Discussion Paper:
Abundance-based Management for BSAI Pacific Halibut PSC Limits

October 2017[1]

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Summary of Document Structure and Content

The following provides a brief summary of main document sections.

1. **Background**: The Pacific halibut (*Hippoglossus stenolepis*) resource is utilized in Alaska for subsistence and personal use as well as recreational (sport) and commercial fisheries. Halibut have significant social, cultural, and economic importance to fishery participants and fishing communities throughout their range. Halibut are also incidentally taken as bycatch (Prohibited Species Catch; PSC) in groundfish fisheries. See Section 1 for additional background on the assessment and management of halibut, PSC limits imposed on groundfish fisheries, and the relative responsibilities of the Council, NMFS and the IPHC.

2. **Purpose and Need**: The Council is considering linking BSAI PSC limits to data on halibut abundance consistent with responsive management that varies with their abundance. The Council wishes to limit total halibut mortality to the extent practical while providing an opportunity for the directed halibut fishery and conserving spawning stock biomass, particularly at low levels of abundance. The Council recognizes that abundance-based halibut PSC limits may increase and decrease with changes in halibut abundance. See Section 2 for additional information on the purpose and need for this action and for considering alternatives which are consistent with the purpose and need.

3. **Indices of Halibut Abundance**: Multiple indices were considered and are detailed in Section 3 along with information on the size composition of the catch in relation to directed halibut and directed groundfish fisheries. Correlation analyses are provided to help describe relationships between indices and fisheries. A comparison of all the indices examined qualities relative to their precision, spatial coverage, availability, and the segment (size/age) of the halibut population the index addresses. These characters were judged against a set of principles considered desirable. The section concludes with rationales for recommending the EBS bottom trawl survey data and the IPHC Area 4abcde setline survey (SLS) data (separately or in combination) for use an abundance based management (ABM) index for setting Pacific halibut PSC limits.

4. **Control rules to establish halibut PSC limits**: Section 4 describes the features of control rules (slope, stability, floor, ceiling, starting point) as well as examples of various control rules used in the BSAI for other PSC management systems. Examples of alternative mechanisms for setting PSC limits (decision tables, multi-dimensional and non-linear control rules) are provided.

5. **Developing Alternatives**: Based on the recommended subset of indices and combinations from Section 3, as well as guidance from the Council in June, some strawmen alternatives with options/variations are provided in Section 5 for further consideration. A range of elements and options are proposed for the Council to begin drafting alternatives for analysis based on the information contained in this paper and previous Council directions

6. **Incentives**: An overview of the ways in which existing programs attempt to minimize bycatch at all times, and how an ABM program might adapt those approaches to the specific context of BSAI groundfish fisheries is presented in Section 6. It also provides a basis for understanding the principles that determine whether an incentive structure can be both effective and appropriate for the sectors involved. Subsections address the current use of incentives in BSAI and GOA fisheries, some general design considerations for incentive programs, the application of a halibut performance standard in BSAI groundfish fisheries, and a discussion of how the proposed elements of an abundance-based limit affect fleet incentives to minimize bycatch

7. **Decision points for the development of alternatives**: Section 7 identifies the stepwise decision points for the Council to begin to draft a suite of alternatives for analysis as well as additional potential discussion points for the Council with respect to continued coordination and collaboration with the IPHC and the appropriate scope of NEPA analysis for this action.

1 Background Information

Pacific halibut (*Hippoglossus stenolepis*) is fully utilized in Alaska as a target species in subsistence, personal use, recreational (sport), and commercial halibut fisheries. Halibut has significant social, cultural, and economic importance to fishery participants and fishing communities throughout the geographical range of the resource. Halibut is also incidentally taken as bycatch in groundfish fisheries.

The Council is examining abundance-based approaches to set halibut PSC limit in the BSAI. Currently halibut PSC limits are a fixed amount of halibut mortality in metric tons (t). When halibut abundance declines, halibut PSC becomes a larger proportion of total halibut removals and can result in lower catch limits for directed halibut fisheries. Both the Council and the IPHC have expressed concern about impacts on directed halibut fisheries under the status quo and identified abundance-based halibut PSC limits as a potential management approach to address these concerns.

1.1 History of this action

In February 2015, in conjunction with initial review of the analysis prepared for Amendment 111 to the BSAI FMP that considered reductions of BSAI Pacific halibut PSC limits (Amendment 111), the Council also requested that Council and IPHC staff evaluate possible approaches to link BSAI halibut PSC limits to data or model-based abundance estimates of halibut.

Following the Council's February 2015 request, IPHC staff took the lead on drafting a paper examining several aspects of exploring abundance-based halibut PSC limits in the BSAI, including a review of harvest policies by both Council and IPHC staff, fishery trends, a range of potential candidate abundance indices, a discussion of basing allocation on yield (biomass) versus spawning capital (relative fishing impact), and a review of research recommendations (Martell et al., 2016). This paper was presented to the AP and the Council at the December 2015 Council meeting[2].

The Council then initiated subsequent discussion papers and requested that analysts from within the different agencies (IPHC, NMFS AFSC, NMFS RO and NPFMC staff) collaborate to provide additional information on appropriate indices for use in indexing halibut abundance to PSC in the Bering Sea. In April 2016, the analysts provided a discussion paper which addressed a number of different issues including a range of indices, information on establishing control rules and data on current usage of halibut bycatch by sector and gear type in the groundfish fisheries[3]. Following review, the Council adopted a Purpose and Need Statement and provided additional direction for the analysts in a subsequent discussion paper.[4]

In October, the Council reviewed a discussion paper which addressed characteristics of a range of indices and control rule combinations as well as provided an overview of development of performance metrics that could be used in the subsequent analysis[5]. These control rule combinations and indices were explored further in the April 2017 discussion paper where strawmen alternatives, or draft Abundance Based Management Alternatives (ABMs) were developed. The Council requested further clarification and a broadening of considerations for these ABM combinations in a subsequent paper. Performance metrics for the analysis of alternatives were discussed at a public workshop in February 2017 as well as in the June 2017 discussion paper along with characteristics of indices.[6] Table 1 provides a summary of the

[2] The paper, Exploring index-based PSC limits for Pacific halibut by S. Martell, I. Stewart and C. Wor can be accessed at: http://goo.gl/hFPRpf
[3] The April document can be found at this link
[4] April 2016 motion
[5] October paper link here
[6] June 2017 paper link

individual topics discussed in previous papers and the specific links to the papers for additional information.

This discussion paper both summarizes and augments information presented iteratively in those focused papers spanning from 2015 to 2017 The intent of this paper is to provide a comprehensive overview of all relevant information pertinent to the development of ABM alternatives for analysis as well as to provide a framework to enable the construction of draft alternatives. In this manner, the analysts have assembled all relevant and requested information in a comprehensive manner to allow for the Council process of the development of alternatives for this action to begin.

Table 1. Information contained in previous materials provided April 2016-June 2017

Information	**Date and document available**	**Link**
Data sources from which to derive indices including strengths and weaknesses of each	April 2016 discussion paper	April 2016
Fishery characteristics (halibut PSC by target; observed trawl and longline effort, CPUE, PSC rates)	Supplement to April 2016 discussion paper	Supplement April 2016
Description of potential abundance indices IPHC assessment; EBS trawl survey; combined and applied in a control rule	April 2016 discussion paper and attachment	April 2016
Control rule background	April 2016 discussion paper; October 2016 Discussion paper; April 2017 Discussion paper	April 2016 October 2016 April 2017
Control rule features	April 2016 discussion paper; October 2016 Discussion paper; April 2017 Discussion paper	April 2016 October 2016 April 2017
Control rule examples already in use	April 2016 discussion paper; April 2017 Discussion paper	April 2016 April 2017
Performance metrics	February Workshop materials; April 2017 discussion paper June 2017 Discussion paper	February 2017 April 2017 June 2017
Incentives	April 2017 Discussion paper	April 2017
Example ABM alternatives	April 2016 discussion paper; October 2016 Discussion paper; April 2017 Discussion paper; Supplement April 2017 Disc paper	April 2016 October 2016 April 2017 Supplmnt Apr 17
Management issues	October 2016 Discussion paper	October 2016
Analytical considerations and example scenarios	April 2016 Discussion paper Supplemental presentation on model October 2016 Discussion paper April 2017 Discussion paper Supplement to April 2017 Discussion paper (example calculations)	April 2016 Supplement ppt October2016 April2017 SupplmntApr17

1.2 Relative authorities of the Council, NMFS and the IPHC under the MSA and the Halibut Act

The International Pacific Halibut Commission (IPHC) and NMFS manage Pacific halibut fisheries through regulations established under the authority of the Northern Pacific Halibut Act of 1982 (Halibut Act) (16 U.S.C. 773-773k). The IPHC adopts regulations governing the target fishery for Pacific halibut under the Convention between the United States and Canada for the Preservation of the Halibut Fishery of the North Pacific Ocean and Bering Sea (Convention), signed at Ottawa, Ontario, on March 2, 1953, as amended by a Protocol Amending the Convention (signed at Washington, DC, on March 29, 1979). For the United States, regulations governing the fishery for Pacific halibut developed by the IPHC are subject to acceptance by the Secretary of State with concurrence from the Secretary of Commerce. After acceptance by the Secretary of State and the Secretary of Commerce, NMFS publishes the IPHC regulations in the Federal Register as annual management measures pursuant to 50 CFR 300.62. Section 773c(c) of the Halibut Act also provides the Council with authority to develop regulations that are in addition to, and not in conflict with, approved IPHC regulations. The Council has exercised this authority in the development of Federal regulations for the halibut fishery such as 1) subsistence halibut fishery management measures, codified at § 300.65; 2) the limited access program for charter vessels in the guided sport fishery, codified at § 300.67; and 3) the Individual Fishing Quota (IFQ) Program for the commercial halibut and sablefish fisheries, codified at 50 CFR part 679, under the authority of section 773 of the Halibut Act and section 303(b) of the Magnuson-Stevens Act (See Appendix Section 9.2 for additional information on the MSA National Standards and the Pacific Halibut Act).

The Magnuson-Stevens Act (MSA) defines bycatch as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. The term does not include fish released alive under a recreational catch and release fishery management program." 16 U.S.C 1802 3(2).

The Magnuson-Stevens Act authorizes the Council and NMFS to manage groundfish fisheries in the Alaska EEZ that take halibut as bycatch. The groundfish fisheries cannot be prosecuted without some level of halibut bycatch because groundfish and halibut occur in the same areas at the same times and no fishing gear or technique has been developed that can avoid all halibut bycatch. However, the Council and NMFS have taken a number of management actions over the past several decades to minimize halibut bycatch in the BSAI groundfish fisheries. Most importantly, the Council has designated Pacific halibut and several other species (herring, salmon and steelhead, king crab, and Tanner crab) as "prohibited species" (Section 3.6.1 of the FMP). By regulation, the operator of any vessel fishing for groundfish in the BSAI must minimize the catch of prohibited species (§ 679.21(b)(2)(i)).

Although halibut is taken as bycatch by vessels using all types of gear (trawl, hook-and-line, pot, and jig gear), halibut bycatch primarily occurs in the trawl and hook-and-line groundfish fisheries. NMFS manages halibut bycatch in the BSAI by 1) establishing halibut PSC limits for trawl and non-trawl fisheries; 2) apportioning those halibut PSC limits to groundfish sectors, fishery categories, and seasons; and 3) managing groundfish fisheries to prevent PSC from exceeding the established limits. Consistent with National Standard 1 and National Standard 9 of the Magnuson-Stevens Act, the Council and NMFS use halibut PSC limits in the BSAI groundfish fisheries to minimize bycatch to the extent practicable while achieving, on a continuing basis, optimum yield from the groundfish fisheries (See Section 9.2). Halibut PSC limits in the groundfish fisheries provide an additional constraint on halibut PSC mortality and promote conservation of the halibut resource. With one limited exception, groundfish fishing is prohibited once a halibut PSC limit has been reached for a particular sector or season. Therefore, halibut PSC limits must be set to balance the needs of fishermen, fishing communities, and U.S. consumers that depend on both halibut and groundfish resources.

IPHC and NMFS regulations authorize the harvest of halibut in commercial, personal use, sport and subsistence fisheries only by hook-and-line gear. In the BSAI (Area 4), halibut is harvested primarily in commercial fisheries and secondarily in personal use, subsistence, and sport fisheries.

1.3 Pacific halibut stock assessment and fishery management in the BSAI management area

The total yields of Pacific halibut greater than 26 inches in length (TCEY) for all IPHC Regulatory Areas are set on an annual basis by the Commission. Anticipated removals over 26 inches from sources not under the direct control of IPHC (i.e., bycatch and non-catch sharing plan removals) are subtracted from the TCEY, leaving catch limits for the directed fishery (FCEY). Each IPHC Regulatory Area has a unique set of rules for catch limit allocation, and the FCEY in one Area may contain some elements not contained in the FCEY of another area. For example, discards from the directed fishery (wastage) is included in the FCEY for Areas 2C and 3A. This method entails the IPHC to first account for sources of removals not under its control in order to achieve its conservation mandate, with the remainder going to the directed fishery. It means that if the TCEY is greater than zero in a Regulatory Area, there is no conservation concern, but it implies that priority is given to non-directed and non-catch sharing plan Pacific halibut fisheries (e.g., unguided sport takes precedence over guided sport, bycatch takes precedence over directed fisheries).

1.3.1 IPHC Regulatory Areas

There are ten IPHC Regulatory Areas (Figure 1), but TCEY is distributed to 8 Areas, where 4C, 4D, and 4E are combined into one Area called 4CDE. NPFMC management areas do not line up with the IPHC Regulatory Areas, and Area 4A overlaps portions of the BSAI and GOA(See also Figure 6 and Table 2).

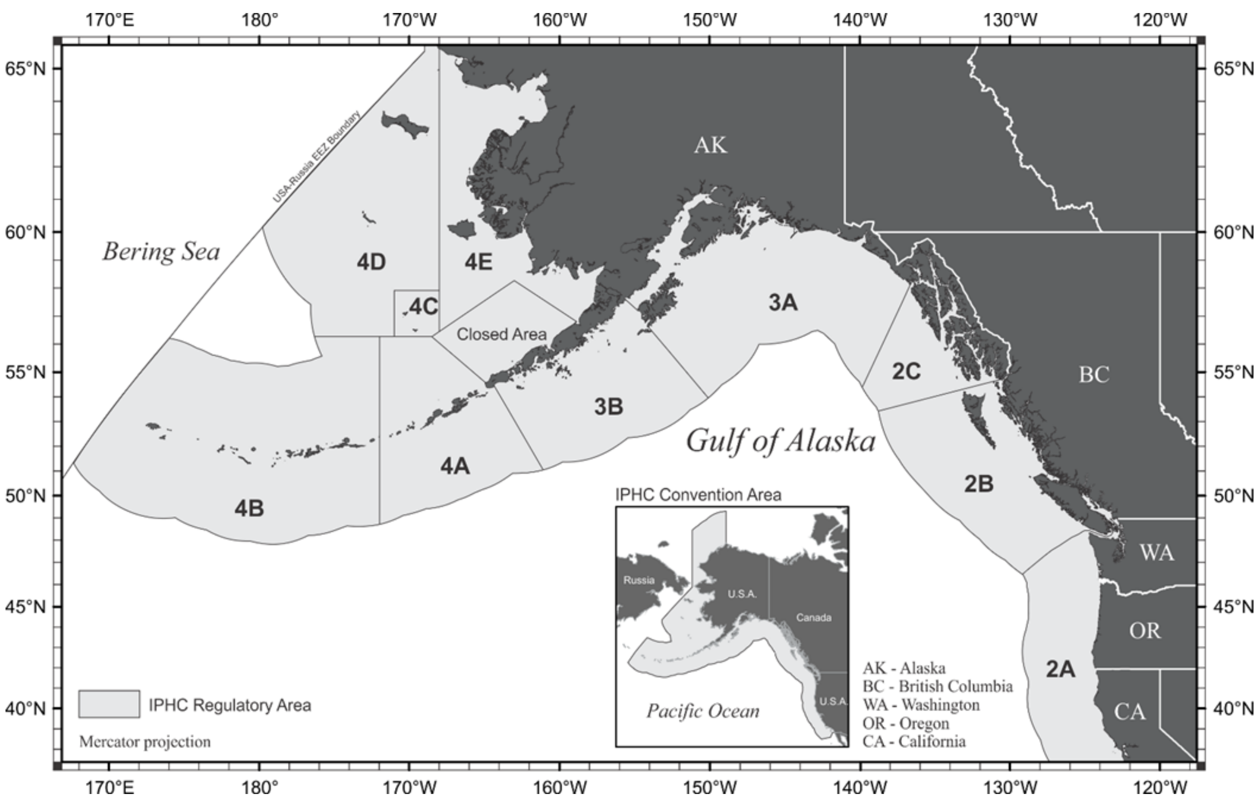


Figure 1. IPHC Regulatory Areas.

1.3.2 Fisheries that encounter Pacific halibut and catch accounting

Many different fisheries encounter Pacific halibut. These include the directed commercial long-line fleet, guided and unguided sport fisheries, personal use and subsistence fisheries, non-directed longline fisheries, pelagic and non-pelagic trawl fisheries, as well as others. The mortality for each fishery has changed over recent years (Figure 2) for a number of reasons including development of the domestic fisheries, changes in weight-at-age, and the implementation of methods aimed to reduce bycatch mortality.

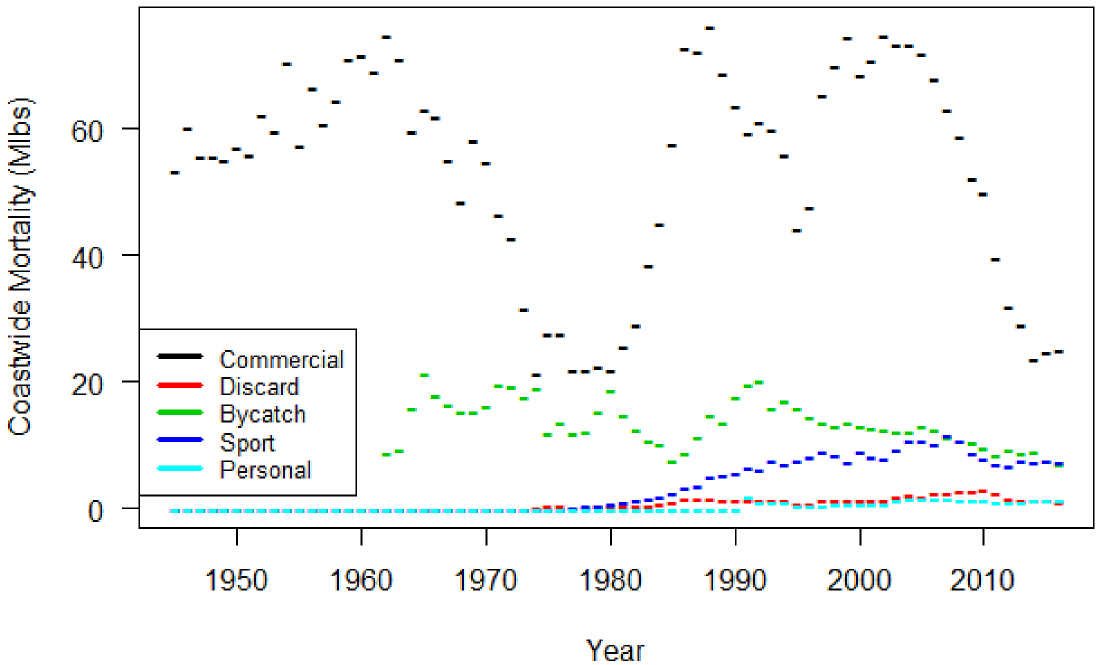


Figure 2. Coastwide mortality (millions of lbs) of Pacific halibut for five different types. Commercial is the directed longline fishery, Discard is the discards from the directed fishery (wastage), Bycatch is mortality from non-directed fisheries, Sport is guided and unguided recreational fisheries, and Personal is personal use and subsistence.

Mortality of halibut greater than 32 inches (O32) from the directed commercial fishery comes from landings and estimates of a small amount of wastage (e.g., from lost gear) and mortality of halibut under 32 inches (U32) is from estimates of discards with a discard mortality rate (DMR) applied. In the directed halibut fisheries, up until 2013, there were no observer data from which to base estimates of discards in the directed halibut fishery, thus estimates in each Regulatory Area assume that the ratio of U32 to O32 halibut observed in setline survey data is the same as that which is encountered by the directed fishery, and an assumed average DMR of 16%.

A key element in the catch accounting system is the estimation of bycatch mortality of halibut in groundfish fisheries (not targeting halibut). Estimation bycatch mortality is based on sampling theory, or assumptions, and is not based on a 100% census. Estimates of halibut bycatch mortality are based on a weighted average of condition factors, or injury codes, observed in each fishery and condition-specific discard mortality rates developed for trawl gears and non-directed hook-and-line gears, based on observer samples. Pacific halibut DMRs used by NMFS for the 2016-2017 management of Alaskan groundfish fisheries are provided by Dykstra (2017) and range from 9% for longline and pot fisheries in BSAI to 90% in the CDQ midwater pollock trawl fleet. These samples are expanded up from the haul level to the entire fleet based on the percent observer coverage in that specific fleet.

1.3.3 Overview of the Pacific halibut stock assessment, harvest policy, and estimated stock size

As the Pacific halibut directed and non-directed fisheries have evolved, the methods to assess the stock and manage the fishery have also evolved over many decades. The stock assessment began with simple catch-per-unit-effort models, moved to yield-per-recruit models in the 1970’s, surplus production models in the early 1980's, catch-at-age models in the 1980's and 1990's, and more recently integrated age-structured models (see Clark 2003 for a brief history of IPHC's first 80 years). Currently, the stock assessment for Pacific halibut uses four integrated age-structured models in an ensemble to account for parameter and structural uncertainty (Stewart & Martell 2015). The advice from the stock assessment ensemble is presented to the Commission as a risk-based decision table with different catch levels as the rows and various performance metrics as columns (Stewart & Hicks 2017).

As with all stock assessment models, the IPHC stock assessment ensemble is a simplification of reality that attempts to capture the trends in the stock, supplies useful management advice, and characterize an appropriate level of uncertainty. The ensemble is composed of coastwide models, which means that the annual estimated biomass is a single value for the entire coast (U.S. and Canada) and migration between areas is not modeled. Natural mortality is estimated in some models and fixed for one sex in others. Each of the models use empirical weight-at-age estimates by year to convert numbers-at-age to biomass. This allows the model to account for the observed large changes in weight-at-age. Steepness (a stock-recruit relationship parameter that relates to productivity/resilience of the stock) was fixed at 0.75 for all models. However, a dominant source of recruitment variability comes from the average recruitment treated a function of environmental conditions where a regime (cool or warm) is determined from the Pacific Decadal Oscillation (PDO, Clark & Hare 2002).

The ensemble modeling provides a more robust assessment approach that acknowledges structural uncertainty and has effectively stabilized management decision tables relative to catch recommendations and potential impacts on spawning biomass (in probabilistic terms). Prior to 2012 assessments for Pacific halibut had consistently overestimated spawning biomass causing an undesirable "retrospective pattern" (and overly optimistic short-term forecasts; Stewart & Martell 2014). Figure 3 shows the retrospective estimates of fishing intensity (a measure of the harvesting rate over all sizes and sources) on the coastwide stock compared to the previous harvest policy (blue line) and the current interim SPR-based harvest policy. The fishing intensity is predicted to have been as much as 1.6 times the current interim fishing intensity ($F_{SPR=46\%}$). However, this is over a period when the stock status was above 30% (i.e., higher than the threshold for concern), a period when weight-at-age was declining (even without fishing, a decline in spawning biomass and recommended catch levels are predicted over this period), and recent recruitment was below average. Large changes in the spawning biomass of Pacific halibut, which do not seem explicitly linked to fishing, have been observed over the more than 100 years of commercial fishing.

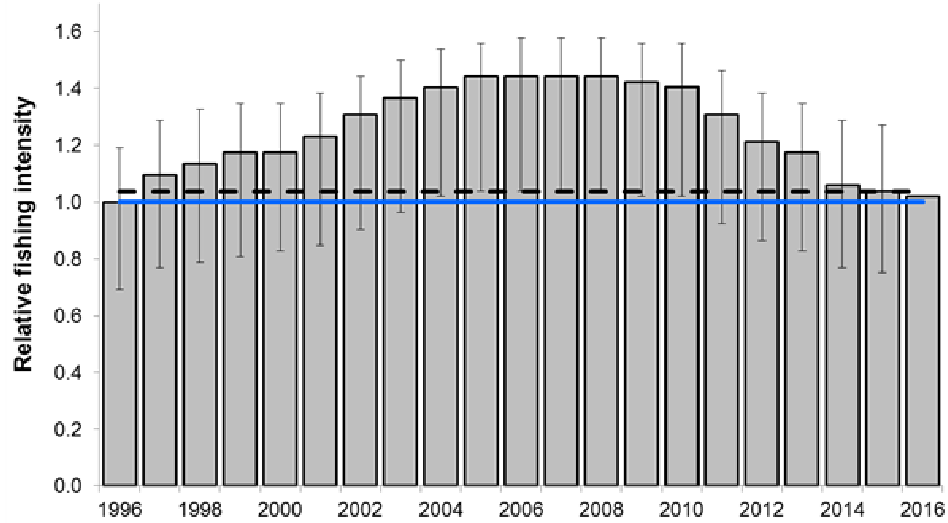


Figure 3. Time-series of estimated coastwide harvest rates (bars) relative to the target harvest rate for all sizes and sources of removals projected for the previous IPHC harvest policy called the Blue Line (horizontal line; $F_{SPR=48\%}$). The current status quo SPR interim harvest policy (dashed horizontal line; $F_{SPR=46\%}$) is also shown. Values are hind-cast based on the current ensemble estimates of Spawning Potential Ratio

The estimated spawning stock biomass has been stable or slightly increasing in recent years, but that follows a considerable decline since the late 1990's (Figure 4). Weight-at-age is a contributing factor to this decline because the average weight-at-age of Pacific halibut has been declining over this same period.

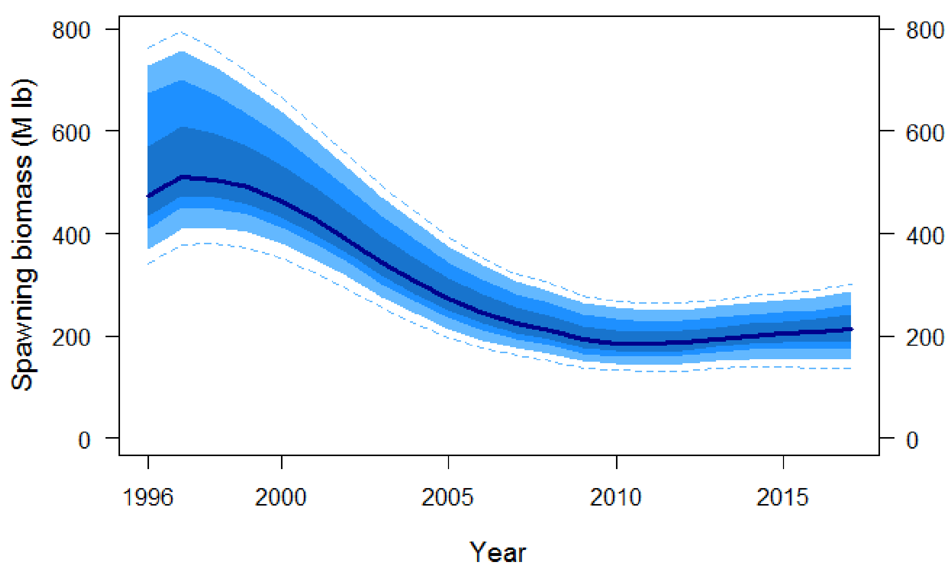


Figure 4. Estimated spawning biomass for the 2016 stock assessment ensemble.

1.3.4 The IPHC harvest policy for Pacific halibut

In 2017, the previous harvest policy paradigm was replaced with a new interim SPR-based (Spawning Potential Ratio) harvest policy (Figure 5). This new paradigm sets a coastwide catch limit and then distributes the catch limits across Regulatory Areas (Figure 1, Hicks & Stewart 2017). Previously, the Regulatory Area catch limits were determined by multiplying the apportioned biomass (based on estimated biomass from survey catches) in each Area by an Area-specific harvest rate. This new paradigm now considers mortality from all sources and sizes when setting a coastwide catch limit, but still uses a similar method (using estimates of biomass from the survey) to distribute the catch limits across Regulatory Areas.

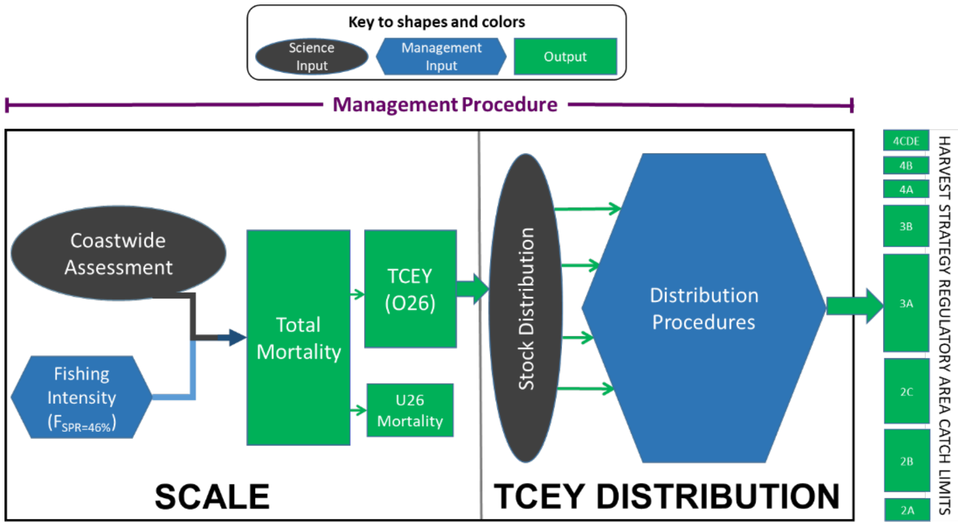


Figure 5. A depiction of the new IPHC SPR-based harvest policy.

The default level of fishing intensity (F_{SPR}) for this interim harvest policy is based on an average of fishing intensities over the years 2014, 2015, and 2016, which are years where the stock is estimated to have been stable or slightly increasing. A control rule is also a part of the harvest policy where the fishing intensity is reduced when the stock status is estimated to be below 30% and set to zero when stock status is estimated to be below 20%. The control rule has never been invoked because the stock status has never been estimated less than 30% since it was a part of the harvest policy. It is expected to mainly affect the directed fisheries, although other agencies may consider action when the stock status of Pacific halibut is estimated to be at critically low levels.

The Total Mortality determined from F_{SPR} is split into halibut under 26" (U26) and halibut over 26" (O26), where the O26 halibut component is called the Total Constant Exploitation Yield (TCEY). The TCEY is distributed among Regulatory Areas based on estimates of biomass from the setline survey and relative harvest rates, where western areas (3B and all of Area 4) are harvested at a lower level (a factor of 0.75). The lower harvest rates in western areas is due to concerns about historical uncertainty and observed declines in those regions and likely different life-history characteristics and population dynamics. The westward areas also differ from the central and eastern regions in the levels of bycatch of juveniles (which can affect the overall productivity of the stock) and evidence that there is net emigration of exploitable halibut from these areas (Hare & Clark 2008, Hare 2011). All of these factors suggest that target harvest rates should be lower in the western Areas.

Annually, a stock assessment is done using all of the available data for that year, and a decision table (e.g., risk analysis) is presented at the Annual Meeting in January. Various advisory bodies as well as the public supply recommendations to the Commissioners. Decisions for Area-specific TCEY's are made, considering all the input received.

Currently, investigations are being done at IPHC in a management strategy evaluation (MSE) framework to determine a level of fishing intensity that meets the long-term objectives of the directed fishery and managers. These include conservation of spawning biomass, total yield, and stability in yield. In the future, investigations of methods to distribute the catch will be done, although allocation between directed and non-directed fisheries will not be specifically investigated as a management procedure without involvement from other agencies and fishing sectors. Currently, a distribution of the amount of bycatch from non-directed fisheries is assumed to integrate over a wide range of possible bycatch scenarios to determine a management procedure that is robust to various levels of bycatch.

1.3.5 Measuring impacts from each fleet

The fishing intensity that results in a specific equilibrium Spawning Potential Ratio (SPR) is now used to determine the overall impact on the stock from all sources and for all sizes. However, the impacts of the individual fleets are not well delineated. Martell et al (2016) explained a new concept call the *fishery footprint* which is "a measure of the fisheries demand on the resource, or the amount of spawning capital required to support a particular fishery." This idea could be used to "allocate" a fraction of the total SPR, instead of allocating fractions of the total yield, but that would require agreements between all agencies involved. Nevertheless, the fishery footprint could also be used to measure impacts from each fleet.

Other ideas explained by Martell et al (2106) are yield equivalency and fisheries interactions. Yield equivalency is the concept of how much one pound removed by one fishery is to a different fishery with a different selectivity. For example, if the bycatch fleet removes one pound of halibut, how many lost pounds does that translate to for the commercial directed fishery? Fisheries interactions is the method of systematically removing each sector from the harvest policy calculations to determine how much yield would be obtained in the other sectors. These calculations require assumptions regarding selectivity of each fleet, natural mortality, average recruitment, and migration, to name a few.

1.3.6 How changes in the IPHC harvest policy may affect ABM management of PSC-limits

Using an SPR-based fishing intensity in a coastwide stock assessment accounts for the mortality from all sources and all sizes. There still are assumptions about the selectivity for each fleet and the proportion of mortality caused for each fleet, for which the assessment uses the best current estimates and the MSE assumes a reasonable uncertainty to develop robust harvest strategies. Nevertheless, this new interim harvest policy is a significant improvement over the previous IPHC harvest policy because the mortality of all fish is considered when determining a sustainable total mortality, and it will naturally lead into calculations involving the spawning capital (e.g., fishery footprint). Although the U26 component is accounted for in the coastwide total mortality, it is currently not considered in the distribution of the total mortality. Reasons for this are that the directed fisheries mainly encounter Pacific halibut larger than 26", the relative abundance of the U26 component is not well indexed by the setline survey, and there are not any indices that do index the U26 halibut on a coastwide level. It is assumed that U26 Pacific halibut are still distributing throughout the coast, thus the coastwide U26 mortality is balanced with O26 mortality in the SPR-based harvest policy.

Martell et al (2016) summarized the conservation concern as follows.

> The conservation concern is that if the PSC limits are based on average recruitment, and it takes 10 years to determine the strength of the cohort from other sources, then during periods of below average recruitment the harvest rates associated with bycatch will be higher than intended. The counter concern is that if there is an above-average recruitment event, then the PSC limits will be set too low, and the non-retention fisheries will be highly constrained due to high encounter rates with an above-average recruitment event (Martell et al 2016).

The IPHC harvest policy is currently being investigated using MSE to evaluate the SPR-based harvest policy and recommend changes to the management procedure that could better meet the objectives of the directed halibut fishery. The fishing intensity (currently an interim value of $F_{SPR=46\%}$), and the control rule (currently 30:20) that adjusts fishing intensity are being investigated. As mentioned earlier, an SPR-based harvest policy will make it easier to determine impacts on the spawning capital, but SPR is affected by changes in selectivity. The stock assessment uses the current best estimates of selectivity for the different fleets, but there may be up to an eight-year lag before the information adequately feeds into the management advice. The MSE assumes a distribution of possible selectivity patterns for each fleet, and the recommended SPR rate should be robust to reasonable changes in selectivity. The control rule protects the stock when the stock status gets low, and monitoring of changes in selectivity will maintain sustainable total mortality levels. However, a conservation concern may arise if harvest levels are above recommended values either due to unknown incoming recruitment or exceeding recommended mortality levels in a specific Area.

The distribution of the TCEY (currently using the setline survey and different harvest rates in the western and eastern Areas) will be investigated in the future using the MSE framework, but requires further discussions with industry to define Area-specific goals & objectives, and further development of multi-area operating models. A change in the distribution procedure may affect the treatment of bycatch in a specific Regulatory Area because mortality limits in that area may change. For example, if a new distribution procedure resulted in fewer fish in 4CDE, that could put a strain on the directed fishery in that Area. Vice versa, an increase in mortality limits would provide more opportunity for the directed fishery. It is unlikely that distribution would change greatly among Areas, but even a small change could be significant for some sectors.

Under consideration, but possibly not evaluated in the MSE in the near future, are size limits (currently 32 inches). A change in the commercial directed fishery size limit could increase efficiency of the commercial fleet, but may result in a change in selectivity. As noted above, a change in selectivity will result in a change to the target SPR that meets the defined goals and objectives, although in the likely range of selectivity, this change in SPR would be slight.

A possible other consideration is how the TCEY is distributed to the various sectors. Currently, a TCEY is determined for each Regulatory Area, and within an Area, bycatch is subtracted first along with non-directed fisheries, and the remainder is allocated to the directed fisheries. An alternative could be to first subtract a minimum amount for the directed fisheries, and then take off the allocation for the non-directed fisheries with the remainder adding to the directed fisheries allocation. This is purely a management decision that would require agreements between various agencies. It may affect bycatch limits in some Areas, but may have no effect in others.

The recent changes to the IPHC harvest strategy policy will benefit the management of the coastwide stock of Pacific halibut and provide opportunity to measure impacts from different fisheries, but it does not solve the difficult issues of allocation between fisheries. We can understand the components of the harvest policy and measure impacts of each fleet, but ultimately it comes down to understanding and balancing the trade-offs between goals and objectives of each fishery.

1.4 Halibut PSC management and usage in the BSAI groundfish fisheries

The BSAI groundfish management areas overlap IPHC regulatory areas 4A, 4B, 4C, 4D, and 4E (Figure 6). The NMFS management areas do not match exactly to IPHC regulatory areas (Table 2, Figure 6). In IPHC management, and for the purposes of this analysis, the groundfish BSAI reporting areas are equated with IPHC areas as shown in Figure 6.

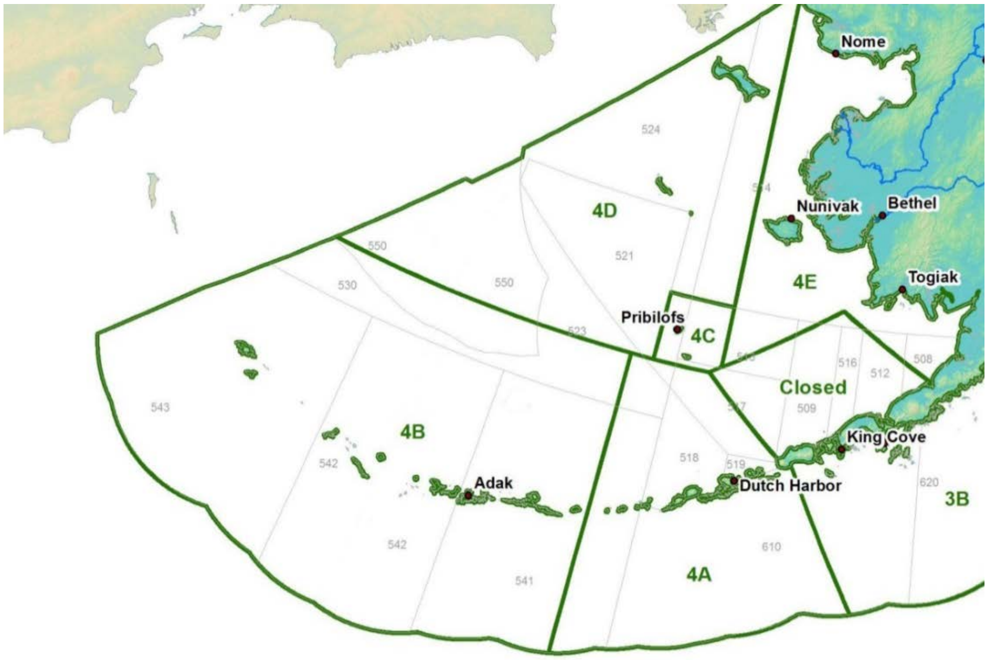
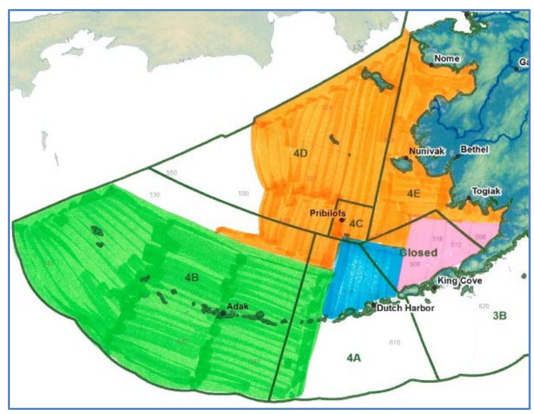


Figure 6. Alaska groundfish reporting areas and IPHC regulatory areas for Pacific halibut.
Source: Adapted from NMFS Alaska Region map by Northern Economics Inc.

Table 2. NMFS management area reassignments used to aggregate groundfish and halibut statistics to IPHC regulatory areas

NMFS Areas	Color on map	IPHC Area	Region
517, 518, 519	Blue	4A	BSAI
541, 542, 543	Green	4B	
513, 514, 521, 523, 524	Orange (4CDE)	4CDE and Closed area	
508, 509, 512, 516	Pink (Closed area)		



1.4.1 Groundfish fishery halibut PSC management

The BSAI FMP requires that annual BSAI-wide Pacific halibut PSC limits for trawl and non-trawl gear fisheries be established in regulations, and may be amended by regulatory amendment. The Secretary, after consultation with the Council, is to consider specific information when initiating a regulatory amendment to change a halibut PSC limit, listed below.

1. estimated change in halibut biomass and stock condition potential impacts on groundfish fisheries;
2. estimated bycatch mortality during prior years;
3. estimated halibut PSC;

4. methods available to reduce halibut PSC;
5. the cost of reducing halibut PSC; and
6. other biological and socioeconomic factors that affect the appropriateness of a specific bycatch limit in terms of FMP objectives.

Halibut PSC limits are established in the BSAI FMP for the trawl Amendment 80 and BSAI trawl limited access sectors (Section 3.7.5.2.1 of the FMP), as well as the total allocation of halibut PSC limit (from trawl and non-trawl) to the CDQ Program (Section 3.7.4.6 of the FMP). Halibut PSC limits for non-trawl fisheries are specified only in regulation.

Amendment 111 to the BSAI FMP applies BSAI halibut PSC limits to four fishery sectors. Amendment 111 was recommended by the Council in June 2015, and was implemented in 2016. The four fishery sectors and resulting reduced halibut PSC limits are described in the following table.

	Current PSC limit	PSC limit reduction	New PSC limit
Amendment 80 cooperatives	2,325 t	-25%	1,745 t
BSAI trawl limited access fisheries	875 t	-15%	745 t
Longline fisheries	833 t	-15%	710 t
CDQ fisheries	393 t	-20%	315 t
TOTAL	4,426 t	-21%	3,515 t

Information from the proposed rule to implement Amendment 111 to the BSAI Groundfish FMP is excerpted and summarized below by sector for further explanation on the relative fishery sectors to which halibut PSC limits apply. For more specific on sector management of halibut PSC limits and vessel participation see the proposed rule for Amendment 111 and the EA/RIR/IRFA for Amendment 111 (NPFMC, 2015).

Amendment 80 Sector

The Amendment 80 sector comprises trawl catcher/processors in the BSAI active in groundfish fisheries other than Bering Sea pollock (i.e., the head-and-gut fleet or Amendment 80 vessels). The Amendment 80 species are the following six species: BSAI Atka mackerel, Aleutian Islands Pacific ocean perch, BSAI flathead sole, BSAI Pacific cod, BSAI rock sole, and BSAI yellowfin sole (§ 679.2). The Amendment 80 Program allocates a portion of the TACs of the Amendment 80 species between the Amendment 80 Program and other trawl fishery participants (72 FR 52668, September 14, 2007). The Amendment 80 Program also allocates crab and halibut PSC limits to constrain bycatch of these species while Amendment 80 vessels harvest groundfish. Fishing under the Amendment 80 Program began in 2008.

The Amendment 80 Program allocated quota shares (QS) for Amendment 80 species based on the historical catch of these species by Amendment 80 vessels. The Amendment 80 Program allows and facilitates the formation of Amendment 80 cooperatives among QS holders who receive an exclusive harvest privilege. This exclusive harvest privilege allows Amendment 80 cooperative participants to collaboratively manage their fishing operations and more efficiently harvest groundfish and PSC allocations.

The Amendment 80 sector can be divided between vessels that focus primarily on flatfish (i.e., Alaska plaice, arrowtooth flounder, flathead sole, rock sole, and yellowfin sole) and those vessels that focus on Atka mackerel. The flatfish-focused vessels have higher rates of halibut bycatch than the Atka mackerel vessels.

Annually, each Amendment 80 QS holder elects to participate either in a cooperative or the limited access fishery. Participants in the limited access fishery do not receive an exclusive harvest privilege for a portion of the TACs allocated to the Amendment 80 Program. Beginning in 2011, all QS holders have participated in one of two Amendment 80 cooperatives. For additional detail see Amendment 80 Cooperative Reports available on the NMFS Alaska Region Web site, *http://alaskafisheries.noaa.gov/sustainablefisheries/amds/80/default.htm*.

NMFS annually establishes a halibut PSC limit for the Amendment 80 sector. This halibut PSC limit is apportioned between Amendment 80 cooperatives and the limited access fishery according to § 679.91. Amendment 80 cooperatives are responsible for coordinating fishing activities to ensure the cooperative halibut PSC allocation is not exceeded. In a year when there are vessels participating in the Amendment 80 limited access fishery, NMFS apportions the halibut PSC limit for the Amendment 80 limited access fishery into PSC allowances for the following six trawl fishery categories in which the vessels could participate: 1) yellowfin sole fishery, 2) rock sole/flathead sole/“other flatfish” fishery, 3) Greenland turbot/arrowtooth flounder/Kamchatka flounder/sablefish fishery, 4) rockfish fishery, 5) Pacific cod fishery, and 6) pollock/Atka mackerel/“other species” fishery, which includes the midwater pollock fishery (see § 679.21(e)(3)(i)(B), (e)(3)(ii)(C), and (e)(3)(iv)).

NMFS manages the Amendment 80 limited access fishery halibut PSC allowances because participants in the Amendment 80 limited access fishery do not have exclusive privileges to use a specific amount of halibut PSC. To manage halibut PSC, NMFS monitors participation and PSC use in the Amendment 80 limited access fishery categories. Except for the pollock/Atka mackerel/”other species” fishery, NMFS has the authority to close a trawl fishery category in the Amendment 80 limited access fishery if NMFS concludes that the fishery category will, or has, exceeded its halibut PSC allowance. A halibut PSC allowance is enforced through the prohibition against conducting any fishing contrary to notification of inseason action, closure, or adjustment (§ 679.7(a)(2)). The regulations establishing the exception for the pollock/Atka mackerel/“other species” fishery are explained below in the section “BSAI Trawl Limited Access Sector.”

