MEMORANDUM

TO: Council, SSC and AP Members

FROM: Chris Oliver
Executive Director

DATE: January 20, 2003

SUBJECT: Rockfish Management

ESTIMATED TIME
4 HOURS
(all D items)

ACTION REQUIRED

Review NMFS discussion paper on rockfish research and management

BACKGROUND

In October 2002, the Council requested that NMFS staff prepare a discussion paper on short and long term approaches to managing BSAI rockfish. The Council requested that the paper first address rockfish management for 2003, including issues associated with reliable identification of species, NMFS strategy for collecting species-specific information, and considerations for breaking out the shortraker/rougheye rockfish TAC in the Aleutians Islands by district. That paper was presented in December 2002.

In December, the Council requested a follow-up discussion paper to address implications for more long term (2004 and beyond) management of the red rockfish complex. Issues of interest include the scientific information/research necessary to support separate species management by area, management implications of separate species OFLs/ABS/TACs, adequacy of existing survey methodology for these species and potential enhancements to existing protocol to address shortcomings, and potential management response to ongoing and perhaps unavoidable bycatch. Dr. Paul Spencer, NMFS AFSC, will present a discussion paper on rockfish research and management (Item D-1(b)(1)).

Sarah Gaichas, AFSC, and Jane DiCosimo, will provide additional information and suggestions for prioritizing the BSAI and GOA rockfish issues from the larger analysis to revise management of all target and non-target groundfish. Staff will continue to consult with the SSC on the analytical approach over the next few meetings.

Discussion Paper on Rockfish Research and Management

Rockfish Working Group
Alaska Fisheries Science Center
January 27, 2003

Executive Summary

The North Pacific Fishery Management Council recently requested a description of the scientific information necessary to manage rockfish on a single-species basis on finer spatial scales, in particular focusing on the issues of stock structure, the adequacy of existing surveys, and the availability of life-history information. The purpose of this discussion paper is to describe our information on these topics, and past and current research on problems relevant to rockfish management. First, we address the question of what information is necessary to scientifically assess the stock structure of rockfish, including genetic and life-history information. Second, we address the question of what information is necessary to adequately assess the population status of north Pacific rockfish stocks, and consider the information available for various rockfish species. Both types of information are viewed as relevant to questions regarding the overall effectiveness of our current management system, as such inquiries can only be considered in the context of the scientific information available on stock structure, life-history, and population status. Current fisheries management practices are designed to provide effective conservation of rockfish stocks given our current understanding of rockfish stock structure and available data. Therefore, biological studies on stock structure are essential in defining the appropriate spatial scales of fisheries management (i.e., establishing harvest quotas by management area), and as new information on stock structure becomes available the question of effective management strategies will need to be revisited. A similar updating of management strategies would also be expected to occur as new information on life-history and population status becomes available for data-poor portions of rockfish populations. A summary of our overall findings and recommendations is presented below.

Genetic studies and spatial units for fisheries management

Identification of stock structure is an essential part of examining whether a particular management scheme is providing conservation of rockfish resources. Genetic research indicates that little stock structure is seen for northern rockfish across wide areas, although a more comprehensive study could be pursued. For shortraker rockfish, weak structure is seen across relatively broad spatial scales and rougheye rockfish are likely two different species that cannot easily be identified in the field. Canadian researchers have found that Pacific ocean perch (POP) off British Columbia show strong stock structure on very fine spatial scales, and some preliminary research from Alaska POP stocks is consistent with this view. The Rockfish Working Group (RWG) supports the continued work by A.J. Gharrett and his colleagues at the Juneau Center for Fisheries and Ocean Sciences (JCFOS) to further refine our understanding of rockfish stock structure.

It is unlikely that the spatial boundaries of stock structure for a particular species will correspond to our current management boundaries or to other related rockfish species. The

establishment of spatial management systems for individual species is dependant, in part, on information such as the identification of areas where reproduction occurs and the duration and mortality of the pelagic life stages. This information is currently unknown for rockfish, and research conducted by Dr. Art Kendall suggests that identification of rockfish larvae is difficult without genetic analyses. In the absence of biological information, spatial management can be influenced by the spatial structure of fishery harvests. For example, recent stock assessments of other red rockfish have identified areas where much of the bycatch of northern rockfish has occurred and fishing closures in these areas could reduce harvests. The eastern Bering Sea (EBS) pollock fishery is currently voluntarily using this approach in order to reduce northern rockfish bycatch.

The management of two stocks (or species) that are intermixed in the same area poses unique problems for management. If distinct reproduction areas can be identified for particular stocks, then fisheries may be able to harvest on these stocks in these areas; however, reproductive isolation may occur by depth as well. Mixed stock analysis (Utter and Ryman 1993) may be useful in these situations.

Survey design

Potential improvements in survey design vary by species. Shortraker and rougheye rockfish are not thought to be highly clustered, but do live in fairly rough habitat relative to other rockfish species. Thus, these species may be best sampled by improving the footrope of survey trawl gear. These species are also obtained in current longline surveys, and the biomass indices from these surveys should be assessed with respect to whether additional sampling would substantially improve rockfish estimates.

For species that are thought to be aggregated, such as POP and northern rockfish, survey designs that explicitly consider "patchiness" such as adaptive cluster sampling (ACS) or trawl and acoustic presence/absence survey (TAPAS) (Iverson et al. 1996) may be useful. POP are generally thought to occur over relatively smooth bottom, but northern rockfish may occur over rough bottom and gear design considerations may need to be pursued here as well.

Implementation of research on survey gear and design are complicated by at least two factors. First, trawl surveys in Alaska federal waters are designed as multispecies surveys, and changes in gear design that would increase the precision of rockfish biomass estimates may decrease the precision for other species. Second, most of our trawl surveys have used a standardized methodology for several years and changes to this methodology without gear standardization field experiments would complicate interpretation of these time series. The increase in frequency of the Aleutian Islands and Gulf of Alaska trawl surveys from triennial to biennial, and the addition of the EBS slope survey, reduces the personnel and equipment available to conduct specialized field work. Specialized surveys focused on rockfish may need to be considered, although this would not be inexpensive.

Biological data collection

Despite recent changes in fishery observer sampling procedures designed to sample more otoliths and increase length measurements of bycatch species, these data remain low for non-POP rockfish species. For example, the number of otoliths collected in the Bering Sea-Aleutian Islands (BSAI) area for northern, rougheye, and shortraker rockfish has not exceeded 200 per species in any year, and the number of lengths taken has not exceeded 1000 for any species since

1996. Steps taken in 2003 to improve species identification of shortraker and rougheye on longline vessels should help with collection of biological data for these species, although further steps may be necessary to improve biological sampling from the fishery.

Otolith collections and length measurements on research surveys has generally been adequate across broad areas, but if smaller spatial areas are to be considered for management then the sample sizes per area may need to increase as well. Much of the genetic sampling of rockfish has focused on the AI and GOA regions because data from the EBS area were not available. POP tissue samples for genetic analyses were collected in the 2000 and 2002 EBS slope surveys, and other species will likely need to be collected in future years in order to address questions of EBS rockfish stock structure.

Maturity studies are required on all rockfish species in the BSAI area. A study on POP maturity (estimated from field classification of maturity state) from the 2000 AI trawl survey produced an estimated length at 50% maturity substantially different from published estimates. Future studies may require histological studies from samples collected near the time of parturition. Because our research surveys may not coincide with the time of parturition, specialized research cruises may be useful here as well.

Age reading of some rockfish species, such as shortspine thornyhead and shortraker rockfish, is limited because of a lack of standardized methodology. Another species, rougheye rockfish, is difficult to age and requires a significant training period. In recent years, rockfish age readers have often taken other positions prior to becoming sufficiently trained to read rougheye rockfish, thus this species has a low number of otoliths read. In the past, only specific personnel were trained as rockfish age readers, thus leaving the group particularly sensitive to personnel losses. A new policy of training all groundfish age readers to read rockfish should stabilize interannual variability in the number of otoliths that can be read.

