IPHC Management Strategy Evaluation and Harvest Strategy Policy

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PURPOSE

To provide the Commission with an update on Management Strategy Evaluation (MSE) progress in 2024 and work supporting the development of the Harvest Strategy Policy (HSP).

EXECUTIVE SUMMARY AND DECISION POINTS

A 2024 MSE workplan was provided by the Commission through intersession decisions ID003 to ID007 (IPHC Circular 2024-015). This included investigating a new objective, evaluating management procedures (MPs), defining exceptional circumstances, drafting a harvest strategy policy, and investigating different FISS design scenarios.

Objectives

The IPHC Secretariat have been discussing two objectives with the Management Strategy Advisory Board (MSAB) and Scientific Review Board (SRB). These are the $B_{36\%}$ threshold objective and the optimise yield objective. Recent adopted TCEYs have been less than the TCEY determined from the reference interim SPR of 43%, and there are concerns of low spawning biomass and low catch-rates within the fishery. The continued departure from the current interim MP and reduction in coastwide TCEY suggests that there may be an additional objective. An objective to maintain the absolute spawning biomass above a threshold may be a useful objective, which may be added in addition to the current $B_{36\%}$ threshold objective or replace it. A new objective related to fishery performance could be phrased as:

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

The SRB made a recommendation to quantify the objective to "optimise yield" (see IPHC-2024-SRB024-R, para 22 above) so that it is meaningful and can have a performance metric that identifies the best performing MP. Optimising yield may include multiple objectives, such as maximising yield and minimising variability in yield, and evaluation may include examining trade-offs between multiple objectives. The MSAB will discuss this at MSAB020.

I. **Decision Point:** *Consider potential recommendations from MSAB020 regarding adding an objective related to absolute spawning biomass and redefining what optimise yield means.*

Evaluation of management procedures

Three elements of an MP were evaluated using the MSE: assessment frequency fishing intensity, and constraints. These simulations showed that reducing the fishing intensity (i.e. higher SPR) would achieve a higher spawning biomass, slightly lower interannual variability in the TCEY, and move towards a potential new objective of avoiding low absolute spawning biomass. However, yield would be reduced, on average. Biennial and triennial assessments may improve yield and lower the interannual variability in the TCEY, also allowing more time to improve assessment and MSE methods, but at the cost of not providing detailed annual information such as stock status. The SRB noted this at SRB025.

IPHC-2024-SRB025-R, para 29: The SRB ACCEPTED that

1) there are significant benefits of moving to a triennial assessment frequency in terms of freeing Secretariat resources to conduct other quantitative analyses (see para. 22); and
2) the MSE analysis showed no apparent cost of triennial assessment in terms of lost yield or increased interannual variability in TCEY

There are trade-offs between the yield, the variability of yield, and the probability that the spawning biomass reaches levels below what has been observed in recent years. The largest effect on yield was the fishing intensity with a reduction of about 1.3 Mlbs in the TCEY, on average, for every 1% increase in the SPR. Variability did not change much across fishing intensities, but was greatly affected by the assessment frequency. The chance that spawning biomass would be less than what was observed in recent years is reduced with a reduction in fishing intensity. The usefulness of the MSE is to highlight these trade-offs for decision-makers.

II. **Decision Point:** *Consider updating the current interim reference MP with a new SPR value (currently 43%), a longer period between stock assessments (currently annual)* , and possib*ly adding a constraint on the annual change in the TCEY.*

III. **Decision Point:** *Recommend further MSE work to support modifications to the management procedure determining the coastwide TCEY.*

Three different FISS designs were also evaluated using an annual assessment frequency, a fishing intensity with SPR=43%, and no constraint. Reducing the FISS to the core areas, and occasionally surveying non-core areas would reduce yield and increase uncertainty and interannual variability in the TCEY.

IV. **Decision Point:** *Consider the MSE results evaluating FISS designs when deciding on future FISS designs.*

Analyses to support further development of the Harvest Strategy Policy

This work supports the development of the harvest strategy policy (IPHC-2024-IM100-17).

V. **Decision Point:** *Recommend further analyses to support the development of the harvest strategy policy.*

1 Introduction

A 2024 MSE workplan was provided by the Commission through intersession decisions ID003 to ID007 (IPHC Circular 2024-015). This included investigating a new objective, evaluating management procedures (MPs), defining exceptional circumstances, drafting a harvest strategy policy, and investigating different FISS design scenarios. Many of these tasks were developed from past Management Strategy Advisory Board (MSAB) and Scientific Review Board (SRB) recommendations, including recommendations related to MSE work made at the 19th session of the MSAB (IPHC-2024-MSAB019-R), the 24th session of the SRB (IPHC-2024-SRB024-R), and the 25th Session of the SRB (IPHC-2024-SRB025-R).

This document reports progress on MSE topics and simulations, and how they support the development of a harvest strategy policy.

2 Harvest Strategy Policy

A Harvest Strategy Policy (HSP) provides a framework for applying a science-based approach to setting harvest levels. At the IPHC, this is specific to the TCEY for each IPHC Regulatory Area throughout the Convention Area where allocation among IPHC Regulatory Areas is part of the decision-making process. 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. The MSE work and guidance from the MSAB and SRB have been a very important part of developing the HSP.

A management procedure (MP) determines the coastwide TCEY which is an input to the decision-making process (Figure 1). The management procedure is an agreed upon method to determine the coastwide TCEY that best meets all conservation and fishery objectives. The MP must be reproducible and include elements such as how to collect data, how often to conduct a stock assessment, and a harvest control rule that determines the fishing intensity (i.e. SPR). A harvest strategy extends the MP to encompass objectives and other procedures such as exceptional circumstances. The harvest strategy policy further includes decision-making, where Commissioners determine the distribution and the TCEY among IPHC Regulatory Areas and may deviate from the outputs of the MP to account for other objectives not considered in the harvest strategy. This may be, for example, to modify the coastwide TCEY to account for economic factors or other current conditions. The decision-making component mostly occurs at the Annual Meeting of the IPHC where stakeholder input is considered along with scientific information. Decision-making variability is one of many sources of uncertainty included in the MSE simulations to ensure that the HSP is robust to all sources of variability and uncertainty.

