IPHC Secretariat MSE Program of Work (2024) and an update on progress

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PURPOSE

To provide the Scientific Review Board (SRB) with an update on Management Strategy Evaluation (MSE) progress and an MSE program of work for 2024.

1 INTRODUCTION

Work from the Management Strategy Evaluation (MSE) Program of Work for 2023–2025 that has been completed is reported in documents IPHC-2024-MSAB019-06 and IPHC-2024-MSE-01. This includes updating the operating model (OM), defining exceptional circumstances and actions to take when an exceptional circumstance occurs, investigating the environmental and fishing effects on the abundance and distribution of Pacific halibut, and evaluating a wide range of fishing intensities (SPR=34% to SPR=56%). Updates to the MSE Program of Work for 2023–2025 are being considered by the Commission.

> **IPHC-2024-AM100-R, para 53**. *The Commission **AGREED** to undertake intersessional discussions on the recommendations contained within paper IPHC-2024-AM100-11, and provide further direction to the IPHC Secretariat*.

The potential additions to the MSE Program of Work discussed in this paper support the development of a harvest strategy policy document.

2 HARVEST STRATEGY POLICY

A Harvest Strategy Policy (HSP) provides a framework for applying a science-based approach to setting harvest levels. At IPHC, this would be specific to the TCEY for each IPHC Regulatory Area throughout the Convention Area. Currently, the IPHC has not formally adopted a harvest strategy policy but has set harvest levels under an SPR-based framework with elements adopted at multiple Annual Meetings of the IPHC since 2017.

Adopting an HSP is important for any fisheries management authority because it outlines the long-term vision for management and specifies the framework for a consistent and transparent science-based approach to setting mortality limits. An HSP:

- identifies an appropriate method to manage natural variability and scientific uncertainty,
- accounts for risk and balances trade-offs,
- reduces the time needed to make management decisions,
- ensures long-term sustainability and profitability,
- increases market stability due to a more predictable management process,

- adheres to the best practices of modern fisheries management that is consistent with other fisheries management authorities and certification agencies, and
- allows for the implementation of the precautionary approach.

Overall, an HSP spells out the management process, which benefits the fish, the stakeholders, and other interested parties.

The MSE work and guidance from the MSAB and SRB have been a very important part of developing the HSP. To move towards formally adopting a HSP at the IPHC in the near term, the SRB recommended separating the coastwide TCEY management procedure (MP) from the distribution procedure.

> **IPHC-2023-SRB023-R, para. 30:** *The SRB* ***RECOMMENDED*** *that the Commission consider revising the harvest policy to (i) determine coastwide TCEY via a formal management procedure and (ii) negotiate distribution independently (e.g. during annual meetings). Such separated processes are used in other jurisdictions (e.g. most tuna RFMOs, Mid Atlantic Fishery Management Council, AK Sablefish, etc.).*

The coastwide TCEY determined from the MP in the harvest strategy would be an input into the allocation decision-making process.

An HSP can be divided into three components: management procedure, harvest strategy, and policy (Figure 1). A management procedure is an agreed upon procedure that determines an output that meets the objectives defined for management. The MP is reproducible and codified such that it can be consistently calculated. The harvest strategy component contains the MP but is broader and encompasses the objectives as well as additional procedures that produce the final necessary outputs but may not be procedural and pre-defined. For example, at the IPHC the harvest strategy consists of the procedure to determine the coastwide TCEY as well as the concept of distributing the TCEY to each IPHC Regulatory Area. Currently, the determination of the coastwide TCEY is defined using a harvest control rule and reference fishing intensity, but there is not an agreed upon procedure to distribute the TCEY. However, a reference TCEY distribution, calculated using a defined procedure, may be useful to inform the decision-making process. The policy component is the aspect of decision-making where management may deviate from the outputs of the harvest strategy to account for other objectives not considered in the harvest strategy. This may be to modify the coastwide TCEY and/or the distribution of the TCEY to account for economic factors, for example. At IPHC, the policy component occurs at the Annual Meeting of the IPHC where stakeholder input is considered along with scientific information to determine the mortality limits for each IPHC Regulatory Area.

Some additional MSE work would be useful for drafting an HSP document for adoption, noting that the HSP may be updated at any time following additional MSE-related work. The MSE tasks to complete are outlined in this document along with other tasks that may be useful for Commission decisions.

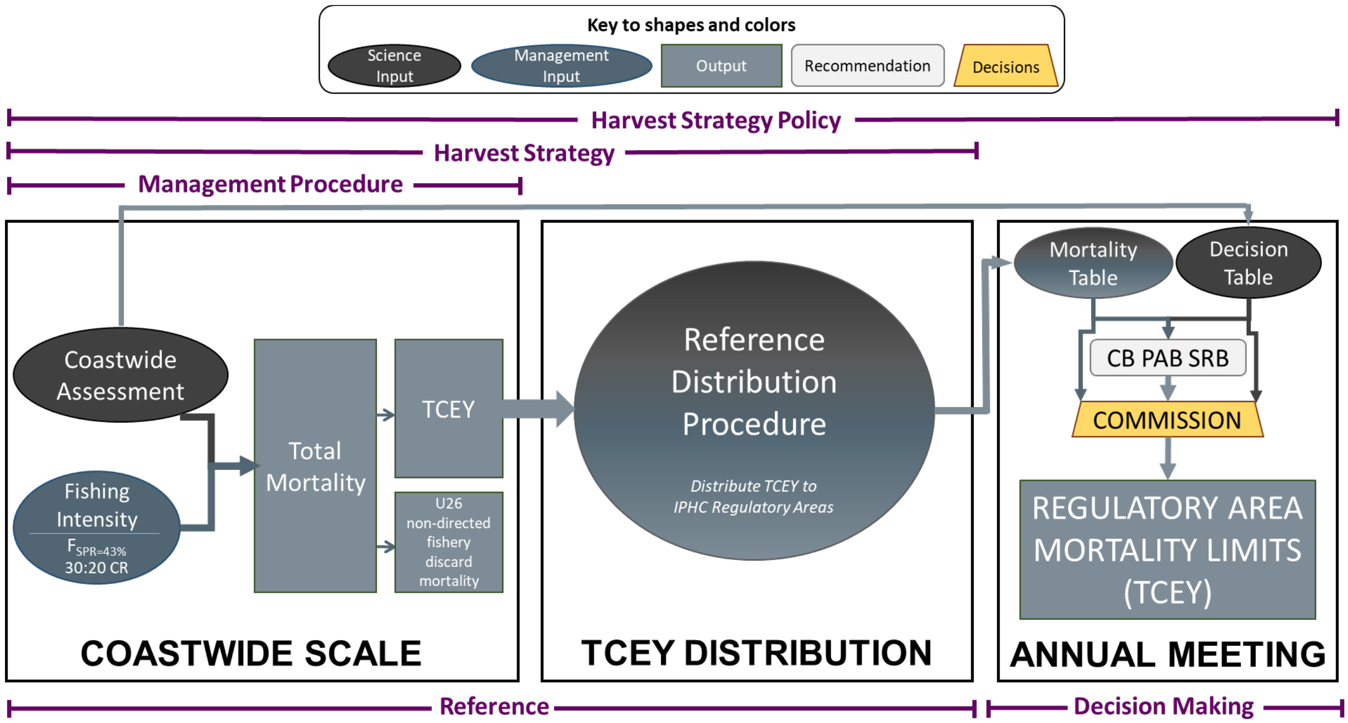

Figure 1. Illustration of the interim harvest strategy policy for the IPHC showing the coastwide scale (management procedure), the TCEY distribution (part of the harvest strategy), and the policy component that mainly occurs at the Annual Meeting.

2.1 Exceptional Circumstances

An exceptional circumstance is an event that is beyond the expected range of the MSE evaluation and triggers specific actions that should be taken to re-examine the harvest strategy. Exceptional circumstances, and actions taken if one or more is met, define a process for deviating from an adopted harvest strategy (de Moor, Butterworth, and Johnston 2022). It is important to ensure that the adopted harvest strategy is retained unless there are clear indications that the MSE may not be accurate. The IPHC interim harvest strategy policy (Figure 1) has a decision-making step after the MP, thus the Commission may deviate from an adopted MP as part of the harvest strategy policy. This decision-making variability is included in the MSE simulations.

The Secretariat, with the assistance of the SRB and MSAB, has defined exceptional circumstances and the response that would be initiated, as well as potential triggers in a management procedure that would result in a stock assessment being done (if time allows) in a year that would normally not have one scheduled (e.g. in multi-year MPs). The following potential triggers for an exceptional circumstance have been defined.

> **IPHC-2023-SRB023-R, para. 27:** ***RECOGNIZING*** *the spatial variability of environmental factors that influence population dynamics, the SRB* ***RECOMMENDED*** *that an exceptional circumstance be defined based on regional as well as stockwide deviations from expectations. For example, an exceptional circumstance could 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.

Furthermore, the following actions may take place if an exceptional circumstance is declared.

IPHC-2023-SRB023-R, para. 28: *The SRB* ***RECOMMENDED*** *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 reevaluated.

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 whether a new MP is appropriate.

The FISS coastwide modelled NPUE was compared to projections from the 2023 OM to determine if an exceptional circumstance has occurred (Figure 2). Predictions intervals from the OM were calculated by simulating 100 indices from 125 OM simulations to incorporate the uncertainty in the FISS index. The current interim reference fishing intensity associated with an SPR of 43% was used because that is the current interim MP and includes decision-making variability to account for departing from that fishing intensity. The 2023 observation from the FISS space-time model is within the 95% prediction interval from the OM, thus an exceptional circumstance has not occurred.

Using similar methods as with the coastwide FISS index, the predicted stock distribution from MSE simulations with an SPR of 43% was compared to the observed stock distribution in 2023 (Figure 3). The observations in 2023 depart from the predictions in Biological Regions 2 and 3. This happens in some previous years and may indicate that there is more uncertainty than the OM is modelling.

Other factors, such as updates to parameters, are considered when determining exceptional circumstances. One important current research project is the examination of maturity-at-age. If the updated maturity-at-age is much different than assumed in the 2023 OM, that may require an update to the OM. This will be evaluated when the new results are available.

The MSAB was also interested in developing exceptional circumstances using fishery-dependent data.

> **IPHC-2024-MSAB019-R, para. 53:** *The MSAB* ***NOTED*** *that the FISS is conducted to measure the population and that it may not be an accurate depiction of the fishery, and that fishery-dependent data may provide insights into fishery concerns that the FISS may not capture.*

> **IPHC-2024-MSAB019-R, para. 54:** *The MSAB* ***REQUESTED*** *that the SRB and Secretariat work together to consider different ways to incorporate fishery-dependent data into an exceptional circumstance.*

The MSE simulations predict many types of fishery-dependent data (e.g. age-compositions) which may be used to develop additional exceptional circumstances. It will be important to delineate between changes in fishery dependant data that should fall within the scope of the MSE predictions and those that may be caused by management actions of other factors that are not part of the MSE and not reflective of Pacific halibut stock dynamics. The response in these two cases may be different.

