IPHC Secretariat MSE Program of Work (2023) and an update on progress

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PURPOSE

To provide the Scientific Review Board (SRB) with an update on MSE progress in 2023 and potential tasks for 2023–2025.

BACKGROUND

This document provides responses to past requests and recommendations from the SRB. It presents the updated 2023 operating model (OM), potential objectives for MSE evaluations, Fishery-Independent Setline Survey (FISS) data scenarios with differing levels of observation error, how the evaluation of management procedures (MPs) may be improved if equalized over a conservation objective, definitions of exceptional circumstances and actions to be taken if an exceptional circumstance is declared, and potential MPs to evaluate in 2023–2025.

OPERATING MODEL

The 2023 MSE OM was conditioned using assumptions, parameters, and outputs consistent with the 2022 full stock assessment, following SRB advice. Details are provided below.

> **IPHC-2023-SRB022-R (para. 26).** *The SRB* ***RECOMMENDED*** *that reconditioning the operating model should be limited to situations where the stock assessment has changed significantly. This likely means a three-year schedule for reconditioning the operating model in the year following each full stock assessment.*
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> **IPHC-2023-SRB022-R (para. 27).** *The SRB* ***RECOMMENDED*** *that the Secretariat consider using explicit informative priors for conditioning the operating model to make fitting constraints more explicit.*

The MSE Operating Model (OM) was updated in 2023 based on assumptions and outputs of the 2022 full stock assessment (IPHC-2023-SA-01) and the data available at the end of 2022 (IPHC-2023-SA-02). The OM is an age-structured population dynamics model with movement between four Biological Regions. Multiple fishing sectors are modelled within IPHC Regulatory Areas along with landings and discard mortality. The OM incorporates four individual models (OM1–OM4) and integrates them into an ensemble to account for structural uncertainty and differing hypotheses about recruitment and distribution.

The OM was developed as a simulation model to explore alternate hypotheses of the population and is parameterized to allow for the specification of alternative hypotheses. However, this introduces the possibility of overparameterization and confounding between parameters. For example, movement between regions and the proportion of recruitment to each region are confounded and not easily separated with the inputs being conditioned to. Therefore, assumptions and priors are used to aid the conditioning process.

Assumptions and priors are described in the Technical Document on the IPHC MSE Research Website. In brief, movement assumptions include fixed movement between some regions (all but 4 to 3 and 3 to 2), age when Pacific halibut first move between regions, a maximum rate of movement-at-age, and a specific parametric function for each region-to-region movement. Assumptions related to distribution of age-0 recruits include that they can only recruit to one of the four regions and regions 3 and 4 receive the highest proportion of recruits.

The proportion of recruitment to each Biological Region and the movement-at-age from Biological Region 4 to 3 and from 3 to 2 were parameterized separately for low PDO years and high PDO years and also differed across OMs. The proportion of recruitment to Biological Region 4 was similar for low and high PDO years in OM1 but increased with high PDO for other OMs (Figure 1). The proportion increased for Biological Region 3 in OM1 but decreased with other OMs for high PDO years. A small amount of recruitment was distributed to Biological Regions 2 and 4B. OM2 had the highest proportion of recruitment to Biological Region 4.

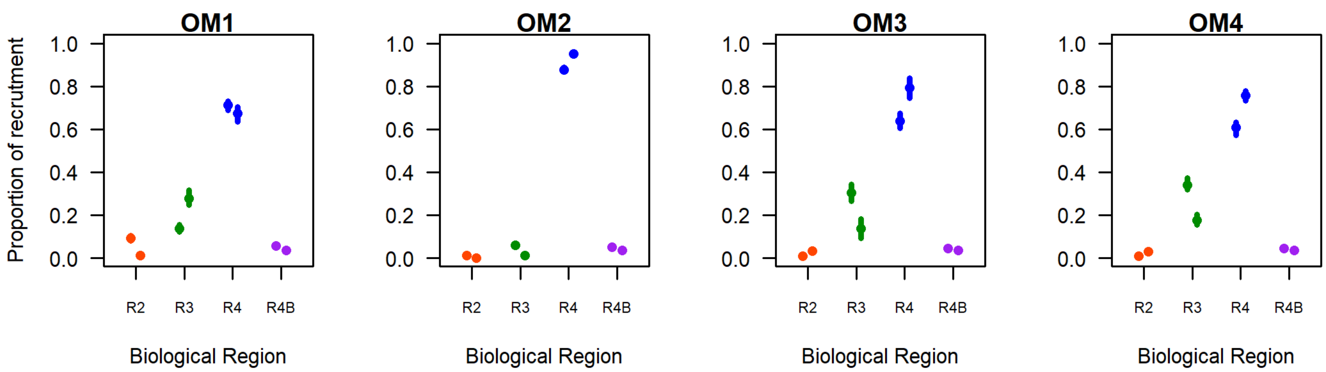

Figure 1. Proportions of recruitment distributed to each Biological Region for each OM. Low and high PDO years are shown as the two close points of the same color with low PDO on the left.

The probability of moving from one region to another over the lifetime of a Pacific halibut was used to summarize movement rates (Figure 2). This statistic was calculated as one minus the product of the age-specific probabilities of not moving to the other region. The lifetime movement rate was similar across OMs from Biological Region 4 to 3 but was slightly higher in low PDO years for OM1 and OM2. The movement from Biological Region 3 to 2 was lowest in OM1 and highest in OM2. Movement from 3 to 2 in OM3 and OM4 was similar to each other and intermediate to OM1 and OM2. Looking at movement and the distribution of recruits together, OM1 shows more widely distributed recruitment and less movement, OM2 shows most recruitment distributed to Biological Region 4 and high movement from west to east, and OM3 and OM4 are similar to each other and intermediate to OM1 and OM2. During the conditioning process, satisfactory outcomes were not found with distribution spread more evenly across IPHC Regulatory Areas. However, more research could be done to specifically investigate two hypotheses: 1) high proportions of recruitment occur in Biological Regions 3 and 4, and a high amount of movement occurs from west to east, or 2) recruitment is spread across IPHC

Regulatory Areas and movement is at lower rates. These four OMs traverse some of the range of these two hypotheses for recruitment distribution and movement.

Specific details of the OM will continue to be updated and published in a technical document available on the IPHC MSE Research Website.