The interim HSP (IPHC-2024-IM100-17) is a complete document that may be endorsed by the Commission, understanding that it may be updated based on recent and continuing MSE work and recommendations from the SRB and MSAB. The MSE work presented here supports the continued development of the harvest strategy policy. More specifically, the following areas of the HSP may be updated given work completed in 2024.

- Update the Commission's priority objectives based on recommendations of the SRB and MSAB.
- Update the following elements of the coastwide management procedure based on recent MSE work: reference SPR, assessment frequency, and a constraint on the interannual change in the TCEY.
- A more complete definition of overfishing.
- Edits to the HSP text.

Outcomes of work related to objectives and results from evaluations of MPs are provided in this document.

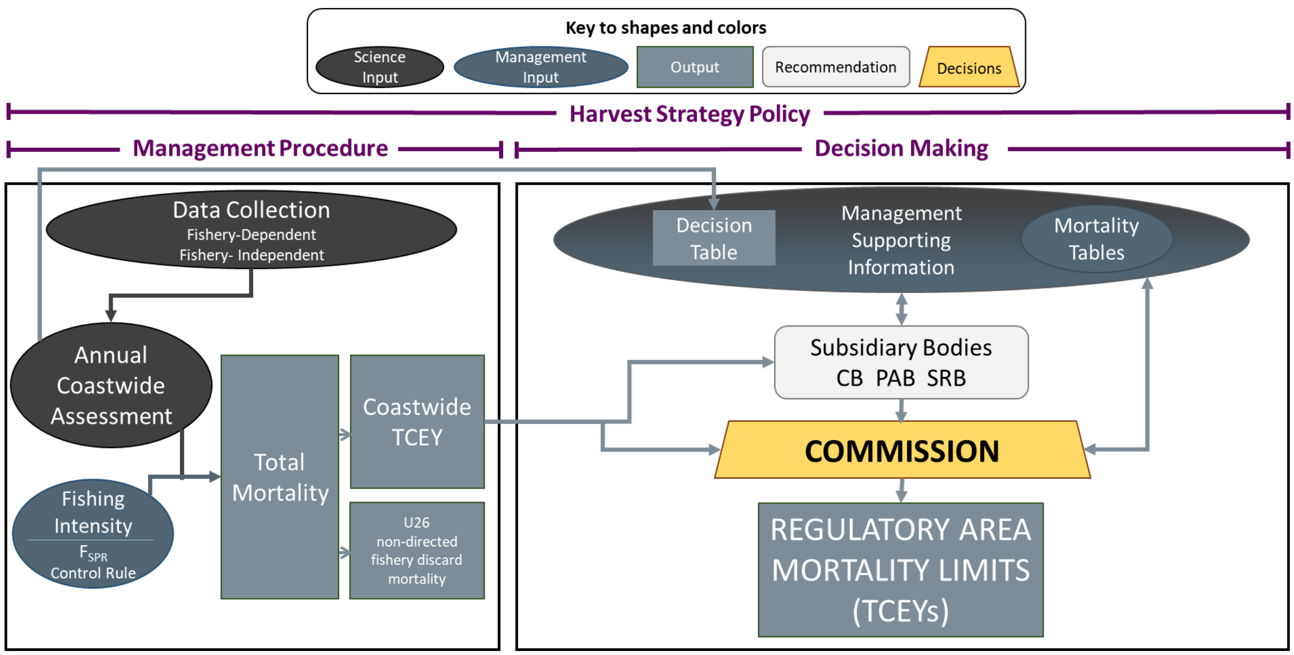

Figure 1. Illustration of the interim harvest strategy policy for the IPHC showing the determination of the coastwide TCEY (the management procedure at the coastwide scale) and the decision-making component that mainly occurs at the Annual Meeting.

2.1 Exceptional Circumstances

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

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

> **IPHC-2024-SRB024-R, para 25**. ***RECALLING*** *paper IPHC-2024-SRB024-03, Appendix A, SRB023-Rec.08 (para. 27), the SRB* ***RECOMMENDED****:*
>
> > *a) removing "exceptional circumstance" item c because the expected timeline of stock assessments and OM updates will automatically revise biological parameters and processes;*
> >
> > *b) removing "exceptional circumstance" item b because:*
> >
> > > • *even though the operating model is an adequate representation of the coastwide dynamics and is useful for development of a coastwide MP, additional work on the regional stock dynamics needs to be done to improve correspondence with regional observations;*
> > >
> > > • *improving estimation of regional stock dynamics is a longer-term project that the Secretariat will continue to work on with input from the SRB;*
> > >
> > > • *as per paragraph 21, the SRB suggests that the annual TCEY distribution should not be included in a MP.*

Therefore, one trigger, using coastwide WPUE or NPUE, for an exceptional circumstance has been defined.

> *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.*

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

> **IPHC-2024-MSAB019-R, para. 53:** *The MSAB* ***NOTED*** *that the FISS is conducted to measure the population and that it may not be an accurate depiction of the fishery, and that fishery-dependent data may provide insights into fishery concerns that the FISS may not capture.*
>
> **IPHC-2024-MSAB019-R, para. 54:** *The MSAB* ***REQUESTED*** *that the SRB and Secretariat work together to consider different ways to incorporate fishery-dependent data into an exceptional circumstance.*

The MSE simulations predict many types of fishery-dependent data (e.g. WPUE, age-compositions) which may be used to develop additional exceptional circumstances. It will be important to delineate between changes in fishery dependant data that should fall within the scope of the MSE predictions and those that may be caused by management actions not reflective of Pacific halibut stock dynamics (e.g. change in catch rates due to avoidance/targeting of other species). The response in these two cases may be different. Further consideration of exceptional circumstances incorporating fishery-dependent data will continue.

