IPHC Management Strategy Evaluation (MSE): update

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1 PURPOSE

To provide an update on the progress of the IPHC Management Strategy Evaluation process to investigate fishing intensity, and to present results of the closed-loop simulations (as of 27 October 2018).

2 INTRODUCTION

At the 93rd Session of the IPHC Annual Meeting (AM093 in 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 is that this corresponds to fishing intensities that have resulted in a stable or slightly increasing stock, indicating that, in the short-term, this may provide an appropriate fishing intensity that will result in a stable or increasing female spawning biomass.

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% adopted by Commissioners at AM093. This was an example of estimation error and something that is inherent in the process due to uncertainty in the data. The SPR of 40% was well within the confidence bounds for SPR reported in the 2017 stock assessment (30-59%) and was most likely less than the adopted SPR because of the updated estimation of recent below average recruitment. The estimation error may easily go either way (above or below the adopted value).

This document (IPHC-2018-IM094-12) focuses on the coastwide simulations and includes the following topics:

1. goals and objectives,
2. simulation framework
3. simulation results,
4. a brief description of topics related to distributing the TCEY, and
5. a review of the five-year work plan.

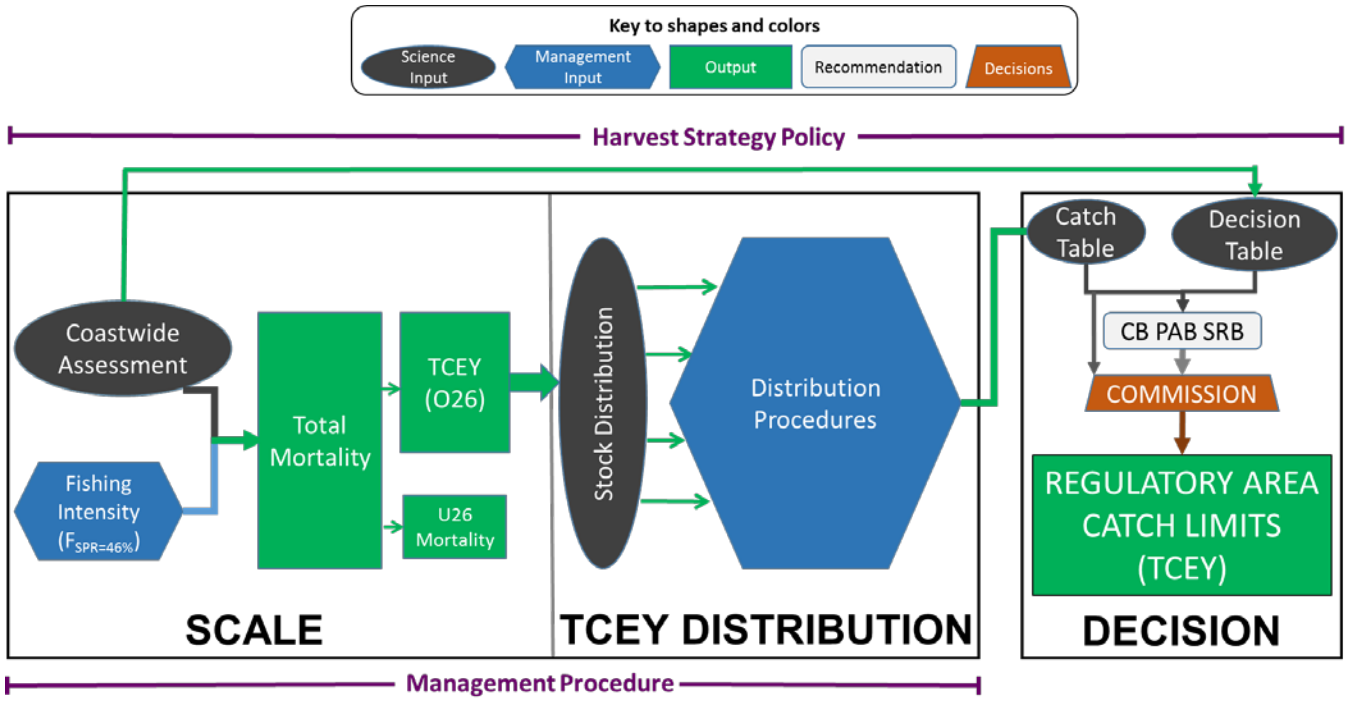

Figure 1. A pictorial description of the interim IPHC harvest strategy policy showing the separation of scale and distribution of fishing mortality. The "decision step" is when policy and decision making (not a procedure) influences the final mortality limits.

3 Goals and Objectives

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 goals with multiple objectives for each. Performance metrics have also been developed from the goals and objectives by defining a measurable outcome, a probability (i.e. level of risk), and time-frame over which it is desired to achieve that outcome. Management procedures will be evaluated by determining which ones meet the objective (via the performance metric).

At MSAB011, these five goals and linked objectives were discussed. It was determined that the goal "serve consumer needs" was not necessary at this time as it would be captured under the goal of "fishery sustainability and stability," and MSAB members appointed an *ad hoc* working group to refine the objectives (IPHC-2018-MSAB011-R, 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 this. 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 some preliminary objectives for distribution of the TCEY.

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 have a measurable outcome and time-frame associated with them. Three measurable objectives are prioritized for evaluation: the biological sustainability objective of maintaining the spawning biomass above 20% at least 90% of the time in the long-term is prioritized over 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 (Appendix Ia). 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 statistics of interest (performance metrics reported for secondary evaluation) 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-2018-SRB012-R, 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.

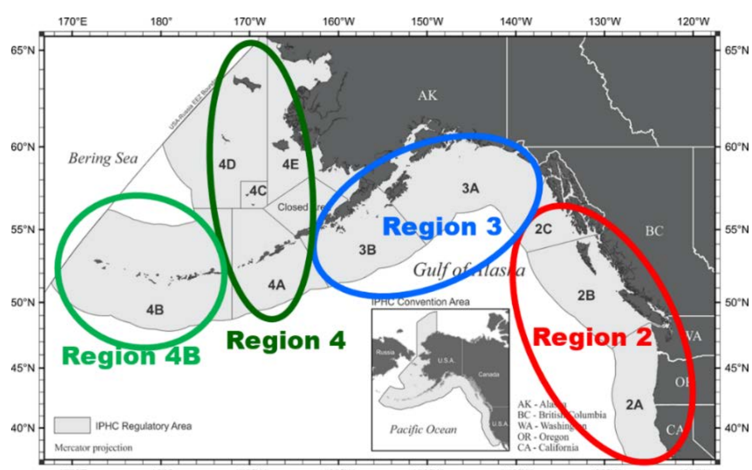

Figure 2. Four biological Regions. They are overlayed on IPHC Regulatory Areas with Region 2 comprised of 2A, 2B, and 2C, Region 3 comprised of 3A and 3B, Region 4 comprised of 4A and 4CDE, and Region 4B comprised solely of 4B.

