Considerations for the Management Strategy Evaluation Program of Work for 2023–2025

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PURPOSE

To provide the Management Strategy Advisory Board (MSAB) with potential topics to consider adding to an MSE program of work in 2024.

1 BACKGROUND

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 IPHC 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.

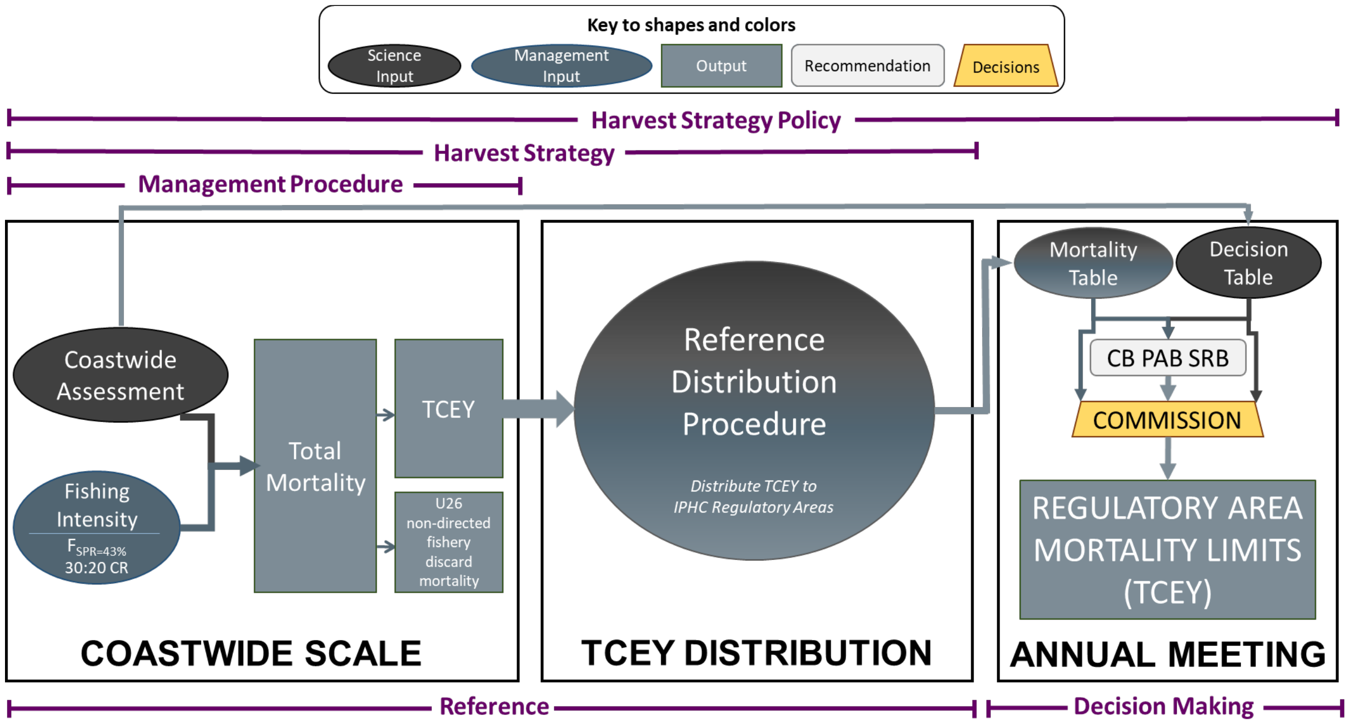

Figure 1. Illustration of the interim harvest strategy policy for the IPHC showing the coastwide scale (management procedure), the TCEY distribution (part of the harvest strategy), and the policy component that mainly occurs at the Annual Meeting.

3 Management Procedures

The MSAB018 made a request to investigate various elements of management procedures related to coastwide scale and distribution of the TCEY.

