Discussion Paper:

Establishing BSAI Pacific halibut prohibited species catch limits using abundance-based management

March 20, 2018[1]

1. Executive Summary

In October 2017, the Council reviewed a discussion paper synthesizing staff work on establishing BSAI abundance-based management (ABM) prohibited species catch (PSC) limits for halibut. In October, the Council requested staff to develop a preliminary analysis of ABM control rules and their relative performance compared to Council objectives, using the Council's suite of elements and options to develop "strawman ABMs" (example ABM alternatives) based on various combinations of trawl and setline survey indices of halibut abundance.

This discussion paper sets out strawman ABMs as requested by the Council. The paper also evaluates how different control rules function, and the relative features of different control rules. We provide a preliminary analysis of the example ABMs that explores tradeoffs among the control rules with respect to setting PSC limits for BSAI groundfish fisheries (by gear type), using both historical data and contrasting scenarios of forward projections to understand how the control rules will function in the light of potential future halibut abundance trends.

In developing the strawman ABMs, we revised the Council's elements and options from October 2017 with the intent of the Council motion but restructured to better suit an analysis of different control rules moving forward and provide contrast relative to the Council's objectives.

At the April 2018 meeting, the Council is scheduled to draft a suite of alternatives for an initial review analysis. Consequently, the revised elements and options provided here are intended to help guide the Council in specifying control rule options for alternatives to be analyzed. For clarity, the options for each element should be limited so as to avoid specifying attributes that achieve the same overall goal. This should help the analysts evaluate and present results to contrast among alternatives.

[1] Prepared by the Halibut ABM Working Group (members include: Diana Stram, NPFMC staff; Jim Ianelli, Dana Hanselman, Carey McGilliard, NMFS AFSC, and Allan Hicks IPHC staff). The Working Group's conclusions presented in the paper may not necessarily reflect consensus of all working group members or support of member affiliated agencies

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2. Introduction

2.1 Summary of previous actions and documents

The Council has been reviewing iterative focused discussion papers on establishing BSAI abundance-based management (ABM) prohibited species catch (PSC) limits for halibut since 2015. Table 1 provides a brief summary of the papers reviewed by the Council and the focus of these papers. The most recent paper reviewed by the Council was in October 2017[2] when a comprehensive synthesis of all available information contained in previous papers was provided. The action by the Council at that time is summarized in the next section and provides the context for requesting this preliminary analysis. The action for the Council at this meeting is to draft the suite of alternatives for analysis.

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

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

[2] The October 2017 discussion paper is available here: October 2017 BSAI Halibut PSC discussion paper

2.2 Overview of Council action in October

Following review of the October 2017 discussion paper, the Council revised the purpose and need statement and put forward a set of Elements and Options that could be used to begin development of a suite of alternatives for analysis.

> ***Purpose and Need Statement:*** *"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, particularly at low levels of abundance. Abundance based PSC limits also could provide an opportunity for the directed halibut fishery, and protect the halibut spawning stock biomass. The Council recognizes that abundance-based halibut PSC limits may increase and decrease with changes in halibut abundance."*

The Council tasked staff to develop a preliminary analysis focusing on providing additional description of control rules, including discussion of features that best meet the Council's objectives, a qualitative evaluation of the control rule, and performance. Specific direction requested that staff:

1. Develop strawman ABMs using the EBS shelf bottom trawl survey and IPHC setline survey for area 4ABCDE as indices. Provide examples and analyze indices applied separately using control rule options in Element 2 below.
2. Additionally, using strawman ABMs, apply indices to control rules individually to each gear type to establish separate PSC limits. Evaluate and provide a description of the tradeoffs of the following control rule features, as well as the impact on PSC limits:
    - IPHC Coastwide stock status (30:20) control rule
    - Explicit consideration of the O26 composition of PSC in a control rule
    - Sloped transitions between stair-steps in a decision table
3. Investigate and evaluate different index/control rule combinations using various tools (e.g., simulation analysis from April 2016 and 2017 discussion paper) as outlined by the SSC. Provide discussion of the tradeoffs of the different control rules and features as it relates to the Councils objectives. In evaluating this, the Council instructs staff to maintain the existing proportional PSC allocation among sectors.

The Council refined the component elements and options for consideration in developing an ABM and instructed staff to confine preliminary analysis to these elements and options.

Element 1 – Abundance index and application

Option 1. Apply EBS trawl survey and IPHC setline survey for 4ABCDE separately to establish a single PSC limit
Option 2. Index trawl gear to EBS survey, index fixed gear to IPHC setline survey
Option 3. Index EBS trawl survey and IPHC setline survey to trawl gear
Option 4. Index EBS trawl survey and IPHC setline to fixed gear

Element 2 – Control Rules

Option 1. Linear
Option 2. Decision table
Option 3. Multi-dimensional

Element 3 – PSC limit responsiveness to abundance changes

Option 1. Include IPHC stock status (30:20) as breakpoints in the control rule
Option 2. Sloped transitions between stair-steps in decision table
Option 3. PSC limit varies proportionally (1:1) with change in abundance index.
Suboption – Different variation above and below (1:1)

Element 4 – Starting point for PSC limit

Option 1. 10% below 2016 PSC use (2,118 t)
Option 2. 2016 PSC use (2,354 t)
Option 3. 2016 PSC limit (3,515 t)
Option 4. 10% above 2016 PSC limit (3,867 t)
Option 5. Additional value within range of Options 1-4

Element 5 – Maximum PSC limit (ceiling)

Option 1. 2016 PSC limit (3,515 t)
Option 2. 2015 PSC limit (4,426 t)
Option 3. No ceiling
Option 4. Additional value to be selected

Element 6 – Minimum PSC limit (floor)

Option 1. No floor (PSC goes to 0)
Option 2. 2016 use (2,354 t)
Option 3. IPHC Control Rule - PSC limit goes to zero at 20% stock status
Option 4. Additional value to be selected

The Council directed NMFS to initiate scoping for the preparation of an Environmental Impact Statement (EIS).

2.3 Overview of Council objectives

The Council derived the following objectives from the purpose and need statement for this action to guide the development of appropriate management measures:

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

As noted in previous discussion papers these objectives have not been prioritized by the Council and may be in opposition to others thus designing a management program which meets all of them equivalently will be challenging. The goal of the analysis of the Council's alternatives, once developed, will be to evaluate how well each alternative meets the purpose and need statement, and these competing objectives. Typically, overarching goals are defined first and translated into measurable objectives, and there may be multiple measurable objectives for each goal. A measurable objective has an outcome ("a certain abundance"), a time-frame ("a specified number of years") and a probability or acceptable risk level. A performance metric can then be defined to evaluate whether a measurable objective has been achieved (e.g., the probability that the spawning stock abundance is above a certain level over a specific number of

years). Developing performance metrics which relate to measurable objectives or these overarching goals will be developed once the Council has a defined a suite of alternatives.

The initial review will provide the Council and the public the ability to evaluate how each alternative meets to varying degrees the Council's objectives for this action. In this paper we provide several different control rules that can be tuned to meet the Council's objectives to various degrees. Information is provided in the strawman ABMs regarding how the design of the ABM and specific options within elements, may address certain objectives. Additional information is provided in Appendix 7.5 using strawman ABM 4 as an example of how a control rule can be tuned to meet specific Council objectives more specifically than others.

2.4 Overview of document structure

The remainder of this document is organized to respond to the Council's motion from October 2017.

- Section 3 provides the working group's "strawman ABMs" (example ABM alternatives), which are organized around a combination of trawl and setline survey indices of halibut abundance and their application to different BSAI groundfish gear sectors.
- Section 4 describes the control rules under consideration, using the range of control rules provided by the Council in the October 2017 motion and concludes with a recommended approach for considering control rules in draft alternatives
- Section 5 provides staff recommendations for reorganizing the Council's October 2017 structure of elements and options. The staff revisions are all a logical outgrowth of the Council's October motion, and retain its intent, but are restructured to better suit an analysis of different control rules moving forward. Control rules are applied to each example ABM alternative.
- Section 6 analyzes each of the example ABM alternatives using the elements and options as revised by staff, and simulates how the control rules behave in each example ABM alternative and to what extent certain options are intended to address Council objectives
- Section 7 contains additional discussion of how the elements and options and ABMs simulated relate to Council objectives and recommendations moving forward
- Section 8 contains a series of appendices, for additional information. These include:
    - Section 8.1: a crosswalk of the Council's October 2017 elements and options with the staff revisions recommended in this paper.
    - Section 8.2: supplemental fishery information as background.
    - Section 8.3: additional control rule complexity using stair-step ramp provisions per Council October request.
    - Section 8.4: supplemental simulations of all control rules and ABMs examined in Section 6.2
    - Section 8.5: example of how the control rule formulation in ABM 4 can be tuned to meet a range of Council objectives for this action

3. Strawman ABMs

The Council's guidance in October was organized into elements and options which could be combined to formulate a potentially large number of scenarios to analyze. As directed by the Council, the workgroup developed some strawman ABMs (described here as example ABM options) which flow from the Council's October motion. This involves separating Element 1 from the October motion (regarding application of the abundance index) as shown below into individual ABM alternatives.

Element 1 – **Abundance index and application (from October 2017 Council motion)**

Option 1. Apply EBS trawl survey and IPHC setline survey for 4ABCDE separately to establish a single PSC limit

Option 2. Index trawl gear to EBS survey, index fixed gear to IPHC setline survey

Option 3. Index EBS trawl survey and IPHC setline survey to trawl gear

Option 4. Index EBS trawl survey and IPHC setline to fixed gear

The Council directed the analysts to evaluate the behavior of different control rules and options to inform the construction of a suite of alternatives for analysis. To evaluate the behavior of control rules, we organized example ABMs around the abundance indices and included an additional baseline ABM (ABM 1-baseline) to illustrate options. We then compared ABM control rule options following the revised Elements 1-4. A set of other example ABM alternatives were developed to contrast combined abundance index applications (ABM 2-4) but with a limited set of options. Details on the EBS trawl survey, IPHC setline survey and the size composition of the survey catches compared with fishery size composition of the bycatch have been detailed in previous discussion papers and are not repeated further here. See section 2.1 and Table 1 for more information on each of these items. These example ABMs are summarized as:

ABM 1 (baseline): PSC is indexed to the EBS trawl survey for a single PSC limit that is then allocated to gear/sector according to the status quo allocation. Note: this example is included only for contrast for the preliminary analysis. It is not part of the Council's October motion.

ABM 2: PSC is indexed to the EBS trawl survey and setline survey for 4ABCDE for a single PSC limit that is then allocated to gear/sector according to the status quo allocation. (Option 1 from October motion)

ABM 3: Trawl PSC is indexed to the trawl to EBS trawl survey. Longline PSC is indexed to the setline survey for 4ABCDE. (Option 2 from October motion)

ABM 4: PSC is indexed to both EBS trawl survey and setline survey. The trawl gear PSC is indexed to both EBS trawl and setline survey for 4ABCDE (Option 3 from October motion). Here the trawl survey forms the primary index while information on the setline survey for 4ABCDE will be used as a secondary index to influence the final PSC limit after the control rule is applied. The fixed gear PSC is indexed to both EBS trawl and setline survey for 4ABCDE, but the setline survey forms the primary index while information on the trawl survey will be used as a secondary index to influence the final PSC limit after the control rule is applied (Option 4 from October motion).

In ABM 4 the secondary index modifies the final PSC when both the primary and secondary index are either above their average values or both are below their average values (the PSC is multiplied by 1.1 when both indices are above their average values and by 0.9 when both indices are below their average values). The minimum PSC (floor) and maximum PSC (ceiling) are applied as a final step such that the PSC never exceeds these values.

4. Control Rule Options

4.1 Control rule description

A control rule is typically a function that is driven by data and results in a regulatory control. In fisheries, a control rule typically determines a catch limit from outputs from a stock assessment. For example, a harvest control rule determines the annual overfishing limit (OFL) for a stock using abundance, fishing mortality rate, and stock status. For ABM of PSC limits, we first describe simpler control rules that determine a PSC limit using a single index of abundance, and then discuss multi-dimensional control rules that use more than one index of abundance. Possible data to drive the control rule follow that.

Finally, specific control rules developed from elements of the October 2017 Council motion are presented.

There are many features of a control rule that could be included in ABM alternatives. Figure 1 provides an illustration with features labelled. The values associated with each of these features are policy decisions to be made by the Council with input from stakeholders when presented with performance measures arising from analytical results.

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

Slope. The slope of the control rule determines how responsive a change in PSC limit is to abundance (Figure 1). A one to one relationship of abundance to PSC limit from the starting point value would mean that when the abundance index increases by 10% then the PSC limit would increase by 10%. More shallow slopes (i.e., slope less than one) from the same starting point would result in a less than one to one relationship and a steeper slope (i.e., slope greater than one) would result in a greater than one to one relationship of PSC to abundance.

Floor and ceiling. A minimum value of the PSC limit (floor) or a maximum value of the PSC limit (ceiling) could be imposed such that the PSC limit is constrained within some range. A narrow range would imply greater stability in the inter-annual variability of the PSC limit. The floor and ceiling would be imposed at a lower breakpoint and an upper breakpoint of the index, respectively (Figure 1).

Cliff. A low value of the index where the PSC limit would be further reduced (possibly to zero) as a precaution due to concerns about the stock and fisheries (Figure 1).

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

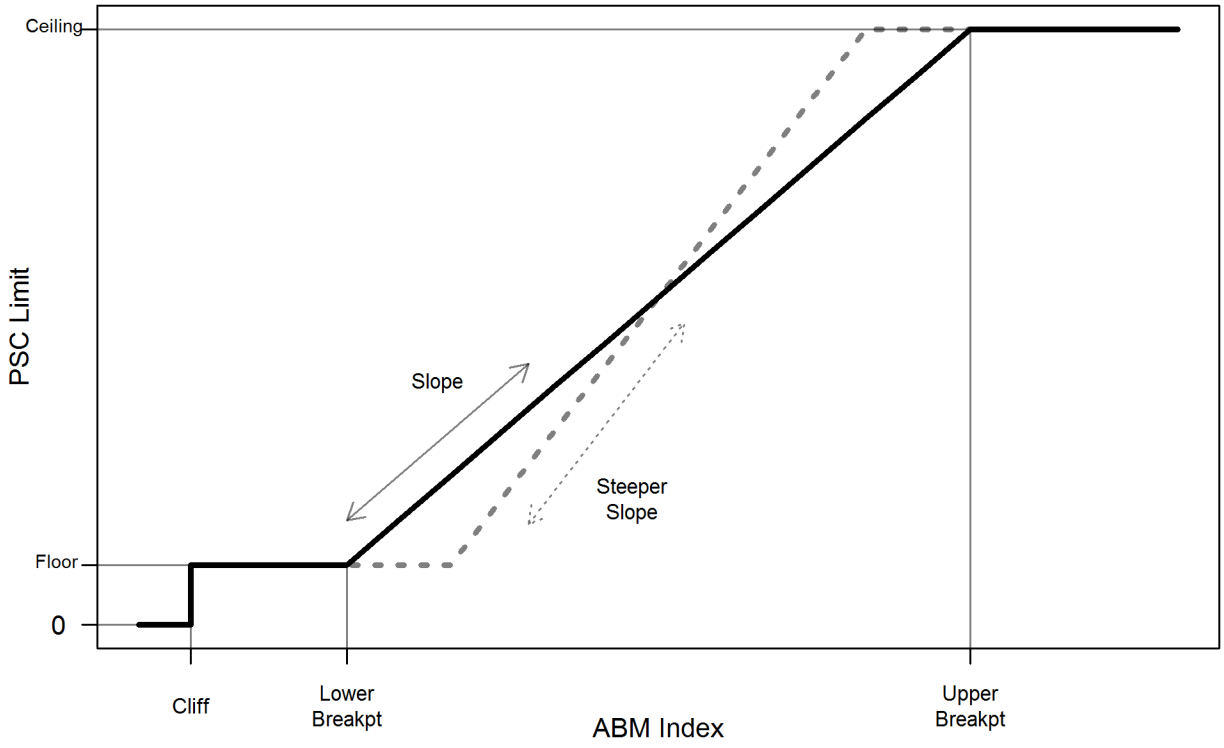

Figure 1. Illustration of control rule outcome or PSC limit (vertical scale) and standardized index or abundance estimate (horizontal scale) with considerations for floor and ceilings etc. as labeled.

4.2 Types of control rules

Control rules can be formulated in many different ways and include many different indices to determine a PSC limit. We generalize control rules as being continuous or discrete, and by the number of dimensions. Starting with a one-dimensional continuous control rule, as shown in Figure 1, other types of control rule formulations are extensions of this simple formulation. The simple control rule and some examples from other fisheries are described below followed by more complex extensions incorporating additional features and indices.

In the illustrative examples below, common parameters for a control rule were used to provide an example of PSC limits. Many arbitrary choices were made in these examples, but some numbers (e.g., starting point) are based on the Council's elements and option from the October motion. A ceiling of 4,426 t and a starting point equal to 3,515 t (when the standardized index is equal to 1.0) were used for all examples. A floor of 1,000 t was an arbitrary choice to illustrate some contrast in the control rule. In some examples, 500 t was used as an even lower floor, or 0 t was used if a cliff was incorporated. Values of the standardized index for classification as low, medium, high, etc were arbitrary choices that were chosen to illustrate the control rule and are not recommendations.

These examples are not meant specifically as an analysis of the control rules. Instead they provide a description of the control rules and may help in identifying appropriate alternatives based on the differences and similarities between examples.

4.2.1 One-dimension linear control rules

A one-dimension linear control is shown in Figure 1 and the PSC limit is determined from a single index (thus one-dimension). Any change in the value of the index results in a change in the PSC limit (continuous), within the floor and ceiling if defined. Examples of one-dimension linear control rules used by NPFMC include Pacific herring PSC limits and EBS snow crab trawl PSC limits.

Amendment 16a to the BSAI groundfish FMP established bycatch management measures for Pacific herring in groundfish trawl fisheries in 1991 (NPFMC 1991). The PSC limit is determined by applying a percentage (slope) to the aggregate biomass (index) of Pacific herring. In the development of alternatives, the Council considered a range of percentage rates applied to the overall estimated biomass of herring in the eastern Bering Sea. Prior to the analysis, exploitation rates by groundfish trawl vessels were estimated to have increased from less than 2% in 1983 to 4%-7% in 1989. At that time herring stocks in nearly all Bering Sea areas were declining prompting the need for some action to further limit the bycatch of herring by trawl gear (NPFMC, 1991). The Council selected 1% as the appropriate rate to apply to the aggregate biomass of herring as a PSC limit. This limit is specified based on updated information on the appropriate biomass estimate for the Bering Sea herring stock by the State of Alaska annually during the specifications process.

The control rule for EBS snow crab builds upon the simplicity of the Pacific herring control rule with a continuous control rule established as a percentage of biomass but with additional features of a floor and a ceiling (Figure 2). EBS snow crab trawl PSC limits are based on the total abundance of snow crab as indicated by the NMFS standard trawl survey. The PSC limit is set at 0.1133% of the snow crab abundance index, with a minimum (floor) of 4.5 million snow crabs and a maximum (ceiling) of 13 million snow crabs (Figure 2)[3]. The limit is then apportioned to fishery categories during the annual specifications process.

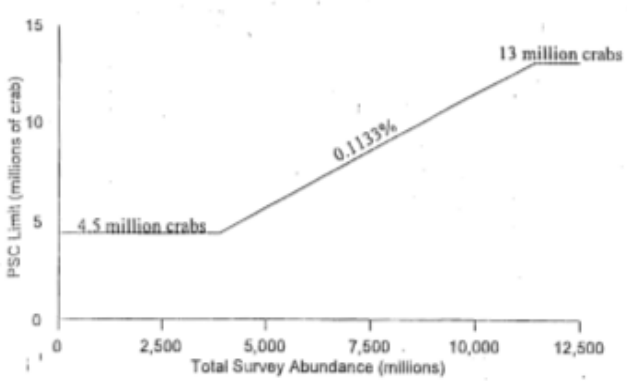

Figure 2. Control rule for snow crab. PSC limit as a function of total survey abundance in millions of crab.

4.2.2 One-dimension stair-step control rules and lookup tables

The one-dimension continuous control rule can be broken into discrete steps at specified index values to create a stair-step control rule (Figure 3). At each of these breakpoints, the PSC limit would change to a new value, but remain static between breakpoints. The breakpoint where the PSC limit would go to zero when the index is below that value is similar to a cliff in the one-dimension linear control rule. The one-dimension stair-step control rule can also be presented as a lookup table, where the index values between each breakpoint would define a PSC limit (Table 2).

[3] This limit is further reduced by 150,000 crabs (not pictured in the figure shown here). In recent years the abundance of snow crab has been taken from the model estimate of survey biomass.

The stair-step control rule potentially results in dramatic changes in the PSC limit at the specified breakpoints. This may result in situations where variability in PSC limits is large because the index is close to a breakpoint and may fluctuate around this breakpoint in subsequent years. This would result in a lack of stability or predictability of the PSC from year to year. One potential modification would be to incorporate a linear ramp in the PSC limit at the breakpoints to reduce the dramatic change when near that breakpoint, as described in Appendix 8.3. This can reduce the large jump at a breakpoint and it does add complexity to the control rule. NMFS has used "floors" and "ceilings" to smooth allocation amounts in the charter and commercial halibut allocations for Areas 2C and 3A to avoid dramatic changes (Figure 4.

