IPHC Management Strategy Evaluation (MSE): update

PREPARED BY: IPHC SECRETARIAT (A. HICKS & I. STEWART; 19 DECEMBER 2018)

PURPOSE

To provide an update on the progress of the IPHC Management Strategy Evaluation process including

- goals, objectives, and performance metrics,
- the investigation and evaluation of management procedures related to coastwide fishing intensity,
- ideas for distributing the TCEY, and
- a five year program of work.

ABSTRACT

At the 93rd Session of the IPHC Annual Meeting (AM093-Rec.04; 2017) Commissioners supported a revised harvest strategy policy that separates the Scale (coastwide fishing intensity) and Distribution of fishing mortality. Using management strategy evaluation (MSE), an SPR-based coastwide fishing intensity has been evaluated and discussions on distributing the TCEY have begun. The MSE process involves determining objectives, identifying management procedures to evaluate, evaluating those management procedures through simulation, and application of the management procedure that best meets the objectives.

Three primary objectives have been determined, and many secondary objectives have been identified. The one primary biological sustainability objective is to maintain the female spawning biomass above 20% of the equilibrium female spawning biomass under current conditions but without fishing (dynamic relative spawning biomass; dRSB) at least 90% of the time in the long-term. In this measurable objective, 20% dRSB is the measurable outcome, long-term is the time-period, and 10% (100-90) is the tolerance. The two fishery sustainability objectives are to 1) maintain the average annual variation in the TCEY (the average percent change from year to year) at a value less than 15% at least 75% of the time in the short-term, and 2) to maximize the median TCEY in the short-term subject to satisfying the other two primary objectives. A management procedure will not be considered further if it does not meet the biological sustainability objective.

Using a closed-loop simulation framework, the SPR values from 30% to 56% (higher SPR translates to lower fishing intensity) were evaluated along with the control rules 40:20, 30:20, and 25:10. The first number in the control rule indicates the value of the estimated dRSB at which the fishing intensity begins to be reduced (fishery trigger) and the second number indicates the value of the estimated dRSB at which the TCEY for the directed fishery is set to zero (fishery limit). Results from the simulations showed that all fishing intensities with an SPR greater than 30% satisfied the biological sustainability objective, but no management procedure satisfied the stability objective. More generally, though, at fishing intensities greater than those associated with an SPR of 40% (i.e., SPR values less than 40%) the variability in mortality limits increased rapidly and the median mortality limit made minimal gains. Given that none of the management procedures met the stability objective, various constraints were added as an element of a management procedure to reduce the annual variability in the mortality limits. Constraints such as simply limiting the percentage change from year to year, implementing a slow-up fast-down approach, or setting mortality limits every third year showed promising results, and are worthwhile to investigate further. Of the management procedures evaluated, an SPR of 40% with a 30:20 control rule and a constraint to not change the annual mortality limit by more than 15% in either direction met all objectives and was ranked the highest based on the primary objectives.

After the coastwide TCEY is determined from the Scale portion of the harvest strategy policy, a number of steps are used to distribute the TCEY among IPHC Regulatory Areas. Emerging understanding of Pacific halibut diversity across the geographic range of the Pacific halibut stock indicates that IPHC Regulatory Areas should only be considered as management units. Balancing the removals against the stock distribution at the level of Biological Regions is likely to conserve spatial population structure that may be important to biological sustainability of the Pacific halibut stock. Therefore, Biological Regions are considered by the IPHC Secretariat, and supported by the SRB, to be the best option for biologically-based areas to meet management needs. Further distribution of the TCEY to the IPHC Regulatory Areas within a Region can be accomplished through distribution procedures that are science- or policy-based and are designed to meet fishery objectives.

A framework to develop management procedures for distributing the TCEY to IPHC Regulatory Areas may contain the following elements.

1. **Coastwide Target Fishing Intensity:** Determine the coastwide total mortality using a target SPR that is most consistent with IPHC objectives defined by the Commission. Separate the total mortality in ≥26 inches (O26) and under 26 inches (U26) components. The O26 component is the coastwide TCEY.
2. **Biological Stock Distribution:** Calculate the stock distribution among four (4) Biological Regions based on the modelled survey results for all sizes of Pacific halibut.
3. **Regional Allocation Adjustment:** Adjust the distribution of the TCEY among Biological Regions, from the Biological Stock Distribution in step 2, to account for other factors.
4. **Regulatory Area Allocation:** Apply IPHC Regulatory Area allocation percentages within each Biological Region to distribute the Region-specific TCEY's to Regulatory Areas. This part represents a management/policy decision, and may be informed by data, based on past or current observations, or defined by an allocation agreement.

The four steps described above would be contained within the IPHC Harvest Strategy Policy as part of the Management Procedure, and are pre-determined steps that have a predictable outcome. The decision making process would then occur.

5. **Annual Regulatory Area Adjustment**: Adjust individual Regulatory Area TCEY limits to account for other factors as needed. This is the policy part of the harvest strategy policy and occurs as a final step where other objectives are considered (e.g. economic, social, etc.).

The MSE Program of Work is expanding the evaluations of the coastwide fishing intensity to incorporate the distribution of the TCEY component. The work in 2019 will involve defining objectives related to distribution of the TCEY, developing a multi-area operating model to simulate the Pacific halibut population, and designing a framework for the closed-loop simulations. The work in 2020 will focus on implementing the MSE framework to evaluate the full management procedure in the harvest strategy policy which includes Scale and Distribution. Results will be delivered at AM097 in 2021.

1 Introduction

At the 93rd Session of the IPHC Annual Meeting (AM093-Rec.04; 2017) Commissioners supported a revised harvest strategy policy that separates the scale and distribution of fishing mortality (Figure 1). Furthermore, the Commission identified an interim "hand-rail" or reference for harvest advice based on a status-quo SPR, which uses the average estimated coastwide SPR for the years 2014–16 from the 2016 stock assessment, resulting in an SPR of 46%. The justification for using an average SPR from recent years was that this corresponded to fishing intensities that resulted in a stable or slightly increasing stock, indicating that, in the short-term, this may provide an appropriate fishing intensity that would result in a stable or increasing female spawning biomass. Retrospective estimates of SPR are variable, but within the estimated confidence bounds.

This document mostly focuses on the results of the simulations of coastwide fishing intensity, but also includes some discussion of topics related to distributing the TCEY. It concludes with a summary of the MSE program of work. Additional information can be found in documents provided for the Management Strategy Advisory Board (MSAB) meetings in May 2018 (MSAB011[1]) and October 2018 (MSAB012[2]).

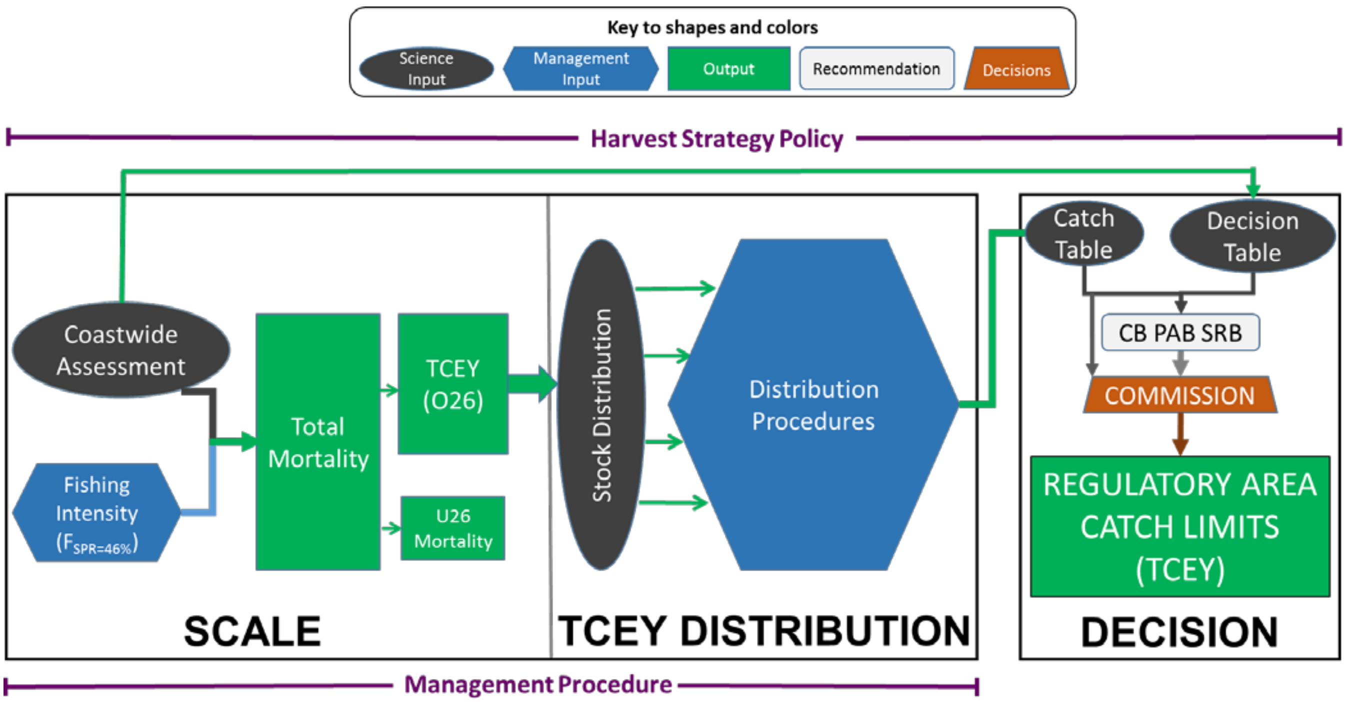

Figure 1. A pictorial description of the interim IPHC harvest strategy policy showing the separation of scale and distribution of fishing mortality. The "decision step" is when policy and decision making (not a procedure) influences the final mortality limits.

2 Goals, Objectives, and Performance Metrics

Defining goals and objectives is a necessary part of a management strategy evaluation (MSE) which should be revisited often to make sure that they are inclusive and relevant. The MSAB originally developed five overarching goals with multiple objectives for each. Performance metrics have also been developed from the objectives by

[1] https://iphc.int/venues/details/11th-session-of-the-iphc-management-strategy-advisory-board-msab011/
[2] https://iphc.int/venues/details/12th-session-of-the-iphc-management-strategy-advisory-board-msab012/

defining a measurable outcome, a time-frame over which it is desired to achieve that outcome, and a tolerance (Table 1). Management procedures were evaluated by determining which ones meet the objectives, via the performance metrics (see Appendix I for objectives that were considered).

These five goals and linked objectives were discussed at MSAB011. It was determined that the goal "serve consumer needs" was currently not necessary as it would be captured under the goal of "fishery sustainability and stability." Furthermore, MSAB members appointed an *ad hoc* working group to refine the objectives (IPHC 2018a, paragraph 20).

This *ad hoc* working group met via webinar on June 26 to discuss and refine the objectives so that they reflect the current objectives of the MSAB and Commission, as well as to reduce redundant objectives, and clarify and simply the objectives for evaluation. There is also an ongoing discussion of objectives related to distributing the stock, although the *ad hoc* working group did not directly address these. These refinements were discussed at MSAB012, and the current goals and objectives used to evaluate the management procedures related to coastwide scale are presented in Appendix I, along with some preliminary objectives for distribution of the TCEY.

Table 1: Definitions and examples of the three components that are derived from a measurable objective to create a performance metric and determine if a management procedure meets that objective.

