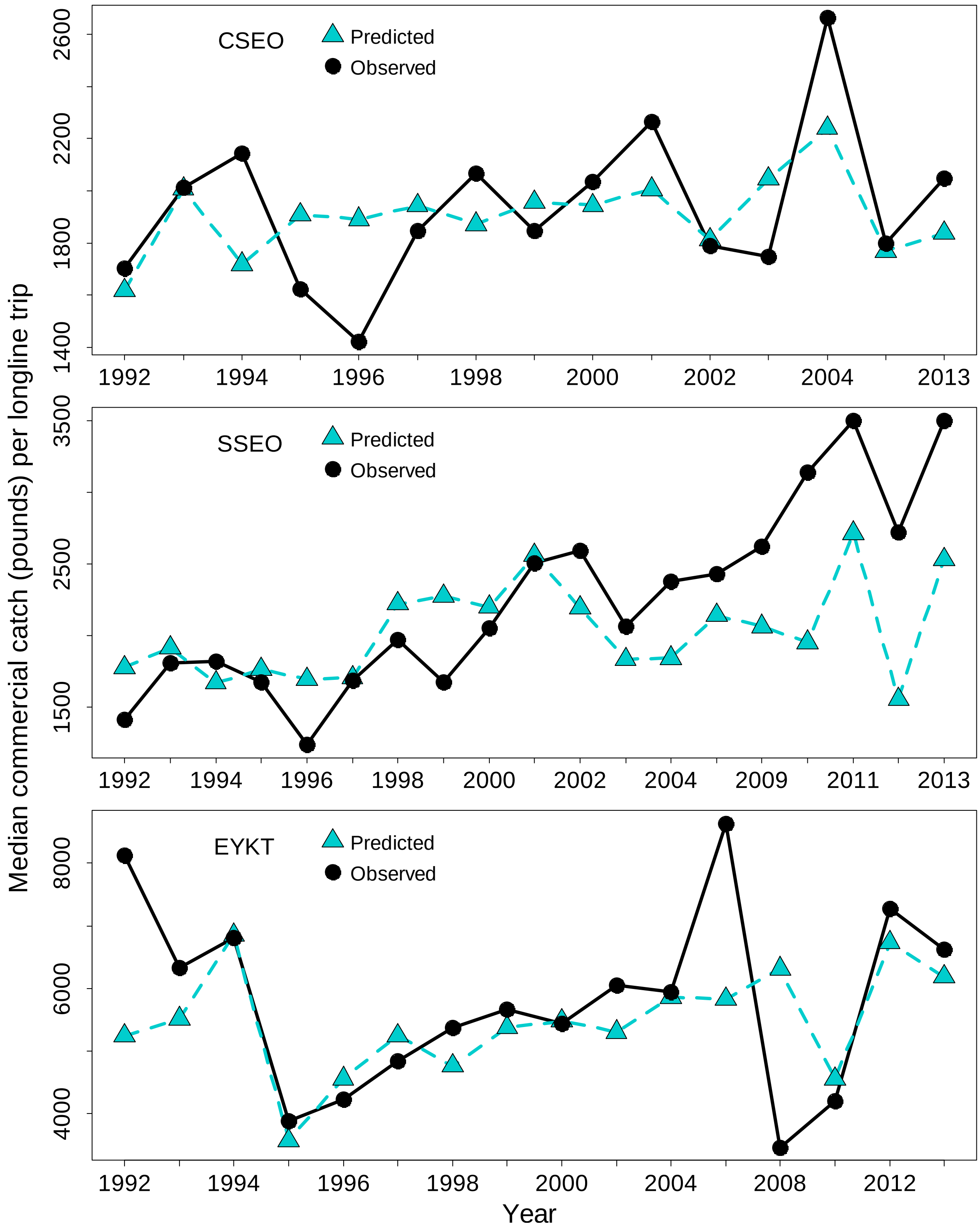


Figure 14. Observed and predicted catch-per-unit-effort for the directed commercial DSR fishery.

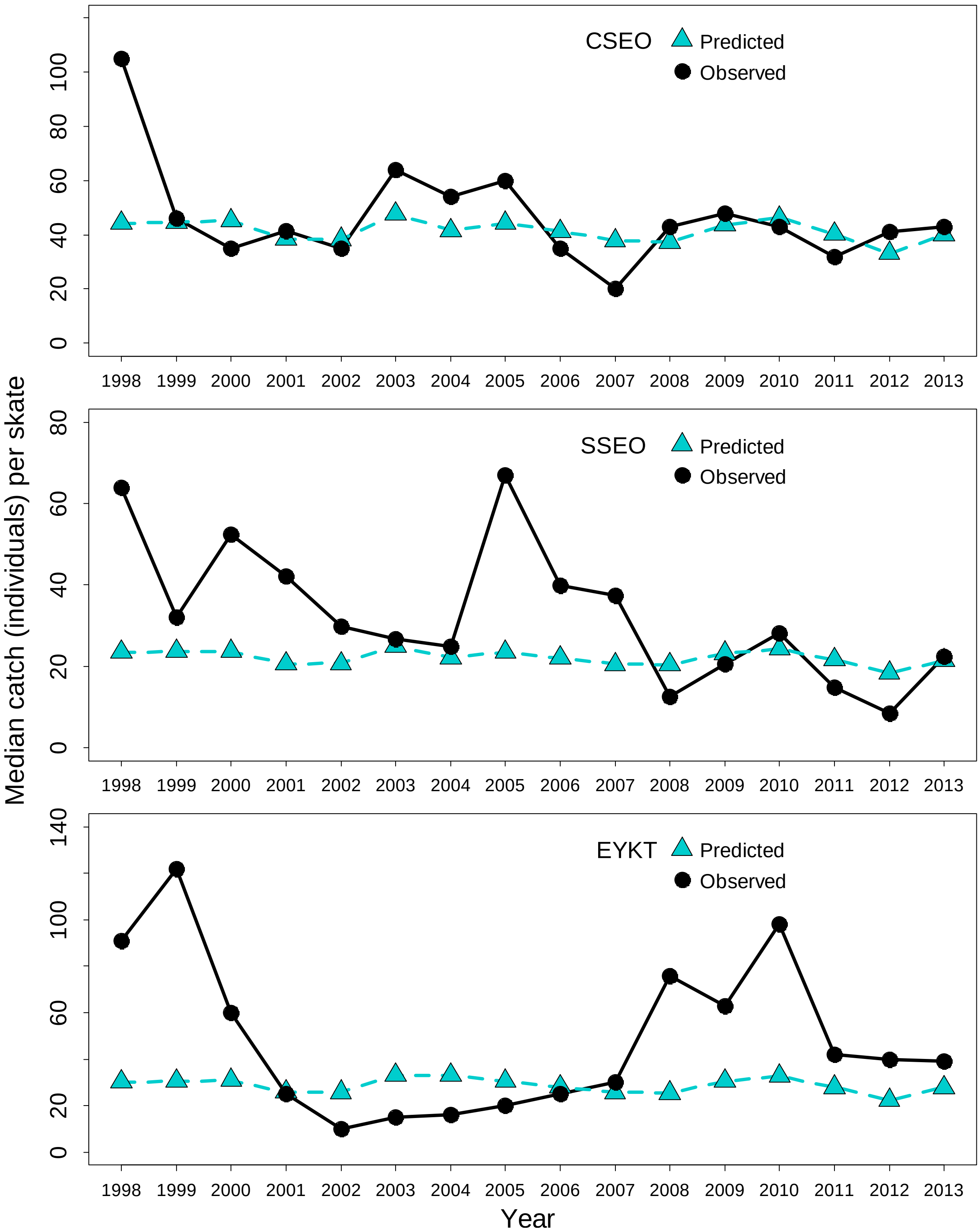


Figure 15. Observed and predicted catch-per-unit-effort from the IPHC longline survey.

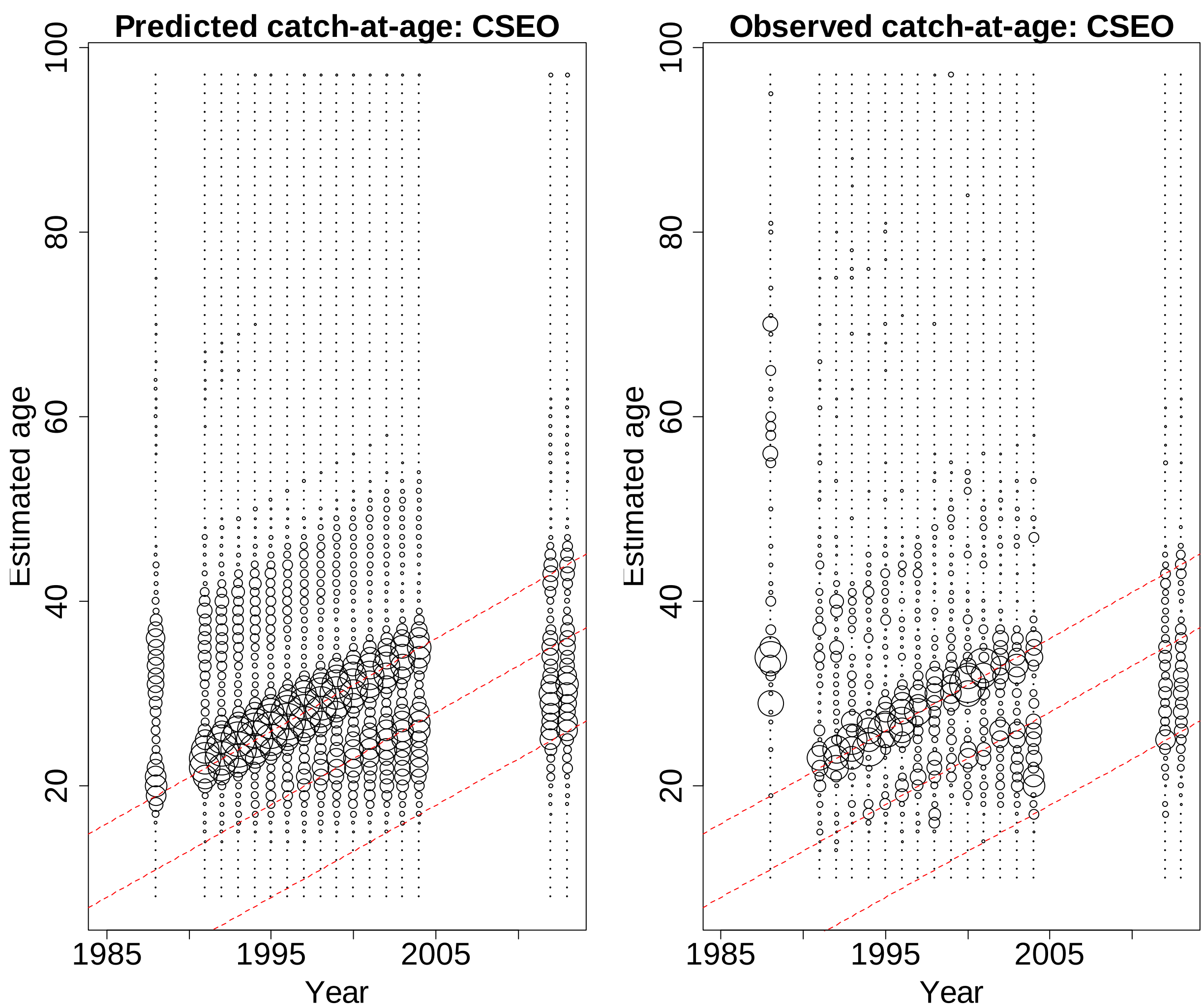


Figure 16. Observed and predicted catch-at-age for the directed commercial DSR fishery in CSEO.

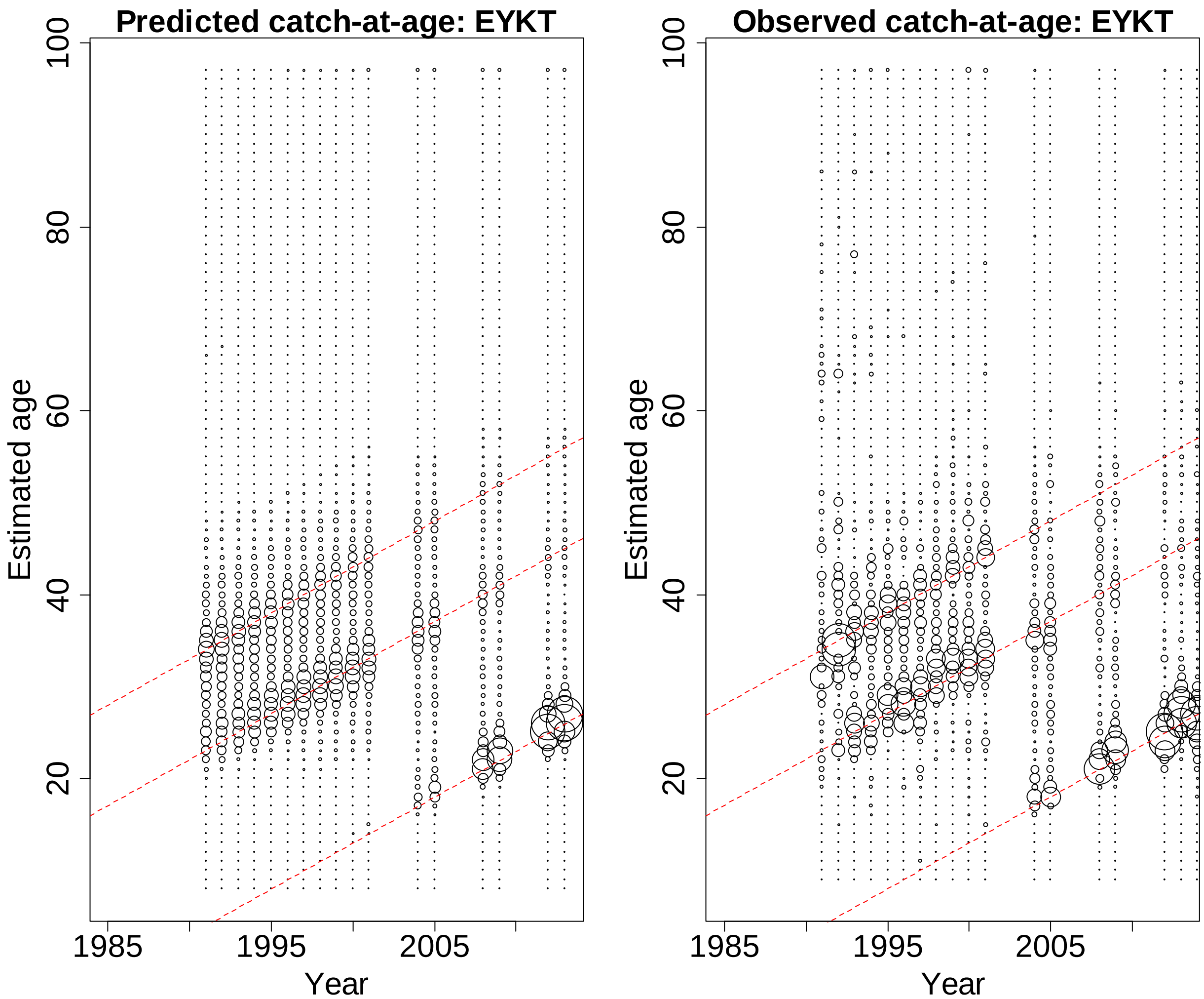


Figure 17. Observed and predicted catch-at-age from the directed commercial DSR fishery in EYKT.

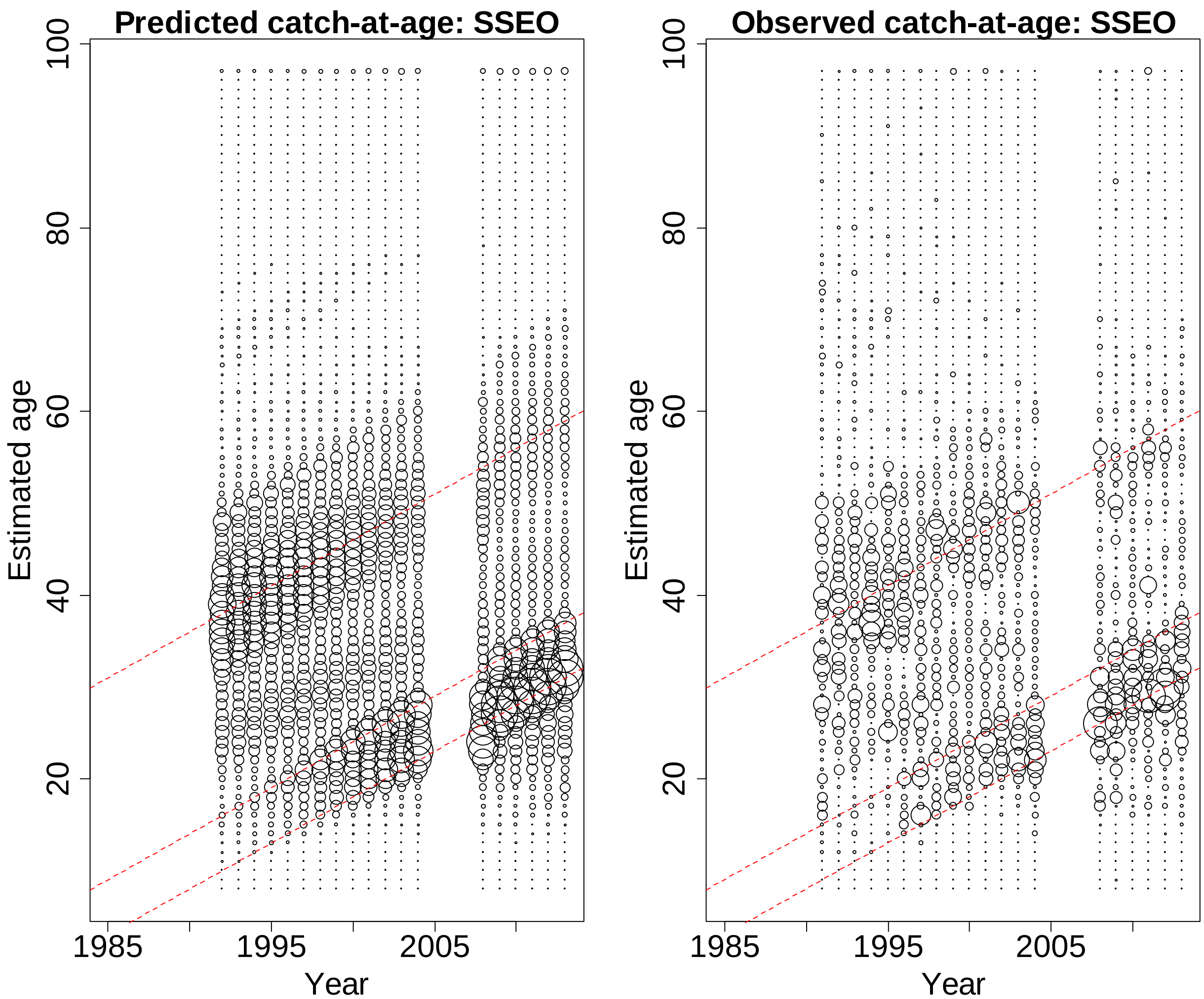


Figure 18. Observed and predicted catch-at-age from the directed commercial DSR fishery in SSEO.

BOX 1: Model parameters and quantities

y	Year
a	Age classes
w_a	Vector of estimated weight-at-age, $a_0 \to a_+$; model input
mat_a	Vector of estimated maturity-at-age, $a_0 \to a_+$; model input
a_0	Age at model recruitment (8)
a_+	Plus class (ages 97+)
μ_r	Mean annual recruitment
μ_f	Mean annual full-recruitment fishing mortality (log)
ϕf_y	Annual fishing mortality deviation for directed DSR fishery
ϕb_y	Annual fishing mortality deviation for commercial halibut incidental catch
ϕs_y	Annual fishing mortality deviation for sport removals
τ_y	Annual recruitment deviation ~ (0, σ_r)
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities-at-age for all fishery removals, $a_0 \to a_+$;
M_a	Natural mortality (1896 – 1984)
M_b	Natural mortality (1985 - 2013)
$F_{y,a}$	Fishing mortality by year y and age a $F_{y,a} = fs_a e^{(\mu_f + \phi f_y + \phi b_y + \phi s_y)}$
$Z_{y,a}$	Total mortality by year y and age a ($Z_{y,a} = F_{y,a} + M$)
$s_{y,a}^{m\_s}$	Survival by year and age at the month m_s of the submarine/ROV survey
$s_{y,a}^{m\_sp}$	Survival by year and age at the spawning month m_sp
$T_{a,a'}$	Aging-error matrix
Z_{1prior}	Prior mean for total mortality 1896 - 1984
Z_{2prior}	Prior mean for total mortality 1985 - 2013
$\mu_{f\,prior}$	Prior mean for mean annual full-recruitment fishing mortality
$\sigma_{r(prior)}$	Prior mean for recruitment variance
$q_{(prior)}$	Prior mean for directed fishery catchability
$q_{iphc(prior)}$	Prior mean for IPHC longline survey catchability
σ^2_{Z1}	Prior CV for total mortality 1896 - 1984
σ^2_{Z2}	Prior CV for total mortality 1985 - 2013
σ^2_r	Prior CV recruitment deviations
σ^2_f	Prior CV for fishing mortality
σ^2_q	Prior CV for directed fishery catchability
$\sigma^2_{q\_iphc}$	Prior CV for IPHC longline survey catchability

BOX 2: Population Dynamics

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * (1 - e^{-Z_{y,a}})}{Z_{y,a}} * w_a$$

Catch equation (directed DSR fishery, commercial longline halibut incidental catch, and sport removals)

$$\hat{D}_y = \sum_a \frac{N_{y,a} * s_{t,a}^{m\_s} * mat_a}{km^2}$$

Survey density (numbers of adults and sub-adults per km^2)

$$\hat{P}_{y,a} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition

$$C_y = qE_y^{\alpha+1} N_y^{\beta+1}$$

CPUE for the directed DSR fishery, where C = median catch over all sets

$$C_{ipch\_y} = q_{iphc} E_{iphc\_y}^{\alpha+1} N_y^{\beta+1}$$

CPUE for the IPHC longline survey, where C = median catch over all sets

Start year

$$N_a = \begin{cases} e^{(\mu_r + \tau_{styr})}, & a = a_0 \\ e^{(\mu_r + \tau_{styr+a_0-a})} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{\mu_r} e^{-(a-a_0)M}}{1-e^{-M}}, & a = a_+ \end{cases}$$

Number at age of recruitment (8)
Number at ages between recruitment and plus class
Number in plus class (97+)

Subsequent years

$$N_a = \begin{cases} e^{(\mu_r + \tau_y)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}} & a = a_+ \end{cases}$$

Number at age of recruitment (8)
Number at ages between recruitment and plus class
Number in plus class (97+)

$$SB_y = \sum_{a=a_0}^{a+} N_{y,a} s_{y,a}^{m\_sp} mat_a w_a / 2$$

Annual female spawning biomass

BOX 3: Likelihood components

$L_1 = \lambda_1 \sum_y \left(\ln(C_y + 0.00001) - \ln(\hat{C}_y + 0.0001)\right)^2$	Commercial catch
$L_2 = \lambda_2 \sum_y \left(\ln(C_y + 0.00001) - \ln(\hat{C}_y + 0.0001)\right)^2$	IPHC bycatch
$L_3 = \lambda_3 \sum_y \left(\ln(C_y + 0.00001) - \ln(\hat{C}_y + 0.0001)\right)^2$	Sport catch
$L_4 = \lambda_4 \sum_y \frac{\left(\ln(D_y) - \ln\left(\hat{D}_y\right)\right)^2}{2*\sigma^2(D_y)}$	Density
$L_5 = \lambda_5 \sum_y \frac{\left(\ln(C_y) - \ln\left(\hat{C}_y\right)\right)^2}{2*\sigma^2(C_y)}$	Commercial CPUE, where $\hat{C}$ = median catch over all sets
$L_6 = \lambda_6 \sum_y \frac{\left(\ln(C_y) - \ln\left(\hat{C}_y\right)\right)^2}{2*\sigma^2(C_y)}$	IPHC longline survey CPUE, where $\hat{C}$ = median catch over all sets
$L_7 = \lambda_7 \sum_{styr}^{endyr} - n_y \sum_{a_0}^{a+} \left(P_{y,a} + 0.0001\right) * \ln\left(\hat{P}_{y,a} + 0.0001\right)$	Fishery age composition (n_y = sample size)
$L_8 = \frac{1}{2\sigma_M^2}\left(\ln\left(M / M_{prior}\right)\right)^2$	Penalty on deviation from log-normal prior probability distribution of natural mortality (1896 – 1984)
$L_9 = \frac{1}{2\sigma_M^2}\left(\ln\left(Z / Z_{prior}\right)\right)^2$	Penalty on deviation from log-normal prior probability distribution of total mortality (1985 – 2013)
$L_{10} = \frac{1}{2\sigma_q^2}\left(\ln\left(q / q_{prior}\right)\right)^2$	Penalty on deviation from log-normal prior probability distribution of recruitment deviations
$L_{11} = \frac{1}{2\sigma_{q_{iphc}}^2}\left(\ln\left(q_{iphc} / q_{iphc\ prior}\right)\right)^2$	Penalty on deviation from log-normal prior probability distribution of recruitment deviations
$L_{12} = \frac{1}{2\sigma_F^2}\left(\ln\left(F / F_{prior}\right)\right)^2$	Penalty on deviation from log-normal prior probability distribution of full-recruitment fishing mortality F
$L_{13} = \left(\tau_y / 2\sigma_r^2\right)^2 + \left(n_y * \ln(\sigma_r)\right)$	Penalty on recruitment deviations
$L_{14} = \lambda_{12} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{total} = \sum_{i=1}^{13} L_i$	Total objective function value

15. Assessment of the Thornyhead stock complex in the Gulf of Alaska

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November 2014

Executive Summary

Alaska rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska (GOA) thornyheads in off-cycle (even) years, we present an executive summary to recommend harvest levels for the next two years. Please refer to the last full stock assessment report presented in 2011 for further information regarding the assessment calculations (Murphy and Ianelli 2011, http://www.afsc.noaa.gov/refm/docs/2011/GOAthorny.pdf). A full stock assessment document with updated assessment results will be presented in next year's SAFE report.

We use the exploitable biomass from the most recent GOA trawl survey (expanded to 700-1000 m) to determine the recommended ABC for thornyhead rockfish, which qualifies as a Tier 5 stock. For an off-cycle year, there is no new survey information for thornyhead rockfish; therefore, the 2013 estimates (Shotwell et al. 2013, http://www.afsc.noaa.gov/REFM/Docs/2013/GOAthorny.pdf) are rolled over for the next two years.

Summary of Changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment inputs since this was an off-cycle year.

Changes in assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015	2016
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	81,816	81,816	81,816	81,816
F_{OFL}	0.03	0.03	0.03	0.03
$maxF_{ABC}$	0.0225	0.0225	0.0225	0.0225
F_{ABC}	0.0225	0.0225	0.0225	0.0225
OFL (t)	2,454	2,454	**2,454**	2,454
maxABC (t)	1,841	1,841	1,841	1,841
ABC (t)	1,841	1,841	**1,841**	1,841
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a

Updated catch data (t) for thornyhead rockfish in the Gulf of Alaska as of October 1, 2014 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org) are summarized in the following table.

Year	Western	Central	Eastern	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
2013	304	541	309	1,154	1,665	1,665
2014	132	624	208	964	1,841	1,841

Gulfwide catch of thornyhead rockfish for 2014 (as of Oct 1) is 16% lower than the 2013 catch with decreases of 57% and 33% occurring in the Western and Eastern GOA, respectively, and an increase in the Central GOA of 15%. The catch decreased by 36% in the sablefish fishery compared to 2013 and increased by 47% in the rockfish fishery and 126% in the flatfish fishery compared to 2013. The catch was lower in the Western GOA than in previous years because the 2014 rockfish trawl fishery in this region was not opened to directed fishing until October 15. Final catch estimates for this region will likely be similar to previous years when the directed fishery catch is included and preliminary estimates suggest this to be the case (225 t as of November 3). In 2014, the Western GOA ABC increased to 235 t which decreases the potential for the Western GOA ABC to be reached or exceeded this year.

In 2013 the restructured observer program began, and the extent that this program affected estimated catches of thornyhead rockfish in the small-boat fisheries is uncertain. Understanding the potential for catch accounting biases due to shifts in observer coverage will require further study and we will continue to monitor the shifts in the future.

For the 2015 fishery, we recommend the maximum allowable ABC of 1,841 t for thornyhead rockfish. Reference values for thornyhead rockfish are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not being subjected to overfishing last year.

Area Apportionment

The following table shows the recommended apportionments for 2015 and 2016 based on the 2013 survey biomass distribution (expanded to account for 701-1000 m). Please refer to the 2011 full stock assessment report for information regarding the apportionment rationale for thornyhead rockfish.

Area Apportionment		Western 13%	Central 47%	Eastern 40%	Total 100%
2015	Area ABC (t)	**235**	**875**	**731**	**1,841**
	OFL (t)				**2,454**
2016	Area ABC (t)	**235**	**875**	**731**	**1,841**
	OFL (t)				**2,454**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Thornyhead rockfish	2013	73,990	2,220	1,665	1,665	1,154
	2014	81,816	2,454	1,841	1,841	964
	2015	81,816	2,454	1,841		
	2016	81,816	2,454	1,841		

Stock/ Assemblage	Area	2014 OFL	ABC	TAC	Catch[2]	2015 OFL	ABC	2016 OFL	ABC
Thornyhead rockfish	W		235	235	132		235		235
	C		875	875	624		875		875
	E		731	731	208		731		731
	Total	2,454	1,841	1,841	964	2,454	1,841	2,454	1,841

[1]Total biomass from trawl survey estimates and includes expansion to 701-1000 m.

[2]Current as of October 1, 2014. Source: NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org).

SSC and Plan Team Comments on Assessments in General

Since this is an off-cycle year and only an executive summary is presented, we respond here to priority comments. For comments relevant to or that require a full assessment, we will present responses in next year's full assessment.

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)

A report for generating the time series of other removals is available on the AKFIN stock assessment dashboard entitled "Non-Commercial Catch" (http://www.akfin.org). We will use this report to update the appendix of other removals in next year's full stock assessment.

"The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

Full assessment updates for GOA rockfish will be completed in 2015 and CIE review comments will be addressed at that time. Additionally, an AFSC response to the rockfish CIE review was prepared that addresses some of their concerns. Please refer to the "Summary and response to the 2013 CIE review of the AFSC rockfish" document presented to the September 2013 Plan Team for further details regarding this response:

http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf.

"The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC." (Plan Team, September 2013)

The AKFIN report on Non-Commercial Catch will be used in next year's full stock assessment for generating the other removals appendix.

"The Plan Teams recommend that assessment authors retain status quo assessment approaches for the November 2012 SAFE report but also apply the Kalman filter or random effects survey averaging methods for Tier 5 stocks and summarize the analytical results for comparison purposes only. ADMB code for implementing the random effects method will be made available." (Plan Team, September 2012)
"The SSC encourages assessment authors of stocks managed in Tier 5 to consider the recommendations found in the draft survey averaging workgroup report." (SSC, December 2012)
"The Teams recommend that stock assessment authors calculate biomass for Tier 5 stocks based on the random effects model and compare these values to status quo. In addition, the Teams recommend that the working group examine autorcorrelation in subarea recruitment when conducting spatial simulations for evaluating apportionment." (Plan Team, September 2014)

Various approaches to calculated biomass based on the random effects model were presented to the Plan Team in September 2013. Continued efforts are underway to determine the most appropriate approach for this species and will be presented in the next full assessment.

SSC and Plan Team Comments Specific to this Assessment

"The Plan Team recommends that in addition to the current assessment methodology, authors use the Kalman filter method to estimate survey biomass and summarize the results for comparison at the September 2013 meeting." (Plan Team, November 2012)
"The SSC agrees with the Plan Team recommendation that trawl surveys extend to 500 m in order to more completely cover available thornyhead habitat and that a Kalman filter approach to estimating biomass be used in the next assessment." (SSC, December 2012)

As stated previously, efforts are underway to determine the most appropriate approach for this species and will be presented in the next full assessment

"The Team recommends the author explore the longline survey as an alternative or additional index to the trawl survey and to consider impacts of the trawl survey sampling fewer stations and restricting depth to shallower than 700m in recent surveys. The Team also recommends further exploration of the random effects model for estimating thornyhead biomass. Finally, the Team recommends the author provide an executive summary for the 2014 assessment as no new data will be available, and to include any outstanding Team or SSC recommendations with the summary." (Plan Team, November 2013)

In response to this recommendation by the Plan Team, we provide an executive summary with Plan Team and SSC comments for this assessment year. Several current research efforts are in progress investigating issues regarding bottom trawl survey catchability and survey biomass estimation. The continued reduction in survey effort over the past several surveys should be considered in these initiatives as there was a 30% drop in stations sampled on the 2013 survey compared to the long-term average. Precision and accuracy of biomass estimates are particularly vulnerable for deep-water species like thornyhead rockfish due to the already low number of stations sampled in the deep strata. We will incorporate the results of these studies when they become available to consider the effects of reduced trawl survey effort on thornyhead rockfish trawl survey biomass estimates. In future assessments we also plan to explore the use of the longline survey as an alternative or additional index.

16. Assessment of the Other Rockfish stock complex in the Gulf of Alaska

Cindy A. Tribuzio and Katy B. Echave
November 2014

Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new trawl survey data. For Gulf of Alaska (GOA) rockfish in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. Please refer to the last full stock assessment report for the Other Rockfish stock complex for further information regarding the assessment calculations of ABC and OFL (Clausen and Echave 2011, available online at http://www.afsc.noaa.gov/refm/docs/2011/GOAorock.pdf). A full stock assessment document with updated assessment results will be presented in next year's SAFE report.

We average the biomass estimates from the three most recent Gulf of Alaska (GOA) trawl surveys to estimate exploitable biomass and determine the recommended ABC for the Other Rockfish stock complex. This complex consists of 25 species of rockfish, as defined in Tribuzio and Echave (2012). This complex is classified as a Tier 5 stock, with the exception of sharpchin rockfish, which qualifies as a Tier 4 stock. The complex ABC and OFL are based on the sum of the Tier 4 and Tier 5 calculations for the individual species. For an off-cycle year, there is no new survey information for the Other Rockfish stock complex; therefore, the 2013 estimates are used in 2014.

Summary of Changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment inputs since this was an off-cycle year.

Changes in assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

For the 2015 fishery, we recommend the maximum allowable ABC of 4,079 t for the Other Rockfish stock complex. Reference values for the Other Rockfish stock complex are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not being subjected to overfishing last year.

The SSC combined the ABC for the Western and Central GOA for the 2014 and 2015 fisheries, to be re-evaluated in the next full assessment. The ABC in the combined Western/Central GOA management areas was not exceeded in 2014, as of October 1. The 2014 Other Rockfish catch was lower in the Western Gulf than previous years because in 2014 the rockfish trawl fishery in this region was not opened to directed fishing in July due to concerns of going over TAC. However, this fishery was subsequently opened to directed fishing on October 15. Therefore, we expect the Other Rockfish catch in the Western/Central GOA management area to increase as a result of the rockfish fishery opening.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015	2016
M (natural mortality rate)[a]	0.02-0.10	0.02-0.10	0.02-0.10	0.02-0.10
Tier[b]	5 or 4	5 or 4	5 or 4	5 or 4
Biomass (t)	83,383	83,383	83,383	83,383
F_{OFL} [a]	0.02-0.10	0.02-0.10	0.02-0.10	0.02-0.10
$maxF_{ABC}$ [a]	0.0015-0.0750	0.0015-0.0750	0.0015-0.0750	0.0015-0.0750
F_{ABC} [a]	0.0015-0.0750	0.0015-0.0750	0.0015-0.0750	0.0015-0.0750
OFL (t)	5,347	5,347	**5,347**	**5,347**
maxABC (t)	4,079	4,079	4,079	4,079
ABC (t)	4,079	4,079	**4,079**	**4,079**
Status	As determined *last* year for:		As determined *this* year for	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a

[a]Values represent a range among species.

[b]All species are Tier 5 except sharpchin rockfish is Tier 4.

Updated catch data (t) for the Other Rockfish stock complex in the GOA are summarized in the following table. Source: NMFS Alaska Regional Office Catch Accounting System accessed through the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org as of October 1, 2014.

Year	Western GOA	Central GOA	Eastern GOA West Yakutat	Eastern GOA E. Yak/ Southeast	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
2013	202	477	77	63	819	4,045	1,080
2014	37	696	48	31	812	4,079	1,811

Area Apportionment

The apportionment percentages recommended below for 2015 are the same as in the 2013 assessment (for the 2014 fishery). For the 2014 fishery, the ABCs for the Western and Central GOA were combined (1,031 t total ABC, if separated, WGOA = 40 t and CGOA = 991 t). Please refer to the last full stock assessment report for information regarding the apportionment rationale for the Other Rockfish stock complex.

	Western/Central GOA	Eastern GOA (74.7%) West Yakutat[1]	Eastern GOA (74.7%) E Yakutat/ Southeast[1]	Total
Area Apportionment	25.3%	14.2%	60.5%	100%
Area ABC (t)	1,031	580	2,468	4,079
OFL (t)				5,347

[1]The West Yakutat and E Yakutat/Southeast values sum to the proportioned ABC of the Eastern GOA (74.7%).

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Other Rockfish	2013	85,774	5,305	4,045	1,080	819
	2014	83,383	5,347	4,079	1,811	812
	2015	83,383	5,347	4,079		
	2016	83,383	5,347	4,079		

Stock/ Assemblage	Area		2014 OFL	2014 ABC	2014 TAC	2014 Catch[2]	2015 OFL	2015 ABC	2016 OFL	2016 ABC
Other Rockfish	WGOA/CGOA			1,031	1,031	733		1,031		1,031
	EGOA	WY		580	580	48		580		580
		EY/SE		2,470[3]	200	31		2,468		2,468
	Total		5,347	4,081	1,811	812	5,347	4,079	5,347	4,079

[1]Total biomass estimates from AFSC trawl surveys.

[2]Current as of October 1, 2014. Source: NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org).

[3]The recommended ABC for EY/SE in 2014 was 2,468 t, but was changed to 2,470 t to account for northern rockfish in the EGOA.

Note: all values include northern rockfish in the eastern Gulf of Alaska only.

Responses to SSC and Plan Team Comments on Assessments in General

Because of the government shutdown in 2013, there was only sufficient time to compile SSC and Plan Team comments in last year's assessment. Since this is an "off" year and only an executive summary is presented, we respond here to priority comments. For comments relevant to or require a full assessment and/or model run, we will present responses in next year's full assessment.

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

The authors of HFICE we unable to delineate the overlap between CAS and HFICE (Tribuzio et al. 2014). The HFICE authors recommended waiting for more years of the restructured observer program so that a comparison between the two procedures can be made. The SSC reviewed that recommendation again with regards to the GOA shark assessment at its October 2014 meeting and agreed with the authors of that assessment (see Appendix 20.A of the 2014 BSAI or GOA shark assessments).

"The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC." (Plan Team, September 2013).

This will be included in the next full assessment.

"The Teams recommend that stock assessment authors calculate biomass for Tier 5 stocks based on the random effects model and compare these values to status quo. In addition, the Teams recommend that the working group examine autorcorrelation in subarea recruitment when conducting spatial simulations for evaluating apportionment." (Plan Team, September 2014)

Various approaches to calculate biomass based on the random effects model were presented to the Plan Team in September 2013. Continued efforts are underway to determine the most appropriate approach for the species in this complex and will be presented in the next full assessment. Survey data do not support this approach for all of the species in the complex, but the authors are investigating using the random effects model on the full complex as well as some of the individual species.

"The SSC encourages assessment authors of stocks managed in Tier 5 to consider the recommendations found in the draft survey averaging workgroup report." (SSC, December 2012)
Please see the above comment in this section.

SSC and Plan Team Comments Specific to this Assessment

"The Team discussed a recommendation in the 2010 GOA Plan Team minutes to apply a productivity-susceptibility analysis, and clarified that this analysis is to be applied to the newly-formed other rockfish complex to evaluate the degree to which the species within the complex have similar life-history parameters and vulnerabilities to fishing pressure… As part of this analysis, the Team requests information on which target fisheries catch other rockfish, and how this may differ between GOA subareas." (Plan Team, November 2011)
The component species of the Other Rockfish complex have changed often over the time series of catch (1992-2014). The current Other Rockfish complex began in 2012 and since then, on average 74% of the catch of the Other Rockfish has come from the rockfish target fishery. We are examining whether it is possible to estimate a more complete time series of catch by target species for the current Other Rockfish complex and will be presented in the next full assessment.

"The SSC supports the Plan Team request for a productivity-susceptibility analysis for the Other Rockfish complex. The SSC also encourages the authors to examine the relationship between environmental conditions and the distribution and abundance of silvergray rockfish and harlequin rockfish because the trawl survey data suggests that these stocks may move in and out of the GOA in response to changing conditions." (SSC, December 2011)
The authors plan to investigate this in the next full assessment.

"In the interim period, the SSC requests that the authors carefully consider the recommendations of the rockfish CIE reviewers and that they work with NMFS Resource Assessment and Conservation Engineering division to evaluate the evidence that harlequin rockfish biomass is underestimated by the NMFS trawl and if this hypothesis is confirmed whether it is possible to develop a correction factor to improve future estimates for this species." (SSC, December 2013)
This issue is common to many species of rockfish and will be reported on in the next full assessment.

"Because DSR species are currently included within the "other rockfish" assessment for NMFS areas north of area 650, there will have to be reconsideration of current species groupings in the GOA. The SSC recommends that respective assessment authors work together to provide detailed examination of fishery catch and survey data by subarea and season for DSR and "Other" rockfish species. Catch data from all sources (retained, discard, State waters) should be included and where data are lacking this should be noted and would feed into the revised assessments(s). Assessment authors should also attempt to derive a plausible range of historical catch trends where catch data may not be available. The goal of this work is to fully account for rockfish catches and align potential rockfish groupings to improve our ability to monitor and identify conservation issues. This may include species groupings that are biologically similar (i.e. with similar life history attributes) or potentially grouped as Tier 6 species where reliable estimates of biomass are unavailable" (SSC, October 2014)
The authors will work with the DSR assessment authors to begin this investigation and will report on it in the next full assessment

Literature Cited

Clausen, D.M. and K.B. Echave. 2011. Assessment of the “Other Rockfish” Stock Complex in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2011. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. Pgs. 1239 – 1280.

Tribuzio, C.A. and K.B. Echave. 2013. Assessment of the Other Rockfish stock complex in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2011. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. Pgs. 1001 – 1028.

Tribuzio, C. A., J. R. Gasper, and S. K. Gaichas. 2014. Estimation of bycatch in the unobserved Pacific halibut fishery off Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-265, 506 p.

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17. Assessment of the Atka mackerel stock in the Gulf of Alaska

Executive Summary

Sandra A. Lowe

November 2014

Gulf of Alaska (GOA) Atka mackerel has been moved to a biennial stock assessment schedule to coincide with the availability of new survey data from the biennial trawl survey. A full assessment was presented in 2011, which included data from the 2011 GOA bottom trawl survey. On alternate (even) years we present an executive summary with updated catch, last year's key assessment parameters, any significant new information available in the interim, and projections for this year. Although a survey was conducted in 2013, we only provided an expanded executive summary with updated catch and the 2013 survey information, due to the government shut-down in October 2013.

Gulf of Alaska Atka mackerel have been managed under Tier 6 specifications since 1996 due to the lack of reliable estimates of current biomass. In 2007, the assessment presented for consideration, Tier 5 calculations of ABC and OFL based on 2007 survey biomass estimates. However, the Plan Team and SSC agreed with the authors that reliable estimates of Atka mackerel biomass were not available and recommended continuing management under Tier 6. The 2012 and 2013 updates presented Tier 6 recommendations and did not present Tier 5 calculations given the large variances associated with the 2011 and 2013 survey biomass estimates, which were essentially based on one to two significant hauls encountered in the western Gulf of Alaska. The Council set the Gulf-wide 2014 (and 2015) OFL, ABC, and TAC for Atka mackerel at 6,200 t, 4,700 t, and 2,000 t, respectively. The 2011 full assessment is available on the web (Lowe *et al*. 2011, http://www.afsc.noaa.gov/refm/docs/2011/GOAatka.pdf). Last year's update with the 2013 survey information is available at http://www.afsc.noaa.gov/REFM/Docs/2013/GOAatka.pdf.

Summary of Changes in Assessment Inputs

New catch information includes updated 2013 catch (1,277 t), and 2014 catch (845 t) as of October 18, 2014 (http://alaskafisheries.noaa.gov/2014/car110_goa.pdf)

The 2014 GOA Atka mackerel catch through October 18 was 42% of the 2014 TAC; the 2013 GOA Atka mackerel catch was 64% of the TAC. Figure 17.1 shows the 2014 distributions of observed catches of Atka mackerel in the Gulf of Alaska summed over 20 km areas. Open circles represent observed catches greater than 1 t. Unlike previous years when large catches were taken in the Shumagin (610) Area and to some extent in the Chirikof (620) Area in the second half of the year, only minimal catches were taken in the Chirikof Area during July to October, 2014.

Since the 2011 assessment and 2013 update, ages from the 2013 GOA fisheries have become available. A total of 144 otoliths were collected from 36 hauls from the Shumagin and Chirikof areas. The data show the strong 2006 and 2007 year classes observed in the Aleutian Islands (Figure 17.2). The 2001 year class, which was very strong in the Aleutian Islands, is still observed in the GOA age distribution.

New survey age information is available from the 2013 summer bottom trawl survey. Similar to the GOA fishery data, the strong 2006 and 2007 year classes are predominant in the survey age composition (Figure 17.3). Also, the 2011 year class was evident in the 2013 GOA survey age composition.

Summary of changes in assessment methodology

There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

There is no new information incorporated into the projection. For the 2015 (and 2016) fishery, we recommend an ABC of 4,700 t. This ABC is equivalent to last year's ABC for 2014. The corresponding reference values for Atka mackerel are summarized below. Because abundance information for Atka mackerel is very limited, they are managed in Tier 6.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	**2015**	2016
M (natural mortality)	0.3	0.3	**0.3**	0.3
Tier	6	6	**6**	6
OFL (t)	6,200	6,200	**6,200**	6,200
maxABC (t)	4,700	4,700	**4,700**	4,700
ABC (t)	4,700	4,700	**4,700**	4,700
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing	n/a	n/a	**n/a**	n/a
(for Tier 6 stocks, data are not available to determine whether the stock is in an overfished condition)				

Area apportionment

There is no area apportionment for GOA Atka mackerel. The Council manages GOA Atka mackerel on a Gulf-wide basis.

Summaries for the Plan Team

Species	Year	Biomass	OFL	ABC	TAC	Catch
Atka mackerel (Gulfwide)	2013	Unknown	6,200	4,700	2,000	1,277
	2014	Unknown	6,200	4,700	2,000	845[1]
	2015	Unknown	6,200	4,700		
	2016	Unknown	6,200	4,700		

1/ Current as of October 18, 2014 (http://alaskafisheries.noaa.gov/2014/car110_goa.pdf).

Responses to SSC and Plan Team Comments on Assessments in General

From the December 2013 SSC minutes: *The SSC asks assessment authors to project the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams.*

GOA Atka mackerel are a Tier 6 species and phase diagrams are not applicable for this assessment.

From the September 2013 Joint Plan Team minutes:
Accounting for total catch removals: The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC.

Other removals are reported in Appendix 17A.—Supplemental Catch Data in the 2011 full assessment, and will be updated and reported in the 2015 full assessment.

<u>Retrospective analyses</u>: In conformity with the main recommendations of the Retrospective Working Group, the Team recommended the following:

1. *Assessment authors should routinely do retrospective analyses extending back 10 years, plot spawning biomass estimates and error bars, plot relative differences, and report Mohn's rho (revised).*
2. *If a model exhibits a retrospective pattern, try to investigate possible causes.*
3. *Communicate the uncertainty implied by retrospective variability in biomass estimates.*
4. *For the time being, do not disqualify a model on the grounds of poor retrospective performance alone.*
5. *Do consider retrospective performance as one factor in model selection.*

GOA Atka mackerel are a Tier 6 species and retrospective analyses are not applicable for this assessment.

<u>Total Current Year Removals</u>: The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals.

GOA Atka mackerel are a Tier 6 species and projections (requiring total current year catch) are not conducted for this assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

***From the December 2013 SSC minutes**: Consideration should be given to doing a sablefish-like assessment in which a combined BSAI and Gulf of Alaska model is developed and used to partition Atka mackerel ABCs and OFLs between the BSAI and GOA. This would only work if the surveys can be effectively combined (perhaps with use of the random effects model) and the allocation proportions have reduced variance compared to those of the survey totals. However, given that there is no evidence for a genetic difference and that the GOA component is just the fringe end of the BSAI stock, it seems more biologically reasonable to do a combined assessment*.

GOA Atka mackerel are a Tier 6 species because reliable estimates of biomass are not available. The 2013 survey biomass estimate of GOA Atka mackerel is associated with a coefficient of variation (*CV*) of 67%, reflecting a variance of 4.96 billion. Most of the GOA survey Atka mackerel biomass (>90%) is distributed within the Shumagin Area of the western GOA, and the 2013 estimate of Shumagin Area biomass is associated with a *CV* of 94%, reflecting a variance of 4.6 billion. Directed fishing for GOA Atka mackerel is prohibited under Steller sea lion protection measures, and there are very limited fishery age data. Unlike the Aleutian Islands fishery age compositions, the GOA data only show 1 to 2 strong year classes in the bycatch which have also been observed in the Aleutian Islands. Unlike sablefish, which exhibit extremely high movement rates throughout their lives, adult Atka mackerel show limited movement and no evidence of migratory behavior. The lack of genetic differences in Alaska Atka mackerel is thought to be due to mixing occurring at the pelagic larval stage. Because Atka mackerel do not migrate and show little movement after settlement , CIE reviewers from the 2014 BSAI Atka mackerel stock assessment review suggested consideration of separate applications of the BSAI model to the 3 Aleutian Islands sub-areas to account for spatial variability in survey and fishery data. For these reasons we continue to recommend separate assessment and management of GOA Atka mackerel.

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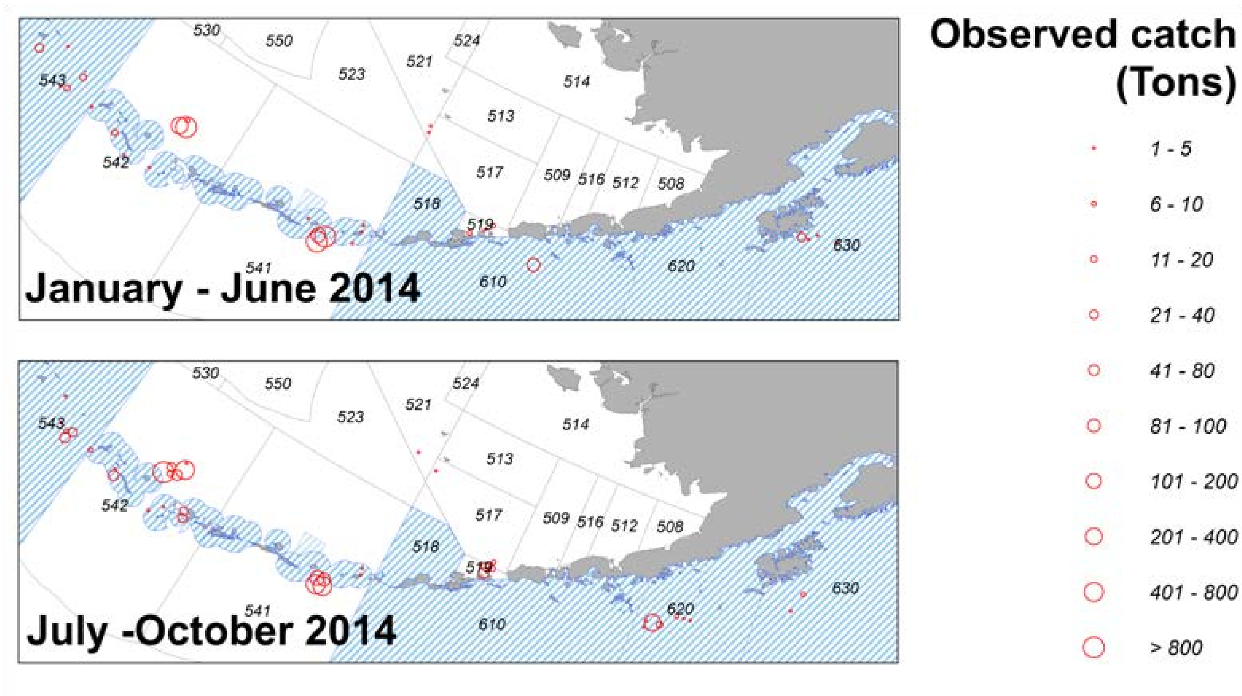

Figure 17.1. Observed catches of Atka mackerel summed for 20 km^2 cells for 2013 where observed catch per haul was greater than 1 t. Shaded areas represent areas closed to directed Atka mackerel fishing.

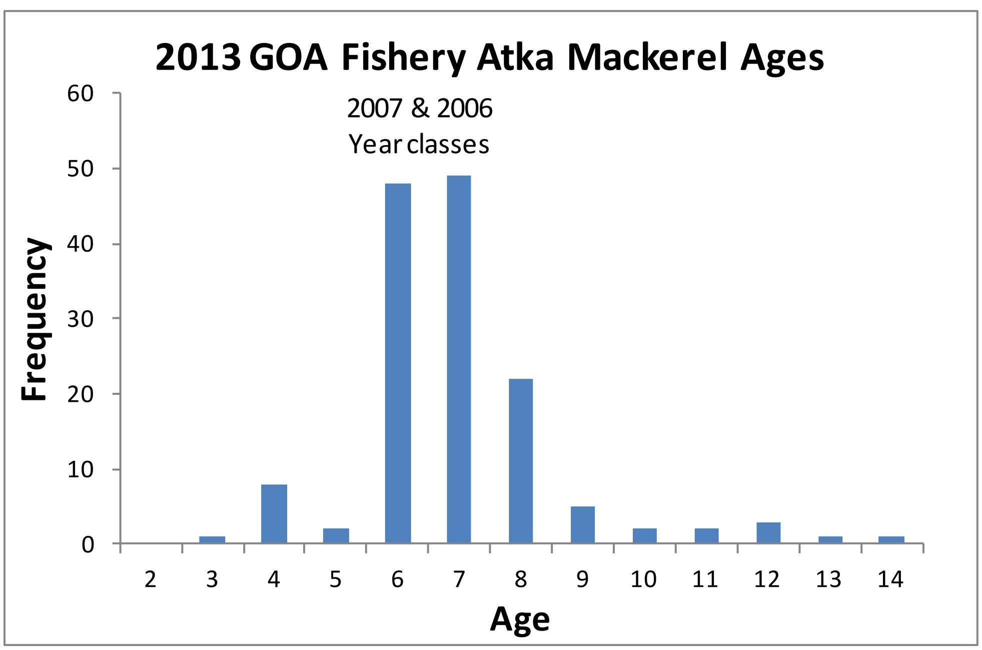

Figure 17.2. Age frequency distribution of Atka mackerel from the 2013 Gulf of Alaska fisheries. A total of 144 otoliths were collected and aged from the Shumagin (610) and Chirikof (620) areas.

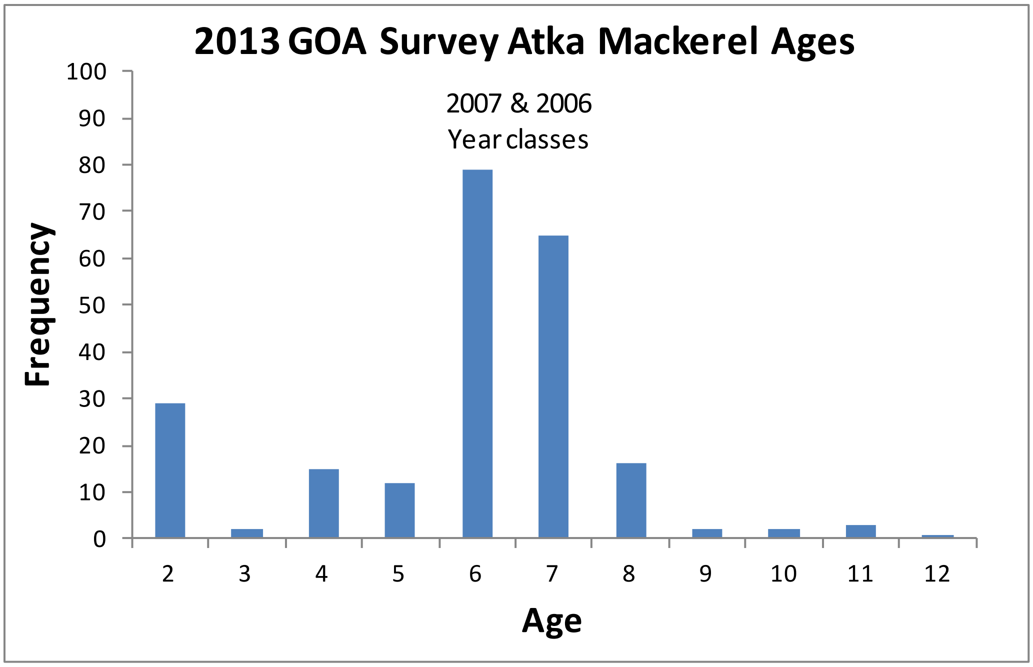

Figure 17.3. Age frequency distribution of Atka mackerel from the 2013 Gulf of Alaska bottom trawl survey. A total of 226 otoliths were collected and aged from the Shumagin (610) and Chirikof (620) areas.

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18. Assessment of the skate stock complex in the Gulf of Alaska

Olav A. Ormseth
NMFS Alaska Fisheries Science Center, Seattle WA

Executive Summary

The Gulf of Alaska (GOA) skate complex is managed as three units. Big skate (*Beringraja binoculata*) and longnose skate (*Raja rhina*) have separate harvest specifications, with gulfwide overfishing levels (OFLs) and Acceptable Biological Catches (ABCs) specified for each GOA regulatory area (western, central, and eastern). All remaining skate species are managed as an "Other Skates" group, with gulfwide harvest specifications. All GOA skates are managed under Tier 5, where OFL and ABC are based on survey biomass estimates and natural mortality rate. Normally, only an executive summary is prepared in even years; because the federal shutdown in 2013 resulted in a truncated stock assessment process, a full assessment was prepared in 2014.

Summary of Changes in Assessment Inputs

Changes in the input data:

1) Fully updated groundfish fishery catch data (2014 catch data as of October 8, 2014).
2) Biomass estimates and length composition data from the 2013 GOA bottom trawl survey.
3) Fishery length composition data through 2013.
4) An appendix containing information on catches of skates not accounted for in the Alaska Regional Office's Catch Accounting System through 2014.

Changes in the assessment methodology:

1) For the first time, this report uses the Joint Plan Team survey averaging working group's recommendation of a random effects (RE) model for estimating biomass. Estimates from the RE model were used for making harvest recommendations, and the report includes a comparison of the RE results to the 3-survey averages used in earlier assessments.

Summary of Results

1) The 2013 survey biomass estimates for longnose skate and "other skates" increased substantially relative to the 2011 estimate, with CVs similar to earlier years. The estimate for longnose skates is the highest in the 1984-2013 time series.

2) The 2013 survey biomass estimate for big skate was down considerably from 2011, when the biomass estimate was inflated by an anomalous single large tow of big skates in the EGOA during the 2011 survey. The 2013 estimate for the WGOA was the highest since 1999, while the estimate for the CGOA, where the majority of big skate biomass is typically observed, decreased by almost half.

3) Application of the RE model to the survey data for big, longnose, and "other skates" provided reliable estimates of biomass that the author considers superior to the 3-survey averages used in

previous assessments. Therefore, the RE estimates were used in developing harvest recommendations.

4) Estimates of incidental catches increased substantially for longnose skates and "other skates" in 2013, mainly in the IFQ halibut target fishery. It is likely that this increase in estimated catch is due to the addition of observer coverage in the IFQ halibut fishery in 2013.

5) In 2013 the catch of big skates in the CGOA exceeded the ABC for that area, as it has every year since 2010.

6) Catches in 2014 are on track to be much lower than in the preceding years. This is likely due to the fact that skates were placed on prohibited status early in 2014 as a result of the catch overages in earlier years.

The harvest recommendation summary table is on the following page. W, C, and E indicate the Western, Central, and Eastern GOA regulatory areas, respectively. Big and longnose skates have area-specific ABCs and gulfwide OFLs; "other skates" have a gulfwide ABC and OFL. For all species summary tables below, the 2014/2015 recommendations use a three year average of the most recent trawl survey biomass estimates (2009, 2011, 2013). For 2015/2016 a RE model was used to estimate biomass for most recent survey year (2013).

big skate (*Beringraja binoculata*)					
		As estimated or *specified last* year for		As estimated or *recommended this* year for:	
Quantity		*2014*	*2015*	**2015**	2016
M (natural mortality)		*0.1*	*0.1*	**0.1**	0.1
Specified/recommended Tier		*5*	*5*	**5**	5
Biomass (t) *2015/2016 recommendations are made using the random effects model; 2014/2015 recommendations used the 3-survey average*	W	*7,857*	*7,857*	**9,775**	9,775
	C	*20,421*	*20,421*	**16,810**	16,810
	E	*21,877*	*21,877*	**16,954**	16,954
	GOA-wide[1]	*50,155*	*50,155*	**43,398**	43,398
F_{OFL} ($F=M$)		*0.1*	*0.1*	**0.1**	0.1
$maxF_{ABC}$		*0.075*	*0.075*	**0.075**	0.075
F_{ABC}		*0.075*	*0.075*	**0.075**	0.075
OFL (t)	GOA-wide	*5,016*	*5,016*	**4,340**	4,340
ABC (t; equal to maximum ABC)	W	*589*	*589*	**731**	731
	C	*1,532*	*1,532*	**1,257**	1,257
	E	*1,641*	*1,641*	**1,267**	1,267
Status		As determined *last* year for:		As determined *this* year for:	
		2012	2013	**2013**	2014
Overfishing?		*no*	*na*	**no**	na
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

[1] The GOA-wide biomass estimate was made using a separate GOA-wide random-effects model, so the sum of the area-specific estimates does not equal the GOA-wide estimate.

longnose skate (*Raja rhina*)					
		As estimated or *specified last* year for		As estimated or *recommended this* year for:	
Quantity		*2014*	*2015*	**2015**	2016
M (natural mortality)		*0.1*	*0.1*	**0.1**	0.1
Specified/recommended Tier		*5*	*5*	**5**	5
Biomass (t) *2015/2016 recommendations are made using the random effects model; 2014/2015 recommendations used the 3-survey average*	W	*1,427*	*1,427*	**2,009**	2,009
	C	*25,806*	*25,806*	**27,575**	27,575
	E	*11,116*	*11,116*	**12,873**	12,873
	GOA-wide[1]	*38,349*	*38,349*	**42,911**	42,911
F_{OFL} (F=M)		*0.1*	*0.1*	0.1	0.1
$maxF_{ABC}$		*0.075*	*0.075*	0.075	0.075
F_{ABC}		*0.075*	*0.075*	0.075	0.075
OFL (t)	GOA-wide	*3,835*	*3,835*	**4,291**	4,291
ABC (t; equal to maximum ABC)	W	*107*	*107*	**152**	152
	C	*1,935*	*1,935*	**2,090**	2,090
	E	*834*	*834*	**976**	976
		As determined *last* year for:		As determined *this* year for:	
Status		2012	2013	**2013**	2014
Overfishing?		*no*	*n/a*	**no**	n/a
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

[1] The GOA-wide biomass estimate was made using a separate GOA-wide random-effects model, so the sum of the area-specific estimates does not equal the GOA-wide estimate.

other skates (*Bathyraja* sp.)					
		As estimated or *specified last* year for		As estimated or *recommended this* year for:	
Quantity		*2014*	*2015*	**2015**	2016
M (natural mortality)		*0.1*	*0.1*	**0.1**	0.1
Specified/recommended Tier		*5*	*5*	**5**	5
Biomass (t)	GOA-wide	26,518	26,518	**29,797**	29,797
F_{OFL} (F=M)		0.1	0.1	**0.1**	0.1
$maxF_{ABC}$		0.075	0.075	**0.075**	0.075
F_{ABC}		0.075	0.075	**0.075**	0.075
OFL (t)	GOA-wide	2,652	2,652	**2,980**	2,980
ABC (t; equal to maximum ABC)	GOA-wide	1,989	1,989	**2,235**	2,235
		As determined *last* year for:		As determined *this* year for:	
Status		2012	2013	**2013**	2014
Overfishing?		*no*	*na*	**no**	na
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

Responses to SSC and Plan Team Comments on Assessments in General

Plan Team September 2014: "The Teams recommend that stock assessment authors calculate biomass for Tier 5 stocks based on the random effects model and compare these values to status quo."

> *Response*: The random effects model was used to generate biomass estimates and harvest recommendations for big, longnose, and other skates. The results were compared to the 3-survey average using a table and several figures.

Responses to SSC and Plan Team Comments Specific to this Assessment

SSC December 2013: "The SSC also supports the Plan Team recommendation for the author to fill out the stock structure template for GOA skates for Plan Team consideration in September 2014 and further recommends the author complete a full assessment for 2014."

> *Response*: A full assessment was prepared for 2014 and is presented here. A stock structure report was presented in September 2014 and is attached to this report as an appendix.

Introduction

Description, scientific names, and general distribution

Skates (family Rajidae) are cartilaginous fishes related to sharks. At least 15 species of skates in four genera (*Raja*, *Beringraja*, *Bathyraja*, and *Amblyraja*) are found in Alaskan waters and are common from shallow inshore waters to very deep benthic habitats (Eschmeyer *et al* 1983; Stevenson *et al* 2007). In general, *Raja* species are most common and diverse in lower latitudes and shallower waters from the Gulf of Alaska to the Baja peninsula, while *Bathyraja* species are most common and diverse in the higher latitude habitats of the Bering Sea and Aleutian Islands, as well as in the deeper waters off the U.S. west coast. Table 1 lists the species found in Alaska, with their depth distributions and selected life history characteristics, which are outlined in more detail below.

In the Gulf of Alaska (GOA), the most common skate species are a *Raja* species, the longnose skate *R. rhina*; a *Beringraja* species, the big skate *B. binoculata*; and three *Bathyraja* species, the Aleutian skate *B. aleutica*, the Bering skate *B. interrupta*, and the Alaska skate *B. parmifera* (Tables 2 & 3, Figure 1). Big skates were previously in the genus *Raja*. The general range of the big skate extends from the Bering Sea to southern Baja California in depths ranging from 2 to 800 m. The longnose skate has a similar range, from the southeastern Bering Sea to Baja California in 9 to 1,069 m depths (Love *et al* 2005). While these two species have wide depth ranges, they are generally found in shallow waters in the Gulf of Alaska. One deep-dwelling *Amblyraja* species, the roughshoulder skate *A. badia*, ranges throughout the north Pacific from Japan to Central America at depths between 846 and 2,322 m; the four other species in the genus *Raja* are not found in Alaskan waters (Love *et al* 2005; Stevenson *et al* 2007). Within the genus *Bathyraja*, only two of the 13+ north Pacific species are not found in Alaska. Of the remaining 11+ species, only three are commonly found in the Gulf of Alaska. The Aleutian skate ranges throughout the north Pacific from northern Japan to northern California, and has been found in waters 16 to 1,602 m deep. The Alaska skate is restricted to higher latitudes from the Sea of Okhotsk to the eastern Gulf of Alaska in depths from 17-392 m (Stevenson *et al* 2007). The range of the Bering skate is difficult to determine at this time as it may actually be a complex of species, with each individual species occupying a different part of its general range from the western Bering Sea to southern California (Love *et al* 2005; Stevenson *et al* 2007).