BSAI Trawl Limited Access Sector

The BSAI trawl limited access sector comprises all the trawl vessels in the BSAI except Amendment 80 catcher/processors. The BSAI trawl limited access sector is a limited access sector because vessels must have a License Limitation Program (LLP) groundfish license to conduct directed fishing for any groundfish in BSAI (see § 679.4(k)(1)). The LLP is a limited access program because a limited number of licenses are issued and a person only received an LLP license if that person met specific eligibility requirements. However, the LLP does not allocate exclusive harvest privileges for a specific portion of a fishery TAC like the Amendment 80 Program does for the six Amendment 80 species or like the AFA does for Bering Sea pollock. Thus, for all species but pollock, vessels in the BSAI trawl limited access sector are in competition with other participants to maximize their harvest of target species before they reach either their halibut PSC limits, or in the case of Bering Sea pollock, Chinook salmon PSC limits.

NMFS annually establishes a halibut PSC limit for the BSAI trawl limited access sector. This halibut PSC limit is apportioned to fishery categories through the annual harvest specification process. NMFS apportions this sector’s PSC limit into PSC allowances among the following trawl fishery categories: 1) yellowfin sole fishery, 2) rock sole/flathead sole/“other flatfish” fishery, 3) Greenland turbot/arrowtooth flounder/Kamchatka flounder/sablefish fishery, 4) rockfish fishery, 5) Pacific cod fishery, and 6) pollock/Atka mackerel/“other species” fishery, which includes the midwater pollock fishery. After NMFS establishes PSC allowances for these trawl fishery categories, NMFS may, through the annual harvest specification process, further apportion the allowances by season, according to criteria specified in regulation (§ 679.21(e)(5)). NMFS apportions some halibut PSC allowances in specific groundfish fisheries by season to ensure that a portion of the halibut PSC allowance for that fishery is available for use earlier in the year and a portion of the halibut PSC allowance remains to support groundfish fishing in that fishery that occurs later in the year. The limits assigned to each season for a groundfish fishery reflect halibut PSC likely to be taken during that season in that fishery.

NMFS has authority under current regulations to close the following trawl fisheries if they will reach their halibut PSC allowance: 1) yellowfin sole fishery, 2) rock sole/flathead sole/“other flatfish” fishery, 3) Greenland turbot/arrowtooth flounder/Kamchatka flounder/sablefish fishery, 4) rockfish fishery, and 5) Pacific cod fishery (§ 679.21(e)(7)(v)). For example, in May 2014, NMFS closed the yellowfin sole fishery throughout the BSAI to prevent that fishery from exceeding its halibut PSC allowance (79 FR 29136, May 21, 2014). The Pacific cod and yellowfin sole fisheries are the primary fisheries that can be constrained by halibut PSC limits in the BSAI trawl limited access sector. The regulations include an exception for the pollock/Atka mackerel/“other species” fishery category[7].

BSAI Non-trawl Sector

The BSAI non-trawl sector comprises all the non-trawl vessels in the BSAI except vessels fishing for groundfish in the CDQ sector. The Council and NMFS have exempted pot gear, jig gear, and the sablefish IFQ hook-and-line gear fishery categories from halibut PSC limits. Hook-and-line catcher/processor vessels that target Pacific cod comprise the greatest number of vessels and amount of harvests in the non-trawl sector. All but one hook-and-line catcher/processor fishing in the BSAI participates in a voluntary cooperative, the Freezer Longline Conservation Cooperative (FLCC). The FLCC has allowed hook-and-line catcher/processors to fish as a coordinated group and has allowed less efficient vessels to decrease fishing or stop entirely.

The BSAI non-trawl sector also includes hook-and-line catcher vessels that exclusively target Pacific cod. Some non-trawl vessels also harvest groundfish other than Pacific cod, but harvests of these other species are limited. Over the past decade, only hook-and-line catcher/processors have participated in the other non-trawl fisheries, specifically targeting Greenland turbot. Under current regulations, the non-trawl sector’s PSC limit is apportioned under the annual harvest specification process. Section 679.21(e)(4)(i)(C) specifies that NMFS will apportion the BSAI non-trawl sector’s PSC limit into PSC allowances “based on each category’s proportional share of the anticipated bycatch mortality of halibut during a fishing year and the need to optimize the amount of total groundfish harvested under the non-trawl halibut PSC limit.” As explained above in “Annual Halibut Bycatch (PSC) limits and Apportionment of PSC limits,” NMFS has apportioned the PSC limit for the BSAI non-trawl sector among three non-trawl fishery categories: 1) Pacific cod hook-and-line catcher vessel fishery, 2) Pacific cod hook-and-line catcher/processor fishery, and 3) other non-trawl fisheries. NMFS has the same authority to apportion, by season, the halibut PSC allowances among the non-trawl fisheries as it has for the trawl fisheries (§ 679.21(e)(5)).

As with trawl fisheries, NMFS manages the halibut PSC allowances for the non-trawl fisheries through fishery closures. Section 679.21(e)(8) specifies that if NMFS concludes that a non-trawl fishery will

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[7] If the pollock/Atka mackerel/“other species” fishery category will reach its halibut PSC allowance, NMFS does not have the authority to close the pollock/Atka mackerel/“other species” fishery category. By a regulation adopted in 1992, if the PSC allowance for the pollock/Atka mackerel/“other species” category will be reached, NMFS only has authority to close directed fishing for pollock to trawl vessels using nonpelagic trawl gear (57 FR 43926, 43935, September 23, 1992; § 679.21(e)(7)(i)). However, in 2000, NMFS prohibited directed fishing for pollock in the BSAI with nonpelagic trawl gear at all times and extended that prohibition to CDQ sector vessels in 2006 (65 FR 31105, May 16, 2000; 71 FR 36694, June 28, 2006; § 679.24(b)(4)). Thus, if the halibut PSC allowance for the trawl fishery category of pollock/Atka mackerel/“other species” will be reached, NMFS does not have authority to take additional action.

reach its halibut PSC allowance (or a seasonal apportionment of an allowance), it will close that non-trawl fishery in the entire BSAI for the rest of the year (or the rest of the season).

CDQ Sector

The CDQ sector includes all trawl and non-trawl vessels that harvest groundfish under the CDQ Program. CDQ vessels primarily target pollock using trawl gear and target Pacific cod using hook-and-line gear. Other species such as yellowfin sole, several flatfish species, Atka mackerel and Pacific ocean perch allocated to the CDQ sector are targeted by vessels using trawl gear.

As specified in Section 3.7.4.6 of the FMP and at § 679.21(e), NMFS annually establishes a halibut PSC limit for the CDQ sector. The halibut PSC limit is divided among the six CDQ groups by established percentages (71 FR 51804 (August 31, 2006). Each CDQ group receives an apportionment of this halibut PSC limit as halibut prohibited species quota (PSQ), which is a specific amount of halibut that vessels fishing for that CDQ group may use in a year. The apportionment of halibut PSQ to each CDQ group is similar to the apportionment of halibut PSC Cooperative Quota to an Amendment 80 cooperative. The CDQ group manages the use of its halibut PSQ apportionment. The CDQ group has the responsibility to ensure that the vessels fishing its CDQ groundfish allocation do not use halibut PSQ in excess of the amount of the CDQ group's halibut PSQ. This limit is enforced at § 679.7(d)(3), which prohibits a CDQ group from exceeding its apportionment of halibut PSQ.

1.4.2 Groundfish fishery halibut PSC usage by sector

The PSC limits since 2008, and the Pacific halibut mortality estimates (and ratio relative to limits) by sector are shown in Table 3 and Table 4, respectively.

Table 3. Evolution of Pacific halibut PSC limits by main sectors in the BSAI region, 2008-2016.

	Am80	BSAI TLA	Longline fisheries	CDQ	Total PSC limit
2008	2,525	875	833	343	4,576
2009	2,475	875	833	343	4,526
2010	2,425	875	833	393	4,526
2011	2,375	875	833	393	4,476
2012	2,325	875	833	393	4,426
2013	2,325	875	833	393	4,426
2014	2,325	875	833	393	4,426
2015	2,325	875	833	393	4,426
2016	2,325	875	833	393	4,426
2016*	1,745	745	710	315	3,515
2017	1,745	745	710	315	3,515

*mid-year implementation of new PSC caps in 2016

Table 4. Pacific halibut mortality estimates (top rows) and mortality relative to the limits (bottom rows) by sector for 2008-2016.

	Am80	BSAI TLA	Longline fisheries	CDQ	Total PSC mortality
2008	1,869	838	593	215	3,515
2009	1,985	815	597	155	3,552
2010	2,154	584	526	162	3,426
2011	1,722	717	498	243	3,179
2012	1,890	1,012	570	272	3,744
2013	2,089	784	471	266	3,611
2014	2,106	717	408	247	3,478
2015	1,362	527	299	130	2,318
2016	1,333	650	197	174	2,354
2017*	699	524	124	92	1,439
	Am80	**BSAI TLA**	**Longline fisheries**	**CDQ**	**% of Total PSC limit**
2008	74%	96%	71%	63%	77%
2009	80%	93%	72%	45%	78%
2010	89%	67%	63%	41%	76%
2011	72%	82%	60%	62%	71%
2012	81%	116%	68%	69%	85%
2013	90%	90%	57%	68%	82%
2014	91%	82%	49%	63%	79%
2015	59%	60%	36%	33%	52%
2016	76%	87%	28%	55%	67%
2017*	40%	70%	17%	29%	41%

* Halibut mortality to date week of 8/14/2017

1.4.3 Halibut PSC mortality by gear and sector

Data were compiled on relative halibut mortality by gear and sector. Data by gear uses all the observed hauls or sets in the EBS for Pelagic Trawl (PT), Non-pelagic Trawl (NPT), and longline (LL) gear during 1998 – 2016 (Figure 7). To appropriately capture trends in catch-per-unit-effort and encounter rate, all hauls were included, not just those that caught halibut. However, directed fishery catches (IFQ) were not included in the longline gear type. A caveat of these data is that the NPT fleet in 2015 and 2016 initiated deck sorting experiments that may have affected the observer coverage.

Data by sector was computed in collaboration with the Alaska Regional Office which assigned individual observed hauls and sets to their management program code. This code allows each haul to be assigned to one of the Amendment 80 (A80), Trawl Limited Access Sector (TLAS), Community Development Quota (CDQ), or the longline (LL) sectors.

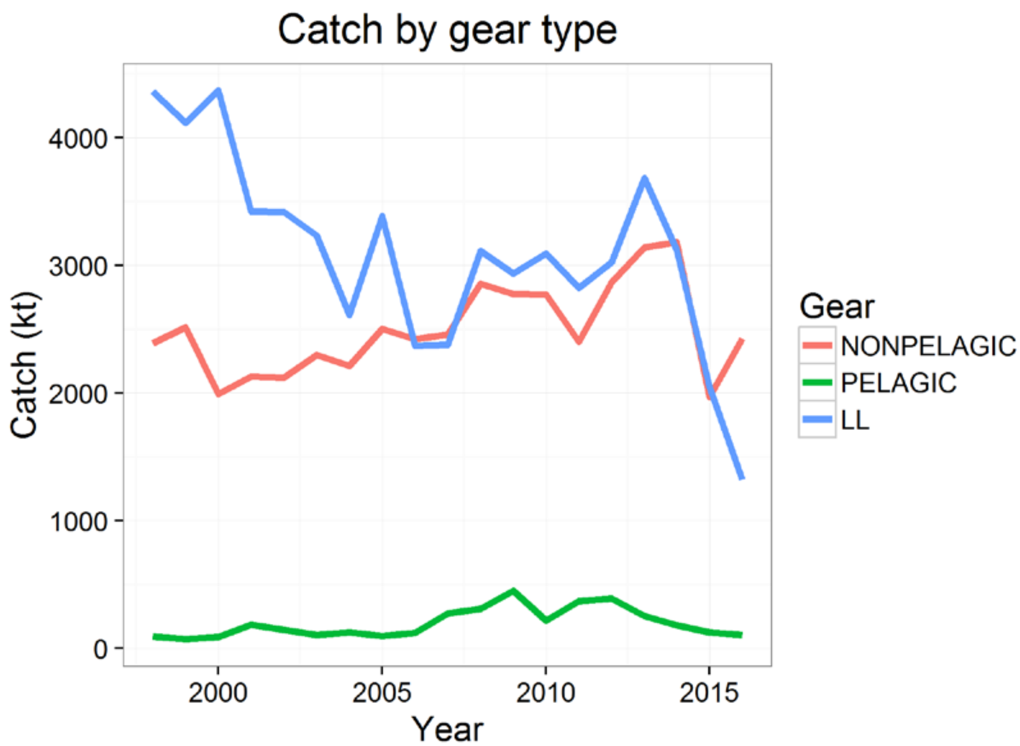

Figure 7. Observed catch by gear type excluding IFQ harvest. These data do not reflect halibut mortality (no DMRs) but what the fisheries are encountering.

For trawl gear, the encounter rates have varied substantially over time but is generally higher for non-pelagic gear (Figure 8). The increase in pelagic trawl encounters during 2008-2010 is likely reflecting lower pollock abundances and the fact that pollock fishing tended to be more dispersed on the shelf region. Encounters with groundfish longline vessels show a steady decline over the last 20 years (Figure 9). In terms of catch rates, the biomass and number of Pacific halibut caught per unit of effort was substantially higher for non-pelagic trawl gear and shows an increase in the middle of the period followed by a decrease in recent years (Figure 10 and Figure 11). Within the trawl fleet, broken out by sector there has been a steady decline in Pacific halibut CPUE in both number and biomass (Figure 12 and Figure 13). This trend likely reflects increased avoidance measures. For the longline groundfish fleet, the catch rates by weight are variable compared to by number, but both suggest a decline in Pacific halibut CPUE (Figure 14 and Figure 15).

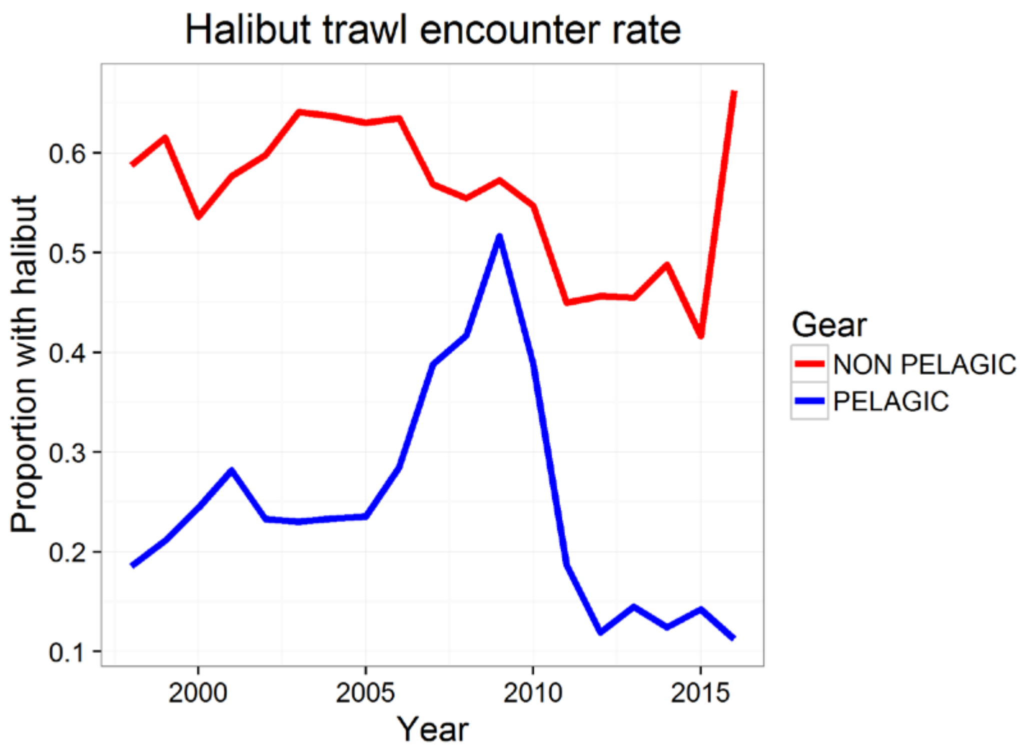

Figure 8. Encounter rate (non-zero) pelagic and non-pelagic trawl gear hauls in the EBS from 1998-2016.

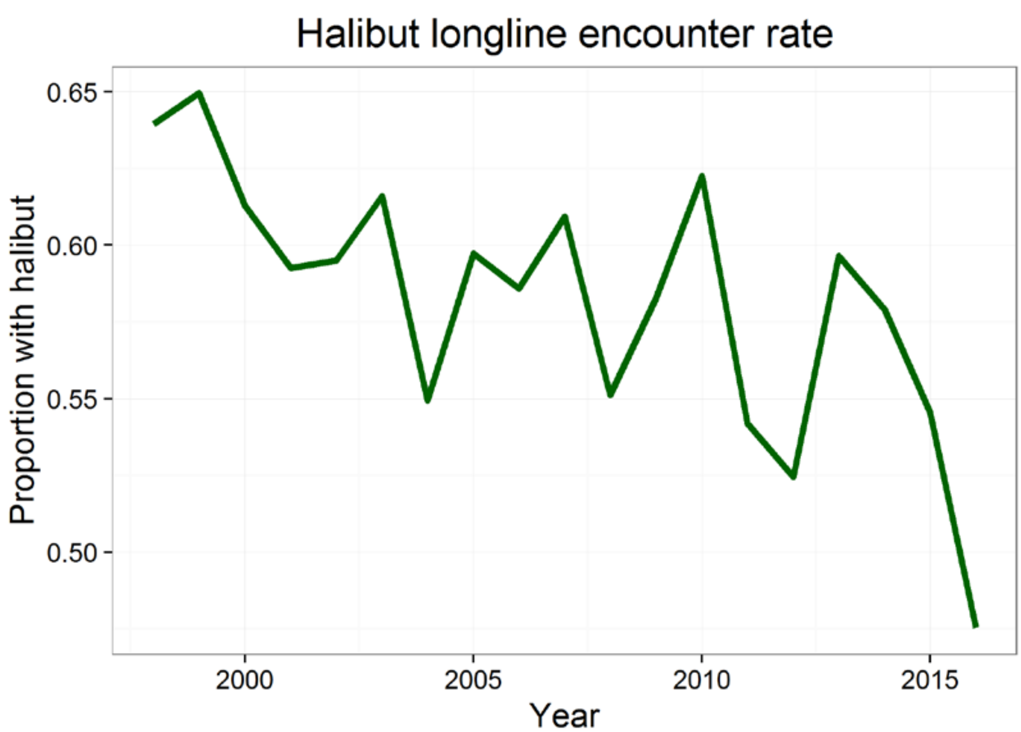

Figure 9. Encounter rate (non-zero) for longline gear sets in the EBS from 1998-2016.

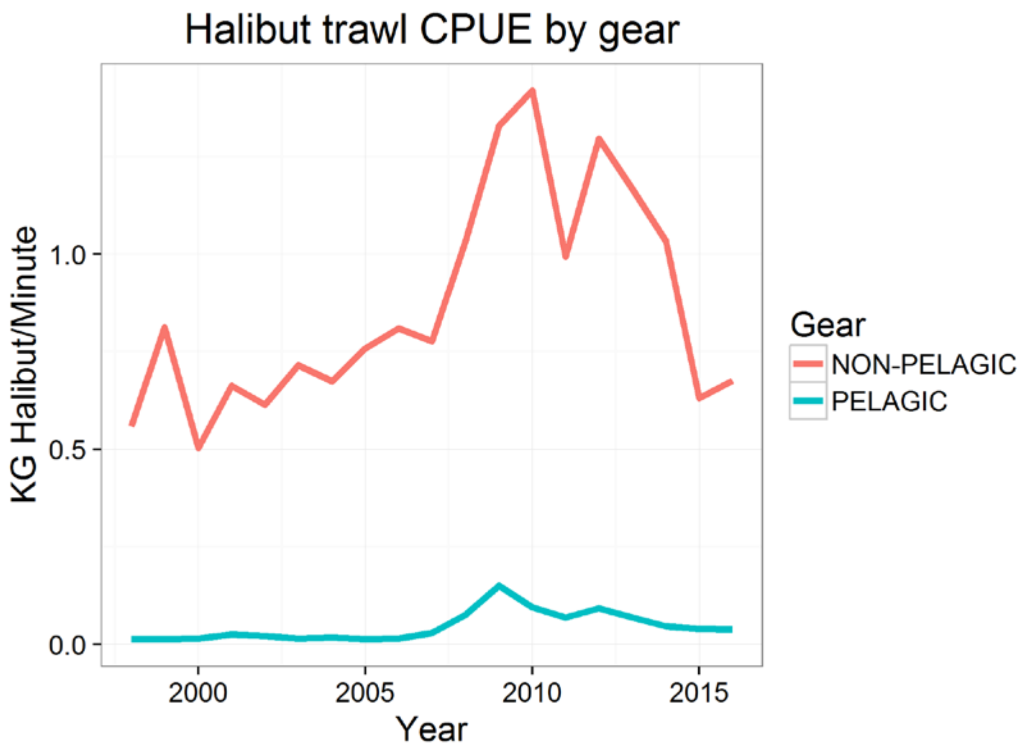

Figure 10. Catch per unit effort of halibut (weight) for pelagic and non-pelagic trawl gear in the EBS from 1998-2016.

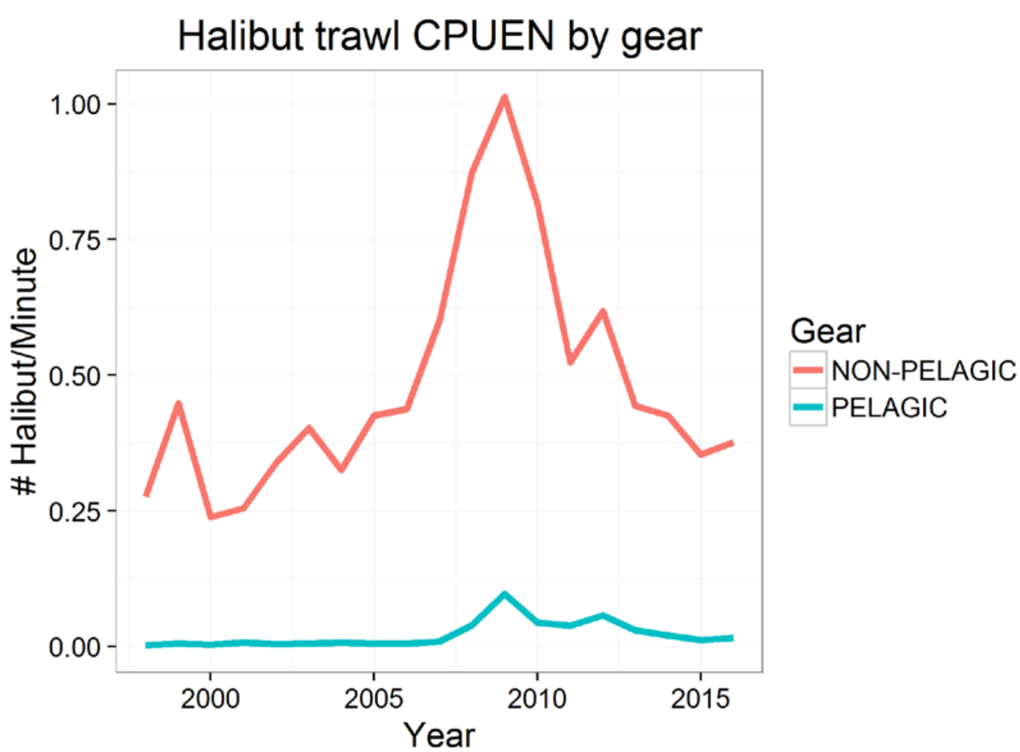

Figure 11. Catch per unit effort of halibut (numbers) for pelagic and non-pelagic trawl gear in the EBS from 1998-2016.

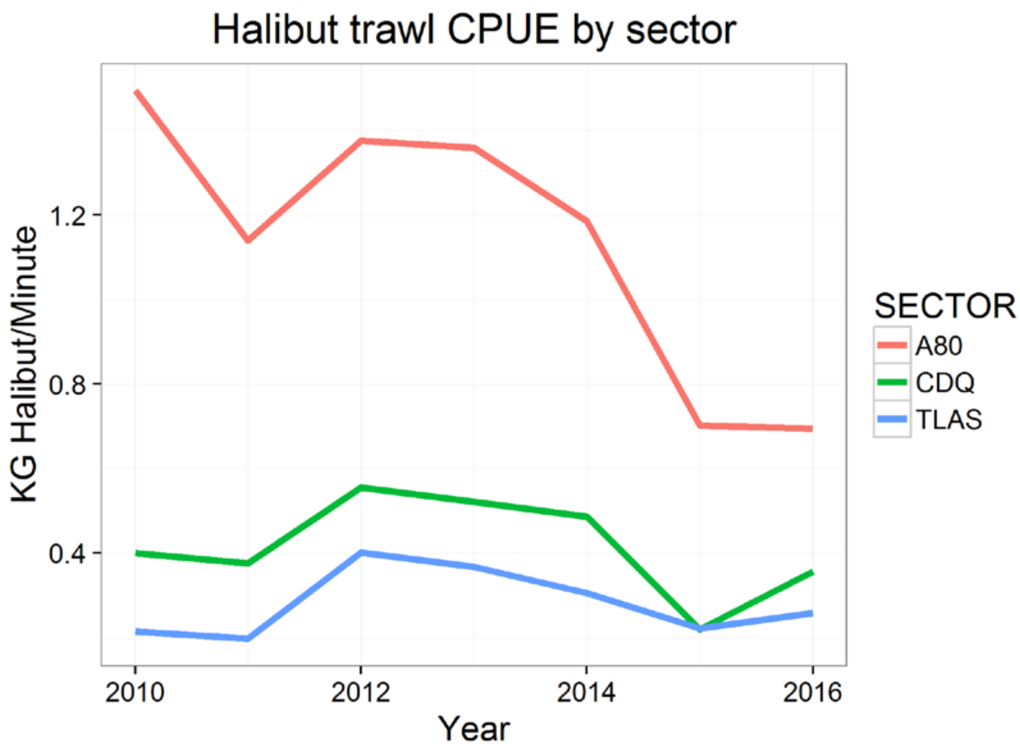

Figure 12. Catch per unit effort (weight) of halibut by trawl sector from 2010-2016.

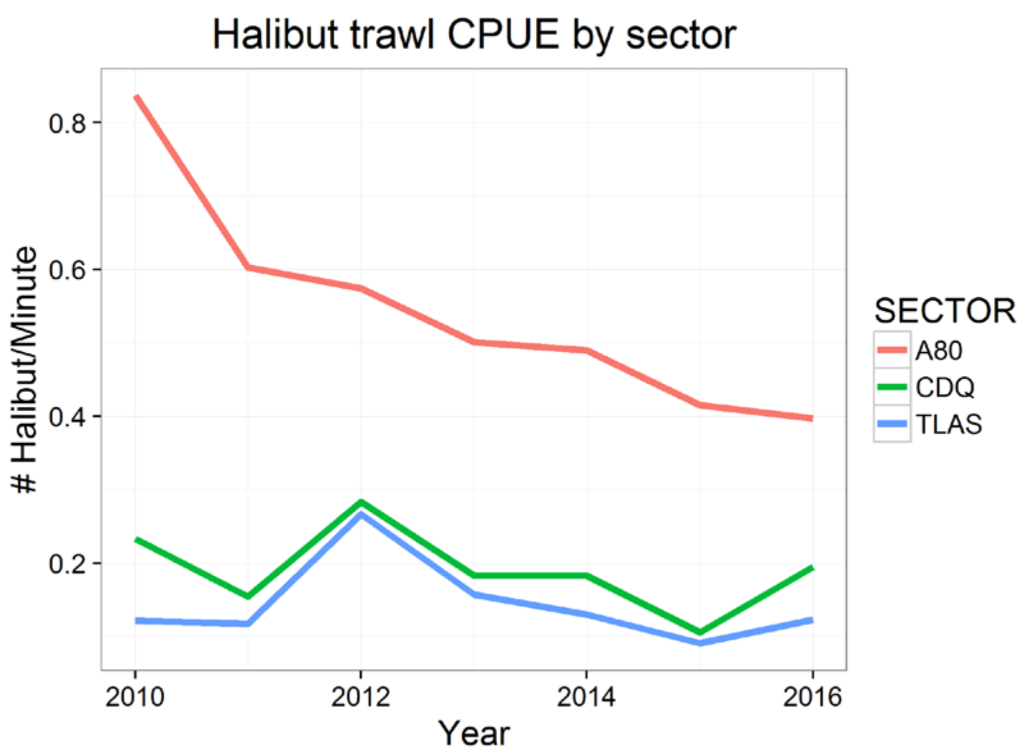

Figure 13. Catch per unit effort (numbers) halibut by trawl sector from 2010-2016.

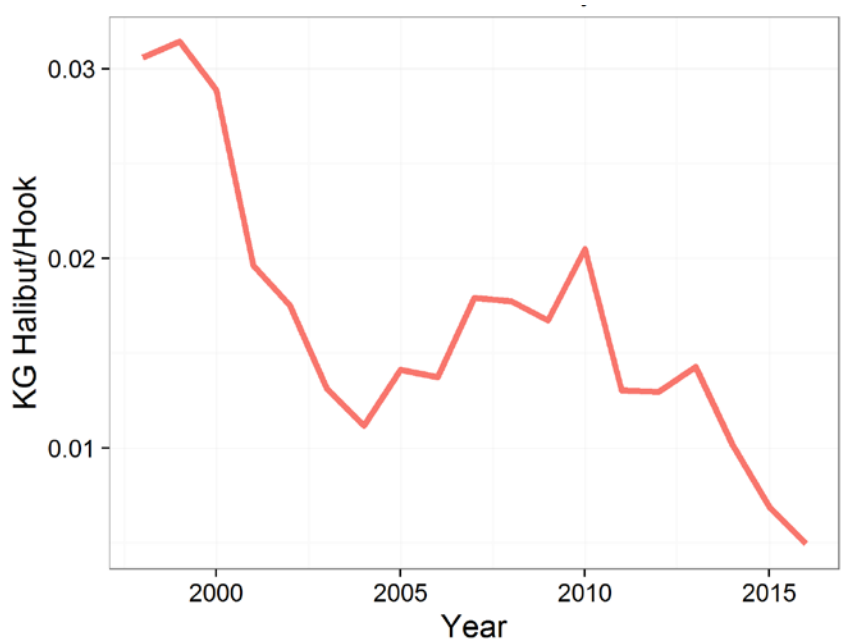

Figure 14. Catch per unit effort of halibut for longline gear (weight) in the EBS from 1998-2016.

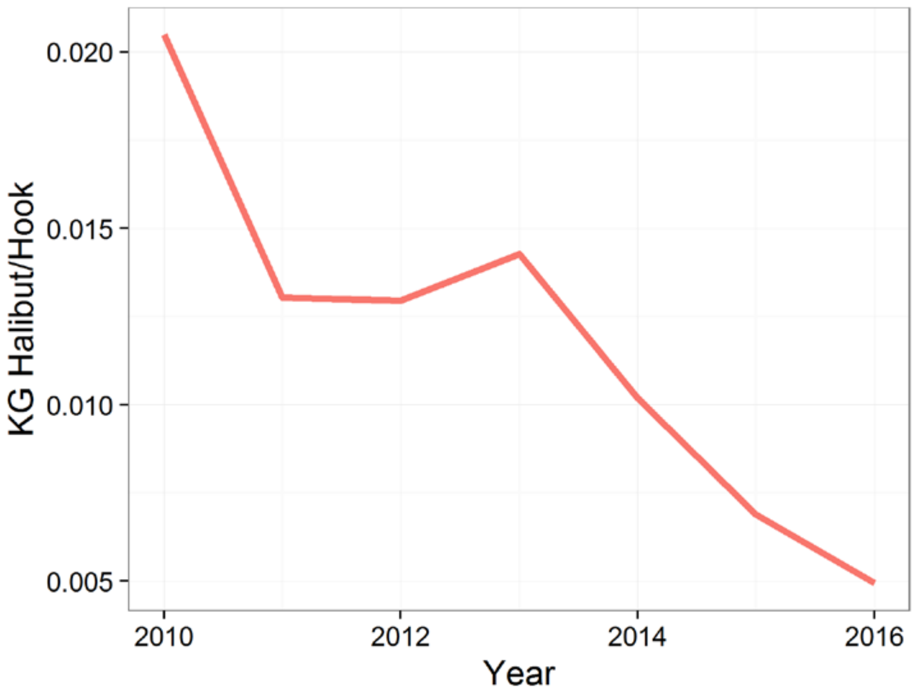

Figure 15. Catch per unit effort (weight) of halibut for longline gear (non-IFQ) in the EBS from 2010 – 2016.

1.4.4 Actions taken by the groundfish fleet and tools available to avoid halibut

This section summarizes efforts to minimize halibut bycatch in three sectors that prosecute the BSAI non-pollock groundfish fishery: longline catcher/processors (FLC), Amendment 80 trawl catcher/processors (A80), and limited access trawlers (TLAS). The following draws on information provided by industry stakeholders that was included in the 2015 BSAI halibut PSC limit reduction analysis (Am. 111) and on follow-up communication with representatives from each sector in 2017.

Freezer Longline Coalition

FLC represents longline catcher/processors that target groundfish. FLC member vessels work to reduce halibut bycatch mortality through measures that promote avoidance, accountability, and the viability of fish that are released. Avoidance measures are generally framed around near real-time communication on the fishing grounds, facilitated through a third party. FLC members can access third-party catch monitoring with location data, including both target and bycatch as well as observed discard mortality rates DMR. Members receive weekly accountability reports on fleet-wide PSC totals and rates. Those internal reports are vessel-specific ("clean/dirty list"), triggering social incentives to avoid activity that would result in lost fishing opportunities for the voluntary cooperative as a whole. Inseason reporting on observed DMRs reinforces the need to prioritize careful release practices to increase viability (fish handling), and can also inform choices about where to set lines. All of these practices are implemented in an environment of full monitoring and transparency, with 100% (or more) observer coverage and flow scales.

As a cooperative, FLC promotes communication and accountability in three ways: an annual symposium for owners, officers, and crew; bycatch status updates for the fleet monthly and at board meetings; and an ad hoc bycatch committee. The annual meeting, or symposium, aims to educate participants – from owners to crew members – on the importance to the fishery and the industry of minimizing halibut mortality and measures like fish handling that can improve outcomes. The event also includes interaction with fishery managers from NMFS and third-party data handlers. FLC formed a bycatch committee in 2014 to engage in the process of developing Am. 111 and to encourage halibut avoidance efforts. That committee has not met on a regular basis, but could be recalled to aid in coordination or reporting.

Amendment 80

A80 vessels have agreed to a Halibut Avoidance Plan that sets out operational practices and accountability measures to avoid halibut and reduce halibut mortality. This plan is responsive to the Council's BSAI halibut PSC limit reduction action in 2015, which called for participants to define avoidance practices and create reduction incentives. Vessels must meet a halibut rate standard (kg halibut per mt groundfish) on an annual basis for each target species, as well as a rate standard for the fourth quarter of the calendar year. The fourth quarter standard is meant to maintain the incentive to avoid halibut throughout the year, preventing scenarios where a vessel might reduce its focus on halibut avoidance if the sector's annual PSC limit (and any internal suballocation) is not expected to be constraining. The A80 fleet is using rate standards because the greatest marginal reduction in halibut mortality comes from focusing on outlier vessels. That approach is a reflection of the fact that halibut and target flatfish are typically comingled on the fishing grounds in a way that pollock and salmon species are not. In other words, marginal returns on avoidance measures diminish long before the typical A80 vessel could bring its bycatch rate to zero. Failure to meet rate standards trigger the incentive: a self-imposed monetary sanction. Failure to meet the standard also subjects the vessel to quarterly monitoring and potentially halibut limit reduction in the following year. Fines for the annual outlier test are imposed on a target basis. Annual rate targets are based on historical fleet performance in each target (e.g., yellowfin sole, rock sole, flathead/arrowtooth). The fourth quarter rate standard is an aggregate across all targets. Fines for each species range from $50,000 to $100,000. The penalty increases along with the amount of groundfish harvested, which creates a disincentive for continuing to harvest groundfish at an unacceptably high bycatch rate.

The avoidance practices identified in the plan include excluders, use of test tows when entering a new area, vessel-to-vessel communication, data sharing and weekly bycatch teleconferences among the fleet, and informed choices about target species choice given a certain location or time of day. Information sharing allows the fleet to reduce bycatch by altering any number of fishing parameters while on the grounds – location, target, depth, tow speed, etc. For example, the sector avoids towing during night-time hours when halibut encounter rates tend to be higher. Furthermore, the A80 sector is in the midst of a multiyear process to develop halibut deck sorting procedures that could reduce the mortality rate of halibut bycatch. The deck sorting effort is being carried out under an EFP. The cooperative research is studying not only viability, but also how to integrate deck sorting into normal vessel operations. The cooperative is working to identify sorting practices that return the greatest marginal gain in viability, balancing the number of fish sorted versus the time that fish spend on deck before being returned to the sea. That might mean sorting for larger halibut first, or ceasing deck sorting when the time elapsed suggests low viability.

The efficacy of using excluders and deck sorting are not necessarily additive in terms of reducing halibut mortality. One reason for this is that excluder devices stir up more bottom material (sand, silt, and mud) during a tow; fish that are covered in silt will have lower viability on deck and thus deck sorting is less effective. The A80 cooperative is working to better understand the trade-off curve along which one practice works better than another. For example, if fishing is relatively clean – low halibut rates – the optimal strategy is to deck sort and not to use an excluder. The higher expected CPUE without an excluder allows the captain to fill the net with a shorter tow, reducing the opportunity to encounter halibut and increasing the survivability of those that are caught. Halibut that end up in the net can be deck sorted quickly, with a priority on larger and more viable fish. An excluder's effectiveness might also depend on the relative size differential between the halibut in the local environment and the groundfish being targeted. Vessels communicate with each other and a third-party data manager on bycatch rates, changes in those rates, effectiveness of excluders, catch rates of O26 halibut, and other factors relevant to O26 bycatch rates that allow captains to tailor their approach (e.g., time of day, depth, water temperature, and effects of any gear modifications).

Trawl Limited Access

The limited access trawl catcher vessel sector includes vessels that are affiliated with AFA pollock cooperatives and vessels that are not AFA-affiliated. The non-AFA portion of the fleet includes vessels that have other cooperative affiliations (A80) through their ownership companies. Both AFA and A80 cooperatives are subject to agreements that include halibut avoidance measures. While unaffiliated vessels are not subject to agreements that carry internal accountability measures, co-op managers communicate with those vessels to share avoidance measures and encourage them to adopt the same.

A80 cooperative tools were covered above. AFA CVs manage halibut through internal halibut bycatch allocations to cooperatives that are proportional to the co-op's sideboards of non-pollock groundfish ("halibut mortality allowance"). After adjustments are made to account for exempt/non-exempt status and a "traditional time and area buffer," co-op vessels receive a halibut mortality allocation. Cooperatives agree to manage their vessels such that PSC limits are not exceeded, and allow PSC that is not needed to harvest the co-op's sideboard allocations to be redistributed in a timely manner to other cooperatives at no cost.

AFA CVs have established Better Practices Protocols that vessels must adhere to when fishing with trawl gear for BS Pacific cod. Vessels must tow halibut excluders that meet agreed upon specifications. The protocols allow room to innovate new designs, as smaller or slower vessels might experience different levels of effectiveness using the same design towed by a larger vessel. Vessels are not allowed to fish for cod during night hours, when halibut encounters tend to be greater. The protocols also set a minimum codend mesh size to allow some escapement of undersized fish. In terms of monitoring, AFA CVs fishing in limited access voluntarily carry 100% observer coverage for the expressed purpose of internally managing cooperative halibut mortality allowances. By virtue of their cooperative affiliations, many TLAS participants also share with each other near real-time catch, bycatch, and location data (including rates) through a third-party. Cooperatives impose internal accountability measures through vessel rankings of PSC rates and through monetary sanctions for vessels that are not complying with Better Practices Protocols.

In recent years, TLAS vessels have been able to coordinate informally on avoidance plans that are responsive to Council objectives, even meeting voluntary mortality reduction targets. That coordination is largely facilitated through existing cooperative programs (i.e. AFA and A80). Entry by newer participants could make coordination more challenging because voluntary cooperatives often parcel out halibut mortality allowances (or the like) based on catch history in the TLAS fishery.

Summary

Across these three sectors, stakeholder representatives indicated that communication about conditions on the fishing grounds is the most important tool for minimizing halibut bycatch. Cooperative-affiliated vessels in each sector contract with the same third-party information manager to facilitate rapid information sharing and to enforce the accountability measures that are written into voluntary avoidance plans. Because halibut are more evenly distributed throughout the groundfish biomass, the fleets rely more on real-time reactions than on the time/area closures that are often used in pollock fisheries that encounter salmon bycatch. The trawl sectors encourage the use of excluders – and require them in certain fisheries (TLA Pacific cod) – but note that their effectiveness varies by target, vessel size, and design relative to local environmental conditions. Cooperatives that encourage or require excluder use allow their vessels latitude in the type or set-up of the modification so that they can experiment and tune for better performance. The trawl fleet continues to study other factors that might affect rates of halibut encounter (e.g. water temperature) so that captains will know when to use an excluder despite the related increase in gear-time on the bottom.

The representatives who updated staff on their sectors' avoidance strategies uniformly noted that they do not know how much of the recent reductions in halibut mortality can be attributed to the efforts described above, acknowledging that some proportion of that outcome is due to natural variations. As a result, their message is that these efforts will continue and even be enhanced, but that additional levers by which to further reduce mortality or to assure reductions are not apparent. In the event that 2016 or 2017 serves as a baseline or a reference point for an abundance-based PSC limit, the groundfish industry emphasizes that these years reflect substantial additional avoidance effort relative to earlier years and might also reflect a time of lower halibut abundance in BSAI groundfish fishing areas.

2 Council Purpose and Need

The following purpose and need statement for this action was developed by the Council and refined over iterative meetings between 2016 to 2017.

> "The current fixed yield based halibut PSC caps are inconsistent with management of the directed halibut fisheries and Council management of groundfish fisheries, which are managed based on abundance. When halibut abundance declines, PSC becomes a larger proportion of total halibut removals and thereby further reduces the proportion and amount of halibut available for harvest in directed halibut fisheries. Conversely, if halibut abundance increases, halibut PSC limits could be unnecessarily constraining. The Council is considering linking PSC limits to halibut abundance to provide a responsive management approach at varying levels of halibut abundance. The Council is considering abundance-based PSC limits to control total halibut mortality, provide an opportunity for the directed halibut fishery, and protect the halibut spawning stock biomass, particularly at low levels of abundance. The Council recognizes that abundance-based halibut PSC limits may increase and decrease with changes in halibut abundance."

Council objectives were derived from the purpose and need statement for this action and used to form overarching goals to guide the development of appropriate management measures and the tradeoffs amongst them. These overarching goals are the following:

1. Halibut PSC limits should be indexed to halibut abundance
2. Halibut spawning stock biomass should be protected especially at lower levels of abundance
3. There should be flexibility provided to avoid unnecessarily constraining the groundfish fishery particularly when halibut abundance is high
4. Provide for directed halibut fishing operations in the Bering Sea.
5. Provide for some stability in PSC limits on an inter-annual basis.

Consistent with the MSA's National Standard 1 and National Standard 9, the Council and NMFS use halibut PSC limits to minimize halibut bycatch in the groundfish fisheries to the extent practicable, while achieving, on a continuing basis, optimum yield from the groundfish fisheries. The groundfish fisheries cannot be prosecuted without some level of halibut bycatch. Although fishermen are required by the BSAI FMP to avoid the capture of any prohibited species in groundfish fisheries, the use of halibut PSC limits in the groundfish fisheries provides a constraint on halibut PSC and promotes conservation of the halibut resource. Halibut PSC limits provide a regulated upper limit to mortality resulting from halibut interceptions, as continued groundfish fishing is prohibited once a halibut PSC limit has been reached for a particular sector and/or season. This management tool is intended to balance the optimum benefit to fishermen, communities, and U.S. consumers that depend on both halibut and groundfish resources.

The IPHC accounts for halibut PSC in the groundfish fisheries, recreational and subsistence catches, and other sources of halibut mortality, before setting commercial halibut catch limits each year. Specifically, the IPHC uses a prediction of the PSC amount for next year to establish the following year's commercial halibut fishery catch limit. Declines in the exploitable biomass of halibut since the late 1990s, and decreases in the Pacific halibut catch limits set by the IPHC for the BSAI commercial halibut fisheries (IPHC Area 4)), especially beginning in 2012 for the commercial halibut fishery in the northern and eastern Bering Sea (Area 4CDE), have raised concerns about the levels of halibut PSC by the commercial groundfish trawl and hook-and-line (longline) sectors. The Council addressed this concern by reducing halibut PSC limits for the BSAI groundfish fisheries by recommending Amendment 111 to the FMP.

The Council recognizes efforts by the groundfish industry to reduce total halibut PSC in the BSAI, but continuing low levels of halibut exploitable biomass have continued to result in reduced directed fishery catch limits in Area 4. Based on the IPHC management objectives as well as estimates of exploitable biomass and PSC, directed fishery stakeholders remain concerned that catch limits will not be sufficient to provide for a directed fishery at the PSC limits implemented by Amendment 111 to the FMP. Therefore, the Council is considering a new approach to link PSC limits to halibut abundance.

The Council does not have authority to set catch limits for the commercial halibut fisheries The Council does set halibut PSC limits in the groundfish fisheries, and this is one of the factors that affects harvest limits for the commercial halibut fisheries. Halibut PSC in the groundfish fisheries are a significant portion of total mortality in BSAI IPHC areas, and have the potential to affect catch limits for the commercial halibut fisheries in Area 4. While the impact of halibut PSC reductions on catch limits for commercial halibut fisheries is partially dependent on IPHC policy and management decisions, linking current halibut PSC limits in the BSAI to halibut abundance could provide additional harvest opportunities in the BSAI commercial halibut fishery, particularly at low levels of abundance.

Under National Standard 8, the Council must provide for the sustained participation of and minimize adverse economic impacts on fishing communities. BSAI coastal communities are affected by reduced catch limits for the commercial halibut fishery, especially in IPHC Area 4CDE. In considering changes to the management of halibut PSC limits in the BSAI, the Council must balance these communities' involvement in and dependence on halibut with community involvement in and dependence on the groundfish fisheries that rely on halibut PSC in order to operate, and with National Standard 4, which states that management measures shall not discriminate between residents of different states. National Standard 4 also requires allocations of fishing privileges to be fair and equitable to all fishery participants. To be consistent with the requirements of the MSA, a Council action to implement abundance-based halibut PSC limits must minimize halibut PSC in the commercial groundfish fisheries to the extent practicable, while preserving the potential for the optimum harvest of the groundfish TACs assigned to the trawl and non-trawl sectors. In making a recommendation, the Council should consider whether abundance-based halibut PSC limits minimize halibut PSC to the extent practicable in consideration of the regulatory and operational management measures currently available to the groundfish fleet, and the need to ensure that catch in the trawl and non-trawl fisheries contributes to the achievement of optimum yield in the groundfish fisheries. Minimizing halibut PSC to the extent practicable is necessary to maintain a healthy marine ecosystem, ensure long-term conservation and abundance of the halibut stock, provide optimum benefit to fishermen, communities, and U.S. consumers that depend on both halibut and groundfish resources, and comply with the MSA and other applicable Federal law.