Potentially useful fishery-dependent metrics to base an exceptional circumstance on relate to the adopted TCEY or realized fishing mortality. These are important sources of uncertainty to simulate, and using them to define an exceptional circumstance would ensure that the simulations are appropriately capturing future realizations. The SRB made the following recommendations related to this topic.

IPHC-2024-SRB025-R, para. 26: The SRB strongly **RECOMMENDED** against using MSE (a strategic tool) in the annual TCEY setting process. Exceptional circumstances checks (on WPUE and CATCH) are used to judge whether management procedures are generating appropriate recommendations in a given year.

IPHC-2024-SRB025-R, para. 30: The SRB **RECOMMENDED** adopting realised coastwide catch as a fishery-dependent indicator for testing exceptional circumstances. Realised coastwide catch each year can be compared to the projected distribution of future TCEY for that year to determine whether biological or management processes (e.g. decision variability) are leading to unexpected TCEY.

Therefore, a second exceptional circumstance could be:

> *The realized coastwide fishing mortality is above the 97.5th percentile or below the 2.5th percentile of the simulated realized coastwide fishing mortality for two or more consecutive years.*

This exceptional circumstance would capture both the decision-making process and the implementation variability of the fisheries (e.g. not realizing the exact adopted TCEY).

3 Goals and Objectives

The Commission defined four priority coastwide objectives and associated performance metrics for evaluating MSE simulations.

> **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).

The SRB recommended reconsidering two of these objectives.

IPHC-2024-SRB024-R, para 22. *The SRB **RECOMMENDED** that the Commission develop a more specific and quantifiable catch objective to replace Objective c) (from AM099–Rec.02) "Optimize average coastwide TCEY".*

IPHC-2024-SRB024-R, para 23. *The SRB **RECOMMENDED** that the Commission consider revising Objective b) (from AM099–Rec.02) "Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point (B36%) 50% or more of the time" to utilise a lower percentile than the 50th (median) to reflect concerns associated with the implications of low CPUE for the fishery at the 36% target for relative spawning biomass. A lower percentile better captures the role of uncertainty in this performance measure.*

3.1 Considering the $RSB_{36\%}$ objective

The MSAB made a similar recommendation at MSAB019 to discuss a new objective, which will be discussed at the 20th Session of the MSAB (MSAB020).

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

Pacific halibut have seen large changes in average weight-at-age and high variability in recruitment, which have changed the stock dynamics considerably. Figure 2 shows the dynamic unfished spawning biomass, the current spawning biomass, and the RSB since 1993,as estimated in the 2023 stock assessment for Pacific halibut (IPHC-2024-SA-01). 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 3), 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 2022 to 2023 and coastwide commercial WPUE was also at its lowest value in the recent time-series, declining by 10% from the 2022 to 2023 (and likely more as additional logbook information is obtained). In contrast, the stock assessment for 2023 estimates current stock status (42%, Figure 2) 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 was projected to result in a greater than 70% chance that the spawning biomass in any of the next three years would be less than the spawning biomass in 2023. The long-term average RSB when fishing consistently at an SPR of 43% is estimated to be near 38%.

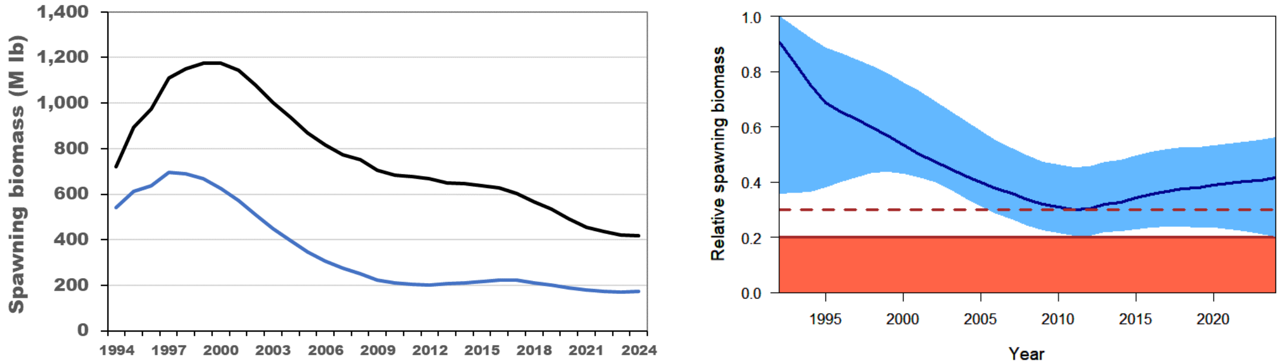

Figure 2. Dynamic unfished spawning biomass (black line) and current spawning biomass (blue line) from the 2023 stock assessment (left) and dynamic relative spawning biomass (right) with an approximate 95% credible interval in light blue and the control rule limit ($B_{20\%}$) and trigger ($B_{30\%}$) in red. Figures from IPHC-2024-SA-01.

