BSAI Halibut Abundance-based PSC limits discussion paper

September 2016[1]

1 Introduction

The Council is examining abundance-based approaches to establishing halibut prohibited species catch (PSC) limits in the Bering Sea and Aleutian Islands (BSAI) because current halibut PSC limits are a fixed amount of halibut mortality in metric tons. When halibut abundance declines, halibut PSC becomes a larger proportion of total halibut removals and can result in lower catch limits for directed halibut

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fisheries. Both the North Pacific Fishery Management Council (NPFMC) and the International Pacific Halibut Commission (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.

While establishing abundance-based halibut PSC limits is an intuitive approach to managing halibut bycatch, the Council realizes that establishing appropriate limits is challenging because of complex Pacific halibut population and fisheries dynamics and the difficulties and uncertainties involved in assessing the spawning biomass of the coastwide Pacific halibut stock. As such, it is clear that any evaluation of impacts due to bycatch on the status of the halibut stock as a whole will be highly uncertain as will impacts on directed Pacific halibut fisheries. An evaluation of the impacts of abundance-based PSC limits on the BSAI groundfish fisheries will also be uncertain because several factors other than halibut abundance affect bycatch rates in these fisheries.

The Council tasked an inter-agency workgroup of NMFS AKR, NMFS AFSC, IPHC, UW and Council staff to develop abundance-based approaches for BSAI halibut PSC limits, building upon previous work by IPHC staff. This inter-agency group have met several times in person as well as via teleconference and via electronic collaboration to coordinate efforts and provide the information and recommendations contained in this paper.

2 Purpose and Need for this action

Following review and discussion of a previously tasked April 2016 discussion paper[2], the Council adopted the following purpose and need statement for this analysis:

> 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 and protect the halibut spawning stock biomass, particularly at low levels of abundance. The Council recognizes that abundance-based halibut PSC limits would increase and decrease with changes in halibut abundance.

The Council further directed the Workgroup to continue to meet to address additional issues (including SSC comments as appropriate) in this discussion paper for October 2016. These issues include the following:

- Focus analysis on the use of the NMFS eastern Bering Sea shelf trawl survey and the biomass estimate from the IPHC stock assessment as potentially appropriate indices and explore a variety of assumptions on the appropriate weighting of indices, including using each index as a bookend. If time is available, focus on potential advantages and challenges of incorporating additional surveys (e.g., the Bering Sea shelf, Aleutian Islands, NMFS longline survey, and Gulf of Alaska trawl surveys to develop an Alaska-wide index of abundance), and the Integrated Model-based index approach outlined in that paper.

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[2] April 2016 discussion paper available at: https://npfmc.legistar.com/View.ashx?M=F&ID=4351913&GUID=FA1DD35A-7E2F-4C90-9CEA-CD5E6373F1E4

- Focus on efforts that describe halibut PSC abundance based on both weight and numbers, with DMRs applied to set PSC limits.
- Describe the potential implications of abundance-based halibut PSC allocations using the proportional allocations to the four sectors defined under Amendment 111 as the basis for structure and comparison.
- Provide further discussion on the potential management and operational implications of control rules (mechanisms for adjusting the PSC limit) that change on an annual basis. (e.g., How would NMFS implement such changes? When are data available to establish a revised limit? How would annual changes impact groundfish operations?)

In this paper we build upon some of the approaches and data summaries explored in the April 2016 paper and develop additional approaches. Here we provide an overview of these considerations building up to a recommendation for an integrated abundance-based index. We also explore control rule formulations, and provide illustrative control rules applied to the recommended abundance index in order to lay out the steps and decisions necessary by the Council for moving forward to drafting alternatives for analysis.

2.1 Current BSAI Halibut PSC Limits and Use

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 halibut PSC limits are described in the following table.

	Previous 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

The PSC limits for the four fishery sectors listed in Table 1 are allocated BSAI-wide at the sector-level and not spatially allocated further by management area in the BSAI. Per Council direction, this action addresses only the BSAI halibut PSC limits and not the GOA halibut PSC limits.

The PSC limits since 2008, and the Pacific halibut mortality estimates by sector (and ratio relative to sector-level PSC limits) are shown in Table 1and Table 2, respectively. Table 1 shows that the total PSC limit has been reduced by 23% since 2008, with most of the reduction occurring from implementation of Amendment 111 in 2016. Table 2 shows that PSC use can vary substantially from year to year. This inter-annual variability is not consistent across sectors, suggesting that PSC use is likely impacted by factors unique to each sector. Halibut mortality for the current 2016 fishing year is provided as of September 6th, 2016. For comparison with previous years (by a similar week-ending date for catch accounting) in 2015 an additional 506 mt of halibut PSC was caught between September 6th and December 31st. This number is lower than in previous years when the mortality accruing after September 6th in 2014 was 846mt and 2,206mt in 2013.

Table 1 Evolution of Pacific halibut PSC limits by main sectors in the BSAI region, 2008-2016. BSAI TLA refers to the BSAI trawl limited access sector.

	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$^+$	1,745	745	710	315	3,515

Table 2 Pacific halibut mortality estimates (top rows) and mortality relative to the total sector specific PSC limits (bottom rows) by sector for 2008-2016. From NMFS AKRO CAS

	Am80	BSAI TLA	Longline fisheries	CDQ	Total PSC mortality
2008	1,969	739	593	214	3,515
2009	2,074	726	597	151	3,548
2010	2,254	483	501	158	3,426
2011	1,810	629	482	241	3,179
2012	1,944	958	556	274	3,744
2013	2,167	706	463	265	3,611
2014	2,179	645	402	243	3,478
2015	1,636	485	293	130	2,318
2016*	1,062	542	140	124	1,868

	Am80	BSAI TLA	Longline fisheries	CDQ	% of Total PSC limit
2008	78%	84%	71%	62%	77%
2009	84%	83%	72%	44%	78%
2010	93%	55%	60%	40%	76%
2011	76%	72%	58%	61%	71%
2012	84%	109%	67%	70%	85%
2013	93%	81%	56%	67%	82%
2014	94%	74%	48%	62%	79%
2015	70%	55%	35%	33%	52%
2016*	61%	73%	20%	39%	53%

*2016 halibut mortality from September 6, 2016 NMFS AKRO CAS.

A summary of halibut mortality (kg) per metric ton of groundfish catch is provided in Table 3. This table shows that while bycatch rates of halibut have generally declined since 2008 for all sectors, the rates are variable from year to year, likely due to changing groundfish TACs, markets, and operating conditions in the fisheries.

Table 3 Pacific halibut bycatch rate in kg of Pacific halibut ***mortality*** per t of groundfish.

	Longline	Pot	Trawl	Total
2008	6.036	0.232	2.181	2.411
2009	5.672	0.074	2.572	2.795
2010	5.712	0.159	2.493	2.678
2011	4.050	0.221	1.716	1.855
2012	4.002	0.190	2.036	2.164
2013	3.429	0.106	1.936	2.016
2014	2.898	0.085	1.891	1.929
2015	1.996	0.093	1.267	1.304
Average	4.007	0.140	1.969	2.092

2.2 Pacific halibut biomass and catch limits

The IPHC has assessed the stock of Pacific halibut using an ensemble of coastwide models for the past several assessments, described in Stewart et al. (2016) and summarized further in Section 4.1 of this document. In this approach, multiple models are included in the estimation of management quantities, and uncertainty about these quantities. The results of the 2015 assessment indicate that the stock declined continuously from the late 1990s to around 2010. Decreasing size-at-age, as well as recent recruitment strengths that are much smaller than those observed through the 1980s and 1990s contributed to this decreasing trend. Since that time period, the estimated female spawning biomass appears to have stabilized near 200 million pounds, with flatter trajectories estimated in coastwide models and slightly increasing trends in areas-as-fleets models (where fishery data from different regions are treated as if from different fishing fleets; Stewart et al. 2016).

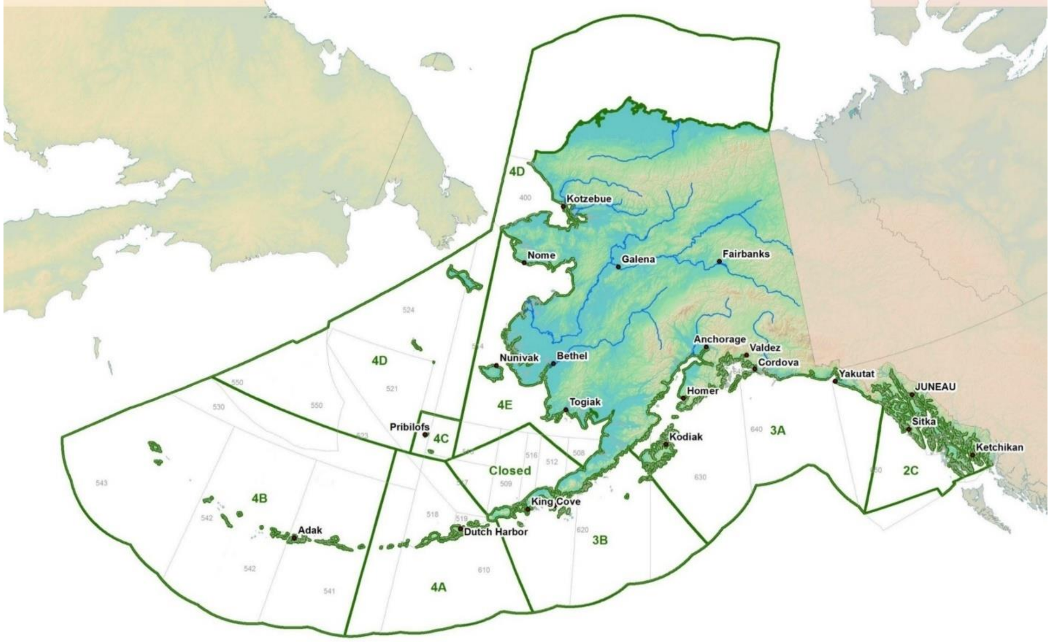
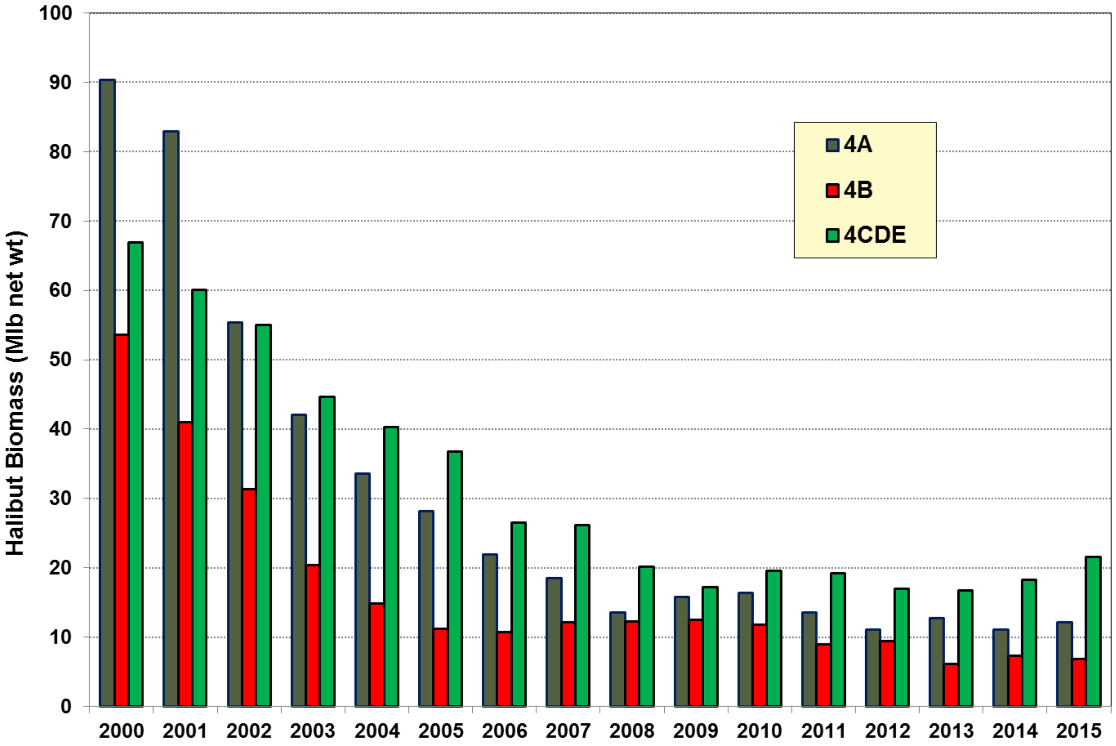


Figure 1 IPHC regulatory areas overlaid on the NMFS management areas in the BSAI and GOA.

The IPHC management areas are shown overlaid on the NMFS management areas in Figure 1. The BSAI management area equates approximately to the IPHC's Area 4 regulatory areas, in addition to the IPHC's closed area (when combined, the IPHC areas in the BSAI are called Area 4). Area 4CDE and the closed area are considered to be a single unit in all IPHC apportionment and harvest policy analyses. The magnitude of Pacific halibut allocated as PSC to federally-managed groundfish sectors within each of the Area 4 regulatory areas (Area 4A, 4B, and 4CDE) is under the jurisdiction of the Council and NMFS, rather than the IPHC. The IPHC has jurisdiction to specify the total catch limit of Pacific halibut by IPHC management area and to allocate the remaining allowable catch (after PSC is taken into account) among sectors within the directed Pacific halibut fishery. The IPHC's harvest policy is based on the coastwide exploitable biomass of halibut, or fish that are accessible in the IPHC setline survey and to the commercial halibut fishery (generally halibut over 26 inches in length; O26).

The IPHC apportions the coastwide exploitable biomass from the stock assessment among IPHC management areas (IPHC areas) using information from its annual setline survey (note more information on the setline survey is described in section 3.6 of this document). Figure 2 provides a graph of the exploitable biomass in the three IPHC areas that comprise the BSAI: Area 4A, Area 4B, and Area 4CDE. The measures of exploitable biomass in Area 4 indicate declines since 2000 that are similar to the coastwide results for trends in female spawning biomass. Catches and quotas for the directed halibut fishery in the BSAI (IPHC Area 4 as shown in Figure 1) are listed in Table 4.



Source: Leaman et al. 2015

Figure 2 BSAI Exploitable Halibut Biomass in the BSAI (IPHC Area 4), 2000 to 2015

Table 4 Catches and quotas (thousands of pounds, net weight) for the directed Pacific halibut fisheries in Regulatory Areas 4A, 4B, and 4CDE. These are preliminary numbers presented in the 2015 RARA. Additional carryover from the underage/overage plans is not included in the quotas. Area 4CDE includes research catch in the IPHC closed area during expansions in 2006 and 2015.

	4A		4B		4CDE	
Year	**Catch**	**Quota**	**Catch**	**Quota**	**Catch**	**Quota**
2006	3,332	3,350	1,590	1,670	3,227	3,550
2007	2,828	2,890	1,416	1,440	3,850	4,100
2008	3,015	3,100	1,763	1,860	3,876	3,890
2009	2,528	2,550	1,593	1,870	3,310	3,460
2010	2,325	2,330	1,829	2,160	3,315	3,580
2011	2,351	2,410	2,054	2,180	3,429	3,720
2012	1,583	1,567	1,738	1,869	2,341	2,464
2013	1,233	1,330	1,253	1,450	1,771	1,930
2014	906	850	1,119	1,140	1,258	1,284
2015	1,343	1,390	1,109	1,140	1,205	1,285
2016		1,390		1,140		1,660

2.3 Relationship of purpose and need to development of alternatives

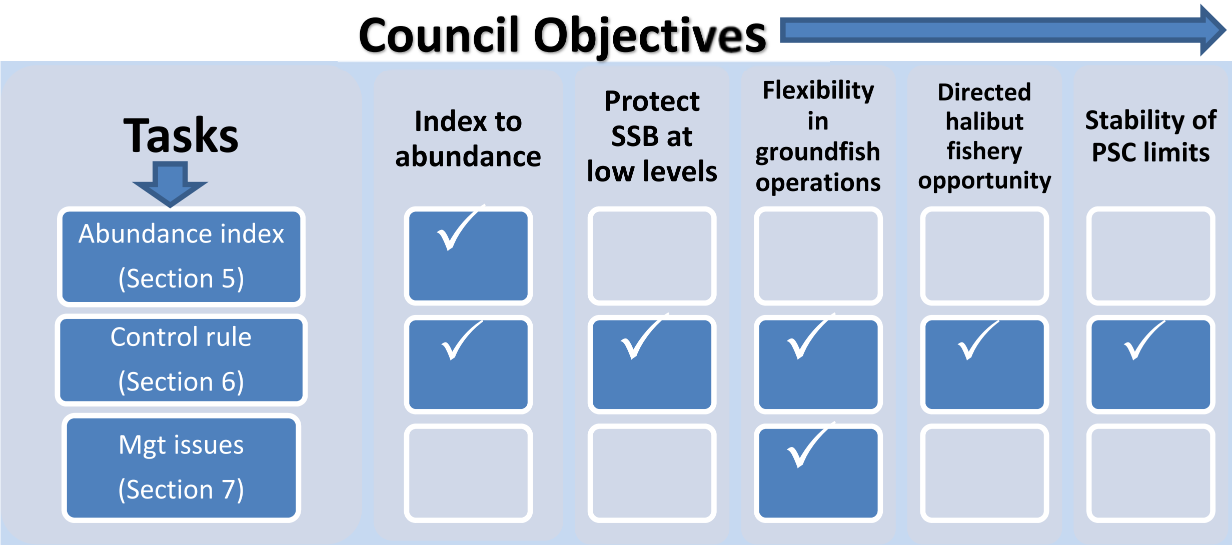
As will be discussed in Sections 5 and 6, different aspects of the Council's objectives as inferred from the purpose and need statement are addressed in the formulation of the draft alternatives (i.e., recommended abundance index and candidate bycatch control rules). Figure 3 indicates general goals and objectives inferred from the Council's purpose and need statement and describes which management alternatives have the potential to address each of these objectives. Explicit prioritization of and balancing amongst different and competing objectives will be necessary by the Council in order to adequately construct alternatives which meet these objectives. Performance metrics will then need to be developed associated with the articulation and prioritization of objectives in order to relate how well each alternatives address these objectives.