Component of a performance metric	**Definition**
Measurable outcome	The specific quantity to measure and, if defined, how it relates to a reference point. For example spawning biomass is less than a limit reference point. Or, more simply, the median coastwide catch limit (i.e., TCEY).
Time-frame	The time-frame has two parts 1. The number of annual time-steps (e.g., years) over which the performance metric is calculated. For example, the performance metric may be average over a ten-year period for a single simulated trajectory, and then the median of that average determined from all simulated trajectories. 2. The period considered, being short-, medium-, or long-term. This period can be any definition of annual time-steps. Long-term is typically associated with equilibrium conditions.
Tolerance	The maximum level of risk that meets the objective. This is associated with a probabilistic measurable outcome (i.e., one that defines how often a quantity may exceed a reference point). For example, it may be tolerable that the spawning biomass (quantity) is less than 20% of unfished biomass (reference point) in no more than 10% of the simulations (tolerance). This can also be stated as, the probability that the spawning biomass will be less than 20% of unfished biomass is not to exceed 10%. Measurable outcomes without a reference point do not have a tolerance defined and are simply a statistic of interest (because they do not have a probability associated with them). However, an objective may be to maximize or minimize a statistic of interest.

The four goals are 1) biological sustainability, 2) optimize directed fishery opportunities, 3) minimize discard mortality, and 4) minimize bycatch mortality. General objectives (broad objectives that are often referred to as means objectives) are defined for each of these goals, except minimize bycatch mortality, which is not being specifically addressed in the MSE at this time. Measurable objectives (more specific objectives often referred to as ends objectives) are defined for each general objective, and each has an associated performance metric, incorporating the components in Table 1. Three measurable objectives were prioritized for evaluation (Appendix Ia) and are called primary objectives.

- The biological sustainability objective of maintaining the spawning biomass above 20% at least 90% of the time in the long-term must be met for further consideration of the management procedure.
- Limit annual changes in the coastwide TCEY to no more than 15% at least 75% of the time in the short-term and maximize (or optimize) the average coastwide TCEY in the short-term.

This prioritization aligns well with a Commission directive from the 2018 Work Meeting.

The Commission ***RECOMMENDED*** *that the MSAB:*

> *While it is recognized that the MSAB has spent considerable time and effort in developing objectives for evaluating management procedures, for the purpose of expediting a recommendation on the level of the coast-wide fishing intensity, and noting SRB11–Rec.02 to develop an objectives hierarchy, the MSAB is requested to evaluate management procedure performance against objectives that prioritize long-term conservation over short-/medium-term (e.g., 3-8 years) catch performance. Where helpful in accelerating progress on scale, the MSAB is requested to constrain objectives to (1) maintain biomass above a limit to avoid critical stock sizes, (2) maintain a minimum average catch, and (3) limit catch variability.*

Various secondary performance metrics were used to understand the results and further rank management procedures when the primary objectives were met similarly (Appendix Ib).

The concept of biological regions (Figure 2) was also discussed at MSAB011 and followed up at SRB012. The SRB agreed that the "defined bioregions (i.e. 2, 3, 4, and 4b described in paper IPHC-2018-SRB012-08) are presently the best option for implementing a precautionary approach given uncertainty about spatial population structure and dynamic of Pacific halibut" (IPHC 2018c paragraph 31). Additional data collected and analyzed in the future may provide guidance on redefining biological regions that best represent spatial diversity and meet management needs.

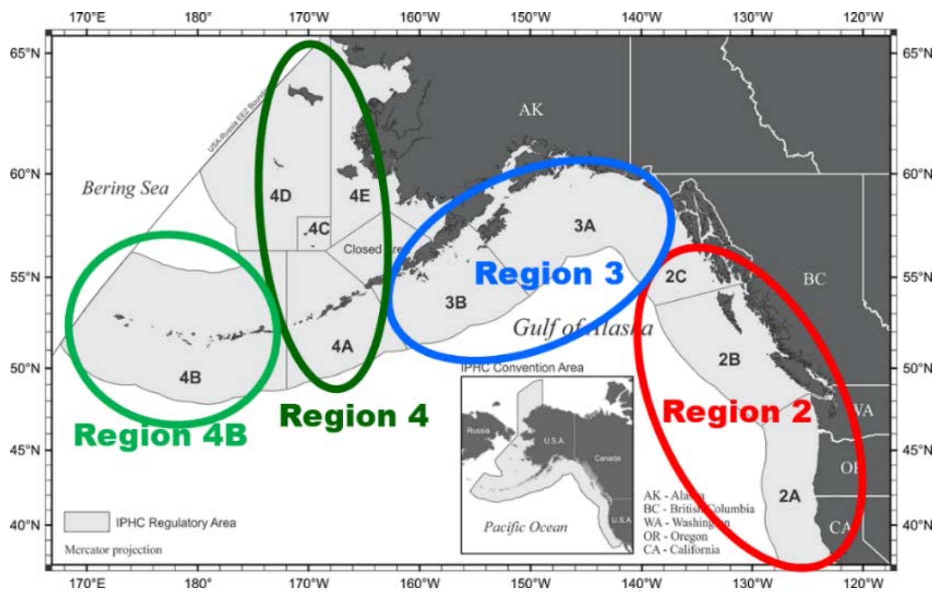

Figure 2. Four biological Regions. They are overlayed on IPHC Regulatory Areas with Region 2 comprised of 2A, 2B, and 2C, Region 3 comprised of 3A and 3B, Region 4 comprised of 4A and 4CDE, and Region 4B comprised solely of 4B.

From this discussion on biological regions, the goal of preserving biocomplexity was considered. The SRB noted that biocomplexity is "poorly defined and not understood for Pacific halibut" (IPHC 2018c paragraph 30). Additionally, "preserve" is not the appropriate term, because conservation is typically the goal of fisheries management. Therefore, *conserve spatial population structure* was defined by the MSAB as a general objective, but does not have measurable objectives associated with it at this time (Appendix Ib).

The MSAB agreed that the Commission should review and provide guidance on the revised goals to be presented at AM095 (IPHC 2018a paragraph 34), as shown in Appendix I.

3 Closed-loop Simulation Framework

The framework of the closed-loop simulations is a map to how the simulations will be performed (Figure 3). There are four main modules to the framework:

1. The **Operating Model (OM)** is a representation of the population and the fishery. It produces the numbers-at-age, accounting for mortality and any other important processes. It also incorporates uncertainty in the processes and may be composed of multiple models to account for structural uncertainty.

2. **Management Procedure**

    a. **Monitoring (data generation)** is the code that simulates the data from the operating model that is used by the estimation model. It can introduce variability, bias, and any other properties that are desired.

    b. The **Estimation Model (EM)** is analogous to the stock assessment and simulates estimation error in the process. Using the data generated, it produces an annual estimate of stock size and status and provides the advice for setting the catch levels for the next time step. However, simplifications may be necessary to keep simulation times within a reasonable amount.

    c. **Harvest Rule** is the application of the estimation model output along with the scale and distribution management procedures (Figure 1) to produce the mortality limit for that year.

3.1 Operating Model

For the simulations to investigate a coastwide fishing intensity, the stock synthesis (Methot and Wetzel 2013) assessment software was used as an operating model. This platform is currently used for the stock assessment, and the operating model was comprised of the two coastwide assessment models (short and long time-series) currently used in the ensemble. For future MSE evaluations (in particular, investigating the Distribution component of the harvest policy) a more complex operating model will be developed that can provide outputs by defined areas or regions and can account for migration between these areas. This model has been referred to as a multi-area model.

The current stock assessment ensemble, composed of four different assessment models, includes a cross between coastwide or fleets-as-areas structuring of the data, and the length of the time series. Using an areas-as-fleets operating model would require generating data and distributing catch to four areas of the coast, which would involve many assumptions. In addition, without a multi-area model, there would not be feedback from migration and productivity of harvesting in different areas. Therefore, only the two coastwide models were used, but with additional variability. These models are structured to use five general sources of mortality (these are aggregated for modelling purposes and do not necessarily correspond to specific fisheries or sectors): the directed commercial halibut fishery (including research landings), commercial discard mortality (previously known as wastage), bycatch (from non-halibut-target fisheries), recreational, and subsistence. The Total Mortality (TM) was distributed to each source in an ad hoc manner using current available information along with guidance from the MSAB.

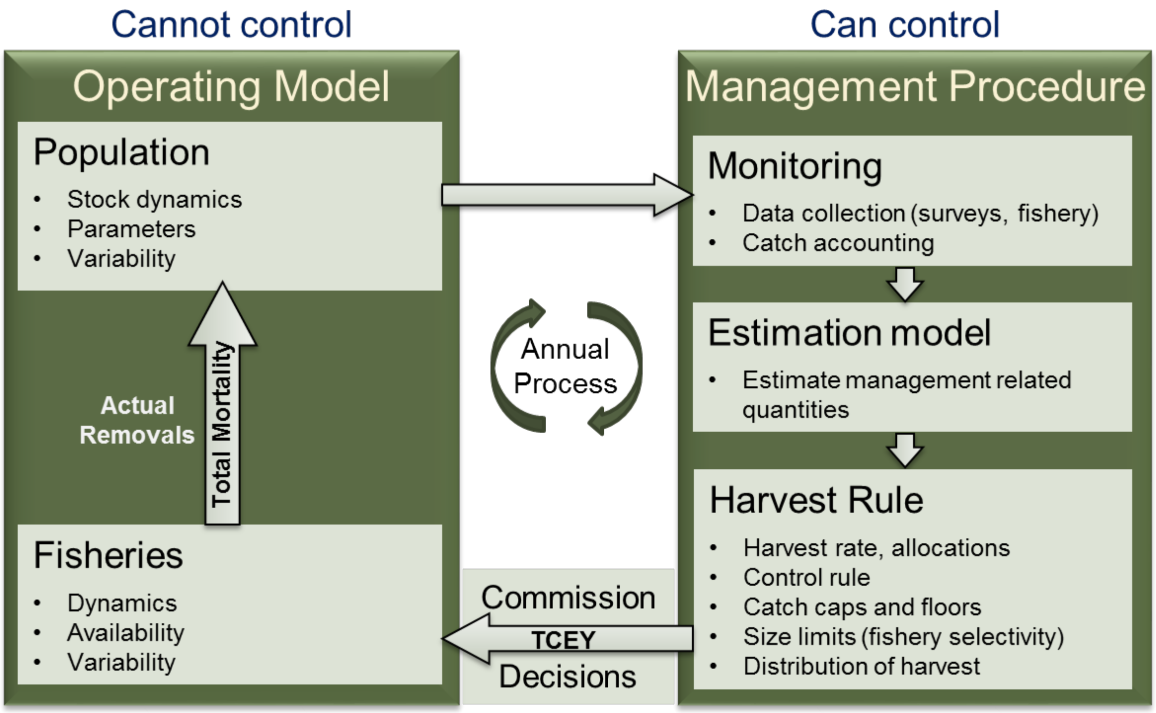

Figure 3. Diagram of the relationship between the four modules in the framework. The simulations run each module on an annual time-step, producing output that is used in the next time-step. See text for a description of operating model, monitoring, estimation model, and harvest rule.

3.1.1 Conditioning the Operating Model

The operating model (OM) should be a reasonable depiction of reality with an appropriate level of uncertainty, which is accomplished through a process called conditioning. The operating model (OM) consists of two Stock Synthesis, or SS (Methot and Wetzel 2013), models parameterized similarly to the short and long coastwide assessment models for Pacific halibut (Stewart & Martell 2016). Each SS model is conditioned by fitting to the same data used in the 2017 stock assessment (Stewart & Webster 2018; Stewart & Hicks 2018). In order to evaluate and choose management procedures that are robust to uncertainty in the population, many assumptions in the assessment model were freed up to characterize a wider range of possibilities in the future. Table 2 shows the parameters that were different from the assessment models. Estimating natural mortality in both models and estimating steepness were the only processes changed from the assessment model when conditioning.