Stock assessment modeling

Several steps can be taken to improve the stock assessment models currently used for BSAI rockfish. In recent years, northern rockfish have been viewed as the most likely candidate for a separate age-structured model, given the size of the stock in the AI area and the availability of otoliths from the survey. Although no fishery otoliths have been aged, a sufficient time series of age composition now exists from the survey data. Thus, the development of an age-structured model should be investigated for the 2003 assessment; this model will likely require using maturity data from the GOA northern rockfish assessment. For other species of BSAI red rockfish, investigation of state-space modeling should be pursued. A model of this type was investigated by Ianelli and Gachais (1999) for other species in the GOA, and has the advantage of providing probability distributions upon quantities of interest, such exploitation rates, given uncertainty in both our observation of biomass and in the year-to year stock dynamics of the species. The biomass estimates of shortraker and rougheye rockfish from longline surveys should also be obtained and possibly used in stock assessments.

Introduction

In the October, 2002, meeting of the North Pacific Fisheries Management Council, the Council requested that NMFS staff present a discussion paper in December 2002 on short and long term approaches to managing BSAI rockfish. A discussion paper describing management strategies for 2003 was presented at the December 2002 Council meeting, with agreement that a discussion paper addressing long term (2004 and beyond) rockfish management issues would be presented to the Council at the January, 2003, meeting. The Council has requested that the long term discussion paper specifically address "*the scientific information/research necessary to support separate species management by area; management implications of separate species OFLs/ABCs/TACs; adequacy of existing survey methodology for these species and potential enhancements to existing protocol to address shortcomings; and potential management response to ongoing and perhaps unavoidable bycatch*".

In the December meeting of the Council's Statistical and Scientific Committee (SSC), the following additional requests for information regarding rockfish were made:

1. *Are current management approaches appropriate; do they effectively provide for conservation of rockfish resources?*
2. *Are surveys effectively estimating stock abundance and providing requisite demographic data?*
3. *What are the strengths and weaknesses of survey data and how might surveys be improved?*
4. *Is knowledge of individual species life history adequate? Do we have reliable estimates of natural mortality, maturity, and growth?*
5. *Do we know the stock structure for managed species?*

Where data deficiencies are noted, the white paper should identify the specific steps to be taken to acquire the needed data.

The purpose of this document is to describe past and ongoing scientific research that addresses the scientific information/research necessary to support separate species management by area. The management implications of managing species separately, as opposed to species complexes, are expected to be provided in a companion discussion paper that uses rockfish as a special example. Much of the research discussed has been conducted by the Alaska Fisheries Science Center's Rockfish Working Group (RWG), a collection of assessment and survey scientists that conducts or supports research on survey methods, genetic larval identification and stock structure, and rockfish habitat associations at various life-history stages.

This discussion paper is organized into two sections. First, we address the question of what information is necessary to scientifically assess the stock structure of rockfish. The available genetic and life-history information for assessing stock structure of north Pacific rockfish is presented, thus addressing questions 4 and 5 from the December Council meeting. In addition, we consider the relation of stock structure to spatial management. Second, we address the question of what information is necessary to adequately assess the population status of north

Pacific rockfish stocks, and consider the information available for various rockfish stocks, thus also addressing question 4 above. This section also considers our current surveys in detail, thus addressing questions 2 and 3 from the December Council meeting.

Information necessary to scientifically assess the stock structure of BSAI rockfish

Effective management would manage each stock (defined here as a reproductively isolated or semi-isolated population unit of a species) according to its level of productivity in order to optimize harvest and reduce the likelihood of overfishing. Thus, information on stock structure is an important consideration for defining and evaluating management measures applied to finer spatial scales. A variety of information types can be used to infer stock structure, including age and length compositions, growth patterns, early life-history studies, and genetic studies. A review of these types of studies is presented below.

Information from age and length compositions and growth patterns

Spatial differences in age or length compositions can be used to infer differences in recruitment patterns that may correspond to population structure. In Queen Charlotte Sound, British Columbia, Gunderson (1972) found substantial differences in the mean lengths of POP in fishery hauls taken at similar depths which were related to differences in growth rates and concluded that Pacific ocean perch (POP) likely form aggregations with distinct biological characteristics. In a subsequent study, Gunderson (1977) found differences in size and age composition between Moresby Gully and two other gullies in Queen Charlotte Sound. Westrheim (1970, 1973) recognized "British Columbia" and "Gulf of Alaska" POP stocks off the western coast of Canada based upon spatial differences in length frequencies, age frequencies, and growth patterns observed from a trawl survey. In a study that has influenced management off Alaska, Chikuni (1975) recognized distinct POP stocks in four areas – eastern Pacific (British Columbia), Gulf of Alaska, Aleutian Islands, and Bering Sea. However, Chikuni (1975) states that the eastern Bering Sea (EBS) stock likely receives larvae from both the Gulf of Alaska (GOA) and Aleutian Islands (AI) stock, and the AI stock likely receives larvae from the GOA stock.

Of particular interest to Bering Sea-Aleutian Islands (BSAI) rockfish is whether length-frequency data suggests stock structure between the eastern Bering Sea management area and the management subareas of the Aleutian Islands. Length frequencies by area and year were obtained from the Aleutian Islands trawl survey for POP (Figure 1), northern rockfish (Figure 2), rougheye rockfish (Figure 3), and shortraker rockfish (Figure 4). This survey was conducted in 1991,1994,1997,2000, and 2002, and covers a portion of EBS management area. With the exception of POP, it is difficult to interpret the data for some species in some year-area combinations because of low sample sizes; this problem is especially apparent for shortraker rockfish. Consistent trends in these data are difficult to visually separate from the sampling variability; for example, the modes of POP length distributions in the western AI appears to be smaller than other AI subareas in the 1997 and 2002 surveys, but this does not appear to the case for the 2000 survey. A statistical analysis of this data will be pursued in the future.

Differences in growth patterns could also correspond to discrete stocks. von Bertalanffy growth curves fit to northern rockfish show a progression of larger predicted size at age from the western AI to the eastern AI (Figure 5); this progression continues into the GOA where northern rockfish show even higher predicted size at age (Heifetz et al. 2002). Given the current research on northern rockfish genetics, it is not clear whether these changes in growth across areas reflect stock structure or phenotypic responses to varying environments.

Information from life-history studies

Stock differentiation occurs from separation at key life-history stages, and another approach to evaluating stock structure involves examination of rockfish life-history stages directly. Because many rockfish species are not thought to exhibit large-scale movements as adults, movement to new areas and boundaries of discrete stocks may depend largely upon the pelagic larval and juvenile life-history stages. Knowledge of specific areas where parturition occurs and the spatial extent of larval drift are therefore important not only to defining stock structure but also to the creation of marine protected areas with appropriate spatial boundaries.

In 2002, the rockfish working group contracted with Dr. Art Kendall to undertake an analysis of archived *Sebastes* larvae collected by Alaska Fisheries Science Center (AFSC). The goals of the study were to investigate a subset of the preserved larvae to assess whether larvae could be identified to groups and species based upon morphological characteristics, and identify the seasonal and geographical variations in distributions of the identified groups. The data used for the analysis originates from two sources: 1) a group of 650 larvae collected off southeast Alaska in 1990 by Dr. Bruce Wing; and 2) the AFSC ichthyoplankton database, containing 16,895 *Sebastes* larvae collected on 58 cruises from 1972 to 1999. The larvae collected by Dr. Wing all showed the same morph, and were too small to have characteristics that would allow species identification. A preliminary examination of the AFSC ichthyoplankton database indicates that most larvae were collected in the spring, the larvae were widespread in the areas sampled, and most are small (5-7 mm). The larvae were organized into three size classes for analysis: <7.9 mm, 8.0-13.9 mm, and >14.0 mm. A subset of the abundant small larvae was examined, as were all larvae in the medium and large groups. Species identification based on morphological characteristics is difficult because of overlapping characteristics among species, as few rockfish species in the north Pacific have published descriptions of the complete larval developmental series. However, all of the larvae examined could be assigned to four morphs identified by Kendall (1991), where each morph is associated with one or more species. Most of the small larvae examined belong to a single morph, which contains the species *S. alutus* (POP), *S. polyspinus* (northern rockfish), and *S. ciliatus* (dusky rockfish). Some larvae belonged to a second morph which has been identified as *S. borealis* (shortraker rockfish) in the Bering Sea.