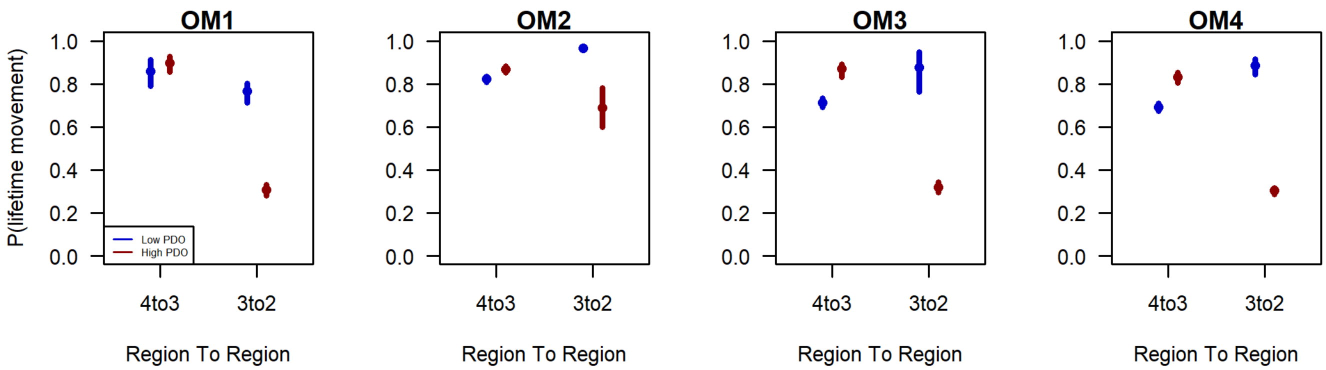

Figure 2. Probability of moving from Biological Region 4 to 3 over the lifetime of a Pacific halibut and the probability of moving from Biological Region 3 to 2 over the lifetime of a Pacific halibut for each OM. Low PDO years are shown in blue and high PDO years are shown in red.

The conditioned historical spawning biomass and projected spawning biomass integrated over the four OMs with no fishing mortality and with fishing intensity equal to a spawning potential ratio (SPR) of 43% are shown in Figure 3. Individual trajectories of spawning biomass are also shown in Figure 3, which show similar shapes with and without fishing. This is because weight-at-age and recruitment are large drivers of spawning biomass while fishing at a constant SPR has a large effect on the overall scale of spawning biomass. The median estimated spawning biomass from the ensemble stock assessment is similar to the median of the integrated OMs, and the integrated OM has a larger amount of uncertainty in recent years when compared to the ensemble stock assessment.

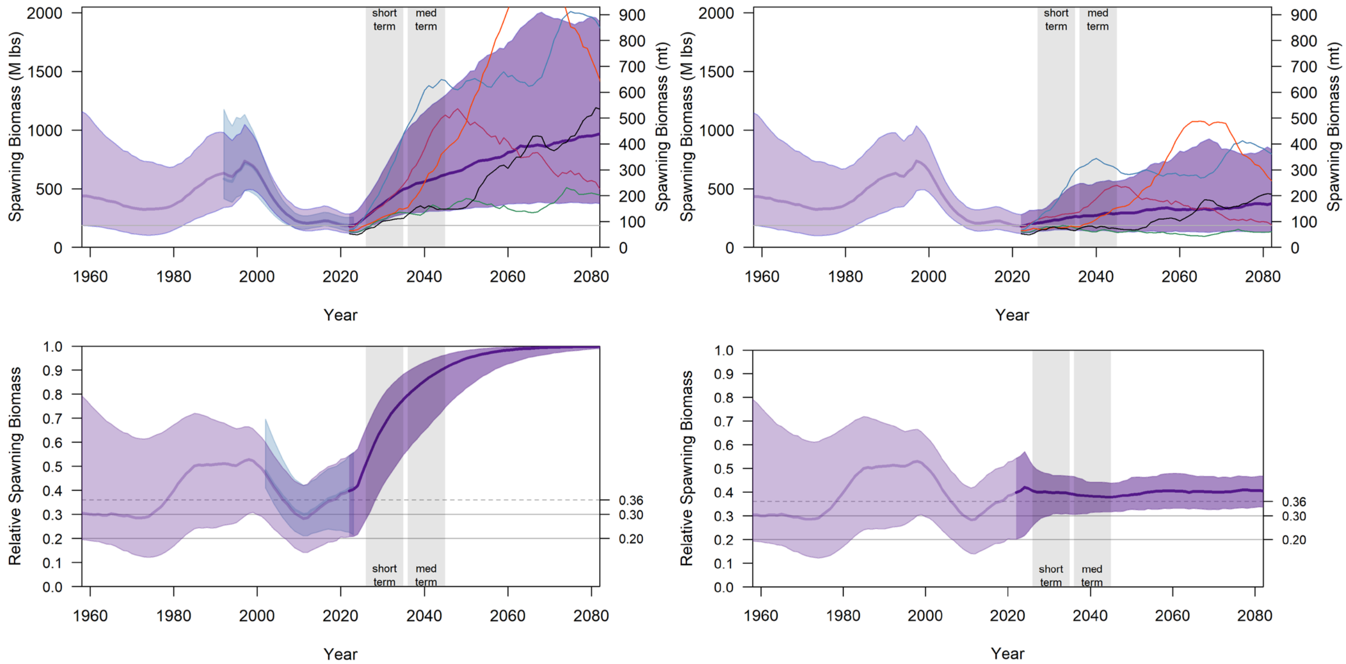

Figure 3. Simulated spawning biomass (top row) and relative spawning biomass (bottom row) assuming no fishing mortality (left column) and a fishing intensity equal to an SPR of 43% (right column). The median is shown by the thick dark line and the 5th and 95th percentiles are shown as the shaded polygon (the darker polygon indicates the projected time-period). Individual trajectories of spawning biomass are shown as small lines of different colors. Grey vertical panels indicate the short and medium time-periods used for calculating performance metrics. The grey horizontal line on the spawning biomass plots (top) indicate the median 2023 spawning biomass. The blue shaded area in the historical period shows the 5th and 95th percentiles from the ensemble stock assessment and the blue line is the median from the ensemble stock assessment for comparison.

OBJECTIVES

MSE objectives are constantly being improved and redefined to better meets the needs of the Commission. Four priority coastwide objectives are currently endorsed for the MSE.

> **IPHC-2023-AM099-R, para. 76.** *The Commission **RECOMMENDED** that for the purpose of a comprehensive and intelligible Harvest Strategy Policy (HSP), four coastwide objectives should be documented within the HSP, in priority order:*
>
> *a) Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point (B20%) at least 95% of the time.*
>
> *b) Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point (B36%) 50% or more of the time.*
>
> *c) Optimise average coastwide TCEY.*
>
> *d) Limit annual changes in the coastwide TCEY.*

A potential additional objective

The result from the 2022 full stock assessment (IPHC-2023-SA-01) using the current interim management procedure with an SPR of 43% was a TCEY of 52.0 million pounds (Mlbs). This TCEY was higher than expected from previous assessments largely because natural mortality (*M*) was estimated higher than a previously fixed value in one of four models in the ensemble, thus increasing the perceived productivity of the stock. In contrast to this optimistic result, the coastwide FISS index of O32 WPUE was at its lowest value observed in the time-series, declining by 8% from the previous year, and a TCEY of 52.0 Mlbs in 2023 would have resulted in a 75% chance of a lower spawning biomass in 2024. The Commission departed from the current interim management procedure at AM099 and chose a TCEY of 36.97 Mlbs for 2023, noting

> **IPHC-2023-AM099-R, para. 94.** *The Commission* ***NOTED*** *that the adopted mortality limits for 2023 correspond to a 38% probability of stock decline through 2024, and a 36% probability of stock decline through 2026.*

Although the status of the stock was above the target relative spawning biomass of 36% and had a small chance (25%) of falling below 30% with any TCEY up to 60 Mlbs, the Commission decided to reduce the TCEY from the reference harvest level TCEY. This implies that there may be an additional objective: reducing the chance of the spawning biomass being less than the 2023 spawning biomass. Therefore, a potential new coastwide objective may be,

- Maintain the long-term coastwide female spawning biomass above the estimated 2023 female spawning biomass at least XX% of the time.