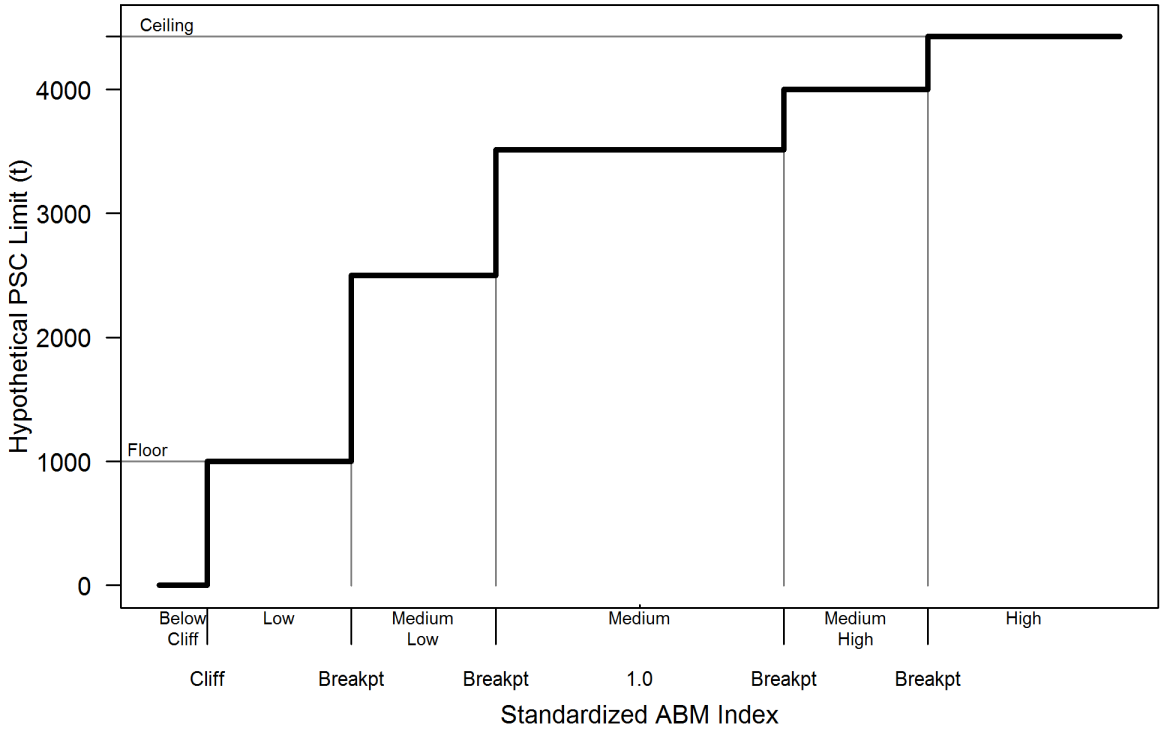

Figure 3. An example of a stair-step control rule with arbitrary classifications between breakpoints of the index shown along the horizontal axis. A starting point of 3,515 t is associated with a value of 1.0 for the standardized index, an arbitrary ceiling of 4,426 t, and an arbitrary floor of 1,000 t are incorporated for illustrative purposes. The hypothetical PSC limit is zero when the index value is below the cliff breakpoint.

Table 2. A one-dimension stair-step control rule (Figure 3) presented as a lookup table with hypothetical, arbitrary values for a PSC limit and arbitrary classifications of the index.

Arbitrary Index Classification	**Below Cliff**	**Low**	**Medium Low**	**Medium**	**Medium High**	**High**
Hypothetical PSC limit	0	1,000	2,500	3,515	4,000	4,426

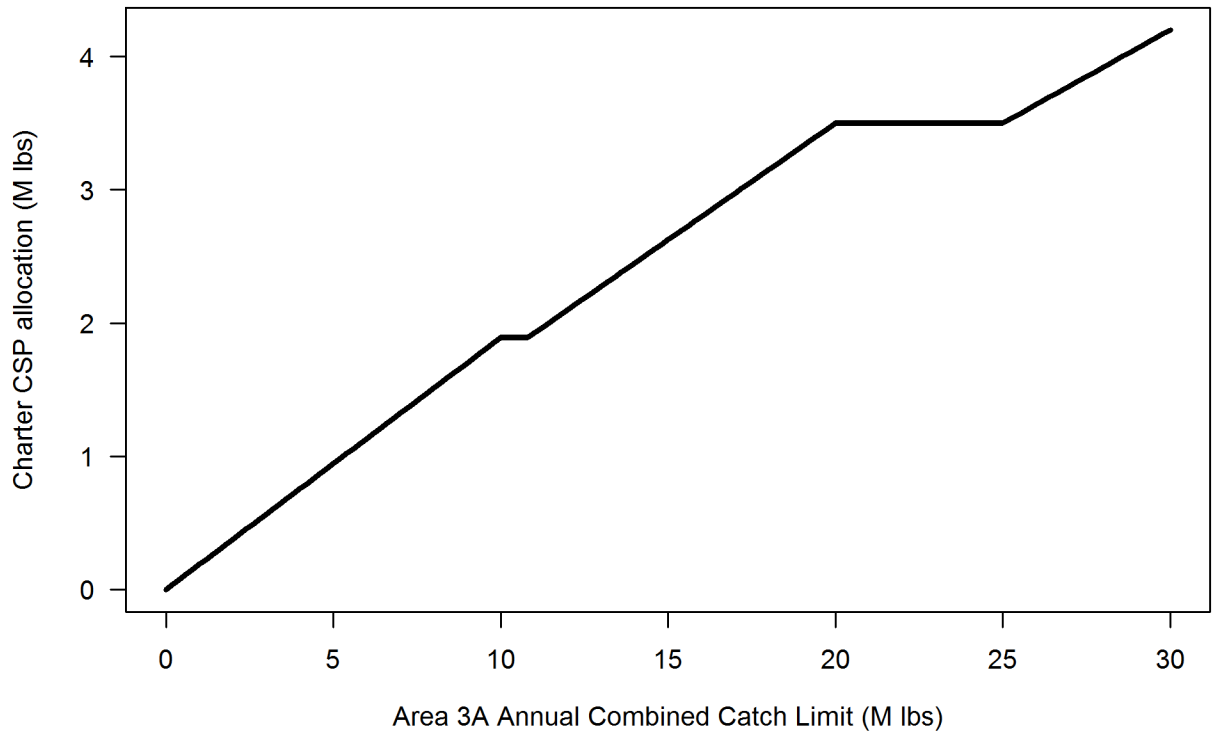

Figure 4 A hybrid control rule with continuous components and stair-step components that is used to allocate Pacific halibut catch limits between the commercial and charter halibut fisheries in IPHC Regulatory Area 3A.

4.2.3 Multidimensional control rules

The control rules described above use a single index to determine a PSC limit. Multiple indices can be incorporated by combining the indices before applying them to the control rule, thus maintaining the one-dimension control rule with a single, but combined, overall index. Defining the method to combine the indices, including the weight given to each, can be challenging. However, once the decision about how to combine them is made, the dimensionality is reduced to a single dimension, thus reducing the complexity of the control rule[4].

Alternatively, the multiple indices can be incorporated individually by expanding the dimensionality of the input to the control rule. This is easiest to describe using and expanding the one-dimension lookup table described above (Table 2). Using two indices (EBS shelf trawl survey index and the IPHC setline survey index in Area 4ABCDE) an example of a two-dimensional lookup table is shown in Table 3. One dimension (rows) contains levels of the IPHC setline survey index in Area 4ABCDE, and the second dimension (columns) contains levels of the EBS shelf trawl survey index. These two dimensions are independent, and the number of levels may differ for each dimension. The number of levels for each dimension will be referred to as the **resolution**. For example, Table 3 is a 3X6 lookup table and each dimension contains discrete bins where management changes (i.e., PSC limit) occur.

[4] Previous ABM examples as listed in Table 1 (and considered in Section 6 as ABM 2) used equal weighting to combine the two indices into a single index and reduced the complexity to a single dimension to which a control rule could be applied.

Table 3. A multidimensional lookup table to set PSC limit based on the level of two indices. The table would be filled in with PSC limits that can be determined in many different ways. For example, they may be *ad hoc*, or based on results of control rules for the specified ranges.

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

A potential downfall of a low resolution is that large changes in the PSC limit may occur between cells, and decision making may become challenging when uncertainty spans across cells. For example, if the IPHC setline survey index is on the Medium and High boundary, and the resulting PSC limit is quite different between those two categories, it may result in a difficult decision for managers and instability in PSC limits for stakeholders. The transitions between categories could be smoothed using a linear, or other type of, ramp (see Appendix 8.3). Or, the resolution could be increased to reduce differences in the PSC limit between categories. Increasing the resolution becomes more like a continuous control rule in each dimension, and using a lookup table, instead of simply defining an equation to determine the PSC limit, becomes more cumbersome.

The management outcomes (i.e., PSC limit) in the lookup table can be determined in many ways. Four possible methods are listed here and described below.

1. Ad hoc specification of the PSC limit for each cell.
2. Use two separate control rules, one for each index. The single PSC limit is determined from the combination of the two control rules. For example, it could simply be the average of the outcomes of each control rule, or it could use the more constraining outcome from the two control rules.
3. A control rule for one index, but features change depending on the other index (e.g., slope changes for EBS trawl survey index depending on setline survey, the lookup table changes, or changes to the starting point).
4. A multiplier on the PSC limit for specific combinations of index levels (i.e., specific cells).

Separate control rules for each index

Separate and independent control rules (e.g., Figure 1) can be defined for each index of a multidimensional lookup table, and then the outcome of each control rule can be combined to produce a single management outcome (i.e., PSC limit). As with combining the indices before inputting them into a control rule, determining the appropriate method to combine the management outcomes into one can be difficult. One method is to determine the management outcome from each control rule, and then combine them in some way to determine a PSC limit. Besides typical averages or weighted means, another option to consider is to use the most constraining management outcome. An example of this is shown in Table 4 and shows that the PSC limit would be low when either index is low, and high only when they both are high.

Table 4a. Example lookup tables to set illustrative PSC limit based on the level of two indices with the PSC limit set at the level of the index that is most constraining. For example and illustration of potential customization, at low levels of halibut abundance observed by the IPHC setline survey, the PSC limit is set at a very low level regardless of the value of the EBS shelf trawl survey index (Table 4a). Vice versa, Table 4b shows extra precaution at low levels of halibut abundance observed by the EBS shelf trawl survey index, the PSC limit is set at a very low level regardless of the value of the IPHC setline survey.

		EBS shelf trawl survey index		
		Low	***Medium***	***High***
IPHC setline survey index in Area 4ABCDE	***High***	Low 1,000	Medium 3,515	High 4,426
	Medium	Low 1,000	Medium 3,515	Medium 3,515
	Low	Very Low 500	Very Low 500	Very Low 500

Table 4b

		EBS shelf trawl survey index		
		Low	***Medium***	***High***
IPHC setline survey index in Area 4ABCDE	***High***	Very Low 500	Medium 3,515	High 4,426
	Medium	Very Low 500	Medium 3,515	Medium 3,515
	Low	Very Low 500	Low 1,000	Low 1,000

The lookup table in Table 4 has a low resolution (3X3) and using arbitrary control rules (creating hypothetical numbers for these illustrative examples) to fill in this lookup table shows the relationship between continuous control rules and lookup tables. As the resolution increases, the lookup table becomes analogous to a multidimensional continuous control rule. Figure 5 shows two arbitrary control rules that are used to fill in a very high resolution lookup table shown in Figure 6. Increasing the resolution has the benefit of a smaller change in the PSC limit when moving between cells, but at the expense of complexity and decreased ability to easily determine the PSC limit from a table.

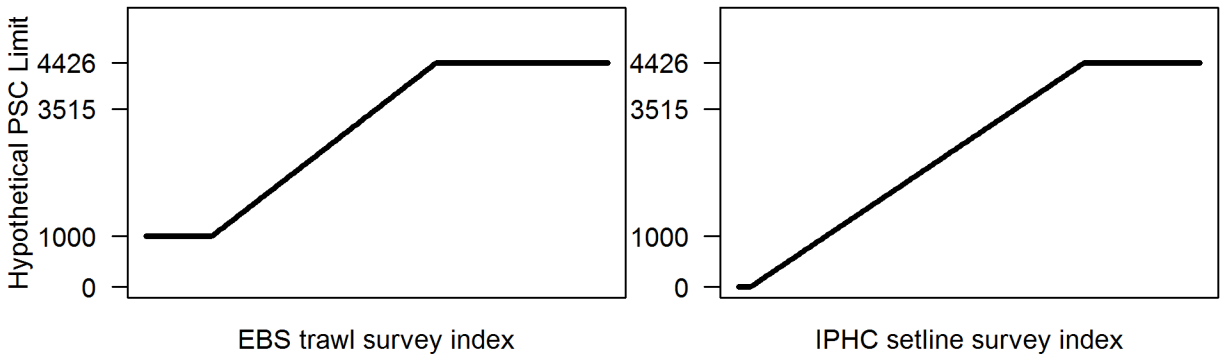

Figure 5. An example of two arbitrary, independent control rules indexing the PSC limit to the EBS shelf trawl survey index and the IPHC setline survey index that could mimic the behavior in the lookup table shown in Table 4a. The features of the control rule were arbitrary decisions that mostly match other examples for illustrative purposes. The PSC limit is 3,515 t when either standardized index is 1.0, and both control rules have an arbitrary ceiling of 4,426 t (matching options specified by the October Council motion, Section 2.2). The floors of 1,000 t and 0.0 t are arbitrary choices for illustrative purposes. Determining the PSC limit from the most constraining result, the PSC limit would go to very low levels at low levels of the IPHC setline survey.

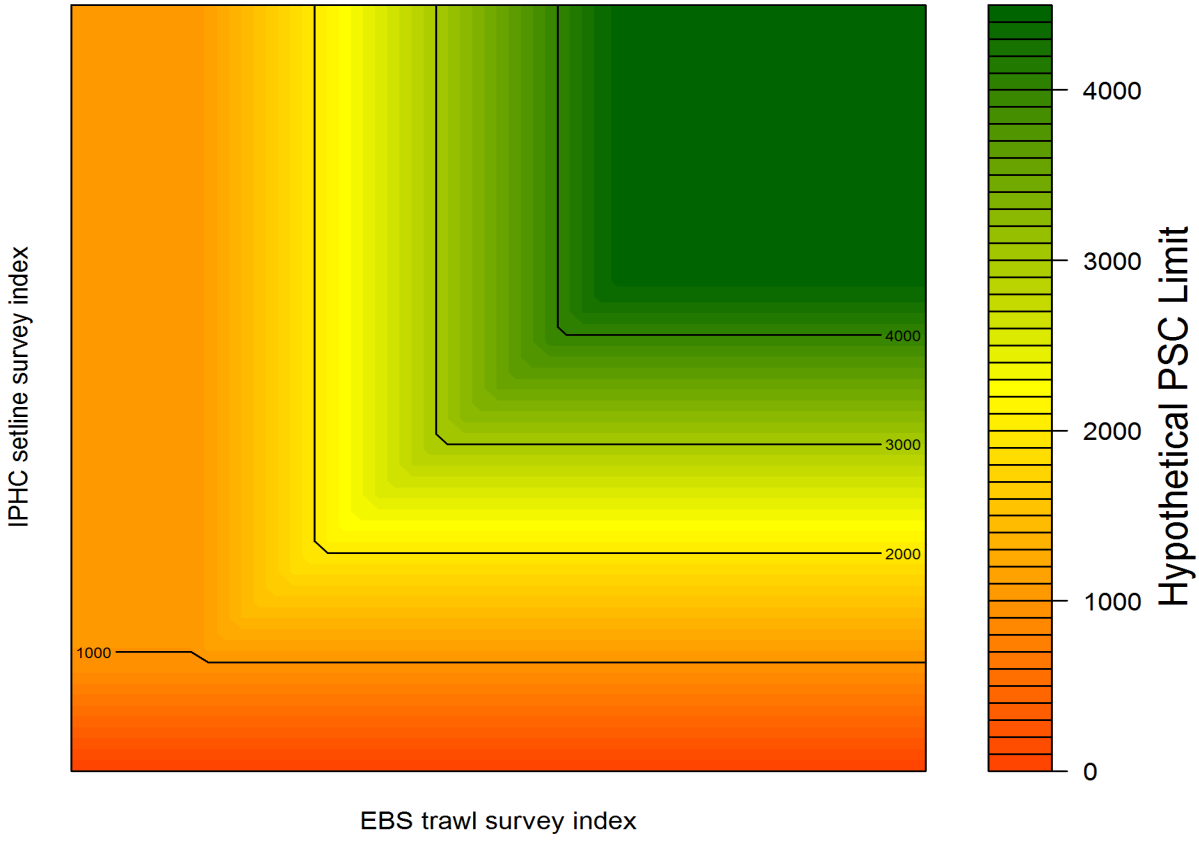

Figure 6. An example of a multidimensional lookup table with high resolution that uses the same hypothetical procedure described in Table 4.

These examples provide a general description of multidimensional lookup tables and control rules and show the relationship between the two. The examples use the constraining PSC limit determined from each control rule, but other procedures may be used. For example, using a weighted average of the PSC limits from both control rules is another valid option. Additionally, the application of the ceiling and floor may occur when determining the PSC limit from each control rule, or after determining the final outcome (e.g., the constraining value, weighted mean, etc.). It is likely that a floor and ceiling would be defined as an overall ceiling and floor, so would be defined after determining the PSC limit from all indices.

Control rule features for index 1 change with the level of index 2

Another method to use two indices and fill in a lookup table is to use a control rule with one index, but certain features of that control rule (e.g., slope, ceiling, floor, or starting point) are dependent on the second index. This can be a hybrid between a continuous control rule and a lookup table, where one index uses a continuous control rule while the other index results in a discrete change to that control rule (Figure 7). However, it could also be used to simply fill in a two-dimension lookup table (Table 5).

For example, say that the EBS shelf trawl survey index uses a control rule to define the PSC limit, and the starting point is defined by the state of the IPHC setline survey index in Area 4ABCDE. When the IPHC setline survey index is at intermediate (medium) values, the starting point may be, say, 3,515 t. But, when the IPHC setline survey index is high, the starting point may be higher, thus increasing the PSC limit (Figure 7). Conversely, when the IPHC setline survey is low, the starting point may be lower, resulting in a lower PSC limit (Figure 7). The starting point shifts the control rule up and down the y-axis and this example essentially takes extra precaution when the IPHC setline survey is low and allows for additional PSC when the IPHC setline survey is high.

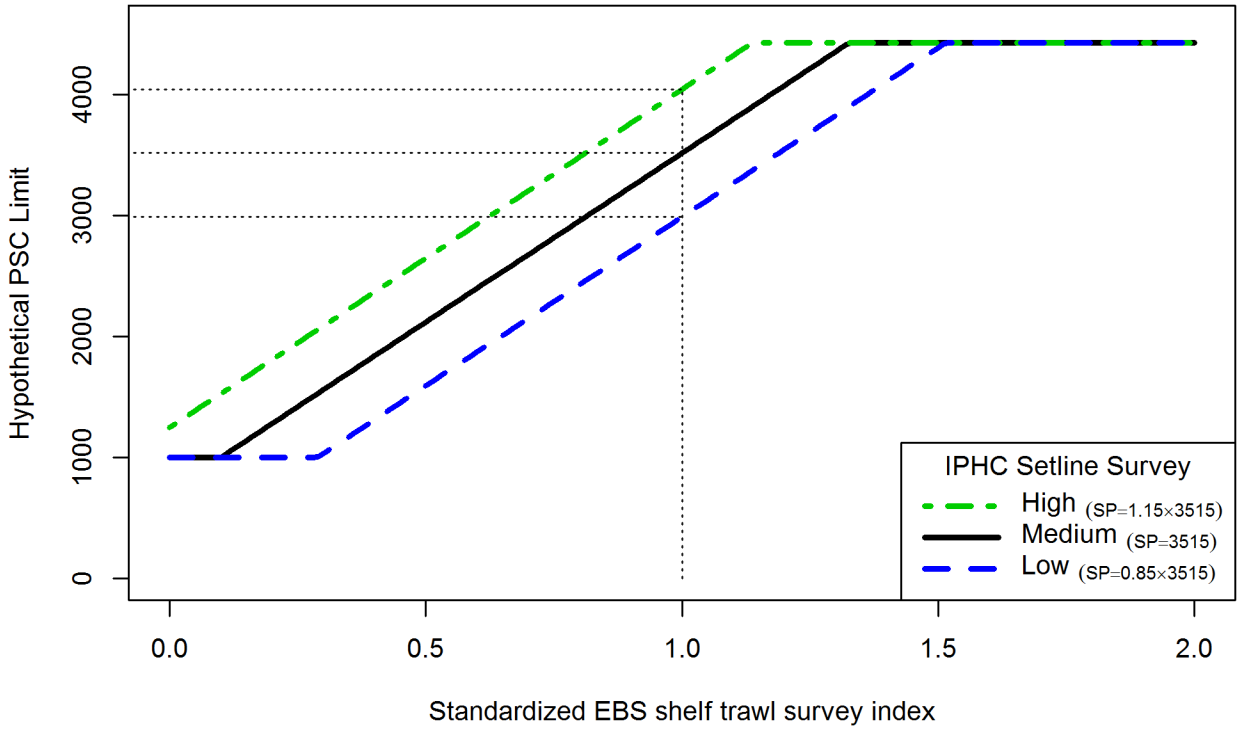

Figure 7. A hypothetical example of a control rule based on the standardized EBS shelf trawl survey index that shifts up or down depending on the level of the IPHC setline survey index in Area 4ABCDE. The starting point for the PSC limit in this hypothetical example is 3,515 t when the EBS trawl survey a value of 1.0 (grey dotted lines). When the IPHC setline survey is at a medium value the starting point is 3,515 t. The starting point is an arbitrary 15% higher or lower when the IPHC setline survey index is high or low, respectively.

Table 5. A hypothetical example of a lookup table based on an arbitrary control rule indexed to the standardized EBS shelf trawl survey index that shifts up or down depending on the level of the IPHC setline survey index in Area 4ABCDE (see Figure 7). The hypothetical values in the cells are illustrative and calculated from the arbitrary control rule using the midpoint of the arbitrary range specified for the standardized EBS shelf trawl survey index.