Table 2. Parameter estimation in the assessment and operating model.

Parameter	**Assessment**	**OM**
Natural Mortality (*M*)	Some estimated	All estimated without priors
Recruitment (lognormal devs)	Variability fixed at 0.6 (long) 0.9 (short)	Same as assessment
Steepness (*h*)	Fixed at 0.75	Estimated variability based on long model centered around 0.75 for both.

Overall, the individual operating models mimic the assessment well, but with additional uncertainty. The most important aspect is to characterize variability and the dynamics of the stock to ensure that the evaluation of management procedures is robust to potential future scenarios. When comparing the combined operating model to the ensemble assessment, the median spawning biomass trajectories are similar, but the variability in the operating model is much greater than the ensemble assessment (Figure 4).

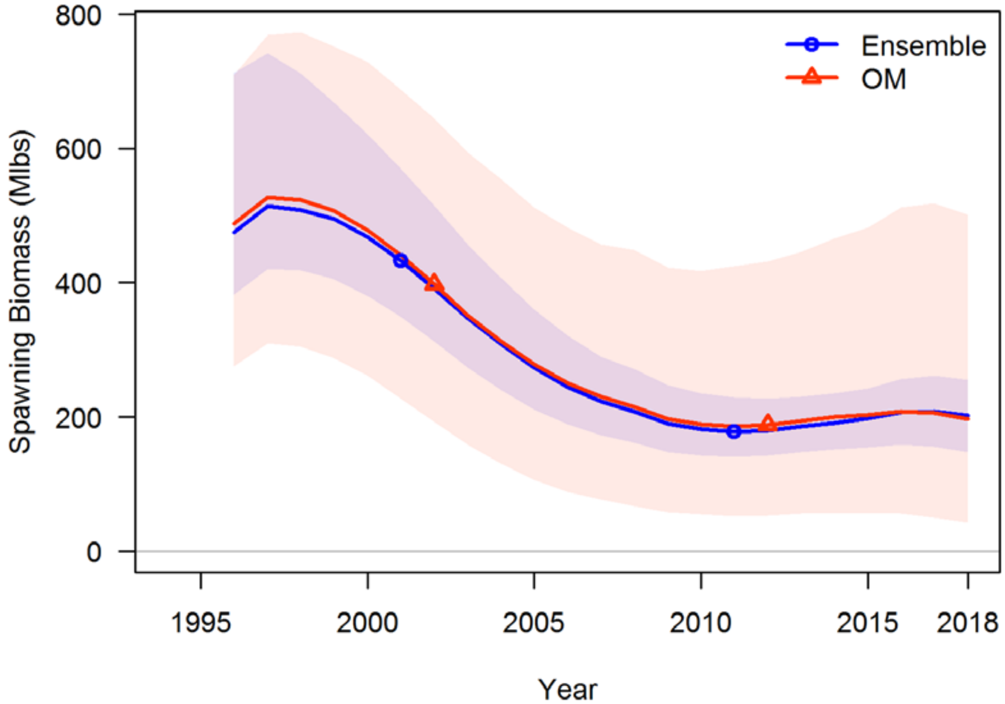

Figure 4. The conditioned operating model (red) compared to the stock assessment ensemble (blue) with 95% confidence intervals on each.

3.1.2 Simulating Forward with the Operating Model

The short and long coastwide models make up the operating model and incorporate variability associated with estimated parameters describing stock and fishery dynamics. Variability from other sources (e.g., weight-at-age, recruitment regimes, and allocation to fishery sectors) was introduced when projecting into the future. Descriptions of these procedures are provided in Hicks (2017), and updates to the procedures are described in Hicks (2018a). An overview of major sources of variability are shown in Table 3.

Table 3. Processes and associated variability in the operating model (OM). TM refers to total mortality.

Process	**Uncertainty**
Natural Mortality (M)	Estimate appropriate uncertainty when conditioning OM
Recruitment	Random, lognormal deviations
Size-at-age	Annual and cohort deviations in size-at-age with bounds
Steepness	Estimate appropriate uncertainty when conditioning OM
Regime Shifts	Autocorrelated indicator based on properties of the PDO to determine average recruitment
TM to sectors	Allocating of TM to sectors with variability

3.2 MANAGEMENT PROCEDURE

The elements of the management procedure are described in reverse order because it is easier to understand the decisions made for modelling them since they are dependent on each other. Therefore, the harvest rule is presented first, followed by the estimation model, and finishing with monitoring.

3.2.1 Harvest Rule

The generalized management procedure to evaluate is shown in Figure 1, but the focus has been on the Scale portion to produce results for the MSAB to evaluate before AM095 in 2019. Specifically, the portion of the management procedure being evaluated is a harvest control rule (Figure 5) that is responsive to stock status and consists of a procedural SPR determining fishing intensity, a fishery trigger based on stock status that determines when the fishing intensity begins to be reduced, and a fishery limit that determines when there is theoretically no fishing intensity (this may differ from the biomass limit defined in objective 1.1 of Appendix Ia).

Simulations have been used in the past to evaluate a range of SPR values from 25% to 60% and trigger values of 30% and 40% (Hicks 2017). Those simulations provided insight into how those different levels of SPR would meet the objectives defined by the MSAB, but few values of SPR below 40% were tested. The simulations evaluated here use an updated simulation framework to investigate management procedures incorporating a finer resolution of SPR values ranging from 30% to 56% and fishery trigger points of 30% and 40%, with the addition of a 25:10 fishery trigger and fishery limit as well as no fishery trigger and fishery limit for comparison. Additionally, management procedures incorporating a constraint on how much the Total Mortality could change from year to year were evaluated.

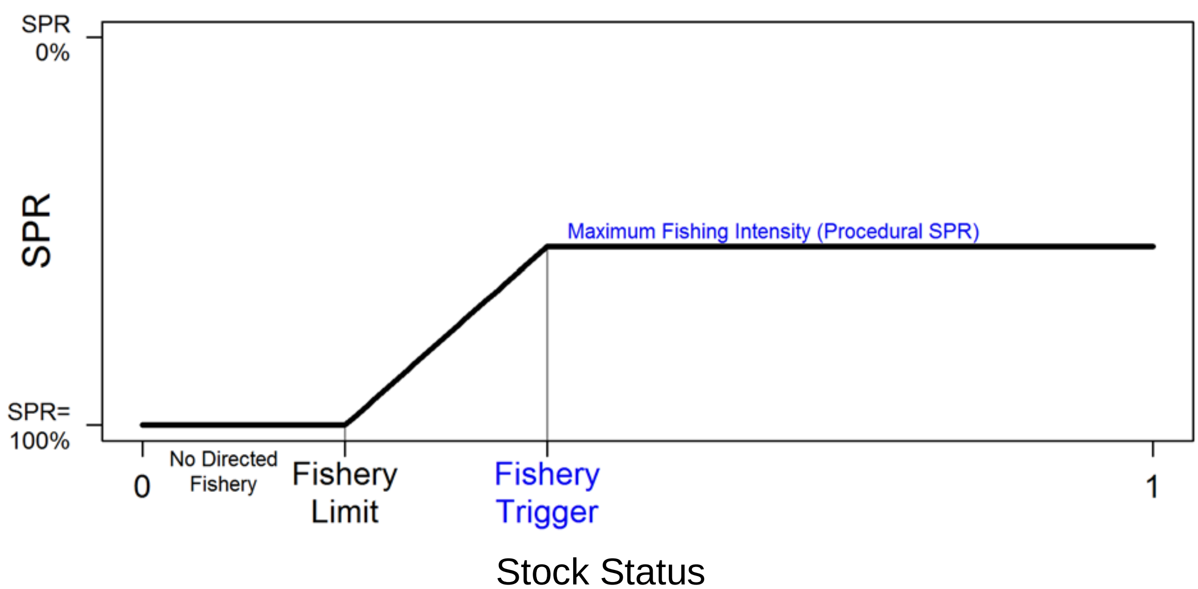

Figure 5. A harvest control rule responsive to stock status that is based on Spawning Potential Ratio (SPR) to determine fishing intensity, a fishery trigger level of stock status that determines when the fishing intensity begins to be reduced, and a fishery limit based on stock status that determines when there is theoretically no fishing intensity (SPR=100%). In reality, it is likely that only the directed fishery would cease. The Procedural SPR and the Fishery Trigger (in blue) are the two values suggested for evaluation by the MSAB (IPHC 2018a).

3.2.2 Estimation Model

Previously, results were presented with No Estimation Model (called Perfect Information at that time). However, this was for reference for the best performance that a management procedure may produce. Although useful for reference, appropriately accounting for the error in an estimation model will provide more realistic performance of the management procedures and should be used in the evaluation.

An example of estimation error can b seen with the result from recent Pacific halibut assessments. The 2017 stock assessment updated the population estimates and determined that the SPR resulting from actual total mortality from all sources in 2017 was 40%, instead of the 45% projected from the mortality limits adopted by Commissioners at AM093, this was updated to an estimated SPR greater than 46% in the 2018 assessment. Furthermore, the Commission suggested mortality limits for 2018 at AM094 that would correspond to an SPR of 41%, which was updated to an SPR near 49% in the 2018 stock assessment. These examples of estimation error are inherent in the process due to uncertainty in the data. All of these updated SPR estimates are within the confidence bounds for the SPR reported in the original stock assessment, and uncertainty in incoming recruitment is likely a large source of the variability. As shown in this three year example, the estimation error may easily be positive or negative (i.e., above or below the adopted value).

In the MSE framework, estimation error was simulated, due to time constraints and the amount of time it takes to perform a single simulation, by adding error to the simulated stock status (used in the harvest control rule to determine when the fishing intensity is reduced) and in the resulting Total Mortality (TM). Investigations of recent stock assessments suggested coefficients of variation on stock status and total mortality of 15% with a correlation of 0.5 between stock status and TM, and an autocorrelation (the persistence of errors in a specific direction) of 0.4. Other levels of error were simulated to determine how sensitive the results are to the assumed estimation error. Overall, this method is a suitable approximation to understand the effects of estimation error and provide results that would be typical when using the current assessment paradigm.

3.2.3 Monitoring (Data Generation)

With the simplified incorporation of estimation error, the generation of data was not required. However, if a stock assessment were simulated, there would be many sources of data to generate, or if a management procedure was based on data (such as only the survey index), those data would need to be generated.

3.3 SUMMARY OF THE FRAMEWORK

A summary of the major specifications for each component is provided below, with the components listed in a specific order where the next component is dependent on the decisions for the previous components.

1) Operating Model
    a) Stock synthesis, based on coastwide assessment models (short and long models).
    b) Five fleets, as in the assessment models (commercial, discards, bycatch, sport, personal use).
    c) Fishing mortality assigned to sectors based on historical information (with variability).
    d) Uncertainty incorporated through parameter uncertainty, model uncertainty, a simulated variability in future weight-at-age and recruitment.