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-2018-SRB012-R, paragraph 30). Additionally, "preserve" is not the appropriate term, because conservation is typically the goal of fisheries management. Therefore, conserving 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-2018-MSAB011-R, paragraph 34), as shown in Appendix I.

3.1 PERFORMANCE METRICS

Goals and objectives are translated into performance metrics to evaluate the management procedures. Many performance metrics have been developed by defining a measurable outcome, a probability (i.e. level of risk), and time-frame over which it is desired to achieve that outcome. Management procedures can then be evaluated by determining which ones meet various objectives (via the performance metrics). Some performance metrics have been defined by the MSAB that are called statistics of interest, and even though they are associated with various objectives, they are secondary to the evaluation of the management procedure. Some of the primary performance metrics and statistics of interest being reported are described in Table 1.

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

Primary Metrics	
Performance metric	**Description**
$P(SB > SB_{Lim})$	Times out of 100 that the stock biomass (status) is above the limit. The limit is defined as 20% of the biomass if no fishing had occurred.
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 quota (TMq) from year to year.
Median TM	Median coastwide Total Mortality (TM) limit. The TM is greater than this value in half of the simulations.

Table 2: Statistics of interest for the long-term to evaluate the management procedures. Primary metrics are the main performance metrics for the evaluation and the statistics of interest 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 SB	The median biomass expected in the long-term
Median # females	The median number of females expected in the long term.
Median AAV	The Median Average Annual Variability, which can be thought of as the average change in the TM from year to year. The AAV is greater than this value in half of the simulations.
P(↓TM > 15%)	Times out of 100 that the TM decreases by more than 15% compared to the previous year.
$AAV\|SB<SB_{Trig}$	The average annual variability when the stock status is below the fishery trigger (often referred to as ‘on the ramp’).
Probability SB<30% in a year	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.
Probability SB<30% in at least 1 of 10 years	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.
Probability commercial allocation = 0 in a year	Times out of 100 for a given year that the allocation for the commercial fishery would be zero. This can occur because the control rule closes the directed fishery, or because after allocation to bycatch, subsistence, and recreational fisheries, there is no catch limit left for the commercial fishery.
Probability commercial allocation = 0 in at least 1 of 10 years	Times out of 100 in at least 1 year of a 10 year period that the allocation for the commercial fishery would be zero. This can occur because the control rule closes the directed fishery, or because after allocation to bycatch, subsistence, and recreational fisheries, there is no catch limit left for the commercial fishery.
5^{th} and 75^{th} percentile of TM	The 5^{th} and 75^{th} percentiles of the Total Mortality limit from the simulations. This means that 5 out of 100 are less than or equal the 5^{th} percentile and 25 out of 100 are greater than or equal to the 75^{th} percentile.
Probability TM<34 Mlbs in a year	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.
Probability TM<34 Mlbs in at least 1 of 10 years	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.
Probability Directed < 50.6 Mlbs* in a year	Times out of 100 that the TM is less than 50.6 Mlbs, which is 70% of the average TM from 1993 to 2012, in a year.
Probability Directed < 50.6 Mlbs* in at least 1 of 10 years	Times out of 100 that the TM is less than 50.6 Mlbs, which is 70% of the average TM from 1993 to 2012, in at least 1 year in a 10 year period.

4 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 catch limit for that year.

4.1 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 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 removals (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 TCEY was distributed to each source in an ad hoc manner using current available information and guided by the MSAB.

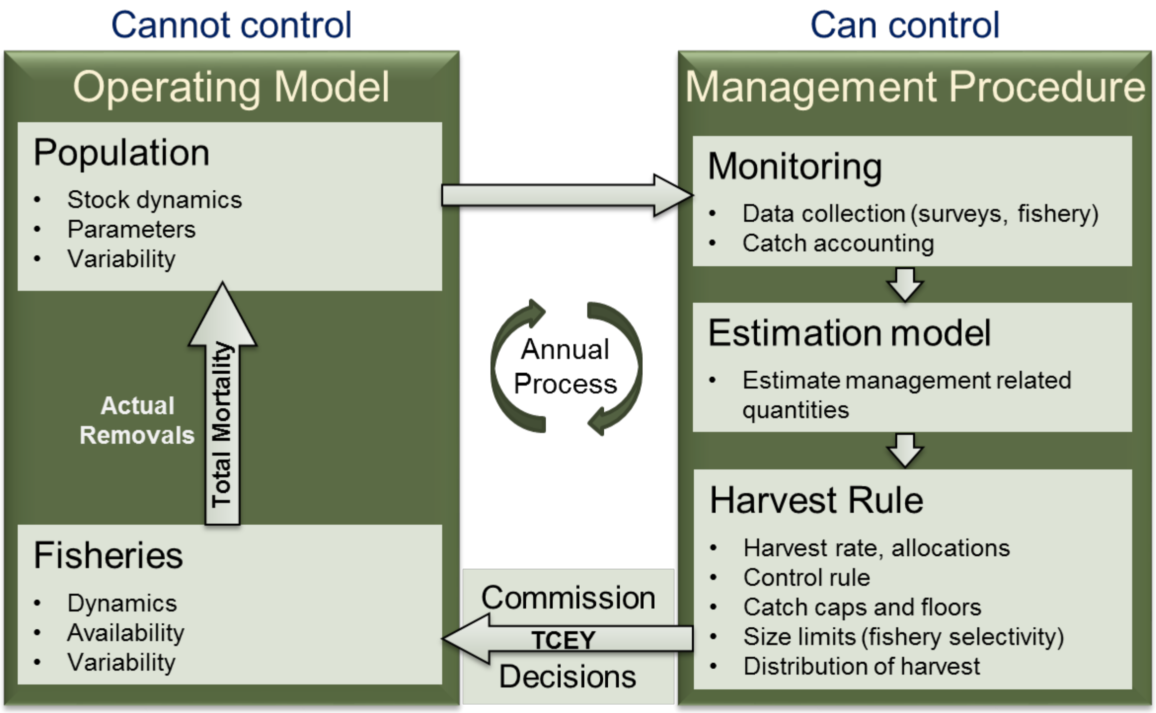

Figure 3. Diagram of the relationship between the four modules in the framework. The simulations run each module on an annual time-step, producing output that is used in the next time-step. See text for a description of operating model, monitoring, estimation model, and harvest rule.