The species within this assemblage occupy different habitats and regions within the GOA groundfish Fishery Management Plan (FMP). In this assessment, we distinguish habitat primarily by depth for GOA skates. The highest biomass of skates is found in the shallowest continental shelf waters of less than 100 m depth, and is dominated by the big skate (Figure 2). In continental shelf waters from 100-200 m depth, longnose skates dominate skate biomass, and *Bathyraja* skate species are dominant in the deeper waters extending from 200 to 1000 m or more in depth (Figure 2). These depth distributions are reflected in the spatial distribution of GOA skates. Big skates are located inshore and are most abundant in the central and western GOA (Figures 3 & 4). Longnose skates (Figures 4 & 5) are located further offshore and appear to be more widespread than big skates

<u>Life history and stock structure (skates in general)</u>

Skate life cycles are similar to sharks, with relatively low fecundity, slow growth to large body sizes, and dependence of population stability on high survival rates of a few well developed offspring (Moyle and Cech 1996). Sharks and skates in general have been classified as “equilibrium” life history strategists, with very low intrinsic rates of population increase implying that sustainable harvest is possible only at very low to moderate fishing mortality rates (King and McFarlane 2003). Within this general equilibrium life history strategy, there can still be considerable variability between skate species in terms of life history parameters (Walker and Hislop 1998). While smaller-sized species have been observed to be somewhat more productive, large skate species with late maturation (11+ years) are most vulnerable to heavy fishing pressure (Walker and Hislop 1998; Frisk *et al* 2001; Frisk *et al* 2002). The most extreme cases of overexploitation have been reported in the North Atlantic, where the now ironically named common skate *Dipturus batis* has been extirpated from the Irish Sea (Brander 1981) and much of the North Sea (Walker and Hislop 1998). The mixture of life history traits between smaller and larger skate species has led to apparent population stability for the aggregated “skate” group in many areas where fisheries occur, and this combined with the common practice of managing skate species within aggregate complexes has masked the decline of individual skate species in European fisheries (Dulvy *et al* 2000). Similarly, in the Atlantic off New England, declines in barndoor skate *Dipturus laevis* abundance were concurrent with an increase in the biomass of skates as a group (Sosebee 1998).

Several recent studies have explored the effects of fishing on a variety of skate species to determine which life history traits and stages are the most important for management. While full age-structured modeling is difficult for many of these data-poor species, Leslie matrix models parameterized with information on fecundity, age/size at maturity, and longevity have been applied to identify the life stages most important to population stability. Major life stages include the egg stage, the juvenile stage, and the adult stage (summarized here based on Frisk *et al* 2002). All skate species are oviparous (egg-laying), investing considerably more energy per large, well protected embryo than commercially exploited groundfish. The large, leathery egg cases incubate for extended periods (months to a year) in benthic habitats, exposed to some level of predation and physical damage, until the fully formed juveniles hatch. The juvenile stage lasts from hatching through maturity, several years to over a decade depending on the species. The reproductive adult stage may last several more years to decades depending on the species.

Age and size at maturity and adult size/longevity appear to be more important predictors of resilience to fishing pressure than fecundity or egg survival in the skate populations studied to date. Frisk *et al* (2002) estimated that although annual fecundity per female may be on the order of less than 50 eggs per year (extremely low compared with teleost groundfish), there is relatively high survival of eggs due to the high parental investment (without disturbance from fishing operations), and therefore egg survival did not appear to be the most important life history stage contributing to population stability under fishing pressure. Juvenile survival appears to be most important to population stability for most North Sea species studied (Walker and Hilsop 1998), and for the small and intermediate sized skates from New England (Frisk *et al* 2002). For the large and long-lived barndoor skates, adult survival was the most important contributor to population stability (Frisk *et al* 2002). In all cases, skate species with the largest adult body sizes (and the empirically related large size/age at maturity, Frisk *et al* 2001) were least resilient to high fishing mortality rates. This is most often attributed to the long juvenile stage during which relatively large yet immature skates are exposed to fishing mortality, and also explains the mechanism for the shift in species composition to smaller skate species in heavily fished areas. Comparisons of length frequencies for surveyed North Sea skates from the mid- and late-1900s led Walker and Hilsop (1998, p. 399) to the conclusion that "all the breeding females, and a large majority of the juveniles, of *Dipturus batis, R. fullonica* and *R. clavata* have disappeared, whilst the other species have lost only the very largest individuals." Although juvenile and adult survival may have different importance by skate species, all studies found that one metric, adult size, reflected overall sensitivity to fishing. After modeling several New England skate populations, Frisk *et al* (2002, p. 582) found "a significant negative, nonlinear association between species total allowable mortality, and species maximum size."

There are clear implications of these results for sustainable management of skates in Alaska. After an extensive review of population information for many elasmobranch species, Frisk et al (2001, p. 980) recommended that precautionary management be implemented especially for the conservation of large species:

> "(*i*) size based fishery limits should be implemented for species with either a large size at maturation or late maturation, (*ii*) large species (>100 cm) should be monitored with increased interest and conservative fishing limits implemented, (*iii*) adult stocks should be maintained, as has been recommended for other equilibrium strategists (Winemiller and Rose 1992)."

<u>Life history and stock structure (Alaska-specific)</u>

Information on fecundity in North Pacific skate species is extremely limited. There are one to seven embryos per egg case in locally occurring *Raja* species (Eschmeyer *et al* 1983), but little is known about frequency of breeding or egg deposition for any of the local species. Similarly, information related to breeding or spawning habitat, egg survival, hatching success, or other early life history characteristics is extremely sparse for Gulf of Alaska skates (although current research is addressing these issues for Alaska skates in the Eastern Bering sea; J. Hoff, AFSC, pers. comm.; see also the 2009 BSAI skate SAFE, Ormseth and Matta 2009).

Slightly more is known about juvenile and adult life stages for Gulf of Alaska skates. In terms of maximum adult size, the *Raja* species are larger than the *Bathyraja* species found in the area. The big skate, *Raja binoculata*, is the largest skate in the Gulf of Alaska, with maximum sizes observed over 200 cm in the directed fishery in 2003 (see the "Fishery" and "Survey" sections below, for details). Observed sizes for the longnose skate, *Raja rhina,* are somewhat smaller at about 165-170 cm. Therefore, the Gulf of Alaska *Raja* species are in the same size range as the large Atlantic species, i.e., the common skate *Dipturus batis* and the barndoor skate, which historically had estimated maximum sizes of 237 cm and 180 cm, respectively (Walker and Hislop 1998, Frisk *et al* 2002). The maximum observed lengths for *Bathyraja* species from bottom trawl surveys of the GOA range from 86-154 cm.

Known life history parameters of Alaskan skate species are presented in Table 1. Zeiner and Wolf (1993) determined age at maturity and maximum age for big and longnose skates from Monterey Bay, CA. The maximum age of CA big skates was 11-12 years, with maturity occurring at 8-11 years; estimates of maximum age for CA longnose skates were 12-13 years, with maturity occurring at 6-9 years. McFarlane and King (2006) completed a study of age, growth, and maturation of big and longnose skates in the waters off British Columbia (BC), finding maximum ages of 26 years for both species, much older than the estimates of Zeiner and Wolf. Age at 50% maturity occurs at 6-8 years in BC big skates, and at 7-10 years in BC longnose skates. However, these parameter values may not apply to Alaskan stocks. The AFSC Age and Growth Program has recently reported a maximum observed age of 25 years for the longnose skate in the GOA, significantly higher than that found by Zeiner and Wolf but close to that observed by McFarlane and King (Gburski *et al* 2007). In the same study, the maximum observed age for GOA big skates was 15 years, closer to Zeiner and Wolf's results for California big skates.

Fishery

Directed fishery, bycatch, and discards in federal waters

Until 2003, skates were primarily caught incidentally in longline and trawl fisheries targeting Pacific halibut and other groundfish (Table 4). Skates became economically valuable in 2003 when the ex-vessel price became equivalent to that of Pacific cod. In 2003, vessels began retaining and delivering skates as a target species in federal waters partly because the market for skates had improved, and partly because catch of Pacific cod could be retained as bycatch in a skate target fishery, even though directed fishing for cod was seasonally closed. This resulted in greater landings of skates in 2003 (Table 4). Lower ex-vessel prices and a possible reduction in skate catch-per-unit effort (T. Pearson, NMFS AKRO, pers. comm.) resulted in a sharp decline in skate catches in 2004-2005. Directed fishing for skates in the GOA has been prohibited since 2005.

Interest in retention of skates and directed fishing for skates remains high (Table 7). The ABC for big skates in the CGOA was exceeded every year during 2010-2013, and the ABC for longnose skates in the WGOA was exceeded in 4 of the years 2007-2013 (Table 5). Incidental catches of big and longnose skates occur in a variety of target fisheries; the greatest catches presently occur in the arrowtooth flounder, Pacific cod, and Pacific halibut longline fisheries (Table 6). Reported retention rates of big and longnose skates was high during the late 2000s, but has declined in 2013 &2014 (Table 7). The 2013 decline may be due to increased observer coverage of the IFQ halibut fishery, where skates are less likely to be retained. In addition, retention of big skate was limited in 2013 & 2014 through management actions. In 2013, retention of big skate was prohibited in the CGOA on May 8 and in 2014, it was prohibited beginning on February 5. These actions reduced retention of big skate but may have increased the retention of longnose and other skates.

Alaska state-waters fishery 2009-2010

Prior to 2006, directed fishing for skates in state waters was allowed by Commissioner's Permit; in 2006 skates were placed on bycatch status only. In 2008, the Alaska state legislature appropriated funds for developing the data collection necessary to open a state-waters directed fishery. In 2009 and 2010, the state conducted a limited skate fishery in the eastern portions of the Prince William Sound (PWS) Inside and Outside Districts. In 2009, the guideline harvest level (GHL) was based on skate exploitation rates in federal groundfish fisheries and NMFS survey estimates of skate biomass. This was changed for 2010, when GHLs were based on ADF&G trawl survey results. The GHLs and harvests for 2009 and 2010 were as follows (in lbs.; harvests exceeding the GHL are indicated in **bold**):

Year	2009		2010	
Skate Species	big	longnose	big	longnose
Inside District GHL (lbs)	20,000	100,000	20,000	110,000
Inside District Harvest (lbs)	**47,220**	68,828	**20,382**	68,681
Outside District GHL (lbs)	30,000	150,000	30,000	155,000
Outside District Harvest (lbs)	**82,793**	59,538	6,190	9,257

* Thanks to Charlie Trowbridge of ADF&G for state-waters skate harvest data.

The big skate GHL was exceeded by a substantial amount in 2009. In 2010, trip limits for big skates were imposed to reduce the potential for exceeding the GHL. The improved management resulted in a much smaller overage in the PWS Inside District and no overage in the PWS Outside District. The state-waters skate fishery was discontinued in 2011.

Management units

Since the beginning of domestic fishing in the late 1980s up through 2003, all species of skates in the GOA were managed under the "Other Species" FMP category (skates, sharks, squids, sculpins, and octopuses). Catch within this category was historically limited by a Total Allowable Catch (TAC) for all "Other Species" calculated as 5% of the sum of the TACs for GOA target species. The "Other Species" category was established to monitor and protect species groups that were not currently economically important in North Pacific groundfish fisheries, but which were perceived to be ecologically important and of potential economic importance as well. The configuration of the "Other Species" group was relatively stable until 2004, when GOA skates were removed from the category for separate management in response to a developing fishery. In 2004 the skate species, which were the targets of the 2003 fishery (big and longnose skates), were managed together under a single TAC in the central GOA (CGOA), where the fishery had been concentrated in 2003. The remaining skates were managed as an "other skates" species complex in the CGOA, and all skates including big and longnose skates were managed as an "other skates" species complex in the western GOA (WGOA) and eastern GOA (EGOA). Since 2005, to address concerns about disproportionate harvest of skates, big skate and longnose skate have had separate ABCs and TACs for the WGOA, CGOA, and EGOA. The remaining skates (”other skates") continue to be managed as a gulfwide species complex because they are not generally retained and are difficult to distinguish at the species level.

Data

Fishery

Catch data: Catches were recorded using the Blend system from 1992-2002 (Table 4). Since 2003 skate catch data are recorded in the Alaska Regional Office Catch Accounting System (CAS; Tables 4 & 5). Additional details are available in the sections above.

Fishery length compositions: Fishery observers have been required to collect length data for skates in selected fisheries since 2009, and fishery length compositions have been constructed for the years 2009-2013 for big skate (Figure 6) and longnose skate (Figure 7). These data suggest that fisheries are capturing a narrower size range of longnose skate relative to big skate. Length compositions do not vary substantially among trawl and longline fisheries (Figure 8); this may be because much of the length data comes from retained skates, and skates are generally retained only if they are above a minimum size.

Survey

Bottom trawl survey biomass estimates: There are several potential indices of skate abundance in the Gulf of Alaska, including longline and trawl surveys. For this assessment, we use the NMFS summer bottom trawl surveys 1984-2013 as our primary source of information on the biomass and distribution of the major skate species (Tables 2, 3 & 8; Figures 9-11). On a gulf-wide basis, big and longnose skate biomass estimates have been fairly stable since the late 1990s (Table 2 & Figure 9). Area-specific biomass has shown greater fluctuations (Table 8 & Figure 10); in particular, big skate biomass has decreased dramatically in the CGOA since 2003. “Other skate” biomass increased in 2013, reversing a declining trend that occurred during 2005-2011 (Table 2 & Figure 11).

Random effects model biomass estimates: Previous assessments used a 3-survey running average to produce a biomass estimate for use in developing harvest specifications. For the 2014 assessment, biomass was also estimated using a random effects (RE) model developed by the Joint Plan Team Survey Averaging Working Group. Estimates were produced for big and longnose skate on an area-specific and gulfwide basis (Tables 9a, 9b & Figures 12, 13); and for other skates on a gulfwide basis only (Table 9c). The RE model produced reasonable results. RE model estimates generally varied more than the running average, but reduced the influence of anomalous survey estimates and large CVs. As a result, the RE model estimates were used for developing harvest recommendations.

Survey length compositions: Length data are collected for skates during the GOA bottom trawl surveys. The survey length composition of big skates is diffuse, with few clear size modes (Figure 14). Since 2003, the composition has been fairly stable, with the majority of individuals clustered between approximately 76 and 148 cm. An apparent abundance of large big skates in 2001 may be due to the lack of survey effort in the Eastern GOA (see below). The 2009, 2011, and particularly 2013 surveys captured more small skates than in previous years, which may indicate an increase in recruitment or a decrease in the number of larger skates. In contrast to big skates, the pre-2011 data for longnose skates displayed a clear size mode at approximately 120 cm (Figure 15). Since 2011 this distribution seems to have shifted slightly, with an increase in smaller sizes and the possible emergence of two length modes.

The length distribution of big skates differs among GOA regulatory areas (Figure 16). The largest big skates tend to be found in the Western GOA and the smallest big skates in the Eastern GOA. Intermediate sizes dominate in the Central GOA, where a size mode is more distinct than in the other areas. The length composition of longnose skates varies much less among the areas (Figure 17). These patterns may reflect differences in migratory behavior. The pattern for big skates is similar to patterns observed in the Alaska skate population in the Bering Sea, where there appears to be an ontogenetic migration offshore as skates mature (Hoff 2007). A similar process may exist for GOA big skates.

Analytic Approach

Skates in the GOA are managed using Tier 5. Under Tier 5, $F_{OFL} = M$ and OFL = F_{OFL} * average survey biomass. Maximum permissible ABC is calculated as 0.75 * F_{OFL} * average survey biomass.

Random effects (RE) models were used in two ways to make harvest recommendations. A separate gulfwide RE model was run for each species or species group (big, longnose, and other skates). The results of that model (i.e. the 2013 RE model biomass estimate) was used to calculate gulfwide OFLs and ABCs. For big skate and longnose skate, the gulfwide ABC was apportioned to each regulatory area according to the proportion of biomass in each area. For apportionment, area-specific RE model results were used.

Parameter estimates

Natural mortality (*M*)

A value of M = 0.1 has been used for GOA skate harvest recommendations since 2003. During the CIE review of non-target stock assessments in 2013, several reviewers felt that the use of 0.1 was overly conservative and di not include the best data. The author agrees that the value of *M* has not been revisited in the light of recent Alaska-specific data and recent analyses of the *F*=*M* methodology. It was not possible to properly review the treatment of M for this assessment in time for the September 2014 Plan Team meetings; such a review is planned for the 2015 SAFE report. For this year the assessment continues to use the 0.1 value for all skates.

Results

Harvest recommendations

<table>
<tr><th colspan="6">big skate (Beringraja binoculata)</th></tr>
<tr><th colspan="2" rowspan="2">Quantity</th><th colspan="2">As estimated or specified last year for</th><th colspan="2">As estimated or recommended this year for:</th></tr>
<tr><th>2014</th><th>2015</th><th>2015</th><th>2016</th></tr>
<tr><td colspan="2">M (natural mortality)</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td></tr>
<tr><td colspan="2">Specified/recommended Tier</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td rowspan="4">Biomass (t) 2015/2016 recommendations are made using the random effects model; 2014/2015 recommendations used the 3-survey average</td><td>W</td><td>7,857</td><td>7,857</td><td>9,775</td><td>9,775</td></tr>
<tr><td>C</td><td>20,421</td><td>20,421</td><td>16,810</td><td>16,810</td></tr>
<tr><td>E</td><td>21,877</td><td>21,877</td><td>16,954</td><td>16,954</td></tr>
<tr><td>GOA-wide[1]</td><td>50,155</td><td>50,155</td><td>43,540</td><td>43,540</td></tr>
<tr><td colspan="2">F_{OFL} (F=M)</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td></tr>
<tr><td colspan="2">$maxF_{ABC}$</td><td>0.075</td><td>0.075</td><td>0.075</td><td>0.075</td></tr>
<tr><td colspan="2">F_{ABC}</td><td>0.075</td><td>0.075</td><td>0.075</td><td>0.075</td></tr>
<tr><td>OFL (t)</td><td>GOA-wide</td><td>5,016</td><td>5,016</td><td>4,354</td><td>4,354</td></tr>
<tr><td rowspan="3">ABC (t; equal to maximum ABC)</td><td>W</td><td>589</td><td>589</td><td>733</td><td>733</td></tr>
<tr><td>C</td><td>1,532</td><td>1,532</td><td>1,261</td><td>1,261</td></tr>
<tr><td>E</td><td>1,641</td><td>1,641</td><td>1,272</td><td>1,272</td></tr>
<tr><td colspan="2" rowspan="2">Status</td><td colspan="2">As determined last year for:</td><td colspan="2">As determined this year for:</td></tr>
<tr><td>2012</td><td>2013</td><td>2013</td><td>2014</td></tr>
<tr><td colspan="2">Overfishing?</td><td>no</td><td>na</td><td>no</td><td>na</td></tr>
<tr><td colspan="6">(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)</td></tr>
</table>

[1] The GOA-wide biomass estimate was made using a separate GOA-wide random-effects model, so the sum of the area-specific estimates does not equal the GOA-wide estimate.

longnose skate (*Raja rhina*)					
Quantity		As estimated or *specified last* year for *2014*	*2015*	As estimated or *recommended this* year for: **2015**	2016
M (natural mortality)		*0.1*	*0.1*	**0.1**	0.1
Specified/recommended Tier		*5*	*5*	**5**	5
Biomass (t) *2015/2016 recommendations are made using the random effects model; 2014/2015 recommendations used the 3-survey average*	W	*1,427*	*1,427*	**2,009**	2,009
	C	*25,806*	*25,806*	**27,575**	27,575
	E	*11,116*	*11,116*	**12,873**	12,873
	GOA-wide[1]	*38,349*	*38,349*	**42,457**	42,457
F_{OFL} (F=M)		*0.1*	*0.1*	0.1	0.1
$maxF_{ABC}$		*0.075*	*0.075*	0.075	0.075
F_{ABC}		*0.075*	*0.075*	0.075	0.075
OFL (t)	GOA-wide	*3,835*	*3,835*	**4,426**	4,426
ABC (t; equal to maximum ABC)	W	*107*	*107*	**151**	151
	C	*1,935*	*1,935*	**2,068**	2,068
	E	*834*	*834*	**965**	965
Status		As determined *last* year for: 2012	2013	As determined *this* year for: **2013**	2014
Overfishing?		*no*	*n/a*	**no**	n/a
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

[1] The GOA-wide biomass estimate was made using a separate GOA-wide random-effects model, so the sum of the area-specific estimates does not equal the GOA-wide estimate.

other skates (*Bathyraja* sp.)					
Quantity		As estimated or *specified last* year for *2014*	*2015*	As estimated or *recommended this* year for: **2015**	2016
M (natural mortality)		*0.1*	*0.1*	**0.1**	0.1
Specified/recommended Tier		*5*	*5*	**5**	5
Biomass (t)	GOA-wide	26,518	26,518	**29,418**	29,418
F_{OFL} (F=M)		0.1	0.1	**0.1**	0.1
$maxF_{ABC}$		0.075	0.075	**0.075**	0.075
F_{ABC}		0.075	0.075	**0.075**	0.075
OFL (t)	GOA-wide	2,652	2,652	**2,942**	2,942
ABC (t; equal to maximum ABC)	GOA-wide	1,989	1,989	**2,206**	2,206
Status		As determined *last* year for: 2012	2013	As determined *this* year for: **2013**	2014
Overfishing?		*no*	*na*	**no**	na
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)					

Ecosystem Considerations

In the following tables, we summarize ecosystem considerations for GOA skates and the entire groundfish fishery where they are caught incidentally. The observation column represents the best attempt to summarize the past, present, and foreseeable future trends. The interpretation column provides details on how ecosystem trends might affect the stock (ecosystem effects on the stock) or how the fishery trend affects the ecosystem (fishery effects on the ecosystem). The evaluation column indicates whether the trend is of: *no concern, probably no concern, possible concern, definite concern,* or *unknown.*

Ecosystem effects on GOA Skates *(evaluating level of concern for skate populations)*

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Non-pandalid shrimp, other benthic organisms	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Sandlance, capelin, other forage fish	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Commercial flatfish	Increasing to steady populations currently at high biomass levels	Adequate forage available for piscivorous skates	No concern
Pollock	High population level in early 1980s declined to stable low level at present	Currently a small component of skate diets, skate populations increased over same period	No concern
Predator population trends			
Steller sea lions	Declined from 1960s, low but level recently	Lower mortality on skates?	No concern
Sharks	Population trends unknown	Unknown	Unknown
Sperm whales	Populations recovering from whaling?	Possibly higher mortality on skates? But still a very small proportion of mortality	No concern
Changes in habitat quality			
Benthic ranging from shallow shelf to deep slope, isolated nursery areas in specific locations	Skate habitat is only beginning to be described in detail. Adults appear adaptable and mobile in response to habitat changes. Eggs are limited to isolated nursery grounds and juveniles use different habitats than adults. Changes in these habitats have not been monitored historically, so assessments of habitat quality and its trends are not currently available.	Continue study on small nursery areas to evaluate importance to population production, initiate study for GOA big and longnose skates	Possible concern if nursery grounds are disturbed or degraded.

Groundfish fishery effects on ecosystem via skate bycatch *(evaluating level of concern for ecosystem)*

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Skate catch	Varies from 6,000 to 10,000 + tons annually including halibut fishery	Largest portion of total mortality for skates	Possible concern
Forage availability	Skates have few predators, and skates are small proportion of diets for their predators	Fishery removal of skates has a small effect on predators	Probably no concern
Fishery concentration in space and time	Skate bycatch is spread throughout FMP areas, but directed skate catch was concentrated in isolated areas in 2003	Potential impact to skate populations if fishery disturbs nursery or other important habitat; but small effect on skate predators	Possible concern for skates, probably no concern for skate predators
Fishery effects on amount of large size target fish	2005 survey sampling suggests possible decrease in largest big skates	Larger big skates more rare due to fishing or other factors?	Possible concern
Fishery contribution to discards and offal production	Skate discard a moderate proportion of skate catch, many incidentally caught skates are retained and processed	Unclear whether discard of skates has ecosystem effect	Unknown
Fishery effects on age-at-maturity and fecundity	Skate age at maturity and fecundity are still being described; fishery effects on them difficult to determine	Unknown	Unknown

Data gaps and research priorities

Because fishing mortality appears to be a larger proportion of skate mortality in the GOA than predation mortality, highest priority research should continue to focus on direct fishing effects on skate populations. The most important component of this research is to fully evaluate the catch and discards in all fisheries capturing skates. It is also vital to continue research on the productive capacity of skate populations, including information on age and growth, maturity, fecundity, and habitat associations. All of this research has been initiated for major skate species in the GOA; it should be fully funded to completion.

Although predation appears less important than fishing mortality on adult skates, juvenile skates and skate egg cases are likely much more vulnerable to predation. This effect has not been evaluated in population or ecosystem models. We expect to learn more about the effects of predation on skates, especially as juveniles, with the completion of Jerry Hoff’s (AFSC, RACE) research on skate nursery areas in the Bering Sea.

Skate habitat is only beginning to be described in detail. Adults appear capable of significant mobility in response to general habitat changes. However, eggs are limited to isolated nursery grounds and juveniles use different habitats than adults.. Disturbance to these habitats could have disproportionate population effects.. Changes in these habitats have not been monitored historically, so assessments of habitat quality and its trends are not currently available. We recommend continued study on skate nursery areas to evaluate importance to population production.

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Literature Cited

Agnew, D.J., C.P. Nolan, J.R. Beddington, and R. Baranowski, 2000. Approaches to the assessment and management of multispecies skate and ray fisheries using the Falkland Islands fishery as an example. Can. J. Fish. Aquat. Sci. 57: 429-440.

Allen, M.J., and G.B. Smith, 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA Technical Report NMFS 66, 151 pp.

Alverson, D.L., and W.T. Pereyra, 1969. Demersal fish explorations in the northeastern Pacific Ocean: An evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish. Res. Bd. Canada 26: 1985-2001.

Alverson, D.L., and M.J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explor. Mer 36:133-143.

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-178, 298 p.

Brander, K., 1981. Disappearance of common skate *Raja batis* from Irish Sea. Nature 290: 48-49.

Casey, J.M. and R.A. Myers, 1998. Near extinction of a large, widely distributed fish. Science 281(5377):690-692.

Charnov, E.L. 1993. Life history invariants some explorations of symmetry in evolutionary ecology. Oxford University Press Inc., New York. 167p.

Dulvy, N.K., J.D. Metcalfe, J. Glanville, M.G. Pawson, and J.D. Reynolds, 2000. Fishery stability, local extinctions, and shifts in community structure in skates. Conservation Biology 14(1): 283-293.

Eschmeyer, W.N., E.S. Herald, and H. Hammann, 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston: 336 pp.

Frisk, M.G., T. J. Miller, and M. J. Fogarty, 2001. Estimation and analysis of biological parameters in elasmobranch fishes: a comparative life history study. Can. J. Fish. Aquat. Sci. 58: 969-981.

Frisk, M. G. , T. J. Miller, and M. J. Fogarty, 2002. The population dynamics of little skate *Leucoraja erinacea*, winter skate *Leucoraja ocellata*, and barndoor skate *Dipturus leavis*: predicting exploitation limits using matrix analysis. ICES J. Mar. Sci. 59: 576-586.

Gaichas, S., J. Ianelli, and L. Fritz, 1999. Other species considerations for the Gulf of Alaska.

Gburski, C.M., S.K. Gaichas, and D.K. Kimura. 2007. Age and growth of big skate (*Raja binoculata*) and longnose skate (*R. rhina*) and implications to the skate fisheries in the Gulf of Alaska. Env. Bio. Fishes 80: 337-349.

Hoenig, J.M., 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82(1): 898-902.

Hoff, G.R. 2007. Reproductive biology of the Alaska skate Bathyraja parmifera, with regard to nursery sites, embryo development and predation. Ph.D. Dissertation, University of Washington, Seattle. 161 pp.

Ishihara, H. and R. Ishiyama, 1985. Two new North Pacific skates (Rajidae) and a revised key to *Bathyraja* in the area. Jpn. J. Ichthyol. 32(2): 143-179.

King, J. R., and G. A. McFarlane, 2002. Preliminary results of Big Skate (*Raja binoculata*) Age Determination Project. Unpub. Man. DFO.

King, J.R., and G.A. McFarlane, 2003. Marine fish life history strategies: applications to fishery management. Fish. Man. And Ecology, 10: 249-264.

Kotwicki, S., and Weinberg, K.L. 2005. Estimating capture probability of a survey bottom trawl for Bering Sea skates (*Bathyraja spp.*) and other fish. Alaska Fishery Research Bulletin 11(2): 135-145.

Love, M.S., C.W. Mecklenberg, T.A. Mecklenberg, and L.K. Thorsteinson. 2005. Resource inventory of marine and estuarine fishes of the West Coast and Alaska: a checklist of north Pacific and Arctic Ocean species from Baja California to the Alaska-Yukon Border. U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104, OCS Study MMS 2005-030 and USGS/NBII 2005-001.

Martin, L. and G.D. Zorzi, 1993. Status and review of the California skate fishery. In Conservation biology of elasmobranchs (S. Branstetter, ed.), p. 39-52. NOAA Technical Report NMFS 115.

McEachran, J.D., and K.A. Dunn, 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). Copeia, 1998(2), 271-290.

McEachran, J.D. and T. Miyake, 1990a. Phylogenetic relationships of skates: a working hypothesis (Chondrichthyes: Rajoidei). In Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.R. Gruber, and T. Taniuchi, eds.), p. 285-304. NOAA Technical Report NMFS 90.

McEachran, J.D. and T. Miyake, 1990a. Phylogenetic relationships of skates: a working hypothesis (Chondrichthyes: Rajoidei). In Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.R. Gruber, and T. Taniuchi, eds.), p. 285-304. NOAA Technical Report NMFS 90.

McFarlane, G.A. and J.R. King. 2006. Age and growth of big skate (*Raja binoculata*) and longnose skate (*Raja rhina*) in British Columbia waters. Fish Res. 78: 169-178.

Moyle, P.B., and J.J. Cech, Jr., 1996. Fishes, an introduction to ichthyology (Third edition). Prentice Hall: New Jersey, 590 pp.

Murray, J.D., 1989. Mathematical Biology. Springer-Verlag: New York. 767 pp.

Musick, J.A., S.A. Berkeley, G.M. Cailliet, M. Camhi, G. Huntsman, M. Nammack, and M.L. Warren, Jr., 2000. Protection of marine fish stocks at risk of extinction. Fisheries 25(3):6-8.

Nelson, J. S., 1994. Fishes of the world, Third edition. John Wiley and Sons, Inc., New York: 600 pp.

NMFS 2000. Skate complex. In Draft 30th Northeast Regional Stock Assessment Workshop (30th SAW), Stock assessment review committe (SARC) consensus summary of assessments, p. 7-173.

NMFS PSEIS 2001. Draft Programmatic Environmental Impact Statement.

Orlov, A.M., 1998. The diets and feeding habits of some deep-water benthic skates (Rajidae) in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka. Alaska Fishery Research Bulletin 5(1): 1-17.

Orlov, A.M., 1999. Trophic relationships of commercial fishes in the Pacific waters off southeastern Kamchatka and the northern Kuril Islands. Pages 231-263 in Ecosystem Approaches for Fishery Management, Alaska Sea Grant College Program AK-SG-99-01, University of Alaska Fairbanks, 756 pp.

Pauly, D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39(2):175-192.

Rikhter, V.A., and V.N. Efanov. 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res. Doc. 76/VI/8. Serial N. 3777. 13p.

Roff, D.A. 1986. The evolution of life history parameters in teleosts. Can. J. Fish. Aquat. Sci. 41:989-1000.

Sosebee, K., 1998. Skates. In Status of Fishery Resources off the Northeastern United States for 1998 (Stephen H. Clark, ed.), p. 114-115. NOAA Technical Memorandum NMFS-NE-115.

Stevenson, D. 2004. Identification of skates, sculpins, and smelts by observers in north Pacific groundfish fisheries (2002-2003), U.S. Department of Commerce Technical Memorandum NMFS-AFSC-142. 67 p.

Stevenson, D.E., J.W. Orr, G.R. Hoff, and J.D. McEachran. 2004. *Bathyraja mariposa*: a new species of skate (Rajidae: Arhynchobatinae) from the Aleutian Islands. Copeia 2004(2):305-314.

Stevenson, D. E., Orr, J. W., Hoff, G. R., and McEachran, J. D. 2007. Field guide to sharks, skates, and ratfish of Alaska. Alaska Sea Grant.

Thompson, G.G., 1993. A proposal for a threshold stock size and maximum fishing mortality rate. Pages 303-320 in Risk evaluation and biological reference points for fisheries management (S.J. Smith, J.J. Hunt, and D. Rivard, eds.). Can. Spec. Publ. Fish. Aquat. Sci. 120, 440 pp.

Wakefield, W.W. 1984. Feeding relationships within assemblages of nearshore and mid-continental shelf benthic fishes off Oregon. M.S. Thesis, OSU.

Walker, P.A., and R. G. Hislop, 1998. Sensitive skates or resilient rays? Spatial and temporal shifts in ray species composition in the central and north-western North Sea between 1930 and the present day. ICES J. Mar Sci., 55: 392-402.

Winemiller, K.O., and K.A. Rose, 1992. Patterns of life history diversification in North American fishes: implications for population regulation. Can. J. Fish. Aquat. Sci. 49: 2196-2218.

Zeiner, S.J. and P. Wolf, 1993. Growth characteristics and estimates of age at maturity of two species of skates (*Raja binoculata* and *Raja rhina*) from Monterey Bay, California. In Conservation biology of elasmobranchs (S. Branstetter, ed.), p. 39-52. NOAA Technical Report NMFS 115.

Tables

Table 1. Life history and depth distribution information available for BSAI and GOA skate species, from Stevenson (2004) unless otherwise noted.

Species	Common name	Max obs. length (TL cm)	Max obs. age	Age, length Mature (50%)	Feeding mode [2]	N embryos/ egg case [1]	Depth range (m) [9]
Bathyraja abyssicola	deepsea skate	135 (M) [10] 157 (F) [11]	?	110 cm (M) [11] 145 cm (F) [13]	benthophagic; predatory [11]	1 [13]	362-2904
Bathyraja aleutica	Aleutian skate	150 (M) 154 (F) [12]	14 [6]	121 cm (M) 133 cm (F) [12]	predatory	1	15-1602
Bathyraja interrupta	Bering skate (complex?)	83 (M) 82 (F) [12]	19 [6]	67 cm (M) 70 cm (F) [12]	benthophagic	1	26-1050
Bathyraja lindbergi	Commander skate	97 (M) 97 (F) [12]	?	78 cm (M) 85 cm (F) [12]	?	1	126-1193
Bathyraja maculata	whiteblotched skate	120	?	94 cm (M) 99 cm (F) [12]	predatory	1	73-1193
Bathyraja mariposa [3]	butterfly skate	76	?	?	?	1	90-448
Bathyraja minispinosa	whitebrow skate	83[10]	?	70 cm (M) 66 cm (F) [12]	benthophagic	1	150-1420
Bathyraja parmifera	Alaska skate	118 (M) 119 (F) [4]	15 (M) 17 (F) [4]	9 yrs, 92cm (M) 10 yrs, 93cm(F) [4]	predatory	1	17-392
Bathyraja sp. cf parmifera	"Leopard" parmifera	133 (M) 139 (F)	?	?	predatory	?	48-396
Bathyraja taranetzi	mud skate	67 (M) 77 (F) [12]	?	56 cm (M) 63 cm (F) [12]	predatory [13]	1	58-1054
Bathyraja trachura	roughtail skate	91 (M) [14] 89 (F) [11]	20 (M) 17 (F) [14]	13 yrs, 76 cm (M) 14 yrs, 74 cm (F)[14, 12]	benthophagic; predatory [11]	1	213-2550
Bathyraja violacea	Okhotsk skate	73	?	?	benthophagic	1	124-510
Amblyraja badia	roughshoulder skate	95 (M) 99 (F) [11]	?	93 cm (M) [11]	predatory [11]	1 [13]	1061-2322
Raja binoculata	big skate	244	15 [5]	4.8 yrs, 68 cm (F) 6.1 yrs, 87 cm (M) [6]	predatory [8]	1-7	16-402
Raja rhina	longnose skate	180	25 [5]	12.3 yrs, 96 cm (F) 8.8 yrs, 72 cm (M) [6]	benthophagic; predatory [15]	1	9-1069

[1] Eschemeyer 1983. [2] Orlov 1998 & 1999 (Benthophagic eats mainly amphipods, worms. Predatory diet primarily fish, cephalopods). [3] Stevenson et al. 2004. [4] Matta 2006. [5] Gburski et al. 2007. [6] Gburski unpub data. [7] McFarlane & King 2006. [8] Wakefield 1984. [9] Stevenson et al. 2006. [10] Mecklenberg et al. 2002. [11] Ebert 2003. [12] Ebert 2005. [13] Ebert unpub data. [14] Davis 2006. [15] Robinson 2006.

Table 2. Gulfwide bottom trawl survey biomass estimates (t) for the three managed skate groups in the GOA, 1984-2013. CV = coefficient of variation.

year	big skate		longnose skate		other skates		total skate biomass (t)
	biomass (t)	CV	biomass (t)	CV	biomass (t)	CV	
1984	27,540	0.22	9,002	0.38	4,647	0.16	41,189
1987	28,093	0.16	6,631	0.36	3,339	0.21	38,063
1990	22,316	0.25	11,995	0.22	13,936	0.25	48,248
1993	39,708	0.18	17,803	0.12	6,191	0.14	63,702
1996	43,064	0.18	26,226	0.14	11,912	0.17	81,201
1999	54,650	0.15	39,333	0.14	18,946	0.11	112,929
2001	39,082	0.19	23,275	0.16	12,857	0.16	75,214
2003	55,397	0.16	39,603	0.09	21,775	0.11	116,775
2005	39,320	0.16	41,449	0.08	30,063	0.11	110,832
2007	38,458	0.19	34,421	0.11	32,334	0.11	105,212
2009	44,349	0.16	36,652	0.09	27,461	0.12	108,463
2011	67,883	0.37	33,911	0.11	21,389	0.10	123,183
2013	38,234	0.26	44,484	0.11	30,705	0.11	113,423

Table 3. Bottom trawl survey biomass estimates (t) for skates in each GOA regulatory area, 1984-2013.

		1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013
WGOA	big	3,339	4,313	1,745	2,287	13,130	11,038	8,425	9,602	9,792	5,872	6,652	6,251	10,669
	longnose	0	41	1,045	105	278	1,747	104	782	1,719	628	1,214	941	2,127
	skate unid	325	259	0	12	13	1	3	1	38	22	850	28	0
	Bathyraja sp	0	91	0	651	453	0	0	0	0	0	0	0	0
	Bering	45	20	28	0	52	218	170	39	86	0	283	237	37
	mud	0	0	0	0	0	46	0	0	0	0	10	7	0
	roughtail	0	0	0	0	43	0	0	0	0	82	0	0	0
	Alaska	0	0	0	0	119	220	1,213	265	211	177	1,728	333	1,124
	Aleutian	358	112	139	292	82	1,928	1,858	4,401	1,453	3,333	3,051	873	2,970
	whiteblotched	0	0	0	0	0	544	0	173	502	197	199	487	0
	whitebrow	0	0	0	0	0	0	0	0	0	33	0	0	0
	total WGOA	**4,067**	**4,837**	**2,956**	**3,348**	**14,168**	**15,741**	**11,774**	**15,264**	**13,799**	**10,344**	**13,987**	**9,157**	**16,926**
CGOA	big	17,635	20,855	9,071	21,586	26,544	34,007	30,658	33,814	25,544	23,249	26,691	21,761	12,810
	longnose	2,280	2,667	8,708	14,158	20,328	29,872	23,171	25,741	29,853	26,034	25,534	23,609	28,274
	skate unid	2,108	1,241	9,618	30	126	32	19	32	58	24	78	21	0
	Bathyraja sp	0	32	0	3,572	1,566	0	14	1	0	16	0	0	0
	Bering	230	519	1,861	107	1,492	3,371	2,423	3,526	3,910	3,466	3,370	3,429	3,501
	mud	0	0	0	0	0	0	0	0	0	0	0	0	0
	roughtail	51	182	0	0	0	614	0	0	139	495	356	0	0
	Alaska	0	14	771	0	810	1,272	2,422	1,579	489	1,618	1,021	708	2,907
	Aleutian	1,235	601	896	60	5,681	8,055	4,734	10,772	22,395	21,928	15,725	13,409	17,972
	whiteblotched	0	0	0	0	0	925	0	0	0	0	0	0	0
	whitebrow	8	0	0	0	0	0	0	0	0	84	0	0	72
	total CGOA	**23,548**	**26,112**	**30,924**	**39,513**	**56,546**	**78,148**	**63,440**	**75,465**	**82,389**	**76,914**	**72,775**	**62,937**	**65,537**
EGOA	big	6,566	2,925	11,501	15,836	3,391	9,606		11,981	3,984	9,337	11,007	39,870	14,755
	longnose	6,722	3,923	2,242	3,539	5,620	7,714		13,081	9,876	7,759	9,904	9,362	14,083
	skate unid	96	173	143	877	5	42		3	19	15	23	2	0
	Bathyraja sp	0	0	0	470	3	0		0	17	0	0	0	0
	Bering	187	68	159	119	673	229		136	341	335	473	191	426
	mud	0	0	0	0	0	0		0	0	0	0	0	0
	roughtail	0	0	0	0	0	63		0	0	371	0	0	0
	Alaska	4	0	107	0	0	76		63	0	0	0	0	0
	Aleutian	0	25	216	0	796	1,310		640	406	138	295	1,663	1,697
	whiteblotched	0	0	0	0	0	0		91	0	0	0	0	0
	whitebrow	0	0	0	0	0	0		52	0	0	0	0	0
	total EGOA	**13,575**	**7,114**	**14,367**	**20,841**	**10,487**	**19,040**		**26,046**	**14,643**	**17,955**	**21,701**	**51,089**	**30,960**
GOA-wide		**41,189**	**38,063**	**48,248**	**63,702**	**81,201**	**112,929**	**75,214**	**116,775**	**110,832**	**105,212**	**108,463**	**123,183**	**113,423**

Table 4. Total allowable catch (TAC) and catch for GOA "Other Species" and skates, with estimated skate catch, 1992-2004. Before 2004, skate were managed as part of the Other Species group; in 2004 skates were managed separately. Management changed again in 2005 and "modern era" results are included in Table 6.

	TAC	**Other Species catch**	**est. skate catch**	**management method**
	W C E		**W C E**	
1992	13,432	12,313	1,835	Other species TAC
1993	14,602	6,867	3,882	Other species TAC
1994	14,505	2,721	1,770	Other species TAC
1995	13,308	3,421	1,273	Other species TAC
1996	12,390	4,480	1,868	Other species TAC
1997	13,470	5,439	3,120	Other species TAC
1998	15,570	3,748	4,476	Other species TAC
1999	14,600	3,858	2,000	Other species TAC
2000	14,215	5,649	3,238	Other species TAC
2001	13,619	4,801	1,828	Other species TAC
2002	11,330	3,748	6,484	Other species TAC
2003	11,260	6,262	4,527	Other species TAC
2004	3,284	5,865	1,569	Big/Longnose CGOA
	3,709		1,451	other skates gulfwide + big/longnose W/E

Sources: TAC and Other species catch from AKRO catch statistics website. Estimated skate catch 1992-1996 from Gaichas et al 1999. Estimated skate catch 1997-2002 from Gaichas et al 2003 (see Table 7 in this assessment). Estimated skate catch 2003-2004 from AKRO Catch Accounting System (CAS).

Table 5. Harvest specifications and catch (t) for skates in the GOA, beginning in 2005 when the current management regime for GOA skates was initiated. ABC and catch are divided by GOA regulatory area (**W**estern, **C**entral, **E**astern) for big and longnose skates; for “other skates”, the ABC column indicates the gulfwide ABC. The additional EGOA field (E_2) includes catches in EGOA inside waters (areas 649 & 659); for “other skates”. Red-shaded cells with bold text indicate years/areas where the catch exceeded the ABC. * 2014 are incomplete; retrieved October 8, 2014.

	species/ group	ABC			OFL	estimated skate catch			
		W	**C**	**E**		**W**	**C**	**E**	**E_2**
2005	big	727	2,463	809	5,332	26	811	65	67
	longnose	66	1,972	780	3,757	37	993	162	173
	other		1,327		1,769		711		719
2006	big	695	2,250	599	4,726	72	1,272	344	388
	longnose	65	1,969	861	3,860	57	682	219	296
	other		1,617		2,156		1393		1,414
2007	big	695	2,250	599	4,726	69	1,518	8	11
	longnose	65	1,969	861	3,860	**76**	982	343	389
	other		1,617		2,156		1,259		1,279
2008	big	632	2,065	633	4,439	132	1,241	45	49
	longnose	78	2,041	768	3,849	34	966	114	131
	other		2,104		2,806		1,379		1,413
2009	big	632	2,065	633	4,439	79	1,903	100	137
	longnose	78	2,041	768	3,849	**79**	1,096	244	319
	other		2,104		2,806		1,548		1,595
2010	big	598	2,049	681	4,438	148	**2,214**	149	179
	longnose	81	2,009	762	3,803	**105**	846	131	197
	other		2,093		2,791		1,491		1,526
2011	big	598	2,049	681	4,438	110	**2,105**	90	134
	longnose	81	2,009	762	3,803	71	892	68	118
	other		2,093		2,791		1,351		1,388
2012	big	469	1,793	1,505	5,023	66	**1,894**	38	62
	longnose	70	1,879	676	3,500	39	793	93	134
	other		2,030		2,706		1,200		1,237
2013	big	469	1,793	1,505	5,023	121	**2,304**	79	221
	longnose	70	1,879	676	3,500	**90**	1,260	426	**846**
	other		2,030		2,706		1,879		**2,075**
2014*	big	589	1,532	1,641	5,016	*124*	*1,086*	*81*	*176*
	longnose	107	1,935	834	3,835	*47*	*939*	*328*	*530*
	other		1,989		2,652		*1,467*		*1,672*

Table 6a. Catches of **big skate** (t) by target fishery, 2004-2014. Data are from the Alaska Regional Office Catch Accounting System. * 2014 are incomplete; retrieved October 8, 2014.

big skate											
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	*2014**
arrowtooth	140	225	163	299	219	433	478	812	677	949	*170*
Pacific cod	331	222	417	539	587	559	948	961	755	650	*646*
IFQ halibut	24	37	608	11	34	171	43	145	39	523	*345*
pollock	1	2	23	38	22	34	47	93	48	212	*172*
rex sole	31	49	99	74	70	264	172	106	140	145	*25*
shallow flatfish	237	251	350	608	413	535	700	190	288	140	*23*
flathead sole	38	21	30	23	66	53	112	31	57	15	*0*
sablefish	6	24	10	7	6	7	12	2	4	9	*3*
rockfish	16	19	4	0	4	4	14	8	13	2	*3*
deep flatfish	4	0	0	0	0	0	1	1	0	0	*0*
total	1,204	904	1,732	1,598	1,422	2,119	2,541	2,350	2,022	2,646	*1,386*

Table 6b. Catches of **longnose skate** by target fishery, 2003-2014. Data are from the Alaska Regional Office Catch Accounting System. * 2014 are incomplete; retrieved October 8, 2014.

longnose skate												
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	*2014**
IFQ halibut	1	35	106	210	424	109	444	112	196	122	1,003	*519*
Pacific cod	10	83	139	165	307	361	352	430	375	327	435	*293*
sablefish	16	120	113	352	303	138	88	116	75	134	351	*183*
arrowtooth	14	63	373	135	165	212	152	166	238	181	224	*275*
shallow flatfish	3	26	278	97	168	227	239	172	78	65	70	*30*
rex sole	0	13	19	29	24	36	82	52	44	45	54	*23*
pollock	0	0	5	13	27	24	35	10	35	9	25	*161*
rockfish	1	32	20	21	17	12	17	12	25	23	23	*21*
flathead sole	9	7	11	11	13	11	24	30	17	60	8	*11*
Atka mackerel	0	0	0	0	0	0	0	0	0	0	1	*0*
deep flatfish	0	3	1	0	0	0	0	1	0	0	0	*0*
total	53	537	1,202	1,035	1,447	1,130	1,495	1,148	1,082	965	2,196	*1,516*

Table 6c. Catches of "**Other skates**" by target fishery, 2003-2014. Data are from the Alaska Regional Office Catch Accounting System. * 2014 are incomplete; retrieved October 8, 2014.

	Other skates											
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	*2014**
Pacific cod	0	0	0	0	0	0	0	0	2	0	0	*0*
IFQ halibut	9	1	1	5	8	5	2	5	1	4	9	*12*
sablefish	191	44	38	12	20	5	13	19	13	17	8	*1*
arrowtooth	0	1	0	0	0	0	0	0	0	0	0	*1*
shallow flatfish	1,971	251	2	3	4	16	30	0	0	0	0	*0*
rex sole	806	490	175	981	531	959	908	1,077	800	704	910	*728*
pollock	11	2	1	5	9	6	3	7	2	6	24	*14*
rockfish	346	46	36	56	103	22	60	41	21	19	33	*21*
flathead sole	346	46	36	56	103	22	60	41	21	19	33	*21*
Atka mackerel	105	19	59	49	20	10	13	28	14	20	18	*22*
deep flatfish	559	65	36	27	79	107	98	35	20	32	44	*18*
total	4,448	984	444	1,241	898	1,160	1,201	1,281	909	840	1,097	*860*

Table 7. Retention rates of skates in GOA fisheries, 2007-2014. Data are from tables published by the Alaska Regional Office. 2014 data are incomplete; retrieved November 3, 2014. Retention rates in 2013 & 2014 were influenced by management actions; see footnotes.

	other skates	**big skate**	**longnose skate**
2007	27%	46%	28%
2008	17%	70%	64%
2009	18%	76%	51%
2010	15%	72%	64%
2011	19%	81%	65%
2012	13%	93%	74%
2013[1]	1%	63%	36%
*2014**[2]	*6%*	*32%*	*49%*

[1] On May 8, 2013 retention of big skate was prohibited in the CGOA.
[2] On February 5, 2014 retention of big skate was prohibited in the CGOA.
* 2014 data are incomplete; retrieved November 3, 2014

Table 8a. Bottom trawl survey biomass estimates (t) for big skates by regulatory area, 1984-2013. CV = coefficient of variation.

big skate						
	WGOA		CGOA		EGOA	
	biomass	CV	biomass	CV	biomass	CV
1984	3,339	0.22	17,635	0.23	6,566	0.60
1987	4,313	0.16	20,855	0.19	2,925	0.47
1990	1,745	0.25	9,071	0.35	11,501	0.39
1993	2,287	0.18	21,586	0.19	15,836	0.37
1996	13,130	0.18	26,544	0.19	3,391	0.30
1999	11,038	0.15	34,007	0.20	9,606	0.34
2001	8,425	0.19	30,658	0.22	n/a	-
2003	9,602	0.16	33,814	0.22	11,981	0.38
2005	9,792	0.16	25,544	0.21	3,984	0.36
2007	5,872	0.19	23,249	0.26	9,337	0.33
2009	6,652	0.16	26,691	0.22	11,007	0.32
2011	6,251	0.37	21,761	0.17	39,870	0.61
2013	10,669	0.26	12,810	0.21	14,755	0.56

Table 8b. Bottom trawl survey biomass estimates (t) for longnose skates by regulatory area, 1984-2013. CV = coefficient of variation.

longnose skate						
	WGOA		CGOA		EGOA	
	biomass	CV	biomass	CV	biomass	CV
1984	n/a	n/a	2,280	0.77	6,722	0.44
1987	41	0.83	2,667	0.30	3,923	0.57
1990	1,045	0.71	8,708	0.29	2,242	0.26
1993	105	0.72	14,158	0.15	3,539	0.19
1996	278	0.64	20,328	0.17	5,620	0.18
1999	1,747	0.52	29,872	0.18	7,714	0.17
2001	104	0.71	23,171	0.16	n/a	n/a
2003	782	0.45	25,741	0.12	13,081	0.15
2005	1,719	0.36	29,853	0.09	9,876	0.18
2007	628	0.47	26,034	0.12	7,759	0.24
2009	1,214	0.64	25,534	0.10	9,904	0.19
2011	941	0.43	23,609	0.14	9,362	0.19
2013	2,127	0.33	28,274	0.14	14,083	0.17

Table 9a. Comparison of big skate biomass estimates (t) from 3 sources: single survey estimates, 3-survey averages, and a random effects (RE) model, 1984-2013, by regulatory area.

	big skate WGOA				big skate CGOA				big skate EGOA			
	survey est.	3-survey ave.	RE est.	RE CV	survey est.	3-survey ave.	RE est.	RE CV	survey est.	3-survey ave.	RE est.	RE CV
1984	3,339		3,418	0.21	17,635		18,412	0.18	6,566		5,645	0.48
1985			3,619	0.32			18,643	0.18			5,234	0.51
1986			3,832	0.31			18,878	0.17			4,854	0.49
1987	4,313		4,058	0.15	20,855		19,115	0.14	2,925		4,501	0.41
1988			3,232	0.31			18,659	0.17			5,801	0.45
1989			2,575	0.33			18,214	0.19			7,477	0.43
1990	1,745	3,132	2,051	0.23	9,071	15,854	17,780	0.20	11,501	6,997	9,638	0.33
1991			2,211	0.33			18,938	0.19			10,259	0.44
1992			2,385	0.32			20,172	0.17			10,920	0.44
1993	2,287	2,782	2,571	0.17	21,586	17,171	21,486	0.14	15,836	10,087	11,623	0.34
1994			4,228	0.31			22,839	0.15			8,485	0.41
1995			6,953	0.31			24,277	0.15			6,194	0.40
1996	13,130	5,720	11,434	0.17	26,544	19,067	25,805	0.14	3,391	10,242	4,522	0.30
1997			11,238	0.31			27,116	0.15			5,574	0.40
1998			11,046	0.30			28,493	0.16			6,871	0.40
1999	11,038	8,818	10,857	0.14	34,007	27,379	29,940	0.14	9,606	9,611	8,471	0.29
2000			9,774	0.27			29,944	0.15			8,695	0.44
2001	8,425	10,864	8,799	0.17	30,658	30,403	29,948	0.14		6,498	8,926	0.48
2002			9,143	0.27			29,723	0.15			9,162	0.45
2003	9,602	9,688	9,501	0.15	33,814	32,826	29,500	0.14	11,981	10,793	9,405	0.32
2004			9,436	0.27			28,000	0.15			7,332	0.37
2005	9,792	9,273	9,372	0.15	25,544	30,005	26,575	0.13	3,984	7,982	5,715	0.32
2006			7,681	0.27			25,581	0.15			7,118	0.37
2007	5,872	8,422	6,295	0.17	23,249	27,536	24,624	0.14	9,337	8,434	8,866	0.27
2008			6,476	0.27			24,023	0.15			10,235	0.35
2009	6,652	7,439	6,662	0.15	26,691	25,161	23,437	0.13	11,007	8,109	11,817	0.26
2010			6,901	0.29			21,904	0.14			15,313	0.40
2011	6,251	6,258	7,149	0.26	21,761	23,900	20,471	0.12	39,870	20,071	19,843	0.43
2012			8,360	0.31			18,551	0.16			18,342	0.47
2013	10,669	7,857	9,775	0.23	12,810	20,421	16,811	0.18	14,755	21,877	16,954	0.44

Table 9b. Comparison of longnose skate biomass estimates (t) from 3 sources: single survey estimates, 3-survey averages, and a random effects model (RE), 1984-2013, by regulatory area.

	longnose skate WGOA				**longnose skate CGOA**				**longnose skate EGOA**			
	survey est.	**3-survey ave.**	**RE est.**	**RE CV**	**survey est.**	**3-survey ave.**	**RE est.**	**RE CV**	**survey est.**	**3-survey ave.**	**RE est.**	**RE CV**
1984				0.00	2,280		3,430	0.42	6,722		4,700	0.33
1985				0.00			3,574	0.39			4,361	0.33
1986				0.00			3,724	0.34			4,046	0.31
1987	41		73	0.79	2,667		3,880	0.28	3,923		3,754	0.28
1988			139	0.95			4,925	0.28			3,463	0.27
1989			264	0.92			6,251	0.26			3,195	0.26
1990	1,045		504	0.69	8,708	4,552	7,934	0.21	2,242	4,296	2,947	0.22
1991			345	0.90			9,537	0.24			3,185	0.23
1992			236	0.88			11,465	0.22			3,442	0.22
1993	105	397	162	0.62	14,158	8,511	13,782	0.13	3,539	3,235	3,721	0.16
1994			201	0.89			15,611	0.21			4,243	0.20
1995			251	0.87			17,683	0.21			4,839	0.20
1996	278	476	312	0.55	20,328	14,398	20,030	0.15	5,620	3,800	5,519	0.15
1997			473	0.84			22,136	0.21			6,162	0.20
1998			717	0.83			24,464	0.21			6,881	0.20
1999	1,747	710	1,086	0.51	29,872	21,453	27,036	0.15	7,714	5,624	7,683	0.15
2000			524	0.73			25,620	0.19			8,535	0.21
2001	104	710	253	0.68	23,171	24,457	24,277	0.13		5,624	9,481	0.22
2002			431	0.74			25,094	0.18			10,532	0.21
2003	782	878	737	0.40	25,741	26,261	25,939	0.10	13,081	8,805	11,700	0.14
2004			1,046	0.66			27,534	0.17			10,841	0.18
2005	1,719	868	1,485	0.34	29,853	26,255	29,228	0.09	9,876	10,224	10,045	0.14
2006			1,055	0.66			27,744	0.17			9,494	0.19
2007	628	1,043	750	0.42	26,034	27,209	26,335	0.11	7,759	10,239	8,973	0.17
2008			900	0.70			25,917	0.17			9,351	0.19
2009	1,214	1,187	1,080	0.50	25,534	27,140	25,505	0.09	9,904	9,180	9,744	0.15
2010			1,061	0.69			24,975	0.17			9,973	0.18
2011	941	928	1,042	0.39	23,609	25,059	24,456	0.12	9,362	9,008	10,208	0.15
2012			1,447	0.65			25,969	0.18			11,463	0.18
2013	2,127	1,427	2,009	0.31	28,274	25,806	27,575	0.13	14,083	11,116	12,873	0.16

Table 9c. Comparison of other skate biomass estimates (t) from 3 sources: single survey estimates, 3-survey averages, and a random effects model (RE), 1984-2013

	other skates GOA-wide			
	survey est.	**3-survey ave.**	**RE est.**	**RE CV**
1984	4,647		4,583	0.155
1985			4,433	0.246
1986			4,288	0.255
1987	3,339		4,148	0.193
1988			5,494	0.256
1989			7,278	0.266
1990	13,936	7,307	9,642	0.230
1991			8,591	0.264
1992			7,655	0.241
1993	6,191	7,822	6,821	0.138
1994			8,180	0.236
1995			9,809	0.238
1996	11,912	10,680	11,762	0.147
1997			13,687	0.235
1998			15,928	0.228
1999	18,946	12,350	18,535	0.110
2000			19,392	0.239
2001			20,289	0.269
2002			21,228	0.238
2003	21,775	17,544	22,210	0.108
2004			25,578	0.196
2005	30,063	23,595	29,456	0.104
2006			30,560	0.195
2007	32,334	28,057	31,706	0.099
2008			29,417	0.196
2009	27,461	29,953	27,293	0.110
2010			24,652	0.196
2011	21,389	27,061	22,266	0.097
2012			25,758	0.196
2013	30,705	26,518	29,797	0.111

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Figures

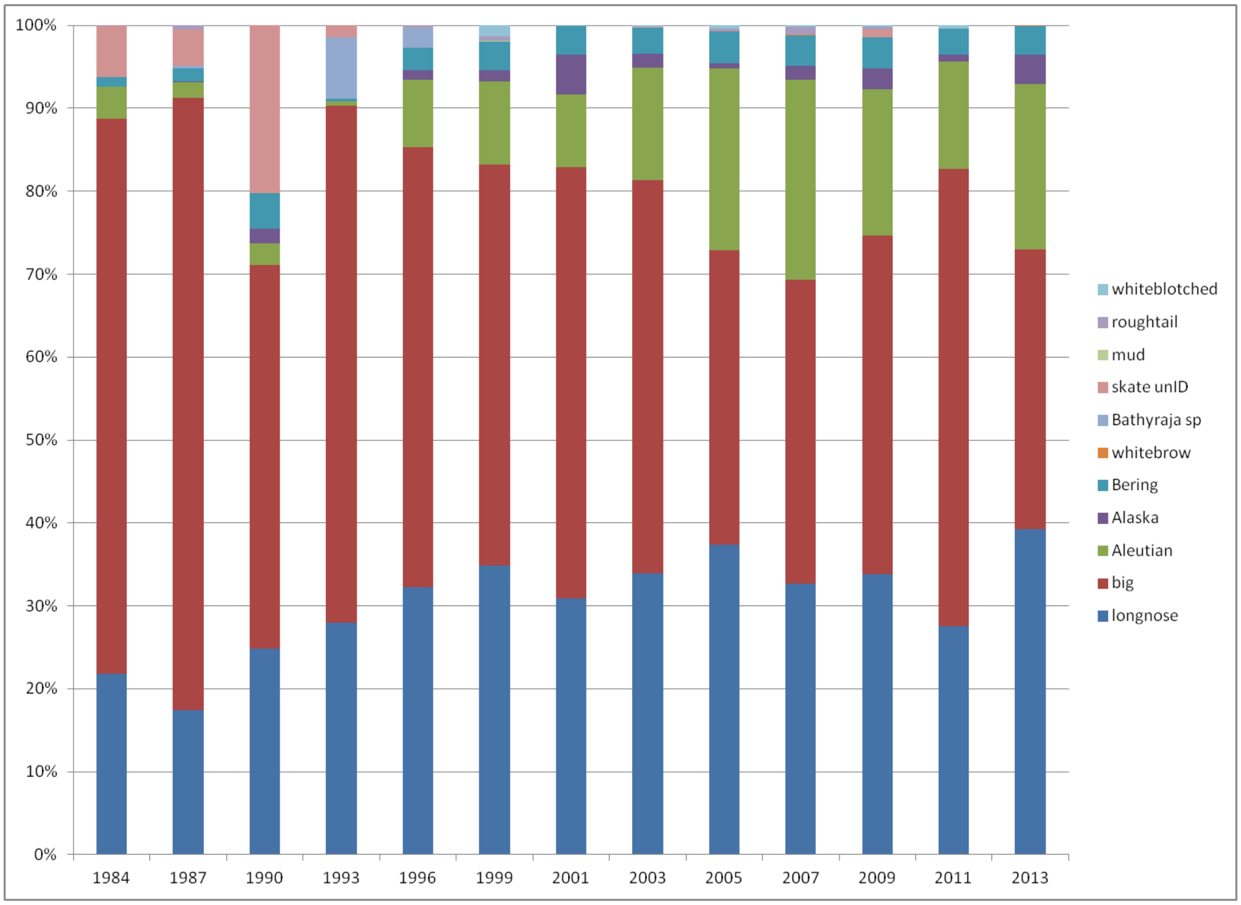


Figure 1. Gulfwide species composition of GOA skates, 1996-2013. The 2001 survey did not sample in the EGOA. The “other skates” assemblage includes all species except for big skate and longnose skate.

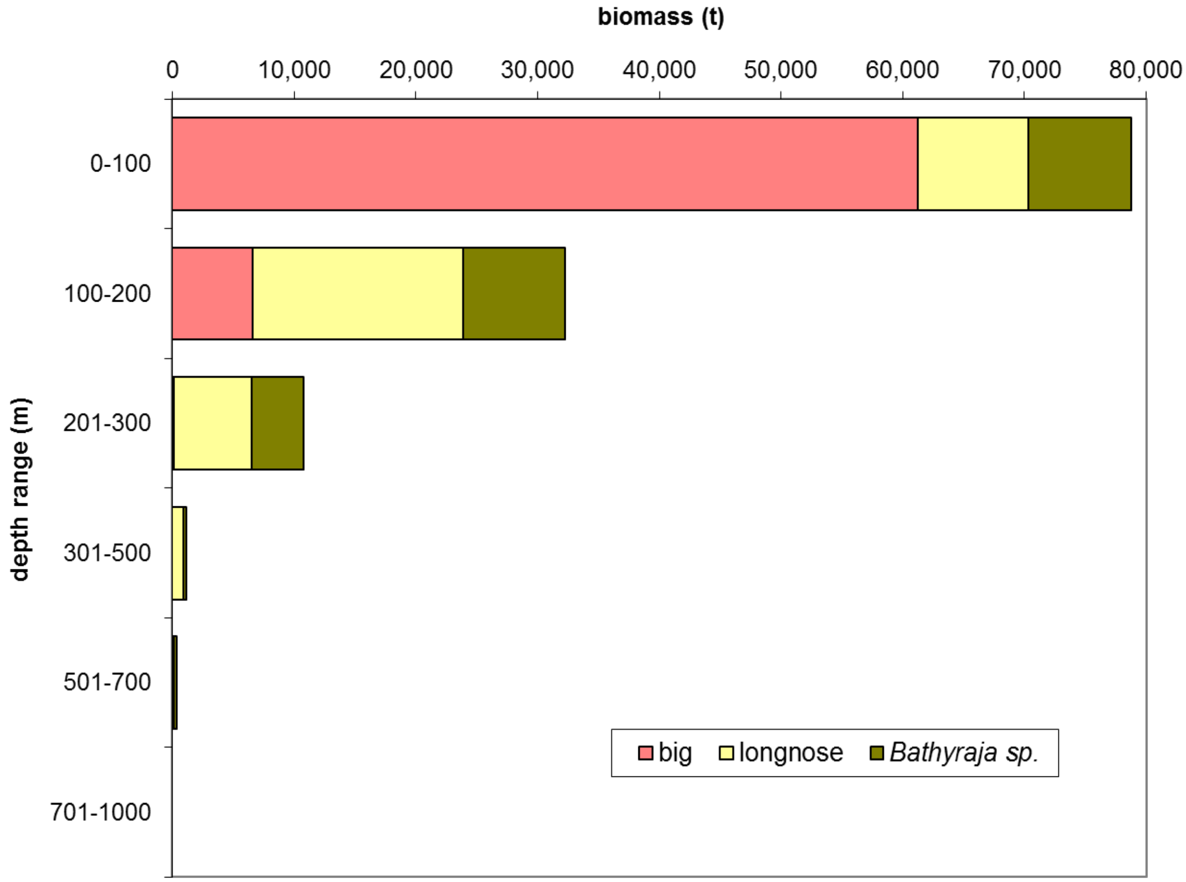


Figure 2. 2013 survey biomass estimates (t) at depth for major GOA skate species: big, longnose, and the *Bathyraja* species complex (i.e. Other Skates).