Three general objectives are inferred by analysts from the Council's purpose and need statement. These are characterized below:

1. Halibut PSC limits should be indexed to and fluctuate with the abundance of halibut
2. Further protection of halibut spawning stock biomass (SSB) is warranted particularly when declining halibut abundance leads to an increase in the proportion of the halibut stock that is allocated towards groundfish PSC, reducing the amount available to the directed halibut fishery
3. There should be some flexibility to avoid constraining the groundfish fishery particularly when halibut abundance is high

These general objectives are subdivided into several explicit considerations noted in the Council's purpose and need statement. Staff have identified additional potential objectives that could be inferred under this action in order to begin the process of developing alternatives (Figure 3). **The Council should explicitly state which of these are objectives for this action and then prioritize them accordingly. The Council**

may have additional objectives for this action that are not captured here and should be explicitly added by the Council in conjunction with modifications to the purpose and need statement.



Council Objectives

Tasks	Index to abundance	Protect SSB at low levels	Flexibility in groundfish operations	Directed halibut fishery opportunity	Stability of PSC limits
Abundance index (Section 5)	✓				
Control rule (Section 6)	✓	✓	✓	✓	✓
Mgt issues (Section 7)			✓		

Figure 3. Consideration of explicit and inferred draft objectives from Council's Purpose and Need (top row) and where these objectives are addressed in the discussion paper "tasks" as requested by the Council for the development of alternatives (horizontal column and section of document indicated).

As shown in Figure 3, some objectives are addressed in more than one component of the alternatives being developed. For instance, indexing halibut PSC to abundance requires the interplay of a control rule with an appropriate index of abundance. Multiple objectives are combined in the development of a control rule. As will be discussed in Section 6, there are several decision-points for the Council in developing control rules to address these (sometimes competing) objectives thus consideration must be given to the prioritization of these objectives in order to develop a control rule (or range thereof) to meet the Council's objectives.

3 Data Sources for use in deriving an abundance index

Data on Pacific 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 Pacific halibut living in the Bering Sea. A list of available data for consideration includes:

- AFSC observer data
- AFSC EBS shelf bottom trawl survey (relative numbers or biomass)
- AFSC EBS slope bottom trawl survey (relative numbers or biomass)
- AFSC GOA bottom trawl survey (relative numbers of biomass)
- AFSC longline survey (relative numbers)
- IPHC coastwide setline survey (relative numbers)
- IPHC coastwide assessment results

The data sources listed here are all active for the period 1997-2015. In odd years, all four AFSC surveys are available while in even years the AFSC GOA bottom trawl and longline surveys are not conducted. Size composition data is also available for both the EBS trawl survey as well as the IPHC setline survey. Similar to the process for establishing groundfish harvest specifications based on the most recent groundfish survey and stock assessment data, the Council could use empirical observations (setline or trawl) and/or data from the coastwide halibut stock assessment from the current year or recent years as indices to set PSC limits for the following fishing season. The following sections discuss the available data and indices,

3.1 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 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.

3.2 AFSC EBS shelf bottom trawl surveys

The National Marine Fisheries Service eastern Bering Sea shelf trawl survey has been conducted annually since 1979. The survey time series is useful for tracking some year classes of Pacific halibut as they move through the population and approach commercial size. There is generally a low or negative correlation of abundance in the EBS shelf trawl survey with either (1) recruitment into the coastwide adult stock of halibut or (2) lagged estimated abundance at age 0 in the coastwide stock (Martell et al. 2015). 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.

As described below, the IPHC operates a coastwide setline survey as 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. In addition, 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 NMFS EBS shelf trawl 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. An IPHC field biologist has been deployed on the survey every year since 1998 to collect halibut samples. The halibut data collection (including ages) and treatment of information collected by the IPHC during the EBS shelf trawl survey is described in: (http://goo.gl/JT6nVn) and the most recent report is here: http://goo.gl/AnJLem)

The EBS shelf trawl survey has different size-selectivity than setline gear, making it necessary to apply a calibration to the EBS shelf trawl survey based on relative selectivity in the two surveys to include these data directly in the IPHC halibut stock assessment. Because of both gear differences, and the depth limits of the survey, halibut are vulnerable to the trawl from about 20 cm fork length (FL), but the directed fishery size limit for halibut is over 32 inches in length (O32 or > 81.3 cm FL). In 2006 and repeated in 2015, 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 trawl survey. The IPHC staff concluded that the trawl survey provided an adequate index of halibut biomass on the EBS shelf (Clark and Hare 2007, Webster 2016) and is a useful tool for constructing a density index for the IPHC stock assessment (Webster 2016). In addition to its use as a stock assessment tool, the EBS shelf trawl survey information is useful as an indicator of U26 Pacific halibut that are subject to bycatch in the other groundfish fisheries. To a lesser extent, 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.

The time series of 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 4). 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 5). Relative to the NMFS EBS bottom trawl survey, the fishery PSC (by trawl vessels) catches a similar size range but misses some of the smallest halibut observed in the survey (1991-2015;Figure 6).

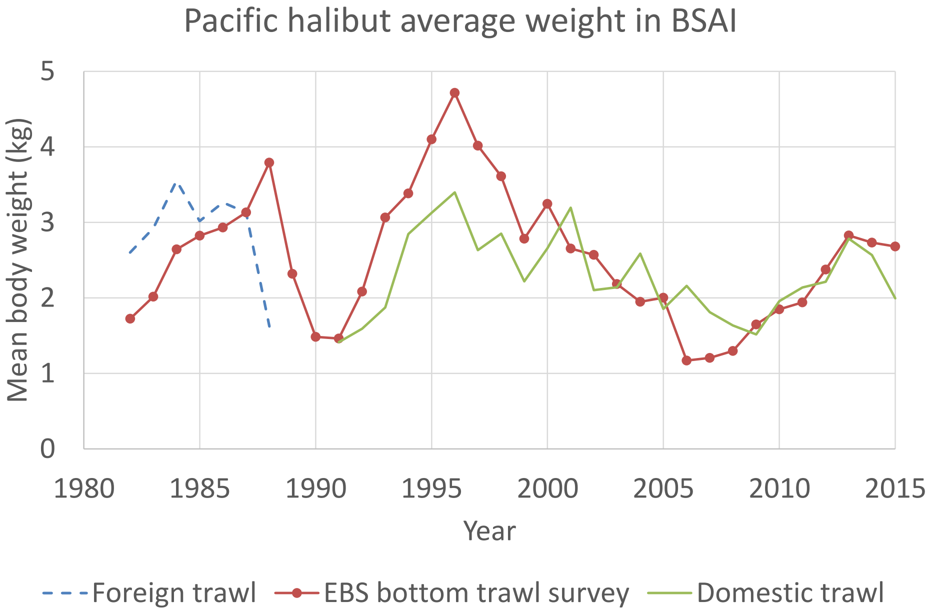


Figure 4 Estimated average weights in the fishery and bottom-trawl survey, 1982-2015. The correlation between the EBS bottom trawl survey and the Pacific halibut PSC domestic trawl fisheries is 0.78.

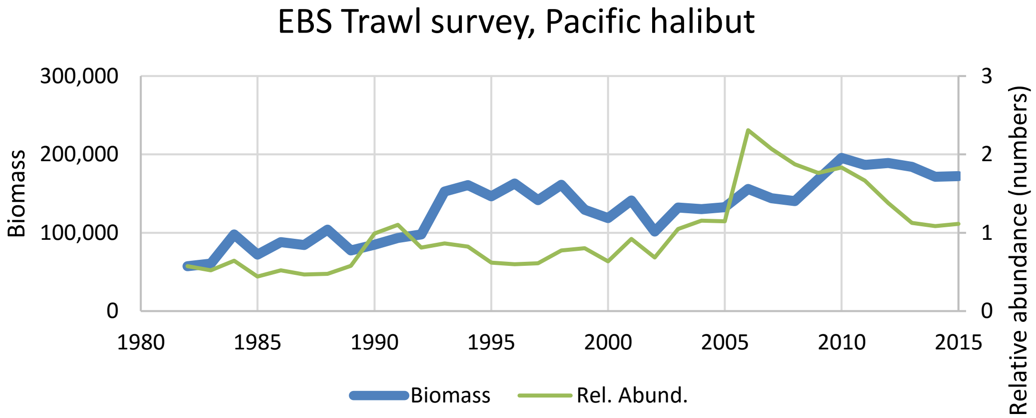


Figure 5 Biomass and relative abundance (in numbers) of Pacific halibut from the EBS bottom trawl survey, 1982-2015.

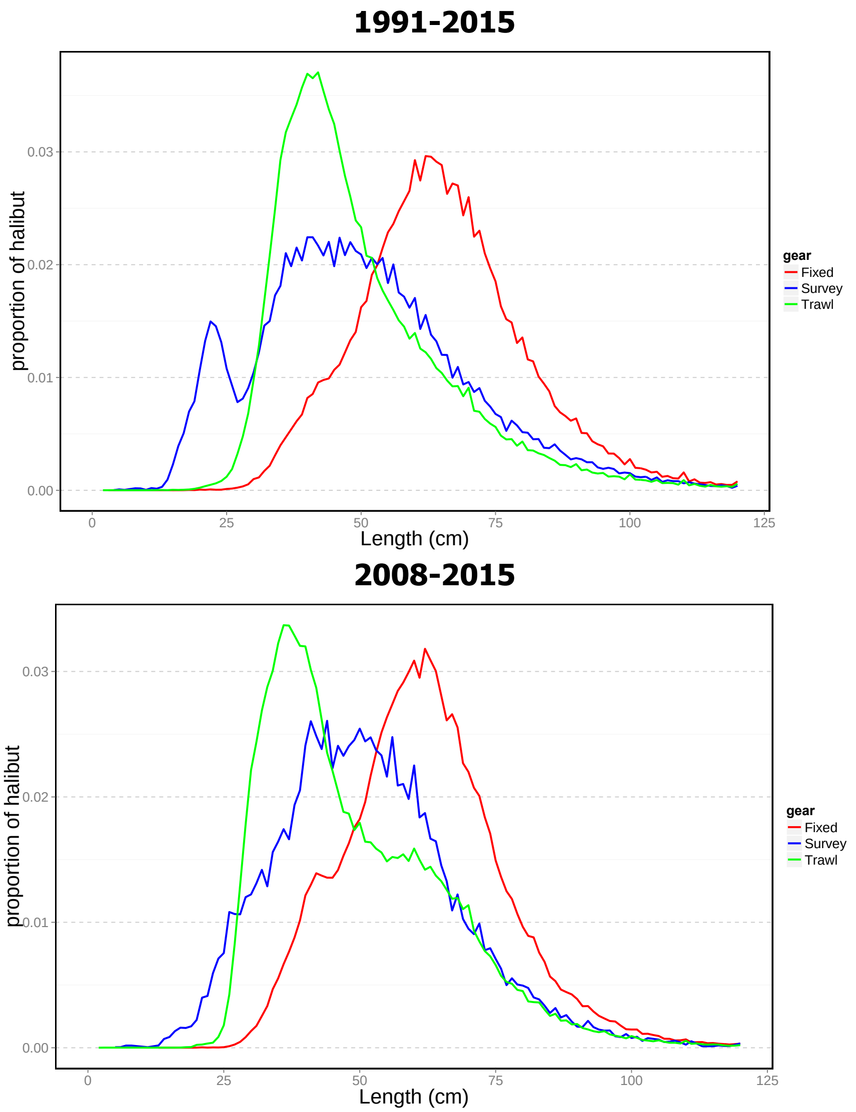
The EBS shelf trawl survey provides a good index of (mostly younger) Pacific halibut taken as bycatch in the BSAI region. However, a weakness of using this survey alone as an index of abundance is that it is limited to the EBS region and it appears to be an inconsistent index of future Pacific halibut that recruit to the directed fisheries. For example, from 2002 – 2010, the EBS bottom trawl survey biomass estimate showed an increasing trend for halibut, while the coastwide estimate of halibut abundance was declining. Therefore, an index using only the EBS bottom trawl survey would not reflect the status of the coastwide stock and likely is not appropriate as a stand-alone index on which to establish abundance-based halibut PSC limits in isolation. The data from the EBS shelf bottom trawl survey is available annually each fall for use in the annual BSAI groundfish harvest specifications process in which the halibut PSC limits are established

3.3 AFSC EBS slope bottom trawl surveys

This—typically biennial—survey covers the western region of the shelf and slope from 200 m to 1,200 meters and may provide an index of Pacific halibut for corroboration with other data. The survey years and index results are shown in Figure 7 and size compositions in Figure 8. The average weights in the survey (along with the other estimates are shown in Table 5.

3.4 AFSC GOA bottom trawl survey

The Gulf of Alaska bottom trawl survey has been conducted since 1984. 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. Similar to the EBS shelf bottom trawl survey, the GOA trawl survey gear provides a reasonable index of a younger segment of the Pacific halibut stock and can provide some insight on the relative recruitment strengths within this region (to supplement the annual information available from the EBS, which could potentially provide a reasonable index of a younger segment of the Pacific halibut stock in Alaska). This survey generally catches Pacific halibut smaller than 81 cm (32 inches—the legal size limit for the directed commercial fishery; Figure 9). There appears to be some variability in the numbers of Pacific halibut that occur in the survey from year to year (Figure 10) and this may reflect changes in the apparent recruitment within the GOA.


1991-2015

2008-2015

Figure 6 Trawl and longline fishery aggregate length frequencies for BSAI Pacific halibut compared to the bottom trawl survey length frequencies, 1991-2015 (top) and 2008-2015 (bottom). The legend label “fixed” refers to the longline fishery gear, “survey” refers to the EBS shelf bottom trawl survey, and “trawl” refers to the BSAI groundfish bottom trawl fishery.

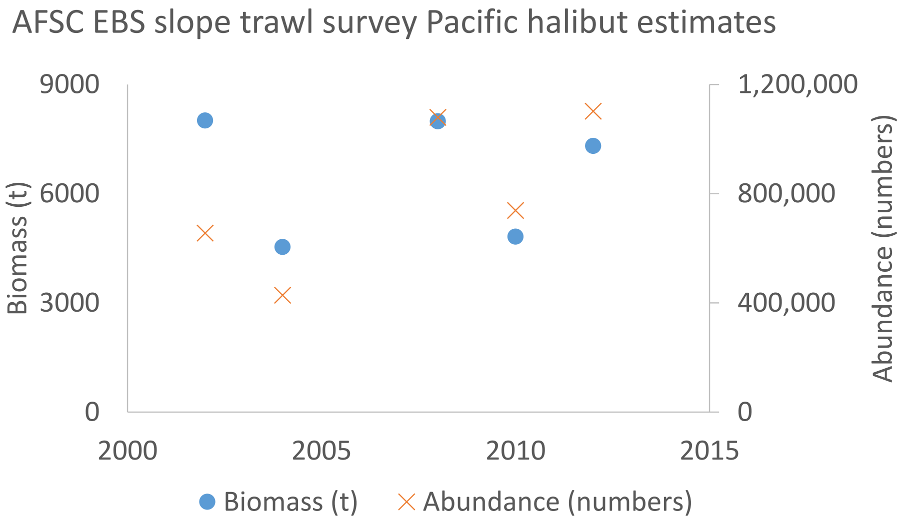


Figure 7 AFSC eastern Bering Sea slope bottom trawl survey biomass and abundance estimates, 2002-2012 (the next survey is planned for 2016).

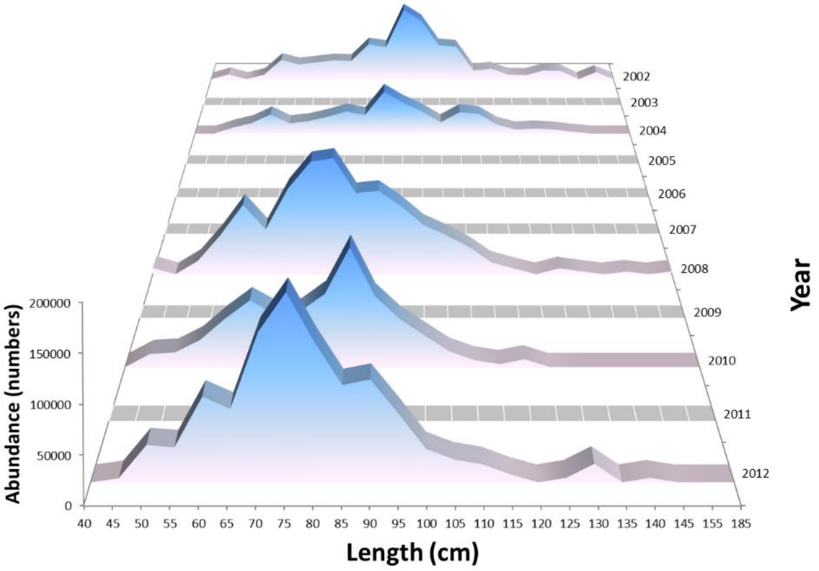


Figure 8 AFSC eastern Bering Sea slope bottom trawl survey population-at-length estimates, 2002-2012 (the next survey is planned for 2016).