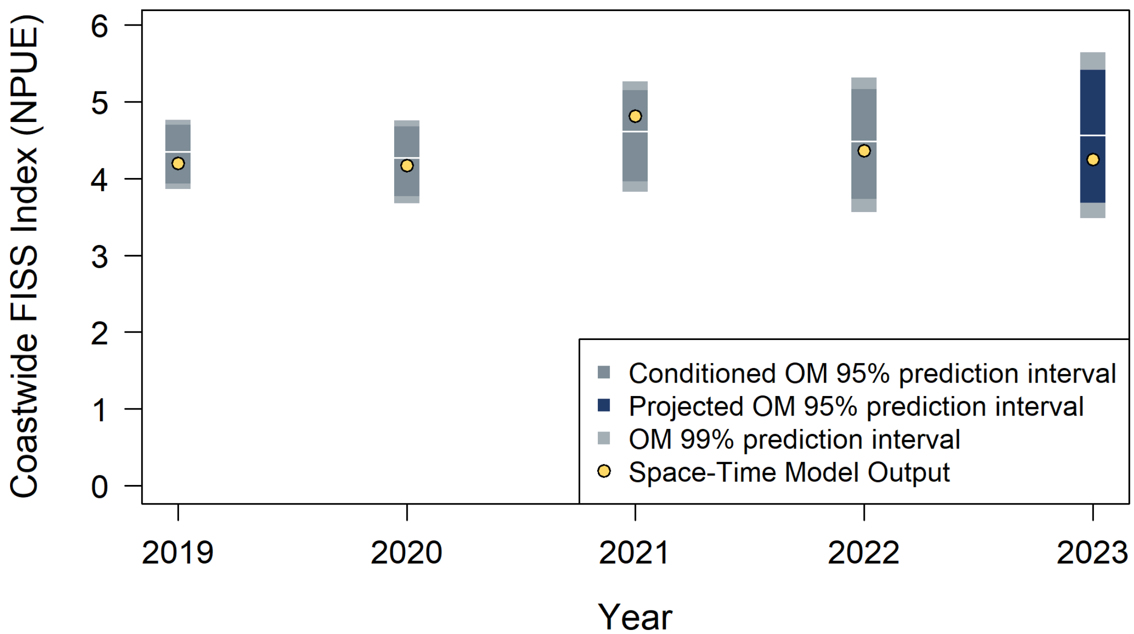

Figure 2. Prediction intervals of the coastwide FISS NPUE index from the 2023 OM (conditioned on data through 2022) projected to 2023 using an SPR of 43, decision-making variability, estimation error, and observation error plotted along with the FISS all-sizes NPUE index from the space-time model (yellow dot). The dark blue box is the 95% prediction interval for all-sizes NPUE from the projected 2023 OM. Lighter extensions of each box show the 99% prediction interval.

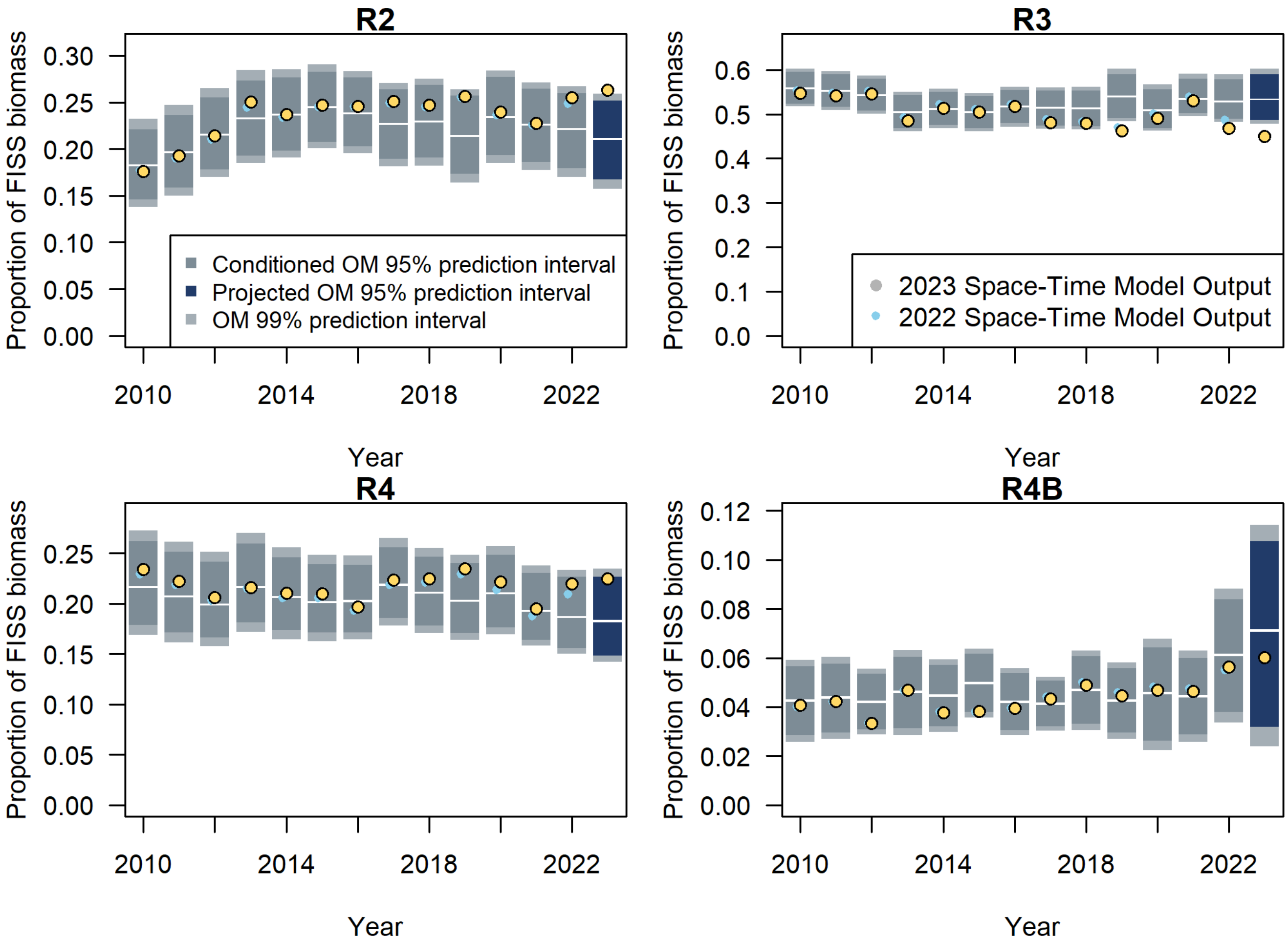

Figure 3. Prediction intervals of the proportion of FISS all-sizes biomass in each Biological Region (stock distribution) from the 2023 OM projected to 2023 using an SPR of 43, decision-making variability, estimation error, and observation error plotted along with the FISS all-sizes stock distribution from the space-time model (yellow dot). The dark blue box is the 95% prediction interval for stock distribution from the projected 2023 OM. Lighter extensions of each box show the 99% prediction interval. Estimated stock distribution from the 2022 space-time model are shown in light blue (which were used when conditioning the OM).

3 Goals and Objectives

The Commission defined a small set of priority coastwide objectives and associated performance metrics for current evaluations.

> **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.

IPHC-2023-AM099-R, para. 77. *The Commission **AGREED** that the performance metrics associated with the objectives in Paragraph 76 are:*

a) P(RSB): Probability that the long-term Relative Spawning Biomass (RSB) is less than the Relative Spawning Biomass Limit, failing if the value is greater than 0.05.

b) P(RSB<36%): Probability that the long-term RSB is less than the Relative Spawning Biomass Reference Point, failing if the value is greater than 0.50.

c) Median TCEY: the median of the short-term average TCEY over a ten-year period, where the short-term is 4-14 years in the future.

d) Median AAV TCEY: the average annual variability of the short-term TCEY determined as the average difference in the TCEY over a ten-year period.

These priority objectives and performance metrics come from a larger list of objectives which includes objectives specific to Biological Regions and IPHC Regulatory Areas (Appendix A).

3.1 Performance metric for multi-year assessments

The MSAB018 also requested that new performance metrics be developed for evaluating assessment frequency.

IPHC-2023-MSAB019-R, para. 38. *The MSAB **REQUESTED** new performance metrics representing the change in the TCEY in non-assessment years and the change in TCEY in assessment years be developed for the evaluation of multi-year assessment MPs*.

Current performance metrics describing the interannual variability in the TCEY include the average annual variation (AAV) and the probability that 3 or more years of a 10-year period have a change in the TCEY greater than 15% from one year to the next (Appendix A). Additional metrics may be useful in understanding the performance of an MP using biennial or triennial assessments, especially if the TCEY is held constant during non-assessment years. The current performance metrics, averaged over a 10-year period, regardless of the assessment frequency, are still useful and simply represent the variability over that 10-year period.

Annual Change (AC) is one performance metric that shows interannual variability in the TCEY and measures the relative percent change in the TCEY from the previous year (see Appendix A for a mathematical description). Figure 4 shows the AC for annual, biennial, and triennial assessment frequencies from simulations performed in 2022 with two empirical rules used to determine the coastwide TCEY in non-assessment years (see IPHC-2023-MSE-01):

a. The same coastwide TCEY from the previous year until a stock assessment is available.
b. Update the coastwide TCEY proportionally to the change in the coastwide FISS O32 WPUE.

The years with an assessment show a wider range of annual change in the TCEY because estimation error from the assessment is greater than fixing the TCEY or changing the TCEY in proportion to the change in the O32 FISS WPUE (noting that a less precise FISS WPUE index would result in more variability in non-assessment years).