Consistent with the Council's purpose and need statement, abundance-based halibut PSC limits may provide harvest opportunities in the Area 4 commercial halibut fishery that meet IPHC and Council management objectives, particularly at low levels of halibut abundance. This would be consistent with the Council's objective to provide for directed halibut fishing operations and IPHC's objective to preserve the halibut fishery. If halibut PSC is reduced relative to the status quo, benefits to BSAI directed halibut fisheries could result from PSC reductions of halibut that are over 26 inches in length (O26). These O26 halibut could be available to the commercial halibut fishery in the area the PSC reductions occurred, in the year following the PSC reductions, or when the fish reach the legal size limit for the commercial halibut fishery (greater than or equal to 32 inches in total length). Longer term benefits to the commercial halibut fisheries could accrue throughout the distribution of the halibut stock, from a reduction of halibut PSC from fish that are less than 26 inches (U26). Benefits from reduced mortality of these smaller halibut could occur both in the Bering Sea and elsewhere as these halibut migrate and recruit into the commercial halibut fisheries. At higher levels of halibut abundance, abundance-based halibut PSC limits may provide the groundfish fisheries with higher PSC limits. This would be consistent with the Council's objective to avoid constraining groundfish harvests, particularly at higher levels of abundance.

In drafting an appropriate range of alternatives to meet the purpose and need for this action as listed above, the Council should consider the relative authorities of the Council and the IPHC. The Council does not have authority to set catch limits for the commercial halibut fisheries, and halibut PSC in the groundfish fisheries is only one of the factors that affects harvest limits for the commercial halibut fisheries. Thus, **while opportunities for directed halibut fishing in the Bering Sea may be an indirect result of any action taken to establish abundance-based limits for halibut in the BSAI, it is not a direct action that can be taken by the Council.** The Council may wish to consider revising its purpose and need statement to be consistent with the Council's authority and clarify that its proposed action could provide an opportunity for the directed halibut fishery, and could protect the halibut spawning stock biomass. The Council is expected to begin drafting alternatives for analysis at this meeting. **The range of alternatives for analysis should be consistent with the purpose and need for this action.**

3 Indices of Halibut Abundance

The Council is considering a PSC management approach for the BSAI groundfish fisheries that would index the annual PSC limit to a specific measure of halibut abundance defined by the Council. This would be similar to the Council's annual process for establishing groundfish harvest specifications based on the most recent groundfish survey and stock assessment data. In an abundance-based halibut PSC management program, the Council could use empirical observations of the identified measure of halibut abundance from the current year or recent years as indices to set PSC limits for the following fishing season. The Council directed staff to limit the set of abundance indices for initial development to those which reflect 1) halibut abundance in the Bering Sea, and 2) halibut encountered by the groundfish fishery in the Bering Sea.

All available data to develop a halibut abundance index consistent with the Council's direction included fishery independent information (surveys) and fishery dependent information (observer data and groundfish fishery catch data). Multiple data sources were considered in order to derive a comprehensive estimate of abundance for Bering Sea Pacific halibut:

- AFSC EBS shelf bottom trawl survey
- AFSC EBS slope bottom trawl survey
- AFSC AI bottom trawl survey
- AFSC GOA bottom trawl survey
- AFSC BS and AI longline surveys
- IPHC coastwide setline survey
- IPHC coastwide assessment results
- AFSC observer data
- BSAI commercial groundfish catch data

These data sources cover the period from 1997 through 2016, but some surveys are conducted every other year. For example, in odd years, the AFSC GOA bottom trawl and AFSC BS and in even years, the AI bottom trawl survey is conducted. A similar alternating pattern occurs for the AFSC longline survey between the EBS and AI.

The quantity and quality of data on halibut varies among the surveys. The IPHC coastwide setline survey is the most comprehensive survey data source for halibut among the list of available data sources because it specifically targets halibut to provide data for the annual halibut stock assessment. However, data from the IPHC setline survey cannot be used to estimate abundance of the total halibut population because the survey does not provide data on the component of the halibut population that is not available to the longline gear used in the survey (and similar to what is used in the directed halibut fishery) and that is smaller than the size of halibut that would be available for harvest in the directed halibut fishery in the next year (26 inches or 66 cm). These smaller and younger halibut are caught in trawl gear, however, and data from the trawl surveys provides data that could potentially be used to estimate the abundance of this segment of the halibut population that is not selected by the IPHC setline survey.

Data from each survey can be used to evaluate whether it would be an appropriate index of halibut abundance and/or an appropriate index of halibut encountered in the groundfish fisheries in the Bering Sea. The IPHC setline survey and stock assessment and several of the trawl surveys produce estimates of halibut abundance in biomass and numbers of fish for the survey area. Several surveys also have sufficient halibut catch to produce catch per unit effort and size composition data. These data can be compared to comparable information from the directed halibut and groundfish fisheries to provide a comprehensive evaluation of available data to determine whether the data can provide an appropriate index of halibut that meets the Council's objectives. The following sections discuss the available data/indices in more detail and organizes them by primary and secondary fishery independent indices as well as fishery dependent data sources.

3.1 Primary Fishery independent indices

Fishery independent data on halibut in the eastern Bering Sea is extensive. Annual bottom trawl surveys are used reasonably successfully to index abundances of 22 groundfish stocks and 6 crab stocks. As such, it should provide reasonable information on some components of halibut living in the Bering Sea.

3.1.1 AFSC EBS shelf bottom trawl surveys

The National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (AFSC) has conducted the eastern Bering Sea shelf bottom trawl survey (EBS shelf survey) annually since 1982 (using standardized protocols). The AFSC designed the EBS shelf survey to describe the composition, distribution and abundance of demersal fish, shellfish and principle epibenthic invertebrate resources of the eastern Bering Sea. The continental shelf area of the eastern Bering Sea has proven to be one of the most productive fishing areas in the world in terms of both species abundance and commercial value.

Results of the EBS shelf survey are necessary for up-to-date estimates of biomass, abundance and population structure of groundfish populations in support of stock assessment and ecosystem forecast models that form the basis for groundfish and crab harvest advice. Additional data collected on the survey are used to improve understanding of life history of the fish and invertebrate species and the ecological and physical factors affecting their distribution and abundance. The EBS shelf survey provide fisheries independent population trends that are invaluable for stock assessments and the development of management strategies for commercially exploited fish and invertebrate species in the Bering Sea. The EBS shelf survey is generally described in a NOAA Technical Memo (Stauffer, 2004)

The main objective of AFSC groundfish trawl surveys is to collect fishery-independent data. The data are used to describe:

- temporal distribution and abundance of the commercially and ecologically important groundfish species.
- changes in the species composition and size and age compositions of species over time and space.
- reproductive biology and food habits of the groundfish community.
- the physical environment of the groundfish habitat.

The primary biological data include relative abundance (catch per unit effort) and size and age compositions of major species including walleye pollock, Pacific cod, yellowfin sole, northern rock sole, red king crab, and snow and tanner crabs. The EBS shelf survey also captures halibut.

The stratified random design of the EBS shelf survey consists of a grid with stations placed at the center of each 20 × 20 nautical square miles (Figure 16). Beginning in 1982, the same 356 stations were sampled annually. The AFSC added 20 stations to the northwest sector in 1987, resulting in a total of 376 stations.

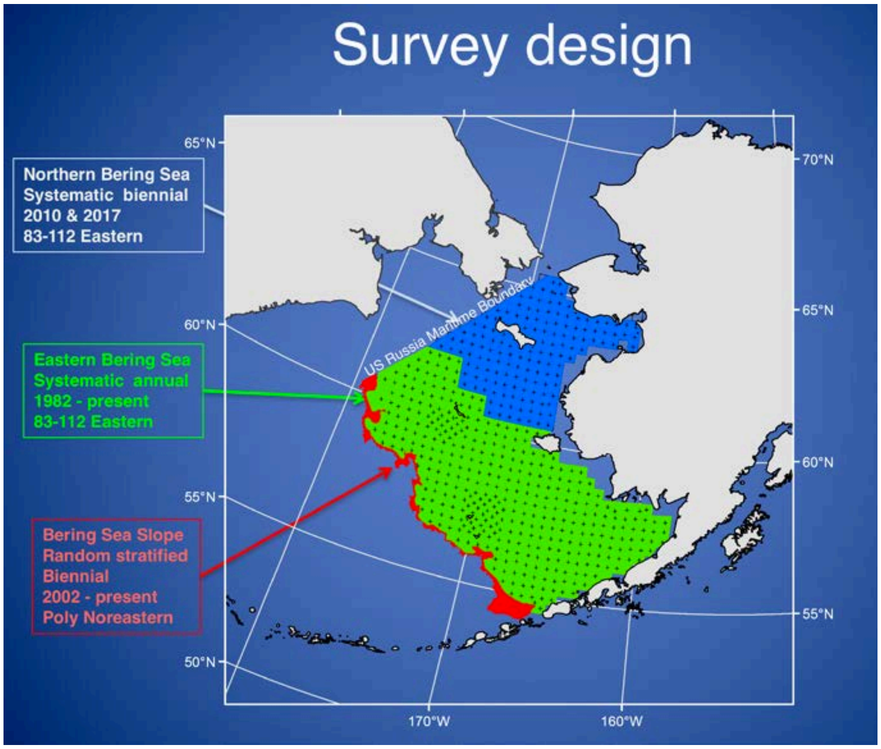

Figure 16. Layout of NMFS trawl survey designs (Source: Bob Lauth, AFSC).

The bottom trawl gear and trawling protocols used in AFSC surveys are described in Stauffer (2004). Samples obtained from the survey's standard 30-min tow range in weight from 30 to 17,800 kg (median = 1,167 kg). The time available to process this volume of catch is approximately equal to the time required for the vessel to traverse the 20 nautical miles to the next towing site (approx. 2 hours). Catches weighing 1,200 kg or less by visual estimate are lifted by crane from the trawl deck to a sorting table, where the catch is sorted and enumerated in its entirety. Catches from these tows are processed completely. However, roughly half of all EBS tows exceed the limits of the sorting table and must be subsampled. This is accomplished by lifting the whole catch off the deck, obtaining its weight with a load cell, and emptying it into a large bin containing a brailing net. The catch is subsampled by lifting the contents of the brailing net to a sorting table. The catch from the sorting table is weighed and enumerated by species, and weights and numbers are extrapolated to the total catch based on weight. The remaining catch on deck is sifted or "whole-hauled" for Pacific halibut (*Hippoglossus stenolepis*) and commercial crabs (*Lithodes* spp., *Paralithodes* spp., *Chionoecetes* spp.) and, in more recent years, other large-bodied species including Greenland turbot (*Reinhardtius hippoglossoides*), Pacific cod (*Gadus macrocephalus*), skates (*Raja* spp., *Bathyraja* spp.) and some species of sculpins (*Hemitripterus bolini*, *Hemilepidotus* spp., *Myoxocephalus* spp.).

Catches larger than the lifting capacity of the crane (approx. 5 metric tons) are emptied on deck and measured volumetrically using a density coefficient applied to calculate total catch weight. Once the weight of these very large catches (approx. 1.5% of all catches) is estimated, a sample is brought to the table for sorting and enumeration, and then extrapolated to the total catch. Whole-hauling occurs for the species mentioned above even on these large catches.

The AFSC developed trawl efficiency and enumeration confidence matrices for both fishes and invertebrates collected during the EBS shelf survey from 1982 through 2014. The trawl efficiency index scores, provided for each taxon code appearing in the survey database, are subjective, but were influenced by the results from several catch efficiency field experiments using NMFS trawl gear (e.g., Weinberg and Munro 1999, Munro and Somerton, 2001, Somerton and Munro, 2001, Weinberg et al. 2002, Kotwicki and Weinberg 2005, Somerton et al. 2007; Weinberg et al. 2016). The efficiency index for Pacific halibut received the highest score, indicating that the AFSC believes the Pacific halibut CPUE calculated from the EBS shelf survey is an accurate and consistent indicator of relative animal density. Pacific halibut also received the highest score for confidence in the enumeration of weight and counts from the EBS shelf survey. A detailed description of the efficiency and enumeration confidence indices is provided in a 2016 NOAA Technical Memo.

The IPHC has deployed a biologist on the EBS shelf survey every year since 1998 to collect halibut samples. The IPHC participates in the EBS shelf survey to gather information collected in its coastwide setline survey. The setline survey is the primary fishery-independent source of data for the halibut stock assessment (Henry et al. 2015). However, Pacific halibut occupy a vast area of the Bering Sea shelf for which the IPHC lacks the financial resources to sample in its entirety. And as described above, the fishing gear used in the coastwide setline survey data generally catches halibut that are over 26 inches in length (O26) and available for harvest in the directed commercial fishery. Therefore, in most years, the EBS shelf survey is the only measure of relative abundance of smaller sizes of halibut (under 26 inches in length or U26) for much of this area. The halibut data collection (including ages) and treatment of information collected by the IPHC during the EBS shelf survey is described and the results are reported in the IPHC Report of Assessment and Research Activities 2016 (IPHC-2016-RARA-26-R).

The EBS shelf survey has different size-selectivity than setline gear, making it necessary to apply a calibration to the EBS shelf survey based on relative selectivity in the two surveys to include these data directly in the IPHC halibut stock assessment. In 2006, the IPHC added shelf stations to its setline survey in the Bering Sea region in order to compare information from setline stations in that area with data collected on the EBS shelf survey. After the study, the IPHC concluded that the EBS shelf survey, along with periodic IPHC survey calibrations, provided an adequate accounting of Pacific halibut biomass on the EBS shelf (Clark and Hare 2007) and is a useful tool for constructing a population-density index for the IPHC stock assessment (Webster 2014). The 2006 study was repeated in 2015 and confirmed the earlier finding (IPHC-2016-RARA-26-R). **Based on this information, the EBS shelf survey would be an appropriate index of halibut abundance in the Bering Sea**.

The IPHC estimate of total Pacific halibut abundance in the EBS using the shelf bottom trawl survey catches in 2016 was 66 million halibut, slightly higher than in 2015. As shown in Figure 17, estimated abundance declined by 4% to 22% annually beginning in 2006 from a high of 133.4 million halibut. However, since 2013, abundance has been fairly stable. In contrast, biomass estimates were down in 2016 with a total of 338.8 million pounds (153,677 t) compared to 380 million pounds (172,365 t) in 2015.

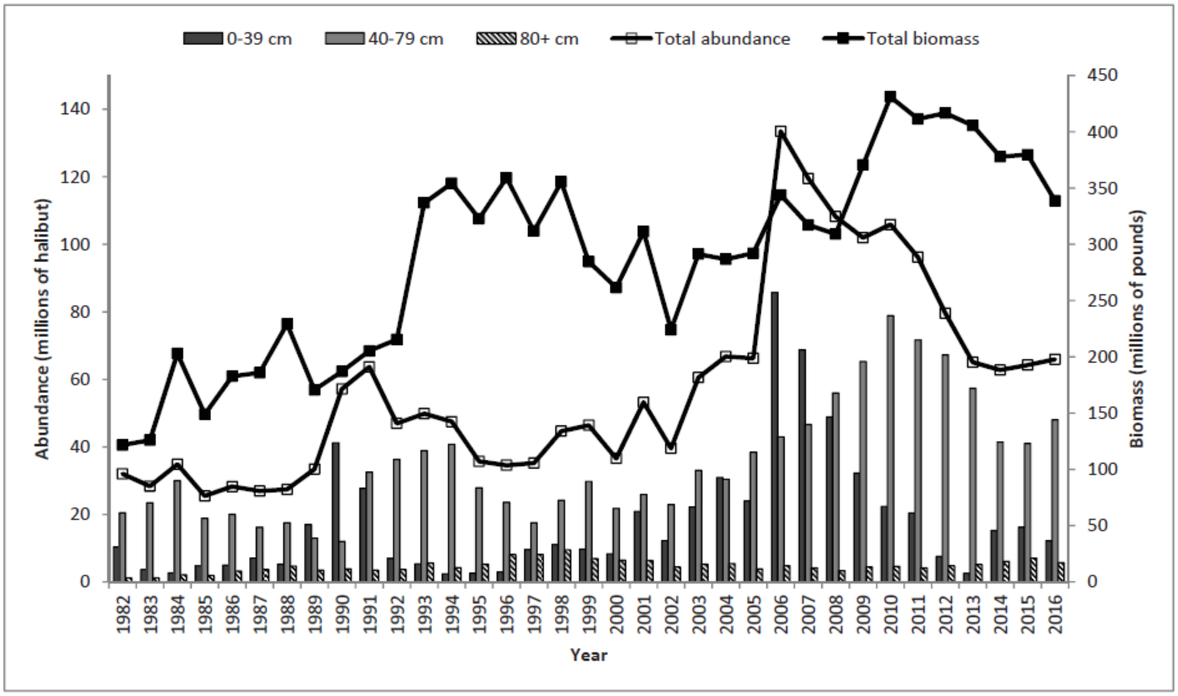

Figure 17. Estimated abundance (numbers of Pacific halibut) by length category, total biomass (pounds) as estimated by the NMFS Bering Sea Trawl survey data, 1982-2016. Source: 2016 IPHC RARA.

Data availability

The EBS shelf survey is conducted annually. The data from the survey is available each year in the fall and is used to prepare groundfish stock assessments. Therefore, the most recent EBS shelf survey data would be available for use as an index for the annual BSAI groundfish harvest specifications process in which the halibut PSC limits are established.

Segment of halibut population represented by the index

Size and age data from halibut caught on the EBS shelf survey provides information on the segment of the halibut population that would be represented if the survey is used as an index of halibut abundance. Most Pacific halibut caught on the EBS shelf survey range in size from about 20 cm to 100 cm (7.9 in to 39.4 in) fork length as shown in Figure 17. Table 5 shows that in 2015, ages for sampled halibut ranged from 2 to 20 years. The shaded cells in the table highlight the ages composing the largest proportion of sampled catch. In 2015, 60% of sampled halibut were ages 3 through 5 with a mean fork length of 37 to 46.3 cm (14.6 to 18.2 in). The 4-year-olds (2011 year class) made up the largest portion of the sample, at 33% of the total aged. The 7-year-olds (2008 year class), which were dominant in the 2014 sample, comprised only about 6% of the sample in 2015. Fish from the older year classes have grown to a size where they are largely capable of avoiding survey trawl gear, which likely influences catches of these fish in the EBS shelf survey (Clark et al. 1997) and relatively few halibut larger than 126 cm (50 inches) in length are caught in the survey.

Table 5. Pacific halibut mean length (cm) and age (years) composition from sampled fish for the 2015 NMFS Bering Sea trawl survey standard grid. Source: IPHC-2016-RARA-26-R.

Age (years)	Mean fork length (cm)	Std. dev. of fork length	No. of fish aged	Year class
2	28.2	2.95	9	2013
3	37.0	4.05	75	2012
4	39.9	3.95	174	2011
5	46.3	4.88	67	2010
6	53.4	5.18	25	2009
7	59.6	6.44	33	2008
8	64.2	6.59	17	2007
9	68.2	7.39	26	2006
10	73.9	8.64	23	2005
11	76.2	8.63	32	2004
12	81.7	13.51	28	2003
13	73.5	8.02	6	2002
14	78.3	8.14	4	2001
15	82.0	9.03	5	2000
16	86.5	9.19	2	1999
17	101.0	22.65	3	1998
18	86.0	n/a	1	1997
20	102.0	14.14	2	1995
Total	51.8	17.46	532	

Table 6 presents information on the size composition of halibut for the surveys identified as potential halibut abundance indices and for the directed halibut and groundfish fisheries in the Bering Sea from 2008 through 2016 and these data are also summarized by mean length in Figure 18.

Table 6 presents the proportion of total halibut catch by four size categories for each year from 2008 through 2016 and an average over that period to provide a basis for comparison of encounters by size among the surveys and fisheries. The size categories correspond roughly with <13 inches (<33 cm), 13 to 26 inches (33 to 65 cm), 26 to 32 inches (66 to 80 cm), and >32 inches (>81 cm). These size categories were selected to separate halibut under 26 inches and over 26 inches in length because that is the delineation the IPHC uses to distinguish halibut that are not available to the directed fishery (U26) from halibut 26 inches and greater in length that are available to the directed fishery (O26).

Table 6 shows that on average, 80% of halibut sampled from the EBS shelf survey catch from 2008 through 2016 were U26. In all years from 2008 through 2016, halibut in the 33 to 65 cm (13 to 26 in) size category were the largest component of total halibut catch in the EBS shelf survey, averaging 69% of total catch. This indicates that the largest proportion of halibut catch in the EBS shelf survey is composed of U26 fish that likely would grow to O26 in the next 1-4 years. The proportion of very small fish (<33 cm or 13 inches) caught in the EBS shelf survey ranged from a low of 3% to a high of 33% from 2008 through 2016 and averaged 11% of total halibut catch from 2008 through 2016. The proportion of O26 halibut in the 66 to 80 cm (26 to 32 inches) category varied from a low of 6% to a high of 22% and averaged 14% of total halibut catch from 2008 through 2016. Table 6 shows that relatively few halibut larger than 81 cm (32 inches) are caught in the EBS shelf survey. The proportion of these larger halibut caught in the survey ranged from 3% to 10% and averaged 6% of total halibut catch from 2008 through 2016.

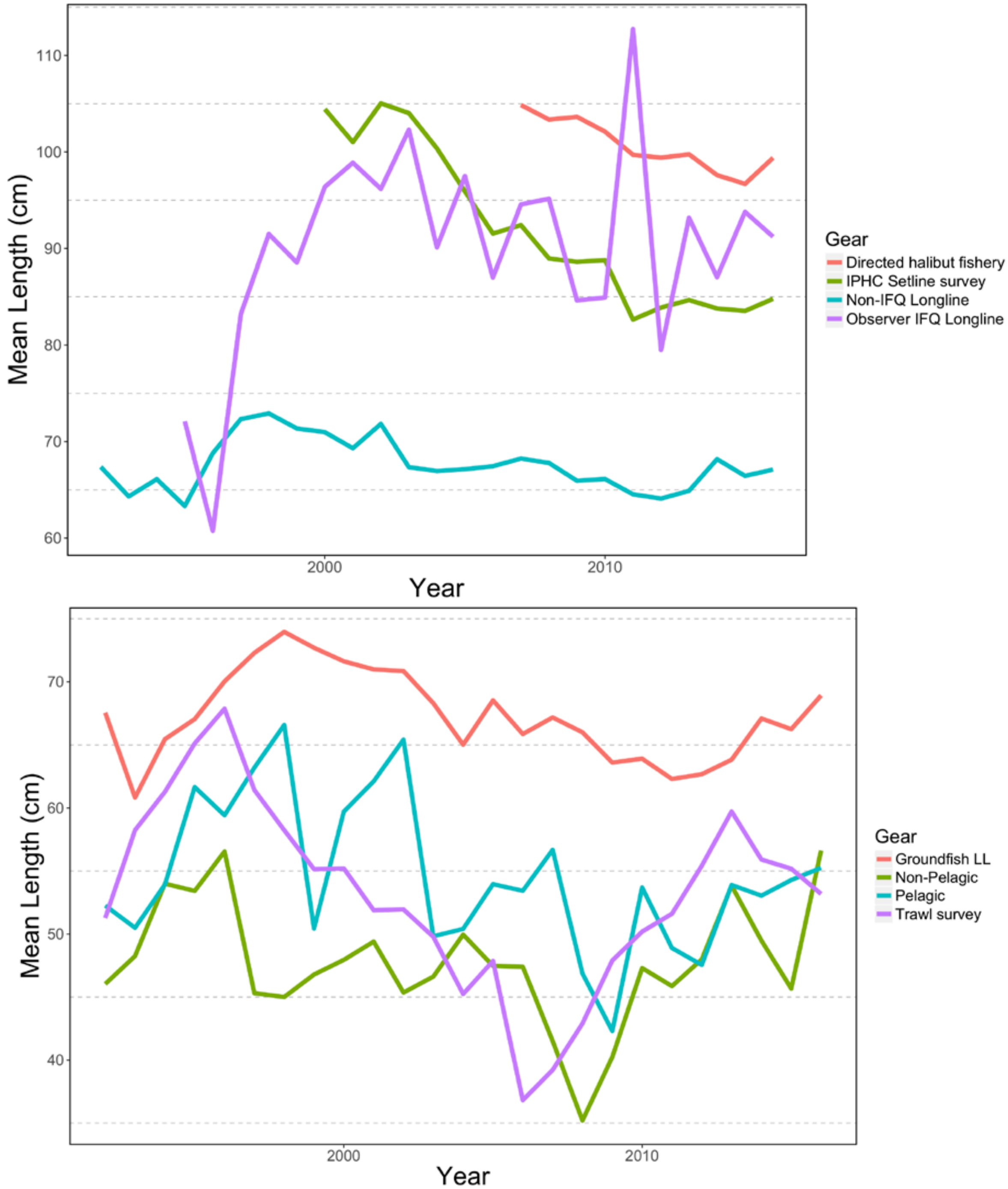

Figure 18. Mean length (cm) of BSAI Pacific halibut by principal survey and fishery gear types, 1992-2016. The directed halibut fishery and setline survey are for areas 4CDE along with NMFS observer data on IFQ and non-IFQ fisheries (top panel) while the bottom panel shows the EBS trawl survey compared to the mean Pacific halibut length observed in NPFMC groundfish fisheries by gear.

Table 6. Proportion of Pacific halibut **catch** (or abundance for surveys) by size categories (in cm, corresponding roughly with <13 inches, 13-26 inches, 26-32 inches, and >32 inches) for NPFMC groundfish fisheries, the directed longline fishery (from IPHC areas 4cde combined), selected AFSC trawl surveys, and the IPHC setline survey, 2008-2016. "NA" means no survey conducted in that year.

Length		2008	2009	2010	2011	2012	2013	2014	2015	2016	mean
EBS Shelf Trawl Survey											
<33cm	<13 in	33%	13%	9%	9%	3%	3%	16%	4%	13%	11%
33-65cm	13-26 in	58%	75%	78%	77%	77%	70%	52%	66%	65%	69%
	Total U26	91%	88%	87%	86%	80%	73%	68%	70%	78%	80%
66-80cm	26-32 in	6%	8%	9%	10%	15%	20%	22%	20%	14%	14%
>81cm	>32 in	3%	4%	4%	4%	5%	7%	9%	10%	8%	6%
	Total O26	9%	12%	13%	14%	20%	27%	31%	30%	22%	20%
IPHC Setline Survey											
<33cm	<13 in	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
33-65cm	13-26 in	7%	9%	11%	15%	13%	12%	11%	9%	6%	10%
	Total U26	7%	9%	11%	15%	13%	12%	11%	9%	6%	10%
66-80cm	26-32 in	30%	27%	27%	36%	36%	37%	38%	41%	42%	35%
>81cm	>32 in	63%	63%	62%	48%	51%	51%	51%	50%	52%	55%
	Total O26	93%	90%	89%	84%	87%	88%	89%	91%	94%	89%
EBS Slope Trawl Survey											
<33cm	<13 in	0%	NA	0%	NA	0%	NA	NA	NA	0%	0%
33-65cm	13-26 in	10%	NA	19%	NA	15%	NA	NA	NA	12%	14%
	Total U26	10%		19%		15%				12%	14%
66-80cm	26-32 in	35%	NA	29%	NA	48%	NA	NA	NA	28%	35%
>81cm	>32 in	55%	NA	52%	NA	37%	NA	NA	NA	60%	51%
	Total O26	90%		81%		85%				88%	86%
Aleutian Islands Trawl Survey											
<33cm	<13 in	NA	NA	0%	NA	0%	NA	0%	NA	0%	0%
33-65cm	13-26 in	NA	NA	69%	NA	82%	NA	62%	NA	51%	66%
	Total U26			69%		82%		62%		51%	66%
66-80cm	26-32 in	NA	NA	19%	NA	15%	NA	30%	NA	38%	26%
>81cm	>32 in	NA	NA	12%	NA	4%	NA	9%	NA	10%	9%
	Total O26			31%		19%		39%		48%	34%
Directed Halibut Fishery											
<65cm	Total U26	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
66-80cm	26-32 in	2%	2%	2%	2%	2%	3%	5%	5%	2%	3%
>81cm	>32 in	98%	98%	98%	98%	98%	97%	95%	95%	98%	97%
	Total O26	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Observer IFQ Longline											
<33cm	<13 in						0%	0%	0%	0%	0%
33-65cm	13-26 in						5%	5%	4%	5%	6%
	Total U26						5%	5%	4%	5%	6%
66-80cm	26-32 in						19%	36%	21%	26%	24%
>81cm	>32 in						76%	59%	76%	69%	70%
	Total O26						95%	95%	97%	95%	94%
Groundfish Non-Pelagic Trawl Fisheries											
<33cm	<13 in	63%	18%	9%	24%	7%	9%	18%	5%	3%	17%
33-65cm	13-26 in	34%	78%	83%	65%	80%	69%	63%	85%	72%	70%
	Total U26	97%	96%	92%	89%	87%	78%	81%	90%	75%	87%
66-80cm	26-32 in	2%	3%	6%	8%	10%	18%	16%	8%	20%	10%
>81cm	>32 in	1%	2%	2%	3%	2%	5%	4%	2%	6%	3%
	Total O26	3%	5%	8%	11%	12%	23%	20%	10%	26%	13%
Groundfish Pelagic Trawl Fisheries											
<33cm	<13 in	13%	7%	1%	8%	1%	0%	10%	3%	1%	5%
33-65cm	13-26 in	75%	90%	85%	81%	95%	84%	66%	66%	81%	80%
	Total U26	88%	97%	86%	89%	96%	84%	76%	69%	82%	85%
66-80cm	26-32 in	8%	2%	10%	10%	4%	13%	21%	23%	13%	12%
>81cm	>32 in	4%	1%	4%	2%	0%	2%	3%	8%	5%	3%
	Total O26	12%	3%	14%	12%	4%	15%	24%	31%	18%	15%
Groundfish Longline Fisheries											
<33cm	<13 in	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
33-65cm	13-26 in	52%	62%	60%	65%	64%	61%	50%	55%	47%	57%
	Total U26	52%	62%	60%	65%	64%	61%	50%	55%	47%	57%
66-80cm	26-32 in	37%	29%	33%	28%	31%	32%	38%	31%	32%	32%
>81cm	>32 in	11%	9%	8%	6%	5%	6%	13%	13%	21%	10%
	Total O26	48%	38%	41%	34%	36%	38%	51%	44%	53%	43%

Segment of index population encountered in directed halibut and groundfish fisheries

The size composition data for halibut caught on the EBS shelf survey can be compared with data on halibut caught in the directed halibut and groundfish fisheries in the Bering Sea to determine the segment of the index population that is encountered in the fisheries.

Directed halibut fishery – The Council specified that it is prioritizing development of abundances indices that represent halibut encountered by the groundfish fisheries in the Bering Sea at this stage of development of an ABM program. However, because the directed halibut fishery would also be impacted by the action under consideration, the Council requested information on the segment of the halibut population represented by each candidate index (index population) that would be encountered in the directed halibut fishery. Table 6 presents size composition data for the directed halibut fishery from two sources. The first source of size data are from IPHC samples of halibut collected at the time of a directed halibut fishery landing (labeled "Directed halibut fishery" in Table 6). Consistent with the minimum size regulation for the fishery, the size composition data from the directed fishery shows that 100% of landed halibut were O26 from 2008 through 2016. The second source of size data for the directed halibut fishery are NMFS observer data from longline vessels during IFQ (halibut and sablefish) fishing trips (labeled "Observer IFQ longline" in Table 6). NMFS observer data do not distinguish halibut and sablefish IFQ trips for purposes of data collection. It may be possible to identify predominantly halibut IFQ operations from the data, but this would take a substantial amount of analyst time and would not result in complete separation of halibut and sablefish trips because regulations require retention of legal size halibut and sablefish if anyone on board the vessel holds sufficient IFQ. For purposes of this analysis, the observer data from longline vessels during IFQ fishing trips are the best available information on the typical size compositions encountered in the directed halibut fishery since observer sampling is at sea rather than in port at the time of landing. The analysts will work with NMFS to identify predominantly halibut IFQ operations in the observer data for the analysis of the proposed ABM action.

Table 6 shows that on average, 96% of halibut catch longline vessels in the IFQ fisheries were O26 from 2013 through 2016. The data shows that 26% of catch is from 26 to 32 in (33 to 65 cm) in length and 70% of the catch is greater than 32 inches (81 cm) in length. As described in the previous section, the size composition data for the EBS shelf survey shows that it would be primarily be an index of U26 halibut. From 2008 through 2016, 80% of halibut catch in the survey was U26 and 20% was O26, suggesting that there is limited overlap between the EBS shelf survey index population segment and the population segment encountered by the directed halibut fishery. Figure 19 demonstrate the lack of overlap between sizes of halibut encountered in the EBS shelf survey and the directed halibut fishery. The figures show that length distribution of halibut for the survey does not track well with that from the IFQ observer data. **Based on the available size composition information, the EBS shelf survey would be inappropriate as an index of halibut encountered by the directed halibut fishery in the Bering Sea as that survey tracks smaller and younger halibut.**

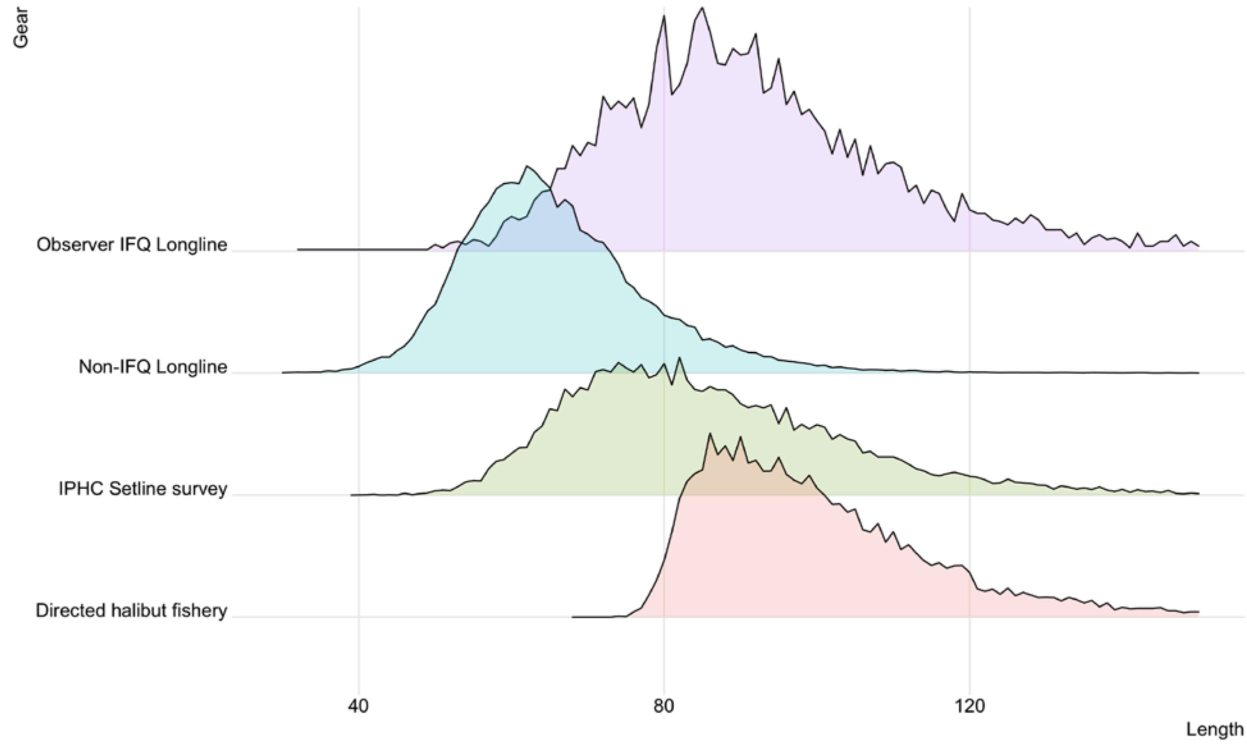

Figure 19. Aggregate 2008-2016 length frequencies for BSAI Pacific halibut for NMFS observer longline data (IFQ and non-IFQ longline) compared to the IPHC setline survey and directed halibut fishery (port samples).

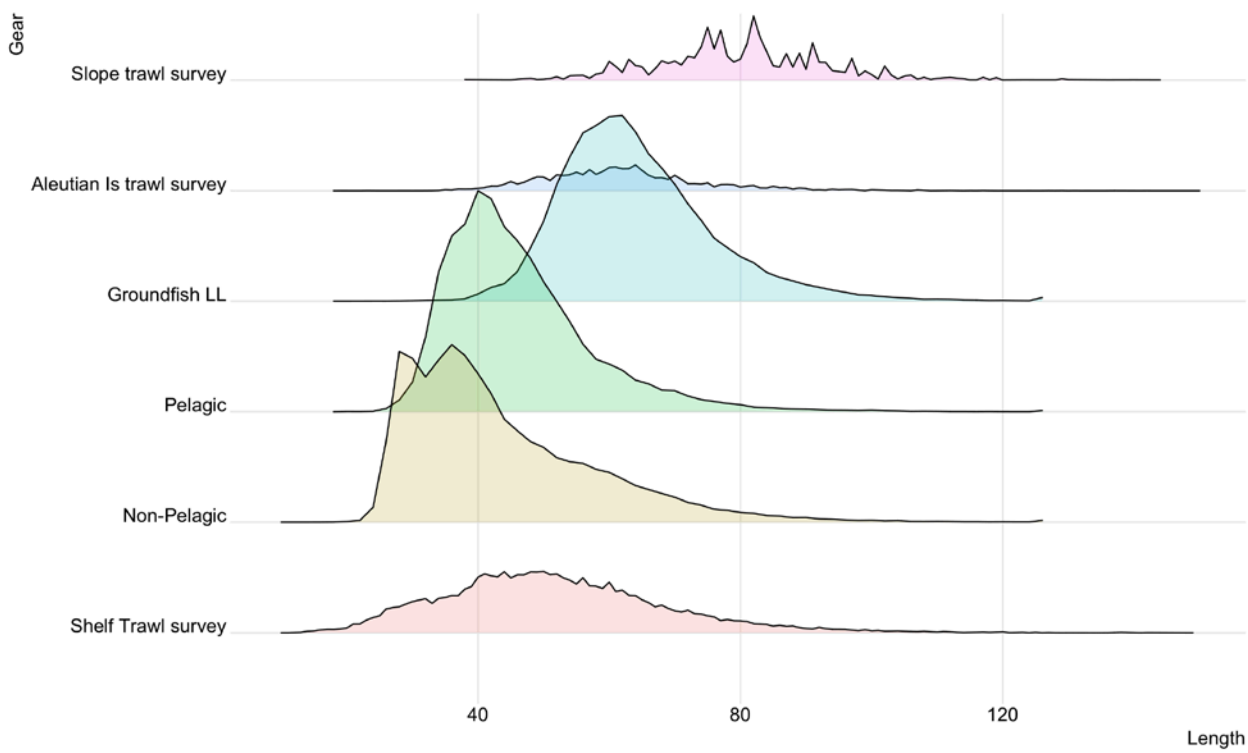

Figure 20. Aggregate length frequencies for BSAI Pacific halibut comparing trawl survey length frequencies with BSAI groundfish pelagic and non-pelagic trawl and longline fisheries, 2008-2016.

Trawl groundfish fisheries - Table 6 and Figure 20 demonstrate the overlap between sizes of halibut caught in the EBS shelf survey and the non-pelagic trawl groundfish fisheries. In terms of length distribution, the vast majority of halibut caught in the EBS shelf survey and in the non-pelagic and pelagic trawl groundfish fisheries in the BSAI ranged from 20 cm to 100 cm (7.9 in to 39.4 in) fork length.

A slightly larger proportion of U26 halibut is caught in the non-pelagic and pelagic trawl groundfish fisheries than in the EBS shelf survey. From 2008 through 2016, 80% of halibut caught on the EBS shelf survey was U26 and 20% was O26. During the same period, 87% of halibut caught in the non-pelagic trawl groundfish fisheries was U26 and 13% was O26.[8] For the pelagic trawl groundfish fisheries, 85% of halibut caught was U26 and 15% was O26 from 2008 through 2016.

The complete time series of EBS shelf survey data shows considerable variability in the average weight in the survey, which is somewhat consistent with what has been observed in the fisheries (including foreign and joint venture period from 1982 onwards; Figure 21). The time series of survey data shows a stable and increasing overall biomass whereas the relative abundance (in numbers of fish, scaled to have mean value of 1.0) showed a showed a sharp increase in 2006 followed by a subsequent decline back to the mean value (Figure 22).

The available size composition and average weight information suggest that it would be appropriate to use the EBS shelf survey as an index of halibut encountered by the trawl groundfish fisheries in the Bering Sea.

Longline groundfish fisheries - Table 6 and Figure 20 show that the segment of the population represented by the EBS shelf survey also matches up well with the segment of the population encountered by the longline groundfish fisheries in the Bering Sea in terms of the distribution of halibut lengths caught. Although the EBS shelf survey catches a larger proportion of very small halibut (<13 inches or <33 cm) than the longline groundfish fisheries, the largest proportion of halibut caught consistently from 2008 through 2016 in both the survey and the fishery are in the 13 to 26 inches (33 to 65 cm) size category (69% in the EBS shelf survey and 57% in the longline groundfish fisheries).

A smaller proportion of U26 halibut are caught in the longline groundfish fisheries than in the EBS shelf survey. This reflects the selectivity of longline fishing gear for larger halibut compared to trawl gear. From 2008 through 2016, 80% of halibut caught on the EBS shelf survey was U26 and 20% was O26. During the same period, 57% of halibut caught in the longline groundfish fisheries was U26 and 43% was O26. Unlike the halibut catches in the EBS shelf survey and the trawl groundfish fisheries, the longline groundfish fisheries catch essentially no halibut <13 inches or <33 cm. Overall, however, the differences in proportions of halibut catch by the designated size categories are anticipated given the differences in selectivity between longline and trawl gear. Figure 20 further demonstrates the overlap between sizes of halibut encountered in the EBS shelf survey and the directed halibut fishery. The figures show that the mean length of halibut for the survey does not track well with that from the IFQ observer data.

The available size composition information suggests that it would be appropriate to use the EBS shelf survey as an index of halibut encountered by the longline groundfish fisheries in the Bering Sea.

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[8] The halibut catch data for the non-pelagic trawl groundfish fisheries shows a significant increase in the proportion of halibut <13 inches in 2008, the first year of the Amendment 80 Program. In 2008, halibut <13 inches composed 63% of the halibut caught in the non-pelagic trawl fisheries. This compares to an average proportion of 9% of halibut <13 inches for all other years of available data.

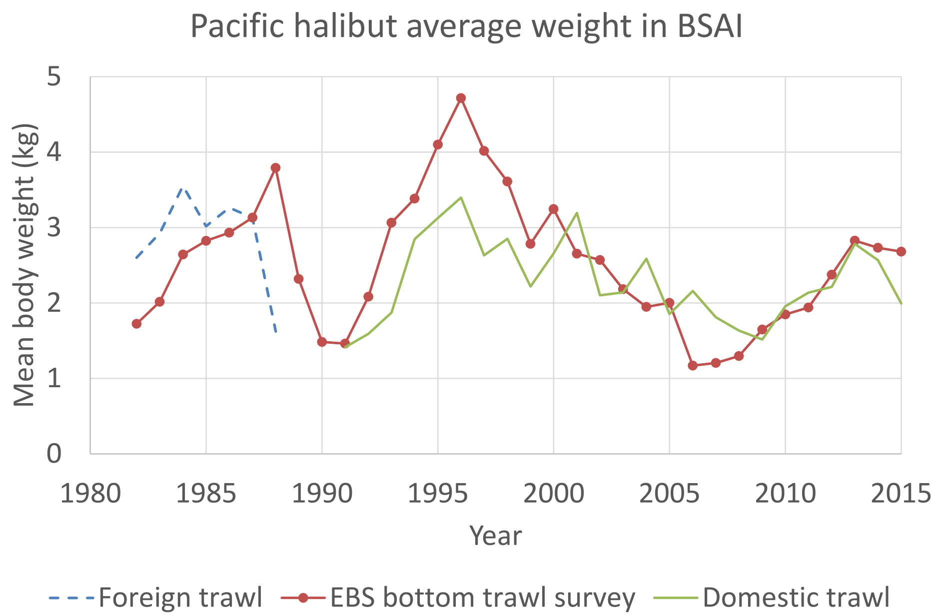

Figure 21. Estimated average weights in the fishery and bottom-trawl survey, 1982-2015. The correlation between the EBS bottom trawl survey and the Pacific halibut PSC domestic trawl fisheries is 0.78.

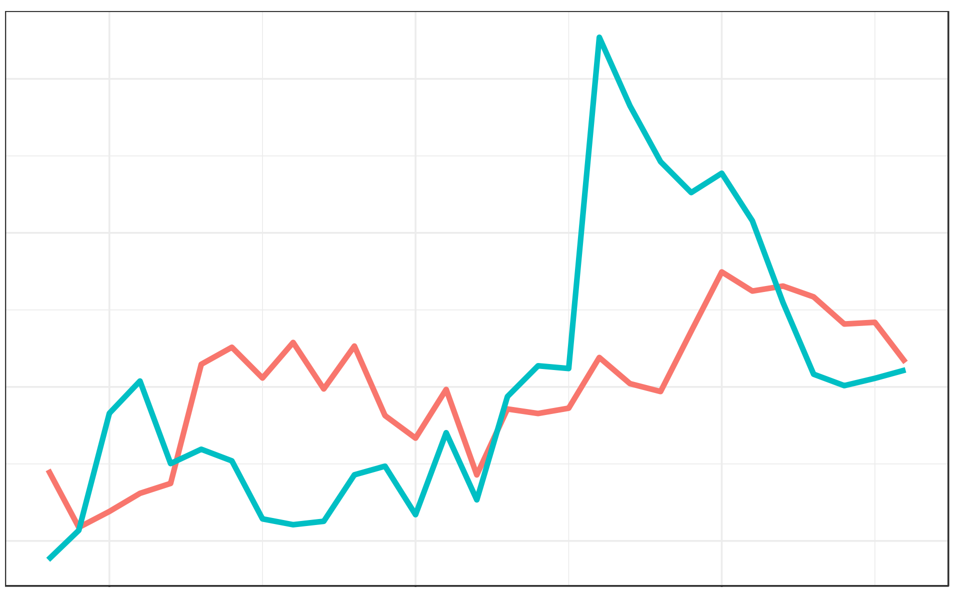

Figure 22. Biomass and relative abundance (in numbers) of Pacific halibut from the EBS bottom trawl survey, 1988-2016.

3.1.2 IPHC Standardized Coastwide Stock Assessment (SSA) Survey or Setline Survey

The IPHC's annual standardized stock assessment (SSA) survey (referred to as the setline survey in this document) is the most important and comprehensive data input to the annual Pacific halibut stock assessment. The main priority of the setline survey is to measure catch rates and biological information for Pacific halibut, but many other projects are included such as tagging of halibut, collection of environmental data, collecting data from other species, and recording observations of seabirds.

The survey typically charters 12 to 14 fishing vessels during the summer months to survey more than 1300 stations on a 10nm by 10nm grid in nearshore and offshore waters of southern Oregon, Washington, British Columbia, southeast Alaska, the central and western Gulf of Alaska, Aleutian Islands, and northern Bering Sea (Henry et al 2017). Depths surveyed typically range from 20–275 fathoms (37–503 m), but shallower stations from 10–20 fathoms (18–37 meters) and deeper stations up to 400 fathoms (732 m) are often surveyed as part of expansion studies.