Rockfish identification can be aided by studies that combine genetic and morphometric techniques and information has been developed to identify individual species based on allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Gharrett et al. 2001, Rocha-Olivares 1998). The Ocean Carrying Capacity (OCC) field program, conducted by the Auke Bay laboratory, uses surface trawls to collect juvenile salmon and incidentally collects juvenile rockfish. These juvenile rockfish are large enough (approximately 25 mm and larger) to allow extraction of a tissue sample for genetic analysis without impeding morphometric studies. In 2002, species identifications were made for an initial sample of 55 juveniles with both morphometric and genetic techniques. The two techniques showed initial agreement on 39 of the 55 specimens, and the genetic results motivated re-evaluation of some of the morphological species identifications. Forty of the specimens were identified as POP, and showed considerably more morphological variation for this species than previously documented. Given the success of this initial examination of the OCC data with these techniques, a more comprehensive study is planned for the near future.

Studies on other life-history stages can also add basic information on rockfish biology. For example, identification of habitat associations of adult rockfish can be combined with habitat maps to identify locations where rockfish may be expected to occur, and such information may be helpful in identifying areas where fertilization or parturition occurs. The RWG has recently funded studies focused on identifying rockfish habitat associations using submersibles and habitat mapping using multibeam sonar. In 2002, the submersible *Delta* was used to conduct line transects to estimate rougheye and shortraker densities near Adak Island in the Aleutian Islands. The overall goal of the study was to estimate densities of rougheye and shortraker across various habitat types. A total 12 dives and 39 transects were completed in four days of field work, with a 20 minute duration for each transect. Also, habitat mapping studies were conducted in 2001 and 2002 in the GOA in conjunction with contractual work conducted by the National Ocean Survey. Some criteria that were considered in the selection of habitat to be mapped were 1) focus on rockfish grounds; 2) a wide variety of habitat, and 3) areas where we have good research trawl data. In 2001, a portion of Portlock Bank in the Gulf of Alaska was mapped. In 2002, a portion near Yakutat was mapped.

Information from genetic studies

Because stocks are, by definition, reproductively isolated population units, it is expected that different stocks would show differences in genetic material due to random drift or natural selection. Thus, analysis of genetic material from north Pacific rockfish is currently an active area of research.

Seeb and Gunderson (1988) used protein electrophoresis to infer genetic differences based upon differences in allozymes from POP collected from Washington to the Aleutian Islands. Discrete genetic stock groups were not observed, but instead gradual genetic variation occurred that was consistent with an isolation by distance model. The study included several samples in Queen Charlotte Sound where Gunderson (1972, 1977) found differences in size compositions and growth characteristics. Seeb and Gunderson (1988) concluded that the gene flow with Queen Charlotte Sound is sufficient to prevent genetic differentiation, but adult migrations were insufficient to prevent localized differences in length and age compositions. However, recent studies of POP using microsatellite DNA indicate population structure at small spatial scales, consistent with the work of Gunderson (1972, 1977), and suggest that adult POP do not migrate far from their natal grounds and larvae are entrained by currents in localized retention areas (Withler et al. 2001).

Interpretations of stock structure are influenced by the particular genetic analysis conducted, as illustrated by the differing conclusions produced from the POP allozyme work of Seeb and Gunderson (1988) and the microsatellite work of Withler et al. (2001); note that these two components of the genome diverge on very different time scales and that, in this case, microsatellites are much more sensitive. Protein electrophoresis examines DNA variation only indirectly via allozyme frequencies, and does not recognize situations where differences in DNA may result in identical allozymes (Park and Moran 1994). In addition, many microsatellite loci may be selectively neutral or near-neutral, whereas allozymes are central metabolic pathway enzymes and do not have quite the latitude to produce viable mutations. The mutation rate of microsatellite alleles can be orders of magnitude higher than allozyme locus mutation rates.

Most current studies on rockfish genetic population structure involve direct examination of either mitochondrial DNA (mtDNA) or microsatellite DNA.

Genetic research on rockfish population structure in the Gulf of Alaska and the BSAI area is an ongoing research activity of Dr. A.J. Gharrett and his colleagues at the University of Alaska's Juneau Center for Fisheries and Ocean Sciences (JCFOS). An initial study, supported by Saltonsall-Kennedy funding, had the objective of conducting a broad survey of genetic population structure of rougheye and shortraker rockfish, and initiating studies on northern rockfish. The northern rockfish research was considered preliminary due to small samples of 20 fish from each of three locations (Kodiak Island, Unimak Pass, and Stalemate Bank). There was no evidence of population structure in these samples from either mtDNA or microsatellite analysis. Although the sample sizes were small and had little power, the authors concluded that the analysis was sufficient to conclude that existing structure is not pronounced. However, this study looked at only a portion of the mtDNA genome and a handful of microsatellite loci, and had small sample sizes. If subtle differences occur, much larger sample sizes would be required in order to identify stock structure.

For rougheye rockfish, both mtDNA and microsatellite analyses indicate evidence of population structure. The microsatellite work was conducted on six collections in the Gulf of Alaska and eastern Aleutian Islands and showed nearly fixed differences in alleles at one loci between the Kodiak and Yakutat samples. In the mtDNA analysis, there were two major clusters of mtDNA haplotypes which correlate nearly perfectly to two homozygous microsatellite genotypes. If there were any interbreeding, there would be a large portion of heterozygous microsatellite genotypes. Some specimens are captured in the same hauls and the overall distributions of the two types overlaps, but are not coincident. These strong differences are suggestive of two species of "rougheye rockfish" that are reproductively isolated, and a further study (described below) supported by the RWG has examined whether color variations in rougheye rockfish correspond to genetic differences.

For shortraker rockfish, population structure was observed in the mtDNA analysis, and weak evidence of population structure was observed in the microsatellite analysis. The pattern of mtDNA haplotypes in northern rockfish was similar to that in shortraker rockfish in that each species was dominated by a single haplotype that was associated with several closely related haplotypes. However, the pattern among the peripheral haplotypes was more complex for shortraker rockfish. In both northern and shortraker rockfish, the relationships among the mtDNA haplotypes suggest a population decline followed by a relatively recent (in geological time) population expansion. A subsequent "phase 2" of the Saltonsall-Kennedy research will increase the sample sizes and sampling locations of shortrakers and rougheye rockfish.

The RWG has funded a separate study, via the CIFAR program, that has two distinct objectives: 1) conduct a thorough examination of mtDNA for POP on samples collected in the GOA and BSAI, and conduct a preliminary analysis of POP microsatellite variation in these regions; and 2) evaluate the genetic characteristics of two distinct color morphologies of rougheye rockfish. The POP mtDNA analysis was performed on 124 fish collected from six regions ranging from southeast Alaska to the Bering Sea slope and central Aleutian Islands. No population structure was observed, as most fish (102) were characterized by a common haplotype. However, the preliminary work with 10 microsatellite loci from the six regions resulted in 7 loci with significant heterogeneity in the distribution of allele frequencies. Additionally, the sample in each region was distinct from those in adjacent regions, suggesting population structure on a relatively fine spatial scale consistent with the results on Gunderson

(1972, 1977) and Wither et al. (2001). Future work with POP will focus on increasing the sample sizes and collection sites for the microsatellite analysis in order to further refine our perception of stock structure.