> **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.*

An evaluation of SPR values (i.e. fishing intensity) was presented in IPHC-2024-MSAB019-06, but further evaluation of fishing intensities would be useful when evaluating other elements of the MP.

3.1 Assessment frequency and an empirical management procedure

The frequency of conducting the stock assessment is a priority element of the MP to be investigated (see IPHC-2023-MSAB018-R, para. 29 above). 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. This may be as simple as setting a constant multi-year TCEY until the next assessment was completed or using empirical observations (e.g. Fishery-Independent Setline Survey (FISS) modelled output) to adjust the coastwide TCEY in non-assessment years. 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.

3.2 Constraints

One of the priority objectives (Appendix A) is to limit annual changes in the coastwide TCEY, and adding a constraint on the change in the TCEY from year to year is a way to ensure that the annual changes in the TCEY are limited. However, this often results in a trade-off with yield (i.e. a lower TCEY on average). Document IPHC-2024-MSAB019-06 presents an analysis of the variability in past TCEYs and the reduction in interannual variability as a result of the decisions of the Commission. MSE simulations can be used to examine the short- and long-term outcomes of applying a consistent constraint in the interannual change in the TCEY.

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 specifying to not exceed a maximum fishing intensity consistent with an SPR of 36%.

The specifications of these constraints can easily be adjusted and tested. The maximum $F_{SPR=36\%}$ could be an added component of a constraint to ensure that the fishing intensity does not exceed the fishing intensity consistent with maximum sustainable yield (see IPHC-2019-SRB015-11 Rev_1).

3.3 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 (interim reference SPR is currently 43%) and possibly alternative trigger reference points (currently 30%) in the harvest control rule may be investigated. This was also recommended by the MSAB (see IPHC-2023-MSAB018-R, para. 29 above).

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.

3.4 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 reasonable distribution procedures spanning the potential range 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 does not constrain the 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 1). 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 2 and Figure 2). A reasonable process to represent distribution of the TCEY to IPHC Regulatory Areas 2A and 2B would be 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 3).

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 3. 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 4.

Table 1. 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 2. 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%