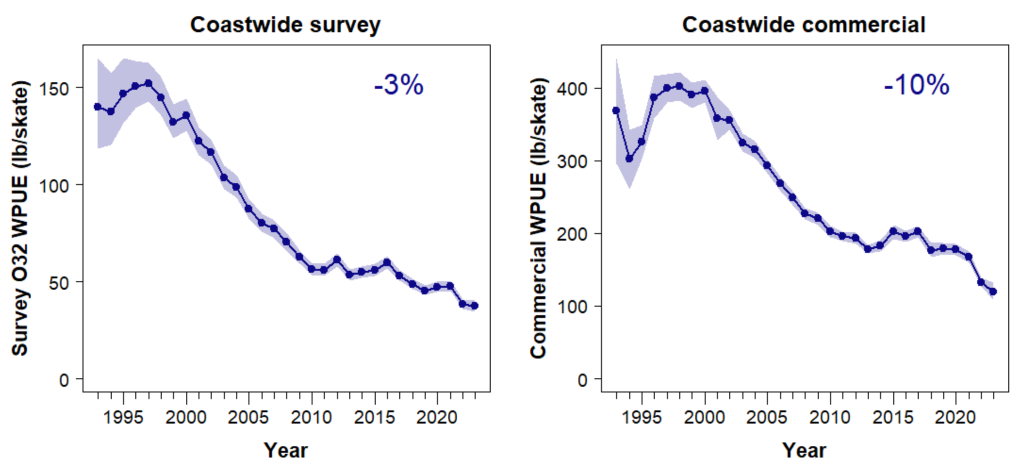

Figure 3. The coastwide FISS O32 WPUE index (left) and coastwide commercial WPUE (right) showing the percent change in the last year (from IPHC-2024-SA-02). Based on past calculations, additional logbooks collected in 2024 will likely further reduce the decline in commercial WPUE to -12%.

Recent Commission decisions (2023 and 2024) have set coastwide TCEYs less than the reference TCEY estimated by the stock assessment and current interim management strategy. 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 a 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 initially made a recommendation to re-evaluate what they called the target objective (IPHC-2023-SRB023-R, para. 25), followed by the recommendation at SRB024 to further modify this objective (IPHC-2024-SRB024-R, para 23). Most recently, the SRB made the following recommendation.

> **IPHC-2024-SRB025-R, para. 31.** The SRB **RECOMMENDED** adding a measurable objective related to absolute spawning biomass under the general objective 2.1 "maintain spawning biomass at or above a level that optimises fishing activities" to be included in the priority Commission objectives after, or in place of, the current relative biomass threshold objective

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 observed fishery catch rates were historically low in 2022 and 2023.

One way to implement this new objective is to continue the use of a conservation limit reference point for relative spawning biomass ($RSB_{20\%}$) and add a fishery biomass threshold reference point for which dropping below would result in serious hardships to the fishery. The fishery biomass threshold reference point could be defined using an absolute metric in units of spawning biomass, for example. A fishery threshold differs importantly from a conservation limit reference point, where a fishery threshold is used to maintain catch-rates and a conservation limit is used to indicate an overfished stock. A fishery absolute spawning biomass threshold may also add extra protection for the stock by further reducing the probability of breaching existing limit and threshold reference points ($RSB_{20\%}$ and $RSB_{36\%}$, respectively). A new objective related to fishery performance could be phrased as:

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

The metric, the threshold value, 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.

3.2 Considering the optimise yield objective

The SRB made a recommendation to quantify the objective to “optimise yield” (see IPHC-2024-SRB024-R, para 22 above) so that it is meaningful and can have a performance metric that identifies the best performing MP. Optimising yield may include multiple objectives, such as maximising yield and minimising variability in yield, and evaluation may include examining trade-offs between multiple objectives. The MSAB will discuss this at MSAB020.

4 Management Procedures Evaluated

The MSAB made two requests at MSAB020, which coincide with SRB and Commission recommendations, providing guidance on management procedures (MPs) to evaluate. The investigation of these MPs will support the development of the harvest strategy policy.

> **IPHC-2024-MSAB019-R, para. 39**. The MSAB **REQUESTED** that the evaluation of annual, biennial, and triennial assessments include, but is not limited to, the following concepts.
>
> - Annual changes in the coastwide TCEY is driven by an empirical rule in non-assessment years of a multi-year MP;
> - A constraint on the coastwide TCEY to reduce inter-annual variability and the potential for large changes in every year or only assessment years. This may be a 10%, 15%, or 20% constraint, a slow-up fast-down approach, or similar approach;
> - SPR values ranging from 35% to 52%.

Elements of MPs that were evaluated included assessment frequency, fishing intensity, and constraints on the interannual change in the TCEY. Additionally, different FISS designs were simulated to evaluate the impacts of reduced sampling including eliminating non-core areas. Distribution of the TCEY to IPHC Regulatory Areas is not under evaluation and is implemented as a source of variability.

4.1 Assessment frequency and an empirical management procedure

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

The mortality limits in a year with a stock assessment can be determined using an SPR-based approach, and in years without a stock assessment, the mortality limits would use an empirical rule. The only empirical rule evaluated in 2024 was to update the coastwide TCEY proportionally to the change in the coastwide FISS O32 WPUE.

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

4.2 Fishing intensity

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

4.3 Constraints

One of the priority objectives (Appendix A) is to limit annual changes in the coastwide TCEY. Due to variability in many different processes (e.g. population, estimation, and decision making) the interannual variability of the TCEY from MSE simulations is typically higher than 15%. Over the past ten years (2015–2024), the interannual variability (average annual variability or AAV) in the adopted coastwide TCEY was 5.4% and the AAV of the reference coastwide TCEY was 14.5%. Across those years, the percent change in the adopted coastwide TCEY ranged from -10% to 8% and the coastwide reference TCEY ranged from -21% to 29% (Table 1). This was a period of relatively stable spawning biomass and higher variability is expected when the stock is increasing or decreasing.