4.1.1 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 2015 appendix of RARA). Each SS model is conditioned by fitting to the same data used in the 2017 stock assessment (Stewart & Hicks 2018, documents 08-10). 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 3 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 3. 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 presence of a slightly higher median spawning biomass in the individual operating models is not a concern because the MSE is focused on ranking procedures and is not meant to predict the exact quantities. 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).

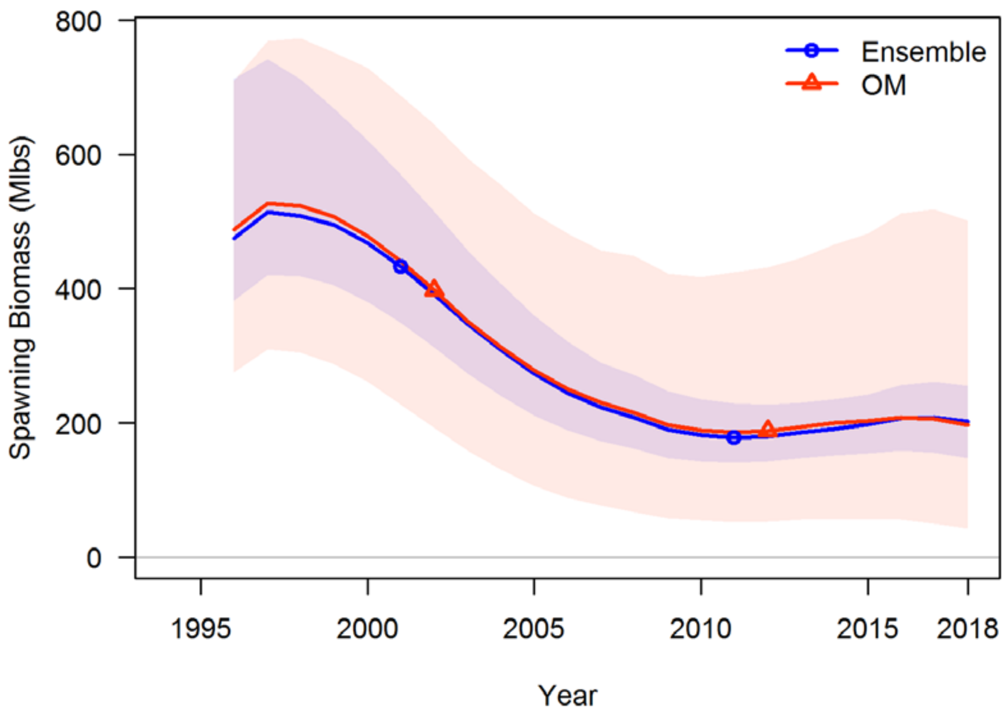

Figure 4. The conditioned operating model (red) compared to the stock assessment ensemble (blue) with 95% confidence intervals on each.

4.1.2 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 IPHC-2017-MSAB010-09 Rev1, and updates to the procedures are described in IPHC-2018-MSAB012-07 Rev_1. An overview of major sources of variability are shown in Table 4.

4.2 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.

Table 4. 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 for regime shift
TM to sectors	Allocating of TM to sectors with variability

4.2.1 Harvest Rule

The generalized management procedure to evaluate is shown in Figure 1, but the focus will be 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 linearly reduced (note that this may differ from the biological threshold), and a fishery limit that determines when there is theoretically no fishing intensity (this may differ from the biological limit). For these simulations, the two coastwide models were used, thus mortality only needed to be distributed to the five coastwide sources of mortality (directed commercial, discard mortality, bycatch mortality, recreational, and subsistence).

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% (IPHC-2017-MSAB10-09 Rev 1). 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. Future simulations will use a finer resolution of SPR values ranging from 30% to 56% and fishery trigger points of 30% and 40% (with the addition of 45% if time allows).

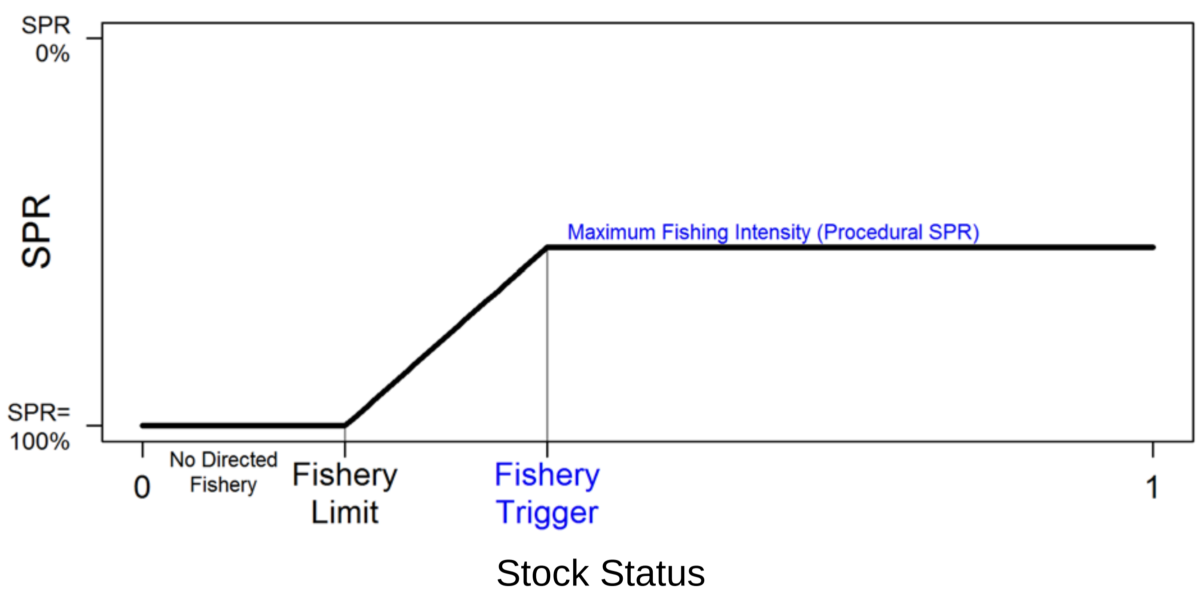

Figure 5. A harvest control rule responsive to stock status that is based on Spawning Potential Ratio (SPR) to determine fishing intensity, a fishery trigger level of stock status that determines when the fishing intensity begins to be linearly reduced, and a fishery limit based on stock status that 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 to be evaluated.