Table 5 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

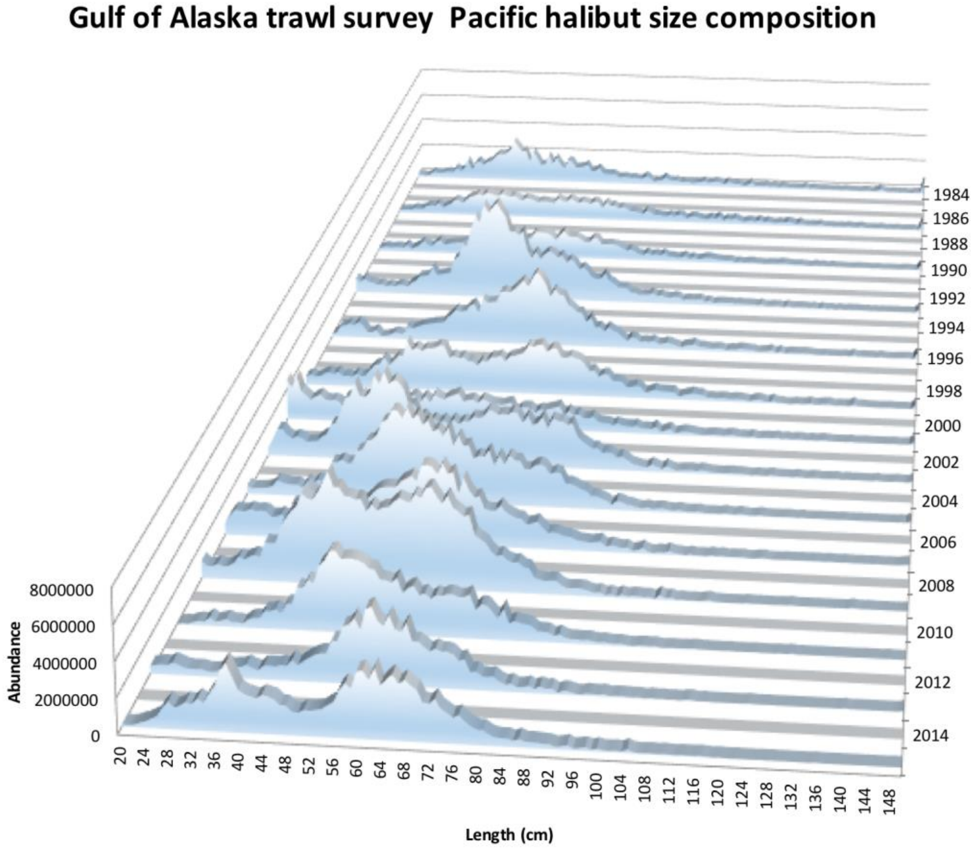


Figure 9 Gulf of Alaska abundance at size (length in cm) based on NMFS summer trawl surveys; 1984-2015. Note that the survey in 2001 only covered part of the GOA.

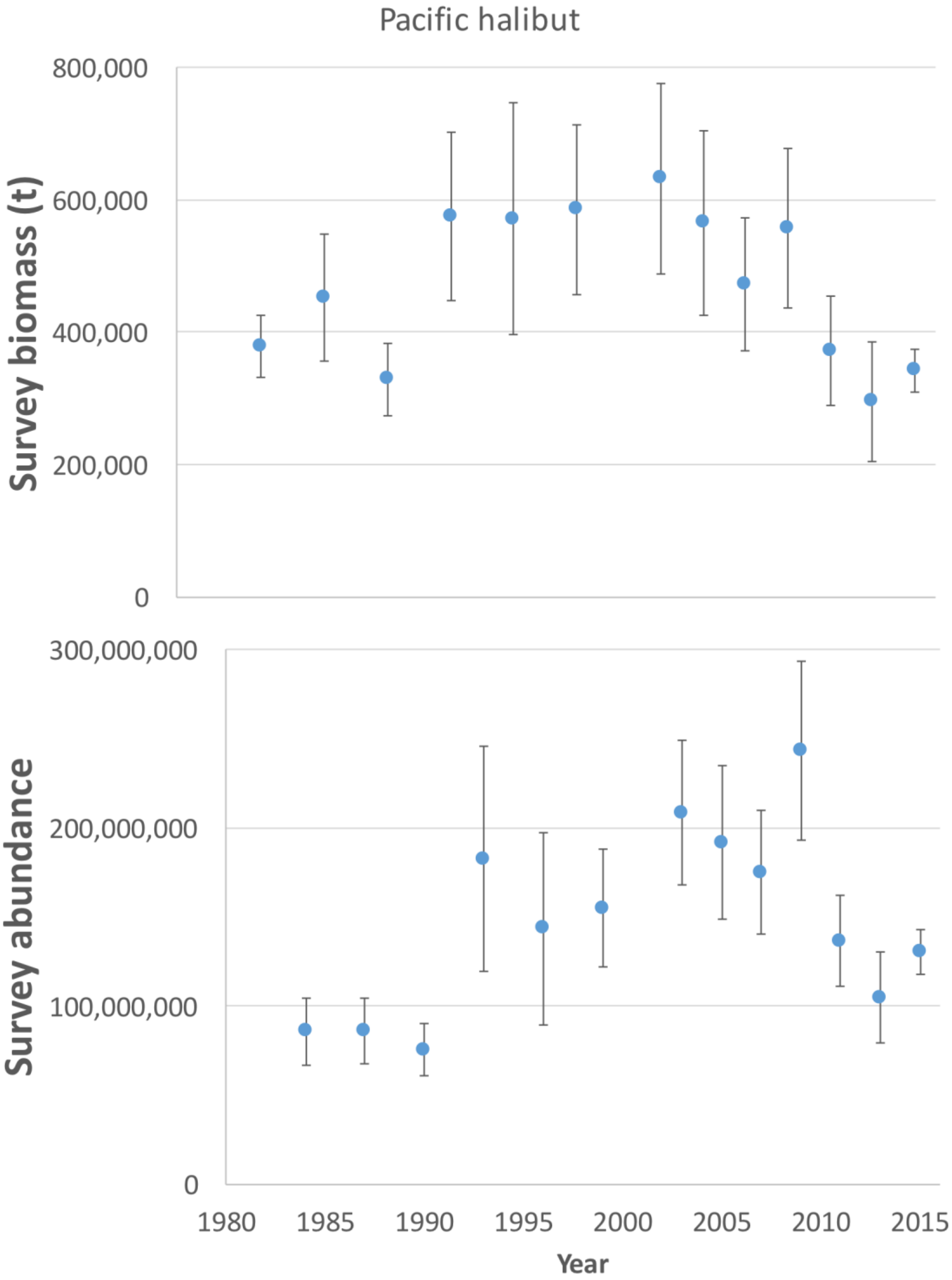


Figure 10 Gulf of Alaska summer survey biomass estimates (top) and abundance estimates (bottom) from trawl data

3.5 AFSC Longline Survey

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. 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. At each station, halibut catch and effort were collected. These data are used to derive annual estimates of relative population numbers (RPN, an abundance index) for species captured during the survey. The RPN indices are computed across six depth strata (150-200 m, 200-300 m, 300-400 m, 400-600 m, 600-800 m, and 800-1000 m). Specifically, 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.

3.6 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 a major data input to the annual Pacific halibut stock assessment. The IPHC completes the survey in late summer and the results are typically available in early November, which is used in the assessment and presented at the interim meeting in November and the annual meeting in January.

IPHC’s setline survey covers most of the range of Pacific halibut and extends from northern California, around the Gulf of Alaska, into the Bering Sea and across the Aleutian Islands at sampling depths from 20-275 fathoms in most areas (Henry et al 2016). Prior to 1997, the survey had less coverage, but data are available for many Regulatory Areas (Stewart & Monnahan 2016). The stations sampled are on a 10 nmi by 10 nmi square grid and certain areas were expanded 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 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, and recording observations of seabirds. The fishing gear used in the setline survey data generally catches halibut that are O26 and available for harvest in the directed commercial fishery.

The 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). Historically, the survey analysis has been a design-based approach with assumptions made to fill in gaps and expand into unsampled areas. Currently, work is being done to investigate geospatial models to analyze these data, and it is expected that improved analysis methods will be used in the near future. For this report, only the design-based methods were available. Figure 11 shows the IPHC setline estimates of Weight-Per-Unit-Effort (WPUE) of O32 Pacific halibut.

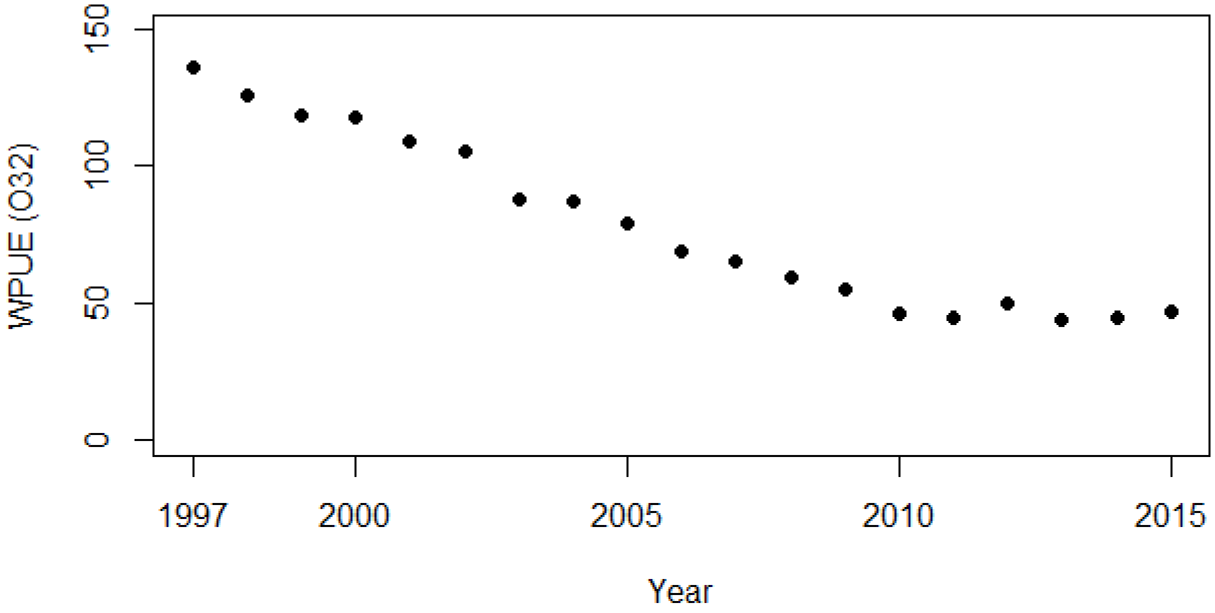


Figure 11. IPHC setline survey coastwide WPUE for Pacific halibut greater than 32 inches.

3.7 Summary of available data from which to derive an index

Table 6 provides a summary of the data sources available for use in compiling and evaluating abundance information on Pacific halibut in the BSAI for use in indexing potential PSC limits, as well as frequency and characteristics of these data sources.

Table 6 Summary of different data available for evaluating abundance based Pacific halibut PSC limits.

Data sources	Frequency	Characteristics
AFSC EBS shelf bottom trawl survey (EBS BTS)	Annual	Size composition matches observed bycatch Mostly smaller Pacific halibut
AFSC GOA bottom trawl survey	Biennial	May index smaller (recruiting) halibut in the GOA
AFSC EBS slope bottom trawl survey	Biennial	Expands adjacent shelf survey coverage
AI bottom trawl survey	Biennial	Limited halibut occurrence
IPHC setline survey	Annual	Size composition similar to directed fishery Limited area in shallower EBS area Mostly larger Pacific halibut
BS AFSC longline survey	Biennial	Size composition similar to directed fishery Indexes larger Pacific halibut Lengths unavailable
AI AFSC longline survey	Biennial	Size composition similar to directed fishery Indexes larger Pacific halibut Lengths unavailable
Observer data	Annual	Comprehensive, especially post-2008 May help form control rule Size composition data needs correcting to be proportional to bycatch
Commercial groundfish catch	Annual	Bycatch rates could inform policy decisions Bycatch per unit effort likely a poor measure of abundance (confounded with changes in behavior)

4 Integrated abundance indices

Several different integrated approaches were considered by the workgroup. These included the IPHC assessment, a geostatistical approach to combine survey indices, combining the EBS shelf trawl survey data with the coastwide assessment results (as recommended by the Council), consideration of BSAI only survey combinations and finally the recommended integrated survey-based approach using EBS shelf and GOA trawl survey data as well as the IPHC setline data. The latter approach is recommended for use by the workgroup for the reasons detailed in Section 5. However for completeness the other three approaches considered are first described briefly below.

The Workgroup compiled a list of objectives to consider in evaluating to what extent an abundance index addresses them (Table 7).

Table 7 Objectives to consider in evaluating an appropriate abundance-based halibut index

Objective for candidate abundance-based index:

1. Addresses older and younger population components
2. Considers the coastwide geographic range
3. Considers the coastwide stock status
4. Addresses recruitment differences in the BSAI and GOA
5. Information to derive the index is available in a timely manner for Council harvest specifications
6. Information to derive the index is easily accessible

Further information to define each objective are listed below:

1. **Addresses both components of population (older and younger fish)**: The three components that we want to address in an index are the coastwide abundance of adult halibut (i.e., stock status), the relative abundance of younger fish in the Bering sea, and the success of younger fish recruiting outside of the Bering Sea. The index should ideally be reflective of changes in these three components.

2. **Consideration of coastwide geographic range:** Halibut are believed to migrate out of the Bering Sea and populate all of the regulatory areas including Canada and the west coast of the US. The downstream impacts of mortality in the Bering Sea on other areas needs to be considered.

3. **Consideration of coastwide stock status:** The Council is concerned with protecting the halibut spawning stock biomass, particularly at low levels of abundance. Therefore, consideration of the status of the coastwide stock in important to include in any index.

4. **Addresses potential for recruitment differences in BSAI and GOA:** The trawl surveys in both the EBS shelf and GOA encounter much smaller halibut than the IPHC coastwide set line survey. Therefore, these surveys represent better indications of recruitment to the coastwide stock, however it is important to note that the trends in the relative proportion of these fish between the areas is variable. Thus consideration of both surveys is desirable to indicate the relative trends in both regions as it relates to downstream impacts from removals in the Bering Sea.

5. **Timeliness of information:** To meet the timeframe of the BSAI groundfish harvest specifications process information from which to derive an index annually to establish PSC limits must be available prior to the December Council meeting each year.

6. **Accessibility:** Information from which to derive an index is assessed for its ease of accessibility. Indices that are already provided annually for other uses and/or which can be easily updated or calculated are considered to meet this criterion.

Each index considered is described below as well as where it was deficient in addressing some of these objectives. A summary table of all the indices considered as well as the recommended approach is included in the subsequent section.

4.1 IPHC Assessment

The IPHC assessment uses many sources of data to predict historical biomass and project forward three years from an ensemble of four model alternatives. The IPHC is the only coastwide estimate of the halibut stock available and is the primary source of information for identifying the trend in halibut stock size. The IPHC's setline survey and fishery data provide proportion-at-age and size-at-age observations. The EBS bottom trawl survey is also included in the assessment as a data source.

The assessment models estimate some biological parameters, such as natural mortality, selectivity parameters and time-varying quantities, and recruitment of age-0 fish. The primary weakness of using the IPHC assessment alone as an index of halibut abundance is that it does not provide an index for the portion of the halibut population that is taken as bycatch in the Bering Sea. The setline survey selects older and larger fish (generally O26), therefore there are no accurate data for young halibut from the survey. The assessment estimates of the size of a cohort (recruitment) are not well informed by survey data until the cohort is many years old. Although the assessment does include EBS shelf bottom trawl survey data, the data is not fit well by any of the assessment models (possibly because proportion of recruitment in the Bering Sea is variable). Therefore, estimates of recent recruitment in the assessment are typically near the mean of the stock-recruit curve. However, an environmental relationship with the Pacific Decadal Oscillation (PDO) is used to adjust the mean recruitment higher in periods with a predominately positive PDO.

The ensemble approach recognizes that there is no perfect assessment model and an important part of the uncertainty comes from structural assumptions of a model. The four models in the ensemble are a crossing of aggregated coastwide and areas-as-fleets assumptions with short and long time-series of data. The areas-as-fleets approach uses a coastwide model but fits to spatially explicit data sets. The four models are each fit by the Stock Synthesis software (Methot & Wetzel 2013) and are combined externally to provide uncertainty estimates and measures of risk for different catch projections. The median spawning biomass in millions of pounds is shown in Figure 12.

The assessment is presented at the IPHC's November interim meeting and the January annual meeting to provide advice to Commissioners when deciding on catch limits for the upcoming Pacific halibut fishing season. It is peer reviewed in September by the IPHC's Scientific Review Board before being used for management.

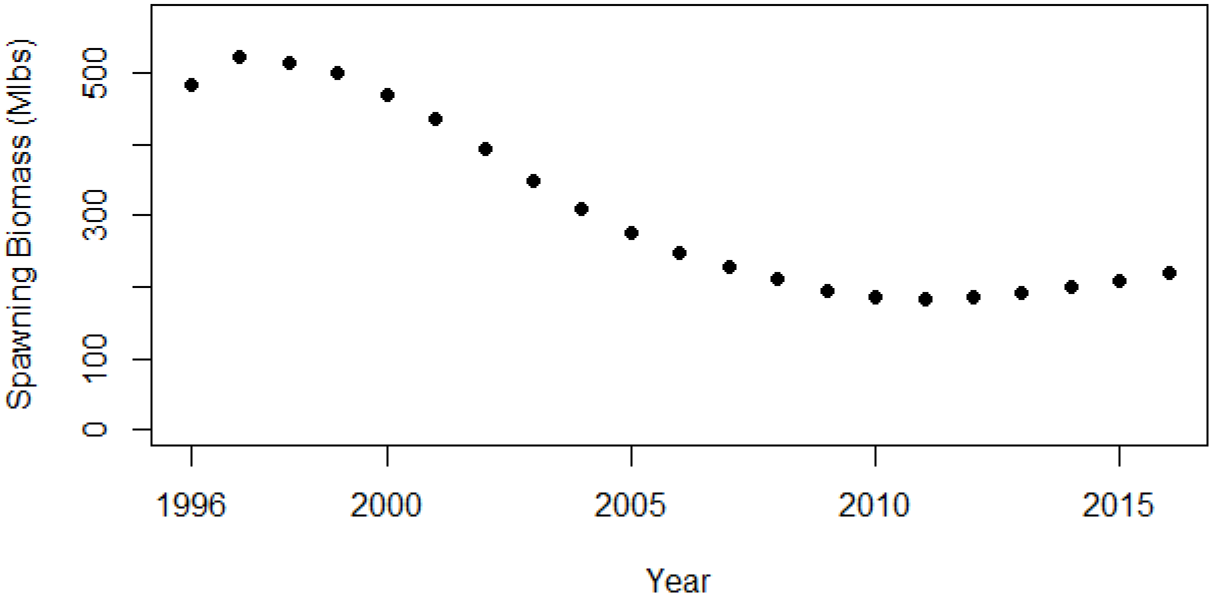


Figure 12 Median predicted beginning of the year spawning biomass (millions of pounds) from 1996 to 2016 from the IPHC assessment using an ensemble of four models.