2) Management Procedure (MP)
   a) Data Generation
      i) Not needed at this time.
   b) Estimation Models
      i) Simulate error in total mortality (cv=0.15) and spawning biomass (cv=0.15), with autocorrelation (0.4), from the simulated time-series to mimic an unbiased stock assessment.
   c) Harvest Rule
      i) Coastwide fishing intensity (F_{SPR}) using a procedural SPR (30% to 56%).
      ii) A fishing trigger to reduce the fishing intensity (increase SPR) when stock status is below a specified level (25%, 30%, and 40%).
      iii) A fishing limit to cease directed fishing when the stock status is less than a specified value (20% and 10%).
      iv) Constraints on the annual change in the TM as follows

         (1) maxChangeBoth: limited the annual change in TM (up or down) to no more than 15%
         (2) maxChangeUp: limited the annual increase in TM to no more than 15%, but allowing the full decrease as determined by the MP.
         (3) slowUpFastDown: limited the annual increase in TM to one-third of the difference between the value determined by the MP and the current TM, and limited the annual decrease in the TM to one-half of the difference between the current TM and the value determined by the MP.
         (4) slowUpFullDown: limited the annual increase in TM to one-third of the difference between value determined by the MP and the current TM, and not limiting the annual decrease in the TM.
         (5) Cap: fixed the TM at either 60 million pounds or 80 million pounds when the TM determined from the MP is greater than the respective cap.
         (6) MultiYear: running the MP every third year to determine a new TM. In-between those years the TM remained constant.

4 Simulation Results

Using the simulation framework described above and in previous documents, many test cases were first investigated to better understand the dynamics of the simulations as well as verify that the results are as expected. Simulations with no fishing produce trajectories of female spawning biomass that increased and ranged from 200 Mlbs to 1,500 Mlbs (91,000 t to 680,000 t). This range of variability in the spawning biomass was due to the variability in weight-at-age and recruitment regimes. Simulations holding weight-at-age at low or high levels and the recruitment regime at a negative or positive phase showed that high weight-at-age with high recruitment produced very large spawning biomasses, and vice versa. However, high weight-at-age with low recruitment, and low weight-at-age with high recruitment overlapped with spawning biomass between 300 Mlbs and 1,000 Mlbs (136,000 t to 454,000 t).

Table 4 and Table 5 show the long-term primary biological performance metric and the medium-term (14-23 years) fishery sustainability performance metrics for the main runs requested at MSAB011 (IPHC 2018a). Table 6 shows the same long-term performance metrics for a control rule of 25:10. Short-term performance metrics were similar for these management procedures because the current spawning biomass is likely to be above the fishery trigger (e.g., 30%), thus are not shown. For long-term results with a control rule the probability that the stock is below 20% of the dynamic unfished equilibrium biomass is less than 0.01 (<1/100) for all cases. This is a result of the control rule limiting the fishing intensity as the stock approaches the 20% threshold even with estimation error present, and since dynamic relative spawning biomass is a measure of the effect of fishing, reducing the fishing intensity reduces the risk of dropping below this threshold. It is rare that positive estimation error persists for a long enough period that fishing intensity remains high and the stock falls below the 20% threshold. The outcome of this reduction in fishing intensity can be seen in the average annual variability (AAV), which is a measure of the change in the mortality limit from year to year. At fishing intensities greater than that associated with an SPR of 40% (i.e., SPR values less than 40%) the probability that the AAV is greater than 15% is greater than two-thirds (>67/100) for all control rules tested. This probability declines to around 0.60 (60/100) at an SPR of 56% for the 30:20 and 25:10 control rules. The 40:20 showed higher variability in the mortality limit, even though the slope is not as steep, because the reduction in fishing intensity occurs more often given the 40% fishery trigger value and the range of SPR values evaluated. The absolute value of the Total Mortality mortality limit was highly variable for a given SPR (Figure 6).

In summary, long-term performance metrics showed little risk of falling below the 20% dynamic biomass threshold; in the medium-term, high variability in catches increased with higher fishing intensities (i.e. lower SPR), and median Total Mortality limits increased slightly with greater fishing intensity. Therefore, all SPR's greater than 30% met the biological sustainability objective, but no management procedure met the stability objective. However, at fishing intensities greater than those associated with an SPR of 40% (i.e., SPR values less than 40%) the variability in total mortality increased rapidly and median total mortality made minimal gains (Figure 6 and Appendix III).

The use of SPR values without a control rule (results not shown) also did not meet the stability objective for any SPR considered, which means that estimation error is a large part of the variability in the total mortality limits. Therefore to meet the stability objective, additional elements of a management procedure need to be included to stabilize the limits. Four different general options for constraining the limit were simulated to evaluate their potential to meet the primary objectives (see Section 4.3, item 2.iv). With the 30:20 control rule and SPR values of 40% and 46%, the biological sustainability goal was met for all constraint options (Table 7). All of the constraint types reduced the variability in the total mortality limits, but capping the limit at a value of 60 million pounds (~27,000 t) showed little reduction to the overall variability. Constraining the annual change in the total mortality limit either by invoking a maximum percentage change or through a slow-up fast-down type approach showed promise in meeting the stability objective, with some loss to median yield and a slight increase to biological sustainability risk. However, it is uncertain how much yield opportunity is lost when the stock is at high abundance. Setting the limit every third year was able to meet the stability objective (calculated on an annual basis) with little loss to median yield and no increase to biological sustainability risk. However, the change that occurs every third year was not investigated, and may exceed the average annual change when using a management procedure without any constraint. Of the management procedures evaluated, an SPR of 40% with a 30:20 control rule and a constraint to not change the annual mortality limit by more than 15% in either direction met all objectives and was ranked the highest based on the primary objectives (Table 7).

Many more performance metrics for the full set of simulated management procedures are available for interactively viewing in a table or on plots at http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSAB012/.

Table 4: Primary performance metrics for a 30:20 control rule, and a range of input SPRs from 0.3 to 0.56. P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Long-term is a ten-year period after simulating 90 annual cycles. Medium-term is a ten-year period after simulating 13 annual cycles (i.e., simulated years 14-23).

Input Control Rule	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**
Input SPR	**56%**	**48%**	**46%**	**44%**	**42%**	**40%**	**38%**	**36%**	**34%**	**32%**	**30%**
Biological Sustainability (Long-term)											
P(all dRSB<20%)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
P(any dRSB_y<20%)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Fishery Sustainability (medium-term)											
P(all AAV > 15%)	0.60	0.66	0.69	0.72	0.76	0.80	0.84	0.88	0.93	0.96	0.98
Median average TM[3]	39.4	45.5	46.8	48.0	49.5	50.6	51.8	52.1	52.4	53.2	52.8
Rankings (lower is better)											
Meet biological objective?[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Meet stability objective?[2]	No	No	No	No	No	No	No	No	No	No	No
Maximum catch (TM)[3]	11	10	9	8	7	6	5	4	3	1	2
Overall Ranking	—	—	—	—	—	—	—	—	—	—	—

[1] This is determined using P(any dRSB < 20%) and the objective to maintain RSB above 20% at least 90% of the time. Note that all procedures meet this objective.

[2] This is determined using P(all AAV >15%) and the objective to maintain AAV below 15%.at least 75% of the time. Note that no procedures meet this objective.

[3] This ranking is determined using median average TM, which may be subject to Monte Carlo error. Note that the highest fishing intensity meets this objective, although the yield curve begins to flatten at those low SPR values.

Table 5: Primary performance metrics for a 40:20 control rule, and a range of input SPRs from 0.3 to 0.56. P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Long-term is a ten-year period after simulating 90 annual cycles. Medium-term is a ten-year period after simulating 13 annual cycles (i.e., simulated years 14-23).

Input Control Rule	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**
Input SPR	**56%**	**48%**	**46%**	**44%**	**42%**	**40%**	**38%**	**36%**	**34%**	**32%**	**30%**
Biological Sustainability (Long-term)											
P(all dRSB<20%)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
P(any dRSB_y<20%)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fishery Sustainability (medium-term)											
P(all AAV > 15%)	0.718	0.843	0.880	0.915	0.954	0.966	0.977	0.987	0.991	0.994	0.995
Median average TM[3]	39.2	44.4	45.5	46.4	47.6	48.3	48.8	48.9	49.4	49.5	49.8
Rankings (lower is better)											
Meet biological objective?[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Meet stability objective?[2]	No	No	No	No	No	No	No	No	No	No	No
Maximum catch (TM)[3]	11	10	9	8	7	6	5	4	3	2	1
Overall Ranking	—	—	—	—	—	—	—	—	—	—	—

[1] This is determined using P(any dRSB < 20%) and the objective to maintain RSB above 20% at least 90% of the time. Note that all procedures meet this objective.

[2] This is determined using P(all AAV >15%) and the objective to maintain AAV below 15%.at least 75% of the time. Note that no procedures meet this objective.

[3] This ranking is determined using median average TM, which may be subject to Monte Carlo error. Note that the highest fishing intensity meets this objective, although the yield curve begins to flatten at those low SPR values.

Table 6: Primary performance metrics for a 25:10 control rule, and a range of input SPRs from 0.3 to 0.56. P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Long-term is a ten-year period after simulating 90 annual cycles. Medium-term is a ten-year period after simulating 13 annual cycles (i.e., simulated years 14-23).

Input Control Rule	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**
Input SPR	**56%**	**48%**	**46%**	**44%**	**42%**	**40%**	**38%**	**36%**	**34%**	**32%**	**30%**
Biological Sustainability (Long-term)											
P(all dRSB<20%)	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.02	0.03	0.05
P(any dRSB_y<20%)	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.02	0.03	0.06	0.10	0.14
Fishery Sustainability (medium-term)											
P(all AAV > 15%)	0.58	0.60	0.63	0.65	0.66	0.67	0.69	0.74	0.77	0.83	0.88
Median average TM[3]	39.4	45.9	47.1	48.5	49.9	51.2	52.6	54.0	55.0	55.3	55.3
Rankings (lower is better)											
Meet biological objective?[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Meet stability objective?[2]	No	No	No	No	No	No	No	No	No	No	—
Maximum catch (TM)[3]	10	9	8	7	6	5	4	3	2	1	—
Overall Ranking	—	—	—	—	—	—	—	—	—	—	—

[1] This is determined using P(any dRSB < 20%) and the objective to maintain RSB above 20% at least 90% of the time. Note that all procedures meet this objective, except for an SPR of 30%.

[2] This is determined using P(all AAV >15%) and the objective to maintain AAV below 15%.at least 75% of the time. Note that no procedures meet this objective.

[3] This ranking is determined using median average TM, which may be subject to Monte Carlo error. Note that the highest fishing intensity meets this objective, although the yield curve begins to flatten at those low SPR values.

Table 7: Primary performance metrics for a 30:20 control rule, input SPRs 0.4 and 0.46, and various constraints on the annual change in the total mortality (see Section 4.3). P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Long-term is a ten-year period after simulating 90 annual cycles. Medium-term is a ten-year period after simulating 13 annual cycles (i.e., simulated years 14-23).

Input Control Rule	**30:20**													
Constraint	**maxChange Both**		**maxChange Up**		**slowUp FastDown**		**slowUp FullDown**		**Cap80**		**Cap60**		**multiYear**	
Input SPR	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**
Biological Sustainability (Long-term)														
P(all dRSB<20%)	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
P(any dRSB_y<20%)	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fishery Sustainability (medium-term)														
P(all AAV > 15%)	0.04	0.05	0.27	0.35	0.07	0.14	0.13	0.26	0.58	0.61	0.45	0.48	0.14	0.26
Median average TM[3]	46.1	49.5	44.0	45.3	45.0	49.5	44.7	49.3	46.4	50.7	46.1	50.0	46.5	50.5
Rankings (lower is better)														
Meet biological objective?[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Meet stability objective?[2]	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	Yes	No
Maximum catch (TM)[3]	9	4	14	11	12	5	13	6	8	1	10	3	7	2
Overall Ranking	**4**	**1**	**—**	**—**	**5**	**2**	**6**	**—**	**—**	**—**	**—**	**—**	**3**	**—**

[1] This is determined using P(any dRSB < 20%) and the objective to maintain RSB above 20% at least 90% of the time. Note that all procedures meet this objective.

[2] This is determined using P(all AAV >15%) and the objective to maintain AAV below 15%.at least 75% of the time. Note that some procedures meet this objective.