			Standardized EBS shelf trawl survey index (arbitrary range)					
		Multiplier on starting point	**Very-low (0.0–0.1)**	**Low (0.1–0.5)**	**Medium Low (0.5–0.8)**	**Medium (0.8–1.2)**	**Medium High (1.2–1.5)**	**High (>1.5)**
IPHC setline survey index in Area 4ABCDE	**High**	**1.15**	1,388	2,086	3,064	4,042	4,426	4,426
	Medium	**1.00**	1,000	1,559	2,537	3,515	4,426	4,426
	Low	**0.85**	1,000	1,032	2,010	2,988	3,966	4,426

Multiplier on the PSC limit

An alternative to using a second index to adjust the features of a control rule, you may use the second index, possibly in combination with the first index, to modify the outcome of the control rule (i.e., PSC limit). A simple example, following above, would be to multiply the PSC limit by a value greater than 1 when the IPHC setline survey is high, and multiply the IPHC setline survey by a value between 0 and 1 when the IPHC setline survey is low. Figure 8 shows the outcome when multiplying by 1.15 or 0.85 when the IPHC setline survey is high or low, respectively. Ceilings and floors are applied after the multiplication.

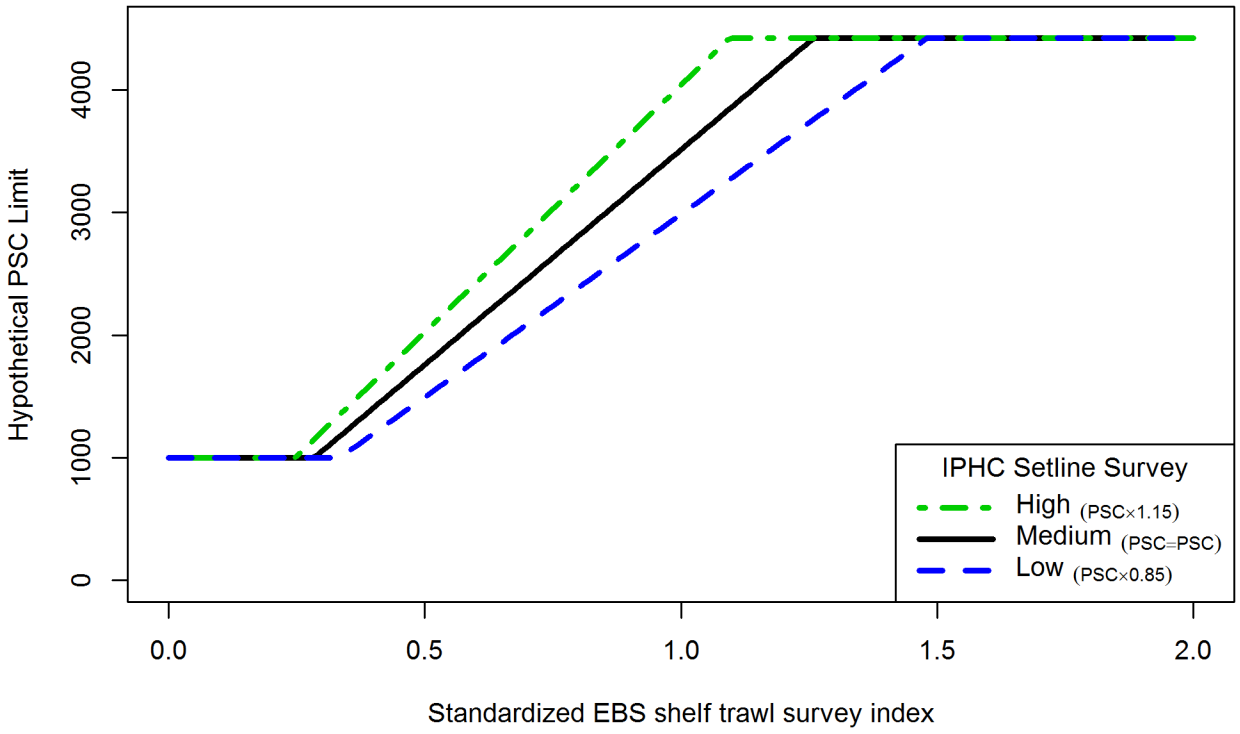

Figure 8. The hypothetical PSC limit determined from a continuous control rule that is multiplied by arbitrary multipliers of 1.15 or 0.85 when the IPHC setline survey is high or low, respectively. An arbitrary floor at 1,000 t and an arbitrary ceiling at 4,426 t are applied after the multiplication.

A different method may be to use both indices in combination to determine a multiplier. For example, if both indices are high then the PSC limit is increased using the multiplier, and when both indices are low, the PSC limit is reduced. The concept here is that when both indices are in agreement, then further adjustment is justified, otherwise the single index is sufficient to determine the PSC limit. This is easiest to illustrate in a lookup table, as in Table 6, but can also be displayed as a continuous control rule relative to the EBS shelf trawl survey index (Figure 9). Note that this results in fairly dramatic changes in PSC limit between states of the surveys due to the resolution of the table.

Table 6. The hypothetical PSC limit determined from a control rule referenced to the EBS shelf trawl survey index that is multiplied by an arbitrary multiplier of 1.15 when the two indices (EBS shelf trawl survey and IPHC setline survey) are both at high values, or an arbitrary multiplier of 0.85 when both indices are at low values. An arbitrary floor at 1,000 t and an arbitrary ceiling at 4,426 t are applied after the multiplication. Arbitrary values of 0.8 and 1.2 were chosen for the breaks to define low and high states of the standardized EBS shelf trawl survey. Shaded cells indicate cells where the hypothetical PSC limit is multiplied by an arbitrary multiplier. Note that the high:high combination hit the arbitrary ceiling.

		Standardized EBS shelf trawl survey index (arbitrary range)		
		Low (0.0-0.8)	***Med (0.8-1.2)***	***High (>1.2)***
Standardized IPHC setline survey index in Area 4ABCDE	**High(>1.0)**	1,406	3,515	4,426
	Low (<0.1)	1,195	3,515	4,306

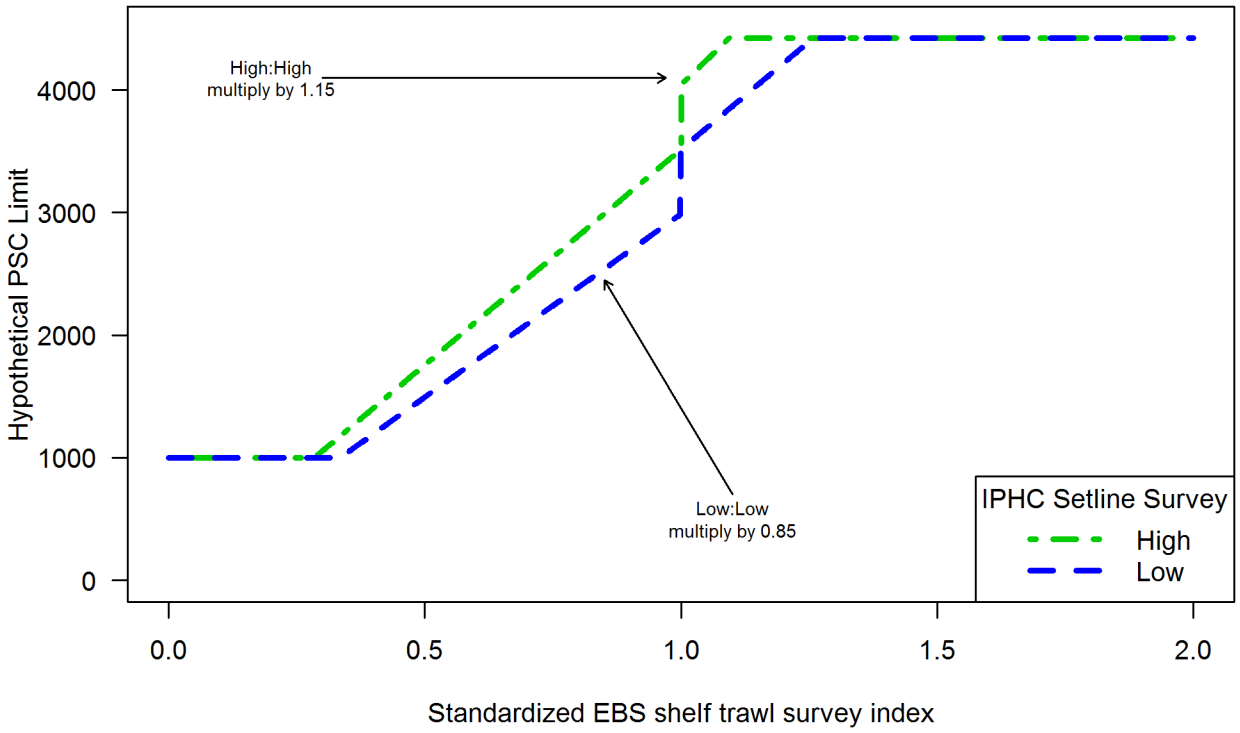

Figure 9. The hypothetical PSC limit determined from a continuous control rule that is multiplied by 1.15 when the two indices are both above a standardized value of 1.0, or 0.85 when both indices are below a standardized value of 1.0. An arbitrary floor at 1,000 t and an arbitrary ceiling at 4,426 t are applied after the multiplication.

4.3 Recommendation for control rules when developing alternatives

The Council's October motion included three options to describe control rules (linear, decision table and multi-dimensional). Note that what the Council referred to as a decision table is called a lookup table in this document. These three options can all be thought of as a continuum and are not necessarily discrete options but are a result of decisions made in other elements of the Council's October motion. For example, a multidimensional control rule will be a necessity if two indices are chosen to be used independently (i.e., not combined into a single index). Furthermore, options under the responsiveness element would determine whether or not a linear control rule or lookup table was used. Therefore, the control rule is a linear function defined by some options defining alternatives, and presentation of the PSC limit (e.g., resolution of a lookup table) represents a different set of decisions.

For the reasons above, we have recommended that the Council's Element 2, as currently worded, be removed and instead an option for each alternative moving forward would address the presentation of the PSC limit. Any of the control rule formulations described in Section 4.2 could be incorporated into the Council's suite of alternatives based upon the dimensions of the indices selected and the desired complexity of the control rule. Any of these may be presented as both a continuous control rule and/or a lookup table. The desired resolution of the lookup table is a separate decision related to the presentation and stability of the PSC limit. Based upon this recommendation as well as the previous one to structure alternatives around the abundance index and application, we have renumbered the Council's Elements and Options into five elements with modifications as described below. For simplicity, we use a linear control rule in the strawman ABM examples, but as explained above, a lookup table is simply a lower resolution of a linear control rule.

Therefore, we do not specifically recommend control rules to consider, but to use the revised elements and options structure to define the qualities of a control rule. The analysts can then build control rules from those options to evaluate further. Specifying additional "anchor points" for the control rule, such as at what value of the index does the floor apply, may provide additional guidance, but is not necessary. Those anchor points may be derived from the other options, and when not, the analysis can span an appropriate range to provide an evaluation for decision making. Overall, specifying a succinct set of options will guide the analysts to create specific control rules for evaluation that will cover the range of interest.

5. Revised Elements and Options

We refined the elements here to reflect a clearer structure to develop ABMs by separating the indices from how they are applied to arrive at a PSC limit. As a result, Element 1 from the Council's October 2017 motion is now embedded in the strawman ABMs in this document and will eventually be the basis for alternatives for analysis (choosing which is the action scheduled for the Council in April 2018). Elements 3-6 of the Council's October motion have been renumbered here by staff as Elements 1-4. We added an element 5, which incorporates the original Element 2 component of the Council's October motion, to illustrate comparisons of using a lookup table (i.e., stairsteps) in the control rule, while also adding options for dimensions beyond the two recommended abundance indices (e.g., IPHC's 30:20 control rule based on stock status, as requested in the October 2017 motion). See Appendix 8.1 for a roadmap to indicate how the Council's October motion has been mapped into the revised elements and options shown here.

(Revised) Element 1: PSC Limit responsiveness to abundance changes

We propose modifying this element for the following options related to the slope of the control rule which more directly relates to the original intent of this element:

Option 1: PSC limit varies proportionally with change in abundance index (1:0.5): slope = 0.5 (LoResponse for ABM 1 only option)

Option 2: PSC limit varies proportionally with change in abundance index (1:1): slope = 1 (default)

Option 3: PSC limit varies proportionally with change in abundance index (1:2): slope = 2 (HiResponse for ABM 1 only option)

These options are shown in the scenarios that follow for ABM 1-baseline (only) to demonstrate the impact of modifying the slope of the control rule. For the remaining elements we use Option 2 as a default to compare other features across the ABMs simulated.

(Revised) Element 2 Starting point for PSC limit

Option 1. 10% below 2016 PSC use (2,119 t)

Option 2. 2016 PSC use (2,354 t)

Option 3. 2016 PSC limit (3,515 t) default

Option 4. 10% above 2016 PSC limit (3,867 t)

Option 5. Additional value within range of Options 1-4

(Revised) Element 3 Maximum PSC limit (ceiling)

Option 1. 2016 PSC limit (3,515 t)

Option 2. 2015 PSC limit (4,426 t) default

Option 3. No ceiling

Option 4. Additional value to be selected

(Revised) Element 4 Minimum PSC limit (floor)

Option 1. No floor (PSC goes to 0)

Option 2. 2016 use (2,354 t) default

Option 3. Additional value to be selected

(Revised) Element 5 Additional features in the control rule

Option 1. A lookup table with a defined resolution for each axis

Option 2. IPHC Control Rule – PSC limit goes to zero at 20% stock status

Option 3. The O26:U26 ratio defines different states of the control rule

The options in Element 5 were not used in the examples provided here because the details of Options 1 and 3 have not been determined, and IPHC stock status in the assessment year has never been estimated to have been below 30%.

6. Strawman ABM Examples and Evaluation of Control Rule Behavior

6.1 Strawman ABM examples

The following shows the list of example ABM alternatives and subset (**in bold**) that have been included in these initial evaluations to demonstrate the behavior of control rule options. Each ABM meets the first Council objective in indexing halibut PSC to abundance. The degree to which specific options are intended to address the remaining objectives (as listed in Section 2.3) is discussed in the design of the ABM alternatives. Conclusions related to whether these options address the objectives adequately are not possible in this preliminary analysis, however a discussion of the options as they relate to and contrast within and across ABMs is provided in section 6.2. The revised Element 5 is omitted for now in this investigation. However, it should be noted that Element 5 option 1, depending on the resolution selected, could address objective 5 to provide for some stability in PSC on an inter-annual basis as discussed in Section 4. Element 5 option 2 would more directly address objective 2 to protect spawning stock biomass

of halibut particularly at low levels of abundance. Element 5 option 3 could be developed to address objective 4 to provide for directed fishing opportunities in the Bering Sea.

The selected ABMs with the specified options are considered in the evaluation in order to show contrast between the different options. These examples have been organized using the revised Elements and Options. Here, ABM 2 is not investigated because it was previously the focus of multiple discussion papers using equal weighting of the indices. It is anticipated that, in constructing a suite of alternatives for analysis, the Council would organize alternatives around an abundance index (or indices) and apply them by gear type. However, in drafting alternatives the Council may wish to narrow the range of indices to be examined and the revised elements and options to avoid overly complicating the analysis.

ABM 1 (baseline for analysis – not a strawman alternative)

Index a single PSC limit to the EBS trawl survey that is then allocated to gear/sector according to the status quo allocation. Note that this is included as a baseline example to demonstrate how the control rule behaves differently based on the various options in Elements 1, 2, 3, and 4, without the added complexity of multiple indices. For this ABM example, the multiple options for Elements 1, 2 and 3 are investigated separately to show how changing these options influences the control rule. For Element 1 in particular, options are contrasted to show the degree to which the range of options considered results in different PSC limits. Element 1 option 1, for example, would be designed to address the Council's 5th objective of providing for some stability in PSC limits on an inter-annual basis

Element 1 – PSC limit responsiveness to abundance changes

Option 1: PSC limit is less responsive to change in abundance index (1:0.5): slope = 0.5 (LoResponse for ABM 1 only option)
Option 2: PSC limit varies with change in abundance index (1:1): slope = 1 (default)
Option 3: PSC limit more responsive to change in abundance index (1:2): slope = 2(HiResponse for ABM1 only)

Element 2 – Starting point for PSC limit

Option 1. 10% below 2016 PSC use (2,119 t)
Option 2. 2016 PSC use (2,354 t)
Option 3. 2016 PSC limit (3,515 t) default
Option 4. 10% above 2016 PSC limit (3,867 t)
Option 5. Additional value within range of Options 1-4

Element 3 - Maximum PSC limit (ceiling)

Option 1. 2016 PSC limit (3,515 t)
Option 2. 2015 PSC limit (4,426 t) default
Option 3. No ceiling
Option 4. Additional value to be selected

Element 4 - Minimum PSC limit (floor)

Option 1. No floor (PSC goes to 0)
Option 2. 2016 use (2,354 t) default
Option 3. Additional value to be selected

Note, for the evaluation of subsequent ABMs 3 and 4, only default options under Elements 1, 2, 3, and 4 are simulated and then compared against the ABM 1 baseline.

ABM 2

Index PSC to EBS trawl survey and setline survey for a single PSC limit that is then allocated to gear/sector according to the status quo allocation. This ABM example is included for discussion purposes but however it is not evaluated here for looking at the behavior of control rules. Multiple previous discussion papers have focused on this example with equal weighting on indices and are included by reference here (See Table 1 for additional information on this ABM 2 example).

ABM 3

Index trawl PSC to EBS trawl survey. Index longline PSC to setline survey.

Element 1 – PSC limit responsiveness to abundance changes

Option 1: PSC limit varies proportionally with change in abundance index (1:0.5): slope = 0.5
Option 2: PSC limit varies proportionally with change in abundance index (1:1): slope = 1 (default)
Option 3: PSC limit varies proportionally with change in abundance index (1:2): slope = 2

Element 2 – Starting point for PSC limit

Option 1. 10% below 2016 PSC use (2,119 t)
Option 2. 2016 PSC use (2,354 t)
Option 3. 2016 PSC limit (3,515 t) default
Option 4. 10% above 2016 PSC limit (3,867 t)
Option 5. Additional value within range of Options 1-4

Element 3 - Maximum PSC limit (ceiling)

Option 1. 2016 PSC limit (3,515 t)
Option 2. 2015 PSC limit (4,426 t) default
Option 3. No ceiling
Option 4. Additional value to be selected

Element 4 - Minimum PSC limit (floor)

Option 1. No floor (PSC goes to 0)
Option 2. 2016 use (2,354 t) default
Option 3. Additional value to be selected

ABM 4

Index trawl gear PSC and fixed gear PSC to both EBS trawl survey and setline survey. The trawl gear PSC is indexed to both EBS trawl and setline surveys. Here the trawl survey forms the primary index while information on the setline survey will be used as a secondary index to influence the final PSC limit after the control rule is applied. The fixed gear PSC is indexed to both EBS trawl and setline surveys, however here the setline survey forms the primary index while information on the trawl survey will be used as a secondary index to influence the final PSC limit after the control rule is applied. The secondary index modifies the final PSC when both the primary and secondary index are either above their average values or both are below their average values (the PSC is multiplied by 1.1 when both indices are above their average values and by 0.9 when both indices are below their average values). The minimum PSC (floor) and maximum PSC (ceiling) are applied as a final step such that the PSC never exceeds these values. ABM 4 can be tuned to address a range of competing objectives. This is shown in Figure 11 and further discussed in appendix 85.

Element 1 – PSC limit responsiveness to abundance changes

Option 1: PSC limit varies proportionally with change in abundance index (1:0.5): slope = 0.5
Option 2: PSC limit varies proportionally with change in abundance index (1:1): slope = 1 (default)
Option 3: PSC limit varies proportionally with change in abundance index (1:2): slope = 2

Element 2 – Starting point for PSC limit

Option 1. 10% below 2016 PSC use (2,119 t)
Option 2. 2016 PSC use (2,354 t)
Option 3. 2016 PSC limit (3,515 t) default
Option 4. 10% above 2016 PSC limit (3,867 t)
Option 5. Additional value within range of Options 1-4

Element 3 - Maximum PSC limit (ceiling)

Option 1. 2016 PSC limit (3,515 t)
Option 2. 2015 PSC limit (4,426 t) default
Option 3. No ceiling
Option 4. Additional value to be selected

Element 4 - Minimum PSC limit (floor)

Option 1. No floor (PSC goes to 0)
Option 2. 2016 use (2,354 t) default
Option 3. Additional value to be selected

6.2 Preliminary analysis of control rule features through strawmen ABMs (ABM1, ABM3, ABM4)

6.2.1 Evaluation methods

ABM1, ABM3, and ABM4 were evaluated by calculating the PSC limits that result from applying the historical values of the EBS shelf trawl and Area 4ABCDE IPHC setline survey for years 1998-2016. For reference, the surveys' halibut abundance values are provided in Figure 10.

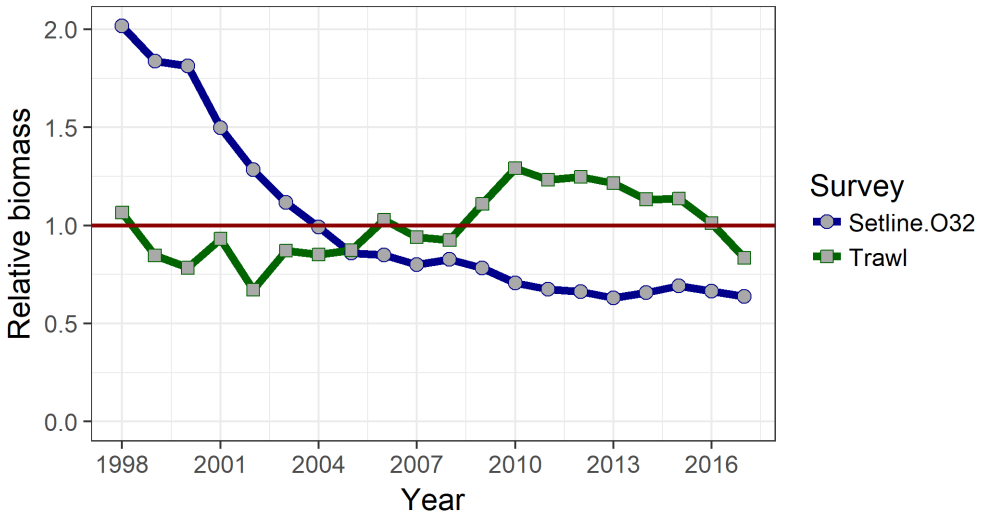

Figure 10 Historical values of Pacific halibut abundance from the EBS shelf trawl and Area 4ABCDE IPHC setline survey for years 1998-2017.