The second objective of the CIFAR study is motivated by the finding of nearly fixed differences between rougheye rockfish at some loci in a preliminary analysis (cited above). In addition, two color morphologies have also been reported for rougheye rockfish, and Seeb (1986) suggested a correlation of the color morphs to allozyme differences but had small sample sizes. Thus, an important question to be addressed in the CIFAR study is whether the color morphs correspond to genetic differences based on mtDNA or microsatellite patterns. Based on the mtDNA analyses, rougheye rockfish can be classified into distinct "type a" and "type b" haplotypes, with these haplotypes corresponding to distinct differences in microsatellite DNA as well. In a sample of 96 fish from the eastern Gulf of Alaska containing both color morphs (light and dark colored "rougheye" rockfish), most lightly colored fish corresponded to mtDNA haplotype *b* and more of the haplotype *a* fish had the dark morphology. Thus, the color morphs show some correlation to genetic differences but are not an unequivocal indicator. Future research questions include examining spatial distributions of the two types of rougheye rockfish, and whether separation occurs from water masses or depth zones.

Correspondence between stock structure and spatially explicit ABC and OFL levels

Current fisheries management practices are designed to provide effective conservation of rockfish stocks through harvest quotas designed to reduce the likelihood of overfishing. Therefore, biological studies on stock structure are essential in defining the appropriate spatial scales of fisheries management (i.e., establishing ABC and OFL levels by management area), and as new information on stock structure becomes available the question of effective management strategies will need to be revisited. Other factors beyond biological stock structure may also be important in the conservation of rockfish stocks; for example, a disproportionate amount of harvest in one area of the stock may cause concern over the potential of localized depletion. ABC levels by subarea in the Aleutian Islands were created for POP and Atka mackerel in order to spatially disperse the harvest, as much of the harvest of these species was taken from the eastern AI subarea. As presented in the rockfish discussion paper presented at the December, 2002, SSC meeting, disproportionate harvest levels are not apparent for shortraker and rougheye rockfish; this may be in part because they are often taken as bycatch in the POP and Atka mackerel fisheries that have spatially allocated ABC levels.

The current information on stock size and demographics can also influence the establishment of ABC and OFL levels. For example, in 2001 the BSAI POP assessment model was changed from having separate models for the AI and EBS subareas to a combined model that treats the entire BSAI POP population as a single stock. Although the existence of a single stock could not be determined from the data available in 2001, the existing biological information was viewed as not supporting a separate age-structured model for EBS POP. Again, as new information on stock structure, population size, and population biology (i.e., growth and maturity) becomes available for POP in this region, the establishment of ABC and OFL levels will need to be revisited. In the section below, we discuss the some of the information necessary to manage stocks, the nature of our resource surveys from which much of this information is obtained, and the current information status for some rockfish species.

Information necessary to assess the population status of north Pacific rockfish stocks

The establishment of fisheries management quotas in the north Pacific requires an estimate of population size and an estimate of a fishing harvest rate that will optimize harvest levels while reducing the likelihood of overfishing. In data-rich situations, this information need is generally supported by age-structured models which incorporate fishery-independent resource surveys, age and length compositions, estimates of maturity and length at age, and natural mortality estimates. If stock structure is thought to occur on spatial scales finer than currently assumed, then this information would also be necessary on these finer scales.

Trawl survey biomass estimates of rockfish show particularly high sampling variability compared to other groundfish species, and this has been an obstacle for management. For example, the coefficient of variation (CV) of EBS flatfish stocks from the EBS shelf survey are generally on the order of 0.10, whereas rockfish CVs from the 2002 AI trawl survey ranged from 0.16 (POP) to 0.27 (northern rockfish). The RWG has been involved in several studies aimed at improving trawl survey biomass estimates, and this information is summarized below. Additionally, the state of our current knowledge regarding age and length composition data, growth, and maturity is also presented, with an aim of identifying data gaps for BSAI rockfish species.

Trawl survey gear and design studies

The imprecision of the area-swept trawl surveys is likely a function of the tendency of rockfish to be patchily distributed, the occurrence of rockfish in habitats difficult to sample, and the vast areas to be surveyed in a limited time. In particular, there are at least two primary problems that may occur in the trawl surveys:

1) *Inadequate sampling of rockfish habitat.* If the trawl survey does not sample areas commonly used by rockfish because the habitat is too rugged for the trawl gear, then the area-swept method would underestimate biomass.

2) *Disproportionate sampling of patchily-distributed rockfish concentrations.* Rockfish may be patchily distributed, perhaps in particular habitat types. If the trawl survey happens to catch large concentrations of rockfish in habitats that constitute a minor fraction of the strata, then the area-swept expansion would overestimate biomass. Conversely, if the trawl survey happens to miss the rockfish patches, then the survey would underestimate biomass (as in problem 1 above). Disproportionate over-sampling or under-sampling of rockfish patches would be exacerbated by inadequate sample size, leading to large interannual variability in estimated biomass levels.

Note that these two problems are not likely to be mutually exclusive. For example, it is reasonable to expect that NMFS trawl surveys do not sample all the areas commonly used by rockfish because of gear restrictions, and that rockfish are patchily distributed. Strategies for addressing the first problem involve evaluating more rugged sampling gear, whereas strategies for the second problem involve developing survey designs that produce more representative sampling of rockfish patches within the time and cost constraints of our resource surveys. The

RWG originated with research on survey gear and design, and has conducted several studies addressing the two problems above.

Research evaluating survey gear

The ability to trawl in steep slope habitat was evaluated in a 1993 study on the *Unimak Enterprise*. This study was conducted on the eastern GOA slope from the Fairweather Grounds to the W-Grounds primarily at depths occupied by shortraker and rougheye rockfish (300-500m) using commercial rockfish trawl gear. All haul locations selected randomly along the slope were successfully trawled except for one location where soft mud clogged the net. Bottom that was too rough or too steep was not encountered. This study demonstrated that a net designed for rough bottom could be fished in a random or uniform design over most shortraker/rougheye habitat and untrawlable bottom would not be a major concern. Haul locations were uniformly distributed over the study area, whereas those of the *Miller Freeman* during the 1993 triennial trawl survey were located at gully openings and absent from steep slope habitat. The *Miller Freeman* hauls tended to have proportionately more zero catches, particularly for shortraker rockfish. The coefficient of variation of the log catch rates was lower for the *Unimak Enterprise* than for the *Miller Freeman*.

A trawl with a rugged footrope designed to sample rough shortraker and rougheye habitat was evaluated in field trials conducted by Ito (1999). The trawl performed well, as the proportion of shortraker and rougheye in the path of the trawl that were captured was about 80% (as inferred from video observations).

Research evaluating survey design

Knowledge of the relationship between physical and environmental variables and fish distribution and abundance is needed to improve survey sampling design and increase the precision of population estimates. Rockfish are believed to have seafloor habitat preferences and the RWG recognized that knowledge of these preferences and knowledge of the distribution of seafloor types could lead to improved survey efficiency and accuracy. The development of acoustic bottom typing techniques could greatly expedite the daunting task of characterizing sediment types on spatial scales meaningful for north Pacific rockfish populations. Two separate studies on using hydroacoustic systems to characterize bottom types have been conducted in recent years.

One approach to classifying bottom type is to interpret the signal from the vessel's echosounder relative to prior signals from known bottom types. This approach, utilized in the QTC View system, was evaluated by von Szalay (1998). Ship speeds between 3 and 12 knots did not significantly impact the consistency of seabed classification, and depths of at least 220 meters did not adversely affect classification performance. However, slope gradient apparently had a major impact on classification accuracy. The study concluded that the ship-mounted transducer would not be feasible in classifying bottom type on sloped habitat. These concerns led to studies in which the transducer is mounted directly on the headrope of a trawl, as in the Biosonics DTX system. Research conducted by Michael Martin has deployed this unit on the headrope of a poly-noreastern trawl at depths ranging from 50 to 770 m off the coast of Alaska, Oregon and California. Concomitant information on depth, temperature, geographic location, and the species composition of the catch has also been collected. The recorded acoustic information is processed and categorized into discrete bottom types using the Impact software package from Quester-Tangent Corporation.