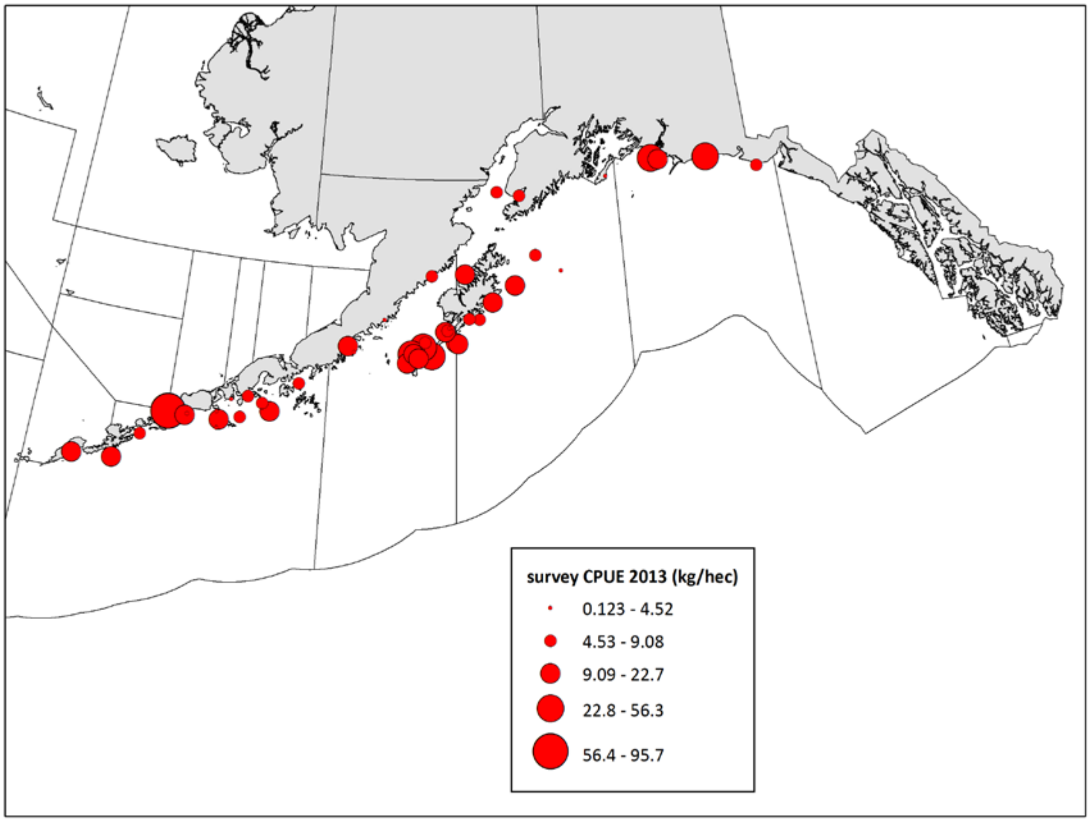


Figure 3. Trawl survey CPUE of **big** skates in 2013. Hauls with CPUE = 0 are not shown.

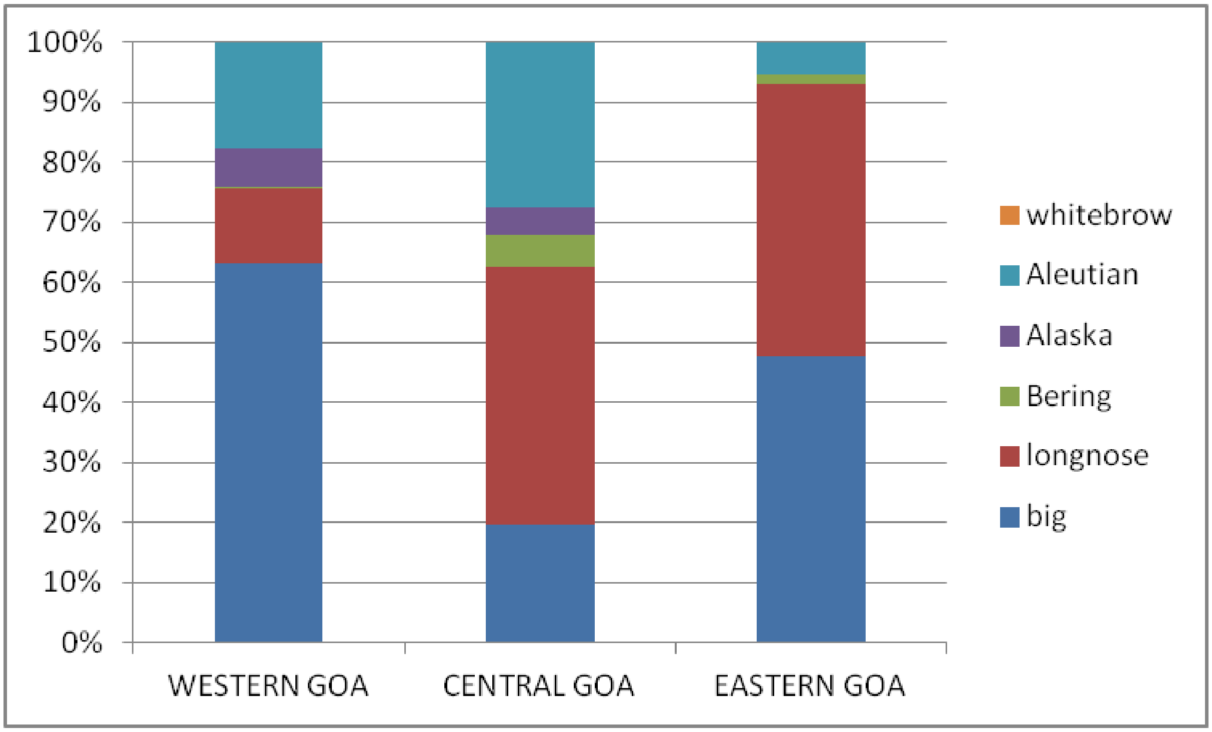


Figure 4. Species composition of GOA skates by GOA regulatory area, 2013. The “other skates” assemblage includes all species except for big skate and longnose skate.

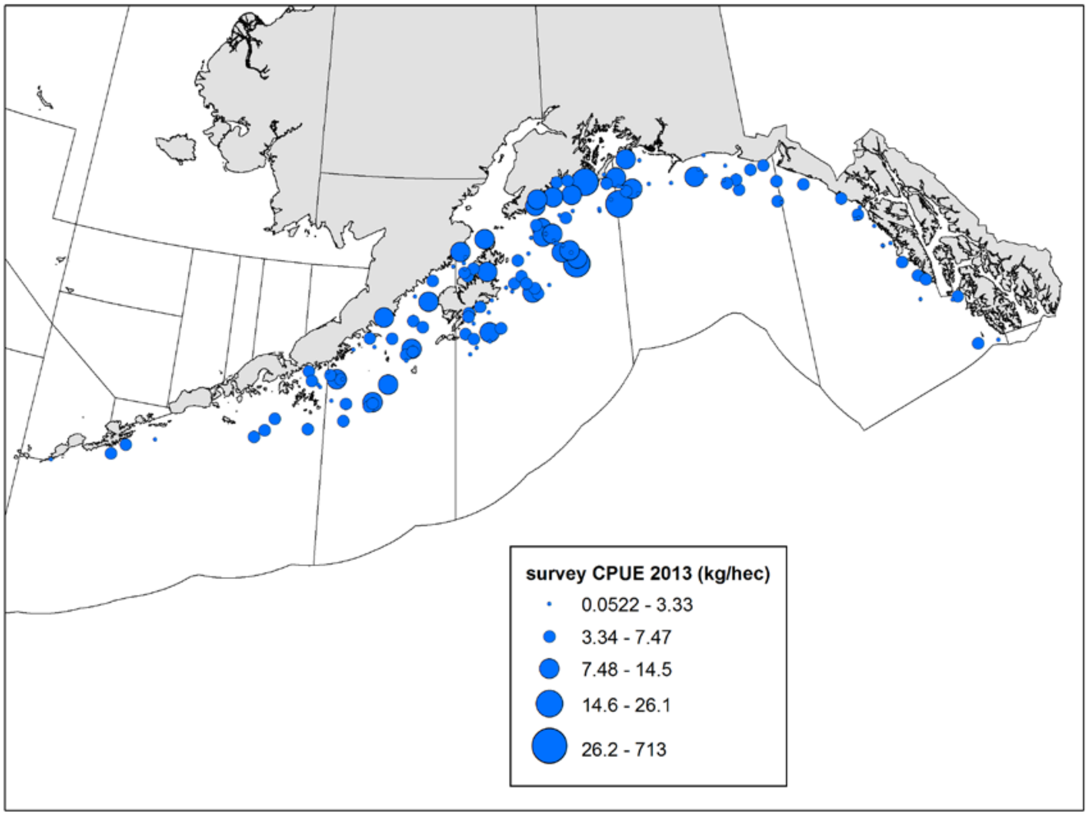


Figure 5. Trawl survey CPUE of **longnose** skates in 2013. Hauls with CPUE = 0 are not shown.

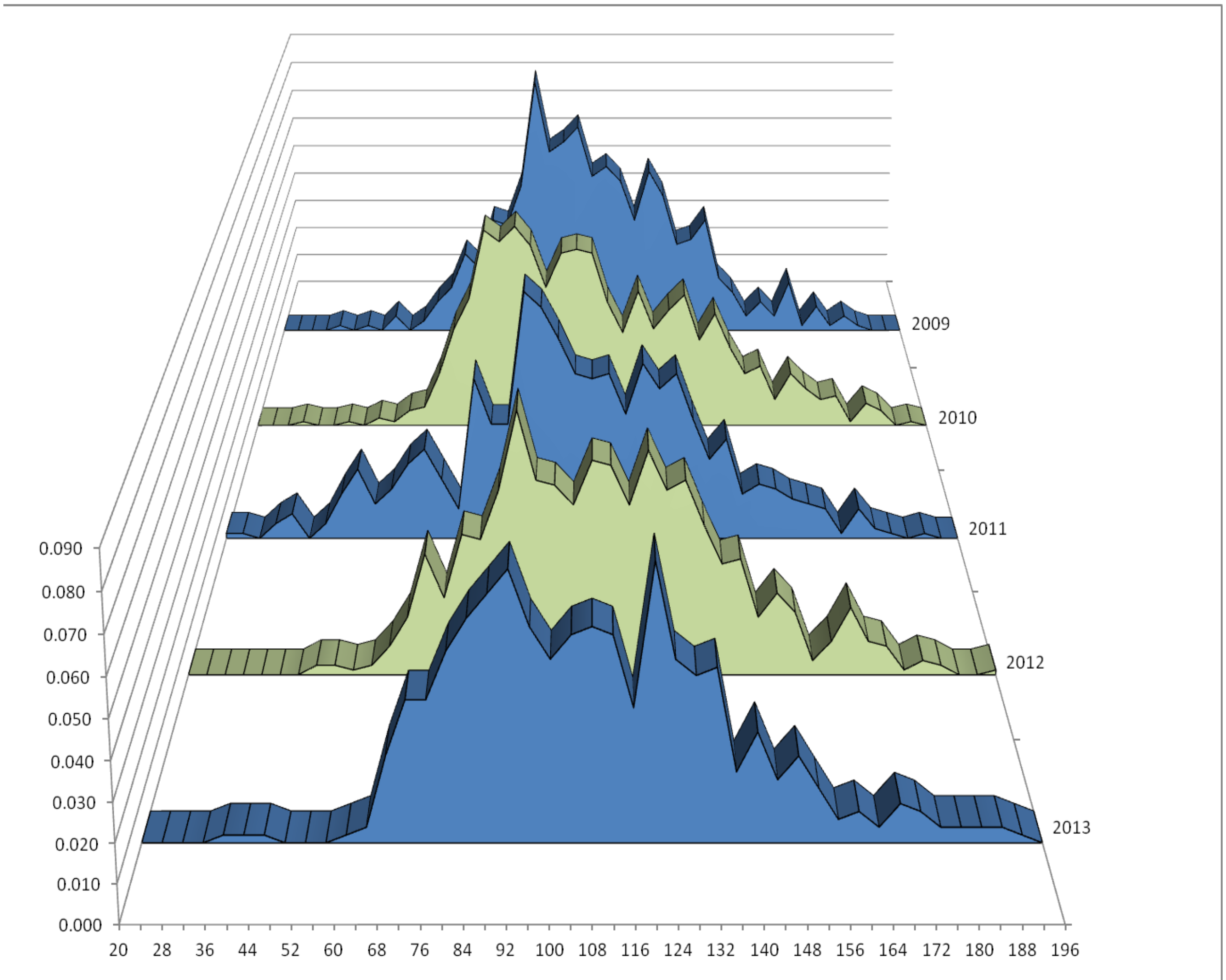


Figure 6. Length compositions of fishery catches (trawl and longline combined) for **big** skates in the GOA, 2009-2013.

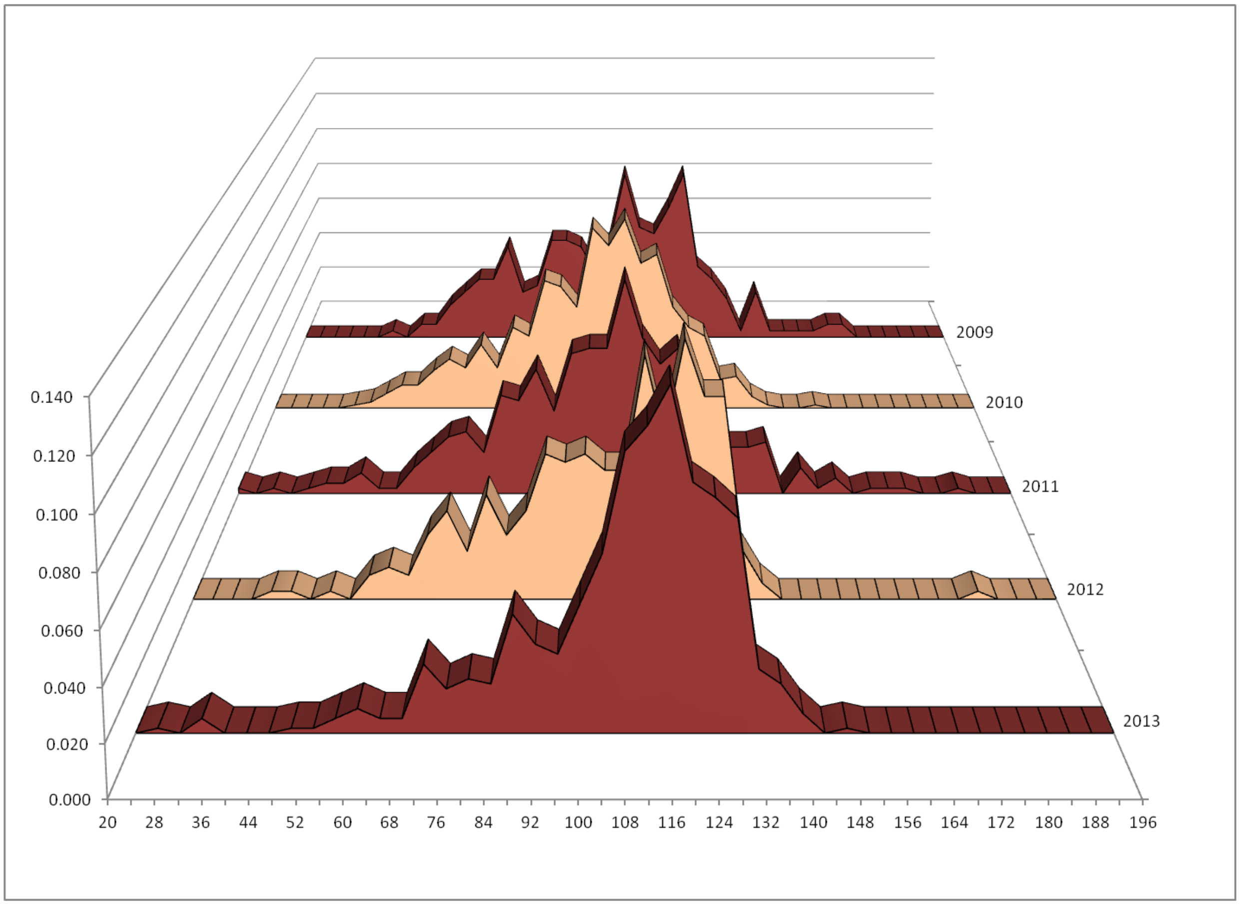


Figure 7. Length compositions of fishery catches (trawl and longline combined) for **longnose** skates in the GOA, 2009-2013.

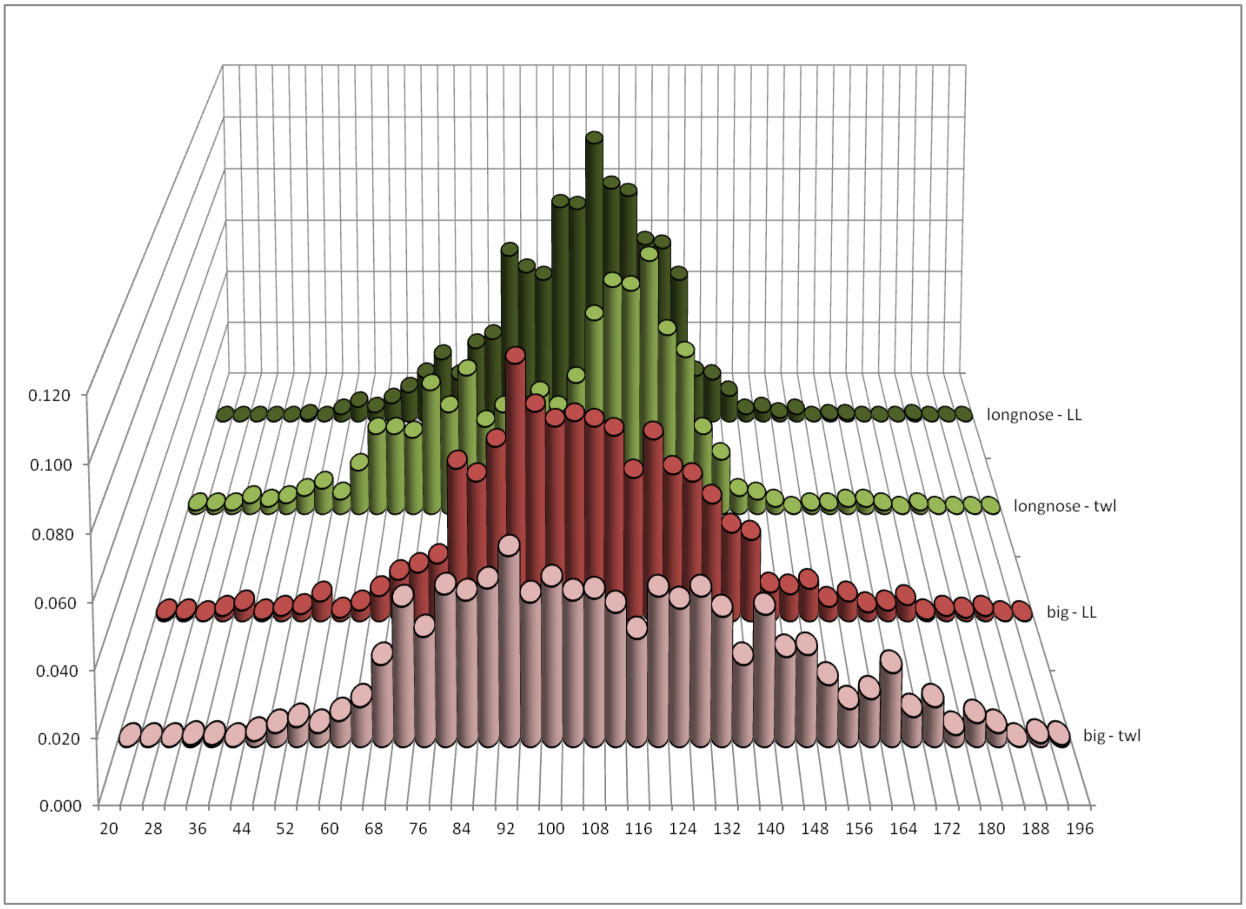


Figure 8. Comparison of trawl and longline fishery length compositions for big and longnose skates in the GOA, all years 2009-2013 combined.

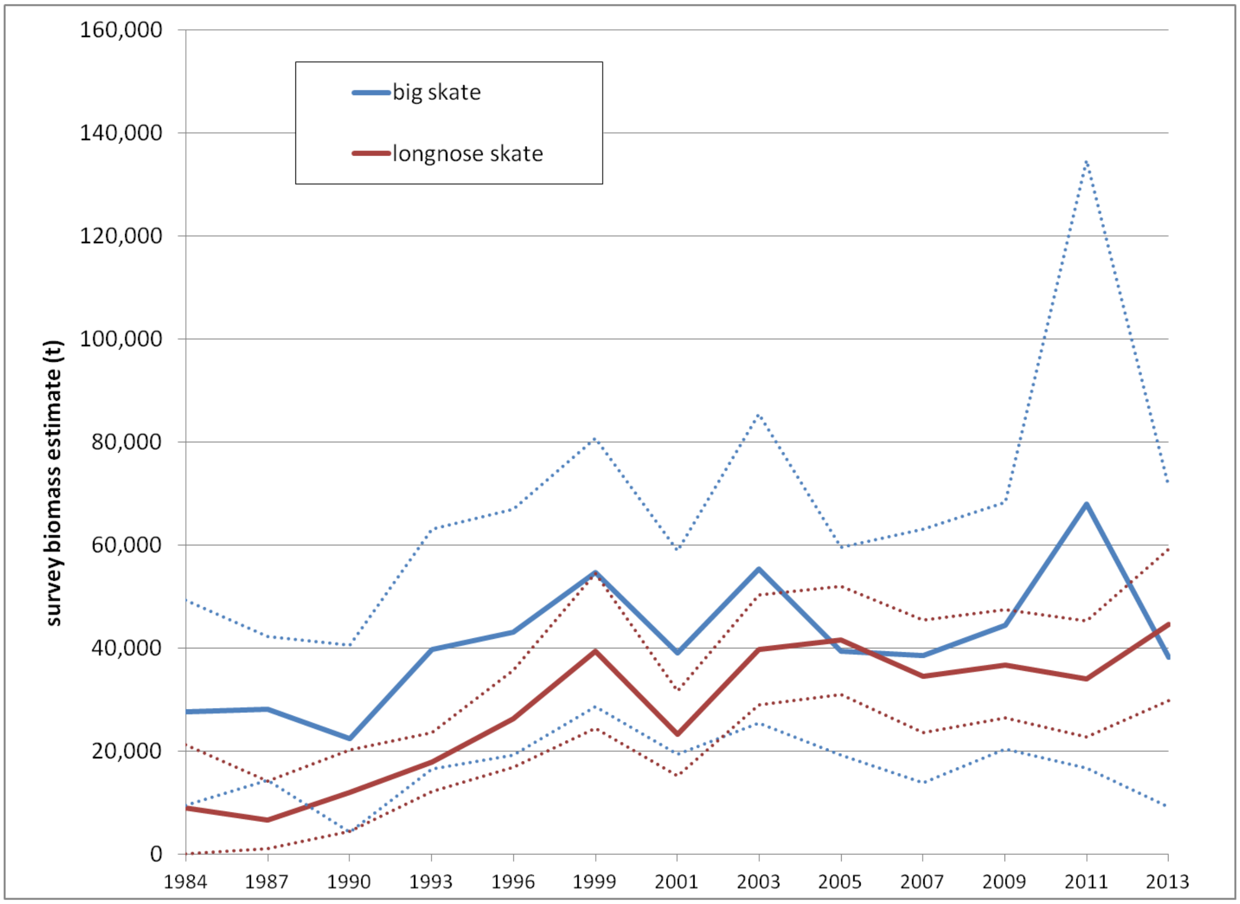
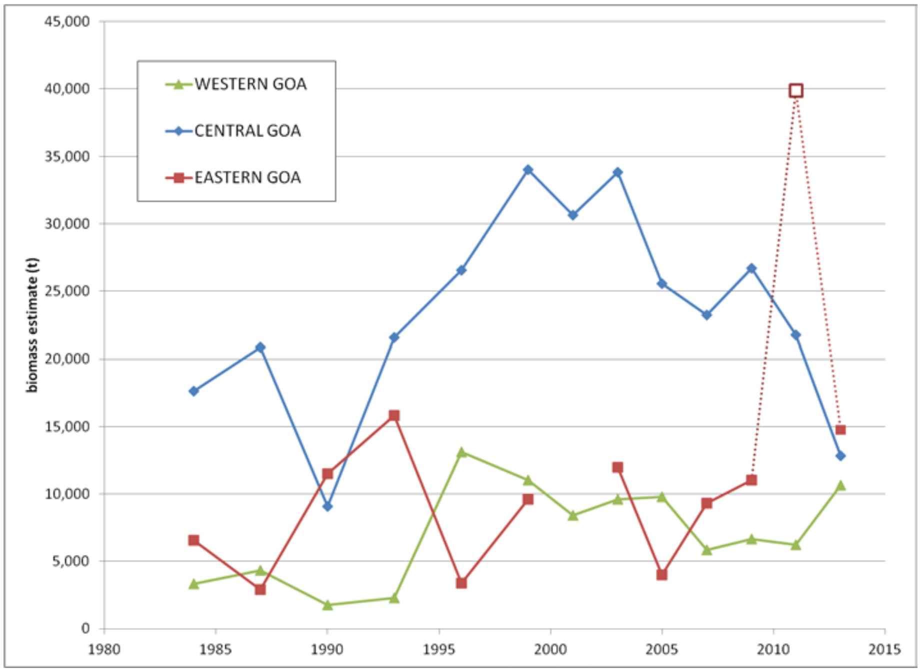


Figure 9. Biomass estimates (t) for big and longnose skates, 1984-2013, from the AFSC bottom trawl survey. Dotted lines (with corresponding colors) indicate 95% confidence intervals.



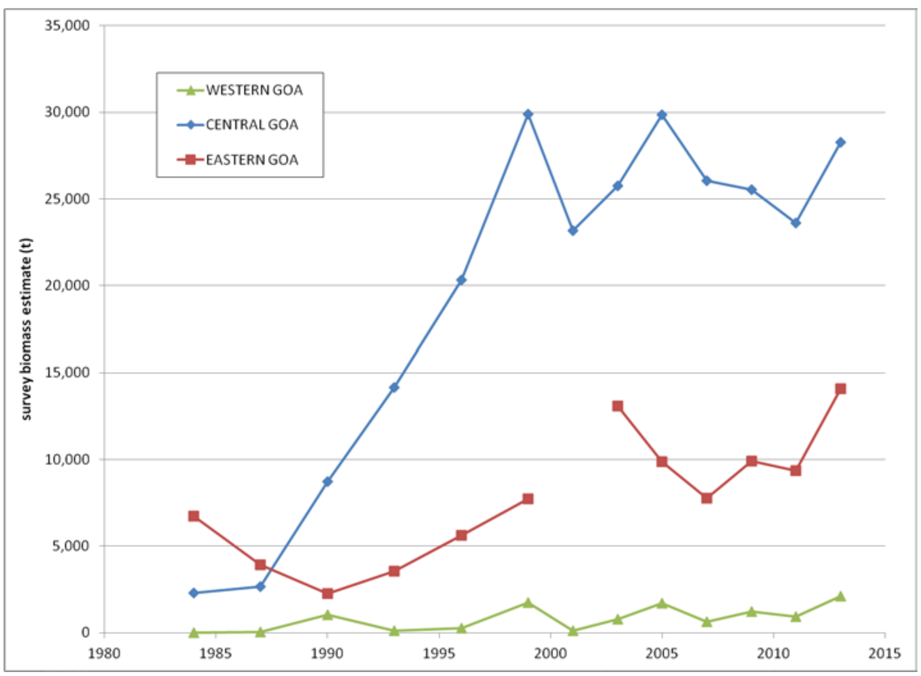


Figure 10. Biomass estimates (t) by regulatory area for big skates (top) and longnose skates (bottom), 1984-2013, from AFSC bottom trawl surveys. Confidence intervals omitted for clarity. Dotted line and open symbol in the upper plot indicate a 2011 EGOA estimate with a high CV.

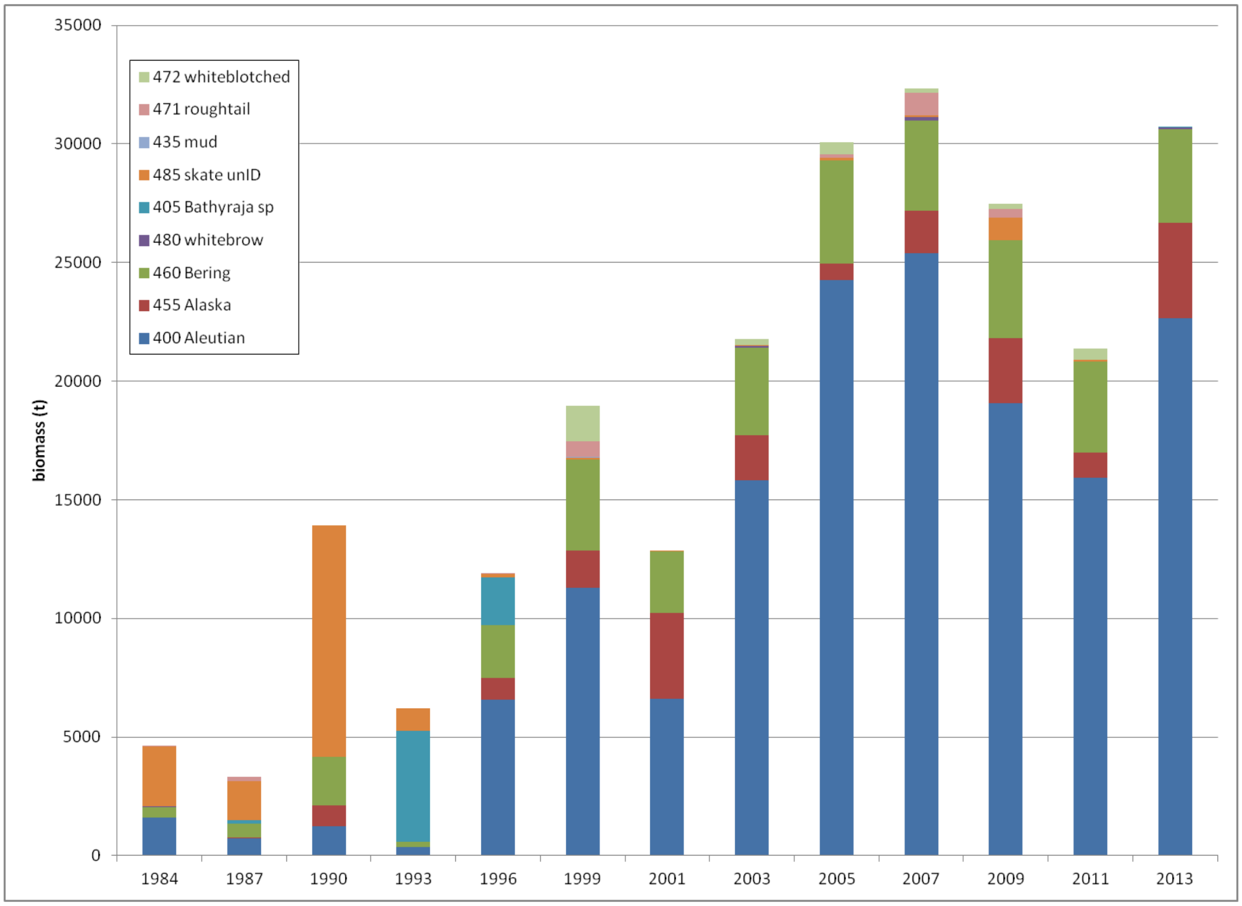


Figure 11. NMFS GOA bottom trawl survey biomass trends for *Bathyraja* skates (“other skates”), 1984-2013. The 2001 survey did not sample in the EGOA.

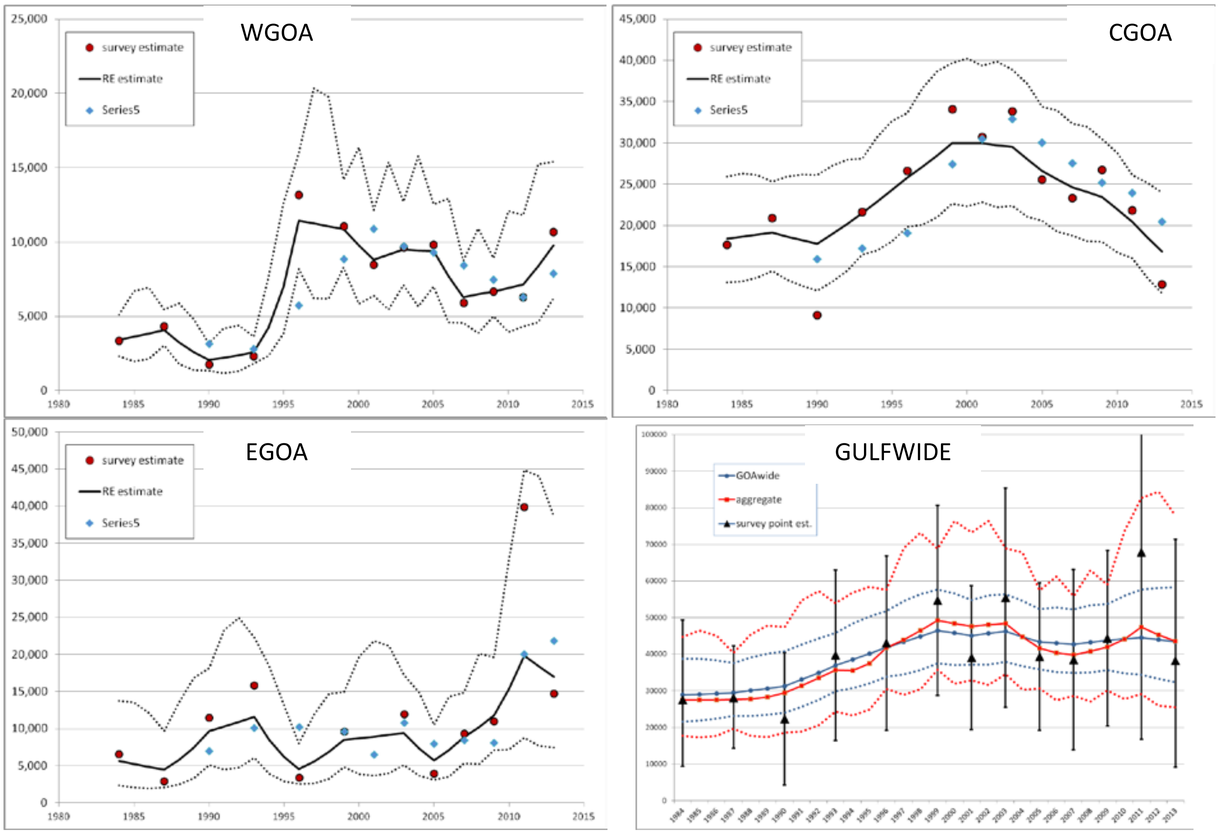


Figure 12. Estimates of **big skate** biomass from different sources. Area-specific plots include point estimates from the bottom trawl survey (red circles), 3-survey running averages (blue diamonds), and the results of the random effects (RE) model (black line); dashed black lines indicate 95% confidence interval (CI) for the RE estimate. The gulfwide plot includes estimates from a gulfwide RE model (blue line) and an aggregate of the 3 area-specific models (red line). Dashed lines indicate 95% CIs for the relevant estimates. Black triangles indicate survey point estimates with 95% CIs.

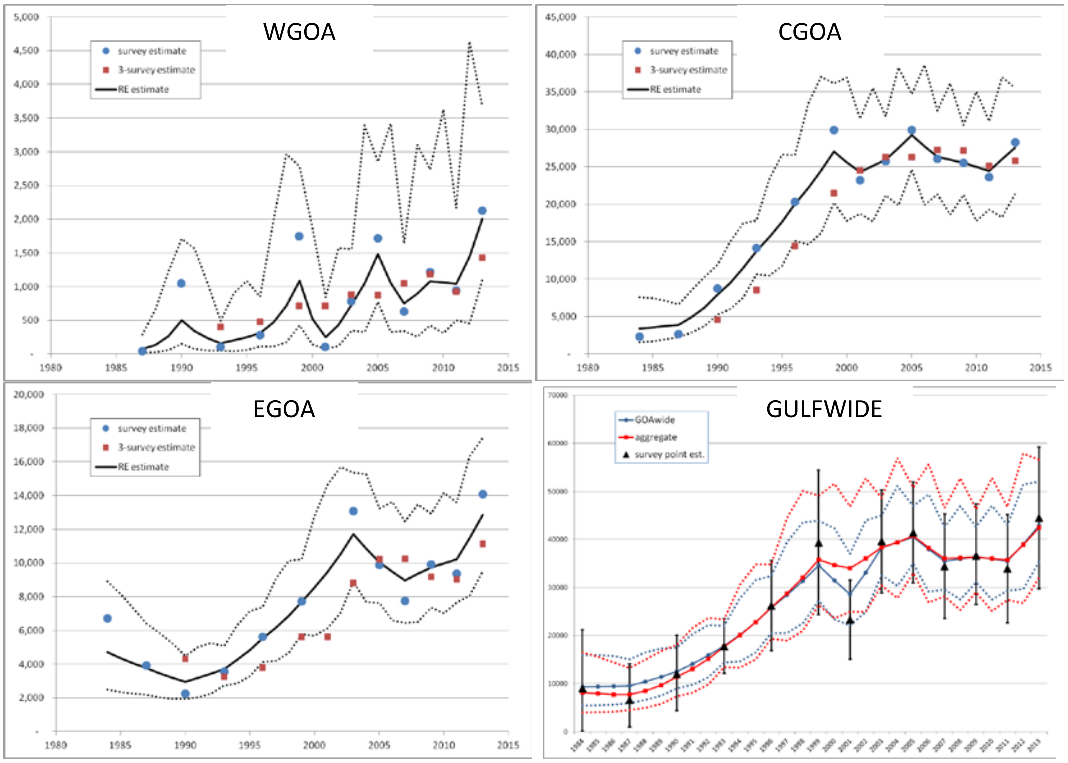


Figure 13. Estimates of **longnose skate** biomass from different sources. Area-specific plots include point estimates from the bottom trawl survey (red circles), 3-survey running averages (blue diamonds), and the results of the random effects (RE) model (black line); dashed black lines indicate 95% confidence interval (CI) for the RE estimate. The gulfwide plot includes estimates from a gulfwide RE model (blue line) and an aggregate of the 3 area-specific models (red line). Dashed lines indicate 95% CIs for the relevant estimates. Black triangles indicate survey point estimates with 95% CIs.

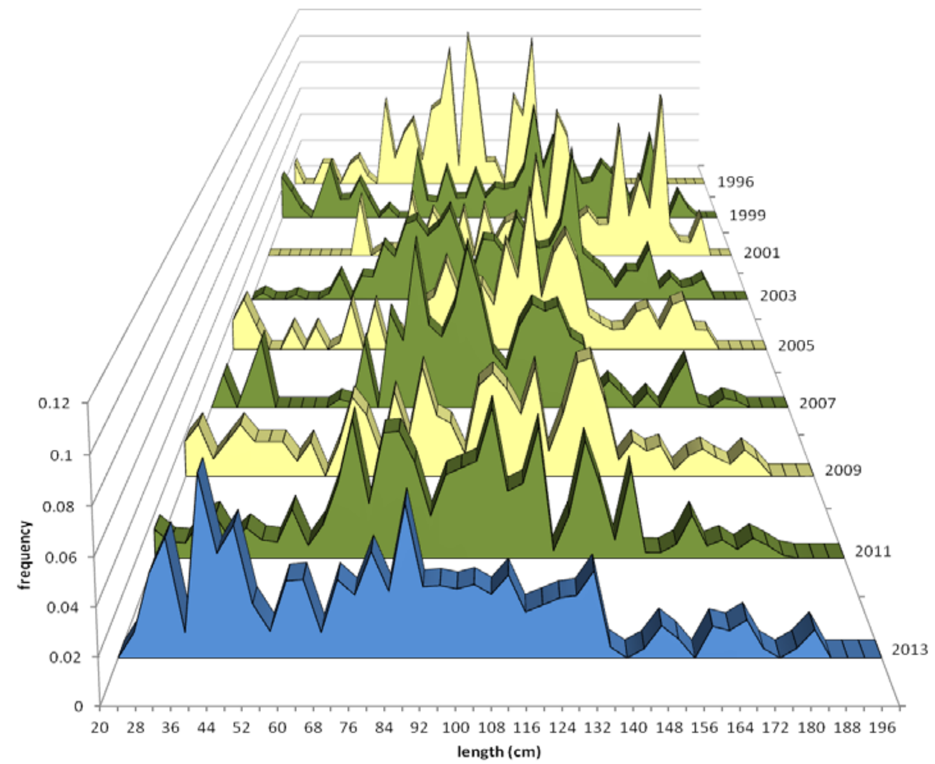


Figure 14. NMFS GOA trawl survey size composition for big skates (both sexes combined) in the entire GOA, 1996-2013. The most recent data (2013) are shown in blue.

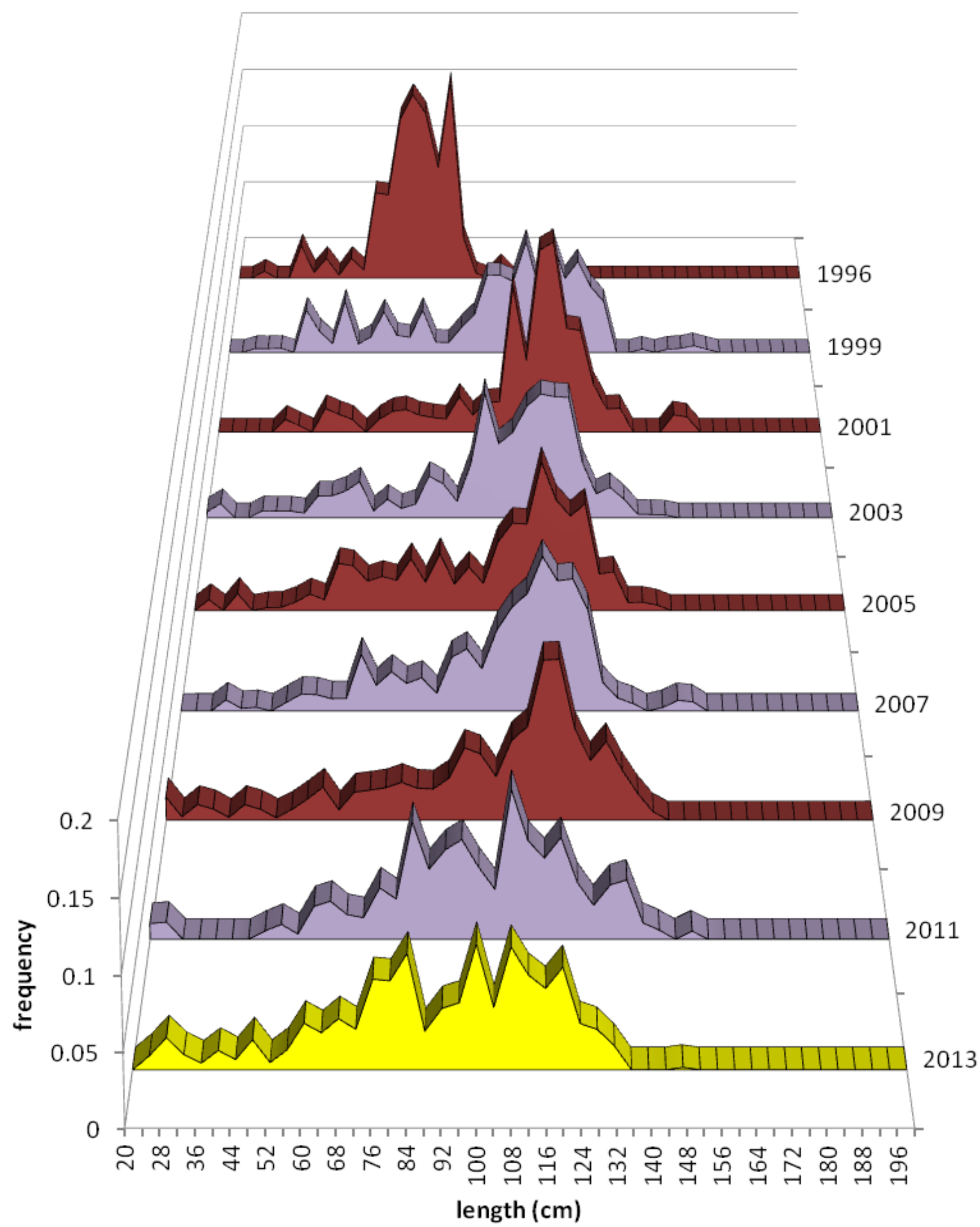


Figure 15. NMFS GOA trawl survey size composition for longnose skates (both sexes combined) in the entire GOA, 1996-2011. The most recent data (2011) are shown in yellow.

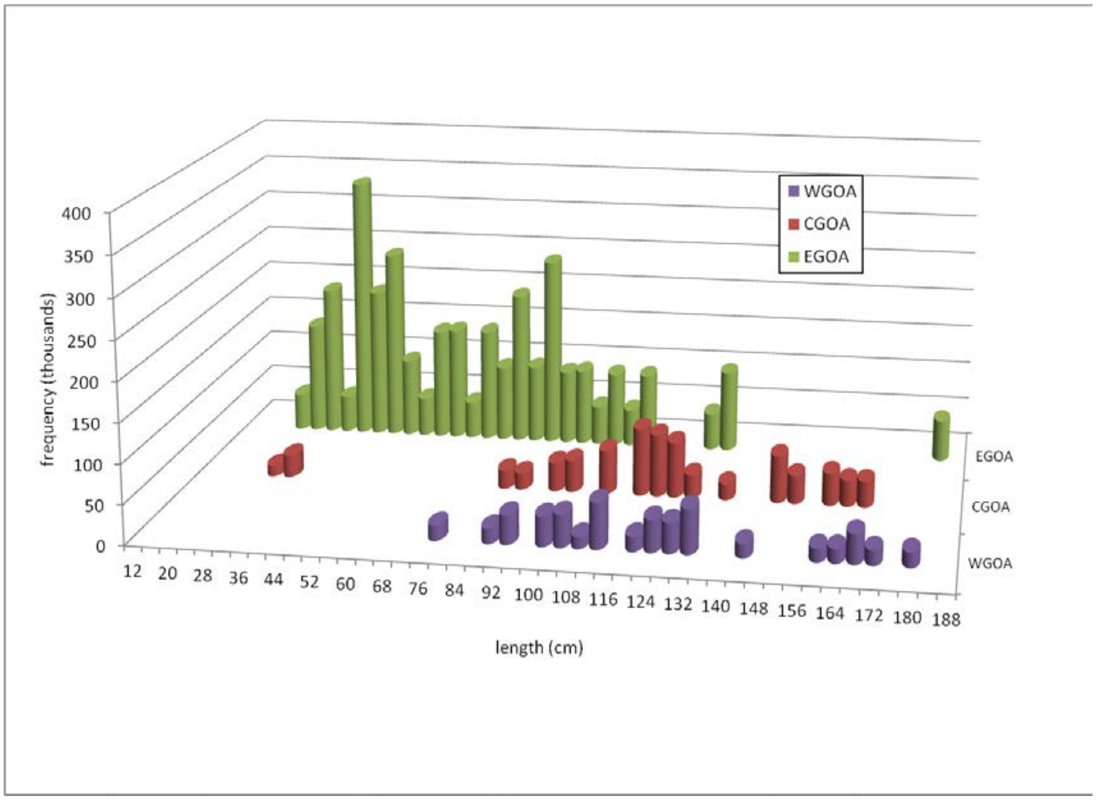


Figure 16. Big skate trawl survey length composition by regulatory area in 2013.

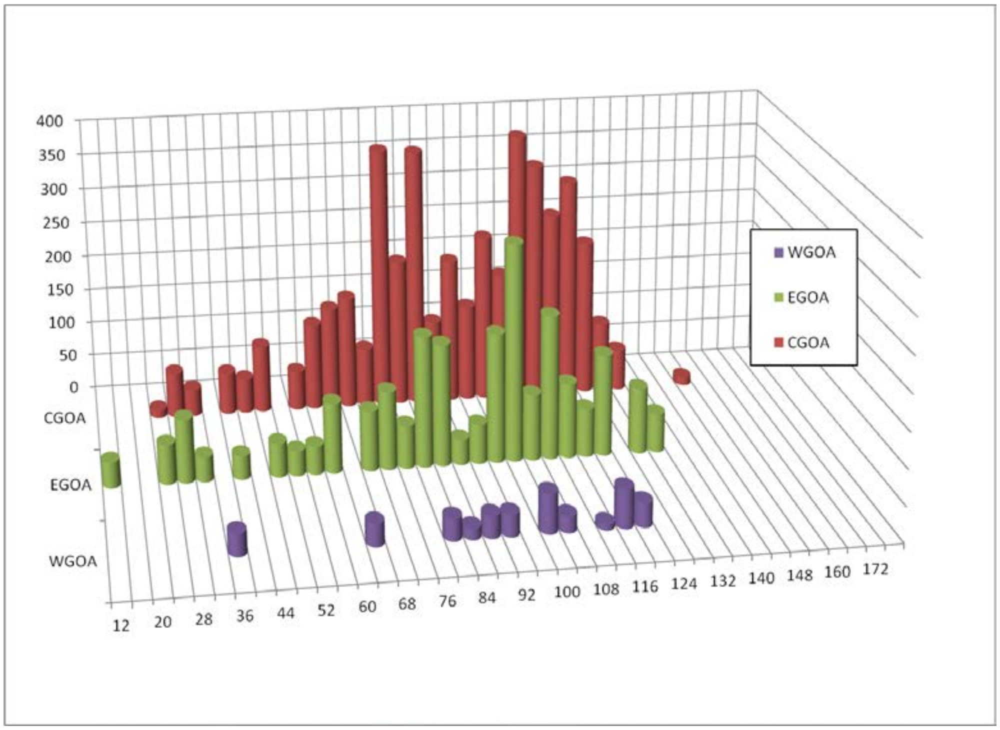


Figure 17. Longnose skate trawl survey length composition by regulatory area in 2013.

Appendix A: Summary of non-commercial catches.

Table A-1. Noncommercial catches (kg) of big skates in the GOA.

	Annual Longline Survey	Gulf of Alaska Bottom Trawl Survey	IPHC Annual Longline Survey	Large-Mesh Trawl Survey	Sablefish Longline Survey	Scallop Dredge Survey	Shelikof Acoustic Survey	Shumigans Acoustic Survey	Small-Mesh Trawl Survey	Grand Total
1999				1,489	22					1,512
2000				1,255	18				96	1,369
2001				744						744
2002				821	17					839
2003				679	25				305	1,009
2004				567	131				445	1,143
2005				924	30	0			172	1,126
2006				1,322	70	0			142	1,534
2007				1,715					36	1,751
2008				670						670
2009	80			609		24				713
2010	369		15,305	6,114			19	39	307	22,153
2011	189	2,542	24,572	6,444					737	34,485
2012	120		26,127	5,519		1			605	32,371
2013	70	1,300	25,562	3,467					127	30,525

Table A-2. Noncommercial catches (kg) of longnose skates in the GOA.

	Annual Longline Survey	Golden King Crab Pot Survey	Gulf of Alaska Bottom Trawl Survey	IPHC Annual Longline Survey	Large-Mesh Trawl Survey	Sablefish Longline Survey	Salmon EFP 13-01	Scallop Dredge Survey	Shumigans Acoustic Survey	Small-Mesh Trawl Survey	Grand Total
1998						2					2
1999					3,418	886					4,304
2000					622	813				70	1,506
2001					2,941	660					3,601
2002					393	643					1,035
2003					2,594	51				255	2,900
2004					891	667				121	1,679
2005					3,028	62		7		398	3,495
2006		8			392	599				280	1,278
2007					1,541					278	1,819
2008					438						438
2009					1,475			10			1,485
2010	11,921			45,818	4,600				14	213	62,566
2011	15,164		1,569	74,655	6,937			13		362	98,700
2012	13,106			59,265	4,352					199	76,922
2013	9,006		1,865	83,970	3,803		85	65		75	98,869

Table A-3. Noncommercial catches (kg) of other skates in the GOA.

	Annual Longline Survey	Golden King Crab Pot Survey	Gulf of Alaska Bottom Trawl Survey	IPHC Annual Longline Survey	Large-Mesh Trawl Survey	Sablefish Longline Survey	Salmon EFP 13-01	Scallop Dredge Survey	Shelikof Acoustic Survey	Small-Mesh Trawl Survey	Subsistence Fishery	Grand Total
1984											151	151
1985											1	1
1989											7	7
1990	9,388											9,388
1991	9,697										182	9,879
1992	10,306										158	10,464
1993	11,351										19	11,370
1994	7,307											7,307
1995	19,191											19,191
1996	17,740										57	17,797
1997	20,490										156	20,646
1998	16,121				2,109			10			29	18,269
1999	17,157				1,385							18,542
2000	17,603				408						50	18,062
2001	15,375				1,201			6				16,583
2002	22,079				342			0				22,421
2003	21,302				1,275			10			138	22,725
2004	17,613				409			19				18,041
2005	16,680				1,288	78		33		46		18,124
2006	21,515	3			974			2		162		22,656
2007	30,233				872			33		95		31,233
2008	25,839							7				25,846
2009	11,493				605			67				12,165
2010	828			44,647	4,153			6	47	53		49,733
2011	445		1,328	24,736	3,512			4		49		30,074
2012	1,513			25,744	3,719					53		31,029
2013	651		1,629	24,110	3,109		8	2		53		29,562

Appendix B. Stock structure report for big and longnose skates in the GOA, presented to the GOA Plan Team in September 2014.

Big skate *Beringraja binoculata* (formerly *Raja binoculata*)

SUMMARY TABLE – BIG SKATE	
HARVEST AND TRENDS	
Factor and criterion	Justification
Fishing mortality	Fishing mortality varies by area but is very high in the CGOA ($F > F_{ABC}$).
Spatial concentration of fishery relative to abundance	The fishery is very concentrated in the CGOA, particularly around Kodiak. Fishery concentrations are somewhat similar to survey CPUE patterns.
Population trends	Trends vary by area. Big skates in the CGOA and WGOA are substantially larger than those in the EGOA and may represent the mature portion of a gulfwide population. **A biomass decline in the CGOA is a major concern.**
Barriers and phenotypic characters	
Generation time	Generation time is unknown. Female $A_{50\%}$ maturity is 5 years.
Physical limitations	No physical limitations are known.
Growth differences	Data are insufficient to address this issue.
Age/size-structure (Significantly different size/age compositions)	Length composition differs by area, with smaller and immature more common in the EGOA and larger mature skates more common in the CGOA and WGOA.
Spawning time differences	Data are insufficient to address this issue.
Maturity-at-age/length differences	Data are insufficient to address this issue.
Morphometrics	Data are insufficient to address this issue.
Meristics	Data are insufficient to address this issue.
Behavior & movement	
Spawning site fidelity	Unknown, but it is likely that big skates return to highly localized nursery areas where they deposit their eggcases.
Mark-recapture data	Extensive tagging work in BC, and limited work in Alaska, indicates limited dispersal with some large-scale movements.
Natural tags	Data are insufficient to address this issue.
Genetics	
Isolation by distance	Data are insufficient to address this issue.
Dispersal distance	Data are insufficient to address this issue.
Pairwise genetic differences	Data are insufficient to address this issue.

<u>Harvest and trends- big skate</u>

- *Fishing mortality*: Fishing mortality differs by area (Table B-1). In the WGOA and EGOA, F is low relative to F_{ABC}. Gulfwide, F is approximately half F_{OFL}. In the CGOA, however, fishing mortality is very high and exceeded F_{ABC} every year during 2010-2013.
- *Spatial concentration of fishery*: Big skate landings are highly concentrated in the CGOA, especially in the vicinity of Kodiak (Figures B-1 and B-2). Other areas with high big skate landings are in the Shumagin Islands and Prince William Sound. These areas also tend to have the highest CPUEs in the survey data, but the areas of concentration in the fishery do not completely match the pattern of survey CPUEs.
- *Population trends*: Population trends differ substantially among regions (Figure B-3). Biomass estimates in the EGOA are more variable than in the other areas. This is consistent with length composition data (described below and in Figure B-4) that suggest younger big skates are predominantly found in the EGOA, and then move to the CGOA and WGOA as they grow. Thus the variability in EGOA biomass may represent a recruitment signal. In contrast, biomass trends in the COGA and WGOA are less variable and may indicate a more temporally stable aggregation of older skates. There has been a steady decline in CGOA big skate biomass since 2003, which is a major concern for this stock.

<u>Barriers and phenotypic characters- big skate</u>

- *Generation time*: Generation time is unknown for big skates, but age at 50% maturity ($A_{50\%}$) for females is 4.8 years. Generation time is probably not excessively long for big skates.
- *Physical limitations*: There do not appear to be any physical barriers to movements of big skates.
- *Age/size structure*: Length compositions are different among the areas (Figure B-4). Big skates in the EGOA are smaller than in the other areas and are mostly immature. In contrast, skates in the CGOA and WGOA are larger and mostly mature. With some variability this pattern among areas is consistent over time (Figure B-5), with the highest mean lengths in the WGOA. These patterns suggest a gulfwide population of big skates, with large-scale ontogenetic movements. Large-scale ontogenetic migration has also been observed in Alaska skate *Bathyraja parmifera* in the eastern Bering Sea (Ormseth 2012).
- The other attributes in this section (growth differences, spawn timing, maturity differences, morphometrics, and meristics) cannot be addressed due to a lack of data.

<u>Behavior and movement- big skate</u>

- *Spawning site fidelity*: Fidelity to spawning sites has not been studied in big skates. In general, skates appear to deposit their embryos (protected by eggcases) in small, highly localized nursery areas (Hoff 2007). Nursery areas of other skate species in the Bering Sea have very high densities of eggcases, and skates appear to use the same areas for many years.
- *Mark-recapture data*: Extensive mark-recapture studies of big skates in British Columbia waters suggest that skates show limited dispersal from fairly small areas (King and McFarlane 2010). A small percentage (1.5%) of big skates made large-scale movements (~1,000 km). Pop-up satellite tags are currently being used to study movements of big skates in the GOA (Thomas Ferrugia, UAF, pers. comm. 2014). Preliminary results

indicate that some big skates had very limited movements (~10 km) but that several moved over 100 km.

- No data were available regarding natural tags.

Genetics – big skate

- No genetics data are available for big skates.

Summary and conclusions – big skate

Although the data are insufficient to make any firm conclusion regarding stock structure of big skates in the GOA, the available information is consistent with a gulfwide population. Small and immature skates are mainly found in the EGOA, while the CGOA and WGOA have mostly mature skates. This pattern suggests a gulfwide population with ontogenetic movement among areas. The abundance patterns for big skates are consistent with this interpretation: higher variability in the GOA may indicate a recruitment signal, while the lower variability in the CGOA and WGOA is consistent with a group of older skates with less annual variation in abundance. In contrast, the limited movement of big skates in British Columbia waters led researchers there to conclude that separate stocks existed even across small spatial scales (King and McFarlane 2010) and that separate management was warranted.

In sum, this analysis suggests that current management practices with a gulfwide OFL is appropriate for big skates in the GOA management area. However the differences in size, and their implication for the spatial distribution of immature and mature skates, also support the use of area-specific ABCs to limit catches in each area. **The decline of big skate biomass in the CGOA, where F has exceeded F_{ABC} every year during 2010-2013, underlines this point and is of major concern.**

Table 1. Catch statistics for big skates, 2009-2013. "EGOA_1" includes only areas 640 & 650. "EGOA_2" includes areas 640 and 650 as well as areas 649 and 659 (inside waters). Colored shading indicates year/area combinations where F/F_{ABC} exceeded 1.

		2009	2010	2011	2012	2013
WGOA	catch	79	148	110	66	121
	ABC	632	598	598	469	469
	F/F_{ABC}	0.13	0.25	0.18	0.14	0.26
CGOA	catch	1,903	2,215	2,105	1,894	2,303
	ABC	2,065	2,049	2,049	1,793	1,793
	F/F_{ABC}	0.92	1.08	1.03	1.06	1.28
EGOA_1	catch	100	149	90	38	79
	ABC	633	681	681	1,505	1,505
	F/F_{ABC} _1	0.16	0.22	0.13	0.03	0.05
EGOA_2	catch	137	179	134	61	221
	ABC	633	681	681	1,505	1,505
	F/F_{ABC} _2	0.22	0.26	0.20	0.04	0.15
gulfwide	catch	2,119	2,542	2,350	2,021	2,645
	OFL	4,439	4,438	4,438	5,023	5,023
	F/F_{OFL}	0.48	0.57	0.53	0.40	0.53

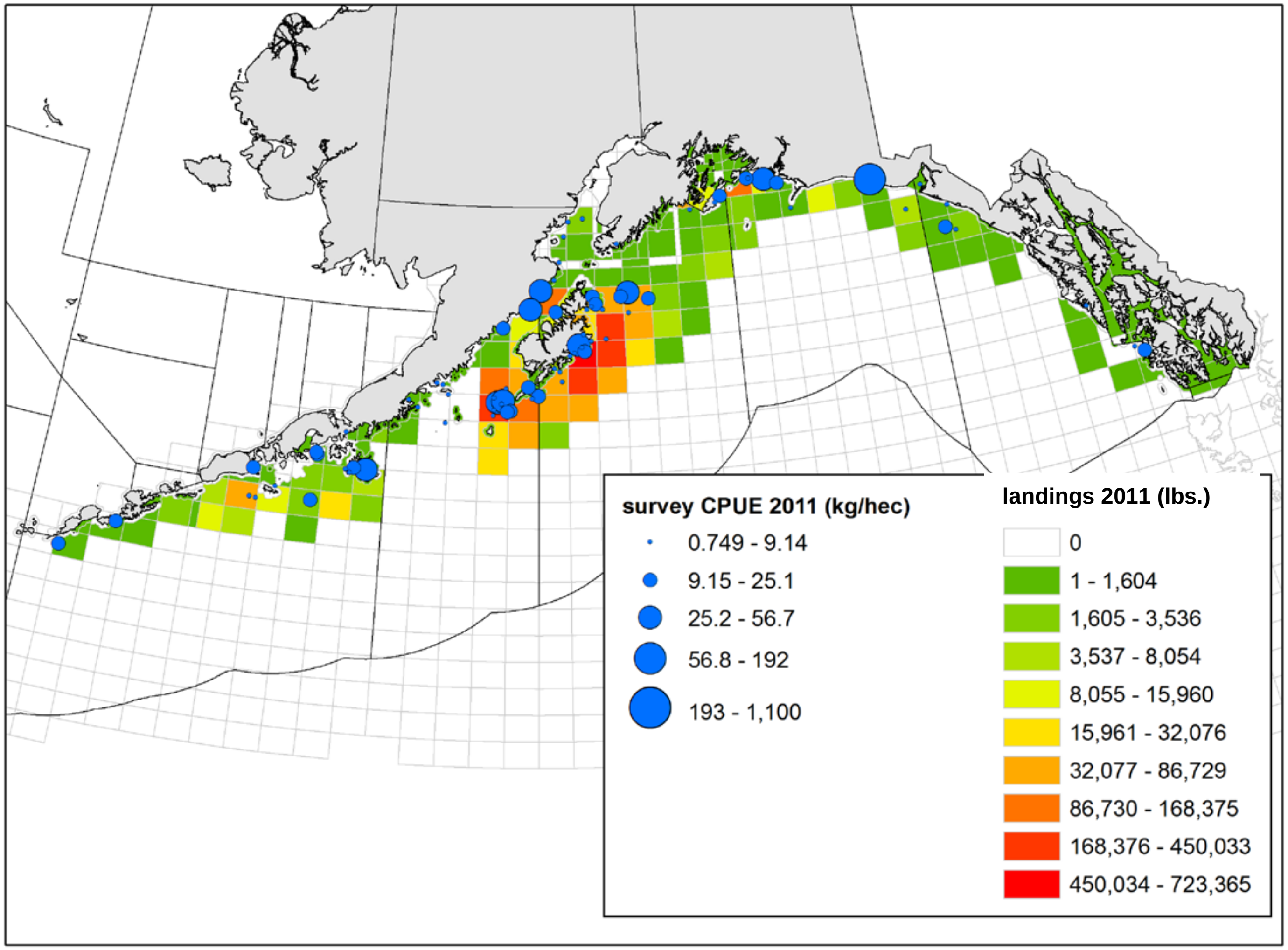


Figure B-1. Bottom trawl survey CPUEs and commercial landings of big skates in the GOA during 2011. Landings data are from ADFG fish tickets and are aggregated by ADFG statistical areas.

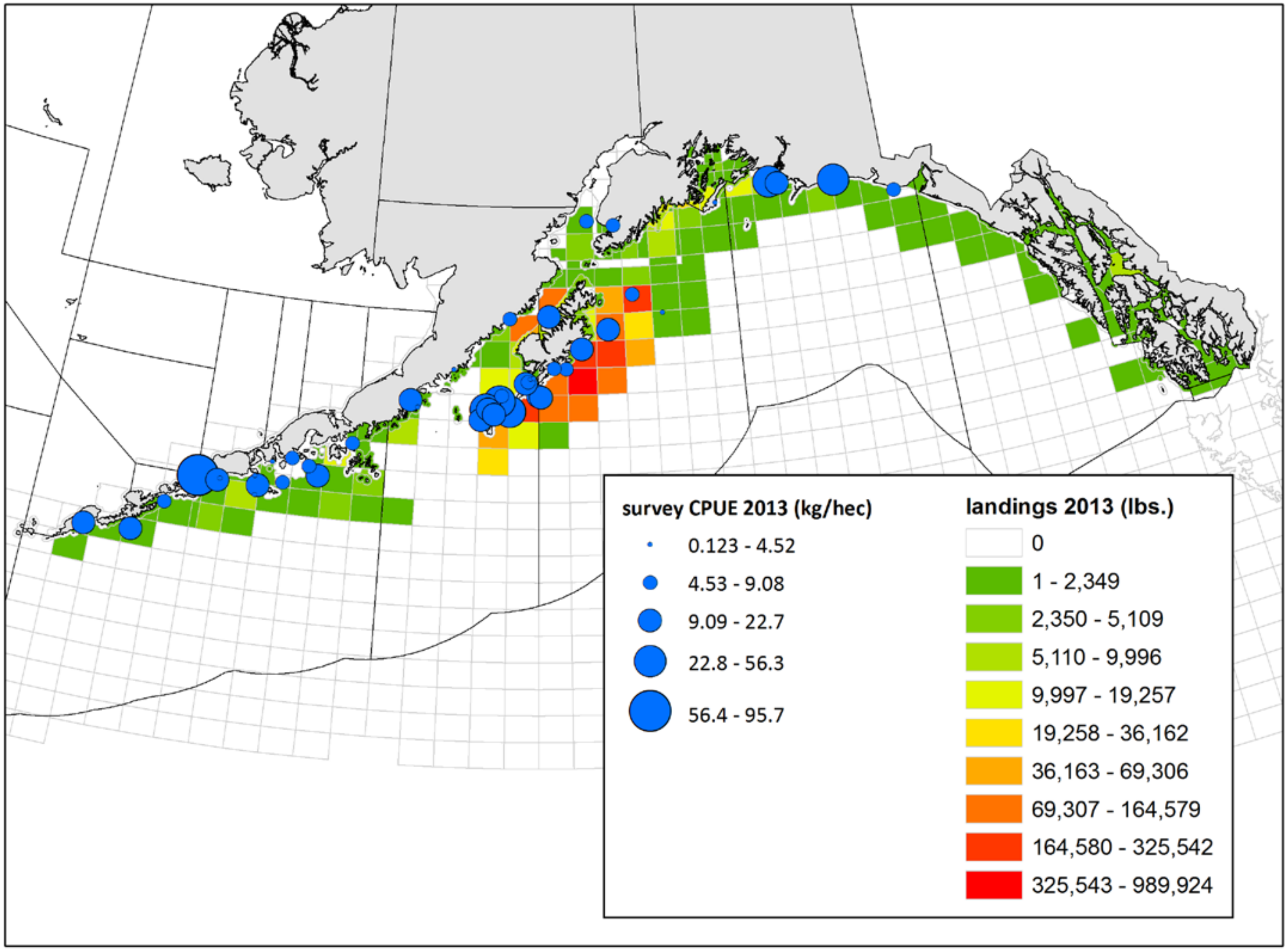


Figure B-2. Bottom trawl survey CPUEs and commercial landings of big skates in the GOA during 2013. Landings data are from ADFG fish tickets and are aggregated by ADFG statistical areas.