Decision-making since 2015 has reduced the interannual variability in the coastwide TCEY, compared to the reference. The adopted TCEYs have a smaller range than the reference TCEYs and tend to cluster around 39 million pounds. The adopted TCEYs also tend to be closer to the status quo (i.e. the TCEY from the previous year) than the reference TCEYs when the reference TCEY difference from status quo was not near zero (Table 1). This is akin to saying the change from one year to the next is less for the adopted TCEYs than the reference TCEYs. The spawning biomass has been relatively stable during the last ten years, and it is not known how the recent decision-making process would react to a rapidly increasing or decreasing spawning biomass. Therefore, decision-making variability was modelled as a normal random process in the OM with a fixed standard deviation of 7Mlbs. This is more variability than recently observed but ensures that the evaluations are robust to potential variability in the future.

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

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

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

Constraints simulated in this round of MSE analyses included the following:

- A maximum 15% change in the coastwide TCEY in either direction from one year to the next (15% up/down).
- A maximum 15% change in the coastwide TCEY only when the TCEY is increasing from one year to the next (15% up).

4.4 FISS designs

An element of the management procedure that can be evaluated is the collection of data from the FISS. The recently implemented FISS design was reduced from the proposed scientific designs in 2022, 2023, and 2024 to maintain revenue neutrality and future reductions may be necessary. The SRB made two recommendations to evaluate FISS designs using the MSE framework:

> **IPHC-2024-SRB024-R, para** 35. *The SRB **REQUESTED** that the Secretariat present preliminary (at SRB025) and final (at SRB026) results of MSE runs with different FISS designs to better understand the actual net cost of the survey after accounting for potential reductions in TCEY associated with the increased uncertainty from reduced FISS designs.*
>
> **IPHC-2024-SRB024-R, para** 43. *The SRB **REQUESTED** that the Secretariat integrate FISS design considerations into the annual MSE workplan and 5-Year Program of Integrated Research and Monitoring to better quantify the value provided by the FISS.*

There are three sources of variability and uncertainty in the simulations, all of which may be affected by the FISS design.

- **FISS uncertainty** affects the estimates of FISS WPUE and NPUE directly. This is used in the empirical rule and affects the stock assessment estimates. It may have some feedback into decision-making variability.

- **Estimation error** is from the stock assessment and is influenced by FISS uncertainty. Estimation error is also influenced by the variability in the population and fishery-dependent data.
- **Decision-making variability** is the variability resulting from decisions made by the Commission to depart from the MP. This could be affected by bias in the FISS and assessment estimates because the Commission may respond similarly based on the trends they perceive (e.g. autocorrelation in the deviations from the MP). It is possible to correlate decision-making with the FISS estimate, but this may mimic a control rule (i.e. element of the MP) and would conflate the estimation error with the decision-making variability, possibly making performance metrics, such as the probability that the spawning biomass is less than the 2023 spawning biomass, less meaningful. Decision-making variability is currently modelled independently of FISS uncertainty.

The MSE framework is capable of examining FISS designs, given the necessary inputs. Projections of estimated uncertainty of FISS O32 WPUE (see document IPHC-2024-SRB024-06) and simulations investigating the outcomes of the stock assessment given different FISS design assumptions (see IPHC-2024-SRB025-06) informed the inputs to the MSE simulations. Unlike the stock assessment simulations, where specific trends in the population are investigated, the MSE simulations have emergent trends influencing uncertainty and bias. The MSE is also able to determine the long-term effects on yield and population status.

Three FISS designs were simulated, representing increasing observation and assessment error (Table 2). The Base Block FISS design includes sampling in all Biological Regions and IPHC Regulatory Areas each year. It relies on a rotating selection of entire charter regions where individual charter regions are sampled every 1-5 years. The Core FISS design samples charter regions in IPHC Regulatory Areas 2B, 2C, 3A, and 3B every year and other areas are not surveyed. The Reduced Core FISS design samples a subset of higher catch-rate charter regions in areas 2B, 2C, 3A, and 3B. Bias is expected in the Core and Reduced Core FISS designs because some areas are not surveyed. It would not be expected that either of these core designs would be implemented in perpetuity without occasionally surveying other areas.

The Core FISS and Reduced Core FISS designs have additional details in how bias is modelled. Bias is additive depending on the trend in spawning biomass, and is halved when a survey is done in non-core areas. When the spawning biomass is large, the survey is more likely to be revenue neutral increasing the ability to survey non-core areas. Further details are provided in IPHC-2024-SRB025-07.

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

Table 2. Assumptions of observation and estimation error for four FISS designs.

FISS Design	Frequency	Coastwide WPUE CV	Coastwide WPUE Bias	Assessment Uncertainty	Assessment Bias
Base Block	Every year	4%	None	18%	None
Core	2-4 years	6%	Increases annually up to 3%	19%	Increases annually up to 2%
Reduced Core	2-4 years	8%	Increases annually up to 4%	20%	Increases annually up to 2.5%

5 Results

5.1 Assessment frequency, fishing intensity, and constraints

Assessment frequency, different fishing intensities (SPR), and a constraint were simulated assuming a Base Block FISS design with estimation error and decision-making variability. Performance metrics associated with the four priority objectives are shown in Table 3. The probability of being below a relative spawning biomass (RSB) of 36% was similar for each assessment frequency at the same fishing intensity, and an SPR of 40% resulted in an RSB near 36%. The short-term median TCEY increased and the AAV decreased as the assessment frequency increased; this is opposite of the expected pattern that a greater TCEY results in a higher AAV. The AAV was lowest with the triennial assessment frequency but was greater than 15% (a past benchmark defined by the MSAB) for all fishing intensities and assessment frequencies. For the annual and biennial assessment frequencies, the AAV was lowest (but above 22%) for a fishing intensity of 46% and increased with lower and higher fishing intensities. This may be a consequence of how decision-making variability was modelled (i.e. constant standard deviation).