In addition, for each control rule feature or strawman ABM evaluation, a projection scenario was created to demonstrate how the feature functions in each of four situations (depicted in Figure 11):

1. both the EBS trawl survey and setline survey are above their average values,
2. the EBS trawl survey is below its average value while the setline survey is above its average value,
3. both surveys are below their average values, or
4. the EBS trawl survey is above its average value while the setline survey is below its average value.

The projection scenarios are useful because it would otherwise be difficult to demonstrate how each element will function using only historical data. The data for the projection scenarios are purposefully exaggerated to fall below and above the Council's options for minimum and maximum PSC limits. Figure 12 illustrates the data series that was used in the projection scenarios.

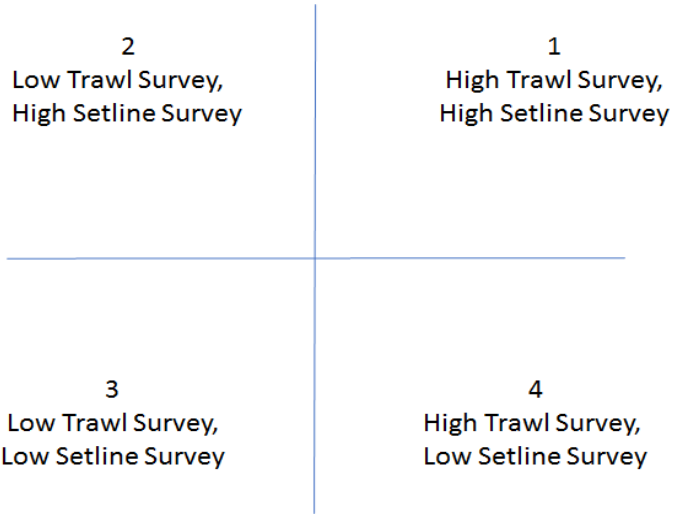

Figure 11. Four categories or quadrants that can be used as a basis for specifying objectives corresponding to the use of both the EBS trawl survey and the setline survey indices when specifying sector-specific PSC limits.

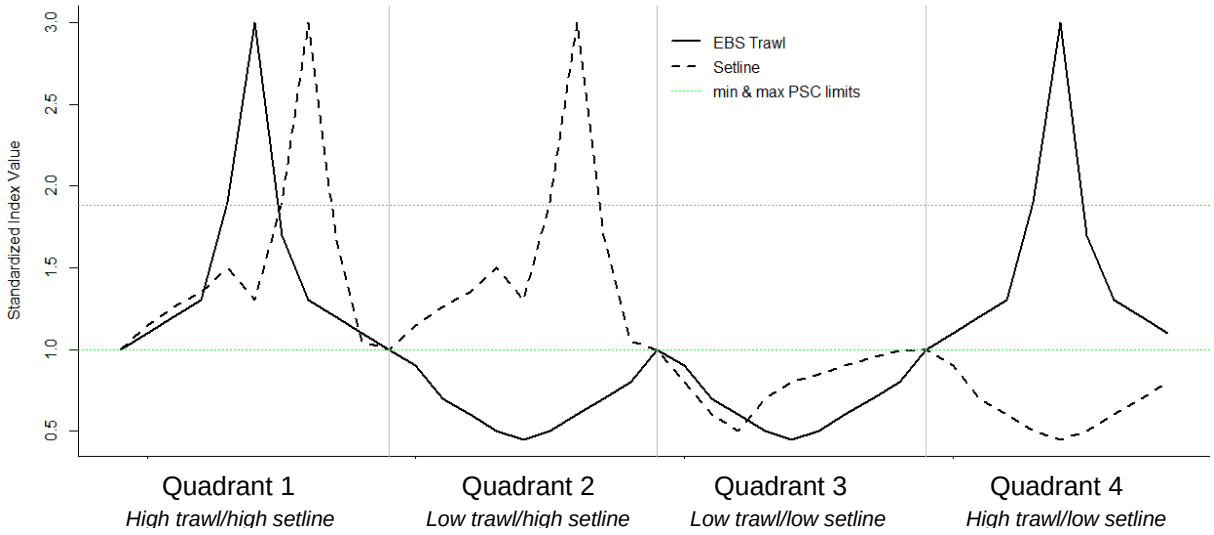

Figure 12. A what-if projection scenario for the EBS trawl and setline survey indices for 4 ten-year periods, using hypothetical data. Each ten-year period is meant to represent one of the four quadrants described in Figure 11. The data are exaggerated to purposefully fall below and above the default options for minimum and maximum PSC limits, represented with dotted green lines, to contrast how each control rule feature functions.

6.2.2 Evaluation results

This evaluation shows how different features of the control rule (as captured in the revised Elements and Options) and the strawman ABMs affect PSC limits. As described above, the evaluation was run using both historical data and projected scenarios to demonstrate what the PSC limit range would be given the elements and options.

The first series of figures examines control rule features that are captured in (revised) Elements 1 through 4, using ABM 1, the baseline ABM that indexes abundance only to the EBS trawl survey. Using ABM 1 allows the reader to see more clearly the effects of the control rule feature, without introducing the complexity of also accounting for the effects of linking to two separate abundance indices. Each Element (1-4) is evaluated separately in Figure 13 through Figure 16, and shows how PSC limits are affected by different options under that element, while holding all other elements to default values (see description in Section 6.1 about which option is considered the default under each element). Additionally, each figure includes two panels: the first, an evaluation using historical data (e.g., if the control rule had been in place during 1998-2016, what would the PSC limits have been). The second panel uses the projection scenarios described in Figure 12 to show how PSC limits would change with hypothetical high and low values for the EBS survey. Note that for ABM1, which is linked only to the trawl survey index, there is no difference in the scenarios for Quadrants 1 and 4, nor for Quadrants 2 and 3.

The following describes which elements are evaluated in which figures:

- Figure 13 evaluates the options included in (revised) Element 1, PSC limit responsiveness to abundance changes
- Figure 14 evaluates the options included in (revised) Element 2, Starting point for PSC limit
- Figure 15 evaluates the options included in (revised) Element 3, Maximum PSC limit (ceiling)
- Figure 16 evaluates the options included in (revised) Element 3, Minimum PSC limit (floor)

The next series of figures provide an evaluation between ABM 1, ABM3, and ABM4, which differ based on which and how abundance indices are used. For this analysis,

- Figure 17 compares PSC limit results under the strawman ABMs for trawl PSC limits, and
- Figure 18 compares PSC limit results under the strawman ABMs for longline PSC limits.

As with the analysis above, all other features of the control rule are kept static and use the default option as defined in Section 6.1. The evaluation for each includes separate panels for historical values and projected scenarios. Additionally, Figure 19 and Figure 20 illustrate the outcome of the strawman ABMs in terms of the total proportional allocation of the resulting halibut PSC limit among trawl and longline sectors.

Element 1 – PSC limit responsiveness to abundance changes

The two panels of Figure 13 evaluate the three options included in (revised) Element 1, applied to ABM1, which indexes halibut abundance to the EBS trawl survey only. Other elements of the control rule are set to the defaults described in Section 6.1: starting point = 3,515 t; ceiling = 4,426 t; floor = 2,354 t. Plots show ABM1 (baseline) for default (medium), low, and high responsiveness (slope) of the control rule.

Element 1, Option 1 = "LoResponse" (slope of 0.5);
Option 2 = "Default" (slope of 1);
Option 3 = "HiResponse" (slope of 2).

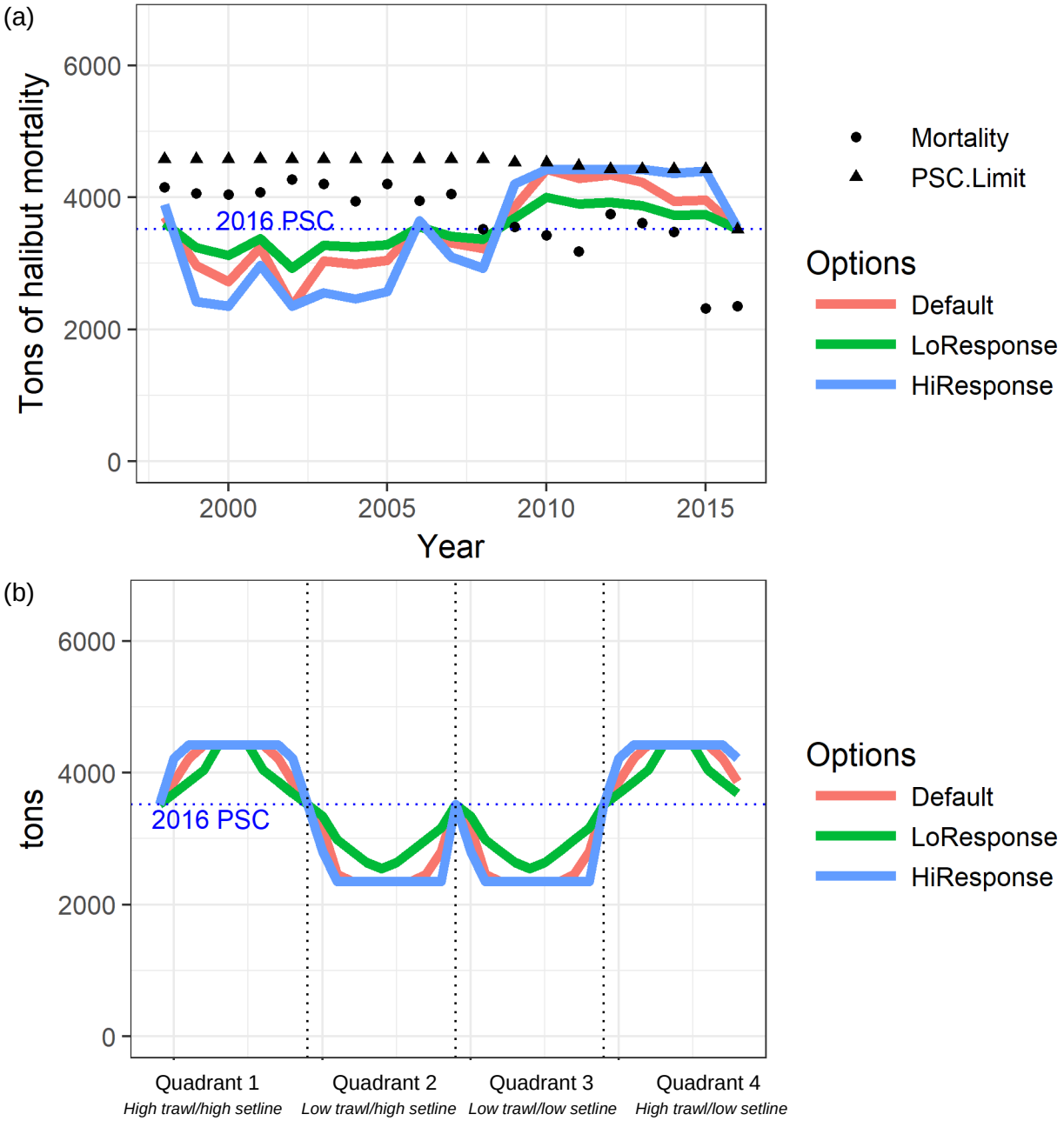

Figure 13. Evaluation of options for Element 1, PSC limit responsiveness to abundance, using (a) historical data (values of the EBS trawl survey from 1998-2016), and (b) projected scenarios that use hypothetical abundance values (as in Figure 12).

Element 2 – Starting Point for PSC limit

The two panels of Figure 14 evaluate three of the options included in (revised) Element 2, applied to ABM1, which indexes halibut abundance to the EBS trawl survey only. Other elements of the control rule are set to the defaults described in Section 6.1: responsiveness = slope of 1; ceiling = 4,426 t; floor = 2,354 t. Plots show ABM1 (baseline) for default (2016 PSC limit), low, and high starting points for the control rule.

Element 2, Option 2 = "LoStartPt" (2016 PSC use, 2,354 t);
Option 3 = "Default" (2016 PSC limit, 3,515 t);
Option 4 = "HiStartPt" (10% above 2016 PSC limit, 3,867 t).

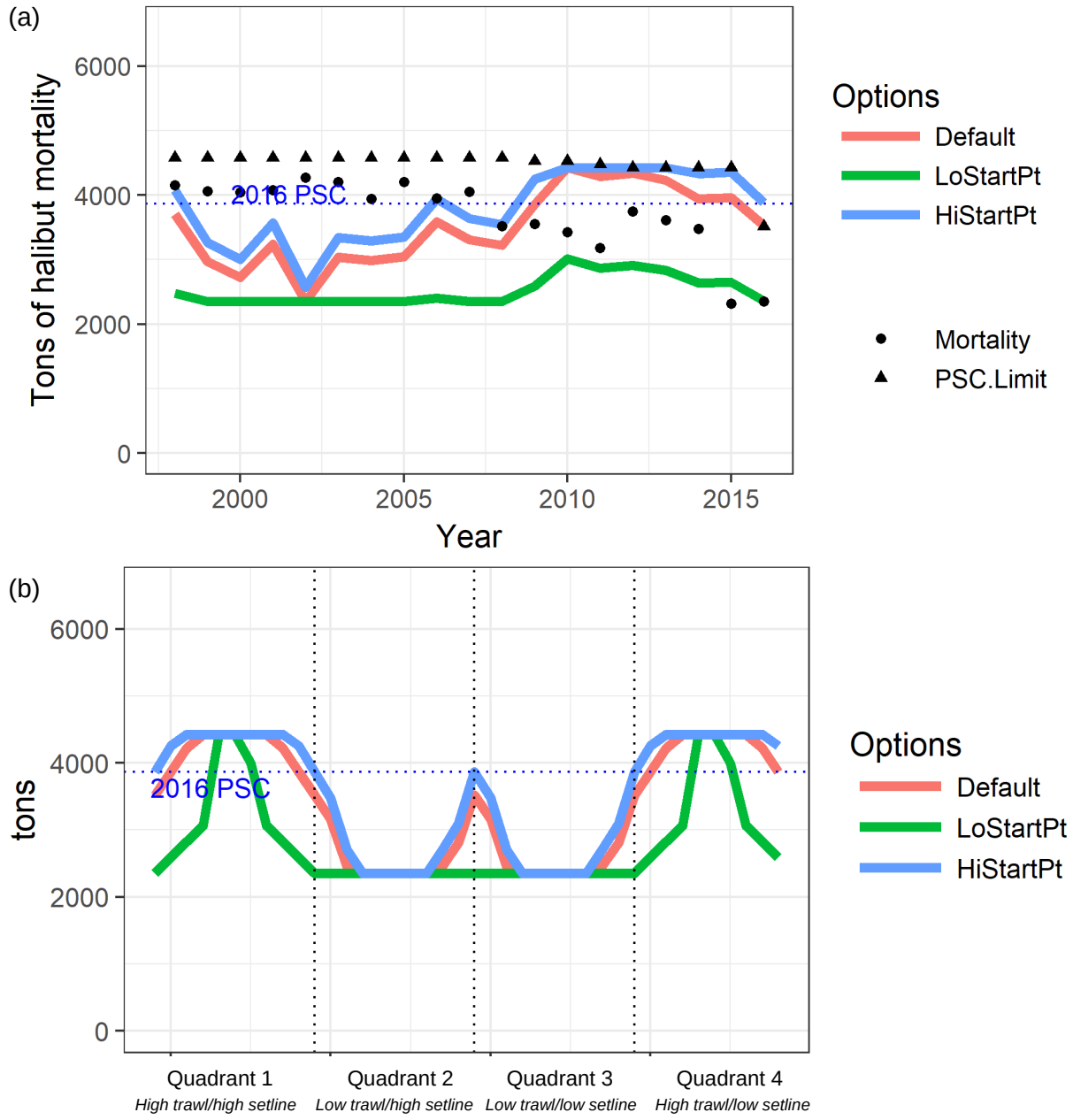

Figure 14 Evaluation of options for Element 2, Starting Point for PSC limit, using (a) historical data (values of the EBS trawl survey from 1998-2016), and (b) projected scenarios that use hypothetical abundance values (as in Figure 12).

Element 3 – Maximum PSC limit (ceiling)

The two panels of Figure 15 evaluate two of the options included in (revised) Element 3, applied to ABM1, which indexes halibut abundance to the EBS trawl survey only. Other elements of the control rule are set to the defaults described in Section 6.1: responsiveness = slope of 1; starting point = 3,515 t; floor = 2,354 t. Plots show ABM1 (baseline) for control rules with a ceiling of 4,426 t, or no ceiling.

Element 3, Option 2 = "Default" (2015 PSC limit (4,426 t);
Option 3 = "NoCeiling" (no maximum PSC limit).

Note that the "NoCeiling" line obscures the 'Default" line when they are identical.

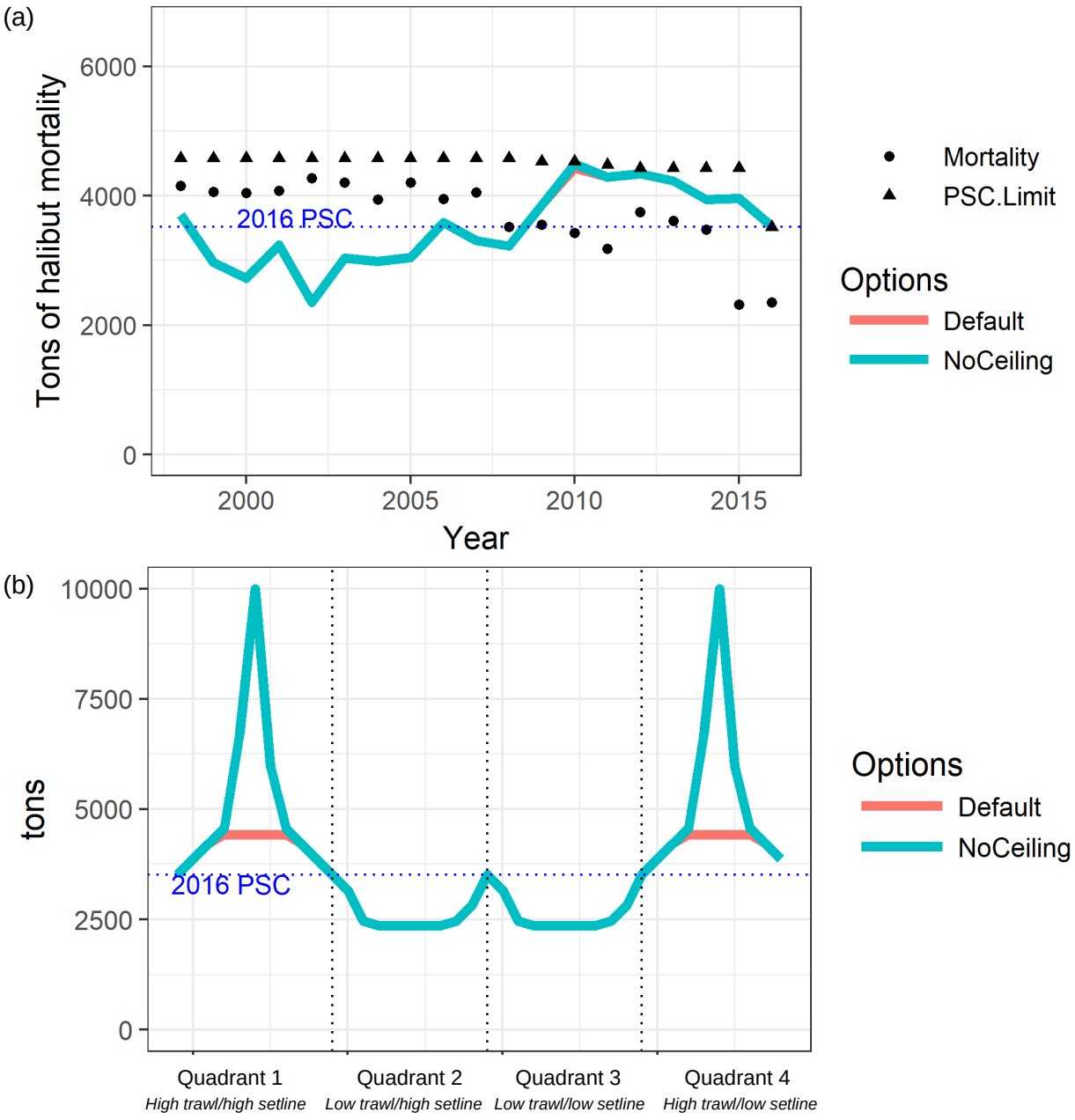

Figure 15 Evaluation of options for Element 3, Maximum PSC limit (ceiling), using (a) historical data (values of the EBS trawl survey from 1998-2016), and (b) projected scenarios that use hypothetical abundance values (as in Figure 12).

Element 4 – Minimum PSC limit (floor)

The two panels of Figure 16 evaluate two of the options included in (revised) Element 4, applied to ABM1, which indexes halibut abundance to the EBS trawl survey only. Other elements of the control rule are set to the defaults described in Section 6.1: responsiveness = slope of 1; starting point = 3,515 t; ceiling = 4,426 t. Plots show ABM1 (baseline) for control rules with a floor of 2,354 t, or no floor.

Element 3, Option 1 = "NoFloor" (PSC goes to 0);
Option 2 = "Default" (2015 PSC use (2,354 t).