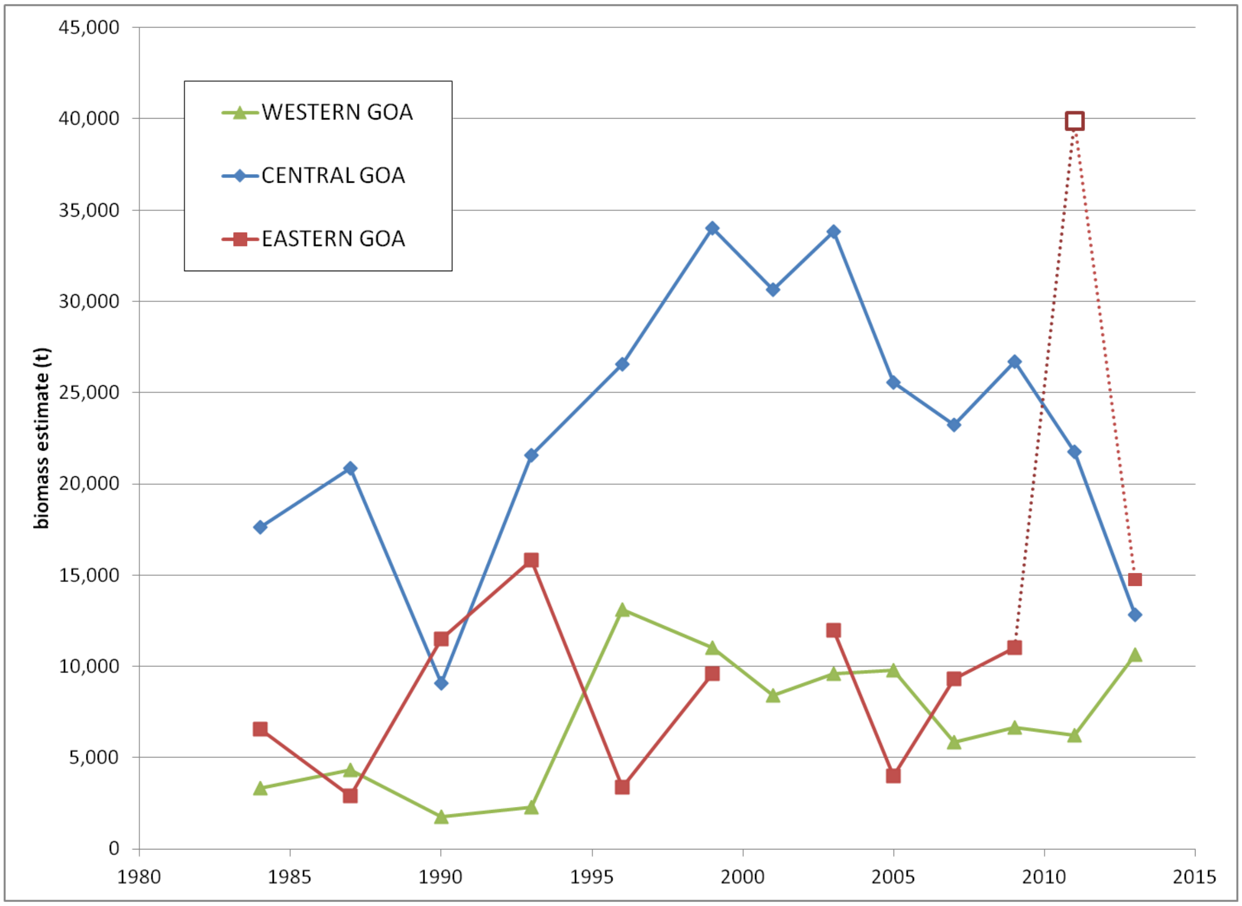


Figure B-3. Time series of survey biomass estimates for big skates in the 3 regulatory areas of the GOA, 1984-2013. Open square and dashed lines in the EGOA dataset indicate the 2011 biomass estimate that was highly influenced by a single vary large tow of big skates and had a much higher CV than the other estimates.

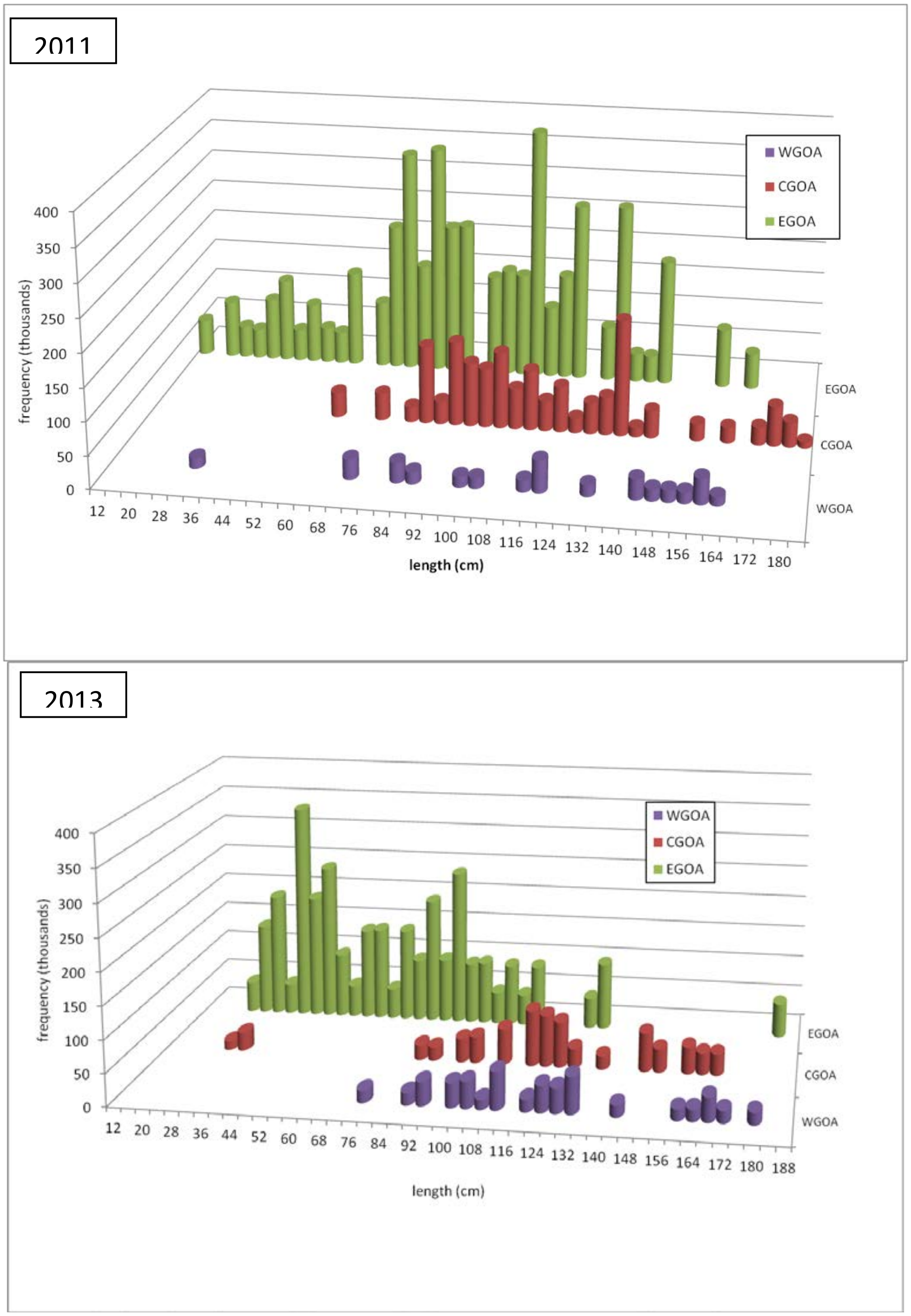


Figure B-4. Trawl survey length compositions of big skates in the GOA, by area, in 2011 (top panel) and 2013 (bottom panel).

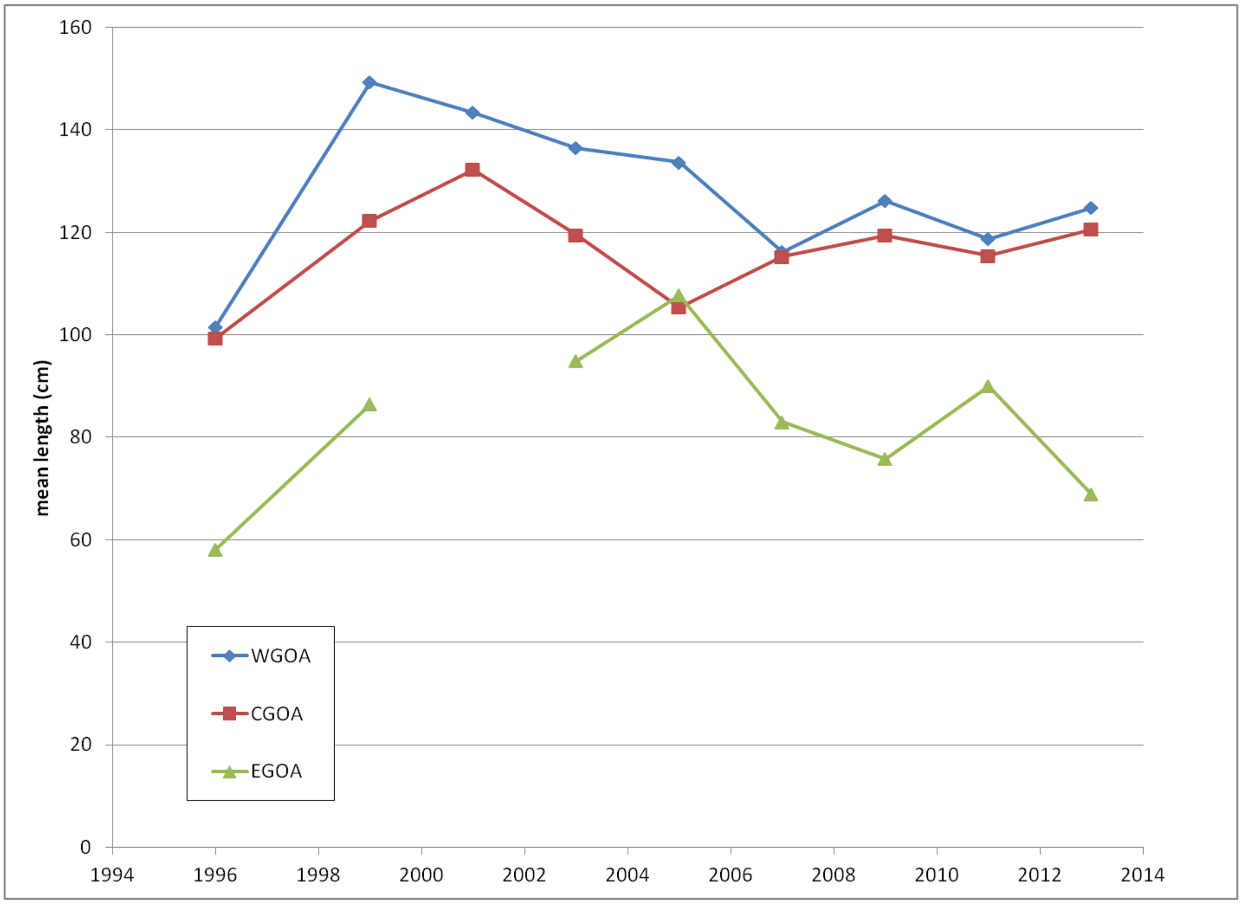


Figure B-5. Annual mean lengths of big skates in the three GOA regulatory areas, 1996-2013.

Longnose skate *Raja rhina*

SUMMARY TABLE – LONGNOSE SKATE	
HARVEST AND TRENDS	
Factor and criterion	Justification
Fishing mortality	Differs by area. $F > F_{ABC}$ in some years in the WGOA, and F may be greater than F_{ABC} in the EGOA depending on which catch data are included.
Spatial concentration of fishery relative to abundance	The fishery is highly concentrated, especially around Kodiak Island. The fishery is more concentrated than are the CPUEs in the survey.
Population trends	Population trends vary substantially among areas. Skate abundance has increased since 1990 in all areas, but the CGOA increase has been much greater than the other areas.
Barriers and phenotypic characters	
Generation time	Unknown, but female $A_{50\%}$ is 12.3 years.
Physical limitations	No physical limitations are known.
Growth differences	Data are insufficient to address this issue.
Age/size-structure	Size structure varies somewhat among the areas. Trends in mean size are fairly similar
Spawning time differences	Data are insufficient to address this issue.
Maturity-at-age/length differences	Data are insufficient to address this issue.
Morphometrics	Data are insufficient to address this issue.
Meristics	Data are insufficient to address this issue.
Behavior & movement	
Spawning site fidelity	Unknown, but it is likely that longnose skates return to highly localized nursery areas where they deposit their eggcases.
Mark-recapture data	Data are insufficient to address this issue.
Natural tags	Data are insufficient to address this issue.
Genetics	
Isolation by distance	Data are insufficient to address this issue.
Dispersal distance	Data are insufficient to address this issue.
Pairwise genetic differences	Data are insufficient to address this issue.

Harvest and trends- longnose skate

- *Fishing mortality*: Fishing mortality for longnose skates varies by area, and results vary depending on whether catch data from inside waters (areas 649 & 659) are included (Table L-1). In the CGOA, F has been approximately ½ of F_{ABC} over the last 5 years. In the WGOA, F has exceeded F_{ABC} in 3 out of the last 5 years. In the EGOA, F was relatively low during 2009-2012 but increased in 2013. When inside waters are included, F was 1.25 times F_{ABC} in 2013. These results are likely due to an increase in catch reporting rather than an increase in the actual F.
- *Spatial concentration of fishery*: The fishery is highly concentrated in several areas (Figures L-1 & L-2). The biggest area of concentration is around Kodiak Island. Landings patterns vary by year but appear to be more highly concentrated than the survey CPUE.
- *Population trends*: The abundance of longnose skates varies among the areas, as does the trend in abundance (Figure L-3). Longnose skates have increased in all areas since 1990, with most of this increase occurring before 2000. The increase has been much greater in the CGOA than in the other two areas, and the WGOA has had the lowest rate of increase.

Barriers and phenotypic characters- longnose skate

- *Generation time*: Generation time is not known for longnose skates. However $A_{50\%}$ for female and male longnose skates is 12.3 and 9 years, respectively. This suggests that generation time is relatively long for this species.
- *Physical limitations*: There are no apparent physical barriers to dispersal for this species in the GOA.
- *Age/size structure*: Length compositions vary somewhat among the areas (Figure L-4). Unlike big skates, however, these differences are minor and do not appear to represent separate segments of a gulfwide population. Mean size has varied over time in each area, and the trends in mean size are fairly similar among areas (Figure L-5).
- The other attributes in this section (growth differences, spawn timing, maturity differences, morphometrics, and meristics) cannot be addressed due to a lack of data.

Behavior and movement- longnose skate

- *Spawning site fidelity*: Fidelity to spawning sites has not been studied in longnose skates. In general, skates appear to deposit their embryos (protected by eggcases) in small, highly localized nursery areas (Hoff 2007). Nursery areas of other skate species in the Bering Sea have very high densities of eggcases, and skates appear to return to the same area for many years.
- No mark-recapture or natural-tag data exist for longnose skates.

Genetics- longnose skate

- No genetics data are available for big skates.

Summary and conclusions- longnose skate

In contrast to big skates, the data for longnose are not indicative of a gulfwide longnose skate population. Although the data are insufficient to conclude that separate longnose populations exist in the GOA, the different abundance trends and the differences in size structure are consistent with some degree of separation of stocks. Investigation of stock structure in GOA longnose skates is a priority for research.

In sum, the use of area-specific ABCs for skate management is warranted by the available data. If better evidence of discrete longnose stocks become available it may also be appropriate to define area-specific OFLs for this species. The problem of unknown stock structure is exacerbated in longnose skates due to the high concentration of fishery removals and their vulnerable life history strategy.

Table L-1. Catch statistics for longnose skates, 2009-2013. “EGOA_1” includes only areas 640 & 650. “EGOA_2” includes areas 640 and 650 as well as areas 649 and 659 (inside waters). Colored shading indicate area/year combinations where F/F_{ABC} was greater than 1.

		2009	2010	2011	2012	2013
WGOA	catch	79	106	71	37	90
	ABC	78	81	81	70	70
	F/F_{ABC}	1.02	1.31	0.88	0.52	1.28
CGOA	catch	1,096	851	892	786	1,260
	ABC	2041	2009	2009	1879	1879
	F/F_{ABC}	0.54	0.42	0.44	0.42	0.67
EGOA_1	catch	244	132	68	79	426
	ABC	768	762	762	676	676
	F/F_{ABC}_1	0.32	0.17	0.09	0.12	0.63
EGOA_2	catch	320	198	118	119	846
	ABC	768	762	762	676	676
	F/F_{ABC}_2	0.42	0.26	0.16	0.18	1.25
gulfwide	catch	1,495	1,155	1,082	941	2,195
	OFL	3,849	3,803	3,803	3,500	3,500
	F/F_{OFL}	0.39	0.30	0.28	0.27	0.63

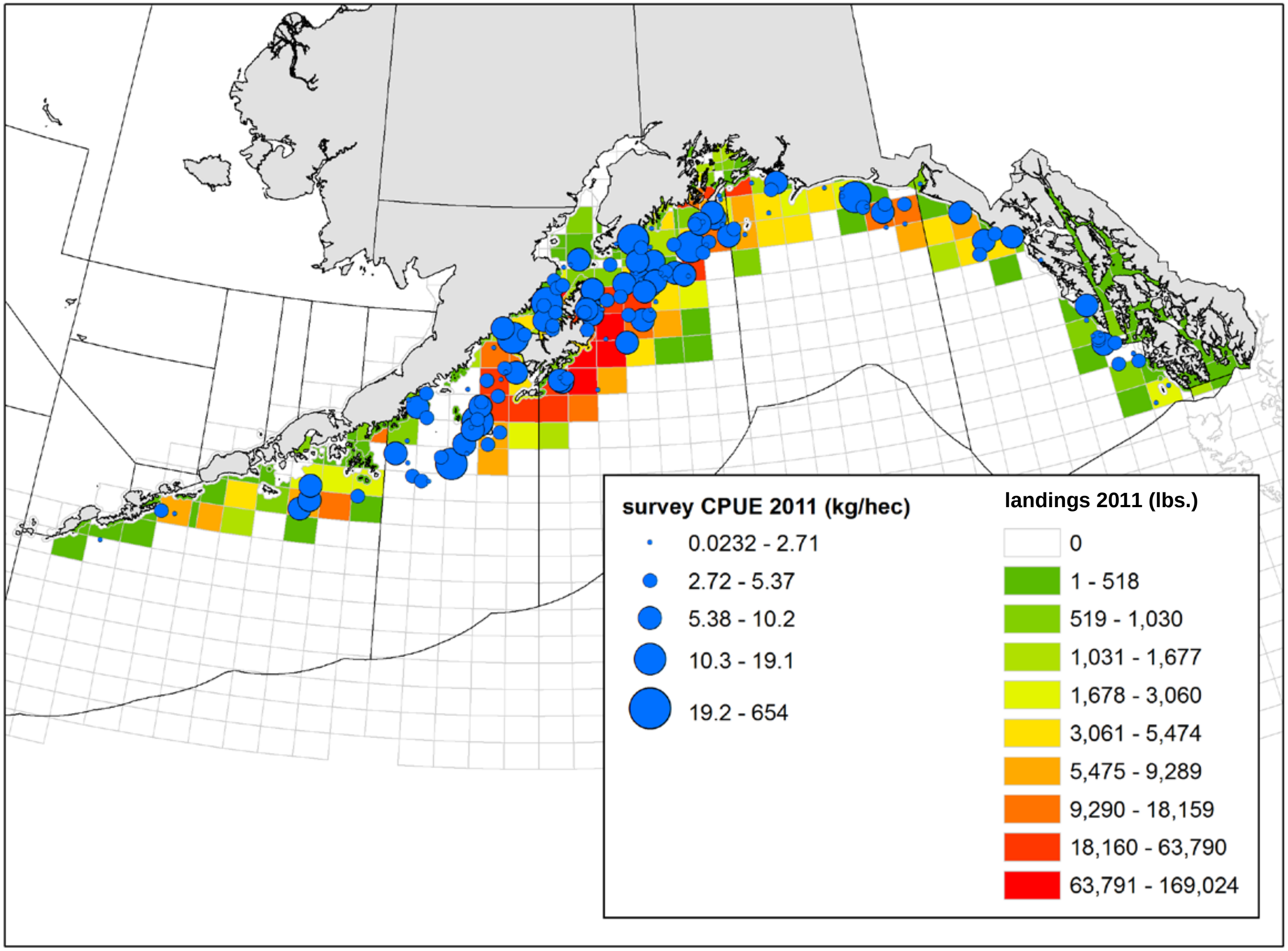


Figure L-1. Bottom trawl survey CPUEs and commercial landings of longnose skates in the GOA during 2011. Landings data are from ADFG fish tickets and are aggregated by ADFG statistical areas.

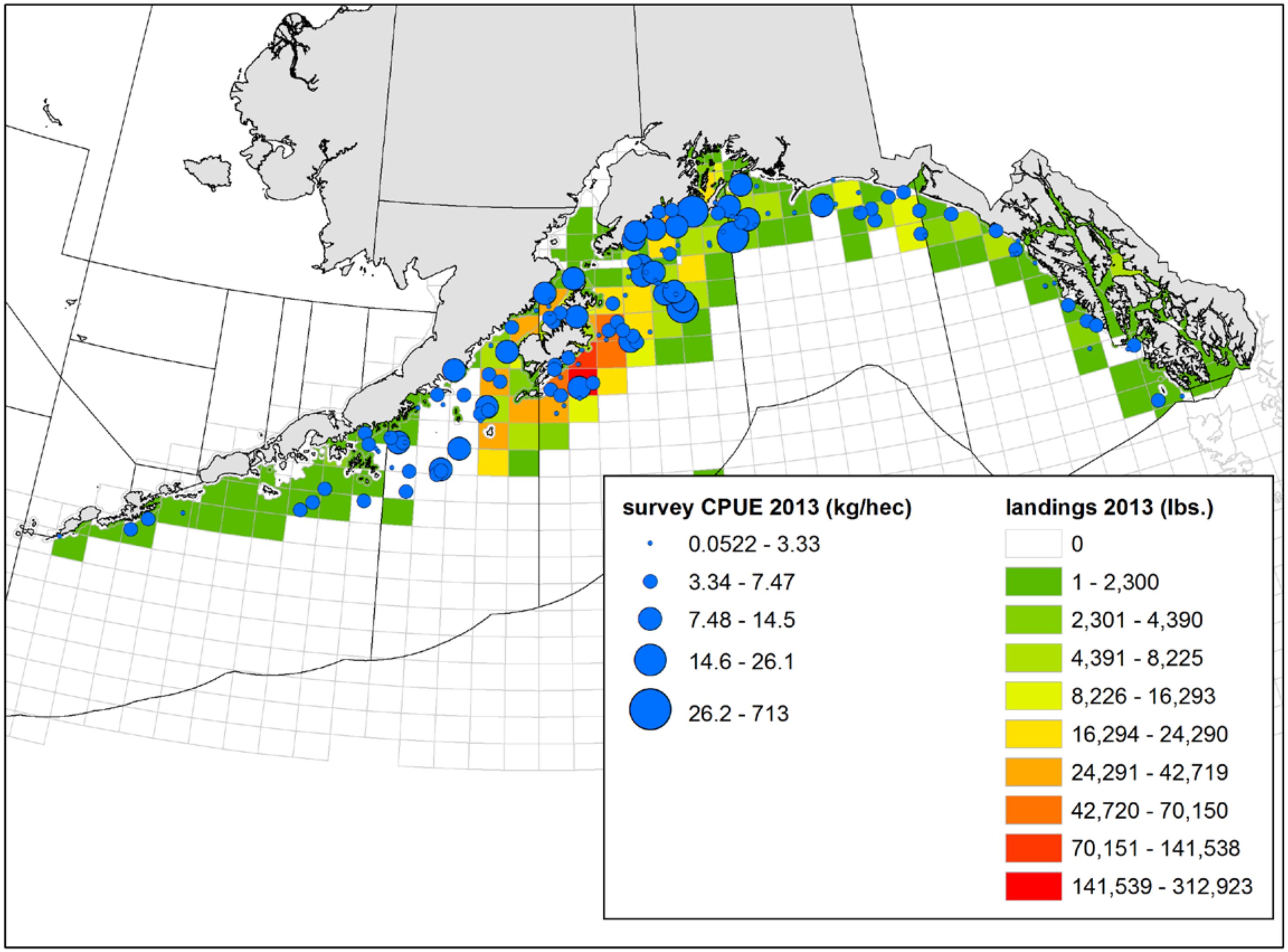


Figure L-2. Bottom trawl survey CPUEs and commercial landings of longnose skates in the GOA during 2013. Landings data are from ADFG fish tickets and are aggregated by ADFG statistical areas.

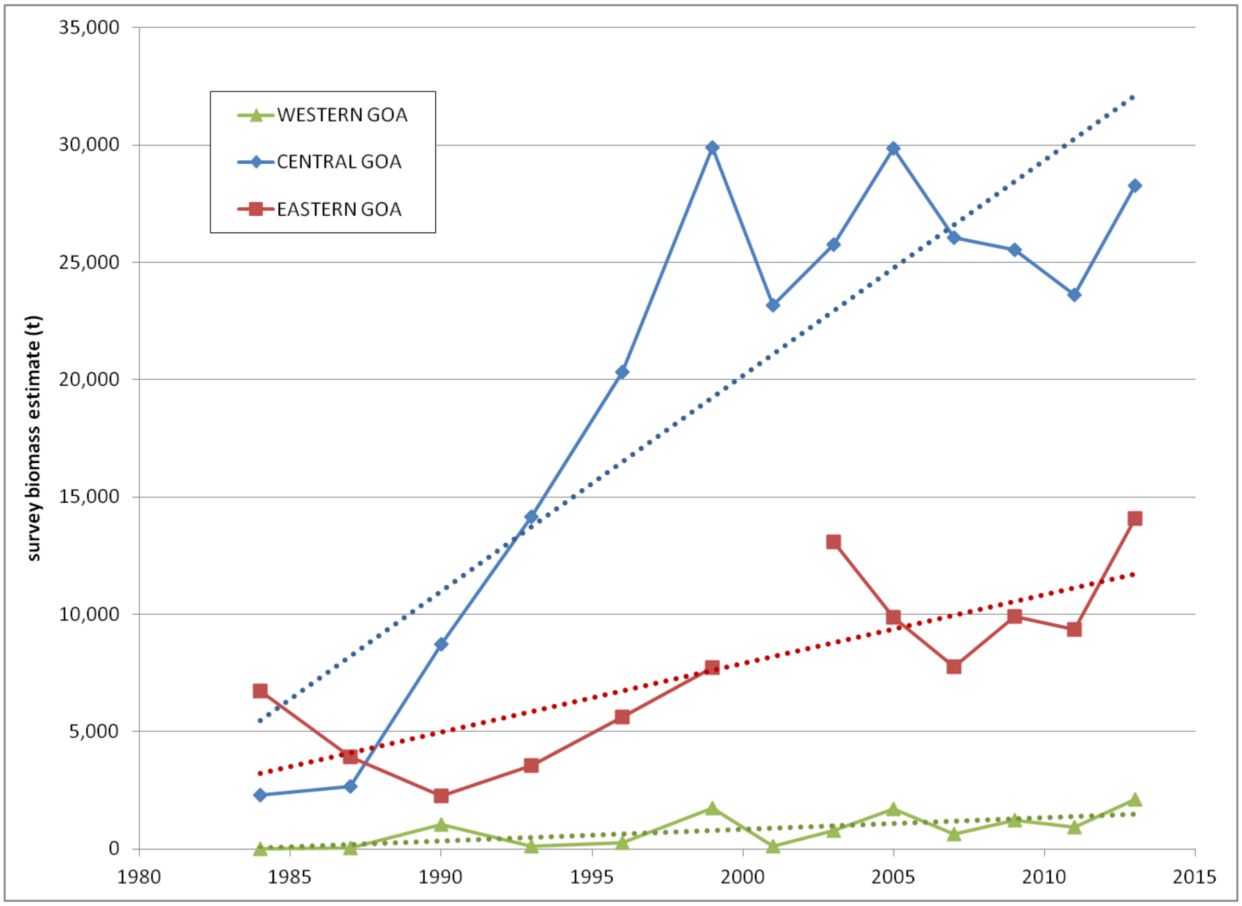


Figure L-3. Time series of survey biomass estimates for longnose skates in the 3 regulatory areas of the GOA, 1984-2013.

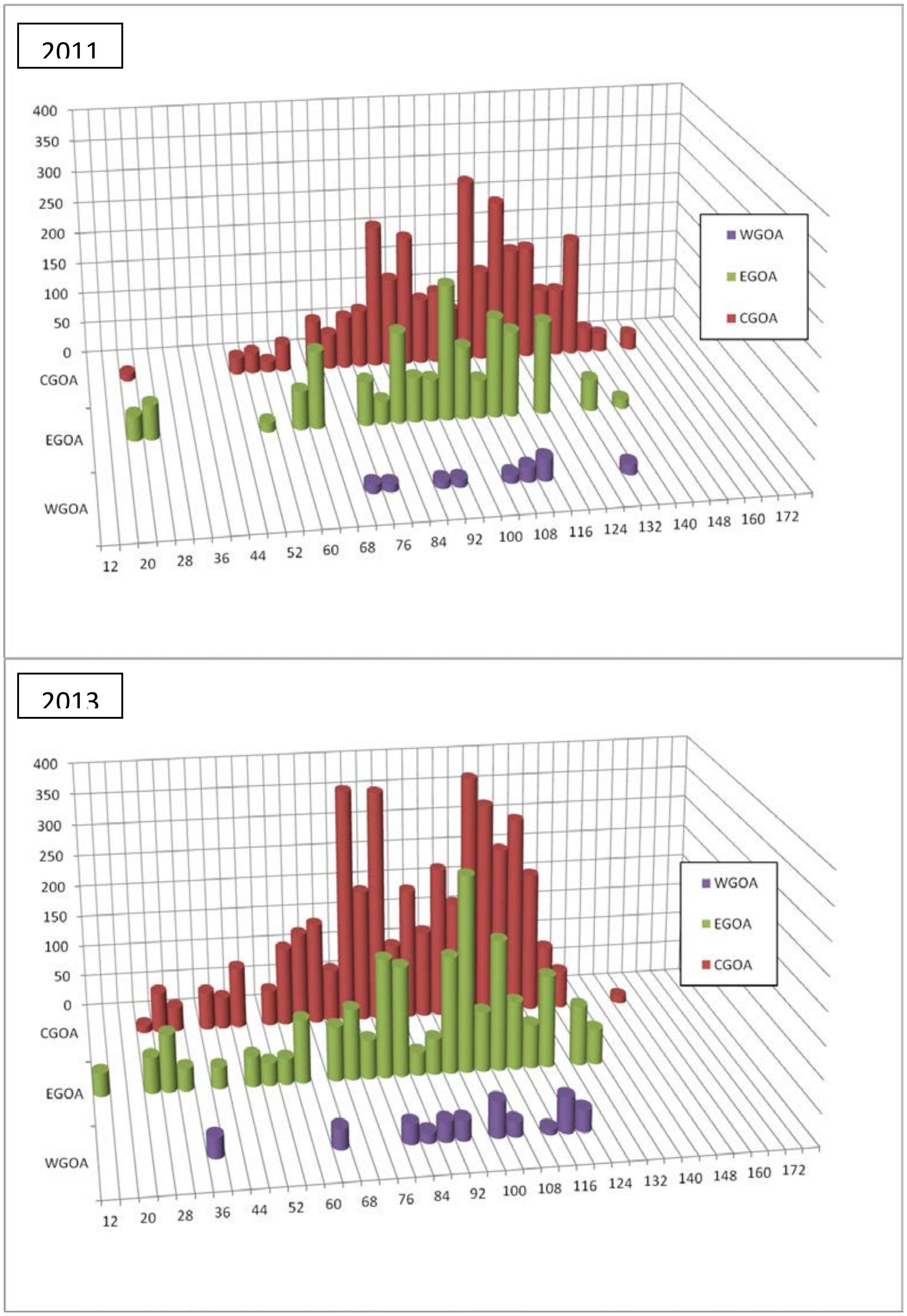


Figure L-4. Trawl survey length compositions of longnose skates in the GOA, by area, in 2011 (top panel) and 2013 (bottom panel).

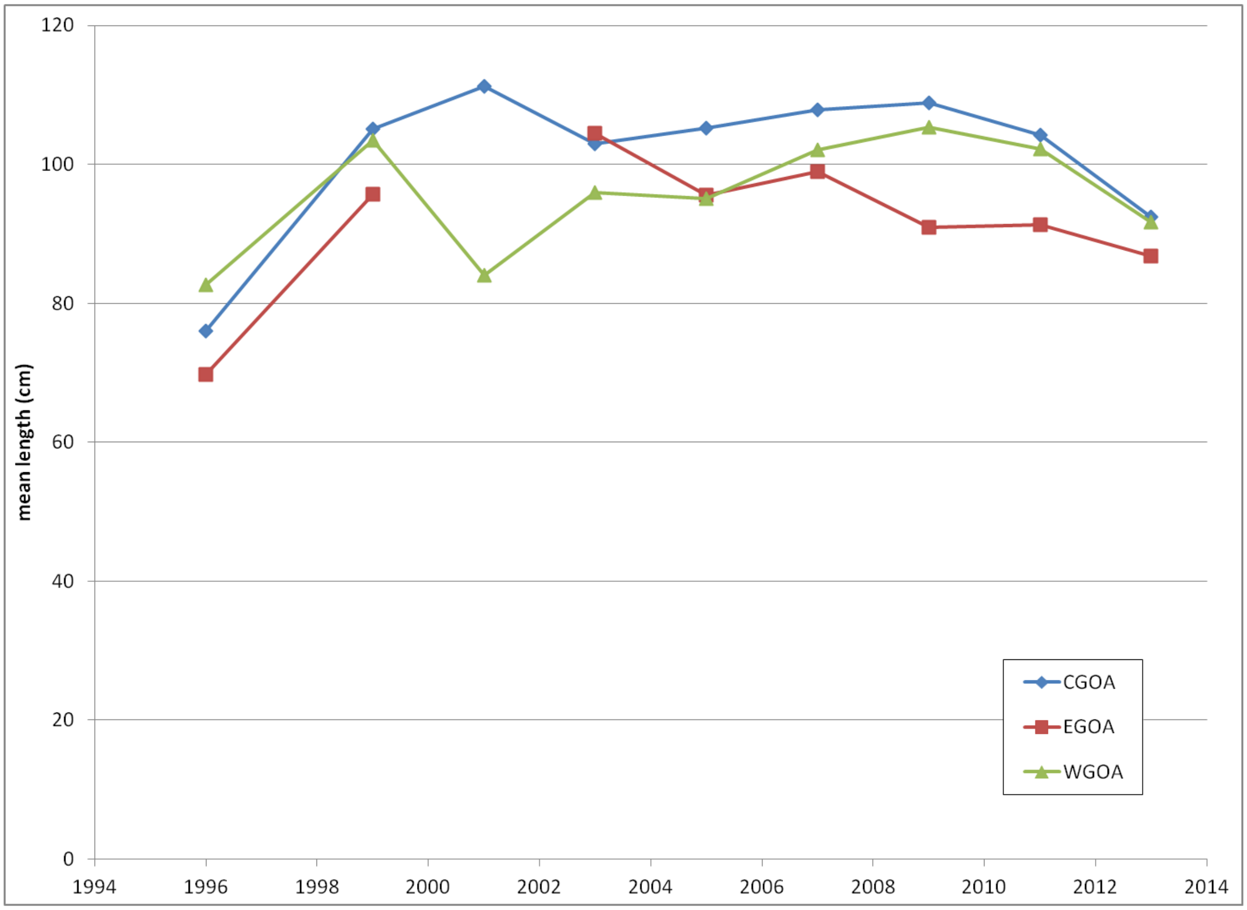


Figure L-5. Annual mean lengths of longnose skates in the three GOA regulatory areas, 1996-2013.

Literature Cited

Hoff GR (2007) Reproduction of the Alaska skate (*Bathyraja parmifera*) with regard to nursery sites, embryo development and predation. PhD dissertation, University of Washington, Seattle.

King JR and GA McFarlane (2010) Movement patterns and growth estimates of big skate (*Raja binoculata*) based on tag-recapture data. Fisheries Research 101: 50-59

Ormseth O (2012) Bering Sea and Aleutian Islands skates. IN: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/ Aleutian Islands regions. North Pacific Fishery Management Council, Anchorage, AK 99501

19. Assessment of the Sculpin complex in the Gulf of Alaska

Ingrid Spies, Dan Nichol, and Todd T. TenBrink
Alaska Fisheries Science Center
National Marine Fisheries Service

Executive Summary

This document consists of an executive summary because no new survey data are available. It also includes specific responses to SSC and Plan Team comments.

Summary of Changes in Assessment Inputs

1). The GOA trawl survey is conducted in odd years, and was not conducted in 2014. There is no new survey data.

2). Complete catch is included for 2013, as well as partial catch for 2014 (through October 21, 2014).

The assessment methodology remained the same.

Summary of Results

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)[1]	0.222	0.222	0.222	0.222
Tier	5	5	5	5
Biomass (t)	33,550	33,550	33,550	33,550
F_{OFL}	0.222	0.222	0.222	0.222
$maxF_{ABC}$	0.166	0.166	0.166	0.166
F_{ABC}	0.166	0.166	0.166	0.166
OFL (t)	7,448	7,448	7,448	7,448
maxABC (t)	5,569	5,569	5,569	5,569
ABC (t)	5,569	5,569	5,569	5,569
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing		n/a		n/a

[1] *This is a sculpin complex average mortality rate, a biomass-weighted average of the instantaneous natural mortality rates for the four most abundant sculpins in the GOA: bigmouth (Hemitripterus bolini), great (Myoxocephalus polyacanthocephalus), plain (Myoxocephalus jaok), and yellow Irish lord (Hemilepidotus jordani).*

Area apportionment

GOA sculpins are managed with a single total allowable catch (TAC) for the entire Gulf of Alaska region; there is no area apportionment.

Responses to SSC and Plan Team Comments on Assessments in General

The SSC recommended in its December 2012 minutes that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL.

Authors' response: Authors will continue to estimate M to three significant digits, as in past assessments.

Responses to SSC and Plan Team Comments Specific to this Assessment

The Team agreed that the sculpin complex ABC for 2014 be based on the previous method of using a four-year survey average (a 3-year average is applied to the BSAI sculpin assessment).

Authors' response: The authors will continue to use the 4-year average for GOA sculpin assessments.

At the November 2013 GOA plan team, there was some discussion of whether species-specific TAC calculations could be compared with catch estimates, but it appeared that delineating catches to individual species would require substantial additional effort due to a lack of comprehensive species identification. The Team recommended that species-specific catch estimates be presented along with species specific ABCs next year.

Authors' response: In response to Plan Team comments, species-specific catch and exploitation rate estimates are presented. Biomass estimates for plain, great, bigmouth sculpin, and yellow Irish lord are shown in Table 1. Table 2 provides a comparison of the proportion of plain, great, bigmouth sculpin, and yellow Irish lord caught in the fishery versus the survey. Total catch from the NMFS AKRO Blend/Catch Accounting System is shown in Table 3. Species-specific catch estimates and species-specific ABCs are provided in Table 4. Catch of plain, great, and bigmouth sculpin were below species-specific ABCs in 2012, 2013, and 2014 through October 13, 2014. There were no cases in which species-specific catches exceeded species-specific ABCs (Table 4).

The Team also recommended the author provide an executive summary for the 2014 assessment as no new data will be available but to include any outstanding Team or SSC recommendations with the summary.

Authors' response: This document is an executive summary that contains Plan Team and SSC recommendations.

The Team made a general recommendation that there should be an investigation into the use of ABC-methods based on survey biomass-weighted M calculations for species complexes. This approach appears to respond to declines in less productive species by increasing the target harvest rate for the complex, an undesirable response. An alternative to this biomass-weighted M approach may be desirable for the sculpin complex.

Authors' response: This is an important consideration, and two alternatives to the biomass-weighted M calculation are presented here: 1) a strict average of species-specific M estimates for the complex, 2) a biomass-weighted M that includes biomass estimates for the entire biomass time series.

The following table calculates weighted average M based on the biomass estimate from the past four research surveys.

	average biomass[1]	proportion of total biomass	M	weighted contribution to M	weighted average M
yellow Irish Lord	19,138	0.57	0.17	0.097	
great	7,654	0.23	0.28	0.064	
bigmouth	3,455	0.10	0.21	0.021	
plain	3,303	0.10	0.40	0.040	
					0.222

[1] Average survey biomass is the mean estimate of biomass from the last four surveys (2007, 2009, 2011, and 2013).

This standard method produces a weighted average M of 0.222. Using a strict average of the M estimates produces M=0.265. Another alternative is using the mean proportion of each species with respect to the total for the entire survey time series, from 2003-2013 (Table 1). This produces M=0.221. The authors' preferred method uses the proportion of each species from the entire time series. This method produces results that are insensitive to short-term changes in species composition.

The Team discussed the utility of using the random effects model for estimating survey biomass. Because the survey trend has been relatively flat over time, this approach produces results that are very similar to those from a four-year survey average. The Team discussed the need for a default method recommendation for applying the random effects approach for survey biomass estimation to species complexes. At issue is whether to apply this method to the aggregate survey data (which may provide a longer time-series in some cases where speciation was incomplete in early years), or to the individual species and then sum the results. A suggestion was made to explore simultaneous estimation for the individual species, and that this approach might be equally applicable to spatial strata for individual species. The Team recommends the survey averaging working group reconvene and provide guidance to authors regarding how to apply the random effects approach to species complexes and to regionally stratified estimates (i.e. Demersal Shelf Rockfish assessment) before the Team endorses the random effects method. The Team encourages the author to use the random effects approach, contingent on the survey averaging working group's recommendations.

Authors' response: There is no recommended method for applying the random effects model to stock complexes. In response to Plan Team comments, biomass was estimated using the random effects model. Estimates were performed two ways: 1) survey biomass estimates and variance were combined for plain, yellow Irish lord, bigmouth, and great sculpins, and provided to the model, and 2) the random effects model was run separately for each species and the results were combined. The results of separate model runs for each species are shown in Figure 1, and are compared with survey estimates. The two methods of estimating biomass are compared in Figure 2. The upper panel of Figure 2 provides results from the first method (all biomass and variance combined prior to running the model) and the lower panel compares both methods. The two methods provide very similar results. The total combined estimate of biomass for GOA sculpins in 2013 was 32,744 t (95% CI: 27,866 – 38,477) using method 1 and 32,614 (95% CI: 27,987 - 37,241) using method 2. The estimate of biomass from the standard method is 33,550 t (95% CI: 29,900 – 37,199).

Summaries for Plan Team

Year	Biomass	OFL	ABC	TAC	Catch[1]
2013	34,732	7,614	5,884	5,884	1,959
2014	33,550	7,448	5,569	5,569	1,290
2015	33,550	7,448	5,569		
2016	33,550	7,448	5,569		

[1] Current as of October 13, 2014, Source: NMFS AKRO Blend/Catch Accounting System.

Data Gaps and Research Priorities

Data gaps exist in sculpin species life history characteristics, spatial distribution and abundance in Alaskan waters. Most importantly no data on maximum age exists for the four main sculpin species in the GOA. Therefore, collections for age data on yellow Irish lord, great sculpin, bigmouth sculpin and plain sculpin are needed from the GOA. Over 90% of all sculpins caught in the fisheries of the GOA in surveys from 2004-2012 were from the genera *Myoxocephalus, Hemitripterus,* and *Hemilepidotus*. Collecting seasonal food habits data (with additional summer collections) would help to clarify the role of both large and small sculpin species within the GOA ecosystem. In addition, there is a need for GOA specific research on natural mortality of sculpin species. These data are necessary to improve management strategies for non-target species.

Tables

Table 1. Biomass estimates for plain sculpin, yellow Irish lord, great sculpin, and bigmouth sculpin, based on random effects model output.

Year	plain sculpin	yellow Irish lord	great sculpin	bigmouth sculpin
2003	2,162	13,692	6,914	5,340
2004	2,386	14,571	6,954	5,107
2005	2,633	15,507	6,995	4,884
2006	2,731	16,143	7,044	4,310
2007	2,832	16,805	7,092	3,803
2008	2,826	18,234	7,127	3,641
2009	2,819	19,783	7,162	3,486
2010	2,874	18,771	7,171	3,532
2011	2,931	17,810	7,180	3,579
2012	2,950	18,324	7,157	3,618
2013	2,970	18,853	7,134	3,657
Average proportion	0.09	0.55	0.23	0.13

Table 2. Composition of observed fishery catches, 2012-2014, and species composition of the 3-survey average biomass estimate of sculpin complex biomass, by species and/or genus. Fishery catch proportions are based on on fishery observer data. *Source: NORPAC database.* Most sculpins are not identified to species; therefore percentages represent relative proportions of those identified to species here.

taxon	GOA fishery catch composition 2012	2013	2014	proportion of average survey biomass
Hemitripterus* spp.*				
H. bolini (bigmouth)	17%	14%	12%	13%
***Hemilepidotus* spp.**				
Hemilepidotus unidentified	11%	24%	24%	-
H. hemilepidotus (RIL)	<1%	1%	< 1%	-
H. jordani (YIL)	61%	51%	56%	55%
H. spinosus (BIL)	<1%	< 1%	< 1%	-
***Myoxocephalus* spp.**				
Myoxocephalus unidentified	1%	1%	<1%	-
M. verrucosus (warty)	<1%	<1%	<1%	-
M. jaok (plain)	<1%	<1%	<1%	9%
M. polyacanthocephalus (great)	10%	9%	6%	23%
Malacottus spp.				
M. zonurus (darkfin)	<1%	<1%	1%	0%

** *Hemitripterus* spp. is likely all *H. bolini*.

§ Miscellaneous sculpins comprises unidentified sculpins as well as a number of minor sculpin species.

Table 3. Total catch estimates for Gulf of Alaska sculpins. Source: NMFS AKRO Blend/Catch Accounting System, as of November 21, 2014.

Year	Catch (t)
2006	582
2007	965
2008	1,932
2009	1,408
2010	916
2011	1,010
2012	1,002
2013	1,724
2014	1,470

Table 4. Species-specific catch estimates (t) and species-specific ABCs (t) for 2012, 2013, and 2014. The 2012 and 2013 estimates are based on random effect model output. *The 2014 estimate of biomass is based on the 2013 estimates. Other sculpin consists of all sculpin species other than the four specified here.

	Year	**plain sculpin**	**yellow Irish lord**	**great sculpin**	**bigmouth sculpin**	**Other sculpin**
	2012					
Estimated Biomass		2,950	18,324	7,157	3,618	946
ABC by species		655	3,051	1,192	602	158
catch		1	588	93	163	157
	2013					
Estimated Biomass		2,970	18,853	7,134	3,657	920
ABC by species		659	3,139	1,188	609	153
catch		6	779	129	205	605
	2014					
Estimated Biomass*		2,970	18,853	7,134	3,657	920
ABC by species		659	3,139	1,188	609	153
catch		1	810	90	167	402

Figures

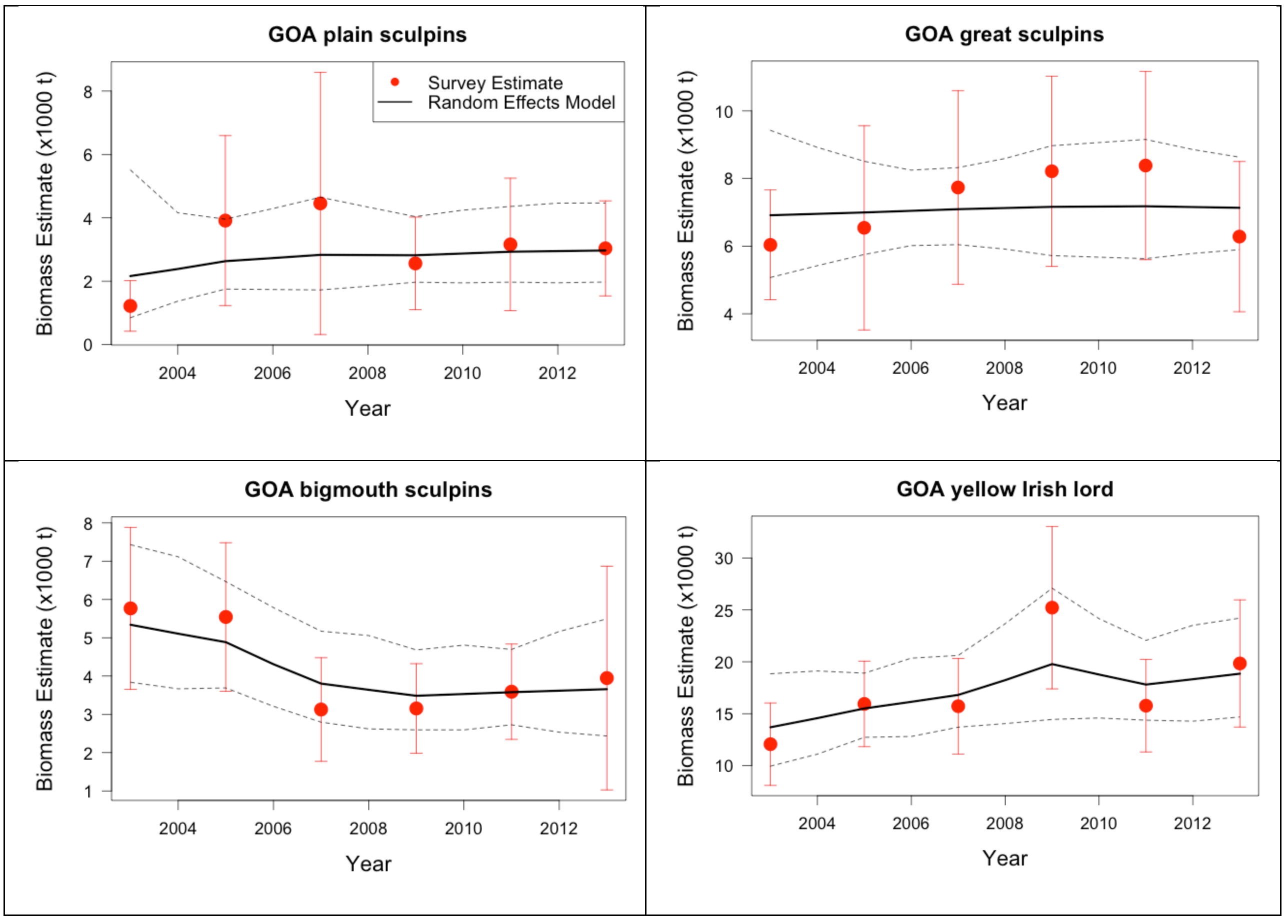


Figure 1. Random effects model estimates for the four most common GOA sculpin species, plain, great, and bigmouth sculpins, and yellow Irish lord. The figure legend in the top left panel applies to all panels; survey estimates of biomass and 95% confidence intervals are red and random effects estimates and 95% confidence intervals are black.

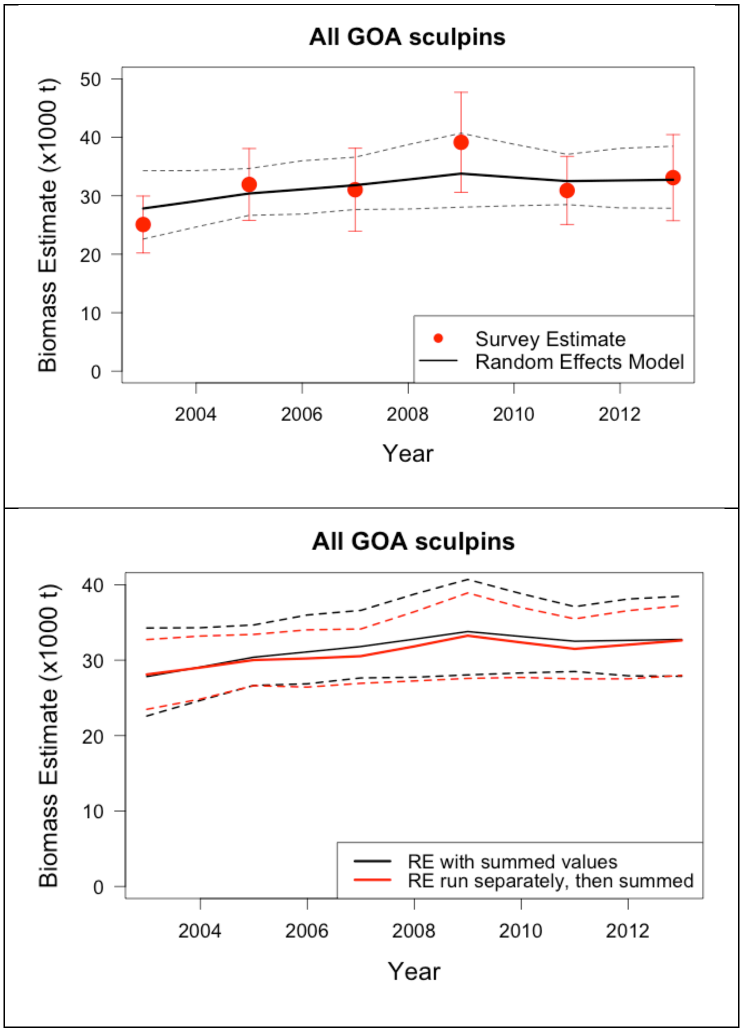


Figure 2. Survey and random effects model estimates for the four most common GOA sculpin species; bigmouth, plain, great, and yellow Irish lord. In the upper panel, the random effects model incorporated summed estimates of biomass and associated variance (black) and summed survey estimates and associated 95% confidence intervals are shown in red. In the lower panel, the black lines represent the random effects model estimate with summed biomass values (and 95% confidence intervals), while the red lines represent the summed results of four random effect models, each with data from one species, and 95% confidence intervals.

20. Assessment of the Shark stock complex in the Gulf of Alaska (Executive Summary)

Cindy A. Tribuzio, Peter Hulson, Katy Echave, Cara Rodgveller
November 2014

Executive Summary

The shark complex (spiny dogfish, Pacific sleeper shark, salmon shark and other/unidentified sharks) in the Gulf of Alaska (GOA) is assessed on a biennial stock assessment schedule. GOA sharks are a Tier 6 complex, however, the ABC and OFL for spiny dogfish are calculated using a Tier 5 approach with the survey biomass estimates considered a minimum estimate of biomass. The complex OFL is based on the sum of the Tier 5 and Tier 6 (average historical catch between the years 1997 - 2007) recommendations for the individual species. For this summary, we have updated the time series of catch through October 1, 2014 to reflect any changes that might have occurred in the Catch Accounting System (for the years 2003 – 2014). For further information regarding the assessment, please refer to the last full stock assessment, which is available online (Tribuzio et al. 2011, http://www.afsc.noaa.gov/REFM/docs/2011/GOAshark.pdf). A full stock assessment document will be presented in next year's SAFE report. A document was presented to the September Groundfish Plan Team and subsequently to the Science and Statistical Committee (SSC) at the October North Pacific Fisheries Management Committee (NPFMC) meeting, which addresses specific concerns expressed by the SSC regarding the potential effects of the observer program restructuring on the estimates of shark catch. That document is appended to this executive summary.

Summary of changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment inputs because this was an off-cycle year.

Changes in assessment methodology: There were no changes in assessment methodology.

Summary of Results

For 2015 we recommend the maximum allowable ABC of 5,989 t and an OFL of 7,986 t for the shark complex. Catch in 2013 was 2,165 t and in 2014 was 954 t (as of October 1, 2014). Prior to the 2013 Observer Restructuring, on average 23% of total shark catch occured after October 1. In 2013, 58% of the shark catch occurred after October 1. The complex was not subjected to overfishing last year. The ABC/OFL for the shark complex is the sum of the computations for the individual species. A Tier 5 approach is used for calculations of spiny dogfish, where exploitable biomass (B) is equal to the average of the biomass estimates from the last three trawl surveys (2009, 2011, 2013), the OFL = M*B, and the ABC = 0.75*OFL. The remaining shark species follow a traditional Tier 6 approach with the OFL = average historical catch (1997 – 2007) and the ABC = 0.75*OFL.

Spiny Dogfish Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)	0.097	0.097	0.097	0.097
Tier	6*	6	6	6
Biomass (t)	76,452	76,452	76,452	76,452
F_{OFL}	0.097	0.097	0.097	0.097
$maxF_{ABC}$	0.073	0.073	0.073	0.073
F_{ABC}	0.073	0.073	0.073	0.073
OFL (t)	7,416	7,416	**7,416**	7,416
maxABC (t)	5,562	5,562	5,562	5,562
ABC (t)	5,562	5,562	**5,562**	5,562
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing		n/a		n/a

*While spiny dogfish are a Tier 6 species, a Tier 5 approach is used. They are not in Tier 5 because the trawl survey biomass is not considered reliable for the species.

Pacific sleeper, salmon and other sharks Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
Tier	6	6	6	6
OFL (t)	571	571	**571**	571
maxABC (t)	427	427	427	427
ABC (t)	427	427	**427**	427
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing		n/a		n/a

Summaries for Plan Team

Species	Year	Biomass[1]	OFL[2]	ABC[2]	TAC	Catch[3]
Shark Complex	2013	76,979	8,037	6,028	6,028	2,165
	2014	76,452	7,986	5,989	5,989	954
	2015	76,452	7,986	5,989		
	2016	76,452	7,986	5,989		

[1]This is spiny dogfish biomass only, because the biomass estimates for the remaining shark species in the complex are not used for ABC and OFL calculations. The biomass used for the spiny dogfish ABC and OFL calculations for 2014 - 2016 is the average of the 3 most recent trawl survey biomasses (2009, 2011, and 2013).
[2]ABC and OFL are the sum of the individual species recommendations, Tier 6 (avg catch 1997-2007) for Pacific sleeper shark, salmon shark and other/unidentified sharks and a modified Tier 6 (biomass * M) for spiny dogfish.
[3]Catch as of October 1, 2014.

Responses to SSC and Plan Team Comments on Assessments in General

Because of the government shutdown in 2013, there was only sufficient time to compile SSC and Plan Team comments in last year's assessment. Since this is an "off" year and only an executive summary is presented, we respond here to priority comments. For comments relevant to or requiring a full assessment and/or model run, we will present responses in the next full assessment.

"The Teams recommend that stock assessment authors calculate biomass for Tier 5 stocks based on the random effects model and compare these values to status quo. In addition, the Teams recommend that the working group examine autocorrelation in subarea recruitment when conducting spatial simulations for evaluating apportionment." (Plan Team, September 2014)

Various approaches to calculate biomass based on the random effects model were presented to the Plan Team in September 2013. Continued efforts are underway to determine the most appropriate approach for the species in this complex and will be presented in the next full assessment. Survey data do not support this approach for all of the species in the complex, but the authors are investigating using the random effects model on the full complex as well as some of the individual species.

"The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC." (Plan Team, September 2013)

This will be included in the next full assessment.

"The SSC encourages assessment authors of stocks managed in Tier 5 to consider the recommendations found in the draft survey averaging workgroup report." (SSC, December 2012)

Please see the first comment in this section.

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

The authors of HFICE we unable to delineate the overlap between CAS and HFICE (Tribuzio et al. 2014). The HFICE authors recommended waiting for more years of restructured observer program data so that a comparison between the two procedures can be made. The SSC reviewed that recommendation again with regards to the GOA shark assessment at its October 2014 meeting and agreed with the authors to delay decisions about using HFICE until more data is available (see Appendix 20.A of the 2014 BSAI or GOA shark assessments).

SSC and Plan Team Comments Specific to this Assessment

"*With respect to the historical catch time series, the Team recommends that authors complete an evaluation of a comparison of HFICE estimates to the new time series."* (Plan Team, September 2014)

The authors are expecting to do a comparison of the new catch time series and the HFICE catch estimates when more data become available.

"Team members also suggested that the authors look into the feasibility of establishing discard mortality rates for shark species and summarize what data and studies have evaluated this." (Plan Team, September 2014)

There is very little literature on the discard mortality of the shark species in the BSAI or GOA. The limited research that has been conducted on spiny dogfish was based on animals captured during research trawls. Hook and line gear is the predominant gear type which catches both spiny dogfish and Pacific sleeper shark and research into the discard mortality from that gear type is necessary. There is ongoing research into the mortality of skates from hook and line gear type, which the authors will consider upon the completion of that project.

"The SSC discussed observed increases in shark catch in 2013 and the implications of incorporating shark catches in areas 649 and 659 in the assessment. With respect to adding catch from areas 649 and 659, the SSC recognizes that if the authors account for catch from additional regions, then they will need to consider how they will adjust the historical catch time series for shark removals from areas 649 and 659. Furthermore, the authors will need to consider the connectivity of the subset of the population in areas 649 and 659 to the other regions in the GOA. Finally, the authors will need to consider whether the catch reported in 2013 is representative of the historical catch or whether it was impacted by the new observer deployment program. The SSC requests a full stock assessment in 2014 because of the importance of these issues when estimating biological reference points for a species managed in Tier 6." (SSC, December 2013)
Please see Appendix 20.A for responses to these comments.

"The SSC notes that the CIE non-target review provided comments on the utility of continued exploration of the length-based and surplus production models. The SSC requests that the authors consider these comments and that they report to their justification for continuing or dropping this line of research. The SSC looks forward to the authors' responses to the CIE review comments." (SSC, December 2013)
Please see Appendix 20.A for responses to these comments.

"The Plan Team encourages the inclusion of the HFICE data in future models, and possibly some measure of fishing effort. Also, the Team suggested that using some alternative series (e.g., the ratio estimator for the period prior to 2003) may be useful for sensitivity analysis." (Plan Team, September 2012)
The authors do not agree with including HFICE catch estimates in models at this time. As described in Tribuzio et al. (2014), the HFICE estimates have a number of caveats associated with them that preclude inclusion. The authors are expecting to do a comparison of the new catch time series and the HFICE catch estimates when more data become available.

"Develop biomass indices for lowest tier species (Tier 5 for crab, Tier 6 for groundfish), such as sharks, and conduct net efficiency studies for spiny dogfish. Explore alternative methodologies for Tier 5 and 6 stocks, such as length-based methods or biomass dynamics models." (SSC, June 2012)
These investigations are underway. The authors are examining the use of tagging data to estimate survey catchability as well as a variety of biomass models for spiny dogfish.

"The assessment authors indicated that they intend to compare results from this demographic modeling analysis with results from planned biomass dynamic models and length-based models. The SSC encourages these efforts and urges the authors to incorporate these models into an improved stock assessment for spiny dogfish in the near future." (SSC, December 2011)
The biomass models are still being developed and are planned to be presented with a comparison to the demographic models in the next full assessment.

"The SSC recommends that total shark catches should be incorporated into the historical catch estimates and OFL/ABC determinations. This is an important issue, as HFICE estimates approach current ABCs." (SSC, December 2011)
The authors agree that the historical catch time series needs to include all sources of removals. However, the authors do not feel that the HFICE catch estimates are appropriate to use to recreate the historical time series. Please see Tribuzio et al. (2014) for descriptions of the concerns over using HFICE, including issues with double counting of catch. The authors are expecting to do a comparison of the new catch time series (i.e. with the new restructured observer program) and the HFICE catch estimates when more data become available, which may enable the recreation of a historical catch time series.

CIE Review of Non-Target Assessments, comments specific to this assessment

"Until recommendation 6 is addressed (review of bottom trawl survey) the bottom trawl surveys as combined are not generally useful as an absolute estimate of stock biomass; and further should not be used for management purposes until these issues are successfully resolved."
The authors agree and do not recommend moving any of the sharks in the BSAI to a Tier 5 method.

"If using the Tier 5 methods, investigate appropriate means of converting survey biomass to absolute biomass (i.e. catchability) and alternative Fmsy proxies besides F=M."
The authors are investigating the possibility of using tagging data to estimate survey catchability, as well as biomass models. Demographic models have been conducted and results will be compared to biomass models in the next full assessment.

"That all shark stocks in the BSAI/GOA area are split to have separate OFL/ABC by species and region, and that the OFL be based on the Tier 6 approach as the average catch of each species individually."
Splitting the shark species in the BSAI may not be feasible, as the ABC/OFLs would be quite small and likely difficult to manage.

"Using the maximum or average catch for Tier 6 may not be appropriate, alternatives could be to use an upper bound of a one-sided 95% or 99% confidence interval."
Alternatives to average and maximum catch (e.g. percentiles of the maximum catch) have been presented in the past for the shark assessments (e.g. Tribuzio et al. 2010a). For this assessment, we present and recommend using the average historical catch. The concern about using average catch is that, by rule, the catch will exceed the average in half of years. In the case of BSAI sharks, current catch is well below the historical average (the historical time series used to calculate ABCs and OFLs is from 1997-2007), and unlikely to increase to that level. Thus, using the average catch is currently the most appropriate option.

*"Dogfish: Clearly, there is some connection to the stock of dogfish residing the Pacific Northwest region just to the south. The connection with the assessed unit to the south should be explored further. One method of doing so would be to simply treat the BSAI through the NWP as a single unit. In the interim, average catch in the 1997-2007 should be feasible for both components. It is recognized that the GOA dogfish uses a biomass*M approach. However, in keeping with conclusion 1 the average catch is probably a more robust measure."*
A coast-wide assessment may be the most biologically appropriate strategy, but it is not possible at this time. The authors agree that using the average catch to calculate ABC/OFLs is more conservative than using an unreliable biomass estimate and assuming that F=M. However, the average catch approach will create ABC/OFLs likely to be exceeded, and given that spiny dogfish are a non-target species and recent changes to the observer program, average catch may not be appropriate. The authors recommend consideration of alternates to the F=M assumption (i.e. Fmsy from demographic models) or using a confidence interval around the average catch, such as 90% upper CI to set ABC/OFLs until a biomass model is approved.

"Salmon shark: they might be better off being assessed outside of the AFMC jurisdiction as a highly migratory species. Regardless, catches and encounters with inshore fisheries needs to be addressed sooner rather than later for this stock. In the interim, average catch can serve as a good proxy, but that suggestion is made grudgingly given how litter is known about this stock."
The authors agree that salmon shark (and the other shark species) may be more appropriately managed as highly migratory species; however, that system does not exist in the GOA or BSAI at this time. Further, catch in Alaska state fisheries is not accounted for, which needs to be addressed to accurately monitor the species.

"Pacific sleeper shark: What data are available is disturbing. While most of the individuals encountered are juvenile, the overall fishery dependent and independent data suggests a declining trend. As such,

while average catch is probably the only measure available for informing an OFL, SSC and managers should be aware that more precaution is warranted until further information is gathered."
The authors agree with the CIE reviewers that trends in Pacific sleeper shark catches are concerning and a more conservative approach may be warranted.

"It is appropriate to base the assessment of shark on Tier 6, and not Tier 5, since the AFSC bottom trawl surveys are directed at groundfish species. Also, the bottom trawl surveys do not necessarily cover the spatial range of many shark species as suggested by the large interannual variability in CPUEs, and therefore do not provide reliable biomass estimates."
The authors agree that the surveys do not reliably represent shark biomass, particularly for Pacific sleeper shark and salmon shark. Spiny dogfish is technically a Tier 6 species, but a Tier 5 approach is used to estimate ABC/OFLs, however, efforts are underway to develop methods to estimate a reliable biomass for this species.