This potential objective would be a reasonable objective to meet concerns expressed at AM099 and would be a useful contrast to the dynamic reference points used in the current priority objectives because it sets an absolute limit to remain above. It also uses an observed reference (estimated 2023 female spawning biomass) that has concrete meaning to stakeholders and may be an indicator for a threshold level of efficiency and opportunity in the Pacific halibut fisheries. MSE simulations with an SPR of 43%, decision-making variability, estimation error, and observation error showed a probability of 20% that the long-term spawning biomass would be less than the 2023 spawning biomass. An initial test of this objective would be to receive input from stakeholders and Commissioners whether dropping below the 2023 spawning biomass estimate with a 1 in 5 chance is acceptable in the long term.

Improving the objective to conserve spatial population structure

The current primary objective to conserve spatial population structure compares proportions of female spawning biomass in each Biological Region to an *ad hoc* threshold determined from historical estimates of stock distribution (Appendix A). This has been problematic because it is difficult to determine the appropriate threshold in the absence of a long time-series of survey-based estimates and no MP evaluated in previous iterations of the MSE process has met this objective for Biological Region 4B. A different objective to conserve spatial population structure was noted recently by the SRB.

> **IPHC-2023-SRB022-R (para. 24).** *The SRB* ***NOTED*** *that the spatial structure objective could be better addressed through a criterion that compares biomass in each region to unfished biomass in the same region rather than using proportions of the total stock-wide biomass.*

The 2023 OM has updated population dynamics based on the recent 2022 full stock assessment and data through 2022. Those updated population dynamics include new estimates of movement and distribution of recruits. Simulations with an SPR of 43% indicate that the current primary objective to conserve spatial population structure is met for all Biological Regions (Figure 4). However, the threshold percentages remain *ad hoc*, and it is uncertain if these are appropriate percentages.

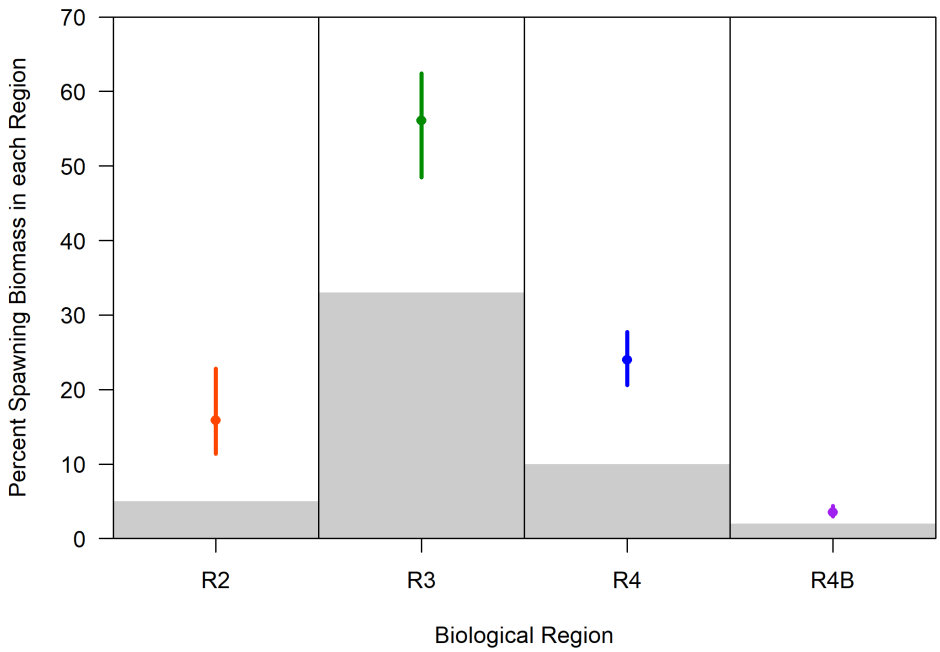

Figure 4. Percent spawning biomass in each Biological Region from 500 simulations based on an SPR of 43% with decision-making variability, estimation error, and observation error. The dot is the median and the vertical lines are the 5th and 95th percentiles. The grey indicates the area below the defined threshold. A vertical line extending into the grey area indicates that the objective is not met, which is not the case for any of these Biological Regions with these simulations.

A different objective may be to use the regional relative spawning biomass (see SRB paragraph 24 above) by comparing the regional biomass to the unfished regional biomass, where unfished regional biomass is calculated as the biomass that would have occurred if there was historically no fishing mortality. This objective would have specific meaning to the Biological Region and be independent of the amount of biomass in other regions. Additionally, relative spawning biomass is a commonly used statistic to measure conservation status. However, the threshold percentage, for which it is desired to remain above, and the tolerance are difficult to specify.

The historical conditioned regional RSB and projected regional RSB are shown in Figure 5. Biological Regions 2 and 3 were low at the beginning of the time-series and Biological Regions 4 and 4B were high. This is because there was little fishing mortality in Biological Regions 4 and 4B before 1958. As fishing mortality spread across the regions (and potentially changes in movement occurred), the historical RSB fluctuated near or below 36% in Biological Regions 2 and 3, remained above 36% in Biological Region 4, and decreased to near 36% in Biological Region 4B before increasing. Projections with decision-making variability, estimation error, and observation error, and using a MP similar to the harvest policy applied in recent years (SPR=43%) stabilized the RSB in each Biological Region, with Biological Region 2 remaining mostly below 30%.

Defining the appropriate threshold for each Biological Region is challenging because movement tends to occur from west to east, with Biological Regions 4 and 4B being source areas and Biological Regions 2 and 3 being sink areas. Therefore, Biological Regions 2 and 3 may be able to sustain lower relative spawning biomasses than Biological Regions 4 and 4B. In fact, the beginning of the time-series shows very low RSB for Biological Region 2, which had the majority of the fishing mortality in the early 1900s. The importance of each Biological Region is uncertain and likely varies across time, and perhaps a good starting point is the threshold for the coastwide spawning biomass (20%) but potentially with a higher tolerance than 5%. However, history has shown that the coastwide spawning stock was maintained even though the RSB in Biological Regions 2 and 3 were historically near or below 30%.

EXAMINING FISS DATA SCENARIOS

The FISS design has been rationalized in recent years and optimised designs are proposed to the Commission annually. However, logistical and funding constraints have sometimes resulted in designs smaller than the optimised designs, including the omission of samples from some survey charter regions and even entire IPHC Regulatory Areas. Even though the space-time model can make predictions for stations that were not sampled, the reduction in survey effort affects the precision of the FISS estimates. The SRB suggested that the effects of the reductions in FISS effort be examined using closed-loop simulations.