4.2 Geostatistical approach

One integrated approach to creating an index of halibut abundance is to combine bottom trawl survey data from three Alaska regions i.e. EBS shelf, GOA and AI. Bottom trawl survey data can provide valuable information about young halibut distribution and relative abundance as it catches smaller fish than other gears such as longline. A geostatistical model by putative age categories (based on length groups) was developed to account for spatio-temporal correlation structure (which a design-based estimate can fail to account for) and the effects of environment covariates such as bottom depth, and sea surface temperature (see detail in Ono et al., *in review*). The approach showed reasonable consistency in the halibut abundance index by age groups (Table 8) and identified few periods of higher halibut recruitment with changes in halibut proportion by regions (Figure 13).

However, the geostatistical approach is not recommended to be used to index the PSC limit. The ideal index should account for the status of young halibut population in the EBS, recruitment proportion within AK regions, the status of the coastwide spawning stock biomass, and need to be accessible and reproducible in a timely manner and the geostatistical model fails to meet some of these recommended criteria (Table 7).

Table 8 Correlation matrix of annually lagged abundance indices by putative age groups from three (one for each age group) independently run Delta-GLM geostatistical models.

	Age 2 (0-21 cm)	Age 3 (22-31 cm)	Age 4 (32-38 cm)
Age 2 (0-21 cm)	1.000	0.859	0.745
Age 3 (22-31 cm) (lag1)	0.859	1.000	0.674
Age 4 (32-38 cm) (lag 2)	0.745	0.674	1.000

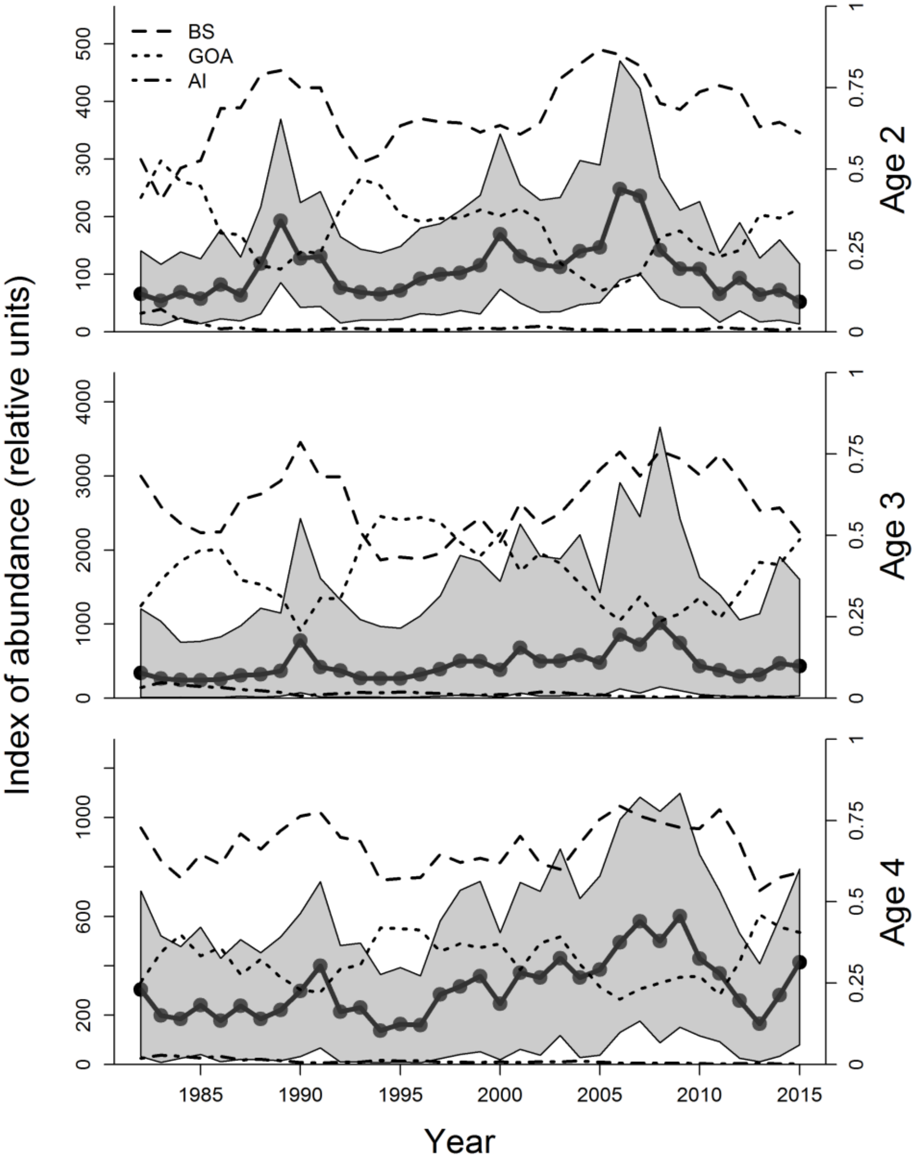


Figure 13 Young halibut abundance index by putative age class (the solid black line is the mean and the grey shaded area is the 95% credible interval) and the associated proportion by region (the dash line is for BS, the dotted line for GOA and dash-dotted line for AI)

4.3 EBS shelf trawl survey integrated with Coastwide assessment results

The concept of integrating the EBS trawl survey with the IPHC coastwide assessment results was considered initially by the workgroup. One strength of integrating the EBS shelf trawl survey with the coastwide assessment would be that it would include different stock components. However, it fails to provide an index of small halibut abundance in Alaska because it does not accommodate the relative amount of small halibut in the GOA. Based on a suggestion from the SSC, the workgroup determined that an index of small halibut for the Alaska region would best represent the years of high and low abundance of small halibut coastwide. Reliance only on the EBS shelf trawl survey could provide for a high relative weighting on the Bering Sea results in years when the coastwide spawning stock biomass continues to decline.

The workgroup also determined that the coastwide assessment would not be appropriate for the ideal index. While the coastwide assessment would provide information on the coastwide range and status of the halibut stock for use in a combined index, the assessment results are based on a model that uses many sources of data to predict historical biomass. The results may change over time based on the choice of models, assumptions used in the model, or available data. The workgroup determined that the ideal index would use direct data sources (i.e., surveys) rather than model results. The workgroup also noted that while conceptually the integration of these two indices would represent an improvement over the use of only one or the other, the EBS shelf trawl survey integrated with the coastwide assessment results would not address recruitment differences in the BSAI and the GOA, which is an important criterion specified in Table 7.

Based on these determinations, the workgroup did not evaluate methods for weighting the EBS shelf trawl survey and the coastwide assessment to develop a potential index for abundance-based halibut PSC limits.

4.4 EBS (only) surveys: AFSC shelf and slope trawl + AFSC longline survey, IPHC setline survey

Consideration was given to developing an EBS only index of the population building upon the EBS trawl survey data by incorporating other available Bering Sea specific surveys to address additional components of the population. The EBS shelf bottom trawl survey was considered to be the most useful for the areas of primary bycatch because of its broad annual coverage and similar size composition to the bycatch in the fishery. The IPHC and AFSC longline surveys cover less area. Both surveys use large hooks (16/0 and 13/0, respectively) so are limited in their ability to capture very small halibut (and may differ from Pacific cod directed fishing). The AFSC longline survey is biennial and only covers the older fish in the population because it surveys the deep slope from 150-1000 meters. The IPHC longline survey has limited geographic coverage compared to the bottom trawl survey. The Bering Sea Slope trawl survey was also discussed, but not evaluated in detail as a candidate for including due to it’s intermittent timing and spatial coverage.

A preliminary analysis showed a method of linking the three Bering Sea surveys described above and weighting them inversely by their coefficients of variation into an integrated index (Figure 14). An index like this might then be linked to some minimum amount of PSC bycatch. The method was considered, but generally thought to be heavily linked to the adult population by including the two longline surveys and does not address any recruitment to the coastwide stock from areas outside of the Bering Sea.

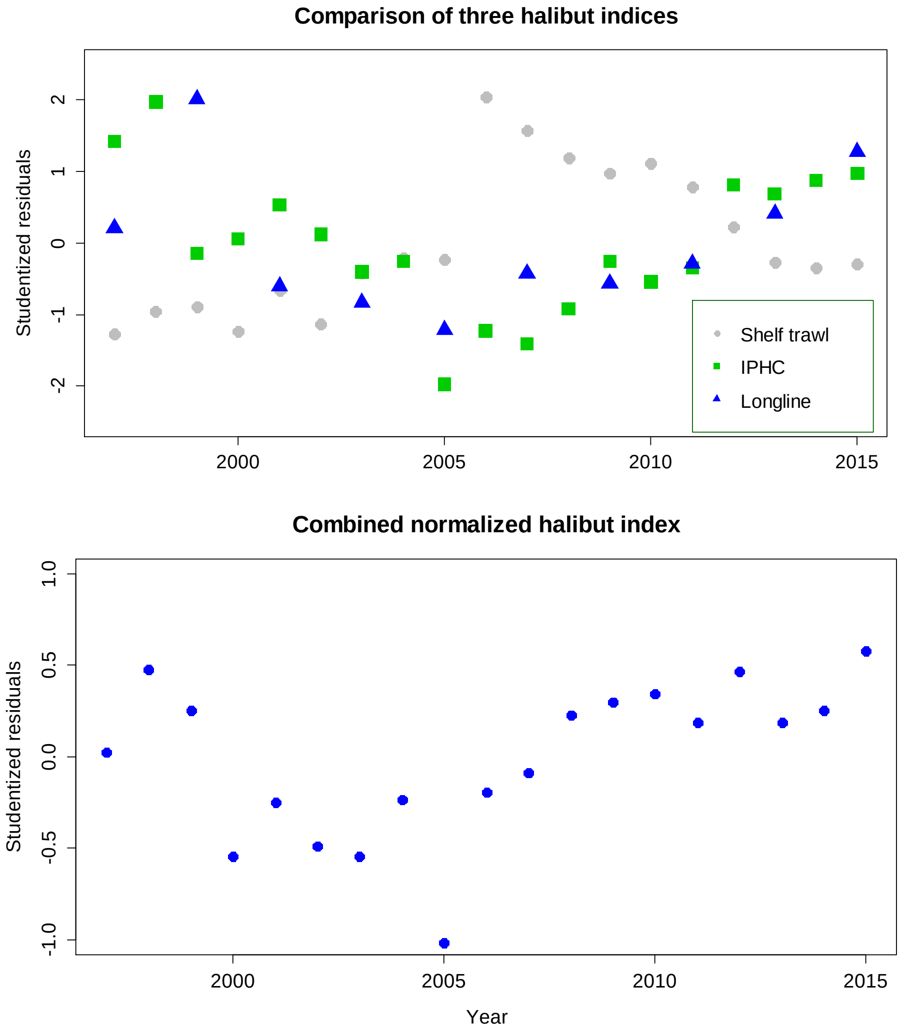


Figure 14 Comparison of some alternative survey trend indices (top) and their normalized combined (inverse-variance) weighted values (bottom); 1997-2015.

5 Recommended Integrated survey abundance based index

Having evaluated the single and combined indices described previously, the workgroup worked to develop an integrated index that would better address some of the limitations of the other considered indices and meet the suggested criteria for the objectives of the index (Table 7). Specifically, the abundance-based working group sees three primary biological concepts that the index should address:

1) The abundance of halibut in the BSAI, including younger halibut that will later potentially recruit to the coastwide spawning stock,
2) The coastwide status of the spawning halibut stock, and
3) Potential incoming recruitment to the coastwide halibut stock from all areas (mainly the GOA).

A description of these concepts and selected combination of sources of data that may address each are given below.

5.1 Abundance of Pacific halibut in BSAI

Many fisheries in the Bering Sea encounter halibut and are subject to PSC limits. These limits have the potential to be constraining, especially when the abundance of halibut in the BSAI area is high. Conversely, when the abundance of halibut in the BSAI area is low, the available total constant exploitation yield (TCEY) may be low and constraining to the directed halibut fishery. Finally, young halibut are believed to migrate from the BSAI area into the Gulf of Alaska and into other regulatory areas, thus the Bering Sea is considered a nursery area where recruitment and mortality can have large effects on the coastwide spawning stock of Pacific halibut.

The NMFS EBS shelf trawl survey occurs annually and captures smaller (i.e., younger) halibut than the IPHC standardized stock assessment survey. This survey also uses similar gear (trawl) as the fisheries that catch the majority of the BSAI halibut PSC (e.g., Amendment 80 fleet and BSAI TLA). It is believed that this index is a measure of halibut abundance in the BSAI that includes both young and old halibut that would be encountered by both directed and bycatch fisheries in that area. Furthermore, the EBS trawl survey enumerates immature and undersized halibut that are important contributors to the future spawning biomass.

The workgroup's recommended integrated index includes the EBS shelf trawl survey results as numbers of fish to reflect the potential for future recruitment to the coastwide spawning stock and the overall abundance of halibut in the BSAI area. This index does not separate between young and old fish, thus a high value could mean that there are a lot of young halibut recruiting to the population, there are a lot of old fish in the area, or both. Mainly, it represents the number of halibut in the area that may be encountered by the various fisheries.

5.2 Coastwide status of the spawning halibut stock

The overall health of the Pacific halibut stock is evaluated by estimating the coastwide spawning stock biomass. The spawning stock biomass is an indication of the size of the resource and the potential for sustainable yield. However, coastwide spawning stock biomass does not indicate the distribution of the stock across Regulatory Areas. We considered two ways to consider the coastwide status of the adult halibut stock. One way is a data only approach, the second is to use results of the stock assessment model.

A major source of information in the stock assessment is the coastwide SSA setline survey conducted annually by the IPHC. A weight-per-unit-effort index for halibut 32 inches and greater (O32) is available in late November or early December. This index is desirable because it is data-based (although a geospatial model may be used to standardize the index), and indexes larger older halibut which is an indirect indicator of the reproductive potential of the spawning females.

The spawning stock biomass is estimated annually using a stock assessment, which is currently an ensemble of four models that integrate many sources of information. A major source of information is the IPHC standardized stock assessment survey, which covers the Pacific Ocean from Northern California, through British Columbia, the Gulf of Alaska, and the Bering Sea, and across the Aleutian Islands. The analysis integrates information from other surveys to fill in missing areas (e.g., the eastern Bering Sea shelf trawl survey) and the result indexes halibut 32 inches and greater. Not all halibut over 32 inches are actively spawning, thus the assessment models translate the index and other information into an estimated spawning biomass. This is a more direct estimate of stock status, but suffers from some drawbacks. The estimated spawning biomass of the halibut stock is available in late November, very close to the Council harvest specification process. This late availability of the assessment estimates could potentially result in some lag time, and in addition to that the model structure could change from one year to the next resulting in variability greater than in the data, and more reflective of the structural decisions in the assessment model. Use of setline survey data for the index avoids these potential future changes in how "ensemble" models are used in the assessment. This will likely result in more consistency in the index and will be closer to being actual "data" similar to NMFS trawl surveys.

5.3 Potential incoming recruitment to the halibut stock

The majority of recruitment of Pacific halibut is believed to occur in the Bering Sea and the Gulf of Alaska, however the annual proportion of recruits in each area is not constant. Recruits in the Bering Sea are believed to migrate out of the Bering Sea into the Gulf of Alaska and even further into other IPHC Regulatory Areas as they age. Therefore, recruitment in the Bering Sea is an important contributor to the overall health and sustainability of the Pacific halibut stock. Additionally, large recruitment events in the Bering Sea may result in higher encounter rates with bycatch fisheries, which may be constraining. Therefore, it is important to make sure that enough recruits survive to become part of the spawning biomass while also accounting for the potential constraints due to a large number of recruits in the Bering Sea.

The EBS shelf bottom trawl survey provides an index which contains young fish, and thus provides information on the potential recruitment in that area. However, there is the possibility that a high number from the Bering Sea trawl survey could be a result of a high number of larger fish that may remain in that area rather than high numbers of young fish. The workgroup's recommended integrated index uses numbers of fish rather than biomass to reduce the inflation of the index from large fish and be a better index of fish that will eventually contribute to spawning biomass.

As mentioned above, the recruitment in the Gulf of Alaska is also an important source of recruitment to the coastwide halibut stock. The GOA trawl survey results in an index that can be an indicator of the potential incoming recruits that will eventually contribute to the halibut spawning biomass. One disadvantage of the GOA survey, compared to the EBS shelf bottom trawl survey, is that the GOA survey is conducted every other year. However, the combination of the EBS shelf bottom trawl survey and the GOA trawl survey may provide a measure of the recruitment of Pacific halibut in those areas.