Note that the "NoFloor" line obscures the 'Default" line when they are identical.

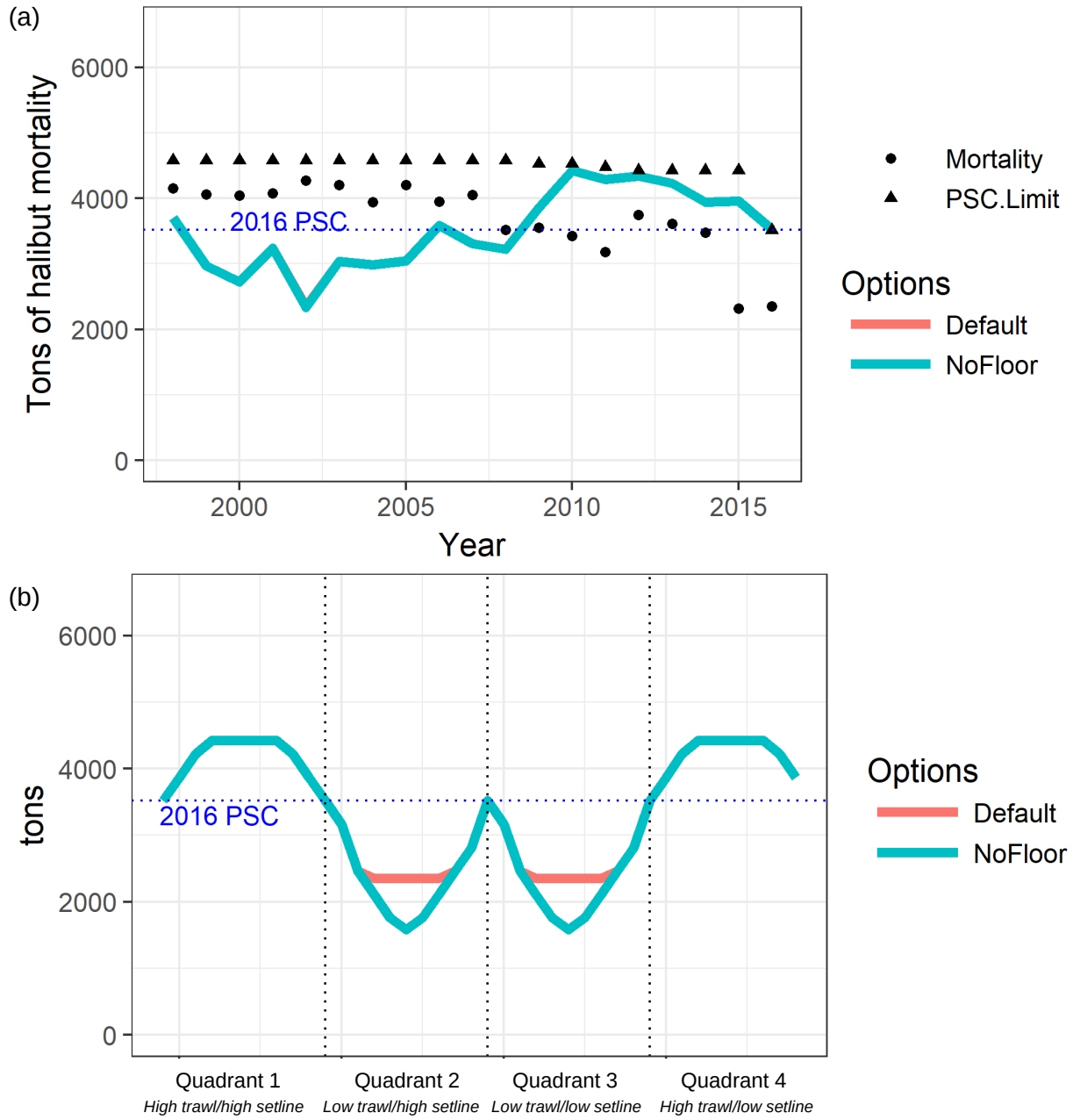

Figure 16 Evaluation of options for Element 3, Maximum PSC limit (ceiling), using (a) historical data (values of the EBS trawl survey from 1998-2016), and (b) projected scenarios that use hypothetical abundance values (as in Figure 12).

Comparison of strawman ABMs for trawl and longline PSC limits

Figure 17 evaluates PSC limits for the trawl sector that would result from applying the strawman ABMs (ABM1, ABM3, and ABM4), while using the default options for Elements 1-4 described in Section 6.1: responsiveness = slope of 1; starting point = 3,515 t; ceiling = 4,426 t; floor = 2,354 t. Under ABM1, the final PSC limit is allocated 79.8% to the trawl sector. Under ABM3 and ABM4, the starting point and minimum/maximum PSC limits are set to 0.798 times the default values. Actual trawl PSC limits and halibut mortality are also shown exclusively for the trawl sector.

ABM1 (Baseline) and ABM3 are identical control rules for the trawl sector, as in both cases, PSC limits are derived exclusively from the EBS trawl survey. The ABM3 line obscures "Baseline", and ABM4 obscures ABM3, when they are identical.

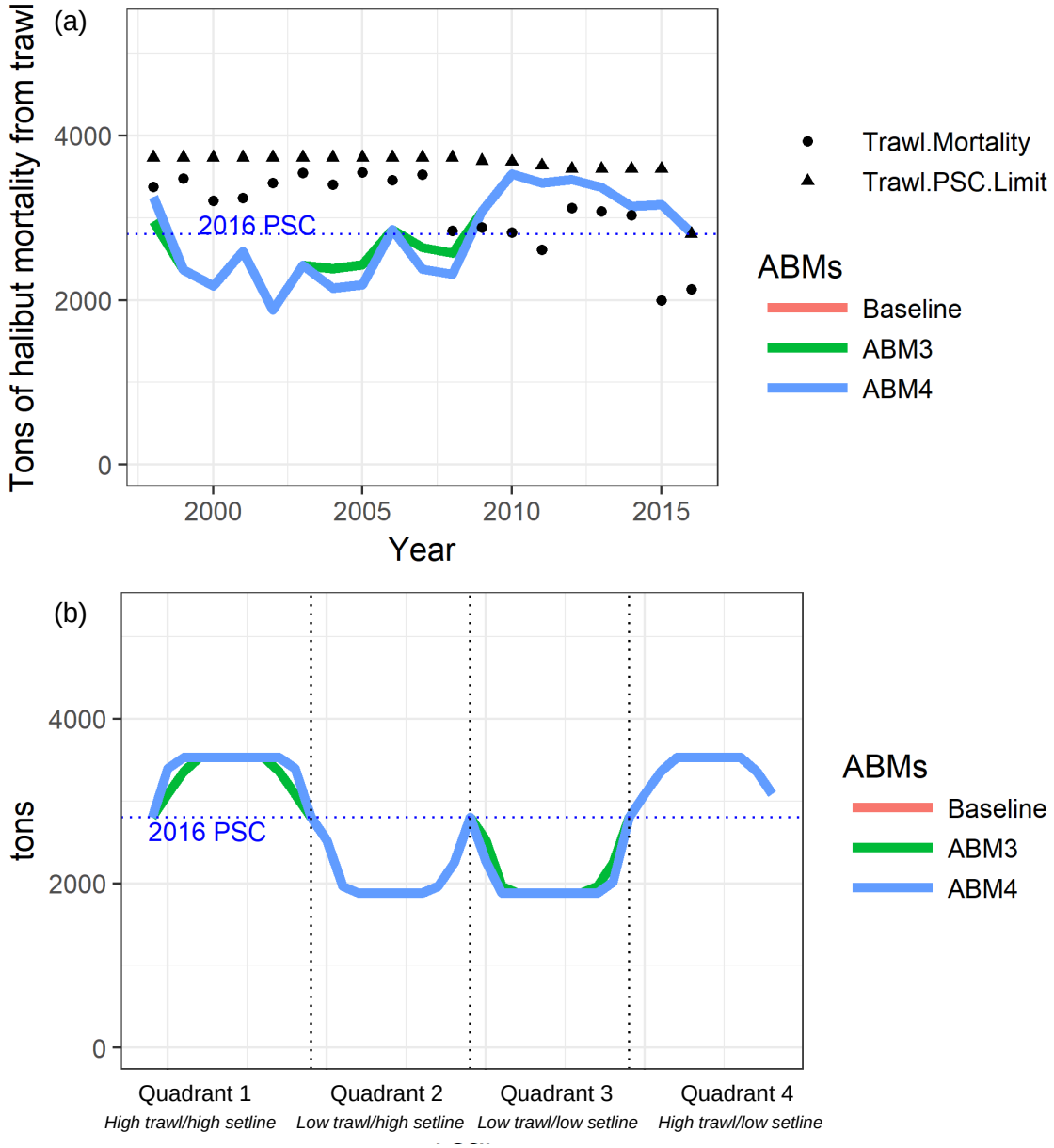

Figure 17 Comparison of PSC limits for the trawl sector under ABM1, ABM3, and ABM4, using (a) historical data (values of the EBS trawl and Area 4ABCDE IPHC setline surveys from 1998-2016), and (b) projected scenarios that use hypothetical abundance values (as in Figure 12).

Figure 18 evaluates PSC limits for the longline sector that would result from applying the strawman ABMs (ABM1, ABM3, and ABM4), while using the default options for Elements 1-4 described in Section 6.1: responsiveness = slope of 1; starting point = 3,515 t; ceiling = 4,426 t; floor = 2,354 t. Under ABM1, the final PSC limit is allocated 20.2% to the longline sector. Under ABM3 and ABM4, the starting point and minimum/maximum PSC limits are set to 0.202 times the default values. Actual longline PSC limits and halibut mortality are also shown exclusively for the longline sector.

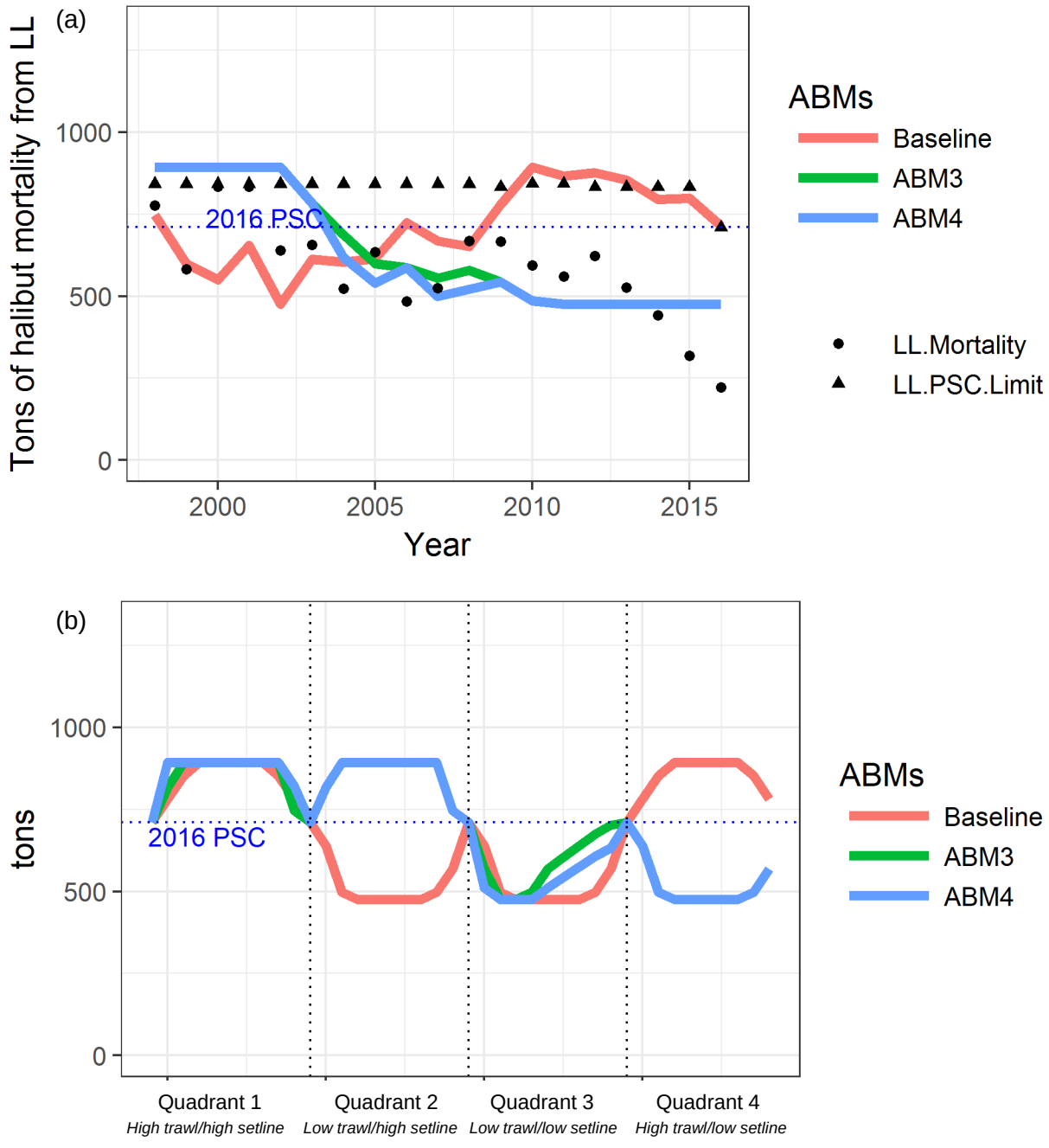

Figure 18 Comparison of PSC limits for the longline sector under ABM1, ABM3, and ABM4, using (a) historical data (values of the EBS trawl and Area 4ABCDE IPHC setline surveys from 1998-2016), and (b) projected scenarios that use hypothetical abundance values (as in Figure 12).

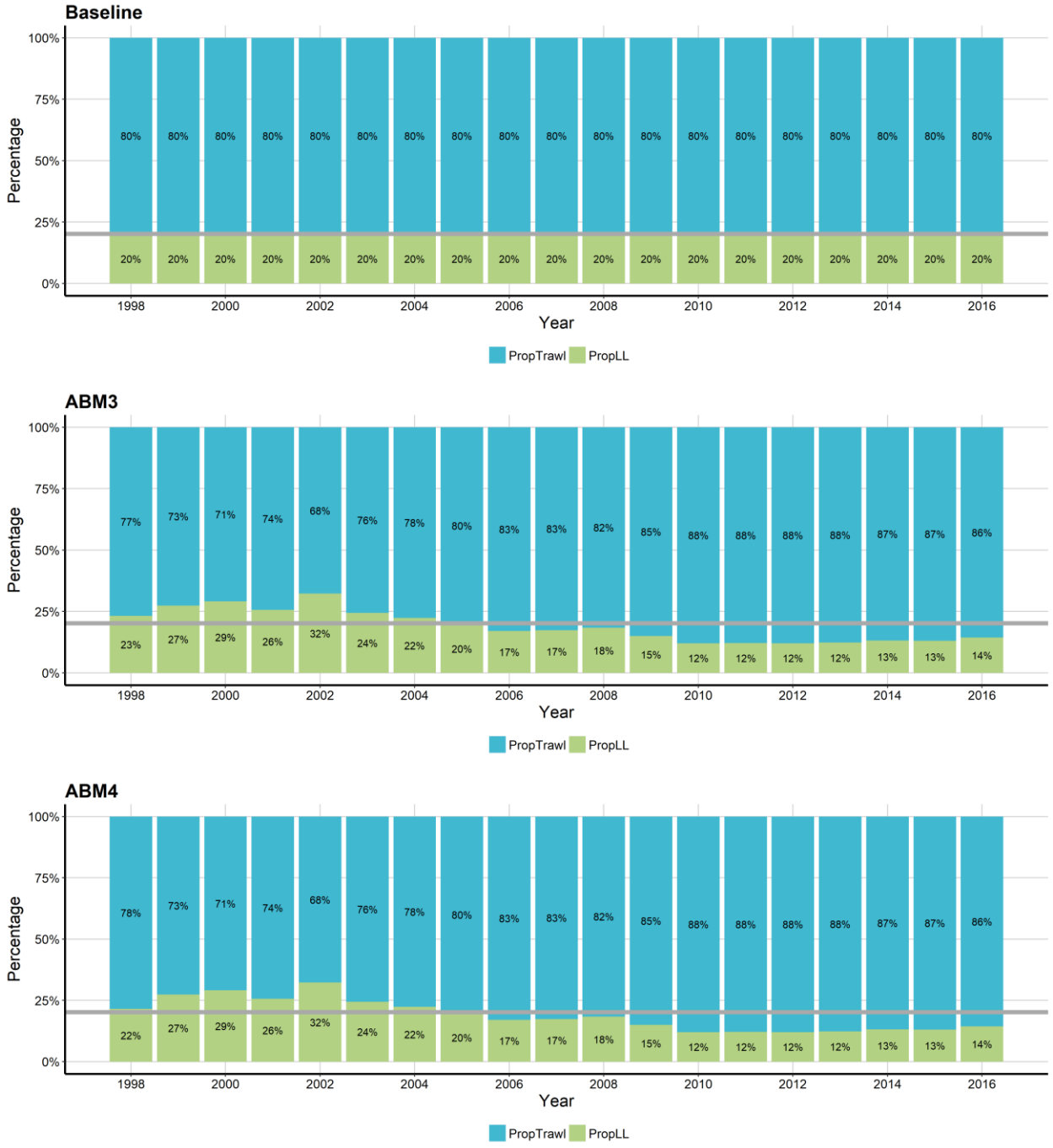

Figure 19. Proportional allocation of PSC limit between the trawl and longline sectors under ABM1 (baseline), ABM3, and ABM4 using historical values of the EBS trawl and Area 4ABCDE IPHC setline surveys from 1998-2016, and corresponding to the results in panel (a) in Figure 17 and Figure 18.

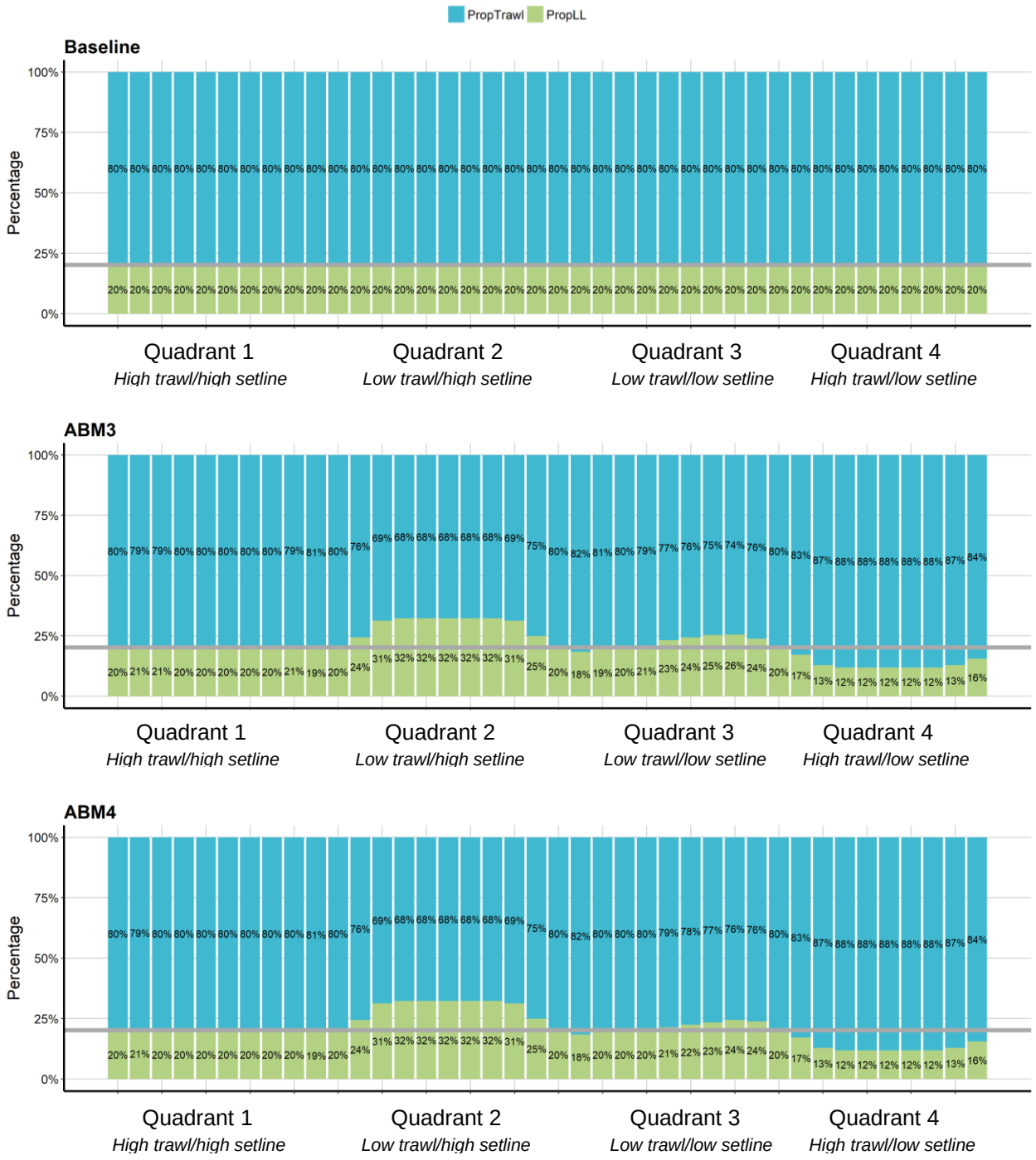

Figure 20. Proportional allocation of PSC limit between the trawl and longline sectors under ABM1 (baseline), ABM3, and ABM4 using projected scenarios that use hypothetical abundance values (as in Figure 12), and corresponding to the results in panel (b) in Figure 17 and Figure 18.