Literature Cited

Tribuzio, C.A., K.B. Echave, C. Rodgveller, P. Hulson, and K.J. Goldman. 2011. Assessment of the Shark Stock Complex in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2011. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. Pgs. 1393 – 1446.

Tribuzio, C. A., J. R. Gasper, and S. K. Gaichas. 2014. Estimation of bycatch in the unobserved Pacific halibut fishery off Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-265, 506 p.

Appendix 20.A GOA and BSAI Shark Assessments

Cindy A. Tribuzio, Cara Rodgveller and Pete Hulson
September 2014

Executive Summary

At the December, 2013 council meeting, the SSC requested a full Gulf of Alaska (GOA) shark assessment for the 2014 assessment cycle (typically full assessments for the GOA sharks are conducted in odd years) to address questions specific to the assessment regarding the catch estimates based on data from the newly restructured observer program. We are presenting this document in lieu of a full assessment to address SSC comments for the following reasons: 1) there was no GOA survey in 2014; 2) the shark complex is dominated by spiny dogfish in the GOA and ABC/OFL calculations are based on the survey biomass for that species; 3) the contribution to the ABC/OFL from the remaining Tier 6 species (catch history) is small (~7% in 2013), thus the impacts to the complex from adjustments (if any) in the ABC/OFL from the observer restructuring would be small; and 4) with only 1 year of the new time series of catch estimates, it is not reasonable to make comparisons to the old time series. A full assessment for the Bering Sea/Aleutian Islands (BSAI) sharks is planned, as is normal for an even year.

Aside from the request for a full GOA assessment, the SSC made the below comments:

"The SSC discussed observed increases in shark catch in 2013 and the implications of incorporating shark catches in areas 649 and 659 in the assessment. With respect to adding catch from areas 649 and 659, the SSC recognizes that if the authors account for catch from additional regions, then they will need to consider how they will adjust the historical catch time series for shark removals from areas 649 and 659. Furthermore, the authors will need to consider the connectivity of the subset of the population in areas 649 and 659 to the other regions in the GOA. Finally, the authors will need to consider whether the catch reported in 2013 is representative of the historical catch or whether it was impacted by the new observer deployment program. The SSC requests a full stock assessment in 2014 because of the importance of these issues when estimating biological reference points for a species managed in Tier 6.

The SSC notes that the CIE non-target review provided comments on the utility of continued exploration of the length-based and surplus production models. The SSC requests that the authors consider these comments and that they report to their justification for continuing or dropping this line of research. The SSC looks forward to the authors' responses to the CIE review comments."

The sections below address these comments. We address the above comments in regards to the BSAI areas as well.

SSC comments regarding the impacts of observer restructuring on the shark assessments

The SSC comments can be paraphrased into four questions:

1) Are the 2013 estimates of shark catch comparable to the historical time series of estimated shark catch?
2) Will (how will) the catch history time series be adjusted if areas 649/659 are included in assessment?
3) Is there connectivity between sharks in 649/659 and the other regions of the GOA?
4) How do these issues affect Tier 6 (catch history) species ABC/OFL estimates?

1) Are the 2013 estimates of shark catch comparable to the historical times series of estimated shark catch?

The restructured observer program was put into effect to address longstanding concerns associated with the old program about data quality and cost equity among participants (77 FR 770062). Implementation of this program is considered an improvement over the previous observer system and an analysis of the first year under the restructured program was presented at the June 2014 council meeting (Faunce et al. 2014). The report presented to the Council explains how the observer program changed, thus we will not be covering the finer points of the restructured observer program in this document. The change from the previous observer deployment regime may result in relatively small changes in estimated catch for target species, but for sharks, there is potential for significant additional estimated catch. In particular, the restructuring includes newly available catch estimates from the Pacific halibut (*Hippoglossus stenolepis*) IFQ fishery, which was not available prior to 2013 due to the lack of observer coverage on vessels participating in this fishery. Here we report the estimated catch from 2003-2012 (historical time series) and from 2013 (restructured observer program data). However, we make no conclusions here regarding changes in the catch time series because of confounding issues in the catch estimates which may or may not be a result of observer restructuring.

The shark assessments include three main species of sharks: spiny dogfish (*Squalus suckleyi*), the Pacific sleeper shark (*Somniosus pacificus*) and the salmon shark (*Lamna ditropis*). However, the salmon shark is rare in federal fisheries and thus this response will focus on spiny dogfish and Pacific sleeper shark. The majority of shark catch occurs in the GOA, hence this response focuses primarily on the GOA region, but for informational purposes we are also including data for shark species in the BSAI.

The restructured observer program covers previously unobserved vessels operating in the Pacific halibut IFQ fishery and small vessels (40-60 ft). In previous assessments we have speculated that these sectors of the fleet (smaller vessels, Pacific halibut IFQ vessels) were a substantial source of catch for sharks in the GOA (Tribuzio et al. 2014), and that the catch estimates from the Alaska Regional Office Catch Accounting System (CAS) were not representative of true catch because of the lack of observer coverage on those vessels and because CAS programming procedures did not include Pacific halibut-only landings. In 2013, modifications were made to CAS so that catch and bycatch estimates could be made for the IFQ Pacific halibut fishery. These changes resulted in shark catch being estimated for all IFQ trips, including those on vessels <60 ft, which comprise a substantial portion of the IFQ fleet and those vessels which do not also land federal groundfish species (which were included prior to 2013). Estimates of shark catch in CAS (both spiny dogfish and Pacific sleeper sharks) on vessels <60 ft substantially increased in the GOA in 2013 (Figure 1) and proportionally contributed to the total catch more than in any other year (Figure 2). In the BSAI, the increase in estimated catch in 2013 was relatively small, but the portion of the catch resulting from vessels <60 ft was substantially larger (Figures 1 & 2).

In 2013, the estimated shark catch in the Pacific halibut fishery was relatively large, possibly due to the new observer coverage and changes in the estimation methods made in CAS. In the GOA, 2006 and 2009 (similarly in 2003 and 2008 in the BSAI) also had large catch estimates of sharks in the Pacific halibut fishery (Figure 3). While the Pacific halibut IFQ fleet was unobserved prior to 2013, catch estimates from vessels landing Pacific halibut would be generated by CAS when those vessels would also land federal groundfish and the catch estimates were based only on the federal groundfish. The anomalous catches have been investigated by staff at the Alaska Regional Office. In general, prior to 2013, there is little to no observer data available to calculate a rate of shark catch for the Pacific halibut target fishery, thus data were from observed mixed sablefish (*Anoplopoma fimbria*) and Pacific halibut IFQ trips. The observer data were used to estimate shark discards when a groundfish species was landed using post-strata described in Cahalan et al. (2010). In brief, post-stratification rules in CAS aggregate observer data to create discard rates using information of the highest possible resolution of spatial and temporal scale that corresponds with the trip characteristics of landed catch. However, when observer data with similar characteristics to the landed catch are lacking, discards must still be estimated. The post-stratification rules in CAS allow estimates to be made using available observer information, which may require observer data to be aggregated across an entire FMP area to create a bycatch rate and estimate (Cahalan et al. 2010). For example, in 2006 and 2009 in the GOA and 2003 and 2008 in the BSAI, the aggregated post-stratification discard rates were driven by a small number of observed hauls in which there were relatively large catches of sharks and a small amount of groundfish retained, resulting in a large shark to groundfish rate. This rate represented the best available information from which to estimate, but it also resulted in relatively large estimates of shark catches. This scenario is not the case in 2013, where there was observer data available to create estimates of shark catch from the Pacific halibut fleet and CAS incorporates landing and discard information from the Pacific halibut fishery. However, it is not possible to determine if the large estimated shark catch in the 2013 Pacific halibut target group was an anomaly, a change in fishing behavior, or a result of the restructured observer program. Regardless, the catch accounting is more comprehensive in 2013 than prior years.

In 2013, the estimated catch of sharks in areas 649/659 also substantially increased (Figure 4). These areas also include the Pacific halibut IFQ fishery, which may occur in conjunction with state managed fisheries (e.g., a trip may include both Chatham sablefish and Pacific halibut). Shark discards are estimated on any trips where a groundfish species or Pacific halibut are landed, thus estimates were made regardless of whether the primary species landed was a state-managed species. It is not possible to determine if the increased 2013 catch estimates are a result of a change in fishing behavior or the observer restructuring, since discards were estimated for a portion of Pacific halibut fleet prior to 2013. The catch in these two areas is relatively small when compared to the total shark catch: on average, 3% of total shark catch prior to 2013 and 10% in 2013. A longer time series is needed to understand catch trends.

The 2013 catch estimates are not directly comparable to the prior 2013 catch estimates. The methods CAS uses to estimate catch of non-retained species have changed. Not only are trips where only Pacific halibut is landed included in CAS, but Pacific halibut is included in the calculation of discard rates. Two procedures would need to be completed to accurately compare 2013 catch estimates to historical catch estimates. First, the estimated catch resulting from Pacific halibut only landings will have to be removed. Second, a new discard rate will have to be calculated which does not include Pacific halibut. Such an analysis is beyond the scope of this document, but may also not be feasible given the structure of CAS.

2) Will (how will) the catch history time series be adjusted if areas 649/659 are included in the federal catch?

Catch of sharks in the Prince William Sound and inside waters of Southeast Alaska (NMFS areas 649/659) comes from a mixture of federal and state managed fisheries that are sometimes landed on the same trip, including Pacific halibut IFQ. Prior to 2013, if a vessel landed both Pacific halibut IFQ and groundfish on the same trip, a discard estimate was generated based on the federal groundfish landings only. However, if a vessel only landed Pacific halibut, discard estimates were not calculated. Starting in 2013, discards were estimated for all trips where Pacific halibut or groundfish species were landed, and estimates are based on both Pacific halibut and groundfish landings. The only trips where discards were not estimated are those containing only non-groundfish species (e.g., lingcod). Due to the complex mixture of fishing activity in state waters, and the lack of observer information on Pacific halibut vessels prior to 2013, the estimated catch in federal fisheries in 649/659 has historically not been included in the shark assessment. While it is not possible to determine if the recent increase in catch in these areas is a result of the observer restructuring and changes to CAS, an anomaly (meaning not representative of the time series), or a change in fishing behavior, these catch estimates are generated when landings of groundfish and Pacific halibut occur (i.e. federal landings) and we recommend that they be included in the GOA federal shark assessment. Further, there is no accounting of shark catch by the State of Alaska and the sharks occurring in areas 649/659 are not biologically distinct from the other regions of the GOA (see below).

Estimates of shark catch in federal groundfish fisheries in areas 649/659 are available for the historical time series. The estimated shark catch in 649/659 over the entire time series is small relative to the other areas of the GOA (Figure 4). At this point, it is unknown if the higher magnitude of 649/659 shark catch estimates (10% of total GOA shark catch) is representative of the new time series or an anomaly. Regardless, including the historical estimated catch from those areas, will have a small impact on the total estimated shark estimated catch.

The addition of estimated catch from the Pacific halibut IFQ fishery may result in an increase in estimated shark catch, particularly in areas 649/659, in which case the historical time series of catch used will need to be adjusted. At this time, we are not prepared to speculate on the appropriate method for making adjustments. Any adjustment methods will need to consider separating estimated catch from vessels fishing only Pacific halibut (added to CAS in 2013) from those that landed both Pacific halibut and groundfish on a trip (in CAS prior to 2013), as well as compare HFICE catch estimates (currently only available 2001-2011, Tribuzio et al. 2014) to the 2013 and forward time series.

We recommend delaying adjusting the time series of estimated shark catch in areas 649/659 for three reasons: 1) it would be unwise to conduct such a calculation based on one year of data under the restructured observer program, and it is unknown how the restructured time series compares to the period prior to restructuring; 2) the estimated shark catch in areas 649/659 is small relative to the estimated shark catch in the rest of the GOA and the impact of including that catch in the total estimated shark catch is small; and 3) it appears likely the observer program restructure will continue to evolve over the next several years. Therefore, it is preferable to delay until sufficient data are available to better assess the magnitude of additional catches and the best method of adjustment.

3) Is there connectivity between sharks in 649/659 and the other regions of the GOA?

There are a number of biological justifications for including 649/659 estimated catches into the assessment. Research on the movement and genetics of the shark species has indicated that the populations are mixed across the full extent of the Gulf of Alaska, including areas 649/659, and much of the North Pacific Ocean. A stock structure analysis was presented for the GOA and BSAI shark assessments in September, 2012 (Tribuzio et al. 2012). The stock structure analysis demonstrated that there is no biological justification for managing the shark species as separate stocks within the GOA (including areas 649/659).

Tagging studies have provided an indication of the connection of these species within and outside of 649/659. Spiny dogfish are highly migratory, with some animals overwintering in GOA waters and others undertaking large migrations as far south as southern California and west to Japan. Spiny dogfish moved both into and out of area 659, and while no fish were tagged in area 649, tagged fish did move into area 649 (Tribuzio, unpublished data). Tagging studies of Pacific sleeper sharks suggested that they had potential for movements into and out of 649/659. Hulbert et al. (2006) showed Pacific sleeper sharks moving into 649 and the data suggested that they likely move regularly in and out of the area. Tagging of Pacific sleeper sharks within area 659 showed that they are highly mobile and have potential to move between areas. Detailed analysis of the tagging effort in area 659 is still underway (D. Courtney, NMFS, SEFSC, pers. comm.).

Genetic analyses support the tagging data, suggesting that the shark species are mixed across the extent of the eastern North Pacific Ocean. For example, Verissimo et al. (2010) did not find any discrete stocks across the range in the North Pacific Ocean for spiny dogfish. Similarly, preliminary results of an ongoing genetics study of Pacific sleeper sharks show that there are two lineages of Pacific sleeper sharks, but that they are evenly mixed across the range of the species, including areas 649/659 (S. Wildes, NMFS, AFSC pers. comm.).

4) How do these issues affect Tier 6 (catch history) species ABC/OFL estimates?

The ABC/OFLs for the shark complex in the GOA are calculated using a blend of Tier 5 and 6 approaches. The spiny dogfish ABC and OFL are calculated using a Tier 5-like approach (but they are still considered a Tier 6 species), where OFL=survey biomass**M* and ABC =OFL*75%, which is then summed with the average catch history ABCs and OFLs of other shark species to arrive at a combined ABC and OFL for the whole complex. The majority of the estimated shark catch in the GOA is from spiny dogfish (total GOA estimated shark catch in 2013 was 2,420 t, of which 2,178 t was spiny dogfish, Figure 5), as well as much of the ABC and OFL coming from that species (ABC = 6,028 t, of which 5,600 t was spiny dogfish). Therefore, adjustments to the catch history in the GOA will likely have a small impact on the complex ABC/OFL because the Tier 5-like approach for spiny dogfish is based on survey biomass rather than catch history and this component represents the majority of ABC/OFL.

In the BSAI, the entire complex ABC/OFL is based on the maximum of the catch history. However, the impacts of the observer restructuring are likely less substantial. Estimated shark catch in the BSAI (2013 total estimated shark catch = 116 t, of which 69 t was Pacific sleeper shark) is substantially lower than the ABC of 1,022 t (Figure 5). Thus, the potential increase in catch from observer restructuring is unlikely to cause the shark catch in the BSAI to approach the ABC. When there is sufficient data (i.e. more years of catch estimates from the restructured observer program), the historical time series of catch may need to be corrected. It is not appropriate at this time to correct the historical time series based on only one year of data.

CIE comments regarding the shark assessments

The CIE reviewers did not have extensive comments regarding the shark assessments. Below are the key comments from the reviewers' documents and brought forward in discussions during the meeting.

From reviewer comments:

1) *Until the relative biomass from the various trawl surveys can be appropriately converted to absolute biomass, it may be better to use Tier 6 methods for sharks.*

   Spiny dogfish ABC and OFLs in the GOA are calculated based on a Tier 5-like approach (but still considered a Tier 6 species). All other species specific ABCs and OFLs are catch history based (average catch in the GOA and maximum historical catch in the BSAI). The Tier 5-like approach for spiny dogfish was adopted for the 2011 fishery (see the SSC minutes from the 2010 December Council meeting: http://www.npfmc.org/wp-content/PDFdocuments/minutes/SSC1210.pdf), based on the 2010 stock assessment (Tribuzio et al. 2010). The justification was that due to pelagic and transitory nature of spiny dogfish it was likely that trawl catchability was low and that the survey biomass estimates were likely a minimum biomass estimate.

2) *If using the Tier 5 methods, investigate appropriate means of converting survey biomass to absolute biomass (i.e. catchability) and alternative Fmsy proxies besides F=M.*

   The authors are investigating approaches for converting survey biomass estimates to absolute biomass. These include length based and surplus production models, as well as age-structured models. We are not presenting these models for PT and SSC review yet, as we plan to incorporate results of ongoing projects. These include results of an NPRB funded ageing study and an investigation into trawl catchability using tag data.

   An alternative F_{msy} proxy of F=0.04 was presented in the 2010 and 2011 assessments, based on demographic analyses (Tribuzio and Kruse, 2011), but were not accepted by the PT and SSC. If the alternative were applied to the most recent 3 year biomass, the ABC/OFL for spiny dogfish would be 2,294 and 3,058 t, respectively (down from 5,562 and 7,416 t, respectively). The resulting total complex ABC/OFL would be 2,722 and 3,629 t, respectively.

3) *Using the maximum or average catch for Tier 6 may not be appropriate; alternatives could be to use an upper bound of a one-sided 95% or 99% confidence interval.*

   Alternatives to average and maximum catch have been presented in the past (e.g. Tribuzio et al. 2010), for the shark and other assessments (e.g. GOA Octopus). However, this is an issue we hope to revisit for the 2015 GOA assessment. A recent study came out demonstrating how static catch history methods have a high probability of resulting in overfishing (Carruthers et al. 2014). Catch based methods with a dynamic adjusted scalar or depletion correction methods resulted in a substantially higher probability of resulting in an overfished population (defined as B/B_{msy}<50%). We plan to explore these depletion methods for Tier 6 alternatives.

4) *Other suggestions: species specific ABC/OFLs; incorporating state of Alaska survey data; coast wide spiny dogfish assessment; move salmon sharks to a highly migratory group for management*

   Unfortunately, many of these suggestions are not possible at this time. Species specific ABC/OFLs are likely too small to be managed for many of the shark species and moving the salmon shark to a highly migratory group is not possible because we do not have such a group in the Alaska region. We are beginning to compile data from state of Alaska surveys to incorporate into the assessment. A coast wide assessment for spiny dogfish makes sense biologically, but the infrastructure is not in place for such a management plan at this time.

Other items that came up during presentations/discussions

5) *Data does not support building a spiny dogfish model at this time*

   See response to #2 above.

6) *Need to continue efforts to improve age estimates*

   The authors are involved in a research project to improve age estimates. This project is funded by the North Pacific Research Board and is scheduled to conclude January of 2015. The goals of the project are to investigate a new method for ageing spiny dogfish and determine if growth estimates can be improved (i.e. reduce the uncertainty in the age estimates and growth parameters).

7) *Need to get more years of new observer data before constructing catch history to use in model*

   The authors agree with this comment, see discussion above.

8) *Investigate Pacific sleeper shark declining catches and survey indices.*

   This is an important topic that is currently under investigation.

Acknowledgements

We would like to acknowledge Craig Faunce and Jennifer Cahalan (FMA) and Jason Gasper and Jennifer Mondragon (AKRO) for their efforts to help us understand the observer restructuring and CAS and their assistance in writing this document.

Literature Cited

Cahalan, J., J. Mondragon, and J. Gasper. 2010. Catch sampling and estimation in the Federal groundfish fisheries off Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-205, 42 p.

Carruthers, T. R., A. E. Punt, C. J. Walters, A. MacCall, M. K. McAllister, E. J. Dick and J. Cope. 2014. Evaluating methods for setting catch limits in data-limited fisheries. Fisheries Research. 153:48-68.

Faunce, C., J. Cahalan, J. Gasper, T. A'mar, S. Lowe, F. Wallace, and R. Webster. 2014. Deployment performance review of the 2013 North Pacific Groundfish and Halibut Observer Program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-281, 74 p.

Hulbert, L. B., Sigler, M. F., and Lunsford, C. R. 2006. Depth and movement behaviour of the Pacific sleeper shark in the northeast Pacific Ocean. Journal of Fish Biology 69 (2), 406-425.

Tribuzio, C. A., K. Echave, C. Rodgveller, J. Heifetz, K. J. Goldman. 2010. Assessment of sharks in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Tribuzio, C. A., K. Echave, C. Rodgveller, and P. J. Hulson. 2012. Assessment of the shark stock complex in the Bering Sea and Aleutian Islands. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands for 2012. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Tribuzio, C. A., J. R. Gasper, and S. K. Gaichas. 2014. Estimation of bycatch in the unobserved Pacific halibut fishery off Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-265, 506 p.

Verissimo, A., J.R. McDowell, and J.E. Graves. 2010. Global population structure of the spiny dogfish, *Squalus acanthias*, a temperate shark with an antitropical distribution. Molecular Ecology. 19:1651-1662.

Weng, K.C., A. Landiera, P.C. Castilho, D.B. Holts, R.J. Schallert, J.M. Morrissette, K.J. Goldman, and B.A. Block. 2005. Warm sharks in polar seas: satellite tracking from the dorsal fins of salmon sharks. Science 310:104-106.

Figures

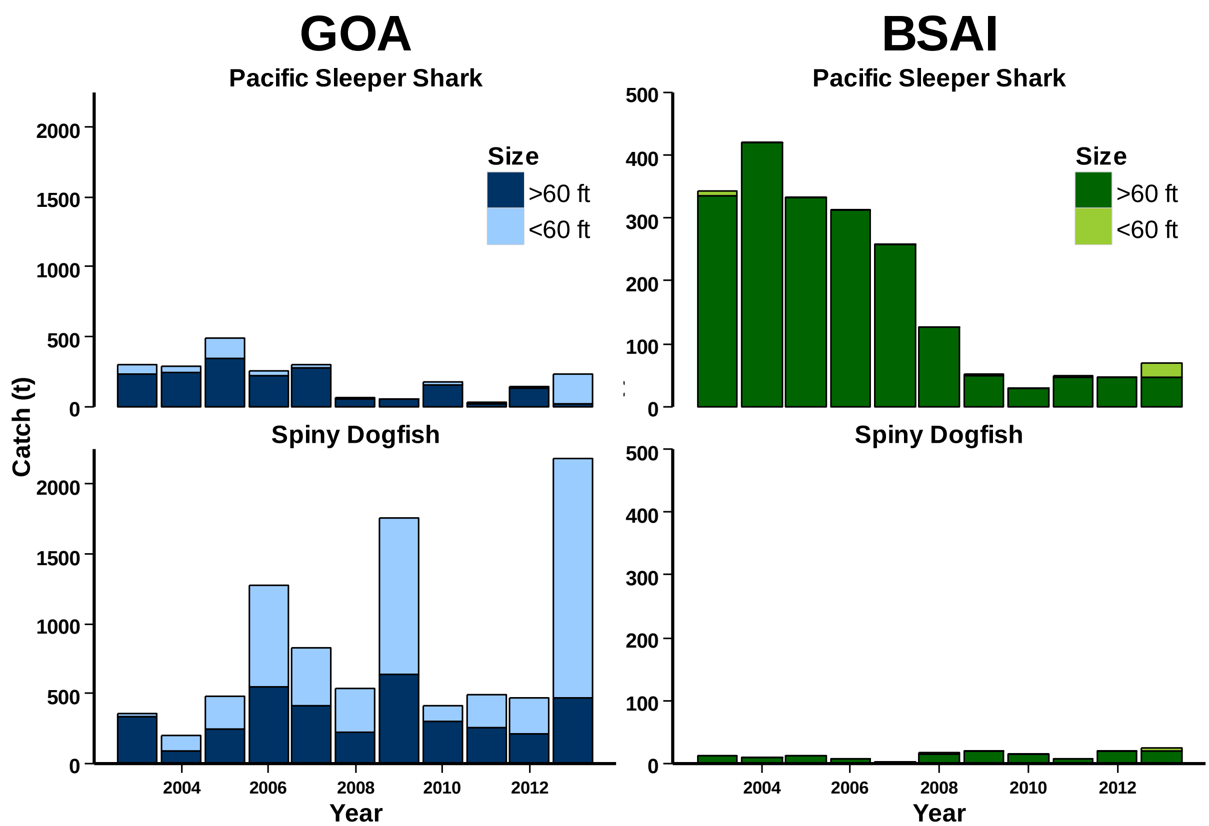


Figure 1. Catch Accounting System catch estimates (t) for Pacific sleeper shark and spiny dogfish in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) by vessel size class.

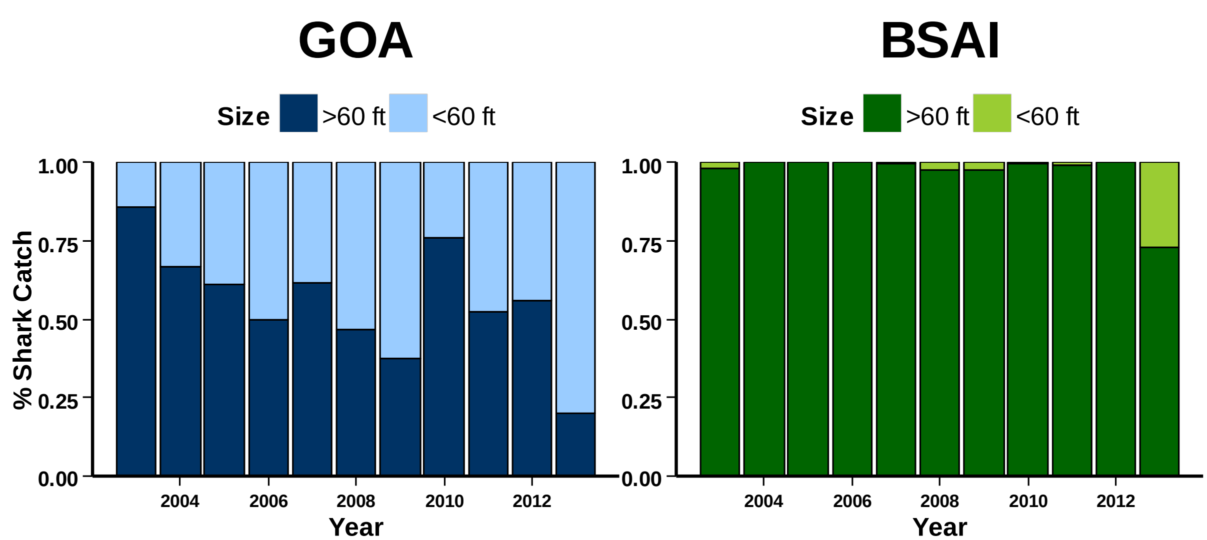


Figure 2. Proportional representation of shark catch by vessel size.

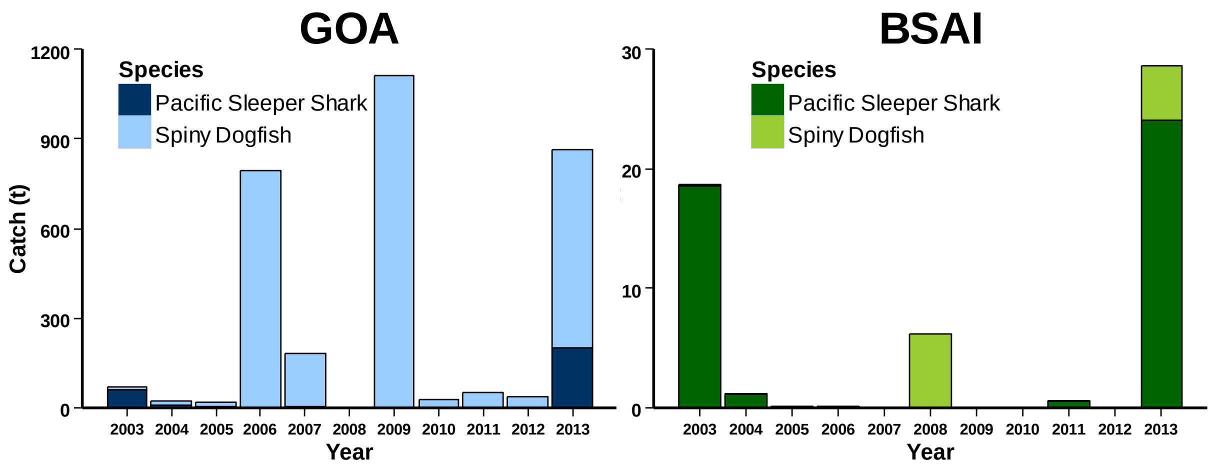


Figure 3. Catch Accounting System catch estimates (t) of spiny dogfish and Pacific sleeper shark in the Pacific halibut target category. Prior to 2013, estimated catch in the Pacific halibut target category was derived from vessels fishing both Pacific halibut and groundfish (generally sablefish IFQ); beginning in 2013 the estimated catches include vessels fishing only Pacific halibut IFQ.

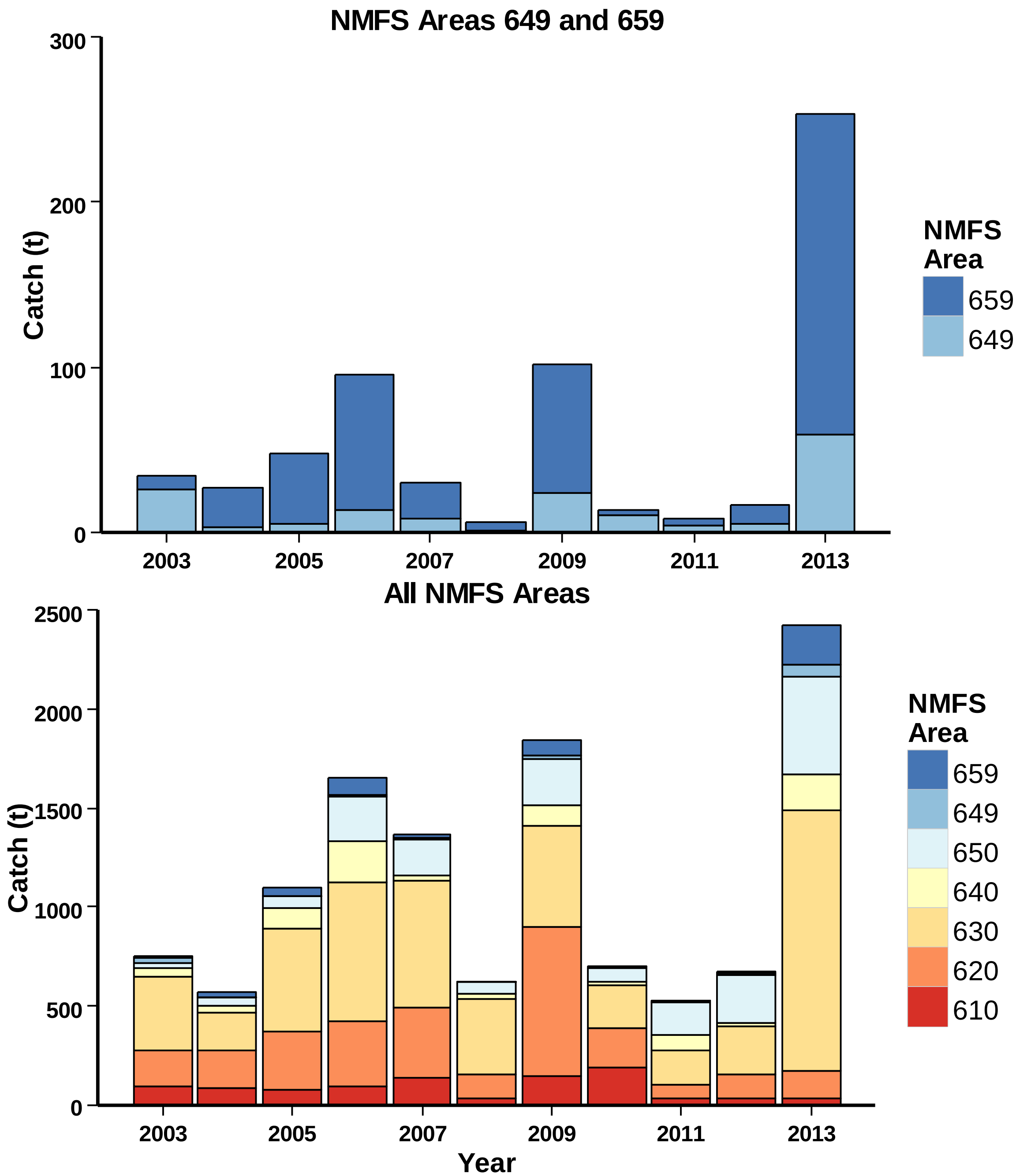


Figure 4. Top panel: Catch Accounting System catch estimates (t) for all sharks in NMFS Areas 649 and 659. Bottom panel: Catch Accounting System catch estimates (t) for all sharks from all Gulf of Alaska NMFS Areas.

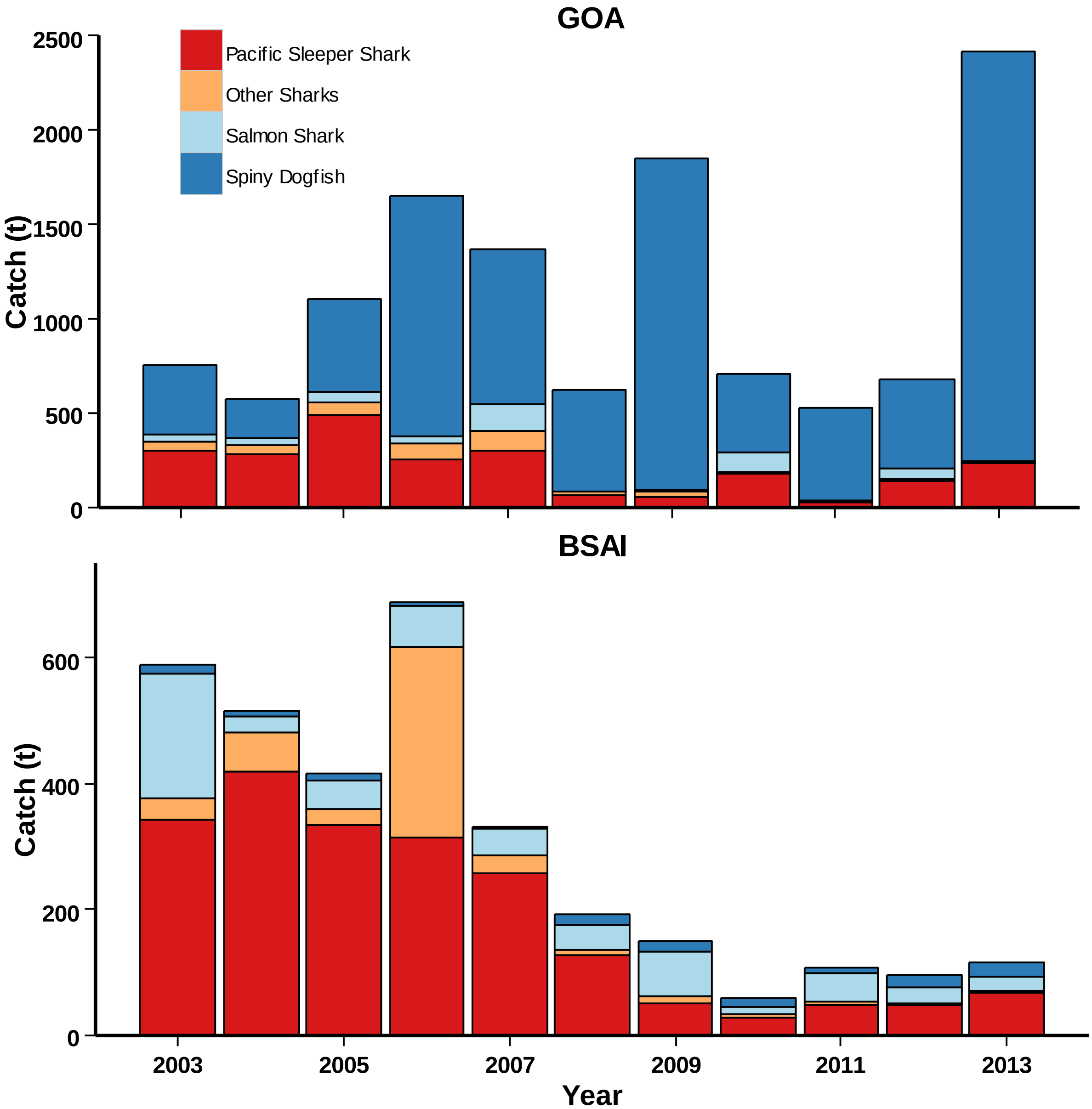


Figure 5. Catch Accounting System catch estimates (t) for all sharks in the GOA (top) and BSAI (bottom).

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21. Assessment of the squid stock complex in the Gulf of Alaska

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Executive Summary

Squids in the Gulf of Alaska (GOA) are managed as a single stock complex comprising approximately 15 species. Harvest recommendations are based on an historical catch approach setting OFL equal to maximum historical catch during 1997 - 2007 and ABC equal to 0.75 * OFL. Gulf of Alaska squids are on a biennial stock assessment schedule, with full assessments due in odd years. The most recent full assessment is from 2011 and is available online (www.afsc.noaa.gov/REFM/docs/2011/GOAsquid.pdf).

Summary of Changes

1) Total catch and retention rates have been updated through October 2014.

Summary of Results

1) The amount of squid catch in 2013 & 2014 is similar to recent years except 2012, when it was anomalously low (Table 2). Squid catch patterns are also similar to earlier years (Tables 3-4). Squid retention rates are variable but indicate that many captured squids are retained (Table 5).

	last year		**this year**	
Quantity/Status	*2014*	*2015*	**2015**	2016
Specified/recommended Tier	*6*	*6*	**6**	6
maximum historical catch 1997-2007	*1,530*	*1,530*	**1,530**	1,530
Recommended OFL (max. hist. catch; t)	*1,530*	*1,530*	**1,530**	1,530
Maximum ABC (0.75*OFL; t)	*1,148*	*1,148*	**1,148**	1,148
Recommended ABC (0.75*OFL; t)	*1,148*	*1,148*	**1,148**	1,148
Status	*As determined last year for:*		As determined this year for:	
	2012	*2013*	2013	2014
Overfishing	*No*	*n/a*	No	n/a
(for Tier 6 stocks, data are not available to determine whether the stock is in an overfished condition)				

Tables

Table 1. Biomass estimates (t) of *Berryteuthis magister*, unidentified squids, and total squids from the GOA bottom trawl survey, 1984-2013. CV = coefficient of variation.

	squid unidentified		*B. magister*		total squids	
	biomass	CV	biomass	CV	biomass	CV
1984	546	0.35	2,762	0.15	3,308	0.14
1987	577	0.30	4,506	0.34	5,083	0.30
1990	276	0.43	4,033	0.17	4,309	0.16
1993	1,029	0.73	8,447	0.13	9,476	0.14
1996	26	0.28	4,884	0.14	4,911	0.14
1999	254	0.46	1,873	0.13	2,127	0.13
2001	703	0.62	5,909	0.30	6,612	0.27
2003	71	0.23	6,251	0.18	6,322	0.18
2005	249	0.51	4,650	0.18	4,899	0.18
2007	310	0.45	11,681	0.20	11,991	0.20
2009	188	0.61	8,415	0.16	8,603	0.16
2011	392	0.65	4,040	0.13	4,431	0.14
2013	568	0.80	9,675	0.16	10,243	0.16

Table 2. Estimated total catches of squid (t) in the Gulf of Alaska groundfish fisheries, 1990-2014 (1990 is the earliest year for which GOA squid catch data are available). This table also includes annual TACs for the Other Species complex and estimated Other Species catch, 1990-2010, as well as specifications for the squid complex beginning in 2011. **Squid catch reported here includes catch in areas 649 & 659, which do not count against the squid TAC.**

	squid catch (t)	Other Species catch (t)	Other Species TAC (t)	squid TAC (t)	squid ABC (t)	squid OFL (t)	management method
1990	60	6,289	n/a				Other Species TAC
1991	117	5,700	n/a				Other Species TAC (incl. Atka)
1992	88	12,313	13,432				Other Species TAC (incl. Atka)
1993	104	6,867	14,602				Other Species TAC (incl. Atka)
1994	39	2,721	14,505				Other Species TAC
1995	25	3,421	13,308				Other Species TAC
1996	42	4,480	12,390				Other Species TAC
1997	97	5,439	13,470				Other Species TAC
1998	59	3,748	15,570				Other Species TAC
1999	41	3,858	14,600				Other Species TAC
2000	19	5,649	14,215				Other Species TAC
2001	91	4,804	13,619				Other Species TAC
2002	43	3,748	11,330				Other Species TAC
2003	97	6,266	11,260				Other Species TAC
2004	162	1,705	12,942				Other Species TAC (no skates)
2005	636	2,513	13,871				Other Species TAC (no skates)
2006	1,530	3,881	13,856				Other Species TAC (no skates)
2007	416	3,035	4,500				Other Species TAC (no skates)
2008	98	2,967	4,500				Other Species TAC (no skates)
2009	345	3,188	4,500				Other Species TAC (no skates)
2010	139	1,724	4,500				Other Species TAC (no skates)
2011	238			1,148	1,148	1,530	squid complex
2012	22			1,148	1,148	1,530	squid complex
2013	361			1,148	1,148	1,530	squid complex
*2014**	*146*			1,148	1,148	1,530	squid complex

Data sources and notes: squid catch 1990-1996, Gaichas et al. 1999; squid catch 1997-2002, AKRO Blend; squid catch 2003-2014, AKRO CAS; Other Species catch, AKRO Blend and CAS; TAC, AKRO harvest specifications. Other Species catch from 1990-2003 does not include catch of skates in the IFQ Pacific halibut fishery, and after 2003 includes no skate catch at all.

* 2014 catch data are incomplete; retrieved October 8, 2014.

Table 3. Estimated catch (t) of all squid species in the Gulf of Alaska combined by target fishery, 2003-2014. Data source: AKRO CAS.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	***2014****
pollock	68	145	632	1,518	410	92	321	129	209	7	347	*122*
rockfish	9	12	2	10	3	5	14	4	12	15	10	*15*
sablefish	0	4	0	0	1	0	0	0	0	0	1	*0*
rex sole	2	0	0	0	0	0	2	3	1	0	1	*0*
Pacific cod	14	0	0	0	0	0	0	0	0	0	1	*0*
arrowtooth	3	1	2	1	2	0	7	2	16	0	0	*8*
flathead sole	0	0	0	0	0	0	0	0	0	0	0	*0*
Atka	0	0	0	0	0	0	0	0	0	0	0	*0*
deep flat	0	1	0	0	0	0	0	0	0	0	0	*0*
shallow flat	0	0	0	0	1	0	1	0	0	0	0	*0*
GOA total	**97**	**162**	**636**	**1,530**	**417**	**98**	**345**	**139**	**238**	**22**	**361**	***146***

* 2014 catch data are incomplete; retrieved October 8, 2014.

Table 4. Estimated catch (t) of all squid species in the Gulf of Alaska combined by NMFS statistical area, 1997-2014. Data sources: 1997-2002, AKRO Blend; 2003-2014, AKRO CAS. The 2014 data are incomplete; retrieved October 8, 2014. **Note that catch from areas 649 and 659 in the GOA are not currently counted towards the squid TAC.**

	NMFS statistical area							
	WGOA	**CGOA**		**EGOA**				**GOA total**
	610	**620**	**630**	**640**	**649**	**650**	**659**	
1997	46	4	36	2	6	4	0	98
1998	18	8	21	3	9	0	0	59
1999	6	11	14	2	8	0	0	41
2000	7	2	8	2	0	0	0	19
2001	19	54	17	1	0	0	0	91
2002	19	12	10	1	0	0	0	42
2003	19	43	13	2	20	0	0	97
2004	15	129	11	2	5	0	0	162
2005	13	607	11	2	3	0	0	636
2006	12	1,485	14	5	14	0	0	1,530
2007	3	403	5	0	0	0	0	412
2008	4	77	2	0	0	0	0	84
2009	12	315	10	1	7	0	0	345
2010	3	121	5	2	8	0	0	139
2011	8	201	18	4	7	0	0	238
2012	5	6	5	2	4	0	0	22
2013	1	278	40	2	39	0	0	361
2014	*1*	*53*	*12*	*2*	*78*	*0*	*0*	*146*

Table 5. Retention rates of squids in federal groundfish fisheries, 2011-2014. Data source: AKRO CAS. The 2014 data are incomplete; retrieved October 25, 2014.

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year	percent retained
2011	77%
2012	12%
2013	92%
*2014**	*62%*

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22. Assessment of the Octopus Stock Complex in the Gulf of Alaska

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Executive Summary

In 2011, the GOA fisheries management plan was amended to provide separate management for, several groups formerly in the "other species" category, including octopus. In compliance with the reauthorized Magnuson-Stevens act, each group must have its own annual catch limit. Catch limits for octopus for 2011 - 2014 were set under Tier 6 with an alternative method based on using the average of the last 3 surveys as a minimum biomass estimate. This method is continued for 2015- 2016.

For management purposes, all octopus species are grouped into a single assemblage. At least seven species of octopus are found in the Gulf of Alaska (GOA). The species composition both of the natural community and the commercial harvest is not well documented, but research indicates that the Giant Pacific octopus *Enteroctopus dofleini* is the most abundant octopus species in shelf waters and makes up the bulk of octopus catches in commercial fisheries. Octopuses are taken as incidental catch in trawl, longline, and pot fisheries throughout the GOA; a portion of the catch is retained or sold for human consumption or bait. The highest octopus catch rates are from Pacific cod pot fisheries in the central and western GOA (NMFS statistical areas 610 and 630).

In general, the state of knowledge about octopus in the GOA is poor. A number of research studies and special projects have been initiated in recent years to increase knowledge for this assemblage; these include studies of delayed mortality of discarded octopus and development of an octopus-specific fishing gear for possible scientific use. A review by the Center for Independent Experts of the stock assessments for North Pacific non-target species was conducted in May 2013. Suggestions and recommendations from this review are discussed below.

Summary of Changes in Data

There was no survey of the GOA in 2014, so survey results from summer 2013 remain the most recent fishery-independent data. Commercial catch data for the octopus complex have been updated through October 17, 2014. The estimated total catch for 2013 was 423 t and the partial catch for 2014 was 709 t.

Summary of Changes in Asessment Methods

There are no proposed changes in assessment methodology.

Summary of Results

The current data are not sufficient for a model-based assessment. The SSC and Plan Teams have discussed the difficulties in applying groundfish methodologies to octopus and have agreed to treat octopus as a Tier 6 species. There are no historical records of directed fishing for octopus, and the authors and Plan Teams are concerned that historical catch methods may result in an overly conservative catch limit. In 2010 - 2014, the GOA Plan Team chose to use an approach where the average of three most recent survey biomass estimates is used as a minimum biomass estimate, and a mortality factor applied. The OFL for octopus in 2014 and 2015 was set at 2010 tons. Since there are no new survey data, this number remains the recommended OFL for 2015 and 2016. There is insufficient data to determine whether the complex is being subjected to overfishing, is currently overfished, or is approaching a condition of being overfished.

Summary of Harvest Recommendations

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
Tier 6 (3 survey biomass * M)	6(alt)	6(alt)	6(alt)	6(alt)
OFL (t)	2,009	2,009	2,009	2,009
ABC (t)	1,507	1,507	1,507	1,507
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing		n/a	n/a	n/a

Responses to SSC and Plan Team Comments

At their December 2013 meeting, the SSC requested information on octopus stock structure and supported the use of a three-survey average for estimating minimum biomass. The SSC and plan team reviewed a random effects model for survey biomass in 2013, but elected to await further research before adopting this approach for species complexes. The SSC also expressed support for several research priorities from the recent CIE review, including estimating mortality from tagging studies, gathering and updating growth rates for octopus from ongoing studies, and investigating the sue of a size-structured model. These projects are all being conducted; a size-structured model for octopus is under development but was not ready for the 2014 assessment cycle. In regards stock structure, a limited amount of research has been conducted recently on octopus genetics; this information will be added to the description of life history of *Enteroctopus dofleini* in the next full assessment. The work to date identifies a possible sub-species within Prince William Sound, but does not indicate any strong variation between octopus sampled at GOA locations from southeast Alaska to Dutch Harbor (Toissant et al. 2012),

Area apportionment of catch for a possible directed octopus fishery was discussed in the 2013 assessment, and the plan teams and SSC accepted an apportionment method based on survey data. The SSC made several recommendations to the Council of factors to be considered before allowing a directed octopus fishery. These included further development of survey techniques through an experimental fishery, a possible minimum size limit, and 100% observer coverage of any directed fishery. The assessment authors are in full concurrence on these recommendations.

Responses to CIE Review Comments

In May 2013, a panel from the Center for independent Experts (CIE) reviewed the AFSC stock assessments for non-target species. The panel reviewed assessments for sculpins, sharks, skates, grenadiers, squid, and octopus. The panel provided comments both on individual assessments and on the overall Tier 5 and Tier 6 process. All of the reviewers agreed that for Tier 5, “The main problem is the assumption that trawl survey biomass indices are legitimate estimates of absolute biomass”. The reviewers suggested that issues of survey coverage, catchability, selectivity, and habitat coverage (i.e. extending survey data to represent untrawlable areas) all made is difficult to treat survey estimates as absolute biomass. These issues are being addressed by the AFSC survey groups as far as funding and staffing will allow, but probably cannot be fully resolved. For octopus, the difficulties with survey biomass estimates include lack of survey coverage of shallow areas and rocky habitats; an unknown but probably large catchability effect, size selectivity issues, and large variance of estimates due to the fairly rare occurrence of octopus in trawl catch. These issues have already been recognized for octopus and are discussed under "Model Parameters". The reviewers agreed with the existing assessments that "The bottom trawl is likely inadequate for sampling other nontarget species such as squid, sharks and octopus."

The reviewers also recommended that the determination of ABC be based on a species-specific assessment of uncertainty rather than a fixed percentage of OFL. Changing this procedure is feasible but would require changes to the regulatory structure of FMPs and is best addressed at the plan teams, SSC, and Council. All three reviewers also noted various problems with the use of historical incidental catch data for stock assessment, and recommended that where there was no other alternative, the time period of historical be selected on a species-specific basis.

Specific to the octopus assessment, the reviewers primarily noted difficulties and limitations with all of the methods that have been used or proposed to date. One reviewer stated "*If budget allows, I recommend that a dedicated survey with habitat pot gear as developed by Conners et al. (2012), with some refinement, be used to track year-to-year variation in octopus biomass overtime in different areas*." Research to develop and refine the pot gear is currently being conducted. Another reviewer concluded that the consumption estimate approach was probably the best of a set of poor alternatives, and suggested several ways to check and refine consumption model estimation. While the consumption model estimates have not been updated for this assessment, the suggested modifications will be examined during the next update of consumption estimates.

The third reviewer strongly advocated that "*The use of M as a proxy for F_{MSY} is unnecessary and may be inappropriate for many species (as F_{MSY} depends strongly on the stock-recruitment relationship and the fishery selectivity). It is preferable to construct a simple species/stock-specific simulation model and use it to explore the plausible parameter space to determine an appropriate proxy for F_{MSY}.*" and provided an example of such a model for octopus. This model suggested that $F_{40\%B0}$ would be a better alternative to catch regulation that F_{MSY}. In the absence of any reliable estimate of B, however, it would be difficult to calculate this quantity.

Based on CIE comments, the author has started to examine a size-based assessment model for octopus, both to use as a simulation model for indentifying monitoring and management metrics and for possible fitting to habitat pot data. This model is not yet ready to present to the plan teams, but will be brought forward in 2015.

Data

Incidental Catch Data

Incidental catch of GOA octopus is shown in Table 1. Catches in 2007-2010 were between 250 and 350 t. Incidental catch in 2011 was the highest ever observed, with a total annual catch over 900 tons. The majority of this very large catch came during the fall Pacific cod pot fishery in statistical areas 610 and 630. Commercial catch data for the octopus complex have been updated through October 17, 2014. The estimated total catch for 2013 was 423t and the partial catch for 2014 was 709t. As in previous years, the majority of the 2013-2014 catch came from Pacific cod fisheries, primarily pot fisheries in statistical reporting areas 610 and 630. Approximately 50% of this catch was retained in each year.

Analytic Approach, Model Evaluation, and Results

The available data do not support population modeling for either individual species of octopus in the GOA or for the multi-species complex. As better catch and life-history data become available, it may become feasible to manage the key species *E. dofleini* through a size-based model. For the last few years, the GOA plan team has elected to use a special approach under Tier 6, which uses a minimum biomass estimate and a mortality rate based on life history parameters, assuming the logistic model used for Tier 5.

Parameters Estimated Independently – Biomass B

Estimates of octopus biomass based on the semi-annual GOA trawl surveys (Table 2, Figure 1) represent total weight for all species of octopus, and are formed using the sample procedures used for estimating groundfish biomass (National Research Council 1998, Wakabayashi et al. 1985). The positive aspect of these estimates is that they are founded on fishery-independent data collected by proper design-based sampling. The standardized methods and procedures used for the surveys make these estimates the most reliable biomass data available. The survey methodology has been carefully reviewed and approved in the estimation of biomass for other federally-managed species. There are, however, some serious drawbacks to use of the trawl survey biomass estimates for octopus.

Older trawl survey data, as with industry or observer data, are commonly reported as *octopus sp.*, without full species identification. In surveys prior to 2003, most octopus collected were not identified to species. In more recent years, a greater fraction of collected octopus is identified to species, but some misidentification may still occur. Efforts to improve species identification and collect biological data from octopus are being made, but the survey is only beginning to provide species-specific information that could be used in a stock assessment model.

As noted in previous assessments, the survey trawl may not be suitable gear for sampling octopus. The bottom trawl net used for the GOA survey has roller gear on the footrope to reduce snagging on rocks and obstacles and may allow benthic organisms, including octopus, to escape under the net. Given the tendency of octopus to spend daylight hours near dens in rocks and crevices, it is entirely likely that the actual capture efficiency for benthic octopus is poor (D. Somerton, personal communication, 7/22/05). Trawl sampling is not conducted in areas with extremely rough bottom and/or large vertical relief, exactly the type of habitat where den spaces for octopus would be most abundant (Hartwick and Barringa 1989). The survey also does not sample in inshore areas and waters shallower than 30m, which may contain sizable octopus populations (Scheel 2002). The estimates of biomass in Table 2 are based on a gear selectivity coefficient of one, which is probably not realistic for octopus. For this reason, these are probably conservative underestimates of octopus biomass in the regions covered by the survey. The large numbers of survey tows with no octopus also tend to increase the sampling variability of the survey estimates; in many years, octopus were present in less than 10% of the survey tows.

There is a considerable difference in size selectivity between survey trawl gear and industry pot gear that catches most of the octopus harvested. The average weight for individual octopus in survey catches is 2.0 kg; over 50% of survey-collected individuals weigh less than 0.5 kg. Larger individuals are strong swimmers and may be more adept at escaping trawl capture. In contrast, the average weight of individuals from commercial pot gear was over 20 kg. Pot gear is probably selective for larger, more aggressive individuals that respond to bait, and smaller octopus can easily escape commercial pots while they are being retrieved. Unlike the BSAI, the depth range of octopus catches in the GOA is similar between industry and survey data, although pot fisheries tend to be concentrated in shallower shelf waters**.** There is also a seasonal difference between summer trawl surveys and the fall and winter cod seasons, when most octopus are harvested. In general, it may be possible to use trawl survey data as an index of interannual variation in abundance, but the relationship between the summer biomass of individuals vulnerable to trawls and the fall or winter biomass available to pot fisheries will be difficult to establish. The biomass of octopus estimated by the trawl survey is expected to be a minimum estimate of octopus biomass, as the larger octopus are not well represented.

Species-specific methods of biomass estimation are needed for octopus and are being explored. Octopus are readily caught with commercial or research pots. An index survey of regional biomass in selected areas of the Kodiak and Shumagin regions would be appropriate and is highly feasible. It may also be feasible to estimate regional octopus biomass using mark-recapture studies or depletion methods (Caddy 1983, Perry et al. 1999). For the 2015 assessment, a size-based stage-structure model is being explored.

Parameters Estimated Independently – Mortality Rate M

It is important to note than not all species of octopus in the GOA have similar fecundity and life history characteristics. This analysis is based on *E. dofleini*, which probably make up the majority of the harvest. Since *E. dofleini* are terminal spawners, care must be taken to estimate mortality for the intermediate stage of the population that is available to the fishery but not yet spawning (Caddy 1979, 1983). If detailed, regular catch data within a given season were available, the natural mortality could be estimated from catch data (Caddy 1983). When this method was used by Hatanaka (1979) for the West African *O. vulgaris* fishery, the estimated mortality rates were in the range of 0.50-0.75. Mortality may also be estimated from tagging studies; Osako and Murata (1983) used this method to estimate a total mortality of 0.43 for the squid *Todarodes pacificus*. Empirical methods based on the natural life span (Hoenig 1983, Rikhter and Efanov 1976) or von Bertalanffy growth coefficient (Charnov and Berrigan 1991) have also been used. While these equations have been widely used for finfish, their use for cephalopods is less well established. Perry et al. (1999) and Caddy (1983) discuss their use for invertebrate fisheries.

If we apply Hoenig's (1983) equation to *E. dofleini*, which have a maximum age of five years, we get an estimated M = 0.86. **Rikhter and Efanov's (1976) equation gives a mortality value of 0.53 based on an age of maturity of 3 years for *E. dofleini*.** The utility of maturity/mortality relationships for cephalopods needs further investigation, but these estimates represent the best available data at this time. The Rikhter and Evanov estimate of M=0.53 represents the most conservative estimate of octopus mortality, based on information currently available. If future management of octopus is to be based on Tier 5 methods, a direct estimate of octopus mortality in the GOA, based on either experimental fishing or tagging studies, is desirable. Tagging studies of octopus in the Bering Sea are expected to produce an estimated mortality rate for large octopus by the 2014 stock assessment.

Projections and Harvest Alternatives

None of the existing groundfish Tier strategies are well suited to the available information for octopus. We recommend that octopus be managed very conservatively due to the poor state of knowledge of the species, life history, distribution, and abundance of octopus in the GOA. Further research is needed in several areas before octopus could be managed by the methods used for commercial groundfish species. Regulatory limits under two different strategies are presented below.

Trawl survey estimates of biomass for the species complex represent the best available data at this time. There are serious concerns, however, about both the suitability of trawl gear for accurately sampling octopus biomass and the extent to which the survey catch represents the population subject to commercial harvest. If future management of the octopus complex under Tier 5 is envisioned, then dedicated field experiments are needed to obtain both a more realistic estimate of octopus biomass available to the fishery and a more accurate estimate of natural mortality rates.

For the last few years, the GOA plan team has elected to use a special approach under Tier 6, which uses a minimum biomass estimate and a mortality rate based on life history parameters, assuming the logistic model used for Tier 5. **If the average biomass from the three most recent surveys (2009, 2011, and 2013) of 3,791 tons and the conservative M estimate of 0.53 are used, the OFL and ABC for GOA octopus would be 2,009 and 1,507 tons, respectively. These limits were presented in the 2013 full stock assessment for GOA octopus, and are recommended for continued use as catch limits for 2015-16.**

Because of the overall lack of biological data and the large uncertainty in abundance estimates, we do not recommend a directed fishery for octopus in federal waters at this time. We anticipate that octopus harvest in federal waters of the GOA will continue to be largely an issue of incidental catch in existing groundfish fisheries.

Literature Cited

Caddy, J.F. 1979. Preliminary analysis of mortality, immigration, and emigration on *Illex* population on the Scotian Shelf. ICNAF Res. Doc. 79/VI/120, Ser. No. 5488.

Caddy, J.F. 1983. The cephalopods: factors relevant to their population dynamics and to the assessment and management of stocks. Pages 416-452 *In* J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.

Charnov E.L. and D. Berrigan. 1991. Evolution of life history parameters in animals with indeterminate growth, particularly fish. Evol. Ecol. 5:63-68.

Hatanaka, H. 1979. Studies on the fisheries biology of common octopus off the northwest coast of Africa. Bull Far Seas Research Lab 17:13-94.

Hartwick, E.B, and I. Barriga (1989) Octopus dofleini: biology and fisheries in Canada (in) Lang, M. A. and F.G. Hochberg (eds.) (1997). Proceedings of the Workshop on the Fishery and market potential of octopus in California. Smithsonian Institutions: Washington. 192 p.

Hoenig, J.N. 1983. Empirical Use of Longevity Data to Estimate Mortality Rates. Fishery Bulletin V. 82 No. 1, pp. 898-903.

National Research Council. 1998. Improving fish stock assessments. National Academy Press, Washington, D.C.

Osako, M. and . Murata. 1983. Stock assessment of cephalopod resources in the northwestern Pacific. Pages55-144 *In* J.F. Caddy, ed. Advances in assessment of world cephalopod resources. FAO Fisheries Tech. Paper 231.

Perry, R.I., C.J. Walters, and J.A. Boutillier. 1999. A framework for providing scientific advice for the management of new and developing invertebrate fisheries. Rev. Fish Biology and Fisheries 9:125-150.

Rikhter, V.A. and V.N. Efanov, 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res.Doc., 79/VI/8, 12p.

Sagalkin, N.H. and K Spalinger. 2011. Annual management report of the commercial and subsistence shellfish fisheries in the Kodiak, Chignik, and Alaska peninsula areas, 2010. ADF&G Fishery Management Report No. 11-43.

Scheel, D. 2002 Characteristics of habitats used by *Enteroctopus dofleini* in Prince William Sound and Cook Inlet, Alaska. Marine Ecology 23(3):185-206.

Toussaint, R.K., D. Scheel, G.K. Sage, and S.L. Talbot. 2012. Nuclear and mitochondrial markers reveal evidence for genetically segregated cryptic speciation in giant Pacific octopuses from Prince William Sound, Alaska. Conservation Genetics. Online First: DOI 10.1007/s10592-012-0392-4.

Wakabayashi, K, R.G. Bakkala, and M. S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys (in) R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S. - Japan groundfish investigations in the Bering Sea during May - August 1979. International North Pacific Fisheries Commission Bulletin 44.

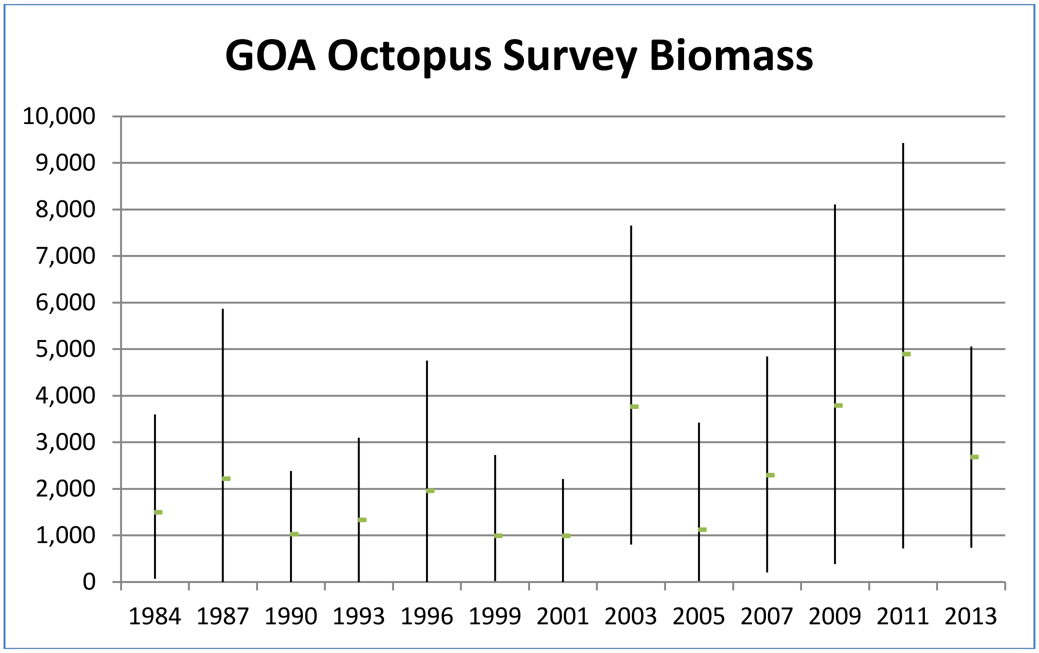
Table 1. Estimated state and federal catch (t) of all octopus species combined, by target fishery. Catch for 1997-2002 estimated from blend data. Catch for 2003-2014 data from AK region catch accounting. *Data for 2014 are as of October 17, 2014; catch figures for flatfish targets have been revised to include the IFQ Halibut fishery.

	Target Fishery						
Year	**Pacific cod**	**Pollock**	**Flatfish***	**Rockfish**	**Sablefish**	**Other**	**Total**
1997	193.8	0.7	1.3	2.3	22.4		232
1998	99.7	3.5	4.3	0.8	0.3		112
1999	163.2	0.0	2.4	0.5	0.2		166
2000	153.5	-	0.7	0.2	0.5		156
2001	72.1	0.2	0.8	0.0	2.0		88
2002	265.4	0.0	17.2	0.7	1.0		298
2003	188.9	-	16.6	0.6	2.9	0.1	210
2004	249.8	0.0	2.8	0.4	0.1	16.5	270
2005	138.6	0.1	2.4	0.2	0.2	1.7	149
2006	151.0	3.4	1.9	0.5	0.3	0.2	166
2007	242.0	1.5	9.7	0.1	1.8	-	257
2008	326.0	0.0	5.2	2.9	0.2	0.1	339
2009	296.8	0.1	10.1	1.2	0.3	0.9	310
2010	263.7	0.8	15.4	3.7	0.5	41.9	326
2011	859.4	2.3	49.9	0.9	0.8	1.1	918
2012	408.1	0.4	4.6	0.9	0.8	-	421
2013	320.4	0.3	112.4	1.5	16.5	0.0	423
2014*	586.9	6.7	79.4	4.4	6.6	2.1	709

Table 2. Biomass estimates for octopus (all species combined) from GOA bottom trawl surveys.

Survey Year	Survey Hauls	Hauls with Octopus Num	%	Estimated Biomass (t)
1984	929	89	9.6%	1,498
1987	783	35	4.5%	2,221
1990	708	34	4.8%	1,029
1993	775	43	5.5%	1,335
1996	807	34	4.2%	1,960
1999	764	47	6.2%	994
2001	489	29	5.9%	994
2003	809	70	8.7%	3,767
2005	839	56	6.7%	1,125
2007	820	71	8.7%	2,296
2009	824	172	20.9%	3,791
2011	704	75	10.6%	4,897
2013	**548**	**62**	**11.3%**	**2,685**

Figure1. GOA octopus survey biomass estimates and confidence intervals.



Assessment of the Grenadier Stock Complex in the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands

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Executive Summary

The Secretary of Commerce approved Amendments 100/91 on August 6, which added the grenadier complex into both FMPs as Ecosystem Components. Under this rule, they are not allowed to be targeted but there is an 8% Maximum Retainable Allowance (MRA) (Federal Register, Proposed Rules, Vol. 79, No. 93). The final rule will publish before the end of the year and so it may be effective for the start of the 2015 fishing year.

As an Ecosystem Component, a stock assessment is not required and there is no ABC or OFL. A full unofficial assessment report was prepared for grenadiers in even years since 2006, even though they were "nonspecified". For 2015, we are presenting an abbreviated SAFE report for the BSAI and GOA combined for the purpose of tracking trends in abundance. This content of future reports is still being evaluated since a SAFE report is not required. This report contains a time series of catch and abundance estimates and unofficial ABC and OFL values based on Tier 5 calculations. These values are not used for management or for determining if overfishing is occurring for Ecosystem Component species/complexes. There is no definition of overfishing for an Ecosystem Component.