5.4 The recommended integrated abundance-based management (ABM) index

The three concepts above can be addressed with data from the EBS shelf bottom trawl survey, the GOA bottom trawl survey, and the IPHC standardized stock assessment survey, with the goal to combine them into a single integrated abundance-based management (ABM) index that can be used to guide the PSC limit. We approached this as a combination of the three concepts, rather than a weighting of the three indices, and we did not attempt to determine the priority of each concept. We standardized each index to eliminate the differences in units and scale, and to ease the interpretation of the integrated index. Each of the three indices is standardized to their respective mean so that an individual index does not overwhelm the integrated index. The years 1997-2015 are used so that a value of one represents the average of the index over this period, which may help determine a starting value for the relationship between the integrated index and a PSC limit. Therefore, the integrated index is simply the mean of the three standardized indices:

$$\begin{aligned} x_y &= \frac{S_y}{\bar{S}} + \frac{B_y}{\bar{B}} + \frac{G_y}{\bar{G}} \\ I_y &= {}^{x_y}\!/_{3} \end{aligned}$$

where S_y is the weight-per-unit-effort measure from the IPHC SSA survey, B_y is the numbers estimated from the EBS shelf bottom trawl survey, and G_y is the numbers estimated from the GOA bottom trawl survey for year y. The mean of each index (e.g., $\bar{S}$) is the mean over the years 1997-2015 (all available data) or can be defined differently if desired. The integrated index (I_y) is the annual mean of these three indices. In the years with no GOA survey, the previous year's value was used. The individual standardized indices are shown in Figure 15, and the resulting integrated index along with the individual indices are shown in Figure 16.

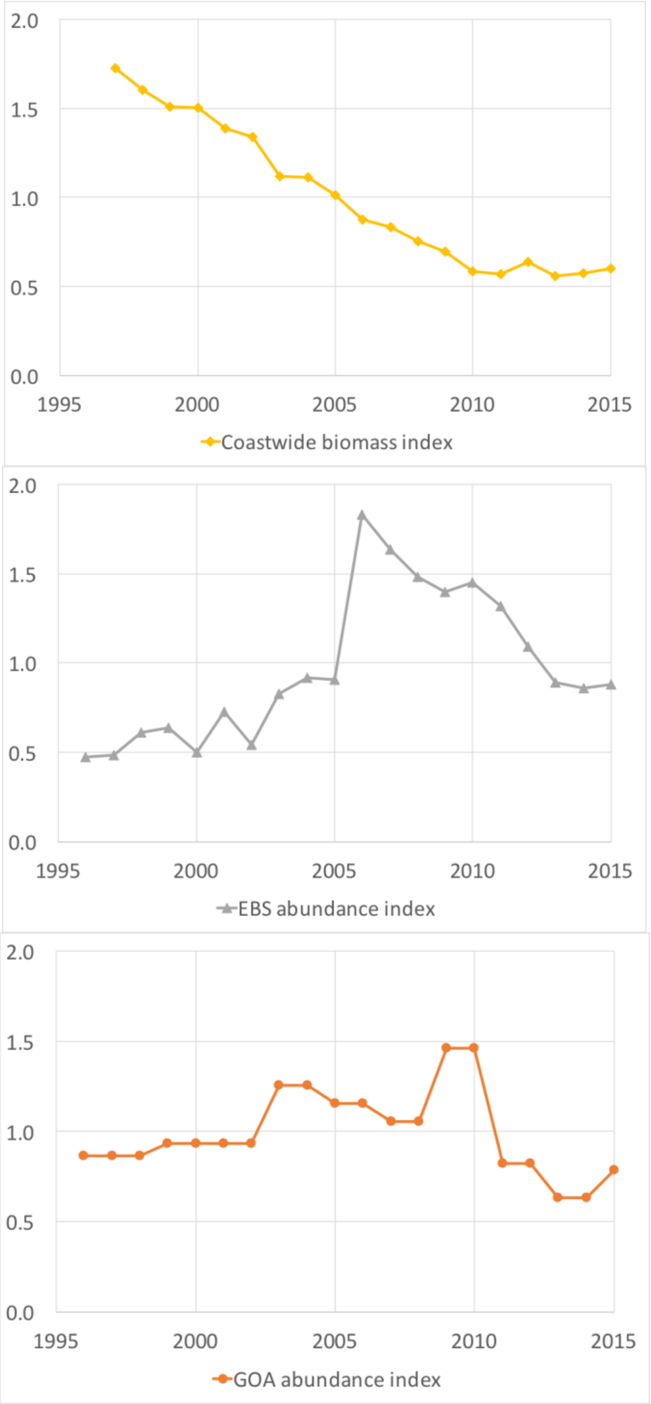


Figure 15. Three data sources that are being integrated to comprise the proposed Abundance-based model (ABM) for indexing to PSC (1997-2015). Top panel: Coastwide biomass index from the IPHC setline survey; middle panel NMFS EBS trawl survey estimate of halibut; bottom panel NMFS GOA trawl survey estimate of halibut. Data are standardized to their respective means

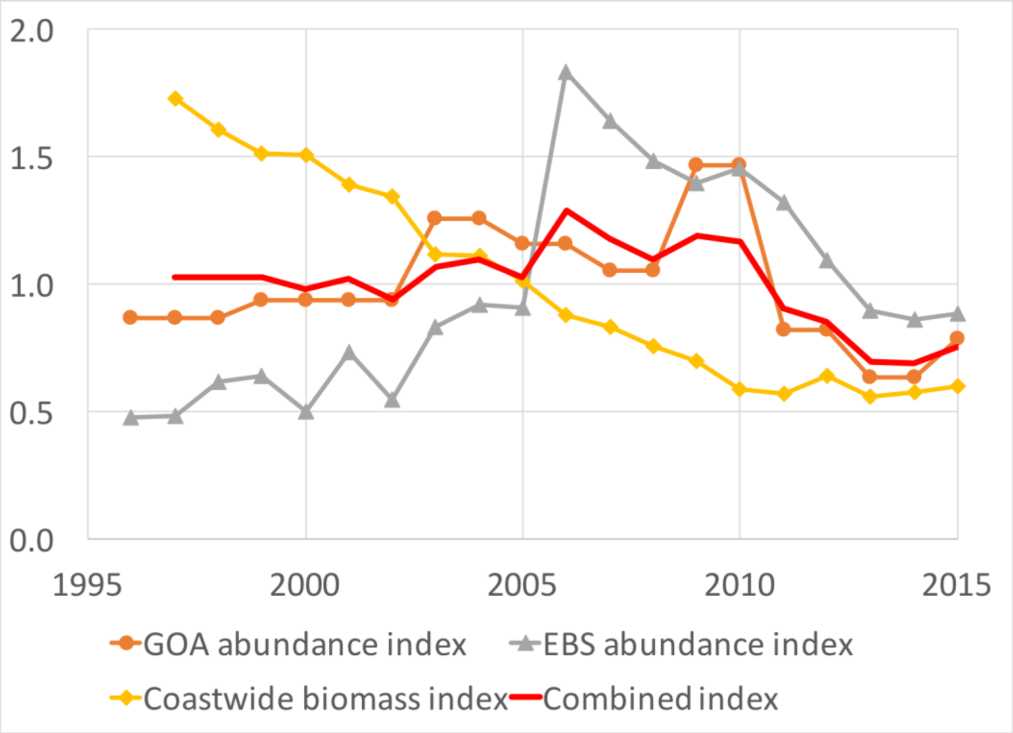


Figure 16. Combined index (red) overlaid on data sources.

The integrated ABM index will be at its highest values when all three indices are at high values, and vice versa, the integrated index will be at its lowest values when the three indices are all low. This is a desirable property because each individual index represents the abundance of a particular segment of the halibut population. A change in any single index, while others stay the same, will result in a reduced change in the same direction of the integrated index due to the combination of the three. This will dampen the variability of a single index. Figure 16 shows the historical integrated index along with each of the three survey indices over time. Figure 17 provides illustrative examples of how the integrated index may change with changes to each individual survey index to indicate how the variability of conflicting trends is dampened.

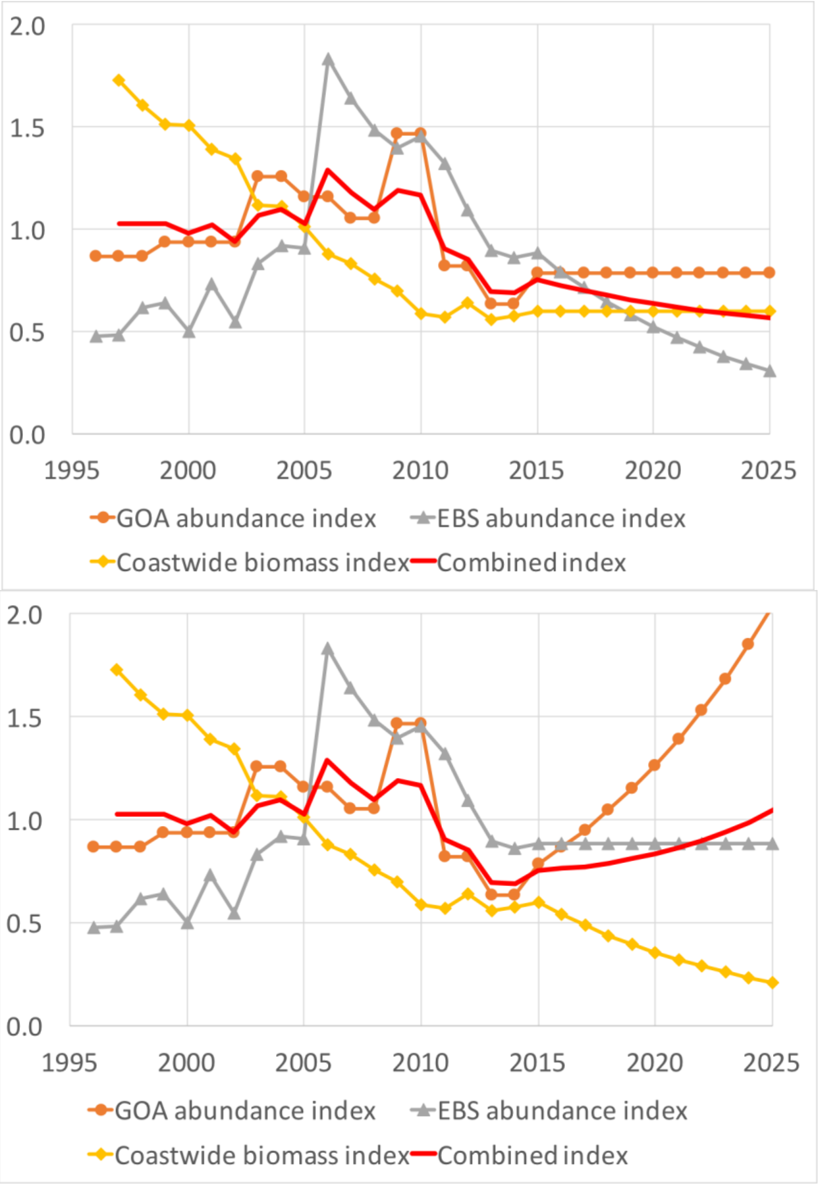


Figure 17 Illustrative example of how changes in the relative value of each survey index influences the resulting integrated index. The upper panel illustrates when the EBS trawl survey index is declining while GOA and coastwide indices are flat. Bottom panel illustrates when the GOA index is increasing while coastwide is declining.

A value of one for the integrated index indicates that the abundance being tracked by the index is equal to the average over the time period considered (i.e., 1997-2015). This doesn't necessarily mean that each of the three indices are equal to their respective average, but that the average of the three individual indices is equal to the average over the time period. A value below one indicates that one or more components of the halibut population is below average, and considering all three components, the population is below the average of the integrated components (see Figure 17). Conversely, a value greater than one indicates that the population as a whole is greater than its average over the time period. In other words a value of one is representative of the average over the time period, thus is a reference point that can be defined by choosing the years included in the average. There is a not a scientific argument to for which years comprise the period of interest, but data availability and consistency may guide this decision.

Figure 18 shows outcomes of the integrated index given different values of the three individual standardized indices. There are cases where one individual index may be high, but low values of the other two result in an integrated index that is near average (a value of 1). For example, a high coastwide setline survey index with low GOA and EBS trawl indices is shown in the upper left part of the bottom panel of Figure 18.

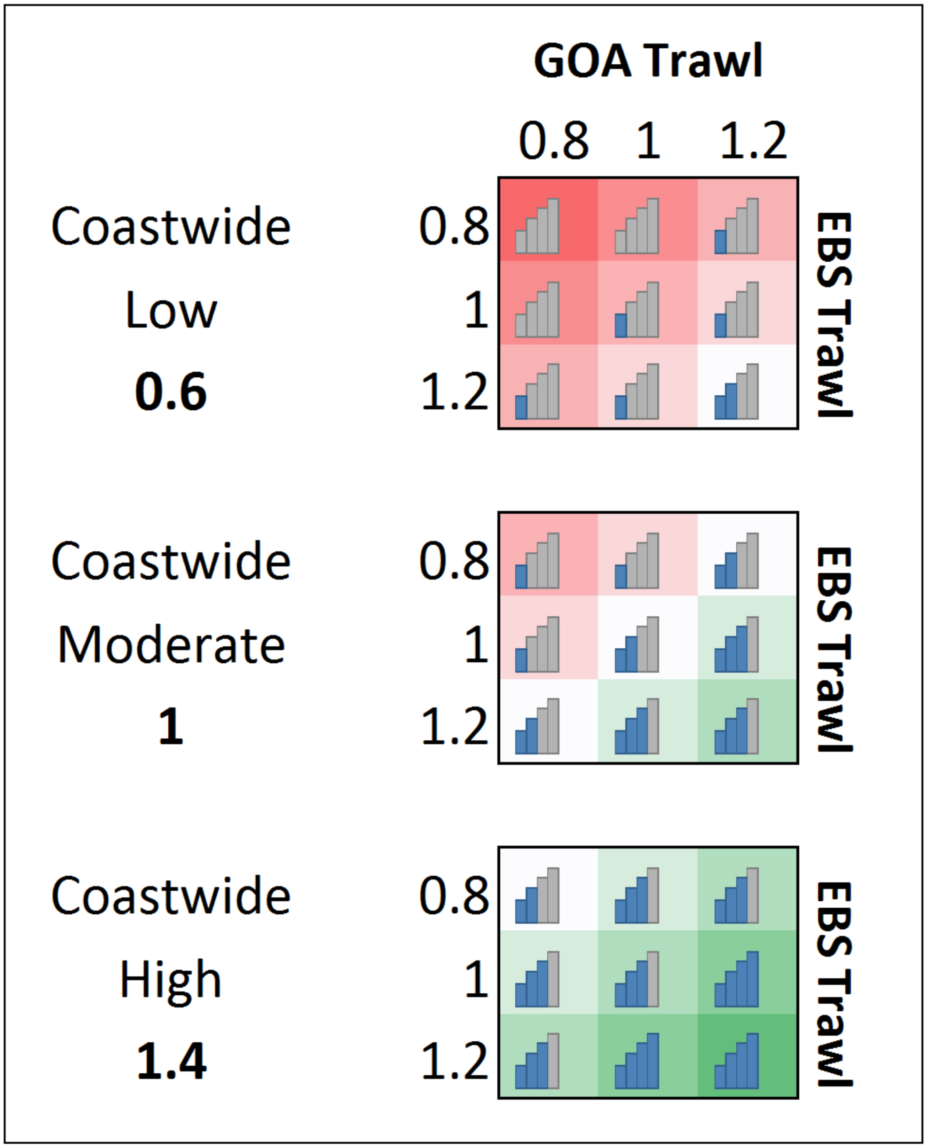


Figure 18 Scenarios for 3 states of the coastwide setline survey that approximate the range of that index. Each box estimates the relative magnitude of the index across a range of values of the trawl survey indices when applied as an integrated index. Red squares with few blue bars are lower values of the integrated index, while green squares with blue bars are higher values of the integrated index.

5.5 Comparison of candidate abundance indices considered

In addition to addressing the three concepts listed in Section 5, selection of an appropriate index will ultimately depend on objectives and relative performance against these objectives. The features listed in Table 7 and defined in Section 4, have been developed for use in rating how well the suite of available indices considered the general goals and objectives for an appropriate biomass index. Table 9 indicates the range of indices that were considered and how well each meets the individual objectives. Note that indices that were briefly considered and described earlier but not carried forward are not included in this comparative list.

Table 9. Objectives to consider in evaluating an index to what extent each abundance index addresses them.

	Objectives					
Abundance index	Addresses older and younger population components	Consideration of CW geographic range	Consideration of CW stock status	Addresses recruitment differences in BSAI and GOA	Timeliness of information	Accessibility
Individual survey indices						
IPHC Coastwide setline survey	No	Yes	Yes	No	Yes	Yes
EBS shelf trawl survey	No	No	No	No	Yes	Yes
Integrated approaches across multiple indices						
IPHC assessment	No	Yes	Yes	No	Yes	Yes
Geostatistical model	No	Partial (AK)	No	Yes	Yes	No
EBS shelf trawl survey with IPHC assessment	Yes	Yes	Yes	No	Yes	Yes
ABM 3 survey combined index (EBS shelf trawl, GOA trawl, IPHC setline)	Yes	Yes	Yes	Yes	Yes	Yes

5.6 Potential downfalls of each index and the integrated index.

While the workgroup is recommending the use of the integrated ABM index for use in establishing PSC limits for halibut in the BSAI, it is clear that is not a perfect measure of the three concepts described previously, and has some potential downfalls. Even though there are three independent survey indices, each index is not specifically designed to address each concept individually. For example, the IPHC SSA survey contains O32 biomass in the Bering Sea, which is related to the coastwide spawning biomass and to the abundance in the Bering Sea. Therefore, it is not clear how the combination of the three survey indices addresses each concept and if some concepts are more represented than others in the integrated ABM index. The appropriate weights for each survey index are difficult to determine and are as much a policy decision as a scientific one. We considered weighting each survey index by the inverse of its respective variance estimate, but we found that the variance estimates are likely not well determined and this would potentially eliminate a concept from the integrated ABM index (i.e., the GOA survey tends to have a larger variance, so the concept of recruitment in the GOA would be down-weighted).