7. Conclusions and Recommendations

This preliminary analysis serves to illustrate the elements and options related to designing control rules to inform which would be best for moving forward as a suite of alternatives for analysis. The range of elements and options considered perform as expected in relative terms but will require a formal analysis to evaluate the actual impact of scenarios on the federally managed groundfish fisheries, directed halibut fisheries and the halibut stock. Importantly, these ultimately will be weighed against how well individual alternatives address competing Council objectives described in Section 2.4. Some differences in inter-annual variability in the PSC limit can be seen with this preliminary exploration and will be summarized as a performance statistic in the forthcoming analysis once alternatives have been finalized. Performance metrics will demonstrate how alternatives meet the Council's objectives. This will occur in the initial review draft analysis.

ABM 1-baseline was used to isolate the individual behavior of specific options being considered in the control rule formulations for all ABM examples. Illustration of each option against a default indicates the relative variability of the range the Council has been considering in the current Elements and options. Contrast is limited due to the similarity in the options being evaluated however the relative change due to each option indicates the behavior of each feature. The Council may use this information to select amongst features it desires in the control rule.

Across the different ABMs, contrast is driven primarily by the selected index and gear allocation. Of note is that the ABM 3 and 4 scenarios result in different effective allocations among gear types than current. All of the ABMs simulated (with a starting point of 3,515) would have resulted in historical total PSC limits lower than the current limits and usage in the earlier part of the time series considered as shown in Section 6.2.

Of the five objectives described in Section 2.4, only the first (index PSC limits to abundance) and fifth (stability of PSC limits) can be addressed with the evaluation presented here. To address relative impacts on spawning biomass and opportunity for the directed fishery and groundfish fisheries, the direction will depend on whether Pacific halibut bycatch is higher or lower on average. However, the absolute impact (and relative impact between alternatives) will require analysis and involve a more complex simulation, with population and fleet dynamics, than provided here. This will occur with the draft EIS once alternatives are specified.

Some additional summary information regarding the current strawmen ABM alternatives, elements and options considered and Council objectives is provided below:

Objective 1 is achieved in any scenario (all are tied to abundance indices). Tradeoffs may result with options that provide slower responsiveness to abundance changes (Element 1, option 1) or constraining ceilings (Element 3 options).

Objective 5 can generally be achieved by most ABMs but depends on the slope or response to changes in the index (or indices) and the presence of a ceiling and/or floor. This objective could conflict with the other objectives if responsiveness to the index reflects poorly on real changes in Pacific halibut abundances. As noted above, the estimated extent of the impact (and the ability to estimate such) will be done when alternatives are developed and analyzed.

Some specific recommendations resulting from this evaluation are the following:

- Recommend the use of the revised elements and options presented in Section 5 in construction of a suite of alternatives for analysis. This includes changes made to elements as described in Section 5.0 to best meet the Council's intent and for clarity of presentation of alternatives.
- Recommend that options for each element should be specific, and succinct. Otherwise, the number of alternatives will be numerous and cumbersome to evaluate.

- ABM options should have a continuous or smooth underlying response to changes in halibut abundance but could be applied as a continuous control rule or look-up table with the resolution determined by Council objectives on stability.
- Recommend the following range of possible methods for setting the PSC limit with one or more indices:
    - Use two separate control rules, one for each index. The single PSC limit is determined from the combination of the output from the two control rules. This could be the sum of the two independent PSCs as determined by those control rules, or any other method.
    - Use a control rule for one index, but features change depending on the other index (e.g., slope changes for EBS trawl survey index depending on the IPHC setline survey, the lookup table changes, or changes to the starting point).
    - Use a multiplier on the PSC limit for specific combinations of index levels (i.e., specific cells).

7.1 Next steps

At this meeting the Council is scheduled to draft a suite of alternatives for analysis. With a defined, finite and ideally streamlined, suite of alternatives, the analysts will begin preparation of a draft EIS. The next time this issue is scheduled for any subsequent Council discussion would be October 2018. However, should alternatives not be defined at this meeting, the timeline for completion of any further discussion paper or analysis will shift. Given the stock assessment responsibilities of the majority of the analysts, and the assessment cycle timing, there will be limited ability for analyses from September to February. Therefore, it is unlikely the Council would be able to review another iteration of this analysis during this time.

8. Appendices

8.1 Mapping of October 2017 alternatives with recommended revisions

Below are the alternatives from the October Council meeting and in **bold** where these have mapped into the revised recommended Elements and Option in this paper for clarity.

Element 1 – Abundance index and application
Option 1. Apply EBS trawl survey and IPC setline survey for 4ABCDE separately to establish a single PSC limit **ABM 2**
Option 2. Index trawl gear to EBS survey, index fixed gear to IPHC setline survey **ABM 3**
Option 3. Index EBS trawl survey and IPHC setline survey to trawl gear **ABM 4**
Option 4. Index EBS trawl survey and IPHC setline to fixed gear **ABM 4**
ADDED ABM 1-baseline: Index PSC to EBS trawl survey for a single PSC limit that is then allocated to gear/sector according to the status quo allocation.
Element 2 – Control Rules FOLDED INTO PRESENTATION OF CONTROL RULES AND NEW ELEMENT 5
Option 1. Linear
Option 2. Decision table
Option 3. Multi-dimensional
Element 3 – PSC limit responsiveness to abundance changes
Option 1. Include IPHC stock status (30:20) as breakpoints in the control rule **MOVED INTO NEW ELEMENT 5**
Option 2. Sloped transitions between stair-steps in decision table ***FOLDED INTO PRESENTATION OF CONTROL RULES***
Option 3. PSC limit varies proportionally (1:1) with change in abundance index. **NEW ELEMENT 1**
Suboption – Different variation above and below (1:1) **TWO OPTIONS PROVIDED IN NEW ELEMENT 1 TO ADDRESS THIS (1:0.5) AND (1:2)**
Element 4 – Starting point for PSC limit SAME BUT CHANGED TO ELEMENT 2
Option 1. 10% below 2016 PSC use (2,118 t)
Option 2. 2016 PSC use (2,354 t)
Option 3. 2016 PSC limit (3,515 t)
Option 4. 10% above 2016 PSC limit (3,867 t)
Option 5. Additional value within range of Options 1-4
Element 5 - Maximum PSC limit *(ceiling)* ***SAME BUT CHANGED TO ELEMENT 3***
Option 1. 2016 PSC limit (3,515 t)
Option 2. 2015 PSC limit (4,426 t)
Option 3. No ceiling
Option 4. Additional value to be selected
Element 6 - Minimum PSC limit *(floor)* ***SAME BUT CHANGED TO ELEMENT 4***
Option 1. No floor (PSC goes to 0)
Option 2. 2016 use (2,354 t)
Option 3. IPHC Control Rule - PSC limit goes to zero at 20% stock status **MOVED INTO NEW ELEMENT 5**
Option 4. Additional value to be selected
NEW ELEMENT 5 Additional features in the control rule
Option 1. A lookup table with a defined resolution for each axis
Option 2. IPHC Control Rule – PSC limit goes to zero at 20% stock status
Option 3. The O26:U26 ratio defines different states of the control rule

8.2 Additional information on bycatch and fishery trends

The following figures relate Pacific halibut bycatch and survey estimates to different fishery indicators.

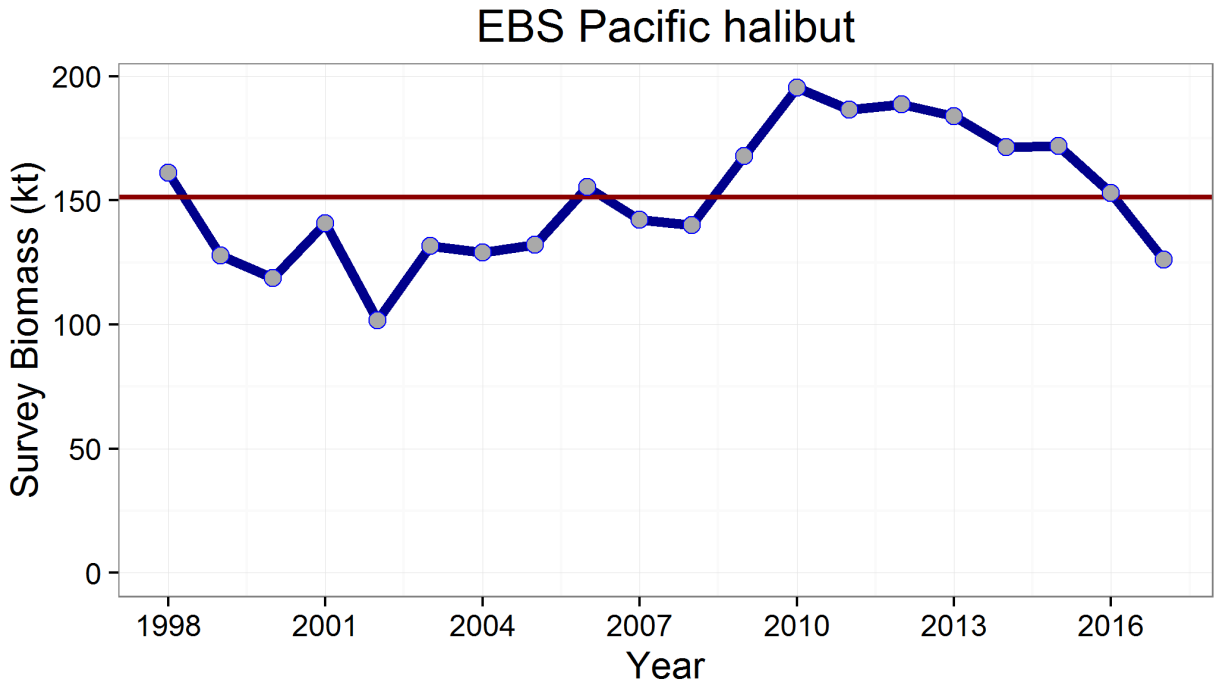

Fig. A-1. Time series of estimated biomass (kilotons) of Pacific halibut in the Eastern Bering Sea from the AFSC bottom trawl survey from 1998 - 2017. Red solid line is the average over the time series.

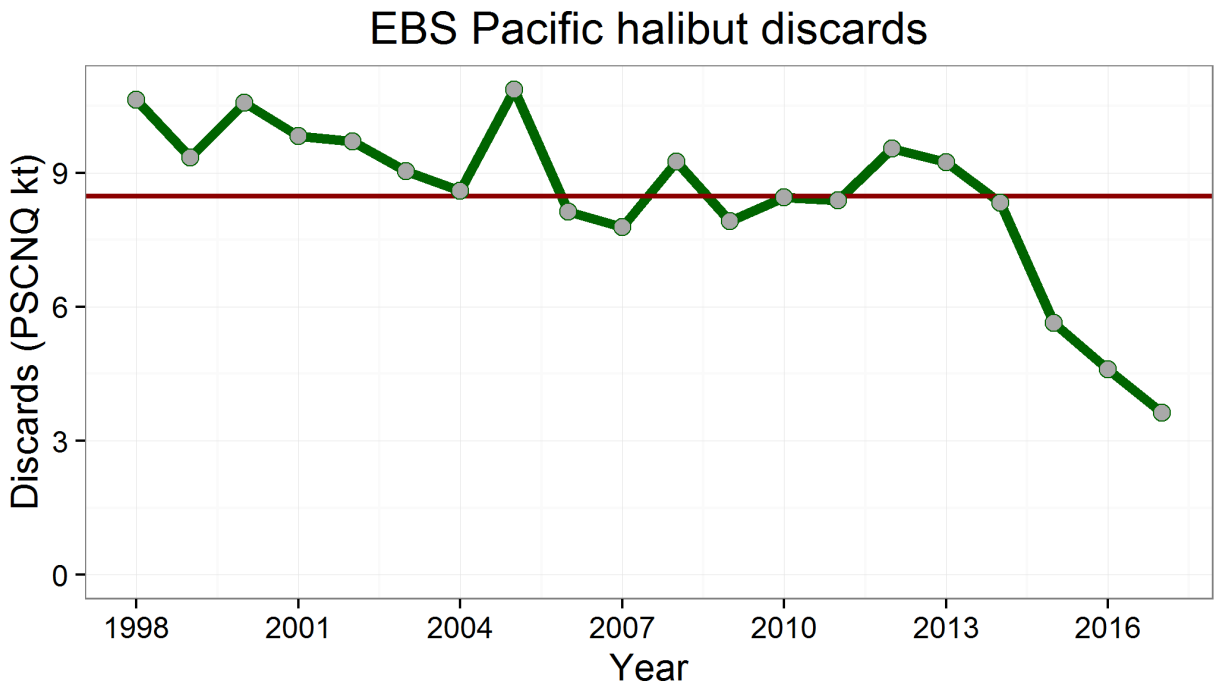

Fig. A-2. Time series of Pacific halibut discards (kilotons) from the groundfish fisheries in the Eastern Bering Sea. Red solid line is the average over the time series.

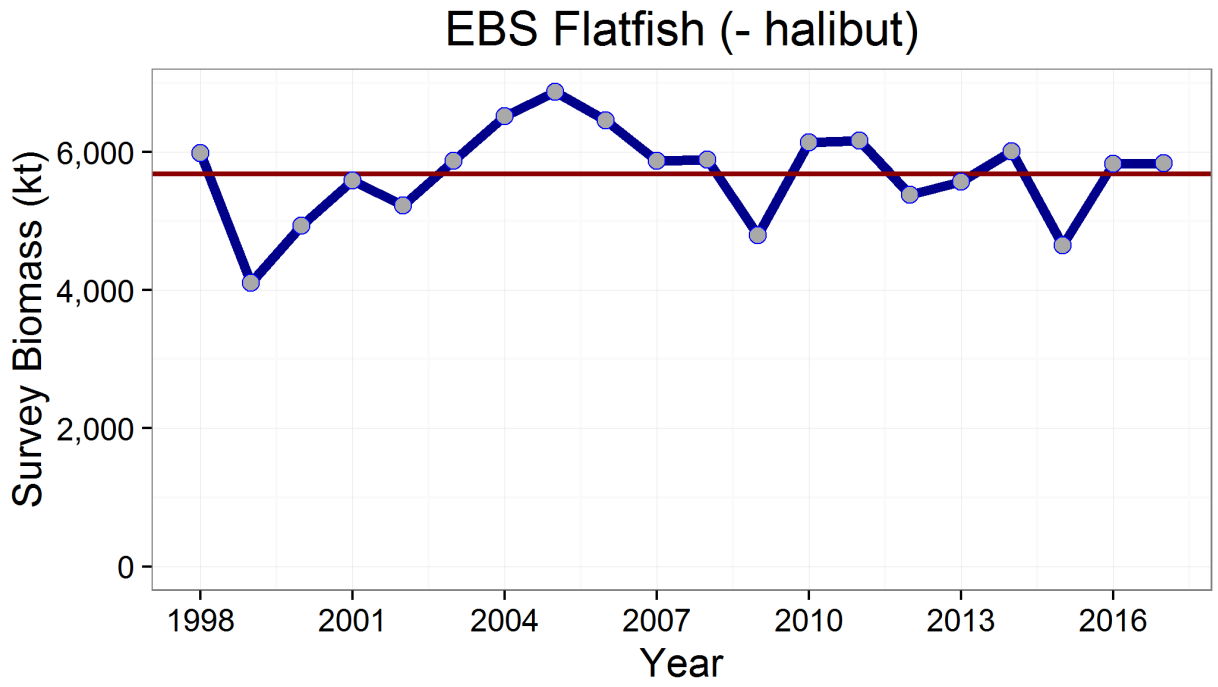

Fig. A-3. Time series of estimated biomass (kilotons) of flatfish (except Pacific halibut) in the Eastern Bering Sea from the AFSC bottom trawl survey from 1998 - 2017. Red solid line is the average over the time series.

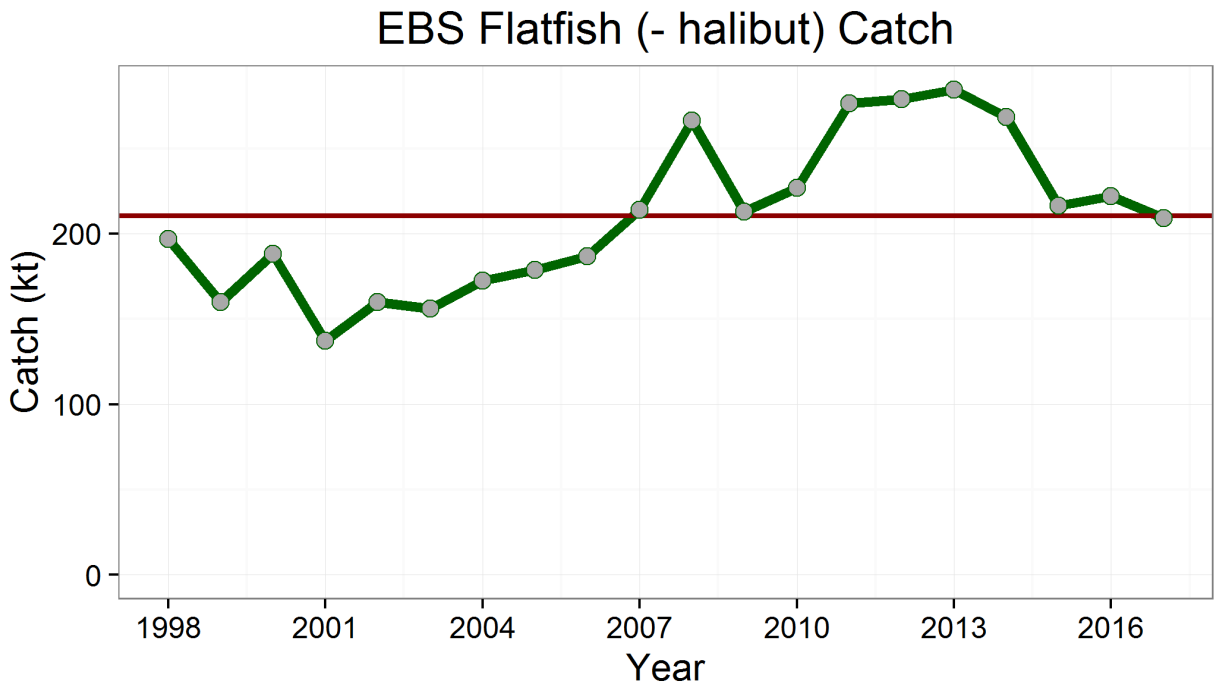

Fig. A-4. Time series of flatfish catch (except halibut, kilotons) in the Eastern Bering Sea from 1998 - 2017. Red solid line is the average over the time series.

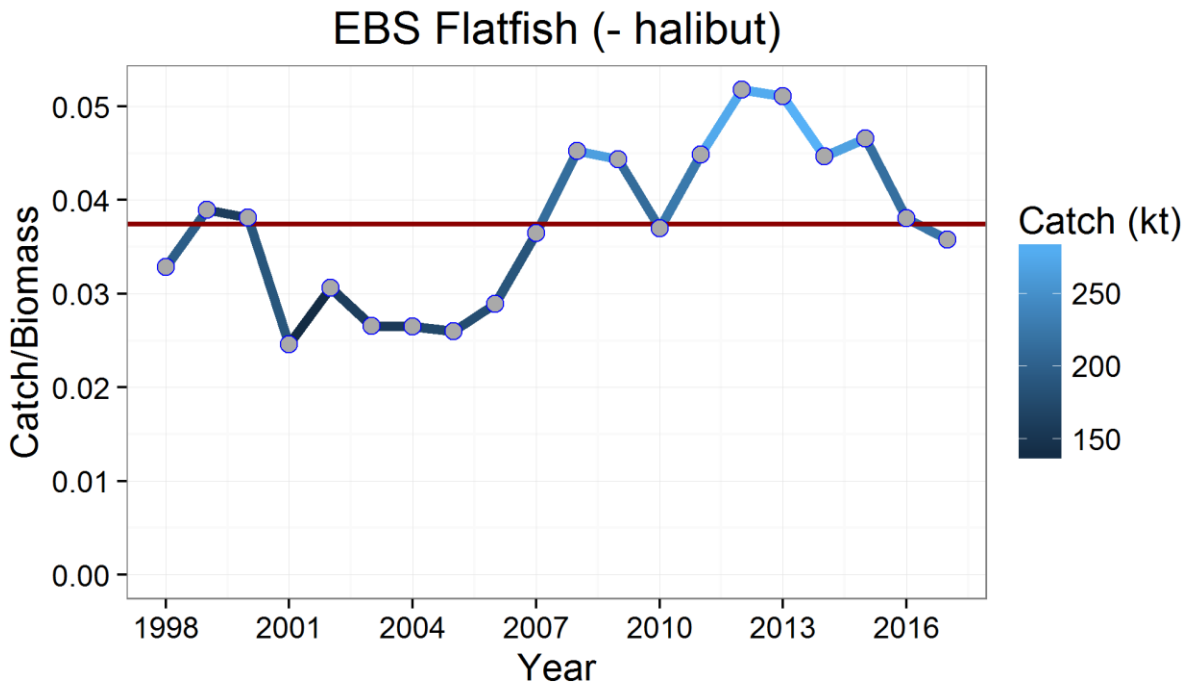

Fig. A-5. Time series of catch of flatfish (except halibut) catch divided by the estimated biomass from the AFSC trawl survey in the Eastern Bering Sea from 1998 - 2017. Red solid line is the average over the time series.