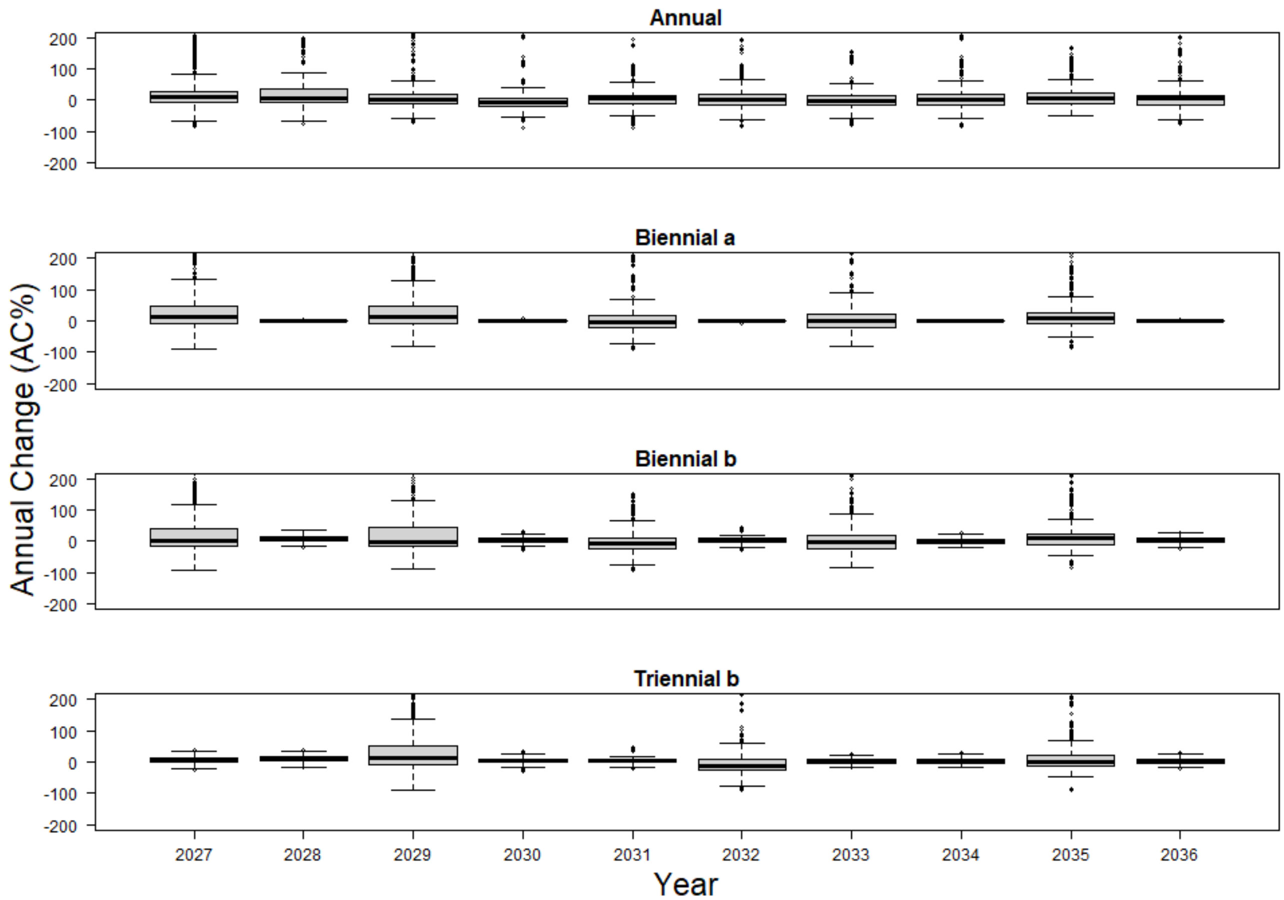

Figure 4. Boxplots of the annual change (AC) in percentage for annual, biennial, and triennial assessment frequencies. The biennial assessment frequency used a static TCEY in non-assessment years (a) and the biennial and triennial assessment frequencies use a proportional change determined from the O32 FISS WPUE (b).

Potential performance metrics to report when evaluating assessment frequency are:

- Reporting the average annual variability (AAV) calculated separately for only the years with an assessment and only the years without an assessment. This can be challenging because the same years need to be compared otherwise the performance metric is confounded with change in the population. This reduces the number of comparable years in a ten-year period, reducing the usefulness of an average.

- The percent change in the TCEY from the previous year calculated separately for assessment years and non-assessment years summarized over a 10-year period and all simulations. As with the AAV, this can be challenging to make sure that the same years are included in the calculation to avoid confounding from other factors.
- The maximum annual change observed in a ten-year period. As with other metrics, assuring that the same years are compared is essential, if separating by assessment and non-assessment years.

The biggest challenge with developing a performance metric to measure changes in assessment years is defining a statistic that is consistent across all MPs and can be summarized in a way that allows for the MPs to be evaluated against each other. With annual, biennial, and triennial MPs, the statistic is reduced to only two comparable years in a ten-year period.

It is important to consider the objective when developing performance metrics, and sometimes multiple performance metrics may be useful to the evaluation. With a well-defined measurable objective, a performance metric is easily defined. Regarding assessment frequency, one consideration is whether a stable period with an occasional larger biennial or triennial change is preferable to an annual assessment and potentially smaller changes in the TCEY. A discussion occurred at MSAB019, and the following notes and recommendation were made:

> **IPHC-2024-MSAB019-R, para. 44:** *The MSAB **NOTED** that various performance metrics were presented that may be used to evaluate interannual variability in the TCEY. These include average annual variation (AAV), annual change (AC), and maximum change. The AC may be specified as a probability of exceeding a value for any number of years, which may be useful to evaluate the assessment frequencies other than annual.*

> **IPHC-2024-MSAB019-R, para. 45:** *The MSAB **NOTED** that a performance metric indicating the duration of stability (e.g. the number of consecutive years below a threshold) may be useful to evaluate the interannual variability in the TCEY, especially across different assessment frequencies.*

> **IPHC-2024-MSAB019-R, para. 47:** *The MSAB **REQUESTED** that the Secretariat report performance metrics noted in paragraph 44 and 45 over ten (10) and fifteen (15) year periods.*

3.2 An objective related to absolute spawning biomass

The spawning biomass reference points in the conservation objective to “maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point...” and in the objective to “maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point…” use relative spawning biomass, which is the estimated female spawning biomass divided by the estimated unfished female spawning biomass (dynamic relative spawning biomass, RSB). Furthermore, unfished female spawning biomass is estimated as the unfished spawning biomass that would have occurred if there was no fishing up to the year of interest. This metric, dynamic unfished spawning biomass (or dynamic B_0) reflects the changes in the population due to natural variability in the population, and therefore RSB measures only the effects of fishing. RSB is useful for managing a fish species because it is consistent with other reference points (e.g. SPR), accounts for changes in biology, incorporates variation in recruitment, and allows for a clear determination of "overfished" without confounding stock changes with natural variability.

Pacific halibut have seen large changes in average weight-at-age and high variability in recruitment, which have changed the stock dynamics considerably. Figure 5 shows the dynamic unfished spawning biomass, the current spawning biomass, and the RSB since 1993. Dynamic unfished spawning biomass is lower than the late 1990's because weight-at-age has decreased considerably, and dynamic unfished spawning biomass has decreased in recent years because of a recent period of low recruitment. The current spawning biomass trajectory (with fishing) has been stable in recent years, resulting in an increasing RSB. Therefore, the Pacific halibut stock is likely to be above the B_{lim} (20%), B_{trigger} (30%), and B_{thresh} (36%) reference points.

However, the coastwide FISS O32 WPUE and coastwide commercial WPUE has been declining in recent years (Figure 6), causing concern about the absolute stock size and fishery catch-rates. The coastwide FISS index of O32 WPUE was at its lowest value observed in the time-series, declining by 3% from the previous year and coastwide commercial WPUE is also at its lowest value in the recent time-series, declining by 10% from the previous year (and likely more as additional logbook information is obtained). In contrast, the stock assessment for 2023 estimates current stock status (42%, Figure 5) above reference levels and a high probability of further decline in spawning biomass at the reference fishing intensity (SPR=43%). The reference coastwide TCEY of 48.9 Mlbs predicts a greater than 70% chance that the spawning biomass in any of the next three years will be less than the spawning biomass in 2023. The long-term average RSB when fishing consistently at an SPR of 43% would be near 38%.

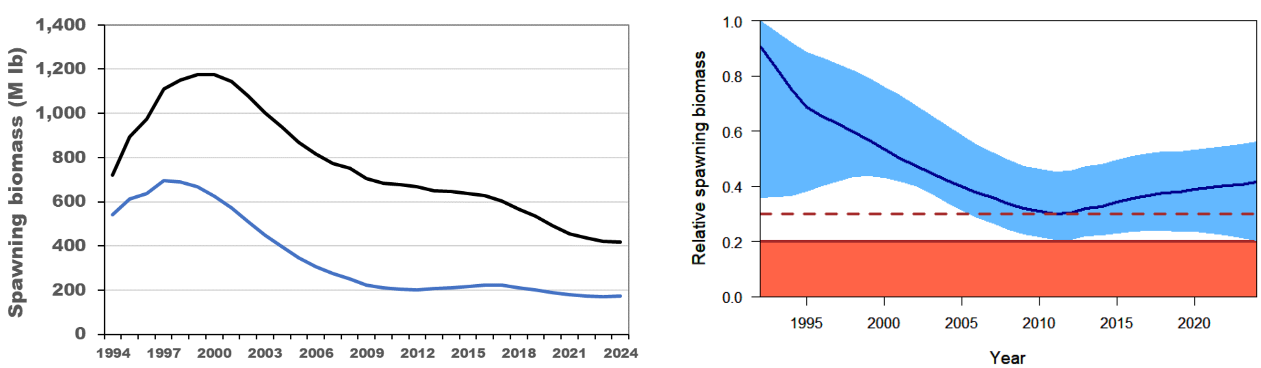

Figure 5. Dynamic unfished spawning biomass (black line) and current spawning biomass (blue line) from the 2023 stock assessment (left) and dynamic relative spawning biomass (right) with an approximate 95% credible interval in light blue and the control rule limit ($B_{20\%}$) and trigger ($B_{30\%}$) in red. Figures from IPHC-2024-SA-01.

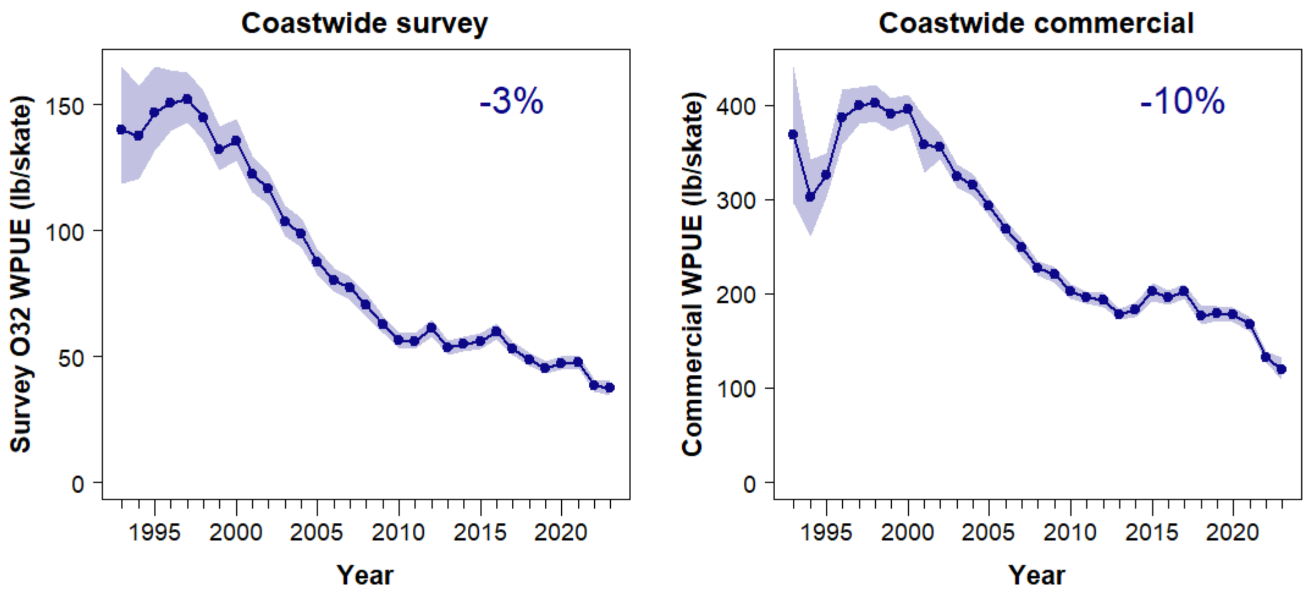

Figure 6. The coastwide FISS O32 WPUE index (left) and coastwide commercial WPUE (right) showing the percent change in the last year (from IPHC-2024-SA-02). Based on past calculations, additional logbooks collected in 2024 will likely further reduce the decline in commercial WPUE to -12%.