[3] This ranking is determined using median average TM, which may be subject to Monte Carlo error. Note that the highest fishing intensity meets this objective, although the yield curve begins to flatten at those low SPR values.

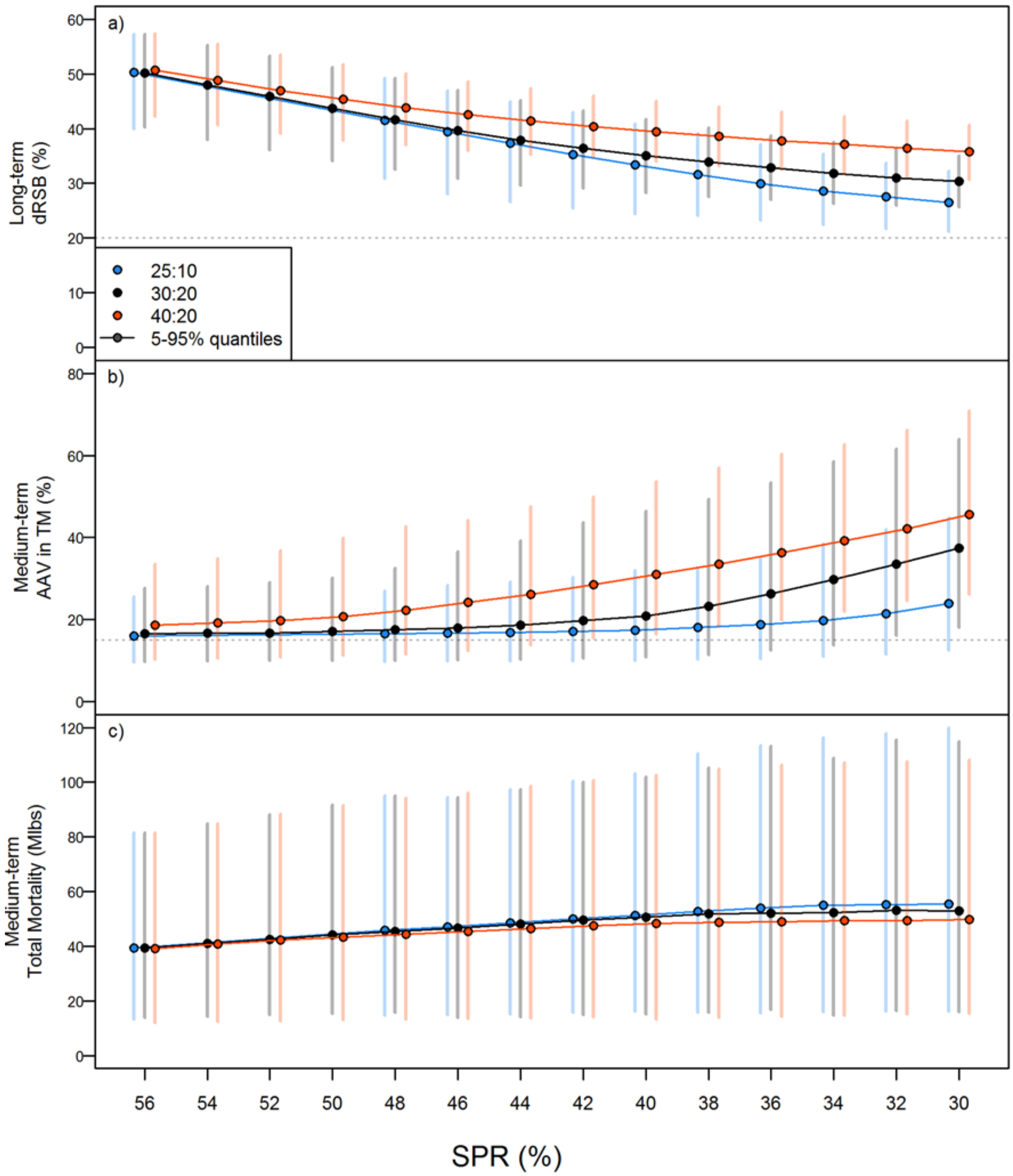

Figure 6. Primary long-term biological sustainability performance metric (dynamic relative spawning biomass), and primary medium-term biological sustainability performance metrics (AAV of TM, and Total Mortality in millions of pounds) for SPR values from 0.3 to 0.56 and control rules 40:20, 30:20, and 25:10. The points are the median values from the simulations and the vertical bars are the 90% intervals (i.e. 5th and 95th percentiles from the simulations).

5 DISTRIBUTING THE TCEY

A considerable amount of discussion related to a description of the harvest strategy policy occurred at previous MSAB meetings. Figure 1 shows an updated depiction of the harvest strategy policy with terms describing the various components. These terms are defined in the IPHC glossary[3], but of note for this paper are TCEY distribution, stock distribution, and distribution procedures. The management procedure is the sequence of elements including the assessment, fishing intensity, stock distribution, and distribution procedures. The goal of the MSAB is to define a management procedure that will be used to output O26 mortality limits (TCEY) for each Regulatory Area that meet the long-term objectives of managers and stakeholders. The "decision" step on the right of Figure 1 is where a deviation from the management procedure may occur due to input from other sources and decisions of the Commissioners that may reflect current biological, environmental, social, and economic conditions.

In 2017, the Commission agreed to move to an SPR-based management procedure to account for the mortality of all sizes and from all fisheries. The procedure uses a coastwide fishing intensity based on spawning potential ratio (SPR), which defines the "scale" of the coastwide catch. The interim management procedure consists of two inputs for distributing the TCEY among IPHC Regulatory Areas: 1) the current estimated stock distribution and 2) relative target harvest rates.

5.1 STOCK DISTRIBUTION

The IPHC uses a space-time model to estimate annual Weight-Per-Unit-Effort (WPUE) for use in estimating the annual stock distribution of Pacific halibut (IPHC-2019-AM095-07). These predictions are then averaged within each IPHC Regulatory Area, and combined among IPHC Regulatory Areas, weighting by the "geographic extent" (calculated area within the survey design depth range) of each IPHC Regulatory Area. It is important to note that this produces relative indices of abundance and biomass, but does not produce an absolute measure of abundance or biomass because it is weight-per-unit-effort scaled by the geographic extent of each IPHC Regulatory Area. These indices are useful for determining trends in stock numbers and biomass, and are also useful to estimate the geographic distribution of the stock. Historically, the O32 stock distribution has been used, despite the logical inconsistency with the TCEY representing mortality that is generally O26.

5.2 USING RELATIVE HARVEST RATES

The distribution of the TCEY is shifted from the estimated stock distribution based on relative target harvest rates. Previously, this was accomplished by applying different harvest rates in western areas (16.125% in IPHC Regulatory Areas 3B, 4A, 4B, and 4CDE)) and eastern areas (21.5% in IPHC Regulatory Areas 2A, 2B, 2C, and 3A). However, with the elimination of EBio and the use of SPR-based fishing intensity to determine the coastwide scale, the TCEY, rather than the esoteric concept of exploitable biomass, is distributed. Therefore, an absolute measure of harvest rate is not necessary. Consistent with the previous approach, relative harvest rates are used in the interim management procedure with a ratio of 1.00:0.75, being equal to the ratio between 21.5% and 16.125%. Applying these relative harvest rates shifts the target TCEY distribution away from the stock distribution by moving more TCEY into IPHC Regulatory Areas 2A, 2B, 2C, and 3A and less TCEY from IPHC Regulatory Areas 3B, 4A, 4B, and 4CDE, thus harvesting at a higher rate in eastern IPHC Regulatory Areas. These relative rates include a mix of biology (historically stock productivity and scientific uncertainty) and policy choices.

5.3 A FRAMEWORK FOR DISTRIBUTING THE TCEY

TCEY distribution is the part of the management procedure for distributing the TCEY among Regulatory Areas (Figure 1) and is composed of a purely scientific component to distribute the TCEY in proportion to its estimated biomass in each region (stock distribution) and steps to further modify the distribution of the TCEY based on additional considerations (distribution procedures). These two components are described below.

[3] https://iphc.int/the-commission/glossary-of-terms-and-abbreviations

5.3.1 Stock Distribution

Emerging understanding of Pacific halibut diversity across the geographic range of the Pacific halibut stock indicates that IPHC Regulatory Areas should only be considered as management units and do not represent relevant sub-populations (Seitz et al. 2017). Balancing the removals against the current stock distribution is likely to protect against localized depletion of spatial and demographic components of the stock that may produce differential recruitment success under changing environmental and ecological conditions. Biological Regions, defined earlier and shown in Figure 2, are considered by the IPHC Secretariat, and supported by the SRB, to be the best option for biologically-based areas to meet management needs, and will help to conserve spatial stock structure.

Biological Regions represent the most logical scale over which to consider conservation objectives related to distribution of the fishing mortality. In addition, the "all sizes" WPUE from the space-time model (**IPHC-2019-AM095-07**), which is largely composed of O26 Pacific halibut (due to selectivity of the setline gear), is more congruent with the TCEY (O26 catch levels) than O32 WPUE. Therefore, when defining the stock distribution, the estimated proportion of "all sizes" WPUE from the space-time model should be used for consistency. Adjusting the stock distribution among Biological Regions accounts for additional considerations via the relative target harvest rates, and further distributing the TCEY to IPHC Regulatory Areas would be done through steps defined in the Distribution Procedures component (Figure 1). Distributing the TCEY from Region to individual IPHC Regulatory Area, may be entirely based on management considerations.

5.3.2 Distribution Procedures

Distribution Procedures contains the steps of further modifying the distribution of the TCEY among Biological Regions and then distributing the TCEY among IPHC Regulatory Areas within Biological Regions. Modifications at the Biological Region or IPHC Regulatory Area level may be based on differences in production between areas, observations in each area relative to other areas (e.g., WPUE), uncertainty of data or mortality in each area, defined allocations, or national shares. Data may be used as indicators of stock trends in each Region or IPHC Regulatory Area, and are included in the Distribution Procedures component because they may be subject to certain biases and include factors that may be unrelated to biomass in that Biological Region or IPHC Regulatory Area. For example, commercial WPUE is a popular source of data that may better represent fishery performance than an index that is proportional to biomass. Types of data to be used may include fishery WPUE, survey observations (not necessarily the IPHC fishery-independent setline survey), age-compositions, size-at-age, and environmental observations.

The steps in the Distribution Procedures may consider conservation objectives, but they will mainly be developed with respect to fishery objectives. Yield and stability in catch levels are two important fishery objectives that often contradict each other (i.e. higher yield often results in less stability), and area-specific fishery objectives may be in conflict across IPHC Regulatory Areas. Pacific halibut catch levels are defined for each IPHC Regulatory Area and quota is accounted for by those Regulatory Areas. Therefore, IPHC Regulatory Areas are the appropriate scale to consider fishery objectives.

5.4 A Framework for a Management Procedure to Distribute TCEY Across the Coast

The harvest strategy policy begins with the coastwide TCEY determined from the stock assessment and fishing intensity determined from a target SPR (Figure 1). When distributing the TCEY among regions, stock distribution occurs first to distribute the harvest in proportion to biomass and satisfy conservation objectives, and then is followed by adjustments across Biological Regions and Regulatory Areas based on distribution procedures to further encompass conservation objectives and consider fishery objectives. The key to these adjustments is that they are relative adjustments such that the overall fishing intensity (target SPR) is maintained (i.e. a zero sum game with respect to fishing intensity). Otherwise, the procedure is broken and it is uncertain if the defined objectives will be met.

A framework for a management procedure that ends with the TCEY distributed among IPHC Regulatory Areas and would encompass conservation and fishery objectives is described below.