4.2.2 Estimation Model

Previously, results were presented with No Estimation Model (called Perfect Information at that time). However, this was for reference of how good a management could possibly perform. 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. Here, estimation error is simulated due to time constraints and the amount of time it takes to perform a single simulation, by adding error to the estimated stock status (used in the harvest control rule to determine when the fishing intensity is reduced) and in the resulting Total Mortality. Coefficients of variation on stock status and total mortality were fixed at 15% with a correlation of 0.5. Autocorrelation (the persistence of errors in a specific direction) was fixed at 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.

4.2.3 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.

4.3 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
    a) Estimation Models
        i) Perfect Information (as a reference if we knew population values exactly when applying the harvest rule).
        ii) 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.
    b) Data Generation
        i) Not needed at this time.
    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%).

5 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 at spawning biomasses between 300 Mlbs and 1,000 Mlbs (136,000 t to 454,000 t).

Table 5 and Table 6 show some long-term performance metrics for the main runs requested at MSAB011 (IPHC-2018-MSAB011-R). Table 7 shows the same long-term performance metrics for a control rule of 25:10. Short-term performance metrics produced the same rankings for these management procedures because the current spawning biomass is likely to be above the fishery trigger (e.g., 30%) and 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 1% for all cases. This is a result of the control rule limiting the fishing intensity as the stock approaches this 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 the estimation persists such 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 catch limit from year to year. At fishing intensities greater than that associated with an SPR 0f 40% (i.e., SPR values less than 40%) the probability that the AAV is greater than 15% is more than 0.90. This probability declines to 0.61 at an SPR of 56%. The median AAV's range from16% to 23% when using a 25:10 control rule (Table 7), 16% to 42% when using a 30:20 control rule (Table 6) and from 21% to 46% when using a 40:20 control rule (Table 5). The 40:20 showed higher variability in the catch limit even though the slope is not as steep because the reduction in fishing intensity occurs more often given the 40% trigger value. The absolute value of the Total Mortality catch 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, high variability in catches that increased with higher fishing intensities (i.e. lower SPR), and median Total Mortality limits that increased slightly with greater fishing intensity.

Table 5. Long-term performance metrics for an estimation error CV of 0.15, autocorrelation of 0.4, 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 statistics of interest 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 relative SPR	56.3%	49.0%	47.4%	45.9%	44.5%	43.5%	42.7%	42.5%	42.4%	42.4%	42.6%
Biological Sustainability											
Median average dRSB	50.2%	41.6%	39.7%	37.9%	36.5%	35.0%	33.9%	32.9%	31.7%	31.0%	30.4%
P(all dRSB<20%)	0.002	0.002	0.003	0.004	0.003	0.002	0.002	0.005	0.006	0.004	0.004
P(any dRSB_y<20%)	0.002	0.003	0.004	0.005	0.004	0.002	0.002	0.006	0.009	0.008	0.011
P(all dRSB<30%)	0.002	0.023	0.031	0.065	0.094	0.142	0.191	0.253	0.338	0.405	0.470
P(any dRSB_y<30%)	0.003	0.044	0.07	0.149	0.202	0.307	0.402	0.545	0.676	0.789	0.867
Fishery Sustainability											
P(all AAV > 15%)	0.606	0.689	0.722	0.771	0.813	0.847	0.905	0.927	0.958	0.988	0.993
P(all TM < 34 Mlbs)	0.507	0.455	0.448	0.436	0.426	0.432	0.425	0.439	0.457	0.458	0.465
P(any TM < 34 Mlbs)	0.662	0.627	0.633	0.641	0.661	0.681	0.718	0.758	0.81	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
P(all decrease TM > 15%)	0.221	0.236	0.244	0.261	0.273	0.285	0.302	0.319	0.336	0.352	0.365
P(any decrease TM > 15%)	0.921	0.932	0.94	0.946	0.958	0.967	0.974	0.982	0.992	0.992	0.997
median AAV TM	16.3%	17.5%	18.4%	19.4%	21.1%	23.9%	26.8%	30.2%	33.1%	37.3%	41.8%
Rankings (lower is better)											
P(<20%)[1]	1	2	3	4	5	6	7	8	9	10	11
P(AAV > 15%)[2]	1	2	3	4	5	6	7	8	9	10	11
Maximum catch (TM)[3]	11	10	9	8	7	6	5	4	3	2	1

[1] This ranking 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 ranking 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 a smoothed relationship for Median average TM to account for variability in the simulations. Note that the highest fishing intensity meets this objective, although the yield curve begins to flatten at those low SPR values.

Table 6. Long-term performance metrics for an estimation error CV of 0.15, autocorrelation of 0.4, 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 statistics of interest 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 relative SPR	55.4%	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	47.2%	43.9%	42.6%	41.5%	40.4%	39.5%	38.6%	37.8%	37.1%	36.4%	35.8%
P(all dRSB<20%)	0.001	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%)	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.003
P(all dRSB<30%)	0.008	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%)	0.011	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%)	0.788	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)	0.483	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)	0.693	0.711	0.735	0.756	0.778	0.801	0.819	0.836	0.856	0.869	0.889
Median average TM	35.6	37.1	37.5	37.9	38.2	38.7	39.0	39.3	39.5	39.7	39.9
P(all decrease TM > 15%)	0.275	0.289	0.310	0.326	0.337	0.349	0.362	0.372	0.381	0.386	0.390
P(any decrease TM > 15%)	0.953	0.973	0.981	0.994	0.996	0.997	0.998	0.998	0.998	0.998	0.999
median AAV TM	21.1%	23.2%	25.9%	28.2%	30.9%	33.5%	36.0%	39.3%	41.9%	43.6%	46.2%
Rankings (lower is better)											
P(<20%)[1]	1	2	3	4	5	6	7	8	9	10	11
P(AAV > 15%)[2]	1	2	3	4	5	6	7	8	9	10	11
Maximum catch (TM)[3]	11	10	9	8	7	6	5	4	3	2	1

[1] This ranking 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 ranking 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 a smoothed relationship for Median average TM to account for variability in the simulations. Note that the highest fishing intensity meets this objective, although the yield curve appears to flatten at those low SPR values.

Table 7. Long-term performance metrics for an estimation error CV of 0.15, autocorrelation of 0.4, 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 statistics of interest 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. Blank columns indicate that those management procedures were not simulated.