Recent Commission decisions (2023 and 2024) have set coastwide TCEYs less than the reference TCEY suggested by the stock assessment and current interim management strategy, noting the following.

> **IPHC-2024-AM100-R, para 38**. *The Commission **NOTED** that the estimated absolute spawning biomass is at a 35-year low and likely to remain low for several more years given recruitments currently in the water.*
>
> **IPHC-2024-AM100-R, para 56**. *The Commission **NOTED** that:*
>
> *a) the status quo coastwide TCEY of 36.97 million pounds corresponds to a 45/100 chance of stock decline over the next 1-3 years;*
>
> *b) coastwide TCEYs at or above 39.1 million pounds would have a greater than a 50% chance of stock decline over the next three years;*
>
> *c) fishing at the reference level (F43%) would equate to a coastwide TCEY of 48.9 million pounds in 2024 and have a high likelihood of stock decline over one-year (74/100) and three-years (72%).*
>
> **IPHC-2024-AM100-R, para 57**. *The Commission **NOTED** several additional risks not included in the harvest decision table:*
>
> *a) the estimated absolute spawning biomass is at a 30+-year low and likely to remain low for several more years given recruitments currently in the water;*
>
> *b) low 2023 catch-rates in the FISS and directed commercial fisheries compared to those observed over the last 30 years;*

c) Biological Region 3 is currently at the lowest observed proportion of the coastwide biomass since 1993 (the full historical range is unknown), and uncertainty associated with changes to the ecosystem and climate remains high.

IPHC-2024-AM100-R, para 59. *The Commission **NOTED** the wide uncertainty intervals around the estimated spawning biomass and that once a mortality limit is selected there is a correspondingly large amount of uncertainty in the actual fishing intensity.*

IPHC-2024-AM100-R, para 88. *The Commission **NOTED** that the adopted mortality limits for 2024 correspond to a 41% probability of stock decline through 2025, and a 41% probability of stock decline through 2027.*

IPHC-2024-AM100-R, para 89. *The Commission **NOTED** that the adopted mortality limits for 2024 correspond to a fishing intensity of F52%, equal to the estimate for 2023.*

Main concerns noted by the Commission include 1) low absolute spawning biomass, 2) low catch-rates in the commercial fishery, 3) high probability of decline in absolute spawning biomass at fishing mortality above 39 Mlbs, and 4) a large amount of uncertainty in the projections.

The continued departure from the current interim MP and reduction in coastwide TCEY suggests that there may be an additional objective. Related to these concerns, the SRB made a recommendation to re-evaluate what they called the target objective. This is objective (b): to maintain the relative spawning biomass above $B_{36\%}$.

IPHC-2023-SRB023-R, para. 25. *The SRB **RECOMMENDED** that the Commission re-evaluate the target objective for long-term coastwide female spawning stock biomass given that estimated 2023 female spawning biomass (and associated WPUE), which was well-above the current target B36%, in part triggered harvest rate reductions from the interim harvest policy. Such ad-hoc adjustments limited the value of projections and performance measures from MSE.*

A higher threshold reference point could be achieved with a lower reference fishing intensity or an alternative control rule, such as 40:20. However, instead of updating the $B_{36\%}$ relative spawning biomass objective, it may better reflect recent Commission actions to consider an absolute spawning biomass, or catch-rate, threshold in a new objective.

Clark and Hare (2006) noted that "[t]he Commission's paramount management objective is to maintain a healthy level of spawning biomass, meaning a level above the historical minimum that last occurred in the mid-1970s." Thompson (1937) stated the following.

In actual practice, capital is accumulated in order that interest may be secured from it, and an accumulated stock of fish may also be profitable.

The most obvious gain is the greater economy of effort in obtaining a catch from a larger accumulated stock. […] It not only means less effort, but also less time at sea before the catch is landed. (William F. Thompson, International Fisheries Commission, 1937)

An objective to maintain the absolute spawning biomass above a threshold may be a useful objective for several reasons. First, the level of spawning biomass likely correlates with catch-rates in the fishery, and a higher spawning biomass would likely result in a more efficient and economically viable fishery. Second, current priority conservation objectives use dynamic relative spawning biomass which may result in a low absolute spawning biomass with a satisfactory stock status. Third, a minimum absolute coastwide spawning biomass may be necessary to ensure successful reproduction (such a level is currently unknown for Pacific halibut). Lastly, an observed reference stock level may have concrete meaning to stakeholders. For example, the recent estimated spawning biomass may be near or below the lowest spawning biomass estimated since the mid-1970's and the Commission noted historically low observed fishery catch rates in 2022 and 2023.

> **IPHC-2023-AM099-R, para 56.** *The Commission* ***NOTED*** *that there are additional risks associated with the stock condition and mortality limit considerations for 2023 that are not quantitatively captured in the decision table, these include:*
>
> > *a) Historically low observed fishery catch rates corresponding to reduced efficiency/performance in 2022;*

The threshold and the tolerance for being below that threshold are not obvious choices. Clark and Hare (2006) used the estimated spawning biomass in 1974, which subsequently produced recruitment resulting in an increase in the stock biomass. However, there is a high uncertainty in the estimates of historical absolute spawning biomass before the 1990's. Recent estimates of spawning biomass may be reasonable as they are relevant to concerns of low catch-rates, but it is unknown how and if the stock will quickly recover from this current state. Setting an absolute spawning biomass to avoid low catch-rates may also *de facto* protect the stock from serious harm (i.e. avoid dropping below the current relative spawning biomass limit of 20%).

A second approach is to define an objective based on catch-rates in the fishery. If an efficient fishery is the objective, then catch-rates may be a reasonable choice for the same reasons listed above for an absolute level of spawning biomass. A subtle difference between catch-rates and spawning biomass are that catch-rates may increase or decrease due to many factors (e.g. improvements in technology, avoidance of non-target species) without a change in spawning biomass.

An alternative way to think about this is to continue the use of a limit reference point for relative spawning biomass ($SB_{20\%}$) and add a fishery biomass limit reference point for which dropping below would result in serious hardships to the fishery. The fishery biomass limit reference point could be defined using an absolute metric that could be in units of spawning biomass, fishery CPUE, FISS WPUE, or some other estimable quantity. Note that a fishery limit reference point is a different objective than a fishing intensity limit, where the former is a threshold used to maintain catch-rates and the latter is a threshold used to indicate the potential for overfishing. As mentioned above, a fishery absolute spawning biomass limit may also add extra protection for the stock by further reducing the probability of breaching existing limit and threshold reference points. A new objective related to fishery performance may be phrased as:

> Maintain the coastwide female spawning stock biomass (or FISS WPUE or fishery catch-rates) above a threshold.

The threshold may be an absolute value of spawning biomass or a defined static biomass reference point such as the spawning biomass in 2023. It is important to first decide if this is a useful general objective. If it is, then specifying a measurable objective would require defining the threshold, the term, and a tolerance. From that, a performance metric would be developed.

At MSAB019, the following notes and recommendations were made.

> **IPHC-2024-MSAB019-R, para. 48:** *The MSAB* ***NOTED*** *that the estimated stock status of Pacific halibut is above a relative spawning biomass of 36% (a priority objective of the Commission, para. 23b), but the FISS WPUE, commercial WPUE, and estimated absolute spawning biomass are at their lowest values observed in many decades.*

> **IPHC-2024-MSAB019-R, para. 49:** *The MSAB* ***NOTED*** *that a healthy stock can be defined with relative spawning biomass, absolute spawning biomass, a robust age structure, and rotund weight-at-age.*

> **IPHC-2024-MSAB019-R, para. 50:** *The MSAB* ***NOTED*** *that from MSE simulation results when fishing at the current reference FSPR=43% there is a 1 in 5 chance in the long-term and a 1 in 3 chance in the short-term that the spawning biomass will be less than that observed in 2023.*

> **IPHC-2024-MSAB019-R, para. 51:** ***NOTING*** *paragraph 48, the MSAB* ***RECOMMENDED*** *developing an objective and identifying a management procedure that addresses the current circumstances and differences in perception of the stock status.*

3.3 Spatial spawning biomass

Maintaining spatial population structure is an important objective that is currently defined in Appendix A, but is not a priority objective of the Commission. This objective uses *ad-hoc* defined percentage of spawning biomass to maintain in each Biological Region. The SRB recently made a recommendation to update this objective.

> **IPHC-2023-SRB023-R, para. 24:** *The SRB* ***RECOMMENDED*** *that an objective to maintain spatial population structure be added or redefined to maintain the spawning biomass in a Biological Region above a defined threshold relative to the dynamic unfished equilibrium spawning biomass in that Biological Region with a pre-defined tolerance. The percentage and tolerance may be defined based on historical patterns and appropriate risk levels recognizing the limited fishery control of biomass distribution.*

Recent MSE simulations showed that the percentage of spatial spawning biomass in each Biological Region is affected by the fishery and the environment (e.g. fitted PDO relationships in the OM), and each Biological Region is affected differently by these two sources. Figure 7 shows that the percentage of the spawning biomass in Regions 2 and 4B are affected by fishing and the environment, in Region 3 is mostly affected by the environment, and in Region 4 is mostly affected by fishing. The regional relative spawning biomass will be examined and reported at the 25th Session of the Scientific Review Board (SRB025).

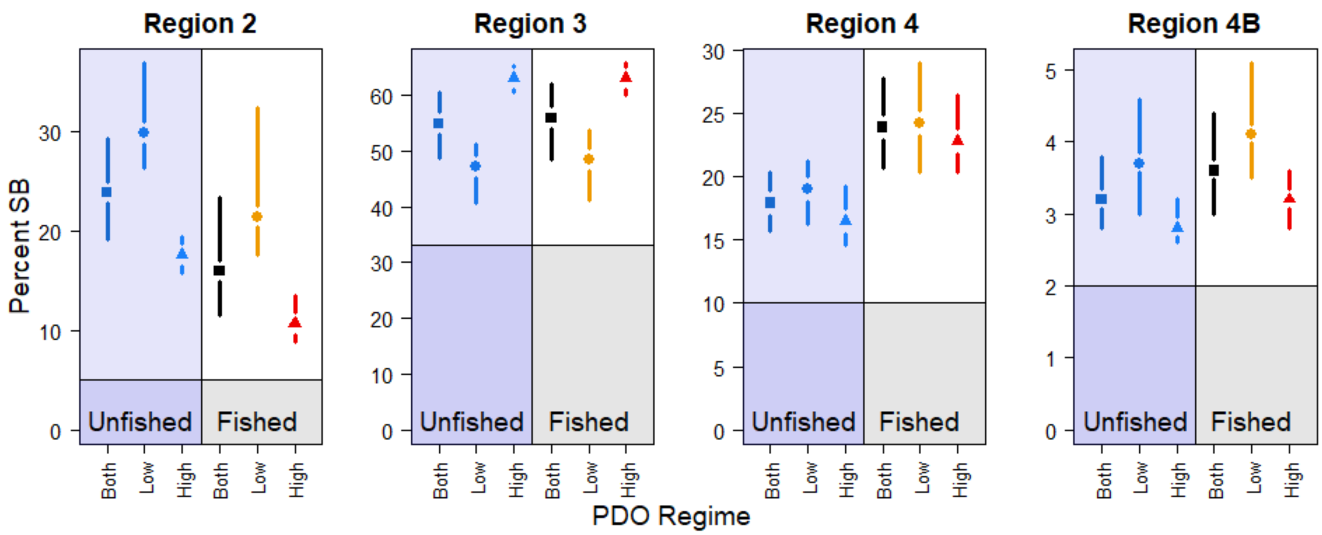

Figure 7. Percentage of spawning biomass in each Biological Region when fished with an SPR of 43% and integrated over a range of distribution procedures (no estimation error, no observation error, and no implementation error), and when not fished. The PDO is modelled with cyclical low and high periods in "Both", is persistently low in "Low", and is persistently high in "High". The darker shaded area indicates the area below the threshold in the spatial conservation objective (Appendix A).