Short- and long-term performance metrics for the probability that the spawning biomass is less than the spawning biomass in 2023 provide insight into the chance of being at spawning biomass levels seen in recent years (Table 4). There is a greater than 25% (1 in 4) chance that the spawning biomass is less than the spawning biomass in 2023 when fishing at an SPR=40% and a near 20% (1 in 5) chance when fishing at an SPR=49% in the long-term. These probabilities increase to 51% and 34% in the short-term (projections of 4–13 years) for those same SPR values.

Including a constraint of 15% when the TCEY goes up or down in the MP reduced the AAV, although the AAV remained above 15% with decision-making variability, and also reduced the yield (Table 5). This resulted in a smaller probability of the RSB being less than 36%. The 15% constraint resulted in a lower potential range of TCEYs with the 5th percentile of the TCEY as low as 14.7 M lbs (Figure 4). The constraint of 15% only when the TCEY is increasing (15% up) showed similar results, but with a slightly higher yield. The yield was less with a constraint because increases from small TCEYs were smaller given a maximum percent change resulting in small absolute changes.

Table 3. Performance metrics associated with priority objectives for various fishing intensities (SPR) and an annual, biennial, or triennial assessment with an empirical rule proportional to FISS O32 WPUE used to determine the TCEY in non-assessment years. All simulations assumed the Base Block FISS design, estimation error, and decision-making variability. No constraints are applied to the interannual change in the TCEY. Relative spawning biomass (RSB) performance metrics are long-term and yield based performance metrics (TCEY and AAV) are short-term metrics.

Assessment Frequency	**Annual**				
SPR	**40**	**43**	**46**	**49**	**52**
P(RSB<20%)	<0.001	<0.001	<0.001	<0.001	<0.001
P(RSB<36%)	0.4534	0.2466	0.0896	0.0144	0.0012
Median TCEY	64.26	60.11	56.08	52.03	47.87
AAV	25.3%	24.2%	23.5%	23.5%	23.7%
Assessment Frequency	**Biennial**				
SPR	**40**	**43**	**46**	**49**	**52**
P(RSB<20%)	<0.001	<0.001	<0.001	<0.001	<0.001
P(RSB<36%)	0.4638	0.2912	0.1294	0.0400	0.0066
Median TCEY	64.96	60.38	56.28	52.27	48.17
AAV	23.3%	22.6%	22.5%	22.8%	23.5%
Assessment Frequency	**Triennial**				
SPR	**40**	**43**	**46**	**49**	**52**
P(RSB<20%)	<0.001	<0.001	<0.001	<0.001	<0.001
P(RSB<36%)	0.4734	0.2882	0.1338	0.0526	0.0094
Median TCEY	65.50	61.04	56.96	53.57	49.11
AAV	20.7%	20.1%	20.0%	20.5%	21.0%

Table 4. The probability that the spawning biomass is less than the spawning biomass in 2023 for various fishing intensities (SPR) and an annual, biennial, or triennial assessment with an empirical rule proportional to FISS O32 WPUE used to determine the TCEY in non-assessment years. All simulations assumed the Base Block FISS design, estimation error, and decision-making variability. No constraints are applied to the interannual change in the TCEY. Short-term performance metrics are 4-13 years into the projection period.

Assessment Frequency	**Annual**				
SPR	**40**	**43**	**46**	**49**	**52**
Long-term P(SB < SB_{2023})	0.308	0.272	0.230	0.196	0.164
Short-term P(SB < SB_{2023})	0.490	0.428	0.362	0.316	0.282
Assessment Frequency	**Biennial**				
SPR	**40**	**43**	**46**	**49**	**52**
Long-term P(SB < SB_{2023})	0.322	0.278	0.248	0.212	0.168
Short-term P(SB < SB_{2023})	0.488	0.442	0.372	0.322	0.288
Assessment Frequency	**Triennial**				
SPR	**40**	**43**	**46**	**49**	**52**
Long-term P(SB < SB_{2023})	0.316	0.282	0.232	0.202	0.172
Short-term P(SB < SB_{2023})	0.510	0.484	0.394	0.340	0.292

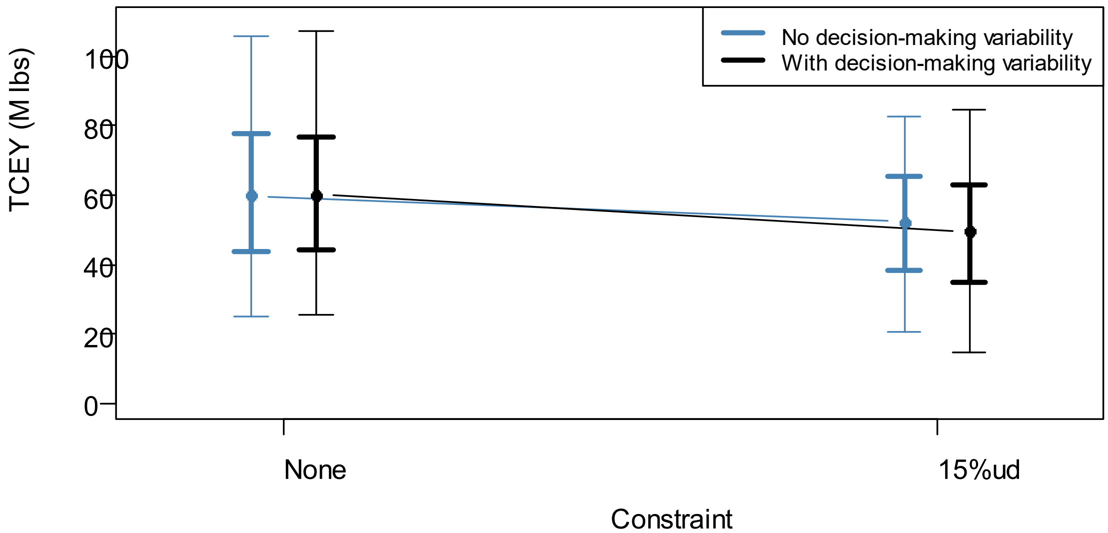

Figure 4. The TCEY (M lbs) for simulations with and without a constraint (15% maximum change up or down) and with and without decision-making variability. All simulations assumed the Base Block FISS design, an annual assessment, and an SPR of 43%. Light whiskers show the 5-95% interval, dark whiskers the 25-75% interval and the dot the median.