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 relative SPR	56.3%		46.5%		42.9%	41.3%	39.8%	38.4%	37.3%	36.6%	36.1%
Biological Sustainability											
Median average dRSB	50.3%		39.3%		35.3%	33.3%	31.6%	29.9%	28.6%	27.5%	26.5%
P(all dRSB<20%)	0.002		0.004		0.005	0.008	0.010	0.011	0.022	0.032	0.048
P(any dRSB_y<20%)	0.003		0.006		0.007	0.014	0.021	0.030	0.060	0.099	0.144
P(all dRSB<30%)	0.008		0.080		0.222	0.312	0.406	0.513	0.626	0.723	0.801
P(any dRSB_y<30%)	0.008		0.140		0.351	0.470	0.597	0.749	0.856	0.935	0.969
Fishery Sustainability											
P(all AAV > 15%)	0.600 0		0.647 0		0.692 0	0.728 0	0.765 0	0.816 0	0.851 0	0.902 0	0.935 0
P(all TM < 34 Mlbs)	0.500		0.435		0.420	0.413	0.410	0.410	0.410	0.417	0.423
P(any TM < 34 Mlbs)	0.654		0.593		0.592	0.589	0.600	0.619	0.643	0.682	0.716
Median average TM	34.4		38.2		39.7	40.4	41.0	41.4	41.8	42.1	42.4
P(all decrease TM > 15%)	0.219		0.227		0.239	0.249	0.259	0.274	0.293	0.309	0.326
P(any decrease TM > 15%)	0.927		0.934		0.941	0.950	0.953	0.964	0.974	0.976	0.985
median AAV TM	16.4%		16.9%		17.8%	18.5%	19.6%	20.9%	22.7%	25.4%	28.3%
Rankings (lower is better)											
P(<20%)[1]	1	2	3	4	5	6	7	8	9	10	11
P(AAV > 15%)[2]	1	2	3	4	5	6	7	8	9	10	11
Maximum catch (TM)[3]	11	10	9	8	7	6	5	4	3	2	1

[1] This ranking 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, except SPR=0.30 meet this objective.

[2] This ranking 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 a smoothed relationship for Median average TM to account for variability in the simulations. Note that the highest fishing intensity meets this objective, although the yield curve begins to flatten at those low SPR values.

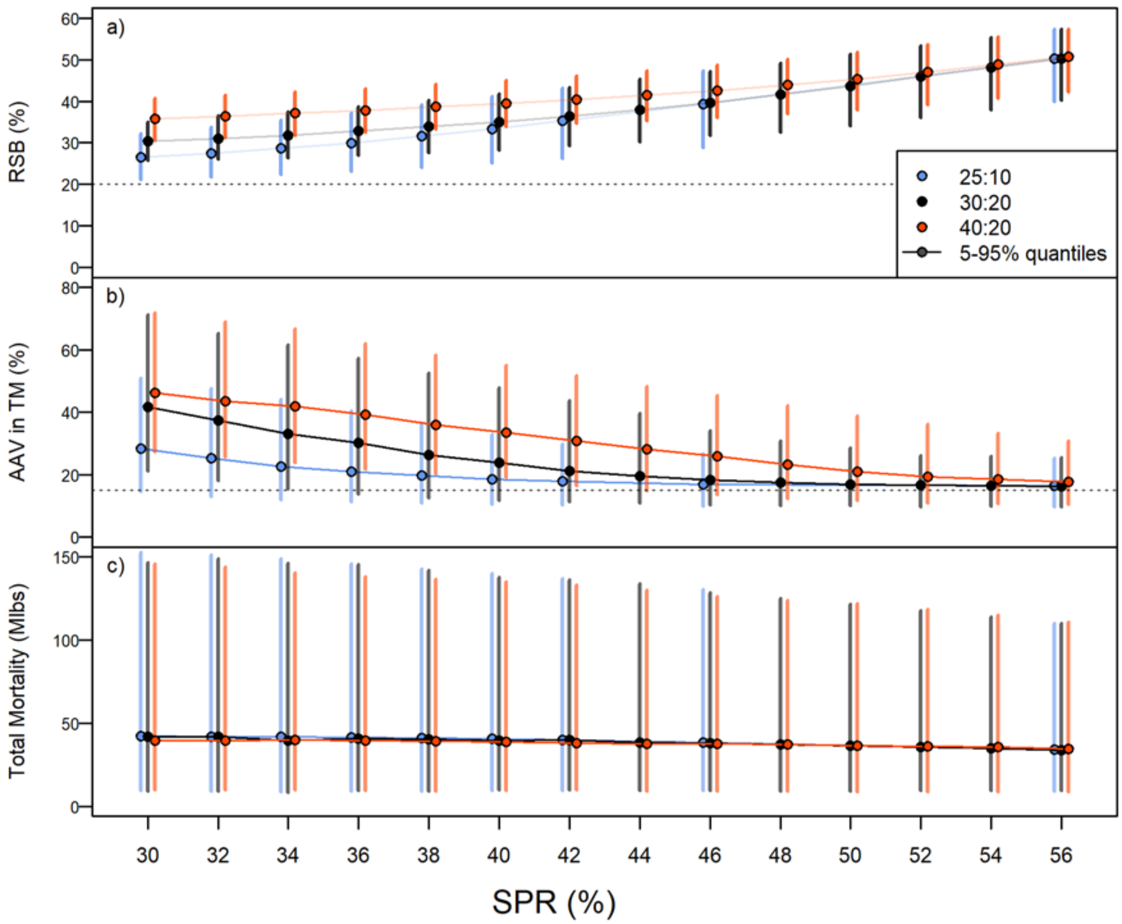

Figure 6. Select long-term performance metrics (dynamic relative spawning biomass, AAV of TM, and Total Mortality (Mlbs)) for a range of SPR values from 0.3 to 0.56 and control rules 40:20, 30:20, and 25:10. The points are the median values from the 1000 simulations and the vertical bars are the 90% intervals (i.e., 5th and 95th percentiles from the 1000 simulations).

6 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[1], 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.

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

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. This eliminates the use of EBio and area-specific absolute harvest rates. Therefore, there are currently two inputs to the current management procedure for distributing the TCEY among IPHC Regulatory Areas: 1) the current estimated stock distribution and 2) relative target harvest rates.

6.1 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 (Webster 2018). Briefly, observed WPUE is fitted with a model that accounts for correlation between setline survey stations over time (years) and space (within Regulatory Areas). Competition for hooks by Pacific halibut and other species, the timing of the setline survey relative to annual fishery mortality, and observations from other fishery-independent surveys are also accounted for in the approach. This fitted model is then used to predict WPUE (relative density) of Pacific halibut for every setline survey station in the design (including all setline survey expansion stations), regardless of whether it was fished in a particular year. 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.