There are several advantages of a self-contained acoustic data collection system over a shipboard system. The surveys are generally conducted aboard chartered fishing vessels, each having a unique combination of hull-mounted transducers, echosounders and frequencies making inter-vessel data comparison difficult, if not impossible. The Biosonics DTX system can be easily moved between vessels with no need to recalibrate or otherwise change the system. High quality, high resolution data are collected at a constant distance from the bottom making data directly comparable regardless of the depth of sampling. Tows are generally made along a depth contour allowing the face of the transducer to remain constantly parallel to the bottom, thus minimizing problems associated with classifying sediments on sloped bottoms. In addition, the acoustic data are collected over exactly the same bottom as the fish information, allowing for an exact correspondence between the acoustic and fish data. This is not possible with shipboard systems, particularly in deeper water. The system was designed to allow the user to easily switch to a different transducer frequency, making it a very versatile tool with many potential applications.

Evaluating the "patchiness" of rockfish distributions is an important step in formulation of survey design. In a study conducted by Chris Lunsford, GOA survey and commercial fishery data were analyzed to determine POP distribution patterns. The survey and the fishery appear to encounter POP in the same areas throughout the GOA, and POP distribution does not appear to change temporally. Analysis of CPUE data indicates POP exhibit a tightly aggregated distribution pattern which is related to habitat type. The improvement of the survey design, or relative efficiency, compared to a random estimate was 65%. Altering the allocation and stratification of the current design may improve the precision of POP biomass estimates but may be limited by the clustered distribution exhibited by POP in the GOA and the need to assess other species.

An effective allocation of sampling effort may be gained from adaptive sampling, in which greater sampling efforts are expended in clusters of high rockfish density. After an initial 1996 field study in the Kodiak area found high density clusters of POP that would be amenable to adaptive sampling, a two year study of adaptive cluster sampling of rockfish was conducted by the UAF-JCFOS and AFSC in 1998-1999. In 1998 the method was tested on POP and shortraker/rougheye in the Kodiak area of the Gulf of Alaska (Quinn et al 1999, Hanselman et al. 2001). In 1999, the method was further tested for these three species in the Yakutat area (Hanselman et al., in press). Adaptive cluster sampling was not found to be more effective than simple random sampling for shortraker rockfish and rougheye rockfish, which are considered to have a less aggregated distribution than POP. For POP, the biomass estimates obtained from random sampling were slightly less precise than for adaptive cluster sampling, primarily due to one very large catch which was mediated by the additional adaptive samples. The benefits of adaptive cluster sampling alone are not clear cut. The effort in determining edge units (low-CPUE hauls defining the extent of the high-CPUE clusters) was not considered in the variance comparison and CV, and the total number of hauls needed for adaptive cluster sampling was not considered in the efficiency comparison of time per haul. Hanselman (2000) suggests that hydroacoustics might be used for determining edge units. Determining edge units (and the cluster) with hydroacoustics would be similar to TAPAS (see below).

Several survey sampling designs involve the combined use of echosounder and trawl information data, with the general rationale being that the echosounder can provide information over relatively broad areas with low effort as compared to the more expensive trawl sampling. During the 1998 and 1999 studies of adaptive sampling, recordings of sonar fish sign were collected during trawl hauls. Sonar categorization criteria were developed on a subset of the 1998 data based on signal patterns and shapes and color. Between scientist agreement of high and low categories varied from 76-87% in 1998; for 1999, onboard scientists agreed with categorizations done by a shoreside scientist on 65% of 49 categorizations. High and low sonar categorizations corresponded with high and low catch rates 66-78% of the time in 1998 and 59-61% of the time in 1999.

Echosounder categorizations can be used to define strata in a simple double sampling design (Cochran 1977). Variance estimates that would result from this sampling design were predicted using the observed within category variances at various levels of first stage (sonar) sampling (Fujioka et al. 2000). Sonar samples are assumed to be considerably less expensive in time and cost than trawl sampling and if 10 times as many sonar samples are taken to stratify the trawl samples, variance improved 18-37% compared to simple random sampling, depending on the data set and the categorizer. If trawl hauls were allocated optimally, the improvement increased from 44%-60% over simple random trawl hauls. To match the variance obtained by double sampling with sonar primary sampling, the number of random trawl hauls would have to be increased 1.8-2.5 fold depending on data set and categorizer. This approach differs from TAPAS (described below) or adaptive double sampling because it does not rely on the concept of clusters or patches. It can be thought of as 2- phased sampling or double sampling for stratification where the first sample would be the sonar samples, indicating which stratum has been encountered, and the second sample would be a trawl haul allocated at a rate specific to each stratum.

A double sampling design, the Trawl and Acoustic Presence/Absence Survey (TAPAS), was developed by United Kingdom scientists design to improve bottom trawl surveys of patchily distributed fish such as the mackerel icefish *Champsocephalus gunnari* (Everson et al. 1996). The design uses echosounder data to estimate the presence and size of possible high density patches of the species. Trawl samples are then made in each high-density patch and in the low-density background. TAPAS is a variation of adaptive double sampling (Thompson 1992). It differs from the adaptive cluster sampling approach examined by Quinn et al. (1999) by using sonar to determine the presence of a cluster. TAPAS, like the double sampling with sonar stratification method, can use a simple binomial categorization of the echosounder signal that correlates with catch rate. Unlike the approach used to assess pollock and hake, it does not rely on a quantified interpretation or integration of the hydroacoustic signal, but a binomial (or multinomial) categorization of the signal.

The sample stratification approaches described above classified sonar signals into as few as two categories (for e.g., high vs. low, present vs. absent). If the signal can be quantified in more detail, a regression approach may provide increased efficiency. Ito (1999) was able to correlate echosign with catch rates of shortraker and rougheye rockfish during a depletion experiment at a site in the central GOA. Krieger et al. (2001) found correlations between data processed from an echosounder and trawl survey catches of rockfish during a triennial survey leg off Southeast Alaska. Ito (1999) describes an approach by Ona (1991) using a hydroacoustic signal regressed with trawl catch rates to increase survey efficiency. This approach would require more sophisticated equipment, as well as more sophisticated training and data processing than the TAPAS and sonar stratification approaches.

Age and length-frequency data, and other biological information for BSAI rockfish

In addition to reliable estimates of survey biomass, the development of age-structured population models requires information on the age and length composition of the fishery and survey catches. Reliable age information is preferred, although the age-structure of populations can be inferred from length data if an age-length growth relationship has been determined. A reasonable number of otoliths have been collected in the AI trawl surveys, although not all of these otoliths have been read (Table 1). Adequate numbers of otoliths in the fishery generally were not collected prior to 1999, when the sampling of otoliths by observers was focused largely upon identified target species and not bycatch species. For example, there were not more than 54 otoliths collected, per species and year, for northern rockfish, rougheye rockfish, shortraker rockfish from the domestic fishery during 1988-1998, and many years had zero otoliths for these species (Table 2). Since 1999, length and otoliths sampling has been based upon the predominant species group in the haul, and when the dominant species group is rockfish, more than one rockfish species is sampled. Although this change has increased rockfish otolith samples, the sample size per species per year (excluding POP) generally remains below 200.

Many of the otoliths sampled from the AI trawl survey have not been read, which is a function of limited personnel and development of reliable aging techniques. Recently, the number of rockfish otoliths which could be read in a given year has dropped from ~ 4500 to ~ 3000 due to personnel losses, although this number should increase as new age readers are currently being trained. In addition, the difficulty of reading shortraker and rougheye otoliths has motivated research on aging techniques and limited the amount of otoliths aged for these species. Species for which age-structured models exist, such as BSAI POP, GOA POP and GOA northern rockfish, generally receive priority for age reading, leading to a limited ability to age archived otoliths of other species. However, since 2000 much of the archived northern rockfish otoliths from the AI survey have been read in preparation for development of an age-structured model.