The range of values of a survey index may also relate to a concept in a nonlinear way. For example, a low value from the EBS trawl survey is likely to be indicative of a low incoming recruitment from the Bering Sea given the sampling uncertainty in the index, but a high value of this survey index could indicate a large number of recruits in the Bering Sea or a large older biomass, which would also be apparent in the IPHC SSA survey. This concern should be partially alleviated by using indices of numbers for the trawl surveys instead of biomass. Additionally, a large number of recruits in the Bering Sea has many stages to pass through before contributing to the coastwide spawning biomass, and therefore is more uncertain in its downstream and future effects. In other words, high values of the EBS trawl survey may or may not be indicative of the addition to future coastwide spawning biomass.

The effects of these relationships and uncertainties to the management of halibut PSC limits as well as the bycatch and directed fisheries can be investigated through simulation models. This would require modelling the halibut population, including spatial relationships between the Bering Sea and the rest of the coast, simulating the survey indices, and modelling the fisheries in each Regulatory Area. These types of analyses would ideally be incorporated into the impact analysis that would accompany the analysis for this amendment package in moving forward.

6 Control Rule Development

There are a variety of options to consider for the formulation of a control rule that may be applied to the recommended ABM index (or another index selected by the Council) to determine how PSC limits would change in response to changes in the index. The critical decision points to design a control rule are contingent upon the objectives of the control rule. Decisions must be made regarding the shape, slope, starting point, upper and lower thresholds, and stability of the bycatch control rule. Here we make assumptions about the Council’s intent in order to provide examples, understanding that these choices are policy decisions that will need to be articulated by the Council.

The SSC and Council recommended in April that PSC limits be considered in both numbers of fish and weight with discard mortality applied. For the process of drafting candidate control rules that will help inform the Council's decisions on crafting a range of alternatives for analysis, we use weight to define the PSC limit in mortality (hence assuming historical DMRs used in mortality calculations). However, the analysis of alternatives will consider PSC limits in both weight and in numbers. The Council should also consider whether separate control rules by gear type would be warranted given the observed differences in size composition of the catch between hook-and-line gear and trawl gear. For these examples we use total mortality across all groundfish gear types.

The Workgroup considered the specific time period that would be most appropriate to consider when looking at historic fishery performance that could guide future PSC limits. The Workgroup recommends that if the Council uses fishery performance data to inform the bycatch control rule, the appropriate time frame would be post-implementation of Amendment 80 (2008 on) to best approximate current fishing participation patterns and practices. However, illustrative examples presented below use bycatch data from 1997-2015 as well as 2008-2015 in order to indicate the contrast and impact of the choice of selection of years. The choice of years is a decision point for the Council in developing control rules.

One additional option that has been discussed and could be incorporated per Council direction, would be to consider both directed halibut fisheries and groundfish fishery bycatch in the control rule formulation (in consideration of appropriate floors and ceilings). One option for doing this would be that in low abundance years (defined either by thresholds in the IPHC stock assessment, some other cut-off for spawning biomass in the assessment or by directed fishery needs in 4CDE), a program could consider PSC allocations based on a minimum allocation to the directed halibut and/or groundfish fisheries. Alternative allocation formulas could explicitly account for the relative size distribution from each bycatch fishery/sector (or gear type) similar to proposals described in the Martell et al. (2015) paper. This type of analysis could also help to inform the ‘starting point’ for the control rule based upon the relative ‘footprint’ impact of different fisheries. This option is not explored in the illustrative examples provided below. The Council would need to provide analysts direction on whether alternative measures such as this should be considered in the suite of available PSC limit formulation and control rule options.

6.1 Shape of the control rule, starting point and maximum/minimum PSC

The SSC recommended the use of a sloping control rule which changes relatively smoothly with abundance. A continuous control rule would establish a PSC limit that increases or decreases at a constant rate based on changes in the halibut abundance index. This control rule option would specify a PSC limit of zero if the halibut abundance index reaches some minimum point. It also provides for a continually increasing PSC limit corresponding with increases in the abundance index.

As with the Crab PSC control rules, average historical bycatch levels (Table 2) or rates (Table 3) can be used to help inform a range of halibut PSC control rule considerations. These may also be used to inform a range of threshold levels for defining floors and ceilings for PSC limits. Here we explore some potential control rule formulations based upon historical mortality and proposed floors and ceilings in order to provide illustrative examples for the indexed PSC limit. Decisions on the shape and starting point for the control rule as well as floors and ceilings are policy decisions that will be established by the Council. The Council may consider a range of alternative control rules as well as different thresholds for floors and ceilings on the limit. Here we explore control rules that are informed by data based upon the realized historical halibut mortality (Table 2) in the groundfish fisheries. A list of the illustrative control rules and their derivation is provided below (Table 10):

Table 10. List of illustrative bycatch control rules (BCR[3]s) considered and the bycatch data employed. Note that for purposes of historical application because neither floors nor ceilings are reached BCR1 and BCR have identical results.

	Bycatch data used	*Referred to as:*
Bycatch Control Rule 1	Total mortality 1997-2015; no floor or ceiling	BCR1
Bycatch Control Rule 2	Total mortality 1997-2015; floor @20% < lowest bycatch year; ceiling @20%>highest bycatch year	BCR2
Bycatch Control Rule 3	Total mortality 2008-2015; no floor or ceiling	BCR3

The bycatch control rule 1 (BCR1) fits a regression line between the integrated abundance index and the total halibut mortality in groundfish fisheries for the years 1997-2015 while also forcing the line to go through the origin, which means that the PSC would be zero when the index is zero (Figure 19). BCR1 presents the relationship between historical changes in the abundance index (ABM) and halibut mortality in the groundfish fisheries. In BCR1, the slope of the line represents a constant rate of change in halibut mortality as the abundance index changes.

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[3] Note that these proposed BCRs are different from the ones considered in the April 2016 discussion paper

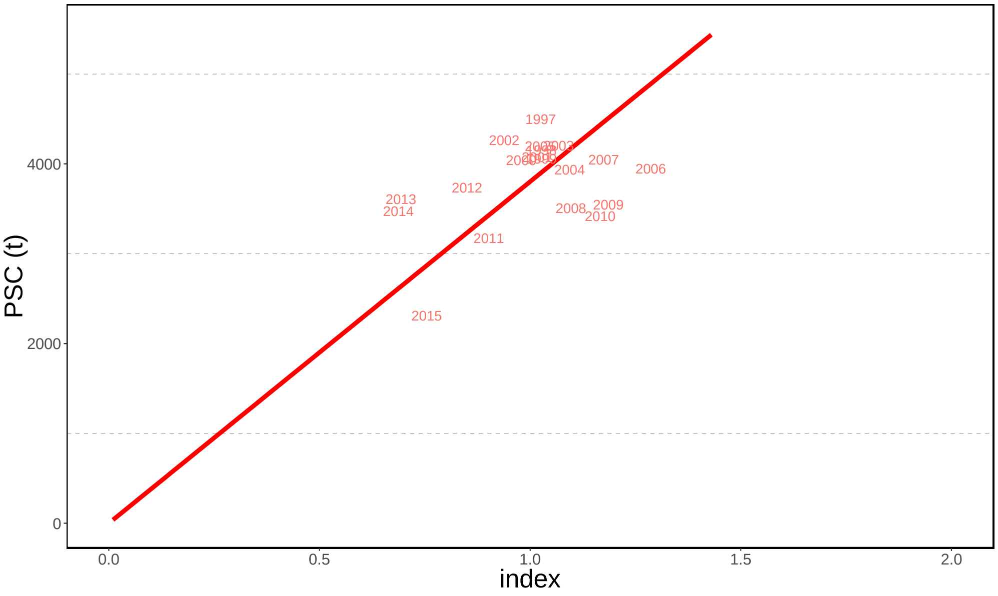


Figure 19 Bycatch Control Rule (BCR1) which is a regression through the bycatch data points in relation to the recommended index (ABM) from 1997-2015

The second control rule option (BCR2) incorporates stair-step thresholds for including minimum (floor) and/or maximum (ceiling) PSC limits. The intent of the floor or ceiling is a policy decision that the Council must make. These decisions could be informed by a variety of considerations such as some critical level of halibut abundance, directed groundfish fishery bycatch usage, directed halibut fishery needs, or other factors. For purposes of BCR2, the slope of the control rule is the same as BCR1, while the upper level is calculated as 20% higher than observed historical bycatch from 1997-2015 with the lower level set at 20% less than the lowest bycatch from 1997-2015 (Figure 20).

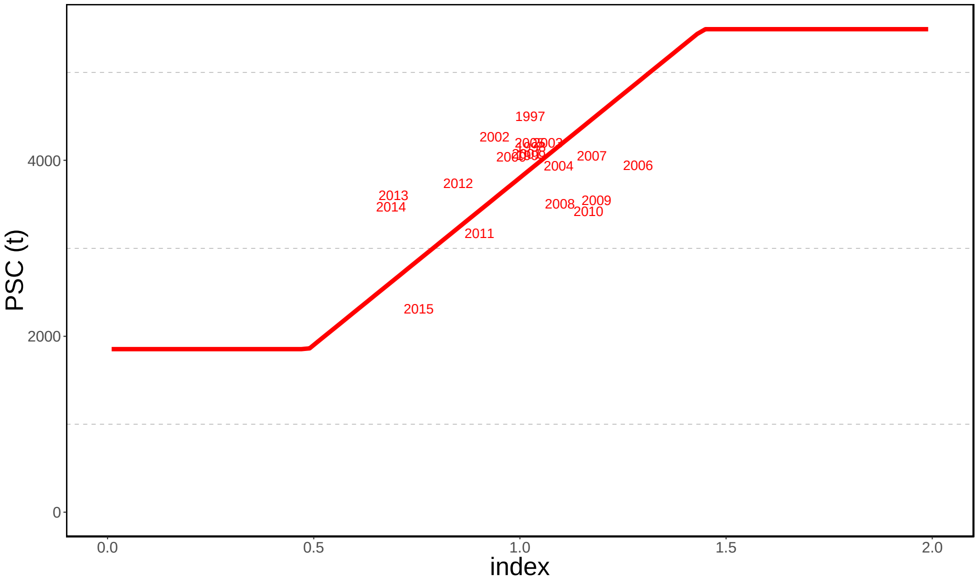


Figure 20 BCR2 which fits to the same data as BCR1 but incorporates a floor (minimum PSC level) and a ceiling (maximum PSC level) without modification of the slope.

The starting point for the control rule is critical to the slope of the control rule. For BCR1 and BCR2 we used the regression fit to the bycatch (1997-2015) as discussed above. Alternative slopes can be fit to highlight different years or Council objectives for what constitutes the starting point for indexing to abundance (Figure 21).

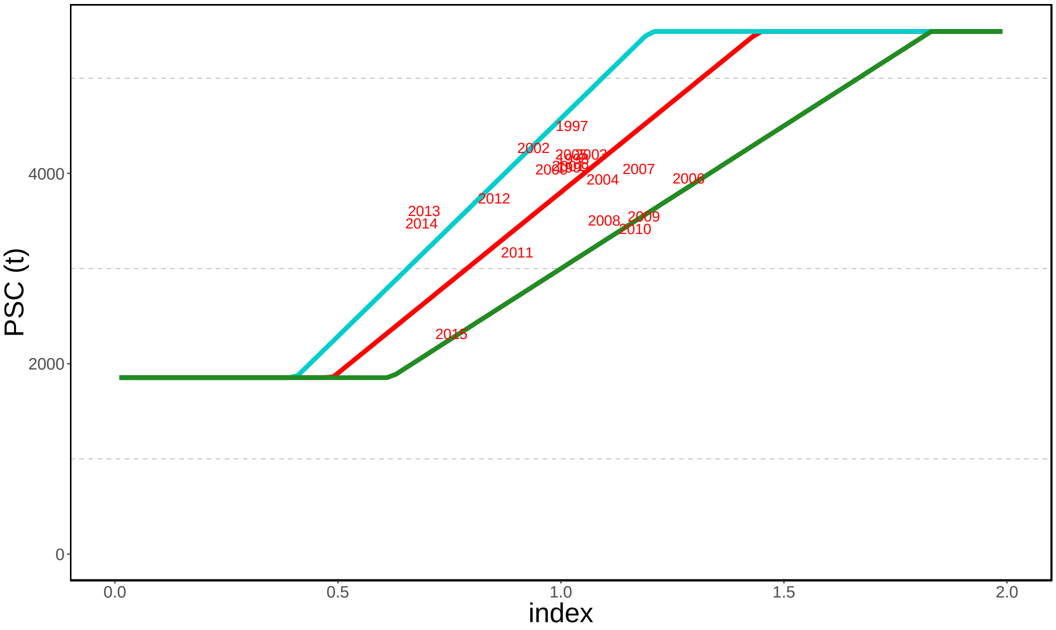


Figure 21 Illustrative example of modification of slopes to meet different control rule objectives. The middle (red) line represents the slope of BCR1 and BCR2.

For contrast we also show results for the regression which uses only 2008-2015 bycatch data (shown as BCR3 in Figure 22) as the recommended time frame following the implementation of Amendment 80. Application of that control rule in contrast to the BCR1 and BCR2 historically would result in a slightly lower overall PSC limit and additional years where historical PSC usage would have been higher than the back-calculated PSC limit (Figure 22).

For all three control rules, the implication of the regression is that when the integrated abundance index is equal to one, the PSC limit will be equal to the average of that time period of bycatch data. However, as seen in Figure 21, the PSC may take any value when the index is one. Since observed bycatch data may not be directly related to abundance (i.e., management decisions have other objectives than specifically abundance), it may be desirable to consider alternative slopes to the control rule or simply use a plug-in estimator, instead of regression, where the decision points are explicitly parameters to be determined by the Council objectives (see Appendix).

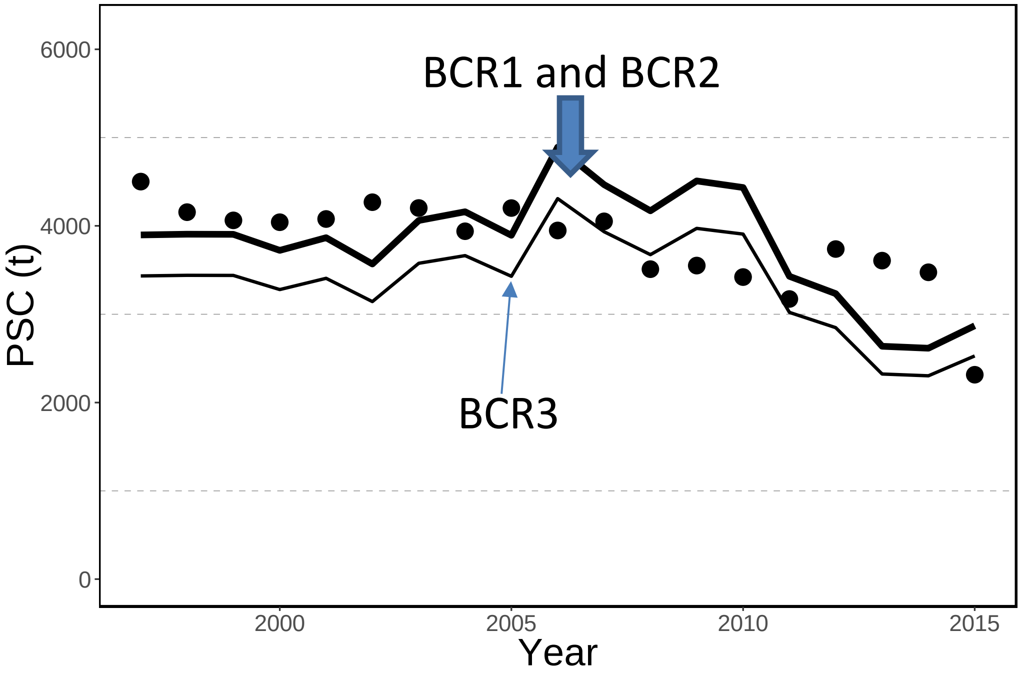


Figure 22 Comparison of historical application of BCR1 and 2 (dark line) with BCR3 (thin line) with actual mortality in those years (dots).

Tables of historical PSC limits generated from the use of these two contrasting control rules are shown in Table 11 and Table 12 (BCR1 and BCR2 PSC limits) and Table 13 and Table 14 (BCR3 PSC limits) allocated to the current proportions by sector per Council direction in April. Here we show the historical usage as a proportion of the limit. The tables show that total halibut mortality would have exceeded a total PSC limit based on the historical relationship of halibut mortality to the ABM in some years. In addition, halibut mortality in the Am 80, BSAI TLA, and CDQ sectors would have exceeded such a limit in some years.

Table 11. BSAI halibut PSC limits calculated using historical results of BCR1(BCR2). PSC limits are allocated according to status quo proportional allocations amongst sectors.

Year	*Am80*	*BSAI TLA*	*Longline fisheries*	*CDQ*	*Total PSC limit*
2008	2,071	884	843	374	4,171
2009	2,238	956	911	404	4,509
2010	2,202	940	896	397	4,435
2011	1,703	727	693	307	3,430
2012	1,605	685	653	290	3,233
2013	1,309	559	533	236	2,637
2014	1,298	554	528	234	2,615
2015	1,425	608	580	257	2,870

Table 12. Historical usage by sector as a proportion of BCR1 (BCR2) PSC limits shown in Table 11.

Year	*Am80*	*BSAI TLA*	*Longline fisheries*	*CDQ*	*Total PSC limit*
2008	95%	84%	70%	57%	84%
2009	93%	76%	66%	37%	79%
2010	102%	51%	56%	40%	77%
2011	106%	87%	70%	78%	93%
2012	121%	140%	85%	95%	116%
2013	166%	126%	87%	112%	137%
2014	168%	116%	76%	104%	133%
2015	115%	80%	51%	51%	81%

Table 13. BSAI halibut PSC limits calculated using historical results of BCR3. PSC limits are allocated according to status quo proportional allocations amongst sectors.