6.2 USING RELATIVE HARVEST RATES

The distribution of the TCEY for 2018 was shifted from the estimated stock distribution to account for additional factors related to productivity and paucity of data in each IPHC Regulatory Area. 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, was distributed. Therefore, an absolute measure of harvest rate is not necessary, but it may still be desired to shift the distribution of the TCEY away from the estimated stock distribution to account for other factors. Consistent with the previous approach, relative harvest rates were used with a ratio of 1.00:0.75, being equal to the ratio between 21.5% and 16.125%. This application shifted 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 (Table 8), thus harvesting at a higher rate in eastern IPHC Regulatory Areas.

Table 8. IPHC Regulatory Area stock distribution estimated from the 2017 space-time model O32 WPUE, IPHC Regulatory Area-specific relative target harvest rates, and resulting 2018 target TCEY distribution based on the IPHC's 2018 interim management procedure (reproduced from Table 1 in IPHC-2018-AM094-11 Rev_1).

	2A	**2B**	**2C**	**3A**	**3B**	**4A**	**4B**	**4CDE**	**Total**
O32 stock distribution	1.7%	11.3%	16.6%	35.6%	10.0%	6.6%	4.8%	13.3%	100.0%
Relative harvest rates	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.75	--
Target TCEY Distribution	1.9%	12.4%	18.2%	38.9%	8.2%	5.4%	3.9%	10.9%	100.0%

6.3 REDEFINING THE DISTRIBUTION OF THE TCEY

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

6.3.1 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.

The overarching conservation goal for Pacific halibut is to maintain a healthy coastwide stock. However, given the wide geographic range of the Pacific halibut stock, there likely is stock structure that we do not fully understand, and this stock structure may be important to coastwide stock health. Therefore, conservation objectives relate to where harvesting occurs, with an objective to retain viable spawning activity in all portions of the stock. One method for addressing this objective is to distribute the fishing mortality relative to the distribution of observed stock biomass. This requires defining appropriate areas for which the distribution is to be conserved. Splitting the coast into many small areas for conservation objectives can result in complications including being cumbersome to determine if conservation objectives are met, being difficult to accurately determine the proportion of the stock in that area, being subject to inter-annual variability in estimates of the proportion, forcing arbitrary delineation among areas with evidence of strong stock mixing, and not being representative of biological importance. Therefore, Biological Regions represent the most logical scale over which to consider conservation objectives related to distribution of the fishing mortality. Adjusting the distribution of the TCEY among Biological Regions to account for additional considerations, and further distributing the TCEY to IPHC Regulatory Areas would be done through steps defined in the Distribution Procedures component (Figure 1).

In addition to using Biological Regions for stock distribution, the “all sizes” WPUE from the space-time model (Figure 7), 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 distributing the TCEY to Biological Regions, the estimated proportion of “all sizes” WPUE from the space-time model should be used for consistency.

6.3.2 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 used to indicate trends in a population, but may not always be 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.

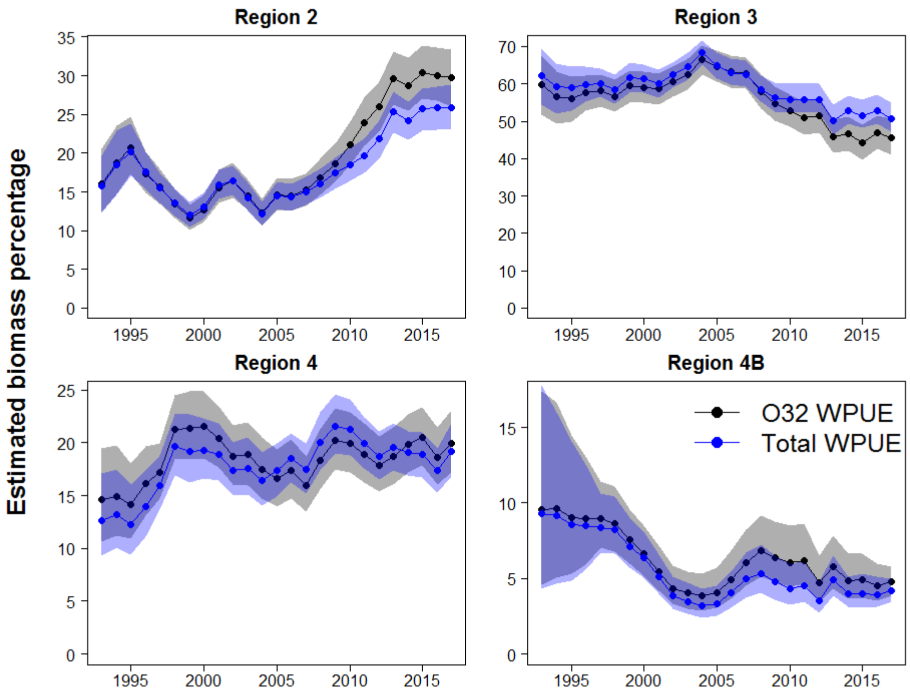

Figure 7. Estimated stock distribution (1993-2017) based on estimate WPUE from the space-time model of O32 (black series) and all sizes (blue series) of Pacific halibut. Shaded zones indicate 95% credible intervals.

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). Additionally, 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.

6.4 A Summary of the Management Procedure for Distributing 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 Regions and Regulatory Area 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). 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 in ≥26 inches (O26) and under 26 inches (U26) components. The O26 component is the coastwide TCEY.
   1.1. Target SPR is scheduled for evaluation at the 2019 Annual Meeting. The current interim target SPR is 46%.
2. **Regional Stock Distribution:** Distribute the coastwide TCEY to four (4) biologically-based Regions using the proportion of the stock estimated in each Biological Region for all sizes of Pacific halibut using information from the IPHC setline survey and the IPHC space-time model.
   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 to account for other factors.
   3.1. For example, 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 WPUE), inspection of historical trends in fishing intensity, recent or historical fishery performance, and biological characteristics of the Pacific halibut observed in each Biological Region. The IPHC Secretariat may be able to provide Yield-Per-Recruit (YPR) and/or surplus production calculations as further supplementary information for this discussion. The regional relative harvest rates may also be determined through negotiation, which is simply an allocation agreement for further Regional adjustment of the TCEY.
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. Finally, 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. **Seasonal 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.