Table 5. Performance metrics associated with priority objectives for an SPR of 43% and an annual assessment with and without a 15% constraint on the change in the TCEY (up/down or only up). All simulations assumed the Base Block FISS design. Relative spawning biomass (RSB) performance metrics are long-term and yield based performance metrics (TCEY and AAV) are short-term metrics.

Constraint	None	15% up/down	15% up
P(RSB<20%)	<0.001	<0.001	<0.001
P(RSB<36%)	0.2466	0.0506	0.0528
Median TCEY	60.11	49.51	51.55
AAV	24.2%	16.6%	16.7%

Without decision-making variability, the AAVs were less for the annual assessment frequency and slightly less than 15% with the constraint (Table 6). Without a constraint the median TCEY was slightly less without decision-making variability, and with a constraint the median TCEY was slightly larger, although less than without a constraint.

Table 6. Performance metrics associated with priority objectives with and without decision-making variability for an SPR of 43% and an annual assessment with and without a 15% constraint on the change in the TCEY (up/down). All simulations assumed the Base Block FISS design. Relative spawning biomass (RSB) performance metrics are long-term and yield based performance metrics (TCEY and AAV) are short-term metrics.

Constraint	**None**		**15% up/down**	
Decision-making variability	**Yes**	**None**	**Yes**	**None**
P(RSB<20%)	<0.001	<0.001	<0.001	<0.001
P(RSB<36%)	0.2466	0.2420	0.0506	0.0564
Median TCEY	60.11	59.92	49.51	52.30
AAV	24.2%	20.8%	16.6%	14.5%

Overall, the range of SPR values investigated and the three assessment frequencies met the conservation objective and the objective to remain above an RSB of 36% at least 50% of the time. The TCEY increased with higher fishing intensity and was slightly higher with a longer interval between assessments. The interannual variability in the TCEY was greater than 15% but lowest with a triennial assessment frequency. The triennial assessment frequency showed potential increases in the TCEY but larger potential change in an assessment year. AAV was lowest with an SPR between 43% and 46%, and unexpectedly increased at lower fishing intensities, which is likely due to decision-making variability.

5.2 FISS Designs

The three FISS designs were compared across multiple fishing intensities, but with the annual assessment frequency only. Decision-making variability was present in all simulations.

The conservation objective of remaining above an RSB of 20% was met for all fishing intensities and FISS designs (Table 7). The probability that the RSB was less than 36% decreased with the reduced FISS designs, indicating that the population size was slightly larger when the non-core areas were not sampled. This occurred because the median TCEY was less when using the Core FISS design compared to the Base Block FISS design, and was less again when using the Reduced Core FISS design compared to the Core FISS design. The AAV increased with the Core and Reduced Core FISS designs (Figure 5).

With an SPR of 43%, the median TCEY declined by 450,000 lbs when moving to the Core FISS design from the Base Block FISS design, and another 450,000 lbs when moving to the Reduced Core FISS design. At $6.00/lb, a 450,000 lb drop in the TCEY would equate to a $2.7 million reduction in economic value. A similar drop occurred for an SPR of 52%. This metric includes the long-term, multi-year result where a reduction in the TCEY may provide fish for future years to spawn or be caught at a larger size. This may be why this value is less than the value determined from the stock assessment simulation results reported in document IPHC-2024-SRB025-06. As also discussed in document IPHC-2024-SRB025-06, there is a non-economic value to the FISS in that it is used for decision-making, comparisons, and to have a better understanding of the population trends.

Table 7. Performance metrics associated with priority objectives for various fishing intensities (SPR) and different FISS designs. All simulations assumed an annual assessment and decision-making variability. No constraints were applied to the interannual change in the TCEY. Relative spawning biomass (RSB) performance metrics are long-term and yield based performance metrics (TCEY and AAV) are short-term metrics.

FISS design	**Base Block**			
SPR	**43%**	**46%**	**49%**	**52%**
P(RSB<20%)	<0.002	<0.002	<0.002	<0.002
P(RSB<36%)	0.2466	0.0896	0.0144	0.0012
Median TCEY	60.11	56.08	52.03	47.87
AAV	24.2%	23.5%	23.5%	23.7%
FISS design	**Core**			
SPR	**43%**	**46%**	**49%**	**52%**
P(RSB<20%)	<0.002	<0.002	<0.002	<0.002
P(RSB<36%)	0.2308	0.0856	0.0164	0.0010
Median TCEY	59.66	55.30	51.23	47.32
AAV	24.9%	24.0%	24.0%	24.4%
FISS design	**Reduced Core**			
SPR	**43%**	**46%**	**49%**	**52%**
P(RSB<20%)	<0.002	<0.002	<0.002	<0.002
P(RSB<36%)	0.2256	0.0860	0.0180	0.0012
Median TCEY	59.21	55.10	50.88	47.07
AAV	26.4%	25.5%	25.0%	25.3%

6 CONCLUSIONS

Three elements of an MP were evaluated using the MSE: assessment frequency fishing intensity, and constraints. These simulations showed that reducing the fishing intensity (i.e. higher SPR) would achieve a higher spawning biomass, slightly lower interannual variability in the TCEY, and move towards a potential new objective of avoiding low absolute spawning biomass. However, yield would be reduced, on average. Biennial and triennial assessments may improve yield and lower the interannual variability in the TCEY, also allowing more time to improve assessment and MSE methods, but at the cost of not providing detailed annual information such as stock status. The SRB noted this at SRB025.