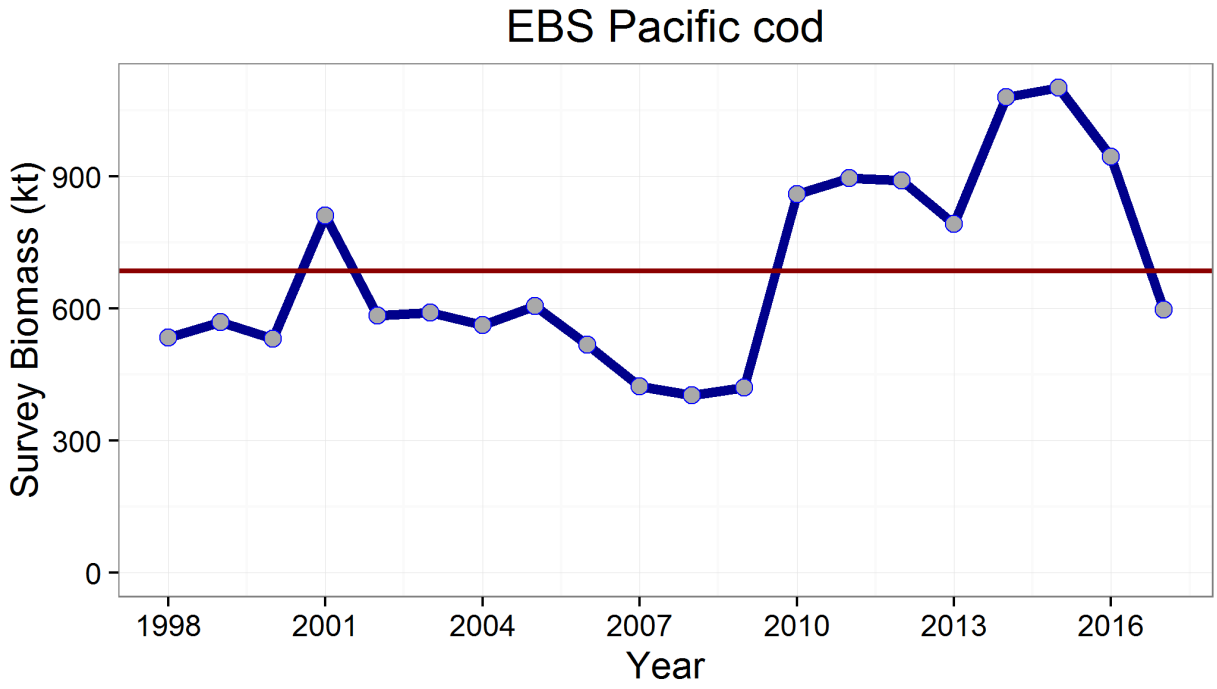

Fig. A-6. Time series of estimated biomass (kilotons) of Pacific cod in the Eastern Bering Sea from the AFSC bottom trawl survey from 1998 - 2017.

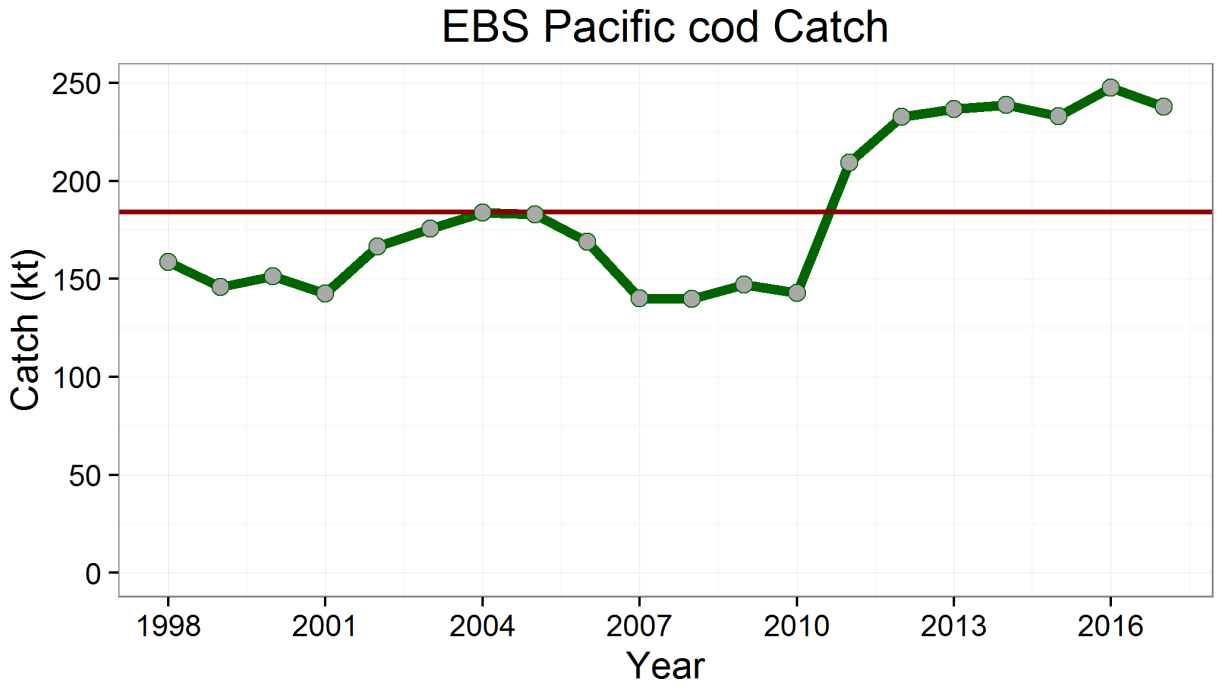

Fig. A-7. Time series of Pacific cod catch (kilotons) in the Eastern Bering Sea from 1998 - 2017. Red solid line is the average over the time series.

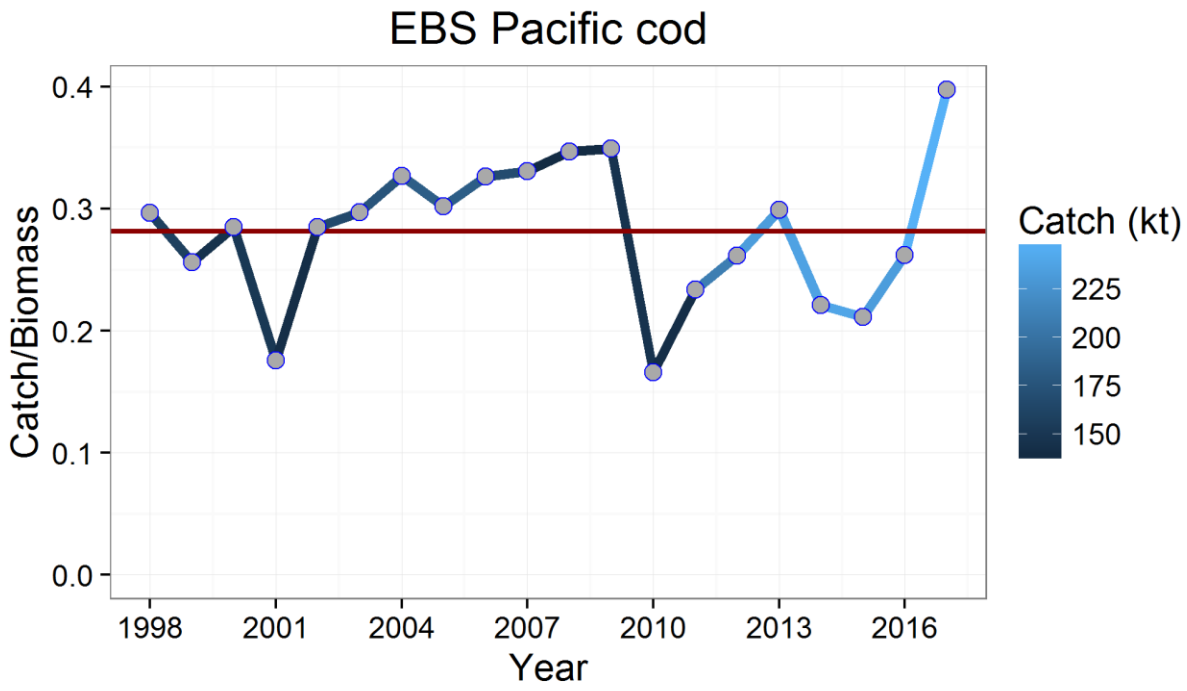

Fig. A-8. Time series of catch of Pacific cod catch divided by the estimated biomass from the AFSC trawl survey in the Eastern Bering Sea from 1998 - 2017. Red solid line is the average over the time series.

8.3 Integrating stair-step and linear control rules

A stair-step control rule can bring the quality of stability to the PSC limit at the expense of occasional large changes when it transitions between steps. The continuous linear control rule has smooth transitions between index values at the expense of annual changes in PSC limits. A hybrid of the linear and stair-step control rules would reduce the sudden change in PSC limit while also maintaining a constant PSC limit over certain ranges of the index (Fig. A-9). This is accomplished by creating a sloped ramp between stair steps.

The steepness of the ramp would be controlled by a defined slope, or by defined values of the index to denote where the ramp occurs and where the PSC limit would be constant. An analogous lookup table would have values for the PSC limit when it is constant between breakpoints and interpolation between those values (Table A-1) that uses a continuous control rule.

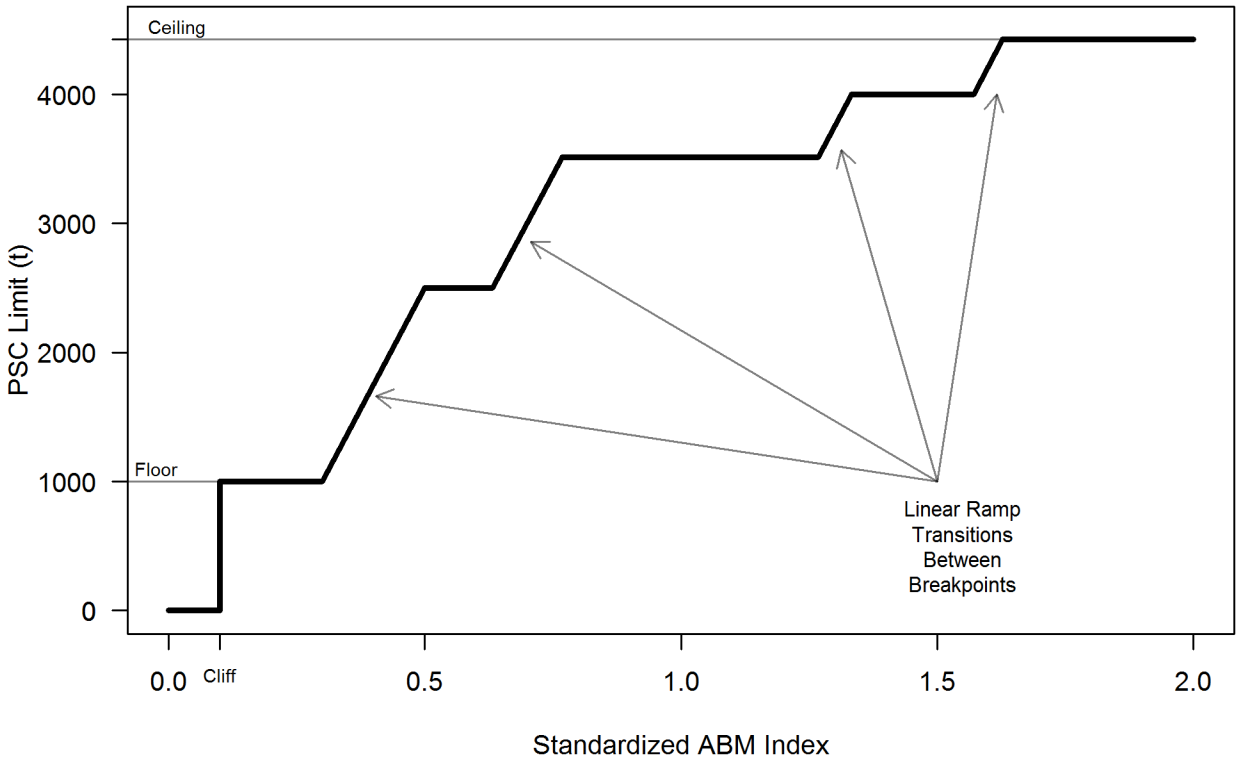

Fig. A-9. A stair-step control rule with linear ramps between breakpoints. The steepness of the linear ramp is controlled by a defined slope but could be defined by specific points where the linear ramp begins and ends. For this example, the PSC limit is 3,515 t when the standardized index has a value of 1 and uses a floor and ceiling of 1,000 t and 4,426 t, respectively. A cliff is also introduced for comparison.

Table A-1. A one-dimension stair-step control rule with linear ramps between breakpoints (Fig. A-9) presented as a lookup table.

Index	Very low	Low	Med-low	Med	Med-High	High
PSC limit	0	1,000	2,500	3,515	4,000	4,426

Although not a PSC limit, the Council has used a hybrid of the one-dimension linear and one-dimension stair-step control rules for allocations of halibut between charter and commercial fisheries in the Gulf of Alaska. The Council established the halibut catch sharing plan in IPHC Regulatory Areas 2C and 3A, which allocates the halibut catch limits between the commercial and charter halibut fisheries based on a control rule that varies with Pacific halibut abundance. The control rule specifies that each sector will be allocated a specific percentage of the available catch limit at different levels of halibut abundance. At lower levels of abundance, the charter sector is allocated a larger proportion of the catch limit than at higher levels of abundance. The control rule also includes a "stair step" that allocates the charter fishery a fixed amount of the catch limit in pounds at specific abundance levels in order to smooth the transition between allocation percentages as abundance increases. Fig. A-10 shows this control rule for IPHC Regulatory Area 3A with two stair-steps and decreasing slopes of the linear portions as abundance increases.

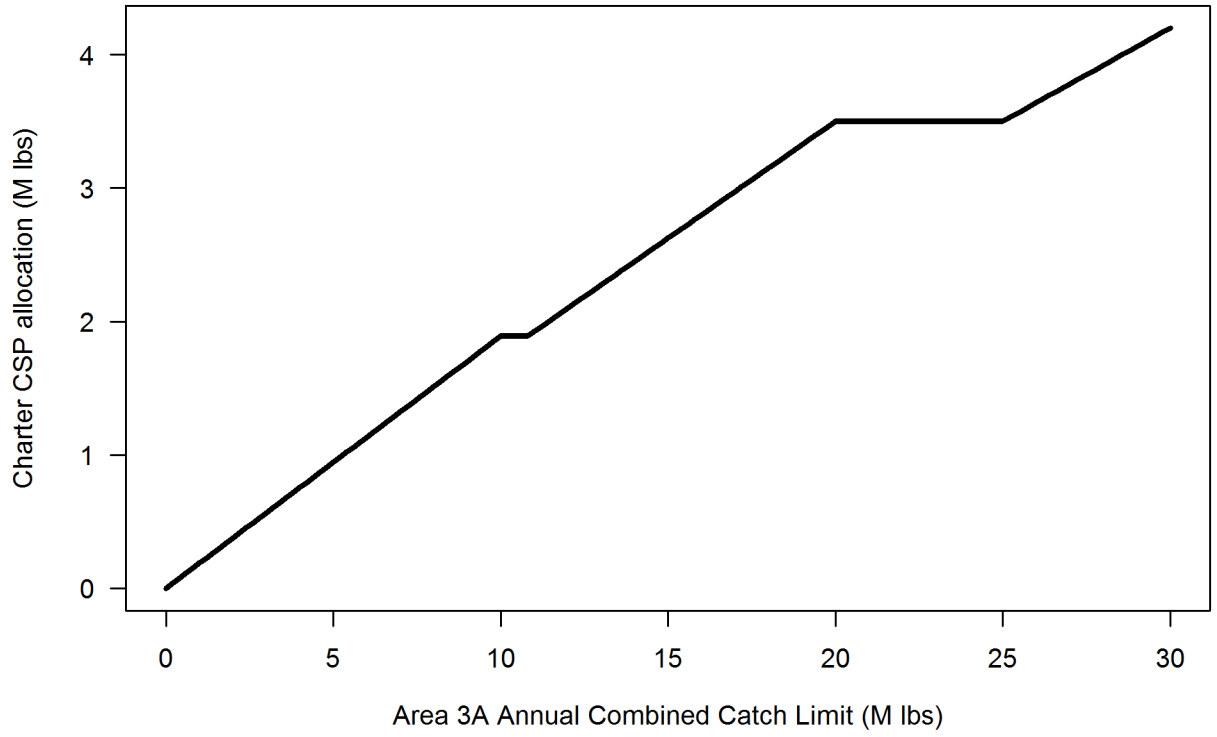

Fig. A-10. A hybrid control rule with continuous components and stair-step components that is used to allocate Pacific halibut catch limits between the commercial and charter halibut fisheries in IPHC Regulatory Area 3A.

8.4 Additional configurations of ABM1 for historical and projected scenarios

The following figures are supplemental and described in their captions.

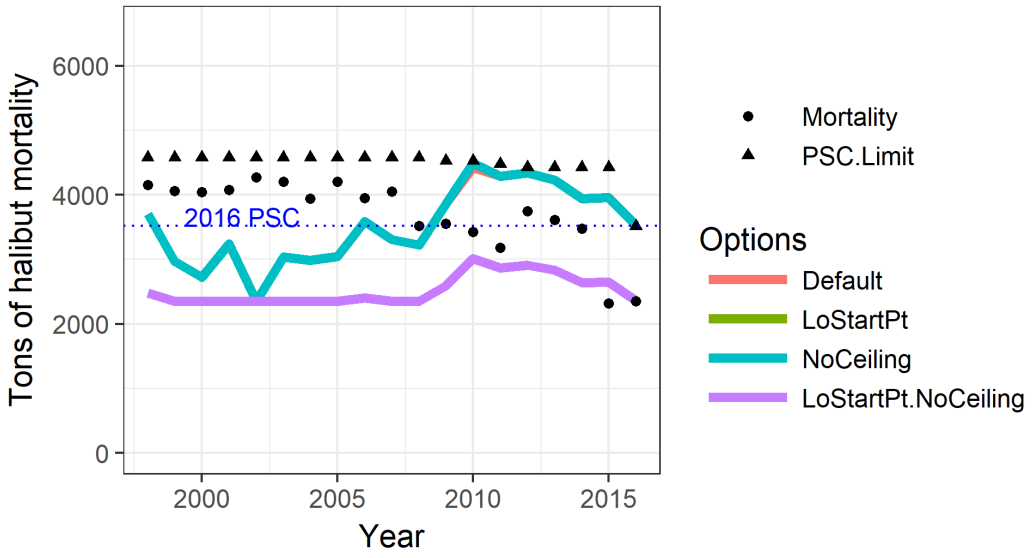

Fig. A-11. Configurations of ABM1 (the baseline ABM) for historical values of the EBS Trawl Survey from 1998-2016. The default refers to a control rule with medium responsiveness (slope of 1), a starting point of 3,515 t, a ceiling of 4,426 t, and a floor of 2,354 t. "LoStartPt" refers to a control rule with all of the listed default options, except with a low starting point of 2,354 t. "NoCeiling" refers to a control rule with all of the listed default options, but without a maximum PSC limit (ceiling). "LoStartPt.NoCeiling" refers to a control rule with the listed default options, but with a starting point of 2,354 t and no maximum PSC limit.

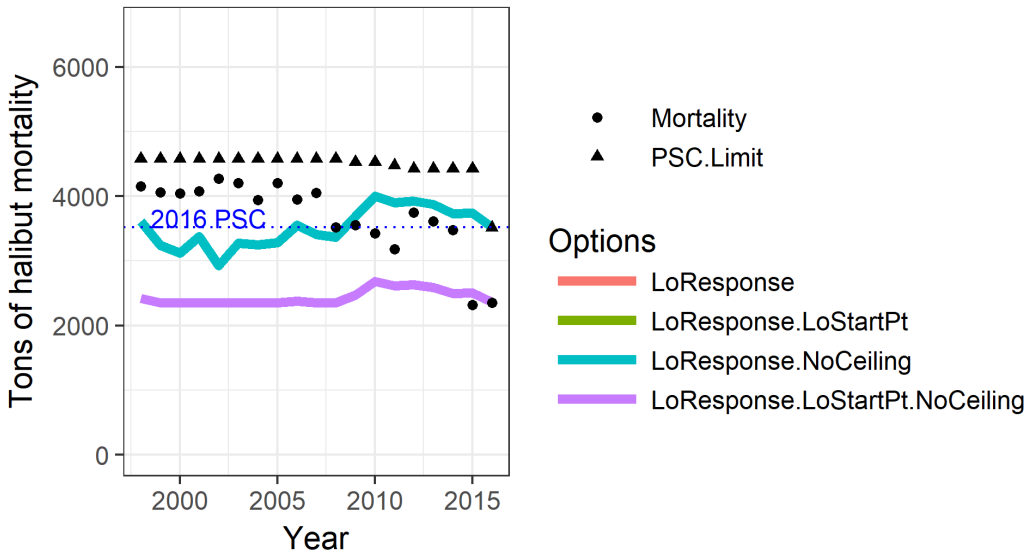

Fig. A-12. Configurations of ABM1 (the baseline ABM) for historical values of the EBS Trawl Survey from 1998-2016. "LoResponse" refers to a control rule with low responsiveness (slope of 0.5), a starting point of 3,515 t, a ceiling of 4,426 t, and a floor of 2,354 t. "LoResponse.LoStartPt" refers to a control rule like that for the "LoResponse" scenario, but with a low starting point of 2,354 t as well. "LoResponse.NoCeiling" refers to a control rule like that for the "LoResponse" scenario, but without a maximum PSC limit (ceiling). "LoResponse.LoStartPt. NoCeiling" refers to a control rule with a slope of 0.5, a starting point of 2,354 t, and no maximum PSC limit.