Relatively small sample sizes for rockfish lengths from the fishery are observed in several years due to the sampling protocols discussed above (Table 3). Although sampled lengths of POP exceed 2000 for each year since 1990, northern rockfish sampled lengths are below 600 from 1990-1992 and from 1997-1998. In addition, rougheye rockfish sampled lengths exceed 600 only in 1990 and 1992-1993, and shortraker rockfish lengths exceed 600 only in 1993. Considerably larger sample sizes for rockfish length frequency distributions are available from the AI trawl survey (Table 4).

Predicted size at age and maturity at age are also required for age-structured population modeling. Sufficient northern rockfish otoliths now allow computation of growth curves, as mentioned above (Figure 5). However, maturity studies are required for all species of BSAI rockfish. Field observations of POP maturity state taken in the 2000 AI trawl survey produced a length at 50% maturity of approximately 40 cm, substantially larger than previously published estimates of approximately 28 - 35 cm (Chikuni 1975, Westrheim 1975). Recent work in the GOA indicates an estimated length at 50% maturity of approximately 36 cm, and this maturity curve is currently used in the BSAI POP assessment. Northern rockfish maturity data collected on a 1996 research cruise in the GOA has also been used to develop a maturity curve for this species in this region (Chris Lunsford, AFSC-Auke Bay Laboratory, pers. comm.).

Finally, estimates of natural mortality are essential for stock assessment modeling. The advent of the break and burn method of reading otoliths has increased our perception of the longevity of POP from about 30 years to approximately 90 years, along with lowering estimates of instantaneous natural mortality (*M*) rates to about 0.05 yr^{-1} (Chilton and Beamish 1982, Archibald et al. 1981). Estimates of *M* for northern rockfish, based upon catch curve analysis, are thought to be about 0.06, whereas estimates of *M* for rougheye and shortraker rockfish to thought to be lower at 0.025 and 0.03, respectively (Alverson and Carney 1975).

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Table 1. Rockfish otoliths collected from the Aleutian Islands trawl survey, by year and species.

		Species				
Year	Data	POP	Northern	Rougheye	Shortraker	Shortspine Thornyhead
1980	Otoliths read	890	0	0	0	
	Otoliths collected	1851	726	36	139	
1983	Otoliths read	2495	0	0	0	0
	Otoliths collected	4082	437	93	499	535
1986	Otoliths read	1860	565	0	0	0
	Otoliths collected	1986	631	535	251	499
1991	Otoliths read	1015	456	0	0	0
	Otoliths collected	1028	466	480	346	437
1994	Otoliths read	849	409	0	0	0
	Otoliths collected	865	419	729	772	694
1997	Otoliths read	1224	652	0	0	0
	Otoliths collected	1237	670	866	1090	456
2000	Otoliths read	1238	725	0	0	0
	Otoliths collected	1269	736	492	629	468
2002	Otoliths read	0	0	0	0	0
	Otoliths collected	1377	522	473	571	534

Table 2. Rockfish otoliths collected from domestic fisheries in the BSAI area, by year and species.

Year	Data	Species POP	Northern	Rougheye	Shortraker	Shortspine Thornyhead
1988	Otoliths read	0				
	Otoliths collected	73				
1989	Otoliths read	19				
	Otoliths collected	20				
1990	Otoliths read	328		0		
	Otoliths collected	346		54		
1992	Otoliths read	0		0		
	Otoliths collected	20		50		
1993	Otoliths read	0				
	Otoliths collected	100				
1996	Otoliths read	0				
	Otoliths collected	39				
1997	Otoliths read	0				
	Otoliths collected	70				
1998	Otoliths read	823	29			
	Otoliths collected	848	30			
1999	Otoliths read	0	0	0	0	0
	Otoliths collected	279	50	8	24	18
2000	Otoliths read	487	0	0	0	0
	Otoliths collected	539	166	26	21	36
2001	Otoliths read	524	0	0	0	0
	Otoliths collected	576	136	78	27	10
2002	Otoliths read	0	0	0	0	0
	Otoliths collected	705	200	67	45	192

Table 3. Rockfish length measurements from domestic fisheries in the BSAI area, by year and species.

Year	POP	Northern	Rougheye	Shortraker
1988	624			
1989	1048			
1990	69426	403	1961	27
1991	16468	145	144	576
1992	38009		1243	413
1993	34812	1809	1048	736
1994	14200	767	27	125
1995	11724	833	42	
1996	16113	4554	14	
1997	10545	1		
1998	12095	543		
1999	4128	917	57	306
2000	3666	976	164	94
2001	2715	661	287	96
2002	3749	889	336	183

Table 4. Rockfish length measurements from Aleutian Island trawl surveys, by year and species.

	Species			
Year	POP	Northern	Rougheye	Shortraker
1980	20796	3351	5449	1945
1983	22873	6535	3914	3514
1986	14804	5881	4390	2255
1991	14262	4853	1060	782
1994	18922	6252	2375	2335
1997	22823	7554	1817	2458
2000	21972	7779	1673	1626
2002	20285	9459	1288	1299