> **IPHC-2023-SRB022-R (para. 30).** *The SRB* ***NOTED*** *that situations in which critical data streams (e.g. FISS index or age data) are unavailable for one or more years does not constitute an "exceptional circumstance" and* ***REQUESTED*** *that the MSE include evaluation of such missing FISS data scenarios for the SRB023.*

> **IPHC-2023-SRB022-R (para. 52).** *The SRB* ***NOTED*** *the presentation demonstrating how secondary FISS objectives influence choices for future FISS designs that may have already been endorsed by the SRB based only on primary objectives. The SRB* ***RECOMMENDED*** *that the MSE include some scenarios in which the FISS is skipped (as also requested above in para. 30) because of occasional (or persistent) economic constraints on executing full FISS designs. Such simulation scenarios would provide some indication of the potential scale of impacts on MP performance of maintaining long-term revenue neutrality of the FISS.*

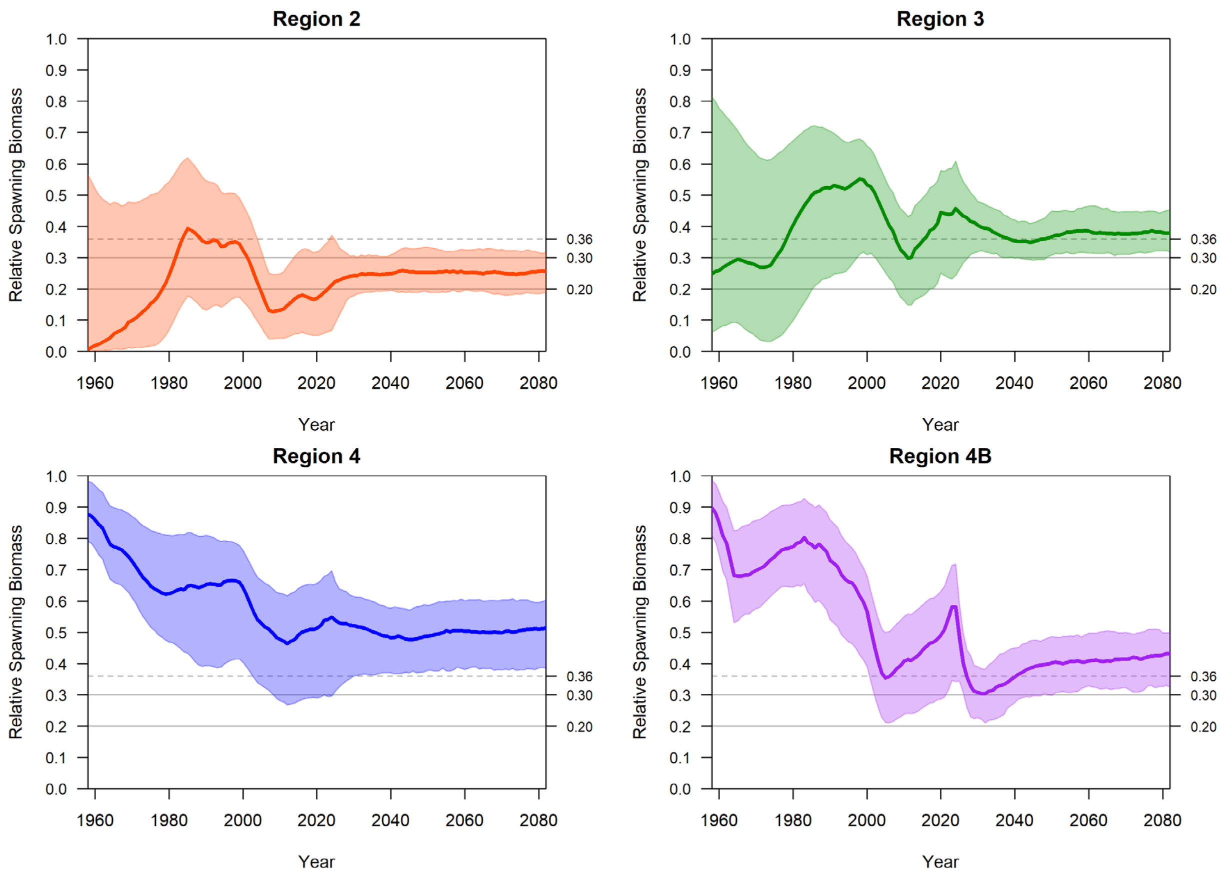

Figure 5. Relative spawning biomass in each Biological Region determined historically (pre-2023) and from projections using an SPR of 43%, a 30:20 control rule, decision-making variability, estimation error, and observation error. The horizontal solid lines are 30% and 20%, and the dashed horizontal line is the current coastwide target defined in objective 2.1 (Appendix A). The earliest years are a result of equilibrium assumptions and may not be representative of actual percentages before simulating through some years as a “burn-in”.

Three FISS scenarios

As a preliminary investigation, three FISS design scenarios were developed related to the survey effort in each IPHC Regulatory Area. There are three types of designs for an individual IPHC Regulatory Area used to make a scenario, each affecting the coefficient of variation (CV) differently.

1) **Full:** sufficient stations are surveyed in an IPHC Regulatory Area to keep the CV near or below the target.
2) **Reduced:** Some stations are surveyed in an IPHC Regulatory Area but the CV is potentially higher than the target for a ‘full’ design.
3) **Missed:** no stations are surveyed in an IPHC Regulatory Area and the CV is in the highest range.

A minimum and a maximum CV for each IPHC Regulatory Area is defined using terminal year CVs since 2017 (Table 1). The minimum CV for the Full Design was determined as the average of the terminal year CVs for 2017 through 2019 for 2A, 4A, 4CDE, and 4B, 2018 through 2022 for 2B and 2C, 2019 through 2022 for 3A, and 2019 through 2022 for 3B. This accounted for years where the survey was nearly "full" and expansion stations had been surveyed. Minimum CVs for Reduced and Missed designs were increased compared to the Full design and the "slope" for the Reduced and Missed Designs is the slope of a linear or logistic function that determines how the CV increases from the min to the max (details explained below). The minimum CV for a reduced survey is the average of the min and max of the Full, and the minimum CV for a missed year is the maximum for a Full year.

Table 1. Assumed ranges of CVs for the three different FISS types of design for each IPHC Regulatory Area.

Design	CV	2A	2B	2C	3A	3B	4A	4CDE	4B
Full	Min	12.0%	6.0%	6.0%	5.0%	8.0%	15.0%	10.0%	13.0%
	Max	15.0%	10.0%	10.0%	10.0%	15.0%	18.0%	11.0%	16.0%
Reduced	Min	13.5%	7.0%	7.0%	7.5%	11.0%	16.5%	10.5%	14.5%
	Slope	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Max	20.0%	15.0%	15.0%	15.0%	15.0%	20.0%	15.0%	25.0%
Missed	Min	15.0%	8.0%	8.0%	10.0%	14.0%	18.0%	11.0%	16.0%
	Slope	1	1	1	1	1	1	1	1
	Max	30.0%	25.0%	25.0%	25.0%	25.0%	25.0%	20.0%	30.0%

The process to adjust the CV given the design in a specific year is described below. It follows a logistic increase/decrease or a linear increase/decrease depending on the design and what occurred previously. The effect of past designs on the CV is tracked by incrementing a counter up or down, with a minimum value of 0 which would result in the minimum CV for that design. The minimum CV is determined from the minimum of the previous year or the defined minimum to avoid sudden jumps in the CV when switching design types.