1. **Coastwide Target Fishing Intensity:** Determine the coastwide total mortality using a target SPR that is most consistent with IPHC objectives defined by the Commission. Separate the total mortality into approximate ≥26 inches (O26) and under 26 inches (U26) components. The O26 component is the coastwide TCEY.
    1.1. The coastwide fishing intensity will continue to be evaluated in the MSE along with distribution related management procedures.
2. **Biological Stock Distribution:** Calculate the stock distributionamong four (4) Biological Regions based on the modelled survey results for all sizes of Pacific halibut.
    2.1. Four Regions (2, 3, 4, and 4B) are defined above (Figure 2).
3. **Regional Allocation Adjustment:** Adjust the distribution of the TCEY among Biological Regions, from the Biological Stock Distribution in step 2, to account for other factors.
    3.1. Relative target harvest rates are part of a management/policy decision that may be informed by data and observations. This may include evaluation of recent trends in estimated quantities (such as fishery-independent CPUE), inspection of historical trends in fishing intensity, recent or historical fishery performance, and biological characteristics of the Pacific halibut observed in each Biological Region. Yield-Per-Recruit (YPR) and/or surplus production calculations may provide further supplementary information for this discussion. The regional relative harvest rates may also be partially determined through negotiation, which is simply an allocation agreement for further Regional adjustment of the TCEY, as long as the regional stock distribution still meets conservation objectives.
4. **Regulatory Area Allocation:** Apply IPHC Regulatory Area allocation percentages within each Biological Region to distribute the Region-specific TCEY's to Regulatory Areas.
    4.1. This part represents a management/policy decision, and may be informed by data, based on past or current observations, or defined by an allocation agreement. For example, recent trends in estimated all sizes WPUE from the setline survey or fishery, age composition, or size composition may be used to distribute the TCEY to IPHC Regulatory Areas. Inspection of historical trends in fishing intensity or catches by IPHC Regulatory Area may also be used. Agreed upon percentages are also an option. This allocation to IPHC Regulatory Areas may be a procedure with multiple adjustments using different data, observations, or agreements

The four steps described above would be contained within the IPHC Harvest Strategy Policy as part of the Management Procedure, and are pre-determined steps that have a predictable outcome. The decision making process would then occur (Figure 1).

5. **Annual Regulatory Area Adjustment**: Adjust individual Regulatory Area TCEY limits to account for other factors as needed. This is the policy part of the harvest strategy policy and occurs as a final step where other objectives are considered (e.g. economic, social, etc.).
    5.1. Departing from the target SPR may be a desired outcome for a particular year (short-term, tactical decision making based on current trends estimated in the stock assessment), but would deviate from the management procedure and the long-term management objectives. Departures from the management procedure may result in unpredictable outcomes, but could also take advantage of current situations.

5.4.1 Potential Elements of the Management Procedures Related to Distribution

The MSAB012 report (IPHC 2018b) listed ten potential tools for use in developing distribution procedures. How each of these potential tools will be used is not completely determined and they will be discussed at future MSAB meetings. Additional potential tools will also be identified at subsequent meetings.

- Relative harvest rates.
- O32:O26 ratios.
- Trends in setline survey WPUE by IPHC Regulatory Area.
- Trends in modelled setline survey WPUE by biological region.
- Trends in fishery CPUE.
- Limiting the amount of change for area-specific catch limits.
- Percentage allocation with a floor (i.e. minimums of 1.5 Mlbs in 2A and 1.7 Mlbs in 4CDE).
- Stair-step allocations.
- A maximum SPR with catch distribution by IPHC Regulatory Area determined from the modelled survey WPUE.
- Coastwide TCEY target and maximum calculated; distribution by target, but with ability to adjust TCEY up to the maximum.

6 PROGRAM OF WORK

The current MSE Program of Work (Hicks 2018b) is a description of activities related to the MSE and the Management Strategy Advisory Board (MSAB) that the IPHC Secretariat will engage in for the next five years. It describes each of the priority tasks, lists some of the resources needed for each task, and provides a timeline for each task. However, this work plan is flexible and may be changed throughout this period with the guidance of the MSAB, Science Review Board (SRB) members, and Commission. The order of the tasks in this work plan represents the sequential development of each task, and many subsequent tasks are dependent on the previous tasks.

6.1 MANAGEMENT STRATEGY EVALUATION (MSE)

Management Strategy Evaluation (MSE) is a process to evaluate alternative management strategies. This process involves the following

1. defining fishery goals and objectives with the involvement of stakeholders and managers,
2. identifying management procedures to evaluate,
3. simulating a halibut population with those management procedures,
4. evaluating and presenting the results in a way that examines trade-offs,
5. applying a chosen management procedure, and
6. repeating this process in the future in case of changes in objectives, assumptions, or expectations.

Figure 7 shows these different components and that the process is not necessarily a sequential process, but there may be movement back and forth between components as learning progresses. The involvement of stakeholders and managers in every component of the process is extremely important to guide the MSE and evaluate the outcomes.

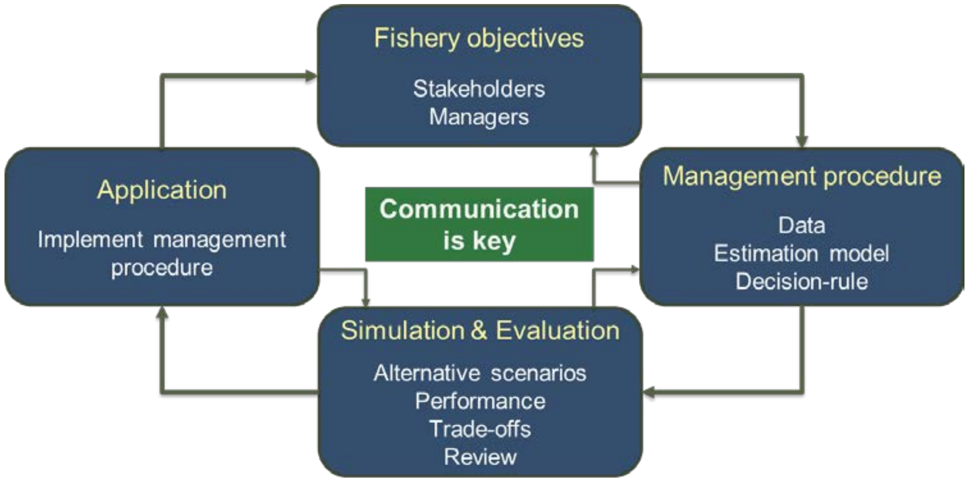

Figure 7. A depiction of the Management Strategy Evaluation (MSE) process showing the iterative nature of the process with the possibility of moving either direction between most components.

Management Strategy Evaluation is a process that can develop over many years with many iterations. It is also a process that needs monitoring and adjustments to make sure that management procedures are performing adequately. Therefore, the MSE work for Pacific halibut fisheries will be ongoing as new objectives are addressed, more complex models are built, and results are updated. This time will include continued consultation with stakeholders and managers via the MSAB meetings, defining and refining goals and objectives, developing and coding models, running simulations, reporting results, and making decisions. Along the way, there will be useful outcomes that may be used to improve existing management, and will influence recommendations for future work.

A detailed program of work has been developed for the next two years, with results for decision-making being presented to the Commission at the Annual Meetings in 2019 and 2021 (Table 8). More specifically, an evaluation of "Scale" (coastwide fishing intensity and the harvest control rule) will be presented at AM095 in January 2019. An evaluation of the entire harvest strategy depicted in Figure 1 (Scale and Distribution) will be completed in late 2020 and presented to the Commission for decision-making at AM097 in January 2021.

The evaluations delivered at AM097 will shape the IPHC harvest policy, but other aspects will become of interest and MSE work will continue afterwards.

Table 8. Timeline for MSE work in 2018–21.

May 2018 MSAB Meeting
Review Goals
Look at results of SPR
Review Performance Metrics
Identify Scale MP's
Review Framework
Identify Preliminary Distribution MP's
October 2018 MSAB Meeting
Review Goals
Complete results of SPR
Review Performance Metrics
Identify Scale MP'S
Verify Framework
Identify Distribution MP's
Annual Meeting 2019
Recommendation on Scale Present possible distribution MP's
May 2019 MSAB Meeting
Evaluate additional Scale MP's
Review Goals
Spatial Model Complexity
Identify MP's (Distn Scale)
Review Framework
October 2019 MSAB Meeting
Review Goals
Spatial Model Complexity
Identify MP's (Distn Scale)
Review Framework
Review multi-area model development
Annual Meeting 2020
Update on progress
May 2020 MSAB Meeting
Review Goals
Review multi-area model
Review preliminary results
October 2020 MSAB Meeting
Review Goals
Review preliminary results
Annual Meeting 2021
Presentation of first complete MSE product to the Commission Recommendations on Scale and Distribution MP

MSE TASKS FOR THE NEXT 5 YEARS

Task 1. Verify that goals are still relevant and further define objectives.

Task 2. Develop performance metrics to evaluate objectives.

Task 3. Identify realistic management procedures of interest to evaluate with a closed-loop simulation framework. This includes management procedures related to coastwide scale (e.g., SPR) and to distributing the TCEY.

Task 4. Design a closed-loop simulation framework and code a computer program to extend the current simulation framework.

Task 5. Develop educational and visualization tools that will engage stakeholders and Commissioners, as well as facilitate communication and evaluation.

Task 6. Further the development of operating models to include multiple areas and additional structural uncertainty.

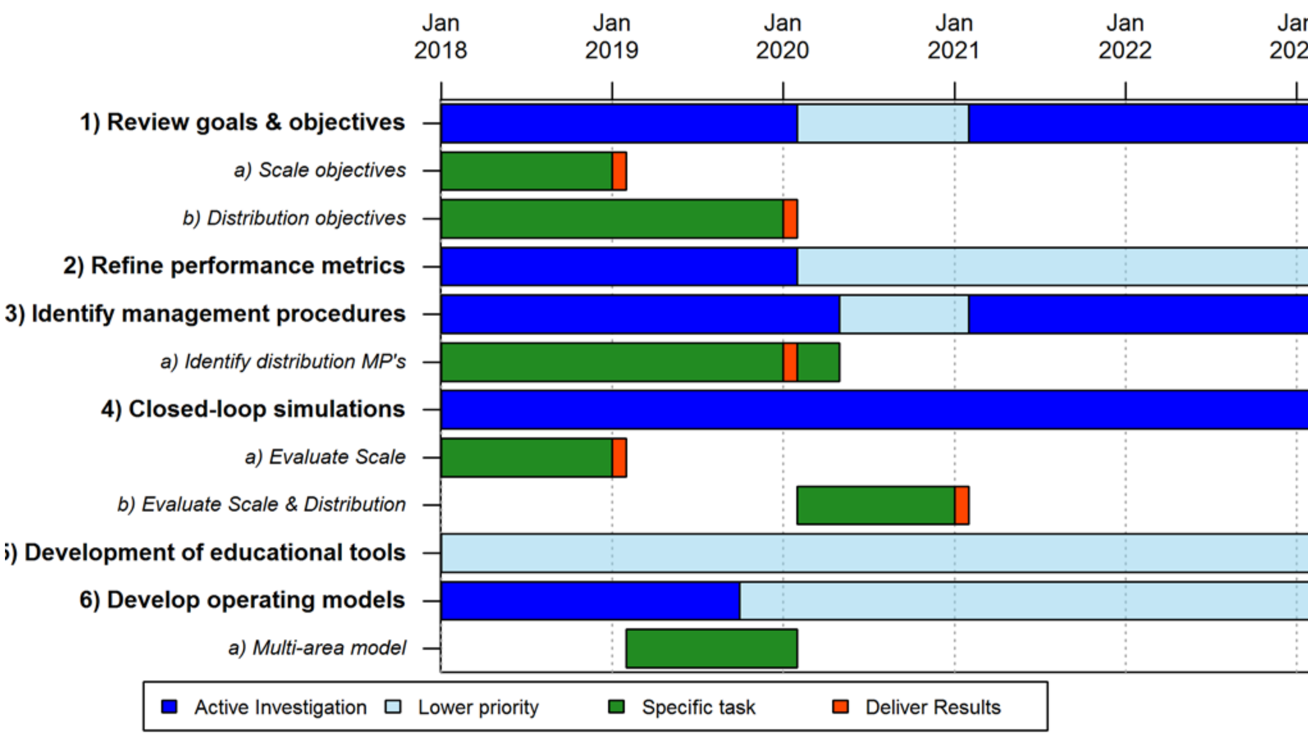

Figure 8. Gantt chart for the five-year program of work. Tasks are listed as rows. Dark blue indicates when the major portion of the main tasks work will be done. Light blue indicates when preliminary or continuing work on the main tasks will be done. Dark green indicates when the work on specific sub-topics will be done. The orange color shows when results will be presented at an Annual Meeting.