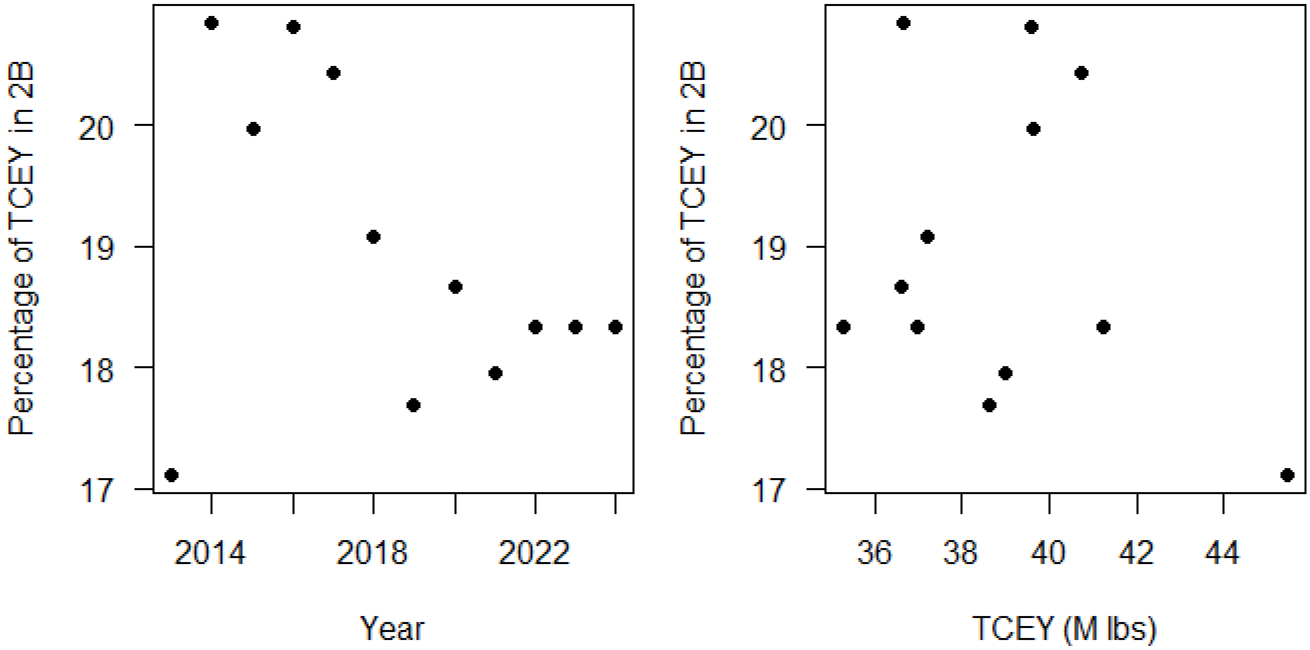

Figure 2. The percentage of the coastwide TCEY in IPHC Regulatory Area 2B plotted against year (left) and the coastwide TCEY (right).

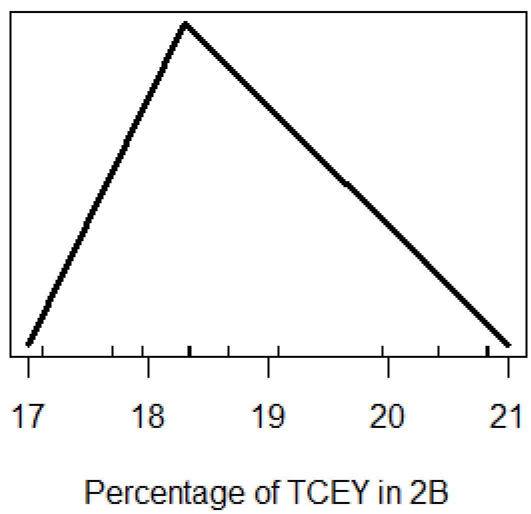

Figure 3. A triangle distribution ranging from 17% to 21% potentially to be used to randomly draw the percentage of the coastwide TCEY in 2B in MSE simulations. The ticks above the axis on the bottom show observed percentages from the past twelve years.