- If the design is Full in year *t* the CV linearly decreases and cannot exceed the max or be less than the minimum. It traverses the maximum to minimum in five years. Where it starts within this range depends on how many Missed or Reduced designs occurred in previous years.
- If the design is Reduced in year *t*
    - If the design in year *t*-1 was Full then the CV increases with a logistic function between the min and max.
    - If the design in year *t*-1 was Reduced then the CV is reduced slightly using a logistic function between the min and max.
    - If the design in year *t*-1 was Missed then the CV is reduced because it uses the Reduced parameters and a linear adjustment to the CV.

- If the design is Missed in year *t* a logistic function increases the CV using the Missed parameters.

The three FISS scenarios are a Full design for all IPHC Regulatory Areas, a Reduced design for some IPHC Regulatory Areas, and a design with Missed IPHC Regulatory Areas. The lettering (a, b, and e) are based on a larger set of scenarios, but there was not enough time to simulate all.

a. A Full design in every IPHC Regulatory Area and every year. This is the best-case scenario and is not cost-optimised. It is hypothetical and unlikely, but useful for comparison.

b. Reduced design for IPHC Regulatory Areas other than 2B and 2C. 2B and 2C are always a Full design. This is based on recent patterns of nearly Full designs in 2B and 2C when other IPHC Regulatory Areas are reduced. However, as stock distribution changes, other areas may be preferable for a Full design (which is not captured here).

e. Miss every other year for IPHC Regulatory Areas 2A, 3B, 4A, 4CDE, and 4B. Reduced otherwise. 2B and 2C always Full and 3A always Reduced. In other words, every other year is only a full survey of 2B and 2C and reduced for 3A.

Given the algorithm defined above, the time-series of CVs used in simulated projections for each scenario and IPHC Regulatory Area are shown in Figure 6. Each time-series starts with the historical CVs determined from this algorithm given the designs that were used. For scenario (a), the CVs quickly go to the minimum CV for the Full design type and remain there. For scenario (b), the CVs in IPHC Regulatory Areas other than 2B and 2C go to the minimum CV for the Reduced design type and remain there. For scenario (e), the CVs in IPHC Regulatory Areas other than 2B, 2C, and 3A increase to a maximum and then oscillate between the maximum for the Reduced design type and the maximum for the Missed design type. Many other scenarios can be created and simulated. In the future, scenarios that are density-dependent (the FISS targets Full designs in areas of high density to maximize revenue) may be considered.

The other consideration for reduced FISS sampling is the effect on the uncertainty in the stock assessment. Currently, the MSE simply simulates the total mortality and the relative spawning biomass from a bivariate normal distribution with a CV of 15% and an autocorrelation of 0.4 for each parameter. To keep the FISS scenarios simple, the estimation error CV is a function of the sum of the observation CVs. Thus, if the design results in a higher observation CV, the estimation CV also increases. The sum of the minimum observation CVs for the Full design is 0.75 and the sum of the maximum observations CVs for the Missed design is 2.05. With an ad hoc linear relationship using an intercept of 0.1125 and a slope of 0.05, the minimum estimation error CV is 15% and the maximum estimation error CV is 21.5%. Basically, the estimation error increases as the uncertainty in the FISS indices increases.

Simulation results examining FISS scenarios

Performance metrics for each FISS data scenario related to the priority objectives, along with some others, are shown in

Table 2. Conservation metrics are similar across the scenarios and the long-term and short-term TCEYs show little difference among scenarios. The variability in the TCEY is most affected by these scenarios with the short-term AAV increasing from 16.3% with the Full design (a) to 19.9% when some IPHC Regulatory Areas are not surveyed (Missed design, e).

The increase in FISS CVs for each IPHC Regulatory Area is expected to affect the yield variability more than any other performance metric. The CVs for each IPHC Regulatory Area result in a higher CV for the coastwide FISS index, which results in a higher estimation error (mimicking the stock assessment). The CV for estimation error is symmetric, although autocorrelated, and increases from 15% to 21.5% based on total FISS error. With symmetric assessment error, the use of a constant SPR will attempt to stabilize the long-term spawning potential at the expense of more variability in yield.

The TCEY and AAV for each IPHC Regulatory Area are shown in Figure 7. The TCEY is similar among FISS scenarios for each IPHC Regulatory Area, but the AAV increases considerably with scenario (e). IPHC Regulatory Area 2A has less variability because the distribution procedure assumes a fixed allocation unless the stock is low in that area. IPHC Regulatory Areas 3B and west have higher AAVs and are more affected by scenario (e).

These preliminary results should be considered as a pilot study to guide future decisions related to how to investigate changes to the FISS design. These results show that increased CVs for FISS coastwide index and stock distribution estimates result in increases to the inter-annual variability in yield and little change in realized yield and no conservation risk to the stock. Given that the variability in yield is above the maximum desired variability specified in some primary objectives for all FISS scenarios, a constraint or alternative approach may be necessary. Introducing an element to stabilize yield will likely result in bigger effects on conservation and yield performance metrics across the FISS scenarios. Recent years suggest that designs in the future could be sparser, resulting in higher CVs than simulated in any of these scenarios. The Full scenario is likely a bookend for the best the survey can do, but the Missed scenario (e) is unlikely a bookend to how uncertain the FISS can become in the future. Therefore, it is important to ensure that realistic observation error is simulated in future MSE work to reflect potential future FISS designs.

Figure 6. Three FISS scenarios (columns) for each IPHC Regulatory Area (row) with the range of CVs for each design type shaded in separate colors.

Table 2. Long-term and short-term performance metrics for three FISS data scenarios and 500 replicates. Metrics in italics are not specified as priority objectives but are useful to evaluate each scenario. The Full scenario is (a), the Reduced scenario is (b), and the Missed scenario is (e).

FISS data scenario	**a**	**b**	**e**
Long-Term Metrics			
Median RSB	*37.8%*	*37.8%*	*37.9%*
P(RSB_y<20%)	<0.002	<0.002	<0.002
P(RSB<36%)	0.580	0.586	0.576
Median TCEY	*65.7*	*65.6*	*65.9*
P(any3 change TCEY > 15%)	*0.834*	*0.862*	*0.920*
Median AAV TCEY	*17.5%*	*18.1%*	*22.2%*
Short-term Metrics (4-13 yrs)			
Median TCEY	59.2	59.2	59.1
P(any3 change TCEY > 15%)	*0.864*	*0.884*	*0.936*
Median AAV TCEY	16.3%	16.8%	19.9%