7 RECOMMENDATIONS

That the Commission:

1) **NOTE** paper IPHC-2019-AM095-12 which provides an update on the MSE including goals and objectives, the simulation framework, results for management procedures consisting of a range of SPR values from 0.56 to 0.30, three control rules (25:10, 30:20, and 40:20), and investigation of constrained management procedures, a framework for a management procedure to distribute TCEY across the coast, possible elements of management procedures related to distribution, and a 5-year program of work.
2) **ENDORSE** the primary objectives and associated performance metrics (Appendix Ia).
3) **NOTE** secondary objectives, performance metrics, and statistics of interest that will be used to supplement the evaluation of management procedures.
4) **RECOMMEND** additional goals and objectives, as well as prioritization of these goals and objectives for the evaluation of management procedures.
5) **NOTE** the primary performance metrics reported for various management procedures incorporating a range of SPR values from 56% to 30% and control rules of 30:20, 40:20, and 25:10.
6) **NOTE** the overall results of the MSE simulations (Section 5) including that all management procedures for SPR values greater than or equal to 32% (lower fishing intensities) met the priority biological objective, but did not meet the catch stability objective. At SPR values less than 40% (higher fishing intensities) the yield curve was flattening and variability in mortality limits increased at a faster rate. Adding a constraint on the total mortality limit resulted in some management procedures meeting all primary objectives. Of the management procedures evaluated, an SPR of 40% with a 30:20 control rule and a constraint to not change the annual mortality limit by more than 15% in either direction met all objectives and was ranked the highest based on the primary objectives.
7) **RECOMMEND** a Management Procedure for the Scale portion of the harvest strategy policy (i.e. coastwide fishing intensity and a constraint) noting that Scale and Distribution components will be evaluated for AM097 in 2021.
8) **RECOMMEND** additional management procedures related to Scale to evaluate in 2019 using the coastwide MSE framework.
9) **ENDORSE** the framework for a management procedure to distribute the TCEY across the coast (Section 6.4) as the framework to develop distribution management procedures.
10) **NOTE** the potential elements of a management procedure that may be useful to distribute the TCEY (Section 6.4.1).
11) **NOTE** the 5-year program of work (Section 7) and the delivery dates January 2019 for coastwide results and January 2021 for Scale and Distribution components of the management procedure for potential adoption by the Commission and subsequent implementation.

8 References

Hicks A. 2017. IPHC Management Strategy Evaluation Update. 18 October 2017. IPHC-2017-MSAB010-09 Rev_1. 35 pp.

Hicks A. 2018a. IPHC Management Strategy Evaluation to Investigate Fishing Intensity. 16 October 2018. IPHC-2018-MSAB012-07 Rev_1. 33 pp.

Hicks A. 2018b. IPHC Secretariat Program of Work for MSAB Related Activities 2019-2023. 21 September 2018. IPHC-2018-MSAB012-09. 15 pp.

IPHC. 2017. Report of the 93rd Session of the IPHC Annual Meeting (AM093). Victoria, British Columbia, Canada. 23-27 January 2017. IPHC-2017-AM093-R. 61 pp.

IPHC 2018a. Report of the 11th Session of the IPHC Management Strategy Advisory Board (MSAB011). Seattle, Washington U.S.A. 7–10 May 2018. IPHC-2018-MSAB011-R. 29 pp.

IPHC 2018b. Report of the 12th Session of the IPHC Management Strategy Advisory Board (MSAB012). Seattle, Washington U.S.A. 22–25 October 2018. IPHC-2018-MSAB012-R. 28 pp.

IPHC 2018c. Report of the 12th Session of the IPHC Scientific Review Board (SRB012). Seattle, Washington U.S.A. 19–21 June 2018. IPHC-2018-SRB012-R. 17 pp.

Methot Jr, R.D., and Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fish. Res. 142(0): 86-99.

Stewart, I., and Hicks, A. 2018. Assessment of the Pacific halibut (Hippoglossus stenolepis) stock at the end of 2017. IPHC-2018-AM094-10. 25 p.

Stewart, I.J., and Martell, S.J.D. 2016. Appendix: Development of the 2015 stock assessment. IPHC Report of Assessment and Research Activities 2015. p. A1-A146.

Stewart, I., and Webster, R. 2018. Overview of data sources for the Pacific halibut stock assessment, harvest policy, and related analyses. IPHC-2018-AM094-09. 83 p.

9 Appendices

Appendix Ia: Primary objectives and associated performance metrics.

Appendix Ib: Additional objectives and associated performance metrics.

Appendix II: Descriptions of performance metrics.

Appendix III: Performance metrics for various simulated management procedures.

APPENDIX IA
PRIMARY OBJECTIVES AND ASSOCIATED PERFORMANCE METRICS

Primary objectives for the evaluation of Management Procedures (MPs) on coastwide scale

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	MEASURABLE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRIC
1.1. KEEP BIOMASS ABOVE A LIMIT TO AVOID CRITICAL STOCK SIZES Biomass Limit	Maintain a minimum female spawning stock biomass above a biomass limit reference point at least 90% of the time	SB < Spawning Biomass Limit (SB_{Lim}) SB_{Lim}=20% spawning biomass	Long-term	0.10	$P(SB < SB_{Lim})$
2.1. LIMIT CATCH VARIABILITY	Limit annual changes in the coastwide TCEY	Average Annual Variability (AAV) > 15%	Short-term	0.25	$P(AAV > 15\%)$
2.2. MAXIMIZE DIRECTED FISHING YIELD	Maximize average TCEY coastwide	Median coastwide TCEY	Short-term	STATISTIC OF INTEREST	$Median\ \overline{TCEY}$

APPENDIX IB
ADDITIONAL OBJECTIVES AND ASSOCIATED PERFORMANCE METRICS

GOAL: Biological Sustainability

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	MEASURABLE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRIC
REPORT A METRIC THAT IS BASED ON NUMBERS OF PACIFIC HALIBUT	An absolute measure	Number of mature female halibut	Long-term	STATISTIC OF INTEREST	*Median Number of Mature Females*
REPORT A METRIC INDICATING THE SPAWNING BIOMASS EXPECTED TO BE ABOVE 50% OF THE TIME (I.E., AN IMPLIED TARGET)	An absolute measure	Spawning Biomass	Long-term	STATISTIC OF INTEREST	$Median\ \overline{SB}$
REPORT A METRIC THAT GIVES AN INDICATION HOW OFTEN THE BIOMASS IS BELOW THE FISHERY TRIGGER	Maintain a biomass that is above the biomass limit and not on the ramp a high percentage of the time	B < Spawning Biomass Limit (Fishery Trigger) Fishery Trigger=30% spawning biomass	Long-term	TOLERANCE NOT DEFINED	$P(SB < Fish_{Trig})$
CONSERVE SPATIAL POPULATION STRUCTURE					

GOAL: Optimize directed fishing opportunities.

General Objective	Measurable Objective	Measurable Outcome	Time-frame	Tolerance	Performance Metric
2.1. Limit Catch Variability	Limit annual changes in the coastwide TCEY	AAV	Long-term Short-term	Statistic of Interest	*AAV and variability*
		Change in TCEY > 15% in any year	Short-term	Statistic of Interest	$\frac{TCEY_{i+1} - TCEY_i}{TCEY_i}$
	Limit annual changes in the TCEY for each Regulatory Area	Average Annual Variability by Regulatory Area (AAV_A) > 15%	Short-term	0.25	$P(AAV_A > 15\%)$
		AAV_A	Long-term Short-term	Statistic of Interest	*AAV and variability*
		Change in TCEY by Regulatory Area > 15% in any year	Short-term	Statistic of Interest	$\frac{TCEY_{A,i+1} - TCEY_{A,i}}{TCEY_{A,i}}$
	Gain insight into the additional variability in the TCEY when on the ramp	AAV while on the ramp	Long-term	Statistic of Interest	*AAV given estimated* $SB < SB_{Trig}$
		Percent of time "on the ramp" (estimated stock status is below the fishery trigger; SB_{trig}) SB_{Trig} to be evaluated (e.g., 30% or 40%)	Long-term	*Tolerance Not Defined*	$P(\widehat{SB} < SB_{Trig})$

GOAL: Optimize directed fishing opportunities (continued).

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	MEASURABLE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRIC
2.2. MAXIMIZE DIRECTED FISHING YIELD	Maintain TCEY above a minimum level coastwide	Coastwide TCEY < $TCEY_{min}$	Long-term Short-term	TOLERANCE NOT DEFINED	$P(TCEY < TCEY_{min})$
	Maximize high yield (TCEY) opportunities coastwide	Coastwide TCEY > 50.6 Mlbs (70% of 1993-2012 average)	Long-term Short-term	TOLERANCE NOT DEFINED	$P(TCEY < 50.6\ Mlbs)$
	Present the range of coastwide TCEY that would be expected	Range of coastwide TCEY	Long-term Short-term	STATISTIC OF INTEREST	*5^{th} and 75^{th} percentiles of TCEY*
	Maximize average TCEY by Regulatory Area	Median Regulatory Area TCEY	Long-term Short-term	STATISTIC OF INTEREST	*Median* $\overline{TCEY_A}$
	Maintain TCEY above a minimum level by Regulatory Area	$TCEY_A < TCEY_{A,min}$	Long-term Short-term	TOLERANCE NOT DEFINED	$P(TCEY_A < TCEY_{A,min})$
	Maximize high yield (TCEY) opportunities by Regulatory Area	$TCEY_A > C_A$ Mlbs (70% of 1993-2012 average)	Long-term Short-term	TOLERANCE NOT DEFINED	$P(TCEY_A < C_A\ Mlbs)$
	Present the range of TCEY by Regulatory Area that would be expected	Range of TCEY by Regulatory Area	Long-term Short-term	STATISTIC OF INTEREST	*5^{th} and 75^{th} percentiles of $TCEY_A$*
MINIMIZE POTENTIAL FOR NO CATCH LIMIT FOR THE DIRECTED COMMERCIAL FISHERY	Minimize fishery closures	Directed commercial allocation = 0	Long-term Short-term	STATISTIC OF INTEREST	*P(Directed Mort = 0)*

GOAL: Minimize Discard Mortality

General Objective	Measurable Objective	Measurable Outcome	Time-frame	Tolerance	Performance Metrics
3.1. Harvest efficiency	Discard mortality is a small percentage of the longline fishery annual catch limit	>10% of annual catch limit	Long-term Short-term	0.25	$P(DM > 10\% FCEY)$
Absolute measure	Absolute	Discard Mortality (DM)	Long-term Short-term	Statistic of Interest	$Median\ \overline{DM}$

GOAL: Minimize Bycatch Mortality

General Objective	Measurable Objective	Measurable Outcome	Time-frame	Tolerance	Performance Metrics

APPENDIX II
DESCRIPTIONS OF PERFORMANCE METRICS

Table II.1 Primary performance metrics and statistic of interest to evaluate the management procedures. Primary metrics are the main performance metrics for the evaluation.