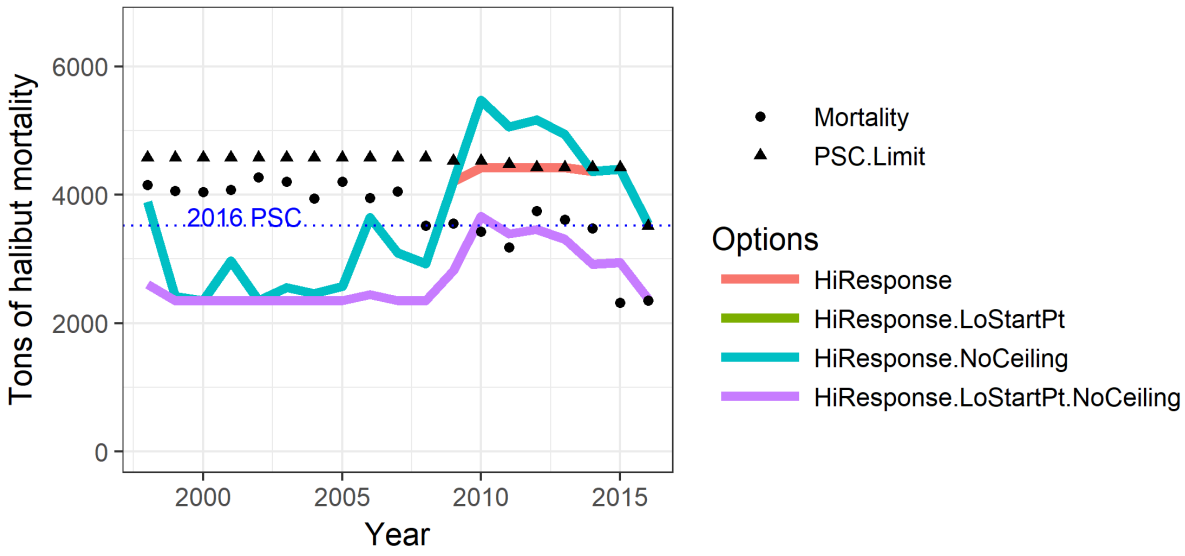

Fig. A-13. Configurations of ABM1 (the baseline ABM) for historical values of the EBS Trawl Survey from 1998-2016. "HiResponse" refers to a control rule with high responsiveness (slope of 2), a starting point of 3,515 t, a ceiling of 4,426 t, and a floor of 2,354 t. "HiResponse.LoStartPt" refers to a control rule like that for the "HiResponse" scenario, but with a low starting point of 2,354 t as well. "HiResponse.NoCeiling" refers to a control rule like that for the "HiResponse" scenario, but without a maximum PSC limit (ceiling). "HiResponse.LoStartPt. NoCeiling" refers to a control rule with a slope of 2, a starting point of 2,354 t, and no maximum PSC limit.

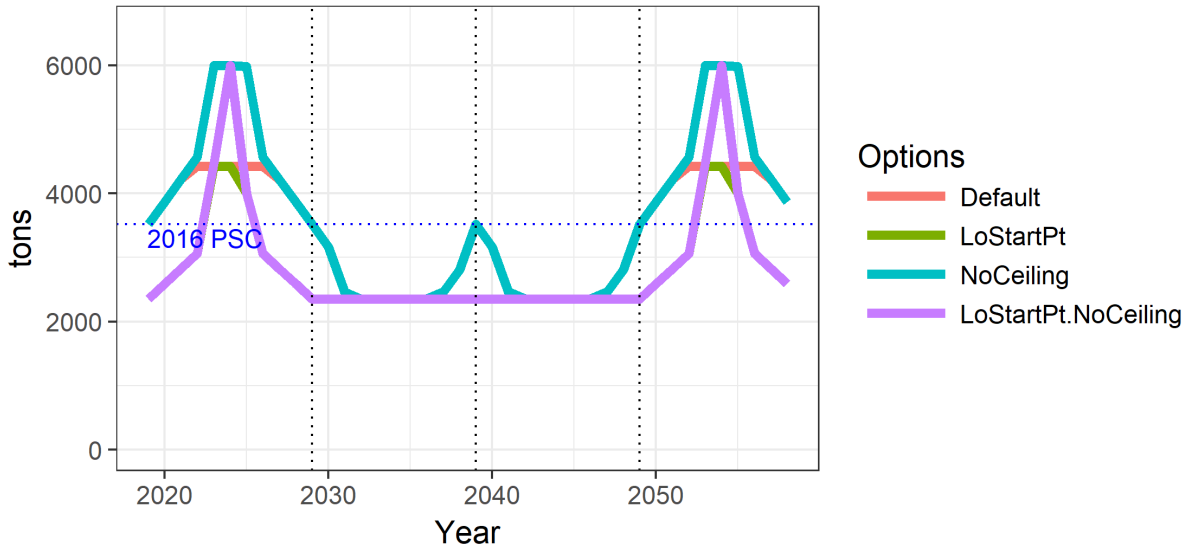

Fig. A-14. Configurations of ABM1 (the baseline ABM) for projected values of the EBS Trawl Survey from 1998-2016. The default refers to a control rule with medium responsiveness (slope of 1), a starting point of 3,515 t, a ceiling of 4,426 t, and a floor of 2,354 t. "LoStartPt" refers to a control rule with all of the listed default options, except with a low starting point of 2,354 t. "NoCeiling" refers to a control rule with all of the listed default options, but without a maximum PSC limit (ceiling). "LoStartPt.NoCeiling" refers to a control rule with the listed default options, but with a starting point of 2,354 t and no maximum PSC limit.

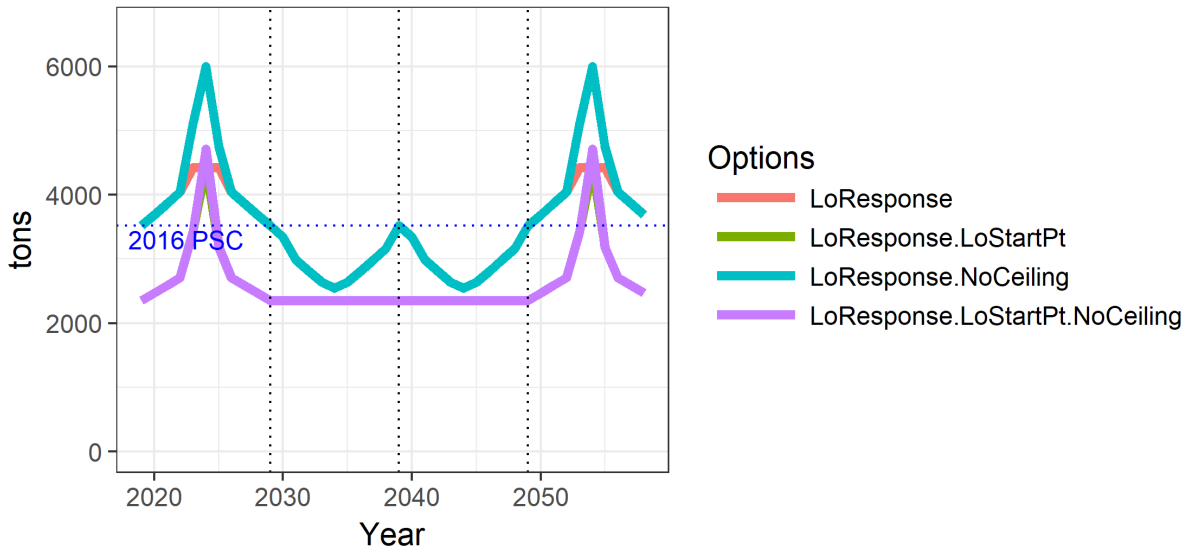

Fig. A-15. Configurations of ABM1 (the baseline ABM) for projected values of the EBS Trawl Survey from 1998-2016. "LoResponse" refers to a control rule with low responsiveness (slope of 0.5), a starting point of 3,515 t, a ceiling of 4,426 t, and a floor of 2,354 t. "LoResponse.LoStartPt" refers to a control rule like that for the "LoResponse" scenario, but with a low starting point of 2,354 t as well. "LoResponse.NoCeiling" refers to a control rule like that for the "LoResponse" scenario, but without a maximum PSC limit (ceiling). "LoResponse.LoStartPt. NoCeiling" refers to a control rule with a slope of 0.5, a starting point of 2,354 t, and no maximum PSC limit.

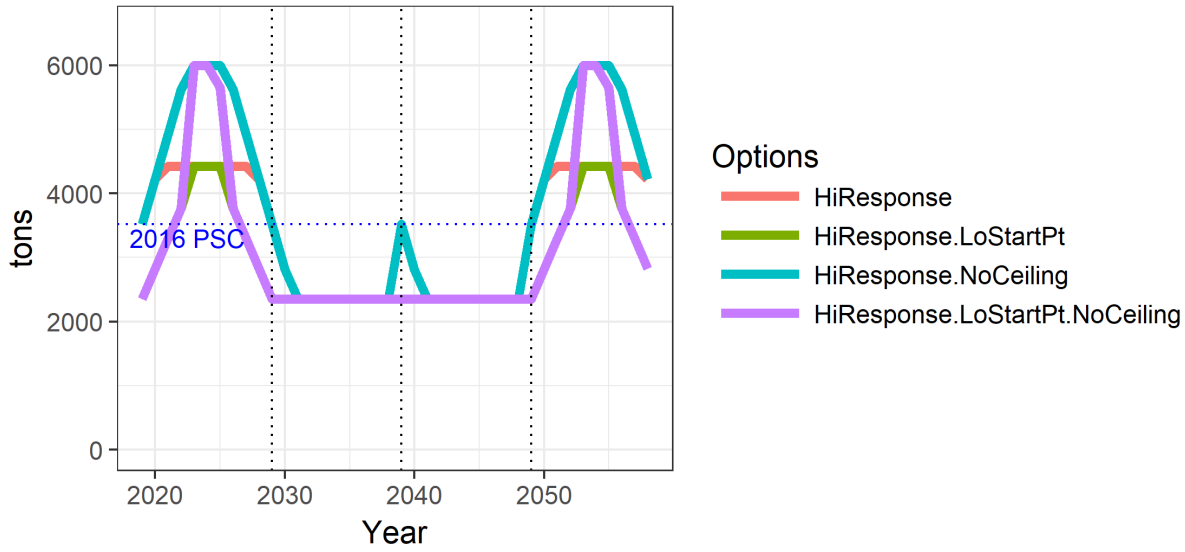

Fig. A-16. Configurations of ABM1 (the baseline ABM) for projected values of the EBS Trawl Survey from 1998-2016. "HiResponse" refers to a control rule with high responsiveness (slope of 2), a starting point of 3,515 t, a ceiling of 4,426 t, and a floor of 2,354 t. "HiResponse.LoStartPt" refers to a control rule like that for the "HiResponse" scenario, but with a low starting point of 2,354 t as well. "HiResponse.NoCeiling" refers to a control rule like that for the "HiResponse" scenario, but without a maximum PSC limit (ceiling). "HiResponse.LoStartPt. NoCeiling" refers to a control rule with a slope of 2, a starting point of 2,354 t, and no maximum PSC limit.

8.5 Use of ABM 4 control rule relative to addressing Council obectives

ABM 4 uses information from both the trawl and setline surveys to establish a PSC limit by gear type. This control rule serves to illustrate how the Council's objectives can be weighed for this action. The quadrants listed for ABM 4 can be considered against different Council objectives.

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

ABM 4 uses information from both the trawl and setline surveys to establish a PSC limit by gear type. The quadrants listed in Fig. A-17 are the same as for our default ABM 4 and how these same quadrants and the resulting control rule could be adjusted and tailored to address different Council objectives.

Council objective 1 is achieved in any scenario while Council objective 5 is achieved by the resolution of the look up table as noted in Element 5 or by the slope of the control rule as shown in Element 1. Fig. A-19 through Fig. A-21 show how information in the combined surveys can be considered directly to address Council objectives 2,3 and 4.

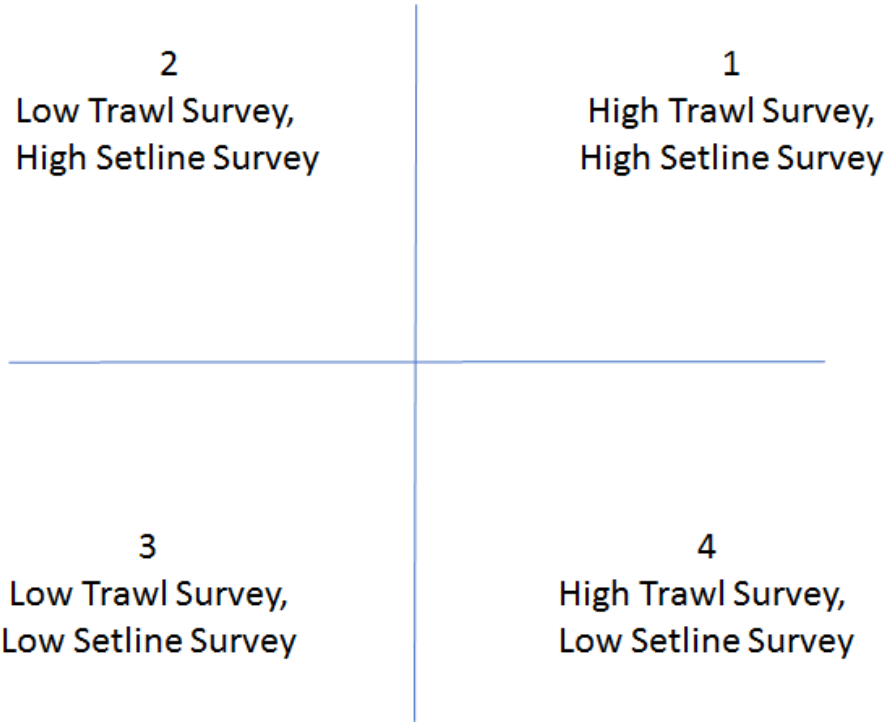

Fig. A-17. Four categories or quadrants that can be used as a basis for specifying objectives corresponding to the use of both the EBS trawl survey and the setline survey indices when specifying sector-specific PSC limits.

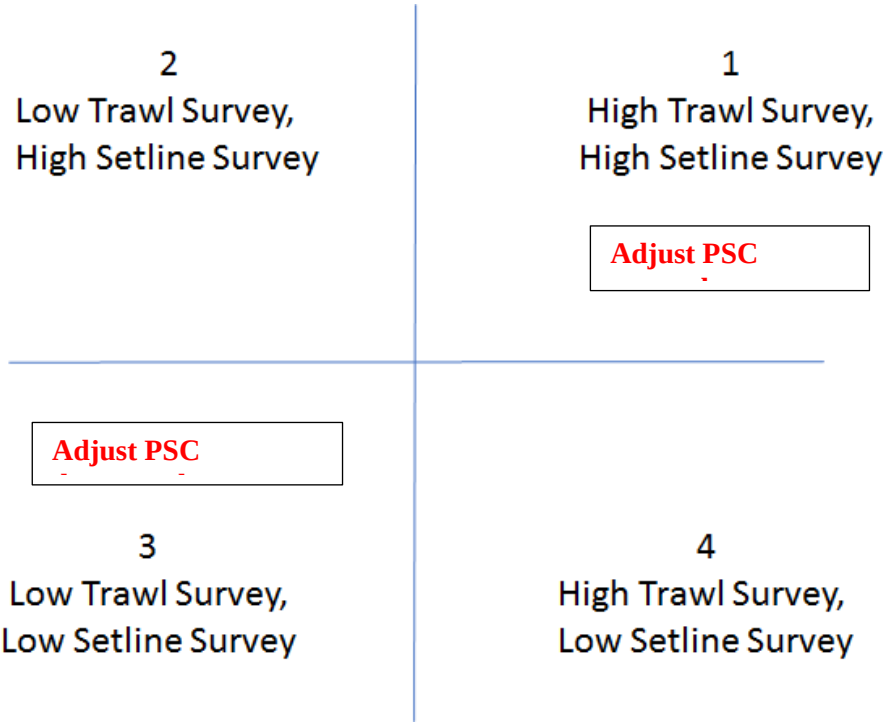

Fig. A-18. Default assumption of directional change in PSC limit used in ABM 4 according to the 4 quadrants.

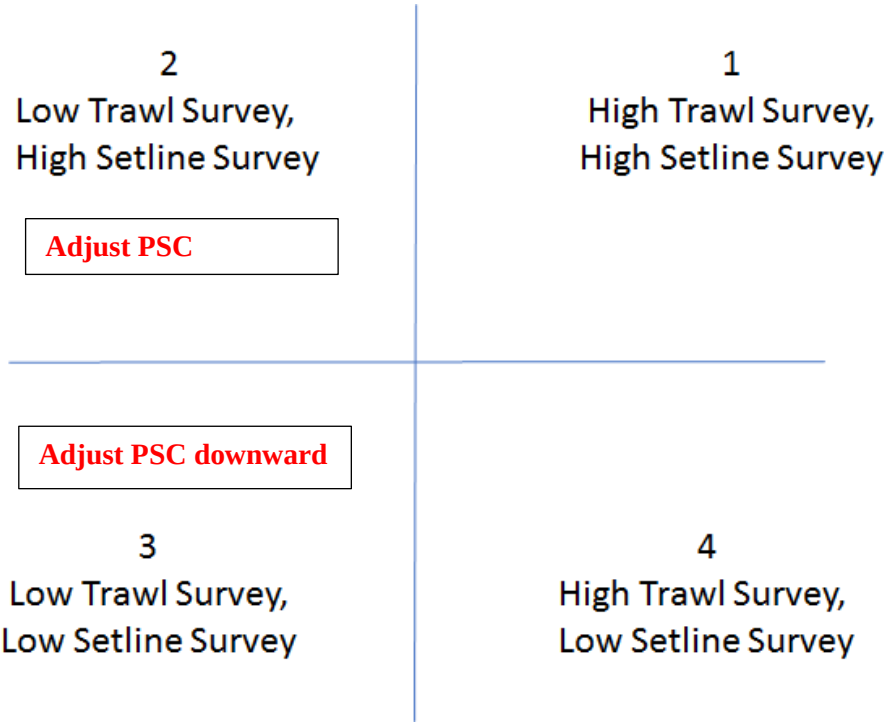

Fig. A-19. Alternative scenario to address Council objective #2: Spawning stock biomass should be protected particularly at low levels of abundance

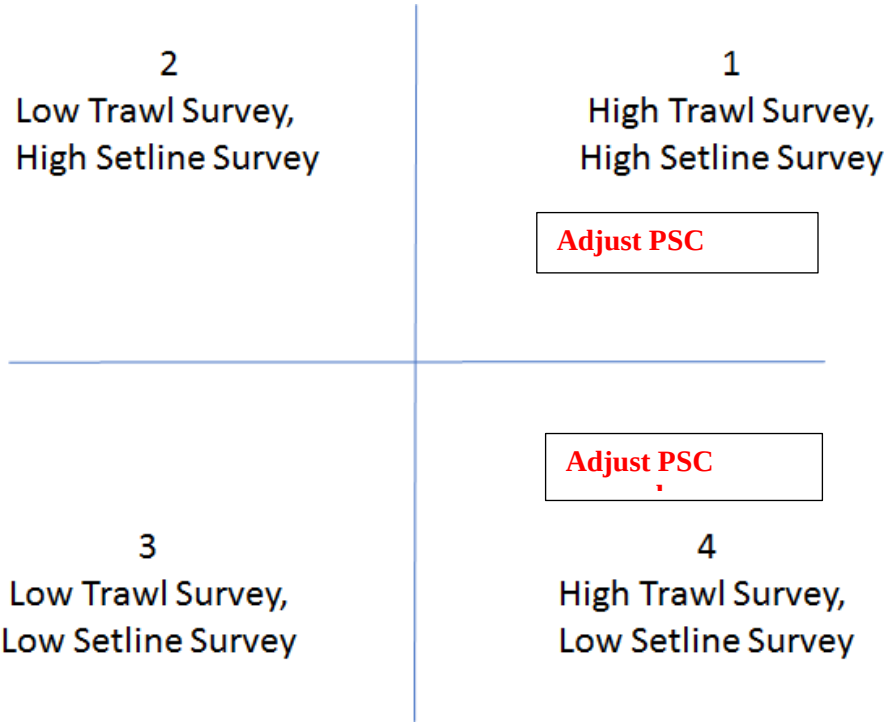

Fig. A-20. Alternative scenario to address Council objective #3: Provide flexibility to avoid constraining the groundfish fisheries especially at high levels of halibut abundance

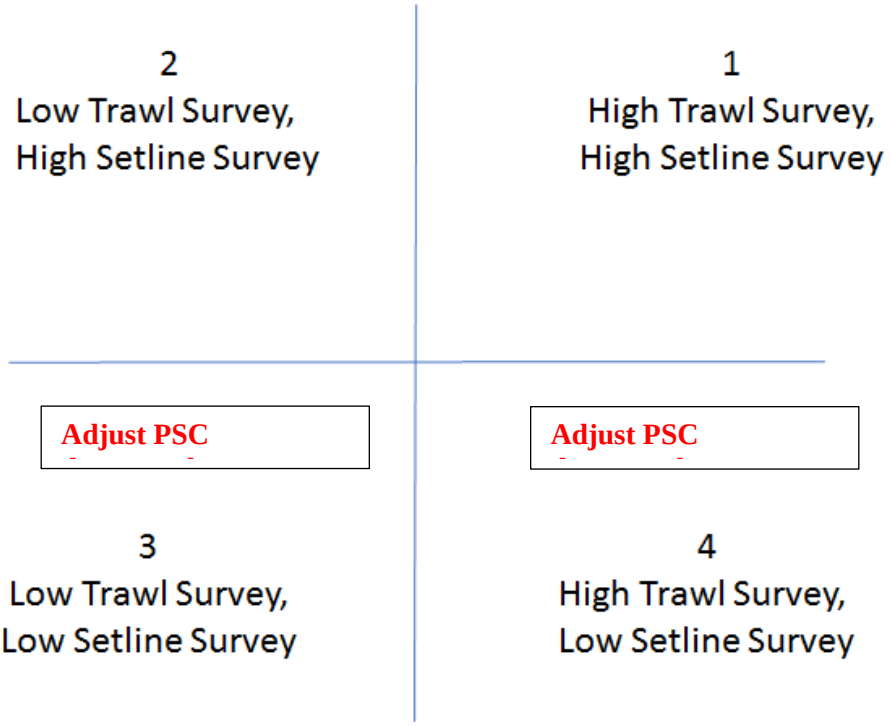

Fig. A-21. Alternative scenario to address Council objective #4: Provide for directed halibut fishing opportunities in the Bering Sea