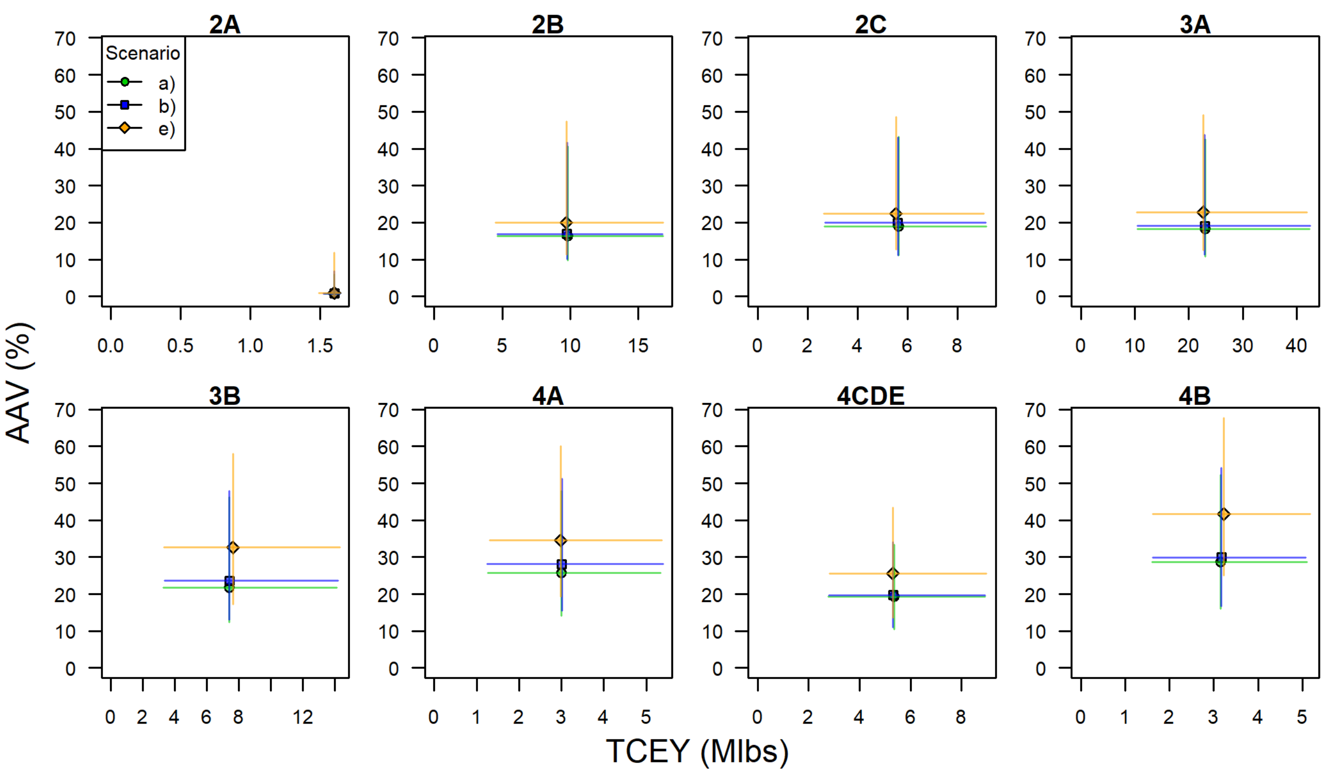

Figure 7. AAV (%) vs TCEY (Mlbs) for each IPHC Regulatory Area using an SPR of 43%, decision-making variability, estimation error, and three FISS data scenarios defining observation error. The lines show the 5th and 95th percentiles along each axis.

EQUALIZING MP PERFORMANCE ON CONSERVATION OBJECTIVES

There are two priority conservation objectives along with other objectives (Appendix A).

a. Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point ($B_{20\%}$) at least 95% of the time.

b. Maintain the long-term coastwide female spawning stock biomass above a biomass reference point ($B_{36\%}$) 50% or more of the time.

These priority conservation objectives are treated as thresholds rather than targets, meaning that for the objective to pass, they can not be exceeded, but the spawning biomass may be above the threshold with a larger probability than defined by the tolerance. For example, an MP that was above $B_{20\%}$ 99% of the time and above $B_{36\%}$ 70% of the time would pass, and the MP would be evaluated against other MPs based on fishery yield and variability, and potentially other objectives.

The SRB recommended equalizing the MPs based on one of the conservation targets to assist with evaluation. This means to specify the MPs such that they exactly meet a conservation objective, effectively removing that objective from the evaluation, and thus can be evaluated based only on other objectives.

> **IPHC-2023-SRB022-R (para. 25).** *To improve comparability of MPs in performance achieving TCEY objectives, the SRB* ***RECOMMENDED*** *equalizing MP performance on one of the conservation objectives.*

Equalizing the MPs being evaluated to one conservation objective would allow for a clear evaluation of the remaining objectives but may present MPs that are not desirable for adoption based on other criteria or result in the development of MPs that do not have desired properties related to yield. For example, meeting the criterion of the female spawning biomass being above $B_{20\%}$ 95% of the time cannot be done with the application of the 30:20 control rule (Figure 8). The female spawning biomass is unlikely to be below $B_{25\%}$ because the control rule reduces the fishing intensity such that the average applied fishing intensity is less than the reference fishing intensity. Using an SPR of 30% with a 30:20 control rule results in a median average long-term applied SPR of 38.6% and a median relative spawning biomass equal to 33%. Therefore, with the 30:20 control rule, the female spawning biomass is always above the biomass limit, but the SPR could be tuned to exactly meet the $B_{36\%}$ objective.

Removing the control rule and using a reference SPR of 30% resulted in a median average RSB equal to 29% and the biomass limit objective not being met (a 7% probability of RSB being 20% or more). The RSB was also less than $B_{36\%}$ in more than 50% of the simulations, and in fact more than 95% of the simulations (Figure 8). The median average long-term SPR was 33.6% and was greater than the reference SPR of 30% due to estimation error and decision-making variability when determining the final mortality limits. Evaluation of MPs could only be equalized on the biomass limit conservation objective if the control rule was eliminated and a high fishing intensity (i.e. low SPR) was used. Alternatively, the MPs could be equalized using the biomass target objective with a control rule. However, either of the options would likely limit the range of SPR values to examine and result in fishing intensities that may be higher than desired given other objectives. For these simulations, an SPR of 34% with a 30:20 control rule resulted in a relative spawning biomass of 35% (Figure 8). Other elements of an MP may be introduced, such as constraints, which would likely result in lower median realized fishing intensities (i.e. higher realized SPR) than the reference fishing intensity.

Furthermore, equalizing the MPs on the biomass limit objective, using SPR, would likely never meet the $B_{36\%}$ objective (given the scope of MPs that are under consideration). In Figure 8, the biomass limit objective is met when the lower end of the line is at or above the horizontal line at 0.20, and the $B_{36\%}$ objective is met when the dot is at or above the horizontal line at 0.36. To meet the biomass limit objective, the realized fishing intensity needs to increase, which results in a further departure from the $B_{36\%}$ objective. Alternatively, equalizing on the $B_{36\%}$ objective would likely meet the biomass limit objective. Alternatively, if the new potential objective, presented above, to maintain the long-term spawning biomass above the 2023 spawning was adopted, this may be a useful objective to equalize the MPs for evaluation.

It takes a considerable amount of time to run these MSE simulations, and searching for the SPR that equalizes MPs may take longer than running a pre-defined set of SPR values. Once a pre-defined set of SPR values is complete, MPs could be compared using the SPR values that approximately meet the biomass target conservation objective, as well as evaluated at different SPR values that pass both conservation objectives but may not meet them exactly.