Table 3. 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%

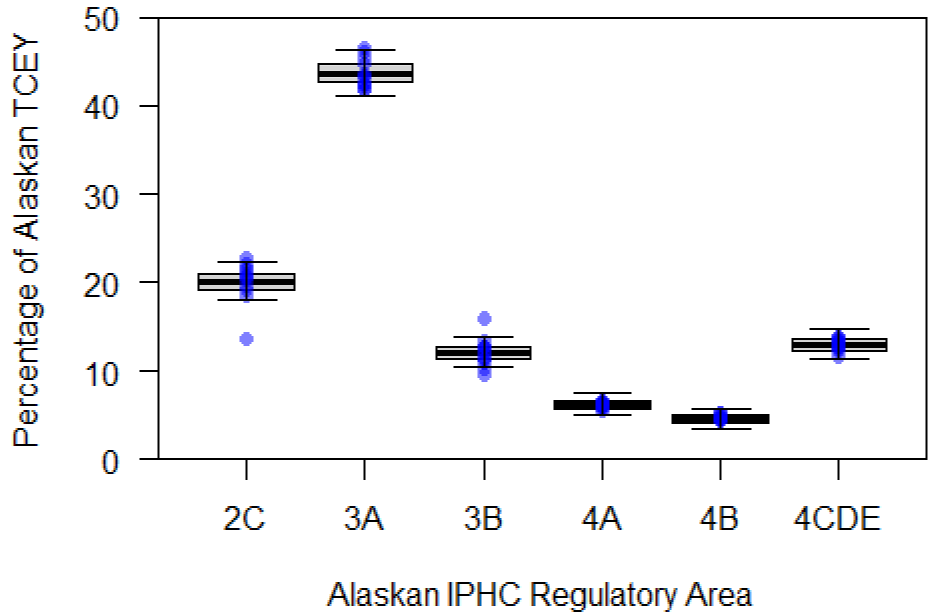

Figure 4. Observed percentage of the TCEY in Alaskan IPHC Regulatory Areas from 2013–2024 (blue points) and simulated percentage of the TCEY in Alaskan IPHC Regulatory Areas showing the median (thick black horizontal line), the central 50% (black box), and the 5th and 95th percentiles of the simulated distribution (black lines).

3.5 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. However, a specific objective to avoid low absolute spawning biomass or catch-rates would need to be added (see Section 4.2 below).

The MSAB suggested investigating methods to reduce the interannual variability in the estimates of stock distribution at MSAB018 (see IPHC-2023-MSAB018-R, para. 29 above). This may include using the average of the stock distribution estimates over the past 3 years, for example. This approach would recognize that there is a lag between the most recent estimate and the next year's fishery, such that there may be actual changes in the distribution, and also that there is observation variability in the estimates themselves, particularly given recent reductions in the FISS design.

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.

4 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).

4.1 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.

MSE simulations were performed in 2022 for annual, biennial, and triennial assessments 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.

Simulations for the triennial assessment frequency used only option (b). These simulations for biennial and triennial assessment frequencies assumed a full FISS design, thus high precision, and the results are available in the MSE Explorer for AM099.

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 2 shows the AC for annual, biennial, and triennial assessment frequencies. 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).