4 Management Procedures

The SRB made a recommendation at SRB023 providing guidance on management procedures (MPs) to evaluate.

> **IPHC-2023-SRB023-R, para. 29.** *The SRB* ***RECOMMENDED*** *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.*

4.1 Assessment frequency and an empirical management procedure

The frequency of conducting the stock assessment is a priority element of the MP to be investigated. This includes conducting assessments annually (every year), biennially (every second year), or triennially (every third year) to determine the status of the Pacific halibut stock and the coastwide TCEY for that year. In years with no assessment, the coastwide TCEY would be determined using a simpler approach and the estimated status of the stock would not be available.

The mortality limits in a year with a stock assessment can be determined as specified by previous defined MPs (i.e. SPR-based approach), and in years without a stock assessment, the mortality limits would need an alternative approach. There are many different empirical rules that could be applied to determine the coastwide TCEY in non-assessment years and two have been previously identified for evaluation.

a. A multi-year TCEY set constant until a stock assessment is available.

b. Update the coastwide TCEY proportionally to the change in the coastwide FISS O32 WPUE.

Other potential methods to set the TCEY in years without an assessment include, but are not limited to, the following.

c. Update the coastwide TCEY proportionally to the change in the coastwide FISS all-sizes WPUE.

d. Use projected TCEY's from the stock assessment with the reference SPR and control rule. This method is common among other fisheries management organizations.

e. Incorporate commercial fishery catch-rates into the empirical rule.

The MSAB requested collaboration between the Secretariat and the SRB to develop empirical rule options.

> **IPHC-2024-MSAB019-R, para 40:** ***RECALLING*** *paragraph 39 item a) the MSAB* ***REQUESTED*** *the Secretariat and SRB develop empirical rule options using the following possible sources of data:*
>
> *a) A static coastwide TCEY determined from the stock assessment;*
>
> *b) FISS O32 WPUE;*
>
> *c) Incorporation of commercial and FISS age data with FISS O32 WPUE.*

Another option, currently not being considered, is to use a simpler approach to determine the coastwide TCEY that is tuned to meet the objectives. This could be an empirical approach, or a simpler statistical model. Stock assessments would be completed periodically to determine the status of the stock and verify that the management procedure is working appropriately.

4.2 Constraints

One of the priority objectives (Appendix A) is to limit annual changes in the coastwide TCEY. Due to variability in many different processes (e.g. population, estimation, and decision making) the interannual variability of the TCEY from MSE simulations is typically higher than 15%. Over the past ten years (2015–2024), the interannual variability (average annual variability or AAV) in the adopted coastwide TCEY was 5.4% and the AAV of the reference coastwide TCEY was 14.5%. The percent change in the adopted coastwide TCEY ranged from -10% to 8% across years and ranged from -21% to 29% for the coastwide reference TCEY across years (Table 1).

Decision-making since 2015 has reduced the interannual variability in the coastwide TCEY, compared to the reference, over the last ten years. The adopted TCEYs have a smaller range than the reference TCEYs and tend to cluster around 39 million pounds (Figure 8). The adopted TCEYs also tend to be closer to the status quo (i.e. the TCEY from the previous year) than the reference TCEYs when the reference TCEY difference from status quo was not near zero (Table 1 & Figure 8). This is akin to saying the change from one year to the next is less for the adopted TCEYs than the reference TCEYs. The spawning biomass has been relatively stable during the last ten years, and it is not known how the recent decision-making process would react to a rapidly increasing or decreasing spawning biomass.

This interannual variability in the coastwide reference TCEY can be reduced by adding a constraint in the MP, mimicking the recent decision-making process. The MSAB has suggested many different constraints including a 15% constraint on the change in the coastwide TCEY from one year to the next, and a slow-up/fast-down approach (TCEY increases by one-third of the increase suggested by the unconstrained MP or decreases by one-half of the decrease suggested by the unconstrained MP). The MSAB has requested further investigating constraints on the coastwide TCEY (Appendix B).

Table 1. Percent change in the adopted TCEY from the previous year (2015–2024) for each IPHC Regulatory Area and coastwide, and for the coastwide reference TCEY determined from the interim management procedure in place for that year.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Coastwide Adopted	Coastwide Reference
2015	-4.5%	3.5%	13.3%	7.9%	-0.3%	25.6%	2.7%	19.3%	8.1%	6.0%
2016	18.9%	4.2%	5.5%	-1.9%	-8.3%	-0.5%	-10.5%	-4.7%	-0.1%	2.3%
2017	16.7%	1.0%	7.6%	1.6%	16.7%	-7.7%	-2.2%	-5.7%	2.9%	7.7%
2018	-10.2%	-14.7%	-9.9%	-3.2%	-17.8%	-3.3%	-4.5%	-5.7%	-8.7%	-20.7%
2019	25.0%	-3.8%	0.0%	7.7%	-11.3%	11.5%	13.3%	10.5%	3.8%	29.0%
2020	0.0%	0.0%	-7.7%	-9.6%	7.6%	-9.8%	-9.7%	-2.5%	-5.2%	-20.3%
2021	0.0%	2.5%	-0.9%	14.8%	0.0%	17.1%	6.9%	2.1%	6.6%	22.3%
2022	0.0%	8.0%	1.9%	3.9%	25.0%	2.4%	3.6%	3.0%	5.7%	5.7%
2023	0.0%	-10.3%	-1.0%	-17.0%	-5.9%	-17.6%	-6.2%	-6.1%	-10.3%	26.0%
2024	0.0%	-4.6%	-1.0%	-6.0%	-6.0%	-6.9%	-8.1%	-3.9%	-4.6%	-5.9%

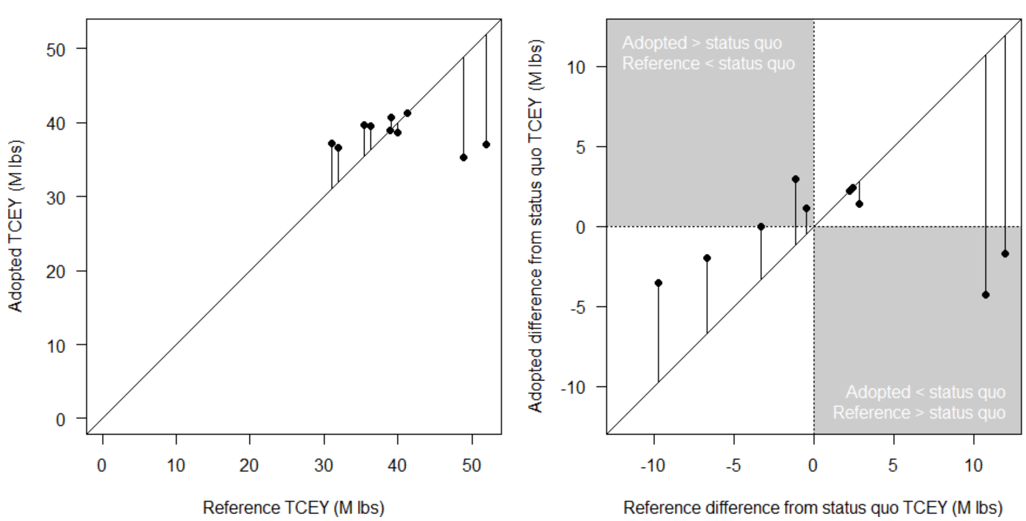

Figure 8. The adopted TCEY vs the reference TCEY (left) and the adopted difference from the status quo TCEY vs the reference difference from the status quo TCEY (right) for the last ten years (2015–2024). The 1:1 line shows when the two are equal. The grey quadrants in the right plot show when the adopted and reference TCEY differences from the status quo are opposite.

Past considerations of constraints included the following:

- A maximum 15% change in the coastwide TCEY in either direction from one year to the next.
- A slow-up/fast-down approach where the TCEY increases by one-third of the increase suggested by the unconstrained MP or decreases by one-half of the decrease suggested by the unconstrained MP.
- A multi-year TCEY set constant for a specified number of years.
- An additional component to any constraint specifying to not exceed a maximum fishing intensity consistent with an SPR of 35% (the approximate SPR_{MSY}; see IPHC-2019-SRB015-11 Rev_1).

The specifications of these constraints can easily be tested and tuned to best meet conservation and fishery objectives.

4.3 Fishing intensity

The fishing intensity is determined by finding the fishing rate (F) that would result in a defined spawning potential ratio (F_{SPR}). Because the fishing rate changes depending on the stock demographics and distribution of yield across fisheries, SPR is a better indicator of fishing intensity and its effect on the stock than a single F. A range of SPR values between at least 35% and 52% (interim reference SPR is currently 43%) will be investigated.

Some results of the evaluation of SPR values were presented in IPHC-2024-MSAB019-06. However, it should be standard to test a range of SPR values when modifying other elements of the MP. For example, a constraint may have significant effects on the performance metrics, which may be mitigated with different SPR values, if desired. The results in IPHC-2024-MSAB019-06 may provide a guide for the range of SPR values to include in future evaluations.

4.4 Distribution of the TCEY

The distribution of the TCEY to IPHC Regulatory Areas is a necessary part of the harvest strategy, but is not a part of the management procedure currently being evaluated. Therefore, distribution of the TCEY is a source of uncertainty. There are many options to include distribution of the TCEY in the MSE simulations. In the past, five distribution procedures spanning a range including recent Commission decisions were integrated into the simulations.

An alternative approach is to use the observed distribution of the TCEY in recent years to define distributions of the potential TCEY or percentage of TCEY in each IPHC Regulatory Area. This approach allows progress to be made in evaluating other components of the harvest strategy pending a formal agreement on a distribution procedure, but still includes some uncertainty during testing. Different methods may be applicable for different IPHC Regulatory Areas based on the recent history of management decisions.