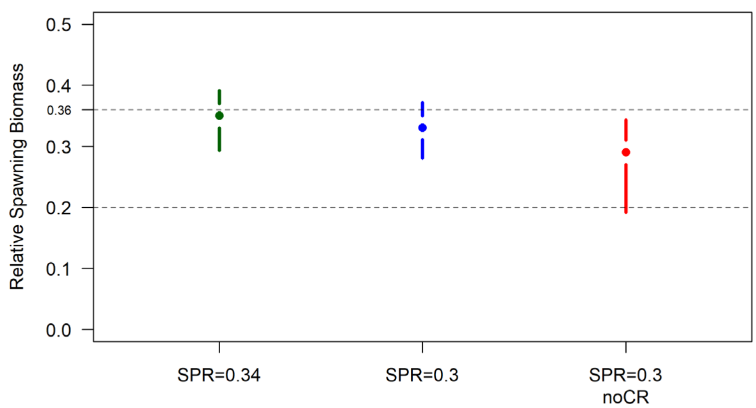

Figure 8. Relative spawning biomass for closed-loop simulations with decision-making variability, estimation error, and observation error. Reference SPR values of 30% and 34% with a 30:20 control rule (green and blue) and an SPR of 30% without a control rule (red) were simulated. The point is the median of 180 replicates, the bottom is the 5th percentile, and the top of the bar is the 95th percentile. The horizontal lines represent the biomass limit and biomass target of the priority conservation objectives. Additional simulations may be necessary to accurately determine the tail probabilities.

EXCEPTIONAL CIRCUMSTANCES

Two recommendations were made at SRB022 that guide the development of exceptional circumstances.

> **IPHC-2023-SRB022-R (para. 28).** The SRB **RECOMMENDED** that exceptional circumstance (i) be evaluated annually based on comparisons between the simulation distribution (e.g. a 95% interval) of FISS values from MSE simulations to the realized FISS estimates; and (ii) be clearly distinguished from "unusual conditions". For

example, exceptional circumstances should have a high threshold for persistent (i.e. more than a single year) deviation from MSE simulations.

> **IPHC-2023-SRB022-R (para. 29).** The SRB **RECOMMENDED** that an initial response to a suspected "exceptional circumstance" should include presentation at the next SRB meeting to establish whether the situation meets the definition of an "exceptional circumstance" and to formulate a response.

An exceptional circumstance is defined as a process for deviating from an adopted MP (de Moor et al. 2022) and is useful to ensure that the adopted harvest strategy is retained unless it is absolutely necessary to deviate from the process. The IPHC interim harvest strategy policy has a decision-making step after the MP, thus the Commission may deviate from an adopted MP. This decision-making variability is included in the MSE simulations. The SRB provided clarity at SRB021 of what an exceptional circumstance is and how it may fit within the IPHC process.

> **IPHC-2022-SRB021-R**, para 60: The SRB **RECOMMENDED** that Exceptional Circumstances be defined to determine whether monitoring information has potentially departed from their expected distributions generated by the MSE. Declaration of Exceptional Circumstances may warrant re-opening and revising the operating models and testing procedures used to justify a particular management procedure.

This statement indicates that exceptional circumstances should be defined using observations rather than model outputs and should be compared to the distribution generated by the MSE simulations. If the observation(s) are outside of that range, and have been for more than one year, revising the MSE framework and conducting additional simulations should be considered. It is important to have clear definitions for when the agreed upon MP should be re-evaluated.

Definitions of exceptional circumstances

Suggested exceptional circumstances are as follows.

a) The coastwide all-sizes FISS WPUE or NPUE from the space-time model falls above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index for two or more consecutive years.
    i. This would be examined annually after the FISS WPUE and NPUE indices are available in November by comparing it to MSE simulations that are most similar to the recent catches. The all-sizes index would be a better option because to calculate O32, the OM makes an assumption of how to split the observations into U32 and O32. If an exceptional circumstance is declared in a year without a stock assessment, it is unlikely that a stock assessment could be produced in time for the Interim Meeting, but an update on stock status may be available for the Annual Meeting.

b) The observed FISS all-sizes stock distribution for any Biological Region is above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index over a period of 2 or more years.

   i. These data were used to condition the OM, so are a reasonable choice for an exceptional circumstance. The all-sizes index would be a better option because to calculate O32, the OM makes an assumption of how to split the observations into U32 and O32. This would be examined annually after the FISS stock distribution estimates are available in November by comparing it to MSE simulations that are most similar to the recent catches. If an exceptional circumstance is declared in a year without a stock assessment, it is unlikely that a stock assessment could be produced in time for the Interim Meeting, but an update on stock status may be available for the Annual Meeting.

c) Recruitment, weight-at-age, sex ratios, other biological observations, or new research indicating parameters that are outside the 2.5^{th} and 97.5^{th} percentiles of the range used or calculated in the MSE simulations.

   i. Most likely, this would be identified during a full stock assessment, and a new OM would be conditioned. However, new understanding of the Pacific halibut population may warrant a reconsideration of MPs to evaluate. The details can be identified further.

Action after an exceptional circumstance is declared

Once an exceptional circumstance is declared a series of actions would occur.

1) A review of the MSE simulations to determine if the OM can be improved and MPs should be re-evaluated. At a minimum, the OM will be updated and reconditioned to the most recent observations, including those that resulted in the exceptional circumstance.
2) If a multi-year MP was implemented and an exceptional circumstance occurred in a year without a stock assessment, a stock assessment would be completed as soon as possible along with the re-examination of the MSE. However, it may not be possible to conduct a stock assessment in time for the Annual Meeting immediately following the declaration of an exceptional circumstance.
3) Consult with the SRB and MSAB to identify why the exceptional circumstance occurred, what can be done to resolve it, and determine a set of MPs to evaluate with an updated OM. Present these recommendations to the Commission.
4) Further consult with the SRB and MSAB after simulations are complete to identify if a new MP is appropriate. Present these recommendations to the Commission.

POTENTIAL MANAGEMENT PROCEDURES AND SCENARIOS TO EVALUATE

The SRB (**IPHC-2023-SRB022-R** paragraphs 30 and 52 listed above) and the MSAB have provided requests to investigate various MP elements.

> **IPHC-2023-MSAB018-R, para. 29:** *The MSAB* ***REQUESTED*** *that subsequent to an agreement on a distribution procedure by the Commission, the evaluation of annual and multi-year assessments include, but not limited to, the following concepts.*

a) Annual changes in the TCEY driven by FISS observations in non-assessment years of a multi-year MP;

b) A constraint on the coastwide TCEY to reduce inter-annual variability and the potential for large changes in assessment years of a multi-year. This may be a 10% or 15% constraint, a slow-up fast-down approach, or similar approach;

c) A smoothing element in the distribution procedure to account for uncertainty in the estimates of stock distribution and reduce the variability in area-specific TCEYs. For example, this may include a 3-year rolling average of stock distribution estimates;

d) SPR values ranging from 30% to 56% and alternate trigger reference points in the harvest control rule.

The following describes elements of MPs that could be evaluated as part of the current MSE Program of Work, categorized as priority elements, secondary elements, and additional elements. Priority elements would be done first, secondary elements would be examined with specific priority elements, and the additional element is optional.

PRIORITY

Annual stock assessment MPs: Management procedures with an annual stock assessment.

Multi-year stock assessment MPs: These are management procedures that conduct a stock assessment every 2nd or 3rd year and use an empirical MP based on the FISS survey trends to determine the TCEY in non-assessment years.

Fishing intensity: A range of SPR values (i.e. fishing intensity, currently 43%) and alternative trigger reference points (currently 30%) in the harvest control rule.