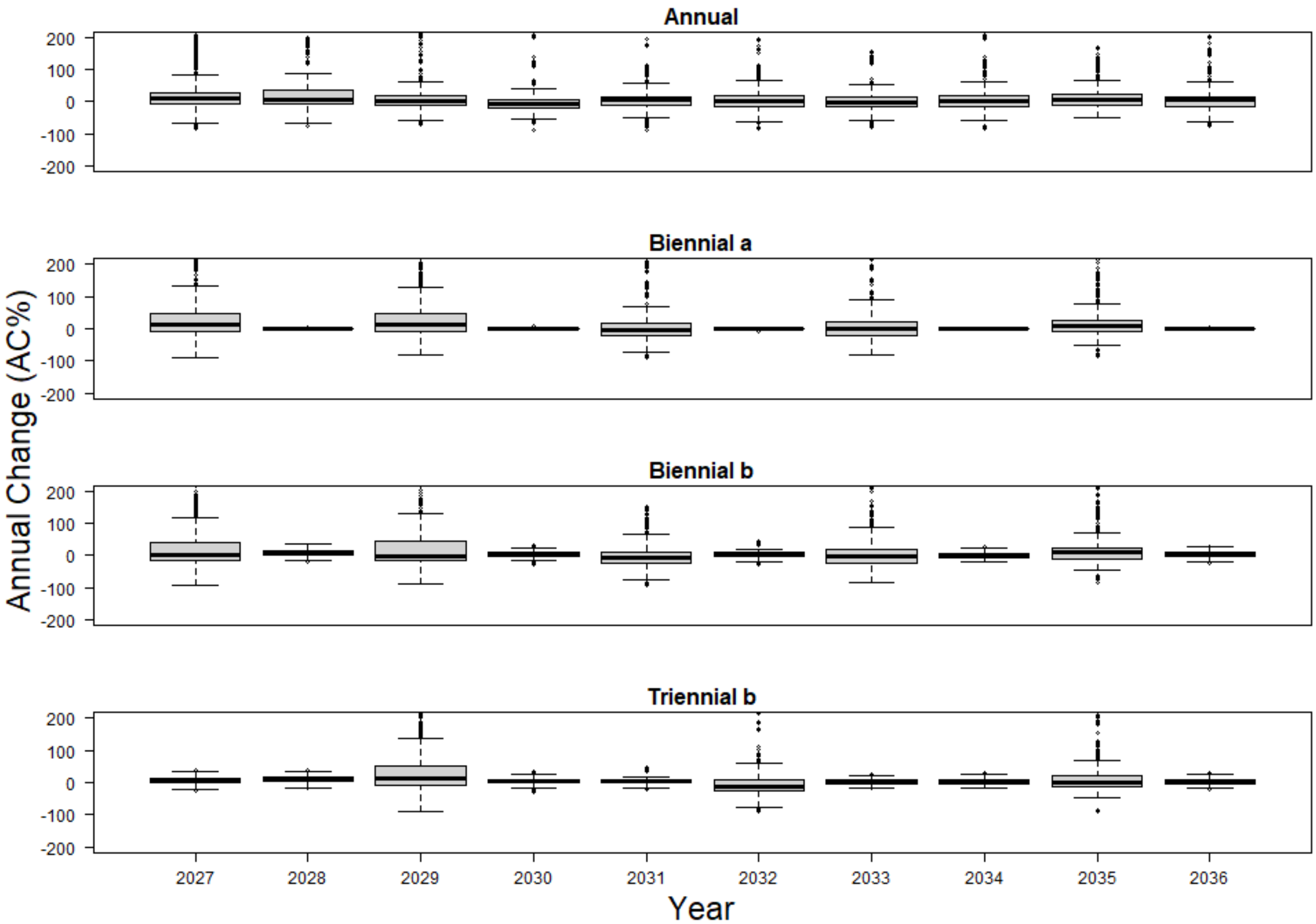

Figure 5. Boxplots of the annual change (AC) in percentage for annual, biennial, and triennial assessment frequencies. The biennial assessment frequency used a static TCEY in non-assessment years (a) and the biennial and triennial assessment frequencies use a proportional change determined from the O32 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. Comparing consistent assessment years across MPs would be much more challenging.

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. If multi-year stability is an important objective, that can be developed into the MP (such as less frequent assessments), then the current performance metrics (AAV and AC) for a ten-year period will measure the overall interannual variability in the TCEY. If maintaining the change in all years to be less than a specific amount is the objective, this can be designed into the MP or measured with a performance metric determining the chance that any annual change in the TCEY for a ten-year period exceeds some threshold. For example, a currently reported performance metric is the probability that the annual change is greater than 15% in any three years of a ten-year period. However, this could also be affected by how many assessment years occur in the time-period. A metric that may not as affected by the number of assessments in a time-period is the maximum change in the TCEY in any one year.

Therefore, before additional performance metrics to evaluate MPs with different assessment frequencies can be developed, it will be useful to revisit the objectives related to interannual variability in the TCEY. One question to ask is whether the measurable outcomes in Appendix A encompass the objectives related to interannual variability in the TCEY. If not, then the following questions may be helpful to define additional objectives.

- What concepts are missing from the measurable outcomes in Appendix A?
- Is a period of stability followed by a year adjusting the TCEY, possibly with a higher percent change than without a period of stability, acceptable?
    - How stable is the period of stability (e.g. fixed TCEY or adjusted using empirical data)?
    - How many years of stability are desired?
- Is a more predictable and transparent empirical rule desired to determine the coastwide TCEY?

- What is the maximum allowable change in any year, and is it acceptable if one, two, or more years exceeds that maximum on a rare occasion?
- Is a ten-year period appropriate to measure stability?
- Is stability prioritized below, the same, or above the yield objective?

If performance metrics are not pertinent to the objectives, they can become confusing and superfluous.

4.2 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 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 has changed the stock dynamics considerably. Figure 3 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 4), 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 3) 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%.

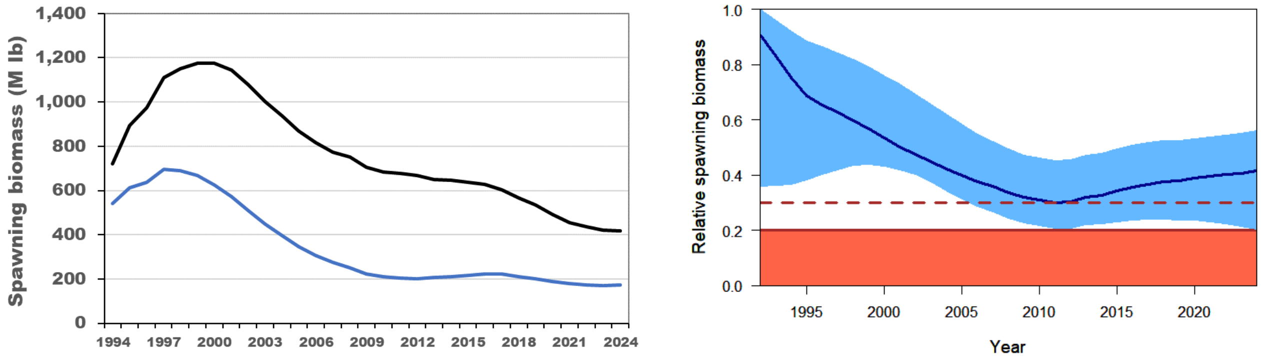

Figure 6. Dynamic unfished spawning biomass (black line) and current spawning biomass (blue line) from the 2023 stock assessment (left) and dynamic relative spawning biomass (right) with an approximate 95% credible interval in light blue and the control rule limit and trigger in red. Figures from IPHC-2024-SA-01.

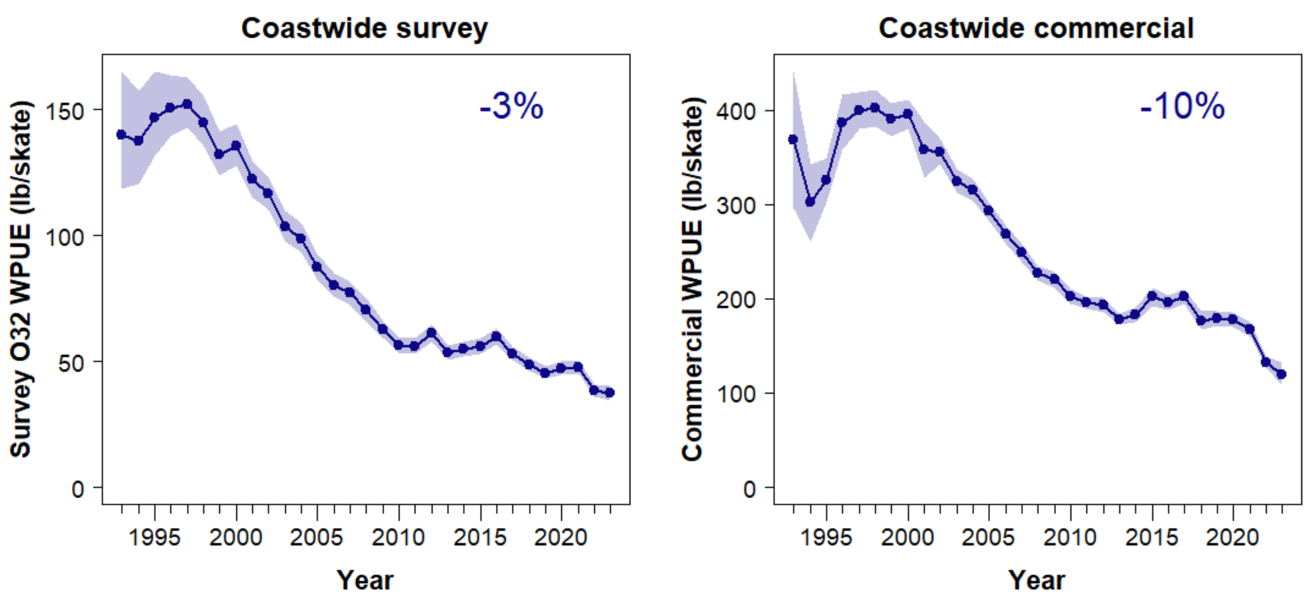

Figure 7. The coastwide FISS O32 WPUE index (left) and coastwide commercial WPUE (right) showing the percent change in the last year (from IPHC-2024-SA-02). Based on past calculations, additional logbooks collected in 2024 will likely further reduce the decline in commercial WPUE to -12%.

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 $B_{36\%}$ 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 be prudent 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)*

The Commission currently has conservation objectives to maintain the spawning biomass above certain thresholds, measured as relative spawning biomass, but these reference points are relative to dynamic unfished spawning biomass, thus may not indicate when spawning biomass is at a low absolute level resulting from non-fishing effects (e.g. weight-at-age and recruitment). An absolute biomass threshold would ensure that the biomass of fish available is above a desired level.

Most fisheries management authorities use an absolute spawning biomass threshold because they do not consider dynamic unfished spawning biomass (dynamic B_0). Instead, reference points are defined as a percentage of a static B_0 that is calculated using a pre-defined productivity regime. This, however, conflates environmental effects with fishing effects. A compromise is to determine status of the stock using a dynamic approach to account for only fishing effects, and to also define an absolute spawning biomass limit to avoid low stock levels (even if not caused by fishing) below a value that may result in unacceptably low catch-rates and/or the potential for reduced reproduction (Bessell-Browne et al. 2024).

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 define a population biomass limit reference point for relative spawning biomass as a threshold for which dropping below would cause serious harm to the stock (the Commission has already adopted $SB_{20\%}$), and a second 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 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.

5 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 et al. 2022) and is useful to ensure that the adopted harvest strategy is retained unless there are 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, is defining 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). Working with the SRB, the following potential exceptional circumstances have been defined:

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.

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.

6 Additional Considerations

The MSE framework is a generalized framework that can be used to evaluate any part of the harvest strategy. A management procedure consists of the elements in fisheries management that can (or are chosen to) be controlled. This 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. Many of these elements can be evaluated using the MSE framework.

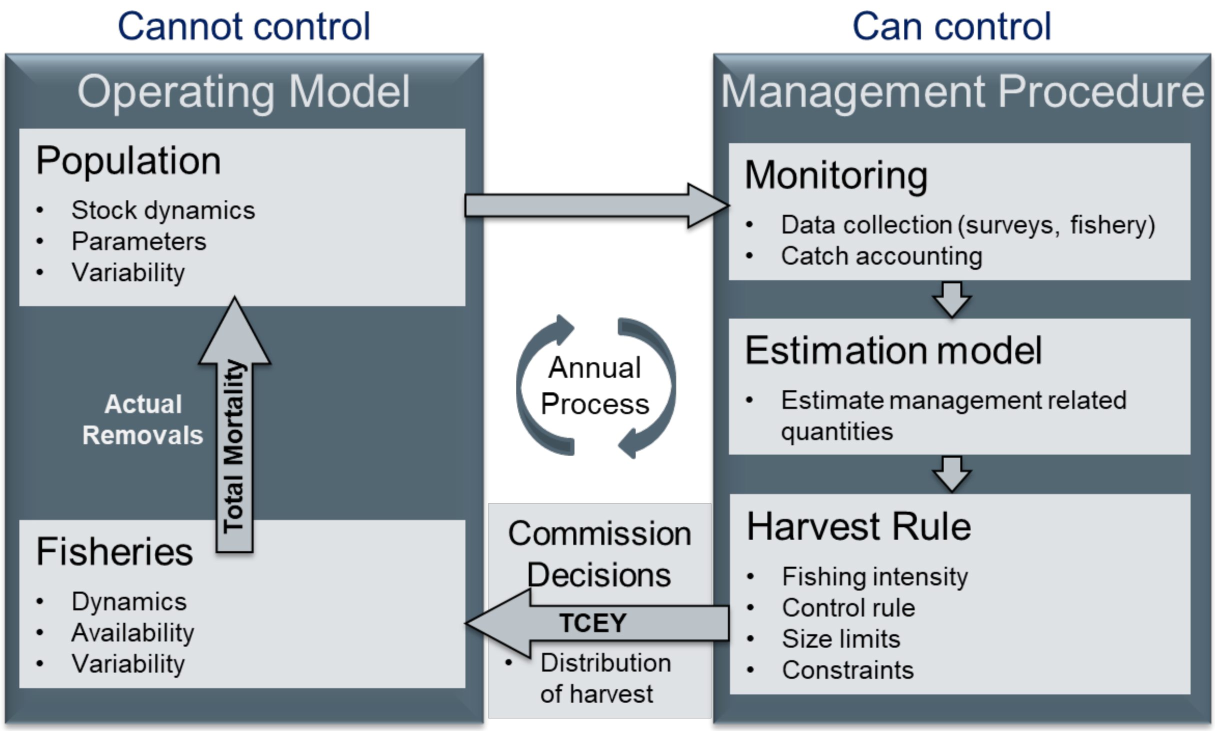

Figure 8. An illustration of the closed-loop feedback between the operating model and the management procedure.

6.1 FISS reductions

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].

The Secretariat will investigate scenarios where the FISS effort is reduced or occasionally eliminated in various IPHC Regulatory Areas. Work is currently being done to determine how FISS design changes affect the inputs into the MSE. Different scenarios will be investigated, ranging from full FISS designs with high precision to reduced FISS designs and missed years showing low precision. Evaluation of FISS scenarios is a high priority for the Commission.

RECOMMENDATION/S

1) The MSAB **NOTE** paper IPHC-2024-MSAB019-07 describing a harvest strategy policy, presenting potential elements of management procedures to evaluate, objectives to consider, and additional considerations for the MSE workplan in 2023–2025.
2) The MSAB **REQUEST** the following elements of MPs to investigate:
    a. Annual, biennial, and triennial assessment frequency with a fixed TCEY or an empirical rule based on O32 FISS WPUE in non-assessment years.
    b. Constraints of a maximum annual change of the TCEY equal to 15% or 20%, or a slow-up/fast-down rule where the TCEY increases by 1/3rd or decreases by 1/2 of the change to the reference TCEY.
    c. A range of fishing intensities from SPR=36% to SPR=56%.
    d. Options for control rules that reduce the fishing intensity when biomass is low.
3) The MSAB **REQUEST** adding the following measurable objective related to variability in TCEY:
    a. The median average of the maximum change in the TCEY for 1, 2, and/or 3 years of a ten-year period.
4) The MSAB **RECOMMEND** equal prioritization for the fishery objectives optimise average coastwide TCEY and limit annual changes in the coastwide TCEY to allow for a more transparent evaluation of trade-offs between the two objectives.
5) The MSAB **RECOMMEND** 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 the current biomass threshold objective:
    a. Maintain the absolute spawning biomass above the estimated 2023 absolute spawning biomass, noting that the threshold, term, and tolerance are yet to be defined.
6) The MSAB **RECOMMEND** 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 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 MSAB **RECOMMEND** adopting the follow actions if an exceptional circumstance occurs:
    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.

REFERENCES

Bessell-Browne P, Punt AE, Tuck GN, Burch P. Penney A. 2024. Management strategy evaluation of static and dynamic harvest control rules under long-term changes in stock productivity: A case study from the SESSF. Fisheries Research 273. https://doi.org/10.1016/j.fishres.2024.106972

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APPENDICES

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

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	$P\left(p_{SB,R} < p_{SB,R,min}\right)$
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

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

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