For the last six years, the TCEY in IPHC Regulatory Area 2A has been 1.65 M lbs (Table 2). Over the last twelve years, the adopted TCEY in IPHC Regulatory Area 2B has ranged from 17.1% to 20.8% of the coastwide TCEY with the three most recent years equal to 18.3% and no relationship with the coastwide TCEY (Table 3 and Figure 9). The distribution of the TCEY to

IPHC Regulatory Areas 2A and 2B could simply assume 1.65 Mlbs for 2A and randomly draw a percentage from a distribution of percentages ranging from 17% to 21% for 2B with the mode of the distribution at 18.3% (Figure 10).

The TCEY in IPHC Regulatory Areas in Alaska could be distributed after the TCEY has been distributed to IPHC Regulatory Areas 2A and 2B. Observed percentages using only Alaskan areas are shown in Table 4. Using the average of these recent observations, a multinomial distribution could be used to randomly draw percentages for each Alaskan IPHC Regulatory Area, as shown in Figure 11.

Table 2. Adopted TCEYs (millions of pounds) for each IPHC Regulatory Area from 2013 to 2024.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
2013	1.11	7.78	5.02	17.07	5.87	2.43	1.93	4.28	45.48
2014	1.11	7.64	5.47	12.05	3.73	1.56	1.49	3.58	36.65
2015	1.06	7.91	6.2	13.00	3.72	1.96	1.53	4.27	39.63
2016	1.26	8.24	6.54	12.75	3.41	1.95	1.37	4.07	39.59
2017	1.47	8.32	7.04	12.96	3.98	1.80	1.34	3.84	40.74
2018	1.32	7.10	6.34	12.54	3.27	1.74	1.28	3.62	37.21
2019	1.65	6.83	6.34	13.5	2.90	1.94	1.45	4.00	38.61
2020	1.65	6.83	5.85	12.2	3.12	1.75	1.31	3.9	36.60
2021	1.65	7.00	5.80	14.00	3.12	2.05	1.40	3.98	39.00
2022	1.65	7.56	5.91	14.55	3.90	2.10	1.45	4.10	41.22
2023	1.65	6.78	5.85	12.08	3.67	1.73	1.36	3.85	36.97
2024	1.65	6.47	5.79	11.36	3.45	1.61	1.25	3.7	35.28

Table 3. Adopted percentage of the coastwide TCEY (millions of pounds) for each IPHC Regulatory Area from 2013 to 2024.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE
2013	2.4%	17.1%	11.0%	37.5%	12.9%	5.3%	4.2%	9.4%
2014	3.0%	20.8%	14.9%	32.9%	10.2%	4.3%	4.1%	9.8%
2015	2.7%	20.0%	15.6%	32.8%	9.4%	4.9%	3.9%	10.8%
2016	3.2%	20.8%	16.5%	32.2%	8.6%	4.9%	3.5%	10.3%
2017	3.6%	20.4%	17.3%	31.8%	9.8%	4.4%	3.3%	9.4%
2018	3.5%	19.1%	17.0%	33.7%	8.8%	4.7%	3.4%	9.7%
2019	4.3%	17.7%	16.4%	35.0%	7.5%	5.0%	3.8%	10.4%
2020	4.5%	18.7%	16.0%	33.3%	8.5%	4.8%	3.6%	10.7%
2021	4.2%	17.9%	14.9%	35.9%	8.0%	5.3%	3.6%	10.2%
2022	4.0%	18.3%	14.3%	35.3%	9.5%	5.1%	3.5%	9.9%
2023	4.5%	18.3%	15.8%	32.7%	9.9%	4.7%	3.7%	10.4%
2024	4.7%	18.3%	16.4%	32.2%	9.8%	4.6%	3.5%	10.5%

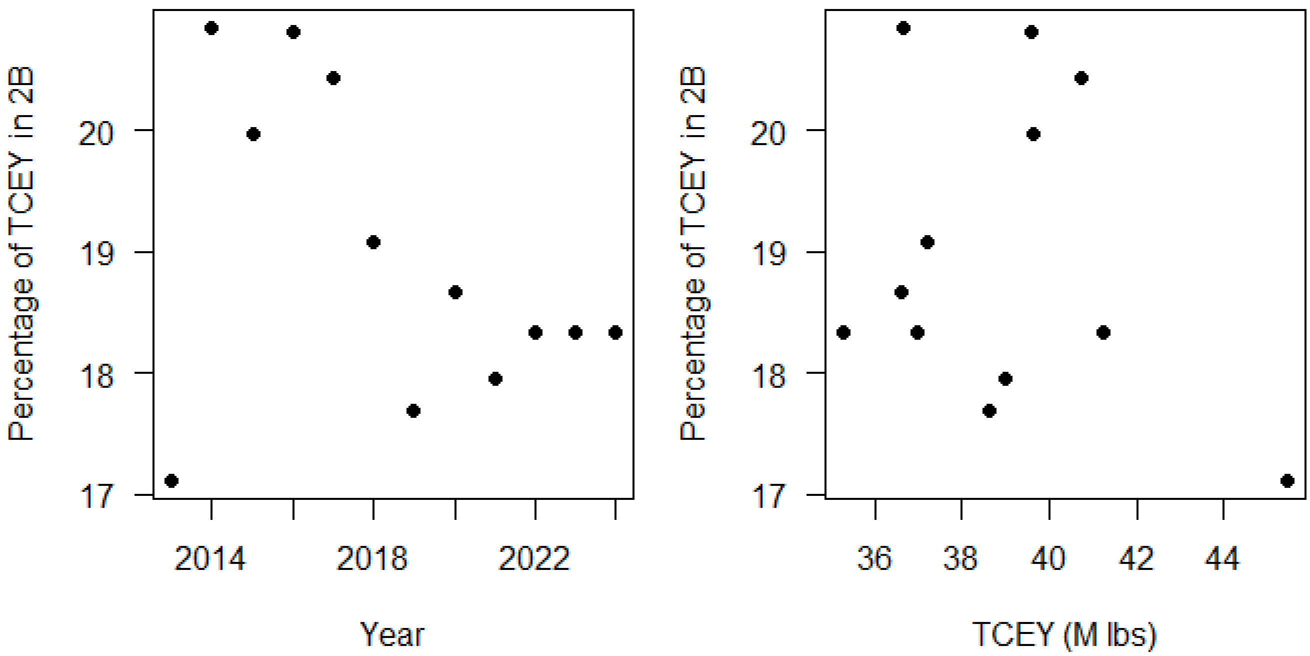

Figure 9. The percentage of the coastwide TCEY in IPHC Regulatory Area 2B plotted against year (left) and the coastwide TCEY (right).

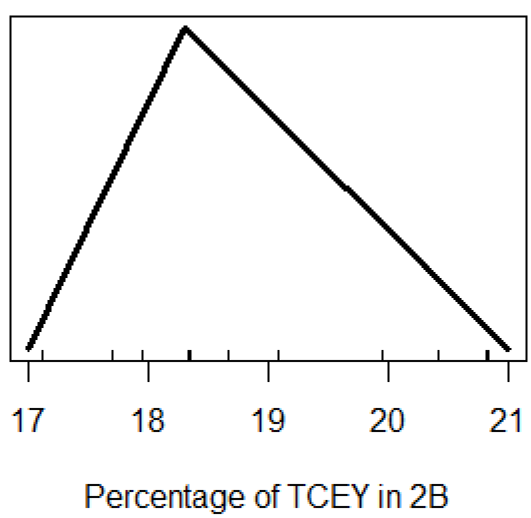

Figure 10. A triangle distribution ranging from 17% to 21% potentially to be used to randomly draw the percentage of the coastwide TCEY in 2B in MSE simulations. The ticks above the axis on the bottom show observed percentages from the past twelve years.

Table 4. Percentage of the adopted TCEY for Alaskan IPHC Regulatory Areas only in each Alaskan IPHC Regulatory Area. IPHC Regulatory Areas 2A and 2B are omitted.

Year	2C	3A	3B	4A	4B	4CDE
2013	13.7%	46.6%	16.0%	6.6%	5.3%	11.7%
2014	19.6%	43.2%	13.4%	5.6%	5.3%	12.8%
2015	20.2%	42.4%	12.1%	6.4%	5.0%	13.9%
2016	21.7%	42.4%	11.3%	6.5%	4.6%	13.5%
2017	22.7%	41.9%	12.9%	5.8%	4.3%	12.4%
2018	22.0%	43.6%	11.4%	6.0%	4.4%	12.6%
2019	21.0%	44.8%	9.6%	6.4%	4.8%	13.3%
2020	20.8%	43.4%	11.1%	6.2%	4.7%	13.9%
2021	19.1%	46.1%	10.3%	6.8%	4.6%	13.1%
2022	18.5%	45.5%	12.2%	6.6%	4.5%	12.8%
2023	20.5%	42.3%	12.9%	6.1%	4.8%	13.5%
2024	21.3%	41.8%	12.7%	5.9%	4.6%	13.6%

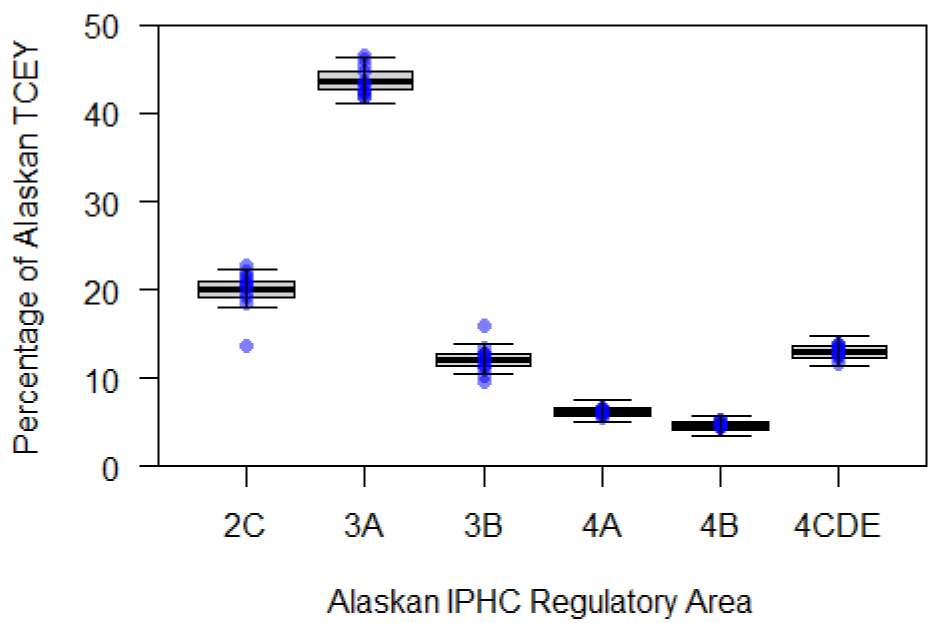

Figure 11. Observed percentage of the TCEY in Alaskan IPHC Regulatory Areas from 2013–2024 (blue points) and simulated percentage of the TCEY in Alaskan IPHC Regulatory Areas showing the median (thick black horizontal line), the central 50% (black box), and the 5th and 95th percentiles of the simulated distribution (black lines).