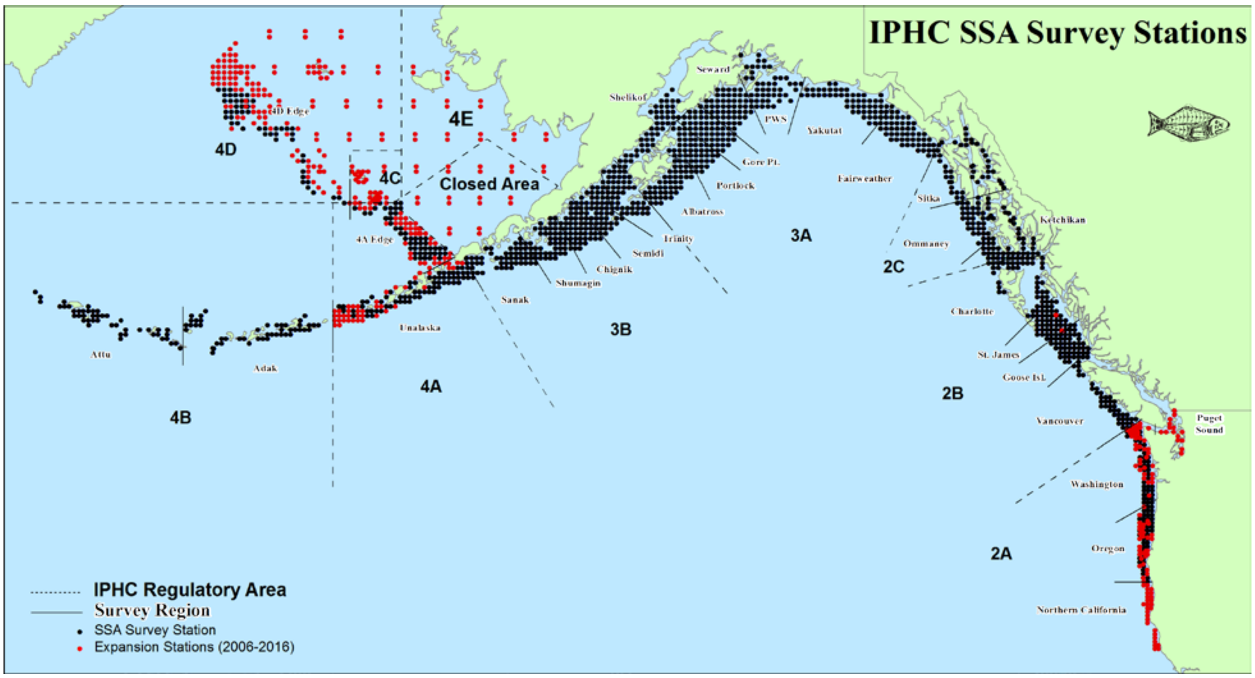

Figure 23. Standard stations (black) and expansion stations (red, 2006–2016) for the IPHC setline survey.

The standard grid of survey stations has been in place since 1998, with the addition of stations around the Pribilof and St. Matthew Islands beginning in 2006, and twelve stations in the Washington/Oregon regions beginning in 2011. Prior to 1997, the survey had less coverage, but data are available for many Regulatory Areas (Stewart & Monnahan 2016). Certain areas include expansion stations (additional stations to cover additional area) in some years to investigate catch rates outside of the normal survey area and to calibrate with other surveys (e.g., the eastern Bering Sea trawl survey).

The fishing gear used in the setline survey data generally catches halibut that are O26 and available for harvest in the directed commercial fishery. Six skates of baited gear were fished in 2016, but the number of skates may increase or decrease in each year depending on the expected encounter rate with Pacific halibut. The other specifications for gear, setting schedule, and soak time have remained consistent since 1998 (Henry et al 2017). A set is considered ineffective for stock assessment if predetermined limits for lost gear, depredation, or displacement from station coordinates are exceeded.

Pacific halibut observations are recorded by IPHC sea samplers on the vessel. The fork lengths of all Pacific halibut were recorded to the nearest centimeter. Each length was converted to an estimated weight using a standard formula (Clark 1992), and these weights were then used to generate the weight per unit effort (WPUE) data. Average WPUE, expressed as net pounds per skate, was calculated by dividing the estimated catch in pounds (net weight) of Pacific halibut equal to or over 32 inches (81.3 cm; O32 Pacific halibut) in length by the number of skates hauled for each station. The sex, state of maturity, prior hook injuries, and depredation are also recorded. Otoliths are collected from a subsample of O32 and U32 halibut. Finally, the presence and abundance of seabird species within a 50-meter radius of the vessel's stern are recorded (Geernaert 2017).

The setline survey data are analyzed to estimate the coastwide numbers-per-unit-effort (NPUE) and weight-per-unit-effort (WPUE) of halibut over 32 inches (O32) and all halibut caught (Total). In 2016, an improved approach (spatio-temporal modeling) was used to estimating density indices (Webster 2017). This space-time model improves estimation by fitting models to the data that account for spatial and temporal dependence, making use of the degree to which the halibut distribution is patchy (has regions of high and low density), and that those patches tend to persist with time. For example, if WPUE is high at a particular location it is more likely to be high at nearby locations, and at the same location in previous and subsequent years. Therefore, we not only have information about density at a location and time from a direct observation, but from other data recorded nearby in space and time. Similarly, such an approach also allows estimation of a density index at a location with no data (e.g., a location between stations, a station with an ineffective set, or a region not surveyed annually). Additionally, auxiliary information collected on the survey (such as station depth) can provide further improvements.

The IPHC annual setline survey does not include stations on the eastern Bering Sea flats, except for those around St Matthew Island and the Pribilof Islands. Instead, data from annual National Marine Fisheries Service (NMFS) trawl surveys are calibrated to the 2006 and 2015 IPHC setline surveys in the eastern Bering Sea (Webster et al. 2016). The annual NMFS trawl survey is used in conjunction with the NMFS/ADFG surveys of Norton Sound (Soong and Hamazaki 2012) to develop an estimate of the density of Pacific halibut in the Bering Sea (see Webster 2014 for details). Additionally, data from the NMFS sablefish longline survey have been used to index deep water (>275 fathoms, 503 meters) on the IPHC Regulatory Area 4D edge.

The WPUE and NPUE are standardized to account for hook competition (competition for baits among Pacific halibut and other species) and timing of the survey relative to the total harvest of Pacific halibut. The hook competition adjustment will increase the raw WPUE or NPUE at an individual station slightly with more competition (fewer baits returned) and is applied before the space-time model is used to account for variability in the standardization among stations. The standardization to account for the amount of harvest taken before the setline survey uses target harvest rates for each IPHC Regulatory Area and is done for each IPHC Regulatory Area instead of individual stations.

The space-time model provides WPUE and NPUE for each IPHC Regulatory Area, where 4CDE is combined into a single area. The IPHC Regulatory Areas can be summed together after weighting by bottom area of suitable habitat for Pacific halibut. Space-time model results of O32 WPUE for IPHC Regulatory Areas 4A, 4B, and 4CDE are shown in Table 7 and Figure 24 along with an appropriately combined O32 WPUE for all three areas (4ABCDE). The correlation between all of these index time-series is high, and we consider 4ABCDE as an index of abundance as a potential ABM index. However, the index for any of the individual areas can easily be substituted.

Table 7. IPHC setline survey O32 WPUE (standardized to the mean of each series) for the entire coast (coastwide), specific areas in IPHC Regulatory Area 4, and the sum of all areas in IPHC Regulatory Area 4 (4ABCDE).

Year	Coastwide	4A	4B	4CDE	4ABCDE
1998	1.67	2.29	2.28	1.39	2.04
1999	1.56	2.04	1.89	1.35	1.82
2000	1.57	2.04	1.70	1.40	1.79
2001	1.43	1.58	1.27	1.35	1.48
2002	1.36	1.40	0.96	1.18	1.26
2003	1.21	1.20	0.79	1.09	1.10
2004	1.14	1.02	0.71	0.98	0.97
2005	1.02	0.90	0.68	0.80	0.84
2006	0.94	0.75	0.75	0.88	0.83
2007	0.90	0.66	0.88	0.76	0.78
2008	0.81	0.72	0.91	0.77	0.82
2009	0.73	0.65	0.75	0.81	0.77
2010	0.67	0.54	0.66	0.78	0.68
2011	0.66	0.51	0.66	0.73	0.65
2012	0.72	0.51	0.55	0.77	0.64
2013	0.63	0.41	0.58	0.77	0.61
2014	0.65	0.43	0.50	0.86	0.63
2015	0.66	0.41	0.50	0.93	0.65
2016	0.69	0.38	0.49	0.92	0.63

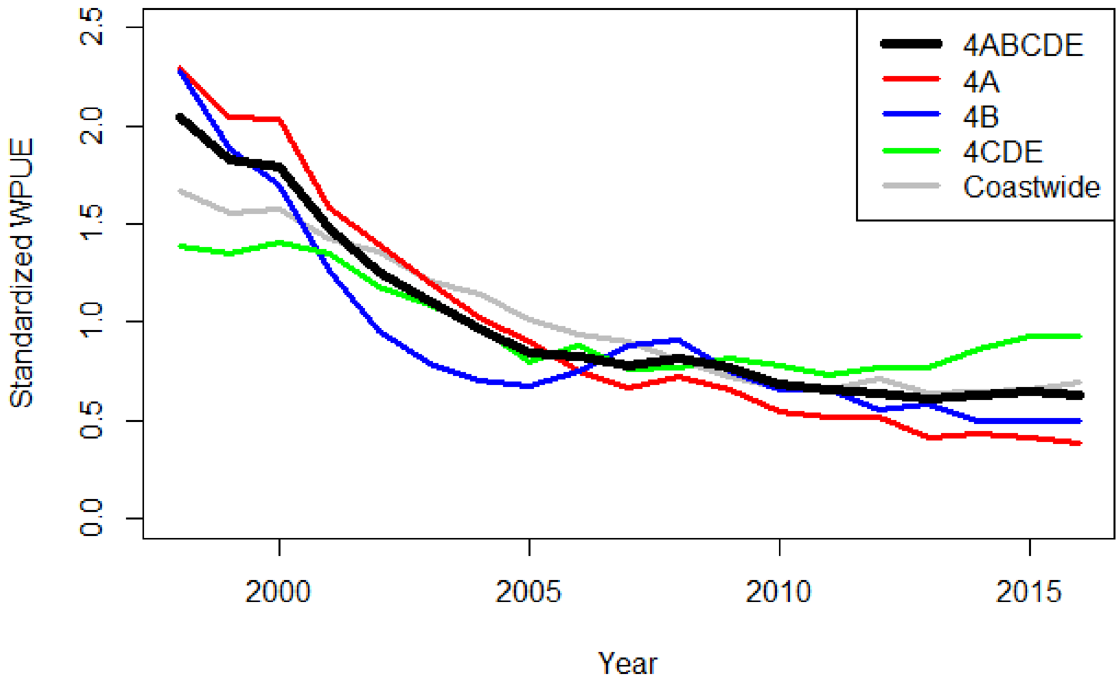

Figure 24. WPUE of O32 Pacific halibut for IPHC Regulatory Areas in Area 4 standardized to the mean of the time series for each Area. Area 4ABCDE is the sum of Areas 4A, 4B, and 4CDE, and Coastwide is all IPHC Regulatory Areas summed. Summed indices are appropriately weighted by bottom area.

Data availability

The IPHC setline survey is typically completed in late summer and preliminary results are presented at the IPHC interim meeting in late November. It is possible that some minor changes due to data quality control and data checking may occur before the IPHC Annual Meeting in January, but these are not likely to be substantial. In the past, only WPUE for O32 and NPUE to all fish (Total) has been reported, but starting in 2017, WPUE will be available for O32 and Total. Therefore, O32 WPUE is used throughout this report, although Total WPUE may also be considered when available.

Segment of halibut population index represents

The IPHC setline survey, coastwide, mostly observes Pacific halibut larger than 26 inches or 66 cm (Table 6 and Figure 19). This is similar for IPHC Regulatory Areas 4B and 4CDE (based on 2016 data), but IPHC Regulatory Area 4A observes smaller fish than those areas (Table 8). However, the proportion of catch over 32 inches (81.3 cm) by numbers and weight is similar across the three areas. Proportions of numbers-at-age show that Pacific halibut younger than age 7 are rarely caught in the IPHC setline survey, and that since 2008, ages 8–14 were seen in the highest proportion. This distribution is shifted to the right of the EBS trawl survey, indicating that the IPHC setline survey encounters fewer small fish and more large fish than the EBS trawl survey.

Even though the EBS trawl survey is used in the IPHC setline survey analysis, the EBS trawl survey is calibrated to shift its selectivity to match the IPHC setline survey (see the calibration curve, Figure 4 in Webster et al., 2016). Therefore, there is some overlap in size or age classes in the EBS trawl survey and the IPHC setline survey, which appears to occur mostly over sizes between 55 and 150 cm, or 22 and 60 inches. Overall, the IPHC setline survey is a useful index for Pacific halibut larger than 26 inches (66 cm).

Table 8. Proportion of catch in the 2016 IPHC setline survey in IPHC Regulatory Areas 4A, 4B, and 4CDE less than the specified size, calculated by weight and by numbers.

	Size (inches)													
	By Weight							By Numbers						
	26	27	28	29	30	31	32	26	27	28	29	30	31	32
4A	6.3	8.3	11.8	14	18.2	21.4	26.1	19.5	24.1	31.2	35.3	42.1	46.8	53
4B	2.5	4	7.4	10.4	16.4	20.7	26	7.8	11.4	18.8	24.7	35.2	41.9	49.4
4CDE	2.4	4.1	7.6	11	17.3	21.2	27.3	7.3	11.4	18.9	25.4	36.2	42.3	50.7

Table 9. Proportions of numbers-at-age from the IPHC setline survey for IPHC Regulatory Areas 4A and 4CDE combined, and 4B.

Area 4CDE, 4A																		
	Directed Commercial Fishery									IPHC Setline Survey								
Age	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.2	0.0	0.2	0.1	0.1	0.4
6	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.8	2.0	1.3	1.0	1.3	0.5	0.7	0.9	0.6
7	0.1	0.2	0.3	0.2	0.2	0.0	0.1	0.1	0.3	4.7	7.2	4.5	2.8	4.1	1.3	1.7	3.1	1.5
8	2.8	2.5	1.7	1.2	1.0	0.9	0.6	0.6	2.1	11.7	10.2	11.0	7.9	8.3	6.1	4.9	5.0	5.7
9	7.2	7.7	4.8	4.5	4.8	3.2	4.3	3.3	3.8	13.8	13.6	10.9	16.3	13.2	10.6	11.2	10.5	6.9
10	13.2	13.3	13.0	8.8	11.1	9.4	11.7	10.2	7.7	14.2	14.3	14.6	15.6	18.6	16.4	14.6	16.4	10.1
11	9.7	15.3	17.7	14.9	12.7	18.4	20.6	17.4	16.1	9.1	11.9	14.3	14.1	12.6	18.9	18.2	16.7	15.7
12	9.2	8.5	15.4	17.0	14.0	14.5	21.3	22.3	18.0	6.9	5.7	11.4	11.3	11.1	11.0	15.7	16.0	16.3
13	8.5	6.0	7.8	12.8	12.3	12.0	13.3	15.2	16.3	6.6	4.9	4.0	8.3	8.5	9.3	9.0	10.0	12.4
14	7.7	7.3	5.7	7.1	8.9	9.8	7.2	9.1	11.5	4.6	4.5	4.0	4.1	5.1	5.5	6.1	4.9	9.4
15	5.1	4.2	4.9	4.7	4.2	7.6	4.6	5.0	7.7	2.9	3.2	3.6	2.7	2.5	4.5	4.6	3.7	6.5
16	3.4	2.8	3.9	3.2	3.5	3.9	3.9	3.1	3.9	2.6	2.2	3.1	2.5	2.3	2.7	3.3	2.6	3.1
17	2.8	2.8	2.5	2.6	3.0	2.5	1.4	2.7	2.8	2.2	2.3	1.7	1.8	1.8	1.9	1.9	1.7	2.3
18	3.3	2.6	1.9	2.3	2.2	2.4	1.5	1.7	1.7	2.0	1.8	1.3	1.3	1.0	1.4	1.5	1.5	1.4
19	3.6	3.8	1.9	1.8	1.9	1.1	1.2	1.4	1.5	2.5	2.2	1.3	0.9	1.0	1.3	0.7	0.9	0.8
20	4.5	4.5	2.7	2.1	2.0	1.3	1.0	0.9	0.8	3.0	2.6	1.2	0.9	1.0	1.2	1.0	0.6	0.6
21	4.3	4.5	2.3	2.3	2.2	0.9	0.6	0.7	0.7	2.7	2.6	1.7	0.8	1.2	0.8	0.6	0.6	0.9
22	3.3	3.7	3.0	2.2	2.6	1.1	0.7	0.4	0.8	2.2	2.2	1.9	1.3	1.1	1.1	0.3	0.2	0.5
23	1.6	1.9	2.8	2.9	2.8	1.4	0.6	0.7	0.3	1.3	1.3	1.7	1.2	0.9	0.7	0.4	0.6	0.4
24	1.1	1.4	1.7	3.5	2.6	1.6	0.8	0.7	0.4	0.9	1.0	1.5	1.3	1.0	0.9	0.4	0.9	0.7
25+	8.7	7.0	5.9	5.9	8.2	8.0	4.7	4.7	4.0	4.4	3.9	5.0	3.7	3.5	3.7	3.5	3.0	3.9

Table 10. Proportions of numbers-at-age from the directed commercial fishery for IPHC Regulatory Areas 4A and 4CDE combined, and 4B.

Area 4B																		
	Directed Commercial Fishery									IPHC Setline Survey								
Age	2008	2009	2010	2011	2012	2013	2014	2015	2016	2008	2009	2010	2011	2012	2013	2014	2015	2016
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.3	0.5	0.4
6	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.2	0.9	1.2	1.1	0.7	0.8	0.6	1.2	1.9
7	0.4	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	5.3	3.3	4.1	3.7	6.1	3.7	1.7	3.8	2.4
8	1.4	2.6	1.8	1.6	1.2	0.4	0.3	0.5	0.3	8.5	7.1	7.8	8.6	9.5	13.3	8.2	6.9	5.7
9	3.4	4.2	4.8	4.2	3.4	2.7	1.8	2.8	1.7	9.7	10.1	10.7	11.6	13.0	16.0	16.6	17.2	5.7
10	8.7	7.0	7.6	10.3	8.2	6.8	5.4	9.1	6.0	6.1	10.9	12.5	13.5	13.7	13.9	14.4	19.1	10.7
11	8.9	7.9	9.5	9.2	12.7	12.1	8.3	12.8	13.3	5.6	7.6	11.9	10.2	13.3	10.0	13.8	14.1	18.9
12	12.8	7.4	9.4	10.8	10.3	14.6	14.6	12.2	18.0	5.8	5.9	6.7	7.8	9.6	10.7	10.0	7.7	17.2
13	10.3	9.2	6.1	9.2	8.2	12.8	13.3	12.2	14.9	7.8	7.1	4.6	4.9	5.2	6.9	9.2	4.2	10.7
14	8.6	7.4	8.2	6.2	7.2	8.9	11.4	10.4	8.5	5.6	5.3	5.9	3.3	4.6	3.7	4.7	3.8	5.9
15	8.3	7.0	6.4	7.1	5.8	7.2	9.0	7.9	9.8	7.6	4.7	4.8	3.3	2.9	2.3	2.9	2.7	5.0
16	7.0	5.0	5.9	5.7	6.1	3.6	6.5	5.0	5.2	7.5	7.3	3.5	5.1	2.0	1.9	2.2	2.1	3.5
17	2.7	4.7	5.3	3.9	5.0	4.2	4.6	4.3	2.9	3.9	5.8	4.9	4.0	3.0	2.1	1.2	1.5	2.1
18	2.0	3.0	4.6	5.2	3.3	2.9	2.9	3.7	2.0	2.0	1.6	3.2	4.2	2.4	1.7	1.9	1.5	1.2
19	2.7	3.5	2.5	3.9	4.0	2.3	2.7	2.9	2.4	2.7	1.1	1.1	3.2	2.0	1.5	1.1	2.0	0.9
20	3.8	5.3	2.6	2.4	2.8	2.1	2.2	2.7	2.8	2.8	1.9	0.9	1.7	1.9	1.9	1.6	1.4	1.2
21	5.0	6.5	3.4	1.2	2.2	2.1	1.7	1.6	1.6	3.5	2.7	2.0	1.1	0.7	1.2	2.2	1.4	1.0
22	3.4	4.7	4.5	1.3	1.5	1.7	0.8	2.0	0.9	3.0	2.9	2.3	0.9	0.8	0.4	0.5	1.4	0.6
23	1.3	2.0	4.2	3.2	2.4	2.0	0.8	1.2	1.9	1.9	1.9	3.5	1.7	1.0	0.7	0.7	1.4	0.4
24	1.3	1.3	2.3	3.5	2.9	2.2	1.3	1.1	1.3	1.0	1.8	1.9	1.6	0.8	0.8	0.7	1.1	0.7
25+	8.3	11.0	10.8	10.8	12.8	11.4	12.4	7.5	6.7	8.4	10.4	6.5	8.7	7.0	6.6	5.7	5.3	4.1

<u>Segment of index population encountered in directed halibut and groundfish fisheries</u>

The size and age compositions for halibut caught on the IPHC setline survey can be compared with data on halibut caught in the directed halibut and groundfish fisheries in the Bering Sea to determine the segment of the surveyed population that is encountered in the fisheries.

Directed Commercial Fishery- Due to the 32-inch size limit for the directed Pacific halibut fishery, landings are almost exclusively fish larger than 32 inches (Table 6). Pacific halibut smaller than 32 inches are released at sea in the directed fishery. In contrast, the IPHC setline survey enumerates some Pacific halibut smaller than 32 inches, but mostly larger than 26 inches (Table 6 and Table 8). Age compositions show the same trend with younger fish observed in the IPHC setline survey (Table 9 and Table 10). **The IPHC setline survey is a good proxy for directed commercial fishery encounters with Pacific halibut because similar gear and chartered fishing vessels are used. Some differences will occur between the fishery and survey due to varying hook sizes in the directed fishery. However, the directed commercial fishery encounters U32 Pacific halibut, but is not allowed to land them, which explains the difference between the setline survey and directed commercial fishery size and age compositions. Overall, the TCEY is based on O26 Pacific halibut and the IPHC setline survey is a good proxy for these fish.**

Trawl Groundfish fisheries- As discussed in Section 3.1.1, the groundfish trawl fisheries commonly catch Pacific halibut smaller than 26 inches. It is possible that trawl fisheries for different species encounter different sizes of Pacific halibut. **However, based on aggregated size composition data of groundfish**

trawl fisheries, the IPHC setline survey would likely perform poorly as index of abundance for groundfish trawl fisheries as a whole.

Longline Groundfish Fisheries- As discussed in Section 3.1.1, some groundfish longline fisheries catch Pacific halibut smaller than 26 inches but the halibut encountered are typically larger than those encountered in the groundfish trawl fisheries (Figure 20). However, the Observer IFQ longline fisheries show a size composition (Figure 18 and Figure 19) in recent years that is similar to the IPHC setline survey. **Based on size composition data of groundfish longline fisheries the IPHC setline survey may be an appropriate index of abundance for groundfish longline fisheries as a whole, but may miss some of the smaller fish.**

3.2 Secondary Fishery independent indices

3.2.1 AFSC EBS slope bottom trawl surveys

The AFSC conducts a bottom trawl survey on the eastern Bering Sea slope (EBS slope survey) every two years to assess the groundfish and invertebrate resources on the eastern Bering Sea upper continental slope. The survey is intended to provide additional survey information for the EBS to complement the EBS shelf. This survey covers the western region of the shelf and slope (see Figure 25). The survey area extends from Unalaska and Akutan Islands to the U.S.-Russian Maritime Boundary near the International Date Line (166° E to 180° W) at depths from 200 to 1,200 m. The 2016 EBS slope survey is the sixth in this series of biennial groundfish surveys that incorporate the AFSC's latest sampling technologies and protocols for survey design, catch data gathering, species identification, and net mensuration monitoring. Eastern Bering Sea slope surveys were conducted in 2002, 2004, 2008, 2010, 2012 and 2016 and the results are detailed in NOAA Technical Memoranda (Hoff and Britt 2003, 2005, 2009, 2011, Hoff 2013).

Trawl operations followed those outlined in the NOAA survey protocols document (Stauffer 2004). The EBS slope survey area was divided into six geographic subareas (1-6) running south to north along the upper continental slope (see Figure 25) based on distinct bathymetric types and underwater features: broad low slope areas, canyon areas, and steep slope inter-canyon faces. Subareas 1 and 6 consist of broad low slope areas with wide bathymetric contours in the 200-600 m depth range and a gradual slope to 1,200 m. Subareas 2 and 4 consist of Pribilof and Zhemchug canyons, respectively, which are characterized by semi-enclosed basins with steep walls and narrow bathymetric contours below 600 m. Subareas 3 and 5 are steep slope intercanyon "faces" with narrow bathymetric contours throughout most depths.

Geographic subareas were stratified by depth every 200 m from 200 to 1,200 m, resulting in five depth strata for each geographic subarea (200-400 m; 400-600 m; 600-800 m; 800-1,000 m; 1,000-1,200 m). The total area of each depth stratum (km2) was calculated using known bathymetry contour lines and stratum area was used to determine sampling density. Sampling densities generally vary due to difficulties in successfully completing all planned stations in some deep strata with large areas of untrawlable bottom. For the EBS slope survey, untrawlable bottom appears to have high bottom relief of rock or other bottom materials resulting in damaged nets or poor bottom contact if tows were attempted.

At the end of each tow, catches were sorted, weighed, and enumerated for all species of fishes and invertebrates. The catch was processed in one of two ways: either by sorting the entire catch and weighing each species in aggregate or by weighing the net codend and discarding the predominant species (except for a weighed and sexed random length frequency sample) and the rest of the catch sorted and weighed by species. Random samples of species that were designated for biological data collection were set aside after weighing. Total weight and numbers for each species were recorded. For large numbers of an individual species in a single haul, the total number was extrapolated from subsample weight and count of 50-200 individuals. In most cases fish length frequency subsamples were used for extrapolation of the total haul count for individual species. A random subsample of 100-150 fish, depending on the size range for the species, was selected for length frequency measurements. The sex of each individual was determined by internal examination of the gonads or by external characters (e.g., claspers for elasmobranchs), and specimens were sorted into baskets of males, females, or undetermined sex. Fork length (FL) was measured for most fishes.

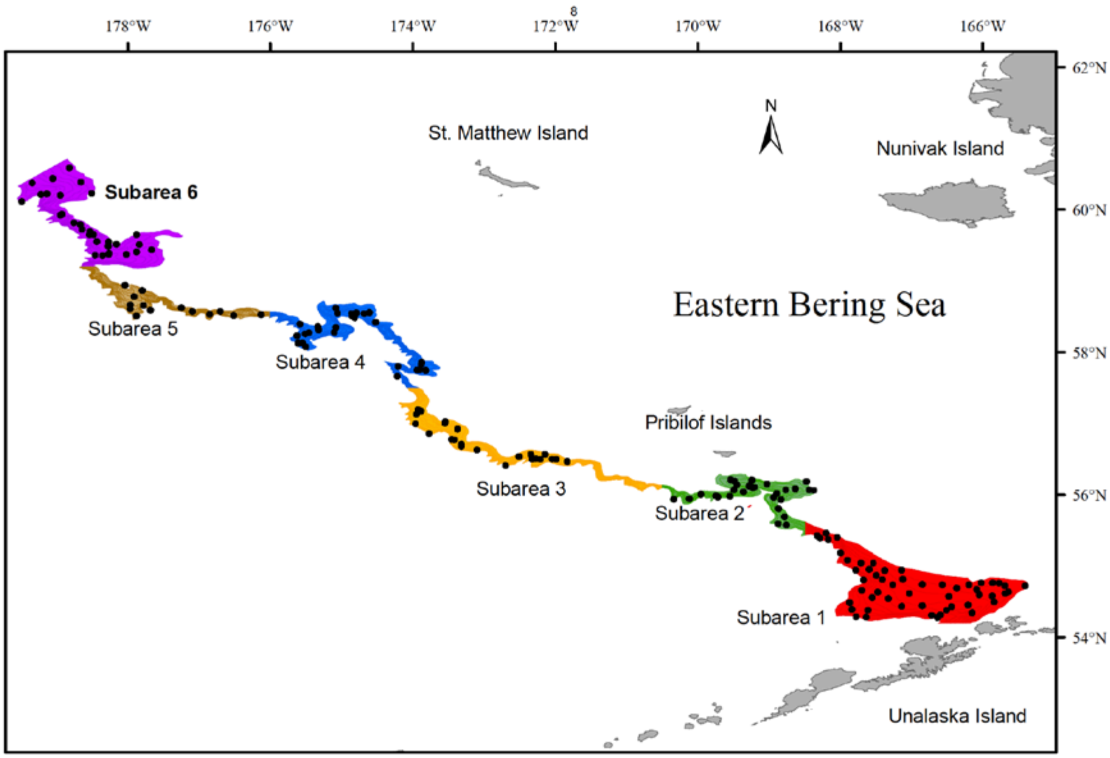

Figure 25.   Map of standard EBS slope survey area.

Catch per unit effort (CPUE) was calculated by dividing catch weight or number for each species by the estimated area swept of the trawl. CPUE is expressed in kilograms per hectare and number of individuals per hectare. Population and biomass estimates were calculated using mean CPUE and extrapolated into the area for each stratum and subsequently summed for all strata. Fish length frequencies were used to estimate the proportion of fish at each length interval weighted by the CPUE and then expanded to the depth strata population. For additional details on the methods see the most recent NOAA Technical Memoranda.

The AFSC estimates the relative abundance of halibut for all of the subareas in the survey. The survey years and index results are shown in Figure 26. The average weights in the survey (along with the biomass and abundance estimates) are shown in Table 11. This information shows that the biomass and abundance estimates of halibut from the EBS slope survey are variable and this is likely due to the fact that the abundance of halibut starts to decline in general deeper than 200 m depth (the minimum depth of the slope trawl survey stations).

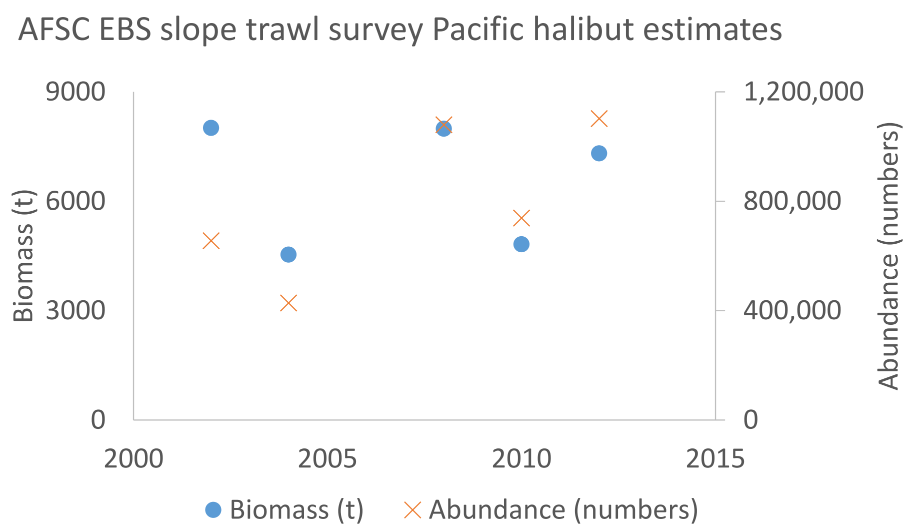

Figure 26. AFSC eastern Bering Sea slope bottom trawl survey biomass and abundance estimates, 2002-2012 (the next survey is planned for 2016).

Table 11. Biomass, abundance, and average weight estimates from the eastern Bering Sea slope bottom trawl survey.

	Biomass (t)	Abundance (numbers)	Avg wt (kg)
2002	8,004	655,153	12.22
2004	4,530	427,892	10.59
2008	7,985	1,079,208	7.40
2010	4,819	737,851	6.53
2012	7,308	1,101,379	6.64

Data availability

The AFSC EBS slope survey is usually conducted biennially in even years.[9] The data from the survey is available in the fall of the years it is conducted and is used to prepare groundfish stock assessments. Therefore, the most recent EBS slope survey data would be available for use in even years as an index for the annual BSAI groundfish harvest specifications process in which the halibut PSC limits in the years the survey is conducted.

Segment of halibut population index represents

The size compositions of halibut caught in the EBS slope survey from 2002 through 2012 are shown in Figure 27. The halibut caught in the EBS slope survey range in length from 50 cm (19.7 inches) to just under 120 cm (47.2 inches). The mean length of halibut caught in the 2016 survey was 82 cm (32.3 inches). The length distribution of halibut in the EBS slope survey skews toward larger halibut compared to the EBS shelf survey. As described in Section 3.1.1.1, very few halibut greater than 100 cm (39.4 inches) are caught in the EBS shelf survey. Therefore, the EBS slope survey provides additional information on larger and older halibut that is not available from the EBS shelf survey.

[9] The slope survey was not conducted in 2006 and 2014 due to budget limitations and contracting issues.

Table 6 shows the length distribution by size categories for the 4 years of EBS slope survey data from 2008 through 2016. The survey data shows that an average 86% of halibut caught on the survey were O26, and 51% of the halibut caught are greater than 32 inches (81 cm). Therefore, the EBS slope survey provides additional information on larger and older halibut in the EBS that is not available from the EBS shelf survey. **However, given the limited depths and area covered by this survey, the relatively limited number of halibut caught on the survey, and the fact that the survey generally only occurs every other year, data from this survey is unlikely to perform well as an abundance index of Pacific halibut in the Bering Sea.**

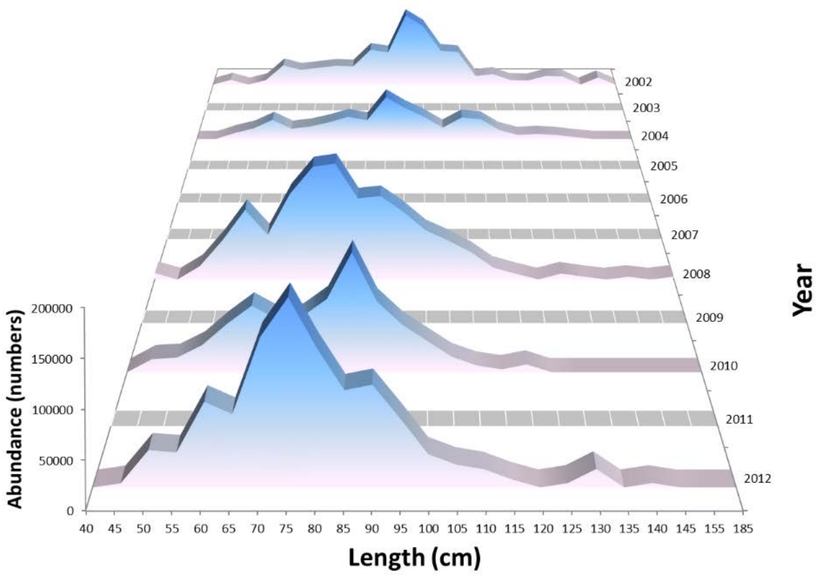

Figure 27. AFSC eastern Bering Sea slope bottom trawl survey population-at-length estimates, 2002-2012 (the next survey is planned for 2016).

<u>Segment of index population encountered in directed halibut and groundfish fisheries</u>

Directed halibut fishery – Pacific halibut sizes caught on the EBS slope survey appear to overlap with those sizes caught in the directed halibut fisheries. As described above and shown in Table 6, 86 percent of halibut caught in the EBS slope survey is O26 and observer IFQ longline data shows that 94% of halibut caught in the IFQ fisheries in O26. Table 6 also shows that the size distribution of catch on the EBS slope survey tracks well with the size distribution of catch in the IPHC setline survey. **However, given the relatively limited area for the EBS slope survey and the fact that it is conducted on a biennial basis, it would not be appropriate to use the only the survey as an index of halibut encountered in the directed halibut fisheries.** Given the strong overlap of catch by size between the IPHC setline and the directed fisheries, the larger area covered by the IPHC setline survey and the annual availability of IPHC setline survey data, the IPHC setline survey is a more appropriate index for purposes of reflecting directed halibut fishery encounters.

Trawl groundfish fisheries - The EBS slope survey represents a similar, but generally larger and older, segment of the halibut population compared to the population segment encountered by the non-pelagic and pelagic trawl groundfish fisheries in the Bering Sea. Although the halibut caught by the EBS slope overlap with some size categories of halibut caught in the trawl groundfish fisheries in the Bering Sea, the utility of this index for Pacific halibut encountered in the Bering Sea trawl groundfish fisheries is relatively limited. This recommendation is based on the limited coverage area of the EBS slope survey and the biennial availability of data. In addition, as described in Section 3.1.1.1, the EBS shelf survey represents essentially the same halibut population encountered by the trawl groundfish fisheries in the Bering Sea and would be the most appropriate index for the trawl groundfish fisheries for the action under consideration.

Table 6 and Figure 20 show the length distribution of halibut caught in the non-pelagic trawl groundfish fisheries. In terms of length distribution, the vast majority of halibut caught in the EBS shelf survey and in the non-pelagic and pelagic trawl groundfish fisheries in the BSAI ranged from 20 cm to 100 cm (7.9 in to 39.4 inches) fork length. The halibut caught in the EBS slope survey range in length from 50 cm (19.7 inches) to just under 120 cm (47.2 inches). Therefore, the EBS slope survey catches halibut from 100 cm (39.4 inches) to 120 cm (47.2 inches) that are not generally caught in the trawl groundfish fisheries in the Bering Sea.

From 2008 through 2016, 87% of halibut caught in the non-pelagic trawl groundfish fisheries was U26 and 13% was O26. For the pelagic trawl groundfish fisheries, 85% of halibut caught was U26 and 15% was O26 from 2008 through 2016. The 2016 EBS slope survey data showed that 86% of halibut caught on the survey was O26 (see Table 6) and 14% was U26, indicating that a substantially larger proportion of halibut caught in the EBS slope survey are larger and older than halibut caught in the trawl groundfish fisheries in the Bering Sea.

Longline groundfish fisheries - The segment of the population represented by the EBS slope survey matches up fairly well with the segment of the population encountered by the longline groundfish fisheries in the Bering Sea in terms of the distribution of halibut lengths caught, although the length distribution of halibut in the EBS slope survey skews toward larger halibut compared to the longline groundfish fisheries. From 2008 through 2016, 57% of halibut caught in the longline groundfish fisheries was U26 and 43% was O26. As described above, the 2016 EBS slope survey data showed that showed that 86% of halibut caught on the survey was O26 (see Table 6) and 14% was U26,. This indicates that a larger proportion of halibut caught in the EBS slope survey are O26, and therefore larger and older, than halibut caught in the longline groundfish fisheries in the Bering Sea.

It may be appropriate to use the EBS slope survey as an index of halibut encountered by the longline groundfish fisheries in the Bering Sea based on the comparison of data, **but the EBS slope survey is not likely an appropriate index of halibut encountered in the Bering Sea longline groundfish fisheries.** This recommendation is based on the limited coverage area of the EBS slope survey and the biennial availability of data. In addition, as described in Section 3.1.1.1, the EBS shelf survey provides a good representation of the halibut population encountered by the longline groundfish fisheries in the Bering Sea. The EBS shelf survey would be a more appropriate index for the longline groundfish fisheries for the action under consideration because the survey area is larger and sampled more frequently.

3.2.2 AFSC GOA bottom trawl survey

The Gulf of Alaska bottom trawl survey has been conducted on a biennial basis since 1984. The survey area (see Figure 28) covers the continental shelf and upper continental slope to 1,000 m in the Gulf of Alaska from Islands of Four Mountains (170°W long.) and approximately 2,800 km across the Gulf of Alaska to Dixon Entrance (133°25'W long.). The survey typically involves conducting fishing at ~800 stratified random stations during every other year and extends from the near shore to depths of 1,000 m in most years.

The survey is designed based upon stratified random sampling consistent with previous GOA surveys (von Szalay et al. 2008, 2010; Britt and Martin 2000; Martin and Clausen 1995; Stark and Clausen 1995; Munro and Hoff 1995). The primary survey objectives are to define the distribution and estimate the relative abundance of the principal groundfish species within the survey area and to collect data to estimate biological parameters useful to groundfish researchers and managers including age, growth, length-weight relationships, feeding habits, and size, sex, and age composition. The survey also collects ancillary data requested by other research groups. Over the entire survey area, arrowtooth flounder was the most abundant groundfish encountered during the survey. Arrowtooth flounder also had the highest CPUE of any species in four of the five survey areas (Shumagins being the exception). Pacific ocean perch, walleye pollock, giant grenadier, and Pacific halibut were also very important components of the Gulfwide species composition.

Survey results include estimates of catch per unit of effort, biomass, population size composition, and length-weight relationships, as well as charts depicting the distribution of catch for commercially important species encountered during the survey. Additional information on the GOA bottom trawl survey is available in the [2015 report].

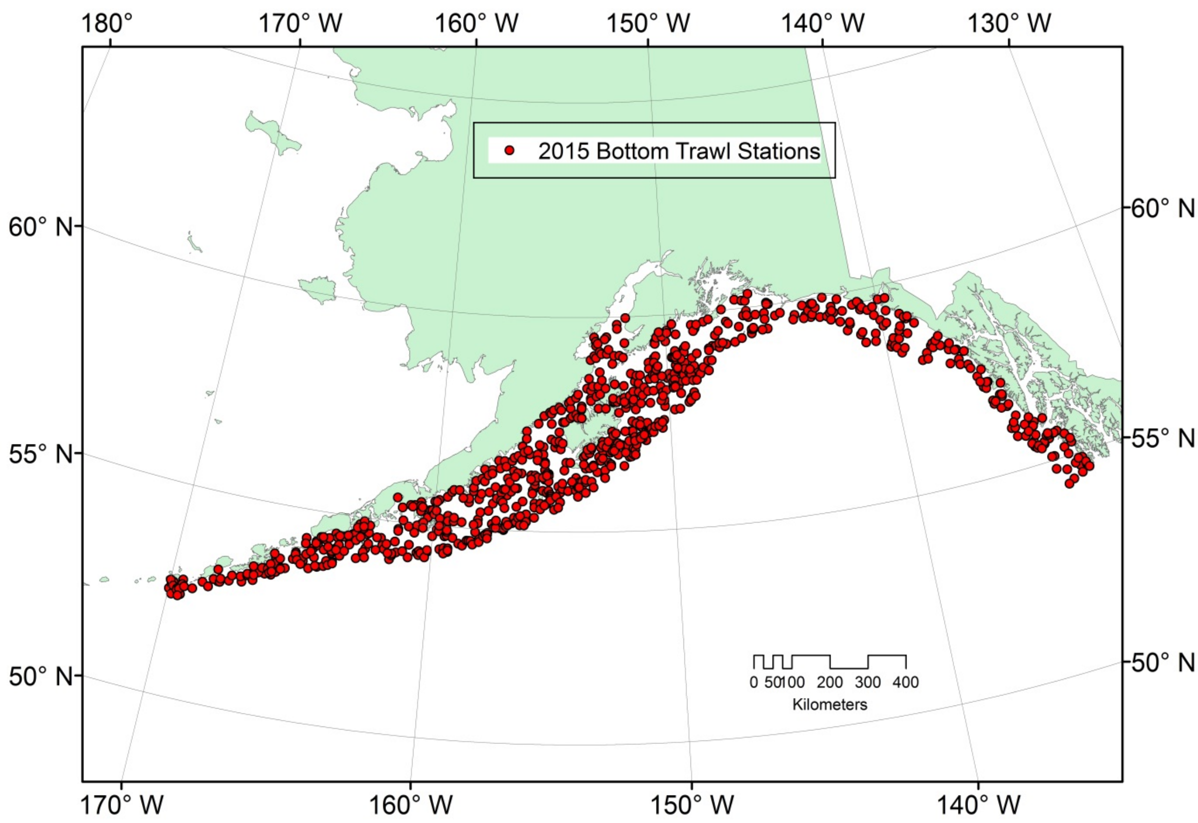

Figure 28. Survey area for GOA bottom trawl survey. Source is AFSC web site at https://www.afsc.noaa.gov/RACE/groundfish/goa.htm.

Numbers and weights of all taxa were recorded for each haul. Catches were sorted to species or other appropriate taxonomic levels and then weighed in aggregate. Catches weighing less than approximately 1,000 kg were emptied directly onto a sorting table, sorted by species, and weighed to the nearest 0.01 kg. Species groups weighing less than about 2 kg were generally weighed to the nearest 2 g. Larger catches were processed using several different techniques depending upon the catch size and sea state. Catches greater than 2 metric tons (t) but less than about 5 t were processed by repeatedly filling the sorting table from the codend, sorting, and weighing until the entire catch had been processed or by weighing the entire catch and net. Afterwards, the sorting table was filled with a portion of the catch and the excess catch was dumped into a deck bin. The dominant species, usually three or fewer, making up the bulk of the catch were identified. The contents of the deck bin were sorted and the dominant species were discarded. The remaining species were retained, sorted, and weighed with those from the table. Total weight estimates for the dominant species were calculated by expanding their proportion by weight from the sorted sample to the difference between the total catch weight and the total weight of all non-dominant species.

Extremely large catches were processed by either measuring the volume in the net or by unloading the net into the deck bin and determining the volume of the catch by measuring the length and width of the bin and taking the average height of the catch. Samples of the catch were then taken from the volume to determine the species composition of primary species and the density of the catch. The density of the catch was divided into the volume to determine the total catch weight. Minor species were individually collected, counted, and weighed and their total weight was subtracted from the total catch weight. The species composition in weight was then applied to the remaining catch weight to estimate the catch weight of each primary species.

In the GOA bottom trawl survey, Pacific halibut were measured and discarded as quickly as possible and their weights were estimated from their lengths. Pacific halibut was the fifth most abundant species caught in the 2015 survey and was among the tenth most abundant species in all five survey areas. Pacific halibut were caught throughout the survey area at depths less than 500 m. The highest densities occurred in the Kodiak region and at depths less than 200 m. Females were significantly larger than males. Size generally increased with depth, but was relatively constant going from west to east. The estimated biomass of Pacific halibut was 341,486 t, and the highest regional biomass was in the Kodiak region, where 46% of the estimated biomass was concentrated.

<u>Data availability</u>

The GOA bottom trawl survey is conducted biennially in odd years. The data from the survey is available in the fall of the years it is conducted and is used to prepare groundfish stock assessments. Therefore, the most recent GOA bottom trawl data would be available for use in odd years as an index for the annual BSAI groundfish harvest specifications process in which the halibut PSC limits in the years the survey is conducted.

<u>Segment of halibut population index represents</u>

The size compositions of halibut caught in the GOA bottom trawl survey from 1984 through 2015 are shown in Figure 29. Based on data from the survey, there appears to be some variability in the numbers of halibut that occur in the survey from year to year and this may reflect changes in the apparent recruitment of halibut within the GOA.