Year	*Am80*	*BSAI TLA*	*Longline fisheries*	*CDQ*	*Total PSC limit*
2008	1,824	779	742	329	3,674
2009	1,972	842	802	356	3,972
2010	1,940	828	789	350	3,907
2011	1,500	640	610	271	3,021
2012	1,414	604	575	255	2,848
2013	1,153	492	469	208	2,323
2014	1,143	488	465	206	2,303
2015	1,255	536	511	227	2,528

Table 14. Historical usage by sector as a proportion of BCR3 PSC limits shown in Table 13.

Year	*Am80*	*BSAI TLA*	*Longline fisheries*	*CDQ*	*Total PSC limit*
2008	96%	108%	95%	80%	65%
2009	89%	105%	86%	74%	42%
2010	88%	116%	58%	63%	45%
2011	105%	121%	98%	79%	89%
2012	131%	137%	159%	97%	107%
2013	155%	188%	143%	99%	127%
2014	151%	191%	132%	86%	118%
2015	92%	130%	91%	57%	57%

As noted previously the shape of the control rule is a main decision point by the Council, and this decision may be aided by 1) determining what the average PSC limit should be and relating that to a specific value of the index (the height of the line), 2) determining how the PSC limit changes with a change in the index (the slope of the line), and 3) the possibility of upper and lower PSC limits (the minimum and maximum of the line). The height of the line (consideration 1) can be a subjective decision, can be related to average historical bycatch, or can be determined as what the PSC limit should be when the index is a specific value. For example, the choice may be to set the PSC limit at the average bycatch observed since 2008 and related to the index at its average observed value since 2008, or determine what the PSC limit should be in 2017 and equate that to the value of the index in 2016 (yet to be determined). An additional important concept is the slope of the line or the proportional change in

PSC limit with a unit change in the index (consideration 2). We have already discussed how regression lines using previous observations may help, but this may also be a subjective decision based on a number of considerations. Finally, upper and lower limits and how those relate to the index should be determined. Data can also be used to determine these, but economic considerations as well as consultation with stakeholders may also help with these. These are policy choices that the Council needs to articulate based on the Council's objectives.

While the floors and ceilings under BCR2 are not reached when applied historically (Figure 22), they could be reached if the halibut abundance index declines or increases consistently over time. Figure 23 shows simulated examples of the difference between a continuous control rule and one with a floor and ceiling under these circumstances. Absent a ceiling the PSC limit will continue to increase as the abundance index trends upwards. In contrast with a floor the limit will remain static below a certain abundance level regardless of continued declines in abundance.

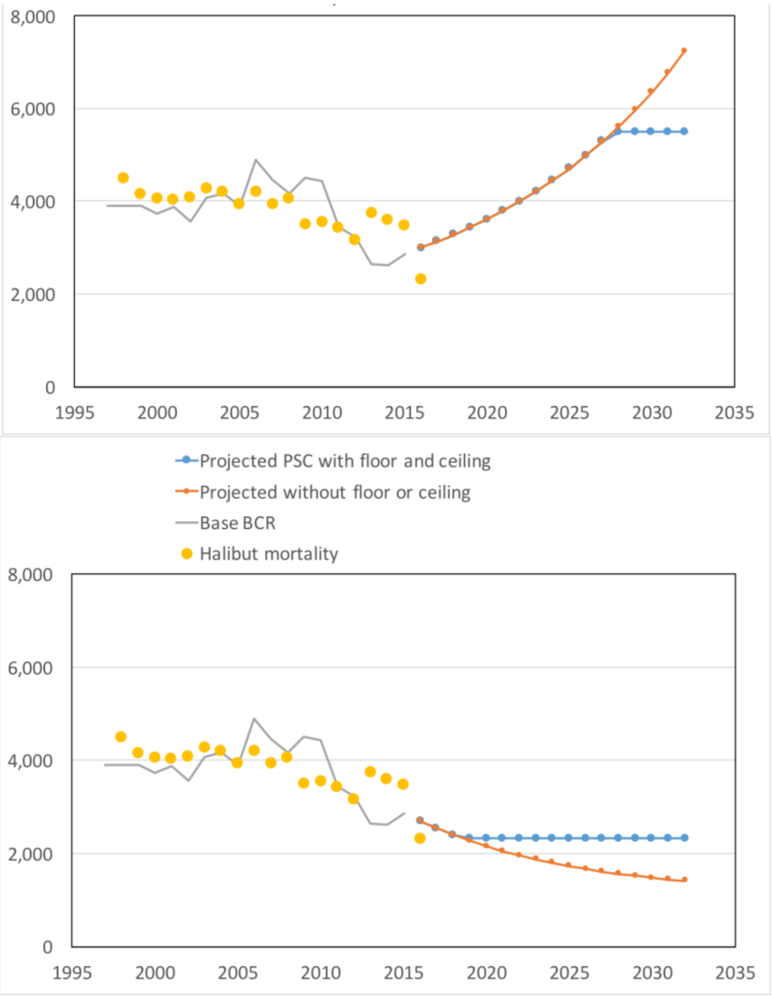


Figure 23. Illustrative example of what would happen to PSC limit if a future scenario of decreasing (top panel) or increasing (bottom panel) where the floor (top) and ceiling (bottom) are employed in the calculation.

6.2 Stability

The Council has included stair-step thresholds in other bycatch control rules to prevent significant annual variability in PSC limits from minor changes in the abundance index used for the control rule. The halibut catch sharing plan also includes stair-step thresholds to maintain stability by providing a constant allocation for the charter sector when abundance levels increase and the charter sector's proportional allocation decreases. The Council should consider how to balance consideration of stability in the bycatch control rule with inter-annual PSC limits indexed to abundance. Figure 24 below shows the inter-annual variability in the PSC limit by use of the BCR1 (and BCR2) control rule when retrospectively calculating the PSC limit.

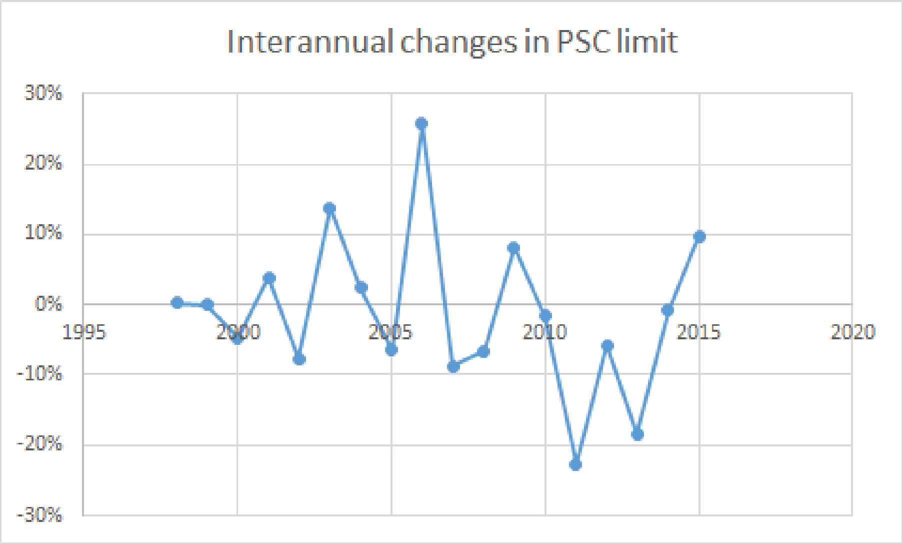


Figure 24. Interannual variability in calculated PSC limits historically using BCR1 (and BCR2)

The Council can reduce the inter-annual variability in the PSC limits by narrowing the distance between the floor and ceiling or reducing the slope of the control rule if stability is a priority over other objectives. An example is shown in Figure 25 of imposing a shallower control rule that does not assume bycatch PSC limit at 0 when abundance is at 0. The application of this control rule to historical abundance results in a much less variable PSC limit than the continuous control rule examples of BCR1 and BCR2 (Figure 25). The Council will need to assert whether stability is a priority in the development of a control rule and provide some metrics by which to assess stability (i.e. minimum or maximum desired percentage change in the PSC by year) and balance against other objectives.

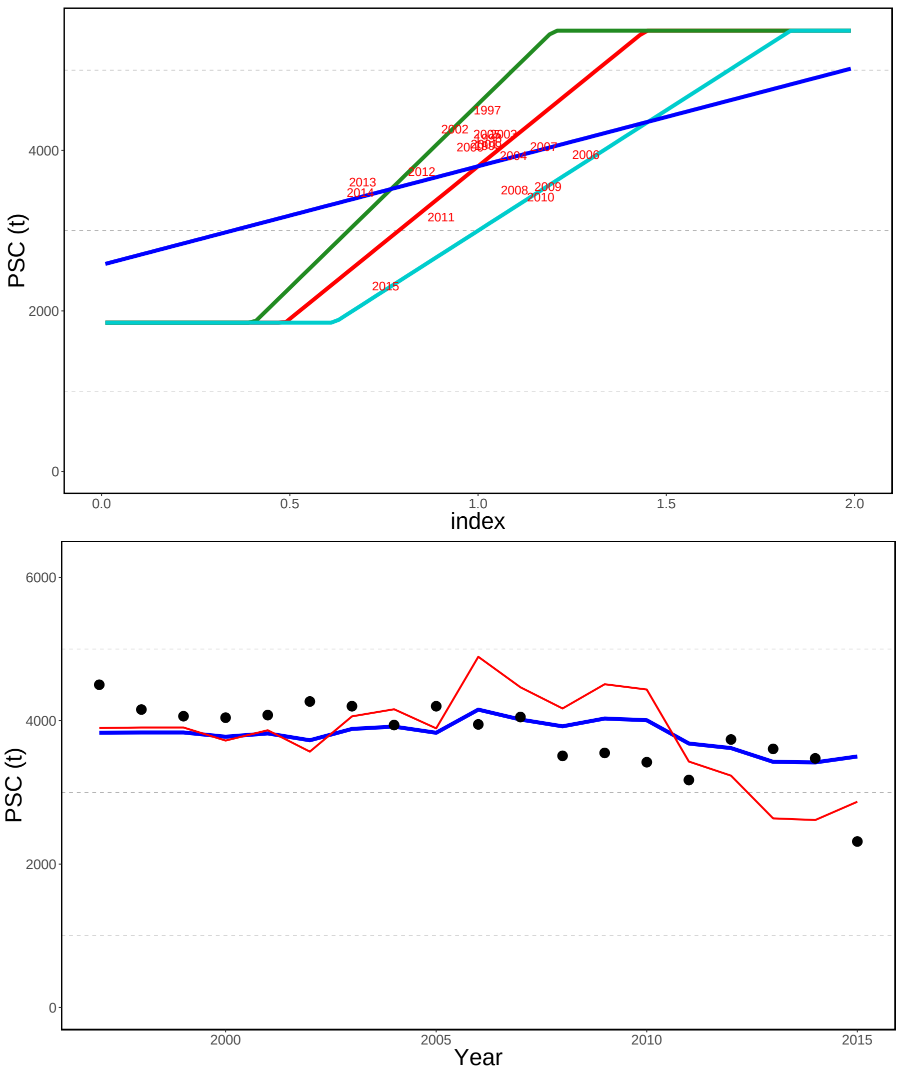
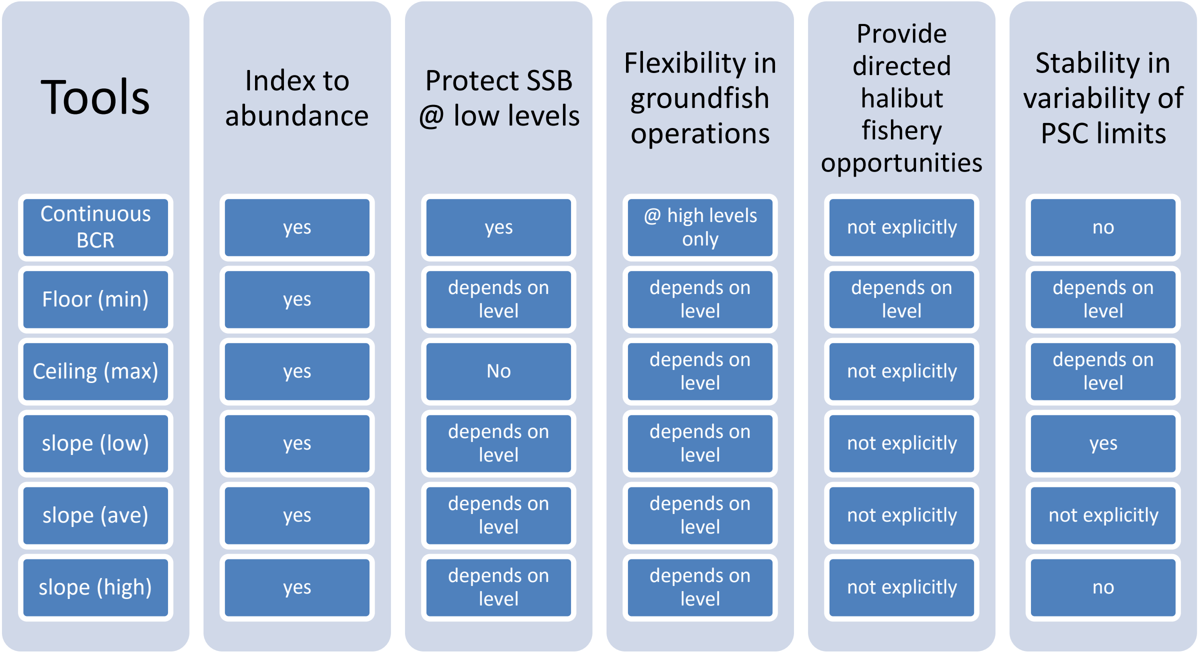


Figure 25. Example of a flatter slope for a control rule which does not go through the origin (upper panel) in conjunction with steeper control rules as discussed previously (green, red, blue lines in upper panel; note red line is BCR1 (BCR2). Lower panel shows contrast in results between the BCR1 results as shown previously (red thin line) as compared with a more shallow control rule (blue thicker line).

6.3 Balancing priorities and decision-making for control rule formulation

In order to develop an appropriate bycatch control rule the Council must articulate some explicit criteria by which to evaluate the performance of each control rule. The workgroup developed some candidate objectives based upon the Council's stated purpose and need for this action (Section 2.3) however consideration of explicit control rules to meet these objectives will require a prioritization across competing objectives. Figure 24 shows the available tools for a control rule and whether the tool could be used to meet the candidate objectives.



Tools	Index to abundance	Protect SSB @ low levels	Flexibility in groundfish operations	Provide directed halibut fishery opportunities	Stability in variability of PSC limits
Continuous BCR	yes	yes	@ high levels only	not explicitly	no
Floor (min)	yes	depends on level	depends on level	depends on level	depends on level
Ceiling (max)	yes	No	depends on level	not explicitly	depends on level
slope (low)	yes	depends on level	depends on level	not explicitly	yes
slope (ave)	yes	depends on level	depends on level	not explicitly	not explicitly
slope (high)	yes	depends on level	depends on level	not explicitly	no

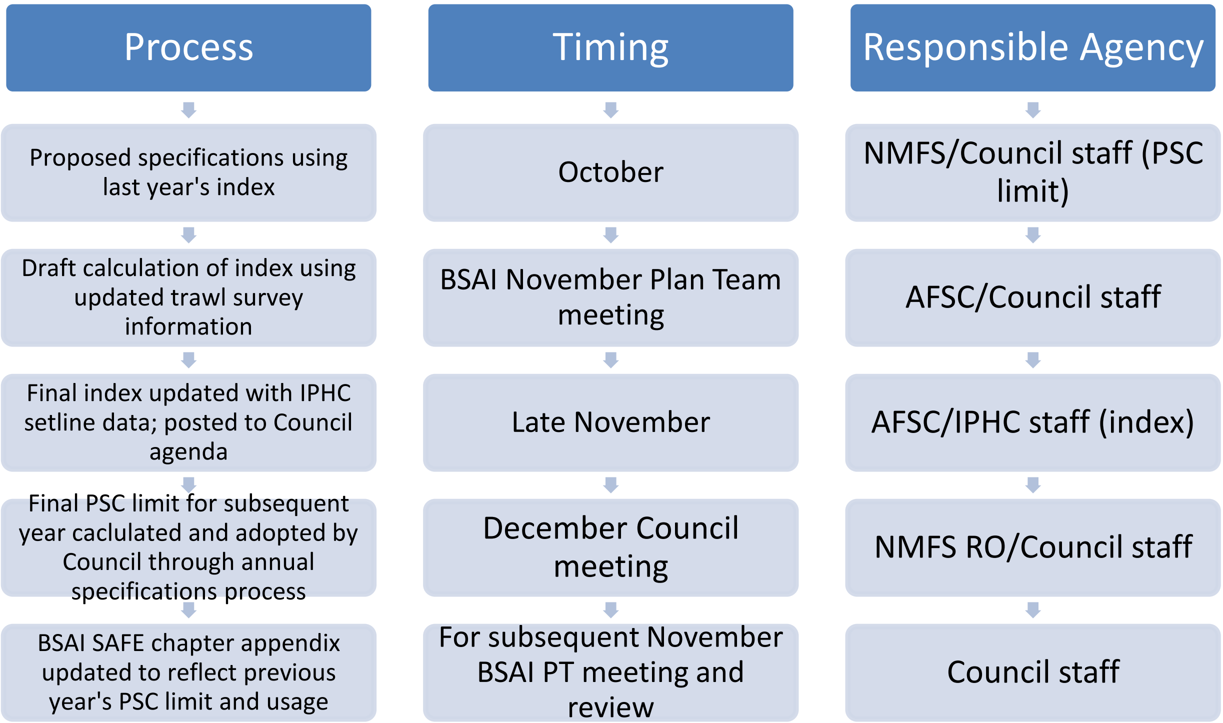
Figure 26. Consideration of features (tools) in developing a bycatch control rule (left column) and the draft objectives inferred from the Council's purpose and need (top horizontal).