6.4.1 Potential Elements of the Management Procedures Related to Distribution

The MSAB012 report (IPHC-2018-MSAB012-R) listed ten potential tools for use in developing distribution procedures. Each of these potential tools is discussed below.

Relative harvest rates. This was discussed above in the context of Regional Allocation Adjustment and Regulatory Area Allocation. The relative harvest rates may be justified by productivity differences, for example, or they may simply be allocation agreements between areas.

O32:O26 ratios. This tool is an indicator of the proportion of the TCEY that is under the size limit. This ratio or quantifying of Pacific halibut in these size ranges would give insight into the encounter rate with undersized Pacific halibut, and there may be objectives defined that are related to minimizing encounters with these undersized fish. Using this ratio to adjust allocation percentages could change the mortality on undersized Pacific halibut. This could occur in the Regional Allocation Adjustment or Regulatory Area Allocation steps.

Trends in setline survey WPUE by IPHC Regulatory Area. This tool applies to the Regulatory Area Allocation step and may be a useful method to inform the distribution to Regulatory Area. However, the Biological Regions are areas where it is likely that within-year movement may occur, and minimal movement occurs between Regions within a year. For this reason, trends from the survey within a Regulatory Area may be inconsistent with the location of Pacific halibut when the fisheries occur. In other words, Pacific halibut may occur anywhere in the Biological Region within a year, but are unlikely to move out of that Region in that year, thus the timing of the survey and the fishery are important to consider.

Trends in modelled setline survey WPUE by biological region. Using trends from the setline survey index that is already used to distribute TCEY to Biological Regions (Regional Stock Distribution) may result in some contradictions. The potential benefit may be that the trend is indicative of what may occur in the future and potentially be a closer representation of stock distribution in the year when the fishery would occur.

Trends in fishery CPUE. Using trends in fishery CPUE to satisfy fishery objectives may be useful in that it is a more direct representation of what the fishery observes. However, fishery CPUE is subject to uncertainty and possibly bias which makes it inappropriate for biological objectives. Therefore, it is not useful for regional stock distribution, but is useful for Regulatory Area Allocation.

Limiting the amount of change for area-specific catch limits. Limiting the change in catch limits could reduce large swings in area-specific catch limits that may be a result of various uncertainties in the estimation and distribution processes. However, these algorithms can slow down a sometimes-necessary response when a trend is occurring. For example, if the stock is trending downwards it may be necessary to reduce catch levels, or if the stock is increasing quickly, it may be reasonable to increase catch levels. These algorithms can be beneficial if the correct level is used.

Percentage allocation with a floor (i.e. minimums of 1.5 Mlbs in 2A and 1.7 Mlbs in 4CDE). A simple method is to agree on pre-determined allocation percentages. However, there are often minimum amounts that a sector needs to be profitable. Defining percentage allocations can be very useful when agreed upon, and minimum amounts may also be useful. But, when the total catch to be allocated is small, there may not be enough to satisfy the minimum amounts. Therefore, agreements must be in place on where catch may be taken (i.e., the percentage allocation declines) when minimum levels are enacted.

Stair-step allocations. This method would simply assign a fixed catch limit to a Regulatory Area when the abundance/biomass of Pacific halibut in that Regulatory Area is within a specified range. Ranges would be identified such that at low abundance, the catch limit would be reduced. This would allow for stability except during times when the abundance crosses a threshold to a new level.

A maximum SPR with catch distribution by IPHC Regulatory Area determined from the modelled survey WPUE. This is interpreted to be a tool similar to status quo where a SPR determines the TCEY and is distributed directly to Regulatory Areas based on survey WPUE. However, status quo also adjusts that distribution with relative harvest rates shifting TCEY to Eastern areas.

Coastwide TCEY target and maximum calculated; distribution by target, but with ability to adjust TCEY up to the maximum. This tool is interpreted to consist of a default SPR which would determine a coastwide TCEY, but also contain a higher fishing intensity (smaller SPR) that would determine a maximum TCEY. This could be viewed similar to the U.S. OFL and ABC concept, where an overfishing limit (OFL) is calculated and an ABC (allowable biological catch) is determined that is less than the OFL, except that in the U.S. system, the difference between ABC and OFL is to account for scientific uncertainty. This tool suggests that the TCEY could exceed the target when necessary, but not exceed the maximum. The danger of this is that it does not guarantee that the TCEY would not be set at the maximum every year, thus making this tool moot. Some clear guidelines would have to included regarding under what circumstances the default could be exceeded.

There are many other tools that could be used and the MSAB will be discussing them throughout 2019.

7 PROGRAM OF WORK

This Program of Work (IPHC-2018-MSAB011-10) 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.

7.1 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 9 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.

7.2 BACKGROUND

Many important tasks have been completed or started and much of the work proposed will use past accomplishments to further the Management Strategy Evaluation (MSE) process. The past accomplishments include:

1. Familiarization with the MSE process.
2. Defining goals for the halibut fishery and management.
3. Developing objectives and performance metrics from those goals.
4. Development of an interactive tool (the Shiny application).
5. Discussions about coast-wide (single-area) and spatial (multiple-area) models.
6. Presentation of preliminary results investigating fishing intensity.
7. Discussions of ideas for distributing the TCEY to Regulatory Areas.

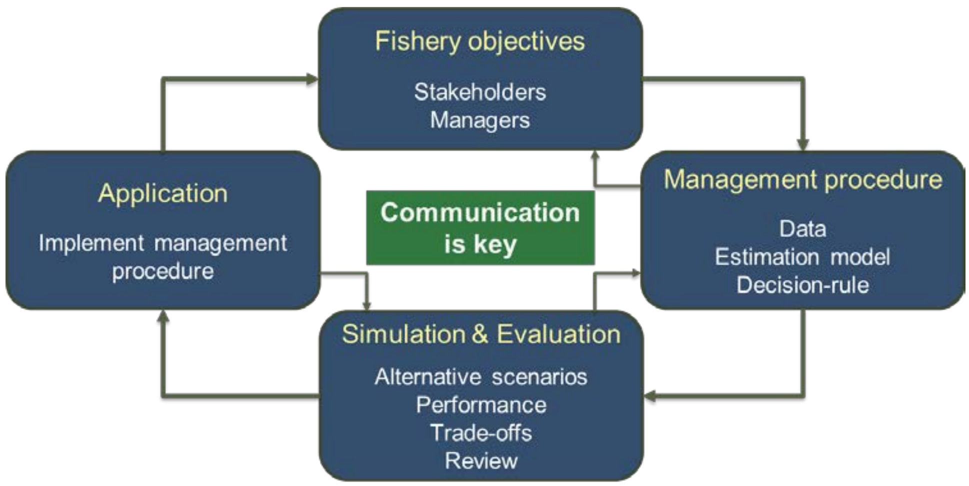

Figure 8. A depiction of the Management Strategy Evaluation (MSE) process showing the iterative nature of the process with the possibility of moving either direction between most components.