The halibut caught in the GOA bottom trawl survey generally range in length from 20 cm (7.9 inches) to 100 cm (39.4 inches), which is a similar length distribution to halibut caught in the EBS shelf survey. Therefore, the GOA bottom trawl survey provides a reasonable index of the smaller and younger segment of the halibut population in the GOA. The feasibility of using the GOA bottom trawl survey as one component of a combined index was previously evaluated based on a suggestion from the SSC (see the April 2017 ABM discussion paper where a combined GOA bottom trawl survey and EBS shelf survey was considered to cover the younger segment of the halibut stock throughout a larger range in Alaska). However, further discussion at the Council and SSC in June 2017 suggested that it would be more appropriate to limit the development of abundance indices to those that reflect halibut abundance in the Bering Sea and halibut encountered by the groundfish fisheries in the Bering Sea. **Consequently, the use of the GOA bottom trawl survey was considered but rejected for purposes of the action under consideration by the Council.**

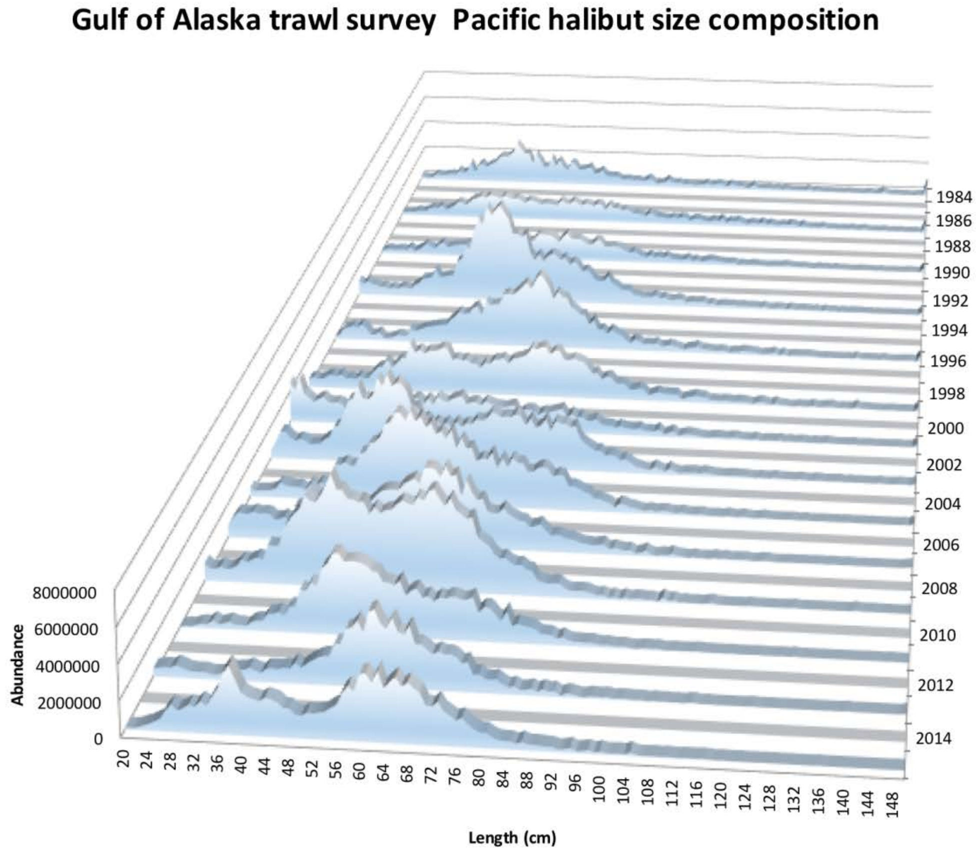

Figure 29. Gulf of Alaska abundance at size (length in cm) based on NMFS summer trawl surveys; 1984-2015. Note that the survey in 2001 only covered part of the GOA.

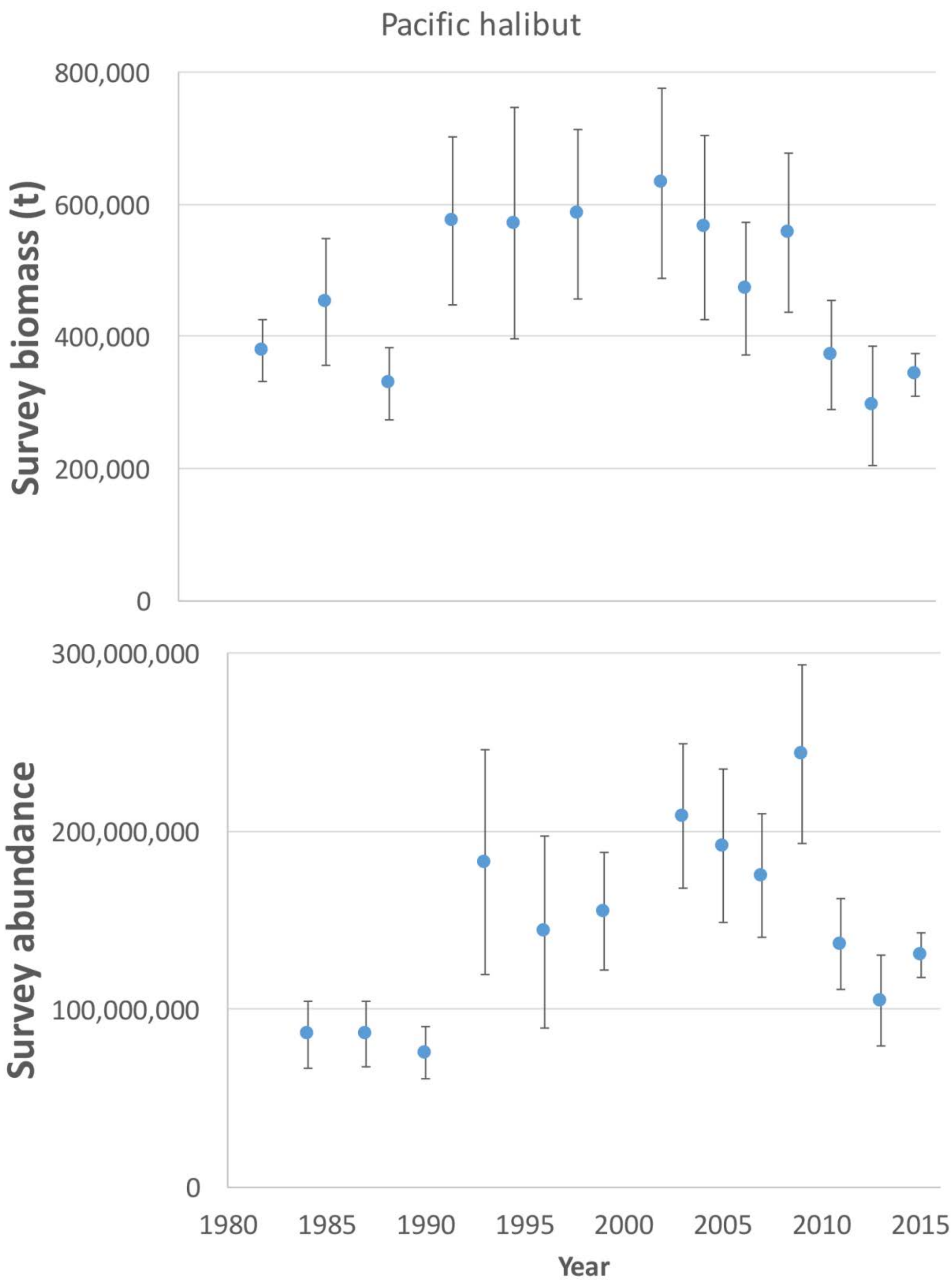

Figure 30. Gulf of Alaska summer survey biomass estimates (top) and abundance estimates (bottom) from trawl data

Segment of index population encountered in directed halibut and groundfish fisheries

The directed halibut and groundfish fisheries that would be affected by the action under consideration by the Council take place entirely in the BSAI and primarily in the Bering Sea. Therefore, these fisheries do not encounter the segment of the halibut population represented by the GOA bottom trawl survey. **Based on this information, the GOA bottom trawl survey as an index of halibut encountered by the directed halibut and groundfish fisheries in the Bering Sea was considered but rejected from further consideration.**

3.2.3 AFSC AI bottom trawl survey

This is a biennial survey (typically alternating with the Gulf of Alaska trawl surveys) that surveys area covered the continental shelf and upper continental slope to 500 m in the Aleutian Archipelago from Islands of Four Mountains (170° W long.) to Stalemate Bank (170° E long.), including Petrel Bank and Petrel Spur (180° long.), and the northern side of the Aleutian Islands between Unimak Pass (165° W long.) and the Islands of Four Mountains (see Figure 31). The surveys conducted prior to 1991 were cooperative efforts involving U.S. and Japanese scientists and vessels. From 1991 to 2000 the surveys were planned and conducted on a triennial basis by NMFS, employing chartered U.S. fishing vessels. Biennial surveys began in 2000. The 2008 survey was cancelled. The primary focus of the AI bottom trawl surveys is to continue a standardized (Stauffer 2004) time series of data to assess, describe, and monitor the distribution, abundance, and biological condition of Aleutian groundfish and invertebrate stocks. Additional information on the AI bottom trawl survey is located in the 2016 report on the survey.

Pacific ocean perch or POP (*Sebastes alutus*) was the most abundant species on the AI bottom trawl survey. Atka mackerel (*Pleurogrammus monopterygius*) and northern rockfish (*Sebastes polyspinis*) were also. Catches of POP were large throughout the survey area at intermediate depths. Arrowtooth flounder (*Atheresthes stomias*) was the most abundant flatfish species, having almost twice the biomass of secondplace northern rock sole (*Lepidopsetta polyxystra*).

Survey results are presented as estimates of catch per unit of effort and biomass, species distribution and relative abundance, population size composition, and length-weight relationships for commercially important species and for others of biological interest.

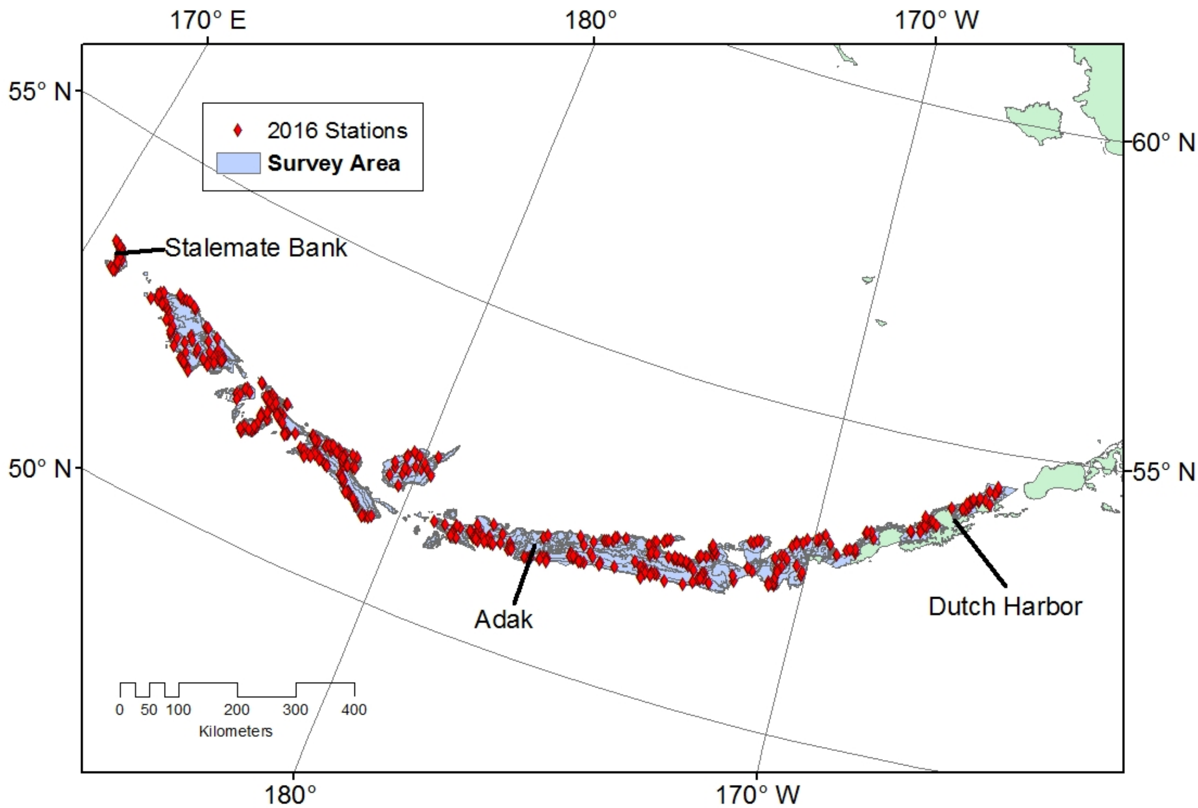

Figure 31. Aleutian Islands bottom trawl survey area.

Data availability

The AI bottom trawl survey is conducted biennially in even years. The data from the survey is available in the fall of the years it is conducted and is used to prepare groundfish stock assessments. Therefore, the most recent AI bottom trawl data would be available for use in even years as an index for the annual BSAI groundfish harvest specifications process in which the halibut PSC limits in the years the survey is conducted.

Segment of halibut population index represents

The size compositions of halibut caught in the AI bottom trawl survey from 1984 through 2015 are shown in Figure 32. Based on data from the survey, there appears to be some variability in the numbers of halibut that occur in the survey from year to year. Estimates indicate relatively low biomass of halibut in the survey area (~37 kt average since 2000). Given that relatively little halibut PSC occurs in this region, the EBS is more likely a source for Pacific halibut into the Aleutian Islands.

Table 6 shows the 4 years of available size composition data from the AI bottom trawl survey for the 4 years the survey was conducted from 2008 through 2016. The table shows that an average 66% of halibut caught on the survey were U26 and all of these fish were in the 13 to 26 inches (33 to 65 cm) size category. An average 26% of halibut caught on the AI bottom trawl survey were in the 26 to 32 inches (66 to 80 cm) size category and overall, 34% of the halibut caught in the survey were O26.

Staff initially considered development of an index that combines the AI bottom trawl survey with the EBS shelf survey to provide an index of the smaller and younger segment of the halibut stock in the BSAI. However, further discussion at the Council and SSC in June 2017 suggested that it would be more appropriate to limit the development of abundance indices to those that reflect halibut abundance in the Bering Sea. **Based on this information, it would not be appropriate to use the AI bottom trawl survey as an index of abundance for the action under consideration by the Council.**

Segment of index population encountered in directed halibut and groundfish fisheries

The directed and groundfish fisheries that would be affected by the action under consideration by the Council take place entirely in the BSAI and primarily in the Bering Sea. Therefore, these fisheries do not encounter the segment of the halibut population represented by the AI bottom trawl survey. **Based on this information, it would not be appropriate to use the AI bottom trawl survey as an index of halibut encountered by the directed halibut and groundfish fisheries in the Bering Sea.**

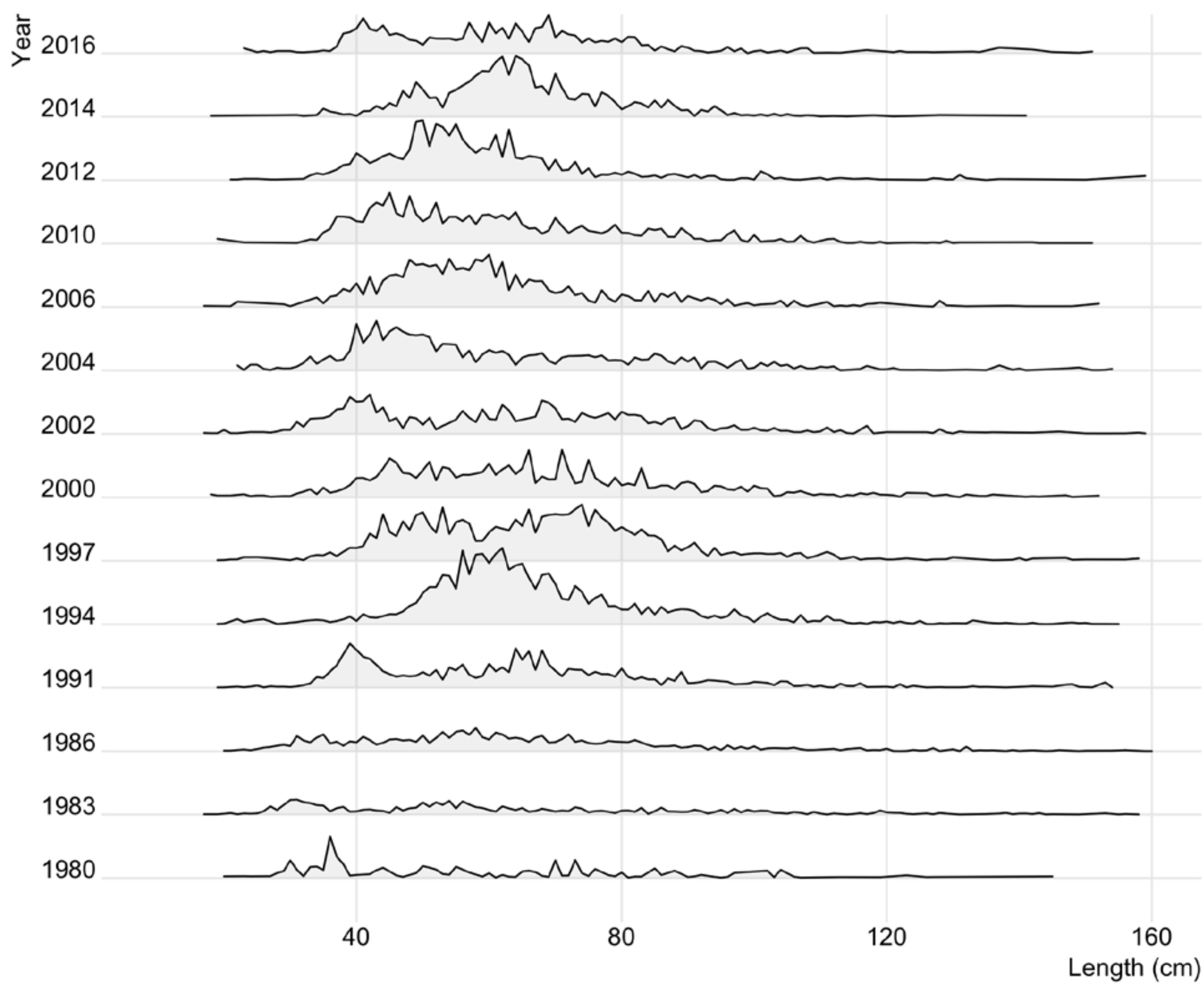

Figure 32. Size composition of Aleutian Islands Pacific halibut based on NMFS bottom trawl surveys.

3.2.4 AFSC BS and AI Longline Survey

The AFSC has conducted annual longline surveys to assess the sablefish stock in Alaska waters since 1978. A cooperative Japan-U.S. longline survey was conducted annually from 1978 to 1994. In 1987, the AFSC began an annual survey intended to replace the cooperative longline survey so that a U.S. vessel, rather than a Japanese vessel, would conduct the survey for what had become a wholly U.S. fishery in 1988. The two surveys overlapped for several years to compare and test for differences between them and thus link the time series of standard longline surveys. By 1994, statistical analyses by Kimura and Zenger (1997) showed that enough data had been collected to complete a valid comparison. As a result, the cooperative longline survey was discontinued after 1994. The annual longline survey begun by the AFSC in 1987 has continued to the present. The AFSC longline survey is generally described in the survey protocol available at https://www.afsc.noaa.gov/ABL/MESA/pdf/LSprotocols.pdf. Data from the 1997 through 2014 surveys are available at https://www.afsc.noaa.gov/ABL/MESA/mesa_sfcruisereports.htm.

NMFS sablefish longline survey stations in the BS and AI are sampled every other year in May-June from 1997 – 2015, with the BS sampled in odd years and the AI in even years. The survey objectives are: 1) Determine the relative abundance and size composition of the commercially important species: sablefish, shortspine thornyhead (*Sebastolobus alascanus*), Greenland turbot (*Reinhardtius hippoglossoides*) and rougheye and shortraker rockfishes (*Sebastes aleutianus* and *S. borealis*); 2) Determine migration patterns of sablefish, shortspine thornyhead, and Greenland turbot by tag and release methods; and 3) Determine the age composition of sablefish through otolith collections.

The survey covers the upper continental slope and selected gullies of the eastern Bering Sea, Aleutians Islands region, and Gulf of Alaska (Figure 33). The survey covers nearly all areas where adult sablefish are found. Depths sampled during the survey of the upper continental slope range from about 150-1,000 m (82-547 fm). Sampling occurs during the summer and lasts 3 months. Survey operations are conducted using a chartered U.S. longline freezer vessel with overall length of about 55 m (150 ft).

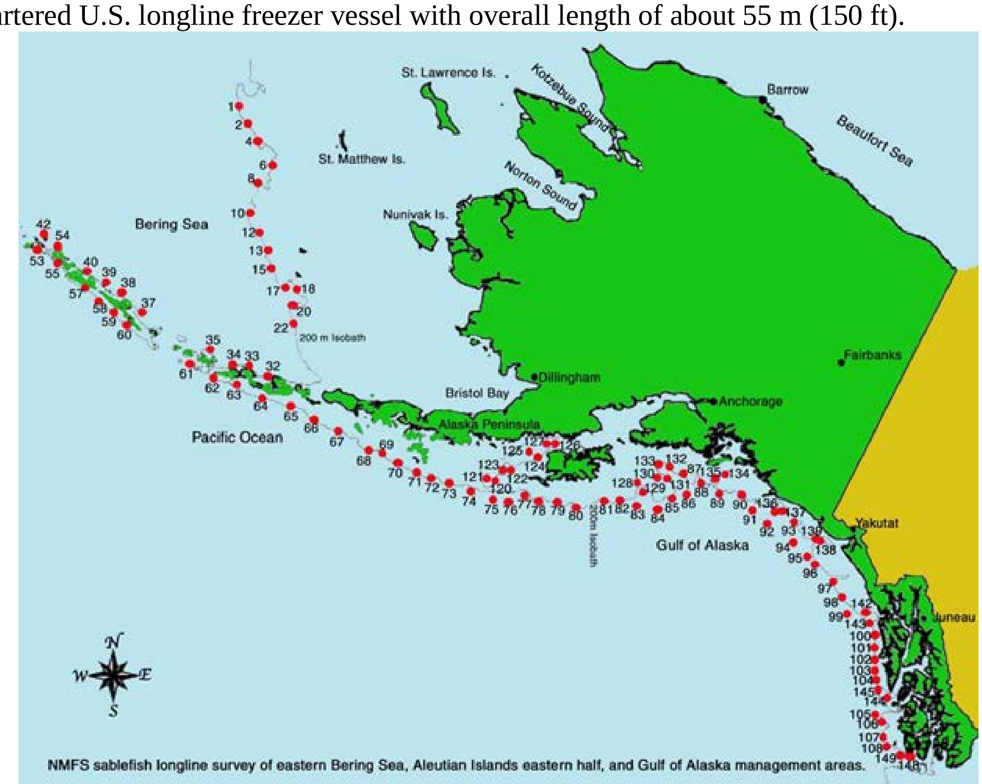

Figure 33. Survey area for Alaska sablefish longline survey. Source is survey protocol at https://www.afsc.noaa.gov/ABL/MESA/pdf/LSprotocols.pdf.

Survey stations generally align with commercial longline fishing grounds along the continental slope and are systematically spaced approximately 30 - 50 km apart. In a given year, each station is fished for one day from shallow to deep (depths ranging from roughly 150 - 1000 m) using two sets hauled end to end. In the BS, each set consists of 90 skates (string of 45 hooks), providing a total of 180 skates (8100 hooks) fished per station. In the AI, 160 skates are fished per day. Hooks are spaced two meters apart and baited with squid. The gear soaks from three to nine hours. Gear retrieval begins after the gear has soaked three hours. The longer soak times occur because of the length of time needed to retrieve the gear.

Catch and effort were collected at each station for species captured during the survey. Sablefish was the most frequently caught species, followed by giant grenadier, Pacific cod, shortspine thornyhead, and Pacific halibut. Giant grenadier was the highest catch in weight, followed by sablefish, Pacific halibut, and Pacific cod. Length was measured by depth stratum for sablefish, Pacific cod, giant grenadier, arrowtooth flounder, Greenland turbot, shortspine thornyhead, spiny dogfish, and multiple rockfish species. Lengths of sablefish, giant grenadier, spiny dogfish, and Pacific cod were recorded by sex. These data are used to derive annual estimates of relative population numbers (RPN, an abundance index) for species captured during the survey.

Halibut CPUE data are computed for each station and depth stratum by dividing total catch by the number of effective hooks fished. CPUE data are then averaged across stations, multiplied by strata-specific habitat area sizes, and summed across depth strata. These halibut CPUE data could potentially be used to supplement information from the IPHC setline survey for those sizes of halibut available only to the NMFS longline gear.

Data availability

The AFSC longline survey is conducted annually and alternates between the BS in odd years and the AI in even years. The data from the survey is available each year in the fall and is used to prepare groundfish stock assessments. Therefore, the most recent AFSC longline survey data would be available for use as an index for the annual BSAI groundfish harvest specifications process in which the halibut PSC limits in the years the survey is conducted.

Segment of the halibut population the index represents

Staff initially considered the AFSC longline surveys for the BS and AI as a candidate abundance index because the size composition of halibut caught on the surveys is likely similar to the directed fishery and would provide an index of larger halibut. However, further examination determined that halibut caught on the surveys are counted and released at the rail without measuring. While the longline survey data provides an estimate of the total number of halibut caught and total halibut catch in weight, the AFSC does not have halibut length information to derive an abundance index from the longline surveys. In addition, the coverage area of the BS survey is limited to the upper slope of the eastern Bering Sea and the stations are at a minimum depth of 150 m. Halibut are often found at shallower depths than those covered by the survey. Furthermore, a relatively small number of halibut are caught on the AI surveys. After considering all of these factors, staff determined that the IPHC setline survey provides broader coverage than the AFSC longline surveys and provides length estimates that can be used to develop an abundance index. **Based on this information, staff do not recommend using the AFSC longline survey data to develop an index of halibut abundance for the action under consideration by the Council.**

Segment of index population encountered in directed halibut and groundfish fisheries

As described above, staff believe the AFSC longline surveys represents the segment of the population encountered by the directed halibut fishery and the IPHC setline survey in the respective areas, which are larger fish compared to surveys and fisheries using trawl gear. However, since length information is not collected for halibut caught on the longline surveys, it is not possible to develop size composition information for a quantitative comparison to other candidate indices and the relevant fisheries. **Based on this information, the AFSC longline survey data may perform poorly to index Pacific halibut encountered in the directed halibut and groundfish fisheries and likely inappropriate as an index for the action under consideration by the Council.**

3.2.5 IPHC Standardized Coastwide Stock Assessment Results

Currently, the stock assessment for Pacific halibut uses four integrated age-structured models in an ensemble to account for parameter and structural uncertainty (Stewart & Martell 2015). The ensemble is composed of coastwide models, which means that the annual estimated biomass is a single value for the entire coast (U.S. and Canada) and migration between areas is not modeled. The ensemble modeling provides a more robust assessment approach that acknowledges structural uncertainty and has effectively stabilized management decision tables relative to catch recommendations and potential impacts on spawning biomass (in probabilistic terms). The assessment is explained in more detail in Section 1.3.3, Stewart & Hicks (2017), and Stewart & Martell (2015).

Outputs from the IPHC Pacific halibut stock assessment for all IPCH Regulatory Areas combined. Outputs of interest to ABM are spawning biomass or summary biomass (age-8 and older biomass). Neither of these outputs would be a useful index for small fish, and there are few data to inform the abundance of Pacific halibut younger than 8 years old. Therefore, the abundance of young fish in the stock assessment is mostly determined from average recruitment. This is fine for the management of the directed longline fishery, which mostly captures fish 8 years and older, but may not be appropriate to index to groundfish trawl fisheries.

Data availability

Preliminary results from the IPHC stock assessment are presented at the IPHC Interim meeting in late November, and final assessment used to provide management advice is presented at the IPHC Annual meeting in January. In the two months between these two meetings, the data are finalized and the assessment is error checked. Therefore, there may be some minor differences between the preliminary and final stock assessment results.

It may be possible to use the preliminary stock assessment for ABM of Pacific halibut PSC limits, which would be available before the December NPFMC meeting. However, the final assessment results would not be available until after the December NPFMC meeting.

Segment of halibut population index represents

The purpose of the stock assessment is to estimate stock status (spawning biomass) and provide O26 catch advice to Commissioners. Given that the stock assessment integrates multiple sources of information to assess Pacific halibut, it is likely the best index of coastwide spawning biomass and coastwide O26 biomass. **Even though this index is a comprehensive index for Pacific halibut, it is a coastwide index that would not be appropriate for indexing to PSC limits in BSAI. However, it is an appropriate index to meet the objective of protecting the halibut spawning stock biomass, particularly at low levels of abundance.** The Council requested that stock status be considered in the context of a control rule however and not in an abundance index. Therefore, this is addressed more directly in Section 4.3.

Segment of index population encountered in directed halibut and groundfish fisheries

The assessment outputs are the best estimate of biomass available to the directed fisheries, and combining these results with the IPHC setline survey results from each IPHC Regulatory Area provides an estimate of O26 biomass in each IPHC Regulatory Area. This would be an appropriate index for the directed fishery in BSAI and possibly the groundfish longline fisheries, but the IPHC setline survey index in BSAI uses fewer assumptions and provides a similar index. **Therefore, staff do not recommend using the IPHC coastwide assessment as an index to represent the directed Pacific halibut fishery, longline groundfish fisheries, and trawl groundfish fisheries in BSAI.**

3.2.6 Recruitment index

Initially, the analysts evaluated several potential indices to attempt to address halibut recruitment, the survival of fish born in the Bering Sea migrating to the coastwide stock, and eventually contributing to coast wide spawning biomass based on the Council's purpose and need statement. In addition, in the January 2017 public workshop, there was considerable interest in considering length based indices and examining the O26 (over 26 inches) portion of the stock as well as the O32 stock.

For the April 2017 Council meeting, we developed several new length based indices in numbers. Indices in numbers were chosen for two reasons, they are better representative of young fish (fewer of each year class has died from fishing and natural mortality), and abundance indices in numbers are more directly derived by length than indices of biomass. We developed four trawl survey indices of abundance using the NMFS trawl surveys of halibut less than 12 inches. These sizes of fish cover approximately the size range of one- and two-year-old halibut. The four indices used the EBS shelf trawl survey, the GOA trawl survey and the AI trawl survey. The fourth index was the sum of these three indices (Table 13,Table 14). The GOA and AI indices were developed under the premise that if recruitment was good outside of the EBS, then there would be less concern about bycatch mortality in the EBS. Similarly, if the sum of U12 index was high, then there was good potential recruitment for halibut Alaska wide. The EBS U12 index alone was considered for potential to represent the potential for future high encounter rates with small halibut.

To address the request to consider O26 fish in some part of a control rule, the analysts developed a trawl index for the EBS that was in numbers of fish under 26 inches (U26). Since early direction was given to try to address different components of the stock, this was a way to use the EBS trawl survey for young fish and the setline survey for adult fish and minimize overlap between the indices.

In June 2017, **the Council and SSC directed the analysts to focus on the broader stock, and not the smallest component because of concerns these fish may not necessarily recruit to the fishery and stock later.**

3.3 Fishery Dependent Information

Data from mandatory fishing industry reports and the North Pacific Groundfish and Halibut Observer Program (Observer Program) are the two sources of information used to estimate total catch in the Federal groundfish fisheries off Alaska. Each data source is confidential under the Magnuson-Stevens Fishery Conservation and Management Act (2007) and therefore can be shared only with authorized persons or in summary form for public dissemination. The unprocessed (raw) data collected by the Observer Program are available in a spatially aggregated form to the public on the Alaska Fisheries Science Center's (AFSC) website: http://www.afsc.noaa.gov/FMA. Aggregated estimates of total catch are available on the NMFS Alaska Regional Office website at: http://www.alaskafisheries.noaa.gov/sustainablefisheries/catchstats.htm.

While useful for looking at trends in catch and catch rates among gear types and sectors, fishery dependent data can be notoriously deficient as an index of abundance. 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). Overfishing of northern (Newfoundland) cod likely was made worse by an incorrect interpretation of fishery catch rates; assessment scientists did not realize that the area occupied by the stock was diminishing while the fishery catch rates remained level (Rose and Kulka

1999). Therefore, we focus mainly on using fishery dependent data to characterize which independent sources are encountering similar parts of the halibut stock.

3.3.1 Industry Reports

In general, vessels participating in Alaska groundfish fisheries can be divided into two broad categories: catcher/processors (CPs), which catch and process fish while at sea, and catcher vessels (CVs), which deliver their catch to either a shoreside processing facility or a vessel with the ability to process fish (including CPs). The types of vessels that only process or transport fish include motherships, stationary floating processors, and tender vessels. Motherships are large processing vessels (generally greater than 200 feet in length) that, unlike a stationary floating processor, are not tied to a single geographic location. Both motherships and stationary floating processors receive and process unsorted catch from CVs. Tender vessels deliver catch received from CVs to shoreside processing facilities.

There is a variety of information, such as fishing effort and catch, that is required to be submitted by the fishing industry to NMFS and is used to manage the fisheries. The majority of these data are available electronically; however, some data sources are not yet automated. The reporting requirements vary depending on the vessel operation, fishing gear, and fisheries. Below we discuss these reporting mechanisms, which can broadly be divided into two categories: 1) landings and production information reported by shoreside processing facilities, CPs, or motherships that is used to assess catch, the location of fishing effort, species disposition, and, in the case of CPs and motherships, product type; and 2) logbook information reported by vessel operators that provides information about effort, location, and total catch.

3.3.2 AFSC observer data

The Fisheries Monitoring and Analysis Division (FMA) or Observer Program monitors groundfish and halibut fishing activities in the Federal fisheries off Alaska and conducts research associated with sampling commercial fishery catches, estimation of catch and bycatch mortality, and analysis of fishery-dependent data. Contracted observers have sampled the catch in Alaska since the early 1990s and routinely collect lengths, weights, and ages of sampled catch. These data are used in stock assessments to track the mortality by age class and help estimate the strength of individual year classes. The catch composition and weights feed into the Catch Accounting System at the NMFS Regional Office to estimate total catch from both directed fishing and as incidental catch in other targeted fisheries. Length composition data from the incidental catch and directed fisheries for halibut can be used to estimate what ages of fish are available to the groundfish and halibut fisheries, and to estimate selectivities for these fisheries. Average weights can be used to estimate halibut mortality in numbers. Catch-per-unit-effort of halibut could potentially be used as an additional index of abundance. Similarly, incidental catch of halibut per catch of target species could also be informative about the relative availability of halibut in the EBS.

3.3.3 Commercial groundfish catch data

The landings data from the BSAI groundfish fisheries provide information on the groundfish species landed to determine bycatch rates of halibut in different groundfish targets among the fleets.

3.4 Extent to which indices meet recommended principles

The following principles for considering index qualities were developed for this discussion paper and modify principles that had been considered in previous discussion papers. These modifications reflect both stakeholder input, analytical efforts and Council direction at previous meetings. Thus in order to move forward with indices that best address the goals and objectives of an abundance-based approach, the following 5 principles are recommended.

1. The ABM index should be independent of management decisions.
2. The ABM index should be parsimonious, easy to understand, and easy to implement in a timely manner.
3. The ABM index should be free of as many assumptions as possible.
4. The ABM index should reflect halibut abundance in the Bering Sea.
5. The ABM index should reflect groundfish fishery encounters in the Bering Sea.

Other qualities and principles that have been considered in previous discussion papers include indices which could represent recruitment (smaller halibut), indicators of the health of the overall coastwide spawning stock biomass, and specific links to O32 halibut as a recognition of that segment of the populations which provides opportunities for the directed fishery. Table 12 summarizes the extent to which the candidate indices discussed in section 3 meet the 5 recommended principles. The remainder of this section provides additional information related to these recommendations.

Principle 1. The ABM index should be independent of management decisions.

This principle specifies that the selected index of halibut abundance should be based solely on scientific information that is not affected by policy or management decisions made the Council, NMFS, or the IPHC. All of the fishery independent information sources considered as a candidate index in section 3 are independent of fishery management decisions because they are derived from fishery independent surveys that are carried out using consistent methods developed by scientific staff.

Principle 2. The ABM index should be parsimonious, easy to understand, and easy to implement in a timely manner.

This principle specifies that the selected index should be a good measure of halibut abundance, but should also be the simplest or most economical metric available that can be easily understood by policy makers and stakeholders. The principle also specifies that the selected index should be independently available for use in the abundance-based halibut PSC management program both in terms of abundance metric(s) and timing.

Principle 3. The ABM index should be free of as many assumptions as possible

This principle specifies that the abundance index should be based on scientific observations as much as possible with minimum assumptions in the statistical analysis used to derive the index. For example, an index created from stock assessment output contains many scientific observations, but also many assumptions about the population dynamics that may introduce bias and may change over time.

Principle 4. The ABM index should reflect the abundance of halibut abundance in the Bering Sea.

This principle specifies that the selected index of halibut abundance should be focused on the Bering Sea, which is the area most impacted by the action under consideration. Although the action would establish abundance-based management of halibut PSC limits that apply to groundfish fisheries in the BSAI management area, the vast majority. i.e., 95 % of the overall groundfish harvests in the BSAI in 2016, take place in the Bering Sea. Therefore, an index of halibut abundance in the Bering Sea would reflect the vast majority of the halibut population encountered by the groundfish fisheries in terms of area.

Principle 5. The ABM index should reflect groundfish fishery encounters in the Bering Sea.

This principle specifies that the selected index should reflect the abundance of the halibut population that is encountered by the groundfish fisheries in terms of area and halibut characteristics such as size and age. This ensures that the abundance-based halibut PSC limits reflect the status of the halibut population encountered on the groundfish fishing grounds and that the groundfish fleet can take measures to avoid. For purposes of selecting an ABM index, it is important to note that the halibut encountered by the groundfish fishery likely is a function of both halibut abundance and fishery behavior. For example, vessels that avoid fishing at night or move to another area to try and lower halibut bycatch rates are changing their rates and patterns of halibut encounters in ways that may be difficult to identify from observer data or catch data.

Table 12. Summary of different data available for evaluating abundance based Pacific halibut PSC limits.

Data source	Characteristics	Meets Recommended Principles
AFSC EBS shelf bottom trawl survey	• Annual • Size composition matches observed bycatch • Mostly smaller Pacific halibut	1 – Yes: Independent of management decisions 2 – Yes: Robust time series of data available for harvest specifications process 3 – Yes: Uses standardized AFSC methodology to analyze data 4 – Yes: Adequate estimate of halibut abundance in the Bering Sea per IPHC 5 – Yes for Trawl: Encounters by size almost identical to trawl groundfish fisheries; Somewhat for longline: Encounters by size similar to groundfish fisheries
IPHC setline survey	• Annual • Size composition similar to directed fishery • Limited area in shallower EBS area • Mostly larger Pacific halibut	1 – Yes: Independent of management decisions 2 – Yes: Robust time series of data presented in standard metrics and available for the annual groundfish harvest specifications process 3 – Yes: Uses standardized IPHC methodology to analyze data 4 – Yes: Best available estimate of halibut available to the EBS directed fishery 5 – Somewhat: Encounters larger halibut than trawl but overlaps with longline groundfish fisheries
AFSC EBS slope bottom trawl survey	• Biennial • Expands adjacent shelf survey coverage • Larger halibut than EBS shelf survey • Limited survey area	1 – Yes: Independent of management decisions 2 – Yes: Biennial time series of data available for harvest specifications process 3 – Yes: Uses standardized AFSC methodology to analyze data 4 – No: Limited survey area 5 – No: Encounters larger halibut than trawl and longline groundfish fisheries
AFSC GOA bottom trawl survey	• Biennial • May index smaller (recruiting) halibut in the GOA	1 – Yes: Independent of management decisions 2 – Yes: Robust time series of data available for harvest specifications process 3 – Yes: Uses standardized AFSC methodology to analyze data 4 – No: Survey area is GOA 5 – No: Survey area is GOA
AI bottom trawl survey	• Biennial • Similar size composition to EBS shelf survey • Limited halibut occurrence	1 – Yes: Independent of management decisions 2 – Yes: Biennial time series of data available for harvest specifications process 3 – Yes: Uses standardized AFSC methodology to analyze data 4 – No: Survey area is AI 5 – No: Survey area is AI
AI AFSC longline survey	• Biennial • Size composition similar to directed fishery • Indexes larger Pacific halibut • Lengths unavailable	1 – Yes: Independent of management decisions 2 – Yes: Biennial time series of data available for harvest specifications process 3 – Yes: Uses standardized AFSC methodology to analyze data 4 – No: Survey area is AI 5 – No: Survey area is AI
IPHC Assessment trend	• Annual • Includes the halibut outside of the EBS area • Generally larger fish than observed in groundfish fisheries	1 – Yes: Independent of management decisions 2 – Yes: Robust time series of data available for harvest specifications process 3 – No: Assessment model uses many assumptions that change over time 4 – Yes: Best estimate of halibut abundance in the Bering Sea 5 – No: Estimates abundance of larger halibut than in the groundfish fisheries
Observer data	• Annual • Comprehensive, especially post-2008 • May help form control rule • Size composition data excludes 2016 due to EFP	1 – No: Dependent on management decisions and fishery behavior 2 – Yes: Robust time series of data available for harvest specifications process 3 – Yes: Uses standardized AFSC methodology to analyze data 4 – No: Estimates affected by fishery behavior 5 – No: Estimates affected by fishery behavior
Commercial groundfish catch data	• Annual • Bycatch rates could inform policy decisions • Bycatch per unit effort a poor measure of abundance	1 – No: Dependent on management decisions 2 – Yes: Robust time series of data available for harvest specifications process 3 – Yes: Uses standardized NMFS methodology to analyze data 4 – No: Estimates affected by fishery behavior 5 – No: Estimates affected by fishery behavior

3.5 Index qualities

We considered several indices to address different aspects of the halibut population (Table 13 and Table 14). Generally, biomass (weight) indices will pertain to a relatively older part of the population (older fish are larger and make up more of a biomass estimate) and have lower variability relative to indices in numbers. This lower variability is because the older mixture of age classes has been subject to fishing and natural mortality over time. Conversely, indices in numbers of fish will have higher variability because younger fish make up a high proportion of these indices (i.e., recent year classes that have been subjected to less fishing and natural mortality).

Indices developed for the EBS shelf survey were primarily intended to define the population segment vulnerable to the groundfish fishery and the directed Area 4CDE halibut fishery. Indices from outside the EBS were considered to account for reproductive status and success of the coastwide or Alaska-wide population and to account for the possible “downstream” movement of young halibut from the EBS shelf to other areas.

Index variability over time ranged from a low of about 17% for the AI trawl survey numbers and the EBS shelf biomass, to a high of 133% for the U12 EBS shelf survey numbers. Part of this variability arises from measurement error/sampling error but also includes “process error”—i.e., the extent that the true but unknown population component varies from year to year. For example, in a relative sense the process error for a recruitment index is expected to be much higher than say an index of adults which represents many age classes.[10]

[10] Index variability could be stabilized within a control rule. For example, ABM1 might be specified such that the b values are a function of the time series CV: $b = \frac{1}{1+CV_{Index}}$ which could reduce sensitivity to the more variable indices.

Table 13. Description of Pacific halibut indices developed for consideration in creating alternative ABM control rule frameworks. Note that the naming convention follows roughly the size:area:gear:units format for Pacific halibut.

Pacific halibut Index Name	Description	Applies to what part of the halibut population
O26/O32.4CDE.Setline.Bio	Biomass of halibut over 32 inches from the IPHC setline survey in the BSAI	Representative of mostly female mature fish, targeted by the directed fishery in the EBS (Area 4CDE)
O26/O32.CW.Setline.Bio	Biomass of halibut over 32 inches from the IPHC setline survey in all areas	Representative of mostly female mature fish and as a proxy to coast wide stock status
SB.Assessment.Bio	Current estimate of spawning biomass from the stock assessment model	Stock assessment estimate of coastwide female spawning biomass, similar to stock status, also representative of large fish
Status.Assessment.Bio	Current level of spawning biomass relative to unfished from the stock assessment	Stock assessment estimate of coastwide stock status, representative of the relative amount of female spawners
Tot.EBSShelf.Trawl.Bio	Biomass of all sizes on the EBS Shelf trawl survey 2016	Representative of the trawl-vulnerable biomass in the EBS and what the groundfish bycatch fishery encounters.
Tot.AI.Trawl.Num	Biomass of all sizes on the AI Shelf trawl survey	Representative of younger population in the AI, possibly of fish successfully leaving the EBS shelf.
Tot.EBSShelf.Trawl.Num	Numbers of all sizes on the EBS Shelf trawl survey 2016	Representative of younger population in the EBS, for tracking recent higher recruitment to the EBS shelf.
Tot.GOA.Trawl.Num	Numbers of all sizes on the GOA trawl survey 2016	Representative of younger population in the GOA, possibly of fish successfully leaving the EBS shelf or coastwide recruitment success.
U12.AI.Trawl.Num	Numbers under 12 inches on the AI trawl survey	Representative of recruitment in the last two years in the AI, possibly indicative of coastwide recruitment success.
U12.AK.Trawl.Num	Combined numbers under 12 inches on the GOA/AI/EBS trawl surveys	Representative of recruitment in the last two years in the overall Alaska stock, probably indicative of coastwide recruitment success.
U12.EBSShelf.Trawl.Num	Numbers under 12 inches on the EBS Shelf trawl survey	Representative of recent recruitment in the EBS, possibly indicative of coastwide recruitment and fish to be encountered soon as bycatch in the EBS.
U12.GOA.Trawl.Num	Numbers under 12 inches on the GOA trawl survey	Representative of recruitment in the last two years in the GOA, possibly indicative of coastwide recruitment success.
O12.EBSShelf.Trawl.Num	Numbers over 12 inches on the EBS Shelf trawl survey	Fish older than 2 in the EBS that could be encountered by both groundfish and directed fisheries
U26.AI.Trawl.Num	Numbers under 26 inches on the AI trawl survey	Representative of younger sub-legal fish in the AI and indicative of recent recruitment.
U26.EBSShelf.Trawl.Num	Numbers under 26 inches on the EBS Shelf trawl survey 2016	Representative of younger sub-legal fish on the EBS shelf vulnerable to the groundfish fishery and indicative of recent recruitment.
U26.GOA.Trawl.Num	Numbers under 26 inches on the GOA trawl survey	Representative of younger sub-legal fish in the GOA and indicative of recent recruitment or movement from the EBS.
U26.AK.Trawl.Num	Combined numbers under 26 inches on the GOA/AI/EBS trawl surveys	Representative of younger sub-legal fish in in Alaska waters, and indicative of recent coastwide recruitment success.

Table 14. Characteristics of indices developed for consideration in creating alternative ABM control rule frameworks. Column labeled “2016 value” represents the “multiplier” or value from the standardized index defined as the index value divided by the index mean from 1998-2016. Index variability is the measure of interannual variance, which contains elements of process and measurement error.