7 Management and operational implications

Some management and implementation and issues have been identified in conjunction with moving forward with an analysis to move to abundance-based, annually varying halibut PSC limits. These are described sequentially below.

7.1 Process for establishing new PSC limits

Revised PSC limits would be annually established in the BSAI groundfish annual harvest specifications. Doing so requires that data to specify an abundance index be available in time for inclusion in the final harvest specifications at the December Council meeting. This was included in the criteria for evaluating recommended index approaches as detailed in Table 9. Using the recommended ABM index would allow for final harvest specifications in December, however a mechanism for annual BSAI Plan Team review and ability to provide informed information for the proposed harvest specifications in October would be desirable. Staff has identified a proposed process to provide for transparent update and timely availability of this information (Figure 27). This process would incorporate annual review of the index by the BSAI Plan Team each fall. Analytical staff responsible for updating the index annually would need to be identified. Council staff and NMFS in-season management staff would then calculate the PSC limit annually as with our current harvest specifications process.



Process	Timing	Responsible Agency
Proposed specifications using last year's index	October	NMFS/Council staff (PSC limit)
Draft calculation of index using updated trawl survey information	BSAI November Plan Team meeting	AFSC/Council staff
Final index updated with IPHC setline data; posted to Council agenda	Late November	AFSC/IPHC staff (index)
Final PSC limit for subsequent year caclulated and adopted by Council through annual specifications process	December Council meeting	NMFS RO/Council staff
BSAI SAFE chapter appendix updated to reflect previous year's PSC limit and usage	For subsequent November BSAI PT meeting and review	Council staff

Figure 27. Proposed process and timing for annually updating the BSAI halibut PSC limit in the annual harvest specifications process.

7.2 Implementation issues

Changing PSC limits or metrics (i.e., halibut mortality in weight or numbers of halibut) would require changes in the existing regulations for and administration of the groundfish fisheries by changing the catch accounting system, in-season management, and other issues that would need to be explored in future discussion papers and analyses.

NMFS' general approach to in-season management of PSC in the BSAI groundfish fisheries would not change with implementation of abundance-based halibut PSC limits. Under the status quo, the PSC limits are annually apportioned to specific fishery categories, for fisheries other than CDQ and Amendment 80, and may also be apportioned seasonally, through the annual groundfish harvest specifications process (guidelines are published in regulation at 50 CFR 679.21). When an annual or seasonal PSC limit is reached, all vessels fishing in that fishery category must stop fishing for the remainder of the year or season.[4] If the Council recommends implementation of abundance-based halibut PSC limits in the BSAI groundfish fisheries, NMFS would continue to use the current process to monitor and manage the groundfish fisheries to ensure that halibut PSC does not exceed established limits.

If the Council recommended implementation of abundance-based halibut PSC limits that may be substantially reduced from historical levels, NMFS may have to reduce the length of some fishing seasons or make a determination not to open specific fisheries if sufficient PSC is not available to support harvest of the groundfish total allowable catches. In other management programs where PSC limits may constrain groundfish fisheries, the Council has provided NMFS with authority to reapportion PSC from fisheries

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[4] The exception is for the PSC limit applying to the pollock/Atka mackerel/"other species" fishery category for trawl gear, where reaching the PSC limit does not result in closure of these fisheries.

and sectors that have unused PSC to fisheries and sectors that are constrained by PSC. Based on previous experience with reapportioning directed fishery allocations and various PSC species, the Council has determined that fishery closures can be avoided or limited by authorizing NMFS to use in-season management actions to reapportion unused amounts of PSC among the fisheries and sectors. The Council has provided this authority to NMFS for to reapportion halibut PSC from the BSAI trawl limited access sector to Amendment 80 cooperatives and for reapportionment of halibut and Chinook salmon PSC among sectors in the Gulf of Alaska groundfish fisheries. If the Council recommends implementation of abundance-based halibut PSC limits in the BSAI that may result in PSC limits that are below historical levels, the Council could consider providing NMFS with authority to reapportion halibut PSC to provide more flexible use of halibut PSC in the groundfish fisheries.

NMFS anticipates that implementation of an abundance-based halibut PSC limit in weight (metric tons of halibut mortality) would require a limited number of changes to the catch accounting system and in-season management because it maintains the status quo metric for PSC. Implementation of an abundance-based halibut PSC limit in numbers of halibut would require fairly substantial changes to the NMFS catch accounting system, but likely would not result in changes to NMFS' process for managing the BSAI groundfish fisheries. If the Council recommends an abundance-based halibut PSC limit in numbers, NMFS would also consider whether the observer sampling protocol for halibut in the BSAI groundfish fisheries would need to be revised to reflect the data needs for estimating mortality in numbers of halibut.

7.3 Management of annually varying limits and groundfish operations

The analysis would need to characterize the potential operational issues by the groundfish fishery and operational decisions that could be modified when faced with annually varying PSC limits. Depending on the nature of the Council's final alternative set, some (or all) options under consideration could include substantially widely varying PSC limits inter-annually. The impacts of these potential changes on groundfish operations and overall harvests of groundfish in the BSAI will need to be characterized in the analysis of impacts.

7.4 Changes in IPHC and Council Process/decision-making

Currently modifying BSAI groundfish fishery halibut PSC limits is solely under the Council's jurisdiction with consultation provided with the IPHC. Any alternative under consideration that would require joint coordination and joint decision-making by both bodies would require a modification in this structure.

8 Analytical considerations

8.1 Use of MST model (AFSC MSE) in impact analysis

The AFSC has been developing an advanced toolset that includes management strategy evaluation (MSE) with a multi-species technical interactions model to simulate the biological, management, and fleet dynamics of the Alaska groundfish fishery. Catches in the model are limited by constraints, including the 2 million t cap, halibut prohibited species catch (PSC) limits, and the constraining nature of the catch limit of one species on the catch of other species in the context of weak stock management. This work was presented at the April 2016 SSC meeting in Anchorage. The work has been subsequently revised to include recommendations from the SSC and the work has been submitted for publication (Ono et al. in review).

8.2 Use of IPHC MSE in impact analysis

The IPHC MSE process has been in development for several years. Initial development has focused on definition of management objectives, management procedures and scenarios to examine, metrics of performance, and development of operating models and evaluation tools. Equilibrium tools have been used to engage the Management Strategy Advisory Board (MSAB) and familiarize it with the MSE process. Much of the discussion with the MSAB has involved articulating coastwide and area-specific objectives for the halibut fishery and the stock.

The IPHC has been using a coastwide operating model for the MSE investigations, although it recognizes that many stakeholder concerns are expressed at an area-specific level because of the existing IQ management structure for the fishery. To that end, the Commission will be moving away from equilibrium models and developing a spatially-explicit operating model or models as companions to the current process. A two-year work plan has been created that describes the process of moving to a closed-loop fully dynamic MSE process using a coastwide model and incorporating estimation and implementation components in the feedback process. Subsequent development will be to incorporate spatially-explicit models into the closed-loop process.

Bycatch mortality is only one of many elements of halibut management that is being examined in the MSE process. It is possible to evaluate abundance-based PSC limits in both the coastwide and spatial MSE models and is of interest to the Management Strategy Advisory Board (MSAB). DMRs associated with each form of management are variables in the MSE evaluations and their evaluation forms a component of the evaluation of management procedures (such as harvest control rules, target harvest rates, fixed or variable bycatch mortality controls, minimum size limits, fishery timing, etc.) being investigated.

8.3 DMR working group and schedule

A workgroup of IPHC, Council, AKFIN, AFSC, and Regional Office staff are working to reevaluate the methodology for determining discard mortality rates (DMRs) that are applied in-season in groundfish fisheries to estimate halibut mortality for the catch accounting system. A discussion paper which provides a new recommended approach for consideration by the Plan Teams, SSC, and Council in will be provided to the Council in October 2016. The intent is to use the newly estimated DMRs for the 2017 groundfish harvest specifications cycle. In the evaluation of alternatives, it may be useful to explicitly consider plausible estimates of uncertainty in the estimates of DMR values, both within the underlying viabilities and the estimation methodology within fisheries.

9 Next steps and Council action

In order to move forward with the development of alternatives, the following decision points are needed by the Council:

1. **Recommendation on appropriate biomass estimate for use in indexing to PSC limits**:
    - SSC review and recommendation to Council on use of proposed ABM index for analysis
2. **Form of control rule**
    - Slope
    - Thresholds
    - Floor and/or ceiling on harvest rate

Analysts need direction from the Council upon what **data to evaluate in developing the bycatch control rule.** Thus decisions on (for example) the following:

- Fishery performance data: what years? Range of years?
- Other consideration to pin the control rule to the abundance index (i.e. relative usage by fishery? Fishery ‘footprint’?)

  - Biomass thresholds: what criteria for establishing floors or ceilings? Range of floors and ceilings?
  - Define explicit objectives for the control rule and their prioritization.
    - Index to abundance
    - Halibut stock spawning biomass (SSB) protection
    - Flexibility in groundfish operations
    - Directed halibut fishery opportunities
    - Stability in inter-annual PSC limit
    - Bycatch reduction?
    - Other objectives?

Once the Council has defined the explicit objectives and their prioritization for the development of the bycatch control rule indexed to abundance then the workgroup can begin to develop appropriate performance metrics by which to evaluate efficacy of alternatives.

3. Allocation
   - Status quo
     - Retain Categories and proportions

Note that the analysis will assume status quo allocation but the Council always has the ability to identify different allocation options at any point during the development of alternatives for this analysis.

- PSC Limits based on: No decision here, Council has already requested that consideration be given to both:
  - Numbers of Pacific halibut
  - Weight of Pacific halibut
- Accounting
  - No decision needed here, already specified that will use with DMRs specified in groundfish specifications process. DMRs to be used in analysis will flow from Council decisions on revised DMRs in Oct/Dec considerations under DMR agenda item

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12 Appendix

The abundance based integrated index could be easily applied as follows:

$$PSC_{y+1} = \left(1 - \left(1 - I_y\right)a\right)X$$

Where PSC_{y+1} is the prohibited species catch limit for the next year calculated as the current year integrated index I_y value, a is a scalar that determines the proportional effect the index has on the PSC limit, and the X is the amount of desired PSC limit when the index is at the long term mean. This value could be the highest catch limit since 2008, the average realized halibut discard mortality, or the maximum realized halibut discard mortality. For example, fitting a regression through the origin between the abundance index and the realized discard mortality estimates would yield average catch for the value of X with a value of 1 for a. The value of a could take on any value depending on whether the induced variability of the abundance index is deemed too high to be practically managed, or too low to reflect real changes in abundance. A value of 1 implies that a 10% increase in the index would be a 10% increase in the PSC limit. Values below 1 would reduce variability and values above 1 would increase variability. An example of this in method with the value of X set at the maximum halibut discard mortality in the 1997 – 2015 period (4,576 tons) across multiple values of a is shown in Figure A.1. An illustration of the application of this control rule across scenarios of varying levels of abundance for each index is shown in Figure A.2.

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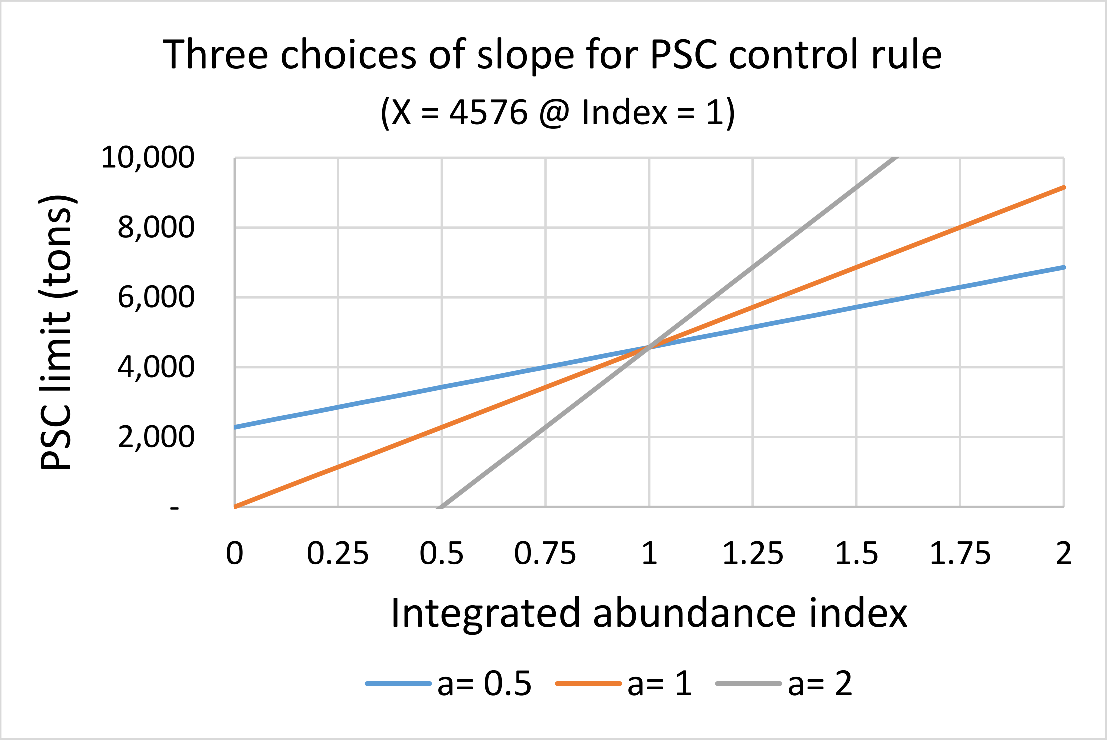

Figure A.1. Examples of different values of the scalar a where the value of the PSC limit at a value of the abundance index is 1 (X) is set at the maximum halibut bycatch mortality suring 1997 – 2015.

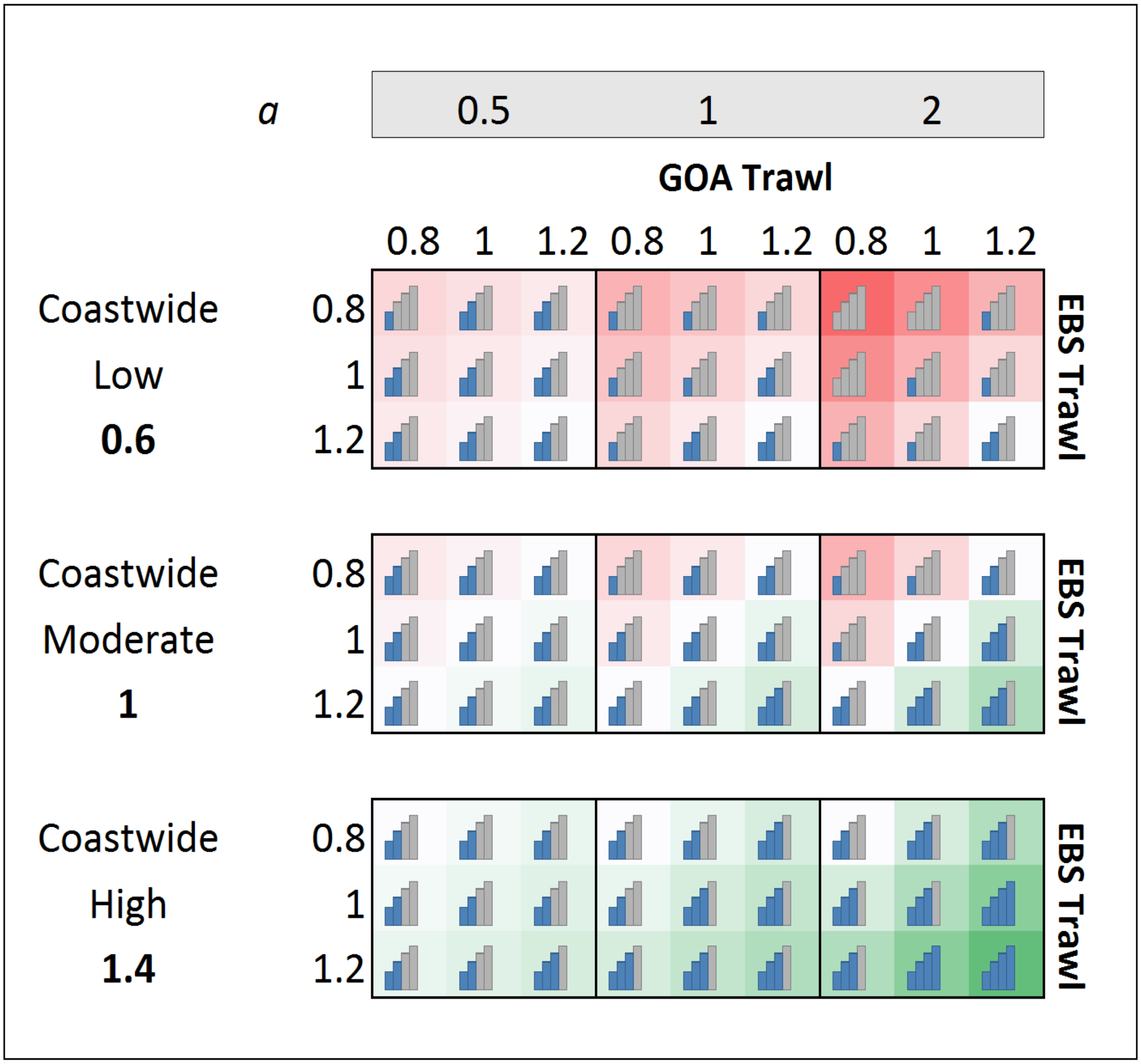

Figure A.2. Scenarios across of individual index values when applied as an integrated index across multiple values of the slope of the equation described in the Appendix. The values of the coastwide axis (0.6 – 1.4) are designed to cover the approximate range of that index. Red boxes with few blue bars are low PSC limits, while green boxes with blue bars are higher PSC limits.