FISS reductions: Further investigate scenarios where the FISS effort is reduced or occasionally eliminated in various IPHC Regulatory Areas.

SECONDARY

Constraints: A constraint on the coastwide TCEY to reduce inter-annual variability. Details have not been determined, but past examples include a 15% constraint and a slow-up/fast-down approach.

Stock distribution: A method to reduce the inter-annual variability in the estimates of stock distribution for use in the MP. This may include using the average of the stock distribution estimates over the past 3 years, for example.

ADDITIONAL

TCEY distribution: If specific distribution management procedures are of interest to Commissioners to assist with coming to an agreement, these can be evaluated using the MSE process.

RECOMMENDATION/S

1) The SRB **NOTE** paper IPHC-2023-SRB023-07 presenting an updated operating model, potential new MSE objectives, evaluation of FISS data scenarios, an examination of how to equalize management procedure performance across conservation objectives, possible exceptional circumstances, and potential management procedures to evaluate in 2023–2025.
2) The SRB **ENDORSE** the 2023 operating model containing four individual models to represent structural uncertainty identified in the ensemble stock assessment.
3) The SRB **RECOMMEND** that an objective to maintain spatial population structure be (added or redefined) to maintaining the spawning biomass in a Biological Region above a defined percentage of the dynamic unfished equilibrium spawning biomass in that Biological Region with a defined tolerance. The percentage and tolerance may be defined based on historical patterns and appropriate risk levels.
4) The SRB **RECOMMEND** that an objective to maintain the long-term coastwide female spawning stock biomass above the estimated 2023 female spawning biomass at least some percentage of the time (to be defined by the Commission) be added to the priority objectives. This provides an absolute measure of biomass that has meaning to stakeholders and Commissioners and may relate to efficiency and opportunity (e.g. CPUE) in the fisheries.
5) The SRB **RECOMMEND** continued examination of FISS scenarios that are representative of future FISS designs.
6) The SRB **RECOMMEND** that an exceptional circumstance be declared if any of the following are met:
    a. The coastwide all-sizes FISS WPUE or NPUE from the space-time model falls above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index for two or more consecutive years.
    b. The observed FISS all-sizes stock distribution for any Biological Region is above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index over a period of 2 or more years.
    c. Recruitment, weight-at-age, sex ratios, other biological observations, or new research indicating parameters that are outside the 2.5th and 97.5th percentiles of the range used or calculated in the MSE simulations.
7) The SRB **RECOMMEND** that if an exceptional circumstance occurred the following actions would take place:
    a. A review of the MSE simulations to determine if the OM can be improved and MPs should be re-evaluated.
    b. If a multi-year MP was implemented and an exceptional circumstance occurred in a year without a stock assessment, a stock assessment would be completed as soon as possible along with the re-examination of the MSE.

   c. Consult with the SRB and MSAB to identify why the exceptional circumstance occurred, what can be done to resolve it, and determine a set of MPs to evaluate with an updated OM.
   d. Further consult with the SRB and MSAB after simulations are complete to identify if a new MP is appropriate.

8) The SRB **RECOMMEND** evaluating fishing intensity and frequency of the stock assessment elements of management procedures and FISS uncertainty scenarios using the MSE framework. MP elements related to constraints on the interannual change in the TCEY and calculation of stock distribution may be evaluated for a subset of the priority management procedures as time allows.

REFERENCES

de Moor CL, Butterworth DS, Johnston S. 2022. Learning from three decades of Management Strategy Evaluation in South Africa. ICES Journal of Marine Science. 79. 1843-1852.

APPENDICES

Appendix A: Primary objectives defined by the Commission for the MSE

Appendix B: Supplementary material

APPENDIX A
PRIMARY OBJECTIVES DEFINED BY THE COMMISSION FOR THE MSE

Table A.1. Primary objectives, evaluated over a simulated ten-year period, accepted by the Commission at the 7th Special Session of the Commission (SS07). Objective 1.1 is a biological sustainability (conservation) objective and objectives 2.1, 2.2, and 2.3 are fishery objectives. Priority objectives are shown in green text.

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	MEASURABLE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRIC
1.1. KEEP FEMALE SPAWNING BIOMASS ABOVE A LIMIT TO AVOID CRITICAL STOCK SIZES AND CONSERVE SPATIAL POPULATION STRUCTURE	Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point ($B_{20\%}$) at least 95% of the time	*B* < Spawning Biomass Limit (B_{Lim}) B_{Lim}=20% unfished spawning biomass	Long-term	0.05	$P(SB < SB_{Lim})$ Fail if greater than 0.05
	Maintain a defined minimum proportion of female spawning biomass in each Biological Region	$p_{SB,2} > 5\%$ $p_{SB,3} > 33\%$ $p_{SB,4} > 10\%$ $p_{SB,4B} > 2\%$	Long-term	0.05	$P(p_{SB,R} < p_{SB,R,min})$
2.1 MAINTAIN SPAWNING BIOMASS AT OR ABOVE A LEVEL THAT OPTIMIZES FISHING ACTIVITIES	Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point ($B_{36\%}$) 50% or more of the time	*B*<Spawning Biomass Reference (B_{Thresh}) B_{Thresh}=$B_{36\%}$ unfished spawning biomass	Long-term	0.50	$P(SB < SB_{Targ})$ Fail if greater than 0.5
2.2. PROVIDE DIRECTED FISHING YIELD	Optimize average coastwide TCEY	Median coastwide TCEY	Short-term		*Median* $\overline{TCEY}$
	Optimize TCEY among Regulatory Areas	Median $TCEY_A$	Short-term		*Median* $\overline{TCEY_A}$
	Optimize the percentage of the coastwide TCEY among Regulatory Areas	Median $\%TCEY_A$	Short-term		*Median* $\overline{\left(\frac{TCEY_A}{TCEY}\right)}$
	Maintain a minimum TCEY for each Regulatory Area	Minimum $TCEY_A$	Short-term		*Median Min(TCEY)*
	Maintain a percentage of the coastwide TCEY for each Regulatory Area	Minimum $\%TCEY_A$	Short-term		*Median Min(%TCEY)*
2.3. LIMIT VARIABILITY IN MORTALITY LIMITS	Limit annual changes in the coastwide TCEY	Annual Change (*AC*) > 15% in any 3 years	Short-term		$P(AC_3 > 15\%)$
		Median coastwide Average Annual Variability (AAV)	Short-term		*Median AAV*
	Limit annual changes in the Regulatory Area TCEY	Annual Change (*AC*) > 15% in any 3 years	Short-term		$P(AC_3 > 15\%)$
		Average AAV by Regulatory Area (AAV_A)	Short-term		*Median* AAV_A

APPENDIX B
SUPPLEMENTARY MATERIAL

The IPHC MSE Research website contains additional documents with more detailed information.

https://www.iphc.int/management/science-and-research/management-strategy-evaluation

The MSE technical document (IPHC-2022-MSE-01) currently available on the IPHC MSE page will be updated with IPHC-2023-MSE-02 in the near future.

The MSE Explorer will be updated as additional results are produced. Links to the current MSE Explorer as well as archived results are available at

http://iphcapps.westus2.cloudapp.azure.com/