Pacific halibut Index Name	Units	2016 Value	Index CV	Range	Frequency
O26/O32.4CDE.Setline.Bio	Biomass	0.95	25%	1998-2016	Annual
O26/O32.CW.Setline.Bio	Biomass	0.69	36%	1998-2016	Annual
SB.Assessment.Bio	Biomass	0.73	40%	1998-2017	Annual
Status.Assessment.Bio	Biomass	0.72	40%	1998-2017	Annual
Tot.EBSShelf.Trawl.Bio	Biomass	1.00	17%	1982-2016	Annual
Tot.AI.Trawl.Num	Numbers	0.72	17%	1980-2016	Biennial
Tot.EBSShelf.Trawl.Num	Numbers	0.88	38%	1982-2016	Annual
Tot.GOA.Trawl.Num	Numbers	0.96	27%	1984-2015	Biennial
U12.AI.Trawl.Num	Numbers	0.94	62%	1980-2016	Biennial
U12.AK.Trawl.Num	Numbers	0.57	75%	1984-2016	Annual*
U12.EBSShelf.Trawl.Num	Numbers	0.43	133%	1982-2016	Annual
U12.GOA.Trawl.Num	Numbers	0.72	53%	1984-2015	Biennial
O12.EBSShelf.Trawl.Num	Numbers	0.98	32%	1982-2016	Annual
U26.AI.Trawl.Num	Numbers	0.68	15%	1980-2016	Biennial
U26.EBSShelf.Trawl.Num	Numbers	0.84	47%	1982-2016	Annual
U26.GOA.Trawl.Num	Numbers	0.83	31%	1984-2015	Biennial
U26.AK.Trawl.Num	Numbers	0.83	33%	1984-2016	Annual*

*Alaska-wide trawl indices use the previous year’s estimate for areas that are in an off year of their biennial cycle (i.e., Aleutians in odd years and Gulf of Alaska in even years).

3.6 Relationships among abundance indices

In principle, the set of indices selected for use in a control rule to establish a BSAI halibut PSC limit should provide information on Pacific halibut stock components and groundfish bycatch encounters. Such data are input to an ABM control rule which can be tuned up to improve performance metrics relative to directed halibut and groundfish fishery objectives. The characteristics of relationships between indices is important to consider.

1) To consider the coastwide status of halibut, an index of abundance from the IPHC assessment and research products should be considered. Indices from their stock assessment model and their setline indices are virtually interchangeable due to their high **positive correlations** (Table 15). This contrasts with EBS trawl-survey indices which are negatively correlated (Figure 34). **Hence, EBS trawl survey indices appear to be unsuitable for tracking coastwide Pacific halibut stock status.**
2) **For indices that track Pacific halibut recruitment, or general presence of young fish, it is probably best to choose an index in numbers.** Such an index may likely be **uncorrelated** with stock status or an index of large fish. For example, the stock assessment estimate of spawning biomass is weakly correlated with a young fish index (U12.AK.Trawl.Num; Table 15, 0.053).
3) Combinations of indices may offset each other since some are highly **negatively correlated.** For example, the IPHC setline index for 4CDE as an index of adult fish and an index of young fish in the EBS (O12.EBSShelfTrawl.Num) are negatively correlated (Table 15, -0.812).

Generally, combining indices that are either uncorrelated or negatively correlated would have properties that would help in explaining different dynamics of the population. Choosing indices that are highly positively correlated would have the effect of adding emphasis to that population component and for simplicity, it would likely be better to use just one of them. Figure 34 shows that there are multiple indices available for each stock attribute being addressed and several are interchangeable.

3.6.1 Relationships with fishery catch rates

In addition to the fishery independent indices, a number of catch-per-unit-effort (CPUE) indices were developed from the commercial catch data in the EBS. These indices included indices by gear during 1998- 2016 (Figure 35) and by sector during 2010 – 2016 when data from all sectors were available. Because of feedback from the June Council meeting, we restricted comparisons of these fishery CPUE indices to abundance indices from only the EBS (but including some parts of the Aleutians in the IPHC 4ABCDE index) both in biomass and numbers. The indices used all available observed hauls or sets (excluding IFQ sets) from the BS, and included hauls and sets with zero halibut, because encounter rate (Figure 36 and Figure 37) is an important aspect of halibut abundance. Catch-per-unit effort indices for trawl gear were constructed with both extrapolated weight (CPUE) and extrapolated numbers (CPUEN). For each trawl gear type, the calculation is the sum of extrapolated weight or numbers divided by the sum of duration (minutes) by year. For longline data, the calculation is the sum of extrapolated weight divided by the sum of total hooks by year.

Data by gear uses all the observed hauls or sets in the EBS for Pelagic Trawl (PT), Non-pelagic Trawl (NPT), and longline (LL) gear during 1998 - 2016. To appropriately capture trends in catch-per-unit-effort and encounter rate, all hauls or sets were included, not just those that caught halibut. However, directed fishery catches (IFQ) were not included in the longline gear type. A caveat of these data is that the NPT fleet in 2015 and 2016 initiated deck sorting experiments that may have affected the observer coverage.

Data by sector was computed in collaboration with the Alaska Regional Office which assigned individual observed hauls and sets to their management program code. This code allows each haul to be assigned to one of the Amendment 80 (A80), Trawl Limited Access Sector (TLAS), Community Development Quota (CDQ), or the longline (LL) sectors. Since data were only available from 2010 – 2016, the power of a correlation analysis is much more limited. A significant correlation with a sample size of 7 at the 0.05 level is 0.76, before accounting for the multiple comparisons performed here.

Correlation analysis of gear specific fishery CPUE and the primary indices revealed several strong relationships. Longline fishery CPUE is positively correlated with the IPHC setline indices, but the correlation of LL CPUE with the setline 4ABCDE is substantially higher than with 4CDE (Table 16 and Figure 36). IPHC 4ABCDE and 4CDE setline indices are probably interchangeable with a very high correlation between them (0.94), but if tracking the CPUE of the longline gear type is desirable, **the 4ABCDE index would be the superior index with a correlation of 0.84 versus 0.66**. **EBS trawl indices are negatively correlated with the longline gear CPUE so would not be appropriate to track that gear type. Likewise, the IPHC setline indices are negatively correlated with all the trawl CPUE and CPUEN indices and would not be able to track those usefully.** EBS trawl survey biomass is highly correlated with both NPT CPUE, while EBS trawl survey numbers is strongly correlated with NPT CPUEN. EBS trawl survey in numbers and biomass is also positively correlated with both PT CPUE and CPUEN. **These high correlations of the EBS shelf trawl survey with the two trawl gear types in both biomass and numbers indicates that it would be a useful index to track encounter rates for this gear type.**

While the time series of sector data is short, correlation analysis of sector specific fishery CPUE and the primary indices revealed several strong relationships (Table 17 and Figure 37). The IPHC 4CDE setline was generally negatively correlated with all other CPUE and abundance indices, while the IPHC

4ABCDE index was strongly positively correlated with the EBS shelf trawl survey numbers index and the A80 CPUEN. The EBS shelf trawl numbers were also strongly correlated with the A80 CPUEN series. Unlike the longer period of gear-specific CPUE, the EBS shelf trawl survey biomass was strongly correlated with the sector longline CPUE **and** the A80 CPUE in weight and numbers. This is because the A80 CPUE and CPUEN are strongly correlated with the LL CPUE and CPUEN in this shorter time series.

In addition to the correlation analysis done previously for the abundance indices, we examined the lagged correlations of the primary abundance indices and the fishery CPUE and CPUEN data (Table 18). The reason to do this is that it might be of interest to have an index that is negatively lagged with the fishery CPUE because we are attempting to predict what future encounters might be. NPT CPUEN and CPUE were strongly correlated with EBS bottom trawl survey numbers in two years. This is relevant because each annual PSC limit may be based on the previous year's abundance index. The results show that CPUE and CPUEN in the NPT trawl correlates higher with the EBS trawl survey biomass index when lagged by one or two years, but the correlation is not much stronger than with no lag. The EBS trawl numbers are highly correlated with trawl biomass at a 4 year lag (i.e., the small fish in the numbers index grow into biomass 4 years later).

Table 15. A subset of all the pairwise correlations between halibut indices. Strong positive and negative between indices (>0.8), and the weakest correlations (<0.1). 53.3% the 135 pairs of correlations were positive

Index 1	**Index 2**	***r***	**Type**
O12.EBSShelf.Trawl.Num	O32.4CDE.Setline.Bio	-0.812	**Strong Negative**
Tot.EBSShelf.Trawl.Bio	U12.AI.Trawl.Num	-0.803	
Tot.EBSShelf.Trawl.Num	U12.GOA.Trawl.Num	-0.098	**Uncorrelated**
U12.EBSShelf.Trawl.Num	O32.CW.Setline.Bio	-0.093	
O32.CW.Setline.Bio	U12.EBSShelf.Trawl.Num	-0.093	
Status.Assessment.Bio	U12.AK.Trawl.Num	-0.053	
SB.Assessment.Bio	U12.AK.Trawl.Num	-0.052	
U12.AI.Trawl.Num	U12.EBSShelf.Trawl.Num	-0.05	
U12.GOA.Trawl.Num	U26.EBSShelf.Trawl.Num	-0.042	
Tot.AI.Trawl.Num	Tot.GOA.Trawl.Num	-0.022	
Tot.EBSShelf.Trawl.Bio	Tot.GOA.Trawl.Num	-0.006	
U12.AI.Trawl.Num	U26.GOA.Trawl.Num	-0.003	
Tot.AI.Trawl.Num	U12.EBSShelf.Trawl.Num	-0.002	
Tot.AI.Trawl.Num	U12.AK.Trawl.Num	0.008	
Tot.AI.Trawl.Num	U12.GOA.Trawl.Num	0.027	
O32.CW.Setline.Bio	U12.AK.Trawl.Num	0.054	
Tot.AI.Trawl.Num	U12.AI.Trawl.Num	0.064	
U12.EBSShelf.Trawl.Num	U12.GOA.Trawl.Num	0.066	
O12.EBSShelf.Trawl.Num	U12.AK.Trawl.Num	0.089	
O12.EBSShelf.Trawl.Num	Tot.EBSShelf.Trawl.Num	0.81	**Strong Positive**
Tot.GOA.Trawl.Num	U26.Tot.Trawl.Num	0.84	
Tot.EBSShelf.Trawl.Num	U26.Tot.Trawl.Num	0.871	
U26.EBSShelf.Trawl.Num	U26.Tot.Trawl.Num	0.891	
O32.4CDE.Setline.Bio	O32.CW.Setline.Bio	0.922	
U26.GOA.Trawl.Num	U26.Tot.Trawl.Num	0.924	
U12.AK.Trawl.Num	U12.EBSShelf.Trawl.Num	0.94	
Tot.GOA.Trawl.Num	U26.GOA.Trawl.Num	0.958	
Status.Assessment.Bio	O32.4CDE.Setline.Bio	0.961	
O32.4CDE.Setline.Bio	Status.Assessment.Bio	0.961	
O32.CW.Setline.Bio	Status.Assessment.Bio	0.986	
O32.CW.Setline.Bio	SB.Assessment.Bio	0.987	
Tot.EBSShelf.Trawl.Num	U26.EBSShelf.Trawl.Num	0.995	

Table 16. Correlations for gear specific data from 1998 – 2016 when values were higher than 0.7 or lower than -0.7.

Index1	Index2	Cor
EBSShelf.Trw.Num	O32.4CDE.Setline	-0.73
EBSShelf.Trw.Bio	Gear.NPT.CPUE	0.713
Gear.NPT.CPUE	Gear.NPT.CPUEN	0.811
Gear.NPT.CPUE	Gear.PT.CPUEN	0.842
Gear.LL.CPUE	O32.4ABCDE.Setline	0.843
Gear.NPT.CPUEN	Gear.PT.CPUEN	0.844
Gear.NPT.CPUEN	Gear.PT.CPUE	0.846
Gear.NPT.CPUE	Gear.PT.CPUE	0.87
O32.4ABCDE.Setline	O32.4CDE.Setline	0.939
Gear.PT.CPUE	Gear.PT.CPUEN	0.984

Table 17. Correlations for sector specific data from 2010 – 2016 when values were higher than 0.8 or lower than -0.8.

Index1	Index2	Cor
EBSShelf.Trw.Bio	O32.4CDE.Setline	-0.846
O32.4CDE.Setline	Sector.A80.CPUE	-0.838
Sector.CDQ.CPUEN	Sector.TLAS.CPUEN	0.812
Sector.CDQ.CPUE	Sector.TLAS.CPUE	0.82
EBSShelf.Trw.Bio	Sector.A80.CPUEN	0.822
Sector.TLAS.CPUE	Sector.TLAS.CPUEN	0.831
EBSShelf.Trw.Num	O32.4ABCDE.Setline	0.833
EBSShelf.Trw.Bio	Sector.A80.CPUE	0.849
EBSShelf.Trw.Num	Sector.A80.CPUEN	0.908
EBSShelf.Trw.Bio	Sector.LL.CPUE	0.909
Sector.A80.CPUE	Sector.LL.CPUE	0.91
Sector.A80.CPUEN	Sector.LL.CPUE	0.932

Table 18. Comparison of fishery CPUE (weight) and CPUEN (numbers with the primary fishery-independent indices of biomass (weight) and abundance (numbers) and their lagged correlations from 1998-2016. Only positive correlations greater than 0.75 shown.

Index 1	Index 2	Lag	Cor
Gear.NPT.CPUEN	EBSShelf.Trw.Num	2	0.84
Gear.NPT.CPUE	EBSShelf.Trw.Num	2	0.83
Gear.PT.CPUE	EBSShelf.Trw.Bio	-1	0.83
Gear.PT.CPUE	EBSShelf.Trw.Num	2	0.82
Gear.NPT.CPUEN	Gear.NPT.CPUE	0	0.81
Gear.NPT.CPUEN	EBSShelf.Trw.Bio	-2	0.81
Gear.NPT.CPUE	EBSShelf.Trw.Bio	-1	0.81
Gear.PT.CPUEN	EBSShelf.Trw.Bio	-1	0.80
Gear.PT.CPUEN	EBSShelf.Trw.Num	2	0.80
EBSShelf.Trw.Num	EBSShelf.Trw.Bio	-4	0.79

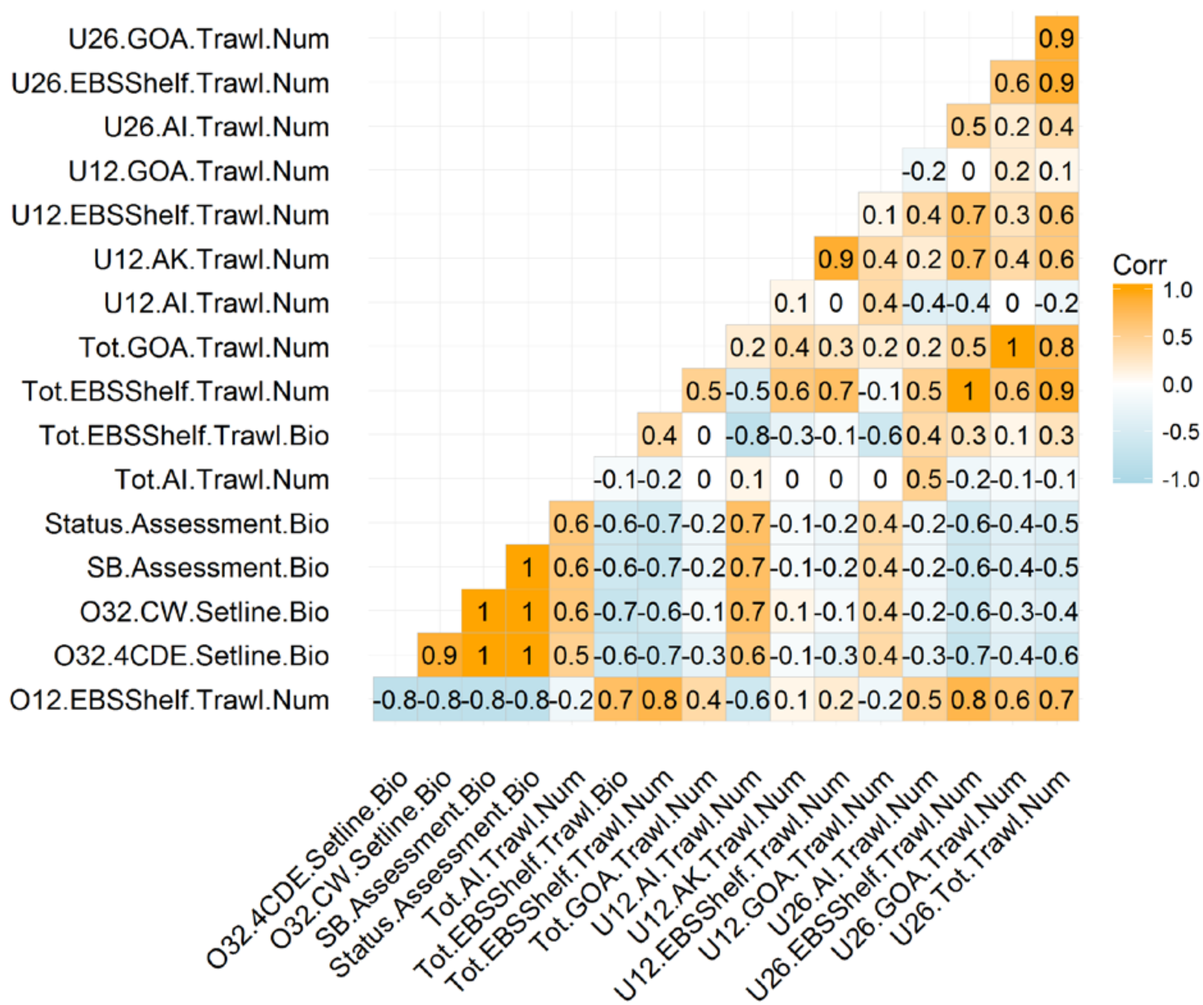

Figure 34. Complete pairwise correlations among indices. Orange is positive and blue is negative.

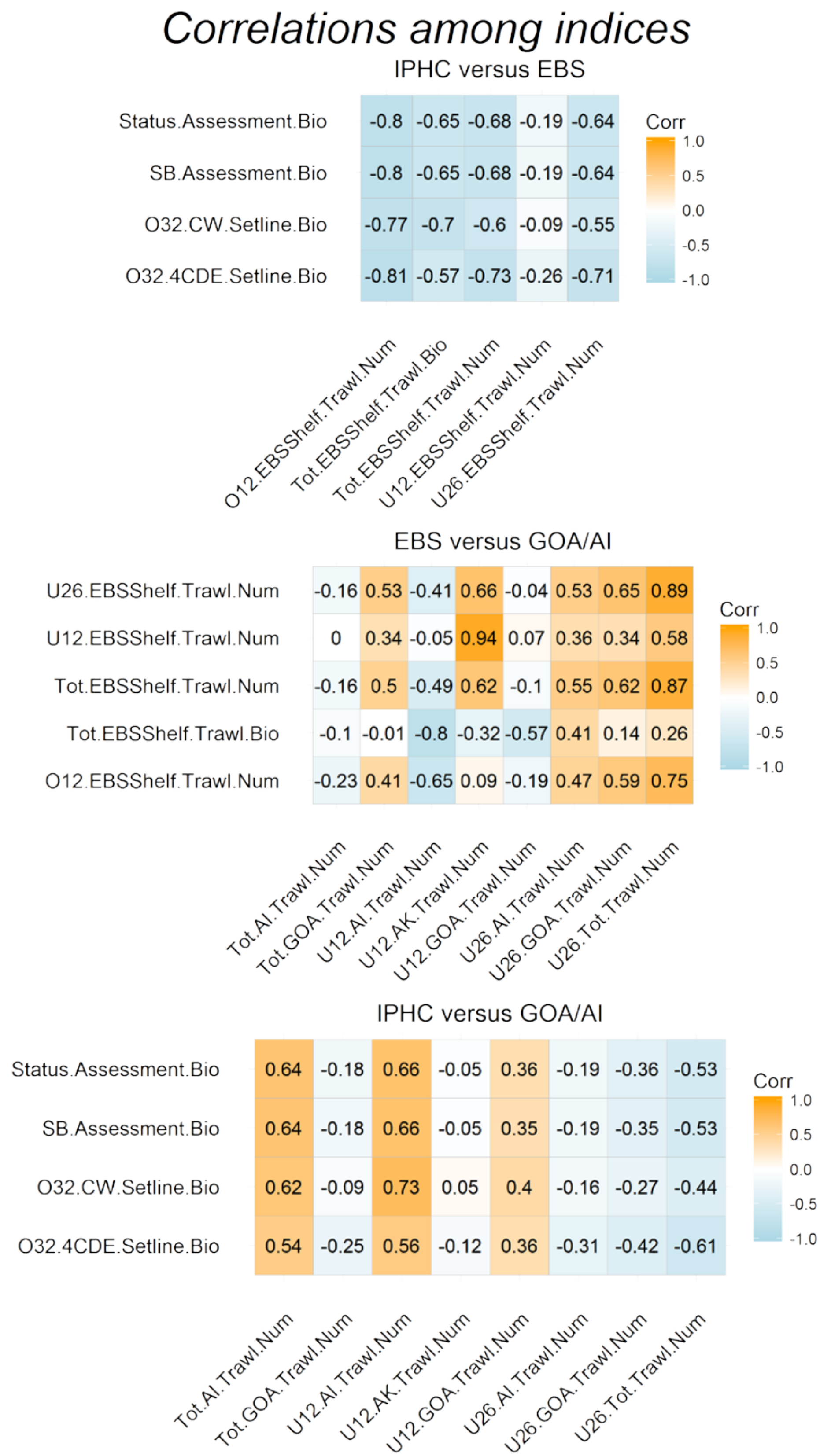

Figure 35. Correlations between groups of indices (IPHC longline, inside the EBS, and outside the EBS).

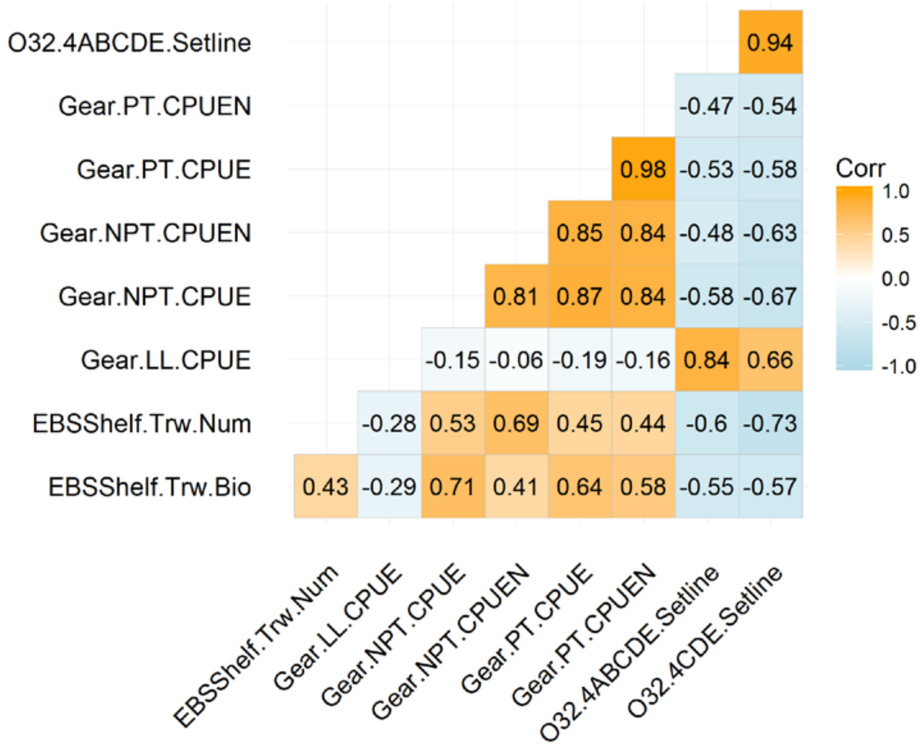

Figure 36. Correlations of gear-specific fishery CPUEs and CPUENs with EBS biomass and abundance indices (1998 – 2016).

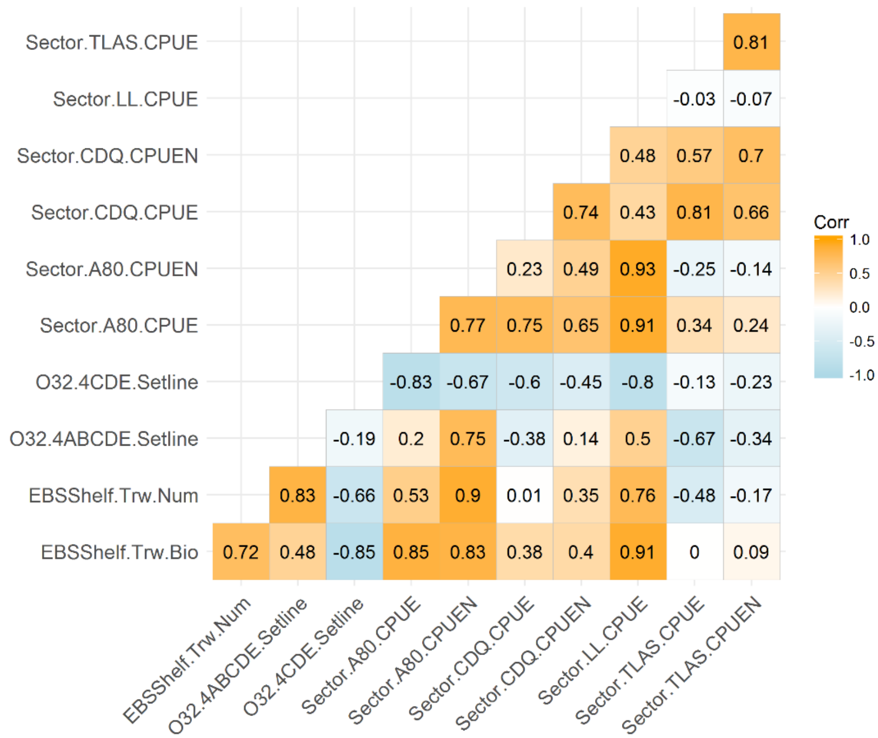

Figure 37. Correlations of sector fishery CPUEs and CPUENs with EBS biomass and abundance indices (2010 – 2016).

3.7 Summary of indices and conclusions

The EBS shelf survey covers a substantially larger portion of the Bering Sea than the IPHC setline survey because the IPHC cannot sample the entire Bering Sea shelf area for halibut each year. In addition, the fishing gear used in the IPHC setline survey generally catches halibut that are over 26 inches in length (O26) and available for harvest in the directed commercial fishery. Therefore, in most years, the EBS shelf survey is the only measure of relative abundance of smaller sizes of halibut (under 26 inches in length or U26) for much of this area. The IPHC considers the EBS shelf survey to be an adequate accounting of Pacific halibut biomass on the EBS shelf for use in the IPHC stock assessment. This suggests that the EBS shelf survey is a good candidate to meet the Council's objective to identify an index that reflects halibut abundance in the Bering Sea.

The EBS shelf survey size and age data show that the halibut caught in the survey with trawl gear are smaller and younger compared to halibut caught with longline gear in the directed halibut fisheries and in the IPHC setline survey, and in other surveys that use non-trawl gear as described in the previous sections. The data also shows that the segment of the population represented by the EBS shelf survey is generally representative of halibut encountered by the trawl and longline groundfish fisheries.

The "downstream" effects of PSC mortality on coastwide spawning biomass and recruitment was initially an explicit consideration in selecting indices in earlier versions. This led to considering indices from the Gulf of Alaska and Aleutian Islands and also coastwide stock status as estimated in the IPHC assessment. In addition, indices were developed that tracked recruitment directly (U12) in the EBS and outside the EBS.

EBS trawl survey estimates of halibut were generally an inconsistent index of stock status. For example, from 2002 – 2010, the EBS shelf survey biomass estimate showed an increasing trend for halibut, while the coastwide estimate of halibut abundance was declining. This low correlation indicates that the EBS shelf survey is not a reliable predictor of coastwide halibut abundance when used as a sole data source. The information on younger Pacific halibut in the EBS may have some limited ability (perhaps only for very strong cohorts) to forecast recruitment into the commercial Pacific halibut fishery. However, in June 2017, the Council adopted a recommendation from the SSC to eliminate development of indices that are intended to represent coastwide stock status or recruitment.

The EBS shelf survey in both numbers and biomass was well correlated with the bycatch trawl gear sectors in the EBS. The size composition of halibut bycatch in the trawl gear sectors was also contained within the range of the sizes encountered by the EBS shelf survey. The EBS shelf survey indices were negatively correlated with the groundfish longline fishery bycatch. The EBS shelf survey likely would not be a useful index for halibut caught in the directed commercial fishery in the EBS because a substantial portion of the commercial-sized halibut population exceeds 85 cm and most of the Pacific halibut caught in the survey are under 82 cm.[11]

The IPHC 4ABCDE setline index was highly correlated with the CPUE of halibut bycatch encountered by vessels using longline gear in the groundfish fisheries. The groundfish longline fishery CPUE is positively correlated with the IPHC setline indices, but the correlation of LL CPUE with the setline 4ABCDE is substantially higher than with 4CDE (Table 16 and Figure 36). The size compositions of the

[11] Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis for Amendment 111 to the Fishery Management Plan for Groundfish of the Bering Sea/Aleutian Islands Management Area to Revise Bering Sea/Aleutian Islands Halibut Prohibited Species Catch Limits, January 2016, available at https://www.regulations.gov/document?D=NOAA-NMFS-2015-0092-0030.

IPHC setline survey and longline gear (Figure 19) were not as similar to one another as were the trawl survey as compared to the trawl fisheries size compositions (Figure 20). However, the size composition of halibut caught in the IPHC setline survey was more similar to the size composition of halibut caught with the longline gear than trawl gear in the groundfish fisheries (Figure 19, Figure 20). If tracking the CPUE of the longline groundfish fishery is desirable, **the 4ABCDE index would be an appropriate index (correlation of 0.84 is high)**. The **EBS trawl indices are negatively correlated with the groundfish longline gear CPUE so would be less appropriate for tracking that gear type.**

Upon presentation of these indices at earlier Council meetings and after examining the relationships with bycatch and directed fisheries, it was recommended that indices should be focused on what would be encountered in the EBS only. With that guidance in mind, we used the following rationale for omitting and retaining each index to form ABM alternatives:

- The EBS shelf survey provides a good index of (mostly younger) Pacific halibut taken as bycatch in the Bering Sea trawl groundfish fisheries because they are highly correlated
- The information on halibut from the EBS shelf survey is a useful index for the halibut encountered by the trawl groundfish fishery in the Bering Sea because it selects sizes of halibut that are similar to those sizes of halibut selected by the vessels in those fisheries. It may also be a useful index for halibut encountered by the groundfish longline fishery given some overlap in size composition (but has a low correlation to CPUE).
- The IPHC 4ABCDE setline index is a useful index for the bycatch encountered in the longline groundfish fishery because they are highly correlated and catch size compositions are similar.
- The IPHC 4ABCDE has a stronger relationship to the EBS longline fishery halibut bycatch than the relationship of the 4CDE index to the EBS longline fishery halibut bycatch.

3.7.1 Recommendations for indices to move forward on construction of Strawmen ABM alternatives

To date the Council has reviewed a large number of indices and options. The current analysis shows that some of these indices, while providing a rigorous evaluation of available data, likely provide qualitatively similar information in terms of trends (i.e., those that are positively correlated). The above also shows that some indices are closely related to the groundfish fisheries CPUE, which provides further support for their inclusion. Finally, the size compositions and mean weights in the catches also show some consistency with the indices. As such, **we recommend considering the EBS bottom trawl survey and the IPHC Area 4ABCCDE setline survey (SLS) as indices for abundance based management of Pacific halibut PSC. We further recommend options for their inclusion separately and/or in combination along with a control rule.** These are presented in the Section 5.1. These satisfy a goal to have indices that appropriately tracks Pacific halibut abundances yet remain transparent in source and implementation.

4 Control Rules to Establish Halibut PSC Limits

A control rule is a function that is driven by data and results in a regulatory control. Here we describe simple classes of control rules which is essentially a continuous linear response (responsiveness can vary) and breakpoints (i.e., ceilings and floors). For any approach selected, a critical decision point for the Council will be selecting a baseline starting point (the PSC limit when indices are at their 2016 values).

4.1 Features of control rules (slope, stability, floor, ceiling, starting point, etc.)

Described below are some of the features of a control rule that could be included in ABM alternatives. Figure 1 provides an illustration of each of the features defined below, besides the starting point. The values associated with each of these features are policy decisions to be made by the Council with input from stakeholders. Following the description of features, some actual formulations in use to establish PSC limits are provided in order to best demonstrate the combination of features that can be included in designing alternatives measures to set halibut PSC limits in the Bering Sea.

Starting point. The starting point is the PSC limit when the ABM index is at its value in the year of choice (2016 in our examples) and this value is a policy choice. The PSC limit in 2016 was 3,515 t, but that does not necessarily need to be the starting point from which the PSC limit will increase or decrease depending on the directional change of the ABM index.

Slope. The slope of the control rule determines how responsive a change in PSC limit is to abundance. A one to one relationship of abundance to PSC limit from the starting point (e.g., if the abundance index increases by 10% then the PSC limit would increase by 10%) value would result in a 45 degree angle (with the line passing through the origin at 0). More shallow slopes from the same starting point would result in a less than one to one relationship and a steeper slope resulting in a greater than one to one relationship of PSC to abundance.

Floor and ceiling. A minimum value of the PSC limit (floor) or a maximum value of the PSC limit (ceiling) could be imposed such that the PSC limit is constrained within some range. A narrow range would imply greater stability in the inter-annual variability of the PSC limit.

Stability provisions. The inter-annual variability of the PSC limit can be dampened by imposing additional measures for some stability in limits from year to year in order to facilitate planning for groundfish operations. This may be done in a variety of ways. A floor and ceiling can be imposed such that limits have a minimum and maximum possible value regardless of the abundance estimate. There can be provisions to setting the limit that regardless of the calculated amount, it cannot vary by greater than a certain percentage of the previous year's limit, or other incentives measures for bycatch reduction carry overs from one year to the next. Some examples of these provisions in PSC management are described below as well as in Section 6 on incentive measures.

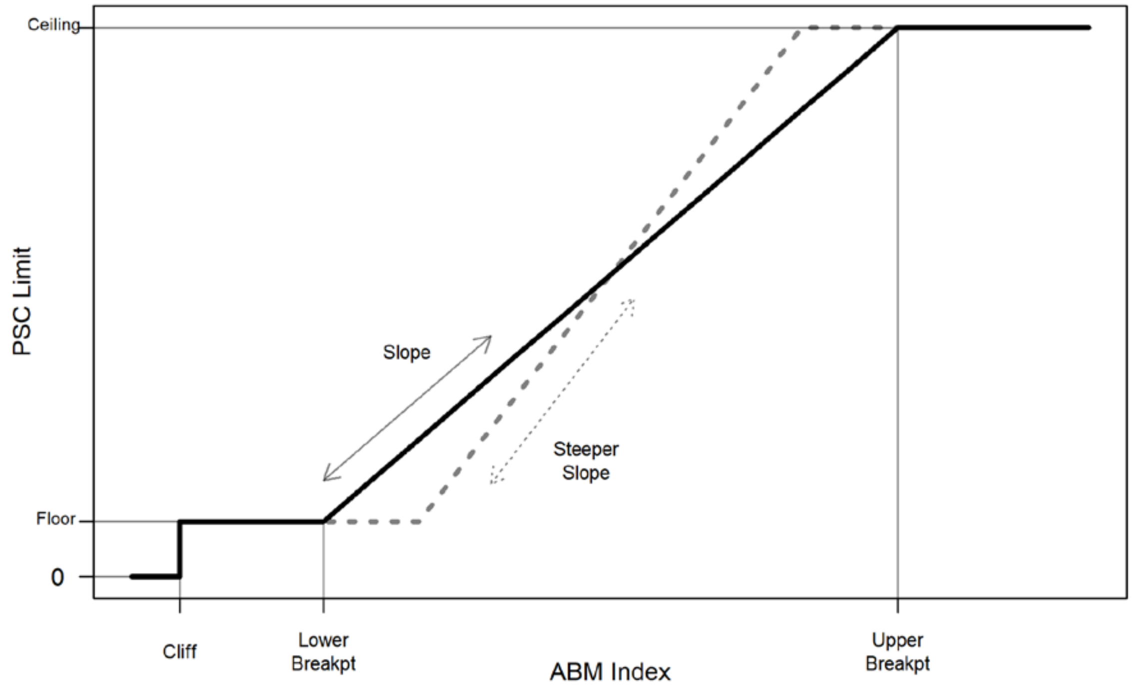

Figure 38. Illustration of control rule outcome or PSC limit (vertical scale) and standardized index or abundance estimate (horizontal scale) with considerations for floor and ceilings etc. as labeled.

4.2 Example control rule formulations

The Council has employed abundance-based PSC limits in the BSAI groundfish fisheries for Bristol Bay red king crab, EBS Tanner crab, Snow crab and herring. For Bering Sea Chinook salmon PSC in the EBS pollock fishery, PSC limits are not explicitly abundance-based being instead established at levels approximating historical bycatch levels by the fishery. However, BSAI Amendment 110, once implemented, adds an additional lower threshold of PSC limits in times of low western Alaska Chinook salmon abundance.[12]

The Council has recommended a range of different type of control rules to establish PSC limits for various fishery management objectives. Several key examples include the abundance-based PSC limits established for crab, and herring, fisheries. Current abundance-based PSC limits for crab and herring in the BSAI groundfish fisheries trigger time and area closures, but do not result in the closure of specific groundfish fisheries as is currently the case for halibut PSC limit in the BSAI. Table 1 indicates these limits, fisheries in the BSAI to which they apply, and closures that are triggered when fishery-specific PSC limits are reached. These PSC limits are annually specified by the Council in the BSAI groundfish harvest specifications process. The process by which the crab caps were initially established was a combination of proposals for limits put forward by the State of Alaska, recommendations from the Crab Plan Team, and by committee discussions amongst interested stakeholders.

[12] Amendment 110 final rule: https://www.gpo.gov/fdsys/pkg/FR-2016-06-10/pdf/2016-13697.pdf

Table 19. Current PSC limits associated with abundance of prohibited species in the BSAI groundfish fisheries

PSC	Limit	Area / action	Limit based on:
Red king crab	Thresholds based on effective spawning biomass (ESB) of BBRKC If ESB < 14.5 million lb PSC limit = 32,000 crab If ESB ≥ 14.5<55.0 mill lb PSC limit = 97,000 crab If ESB > 55.0 million lb PSC limit = 197,000 crab	Zone 1	Thresholds relate to state harvest strategy for BBRKC. Lower limit is based on the level of bycatch observed in the 1995 flatfish fisheries in Zone 1 with the Crab Savings Area closed to trawling Middle limit corresponds to a 50% reduction from the previous PSC limit. Limit is the same percentage as applied by the BOF in 1996
EBS Tanner crab	Zone 1 limits 0-150 million crabs 150-270 million crabs 270-400 million crabs over 400 million crabs Zone 2 limits 0-175 million crabs 175-290 million crabs 290-400 million crabs over 400 million crabs	Zone 1 0.5% of abundance 730,000 830,000 980,000 Zone 2 1.2% of abundance 2,070,000 2,520,000 2,970,000	Lower threshold limits were based upon the average observed bycatch for the stock at that level of abundance. The upper range of the limit was based on negotiated amounts when the stock was at a high abundance in 1988. The middle "step" level was established at an intermediary level between steps 1 and 3
EBS snow crab	Survey abundance of crabs *0.1133 with 4.35 million minimum and 13 million maximum	COBLZ	Council committee charged with negotiating acceptable limits between trawl industry and crab industry
Herring	1% of EBS biomass estimate from State	Herring saving closures	Council considered range of 1-8% based on historical exploitation rates by groundfish fisheries on herring.
EBS Chinook salmon	If 3-river index >250,000 fish then 60,000/47,591 else 45,000/33,318 If lower cap reached >3 times in a rolling 7 year period then lower cap in place permanently (and subject to reduced cap level in years of low abundance)	Seasonal and sector allocated limits. If reached closes directed fishing for pollock for that sector (season or remainder of year). Area is Eastern Bering Sea.	PSC limits considered by Council ranged from 25,000 – 85,000 based on historical bycatch in EBS fishery.

Continuous Control Rule with no floor or ceiling

The most basic example of a control rule with no additional features (floor, ceiling, thresholds etc) is a straight percentage applied to a biomass estimate to determine the PSC limit. Amendment 16a to the BSAI groundfish FMP established bycatch management measures for Pacific herring in groundfish trawl fisheries in 1991 (NPFMC 1991). The adopted PSC limits trigger area closures (Herring savings areas) as indicated in Table 1. In the development of alternatives, the Council considered a range of percentage rates applied to the overall estimated biomass of herring in the eastern Bering Sea. Prior to the analysis, exploitation rates by groundfish trawl vessels were estimated to have increased from less than 2% in 1983 to between 4%-7% in 1989. At that time herring stocks in nearly all Bering Sea areas were declining prompting the need for some action to further limit the bycatch of herring by trawl gear (NPFMC, 1991). The Council selected 1% as the appropriate rate to apply to the aggregate biomass of herring as a PSC limit. This limit is specified based on updated information on the appropriate biomass estimate for the Bering Sea herring stock by the State of Alaska annually during the specifications process.

Although not a PSC limit, the Council has also used a sloped control rule for allocations of halibut between charter and commercial fisheries in the Gulf of Alaska. The Council established the halibut catch sharing plan in Areas 2C and 3A, which allocates the halibut catch limits between the commercial and charter halibut fisheries based on a control rule that varies with halibut abundance. The control rule specifies that each sector will be allocated a specific percentage of the available catch limit at different levels of halibut abundance. At lower levels of abundance, the charter sector is allocated a larger proportion of the catch limit than at higher levels of abundance. The control rule also includes a "stair step" that allocates the charter fishery a fixed amount of the catch limit in pounds at specific abundance levels in order to smooth the transition between allocation percentages as abundance increases.

Continuous Control Rule with a floor and a ceiling

The control rule for EBS snow crab builds upon the simplicity of the herring control rule with a continuous control rule established as a percentage of biomass but with additional features of a floor and a ceiling. EBS snow crab trawl PSC limits are based on the total abundance of snow crab as indicated by the NMFS standard trawl survey. In recent years, the assessment model estimate of trawl survey crab numbers is used to calculate the limit. The cap is set at 0.1133% of snow crab abundance index, with a minimum (floor) of 4.5 million snow crabs and a maximum (ceiling) of 13 million snow crabs; the cap is further reduced by 150,000 crabs (Figure 39). These limits are apportioned to fishery categories during the annual specifications process.

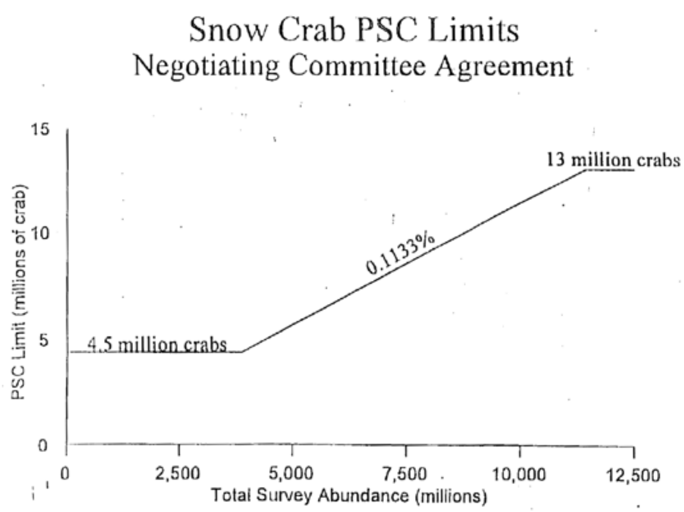

Figure 39. Control rule for snow crab. PSC as a function of total survey abundance in millions of crab.

Thresholds for stair-step modifications in PSC limits based upon biomass:

Three examples in the Bering Sea are currently in use by the Council which establish PSC limits based upon some measure of biomass with modifications to the control rule based upon specific biomass thresholds. These examples are for PSC limits for all groundfish fisheries for Tanner crab and Bristol Bay red king crab, and PSC limits Chinook salmon in the Bering Sea pollock fishery.

Tanner crab PSC limits in the BSAI groundfish fisheries

For Tanner crab, Amendment 41 to the BSAI FMP established a "stair step" approach to for Tanner crab PSC limits that are determined based on the EBS bottom trawl survey. The specific "floor" "slope" and "ceiling" were established through an iterative process through the Council and based on observed bycatch at the levels of abundance when the measure was considered in 1996. Proposed lower threshold limits were based upon the average observed bycatch for the stock at that level of abundance (NPFMC 1996). The upper range of the limit was based on negotiated amounts when the stock was at a high abundance in 1988 (NPFMC 1996). The middle “step” level was established at an intermediary level between steps 1 and 3. These limits are apportioned to fishery categories during the annual specifications process.

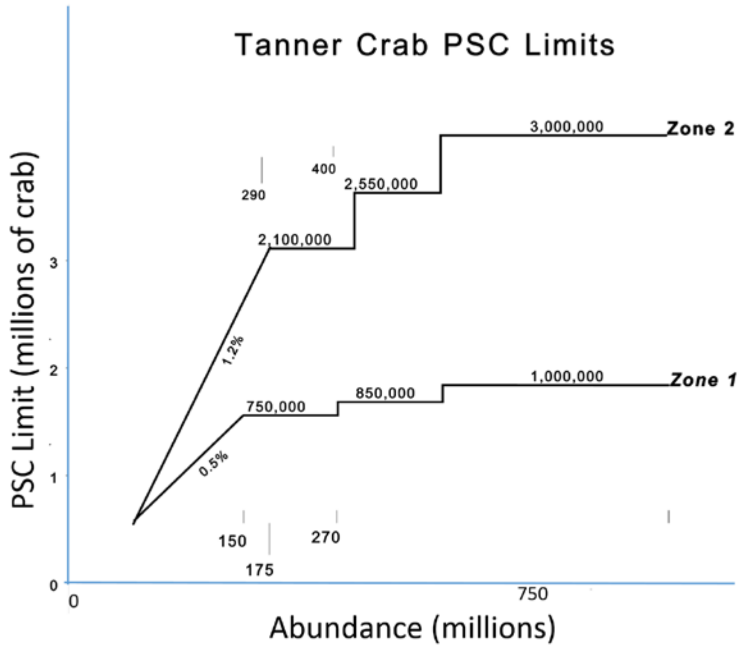

Figure 40. PSC limits for Tanner crab as a function of trawl survey abundance in millions of crab

Bristol Bay red king crab PSC limits in the BSAI groundfish fisheries:

Bristol Bay red king crab PSC limits were established in 1996. At that time, the Council recommended adoption of a stair-step limit regime for red king crab in Zone 1 based on abundance rather than a straight rate-based percentage because stair-steps smoothed year-to-year variability while providing for reduced bycatch limits at low stock sizes. The stair-step limits were originally recommended by the Crab Plan Team and based on the number and weight of crab, with the levels corresponding to the State’s definition for the harvest threshold for Bristol Bay red king crab in the State harvest strategy. These limits are apportioned to fishery categories during the annual specifications process.

Chinook salmon PSC limits in the EBS pollock fishery:

Chinook salmon PSC limits are specified for the EBS pollock fishery. The limits are specified by fishery sector and further managed within each sector and cooperative to the vessel level. However the overall limit prior to sector-specific allocation, varies according to an estimates level of Chinook salmon abundance such that the bycatch cap can be reduced when an index of western Alaskan and Upper Yukon Chinook salmon abundance is below a designated threshold. An index of the combined run sizes from three river system (‘3 System Index’) using the river systems Unalakleet, Upper Yukon, and Kuskokwim establish a determination of high or low abundance. Low abundance is defined as an annual combined 3-system run size of ≤250,000 Chinook salmon. When the combined index is below this threshold, the overall PSC cap is reduced from 60,000 salmon to 45,000 salmon with the performance standard reduced an equivalent amount. This measure was incorporated into the Council’s existing management approach in recognition of the need for more stringent measures in times of critically low western Alaskan Chinook abundance. The reduction in cap levels (from 47,491 to 33,318, and from 60,000 to 45,000) in times of low abundance is designed to provide for increased incentives to the pollock fleet to reduce bycatch to the extent practicable to help in efforts to rebuild critically low western Alaskan Chinook stocks. These reduced cap levels are enacted in all years where the index for assessing the status of western Alaskan Chinook stocks is below a designated threshold that indicates very poor run sizes. All other provisions of bycatch management are in place in those years.