Summary of Changes in Assessment Inputs

Changes in the input data: New data inputs include: 1) updated catch data for 2003-2014; 2) updated 2000-2014 Aleutian Island (AI) biomass from 1-1,000 m using the estimation method presented in the 2012 SAFE; 3) NMFS longline survey results for 2013 and 2014; 4) updated GOA biomass using a random effects model. There was no EBS slope trawl survey in 2014.

Changes in assessment methodology: This year we use a random effects model (a similar method, a Kalman filter, was presented in the 2012 SAFE report (Rodgveller et al. 2012)), that utilizes trawl survey data from 1984-2013 to estimate the exploitable biomass in 2013. Since there was no trawl survey in the GOA in 2014, the estimate for 2013 is used as the most recent value of exploitable biomass.

Summary of Results

For 2015, the maximum allowable ABC for the BSAI is 75,274 t and for the GOA is 30,691 t. This ABC is a 12% increase for the BSAI and a 12% decrease for the GOA. The corresponding reference values for grenadier are summarized in the following tables, with the recommended ABC and OFL values in bold. Overfishing is not occurring in either the BSAI or GOA.

Gulf of Alaska Grenadiers

Quantity	As estimated or specified *last* year for[a]:		As estimated or recommended *this* year for:	
	2014	2015	2015	2016
M (natural mortality)	0.078	0.078	0.078	0.078
Specified/recommended Tier	5	5	5	5
Biomass (t)	597,884	597,884	524,624	524,624
F_{OFL} (F=M)	0.078	0.078	0.078	0.078
$maxF_{ABC}$ (maximum allowable = 0.75x F_{OFL})	0.0585	0.0585	0.0585	0.0585
F_{ABC}	0.0585	0.0585	0.0585	0.0585
OFL (t)	**46,635**	46,635	**40,921**	40,921
maxABC (t)	34,976	34,976	**30,691**	30,691
ABC (t)	**34,976**	34,976	**30,691**	30,691
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a

[a]The values for biomass, OFL, and ABC in these two columns are based on Rodgveller and Hulson 2013. They are an average of the last three trawl surveys that sampled down to 1,000 m. The current values (for 2015 and 2016) are from the random effects model fit to survey biomass by region and depth strata.
These are unofficial ABC and OFL values since grenadier are an Ecosystem Component, which do not have ABCs or OFLs.

Bering Sea and Aleutian Islands Grenadiers

Quantity	As estimated or specified *last* year for[a]:		As estimated or recommended *this* year for:	
	2014	2015	2015	2016
M (natural mortality)	0.078	0.078	0.078	0.078
Specified/recommended Tier	5	5	5	5
Biomass (t)	1,152,284	1,152,284	1,286,734	1,286,734
F_{OFL} (F=M)	0.078	0.078	0.078	0.078
$maxF_{ABC}$ (maximum allowable = 0.75x F_{OFL})	0.0585	0.0585	0.0585	0.0585
F_{ABC}	0.0585	0.0585	0.0585	0.0585
OFL (t)	**89,878**	89,878	**100,365**	100,365
maxABC (t)	67,409	67,409	**75,274**	75,274
ABC (t)	**67,409**	67,409	**75,274**	75,274
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
Overfishing	No	n/a	No	n/a

[a]The values for biomass, OFL, and ABC in these two columns are based on Rodgveller and Hulson 2013.
These are unofficial ABC and OFL values since grenadier are an Ecosystem Component, which do not have ABCs or OFLs.

Tier 5 computations for giant grenadier OFL and ABC are summarized as follows (AI = Aleutian Islands, EBS = Eastern Bering Sea, GOA = Gulf of Alaska; biomass, OFL, and ABC are in mt) for 2015:

BSAI and GOA grenadiers

Area	Biomass	Natural mortality *M*	OFL definition	OFL	ABC definition	ABC
EBS	553,557	0.078	biom x *M*	43,177	OFL x 0.75	32,383
AI	733,177	0.078	biom x *M*	57,188	OFL x 0.75	42,891
BSAI total	1,286,734			100,365		75,274
GOA	524,624	0.078	biom x *M*	40,921	OFL x 0.75	30,691
Grand total	1,811,358			141,286		105,965

These are unofficial ABC and OFL values since grenadier are an Ecosystem Component, which do not have ABCs or OFLs.

The specifications in the GOA for 2015 differ from last year because a random effects model fit to the survey biomass was used as a proxy for the exploitable biomass in this year's assessment (following the recommendation of the Survey Averaging Working group). In the BSAI the ABC and OFL include the AI biomass estimated using the method presented in the 2012 SAFE report (Rodgveller et al. 2012). Further discussion of this method is below under SSC comments and under the Survey Data section. Catches are not approaching unofficial OFLs.

Summaries for Plan Team

Species	Year	BSAI Biomass	BSAI ABC	BSAI Catch[1]	GOA Biomass	GOA ABC	GOA Catch[1]	Total Catch[1]
grenadiers	2013	1,733,797	101,427	4,164	597,884	34,976	11,339	15,504
	2014	1,152,284	89,878	2,627	597,884	34,976	5,236	7,863
	2015	1,286,734	75,274		524,624	30,691		
	2016	1,286,734	75,274		524,624	30,691		

[1]Current as of October 7, 2014. Source: NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org).

SSC and Plan Team Comments on Assessments in General

There were no comments on assessments in general that pertains to this assessment.

SSC and Plan Team Comments Specific to this Assessment

Here we report comments from the SSC in 2012 and 2013, since there was an executive summary in 2013. We also present comments from 2013 regarding the EA/RIR/IRFA on grenadier that pertain to stock assessment. Responses to these comments and additions to the document were also made in the final EA/RIR/IRFA document (NMFS 2014.)

"The authors introduced a new method for determining AI biomass and variance estimates. The SSC cautions that this is an uncertain extrapolation method. The catchability and size selection of longline surveys is known to differ from the trawl survey. This method assumes that the ratio between longline and trawl surveys in shallow water will be the same for the ratio of longline and trawl surveys in deep water. The SSC encourages the authors to verify whether this assumption is valid." **(SSC, 2012)**

The primary problem with using the AI trawl survey biomass estimates for giant grenadier is that the survey does not sample deeper than 500 m; where the majority of the giant grenadier population can be found. To account for the missing biomass from the trawl survey an expansion method is needed, for which we use the AFSC longline survey data, the only survey that samples deeper than 500 m in the AI.

The primary uncertainty associated with this method centers on the use of a ratio estimator between trawl survey biomass and longline survey RPWs. The ratio between trawl survey biomass and longline survey RPWs is assumed to be the same in shallow depths (1-500 m, for which we have trawl survey data) and deep depths (500-1000 m, for which we do not have trawl survey data), an assumption that must be made due to the available data. There may be uncertainty associated with extrapolating trawl survey biomass in this manner. Our opinion is that it is important to present estimates of deep-water biomass so that a better reflection of the potential grenadier biomass in the AI can be presented.

A comparison of the ratio of longline and trawl survey data in shallow- and deep-waters in the Gulf of Alaska is presented in an attempt to verify the assumption of constant catchability in each survey in shallow- and deep-water (See "Biomass estimation in the AI" under the "Trawl Surveys" section). Ratios between the two surveys in shallow- and deep-water were almost identical in the GOA, indicating that the assumption is valid.

The trends in RPWs and biomass were compared in the EBS and the GOA to determine if the two surveys are sampling the same population. Trends in the EBS tracked well, but trends in the GOA were not consistent among the two surveys (See "RPWs" under the "Longline surveys" section), so this did not validate nor contradict the effect of the differing selectivities of the two surveys.

"In response to SSC comments, the authors included a Kalman filter model for estimating biomass. The Kalman filter estimates miss the most recent trawl biomass estimate in the GOA resulting in a substantially lower biomass estimate. For future assessments, the SSC encourages continued exploration of the Kalman filter method and we ask the authors to consider the recommendations in the Plan Team survey averaging work group **(SSC, Dec. 2012)."**

The survey averaging working group has recommended that for Tier 5 stocks authors should compare biomass estimates using random effects models to the standard calculations. We compared status quo to a Kalman filter in 2012 (Rodgveller et al. 2012). Here we use the random effects model to estimate GOA biomass for 2013. Approximately ½ of the grenadier biomass was in the deepest stratum (701-1,000 m) and this stratum was not sampled in 2011 or 2013. It is likely that it will not be sampled in 2015. The random effects model provides a method to incorporate all available trawl survey data since 1984. See the section titles "Biomass Estimation in the GOA" under the "Surveys" heading for details.

"As a non-specified species complex the Plan Teams and the SSC are not required to provide harvest specifications for this species group. Given the potential that grenadier management may change in 2014, the SSC requests a full assessment next year." **(SSC, Dec. 2013)**

Because grenadiers were put into the FMPs as an Ecosystem Component in 2014, there are still no harvest specifications and no requirement to produce SAFE reports. Therefore, instead of presenting a full assessment, we are presenting an abbreviated assessment that contains a time series of catch and survey data and descriptions of new methodologies used for estimating biomass.

Comments on the EA/RIR/IRFA in 2013

"The SSC reviewed the document and concluded that it is very well done and ready for release for public review. *However, the SSC identified several areas where the document could be improved and requests that staff strive to make these improvements prior to release."* (SSC, Dec. 2013)

***"It would be useful to develop a food web for the slope regions as part of the ecosystem concerns chapter..."* (SSC, Dec. 2013)**

Little information is available on food web and habitat interactions between grenadiers and other groundfish. The information that is available indicates that in the Aleutian Islands, the diet of grenadiers is comprised mostly squid and bathypelagic fish (myctophids) (Yang 2003), whereas in the Gulf of Alaska, squid and pasiphaeid shrimp predominated as prey (Yang et al. 2006). Thus, other groundfish do not appear to compose the prey field of grenadiers.

***"The 2012 appendix revealed strong spatial partitioning of the sexes by depth. The SSC requests the author to estimate the sex ratio for survey biomass estimates in the assessment. The SSC requests that, if possible, the document should provide trawl and longline survey biomass estimates by sex and depth."* (SSC, Dec. 2013)**

In response to these comments, an appendix was added to the EA/RIR/IRFA with tables and figures that broke out catch, biomass, and RPWs by sex and depth (NMFS, 2013; see pages 77-82). We include a summary of that analysis as well as the data tables and figures presented in the EA/RIR/IRFA as an appendix to this SAFE report.

***"With respect to depth, the SSC requests that the document includes a short discussion of the potential uncertainty associated with the expansion method used to estimate grenadier biomass at deeper depths in the AI."* (SSC, Dec. 2013)**

See SSC comment from 2012 (above).

"The SSC also encourages the author to address comments and suggestions made by the non-target CIE review team if they are relevant to the grenadier appendix." (SSC, Dec. 2013)

See below.

Center of Independent Expect Review Comments

In May, 2013 there was a Center of Independent Expert (CIE) review of non-target assessments at the AFSC. Three reviewers participated and each produced a report without collaboration from NMFS or other reviewers. Here I will summarize the comments pertaining to grenadier. General comments about the tier system are excluded.

1) The three CIE reviewers did not consider the estimates of absolute biomass to be reliable for grenadier, or for other reviewed species. The catchabilities of grenadier by the bottom trawl surveys is the EBS, AI, and GOA are unknown, but are currently assumed to be 1. One reviewer recommends using expert knowledge to estimate the availability, vulnerability, and density in trawlable and untrawlable grounds to explore converting the trawl survey data to absolute biomass.

There is some evidence, based on diets and anecdotal evidence of higher catch rates when longline gear is held off off-bottom by rocky topography, that grenadier spend time off-bottom. If this is true, q is likely <1 for trawl gear. There have been no studies to estimate q for grenadier.

2) There were concerns over the ratio that is used to extrapolate the relative population numbers and weights in the western AI from a ratio of western to eastern AI data from the 1980's.

The western AI has not been sampled by the domestic NMFS longline survey. Data from Japanese surveys are used to extrapolate western AI abundance. This method is used for all species, including sablefish, since it is the only available data.

3) The reviewers supported using models for estimating biomass, such as a Kalman filter or random effects model.

This year we use a random effects model to estimate GOA biomass.

4) A reviewer said that maximum age methods used for estimating natural mortality are acceptable, but recommended for swapping otoliths with other labs.

The AFSC lab is the only lab that ages giant grenadier. A method was developed by Charles Hutchinson in the Age and Growth Laboratory for a previous age at maturity study (Rodgveller et al. 2010). Ages could not be validated using C14. This is likely because young fish are not in shallower waters (<200 m). Young fish are needed to confirm annuli at age 1-5; however, no young fish have been found in surveys or fisheries.

Introduction

Grenadiers (family Macrouridae) are deep-sea fishes related to hakes and cods that occur world-wide in all oceans. Also known as "rattails", they are especially abundant in waters of the continental slope, but some species are found at abyssal depths. At least seven species of grenadier are known to occur in Alaskan waters, but only three are commonly found at depths shallow enough to be encountered in commercial fishing operations or in fish surveys: giant grenadier (*Albatrossia pectoralis*), Pacific grenadier (*Coryphaenoides acrolepis*), and popeye grenadier (*Coryphaenoides cinereus*) (Mecklenburg et al. 2002). Of these, giant grenadier has the shallowest depth distribution and the largest apparent biomass, and hence is by far the most frequently caught grenadier in Alaska. Because of this importance, this report will emphasize giant grenadier, but it will also discuss the other two species.

Distribution: Giant grenadier range from Baja California, Mexico around the arc of the north Pacific Ocean to Japan, including the Bering Sea and the Sea of Okhotsk (Mecklenburg et al. 2002), and they are also found on seamounts in the Gulf of Alaska and on the Emperor Seamount chain in the North Pacific (Clausen 2008). In Alaska, they are especially abundant on the continental slope in waters >400 m depth.

These fish are the largest in size of the world's grenadier species (Iwamoto and Stein 1974); maximum weight of one individual in a Bering Sea trawl survey was 41.8 kg[1].

Speciation: Previous publications (Clausen 2006 and 2008) speculated that more than one species of giant grenadier may exist in Alaska because two morphs of the fish have been observed based primarily on the relative size of the eye to the head, as well as three very different patterns of otolith morphology. Tissue and otoliths samples were collected on the AFSC longline survey in 2013 for a more definitive analysis of speciation, stock structure, and otolith morphometrics.

Biology: There is some known biological information on adult giant grenadier, but data on larvae and juvenile grenadiers is nonexistent. The spawning period is thought to be protracted and may even extend throughout the year (Novikov 1970; Rodgveller et al. 2010). Two papers provide purported descriptions of larvae of giant grenadier in the North Pacific (Endo et al. 1993; Ambrose 1996), but Busby (2004) points out that these descriptions appear so different that they probably represent separate species. At any rate, no larvae have ever been collected in Alaska that correspond to either of these descriptions or to the description of a third form (Busby 2004) that is also giant grenadier-like[2]. Small, juvenile fish less than ~15-20 cm pre-anal fin length (PAFL) are virtually absent from bottom trawl catches (Novikov 1970; Ronholt et al. 1994; Hoff and Britt 2009, 2011), and juveniles may be pelagic in their distribution. (Because the long tapered tails of grenadiers are frequently broken off when the fish are caught, PAFL is the standard unit of length measurement for these fish. PAFL is defined to be the distance between the tip of the snout and the insertion of the first anal fin ray). Bottom trawl studies indicate that females and males have different depth distributions, with females inhabiting shallower depths than males. For example, both Novikov (1970) in Russian waters and Clausen (2008) in Alaskan waters found that nearly all fish <600 m depth were female, and the Novikov study was based on trawl sampling throughout the year. Presumably, some vertical migration of one or both sexes must occur for spawning purposes; Novikov (1970) speculates that females move to deeper water inhabited by males for spawning.

Ecology: The habitat and ecological relationships of giant grenadier are likewise little known and uncertain. Clearly, adults are often found in close association with the bottom, as evidenced by their large catches in bottom trawls and on longlines set on the bottom. However, based on a study of the food habits of giant grenadier off the U.S. west coast, Drazen et al. (2001) concluded that the fish feeds primarily in the water column. Most of the prey items found in the stomachs were meso- or bathypelagic squids and fish, and there was little evidence of benthic feeding. Smaller studies of giant grenadier food habits in the Aleutian Islands (Yang 2003) and Gulf of Alaska (Yang et al. 2006) showed similar results. In the Aleutian Islands, the diet comprised mostly squid and bathypelagic fish (myctophids), whereas in the Gulf of Alaska, squid and pasiphaeid shrimp predominated as prey. The hypothesis regarding the tendency of the fish to feed off bottom is supported by observations of sablefish longline fishermen, who report that their highest catches of giant grenadier often occur when the line has been inadvertently "clothes-lined" between two pinnacles, rather than set directly on the bottom[3]. Pacific sleeper sharks (*Somniosus pacificus)* and Baird's beaked whales (*Berardius bairdii*) have been documented as predators on giant grenadier (Orlov and Moiseev 1999; Walker et al. 2002). Sperm whales (*Physeter macrocephalus*) are another likely predator, as they are known to dive to depths inhabited by giant

[1] G. Hoff, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. comm. March 2005.
[2] M. Busby, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. comm. October 2006.
[3] D. Clausen, National Marine Fisheries Service, Alaska Fisheries Science, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. observ. October 2004.

grenadier on the continental slope and have been observed in Alaska depredating on longline catches of giant grenadier[4].

Distribution of Pacific and popeye grenadier: Pacific grenadier have a geographic range nearly identical to that of giant grenadier, i.e., Baja California, Mexico to Japan. Popeye grenadier range from Oregon to Japan. Compared to giant grenadier, both species are much smaller and generally found in deeper water. They appear to be most abundant in waters >1,000 m, which is deeper than virtually all commercial fishing operations and fish surveys in Alaska. For example, in a recent experimental longline haul in the western Gulf of Alaska at a depth of 1400-1500 m, 56% of the hooks caught Pacific grenadier[5]. This indicates that at least in some locations in deep water, abundance of Pacific grenadier in Alaska can be extremely high. Few popeye grenadier are caught on longline gear, apparently because of the relatively small size of these fish, and most of the information on this species comes from trawling. Food studies off the U.S. West Coast indicate that Pacific grenadier are more benthic in their habitat than are giant grenadier, as the former species fed mostly on bottom organisms such as polychaetes, mysids, and crabs (Drazen et al. 2001).

Evidence of stock structure: Stock structure and migration patterns of giant grenadier in Alaska are unknown, as no genetics studies have been done (except for brief genetic investigation of the two morphs of this species that was previously mentioned), and the fish cannot be tagged because all individuals die due to barotrauma when brought to the surface. One study in Russian waters, however, used indirect evidence to conclude that seasonal feeding and spawning migrations occur of up "to several hundred miles" (Tuponogov 1997).

Natural mortality: In the 2014 assessment we continue to use the natural mortality estimate (*M*) of 0.078, calculated using Hoenig's (1983) longevity equation with a maximum age of 58 from a study of age at maturity for giant grenadier (Rodgveller et al. 2010). A discussion of the four methods employed by Rodgveller et al. (2010) and the reason for choosing Hoenig's (1983) method can be found in the 2010 grenadier SAFE (Clausen and Rodgveller 2010). Giant grenadier greater than 60 cm PAFL have been caught on the AFSC longline survey, whereas the greatest length in the age samples was 53 cm (Rodgveller et al. 2010). Therefore, it is probable that fish older than 58 exist. An older maximum age would result in a decrease in *M*. Because fish older than 58 years may exist, we suggest revisiting the determination of *M* for giant grenadier if more age samples become available in the future.

Fishery

Catch History

Catches since 1997 have been estimated for the eastern Bering Sea (EBS), Aleutian Islands (AI), and GOA based largely on data from the Alaska Fishery Science Center's Fishery Monitoring and Analysis program. The estimates for 1997-2002 were determined by simulating the catch estimation algorithm used for target species by the NMFS Alaska Regional Office in what was formerly called their "blend catch estimation system" (Gaichas 2002 and 2003). Although these estimates may not be as accurate as the official catch estimates determined for managed groundfish species, they are believed to be the best possible based on the data available. They do not appear unreasonable compared to the official catches of other species caught along with giant grenadier on the continental slope in Alaska, such as sablefish and

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[4] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm. October 2006.
[5] D. M. Clausen and C. J. Rodgveller, 2010. Deep-water longline experimental survey for giant grenadier and sablefish in the western Gulf of Alaska, August 2008. National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Unpubl. manuscr. 23p.

Greenland turbot. The estimates for 2003-2014 were computed by the NMFS Alaska Regional Office based on their Catch Accounting System, which replaced the "blend" system in 2003. All the data are presented as "grenadiers, all species combined".

In 2013 the observer program underwent restructuring. Implementation of this program is considered an improvement over the previous observer system and an analysis of the first year under the restructured program was presented at the June 2014 council meeting (Faunce et al. 2014). It is too early to determine if there are any changes in the time series due to this restructuring. More years of data are needed. There is now observer coverage of vessels <60 ft and of the IFQ Pacific halibut fleet. A description of changes in bycatch rate calculations and changes that occurred in CAS that relate to non-target species can be found in Tribuzio et al. (2014).

Overall, the estimate of total catch of grenadier in 2013 (15,504 mt) was almost the same as in 2012 (15,119 mt) (Table 1). Catch in 2013 was up 13% from the 2003-2012 average. Even though the great majority of grenadier catch occurs by Oct. 1, the catch estimate in 2014 is only 7,863 mt. For example, by Oct. of 2013 95% of the catch was taken. Thus we expect that the final catch estimate for 2014 will be much lower than average. It is possible that this is related to observer restructuring.

In the BSAI catch was down 21% (1,092 mt) from average in 2013 (Table 1). This was primarily in the Greenland turbot fishery in the BS and the Kamchatka flounder fishery in the AI (Table 2). In the GOA, grenadier catch was higher in 2013 than in previous years (2,890 mt above average; 34%; Table 1). The majority of this increase was in rockfish (461 mt; 84% above average), sablefish (1,476 mt; 22% above average) (Table 2), and the deep-water flatfish fisheries (1,063 mt; 581% above average) (Table 2). Surprisingly, the estimate of grenadier catch in the halibut target group was 47% below average in 2013; although, catch estimates in this target group have always been variable.

Survey Data

Trawl Surveys

Biomass estimation in GOA: The Plan Team Survey Averaging Plan Team working group and the SSC suggested that for tier 5 species authors should compare biomass estimates using a random effects model to standard calculations. For grenadier a Kalman filter model was presented in 2012 (Rodgveller et al. 2012). This year we used a random effects model to estimate exploitable biomass for unofficial ABCs and OFLs (Table 3). The only GOA trawl surveys that extended to 1,000 m include the surveys in 1984, 1987, 1999, 2005, 2007, and 2009. In 1990, 1993, 1996, and 2001 the trawl survey only sampled depths down to 500 m, and in 2003 and 2011 the trawl survey sampled depths up to 700 m. Due to the differences in the depth sampled among the various trawl surveys, and the distribution of giant grenadier biomass across depth strata, we applied the random effects model to biomass estimates for the 1-500 m, 501-700 m, and 701-1000 m depth strata by region separately. This resulted in three time series of biomass estimates: one for each depth stratum. The full time series of biomass estimates in the GOA from the random effects model were then obtained by summing the biomass estimates across the three depth strata (Figure 1). Biomass in the GOA, estimated using the random effects model, increased until 2005 and then decreased slowly and then increased in 2013 (Figure 1). Compared to status quo, biomass estimates from the random effects model are lower (Table 3) (ratios of random effects biomass/status quo biomass range from 0.76 to 0.97).

Biomass estimation in AI: The Aleutian Islands have presented a special problem for biomass estimation because no trawl surveys since 1986 have sampled waters deeper than 500 m, where most giant grenadier biomass is found. In previous SAFEs (Clausen 2006; Clausen and Rodgveller 2008, Clausen and

Rodgveller 2010) an AI biomass was estimated by using a combination of data from other areas and surveys: the GOA and EBS slope trawl surveys and the AFSC longline survey (Clausen and Rodgveller, 2010).

In 2012, a new method was used to estimate giant grenadier biomass that utilizes only AI survey data (Rodgveller et al. 2012; Appendix 1A and in the "survey data" section), and we continue to use this method. The AI trawl survey biomass estimates from the "shallow" depths, which are regularly sampled (1-500 m), and AI longline survey RPWs from "shallow" (200-500 m) and "deep" depths (501-1000 m) are used to estimate the total AI biomass using the following equation:

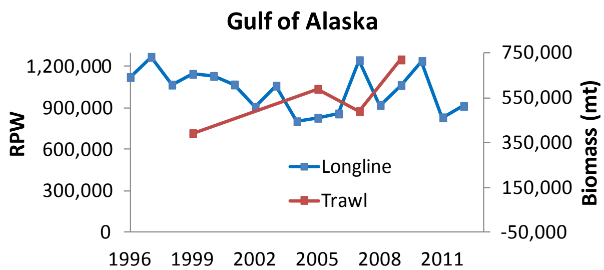
$$(1)\ B_y = \bar{r}W_y$$

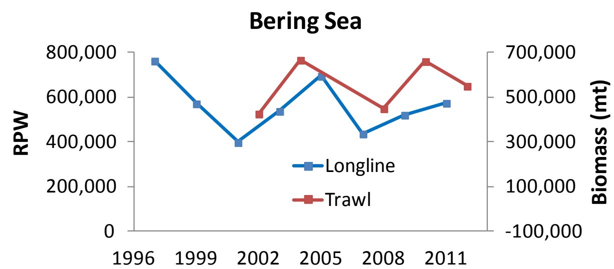
where B_y is the total biomass in year y, $\bar{r}$ is the ratio of the sum of bottom trawl survey biomass estimates to the sum of longline RPWs in the shallow depth stratum for years when both surveys occurred (2000, 2002, 2004, 2006, 2010, 2012, 2014), and W_y is the total RPW in year y. $\bar{r}$ of "shallow" biomass to "shallow" RPWs for these years was 0.223. For those years when the AFSC longline survey occurs in the AI, an AI biomass estimate is now available (Table 4). Estimated biomass increased in 2014 by 53%. It is now similar to the estimated biomass in 2010.

When using this method, there is an assumption that the ratio between longline and trawl surveys in shallow water is the same as the ratio of longline and trawl surveys in deep water. In an attempt to validate this assumption, we examined the ratios of the two surveys in shallow- and deep-water in the GOA, where the trawl survey sampled down to 700 m in 2003 and 2011 and to 1,000 m in 1999, 2005, 2007, and 2009. In the GOA, the shallow ratio was nearly the same as the deep ratio (using the same method employed for calculating the AI shallow ratio), indicating that the assumption that the shallow- and deep-water ratios in the AI are similar is likely valid.

max depth	years	shallow ratio	deep ratio
700 m	2003,2011	0.60	0.62
1,000 m	1999,2005,2007,2009	0.52	0.51
all years		0.60	0.52

There is some evidence that trawl and longline survey abundance trends are similar. This may indicate that these surveys are sampling the same population and lend credence to the method we use to extrapolate AI biomass from longline survey data. Trawl and longline survey abundance trends can be compared in the GOA and EBS, since some trawl surveys sampled to at least 1,000 m in these areas. Longline and trawl surveys did not occur in the same years in the EBS (trawl survey was in even years and longline was in odd). The trends in the two surveys in the EBS tracked well. The trends in the GOA were not similar; however, there were not many trawl surveys in the GOA that sampled down to 1,000m within a short time frame (4 surveys over 10 years) vs. 5 years in the EBS.





Biomass in the EBS: There was no slope trawl survey in 2014. Biomass point estimates have ranged from 426-660 thousand mt between 2002 and 2012 (Table 4). Biomass was almost identical to the average in 2012 (550,266 mt), which was 17% lower than the estimate in 2010.

Longline Surveys

RPWs: RPWs of giant grenadier in the GOA had a general decreasing trend from 1999 through 2004, increased through 2007, and have been somewhat decreasing since then (Table 5). In 2014 the RPW in the GOA was 19% below average, which is well within the range of values in other years. RPWs in the Bering Sea have been increasing since 2007. In 2013 the biomass was 7% above average. The biomass of giant grenadier in the AI is larger than in other areas. This is because there is a large population estimated to be in the western Aleutians. This area is not currently sampled, but a ratio of eastern to western areas from previous surveys is used to extrapolate RPWs to these areas. In 2014, the AI RPW was 26% above average.

Analytic Approach

Modeling Approach

The tier 5 computations have been based only on giant grenadier because virtually none of the other species are caught in the commercial fishery or surveys. The exploitable biomass in the GOA was previously based on averaging the biomass estimates in the last three trawl surveys that extended to 1,000 m. The deepest stratum (701-1,000 m) was not sampled in 2011 or 2013, therefore, since 2009 the same estimate of biomass has been used for ABC/OFL calculations. This year we use a random effects model, presented in the 2012 SAFE report (Rodgveller et al. 2012), which utilizes trawl survey data from 1984-2013 to estimate the exploitable biomass in 2013 (see section above under Survey data, trawl surveys). Since there was no trawl survey in the GOA in 2014, the estimate for 2013 is used as the most recent value of exploitable biomass. To estimate exploitable biomass in the BS and AI, we continue to use an average of the three most recent trawl surveys with data available down to 1,000 m. For the BS that is 2008, 2010, and 2012. For the AI that is 2010, 2012, 2014. In the future we may use a random effects model in the Bering Sea to estimate biomass.

Parameter Estimates

Maximum Age: The most recent aging studies for giant grenadiers (Burton 1999 and Rodgveller et al. 2010) found the maximum age to be 56 and 58 years, respectively, based on specimens from the GOA. There have been no aging studies for Pacific grenadier in Alaska, but Andrews et al. (1999) found a maximum age of 73 years for this species off the U.S. west coast.

Natural mortality: In the 2014 assessment we continue to use the natural mortality estimate (*M*) of 0.078, calculated using Hoenig's (1983) longevity equation with a maximum age of 58 from a study of age at maturity for giant grenadier (Rodgveller et al. 2010).

Results

Harvest Recommendations

Parameters used: In the previous stock assessment for grenadiers (Rodgveller et al. 2013), the NPFMC's tier 5 approach for determining the OFL and ABC was recommended, and this approach was supported by both the GOA Groundfish Plan Team and the NPFMC's Scientific and Statistical Committee. We again use tier 5 unofficial ABC and OFL calculations.

Methods: Current biomass estimates in this assessment for giant grenadier in the EBS and GOA were calculated based on the average of the three most recent deep-water trawl surveys that sampled down to 1,000 or 1,200 m. In the EBS, these are now the 2008, 2010, and 2012 surveys. In the AI a method used in the 2012 SAFE was used to calculate biomass down to 1,000 m, even when trawl surveys sampled only to 500 m. Details are in Rodgveller et al. (2012). Estimates of AI biomass used for calculations of ABC and OFL are now based on 2010, 2012, and 2014.

The current GOA biomass was estimated using a random effects model (see section above under "Trawl Surveys"); therefore a single estimate is used as an estimate of exploitable biomass. This method is preferable to averaging the last three trawl surveys that sampled down to 1,000 m because trawl surveys have not extended this deep since 2009. The deepest stratum (700-1,000 m) will not likely be sampled in the near future.

The NPFMC's tier 5 definitions for OFL and ABC are: OFL = M x *Biomass*, where M is the estimated natural mortality rate, and ABC is $\leq$(0.75 x OFL). Based on our discussion above, tier 5 recommendations for OFL and ABC of grenadiers are listed below (biomass, OFL, ABC, and mean catch are in mt).

BSAI and GOA grenadiers

Area	Biomass	Natural mortality M	OFL definition	OFL	ABC definition	ABC
EBS	553,557	0.078	biom x M	43,177	OFL x 0.75	32,383
AI	733,177	0.078	biom x M	57,188	OFL x 0.75	42,891
BSAI total	1,286,734			100,365		75,274
GOA	524,624	0.078	biom x M	40,921	OFL x 0.75	30,691
Grand total	1,811,358			141,286		105,965

Gulf of Alaska Grenadiers

Quantity	As estimated or specified *last* year for[a]: 2014	2015	As estimated or recommended *this* year for: 2015	2016
M (natural mortality)	0.078	0.078	0.078	0.078
Specified/recommended Tier	5	5	5	5
Biomass (t)	597,884	597,884	524,624	524,624
F_{OFL} (F=M)	0.078	0.078	0.078	0.078
$maxF_{ABC}$ (maximum allowable = 0.75*x* F_{OFL})	0.0585	0.0585	0.0585	0.0585
F_{ABC}	0.0585	0.0585	0.0585	0.0585
OFL (t)	**46,635**	46,635	**40,921**	40,921
maxABC (t)	34,976	34,976	**30,691**	30,691
ABC (t)	**34,976**	34,976	**30,691**	30,691
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	No	n/a	No	n/a

[a]The values for biomass, OFL, and ABC in these two columns are based on Rodgveller and Hulson 2013. They are an average of the last three trawl surveys that sampled down to 1,000 m. The current values (for 2015 and 2016) are from the random effects model fit to survey biomass by region and depth strata.

Bering Sea and Aleutian Islands Grenadiers

Quantity	As estimated or specified *last* year for[a]: 2014	2015	As estimated or recommended *this* year for: 2015	2016
M (natural mortality)	0.078	0.078	0.078	0.078
Specified/recommended Tier	5	5	5	5
Biomass (t)	1,152,284	1,152,284	1,286,734	1,286,734
F_{OFL} (F=M)	0.078	0.078	0.078	0.078
$maxF_{ABC}$ (maximum allowable = 0.75*x* F_{OFL})	0.0585	0.0585	0.0585	0.0585
F_{ABC}	0.0585	0.0585	0.0585	0.0585
OFL (t)	**89,878**	89,878	**100,365**	100,365
maxABC (t)	67,409	67,409	**75,274**	75,274
ABC (t)	**67,409**	67,409	**75,274**	75,274
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	No	n/a	No	n/a

[a]The values for biomass, OFL, and ABC in these two columns are based on Rodgveller and Hulson 2013.

Not subject to over fishing: The recommended OFLs and ABCs in the above tables are much larger than the mean catches for grenadiers and also much larger than the catch in any single year, which indicates catches could increase without endangering the stocks. This is especially true for the EBS and AI, where the exploitation rate appears to be quite low.

Ecosystem Considerations

A determination of ecosystem considerations for grenadiers in Alaska is hampered by the extreme lack of biological and habitat information for these species and by limited knowledge in general on the deep slope environment inhabited by these fish.

Ecosystem Effects on the Stocks

Prey availability/abundance trends: The only food studies on grenadiers in the northeast Pacific have been on adults. One study of giant grenadier off the U.S. west coast concluded that the fish fed primarily off-bottom on bathy- and mesopelagic food items that included gonatid squids, viperfish, deep-sea smelts, and myctophids (Drazen et al. 2001). Smaller studies of giant grenadier food habits in Alaska showed generally similar results. In the Aleutian Islands, the diet comprised mostly squid and myctophids (Yang 2003), whereas in the Gulf of Alaska, squid and pasiphaeid shrimp predominated as prey (Yang et al. 2006). Research on these deep-sea prey organisms in Alaska has been virtually non-existent, so information on prey availability or possible variations in abundance of prey are unknown. Very few juvenile giant grenadier have ever been caught, so nothing is known about their food preferences.

In contrast to giant grenadier, a study of Pacific grenadier food habits off the U.S. west coast found a much higher consumption of benthic food items such as polychaetes, cumaceans, mysids, and juvenile Tanner crabs (*Chionoecetes* sp.), especially in smaller individuals (Drazen et al. 2001). Carrion also contributed to its diet, and larger individuals consumed some pelagic prey including squids, fish, and bathypelagic mysids.

Predator population trends: The only documented predators of giant grenadier are Pacific sleeper sharks (Orlov and Moiseev 1999) and Baird's beaked whales (Walker et al. 2002). According to Orlov's and Moiseev's study, giant grenadier was ranked third in relative importance as a food item in the diet of these sharks. Sperm whales are another potential predator, as they are known to dive to depths inhabited by giant grenadier on the slope and have been observed depredating on longline catches of giant grenadier[6]. Giant grenadier is a relatively large animal that is considered an apex predator in its environment on the deep slope (Drazen et al. 2001), so it may have relatively few predators as an adult. Predation on larval and juvenile giant grenadiers would likely have a much greater influence on the ultimate size of the adult population size, but information on predators of these earlier life stages is nil.

Changes in habitat quality: Little or no environmental information has been collected in Alaska for the deep slope habitat in which grenadiers live. This habitat is likely more stable oceanographically than shallower waters of the upper slope or continental shelf. Regime shifts on the continental shelf and slope in Alaska in recent decades have been well documented, but it is unknown if these shifts also extend to the deep slope. Regime shifts could have a pronounced effect on giant grenadier if their larvae or post-larvae inhabited upper portions of the water column. However, no larvae or post-larvae for this species have ever been collected in Alaska. The absence of larvae or post-larvae giant grenadier in larval surveys in Alaska, which have nearly all been conducted in upper parts of the water column, implies that larval giant grenadier may reside in deeper water, where they may be less affected by regime shifts since water temperatures in deep water tend to be more stable.

Fishery Effects on the Ecosystem

[6] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm. Oct 2012.

Because there has been virtually no directed fishing for grenadiers in Alaska, the reader is referred to the discussion on Fishery Effects in the sablefish SAFE report. The sablefish longline fishery is the main fishery that takes giant grenadier as bycatch, so the Fishery Effects section in the sablefish report is applicable to giant grenadier and is an indication of what the effects might be if a directed fishery for giant grenadier were to develop. It should be noted that because all grenadiers presently caught in the sablefish and Greenland turbot fisheries are discarded and do not survive, this constitutes a major input of dead organic material to the ecosystem that would not otherwise be there.

Data Gaps and Research Priorities

Research priorities

1) Because early life history information for giant grenadier is nil, studies are also needed to investigate where larvae and young juveniles reside.
2) Evaluation of the catchability of giant grenadier in the bottom trawl surveys, which would affect the accuracy of subsequent biomass estimates. Studies are needed on whether this fish is a completely benthic species or if individuals sometimes move off-bottom.
3) Validation of the AFSC REFM Division aging methodology for giant grenadier.
4) Further analysis and study of competition for hooks that may affect giant grenadier catch rates on the AFSC longline survey.
5) Continue a study to examine if the three different shapes of otoliths found in giant grenadier represent separate species or subpopulations. This is an ongoing cooperative project between the Marine Ecology and Stock Assessment program at Auke Bay Laboratories (ABL), REFM Age and Growth Lab, and the ABL genetics lab.

Current Research

Three otolith shapes were previously identified by Charles Hutchinson, AFSC Age and Growth Lab, in giant grenadier. A review of the literature revealed that this level of variability in otolith shape is extremely unusual for an individual fish species. These three otolith types may indicate that genetic subspecies or subpopulations exist for giant grenadier in Alaska that are not apparent based on the external morphology of the fish. Tagging studies are a traditional way to determine migration patterns and spatial stock structure for fish. However, these studies are not possible for giant grenadier because the fish do not survive the pressure difference when caught at depth and brought to the surface. Genetic and otolith microchemistry studies are an alternative means for determining patterns of stock structure.

In 2013, otolith and tissue samples were collected from giant grenadier in the eastern, central and western GOA and the EBS. Otoliths will be aged and photographed for morphometric measurements in 2015. Tissues are currently being analyzed by Scott Vulstek and Charles Guthrie, AFSC Auke Bay Laboratories genetics program. After genetic and morphometric data is collected, we will compare results from the two studies.

Literature cited

Ambrose, D. A. 1996. Macrouridae: grenadiers. *In*: Moser, H. G. (ed.). The early stages of fishes in the California Current region. CALCOFI Atlas No. 33. Calif. Coop. Oceanic Fish. Invest., La Jolla, CA, pp. 483-499.

Andrews, A. H., G. M. Cailliet, and K. H. Coale. 1999. Age and growth of Pacific grenadier (*Coryphaenoides acrolepis*) with age estimate validation using an improved radiometric ageing technique. Can. J. Fish. Aquat. Sci. 56: 1339-1350.

Burton, E. J. 1999. Radiometric age determination of the giant grenadier (*Albatrossia pectoralis*) using ^{210}Pb:^{226}Ra disequilibria. Master's thesis, San Francisco State University, 91 p.

Clausen, D. M. 2006. Grenadiers in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska and Bering Sea/Aleutian Islands regions, Appendix F, p. 563-600. North Pacific Fishery Management Council, 605 W 4th Ave., Suite 306, Anchorage AK 99501.

Clausen, D. M. 2008. The giant grenadier in Alaska. *In* A. M. Orlov and T. Iwamoto (Editors), Grenadiers of the world oceans: biology, stock assessment, and fisheries, p. 413-450. Amer. Fish. Soc Sympos. 63. (Published by Amer. Fish. Soc., Bethesda, MD).

Clausen, D. M., and C. J. Rodgveller. 2010. Assessment of grenadiers in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska and Bering Sea/Aleutian Islands regions, Appendix 1, p. 797-846. North Pacific Fishery Management Council, 605 W 4th Ave., Suite 306, Anchorage AK 99501.

Rodgveller, C. J., D. M. Clausen, and P.-J. Hulson. 2012. Assessment of grenadiers in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska and Bering Sea/Aleutian Islands regions, Appendix 1, p. 797-846. North Pacific Fishery Management Council, 605 W 4th Ave., Suite 306, Anchorage AK 99501.

Drazen, J. C., T. W. Buckley, and G. R. Hoff. 2001. The feeding habits of slope dwelling macrourid fishes in the eastern North Pacific. Deep-Sea Res. I 48:909-935.

Endo, H., M. Yabe, and K. Amaoka. 1993. Occurrence of the macrourid alevins genera *Albatrossia* and *Coryphaenoides* in the northern North Pacific Ocean. Japan J. Ichthyol. 40(2): 219-226.

Faunce, C., J. Cahalan, J. Gasper, T. A'mar, S. Lowe, F. Wallace, and R. Webster. 2014. Deployment performance review of the 2013 North Pacific Groundfish and Halibut Observer Program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-281, 74 p.

Gaichas, S. 2002. Squid and other species in the Bering Sea and Aleutian Islands. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands Regions November 2002, p. 669-699. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK 99501.

Gaichas, S. 2003. Squid and other species in the Bering Sea and Aleutian Islands. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region, November 2003, p. 777-808. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage AK 99501.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82(1): 898-902.

Hoff, G. R., and L. L. Britt. 2009. Results of the 2008 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-197, 294 p.

Hoff, G. R., and L. L. Britt. 2011. Results of the 2010 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources, 300 p.

Iwamoto, T., and D. L. Stein. 1974. A systematic review of the rattail fishes (Macrouridae: Gadiformes) from Oregon and adjacent waters. Occasional Papers of the California Academy of Sciences No. 111, 79 p.

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson. 2002. Fishes of Alaska. Amer. Fish. Soc., Bethesda, Maryland, 1,037 p.

NMFS. 2014. Environmental Assessment, Regulatory Impact Review, and Initial Regulatory Flexibility Analysis for Amendment 100 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands, and Amendment 91 to the Fishery Management Plan for Groundfish of the Gulf of Alaska: Inclusion of Grenadiers (Family Macrouridae) in Groundfish Management. February 2014, U.S.DOC, NOAA, NMFS; Alaska Region, P.O. Box 21668, Juneau, AK 99802-1668.

Novikov, N. P. 1970. Biology of *Chalinura pectoralis* in the North Pacific. *In*: P. A. Moiseev (Editor), Soviet fisheries investigations in the northeastern Pacific, Part V (In Russian). All-Union Scientific Research Institute of Marine Fisheries and Oceanography (VNIRO), Proceedings Vol. 70, and Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Proceedings Vol. 72. (Translated by Israel Program for Scientific Translations, Jerusalem, 1972, p. 304-331).

Orlov, A. M., and S. I. Moiseev. 1999. Some biological features of Pacific sleeper shark, *Somniosus pacificus* (Bigelow *et* Schroeder 1944) (Squalidae), in the northwestern Pacific Ocean. Polish Academy of Sciences, National Scientific Committee on Oceanic Research, Institute of Oceanography, University of Gdansk. Oceanological Studies FVIII No. 1-2: 3-16.

Rodgveller, C. J., D. M. Clausen, J. J. Nagler, and C. Hutchinson. 2010. Reproductive characteristics and mortality of female giant grenadiers in the northern Pacific Ocean. Mar. Coast. Fish.: Dynamics, Management, and Ecosystem Sci. 2:73-82.

Rodgveller, C, J, D. M. Clausen, P. Hulson. 2012. Assessment of the grenadier stock complex in the Gulf of Alaska, Eastern Bering Sea, and the Aleutian Islands. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska for 2013. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. http://www.afsc.noaa.gov/REFM/Docs/2012/GOAgrenadier.pdf

Ronholt, L. L., K. Teshima, and D. W. Kessler. 1994. The groundfish resources of the Aleutian Islands region and southern Bering Sea 1980, 1983, and 1986. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-31, 351 p.

Tribuzio, C. A., C. Rodgveller, and P.-J. Huslon. 2014. GOA and BSAI shark assessments. September

Plan Team document. http://www.afsc.noaa.gov/REFM/stocks/plan_team/2014_sharks_SeptPT.pdf

Tuponogov, V. N. 1997. Seasonal migrations of the grenadier *Coryphaenoides pectoralis* in the Sea of Okhotsk and contiguous waters. Russ. J. Mar. Bio. 23(6):314-321.

Walker, W. A., J. G. Mead, and R. L. Brownell, Jr. 2002. Diets of Baird's beaked whales, *Berardius bairdii*, in the southern Sea of Okhotsk and off the Pacific coast of Honshu, Japan. Marine Mammal Science 18(4): 902-919.

Yang, M-S. 2003. Food habits of the important groundfishes in the Aleutian Islands in 1994 and 1997. AFSC Processed Rep. 2003-07, 233 p. (Available from National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle WA 98115).

Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-164.

Table 1.—Updated catch data (mt) for grenadiers, nearly all of which are thought to be giant grenadier, as of October 7, 2014 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org). The estimates for 2003-2012 were computed by the NMFS Alaska Regional Office based on their Catch Accounting System, which replaced the “blend” system in 2003. Observer restructuring began in 2013 so the mean from 2003-2012 is presented for comparison to 2013 and 2014.

	Eastern Bering Sea	Aleutian Islands	Gulf of Alaska	Total
1997	2,964	2,887	12,029	17,881
1998	5,011	1,578	14,683	21,272
1999	4,505	2,883	11,388	18,776
2000	4,067	3,254	11,610	18,931
2001	2,294	1,460	9,685	13,439
2002	1,891	2,807	10,479	15,177
2003	2,641	3,036	10,843	16,520
2004	2,225	1,251	10,471	13,946
2005	2,633	1,795	6,606	11,034
2006	2,068	2,225	8,515	12,808
2007	1,645	1,817	9,629	13,091
2008	1,687	1,800	11,167	14,654
2009	2,983	3,681	6,696	13,360
2010	2,928	3,690	5,564	12,181
2011	4,333	2,578	7,437	14,349
2012	2,926	4,625	7,568	15,119
2013	1,629	2,535	11,339	15,504
2014	876	1,751	5,236	7,863
Mean 2003-2012	2,607	2,650	8,450	13,706

Table 2.—Estimated catch (mt) of grenadiers (all species combined) in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska, by target species/species group, 2003-2011. Arrow = arrowtooth flounder; DW flat = deep-water flatfish; GT = Greenland turbot; halibut = Pacific halibut; Kam = Kamchatka flounder; cod = Pacific cod; rex = rex sole; sable = sablefish; other sp. = other species combined (including yellowfin sole, rock sole, shallow-water flatfish, "other flatfish", flathead sole, and all other species). Source: Regional Office Catch Accounting System accessed through the Alaska Fisheries Information Network (AKFIN), October 7, 2014.

	Target species/species group									
Year	arrow	DW flat	GT	halibut	Kam	cod	rex	rockfish	sable	other
					Aleutian Islands					
2003			113	1,376		46		6	1,494	0
2004			14	414		13		60	748	1
2005			161	617		2		21	979	16
2006	341		328	172		121		154	1,109	0
2007	108		342	69		41		21	1,161	76
2008	397		67	229		26		59	746	276
2009	1,377		414			12		152	1,642	84
2010	1,674		210	44		259		168	1,127	206
2011	51		83	13	723	18		292	1,292	105
2012	264			113	2,56	55		38	1,167	428
2013	278		44	239	406	3		215	1,139	212
2014	254			63	295	23		218	842	56
					Eastern Bering Sea					
2003	38		1,452	355		240		9	370	164
2004	24		1,315	254		240		22	287	83
2005	11		1,977	143		333		32	108	31
2006	125		1,192	174		130		12	420	16
2007	2		1,073	89		179		17	215	70
2008	69		708	392		163		3	127	226
2009	243		1,823			212		6	692	8
2010	186		2,036	36		390		126	145	8
2011	807		1,799	7	241	1,13		17	316	5
2012	673		1,464	61	5	514		3	179	27
2013	272		533	321	12	274		47	166	4
2014	120		377	143	10	100		2	113	10

Table 2.—continued.

	Target species/species group									
Year	Arrow	DW flat	GT	Halibut	Kam Fl	Cod	Rex	Rockfish	Sable	Other
					Gulf of Alaska					
2003	27	474		710		5	325	613	8,464	223
2004	171	178		156		0	5	2,231	7,657	74
2005	103			488			4	212	5,743	56
2006	18			766		22	4	338	7,243	124
2007	90	20		530		79	5	198	8,702	5
2008	3			1,918		97	89	164	8,651	244
2009				1,430		79	102	227	4,816	43
2010	40	60		243		149	140	511	4,359	62
2011	114			172	723	69	229	529	6,208	116
2012	155			18	2,561	173	2	438	6,666	116
2013	161	1,246		338	406	169	4	1,008	8,327	87
2014	387			259	295	162	5	602	3,803	19

Table 3.—Biomass estimates for grenadier in the Gulf of Alaska using a random effects model. Estimates are for 1-1,000 m in all years. Left: estimates from using a random effects model. Center: estimates from NMFS trawl surveys that sampled down to 1,000 m. Right (status quo): biomass estimates used in SAFE reports for specifications of unofficial ABCs and OFLs since 2006. Biomass in 2006 was calculated as the average of the last two trawls surveys that sampled down to 1,000 m. Years after that the last three trawl surveys were averaged.

	Random Effects			Surveys down to 1,000 m			
Year	Biomass	U 95% CI	L 95% CI	Biomass	U 95% CI	L 95% CI	Status quo
1984	175,388	227,242	135,366	169,708	228,015	111,401	
1985	170,807	225,204	129,548				
1986	166,557	218,599	126,905				
1987	162,617	208,284	126,963	135,971	188,211	83,731	
1988	167,761	226,612	124,193				
1989	173,766	244,626	123,432				
1990	180,602	262,528	124,242				
1991	193,747	286,163	131,177				
1992	209,763	311,007	141,477				
1993	229,936	337,265	156,763				
1994	243,428	356,531	166,204				
1995	257,863	371,900	178,794				
1996	273,315	381,925	195,591				
1997	299,036	404,975	220,811				
1998	331,011	428,314	255,814				
1999	371,879	443,349	311,930	389,908	466,030	313,786	
2000	397,273	505,803	312,029				
2001	427,155	544,558	335,063				
2002	453,259	588,879	348,873				
2003	482,870	598,383	389,656				
2004	493,499	626,562	388,695				
2005	507,214	609,381	422,176	587,346	754,202	420,489	
2006	477,897	596,180	383,081				488,627
2007	463,065	568,252	377,349	487,987	629,173	346,802	488,414
2008	452,765	624,873	328,061				488,414
2009	455,461	749,608	276,738	718,320	1,484,296	0	597,884
2010	460,223	818,702	258,709				597,884
2011	473,685	898,965	249,595				597,884
2012	496,996	996,834	247,789				597,884
2013	524,624	1,099,917	250,229				597,884
2014	524,624	1,194,419	230,431				597,884

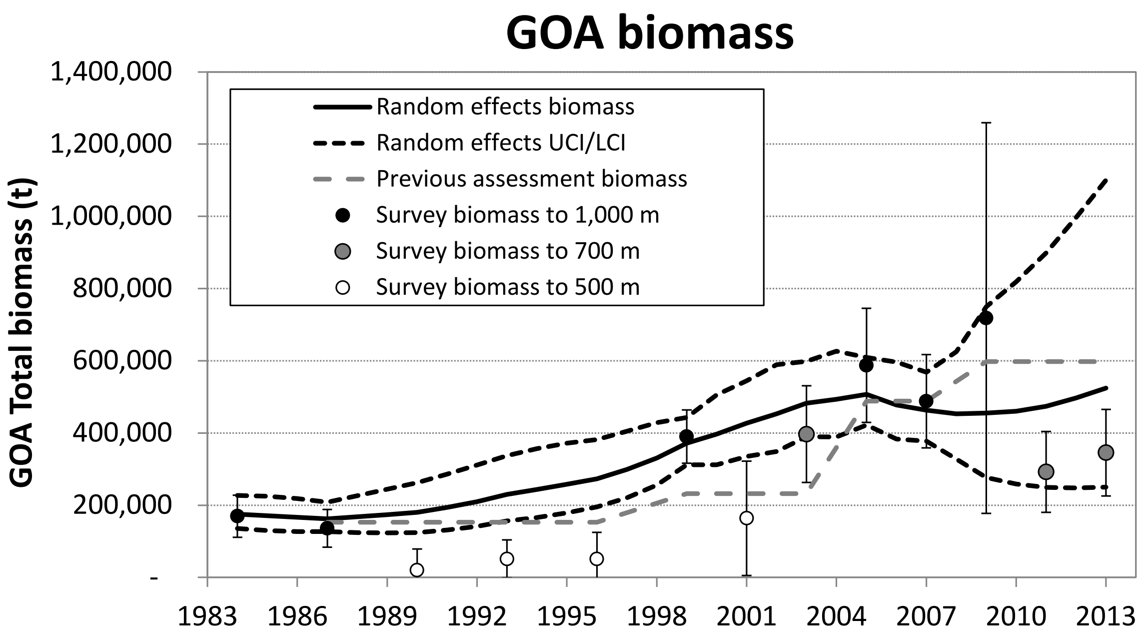
Table 4.—Biomass estimates (mt) and associated 95% confidence bounds (mt), variances, and coefficients of variation (cv) for giant grenadier in recent NMFS surveys in Alaska that sampled the upper continental slope. The Gulf of Alaska surveys included depths to 1,000 m, whereas the eastern Bering Sea slope surveys included depths to 1,200 m. Aleutian Islands biomass was estimated from trawl survey biomass estimates from 1-500 m and AFSC longline survey relative population weights from 200-1000m (see section titled "survey data").

			95% Conf. bounds			
Region	Year	Biomass	Lower	Upper	Variance	cv (%)
Aleutian Islands	2000	560,200	290,106	830,294	18,989,690,223	24.6
Aleutian Islands	2002	570,239	295,651	844,828	19,626,898,754	24.6
Aleutian Islands	2004	575,396	297,497	853,295	20,103,051,745	24.6
Aleutian Islands	2006	721,531	373,113	1,069,950	31,600,203,801	24.6
Aleutian Islands	2008	365,940	189,744	542,136	8,081,265,243	24.6
Aleutian Islands	2010	688,251	356,757	1,019,745	28,604,825,470	24.6
Aleutian Islands	2012	478,991	246,867	711,115	14,025,825,748	24.7
Aleutian Islands	2014	733,177	379,987	1,086,366	32,471,605,527	24.6
Eastern Bering Sea	2002	426,397	344,922	507,871	1,659,519,194	9.6
Eastern Bering Sea	2004	666,508	527,524	805,491	4,829,084,657	10.4
Eastern Bering Sea	2008	449,777	353,902	545,652	2,298,003,647	10.7
Eastern Bering Sea	2010	660,528	521,035	800,021	4,864,588,623	10.6
Eastern Bering Sea	2012	550,366	433,097	667,635	3,437,997,235	10.6

Table 5.—Giant grenadier relative population weight, by region, in AFSC longline surveys in Alaska, 1990-2014. Dashes indicate years that the eastern Bering Sea or Aleutian Islands were not sampled by the survey. Gulf of Alaska values include data only for the upper continental slope at depths 201-1,000 m and do not include continental shelf gullies sampled in the surveys. Note: relative population weight, although an index of biomass (weight), is a unit-less value. NA indicates that length data is not available for calculations of RPWs. AFSC longline survey database query, October 2014.

Year	Eastern Bering Sea	Aleutian Islands	Gulf of Alaska
1992	-	-	686,827
1993	-	-	1,041,508
1994	-	-	1,018,292
1995	-	-	1,264,245
1996	-	2,281,815	1,121,058
1997	762,639	-	1,266,800
1998	-	2,268,918	1,066,477
1999	571,852	-	1,277,141
2000	-	3,039,523	1,143,980
2001	398,950	-	1,067,335
2002	-	3,093,994	904,922
2003	538,190	-	1,058,570
2004	-	3,121,973	801,271
2005	694,456	-	826,495
2006	-	3,914,871	857,510
2007	437,268	-	1,242,833
2008	-	1,985,511	919,083
2009	521,179	-	1,063,104
2010	-	3,734,301	1,236,692
2011	574,349	-	829,476
2012	-	3,230,202	911,728
2013	605,727	-	896,776
2014	-	3,978,057	848,321
mean	567,179	3,151,928	1,012,140

Figure 1.—Biomass estimates of giant grenadier from NMFS bottom trawl surveys and from a random effects model that utilizes trawl survey biomass estimates from all years (with 95% confidence intervals). The estimates of exploitable biomass used in previous assessments are also presented. From 1987-1996 this was the average of the last two trawl surveys that extended down to 1,000 m. From 1999-2013, it was the average of the biomass from the most recent three surveys that sampled down to 1,000 m.



Appendix A. Giant grenadier depth distribution by sex in fisheries and surveys.

Method and Results

Catch

Observed grenadier catch, not estimated total catch, was split by sex using sex ratios from observer specimen data, i.e., fish that had their lengths taken from 2003-2013 (Table 1; Figure 1). This timeframe was chosen because catch estimates are available for grenadier since 2003. Length frequencies by sex, stratum, and FMP area were converted to weights using area (BS, AI, and GOA) and sex specific growth curves from AFSC trawl surveys. The percent males by weight were used to split the observed catch for the Bering Sea (BS), Aleutian Islands (AI), and the Gulf of Alaska (GOA) by stratum (Table 2). The same percentages were used for splitting BS and AI observed catch (Table 1).
Total estimated grenadier catch from the Catch Accounting System (CAS) was split by sex using sex ratios of weight from observer specimen data (Table 3), as described above, except a single proportion was used for all depth strata combined because catch is not available by depth from CAS. The percent male was 13% in the BSAI and 15% in the GOA.

AFSC Longline Survey

The AFSC longline survey stations are spaced systematically (~20-30 km apart) along the slope from the eastern Gulf of Alaska west to the Aleutian Islands and north into the eastern Bering Sea. At each station, depths from ~150-1000 m are sampled. Giant grenadier are caught in great numbers throughout the survey range, primarily in depths from 400-1,000 m. The Aleutian Islands are sampled in even years, the Bering Sea in odd years, and the Gulf of Alaska is sampled annually. Because the area that is sampled by the longline cannot be defined, an index of abundance in weight is calculated, called relative populating weight (RPW), but is not a measure of absolute biomass. The index is used for tracking trends in abundance.

Giant grenadier length frequencies are available since 2006. Length frequencies by sex, stratum, and area (AI, BS, GOA) were converted to weights using area and sex specific growth curves from AFSC trawl surveys. The percent males, by weight, for each depth strata and area were calculated (Table 4) and used to split the RPWs by sex and stratum (Table 5, Figure 2).

AFSC Gulf of Alaska Trawl Survey

The AFSC GOA trawl survey samples the continental shelf and slope where stations are randomly chosen within depth strata. Only surveys that sampled down to 1,000 m were included in this analysis (1999, 2005, 2007, and 2009); surveys in 1984 and 1987 were not included because survey methodology changed in 1996. In other years, surveys sampled down to only 500 or 700 m and are not reflective of the extent of grenadier distribution by sex.

Giant grenadier population length frequencies are available split by sex for each depth stratum. We converted these population length frequencies to weight (biomass) using sex specific growth curves from GOA trawl survey data (Table 6). The biomass split by sex, year, and strata, as well as the percent of giant grenadier biomass that is male, is presented in Table 6. For comparison to the longline survey and observed catch, the average biomass by sex and strata are shown in Figure 3. Bering Sea trawl survey biomass estimates spilt by sex are not currently available and will be examined in the future.

Discussion

The observed catch is primarily between depths of 201-400 m; however, this is not where the bulk of giant grenadier biomass is found (e.g., see figures 1 and 2 for AFSC longine and trawl survey data). Observer length data shows that the percent of the catch that is male, by weight, increases with depth in the GOA, but there is the opposite trend in the BSAI. Although, the decreasing trend in male abundance is not dramatic in the BSAI and sample sizes for several depths strata are small. Due to small sampled sizes, the apparent trend in the BSAI may not be representative of the true distribution of giant grenadier. There is a much greater proportion of male grenadier in the catch data compared to the longline survey. This could be partially explained by the diverse gear types in the fisheries that incidentally catch grenadier; however, a large proportion of the observed grenadier catch is from longline fisheries. The difference between the proportion of males in longline survey and fishery could also be attributed to seasonal variation in depth distribution. The longline survey takes place only in the summer, whereas fisheries take place nearly year round. More time is required to explore distribution differences in the fishery by season and we plan to examine this in the future.

The trawl survey had a greater proportion of males than the longline survey and the proportion of males increased with depth in all surveys. The sex proportions in the trawl survey were more similar to the fishery than the longline survey when all depths are considered; however, in the 1-500 depth stratum the trawl survey had a very low percentage of males (2-5%), whereas the majority of the fishery data was from 201-400 m and the percentage male was larger than 5% (12-16%).

In all data sources, including surveys and fisheries, the large majority of catch is females. Also, overall the proportion of male grenadier, by weight, increases with deeper depths. Taken together, this information indicates that our surveys and fisheries may not completely cover the range of grenadier distribution. However, it also indicates that a disproportionate harvest of females is occurring, and should continue to be monitored.

Although a portion of the male population may reside in depths deeper than surveys and fisheries, it is possible that there is not a 1:1 ratio of males to females. We have not aged males and, therefore, it is not known if the natural mortality rate is different between sexes for grenadiers. Given the sexual dimorphism in growth and differences in distribution by sex, it could be postulated that other life-history parameters, like natural mortality, may also vary by sex. For example, in some flatfish species there is sexual dimorphism in natural mortality, where males have a much higher rate than females (e.g., arrowtooth flounder, 0.2 for females and 0.35 for males). If this is true for grenadier, the sex ratio may not be 1:1. The number of females could be larger than the number of males. Even in a deep-water AFSC longline survey (down to 1,600 m in the WGOA), on average 24% were male by number. Also, because females were much larger at depths >1,000 m than depths <1,000 m, the weight ratio would likely be much less than 24%.

Table 1. Sum of observed giant grenadier catch in mt for males (M) and females (F) from 2003-2013.

	Aleutian Islands			Bering Sea			Gulf of Alaska		
Depth strata	AI	AI F	AI M	BS	BS F	BS M	GOA	GOA F	GOA M
1-100	31	27	5	441	383	58	69	59	10
101-200	802	701	106	1,280	1,113	166	1,891	1,607	284
201-300	10,183	8,855	1,328	5,300	4,610	692	8,849	7,522	1,327
301-400	6,338	5,512	828	8,457	7,355	1,104	8,726	7,415	1,309
401-500	265	230	34	788	684	104	671	570	101
501-600	4	4	0	8	6	0	20	16	1
601-700	0	0	0	2	2	0	4	4	0
701-800	0	0	0	0	0	0	3	3	0
801-900	0	0	0	0	0	0	1	1	0

Table 2. Percent of male giant grenadier in observed catch from 2003-2013 in numbers and weight. Weights were calculated from length frequencies by depth, sex, and area using sex specific growth curves from the AFSC trawl survey. The total sample size (n) for length frequencies is presented for each sex.

	BSAI		GOA	
Depth (m)	% male (numbers, weight)	n	% male (numbers, weight)	n
1-100		0	17%, 15%	6
101-200	25%, 22%	296	9%, 7%	690
201-300	19%, 16%	4,535	14%, 12%	6,623
301-400	17%, 14%	8,013	20%, 16%	11,986
401-500	23%, 17%	719	28%, 21%	1,603
501-600	20%, 13%	155	37%, 24%	123
601-700	11%, 6%	22	56%, 54%	18
701-800		0	20%, 12%	5

Table 3. Total estimated grenadier catch from 2003-2013 split by sex (mt). Observed lengths were converted to weights using area and sex specific growth curves and the percent male was calculated using these weights. The average proportion of males and females by weight in the catch was used to split catch.

Year	BS total	BS male	BS female	AI total	AI Male	AI Female	GOA total	GOA male	GOA female
2003	2,869	373	2,439	3,558	463	3,024	12,253	1,838	10,415
2004	2,223	289	1,890	1,251	163	1,063	11,989	1,798	10,191
2005	2,633	342	2,238	1,795	233	1,526	7,251	1,088	6,163
2006	2,067	269	1,757	2,195	285	1,866	8,429	1,264	7,165
2007	1,631	212	1,386	1,544	201	1,312	9,119	1,368	7,751
2008	2,820	367	2,397	2,525	328	2,146	11,333	1,700	9,633
2009	2,902	377	2,467	3,739	486	3,178	6,326	949	5,377
2010	2,799	364	2,379	3,553	462	3,020	5,419	813	4,606
2011	4,221	549	3,588	2,596	337	2,207	8,216	1,232	6,984
2012	2,276	296	1,935	4,383	570	3,726	7,206	1,081	6,125
2013	1,482	193	1,260	2,367	308	2,012	10,525	1,579	8,946
average	2,538	330	2,158	2,682	349	2,280	8,915	1,337	7,578

Table 4. Percent of fish that were male caught during the AFSC longline survey 2006-2013 in numbers and weight. Weights were calculated from length frequencies by depth, sex, and area using sex specific growth curves from the AFSC trawl survey. The total sample size (n) for length frequencies is presented for each sex.

	Aleutian Islands		Bering Sea		Gulf of Alaska	
Depth (m)	% male (numbers, weight)	n	% male (numbers, weight)	n	% male (numbers, weight)	n
101-200	0%, 0%	20	0%, 0%	9	0%, 0%	11
201-300	0%, 0%	312	0%, 0%	582	0.5%, 0.8%	2,098
301-400	0%, 0%	1,280	0%, 0%	1,559	1%, 0.5%	9,947
401-600	2%, 2%	2,912	0%, 0%	2,949	2%, 1%	19,527
601-800	6%, 5%	2,533	2%, 1%	3,038	5%, 3%	17,378
801-1000	20%, 15%	777	6%, 4%	1,015	9%, 6%	8,603
Total	5%, 4%	7,834	2%, 1%	9,255	4%, 3%	58,828

Table 5. Average AFCS longline survey Relative Population Weights split by sex and strata from 2006-2013.

Strata (m)	Aleutian Islands		Bering Sea		Gulf of Alaska	
	AI M	AI F	BS M	BS F	GOA M	GOA F
201-300	0	16,322	7	9,263	152	17,772
301-400	189	93,257	0	39,385	477	95,590
401-600	6,707	299,368	285	121,839	3,613	279,659
601-800	17,890	348,645	2,854	232,902	10,020	283,846
801-1000	37,164	218,898	6,692	148,634	17,131	271,927

Table 6. AFCS Gulf of Alaska trawl survey biomass estimates from recent years when the survey sampled down to 1,000 m (1999, 2005, 2007, 2009).