Primary Metrics	
Performance metric	**Description**
P(all dRSB<20%)	Times out of 100 for a given year that the estimated spawning biomass (status) is less than 20% (SB_{lim}) of the unfished equilibrium biomass given recent stock conditions.
P(any dRSB_y<20%)	Times out of 100 that at least 1 year of a 10 year period will have a spawning biomass (status) less than 20% (SB_{lim}) of the unfished equilibrium biomass given recent stock conditions.
P(AAV > 15%)	Times out of 100 that the average annual variability (AAV) is greater than 15%. AAV can be thought of as the average change in the Total Mortality (TM) limit from year to year.
Median average TM	Median coastwide Total Mortality (TM) limit. The TM is greater than this value in half of the simulations.

Table II.2 Some of the secondary performance-metrics used to evaluate the management procedures. Primary metrics are the main performance metrics for the evaluation and these secondary performance metrics are intended to supplement and inform that evaluation.

Secondary Metrics	
Statistic of interest	**Description**
Median realized SPR	The realized SPR after reductions by the control rule. The SPR was greater than this value in half of the simulations, but will always be less than or equal to the procedural (input) SPR.
Median average dRSB	The median dynamic relative spawning biomass expected in the long-term. The dRSB is greater than this value in half of the simulations.
P(all dRSB<30%)	Times out of 100 for a given year that the estimated spawning biomass (status) is less than 30% of the unfished equilibrium biomass given recent stock conditions.
P(any dRSB_y<30%)	Times out of 100 that at least 1 year of a 10 year period will have a spawning biomass (status) less than 30% of the unfished equilibrium biomass given recent stock conditions.
P(all TM<34 Mlbs)	Times out of 100 for a given year that the Total Mortality quota (TM) would be set below a minimum value. The minimum TM has not been determined, and is currently an *ad hoc* value of 34 Mlbs, which is the minimum Total Mortality observed (TM) since 1906.
P(any TM<34 Mlbs)	Times out of 100 in at least 1 year of a 10 year period that the Total Mortality quota (TM) would be set below a minimum value. The minimum TM has not been determined, and is currently an *ad hoc* value of 34 Mlbs, which is the minimum Total Mortality observed (TM) since 1906.
Median AAV TM	The Median Average Annual Variability, which can be thought of as the average change in the Total Mortality (TM) from year to year. The AAV is greater than this value in half of the simulations.

APPENDIX III
PERFORMANCE METRICS FOR VARIOUS SIMULATED MANAGEMENT PROCEDURES

See also http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSAB012/

Table III.1. Long-term performance metrics for, a 30:20 control rule, and a range of input SPRs from 0.3 to 0.56. P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Primary performance metrics are noted in regular text while secondary performance metrics are labeled in italics. Median TM is smoothed over the range of SPRs to produce more realistic results and account for Monte Carlo error that results naturally with a small number of simulations for a highly variable quantity.

Input Control Rule	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**	**30:20**
Input SPR	**56%**	**48%**	**46%**	**44%**	**42%**	**40%**	**38%**	**36%**	**34%**	**32%**	**30%**
Median realized SPR	56.3%	49.0%	47.4%	45.8%	44.5%	43.6%	42.7%	42.5%	42.6%	42.4%	42.6%
Biological Sustainability											
Median average dRSB	50.2%	41.6%	39.7%	37.9%	36.4%	35.1%	33.9%	32.9%	31.8%	31.0%	30.4%
P(all dRSB<20%)	0.002	0.002	0.003	0.004	0.002	0.003	0.004	0.005	0.005	0.004	0.004
P(any dRSB_y<20%)	0.002	0.003	0.004	0.004	0.003	0.004	0.005	0.006	0.008	0.008	0.011
P(all dRSB<30%)	0.002	0.023	0.043	0.073	0.096	0.146	0.199	0.253	0.343	0.405	0.470
P(any dRSB_y<30%)	0.003	0.044	0.088	0.151	0.209	0.317	0.409	0.545	0.684	0.789	0.867
Fishery Sustainability											
P(all AAV > 15%)	0.606	0.689	0.717	0.767	0.812	0.849	0.905	0.927	0.957	0.988	0.993
P(all TM < 34 Mlbs)	0.507	0.455	0.460	0.453	0.446	0.450	0.440	0.439	0.465	0.458	0.465
P(any TM < 34 Mlbs)	0.662	0.627	0.637	0.644	0.665	0.686	0.721	0.758	0.810	0.862	0.891
Median average TM	33.9	37.3	38.0	38.6	39.2	39.7	40.1	40.6	41.0	41.4	41.7
median AAV TM	16.3%	17.5%	18.4%	19.6%	21.3%	23.6%	26.4%	30.2%	34.0%	37.3%	41.8%

Table III.2. Long-term performance metrics for, a 40:20 control rule, and a range of input SPRs from 0.3 to 0.56. P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Primary performance metrics are noted in regular text while secondary performance metrics are labeled in italics. Median TM is smoothed over the range of SPRs to produce more realistic results and account for Monte Carlo error that results naturally with a small number of simulations for a highly variable quantity.

Input Control Rule	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**	**40:20**
Input SPR	**56%**	**48%**	**46%**	**44%**	**42%**	**40%**	**38%**	**36%**	**34%**	**32%**	**30%**
Median realized SPR	56.9%	51.3%	50.4%	49.6%	49.1%	48.6%	48.3%	48.1%	47.9%	47.9%	47.7%
Biological Sustainability											
Median average dRSB	50.7%	43.9%	42.6%	41.5%	40.4%	39.5%	38.6%	37.8%	37.1%	36.4%	35.8%
P(all dRSB<20%)	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002
P(any dRSB_y<20%)	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.003
P(all dRSB<30%)	0.003	0.006	0.008	0.007	0.007	0.014	0.018	0.028	0.044	0.059	0.083
P(any dRSB_y<30%)	0.003	0.007	0.011	0.015	0.022	0.036	0.052	0.102	0.16	0.214	0.309
Fishery Sustainability											
P(all AAV > 15%)	0.688	0.88	0.921	0.948	0.974	0.985	0.986	0.994	0.994	0.996	0.998
P(all TM < 34 Mlbs)	0.494	0.459	0.460	0.463	0.465	0.468	0.470	0.476	0.479	0.488	0.495
P(any TM < 34 Mlbs)	0.672	0.711	0.735	0.756	0.778	0.801	0.819	0.836	0.856	0.869	0.889
Median average TM	34.7	37.1	37.5	37.9	38.2	38.7	39.0	39.3	39.5	39.7	39.9
median AAV TM	17.6%	23.2%	25.9%	28.2%	30.9%	33.5%	36.0%	39.3%	41.9%	43.6%	46.2%

Table III.3. Long-term performance metrics for, a 25:10 control rule, and a range of input SPRs from 0.3 to 0.56. P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Primary performance metrics are noted in regular text while secondary performance metrics are labeled in italics. Median TM is smoothed over the range of SPRs to produce more realistic results and account for Monte Carlo error that results naturally with a small number of simulations for a highly variable quantity.

Input Control Rule	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**	**25:10**
Input SPR	**56%**	**48%**	**46%**	**44%**	**42%**	**40%**	**38%**	**36%**	**34%**	**32%**	**30%**
Median realized SPR	56.3%	48.4%	46.6%	44.8%	43.0%	41.4%	39.8%	38.4%	37.3%	36.6%	36.1%
Biological Sustainability											
Median average dRSB	50.3%	41.5%	39.4%	37.3%	35.3%	33.4%	31.6%	29.9%	28.6%	27.5%	26.5%
P(all dRSB<20%)	0.002	0.004	0.006	0.006	0.008	0.011	0.010	0.011	0.022	0.032	0.048
P(any dRSB_y<20%)	0.003	0.004	0.008	0.008	0.012	0.018	0.021	0.030	0.060	0.099	0.144
P(all dRSB<30%)	0.008	0.046	0.095	0.153	0.231	0.317	0.406	0.514	0.626	0.723	0.801
P(any dRSB_y<30%)	0.008	0.079	0.154	0.248	0.357	0.477	0.597	0.749	0.856	0.935	0.969
Fishery Sustainability											
P(all AAV > 15%)	0.600	0.634	0.648	0.671	0.689	0.720	0.765	0.816	0.851	0.902	0.935
P(all TM < 34 Mlbs)	0.500	0.445	0.453	0.442	0.437	0.429	0.410	0.406	0.410	0.417	0.423
P(any TM < 34 Mlbs)	0.654	0.598	0.600	0.595	0.595	0.593	0.600	0.619	0.643	0.682	0.716
Median average TM	34.5	37.5	38.2	39.0	39.7	40.3	40.8	41.3	41.7	42.1	42.4
median AAV TM	16.4%	16.7%	16.9%	17.2%	17.7%	18.3%	19.6%	20.9%	22.7%	25.4%	28.3%

Table III.3. Long-term performance metrics for, a 30:20 control rule, input SPRs of 0.40 and 0.46, and various constraints. P(all …) is the probability of that the event occurs in a given year, and P(any …) is the probability that the event occurs in at least 1 year out of a 10 year period. Primary performance metrics are noted in regular text while secondary performance metrics are labeled in italics.

Input Control Rule	**30:20**											
Constraint	**maxChangeBoth**		**maxChangeUp**		**slowUp FastDown**		**slowUp FullDown**		**Cap60**		**multiYear**	
Input SPR	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**	**46%**	**40%**
Median realized SPR	47.2%	42.8%	49.4%	47.1%	48.2%	44.4%	49.6%	45.4%	49.6%	47.4%	47.5%	44.1%
Biological Sustainability												
Median average dRSB	40.0%	35.4%	43.7%	40.8%	40.3%	36.0%	42.3%	37.7%	41.9%	37.2%	39.3%	34.8%
P(all dRSB<20%)	0.019	0.017	0.000	0.000	0.002	0.000	0.001	0.003	0.003	0.003	0.003	0.004
P(any dRSB_y<20%)	0.019	0.020	0.000	0.001	0.002	0.000	0.001	0.003	0.003	0.005	0.003	0.008
P(all dRSB<30%)	0.057	0.178	0.005	0.019	0.041	0.130	0.016	0.066	0.040	0.125	0.068	0.196
P(any dRSB_y<30%)	0.109	0.350	0.013	0.065	0.088	0.316	0.039	0.174	0.086	0.257	0.149	0.410
Fishery Sustainability												
P(all AAV > 15%)	0.038	0.084	0.350	0.474	0.085	0.218	0.136	0.348	0.459	0.525	0.186	0.385
P(all TM < 34 Mlbs)	0.436	0.443	0.497	0.506	0.457	0.448	0.476	0.455	0.452	0.426	0.463	0.454
P(any TM < 34 Mlbs)	0.570	0.583	0.636	0.665	0.581	0.612	0.614	0.638	0.585	0.586	0.603	0.648
Median average TM	38.5	39.5	35.2	34.8	37.8	39.3	36.6	39.0	38.6	41.1	37.5	39.1
median AAV TM	11.3%	12.1%	13.4%	14.5%	7.7%	10.1%	9.8%	12.3%	13.7%	16.2%	8.9%	12.3%