IPHC-2024-SRB025-R, para 29: The SRB **ACCEPTED** that

3) there are significant benefits of moving to a triennial assessment frequency in terms of freeing Secretariat resources to conduct other quantitative analyses (see para. 22); and
4) the MSE analysis showed no apparent cost of triennial assessment in terms of lost yield or increased interannual variability in TCEY

Furthermore, three different FISS designs were evaluated with an annual assessment frequency, a fishing intensity with SPR=43%, and no constraint. Reducing the FISS to the core areas, and occasionally surveying non-core areas would reduce yield and increase uncertainty and interannual variability in the TCEY.

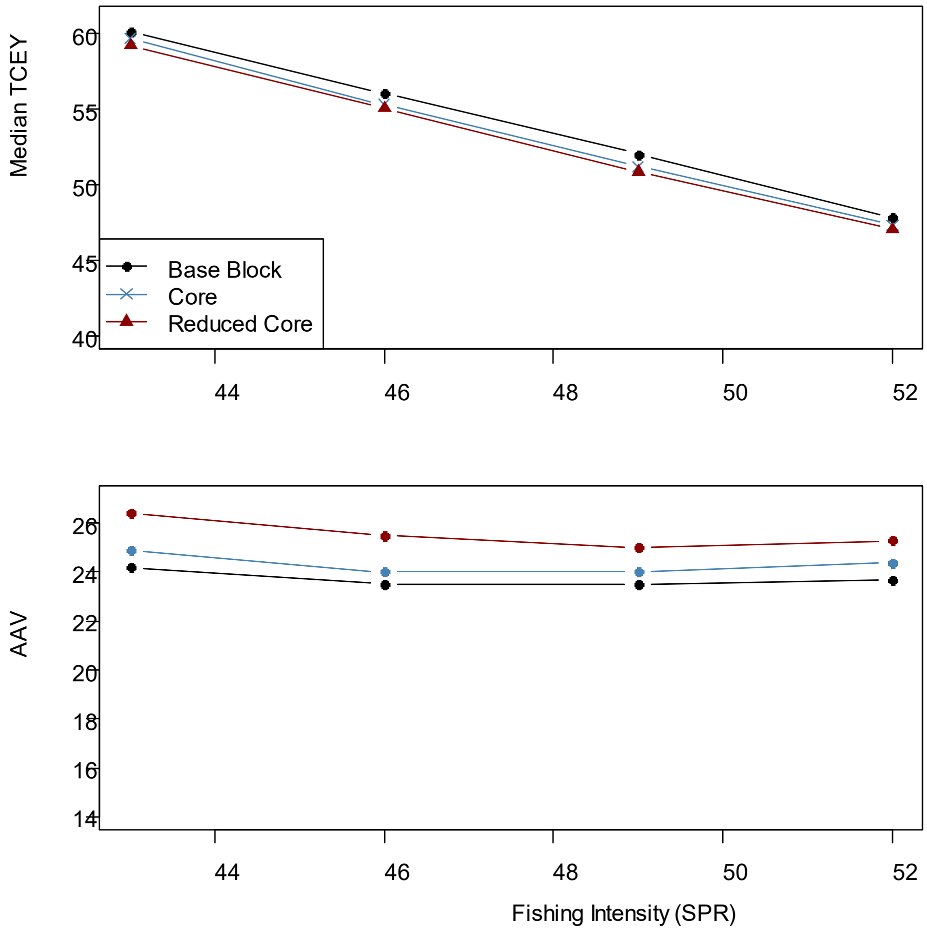

Figure 5. Median TCEY (top) and AAV (bottom) for different fishing intensities (SPR) and FISS designs.

There are trade-offs between the yield, the variability of yield, and the probability that the spawning biomass reaches levels below what has been observed in recent years. The largest effect on yield was the fishing intensity with a reduction of about 1.3 Mlbs in the TCEY, on average, for every 1% increase in the SPR. Variability did not change much across fishing intensities, but was greatly affected by the assessment frequency and the FISS design. The chance that spawning biomass would be less than what was observed in recent years is reduced with a reduction in fishing intensity. The usefulness of the MSE is to highlight these trade-offs for decision-makers.

This work supports the development of the harvest strategy policy (IPHC-2024-IM100-17). Next steps include working with the MSAB to recommend updated objectives and endorse the MSE simulation results, and then presenting this work to the Commission along with an updated harvest strategy policy for their endorsement.

RECOMMENDATION/S

That the Commission:

1) **NOTE** paper IPHC-2024-IM100-12 presenting recent MSE work including exceptional circumstances; goals and objectives; evaluating assessment frequency, a constraint and fishing intensity; and investigating the effects of reduced FISS designs.
2) **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, or in place of, the current biomass threshold objective.
3) **RECOMMEND** redefining the general objective to optimize yield to include measurable objectives with specifics related to amount of yield and possibly variability in yield.
4) **RECOMMEND** updating the current interim reference MP with a new SPR value (currently 43%), a longer period between stock assessments (currently annual), and possibly a constraint on the annual change in the TCEY.
5) **RECOMMEND** further analyses to support the development of the harvest strategy policy.
6) **REQUEST** any further analyses to be provided at IM100.

REFERENCES

de Moor, C. L., D. Butterworth, and S. Johnston. 2022. "Learning from three decades of Management Strategy Evaluation in South Africa." *ICES Journal of Marine Science* 79: 1843-1852.

APPENDICES

Appendix A: Primary objectives 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

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

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