4.3 Alternative mechanisms for setting PSC limits: Decision-table control rule, multi-dimensional and non-linear control rules

Following review of the October 2016 staff discussion paper on halibut ABM and control rules[13], the SSC had suggested consideration of multi-dimensional control rules in the form of a decision table. The example given originally used two bookends of the coastwide spawning biomass with EBS biomass. This example formulation has been modified from the SSC's to reflect abundance of halibut from the IPHC setline survey in Area 4ABCDE for consistency with the indices being recommended (See Section 3.7.1). This modified example is shown in Table 20 with additional information provided as to how these metrics could be used to set PSC limits at a level recommended by the Council.

This approach would associate low, intermediate and high levels of the spawning biomass with low, intermediate and high levels of PSC (similarly for the abundance index in the EBS trawl survey or the IPHC setline survey (exploitable biomass) index). PSC could then, for example, be determined based on the level of the index that is most constraining as illustrated below:

Table 20. Example decision table to set PSC limit based on the level of two indices. The PSC limit is set at the level of the index that is most constraining. For example, at low levels of halibut abundance in Area 4ABCDE from the IPHC setline survey, PSC is set at a low level regardless of the value of the trawl survey index.

		EBS shelf trawl survey index		
		Low	***Medium***	***High***
IPHC setline survey index in Area 4ABCDE	***High***	Low	Intermediate	High
	Medium	Low	Intermediate	Intermediate
	Low	Low	Low	Low

In this example, each 'box' in the decision-table would be associated with a specific level of PSC. For example, the Council could select associated values of PSC to correspond to indications of relative abundance in each index. The example below uses high and low values associated with the current PSC limit and 50% above and below that limit to set PSC levels. This type of decision table would then set more conservative PSC limits whenever there was a decline to defined 'low' values of either index. Decisions by the Council would determine both the breakpoint to determine what "low", "medium" and "high" levels correspond to within each index as well as the PSC level associated with this determination. This is similar to how crab PSC levels according to stock abundances in Bristol Bay red king crab and Tanner crab are established, as well as somewhat similar to the breakpoint used to determine a low Chinook salmon status and which affects the PSC.

[13] October paper link here

Table 21 Example decision table to set PSC based on the level of two indices. PSC is set at the level of the index that is most constraining. Here example PSC values are shown corresponding to levels of abundance as in Table 20. These example PSC levels use the current PSC as the level for 'medium' and 50% below that for 'low' with 50% above that for 'high'.

		EBS exploitable biomass index		
		Low	***Medium***	***High***
IPHC Setline abundance in Area 4ABCDE	***High***	1,758	3,515	5,273
	Medium	1,758	3,515	3,515
	Low	1,758	1,758	1,758

Previous discussion papers as well as SSC minutes have suggested an additional approach employing a two-dimensional or three-dimensional control rule. For example, the SSC minutes from October 2016 propose the following to formulate continuous control rules that would avoid abrupt changes in PSC. These control rules could similarly be combined in a 2- or 3-dimensional framework for setting PSC as illustrated below and represent a simple extension of the decision table.

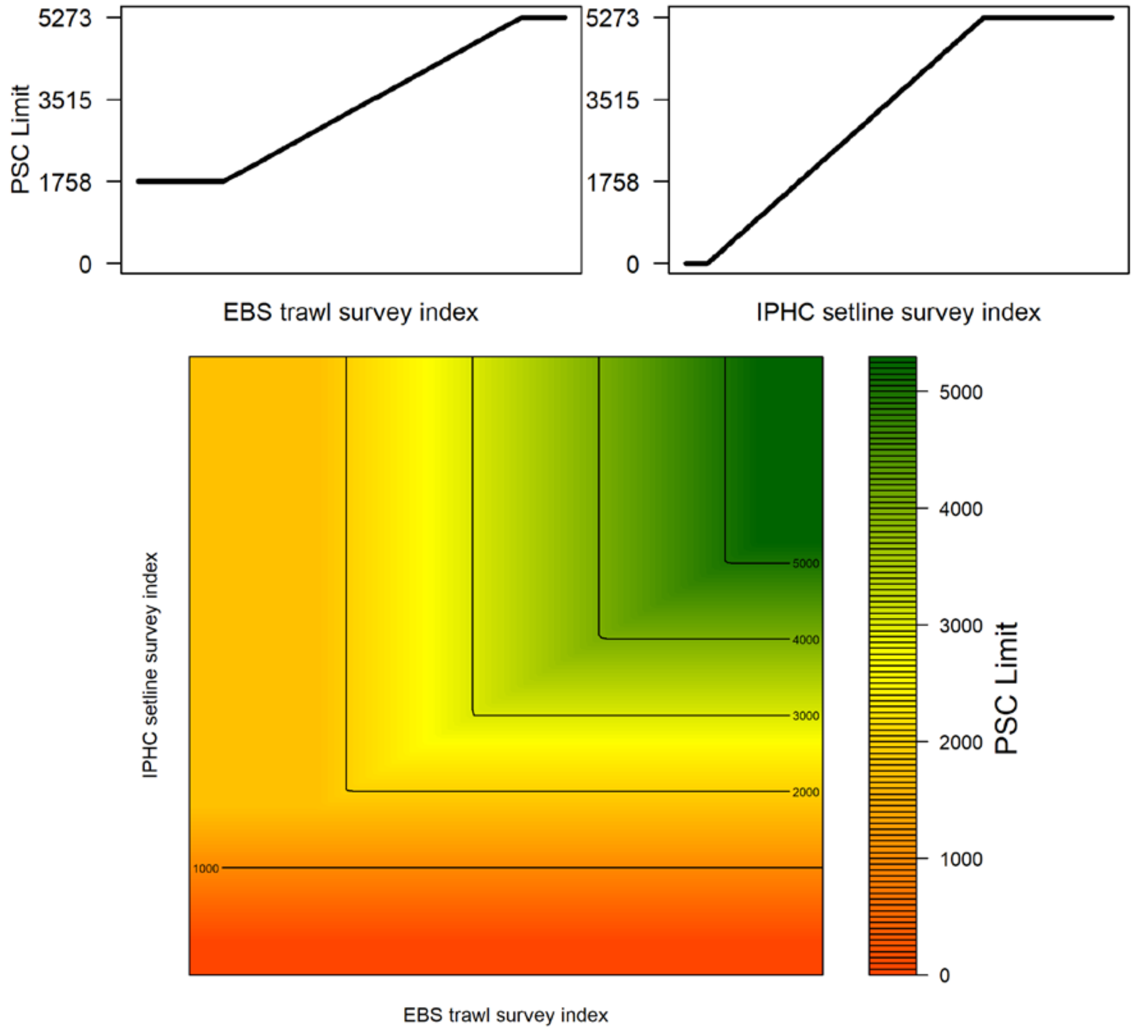

Figure 41. An illustration of PSC control rules. Top panel illustrates potential control rules linking PSC to a trawl survey abundance index and to IPHC setline survey, respectively. The control rules are combined in the bottom panel by setting PSC to the value for the index that is most constraining at a given combination of index levels. In this example, PSC limits are set to zero (red) at very low levels of the IPHC setline survey, regardless of the level of the trawl survey abundance index. In contrast, at high values of the IPHC setline survey, PSC increases with the trawl survey index according to the rule in the upper left panel and is not constrained by spawning biomass.

This framework allows different control rules to address different objectives. As in the example above (Figure 41), a control rule that reflects directed fishery opportunity (say, IPHC setline survey) could have a different shape than a control rule that reflects groundfish opportunity (say, EBS trawl survey), as determined by the Council. Furthermore, this concept can easily incorporate additional controls, such as a reduction in the PSC limit when the coastwide spawning biomass is below some threshold.

The current IPHC harvest policy includes a control rule that reduces the fishing intensity when the stock status is below 30% and halts all directed fishing when the stock status is below 20%. Some coordination between IPHC and the NPFMC of implementing a control rule, such as this 30:20 one, to protect spawning biomass may be desirable. This can easily be included in this framework by simply adding a control rule which sets the PSC limit at it maximum when the coastwide stock status is greater than 30%, reduces the PSC limit when the stock status is between 20% and 30%, and sets the PSC limit at some minimum value when the stock status is less than 20% (Figure 42). The maximum and minimum PSC limits, as well as the stock status reference points, can be specifically determined by the Council and do not need to necessarily synchronize with IPHC's harvest policy. Additionally, the function determining the reduction between the reference points may be linear or non-linear.

Alternatively, the outcome of the control rule for coastwide stock status may simply be a multiplier to the PSC limit from an ABM index. For example, this multiplier would be 1.0 at stock statuses above 30% and some minimum value when stock status was less than 20%. As explained above, the minimum multiplier, the reference points, and the shape of the sloped portion of the control rule are Council decision points (see Figure 42).

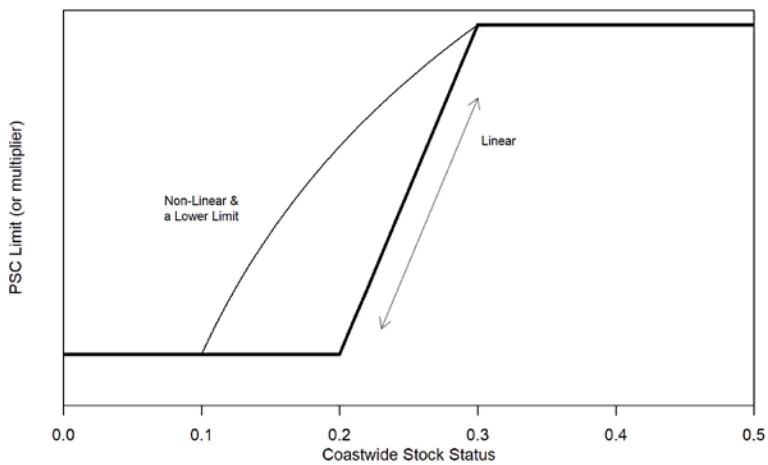

Figure 42. Examples of a linear control rule with stock status reference points at 30% and 20% stock status, and a non-linear control rule with stock status reference points at 30% and 10%.

We developed several examples of non-linear control rules for illustration purposes (Figure 43). There may be situations where it would be preferred to have a stable PSC limit when abundance is near average but where the control rule is more responsive when abundance becomes substantially above or below average; this is illustrated by the cubic relationship in Figure 43. Using a sigmoid curve like the logistic relationship has the advantage that it avoids discontinuities as "floors and ceilings" are approached as these could be set to asymptote at desired levels. Other factors might be considered by using an asymmetric control rule. The example provided here is to have a situation where PSC limits increase slower when the abundance index is above average, but decline quicker when abundance is below average. Here, the asymmetric shows a control rule that has different responses when above and below average abundance, the cubic shows a relationship that is stable near average abundance but is responsive with large departures from average while the logistic is more responsive than linear when abundance departs from average but responds slower when far from average abundance. Although nonlinear control rules may have some desirable properties, a strong disadvantage is that they cannot be parameterized in a straightforward way like a linear control rule. For example, a linear control rule can be set so that as the abundance index increases, the PSC limit increases by a proportional amount, but a non-linear control rule would have varying relationships with abundance throughout the range of an index.

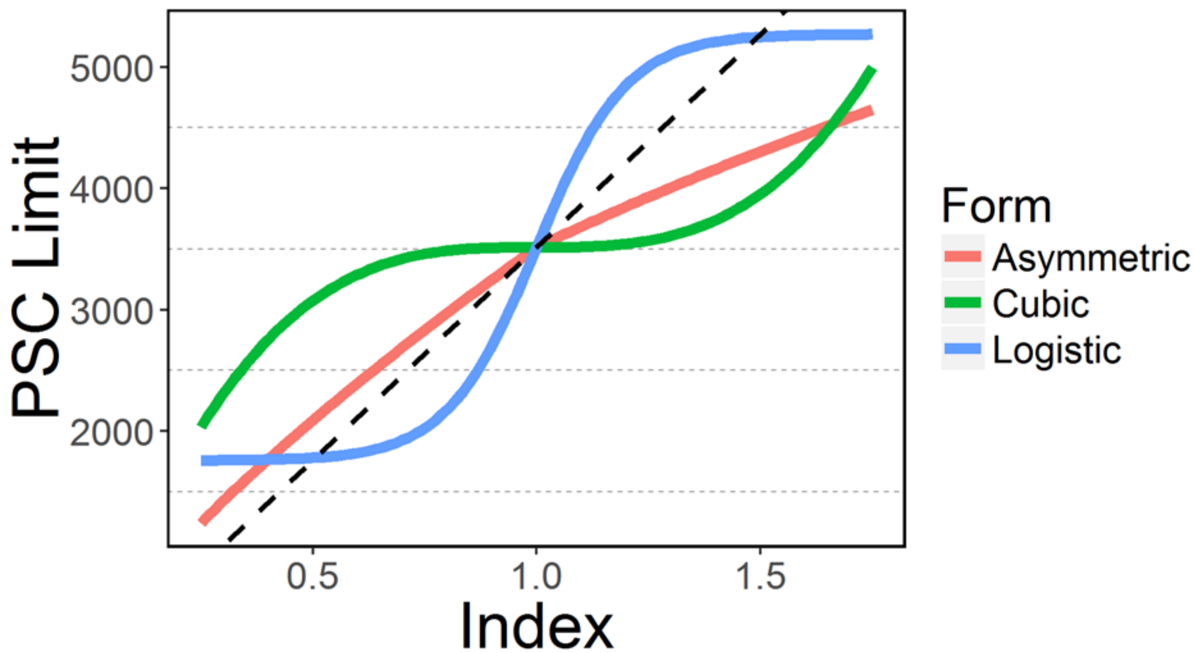

Figure 43. Three example control rules where the index has a non-linear effect on the PSC (vertical axis). Asymmetric shows a control rule that has different responses when above and below average abundance. Cubic shows a relationship that is stable near average abundance but is responsive with large departures from average. Logistic is more responsive than linear when abundance departs from average but responds slower when far from average abundance. Dashed line is a linear control rule for context.

5 Developing Alternatives

Given that our analysis suggests a subset of proposed indices to captures the Council's intent to have abundance based PSC management for Pacific halibut, the next step is to combine them with options for control rules. As such, this section outlines some strawmen alternatives and options/variations for further consideration. A range of elements and options are proposed below for the Council to begin drafting alternatives for analysis based upon the information contained in this paper and building upon direction from the Council in recent motions. Each of these elements, options and suboptions have been described conceptually in Section 3.0 of this paper. Some combinations of options have been considered previously but are not included in this draft alternative set for the reasons described below. Not all elements must be selected in constructing alternatives. The following examples use only Elements 1 through 3 but features shown under Elements 4 and 5 could also be selected to augment any of the examples shown. This information and examples are provided to assist the public and the Council in drafting an alternative set for analysis.

Table 22. Draft Alternative elements and options for establishing ABM PSC management alternative sets for analysis. Note most elements and options are not mutually exclusive nor are all elements necessary to construct alternatives (* = mandatory selections)

Element 1* – Abundance index

- Option 1. EBS trawl survey
  - Suboption 1: index in biomass
  - Suboption 2: index in numbers
- Option 2. IPHC setline survey (O32) in Area 4ABCDE
- Option 3. EBS trawl survey and IPHC setline survey (biomass)
  - Suboptions (to Option 3 only):
    - Suboption 1: Equal weighting
    - Suboption 2: EBS trawl survey weighted higher
- Option 4. Index trawl gear to EBS survey, index fixed gear to IPHC setline survey

Element 2* – PSC limit responsiveness to abundance changes

- Option 1. PSC limit varies proportionally with change in abundance index
  - Suboptions (to Option 1 only):
    - Suboption 1: varies 1:1 with abundance
    - Suboption 2: varies X:X with abundance
    - Suboption 3: varies non-linearly with abundance
- Option 2. Limit PSC change to a maximum percentage
- Option 3. Change PSC only every x number of years
- Option 4. Threshold values(breakpoints) to modify PSC limit (e.g., IPHC stock status, other)

Element 3* – Starting point for PSC limit

- Option 1. 2016 PSC limit (3,515 t)
- Option 2. 50% of 2016 PSC limit = (1,758)
- Option 3. 150% of 2016 PSC limit (= 5,273)
- Option 4. Additional value within range of Options 1-3

Element 4 - Maximum PSC limit *(ceiling)*

- Option 1. 2016 PSC limit (3,515 t)
- Option 2. 20% - 50% increase from 2016 PSC limit
- Option 3. Average of 2008 – 2016 PSC limit (4,369)
- Option 4. Additional value to be selected

Element 5 - Minimum PSC limit *(floor)*

- Option 1. No floor (PSC goes to 0)
- Option 2. 20% - 50% reduction from 2016 PSC limit
- Option 3. Average of 2014 - 2016 PSC use (3,265)
- Option 4. Additional value to be selected

In order to begin the process of drafting alternatives, a stepwise approach is used starting with selection of an abundance estimate under element 1 in Table 22. Here we employ 4 abundance-based management strawmen alternatives (noted as ABM1, ABM2, …) numbered according to Element 1 option numbers. Table 23 provides additional details in delineating 4 strawmen alternatives based upon the selection of abundance index from Element 1. Since the first step is selecting an index, we selected a naming convention for the strawmen alternatives where ABM1 refers to an alternative that uses the EBS trawl survey index, ABM2 uses only the setline survey index, ABM3 uses both indices with variable weights, and ABM4 uses both indices but independently (with the intention that they could be applied to their respective groundfish gear types).

Table 23. ABM choices for Element 1 **abundance index selection** of Table 22. Note that selection of the abundance indices is the first step for construction of strawmen alternatives (labeled as ABM1, ABM2, ABM3, ABM4)

Corresponding abundance estimate	Option / suboption	Alternative
EBS trawl survey (biomass)	Option 1, suboption 1	ABM1
IPHC setline survey (O32) in Area 4ABCDE	Option 2	ABM2
EBS trawl survey and IPHC setline survey (O32) in Area 4ABCDE (biomass). Equal weighting on both indices	Option 3, suboption 1	ABM3
EBS trawl survey and IPHC setline survey (O32) in Area 4ABCDE (biomass). Indices considered separately for trawl gear (EBS trawl survey) and fixed gear (IPHC survey)	Option 4	ABM4

Here for ABM3 integrating the EBS trawl survey with the IPHC setline survey for simplicity we selected the suboption for equal weighting of both indices (suboption 1). Additional consideration will be given to modifications in the weightings and selection of additional suboptions in the sensitivity analysis contained in Section 5.1.1. Note that suboptions under Element 1, Option 3 do not consider downweighting the EBS trawl survey compared to the IPHC setline survey as this seemed to be counter to the Council's Purpose and Need for this action as described in Section 2.

The next step in constructing alternatives is to delineate the shape and starting points for the control rule. These features are described under Elements 2-5 and various options. For purposes of simplicity in these ABM examples and consistent with the Council's June motion guidance, only Elements 2 and 3 are used for ABMs 1-4. The Council direction in June was to consider continuous control rule examples and the range of starting points above and below the 2016 PSC limit. As such, additional elements and options applied to the 4 strawmen ABM alternatives are shown in Table 24. Note that for simplicity all four ABM alternative have the same linear (1:1) slope to the control rule (Element 2, option 1, suboption 1) and the same starting point of 3,515 (Element 3, Option 1).

Table 24. ABM choices for Elements 2 and 3 (Table 22) **shape and features of the Control Rule** as the second step in constructing strawmen alternatives. These ABM alternatives build upon the selection of abundance indices as defined in Table 23.

Features of control rules (Elements 2 and 3 in Table 22)	Element/Option/[suboption]	Alternative
PSC varies proportion to abundance (1:1) Starting point is the current PSC limit (3,515)	Element 2: Option 1, suboption 1 Element 3, Option 1	ABM1
PSC varies proportion to abundance (1:1) Starting point is the current PSC limit (3,515)	Element 2: Option 1, suboption 1 Element 3, Option 1	ABM2
PSC varies proportion to abundance (1:1) Starting point is the current PSC limit (3,515)	Element 2: Option 1, suboption 1 Element 3, Option 1	ABM3
PSC varies proportion to abundance (1:1) Starting point is the current PSC limit (3,515)	Element 2: Option 1, suboption 1 Element 3, Option 1	ABM4

Additional features (floors and ceilings under Elements 4 and 5) could be added to these examples in drafting alternatives for analysis. However, at this stage for illustration we have retained the ABMs 1-4 in a simplified manner and omit for presentation Elements 4 and 5. It should be noted that some options within elements interact. For example, selecting a “slope” parameter for the control rule to be proportional (i.e., 10% change in abundance implies a 10% change in PSC limit) and adding an option to smooth the variability (e.g., maximum percentage PSC limit change) may have a similar effect as simply reducing the slope to be less than one.

5.1 Strawmen draft ABM alternatives based on selected indices

The four ABM alternatives laid out in Table 23 and Table 24, can be applied to historical periods to help evaluate and visualize their responsiveness and impacts on PSC limits using the equations listed in the appendix Section 9. For example, the contrast of ABM1 which generally shows an increasing trend compared with ABM2 (a decreasing trend) and ABM3 which weights these indices equally is shown in Figure 44. In most years the actual Pacific halibut mortality is less than the value shown for ABM3 but for the other two, the total PSC is larger in a number of years, especially for ABM1.

The drafted ABM4 is designed to split the PSC by gear type which implies that the relative percentages will vary by gear type over time. For this illustration, we assumed that the starting point for the two independent indices is the same as in 2016 (as allocated under the PSC limit, and assuming for illustration that the CDQ portion of the limits would be combined into the trawl gear limit). ABM4 is illustrated similar to the others in Figure 45.

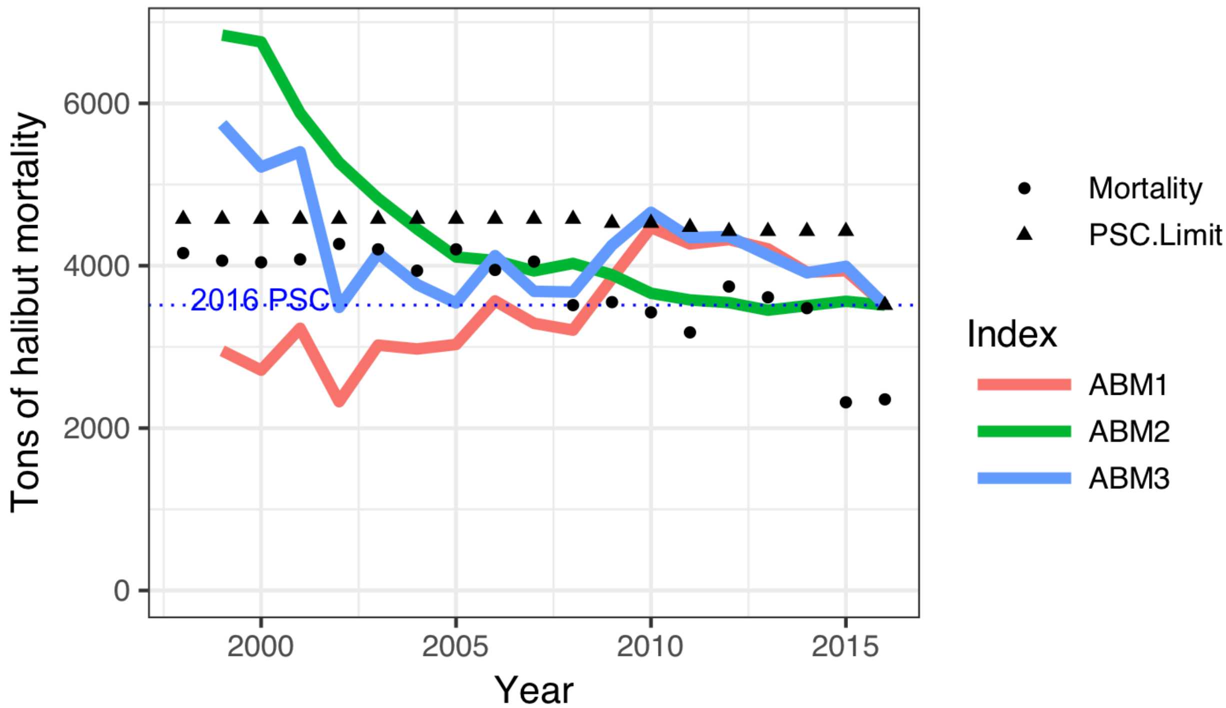

Figure 44. PSC limits using selected indices (Table 24) compared to historical actual limits (triangles) and Pacific halibut mortality estimates (solid dots).

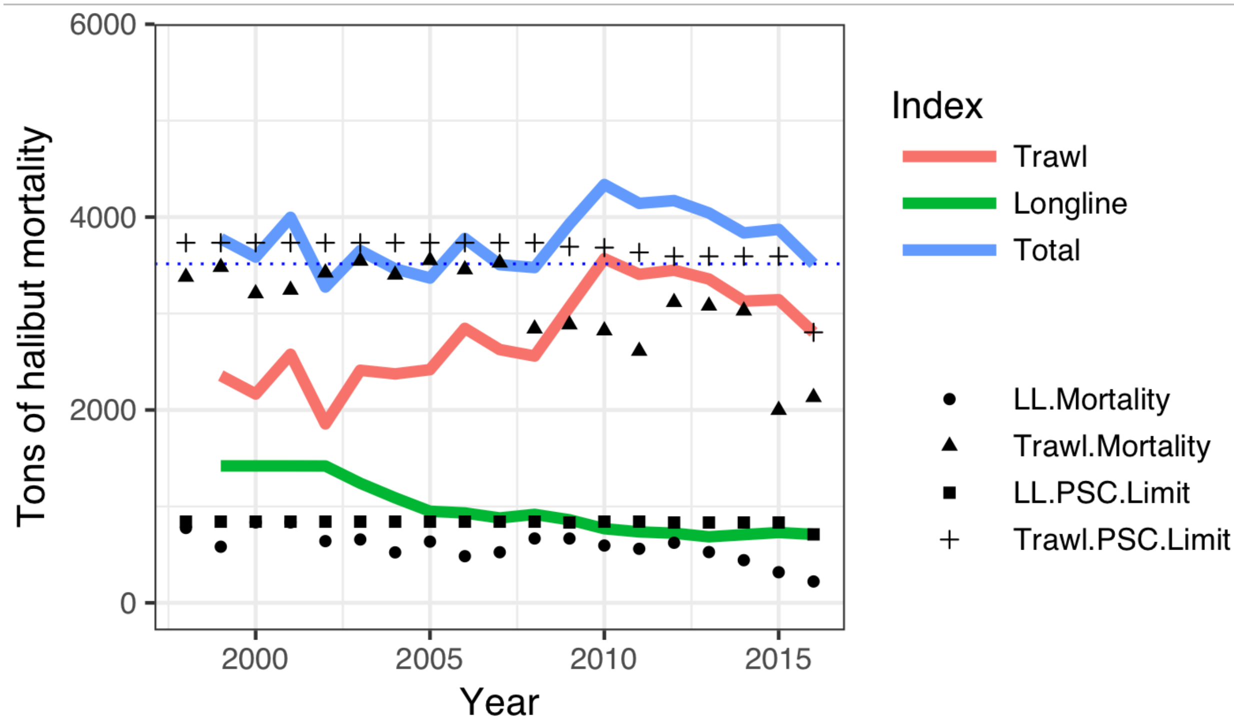

Figure 45. PSC limits using selected indices (Table 24) for ABM4 compared to historical actual limits and Pacific halibut mortality estimates by main gear types. Note that for exposition purposes, PSC "allocations" include CDQ as part of the Trawl PSC limit (which results in 2016 values of 2,805 t for trawl and 710 t of mortality for longline).

5.1.1 Sensitivities and further variations on the four ABMs

The ABMs presented thus far are with a fixed set of options and suboptions. To explore further combinations (variations for sensitivity analysis) a set of ABMs were constructed (Table 25). These examples are responsive to the Council's directive as described previously to provide simple examples, starting point ranges (i.e., different values of PSC_0 set to half and double the current PSC limit), and some variations controlling stability relative to the indices (i.e., setting different "slopes" or *b* values), and including both or each index separately (see appendix for details on control rule specifications). Given the same starting point, those multipliers result in historical PSC limits that vary differentially by year but all result in the current PSC limit for 2016 (e.g., Figure 44).

Adjusting the responsiveness of the indices for ABM1 showed that lower variability (ABM1.LOV) was more stable historically than the 1:1 and higher variability option (Figure 46). Data used can result in indices being relatively more variable and/or less precise. The control rule application can dampen this variability by reducing the slope or "*b*" parameter as illustrated in Figure 46. Here the single EBS trawl index as applied in ABM1 becomes more variable for b_1=2.0 and less variable when set to 0.5. Switching ABM1 to be in numbers instead of biomass also resulted in a higher degree of variability, at least given historical patterns (Figure 47). This figure also illustrates that a low variability option could be applied to help lower PSC variability (Figure 47, bottom panel). Similarly, these parameters can affect the PSC limit when set differentially by the integrated index component as in ABM3 vs ABM3.ALL where the latter weights the two indices according to their current trawl to longline groundfish-fishery allocations (Figure 48).

The Council requested examining a range of "starting point" values relative to the current PSC limit. Applying these to the historical timeframe for ABM3 shows the expected range in PSC limits (Figure 49).

Table 25. Illustrative example options (sensitivities) to the strawmen ABM alternatives.

Alternative	**Control rule features**
ABM1.LOV	Less responsive to trawl survey index, $b = 0.5$
ABM1.HIV	Highly responsive to changes in trawl survey index, $b = 2.0$
ABM1.NOS	Use numbers instead of biomass
ABM1.NOS.LOV	Use numbers instead of biomass, with lower variability ($b=0.5$)
ABM3.ALL	Relative weights based on relative allocations
ABM3.HSP	$PSC_0=5{,}273$ *t*, high starting point
ABM3.NON	Non-linear
ABM3.SSD	Include a discontinuity in control rule at low stock status levels (from IPHC)

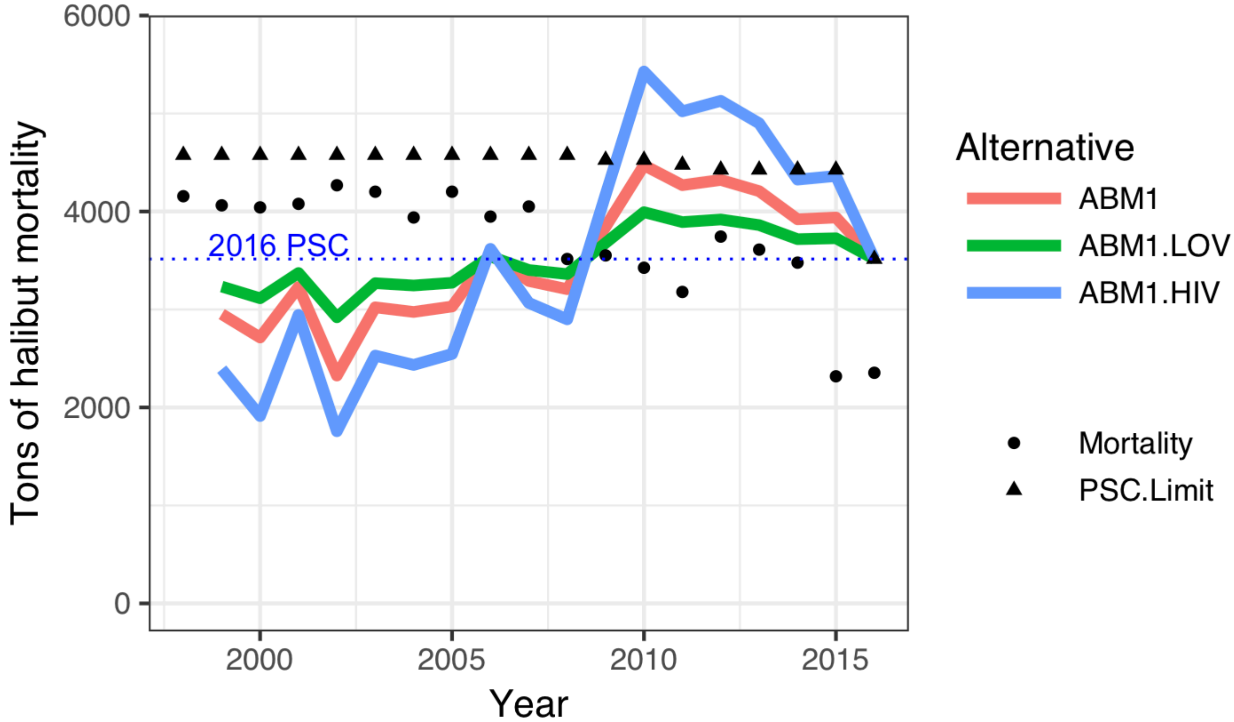

Figure 46. PSC limits from ABM1 and sensitivities as outlined in Table 25. ABM1.LOV is specified to have lower responsiveness to the index (lower variability) whereas ABM1.HIV is specified to be highly responsive to the trawl survey index.

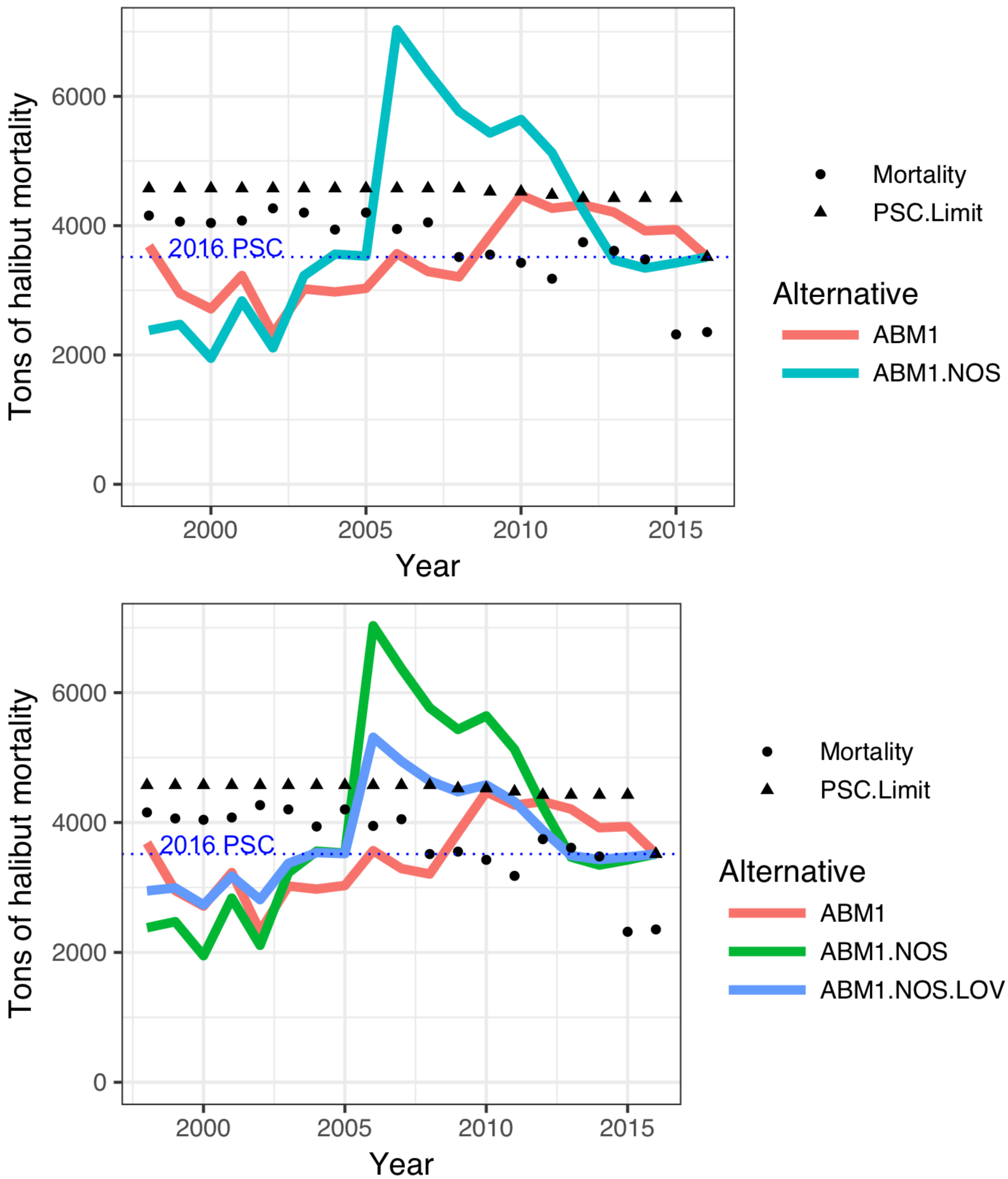

Figure 47. PSC limits from ABM1 and sensitivities as outlined in Table 25. ABM1.NOS is based on the trawl survey index in terms of numbers of fish rather than biomass.

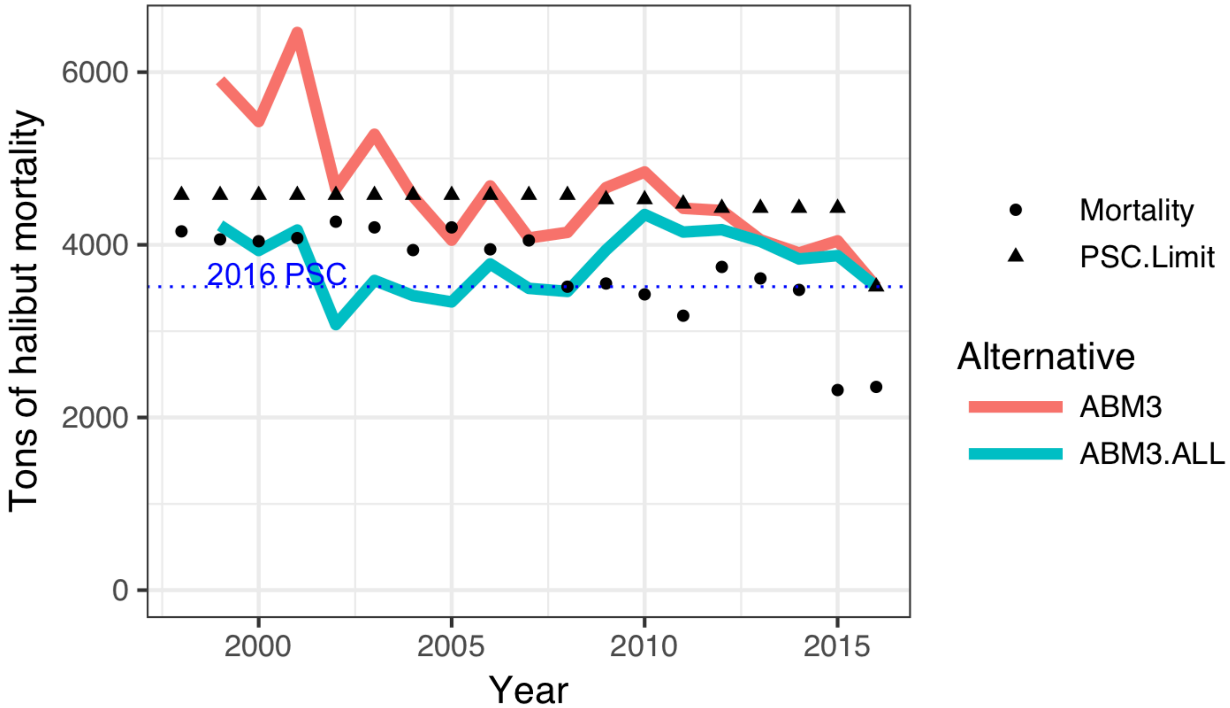

Figure 48. PSC limits from ABM3 and sensitivities as outlined in Table 25. ABM3.ALL is specified to have the same weight between the trawl and longline survey indices as the relative allocation between trawl and longline PSC (roughly 80:20).

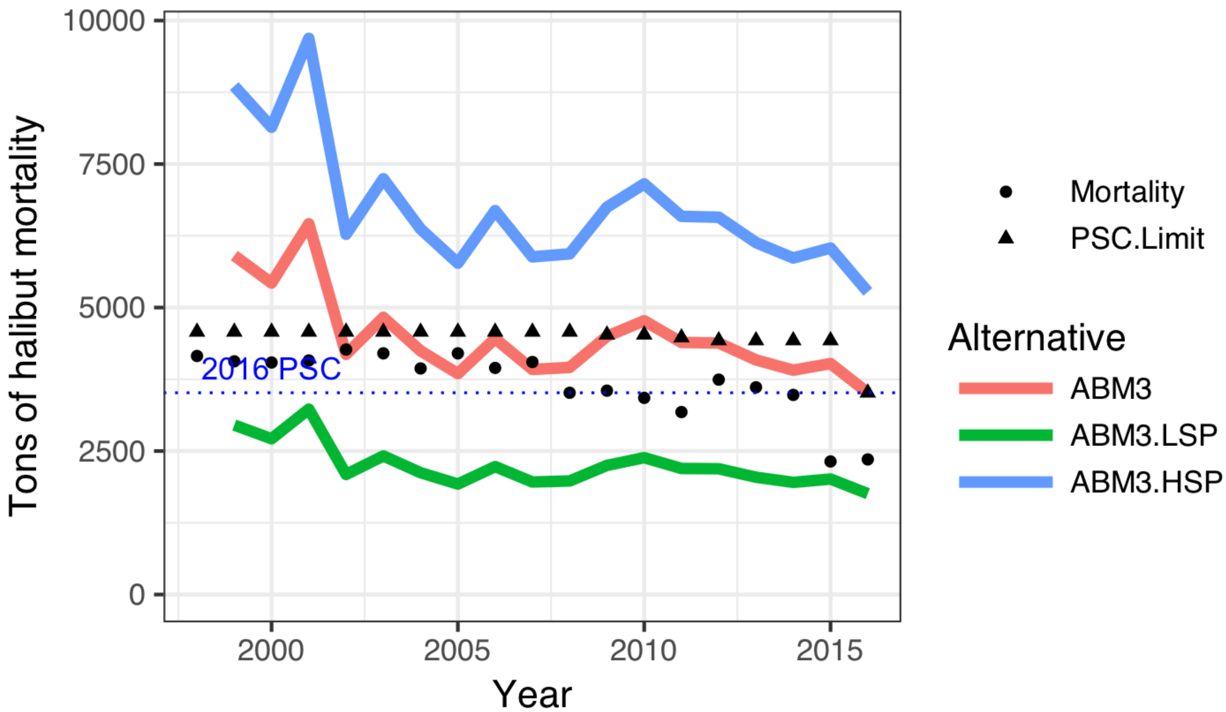

Figure 49. PSC limits from ABM3 and sensitivities as outlined in Table 25. ABM3.LSP is specified to have a low starting point (50% of the current) and ABM3.HSP has a starting point of 50% higher than the current.

5.1.2 Example ABM comparisons with historical use by sector

The sector specific scenarios for the developed indices can be used to give some idea of how an alternative PSC limit compares with historical levels of mortality. For example, using ABM1 with different starting points shows unsurprisingly that if the starting point was set to 50% of the current level, in most years the estimated Pacific halibut mortality by sector exceeded the value under that alternative (Table 26). With the starting point specified at 3,515 t, overall the limit was exceeded only in 2008 and in two other years, the Amendment 80 sector estimates were slightly higher than the limit (Table 26).

Table 26. PSC limits for ABM1 (EBS trawl survey as the index) apportioned by sector given the current rates. Top section (2008-2016) is with the current PSC limit as the "starting point" whereas the middle and bottom sections are for low and high starting point values. Values in parenthesis is the percentage above (or below if negative) the putative PSC limit given current Pacific halibut mortality estimates shown in Table 3.

Current, starting point = 3,515 t	Total	Am80	BSAI TLA	LL	CDQ
2008	3,207 (10%)	1,592 (17%)	680 (23%)	648 (-8%)	287 (-25%)
2009	3,844 (-8%)	1,908 (4%)	815 (0%)	777 (-23%)	345 (-55%)
2010	4,472 (-23%)	2,220 (-3%)	948 (-38%)	903 (-42%)	401 (-60%)
2011	4,269 (-26%)	2,119 (-19%)	905 (-21%)	862 (-42%)	383 (-36%)
2012	4,322 (-13%)	2,146 (-12%)	916 (10%)	873 (-35%)	387 (-30%)
2013	4,208 (-14%)	2,089 (0%)	892 (-12%)	850 (-45%)	377 (-29%)
2014	3,920 (-11%)	1,946 (8%)	831 (-14%)	792 (-48%)	351 (-30%)
2015	3,939 (-41%)	1,955 (-30%)	835 (-37%)	796 (-62%)	353 (-63%)
2016	3,515 (-33%)	1,745 (-24%)	745 (-13%)	710 (-72%)	315 (-45%)
Low, starting point = 1,758 t	**Total**	**Am80**	**BSAI TLA**	**LL**	**CDQ**
2008	1,604 (119%)	796 (135%)	340 (147%)	324 (83%)	144 (50%)
2009	1,922 (85%)	954 (108%)	407 (100%)	388 (54%)	172 (-10%)
2010	2,236 (53%)	1,110 (94%)	474 (23%)	452 (16%)	200 (-19%)
2011	2,134 (49%)	1,060 (63%)	452 (58%)	431 (16%)	191 (27%)
2012	2,161 (73%)	1,073 (76%)	458 (121%)	437 (31%)	194 (40%)
2013	2,104 (72%)	1,044 (100%)	446 (76%)	425 (11%)	189 (41%)
2014	1,960 (77%)	973 (116%)	415 (73%)	396 (3%)	176 (41%)
2015	1,969 (18%)	978 (39%)	417 (26%)	398 (-25%)	176 (-26%)
2016	1,758 (34%)	873 (53%)	373 (74%)	355 (-45%)	158 (10%)
High, starting point = 5,273 t	**Total**	**Am80**	**BSAI TLA**	**LL**	**CDQ**
2008	4,811 (-27%)	2,388 (-22%)	1,020 (-18%)	972 (-39%)	431 (-50%)
2009	5,766 (-38%)	2,863 (-31%)	1,222 (-33%)	1,165 (-49%)	517 (-70%)
2010	6,707 (-49%)	3,330 (-35%)	1,422 (-59%)	1,355 (-61%)	601 (-73%)
2011	6,403 (-50%)	3,179 (-46%)	1,357 (-47%)	1,293 (-61%)	574 (-58%)
2012	6,483 (-42%)	3,219 (-41%)	1,374 (-26%)	1,310 (-56%)	581 (-53%)
2013	6,311 (-43%)	3,133 (-33%)	1,338 (-41%)	1,275 (-63%)	566 (-53%)
2014	5,880 (-41%)	2,919 (-28%)	1,246 (-42%)	1,188 (-66%)	527 (-53%)
2015	5,908 (-61%)	2,933 (-54%)	1,252 (-58%)	1,193 (-75%)	529 (-75%)
2016	5,273 (-55%)	2,618 (-49%)	1,118 (-42%)	1,065 (-82%)	473 (-63%)

5.1.3 Other considerations on inter-annual variability in PSC limits
In addition to reducing the parameter governing the responsiveness of PSC limits to the index or indices, the Council may also wish to have a simple, add-on constraint on PSC changes. For example, the limit could be restricted to change by no more or less than a specified percentage in each year similar to stair-step that the SSC has applied to groundfish ABC specifications when there is a big increase.