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 9). 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 9. 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.

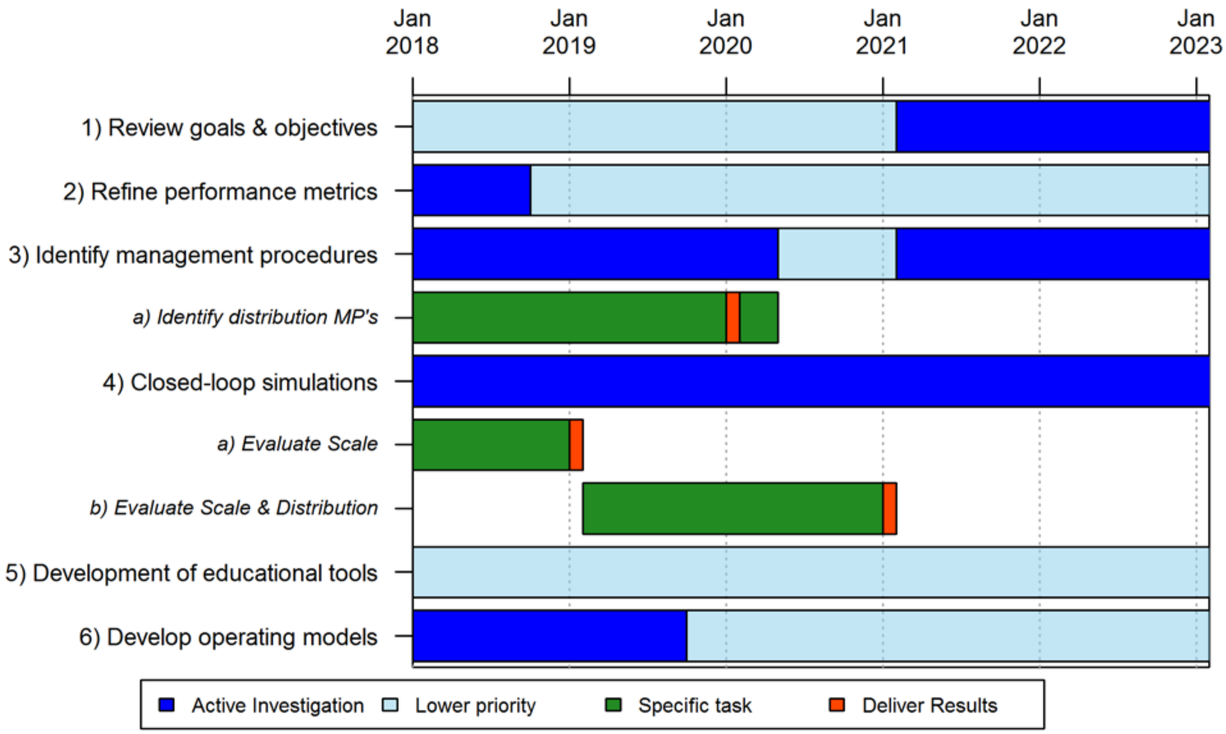

Figure 9. Gantt chart for the five-year program of work. Tasks are listed as rows. Dark blue indicates when the major portion of the main tasks work will be done. Light blue indicates when preliminary or continuing work on the main tasks will be done. Dark green indicates when the work on specific sub-topics will be done. The orange color shows when results will be presented at an Annual Meeting.

8 RECOMMENDATIONS

That the Commission:

1) **NOTE** paper IPHC-2018-IM094-12 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 and three control rules: 25:10, 30:20, and 40:20, a distribution framework, possible elements of management procedures related to distribution, and a 5-year program of work.
2) **RECOMMEND** additional goals and objectives, as well as prioritization of these goals and objectives for the evaluation of results.
3) **NOTE** the performance metrics reported for various management procedures and the priority objectives as well as the statistics of interest.
4) **NOTE** the results of the MSE simulations including that all management procedures for SPR values greater than or equal to 0.32 (lower fishing intensities) met the priority biological objective, but did not meet the catch stability objective. At SPR values less than 0.40 (higher fishing intensities) the yield curve was flattening and there was less different between median total mortality.
5) **RECOMMEND** additional management procedures to evaluate using the coastwide MSE framework.
6) **NOTE** the distribution framework and the potential elements of management procedures that may be useful to distribute the TCEY.
7) **NOTE** the 5-year program of work 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.

9 APPENDICES

APPENDIX IA: Primary objectives and associated performance metrics.

APPENDIX IB: Additional objectives and associated performance metrics.

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
ADDITONAL 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*	*STATISTIC OF INTEREST*	$P(SB < Fish_{Trig})$
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*	*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%	Long-term	0.25	$P(AAV > 15\%)$
		AAV_A	*Long-term*	*STATISTIC OF INTEREST*	*AAV and variability*
		Change in TCEY by Regulatory Area > 15% in any year	*Short-term*	*STATISTIC OF INTEREST*	$\frac{TCEY_{i+1} - TCEY_i}{TCEY_i}$
	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*	*STATISTIC OF INTEREST*	$P\left(\widehat{SB} < SB_{Trig}\right)$

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	?? ??	$P(TCEY < TCEY_{min})$
	Maximize high yield (TCEY) opportunities coastwide	*Coastwide TCEY > 50.6 Mlbs (70% of 1993-2012 average)*	*Long-term* *Short-term*	*STATISTIC OF INTEREST*	$P(TCEY < 50.6\ Mlbs)$
	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 coastwide TCEY*	*Long-term* *Short-term*	*STATISTIC OF INTEREST*	Median $\overline{TCEY}$
	Maintain TCEY above a minimum level by Regulatory Area	$TCEY_A < TCEY_{A,min}$	Long-term Short-term	?? ??	$P(TCEY < TCEY_{min})$
	Maximize high yield (TCEY) opportunities by Regulatory Area	*$TCEY_A$ > 50.6 Mlbs (70% of 1993-2012 average)*	*Long-term* *Short-term*	*STATISTIC OF INTEREST*	$P(TCEY < 50.6\ Mlbs)$
	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*
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*	***NA***	*Median* $\overline{DM}$

GOAL: Minimize Bycatch Mortality

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	MEASURABLE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRICS