IPHC Management Strategy Evaluation and Harvest Strategy Policy: FOR DECISION

PREPARED BY: IPHC SECRETARIAT (A. HICKS, I. STEWART & D. WILSON; 20 DECEMBER 2023)

PURPOSE

To provide the Commission with results of the Management Strategy Evaluation (MSE) simulations of size limit and multi-year stock assessment management procedures (MPs), and to request decisions from the Commission on the Objectives, Performance Metrics, and Management Procedures.

BACKGROUND AND DISCUSSION

1) **Operating Model:** the Scientific Review Board (SRB) has reviewed the IPHC's MSE Operating Model (OM) at the 21st and 22nd Sessions of the Scientific Review Board. Additional details can be found in document IPHC-2023-MSE-01 on the IPHC MSE Research Website. The IPHC's MSE Operating Model has been thoroughly reviewed by the SRB and is performing well for evaluating management procedures, noting that further adjustments may be made, at the request of the Commission, to align with the stock assessment (i.e. conditioning to updated stock assessment outputs).

2) **Objectives:** The IPHC Secretariat is requesting that the Commission agree to a reduced set of MSE objectives. These are a reduced set of important coastwide objectives taken from the larger set presented in Appendix B and reworded for clarity. They are presented here in an order of importance.

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

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

    c. Optimise average coastwide TCEY.

    d. Limit annual changes in the coastwide TCEY.

3) **Performance Metrics:** The IPHC Secretariat is requesting that the Commission endorse the following Performance Metrics to move forward with, which is a subset from the range of metrics presented in Appendix B:

    P(RSB<20%): Probability that the long-term Spawning Biomass is less than the Spawning Biomass Limit: SB_{Lim}=20% of unfished spawning biomass. This is associated with objective (a) and is reported as a pass if the probability is less than 0.05.

    P(RSB<36%): Probability that the Spawning Biomass is less than the Spawning Biomass Target: SB_{Targ}=36% of unfished spawning biomass. This is associated with objective (b) and is reported as a probability.

Median TCEY: The median of the short-term average TCEY over a ten-year period. This is a measure of the TCEY in the next 4-13 years and is associated with objective (c). This is only reported if the spawning biomass objectives are passed.

Median AAV TCEY: The median of the average annual variability of the short-term TCEY determined as the average difference in the TCEY over a ten-year period. This is a measure of the inter-annual variability of the TCEY in the next 4-13 years and is associated with objective (d). This is reported only if the spawning biomass limit objective is passed.

4) **Management Procedures:** The IPHC Secretariat is requesting that the Commission note the following reduced set of MPs presented for decision-making at AM099 or further testing.

MP-A32: Annual assessment frequency and a 32-inch size limit for the directed commercial fishery.

MP-A26: Annual assessment frequency and a 26-inch size limit for the directed commercial fishery.

MP-A0: Annual assessment frequency and no size limit (full retention) for the directed commercial fishery.

MP-Bb32: Biennial assessment frequency and a 32-inch size limit for the directed commercial fishery. The coastwide TCEY in non-assessment years is determined from the change in the coastwide O32 FISS index. The distribution of TCEY is calculated using the FISS observations within a defined distribution procedure.

MP-Tb32: Triennial assessment frequency and a 32-inch size limit for the directed commercial fishery. The coastwide TCEY in non-assessment years is determined from the change in the coastwide O32 FISS index. The distribution of TCEY is calculated using the FISS observations within a defined distribution procedure.

5) **Results:** MSE simulation results are shown below using the four (4) performance metrics described above. The reference fishing intensity, SPR=43%, was used for all MPs. The MP most similar to the recent interim harvest strategy is shaded in grey.

MP name	**MP-A0**	**MP-A26**	**MP-A32**	**MP-Bb32**	**MP-Tb32**
Assessment Frequency	**Annual**	**Annual**	**Annual**	**Biennial**	**Triennial**
Size Limit	**0**	**26**	**32**	**32**	**32**
Empirical Rule	**–**	**–**	**–**	**b**	**b**
P(RSB<20%)	PASS	PASS	PASS	PASS	PASS
P(RSB<36%)	0.174	0.174	0.180	0.164	0.197
Median TCEY	60.5	59.9	58.3	58.5	58.3
Median AAV TCEY	17.2%	17.5%	17.8%	17.0%	14.1%

The IPHC Secretariat is currently in the process of updating the IPHC harvest strategy policy document, which was first developed in 2019, based on decisions of the Commission at IM098 and AM099.

RECOMMENDATION/S

1) That the Commission **NOTE**:
    a. paper IPHC-2023-AM099-13 incorporating Appendix A that describes the MSE framework, size limit and multi-year assessment management procedures, and simulation results.
2) That the Commission **AGREE** to the following MSE priority coastwide objectives, presented in an order of importance:
    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 above a biomass target reference point (B36%) at least 50% of the time.
    c) Optimise average coastwide TCEY.
    d) Limit annual changes in the coastwide TCEY.
3) That the Commission **ENDORSE** the following Performance Metrics, associated with the priority coastwide objectives:
    a) **P(RSB<20%)**: Probability that the long-term Spawning Biomass is less than the Spawning Biomass Limit, failing if the value is greater than 0.05.
    b) **P(RSB<36%)**: Probability that the Spawning Biomass is less than the Spawning Biomass Target.
    c) **Median TCEY**: The median of the short-term average TCEY over a ten-year period, reported only if the spawning biomass limit objective is passed.
    d) **Median AAV TCEY**: Average annual variability of the short-term TCEY determined as the average difference in the TCEY over a ten-year period, reported only if the spawning biomass limit objective is passed.
4) That the Commission **ENDORSE** the following reduced set of MPs presented for decision-making at AM099 or further testing.
    a) **MP-A32:** Annual assessment frequency and a 32-inch size limit for the directed commercial fishery.
    b) **MP-A26:** Annual assessment frequency and a 26-inch size limit for the directed commercial fishery.
    c) **MP-A0:** Annual assessment frequency and no size limit (full retention) for the directed commercial fishery.
    d) **MP-Bb32:** Biennial assessment frequency and a 32-inch size limit for the directed commercial fishery. The coastwide TCEY in non-assessment years is determined from the change in the coastwide O32 FISS index. The distribution of TCEY in all

years is calculated using the FISS observations within a defined distribution procedure.

e) **MP-Tb32:** Triennial assessment frequency and a 32-inch size limit for the directed commercial fishery. The coastwide TCEY in non-assessment years is determined from the change in the coastwide O32 FISS index. The distribution of TCEY in all years is calculated using the FISS observations within a defined distribution procedure.

5) That the Commission **NOTE** that:

a) for all management procedures evaluated, the long-term relative spawning biomass passed both spawning biomass objectives for all MPs and was more often above the target for SPR values ranging between 40% and 46%;

b) removal of a size limit results in a 3.7% increase, on average, for the short-term median coastwide TCEY and a 2.7% increase, on average, for the long-term median coastwide TCEY. A majority of that increase occurs when reducing the size limit for directed commercial fisheries to 26 inches;

c) without a size limit for the directed commercial fishery, landings of O32 fish would likely decline while U32 landings would likely increase, and the trade-off is dependent on population characteristics such as incoming recruitment and size-at-age;

d) without a size limit for the directed commercial fishery, short-term coastwide directed commercial fishery discard mortality would decline by, on average, 78%;

e) for the directed commercial fishery without a size limit to maintain equal value to the fishery with a 32-inch size limit, the price of U32 fish would have to be near one-half the price of O32 fish, on average, and this equal value price ratio would most likely range between zero and one, depending on stock conditions;

f) a biennial assessment frequency with an empirical rule using FISS observations in non-assessment years shows similar results to an annual assessment;

g) a triennial assessment frequency with an empirical rule using FISS observations in non-assessment years shows a similar short-term median TCEY along with a significant reduction in inter-annual variability of the TCEY;

h) costs associated with multi-year assessments include 1) lack of detailed management information every year, 2) possibly a loss in long-term yield, and 3) a chance of a smaller stock size. Benefits include 1) reduced inter-annual variability in the TCEY, 2) use of the annual FISS index in a transparent process, 3) more focused assessment research, 4) potential for additional collaboration within the Secretariat, 5) consistency with the three-year cycle of update and full assessments, and 6) following the precedent of other fisheries commissions.

APPENDICES

Appendix A: A summary of the IPHC MSE results for 2022

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

Appendix C: Results using metrics associated with the primary objectives

Appendix D: Supplementary material

APPENDIX A

A summary of the IPHC MSE results for 2022

This paper presents the outcomes of the MSE Program of Work for 2021–2023 which included tasks related to the MSE framework, investigating management procedures (MPs) related to size limits and multi-year assessments, and improving the process of evaluating MPs (Table 1). Using the primary objectives of the Commission as well as other metrics, results of size limit and multi-year assessment MPs are presented.

Table 1. Tasks recommended by the Commission at SS011 (IPHC-2021-SS011-R para 7) for inclusion in the IPHC Secretariat MSE Program of Work for 2021–2023.

ID	Category	Task	Deliverable
F.1	Framework	Develop migration scenarios	Develop OMs with alternative migration scenarios
F.2	Framework	Implementation variability	Incorporate additional sources of implementation variability in the framework
F.3	Framework	Develop more realistic simulations of estimation error	Improve the estimation model to more adequately mimic the ensemble stock assessment
F.5	Framework	Develop alternative OMs	Code alternative OMs in addition to the one already under evaluation.
M.1	MPs	Size limits	Identification, evaluation of size limits
M.3	MPs	Multi-year assessments	Evaluation of multi-year assessments
E.3	Evaluation	Presentation of results	Develop methods and outputs that are useful for presenting outcomes to stakeholders and Commissioners

1 PRIMARY GOALS AND OBJECTIVES

The Management Strategy Advisory Board (MSAB) has previously suggested four potential goals for evaluating management procedures, and the Commission has identified two of these as primary goals, each one with one or more objectives.

1. Biological Sustainability (also referred to as a conservation goal)
   1.1. Keep biomass above a limit to avoid critical stock sizes
2. Optimise directed fishing opportunities (also referred to as a fishery goal)
   2.1. Maintain spawning biomass around a level (i.e. a target biomass reference point) that optimises fishing activities
   2.3. Provide directed fishing yield
   2.2. Limit variability in mortality limits

Details of the primary goals and objectives defined by the Commission, along with performance metrics, are shown in Appendix B. The objectives are listed above in an order of importance that should be considered when evaluating management procedures.

Metrics or statistics (both words are used interchangeably) are developed from these objectives. For objectives with defined thresholds and tolerances, performance metrics can be developed. A performance standard is the binary outcome of whether an objective is met and can be determined from the performance metric (e.g. does not exceed the tolerance). Evaluation is performed by examining the metrics associated with the primary objectives, but in many cases additional metrics are useful to understand the trade-offs and important outcomes between management procedures.

Priority metrics include the probability that the female spawning biomass is less than 20% of unfished spawning biomass (objective 1.1), probability that the female spawning biomass is less than 36% of unfished spawning biomass (objective 2.1), the median TCEY determined from the simulations averaged over a ten-year short-term period in each simulation (objective 2.3), and the median annual variability determined from the simulations averaged over a ten-year short-term period in each simulation (objective 2.2; AAV). These are presented in order of importance. Additional objectives and performance metrics can be found in Appendix B.

1.1 Clarification of a spawning biomass target

The primary objectives have been endorsed by the Commission, but additional clarity on one objective may be useful.

> **IPHC-2019-AM095-R, para 59a.** *The Commission **ENDORSED** the primary objectives and associated performance metrics used to evaluate management procedures in the MSE process (as detailed in paper IPHC-2019-AM095-12).*
>
> **IPHC-2022-MSAB017-R, para. 28**. *The MSAB **NOTED** that objective 2.1 is stated as a target that has also been interpreted as a threshold and **REQUESTED** clarification from the Commission.*

The development of a spawning biomaaaass target (i.e. a biomass level with a 50% probability of being above or below) was discussed extensively at MSAB013 following the direction of the Commission.

> **AM095-R, para 59c.** *The Commission **RECOMMENDED** the MSAB develop the following additional objective, as well as prioritize this objective in the evaluation of management procedures, for the Commission's consideration.*
>
> *i. A conservation objective that meets a spawning biomass target.*

Four dynamic equilibrium reference points were estimated previously for the Pacific halibut stock: 1) unfished equilibrium dynamic spawning biomass (SB_0), 2) MSY, 3) B_{MSY} as a percentage of SB_0 (RSB_{MSY}), and 4) the equilibrium fishing intensity to achieve MSY using spawning potential ratio (SPR_{MSY}), using three different methods (IPHC-2019-SRB015-11 Rev_1). Estimates of the dynamic equilibrium RSB_{MSY} for Pacific halibut are likely to be in the range of 20% to 30% and SPR_{MSY} to likely be between 30% and 35%. A reasonable RSB_{MSY} proxy, including a precautionary allowance for unexplored sources of uncertainty, would be 30%, and would put a proxy for SB_{MEY} between 36% and 44% given the recommendations of Rayns (2007) and Pascoe et al. (2014).

The objective of maintaining the spawning biomass around a target or above a level that optimises fishing activities was not specifically stated, and objective 2.1 in Appendix B is ambiguous with the general objective and measurable objective potentially in conflict. Below are some insights into the implications of 'around a target' and 'above a level/threshold'.

1.1.1 Around a target

Specifying objective 2.1 in Appendix B as a target implies that a management procedure would be tuned to specifically meet this target with a 50% chance. This means that the expectation is to be above the target spawning biomass half of the time and below the target spawning biomass half of the time. How much above and below is not specified, other than the spawning biomass limit of 20% specified in Objective 1.1. This would typically be accomplished by adjusting the fishing intensity (i.e. SPR) for a specific management procedure until the target is met. If this was a strict performance standard (the probability of 0.5 must be met) it would potentially disregard the trade-offs between the other primary objectives of limiting the variability in mortality limits and provide directed fishing yield. However, other elements introduced into a MP could possibly allow for variability in mortality limits to be minimized, although it would likely result in a complex MP with many elements each aimed at achieving various objectives.

1.1.2 Above a level/threshold

Defining objective 2.1 in Appendix B as a threshold would allow some flexibility in the evaluation. However, this could result in a less clear identification of MPs that meet the objectives, and instead focus the evaluation on identifying trade-offs between objectives. A threshold simply means that the spawning biomass may not drop below the threshold more than 50% of the time (i.e. in half of the simulations) but may remain above the threshold more often. This is similar to the biological sustainability objective 1.1. It would identify MPs with fishing intensities too high to satisfy this objective, but allow for lower fishing intensities that would possibly meet other objectives.

1.1.3 At or above a target

It may seem contradictory to define an objective using the phrase 'above a target', but that may be useful to allow for flexibility in the evaluation of MPs, increase the utility of other objectives, allow for less complex and more transparent MPs, incorporate the precautionary approach, and meet international fisheries guidance as well as ecocertification standards. Furthermore, the concept of a 'target' could be incorporated into the harvest policy in other ways, such as in a definition of overfishing.

Defining a target is common practice in fisheries and is often combined with balancing other objectives. When describing the precautionary approach, FAO states:

> ***FAO (1996) para. 29****. Targets identify the desired outcomes for the fishery. For example, these may take the form of a target fishing mortality, or a specified level of average abundance relative to the unfished state. In some cases, these targets are likely to be identical with those that would be specified for fisheries management, regardless of whether a precautionary approach was to be adopted.*

In other cases, targets may need to be adjusted to be precautionary, for example, by setting the target fishing mortality lower than FMSY.

The Canadian Fisheries Act[1], under 'measures to maintain fish stocks', uses the phrase 'at or above' when describing a level necessary for sustainability.

> ***Canadian Fisheries Act, § 6.1 (1)***: *In the management of fisheries, the Minister shall implement measures to maintain major fish stocks at or above the level necessary to promote the sustainability of the stock, taking into account the biology of the fish and the environmental conditions affecting the stock.*

National Standard 1 of the U.S. Magnusson-Stevens Act[2] defines optimal yield (OY) as a value to achieve, on a continuing bases, and that the OY must not exceed MSY. Furthermore, it states to maintain the long-term average biomass near or above Bmsy.

> ***U.S. Magnusson-Stevens Act § 600.310 (b)(2)(i):*** *MSY. The Magnuson-Stevens Act establishes MSY as the basis for fishery management and requires that: The fishing mortality rate does not jeopardize the capacity of a stock or stock complex to produce MSY; the abundance of an overfished stock or stock complex be rebuilt to a level that is capable of producing MSY; and OY not exceed MSY.*
>
> ***U.S. Magnusson-Stevens Act § 600.310 (b)(2)(ii)****: OY. The determination of OY is a decisional mechanism for resolving the Magnuson-Stevens Act's conservation and management objectives, achieving a fishery management plan's (FMP) objectives, and balancing the various interests that comprise the greatest overall benefits to the Nation. OY is based on MSY as reduced under paragraphs (e)(3)(iii) and (iv) of this section…*
>
> ***U.S. Magnusson-Stevens Act S 600.310 (e)(3)(i)*** *(B) In NS1, use of the phrase "achieving, on a continuing basis, the optimum yield from each fishery" means producing, from each stock, stock complex, or fishery: a long-term series of catches such that the average catch is equal to the OY, overfishing is prevented, the long term average biomass is near or above Bmsy, and overfished stocks and stock complexes are rebuilt consistent with timing and other requirements of section 304(e)(4) of the Magnuson-Stevens Act and paragraph (j) of this section.*

Allowing for the spawning biomass to be above the target while accounting for other objectives would still meet ecocertification standards, such as those defined by the Marine Stewardship Council (MSC). The criteria to achieve a score of 100 for stock status in relation to achievement of Maximum Sustainable Yield (MSY), according to the MSC fishery standard V2.01, is "there is a high degree of certainty that the stock has been fluctuating around a level consistent with MSY or has been above this level over recent years." This allows for the principle to be met while also allowing for other objectives.

[1] https://laws-lois.justice.gc.ca/PDF/F-14.pdf

[2] https://www.govinfo.gov/content/pkg/CFR-2012-title50-vol12/pdf/CFR-2012-title50-vol12-part600.pdf

2 CLOSED-LOOP SIMULATION FRAMEWORK

The closed-loop framework with a multi-area operating model (OM) and three options for examining estimation error was initially described in Hicks et al. (2021). Technical details are described in IPHC-2022-MSE-01 on the IPHC MSE Research website and updated as needed. Improvements to the framework have been made in accordance with the MSE program of work and a new OM has been developed.

2.1 Development of a new Operating Model

The IPHC stock assessment (Stewart & Hicks 2022) consists of four stock synthesis models integrated into an ensemble to provide probabilistic management advice accounting for observation, process, and structural uncertainty. A similar approach was taken when developing the models for the closed-loop simulation framework along with some other specifications to improve the efficiency when conditioning models and running simulations. Specific details are provided in IPHC-2023-MSE-01 on the IPHC MSE Research website.

2.2 Projections

The multiple trajectories from the conditioned OM provide replicate time-series of population and fishery processes and are the starting point for the closed-loop simulation to project forward in time using various management procedures (MPs) and assumptions. Processes such as weight-at-age, selectivity/retention deviations, the environmental regime, recruitment, and implementation variability are simulated during the closed-loop simulations. These processes may or may not depend on the size of the population, or a certain demographic. An example of the projection period is shown in Figure 1.

2.2.1 Implementation variability and uncertainty

Implementation variability is defined as the deviation of the fishing mortality from the mortality limit determined from an MP. It can be thought of as what actually (or is believed to have) happened compared to the limits that were set. Decision-making variability is the difference between the MP mortality limits and the adopted mortality limits set by the Commission.

Decision-making variability was simulated as a random process that could modify the coastwide TCEY from the MP TCEY and also modify the distribution of the TCEY among IPHC Regulatory Areas. For these simulations, the coastwide TCEY is equal to the coastwide TCEY from the MP, but distribution of the TCEY is subjected to decision-making variability. The variability was parameterised by comparing adopted TCEYs since 2013 to TCEYs from the MP to reflect potential variability among IPHC Regulatory Areas. Simulations were also performed where the adopted coastwide TCEY may deviate from the MP, along with distribution, but are not reported in this document.

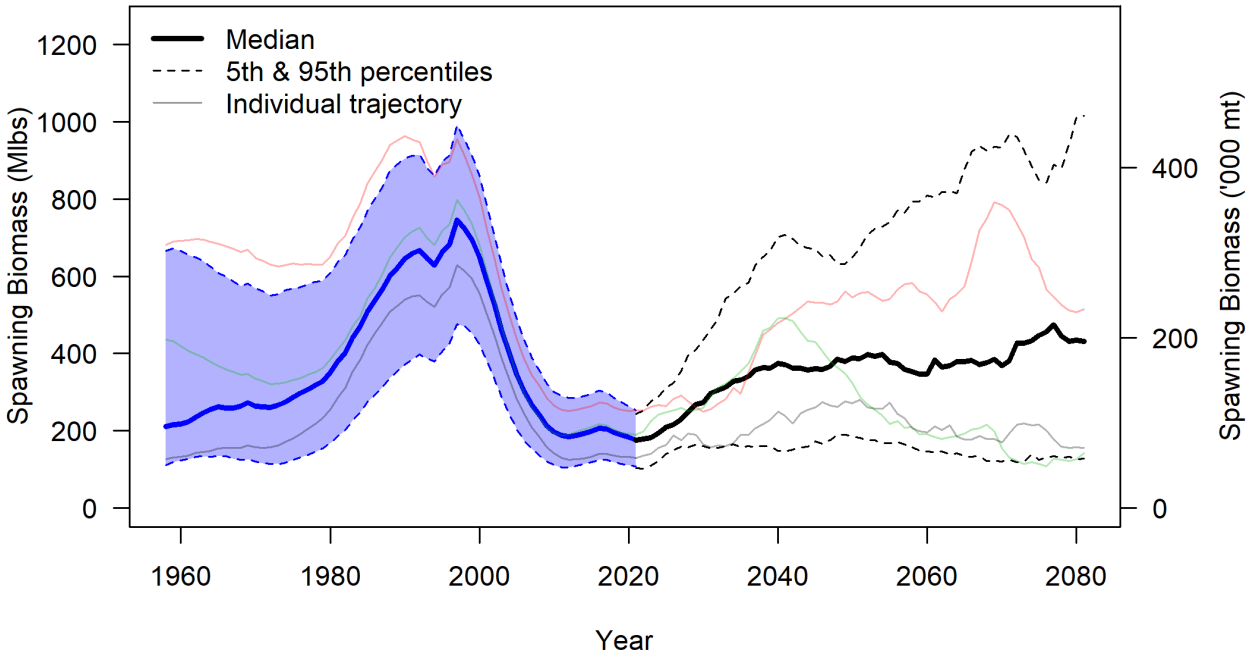

Figure 1. Median, 5th percentile, and 95th percentile of projected spawning biomass when using an SPR of 43%. Three individual trajectories (chosen ad hoc) are shown as thin lines to provide an idea of the variability in one trajectory over the entire period.

3 MANAGEMENT PROCEDURES FOR EVALUATION

Two categories of MPs were prioritised in the MSE Program of Work for 2021–2023 (Table 1). One was the investigation of size limits (M.1) and the other was to investigate multi-year stock assessments (i.e. not conducting the stock assessment annually; M.3). Due to improvements in the MSE framework, changes in the OM, and alternative MPs, select additional MP elements investigated previously, such as SPR, may need to be re-evaluated.

3.1 Size limits

The Commission requested that three size limits be investigated: 32 inches, 26 inches, and no size limit.

> **IPHC-2022-AM098-R, para. 61**: *The Commission **RECALLED** SS011-Rec.01 and **REQUESTED** that the current size limit (32 inches), a 26 inch size limit, and no size limit be investigated. to understand the long-term effects of a change in the size limit.*

The removal of a size limit resulted in a 3.7% increase, on average, in the short-term median coastwide TCEY and a 2.7% increase, on average, in the long-term median coastwide TCEY (Table 2). A majority of that increase occurs when reducing the size limit for directed commercial fisheries to 26 inches. Even though a gain in overall yield is likely, reducing the size limit for the directed commercial fishery would likely result in a decline in directed commercial landings of

O32 Pacific halibut while U32 landings would likely increase (Figure 2), which is dependent on population characteristics such as incoming recruitment and size-at-age. Without a size limit for the directed commercial fishery, short-term directed commercial fishery discard mortality would decline by, on average, 80% coastwide and between 67% to 89% across IPHC Regulatory Areas.

Table 2. Performance metrics related to primary objectives for size limit MPs with an annual assessment, estimation error and decision-making variability option 1. Biological sustainability metrics are long-term and fishery sustainability are short-term (4–13 years).

MP name	**MP-A0**	**MP-A26**	**MP-A32**
Size Limit	**0**	**26**	**32**
SPR	**0.43**	**0.43**	**0.43**
Replicates	1100	1100	1100
Biological Sustainability			
Median average RSB	38.9%	38.9%	38.8%
P(any RSB_y<20%)	<0.001	<0.001	<0.001
Fishery Sustainability			
P(all RSB<36%)	0.174	0.174	0.180
Median TCEY	60.5	59.9	58.3
P(any3 change TCEY > 15%)	0.880	0.894	0.906
Median AAV TCEY	17.2%	17.5%	17.8%

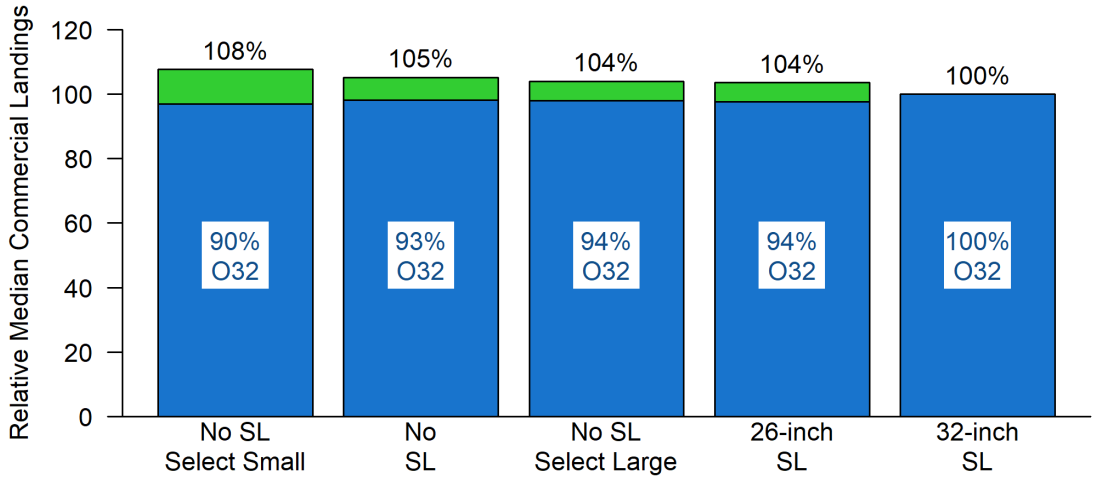

Figure 2. Median short-term directed commercial landings relative to the landings (bar height) with the current size limit (32-inches) for three no size limit scenarios (selecting smaller fish, recent selectivity, and selecting larger fish), a 26-inch size limit, and the current size limit. The percentage of O32 Pacific halibut in the directed commercial landings is shown in blue (bottom) and the percentage of U32 Pacific halibut in the directed commercial landings is shown in green (top).

An important concept to bring into the evaluation of size limits is market considerations. Stewart et al. (2021) used the ratio between the U32 price and O32 price for Pacific halibut to determine what ratio is necessary for the fishery to break even economically. Here, we call that the Equal Value Price Ration (EVPR), and a value between 0 and 100 indicates the percentage the price for U32 fish compared to the price of O32 fish must be for the Pacific halibut fishery to have the same value as with a 32-inch size limit (Figure 3).

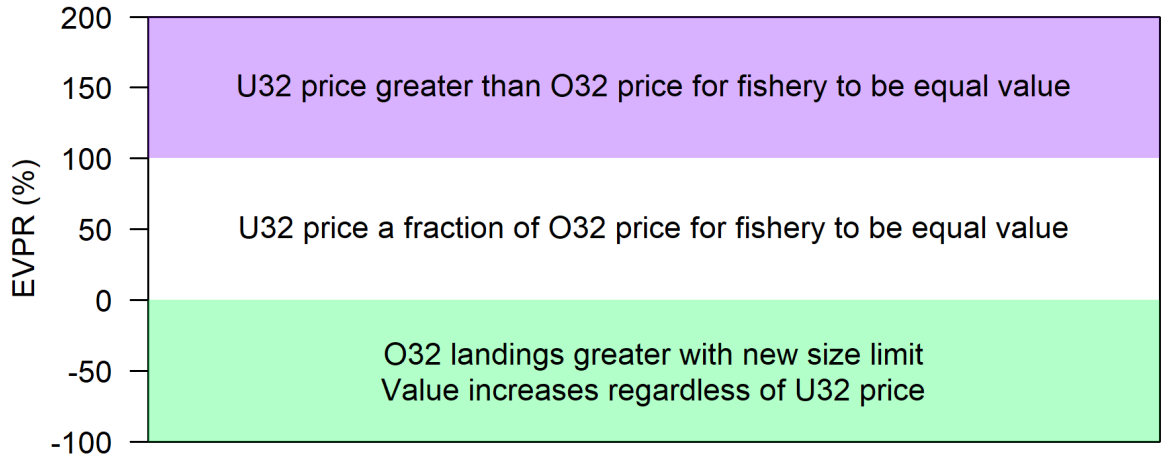

Figure 3. Descriptions of the meaning of EVPR for three different ranges.

The EVPR may be another useful metric for evaluating size limits and it is worth noting that the SRB recently requested a similar product.

> **IPHC-2021-SRB019-R** (para 61): *The SRB **REQUESTED** further information (e.g. inverse demand curves), to be presented at SRB020, on the regional supply-price relationships for commercial landings, as well as localized importance of the Pacific halibut fishery to communities.*

It is unknown what prices will be for U32 Pacific halibut if a size limit was removed, but the FISS has recently begun selling U32 fish, which may be an indicator for the potential price of small fish. This empirical price ratio was near 88% in 2022 and has been above 80% in recent years (see Table 4 in IPHC-2021-ECON-02-R03).

The short-term Equal Value Price Ratio (EVPR) shows a median near 0.5 for both comparisons of no size limit to the current size limit and a 26-inch size limit compared to the current size limit (Figure 4). Most of the distribution of the short-term EVPR was between 0 and 1 although a small proportion was less than 0 (O32 commercial landings increased with a lower size limit) and above 1 (the price of U32 Pacific halibut would have to be greater than the price of O32 Pacific halibut for equal fishery value).

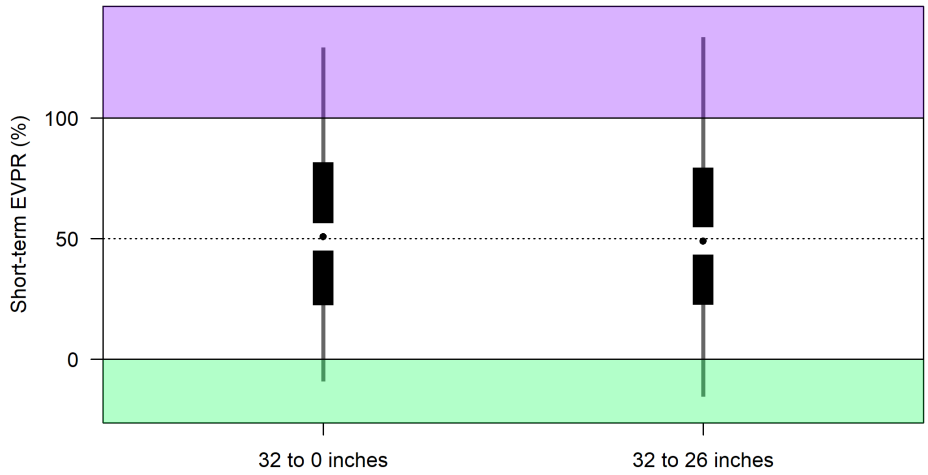

Figure 4. The short-term Equal Value Price Ratio (EVPR) for simulations comparing no size limit to the current size limit (left) and a 26-inch size limit compared to the current size limit (right). The black dot is the median of 1,100 simulations, the thick bar shows the 25th and 75th percentiles, and the thin line shows the 5th and 95th percentiles. Various ranges of values of the EVPR are shaded in colors corresponding to Figure 3.

3.2 Multi-year assessments

Management procedures with multi-year assessments incorporate a process where the stock assessment occurs at intervals longer than annually. The mortality limits in a year with the stock assessment can be determined as in previously defined MPs, but in years without a stock assessment, the mortality limits would need an alternative approach. This may be as simple as maintaining the same mortality limits for each IPHC Regulatory Area in years with no stock assessment, or as complex as invoking an alternative MP that does not require a stock assessment (such as an empirical-based MP relying only on data/observations).

The Commission requested that the Secretariat investigate biennial assessments and potentially longer intervals as time allows.

> **IPHC-2022-AM098-R, para 64**: *The Commission **REQUESTED** that multi-year management procedures include the following concepts:*
>
> *a) The stock assessment occurs biennially (and possibly triennial if time in 2022 allows) and no changes would occur to the FISS (i.e. remains annual);*
>
> *b) The TCEY within IPHC Regulatory Areas for non-assessment years:*
>
> *i. remains the same as defined in the previous assessment year, or*
>
> *ii. changes within IPHC Regulatory Areas using simple empirical rules, to be developed by the IPHC Secretariat, that incorporate FISS data.*

Furthermore, in 2022, the SRB made a request for triennial assessments.

> **IPHC-2022-SRB021-R, para. 30**. *The SRB **REQUESTED** that the Secretariat examine MPs based on a three-year assessment cycle with annual TCEY changes proportional to changes in the FISS index because (i) this approach would be simpler and more transparent than a model, which has not yet been developed); (ii) the high benefit to cost ratio for multi-year TCEYs; (iii) it matches the current three-year full assessment cycle; and (iv) the general approach has precedents in other fishery commissions (e.g. Southern Bluefin Tuna).*

There are many different empirical rules that could be applied to determine the TCEY in non-assessment years. We identified three empirical rules for determining IPHC Regulatory Area specific TCEYs in non-assessment years, which either use no observations or FISS observations.

a. The same TCEY from the previous year for each IPHC Regulatory Area.
b. Updating the coastwide TCEY proportionally to the change in the coastwide FISS O32 WPUE and updating the distribution of the TCEY using FISS results and the applied distribution procedure.
c. Maintaining the same coastwide TCEY as the previous year but updating the distribution of the TCEY using FISS results and the applied distribution procedure.

Empirical rule (a) does not update the TCEY in IPHC Regulatory Areas, which may deviate from distribution agreements related to a percentage of the coastwide TCEY, if present, due to changes in the distribution of biomass. Empirical rules (b) and (c) both adjust the distribution of the coastwide TCEY and would maintain any agreements related to distribution.

Table 3. Performance metrics related to primary objectives for annual, biennial, and triennial MPs with a size limit of 32 inches simulated with estimation error and option 1 decision-making variability. Biological sustainability metrics are long-term and fishery sustainability are short-term (4–13 years). Empirical rules for non-assessment years are described in the text.

MP name	**MP-A32**	**MP-Ba32**	**MP-Bb32**	**MP-Bc32**	**MP-Tb32**
Assessment Frequency	**Annual**	**Biennial**	**Biennial**	**Biennial**	**Triennial**
Size Limit	**32**	**32**	**32**	**32**	**32**
Empirical Rule	**–**	**a**	**b**	**c**	**b**
SPR	**0.43**	**0.43**	**0.43**	**0.43**	**0.43**
Replicates	1100	1100	1100	1100	1100
Biological Sustainability					
Median average RSB	38.8%	38.7%	38.9%	38.7%	39.1%
P(any RSB_y<20%)	<0.001	<0.001	<0.001	<0.001	<0.001
Fishery Sustainability					
P(all RSB<36%)	0.180	0.164	0.164	0.168	0.197
Median average TCEY	58.3	57.8	58.5	57.7	58.3
P(any3 change TCEY > 15%)	0.906	0.682	0.809	0.682	0.628
Median AAV TCEY	17.8%	13.2%	17.0%	13.2%	14.1%

A biennial assessment frequency with an empirical rule using FISS observations in non-assessment years shows similar results to an annual assessment (Table 3). This occurs because the FISS index tracks closely with the stock assessment. A triennial assessment frequency with an empirical rule using FISS observations in non-assessment years shows a slight reduction in the long-term TCEY along with a significant reduction in short-term and long-term inter-annual variability in the TCEY.

The Secretariat worked with the SRB to identify costs and benefits of multi-year stock assessments, which are outlined in paragraph 27 from IPHC-2022-SRB020-R and paragraph 30 from IPHC-2022-SRB021-R. Also incorporating comments from IPHC-2022-MSAB017-R, a list of costs and benefits is provided below.

1) Costs include
    a) Detailed management information is not available every year (e.g. stock status),
    b) The TCEY in non-assessment years may not follow stock trends (for options a and c without an empirical rule on coastwide TCEY),
    c) Potentially a small loss in yield (for options a and c with a constant coastwide TCEY across non-assessment years),
    d) Potentially may not meet distribution agreements, if any (only for option a),
    e) A slightly higher chance of a smaller stock size.
2) Benefits include
    a) Reduced inter-annual variability in the TCEY,
    b) Multi-year stability and short-term predictability of the TCEY,
    c) Use of the annual FISS index in a transparent process to determine the TCEY in non-assessment years,
    d) More focused assessment research,
    e) Potential for additional time to collaborate within the Secretariat,
    f) A triennial assessment frequency would be consistent with the current assessment cycle of update and full assessments,
    g) The multi-year approach has precedent at other fisheries commissions

4 NEXT STEPS

A secondary set of MPs can be developed based on the performance of the primary set presented above. This may include crossing size limits with biennial assessments, tuning SPR values to best meet objectives, examining different levels of estimation error, incorporating various forms of implementation variability, or examining additional MP elements such as constraints on the inter-annual change in TCEY. This secondary set would not be a full factorial, but instead a specific investigation of relevant factors with the goal to refine the best performing MPs relative to stock and fishery objectives. Other tasks include developing performance metrics for other objectives, such as reducing discard mortality, or specifying and evaluating elements of the Harvest Strategy Policy (e.g. overfishing limit).

An important task for the MSE would be to tune the coastwide specifications to optimise a selected distribution procedure. At a minimum, that would include evaluating SPR values, but may also incorporate investigations of the control rule, size limits, assessment frequency, and constraints on the inter-annual change in TCEY. Furthermore, the MSE may evaluate elements of distribution procedures for future incorporation by the Commission.

5 SCIENTIFIC ADVICE

5.1 Clarifying a target objective

Objective 2.1 could be phrased consistently as currently stated under measurable objective to reflect that the objective is met when the relative spawning biomass is above the target (Appendix B). This would mean editing the description under "General Objective" in Appendix B to "Maintain spawning biomass [above] a level that optimi[s]es fishing activities". The Commission may choose to "tune" the SPR value such that the relative spawning biomass is more often closer to the target, while accounting for other objectives.

5.2 Size limits

The removal of a size limit meets or optimises all of the primary objectives, resulting in a 3.7% increase, on average, in the short-term median coastwide TCEY and a 2.7% increase, on average, in the long-term median coastwide TCEY. A majority of that increase occurs when reducing the size limit for directed commercial fisheries to 26 inches. Furthermore, short-term and long-term yield in all IPHC Regulatory Areas increased. Reducing the size limit for the directed commercial fishery would replace some directed commercial landings of O32 Pacific halibut with U32 landings. The magnitude of U32 landings at any point in time is dependent on population characteristics such as incoming recruitment and size-at-age. Over the long term, the price for U32 landings would need to be at least 50% of that for O32 landings to maintain a higher value in the absence of a size limit. Without a size limit for the directed commercial fishery, short-term directed commercial fishery discard mortality would decline by, on average, 78% coastwide and between 67% to 88% across IPHC Regulatory Areas.

5.3 Multi-year Assessments

A biennial assessment frequency with an empirical rule using FISS observations in non-assessment years shows similar performance to an annual assessment. This occurs because the FISS index tracks closely with the stock assessment. A triennial assessment frequency with an empirical rule using FISS observations in non-assessment years shows a slight reduction in the long-term TCEY along with a significant reduction in short-term and long-term inter-annual variability in the TCEY. Costs associated with a triennial assessment using an empirical MP that adjusts the coastwide TCEY and distribution using FISS data include 1) lack of detailed management information (e.g. estimates of SPR, stock status) every year, 2) possibly a loss in long-term yield, and 3) a chance of a smaller stock size. Benefits include 1) reduced inter-annual variability in the TCEY, 2) multi-year stability and short-term predictability of the TCEY, 3) use of the annual FISS index in a transparent process, 4) more focused assessment research, 5) potential of additional time for collaboration within the Secretariat, 6) consistency with the three-

year cycle of update and full assessments, and 7) following the precedent of other fisheries commissions.

5.4 Uncertainties not included in these MSE simulations

Relevant uncertainty was captured with the use of four OMs and five distribution procedures. However, it is unknown if the range of the five distribution procedures captures the future distribution procedures that are used. An extreme departure from the five distribution incorporated here may have an unexpected outcome on the results.

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APPENDIX B
OBJECTIVES USED BY THE COMMISSION FOR THE MSE

Table B1. Objectives, evaluated over a simulated ten-year period, reviewed 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.

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 a female spawning stock biomass above a biomass limit reference point at least 95% of the time	*SB* < Spawning Biomass Limit (SB_{Lim}) SB_{Lim}=20% unfished spawning biomass	Long-term	0.05	$P(SB < SB_{Lim})$
	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 AROUND A LEVEL THAT OPTIMIZES FISHING ACTIVITIES	Maintain the coastwide female spawning biomass above a biomass target reference point at least 50% of the time	*SB*<Spawning Biomass Target (SB_{Targ}) SB_{Targ}=36% unfished spawning biomass	Long-term	0.50	$P(SB < SB_{Targ})$
2.2. 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
2.3. 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)*

APPENDIX C
RESULTS USING METRICS ASSOCIATED WITH THE PRIMARY OBJECTIVES

Table C1. Short-term metrics associated with primary objectives for simulations (1,100 replicates) with simulated estimation error, decision-making variability option 1, and SPR=43%.

	MP	MP-A0	MP-A26	MP-A32	MP-Bb	MP-Tb
Short-term	**Biological Sustainability**					
	P(any RSB_y<20%)	0.005	0.005	0.005	0.005	0.005
	Fishery Sustainability					
	P(all RSB<36%)	0.369	0.372	0.376	0.411	0.403
	Median average TCEY	60.46	59.92	58.33	58.46	58.32
	Median average TCEY-2A	1.63	1.63	1.62	1.60	1.60
	Median average TCEY-2B	8.86	8.82	8.52	8.36	8.43
	Median average TCEY-2C	6.66	6.60	6.33	6.39	6.35
	Median average TCEY-3A	24.29	24.04	23.24	23.38	23.39
	Median average TCEY-3B	7.42	7.36	7.13	7.09	7.17
	Median average TCEY-4A	3.52	3.48	3.35	3.39	3.41
	Median average TCEY-4CDE	4.06	4.04	3.92	3.94	3.91
	Median average TCEY-4B	2.86	2.82	2.70	2.71	2.72
	P(any3 change TCEY > 15%)	0.880	0.894	0.906	0.809	0.628
	P(any3 change TCEY 2A > 15%)	0.254	0.252	0.264	0.357	0.288
	P(any3 change TCEY 2B > 15%)	0.644	0.639	0.679	0.639	0.432
	P(any3 change TCEY 2C > 15%)	0.696	0.711	0.722	0.641	0.434
	P(any3 change TCEY 3A > 15%)	0.738	0.750	0.757	0.669	0.447
	P(any3 change TCEY 3B > 15%)	0.756	0.759	0.777	0.751	0.526
	P(any3 change TCEY 4A > 15%)	0.782	0.778	0.804	0.723	0.496
	P(any3 change TCEY 4CDE > 15%)	0.514	0.527	0.524	0.430	0.241
	P(any3 change TCEY 4B > 15%)	0.771	0.753	0.781	0.709	0.442
	Median AAV TCEY	17.2%	17.5%	17.8%	17.0%	14.1%
	Median AAV TCEY 2A	2.5%	2.6%	2.7%	4.3%	1.9%
	Median AAV TCEY 2B	16.6%	17.0%	17.4%	18.4%	15.2%
	Median AAV TCEY 2C	17.8%	17.8%	18.2%	18.2%	15.0%
	Median AAV TCEY 3A	18.9%	19.1%	19.4%	19.0%	15.3%
	Median AAV TCEY 3B	19.9%	20.2%	20.7%	20.2%	16.1%
	Median AAV TCEY 4A	20.0%	20.1%	20.5%	20.8%	16.7%
	Median AAV TCEY 4CDE	15.0%	15.1%	14.9%	14.1%	11.7%
	Median AAV TCEY 4B	20.0%	19.8%	20.3%	20.5%	15.9%

Table C2. Long-term metrics associated with primary objectives for simulations (1,100 replicates) with simulated estimation error, decision-making variability option 1, and an SPR of 43%.

	MP	MP-A0	MP-A26	MP-A32	MP-Bb	MP-Tb
Long-term	**Biological Sustainability**					
	P(any RSB_y<20%)	<0.001	<0.001	<0.001	<0.001	<0.001
	Fishery Sustainability					
	P(all RSB<36%)	0.174	0.174	0.180	0.164	0.197
	Median average TCEY	63.88	63.53	62.21	61.26	62.95
	Median average TCEY-2A	1.63	1.63	1.62	1.61	1.61
	Median average TCEY-2B	9.32	9.21	9.09	8.83	8.97
	Median average TCEY-2C	7.11	7.07	6.97	6.80	6.93
	Median average TCEY-3A	26.10	26.08	25.69	25.43	26.08
	Median average TCEY-3B	8.00	8.03	7.83	7.81	7.99
	Median average TCEY-4A	3.04	3.02	2.92	2.94	2.94
	Median average TCEY-4CDE	3.46	3.40	3.32	3.44	3.46
	Median average TCEY-4B	2.85	2.82	2.70	2.69	2.66
	P(any3 change TCEY > 15%)	0.855	0.852	0.852	0.781	0.515
	P(any3 change TCEY 2A > 15%)	0.226	0.232	0.245	0.340	0.249
	P(any3 change TCEY 2B > 15%)	0.630	0.637	0.637	0.617	0.385
	P(any3 change TCEY 2C > 15%)	0.693	0.704	0.711	0.636	0.281
	P(any3 change TCEY 3A > 15%)	0.720	0.720	0.715	0.631	0.343
	P(any3 change TCEY 3B > 15%)	0.778	0.778	0.784	0.689	0.423
	P(any3 change TCEY 4A > 15%)	0.785	0.788	0.820	0.766	0.500
	P(any3 change TCEY 4CDE > 15%)	0.484	0.464	0.452	0.390	0.218
	P(any3 change TCEY 4B > 15%)	0.776	0.766	0.776	0.760	0.507
	Median AAV TCEY	15.9%	16.1%	16.3%	15.7%	11.9%
	Median AAV TCEY 2A	1.5%	1.5%	1.6%	1.9%	1.3%
	Median AAV TCEY 2B	15.8%	15.8%	16.1%	17.7%	13.7%
	Median AAV TCEY 2C	16.7%	16.9%	17.0%	17.4%	13.1%
	Median AAV TCEY 3A	16.8%	16.9%	17.2%	17.5%	13.4%
	Median AAV TCEY 3B	18.4%	18.0%	18.5%	18.7%	14.6%
	Median AAV TCEY 4A	18.5%	18.7%	19.2%	19.6%	15.3%
	Median AAV TCEY 4CDE	13.6%	13.6%	13.5%	13.0%	9.0%
	Median AAV TCEY 4B	18.3%	18.3%	18.6%	19.3%	15.7%

APPENDIX D
SUPPLEMENTARY MATERIAL

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

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

This includes a more detailed description of the MSE framework and current results in document IPHC-2023-MSE-01, and a technical description in document IPHC-2022-MSE-01.

The MSE Explorer will be updated as additional results are produced.

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/MSE-Explorer/

Results with 500 simulations, that examine a wider range of options and elements and were presented at MSAB017, are available at

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSE-MSAB017/