Depth strata (m)	Year	GOA M	GOA F	% male
1-500	1999	2,183	126,234	2%
1-500	2005	10,698	226,337	5%
1-500	2007	3,163	103,382	3%
1-500	2009	1,510	89,961	2%
501-700	1999	15,336	136,471	10%
501-700	2005	25,470	221,437	10%
501-700	2007	16,467	218,538	7%
501-700	2009	29,116	142,184	17%
701-1000	1999	28,466	81,219	26%
701-1000	2005	28,522	74,882	28%
701-1000	2007	46,574	99,862	32%
701-1000	2009	83,034	372,514	18%

Figure 1. Summed observed grenadier catch from 2003-2013, not total estimated catch, split by sex and depth strata.

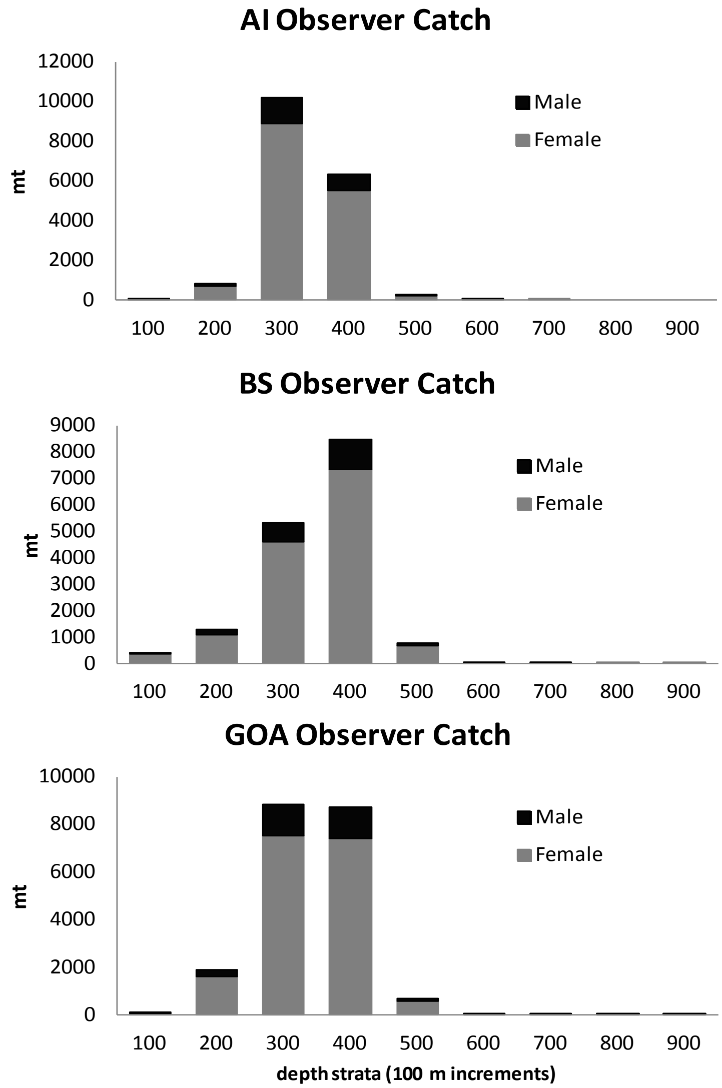


Figure 2. Average AFCS longline survey giant grenadier Relative Population Weights from 2006-2013 split by sex and depth stratum.

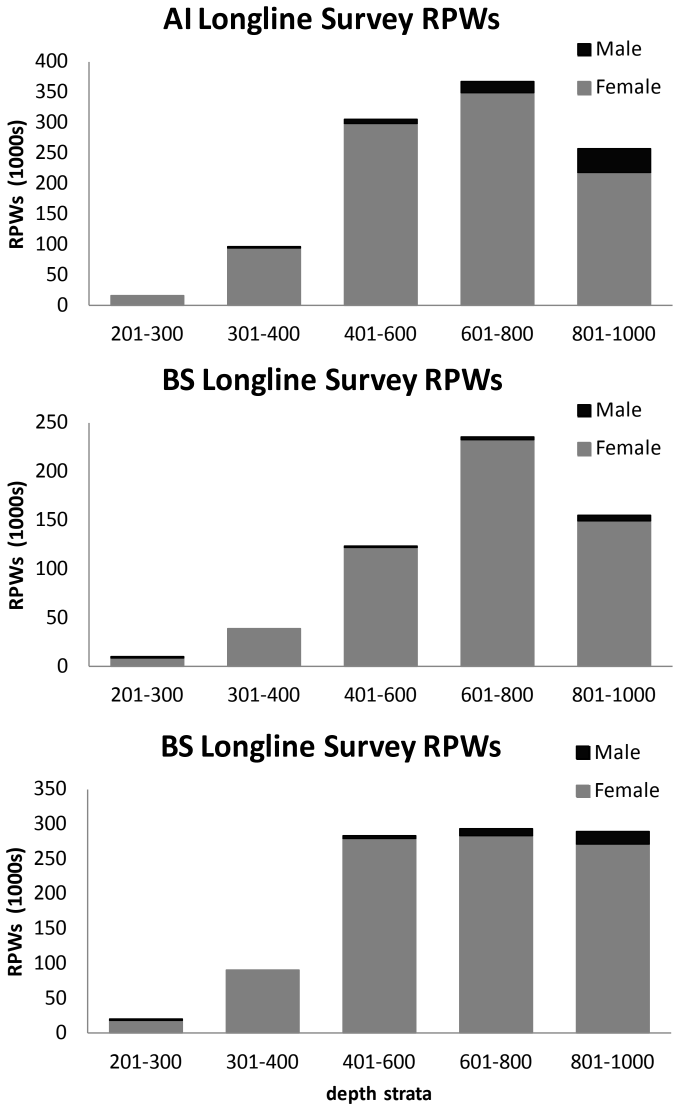
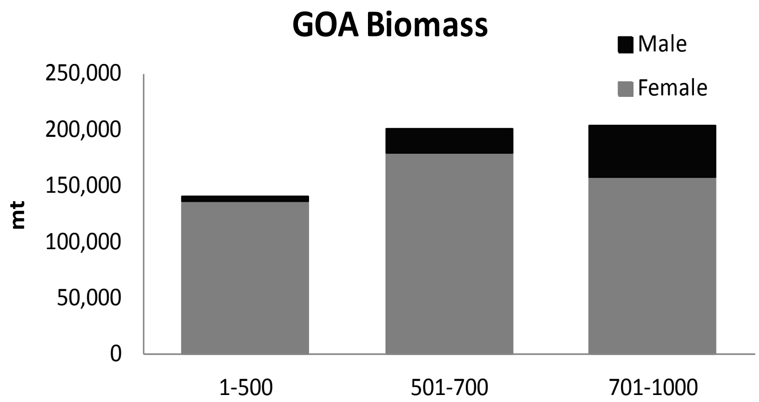


Figure 3. Average GOA AFCS trawl survey giant grenadier biomass estimates in 1999, 2005, 2007, and 2009 split by sex and strata (recent years when the survey sampled down to 1,000 m).



Appendix B

Tabbe 1B-1.—Research catch (mt) of grenadier (giant, popeye, and pacific grenadier, but primarily giant grenadier) in AFSC trawl and longline (LL) surveys and the International Pacific Halibut Commission (IPHC) longline survey. Only numbers are available from the IPHC survey through 2009; 2010 and 2011 catch in weight is available. 0s indicate that there was catch but it is <1 mt.

	BSAI					GOA					
Year	IPHC #s	IPHC wt	AFSC Trawl	AFSC LL	Total BSAI	IPHC #s	IPHC wt	AFSC Trawl	AFSC LL	Total GOA	Total
1979			33		33			0		0	33
1980			85		85			1		1	86
1981			66		66			3		3	69
1982			124		124			0		0	125
1983			136		136			0		0	136
1984								59		59	59
1985			165		165			9		9	174
1986			90		90			0		0	90
1987			0		0			42		42	42
1988			30		30						30
1989											
1990								3	128	131	131
1991			10		10				113	113	123
1992									117	117	117
1993								6	135	141	141
1994			6		6				134	134	140
1995									191	191	191
1996				38	38			8	173	181	219
1997	1,184		9	78	87	258			169	169	256
1998	556			59	59	681		12	141	153	212
1999	165		0	57	57	660		47	157	204	261
2000	774		118	88	206	621			160	160	366
2001	1,313			43	43	287		11	161	173	215
2002	987		23	81	104	942			129	129	233
2003	1,792		91	50	141	1,344		27	151	178	320
2004	2,111		196	78	274	1,110			109	109	383
2005	1,404			71	71	1,266		49	120	169	240
2006	941		20	76	96	919			112	112	208
2007	1,224			77	77	849		44	166	209	286
2008	1,331		123	47	170	755			120	120	290
2009	2,710			86	86	785		39	154	193	279
2010	2,451	9	156	66	231	1,265	6		164	170	401
2011	1,808	7		75	82	751	2	20	124	145	227
2012		5	135	43	177		2		132	132	310
*2013		5		83	88		2		132	134	222
*2014				73	73				127	127	200

*GOA trawl survey data is not available through the AKRO for grenadier for 2013 (accessed through AKFIN, October 2014). Only AFSC longline survey data is available for 2014.

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Appendix 2. Forage species report for the Gulf of Alaska

November 2014

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Overview of forage species and their management

Defining "forage species" can be a difficult task, as most fish species experience predation at some point in their life cycle. A forage fish designation is sometimes applied only to small, energy-rich, schooling fishes like sardines and herring (e.g. Lenfest 2012), but in most ecosystems this is too limiting a description. Generally, forage species are those whose primary ecosystem role is as prey and that serve a critical link between lower and upper trophic levels. For this report, the following species or groups of species are considered to be critical components of the forage base in the Gulf of Alaska:

- members of the "forage fish group" listed in the GOA Fishery Management Plan (FMP)
- Pacific herring *Clupea pallasii*
- juvenile groundfishes and salmon
- shrimps
- squids

Forage fish group in the FMP

Prior to 1998, forage fishes in the GOA were either managed as part of the Other Species group (nontarget species caught incidentally in commercial fisheries) or were classified as "nonspecified" in the FMP, with no conservation measures. In 1998 Amendment 39 to the GOA FMP created a separate forage fish category, with conservation measures that included a ban on directed fishing. Beginning in 2011, members of this forage fish group (the "FMP forage group" in this report) are considered "ecosystem components". The group is large and diverse, containing over fifty species from these taxonomic groups (see the appendix at the end of this report for a full list of species):

- Osmeridae (smelts; eulachon *Thaleichthys pacificus* and capelin *Mallotus villosus* are the principal species)
- Ammodytidae (sand lances; Pacific sand lance *Ammodytes hexapterus* is the only species commonly observed in the GOA and BSAI)
- Trichodontidae (sandfishes; Pacific sandfish *Trichodon trichodon* is the main species)
- Stichaeidae (pricklebacks)
- Pholidae (gunnels)
- Myctophidae (lanternfishes)
- Bathylagidae (blacksmelts)
- Gonostomatidae (bristlemouths)
- Euphausiacea (krill; these are crustaceans, not fish, but are considered essential forage)

The primary motivation for the creation of the FMP forage group was to prevent fishing-related impacts to the forage base in the GOA; it was an early example of ecosystem-based fisheries management

(Livingston et al. 2011). The management measures for the group are specified in section 50 CFR 679b20.doc of the federal code:

50 CFR 679b20.doc § 679.20 General limitations

(i) Forage fish

(1) Definition. See Table 2c to this part.

(2) Applicability.

The provisions of § 679.20 (i) apply to all vessels fishing for groundfish in the BSAI or GOA, and to all vessels processing groundfish harvested in the BSAI or GOA.

(3) Closure to directed fishing.

Directed fishing for forage fish is prohibited at all times in the BSAI and GOA.

(4) Limits on sale, barter, trade, and processing.

The sale, barter, trade, or processing of forage fish is prohibited, except as provided in paragraph (i)(5) of this section.

(5) Allowable fishmeal production.

Retained catch of forage fish not exceeding the maximum retainable bycatch amount may be processed into fishmeal for sale, barter, or trade.

Directed fishing for species in the FMP forage fish group is prohibited, catches are limited by a maximum retention allowance (MRA) of 2% by weight of the retained target species, and processing of forage fishes is limited to fishmeal production. While the basis for a 2% MRA is not entirely clear, it appears this percentage was chosen to accommodate existing levels of catch that were believed to be sustainable (Federal Register, 1998, vol. 63(51), pages 13009-13012). The intent of amendment 36 was thus to prevent an increase in forage fish removals, not to reduce existing levels of catch. In 1999, the state of Alaska adopted a statute with the same taxonomic groups and limitations, except that no regulations were passed regarding the processing of forage fishes. This exception has caused some confusion regarding the onshore processing of forage fishes for human consumption (J. Bonney, pers. comm., Alaska Groundfish Databank, Kodiak, Alaska).

Pacific herring

Herring are abundant and ubiquitous in Alaska marine waters. Commercial fisheries, mainly for herring roe, exist throughout the GOA. Sitka Sound in Southeast Alaska and Kodiak Island had the highest commercial catches during 2007-2011 (19,429 and 2,937 short tons, respectively, in 2011). Herring stocks in Prince William Sound fell dramatically following the Exxon Valdez Oil Spill and have yet to recover sufficiently to permit a directed fishery. The herring fishery is managed by the Alaska Department of Fish & Game (ADFG), which uses a combination of various types of surveys and population modeling to set catch limits. In federal groundfish fisheries, herring are managed as Prohibited Species, where directed fishing is banned and any bycatch must be returned to the sea immediately. The amount of herring bycatch allowed is also capped, and if the cap is exceeded the responsible target fishery is closed to limit further impacts to the species.

Juvenile groundfishes and salmon

Members of this group, particularly age-0 and age-1 walleye pollock *Theragra chalcogramma*, are key forage species in some parts of the GOA. As they are early life stages of important commercially fished species, however, their status depends almost entirely on the assessment and management of the recruited portion of the population. Information regarding these species is available in NPFMC stock assessments and ADFG reports.

Shrimps

A variety of shrimps occur in the GOA. Four species are targeted by commercial fisheries: northern (*Pandalus borealis*), coonstripe (*Pandalus hypsinotis*), spot (*Pandalus platyceros*), and sidestripe (*Pandalopsis dispar*). Large fisheries, mainly for northern shrimp, used to occur in the central and western GOA, but populations declined and fishing for shrimp has been closed since 1984 in these areas. Currently, almost all of the commercial catch occurs in Southeast Alaska. Detailed information on shrimps in waters off Alaska is available from ADFG. This report includes incidental catch data of shrimps in federal fisheries as well as an overview of the commercial catch.

Squids

The GOA may be inhabited by up to 15 species of squids, which are mainly distributed along the shelf break. Although no directed fisheries currently exist for squids, they are managed as "in the fishery" due to high levels of incidental catch, mainly in the fisheries for walleye pollock. This report contains limited information regarding squids; detailed information regarding GOA squids can be found in the GOA stock assessment report.

Distribution and abundance of forage species in the GOA

Overview of available surveys

Bottom trawl survey: Since 1984, the Alaska Fisheries Science Center (AFSC) has conducted a biennial (triennial prior to 1999) bottom trawl survey of the GOA for the purposes of groundfish stock assessment. The survey employs a bottom trawl with roller gear and a 5-inch mesh size, and covers areas of the continental shelf and upper slope from depths of 30m to approximately 500 m. Most forage fishes are small and occupy pelagic habitats. The large mesh size of the trawl survey gear and the limitation to sampling demersal habitats, likely results in high escapement and incomplete sampling of forage fish. In addition, species with primarily nearshore habitats may be poorly represented and forage fishes are often characterized by patchy distribution.

Acoustic survey: The AFSC also performs echo integration-trawl (EIT) surveys directed towards assessment of walleye pollock. These surveys focus on the Shelikof Strait area west of Kodiak during the winter, but have occasionally covered a greater area. Summer EIT surveys in the GOA have also occurred in some years. Midwater echosign is sampled by trawling to identify species composition and provide biological information. Catches of capelin and eulachon in these tows can be used as a crude measure of relative abundance.

Small-mesh survey: A third source of forage fish data in the GOA are small-mesh surveys (32 mm stretched mesh) conducted by NMFS and the Alaska Department of Fish & Game (ADF&G) at multiple nearshore locations in the central and western GOA. These surveys were designed to sample shrimp populations, but the small mesh net has proven to be effective at capturing smelt and other forage species when they are present. As is the case for the AFSC bottom trawl survey, the small-mesh survey samples only demersal habitats.

Cross-shelf distribution

Methods: The cross-shelf distribution of forage fishes in the GOA (i.e. nearshore vs. offshore) was investigated using data from the bottom trawl survey conducted in the region by the AFSC. Data were categorized by the bottom depth at the location of survey hauls. Because the species examined normally have pelagic distributions, the bottom depth is not indicative of the depths inhabited by these species. Rather the bottom depth at the haul location reveals the cross-shelf location of the haul, from the most nearshore hauls (in about 20 m depth) to the outermost hauls on the continental slope (> 1000 m depth). Because the survey gears and fishing methods are not optimized for catching these species, data from any one year likely provide inaccurate depictions of distribution and relative abundance. Therefore, all trawl survey data from 2000-2011 were aggregated and a mean catch-per-unit-effort (CPUE; numbers/hectare) was calculated for each 1 m bottom depth bin. The data were normalized to 1 to enhance comparability.

Results and discussion: Interpretation of the results is made somewhat complicated due to the complex topography of the GOA (i.e. the presence of deep waters close to shore). However the analysis serves as a starting point for investigating differences in spatial distribution, and species and species groups appear to be fairly well segregated (Fig. 1). Pacific sandfish and Pacific sand lance are captured only in hauls where the bottom is <100 m, i.e., inshore areas of the GOA. Pacific herring and capelin are mainly distributed in areas with depths <100 m, but some herring are captured where the bottom is 100-200 m and capelin can occur out to approximately 300 m depth. This result for capelin may reflect their inhabitation of the deep canyons to the east of Kodiak Island (discussed in more detail below). The depths at eulachon locations range from approximately 100 m – 400 m. In the case of eulachon, they are primarily a shelf species, but are abundant in deep troughs in the western GOA such as the Shelikof Sea Valley. The distribution of myctophids appears to be limited to the slope. The distributions of shrimps and squids (Fig. 2) also show some differences. While shrimp appear to be ubiquitous, squids are mostly distributed on the slope.

Geographic distribution – bottom trawl survey data

Methods: To further analyze the distribution of forage species in the GOA, maps of mean survey CPUE were generated for the six fish groups included in the cross-shelf analysis, as well as shrimps. Point data for each survey haul (latitude, longitude, CPUE by number) during the period 2007-2013 was mapped in ArcGIS. Using the point-to-raster function within ArcGIS, individual haul data were aggregated into 40 km x 40 km cells and a mean CPUE was calculated for each cell using data from all years. The values were symbolized using the “natural breaks” method to visualize areas with high mean CPUEs. Grids with zero CPUE were also plotted to show surveyed areas where no individuals were encountered during the entire time period.

Results and discussion: As suggested by the cross-shelf analysis, sandfish are limited to nearshore areas of the GOA (Fig. 3). They are distributed throughout the GOA except for Southeast Alaska. Sand lance are also primarily a nearshore species (Fig. 4). The analysis suggests that sand lance are concentrated in the western GOA, but unpublished data (Ormseth) indicate that they are also abundant in the eastern GOA. The survey is likely to be very poor at sampling sand lance, and it may be that they are found throughout the GOA but are sufficiently more abundant in the western GOA that the mean CPUE there is higher. Because the GOA trawl survey works from west to east over a 3-month period, the spatial pattern may also reflect seasonal differences in availability to the survey. As expected, herring are distributed throughout the GOA (Fig. 5), except that they are rarely encountered west of Kodiak Island. “Hotspots” off Kodiak and Southeast Alaska correspond to the locations of the major commercial fisheries.

Capelin are ubiquitous in the GOA, although they appear less abundant in the eastern GOA (Fig. 6). The survey CPUEs appear highest to the east of Kodiak, where they have been demonstrated to occur in abundance in Barnabas & Chiniak troughs (Logerwell 2007; Guttormsen and Yasenak 2007). Thus the results of this analysis are consistent with other studies. Eulachon are the most widespread and abundant species in the trawl survey (Fig. 7), which is likely due to attributes (including larger size and deeper distribution) that make them more likely to captured in the survey. High CPUEs in the Shumagin Islands and Shelikof Strait are consistent with patterns of eulachon catch in acoustic trawl surveys and commercial fisheries. Myctophids are distributed along the slope area sampled by the survey (Fig. 8) and show high CPUEs off Cross Sound in the eastern GOA. Pandalid shrimps are encountered throughout the survey area but the highest CPUEs occur in nearshore areas (Fig. 9).

Capelin distribution in acoustic surveys

In 2003 and 2005, acoustic surveys were conducted for pollock in the central and western GOA. Biomass estimates and distribution maps were generated for capelin using backscatter data and information from representative midwater tows. The results (Fig. 10) are consistent with the analysis described above: capelin were found in the troughs east of Kodiak Island and on Portlock Bank north of the island. The 2005 survey was limited due to equipment problems, but a comparison of the spatial extent of the 2003 acoustic survey with the distribution observed in the bottom trawl survey suggests that the full summer GOA acoustic survey may adequately sample the areas inhabited by capelin and that biomass estimates from a full acoustic survey may have some validity. A full GOA summer acoustic survey was conducted in 2013; results from that survey are available but an ongoing project to place those survey results in the context of other current research on GOA capelin was not completed in time for it to be included in this report. This issue will be addressed in the 2016 report.

Abundance estimates

Abundance estimates for GOA forage fishes are highly uncertain. Biomass estimates can be made using the bottom trawl survey data, but are not considered to be reliable. In 2003 and 2005, biomass estimates of capelin were produced using data from the acoustic survey. A third source of biomass estimates comes from the mass-balanced ecosystem model created for the GOA (Aydin et al. 2007). Comparing the estimates from these three data sources for capelin, eulachon, and sand lance illustrates the level of uncertainty regarding abundance of GOA forage species:

	capelin	eulachon	sand lance
2011 bottom trawl biomass estimate (t)	491	71,507	3
ecosystem model biomass estimate (t)	2,050,112	335,636	712,880
2003 acoustic survey biomass estimate (t)	116,000	n/a	n/a

The level of disagreement among these estimates stems from several sources. As discussed above, the bottom trawl survey estimates are poor samplers of forage fishes and the estimates are highly unreliable. The inadequacy of the bottom trawl survey also varies among species. Of the three species presented in the table, the bottom trawl survey is most effective at catching eulachon, as they are the largest and the species that is distributed closest to the bottom. In contrast the survey is especially poor at sampling sand lance, likely due to a combination of their small size, nearshore distribution, and the fact that they spend much of their time burrowed into sand. In general the bottom trawl survey likely underestimates the biomass of most forage species, but the degree by which it does so is highly uncertain.

The highest biomass estimates come from the ecosystem model. These estimates are derived by calculating, the amount of forage required by upper trophic level predators; the abundance of predators is taken from independent populations assessments. The advantage of the model estimates is that they are based on predator diets, and predators are highly effective samplers of the forage base. However, the models employ a large number of assumptions regarding consumption rates and other variables, and the diet composition data come from many different sources and from different time periods. Therefore, while predator diets can be a good indicator of relative forage fish abundance they are not a reliable source of absolute abundance estimates.

Acoustic surveys such as the one conducted in summer of 2003 probably have the greatest potential for producing reliable biomass estimates. The analysis of capelin distribution suggests that the 2003 survey covered much of the area inhabited by capelin in the central and western GOA. The pollock-centric nature of the survey does however limit the usefulness of the survey. It is unclear how much of the capelin population is not surveyed (e.g. how many capelin may be in unsurveyed nearshore regions), and how that effect varies with season. In addition, sampling tows are directed towards echosign typical of pollock and it is likely that capelin are undersampled. In sum, the acoustic survey estimate- as long as the survey has the same spatial extent as in 2003- might be considered a reliable minimum biomass estimate. Unfortunately the survey has not been repeated to that extent since then. Vessel and gear problems resulted in truncated surveys in 2005 and 2011, and it is unclear how future budget constraints will affect the summer survey. These uncertainties make the acoustic survey unreliable as a time series.

Bycatch and other conservation issues

FMP forage group

Data regarding incidental catches of this group exist from 2003 and are maintained by the Alaska Regional Office (Table 1). Prior to 2005, species identification by observers was unreliable and many smelt catches were recorded as “other osmerid”. While identification has improved since then, smelts in catches are often too damaged for accurate identification and much of the catch is still reported as "other osmerid". Eulachon are the most abundant forage fish in catches, and it is likely that they make up the majority of the "other osmerid" catch. Most of the osmerid bycatch occurs in the central GOA (Table 2 & Fig. 11) in the vicinity of Shelikof Strait. Almost all of the bycatch is in the pelagic trawl fishery for walleye pollock (Table 3) and is concentrated in the southeastern Bering Sea. Catches of eulachon & "other osmerids" were particularly high in 2005 & 2008.

Shrimps

The bycatch of pandalid shrimps in federal fisheries is generally low (Table 4 & Fig. 12) but is also highly variable. Catches occur mainly in the central GOA.

Pacific herring

Data regarding the Prohibited Species Catch (PSC) of herring exist from 1991 and are maintained by the Alaska Regional Office (Table 5 & Fig. 13). The PSC is generally low but was exceptionally high in 1994 and 2004. Recently, most catches have occurred in the central GOA.

Monitoring

The monitoring section of this report is the most important section, but also the most difficult to address. Due to the complete lack of surveys dedicated to sampling forage fishes, monitoring of forage species relies on gleaning what data are available from existing surveys and the use of proxies (e.g. predator diets). This section of the report is an ongoing effort to develop a full suite of indices relevant to forage abundance and availability. For this year this section includes data from the GOA bottom trawl surveys, the GOA acoustic survey, and the ADFG small-mesh survey. Data from these surveys should be treated with extreme caution, particularly for some species such as sand lance. The time series include estimated confidence intervals (CIs), but the presence of a small CI does not necessarily mean that the data are valid indicators of population status. In general, analyses of these data should be limited to interpretation of broad trends or to common patterns among time series from different surveys.

Patterns in capelin distribution and abundance

The disappearance of capelin from catches in the ADFG small-mesh survey during the 1980s has been well-documented (Anderson & Piatt 1999), and their presence in the survey continues to be diminished (Fig. 14). This is in contrast to results from the bottom trawl survey (Fig. 15) and bycatch rates in the acoustic survey hauls (Fig. 16) that suggest an increase in capelin abundance since 2000. The increased availability of capelin is also supported by comparing maps of mean survey CPUE (using the methods described above, including aggregating data from multiple years) for three time periods: 1984-1989, 1990-1999, and 2000-2011 (Fig. 17). This comparison indicates that capelin catch rates in the survey have increased and that the distribution and density of capelin has increased in the central and western GOA. It is unclear why capelin continue to be missing from the small-mesh survey despite an apparent increase in their population. The spatial extent of capelin does not appear to have changed. This is also true in the small-mesh survey when capelin catch rates are compared between the two time periods 1970-1984 and 1985-2011 (Fig. 18; the breakpoint is when capelin largely disappeared from the survey). Although much larger catches of capelin occurred in the 1970-1984 period, the spatial extent of catches is very similar between the periods. Further exploration of this preliminary analysis will be a priority for this assessment.

<u>Exploration of eulachon timeseries</u>

One of the goals of this report is to identify time series of data that can be used as indicators of forage fish abundance. As a first step, four types of eulachon abundance data were compared: mean CPUE by sampling site in the small-mesh survey (Fig. 19), annual geometric mean CPUE in the small-mesh survey (Fig.20), biomass estimates from the GOA bottom trawl survey (Fig. 21), and the rate of incidental catches is acoustic survey sampling tows (Fig. 22). The small-mesh data and the acoustic survey data show high CPUEs in two eras, although the timing of these eras is offset between the surveys. In the small-mesh data, eulachon abundance peaks around 1980 and 2004 (Fig. 20). In the acoustic survey, CPUE peaks around 1991 and 2008 (Fig. 22). The bottom trawl survey suggests an increase in biomass during the 2000s. Although the results for each survey differ somewhat, there seems to be strong evidence for an increase in eulachon biomass during the late 2000s. This is supported by the large incidental catches observed in 2005 and 2008.

<u>Other indices</u>

In contrast to capelin and eulachon, there seems to be little agreement among time series for sand lance, sandfish, and stichaeids (Fig. 23). However, comparison of trends in small-mesh CPUE for sandfish, stichaeids, and herring (Figs. 24-26) seems to indicate a general decrease in those fish species in the survey area after a period of abundance in the 1970s and early 1980s.

Acknowledgments

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Literature Cited

Anderson P and JF Piatt (1999) Community reorganization in the Gulf of Alaska following ocean climate regime shift. *Marine Ecology Progress Series* 189: 117-123.

Guttormsen MA and PT Yasenak (2007) Results of the 2003 and 2005 echo integration-trawl surveys in the Gulf of Alaska during summer, Cruises MF2003-09 and OD2005-01. *AFSC Processed Report* 2007-04, 61 p.

Livingston P and coauthors (2011) Alaska Marine Fisheries Management: Advancements and Linkages to Ecosystem Research. Pages 113-152 *in* A. Belgrano, C. Fowler, editor. Ecosystem Based Management: An Evolving Perspective. Cambridge University Press, Cambridge.

Logerwell EA, PJ Stabeno, CD Wilson, AB Hollowed (2007) The effect of oceanographic variability and interspecific competition on juvenile pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*) distributions on the Gulf of Alaska shelf. *Deep Sea Research Part II* 54: 2849-2868

Mecklenburg CW, TA Mecklenburg, LK Thorsteinsson (2002) Fishes of Alaska. American Fisheries Society, Bethesda, Maryland, USA

Table 1. Incidental catches (t) of fishes in the GOA "FMP forage" group, 2003-2014. The 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office. "Osmerid" in the bottom 2 rows of the table indicates the combination of eulachon, other osmerids, capelin, and surf smelt.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	*2014**
eulachon	18.1	169.6	852.1	397.7	231.3	760.9	223.5	232.1	331.3	196.0	29.6	*225.3*
other osmerids	353.1	66.2	185.7	183.5	49.1	406.1	174.0	6.9	79.2	88.7	12.7	*68.5*
capelin	6.2	68.0	2.8	0.1	0.0	0.0	0.0	0.0	7.9	0.0	0.0	*5.0*
surf smelt	0.0	0.4	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	*0.0*
gunnels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	5.4	*0.0*
pricklebacks	0.5	0.1	2.2	0.9	0.3	0.1	2.8	0.8	0.5	0.1	0.8	*0.5*
Pacific sand lance	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	*0.0*
lanternfishes	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*
total	**378.0**	**304.4**	**1,043.5**	**582.2**	**280.7**	**1,167.3**	**400.4**	**239.9**	**418.9**	**286.5**	**48.6**	***299.2***
% osmerid	99.9%	100.0%	99.8%	99.8%	99.9%	100.0%	99.3%	99.7%	99.9%	99.4%	87.1%	*99.8%*
% eulachon in osmerid	4.8%	55.7%	81.8%	68.4%	82.5%	65.2%	56.2%	97.1%	79.2%	68.8%	70.0%	*75.4%*

* 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

Table 2. Incidental catches (t) of "osmerids", which includes the following groups: eulachon, capelin, surf smelt, and "other osmerids", by NMFS statistical area, 2003-2014. The 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	*2014**
WGOA	610	46.2	12.0	49.3	34.1	63.1	272.9	27.8	34.1	69.4	41.3	1.1	*3.6*
	WGOA total	**46.2**	**12.0**	**49.3**	**34.1**	**63.1**	**272.9**	**27.8**	**34.1**	**69.4**	**41.3**	**1.1**	***3.6***
CGOA	620	264.8	224.1	864.8	440.9	149.4	678.1	284.5	186.2	308.5	219.6	35.3	*215.7*
	630	57.6	64.8	105.6	92.1	65.1	190.6	73.3	9.4	28.2	11.6	4.6	*73.2*
	CGOA total	**322.4**	**288.9**	**970.4**	**533.0**	**214.5**	**868.6**	**357.8**	**195.6**	**336.7**	**231.2**	**39.9**	***289.0***
EGOA	640	4.9	1.2	18.6	5.6	0.5	15.9	4.3	3.7	3.7	2.9	1.2	*1.4*
	649	4.0	1.8	2.4	8.5	2.3	9.6	7.6	5.7	8.7	9.4	0.1	*4.7*
	EGOA total	**8.8**	**3.0**	**21.0**	**14.1**	**2.8**	**25.5**	**11.9**	**9.4**	**12.4**	**12.3**	**1.3**	***6.1***
GOA total		**377**	**304**	**1,041**	**581**	**280**	**1,167**	**397**	**239**	**418**	**285**	**42**	***299***

* 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

Table 3. Incidental catches (t) of “osmerids”, which includes the following groups: eulachon, capelin, surf smel, and “other osmerids”, by target fishery, 2003-2014. The 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	***2014****
walleye pollock	373	303	1,006	561	278	1,165	361	234	395	282	41	*294*
arrowtooth flounder	0.3	0.5	14.4	2.1	0.8	0.6	33.8	3.8	22.9	2.2	0.9	*4.7*
Pacific cod	0.0	0.0	0.0	2.5	0.0	0.6	0.0	0.6	0.0	0.0	0.0	*0.3*
shallow flatfish	0.0	0.0	0.0	0.0	0.1	0.0	1.6	0.1	0.0	0.0	0.0	*0.0*
rex sole	0.1	0.0	0.0	0.0	0.9	0.0	0.8	0.2	0.0	0.1	0.0	*0.0*
rockfish	0.6	0.4	0.1	0.6	0.1	0.0	0.2	0.0	0.0	0.0	0.1	*0.0*
flathead sole	3.2	0.0	20.4	15.5	0.0	0.2	0.1	0.3	0.2	0.0	0.4	*0.0*
sablefish	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	*0.0*
GOA total	**377**	**304**	**1,041**	**581**	**280**	**1,167**	**397**	**239**	**418**	**285**	**42**	***299***

* 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

Table 4. Incidental catches (t) of pandalid shrimps in the GOA, by NMFS statistical area, 2003-2014. The 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

		2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	***2014****
WGOA	610	0.10	0.08	0.73	1.54	1.02	0.31	0.02	0.30	0.05	0.02	0.00	*0.00*
	WGOA total	**0.10**	**0.08**	**0.73**	**1.54**	**1.02**	**0.31**	**0.02**	**0.30**	**0.05**	**0.02**	**0.00**	***0.00***
CGOA	620	0.76	1.01	6.78	1.61	0.89	0.49	0.21	0.94	0.46	0.28	0.33	*0.23*
	630	2.55	1.68	3.07	1.01	0.43	0.52	1.04	2.14	4.69	4.09	3.19	*3.79*
	CGOA total	**3.30**	**2.70**	**9.85**	**2.63**	**1.32**	**1.01**	**1.25**	**3.08**	**5.15**	**4.37**	**3.52**	***4.02***
EGOA	640	0.02	0.01	0.20	0.02	0.02	0.02	0.01	0.15	0.02	0.00	0.00	*0.02*
	649	0.00	0.00	0.01	0.00	0.00	0.01	0.05	0.02	0.00	0.00	0.00	*0.00*
	EGOA total	**0.02**	**0.02**	**0.21**	**0.02**	**0.03**	**0.03**	**0.06**	**0.17**	**0.02**	**0.00**	**0.00**	***0.02***
GOA total		**3.42**	**2.79**	**10.80**	**4.18**	**2.36**	**1.35**	**1.34**	**3.56**	**5.22**	**4.38**	**3.52**	***4.04***

*2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

Table 5. Prohibited Species Catch (t) of herring in federal fisheries in the GOA, by NMFS regulatory and statistical areas, 1991- 2013. Data are from the Alaska Regional Office.

regulatory area	WGOA	CGOA		EGOA				**total GOA**
statistical area	610	620	630	640	650	649	659	
1991	0.6	0.0	0.6	0.0	0.0	0.0	0.0	**1.3**
1992	17.3	8.4	1.1	0.0	0.0	0.0	0.0	**26.8**
1993	0.7	0.6	5.0	0.0	0.0	0.0	0.0	**6.3**
1994	78.2	19.6	2.3	0.0	0.0	0.0	0.0	**100.2**
1995	2.1	43.5	1.5	0.1	0.2	1.2	0.0	**48.6**
1996	1.5	0.6	1.3	0.1	0.0	0.0	0.0	**3.6**
1997	1.4	5.8	2.0	0.0	0.0	0.0	0.0	**9.2**
1998	0.3	2.8	17.1	0.0	0.0	0.0	0.0	**20.2**
1999	0.7	8.5	1.6	0.0	0.0	0.0	0.0	**10.8**
2000	1.4	2.2	1.7	0.0	0.0	0.0	0.0	**5.3**
2001	0.5	4.9	1.5	0.0	0.0	0.0	0.0	**6.9**
2002	0.0	1.4	0.7	0.0	0.0	0.0	0.0	**2.2**
2003	0.0	0.1	11.7	0.0	0.0	0.0	0.0	**11.8**
2004	9.1	167.9	90.8	0.0	0.0	1.9	0.0	**269.8**
2005	1.0	10.5	0.1	0.6	0.0	0.0	0.0	**12.3**
2006	0.2	7.9	0.7	0.0	0.0	0.0	0.0	**8.9**
2007	1.4	5.2	13.5	0.0	0.0	0.0	0.0	**20.1**
2008	0.2	0.3	0.6	0.0	0.0	0.0	0.0	**1.0**
2009	0.1	7.9	0.6	0.1	0.0	0.3	0.0	**8.9**
2010	0.2	0.7	1.0	0.1	0.0	0.0	0.0	**1.9**
2011	0.8	9.4	0.0	0.1	0.0	0.3	0.0	**10.7**
2012	0.0	1.3	0.0	0.0	0.0	0.0	0.0	**1.4**
2013	0.1	8.8	1.6	0.1	0.0	0.0	0.0	**10.7**

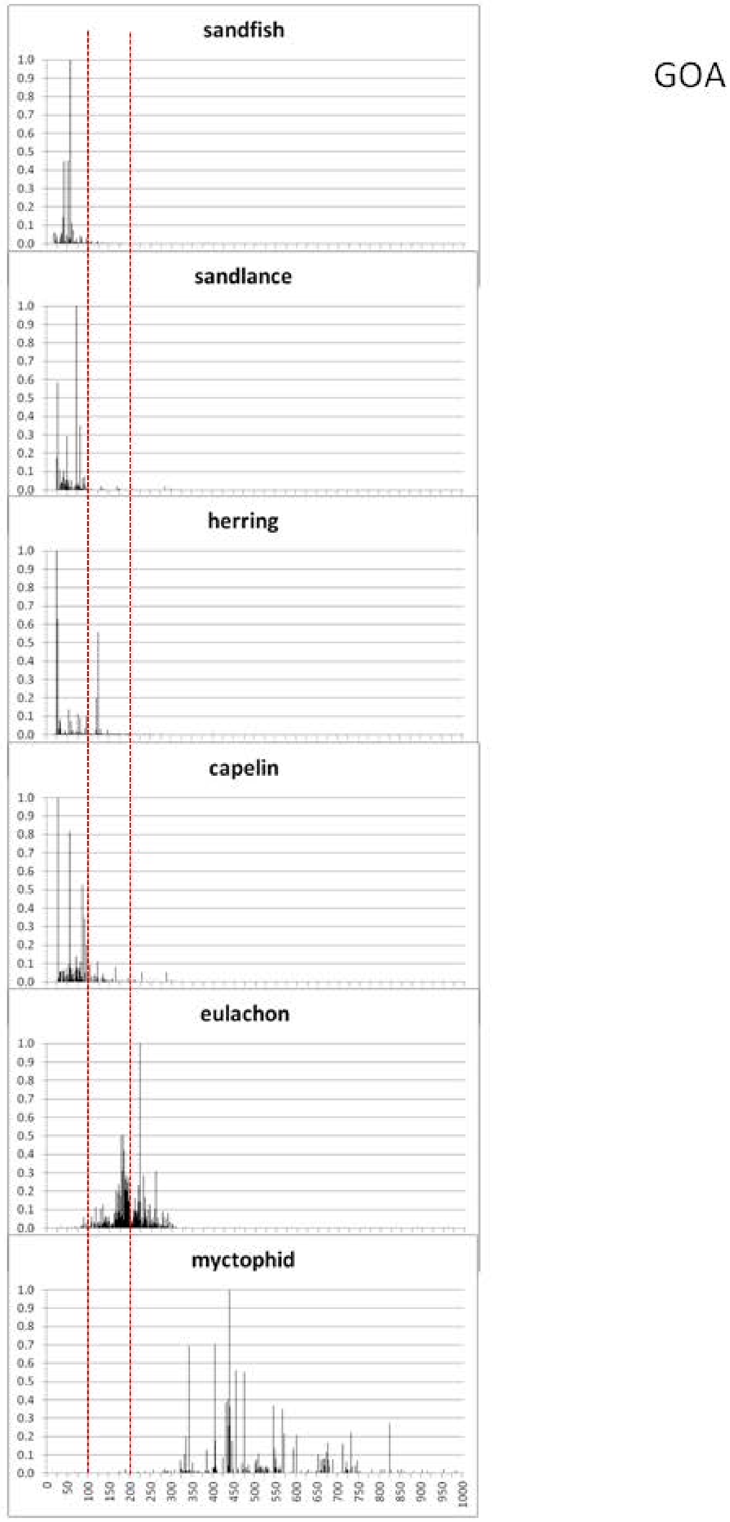


Figure 1. Normalized mean bottom trawl survey CPUE versus bottom depth (m) of haul for six forage fish groups in the Gulf of Alaska. Dashed red lines indicate depths of 100m and 200m.

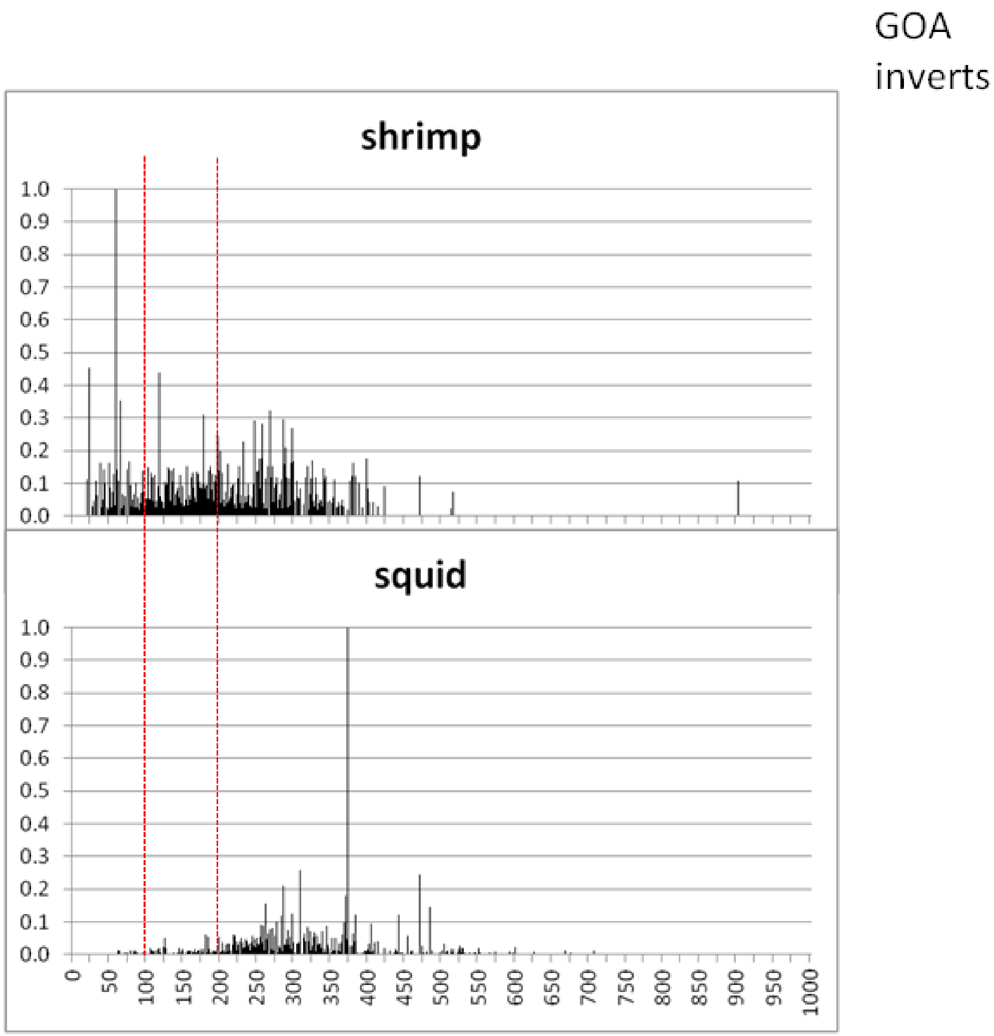


Figure 2. Normalized mean bottom trawl survey CPUE versus bottom depth (m) of haul for shrimps and squids in the Gulf of Alaska. Dashed red lines indicate depths of 100m and 200m.

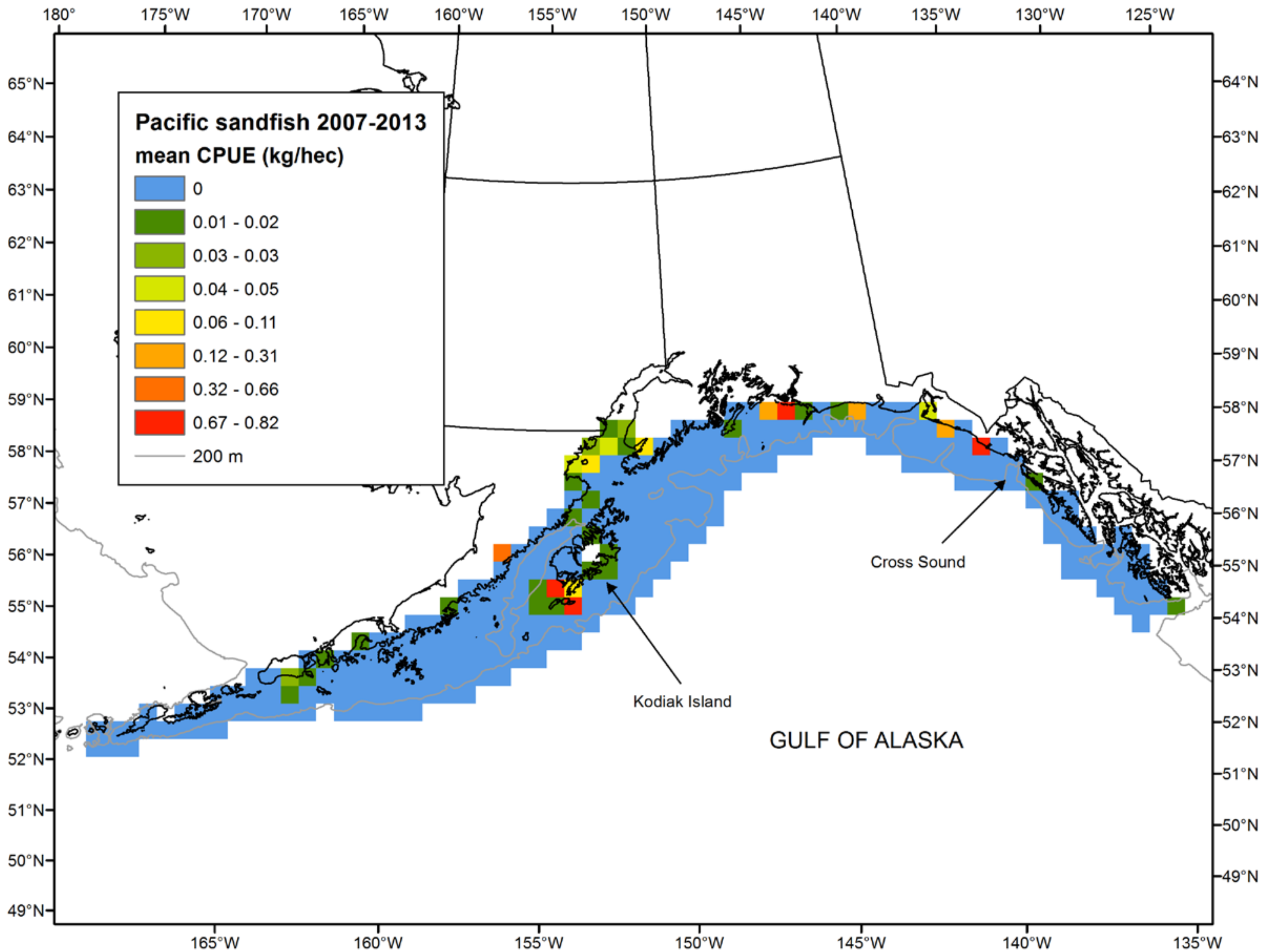


Figure 3. Mean bottom trawl survey CPUE (kg/hectare) of Pacific sandfish in the Gulf of Alaska, 2007-2013. Grid cells are 40 km X 40 km.

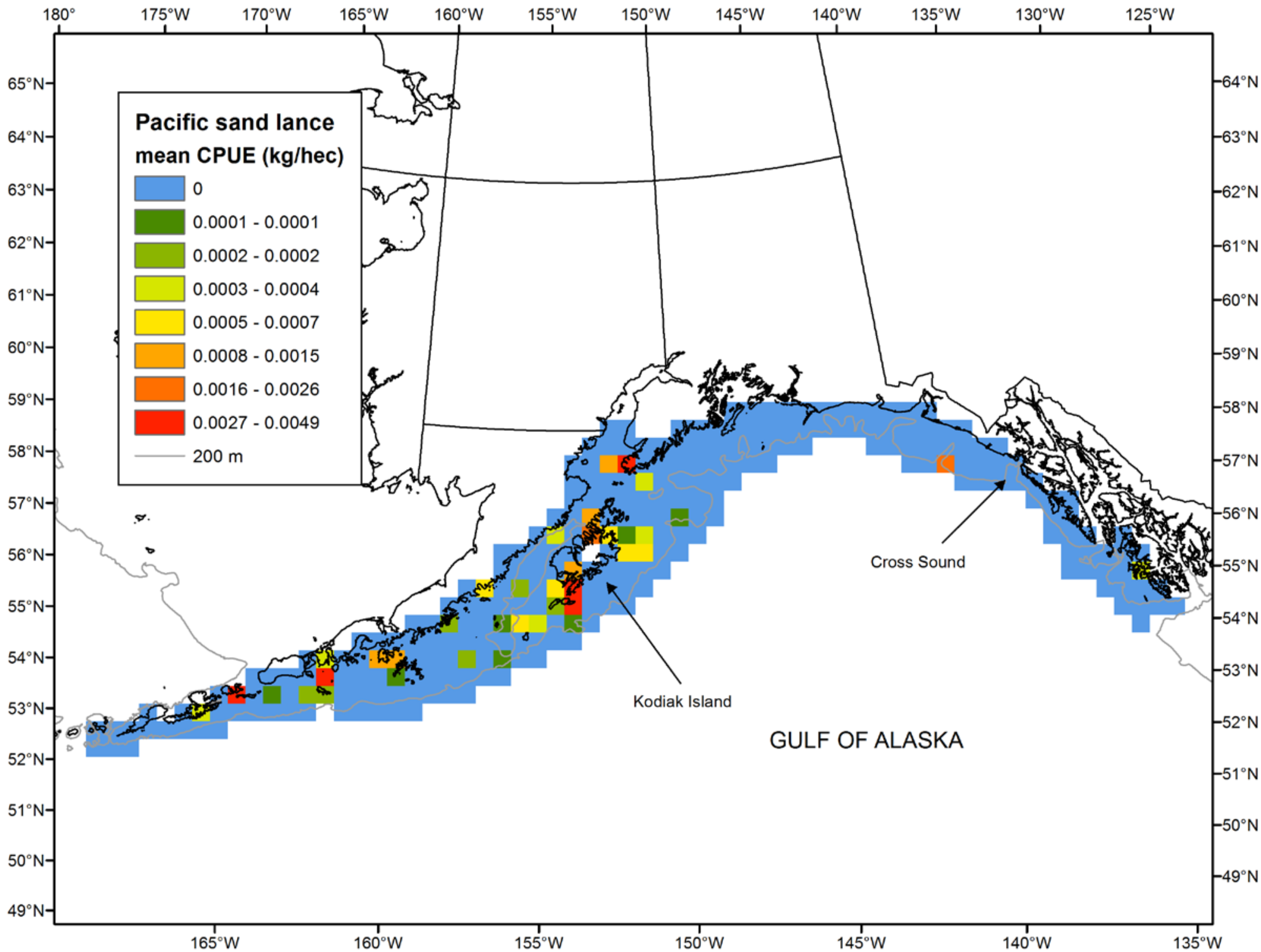


Figure 4. Mean bottom trawl survey CPUE (kg/hectare) of Pacific sand lance in the Gulf of Alaska, 2007-2013. Grid cells are 40 km X 40 km.

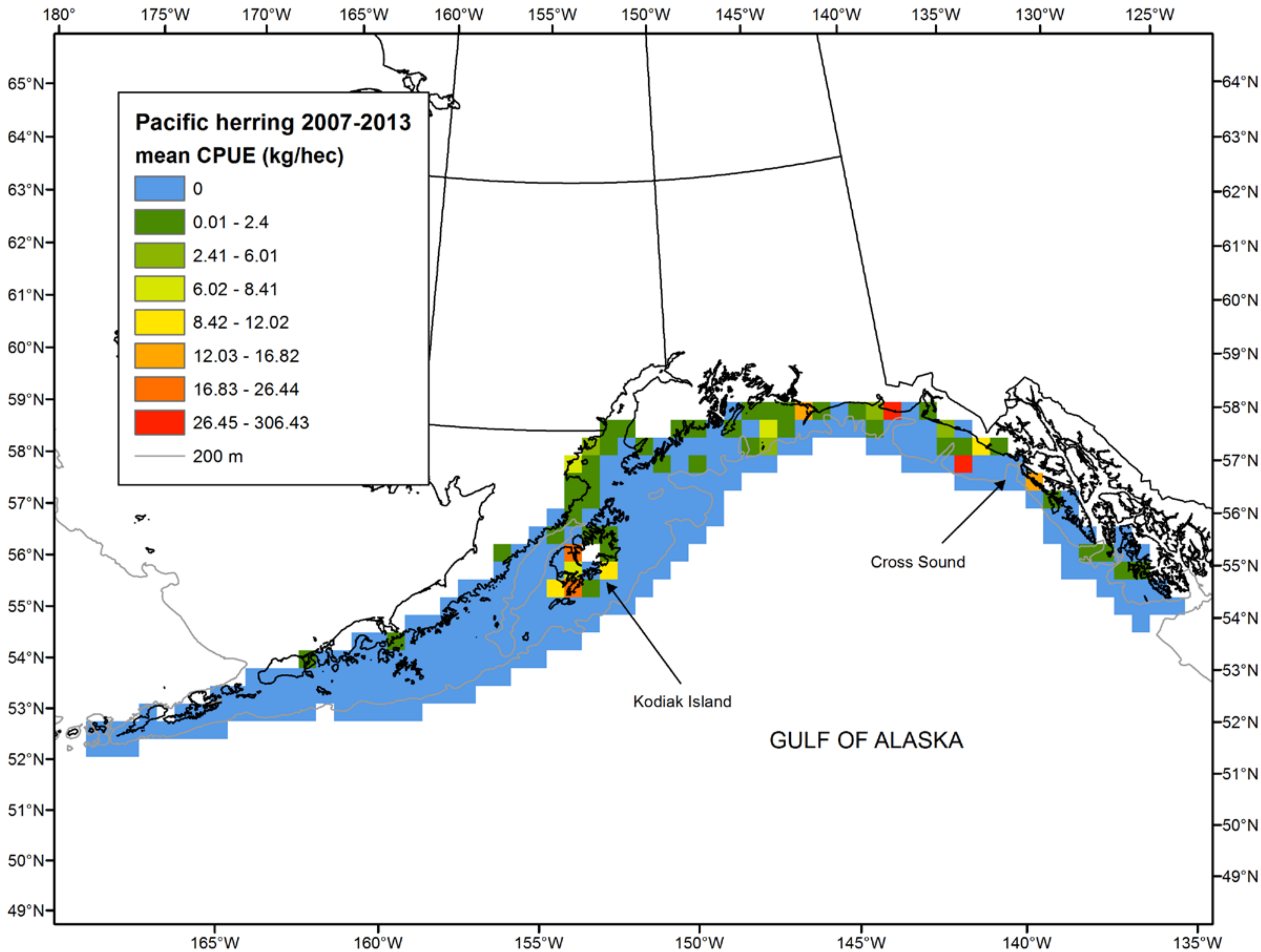


Figure 5. Mean bottom trawl survey CPUE (kg/hectare) of Pacific herring in the Gulf of Alaska, 2007-2013. Grid cells are 40 km X 40 km.

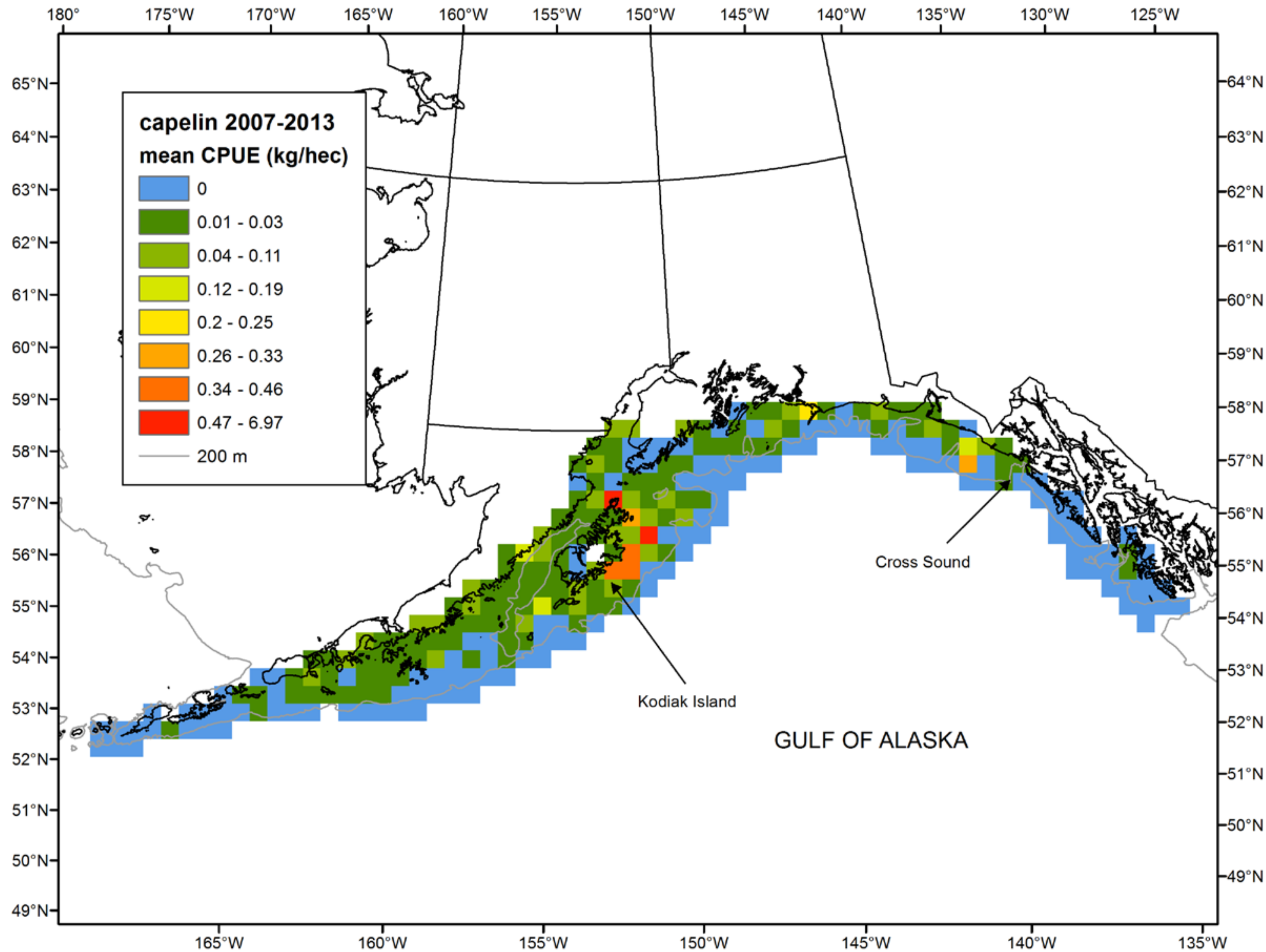


Figure 6. Mean bottom trawl survey CPUE (kg/hectare) of capelin in the Gulf of Alaska, 2007-2013. Grid cells are 40 km X 40 km.

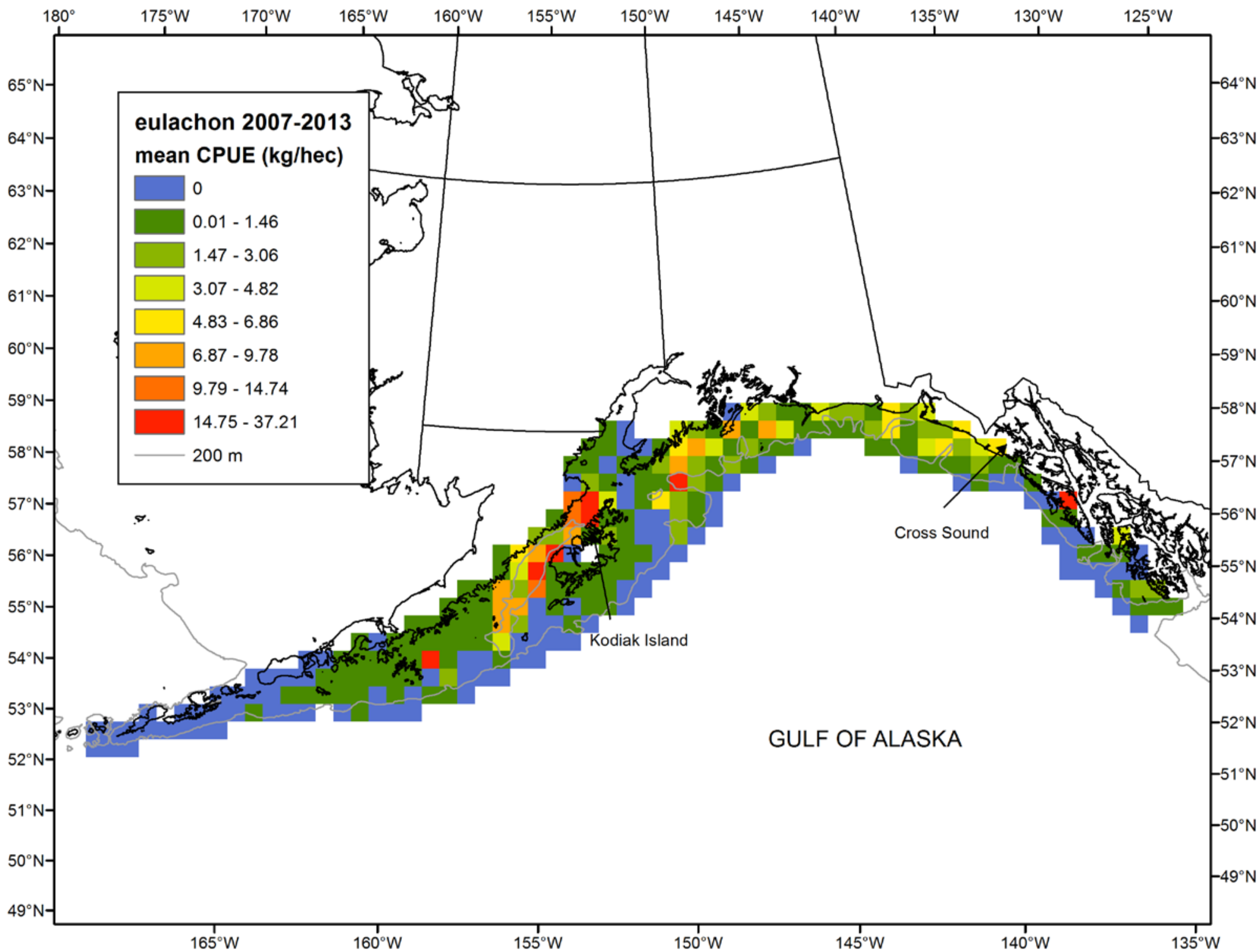


Figure 7. Mean bottom trawl survey CPUE (kg/hectare) of eulachon in the Gulf of Alaska, 2007-2013. Grid cells are 40 km X 40 km.