4.5 Additional MPs to evaluate

There are an endless number of MPs that could be evaluated with the MSE framework. Some potential MPs of interest include evaluating different triggers in the control rule (currently 30%) resulting in reductions in fishing intensity, an element related to maintaining the absolute spawning biomass above a threshold, and specific procedures for distribution of the TCEY to IPHC Regulatory Areas.

An MP to maintain the absolute spawning biomass above a threshold could be similar to the control rule currently used for stock status. A ramp could reduce the fishing intensity when the absolute spawning biomass (or catch-rates) fall below a specified threshold. Alternatively, a reduced reference fishing intensity could be used to avoid low stock sizes and be tuned to meet current Commission objectives, including the potential objective to avoid low absolute spawning biomass or catch-rates.

The distribution of the TCEY to IPHC Regulatory Areas is not a part of the MP in the harvest strategy, but it is a required output of the harvest strategy. Investigating methods to produce a reference TCEY distribution to inform the decision-making process may be useful to assist the Commission. This could be one part of the products presented at the Annual Meeting.

5 OTHER ANALYSES

The MSE framework is a generalized framework that can be used to evaluate any part of the harvest strategy. A management procedure includes how data are collected and analysed, how those data are synthesized in an estimation model (e.g. stock assessment), and the rules that determine how the TCEY is calculated. Any of these elements can be evaluated using the MSE framework.

Additionally, assumptions in the operating model can be tested as scenarios to indicate the effect on management outcomes and the robustness of a management procedure. Assumptions about the biology and life-history of Pacific halibut can be changed, such as the effect of the environment, or assumptions about how the fisheries operate (e.g., selectivity) can be modified. These are elements that are not under the control of the Commission, but instead are a source of uncertainty that is important to incorporate.

5.1 FISS Designs

An element of the management procedure that can be evaluated is the collection of data from the FISS. The FISS design was reduced in 2022, 2023, and 2024 to maintain revenue neutrality and future reductions may be necessary. The Commission is interested in understanding how FISS designs may affect management outcomes, as noted in the report from the 99th Interim Meeting (IM099).

> **IPHC-2023-IM099-R, para. 38:** *The Commission **NOTED** that:*
>
> a) *to understand how reductions in the FISS design may affect management outcomes, the evaluation of FISS design scenarios using the MSE framework was recommended by the SRB at SRB023;* [see IPHC-2023-SRB023-R paragraphs 29 and 64].

There were many recommendations and requests from SRB023 related to the investigation of FISS design scenarios.

> **IPHC-2023-SRB023-R ,para. 26:** *The SRB* ***RECOMMENDED*** *continued examination, within the MSE, of FISS scenarios that are better representative of the levels of uncertainty and bias that may result from future reductions in FISS sampling.*
>
> **IPHC-2023-SRB023-R, para. 29.** *The SRB* ***RECOMMENDED*** *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.*
>
> **IPHC-2023-SRB023-R, para. 57:** *The SRB* ***REQUESTED*** *that the Commission NOTE the addition of cost estimates to the presentation of alternative FISS designs. The short-term risk implications in 2024 to the stock and TCEY of a drastically reduced FISS design (e.g. approx. revenue neutral Design 9 with efficiencies) are probably not profound given that the estimated current abundance is still above the implied B36% target. Impacts may appear more in the estimates of stock distribution since unsampled areas will be more dependent on the space-time model than actual data.*
>
> **IPHC-2023-SRB023-R ,para. 59:** *The SRB* ***RECOMMENDED*** *that the Secretariat continue exploring ways of estimating the impacts of different FISS designs and efficiency decisions on stock assessment outputs and fishery performance objectives. The end goal should be to provide a decision support tool that can frame decisions about FISS design in terms of costs and benefits in comparable currencies.*
>
> **IPHC-2023-SRB023-R, para. 60:** *The SRB* ***REQUESTED*** *that the Commission NOTE that some longer-term (2025 and beyond) implications of reduced FISS designs are predictable and potentially consequential. For instance, higher FISS CVs will generally result in higher inter-annual variation in TCEY under the current decision-making process. This would occur for two reasons: (1) biomass estimates and projections from the assessment model will have greater uncertainty and therefore greater variability in outputs and (2) ad hoc management adjustments to the interim harvest policy recommendations would be more frequent and/or more variable for greater input uncertainty. The SRB therefore REQUESTED the following analyses for SRB024: a) Assessment of reduced FISS designs (2025-2027) via simulation tests of assessment model outputs (e.g. probability of decline, estimated stock abundance and status, TCEY) under alternative revenue-neutral FISS designs using the existing stock assessment ensemble; b) Mitigation options of reduced FISS designs (short-term and long-term) via MSE simulations of management procedures that deliberately aim to reduce inter-annual variability in TCEY via multi-year TCEYs and (possibly) fixed stock distribution schemes; c)*

Components (a,b) above would be integrated since (a) will need to inform simulations in (b).

IPHC-2023-SRB023-R, para. 61: *The SRB* ***REQUESTED*** *that simulations above (para. 60) include: a) a relationship in which the FISS CV is relatively higher at lower stock abundance (i.e. the current CV issue is a function of stock abundance rather than a short-term condition); b) target regulatory area CVs of 15%, 20%, 25%, and 30%; c) coastwide target CV of 15% without controlling specific regulatory area CVs.*

IPHC-2023-SRB023-R, para. 64: ***NOTING*** *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 similarly requested above in paras. 62 and 63) because of occasional (or functional) 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.*

The MSE framework is capable of examining FISS designs, given the necessary inputs. Changes to the FISS design affect the estimation uncertainty (i.e. stock assessment) and possibly some management inputs, such as stock distribution. Outcomes from simulations investigating the outcomes of the stock assessment given different FISS design assumptions (see IPHC-2024-SRB024-08) will be used as inputs to the MSE simulations, following the recommendation in paragraph 60 from SRB023. Three (3) FISS trends and three (3) FISS designs will be tested, as is being done with the stock assessment (IPHC-2024-SRB024-08).

Table 5. Design matrix for proposed simulations of FISS design effects on the stock assessment to inform MSE simulation to investigate FISS design effects on management outcomes (reproduced from IPHC-2024-SRB024-08).

'True' FISS trend	Estimation model	Inference
No trend	No trend, base block design, 3 years No trend, core design, 1 & 3 years No trend, educed core, 1 & 3 years	Effect of increased CV due to reduced designs
+15% over 3 years	+15%, base block design, 3 years No trend, core design, 3 years No trend, reduced core, 3 years	Effect of failing to identify an increasing trend
-15% over 3 years	-15%, base block design, 3 years No trend, core design, 3 years No trend, reduced core, 3 years	Effect of failing to identify a decreasing trend

As mentioned in IPHC-2024-SRB024-08, the MSE analysis of FISS designs will not capture the stakeholder perception and possible lack of confidence in the FISS as a tool for management. FISS observations have been important for the stock assessment, distribution of the TCEY, general understanding of the trends in each IPHC Regulatory Area, and in negotiations of the coastwide and area-specific TCEYs.

5.2 Depensation Stress Test

Depensation occurs if the per-capita rate of growth decreases as the density or abundance decreases to low levels (Liermann and Hilborn 2001). In other words, it is inverse density dependence at low population sizes and is also referred to as the Allee effect (Dennis 2002). The Beverton-Holt stock-recruit curve in Figure 12 shows the recruits vs. spawners and recruits-per-spawner vs spawners without and with depensation. The inverse density dependence can be seen at low population sizes with depensation.

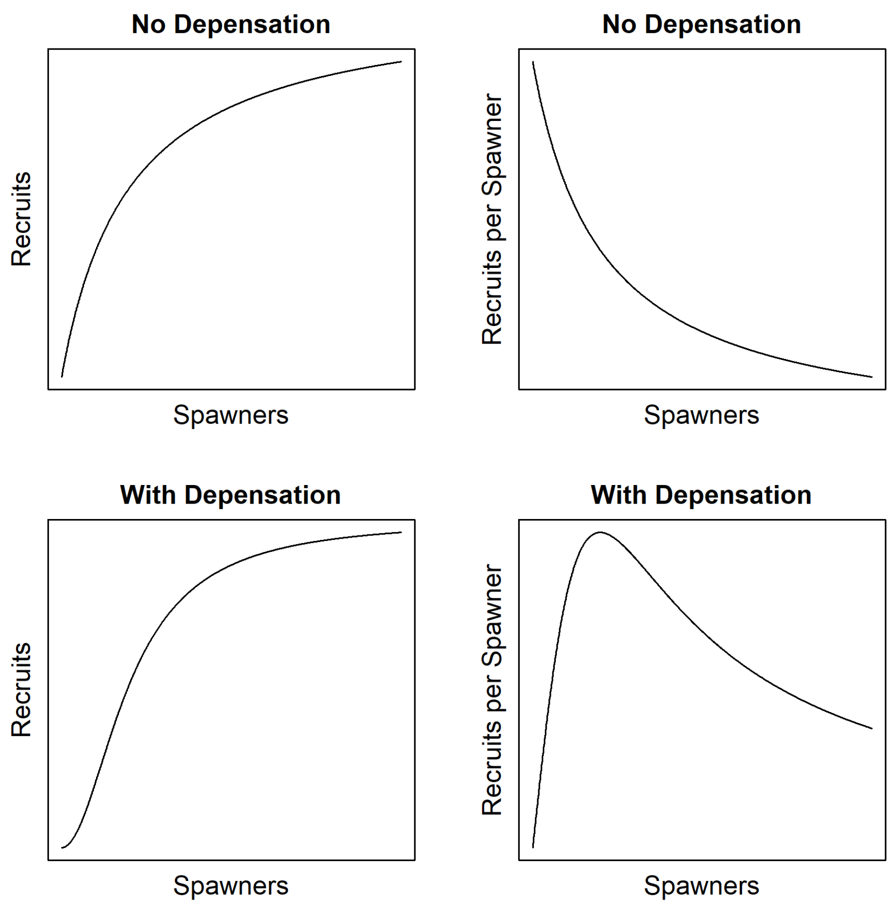

Figure 12. Theoretical Beverton-Holt stock-recruit curves (recruits vs spawners) without and with depensation (left) and for recruits-per-spawner vs spawners (right).

There are many mechanisms that may result in depensation (Liermann and Hilborn 2001), such as increased adult mortality observed in Northwest Atlantic cod (*Gadus morhua*) stocks (Kuparinen and Hutchings 2014). Table 6 lists some mechanisms for depensation and whether they are likely to result in depensation in the Pacific halibut stock.

Table 6. Mechanisms for depensation and if it is likely for the Pacific halibut population.

Mechanism	**For Pacific halibut**
Environmental effects (poor/good recruitment regimes)	**Possible** given the effect of the environment on life-history characteristics
Predator/prey interactions and increase in M	**Probably not likely** given that Pacific halibut are a generalist and have a wide range. Similar predators (e.g. arrowtooth flounder) may have some effect if the Pacific halibut population is low.
Reduced probability of fertilization	**Probably not likely** until very low population size given that the life-history of Pacific halibut is to migrate to spawning areas.
Impaired group dynamics	**Probably not likely** given that Pacific halibut are capable of making long feeding and spawning migrations.

The SRB recommended examining the effects of possible depensation in the Pacific halibut stock using the MSE framework.