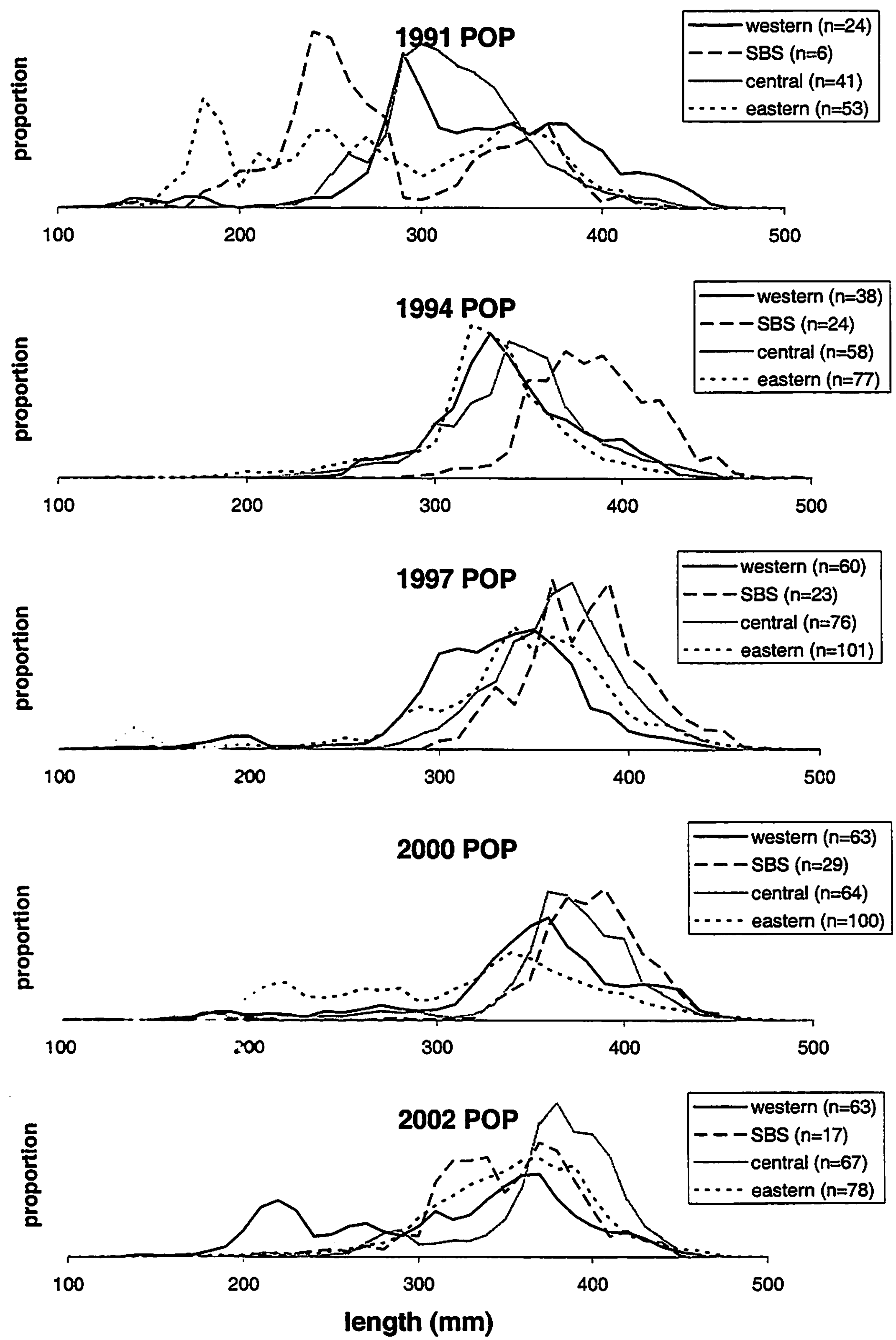

Figure 2. POP length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

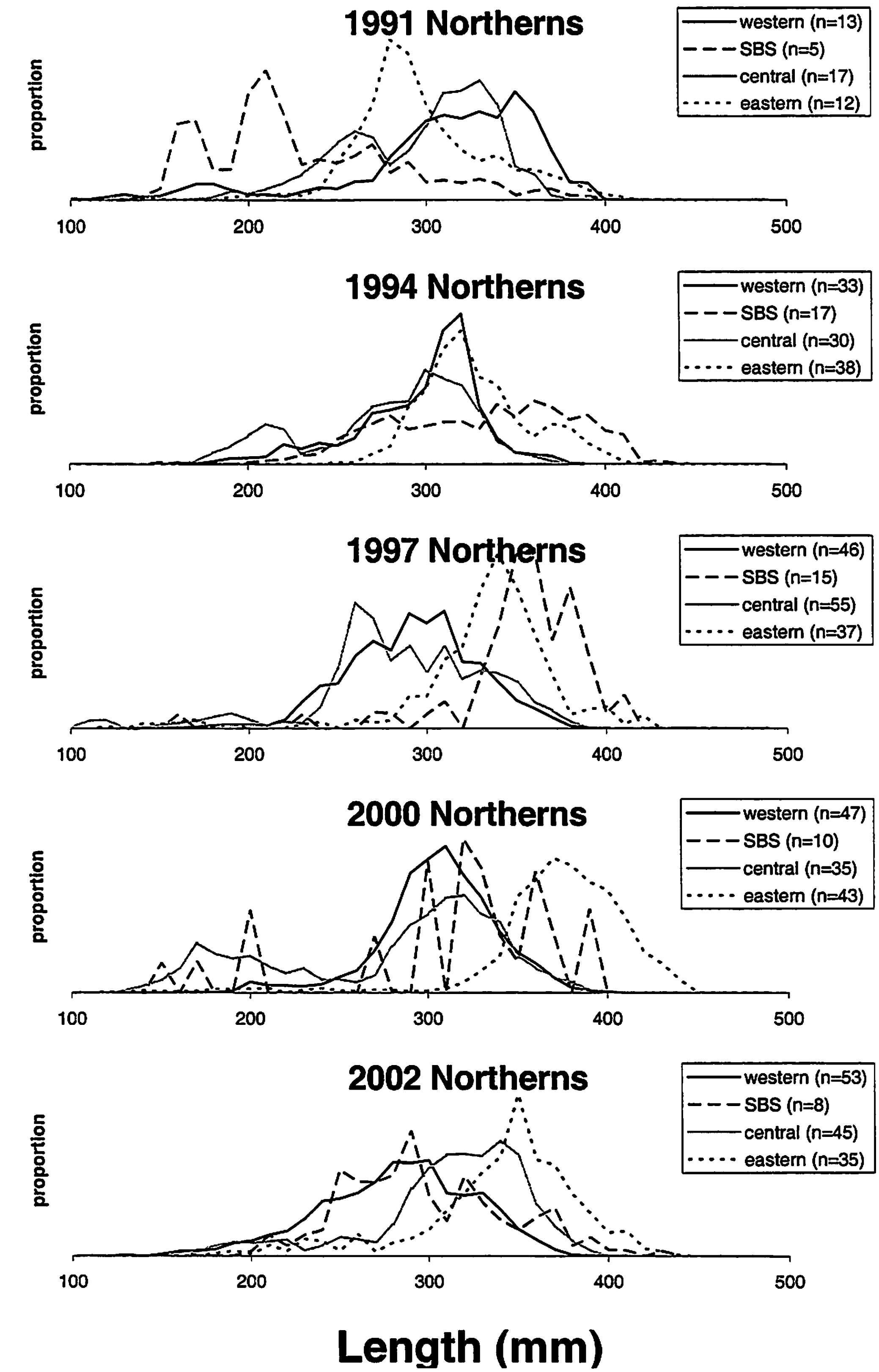

Figure 3. Northern rockfish length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

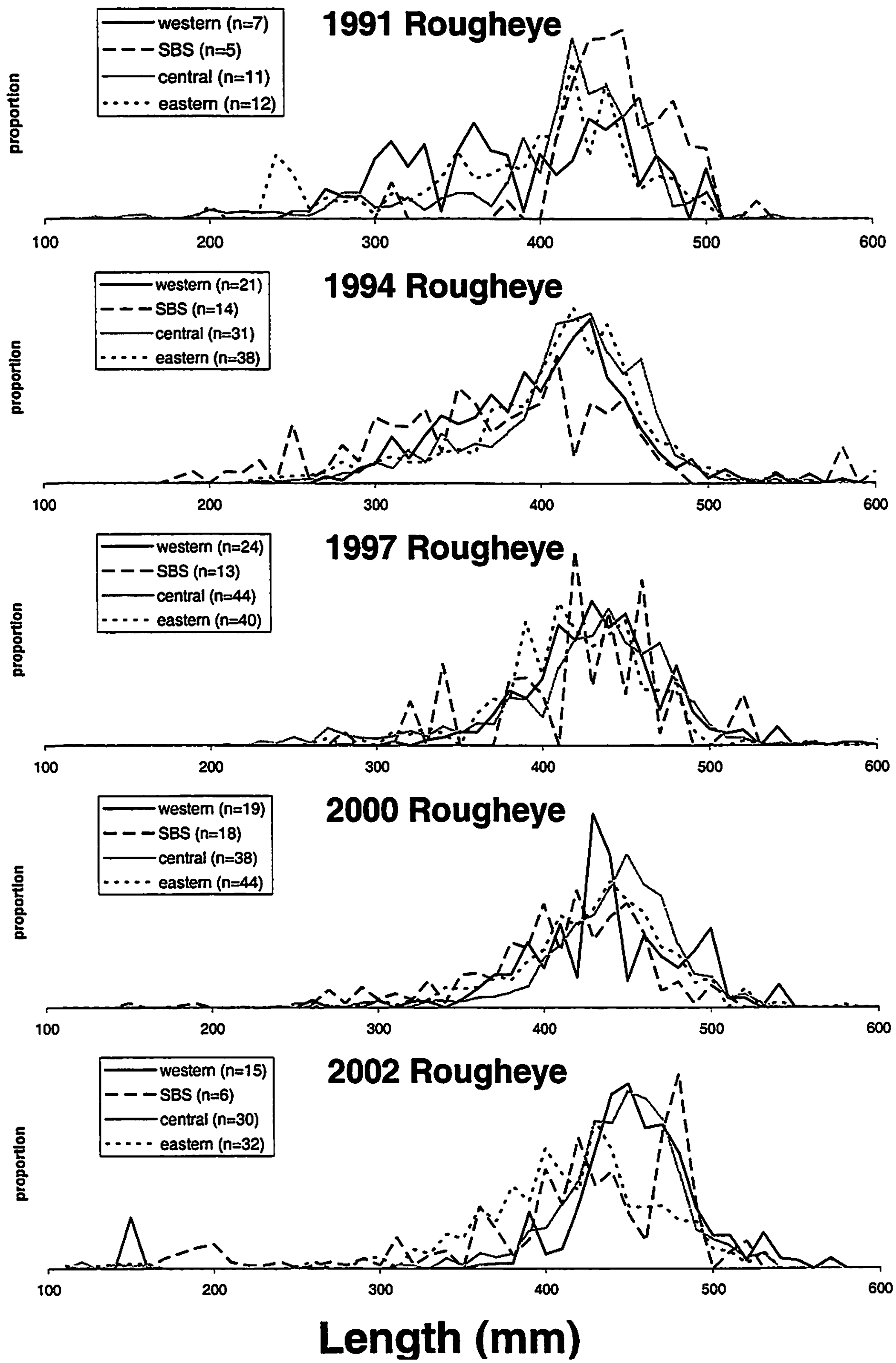

Figure 3. Rougheye rockfish length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