5.1.4 Alternatives considered but not carried forward for consideration
As noted previously, some weighting combinations were not carried forward in the examples described here. Notably while we consider a suboption to downweight the IPHC setline survey when integrating with the EBS trawl survey, we do not propose a weighting scheme to downweight the EBS trawl survey compared to the IPHC setline survey. Downweighting the EBS trawl survey appears inconsistent with the objective of focusing upon indices which reflect the halibut encountered by the groundfish fishery in the Bering Sea. Per Council direction in June we also no longer consider the IPHC Coastwide stock status as a component index for the integrated indices options. Stock status for the Coastwide stock is instead considered within the options available to set threshold values and breakpoints on the control rule which upon reaching would modify the PSC limit (Element 2 Option 5). This has been discussed previously under Section 4.3. Previous discussion papers as listed in Table 1 have described additional ABM alternatives that are no longer carried forward to analysis for reasons that are described in SSC minutes from those meetings as well as subsequent Council motions.

6 Incentives

This section addresses the Council's June 2017 request, based on SSC comments, that staff consider the ways in which bycatch limits that are established based on a control rule and abundance indices might incentivize the groundfish fleet to minimize bycatch at all levels of abundance. This section should provide the reader with a basis for understanding the principles that determine whether an incentive structure can be both effective and appropriate for the sectors involved.[14] This section also responds to the Council's request that staff discuss how a performance standard could be incorporated into an abundance-based approach to bycatch limits. This paper considers types of control rules – e.g., with or without a floor and ceiling, or linear vs. non-linear – but will not wade into the incentives and behaviors associated with particular index/rule/starting-point combinations until the Council has defined a range of alternatives for analysis.

Designing a system to manage halibut bycatch in groundfish fisheries requires the balancing of several MSA national standards – most notably NS 1 (Optimum Yield) and NS 9 (minimize bycatch to the extent practicable). Halibut bycatch rates vary across time and space in a manner that has both predictable and unpredictable characteristics. Halibut and target groundfish populations are comingled to differing degrees depending on the local environment, therefore the cost of avoiding halibut is not consistent across time, location, or individual events. A well-crafted bycatch management program will enable groundfish vessels to determine the best methods to reduce bycatch within their operational plan, and leave room for innovation that could further improve performance on a rate basis.

6.1 Use of incentives in North Pacific bycatch management
The NPFMC has built incentives into its bycatch management strategy for both halibut and salmon in groundfish fisheries. Incentives to minimize bycatch at all times might come in the form of bycatch limit rollovers, earned bycatch credits, higher limits for sectors that meet a performance standard during a previous period, reduced limits for poor performance, and greater management flexibility for cooperatives and their member vessels that create an approved bycatch management plan. The Council has also recommended regulations that permit bycatch allocations to be traded within or between

[14] Additional detail on each sector's efforts to minimize halibut bycatch mortality is provided in Section 1.4.4

cooperatives, thus providing internal incentives to entities that might realize an economic gain from bycatch avoidance.

Recent instances where the Council prescribed incentive tools or called on stakeholders to develop them cooperatively include the BSAI salmon bycatch management program (BSAI Ams. 91 and 110), the “earned incentive buffer” for GOA non-pollock trawl Chinook salmon PSC limits (GOA Am. 97), and directives to the A80 trawl fleet as part of BSAI Amendment 111. The most effective measures prompt the fleet to avoid bycatch regardless of whether a season is nearing its end or a PSC hard cap is likely to be reached. Effective measures also set clear benchmarks with adequate time to respond, and retain latitude for operators to experiment with methods in a dynamic environment. The BSAI groundfish fleet is distinct in that most of its operators are connected through regulated or voluntary cooperative arrangements. The program under consideration can and should make use of the fact that, for the most part, the groundfish sectors subject to BSAI halibut bycatch limits have infrastructure in place to take proactive bycatch avoidance measures. The measures taken to date by those sectors are detailed in Section 1.4.4; they are generally framed around monitoring, near real-time communication, cooperation, internal accountability, and experimentation.

Cases where performance in one year translates to a higher bycatch cap in a subsequent year include the GOA pollock/non-pollock trawl fisheries and the EBS pollock trawl fishery. These are described in more detail below.

In the Gulf of Alaska, the CV groundfish trawl sector fishes under a shared hard cap for Chinook salmon PSC. If that sector limits its annual Chinook salmon bycatch to a certain threshold below the cap then its cap for the following year is set higher. This measure functions as an earned insurance policy for years in which bycatch of Chinook – a rare and unpredictable bycatch species – approaches the cap despite the best efforts of a fleet that does not have the benefit of cooperative measures and accountability. GOA trawl CVs do not operate under cooperatives or target quota allocations to vessels, so efforts to avoid bycatch sometimes provide an external benefit at an individual cost. The amount of that added PSC limit buffer in subsequent year is limited by regulation so that “savings” do not accrue over consecutive years of low bycatch or low Chinook abundance to the point that an annual PSC allowance reaches a level that triggers consultation for ESA-listed Chinook salmon.

The GOA groundfish trawl sector also includes the Central GOA Rockfish Program (RP), which is a LAPP. CVs participating in CGOA RP cooperatives are collectively limited to a Chinook salmon hard cap, but a portion of the unused Chinook PSC in that fishery may be rolled over into late-year non-rockfish trawl fishing. Because RP CVs tend to also fish in the non-rockfish fisheries, this rollover functions as an internal incentive to conserve Chinook salmon so that it will be available later. The shortcoming of this program design is that some RP CVs might not plan to fish in the late season, and thus would not have an incentive to conserve Chinook PSC that only has economic value for a subset of groundfish trawl vessels during years when the hard cap is a constraint. The RP also has a halibut bycatch cap, and a portion of that unused PSC may also be rolled over to support late-year non-rockfish trawl fishing in the GOA. This rollover has not generally been used for late-year fishing due to limited participation.

In the EBS pollock trawl fishery, the Chinook PSC dual-cap and opt-out system encourages all participants to join an Incentive Plan Agreement (IPA). A sector that joins an IPA may fish under a higher PSC cap than it would if it were an “opt out” participant. NMFS is only able to regulate to the sector level, but the cooperative structure allows vessels that are party to an IPA to be managed under vessel caps that are higher than they would be in the absence of the agreement. Since its inception in 2011, all vessels in the EBS pollock fishery are operating under IPAs; no vessel has opted out of the program. Providing vessels that perform to a lower bycatch standard allows a measure of earned flexibility to those vessels in years of unpredictably high bycatch, while retaining a lower performance standard for years when bycatch encounters are fewer or more predictable in nature. The IPAs are structured to ensure that incentives exist to conserve bycatch at all levels of encounter rates. Even when encounters are low, IPAs include provisions to ensure that members continue to reduce Chinook bycatch rates at levels below the allocated performance standard. Approved IPAs must include measures demonstrating that vessels are constantly avoiding salmon. Many IPAs specify a contract with a third-party data manager that helps vessels move away from bycatch hot spots in near-real time. Experience under the program shows that some vessels have consistently higher bycatch rates than other vessels, even when overall bycatch is lower. As a result, BSAI Amendment 110 included additional provisions to ensure that all vessels continued to minimize their rates over the entire season. Additional penalties are enacted on outlier vessels that have higher rates than other vessels operating at the same time, even if the vessel is fishing beneath its individual cap. In particular, IPAs restrict vessels with high bycatch rates from fishing in the fall when Chinook encounter rates are expected to be higher.

In general, allocating additional PSC to good performers or reallocating PSC from poor performers by regulation requires an action by NMFS that must stand up to close scrutiny. Any regulation that takes allocated PSC away from a cooperative or a vessel must also provide the opportunity for an appeals process. The Agency would need to carefully consider whether or not the available sources of data – at the relevant level of granularity – can factually demonstrate the difference between an adequate and a poor performer.

Fishing cooperatives sometimes receive greater management flexibility if they establish a harvest plan, which might include bycatch avoidance procedures. As described above, Am. 110 allows vessels that join an IPA to fish under a higher Chinook salmon PSC limits. The limit is "higher," relative to vessels that are not signed onto an IPA, regardless of whether the base PSC limit is set at its normal level or reduced for conservation reasons according to the three-river index. Am. 110 also provides flexibility by allowing sectors – effectively vessels – to fish up to 5% more than the A Season pollock TAC so that harvest can be shifted towards the time of year when salmon bycatch rates are lower when that is the case.

GOA groundfish trawl fisheries are largely limited access fisheries and do not benefit from a cooperative structure. However, in some cases under the constraint of a nearing bycatch cap, the participants in the fishery can work with NMFS to create a voluntary plan to accommodate additional fishing when effort and expected bycatch rates are reasonably well understood. These arrangements are labor intensive on both sides, and sometimes tenuous. They may provide additional fishing opportunities, but only relate to bycatch minimization insofar as they are governed by PSC hard caps set in regulation.

Amendment 80 cooperatives and CDQ groups are permitted to trade halibut PSC internally. The ability to trade PSC creates an incentive to minimize bycatch at an individual or cooperative level so that it may be used as a tool to optimize aggregate harvest when necessary. Compared to the alternative, the policy to allow trading likely results in more halibut mortality than would otherwise occur, as some entities would have to cease fishing when they do not have halibut bycatch to support it. Rather, the policy reflects a desire to optimize harvest *within* the PSC limit constraint. Individuals can benefit by reducing their own bycatch and trading that quota, thus tradability creates an incentive for individuals and cooperatives to experiment with technological or knowledge-based approaches to halibut avoidance. The strength of the trading incentive for an individual or cooperative to reduce halibut mortality depends on how bycatch limits are currently allocated, which varies across sectors (e.g. A80 vessels, AFA-affiliated TLAS vessels, or the FLC).

Existing management in the North Pacific includes one example of bycatch species abundance informing limits. However, the three-river index for EBS salmon bycatch and its attendant lower PSC limit was implemented as a salmon conservation measure and not an incentive to the pollock fleet (see Section4.3).

6.2 General program design considerations

As requested in the SSC's June 2017 minutes, this section revisits the incentive-related concepts put forward in the April 2017 Halibut ABM discussion paper. The scope of this discussion is limited to the potential action in front of the Council; that is, changing the way that existing sector PSC limits are determined.

The Council always weighs the flexibility afforded to the fleet under a regulatory solution to a problem against the rigidity necessary to keep all stakeholders moving their behavior in the desired direction. In the context of groundfish fisheries, flexibility is giving entities within sectors – those that do the actual fishing – the freedom to seek the most appropriate means to a desired end. The cost of avoiding halibut differs across gear groups, targets, time, location, and otherwise similar vessels. Commanding that all vessels achieve the same standard of bycatch avoidance is inefficient and has distributional impacts; it could also result in all vessels making the same choice to avoid a certain target species or time of year, which affects the achievement of optimum yield. Commanding that all vessels adopt a certain avoidance strategy, such as excluders, stifles experimentation with other methods that might not work in concert with that tool. There will always be vessels within a sector that are more easily able to avoid halibut. This could be due to their target, their gear, or even their experience with a particular fishery or area. Allowing flexibility for entities within the sector to work together towards the goal of bycatch minimization in the aggregate reduces total costs, and takes advantage of the cooperative infrastructures that already exist.

On the other hand, the Council might take a more rigid approach to individuals' minimum bycatch performance levels. If the vessels within a sector for which avoidance is relatively costly are able to free-ride on the efforts of others, the "tide" of the program does not "lift all boats." In short, it does not make sense to hold all entities to the same standard, but all entities should be held to some standard. The gradient along which that occurs is most efficiently determined by participants. For this reason, sectors have chosen to focus on outlier vessels when asked to design a voluntary plan to address halibut bycatch. Examples of plans that focus on outliers include the A80 halibut avoidance plan, and some of the EBS pollock fisheries Chinook salmon incentive plan agreements.

Regulations tend to be rigid by definition and might not be easily adapted to changes in the environment, markets, or technology. For example, target bycatch rates that are specified in regulation for each groundfish species could fall out of step with how the fishery is prosecuted or improvements in our understanding of how the resource moves. The Council would not want to set up a system that needs frequent adjustment through the NEPA process. Moreover, strictly regulating behavior and restricting fishermen's decision-making ability is not robust to unforeseen effects of this or future actions. Abbott and Haynie (2012) found that area closures have not worked for halibut avoidance, and that closures to protect other species (red king crab) resulted in greater halibut bycatch because the fleet's flexibility was reduced. In general, effective incentives place the responsibility to achieve an end with the persons who are making decisions on the fishing grounds.

Where cooperative structures already exist in the groundfish fleet, it makes sense to rely on them to translate sector-level limits to the vessels. They are also better situated than NMFS to establish and enforce incentives that might be based on target-specific or seasonally-defined bycatch rates, and to revise them as they experience changes in the fishery environment. However, it is possible that vessels which are subject to halibut PSC limits will not be affiliated with a cooperative. This might be a vessel in the trawl limited access fishery or, less likely, a freezer longliner that someday chooses not to participate in the voluntary FLC cooperative. In developing this program, the Council might consider how those vessels can be incentivized to minimize bycatch at all times, and not to free ride on cooperatives' efforts to fish below sector-level PSC limits.

The Council should consider whether it is aligning incentives with the specific objectives of the broader action, as described in Section 2. The Council's objectives include protecting the halibut spawning stock biomass, and (indirectly) providing opportunity for the directed halibut fishery. Those objectives might call for incentives that direct bycatch toward or away from certain segments of the halibut biomass. That could mean providing future rewards to sectors that maintain a desired ratio of halibut bycatch that is over or below a certain size threshold, or calling on cooperatives to include that metric in any avoidance plans that they are asked to formalize. A bycatch size ratio might be appropriate, because a PSC limit denominated in weight could create a perverse incentive for groundfish vessels to stay in an area where they are encountering smaller halibut, which could have a delayed but important effect on future biomass. A reward could take the form of additional bycatch in years of higher abundance (e.g., a non-linear control rule applied to the sector), or management flexibility to fish in certain areas to the extent that the effect of bycatch in a certain area on halibut abundance becomes better understood over time. Conversely, a sector might be penalized if it overharvests a segment of the halibut population.

6.3 Application of a halibut performance standard to the BSAI groundfish fisheries

Generally speaking, a performance standard is a defined bycatch amount that is less than the PSC limit defined in regulation. The limit, and thus the standard, could be enforced at any number of levels – FMP, sector, area, area/sector, cooperative, or the individual entity. The achievement or failure to achieve the standard at the relevant level triggers rewards or sanctions that could also take a variety of forms. This section includes three examples of bycatch performance standards – two for salmon and one for halibut – followed by a discussion of key factors when considering a performance standard. Performance standards for salmon bycatch have been set in regulation in both the GOA and the BSAI.

Two subsectors of the GOA non-pollock trawl fishery (CPs, and non-Rockfish Program CVs) are able to fish at a higher Chinook salmon PSC limit in one year if they met a performance standard in the previous year. The standard is set at 86.7% of each sector's base annual PSC limit. If met, the sector may take up to 113.3% of its base limit the following year. That marginal earned incentive buffer is set at exactly 13.3% of the base limit regardless of the amount by which the sector outperformed the standard in terms of Chinook salmon avoidance in the previous year. One could argue that capping the value of the earned buffer at 13.3% of the base limit removes any incentive to reduce bycatch to a level lower than the performance standard. The buffer is set at that precise delta and does not accrue over multiple years of meeting the standard so that no two consecutive years of PSC limits, if fully taken, could possibly reach a level that might threaten an aggregate GOA trawl Chinook limit across all sectors that would trigger ESA consultation. Moreover, given the nature of salmon bycatch as a rare and unpredictable occurrence and the inherent difficulties of PSC estimation in a partially observed fishery (CV sector), the Council made its recommendation under the presumption that a sector could only reasonably *expect* to meet its performance standard if maximum efforts to avoid salmon were made at all times and throughout the fishing year. This measure functions only as a potential reward. There is no opportunity for a sanction because the affected sectors are never allowed to go over their base PSC limit in one year on the condition of a lower limit the next year; that sector would simply be forced to stop fishing when the PSC limit was reached.

Regulations set both a salmon PSC limit and a lower performance standard for the EBS pollock trawl fishery. In this case the measure functions only as a potential sanction for failure to meet the performance standard in three of the seven most recent years. If that sanction becomes effective, the sector is limited to its pro rata portion of the lower performance standard-level PSC limit, which itself could toggle between higher and lower values depending on the three-river index. The change to that sector's PSC limit would be permanent. While the limit and the standard are applied at the sector level, the existence of AFA pollock cooperatives and 100% (or greater) observer monitoring means that the program can essentially function at the vessel level. Cooperatives have developed and are accountable to incentive plan agreements. Cooperative infrastructure with robust catch accountability are preconditions to applying a performance standard at anything more granular than the sector level.

The A80 sector developed a Halibut Avoidance Plan that sets internal rate-based performance standards at the vessel level for each key groundfish target. The plan includes a separate standard for the last calendar quarter when the incentive of the annual performance standard might be lower during a year in which, for any number of reasons, realized halibut bycatch is low relative to the limit (refer to Section 1.4.4). Similar to the BSAI pollock fleet, the A80 sector has in place a cooperative structure, which is necessary for enforcing a performance standard at the vessel level. The sector also operates under full observer coverage, so participants and managers have a relatively high degree of confidence in the precision of bycatch and bycatch rate estimation at the target fishery level. However, whereas AFA vessels are avoiding comparatively rare salmon species, A80 vessels must manage a bycatch species that is typically comingled with the target groundfish. While the number of halibut brought onboard A80 vessels is small relative to the number of groundfish, the nature of the two species groups means that even the vessel taking the most aggressive actions to avoid halibut reaches diminishing returns more quickly, relative to avoiding salmon, when trying to push the bycatch rate towards zero. This reality means that vessels can rely less on avoidance strategies like staying out of identified hot spots, and need to focus on developing knowledge about expected rates in a particular context (target species, vessel characteristic, time/area, local size composition of halibut biomass) and tools that best reduce bycatch rates in that context (excluder use/design, shorter tows, deck sorting). Because no A80 vessel can expect a bycatch rate that approaches zero, the accountability measures in the sector’s plan are directed towards vessels with outlier bycatch rates. This approach focuses on the opportunities to minimize aggregate bycatch with the lowest marginal cost, e.g. bringing the poorest performing vessels closer to the average rather than asking the best performing vessels to find a way to move its rates from “best” to “exceptional” – or perhaps “improbable.”

Selecting a level for a performance standard will be a complex task because, by definition, it triggers conversation about rewards or sanctions that have distributional impacts across entities and their business plans. Even the lack of a reward could be viewed as a sanction. Moreover, monitoring and managing performance relative to the standard carries a cost for the agency. Therefore, the Council should consider whether the performance standard that it includes is meaningful. For the standard to be meaningful, there should be some expectation that the difference in halibut bycatch at the PSC cap versus bycatch at the performance standard level provides a benefit to the resource and to other users.

The metric for the standard could be defined in tons of bycatch mortality, a number of halibut, a bycatch rate (in either denomination), or a measure that aims to achieve a resource-building goal such as a ratio of O26:U26 bycatch. In making this choice, the Council should consider two things: (1) does the agency have the necessary information on the required timeline to track and manage the standard, and (2) can the fleet reasonably be expected to take steps towards this goal throughout the fishing year and under all circumstances – years of high/low halibut abundance, high/low groundfish TACs.[15] If the standard is denominated in a way that the fleet does not have tools to achieve when acting in good faith, then it functions more so as an item of chance.

In the EBS pollock fishery, performance standards have been denominated in the same units as the PSC limit (number of salmon). If that were also the case for halibut bycatch in BSAI groundfish fisheries then the standard would likely be set as a percentage of the total abundance-based PSC limit (tons or number of halibut), and it would float up and down with the selected index and control rule. Because the performance standard will be lower than the PSC limit, it will be the first benchmark that reaches an

[15] Because different groundfish targets tend to carry different expected halibut PSC rates, a sector’s PSC limit (or performance standard) might seem more or less constraining depending on the harvest specifications for the year. Those specifications are foremost based on stock assessment but also have an element of policy choice, particularly as the Council determines how to parcel out the 2 million metric ton BSAI groundfish cap. A performance standard that carries penalties for sectors that do not meet it could affect choices about where to set groundfish TACs.

unattainably low level during times of low halibut abundance. This is not a problem if the performance standard is designed as a positive incentive – e.g., a sector receives management flexibility or a PSC rollover if the standard is met. However, if failure to meet the standard triggers a sanction, including it only increases the expectation that groundfish harvests might be adversely impacted as the halibut resource fluctuates downward. If the standard is designed as a trigger for sanctions, the Council might consider a floor for the standard such that the percentage difference between it and the PSC limit gets smaller when the PSC limit is lower.

For regulations that might entail sanctions, the Council should bear in mind that NMFS must provide an appeal process for the regulated entity. Therefore, it is important that the metric for the incentive is a piece of information that is well collected and verifiable on the appropriate timeline. Regulatory standards that are judged on a short timeline (e.g., quarterly as opposed to annually) might be difficult to enforce with due process. Standards that are based on a very refined metric, such as a ratio of small to large fish, should only be chosen if the agency is confident in its ability to monitor catch and discards to the level at which the standard is applied (sector, cooperative, or vessel).

One of the challenges with designing a performance standard is how to provide an incentive to minimize bycatch at all times. Absent other provisions, the entity constrained by a bycatch limit is indifferent to the amount of bycatch that occurs as long as the limit is not reached. A performance standard without an associated carrot or stick is nothing more than a lower PSC limit. Entities need an incentive not to leave bycatch savings “on the table.” Provisions that give some value to each marginal halibut that is not taken might encourage avoidance regardless of where the sector stands in relation to the limit, so long as the perceived value of the incentive (or disincentive) is greater than the cost of modifying operations to avoid halibut. Some programs include bycatch credits that can be rolled over, or the ability to trade halibut bycatch allowances. As one example, a new program might include a PSC limit that closes the sector and a performance standard below which unused bycatch allowances are bankable or tradable.

Incentives in the context of Halibut ABM

This section briefly puts the general discussion of incentives into the context of the design choices that the Council is considering, such as PSC limits, abundance indices, and control rules. It is useful to understand how participants might be sensitive to certain program elements, and how design choices might affect incentives to avoid halibut on the margin. This discussion will be further developed after the Council defines alternatives for analysis.

When the Council selects an abundance index for analysis, it will be important to illustrate how much that index value has varied from year to year. Volatility in the index could have a cost in terms of business planning. A significant shock could affect decisions about whether to participate in the fishery, or whether to pursue certain groundfish targets, thus potentially affecting the likelihood of achieving optimum yield. The slope of the control rule is also linked to volatility. A steeper slope means that the limit is more sensitive to small changes in the index value. In the case of a volatile index or a steep control rule, the Council might consider one of its options to limit the amount that the abundance-based PSC limit can change over a given period of time.

As described in Section 3, different candidate indices measure different parts of the halibut biomass. However, it is not clear how the nature of the index would affect fishermen’s incentive to move toward larger or smaller halibut. If the Council selects an index that tends to capture larger fish, the fleet might tend to move toward bycatch of larger halibut so that smaller fish can grow larger and contribute to a higher index value and a higher PSC limit in the future. On the other hand, if the PSC limit is denominated in weight then fishermen will always have an incentive to take smaller fish as bycatch. As noted in Section 5.2, it might be appropriate to consider incentives to aim for a certain ratio of large and small halibut at the sector-level.

The selected index or indices might also differ in the timing of when the value is known for the upcoming year. The halibut PSC limit is an important factor in the Council's decisions during the annual harvest specification process. A higher or lower limit might affect how the Council determines the apportionment of the 2 million ton BSAI groundfish cap. A low limit could result in shifting TAC away from target species with higher expected PSC rates. The industry's own planning discussions and input into the specifications process would be more difficult if a factor that determines the PSC limit is not yet known or only recently publicized when the planning process begins in the fall.

The shape of the control rule and inclusion of a floor or ceiling could affect fishermen's incentive to avoid halibut. A flatter control rule provides relatively more stability and predictability for the fleet and for managers in making harvest specifications. However, one would expect fishermen to be marginally less likely to fish in a way that promotes abundance (as it is measured by the selected index) if the resulting change in future PSC limits will be small. The weaker incentive might also have a positive effect if it means that the fleet is less likely to attempt to "game" the index by focusing bycatch on a particular segment of the halibut population (i.e., large or small fish) in way that harms the resource. A non-linear control rule may have one or several inflection points where the slope goes from flat to steep, around which the fleet's incentive to promote future abundance might change. The most extreme example of an inflection point would be a control rule floor or ceiling. If the index value is approaching either a floor or a ceiling from the direction of the starting point, the fleet would likely display a diminishing response, because the expected marginal change in future PSC limits goes to zero. Once a floor or ceiling is reached, the fleet can be expected to behave in a manner that pushes the index back towards the middle and the limit towards the starting point. For example, if abundance is high but the PSC limit is not increasing beyond the ceiling, the fleet would have a weaker incentive to take on extra costs to further promote abundance through bycatch avoidance measures. It should be noted, however that this discussion is likely overstating the effect of the groundfish fleets behavior on halibut abundance. While surely a factor, halibut abundance is also a function of many non-fishing factors, some of which are not perfectly understood.

Sectors might experience different incentives to avoid halibut depending on the perceived constraint of the PSC limit. If a vessel or sector views the likelihood of reaching the limit is low, then it might not bear costs to avoid halibut. This could apply to an entire year if, to name one example, the groundfish target in the TLAS fishery that has the highest expected bycatch rate is allocated a low TAC in the harvest specifications process. It could also apply near the end of the year if encounter rates have been low to that point. If the cap is very likely to be reached, vessels might individually anticipate a fishery closure and race to harvest groundfish with less regard for bycatch while the season is still open. These cases underline the importance of cooperative or regulatory incentive measures to minimize bycatch at all times, including but not limited to rate-based performance standards. The effect of a performance standard largely depends on the strength of the incentive associated with it. Weak negative incentives or positive incentives might cause the performance standard to be viewed as a non-binding cap, whereas a measure with punitive and long-lasting implications would essentially function as a reduced PSC limit.

Finally, under either an abundance-based approach or the status quo, sectors in the groundfish fleet have an ongoing incentive to reduce mortality by lowering their discard mortality rates. Because DMRs are now specified by operational type (e.g., trawl vs. hook-and-line; pelagic vs. non-pelagic trawl; and CP vs. CV) instead of by target species, vessels do not have an incentive to manipulate a trip's catch composition to be accounted at a lower rate. Specification by operational type also highlights the sectors that were causing higher mortality and incentivizes them to reduce it. The fact that DMRs are now based on three year moving averages and re-estimated annually (as opposed to stable 10 year averages) can also be incentivizing because the feedback loop between better fish handling and lower DMRs – and thus the benefits – is tightened. However, there is not a direct connection between lower DMRs and less total mortality because vessels have an incentive to fish until the TAC is harvested or the PSC limit is reached.

7 Decision Points for Council in Developing Alternatives for this Action

The following section identifies the stepwise decision points for the Council to begin to draft a suite of alternatives for analysis as well as additional potential discussion points for the Council at this meeting.

7.1 Developing Alternatives, Elements and Options

Each alternative will begin with selection of a single abundance estimate option under Element 1 (See summary tables below as well as a schematic of alternative development choices Figure 50). Stepwise decisions then add in features of the control rule under Elements 2 through 5. Selection of some option necessitates additional decisions as noted in the column to the right (*in italics*) as appropriate. Additional elements and options pertaining to incentives or other provisions of alternative PSC management may also be drafted and added to the alternative set once a draft range of alternatives have been assembled.

Element 1 Abundance Estimate: SELECT ONE PER ALTERNATIVE	
Option 1. EBS trawl survey	*Choose suboption:* *1) Index in biomass* *2) Index in numbers*
Option 2. IPHC setline survey (O32) in Area 4ABCDE (*no suboptions*)	
Option 3. EBS trawl survey and IPHC setline survey (biomass)	*Choose suboption:* *1) Equal weighting* *2) EBS trawl survey weighted 80:20*
Option 4. Index trawl gear to EBS survey, index fixed gear to IPHC setline survey (*no suboptions*)	

Element 2 PSC Limit responsiveness to abundance changes: Can select more than one option and suboption		
Option 1. PSC limit varies proportionally with change in abundance index	*Choose suboption:* *1) varies 1:1 with abundance* *2) varies X:X with abundance* *3) varies nonlinearly with index*	 *Select proportion* *Select shape*
Option 2. Limit PSC change to a maximum percentage	*Choose %*	
Option 3. Change PSC only every x number of years	*Choose # of years*	
Option 4. Threshold values(breakpoints) to modify PSC limit (e.g., IPHC stock status, other)	*Choose values for breakpoints or thresholds*	

Element 3 Select Starting point for PSC limit. A range of options may be selected as desirable for each alternative	
Option 1. 2016 PSC limit (3,515 t)	
Option 2. 50% of 2016 PSC limit = (1,758)	
Option 3. 150% of 2016 PSC limit (5,273)	
Option 4. Additional value within range of Options 1-3	*Select value*
Element 4 Select Maximum PSC Limit (ceiling)	
Option 1. 2016 PSC limit (3,515 t)	
Option 2. 20% - 50% increase from 2016 PSC limit	
Option 3. Average of 2008 – 2016 PSC limit (4,369)	
Option 4. Additional value to be selected	*Select value*
Element 5 Select Minimum PSC Limit (floor)	
Option 1. No floor (PSC goes to 0)	
Option 2. 20% - 50% reduction from 2016 PSC limit	
Option 3. Average of 2014 - 2016 PSC use (3,265)	
Option 4. Additional value to be selected	*Select value*

- Developing a range of ABM Alternatives -

☛ **For each alternative you want to construct, go through steps 1-5 below.**

1. Choose which abundance index will drive the PSC limit. (Element 1)

You must choose ***one option only per Alternative.***

- ☐ Option 1: EBS trawl survey
- ☐ Option 2: IPHC setline survey (O32) in Area 4 (all subareas - 4A, 4B, 4CDE)
- ☐ Option 3: EBS trawl survey biomass and IPHC setline survey
- ☐ Option 4: EBS trawl survey for trawl gear, IPHC setline survey for fixed gear

➢ Did you choose Option 1?

NO Keep going

YES Which EBS trawl survey index are you linking to?
- Biomass of halibut (Suboption 1)
- Numbers of halibut (Suboption 2)

➢ Did you choose Option 3?

NO Keep going

YES How will you weight the two surveys?
- 50:50 (Suboption 1)
- 80:20 (Suboption 2)

2. How responsive is the PSC limit is to abundance changes? (Element 2)

You may select multiple options.

➢ Does the PSC limit vary proportionally with index (from Element 1)? (Option 1)

NO PSC limit will stay fixed (status quo)

YES How should it vary?
- 1:1 with abundance (Suboption 1)
- X:X select the values (Suboption 2)
- Nonlinearly – select shape (Supoption 3)

➢ Should there be a maximum amount that the PSC limit can change? (Option 2)

NO PSC limit can fluctuate freely

YES Choose the maximum % by which PSC limit can change

➢ Should you constrain how often the PSC limit can change? (Option 3)

NO PSC limit can change annually

YES Choose how often the PSC limit can change (e.g., every X number of years)

➢ Should there be threshold values (break points) for when to change the PSC limit? (Option 4)

NO PSC limit changes with each new survey

YES Choose what thresholds will trigger changing the PSC limit (e.g., IPHC stock status)

Figure 50. Schematic for the development of Alternatives given the 5 Elements and Options as discussed in the ABM examples and Table 22 (continued on next page)

Developing Alternatives (continued)

3. Choose what starting point for the PSC limit. (Element 3)
Select value(s) that fall within the following range.

You may select multiple options

50% of 2016 limit 1,758 (Option 2)	2016 limit 3,515 (Option 1)	150% of 2016 limit 5,273 (Option 3)

Option 4: Choose a different value in the range

4. Do you want to set a ceiling (maximum) for the PSC limit? (Element 4)

NO PSC limit has no ceiling.

YES Select one of these options:
- 2016 limit – 3,515 t (Option 1)
- 20-50% increase from 2016 limit (Option 2)
- Average PSC limit 2008-2016: 4,369 t (Option 3)
- Select another value (Option 4)

5. Do you want to set a floor (minimum) for the PSC limit? (Element 5)

NO You have automatically selected Option 1, no floor.

YES Select one of these options:
- 20-50% reduction from 2016 limit (Option 2)
- Average PSC usage 2014-2016: 3,265 t (Option 3)
- Select another value (Option 4)

☛ **Repeat steps 1-5 for each alternative to be analyzed.**

7.2 Coordination with IPHC

Developing these alternatives is under the Council purview and determines the process for establishing PSC limits for Council managed BSAI groundfish fisheries. However, the IPHC is responsible for setting the overall TCEY for each Regulatory Area, which takes into account mortality from all sources. The remainder of the TCEY (after removing mortality from non-directed fisheries, including predicted PSC in the BSAI) goes to the directed halibut fisheries. It is clear which actions are the purview of each agency, but the resulting allocation to each fishery is a combination of the actions of each agency involved. Therefore, coordination is very important. Synchronization of goals and objectives between agencies may also be helpful to identify when conservation measures should be prioritized.

Currently, an IPHC staff member is a participant and contributor to the working documents, and a different IPHC staff member is on the SSC, often reviewing the ABM working documents. Additionally, a Council member is a participant in the Management Strategy Advisory Board (MSAB) even though ABM has not been specifically investigated. Finally, there have been joint meetings between the Council and IPHC where ABM of PSC limits has been discussed.

Continuing this coordination will help the Council to understanding IPHC's management process, and being aware of the developments and changes to IPHC's harvest policy. The IPHC will benefit by being aware of the management measures that the Council is proposing and understanding the tools and methods that Council is using to manage bycatch. Finally, both agencies will benefit from identifying goals and objectives that are similar and different between agencies so that similar objectives can be met and trade-offs can be examined.

7.3 Appropriate NEPA document

The Council may wish to begin the discussion at this meeting of what is the appropriate breadth of analysis to meet the NEPA requirements. As such NMFS has provided some guidance below on the selection of the appropriate (EA, EIS) analysis for this action. Selection of an EIS rather than an EA has some timing and scheduling implications that staff will be prepared to provide should the Council wish to discuss this at this meeting.

Summary of primary points

1. NMFS recommends that the Council consider preparing an Environmental Impact Statement (EIS) for its proposed action to implement abundance-based halibut PSC limits. The EIS would assess the impacts of the proposed management program alternatives on the human environment. An EIS will assist the Council and NMFS in planning and decision-making as it develops the management program.
2. We recommend preparation of an EIS because:
    - the program could result in comprehensive changes to the management of groundfish fisheries in the BSAI and,
    - the effects of these changes on the human environment are likely to be highly controversial.
3. Preparation of an EIS will not delay Council action on development of the halibut ABM program or its implementation. If the Council provides guidance to prepare an EIS, NMFS would begin scoping by publishing a Notice of Intent.

NMFS recommends preparation of an EIS because the halibut ABM program could substantially change the way the BSAI groundfish fisheries are prosecuted and managed. The implementation of halibut PSC limits that float with abundance could result in complex operational, management, monitoring, and enforcement changes that will affect the prosecution of the BSAI groundfish fisheries.

An EIS is appropriate because the impacts of these changes are likely to be comprehensive. An EIS assesses the anticipated impacts of the changes with the best available information. This is particularly important for the halibut ABM program, which is likely to have impacts on halibut, groundfish species, and fisheries operations that are uncertain. The comprehensive nature of the proposed action makes it difficult to determine at this stage that the analysis would result in a finding of no significant impact (FONSI). An EIS provides the analytical structure to address this uncertainty while still allowing the Council to move forward with a recommendation for final action.

In addition, an EIS is appropriate for the halibut ABM action because the impacts of the action on the human environment are likely to be controversial. Comments received by the Council for the halibut ABM program thus far and for other bycatch reduction actions implemented in recent years indicate that some members of the public would express concerns about 1) the extent to which halibut PSC would be reduced under the proposed action, 2) the impacts of PSC on halibut stocks, 3) the impacts of PSC reductions on directed fisheries for halibut, and 4) the economic and social impacts of implementing a halibut PSC limit that floats with abundance. As described above, preparation of an EIS does not require a FONSI to move forward with the recommended action, even if the identified impacts are uncertain and controversial.

8 References

Abbott, J. K., & Haynie, A. C. (2012). What are we protecting? Fisher behavior and the unintended consequences of spatial closures as a fishery management tool. Ecological Applications, 22(3), 762–777. http://doi.org/10.1890/11-1319.1

Clark, W. G. (2003). A model for the world: 80 years of model development and application at the International Pacific Halibut Commission. Natural Resource Modeling, 16: 491–503. doi:10.1111/j.1939-7445.2003.tb00125.x

Clark, W. G. 1992. Estimation of halibut body size from otolith size. Int. Pac. Hal. Comm. Sci. Rep. 75.

Clark, W. G., G. St-Pierre, and E. S. Brown. 1997. Estimates of halibut abundance from NMFS trawl surveys. Int. Pac. Hal. Comm. Tech. Rep. No. 37. 51 p.

Clark, W. C. and S. R. Hare. 2007. Motivation and plan for a coastwide stock assessment. Int. Pac. Halibut Comm. Report of Research and Assessment Activities 2006: 83-96.

Clark, W.G., and Hare, S.R. 2002. Effects of Climate and Stock Size on Recruitment and Growth of Pacific Halibut. North American Journal of Fisheries Management **22**: 852-862

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.

Dykstra CL. 2017. Incidental catch and mortality of Pacific halibut, 1990–2016. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016: 71-89.

Geernaert TO. 2017. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016. IPHC-2016-RARA- 26-R: –.

Hare, S. R. and Clark, W. C. 2008. 2007 IPHC harvest policy analysis: past, present and future considerations. Int. Pac. Halibut Comm. Report of Research and Assessment Activities 2007: 275-296.

Hare, S. R. 2011. Potential modifications to the IPHC harvest policy. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2010: 177-199.

Henry E, Soderlund E, Geernaert TO, Ranta AM, Kong TM, Forsber J. 2017. 2016 IPHC fishery-independent setline survey. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016. IPHC-2016-RARA- 26-R: 175–215

Hicks, A. C. and Stewart, I. J. 2017. An investigation of the current IPHC harvest policy and potential for improvement. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016. IPHC-2016-RARA- 26-R: 421–438.

Hoff, G.R. 2016. Results of the 2016 Eastern Bering Sea Upper Continental Slope Survey of Groundfish and Invertebrate Resources. NOAA Technical Memorandum NMFS-AFSC-339. https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-339.pdf

Kotwicki, S., A. De Robertis, J. N. Ianelli, A. E. Punt, and J. K. Horne. 2013. Combining bottom trawl and acoustic data to model acoustic dead zone correction and bottom trawl efficiency parameters for semi-pelagic species. Can. J. Fish. Aquat. Sci. 70:208–219.

Kotwicki, S., A. De Robertis, P. von Szalay, and R. Towler. 2009. The effect of light intensity on the availability of walleye pollock (Theragra chalcogramma) to the bottom trawl and acoustic surveys. Can. J. Fish. Aquat. Sci. 66:983–994.

Kotwicki, S., J. K. Horne, A. E. Punt, and J. N. Ianelli. 2015. Factors affecting the availability of walleye pollock to acoustic and bottom trawl survey gear. ICES J. Mar. Sci. 72:1425–1439.

Kotwicki, S., J. N. Ianelli, and A. E. Punt. 2014. Correcting density-dependent effects in abundance estimates from bottom-trawl surveys. ICES J. Mar. Sci. 71:1107–1116.

Kotwicki, S., M. H. Martin, and E. A. Laman. 2011. Improving area swept estimates from bottom trawl surveys. Fish. Res. 110:198–206.

Kotwicki, S., and K. L. Weinberg. 2005. Estimating capture probability of a survey bottom trawl for Bering Sea skates (Bathyraja spp.) and other fish. Alaska Fish. Res. Bull. 11(2):135–145.

Martell SJD, Stewart IJ, Wor C. 2016. Exploring index-based PSC limit for Pacific halibut. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2015: 238–285.

Munro, P. T., and D. A. Somerton. 2001. Maximum likelihood and non-parametric methods for estimating trawl footrope selectivity. ICES J. Mar. Sci. 58:220–229.

Munro, P. T., and D. A. Somerton. 2002. Estimating net efficiency of a survey trawl for flatfishes. Fish. Res. 55:267–279.

NPFMC, 2015. Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis for Amendment 111 to the Fishery Management Plan for Groundfish of the Bering Sea/Aleutian Islands Management Area to Revise Bering Sea/Aleutian Islands Halibut Prohibited Species Catch Limits, January 2016, available at https://www.regulations.gov/document?D=NOAA-NMFS-2015-0092-0030.

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.

Soong, J. and T. Hamazaki. 2012. Analysis of Red King Crab Data from the 2011 Alaska Department of Fish and Game Trawl Survey of Norton Sound. Alaska Department of Fish and Game Fishery Data Series No. 12-06

Somerton, D.A. and Munro, P. 2001. Bridle efficiency of a survey trawl for flatfish. *Fish. Bull.* **99**:641–652.

Somerton, D. A., P. T. Munro, and K. L. Weinberg. 2007. Whole-gear efficiency of a benthic survey trawl for flatfish. Fish. Bull.105: 278–291.

Stauffer, 2004. NOAA Protocols for Groundfish Bottom Trawl Surveys of the Nation's Fishery Resources. NOAA Technical Memorandum NMFS-SPO-65. http://spo.nmfs.noaa.gov/sites/default/files/tm65.pdf

Stevenson, D.E., Weinberg, K.L. and R.R. Lauth. 2016. Estimating Confidence in Trawl Efficiency and Catch Quantification for the Eastern Bering Sea Shelf Survey. NOAA Technical Memorandum NMFS-AFSC-335. https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-335.pdf

Stewart IJ and Hicks AC. 2017. Assessment of the Pacific halibut stock at the end of 2016. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016: 365-394.

Stewart, I.J., and Martell, S.J.D. 2014. A historical review of selectivity approaches and retrospective patterns in the Pacific halibut stock assessment. Fish. Res. **158**: 40-49.

Stewart, I.J., and Martell, S.J.D. 2015. Reconciling stock assessment paradigms to better inform fisheries management. ICES J. Mar. Sci. **72**(8): 2187-2196

Stewart IJ and Martell SJD. 2017. Development of the 2015 stock assessment. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2015: A1-A146.Stewart & Monnahan 2016

Webster, R. A., Dysktra, C. L., and Henry, A. M. 2016. Eastern Bering Sea setline survey expansion and trawl calibration. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2015: 530-543

Webster, R. A. 2014. Construction of a density index for Area 4CDE. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2013: 261-288.

Webster, R.A. 2017. Results of space-time modelling of IPHC fishery-independent setline survey WPUE and NPUE data. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016. IPHC-2016-RARA-26-R: 241–257.

Weinberg, K. L., D. A. Somerton, and P. T. Munro. 2002. The effect of trawl speed on the footrope capture efficiency of a survey trawl. Fish. Res. 58:303–313.

Weinberg, K.L., and P. T. Munro. 1999. The effect of artificial light on escapement beneath a survey trawl. ICES J. Mar. Sci. 56:266–274.

9 Appendix

9.1 Index and control rule model

In the April 2017 discussion paper the Council reviewed some example indices as applied to alternative control rule options for setting PSC limits. Briefly, the process for determining a PSC limit using a control rule applied to indices was provided in the April 2017 discussion paper. In that paper, the current PSC limit (3,515 t) was used as the *Starting Point* in all of the strawman alternatives. The equations presented in that paper are the same as before to determine the PSC limit.

$$c_t = PSC_0 \prod_k \left[1 - (1 - x_{k,t})\, b_k\right]$$

$$PSC_t = \begin{cases} PSC_{min} & c_t < PSC_{min} \\ c_t & PSC_{min} < c_t < PSC_{max} \\ PSC_{max} & c_t > PSC_{max} \end{cases}$$

$$x_{k,t} = \begin{cases} x_{k,min} & x_{k,t} < x_{k,min} \\ x_{k,t} & x_{k,min} < x_{k,t} < x_{k,max} \\ x_{k,max} & x_{k,t} > x_{k,max} \end{cases}$$

where these and all variables used in the alternatives are described in Table 27. Section 3 presents example PSC limits that would result from applying the combined indices as described for some index and also shows the sensitivity of the PSC range constraints. Note that for clarity, the presentation below omits the "floor and ceiling" options (PSC_{min} and PSC_{max}).

Table 27. Parameters used in the ABM equations.

Parameter	Description
k	Index for abundance time series
t	Index for year
$x_{k,t}$	Normalized value of abundance index *k* in year *t*
b_k	Proportionality constant for index *k*
PSC_0	Prohibited species catch limit when all indices are average (1)
PSC_t	Prohibited species catch limit in year *t*
PSC_{min}	Floor (minimum value) of the prohibited species catch limit
PSC_{max}	Ceiling (maximum value) of the prohibited species catch limit
c_t	Defines the PSC limit prior to application of floors and ceilings
$x_{k,min}$	Floor (minimum value) of index *k*
$x_{k,max}$	Ceiling (maximum value) of index *k*

9.2 Magnuson-Stevens Act and Pacific Halibut Act Considerations

9.2.1 Magnuson-Stevens Act National Standards

Below are the 10 National Standards as contained in the MSA. This section is included in a NEPA analysis of alternative management measures (i.e. one that would be forthcoming for this action once alternatives have been adopted). At final action, in recommending a preferred alternative for a management action, the Council must consider how to balance the national standards. For each of the national standards, a reference would then be provided to areas in the NEPA analysis that are particularly relevant to the consideration of the national standard, although they may not be the only information that is relevant to the issue.

National Standard 1 — Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery.

National Standard 2 — Conservation and management measures shall be based upon the best scientific information available.

National Standard 3 — To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

National Standard 4 — Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various U.S. fishermen, such allocation shall be (A) fair and equitable to all such fishermen, (B) reasonably calculated to promote conservation, and (C) carried out in such a manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

National Standard 5 — Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources, except that no such measure shall have economic allocation as its sole purpose.

National Standard 6 — Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

National Standard 7 — Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

National Standard 8 — Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities.

National Standard 9 — Conservation and management measures shall, to the extent practicable, (A) minimize bycatch, and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.

National Standard 10 — Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

9.2.2 Pacific Halibut Act

The fisheries for Pacific halibut are governed under the authority of the Northern Pacific Halibut Act of 1982 (Halibut Act, 16 U.S.C. 773-773k). For the United States, the Halibut Act gives effect to the Convention between the United States and Canada for the Preservation of the Halibut Fishery of the North Pacific Ocean and Bering Sea. The Halibut Act also provides authority to the Regional Fishery Management Councils, as described in § 773c:

> *(c) Regional Fishery Management Council involvement*
>
> *The Regional Fishery Management Council having authority for the geographic area concerned may develop regulations governing the United States portion of Convention waters, including limited access regulations, applicable to nationals or vessels of the United States, or both, which are in addition to, and not in conflict with regulations adopted by the [International Pacific Halibut Commission]. Such regulations shall only be implemented with the approval of the Secretary, shall not discriminate between residents of different States, and shall be consistent with the limited entry criteria set forth in section 1853(b)(6) of this title. If it becomes necessary to allocate or assign halibut fishing privileges among various United States fishermen, such allocation shall be fair and equitable to all such fishermen, based upon the rights and obligations*

in existing Federal law, reasonably calculated to promote conservation, and carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of the halibut fishing privileges.

9.3 List of Tables and Figures