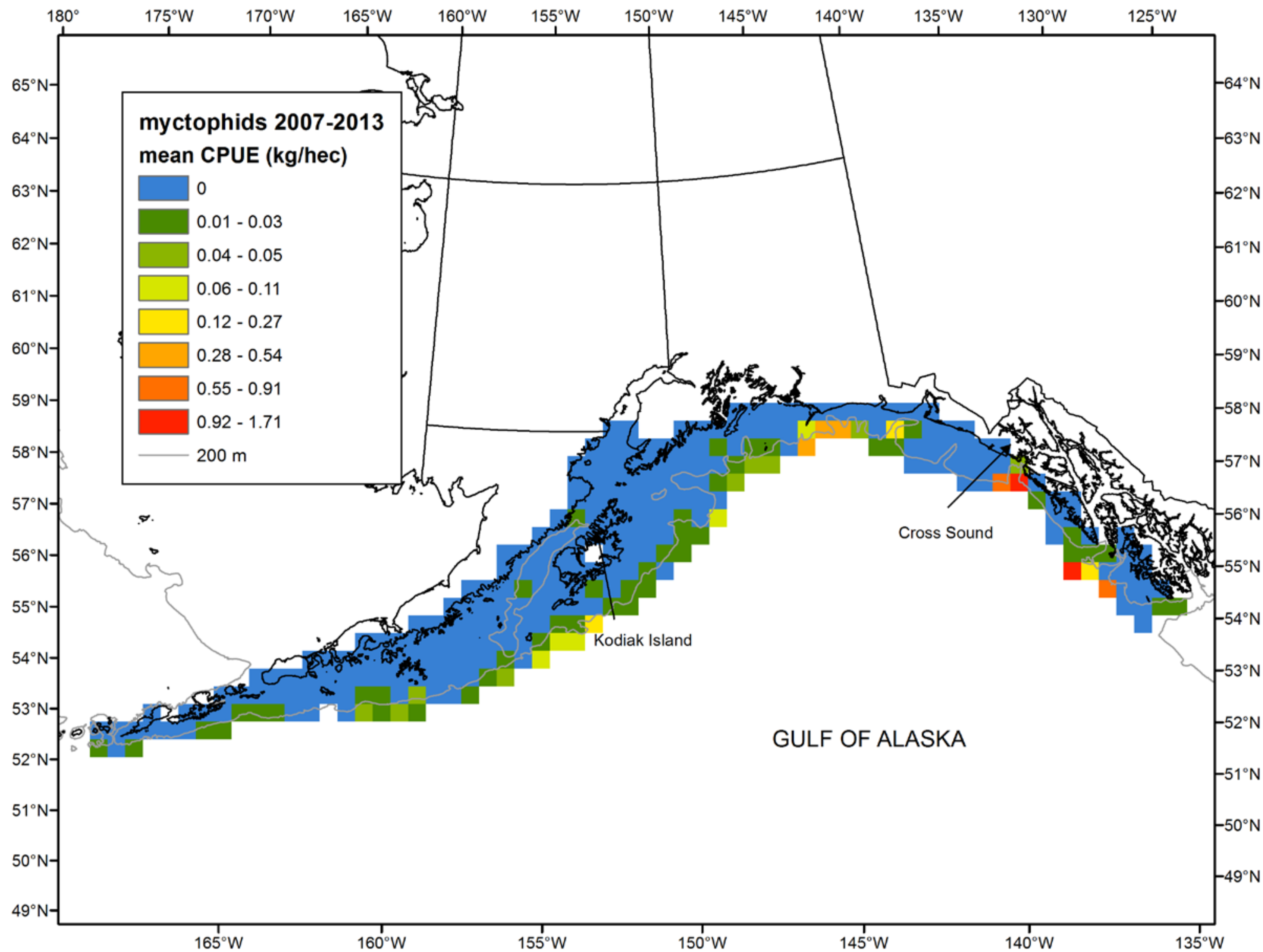
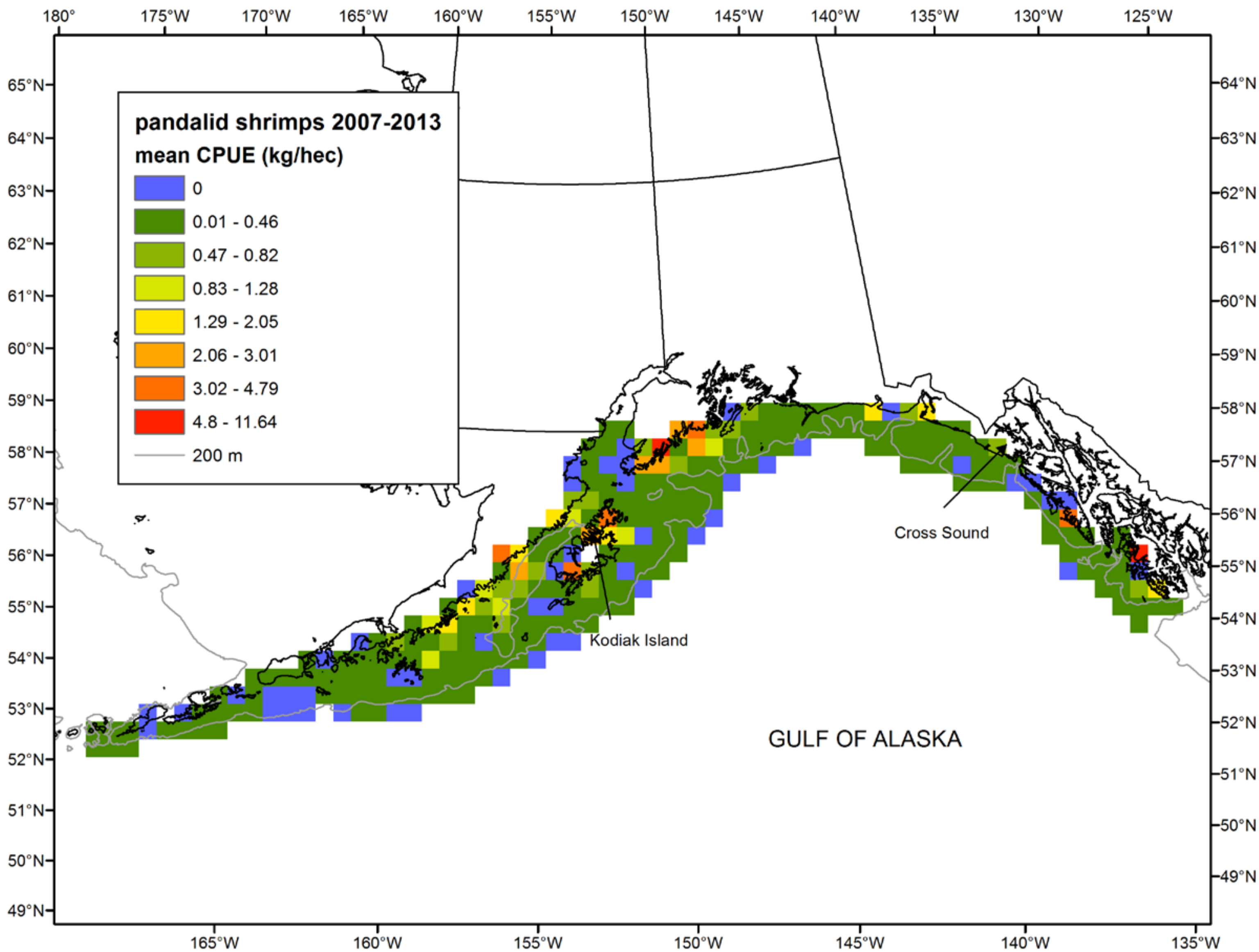


Figure 8. Mean bottom trawl survey CPUE (kg/hectare) of myctophids in the Gulf of Alaska, 2007-2013. Grid cells are 40 km X 40 km.



. Figure 9. Mean bottom trawl survey CPUE (kg/hectare) of pandelid shrimps in the Gulf of Alaska, 2007-2013. Grid cells are 40 km X 40 km.

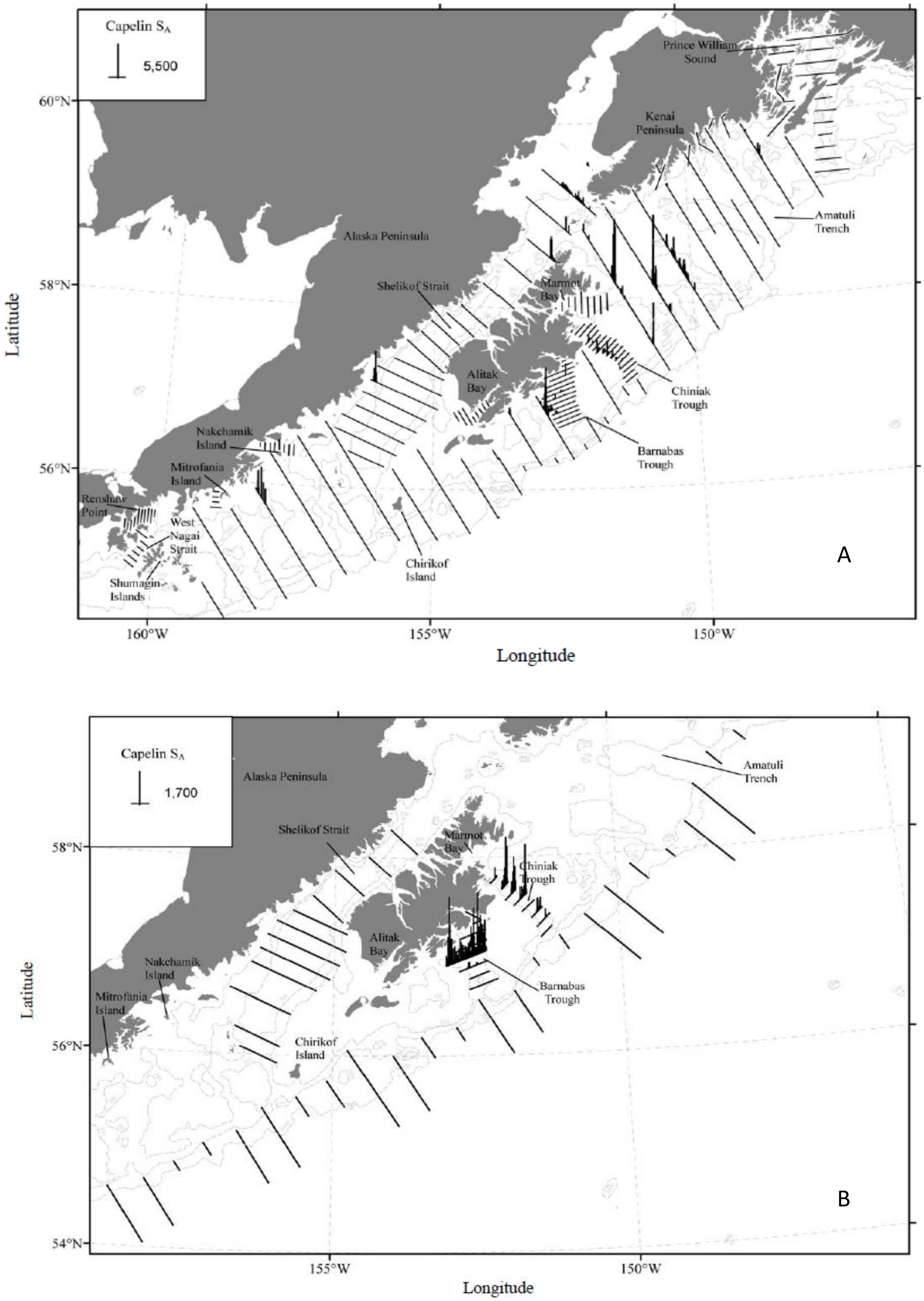


Figure 10. Acoustic backscatter attributed to capelin during acoustic surveys conducted in the GOA in 2003 (A) and 2005 (B). Figures are from Guttormsen and Yasenak (2007).

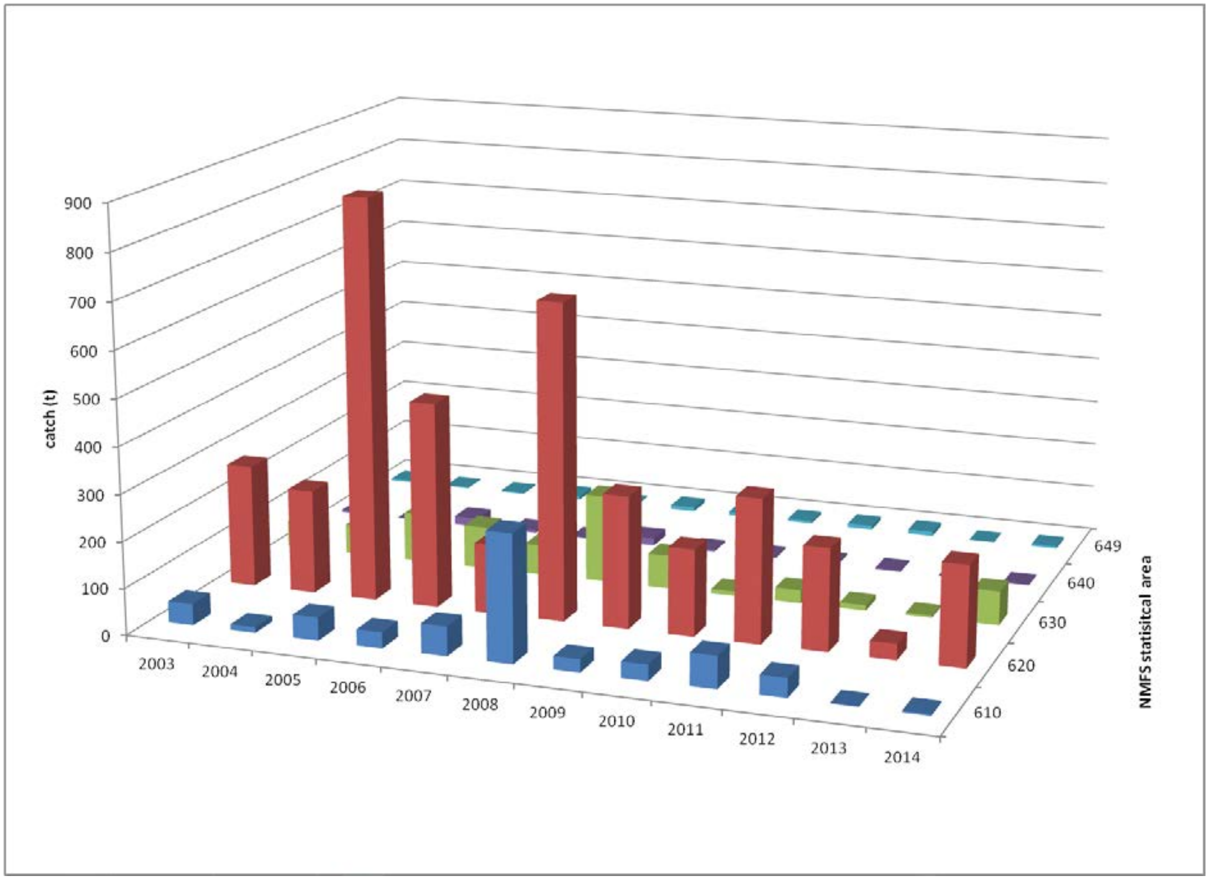


Figure 11. Incidental catches (t) of eulachon & “other osmerids” in the GOA, by NMFS statistical area, 2003-2014. The 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

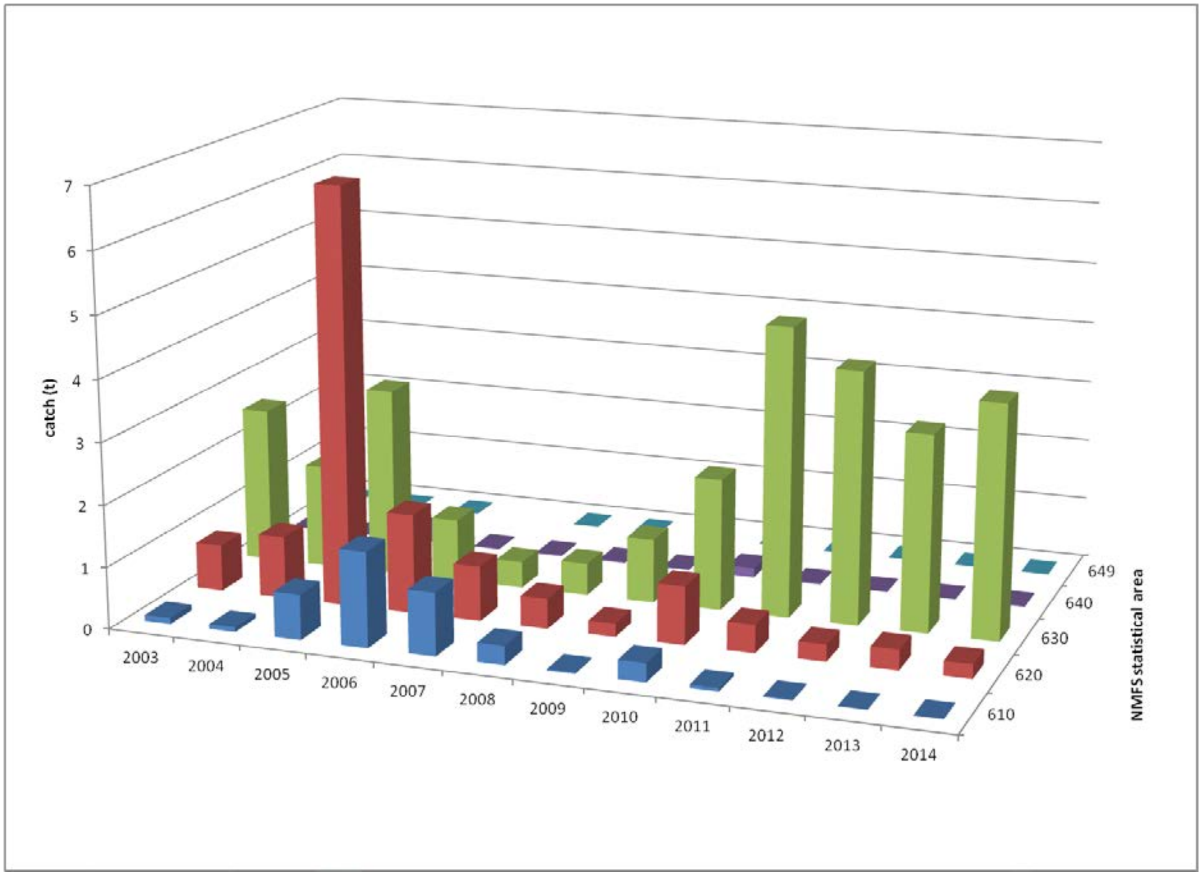


Figure 12. Incidental catches (t) of pandalid shrimps in the GOA, by NMFS statistical area, 2003-2014. The 2014 data are incomplete; retrieved October 8, 2014. Data are from the Alaska Regional Office.

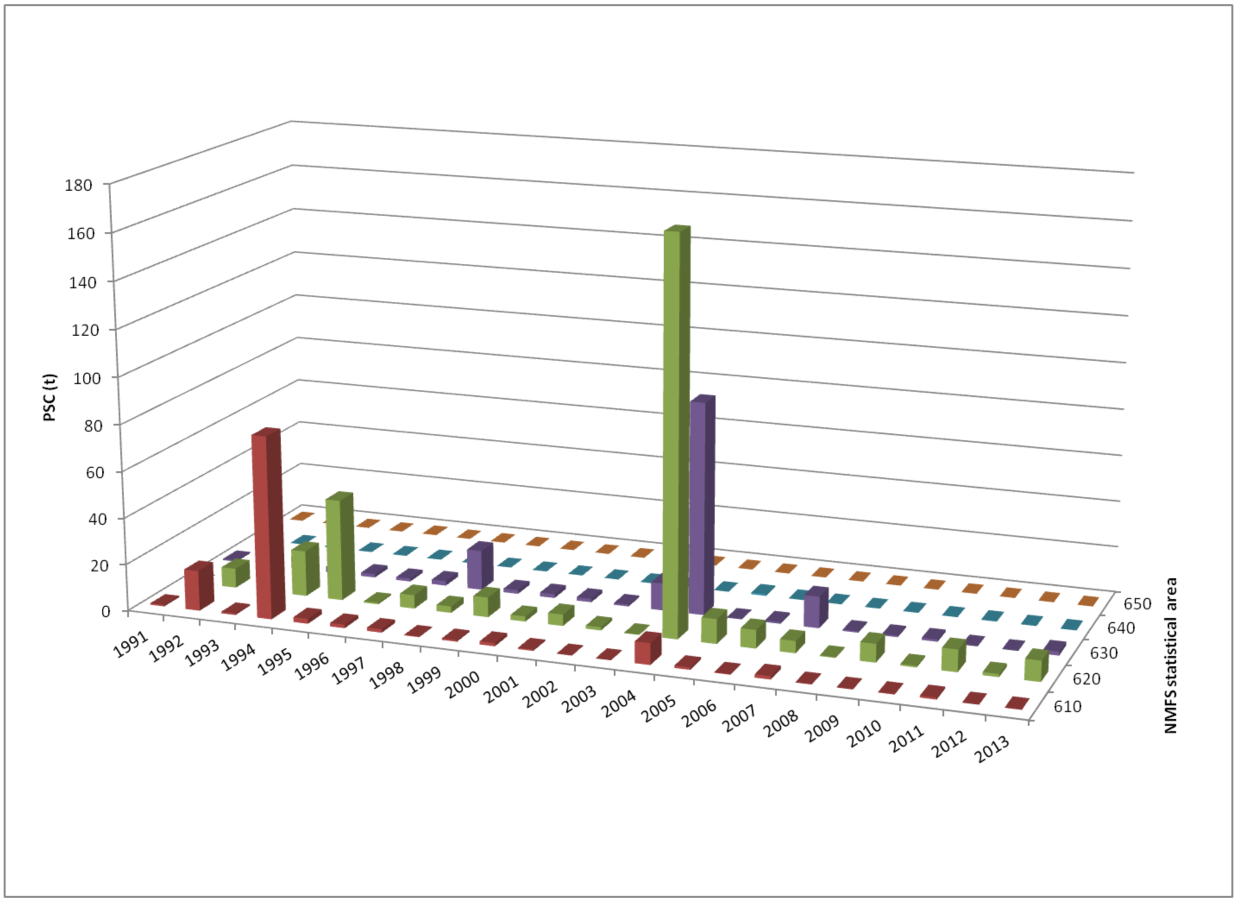


Figure 13. Prohibited Species Catch (t) of herring in federal fisheries in the GOA, by NMFS statistical area, 1991- 2013. Data are from the Alaska Regional Office.

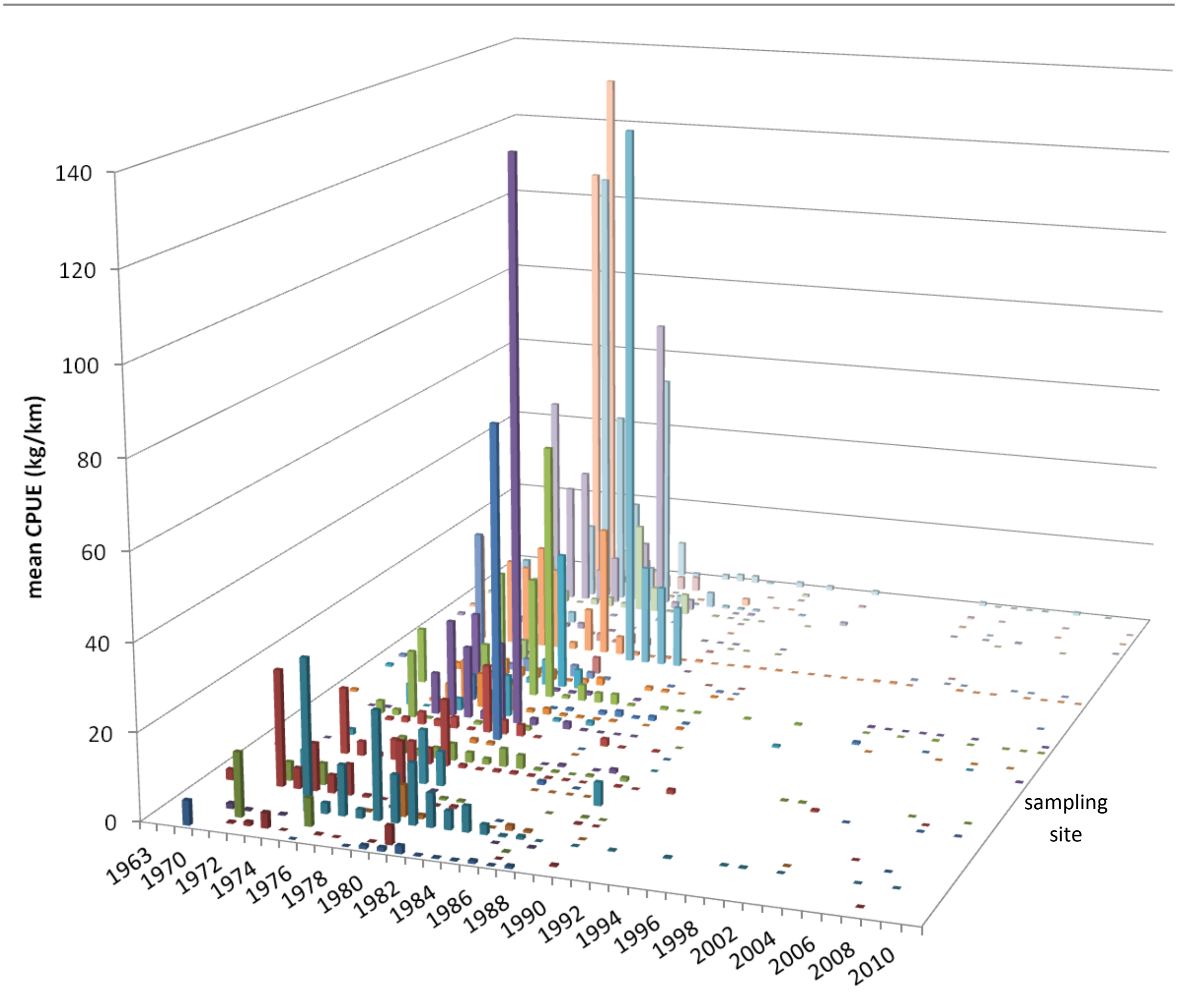


Figure 14. Mean CPUE (kg/km trawled) of capelin in the ADFG small-mesh survey, by year and bay, 1963-2011. The z-axis (corresponding to chart depth and labeled “sampling site”) represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

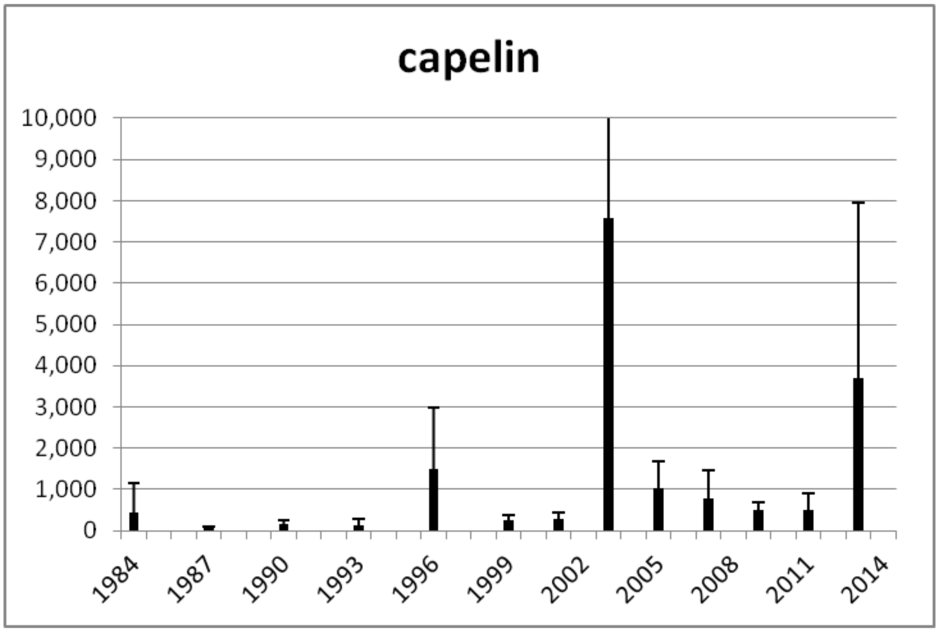


Figure 15. Biomass estimates (t) of capelin from the GOA bottom trawl survey, 1984-2013. Error bars represent upper 95% confidence interval.

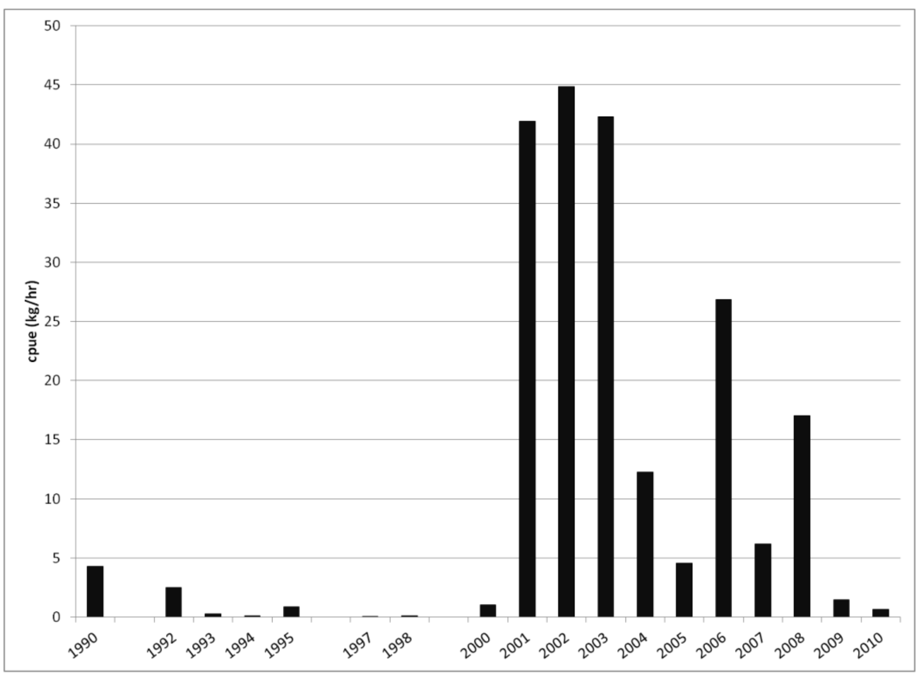


Figure 16. Capelin CPUE (kg/hr.) in sampling tows conducted during AFSC acoustic trawl surveys in the GOA, 1990-2010.

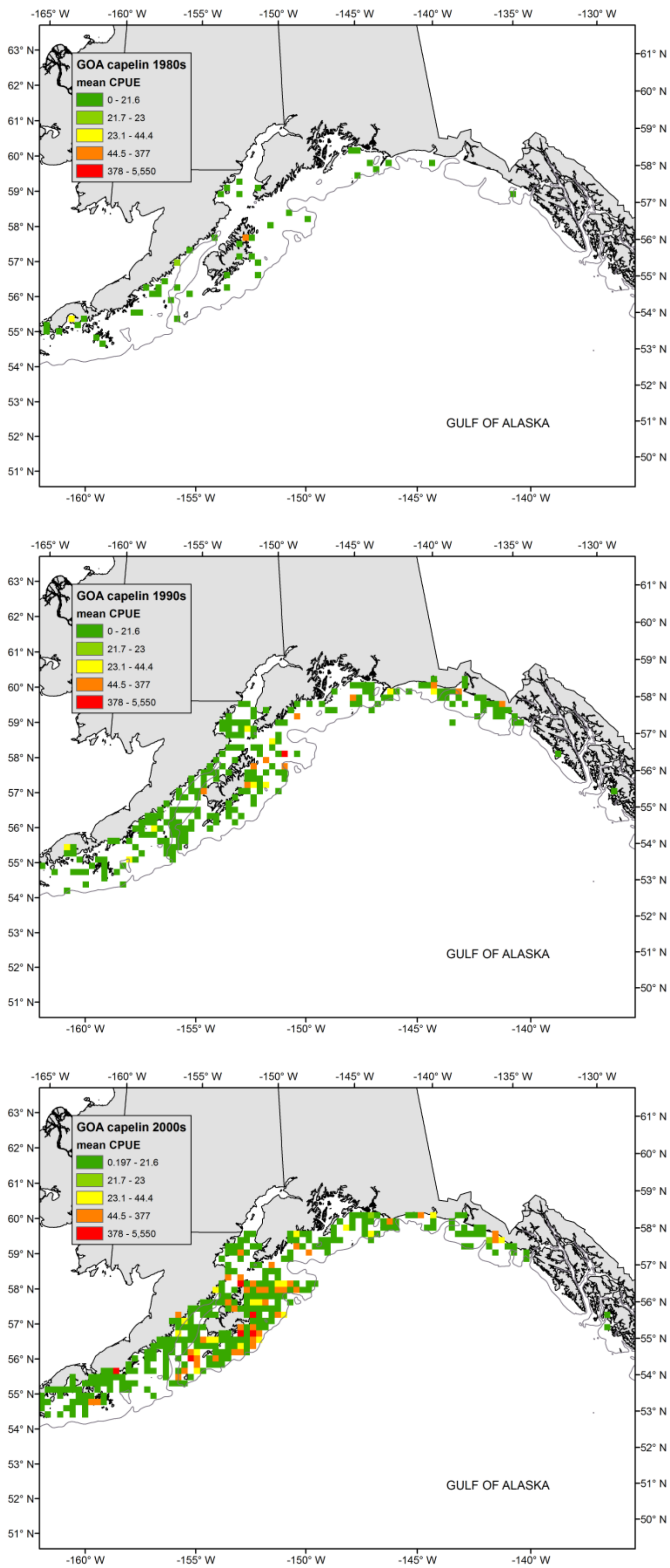


Figure 17. Mean bottom trawl survey CPUE (kg/hectare) of capelin in the Gulf of Alaska for three time periods: 1984-1989 (top panel), 1990-1999 (middle panel), and 2000-2011 (bottom panel). Grid cells are 20 km X 20 km and color levels are identical for all figures.

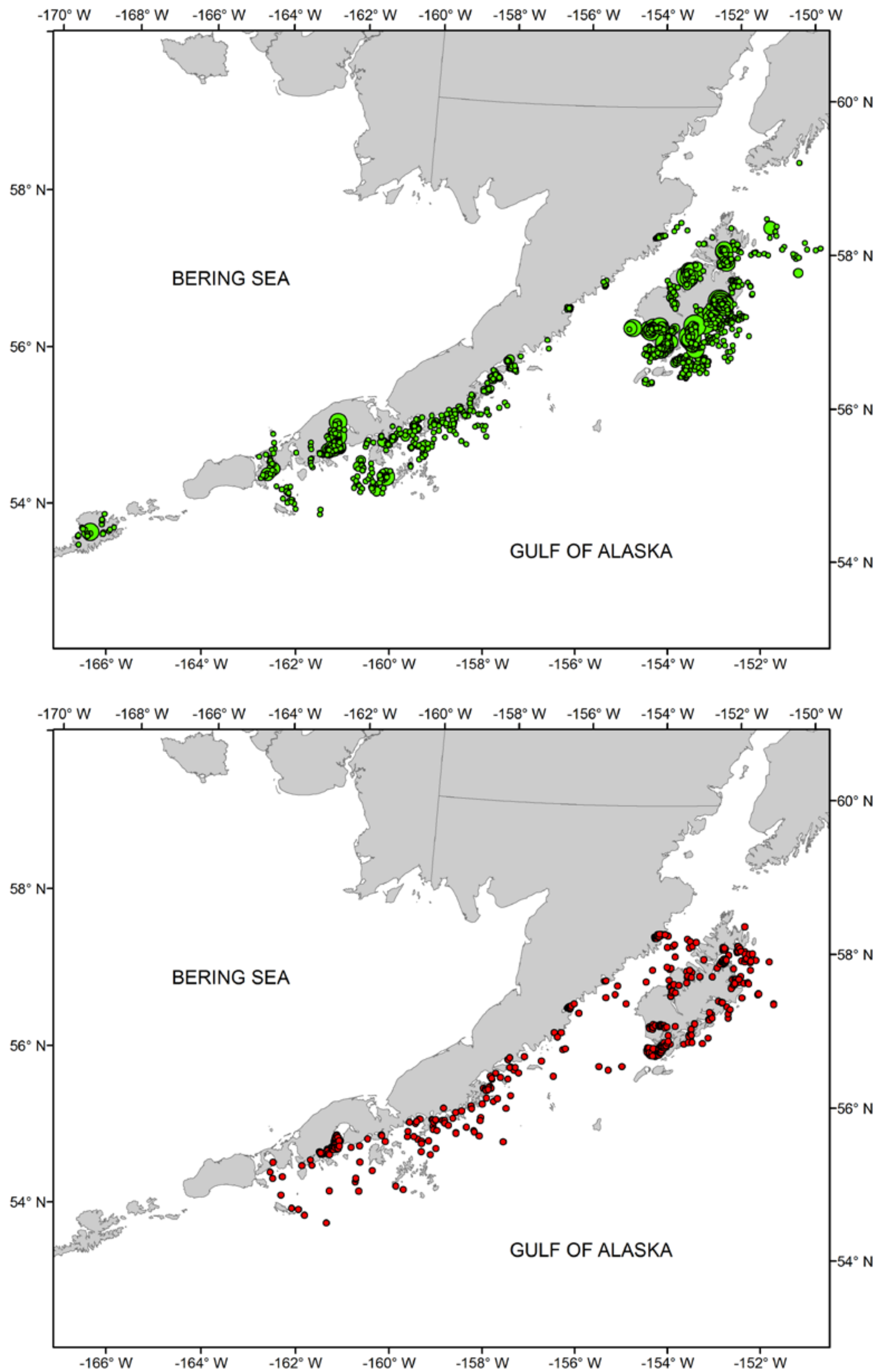


Figure 18. Mean CPUE (kg/km trawled) of capelin in the ADFG small-mesh trawl survey for two time periods, 1970-1984 (top panel) and 1985-2011 (bottom panel) Symbol size represents CPUE and the scale is identical between the plots.

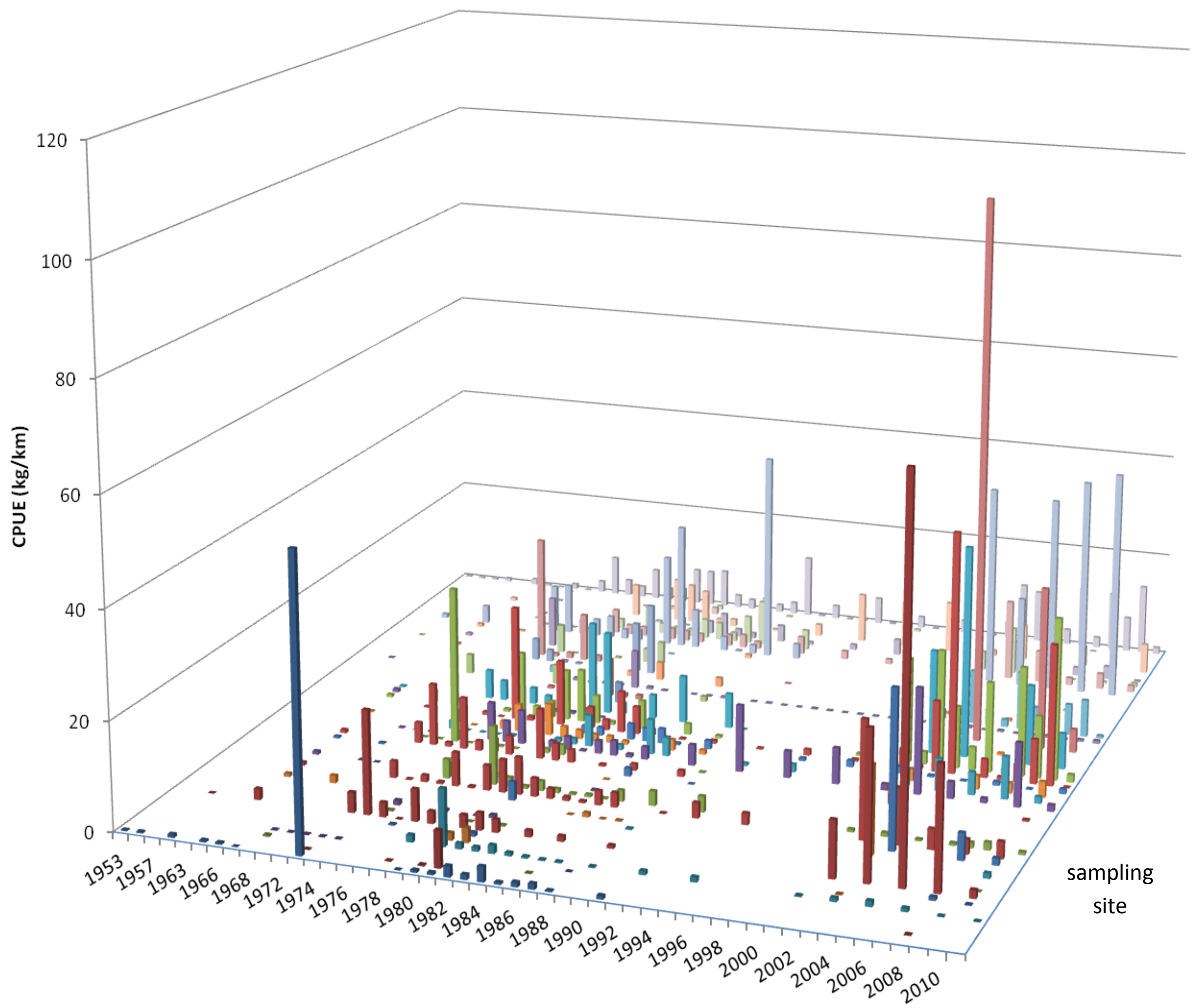


Figure 19. Mean CPUE (kg/km trawled) of eulachon in the ADFG small-mesh survey, by year and bay, 1953-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

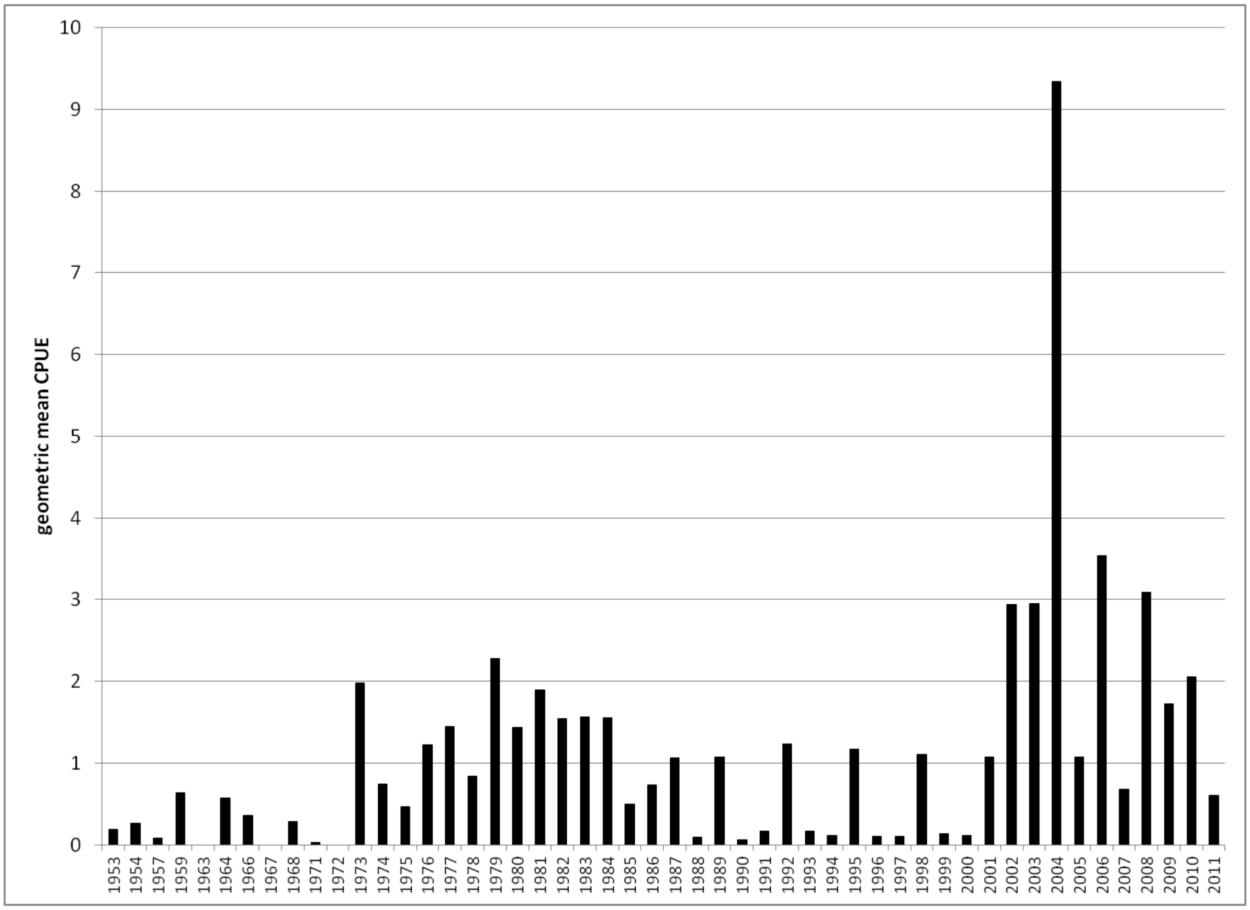


Figure 20. Annual geometric mean CPUE (kg/km trawled) of eulachon in the ADFG small-mesh survey, 1953-2011.

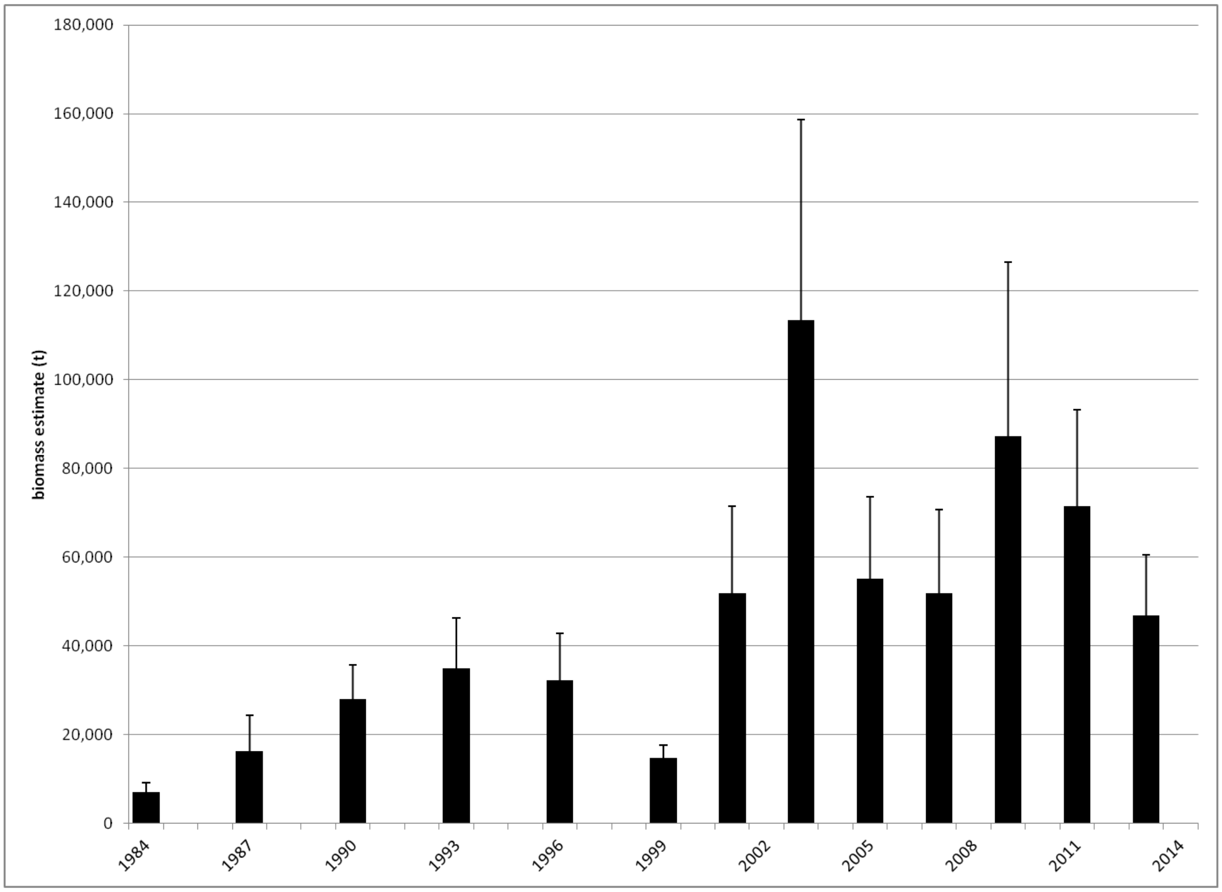


Figure 21. Biomass estimates (t) of eulachon from the GOA bottom trawl survey, 1984-2013. Error bars represent upper 95% confidence interval.

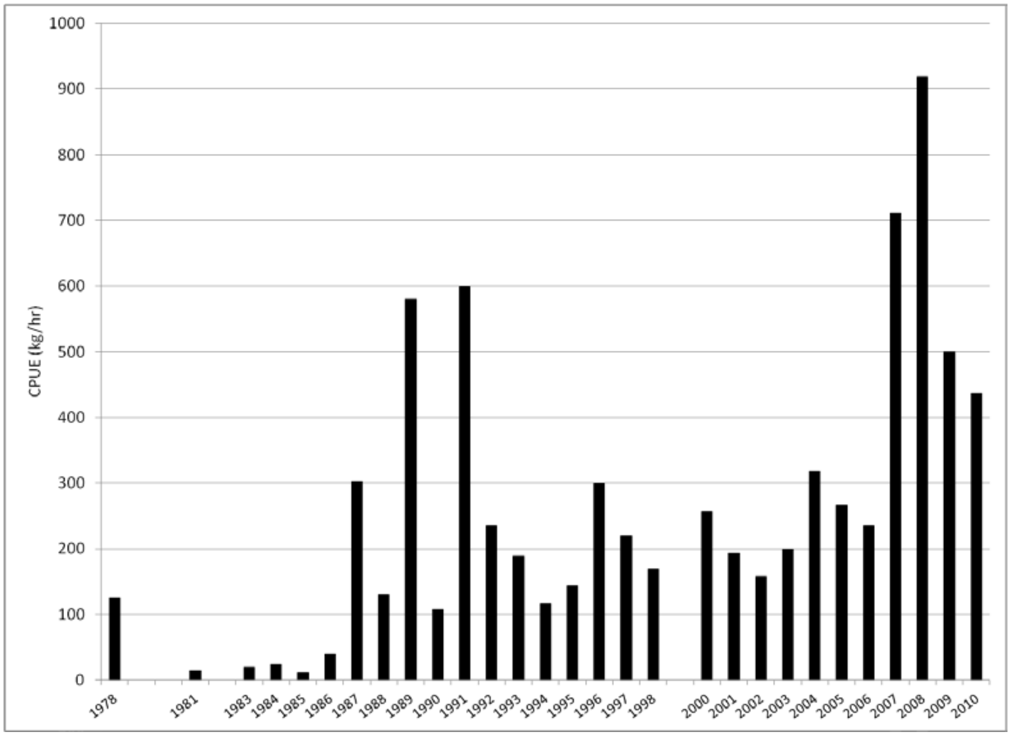


Figure 22. Eulachon CPUE (kg/hr.) in sampling tows conducted during AFSC acoustic trawl surveys in the GOA, 1978-2010.

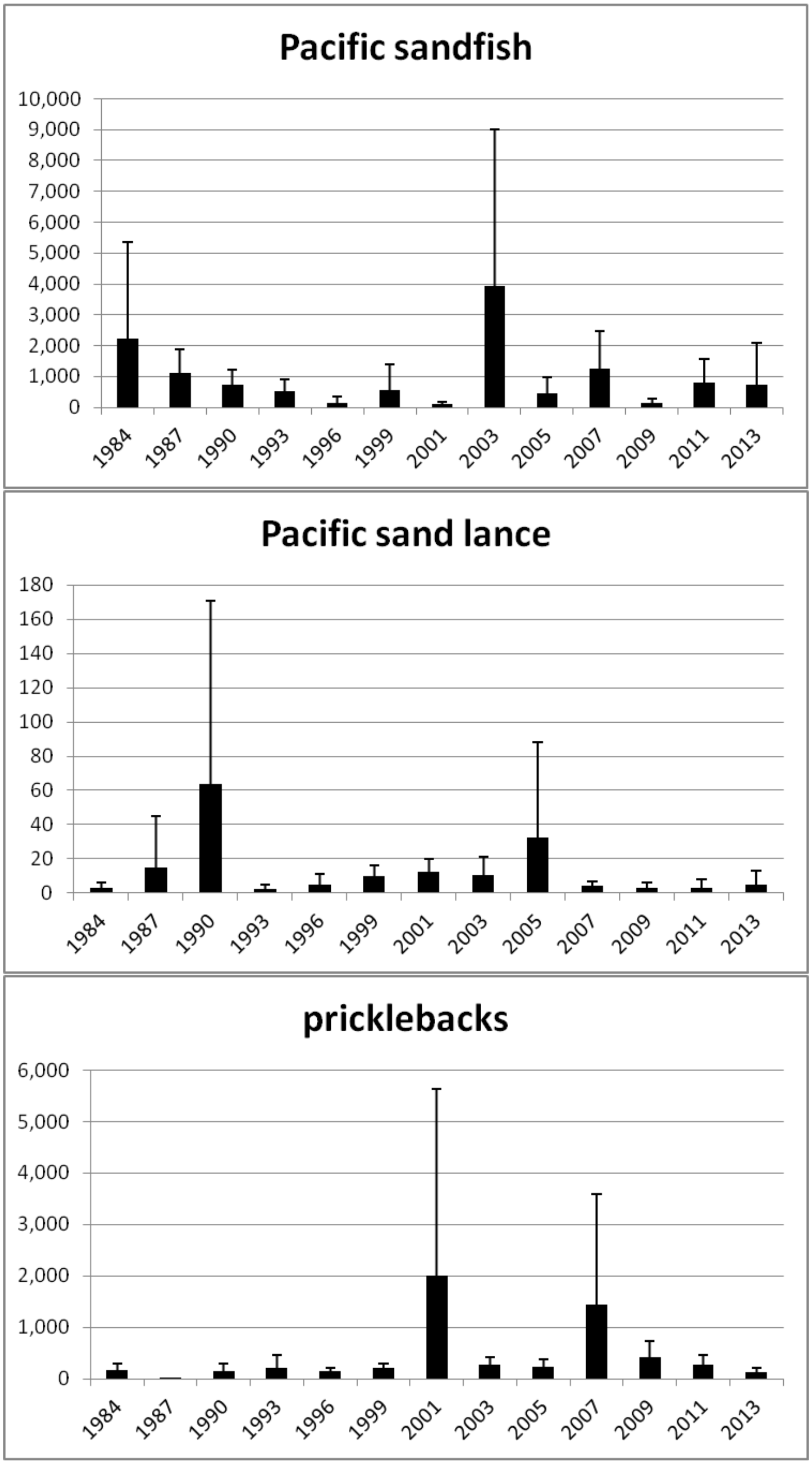


Figure 23. Biomass estimates (t) from the GOA bottom trawl survey for Pacific sandfish, Pacific sand lance, and pricklebacks, 1984-2013. Error bars represent upper 95% confidence interval.

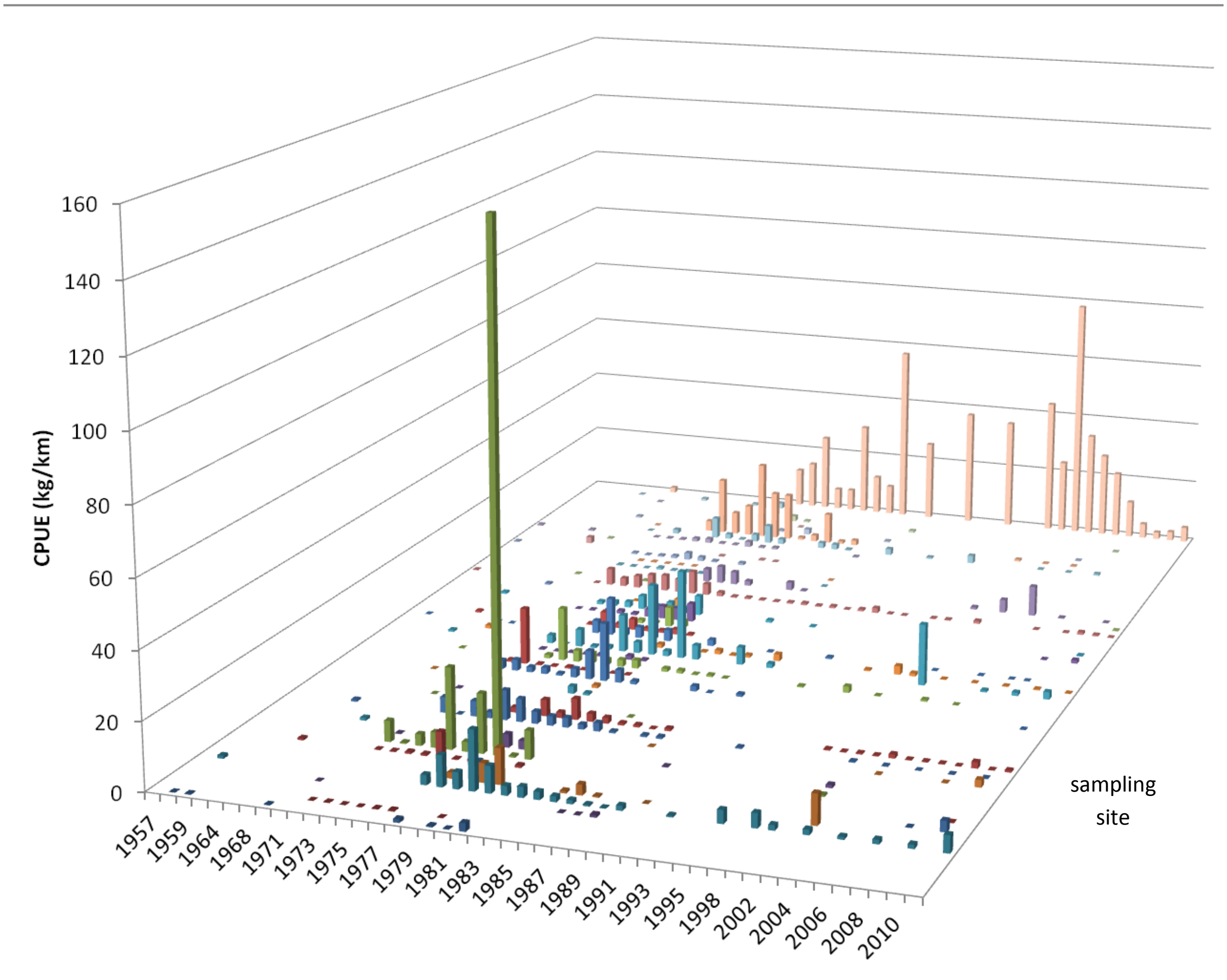


Figure 24. Mean CPUE (kg/km trawled) of Pacific sandfish in the ADFG small-mesh survey, by year and bay, 1957-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

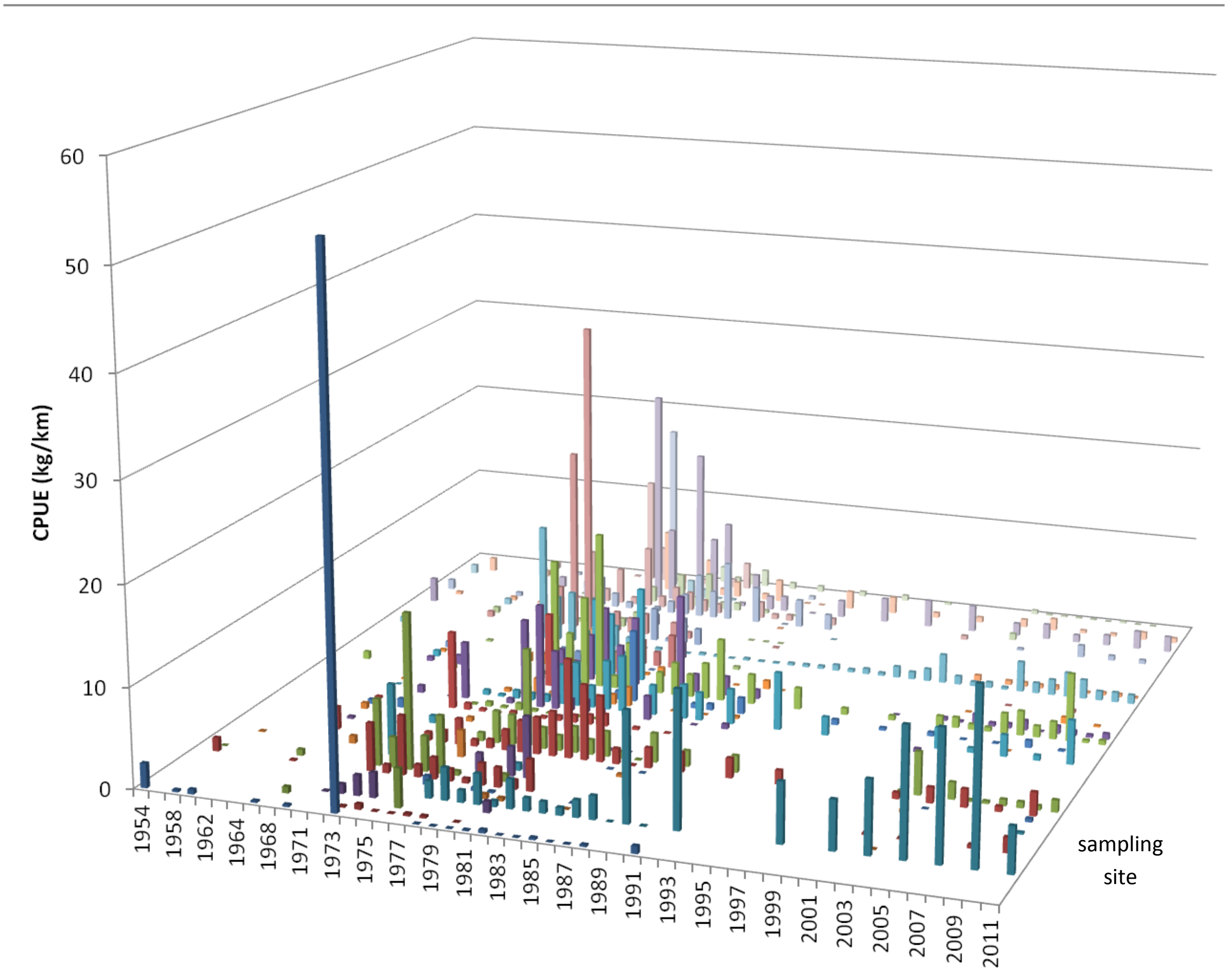


Figure 25. Mean CPUE (kg/km trawled) of stichaeids (all species combined) in the ADFG small-mesh survey, by year and bay, 1954-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

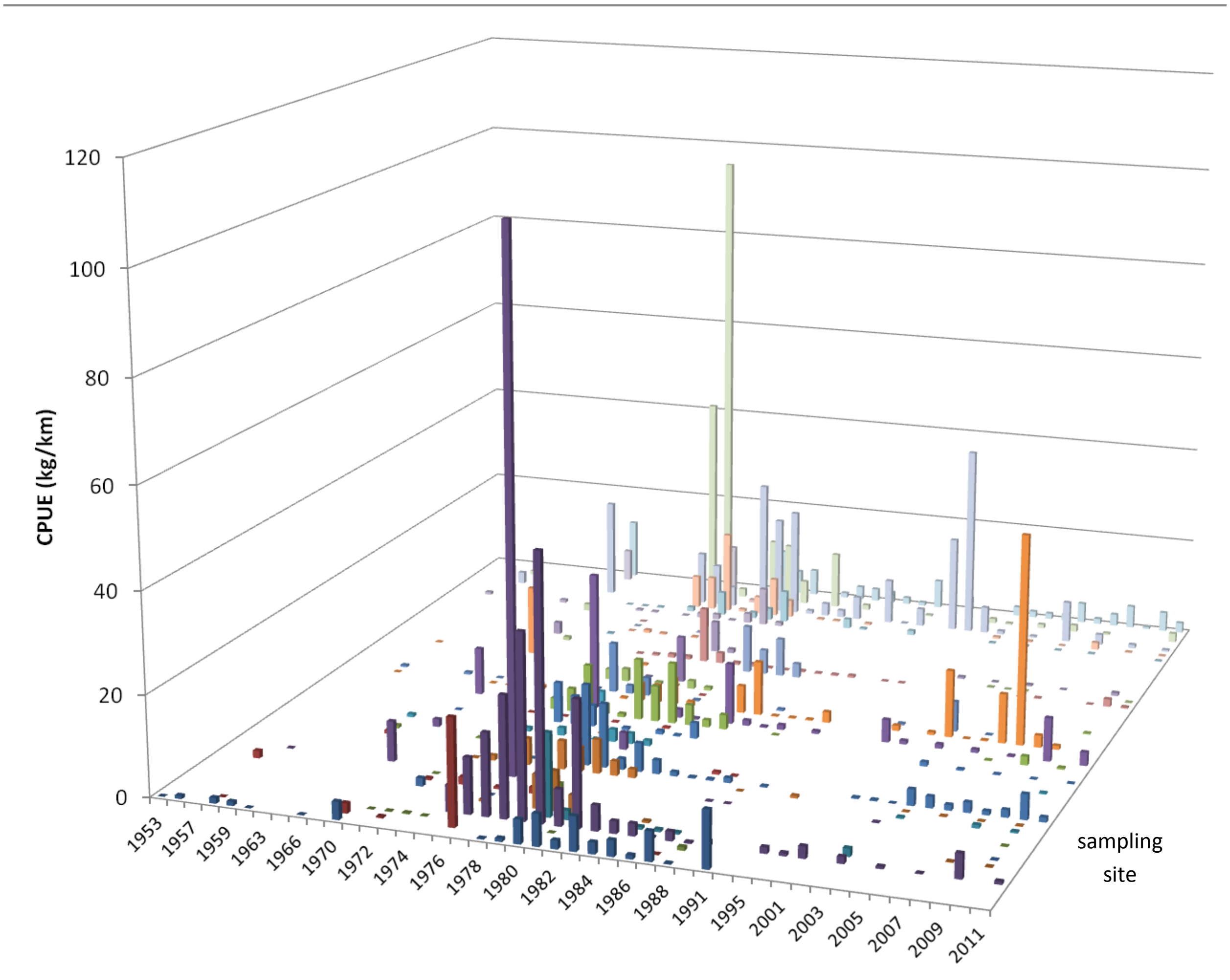


Figure 26. Mean CPUE (kg/km trawled) of Pacific herring in the ADFG small-mesh survey, by year and bay, 1953-2011. The z-axis (corresponding to chart depth and labeled "sampling site") represents the numerous nearshore sites (bays) sampled during the surveys. For clarity, bay names are not included on the chart and the sites are not located on the axis in any meaningful way (i.e. the data are arranged alphabetically by bay name and are not related to any geographic quantity).

Appendix: List of scientific and common names of species contained within the “FMP forage fish” category. Data sources: BSAI FMP, Fishes of Alaska (Mecklenburg et al. 2002).

Scientific Name	**Common Name**
Family Osmeridae	smelts
Mallotus villosus	capelin
Hypomesus pretiosus	surf smelt
Osmerus mordax	rainbow smelt
Thaleichthys pacificus	eulachon
Spirinchus thaleichthys	longfin smelt
Spirinchus starksi	night smelt
Family Myctophidae	lanternfish
Protomyctophum thompsoni	bigeye lanternfish
Benthosema glaciale	glacier lanternfish
Tarletonbeania taylori	taillight lanternfish
Tarletonbeania crenularis	blue lanternfish
Diaphus theta	California headlightfish
Stenobrachius leucopsarus	northern lampfish
Stenobrachius nannochir	garnet lampfish
Lampanyctus jordani	brokenline lanternfish
Nannobrachium regale	pinpoint lampfish
Nannobrachium ritteri	broadfin lanternfish
Family Bathylagidae	blacksmelts
Leuroglossus schmidti	northern smoothtongue
Lipolagus ochotensis	popeye blacksmelt
Pseudobathylagus milleri	stout blacksmelt
Bathylagus pacificus	slender blacksmelt
Family Ammodytidae	sand lances
Ammodytes hexapterus	Pacific sand lance
Family Trichodontidae	sandfish
Trichodon trichodon	Pacific sandfish
Arctoscopus japonicus	sailfin sandfish
Family Pholidae	gunnels
Apodichthys flavidus	penpoint gunnel
Rhodymenichthys dolichogaster	stippled gunnel
Pholis fasciata	banded gunnel
Pholis clemensi	longfin gunnel
Pholis laeta	crescent gunnel
Pholis schultzi	red gunnel

Scientific Name	**Common Name**
Family Stichaeidae	pricklebacks
Eumesogrammus praecisus	fourline snakeblenny
Stichaeus punctatus	arctic shanny
Gymnoclinus cristulatus	trident prickleback
Chirolophis tarsodes	matcheek warbonnet
Chirolophis nugatory	mosshead warbonnet
Chirolophis decoratus	decorated warbonnet
Chirolophis snyderi	bearded warbonnet
Bryozoichthys lysimus	nutcracker prickleback
Bryozoichthys majorius	pearly prickleback
Lumpenella longirostris	longsnout prickleback
Leptoclinus maculates	daubed shanny
Poroclinus rothrocki	whitebarred prickleback
Anisarchus medius	stout eelblenny
Lumpenus fabricii	slender eelblenny
Lumpenus sagitta	snake prickleback
Acantholumpenus mackayi	blackline prickleback
Opisthocentrus ocellatus	ocellated blenny
Alectridium aurantiacum	lesser prickleback
Alectrias alectrolophus	stone cockscomb
Anoplarchus purpurescens	high cockscomb
Anoplarchus insignis	slender cockscomb
Phytichthys chirus	ribbon prickleback
Xiphister mucosus	rock prickleback
Xiphister atropurpureus	black prickleback
Family Gonostomatidae	bristlemouths
Sigmops gracilis	slender fangjaw
Cyclothone alba	white bristlemouth
Cyclothone signata	showy bristlemouth
Cyclothone atraria	black bristlemouth
Cyclothone pseudopallida	phantom bristlemouth
Cyclothone pallida	tan bristlemouth
Order Euphausiacea	krill

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