> **IPHC-2023-SRB023-R**, ***para. 45:*** *The SRB* ***RECOMMENDED*** *that the compensatory assumption of the stock recruitment models be critically evaluated via a MSE stress test scenario in which recruitment is depensatory at some low spawning biomass.*

The ensemble stock assessment uses four models, of which two use a short time-series starting in 1992. These three decades of data span mostly high PDO years, making it difficult to examine the spawner-recruit relationships in different environmental regimes. Therefore, we examine estimates of recruitment and spawning biomass from only the two long models. The estimated spawning biomass is different historically with the long coastwide (long CW) model estimating lower spawning biomass than the long areas-as-fleets (long AAF) model (Figure 13). This is largely due to the uncertainty in spatial dynamics due to poor data from much of the geographical range in the historical period and has been explored in the stock assessment. Plots of estimated recruits-per-spawner vs spawning biomass do not show depensation, but there are no data at low spawning biomass levels. Separating this relationship by PDO regime does not show depensation for one particular PDO regime.

The spawning biomass of Pacific halibut is currently at low values and may be at the lowest values observed historically. However, stock status remains above 30% (see section 3.2) and the spawning biomass of Pacific halibut has likely remained above levels where depensation can be detected, if present. Therefore, parameterizing depensation in the MSE simulations will be theoretical to conduct a “stress-test” and show the potential effects if present.

We propose to conduct at least six (6) simulations using the MSE framework to examine the effects of depensation. These are a “No Depensation” assumption and a “Depensation” assumption crossed with three levels of fishing intensity (low, current reference, and high). The level of depensation is yet to be determined, but alternative values may be examined until an effect is seen. The low fishing intensity will be 52%, corresponding to recent adopted TCEYs. The reference fishing intensity is SPR=43% and a high fishing intensity will be the fishing intensity associated with the proxy MSY (SPR=35%). Higher fishing intensities and removing the 30:20 control rule may be implemented to force low spawning biomasses and induce an effect of depensation. However, high fishing intensities that would result in depensation are unlikely to be realized in the management of Pacific halibut (see Section 3.2).

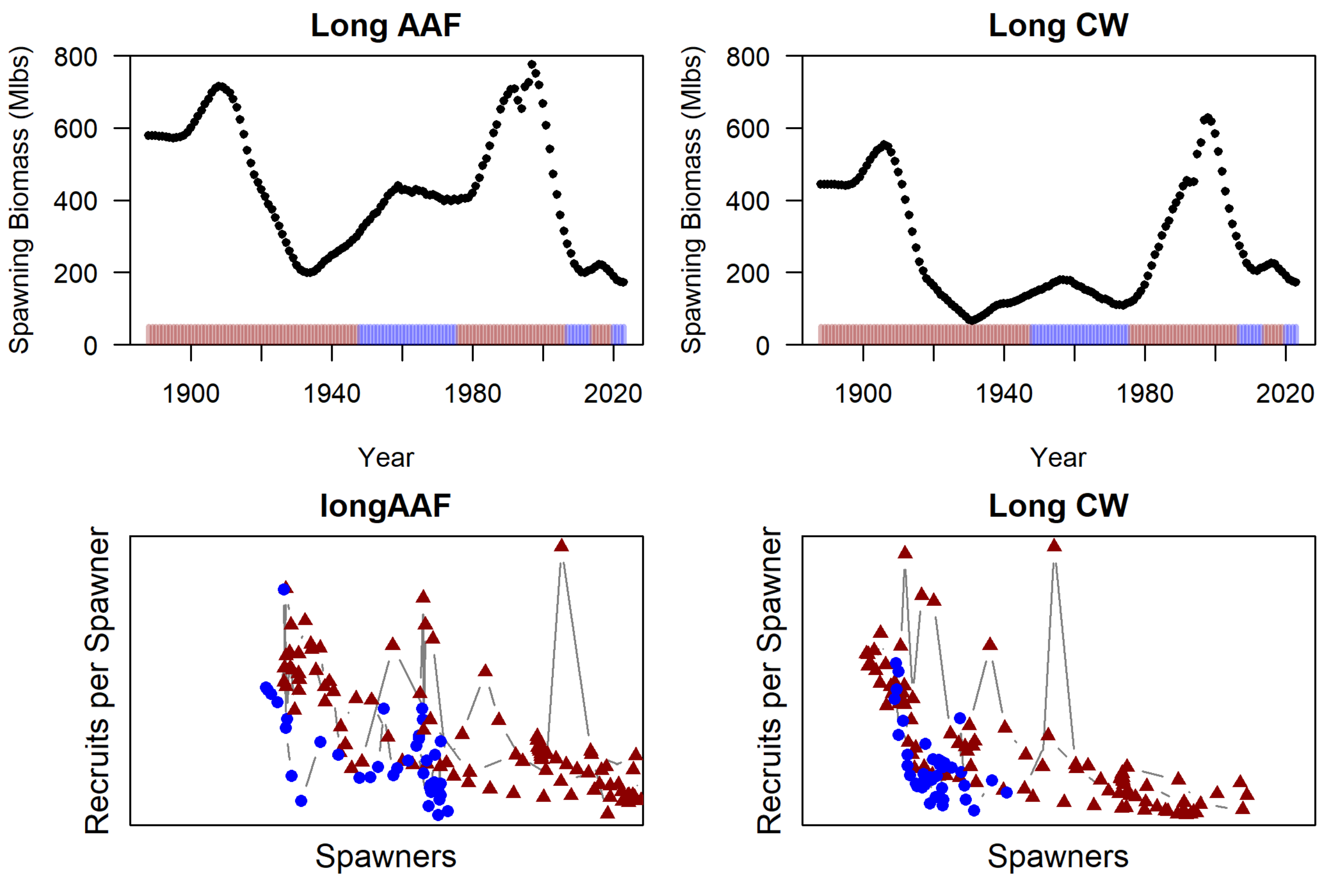

Figure 13. Estimated spawning biomass time-series for the two stock assessment long models (top) with low (blue) or high (red) PDO indices shown, and recruits-per-spawner plotted against spawning biomass (bottom) for the two stock assessment long models (top) with low PDO (blue) or high PDO (red) years.

RECOMMENDATION/S

That the SRB:

1) **NOTE** paper IPHC-2024-SRB024-07 presenting recent MSE work including exceptional circumstances, goals and objectives, management procedures, and additional analyses.
2) **REQUEST** any additional exceptional circumstances using fishery-dependent data.
3) **REQUEST** adding a measurable objective related to absolute spawning biomass under the general objective 2.1 "maintain spawning biomass at or above a level that optimizes fishing activities" to be included in the priority Commission objectives after, or in place of, the current biomass threshold objective.
4) **REQUEST** empirical rules to simulate with biennial and triennial assessment frequencies.
5) **REQUEST** examining alternative methods to simulate the uncertainty in the distribution of the TCEY.
6) **REQUEST** modifications to the proposed FISS design simulations and guidance on conducting them with the MSE framework.
7) **REQUEST** modifications to the proposed simulations investigating depensation.
8) **REQUEST** any further analyses to be provided at SRB025.

REFERENCES

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APPENDICES

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

Appendix B: Recommendations and requests from the 19th Session of the Management Strategy Advisory Board (MSAB019)

Appendix A
Primary objectives used by the Commission for the MSE

Table A1. 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	$P(B < B_{Lim})$ PASS/FAIL 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	$P(B < B_{Thresh})$ 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

$$AAV_t = \frac{\sum_{t+1}^{t+9} |TCEY_t - TCEY_{t-1}|}{\sum_t^{t+9} TCEY_t}$$

$$AC_t = \frac{|TCEY_t - TCEY_{t-1}|}{TCEY_{t-1}}$$

APPENDIX B
RECOMMENDATIONS AND REQUESTS FROM 19TH SESSION OF THE MANAGEMENT STRATEGY ADVISORY BOARD (MSAB019)

IPHC-2024-MSAB019-R, para 32: The MSAB **REQUESTED** that outreach materials be developed by the Secretariat that synthesize the effect of the PDO (e.g. via recruitment) on the coastwide and regional stock dynamics and the relative effect of fishing in simple terms with interpretation and consequences of the outcomes. This may be a pamphlet or a short document to be reviewed via email by MSAB members before the 100th Session of the IPHC Interim Meeting (IM100).

IPHC-2024-MSAB019-R, para 39: The MSAB **REQUESTED** that the evaluation of annual, biennial, and triennial assessments include, but is not limited to, the following concepts.

a) Annual changes in the coastwide TCEY is driven by an empirical rule 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 every year or only assessment years. This may be a 10%, 15%, or 20% constraint, a slow-up fast-down approach, or similar approach;

c) SPR values ranging from 35% to 52%.

IPHC-2024-MSAB019-R, para 40: **RECALLING** paragraph 39 item a) the MSAB **REQUESTED** the Secretariat and SRB develop empirical rule options using the following possible sources of data:

a) A static coastwide TCEY determined from the stock assessment;

b) FISS O32 WPUE;

c) Incorporation of commercial and FISS age data with FISS O32 WPUE.

IPHC-2024-MSAB019-R, para 42: The MSAB **REQUESTED** that the Commission provide guidance on whether and how to incorporate distribution in the MSE simulations. Three potential options are:

a) Integrating over multiple distribution procedures;

b) Use a single distribution procedure and add uncertainty;

c) Use recent years to define percentage of TCEY in each IPHC Regulatory Area and add uncertainty.

IPHC-2024-MSAB019-R, para 47: The MSAB **REQUESTED** that the Secretariat report performance metrics noted in paragraph 44 and 45 over ten (10) and fifteen (15) year periods.

IPHC-2024-MSAB019-R, para 51: NOTING paragraph 48, the MSAB **RECOMMENDED** developing an objective and identifying a management procedure that addresses the current circumstances and differences in perception of the stock status.

IPHC-2024-MSAB019-R, para 52: The MSAB **RECOMMENDED** adopting the following exceptional circumstances:

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 for two or more consecutive 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.

IPHC-2024-MSAB019-R, para 54: The MSAB **REQUESTED** that the SRB and Secretariat work together to consider different ways to incorporate fishery-dependent data into an exceptional circumstance.

IPHC-2024-MSAB019-R, para 55: The MSAB **RECOMMENDED** adopting the follow actions if an exceptional circumstance occurs:

a) 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 a possibly updated OM.

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 reexamination of the MSE.

c) Further consult with the SRB and MSAB after simulations are complete to identify whether a new MP is appropriate.

IPHC-2024-MSAB019-R, para 56: The MSAB **REQUESTED** that the Secretariat assist with hosting an ad-hoc working group (in accordance with the MSAB Terms of Reference and Rules of Procedure (Appendix V, Sect. V, para 10), in 2024 to discuss potential management procedures that include adjusting fishing intensity at low spawning biomass, low FISS WPUE, low commercial fishery catch-rates, or low productivity.

IPHC-2024-MSAB019-R, para 57: The MSAB **RECOMMENDED** a one- to two-day hybrid MSAB meeting in the fall of 2024, prior to the 100th Session of the IPHC Interim Meeting (IM100), to discuss results from the ad-hoc working group (para. 56) and review any simulation designs and results.