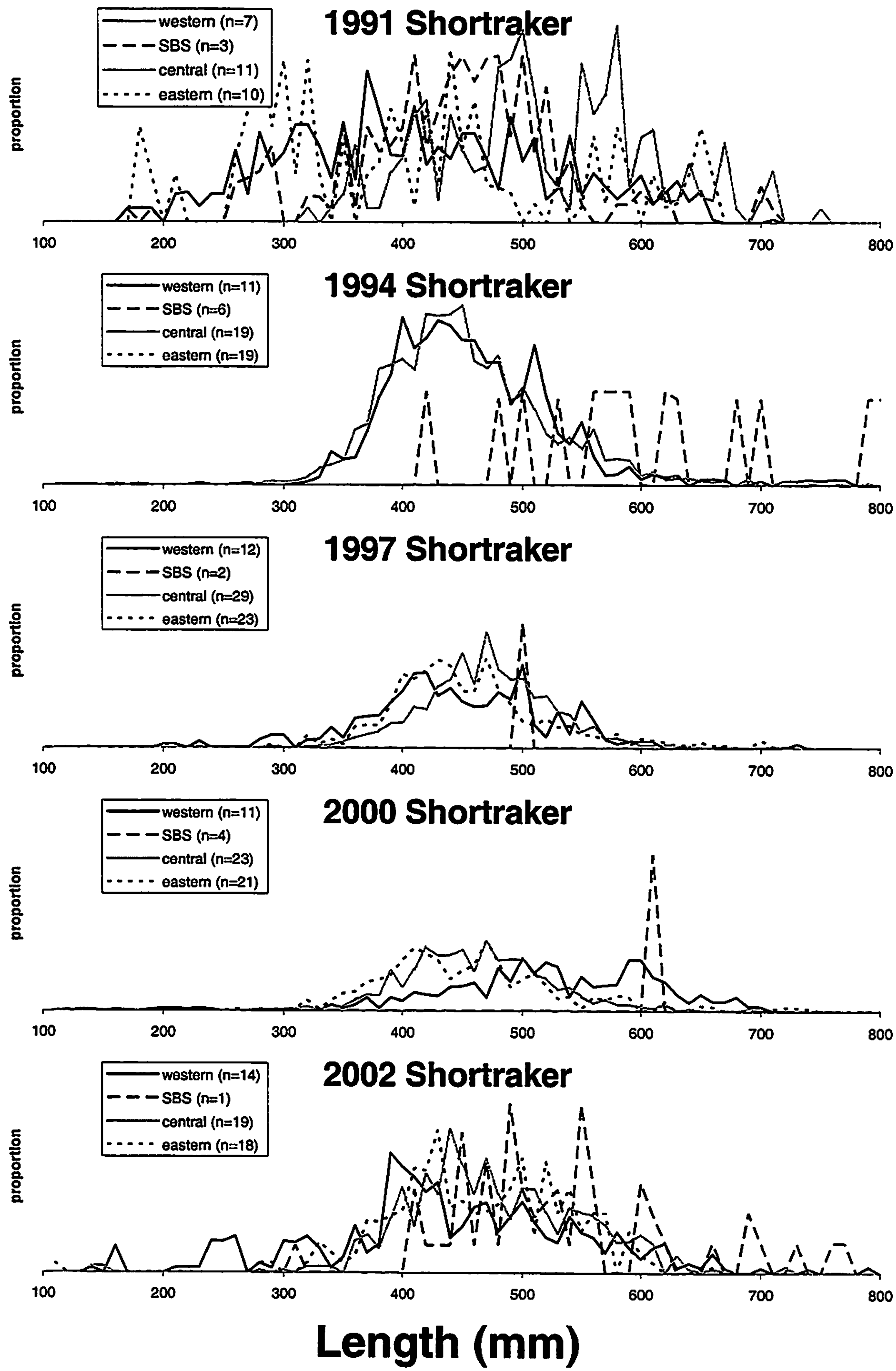

Figure 4. Shortraker rockfish length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

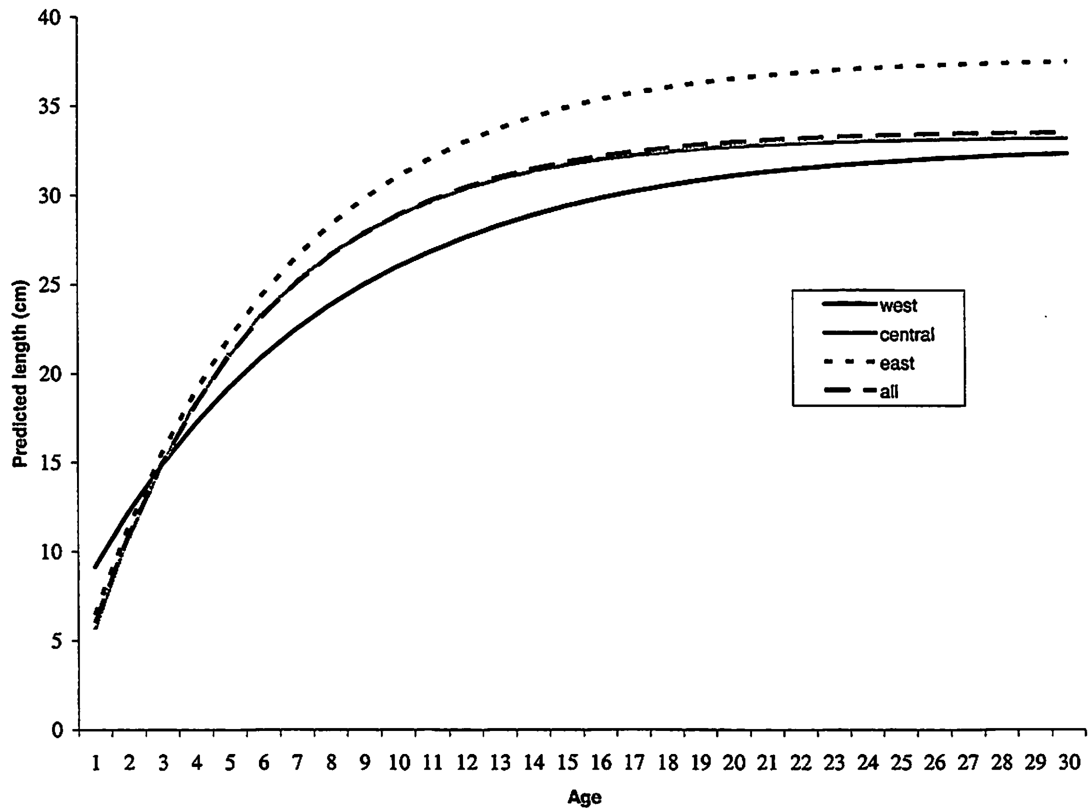

Figure 5. Northern rockfish growth curves by subarea within the Aleutian Islands; data were obtain in trawl surveys conducted from 1986-2000.

PUBLIC TESTIMONY SIGN-UP SHEET FOR AGENDA ITEM D-1 (B) ROCKFISH

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3.	Whit Sheard	The Ocean Conservancy
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