



MSE update on progress in 2024 and development of a revised Harvest Strategy Policy

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PURPOSE

To provide the Management Strategy Advisory Board (MSAB) with an update on Management Strategy Evaluation (MSE) progress in 2024 and work supporting the development of the harvest strategy policy (HSP).

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 MSAB and Scientific Review Board (SRB) recommendations, including recommendations related to MSE work made at the 19th session of the MSAB and the 24th session of the SRB ([IPHC-2024-SRB024-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 could be specific to the TCEY for each IPHC Regulatory Area throughout the Convention Area, or it could apply to coastwide decisions, leaving specific allocation among areas and sectors to 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. To move towards formally adopting a HSP at the IPHC in the near term, the SRB recommended separating the coastwide TCEY management procedure (MP) from the distribution procedure.

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

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

Therefore, the IPHC HSP can be divided into two components: management procedure and decision-making (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 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 management may deviate from the outputs of the MP to account for other objectives not considered in the harvest strategy. This may be to modify the coastwide TCEY and/or the distribution of the TCEY to account for economic factors or other current conditions. At the IPHC, the policy component mostly occurs at the Annual Meeting of the IPHC where stakeholder input is considered along with scientific information to determine the coastwide mortality limit and allocations to each IPHC Regulatory Area. Decision-making variability is included in the MSE simulations to ensure that the HSP is robust to all sources of variability and uncertainty.

The MSE work presented here supports the continued development of the harvest strategy policy.

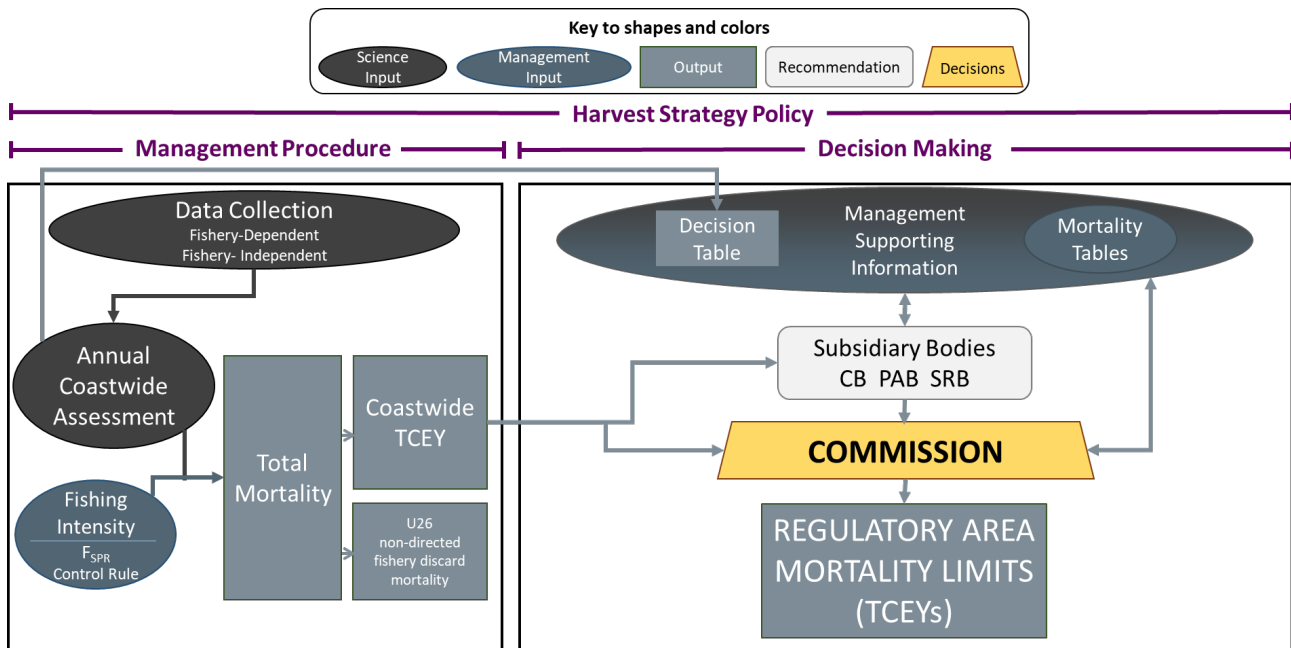


Figure 1. Illustration of the interim harvest strategy policy for the IPHC showing the determination of the coastwide TCEY (the management procedure at the coastwide scale) and the decision-making component that mainly occurs at the Annual Meeting.

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. This decision-making variability is included in the MSE simulations.

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

- a) A review of the MSE simulations to determine if the OM can be improved and MPs should be reevaluated.
- b) If a multi-year MP was implemented and an exceptional circumstance occurred in a year without a stock assessment, a stock assessment would be completed as soon as possible along with the re-examination of the MSE.
- c) Consult with the SRB and MSAB to identify why the exceptional circumstance occurred, what can be done to resolve it, and determine a set of MPs to evaluate with an updated OM.
- d) Further consult with the SRB and MSAB after simulations are complete to identify whether a new MP is appropriate.

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

[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 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.*

The 4th ad hoc meeting of the MSAB met in July to discuss objectives, which is summarized in an informational document for MSAB020 ([IPHC-2024-MSAB020-INF01](#)). Some highlights include the following, which will be discussed at MSAB020.

10. A management procedure defined as a reference fishing intensity or more conservative would provide flexibility to the Commission to reduce fishing intensity when short-term trends are of concern.

12. The objective “optimize yield” may include reducing interannual variability in yield.

13. A new objective may be defined using absolute biomass, commercial catch-rates, or TCEY. However, commercial catch-rates may not be the best option because they are dependent on other factors. TCEY and/or a reference absolute spawning biomass based on what has been observed may be more meaningful, but all have downsides in being a holistic metric. The MSAB should explore these metrics (and possibly FISS WPUE) for use in updating the objectives.

14. Evaluating MPs based on performance of the worst conditions (e.g. low productivity regime) may result in avoiding low stock sizes under any conditions.

15. Objectives, such as avoiding low stock sizes or low catch-rates, may be met by adding elements to the MP, such as reducing fishing intensity when the SB is below a threshold.

17. There is likely a desire to remain above the absolute spawning biomass in 2023 and the tolerance could be 80 or 90%

The 4th ad hoc meeting of the MSAB discussed the objective “optimize yield” and realized that optimizing yield may include multiple factors such as high yields and low interannual variability. Both of these concepts are important objectives and will be discussed at MSAB020.

Much of the discussion at the 4th ad hoc meeting of the MSAB centered around understanding the underlying objectives based on recent decisions to reduce the TCEY from the reference TCEY. This is due to a contrast between the stock status being above 36% (a healthy zone) and a continually declining absolute spawning biomass. The MSAB made a recommendation at MSAB019 to discuss a new objective.

[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. 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 the previous year and coastwide commercial WPUE is also at its lowest value in the recent time-series, declining by 10% from the previous year (and likely more as additional logbook information is obtained). In contrast, the stock assessment for 2023 estimates current stock status (42%, Figure 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%.

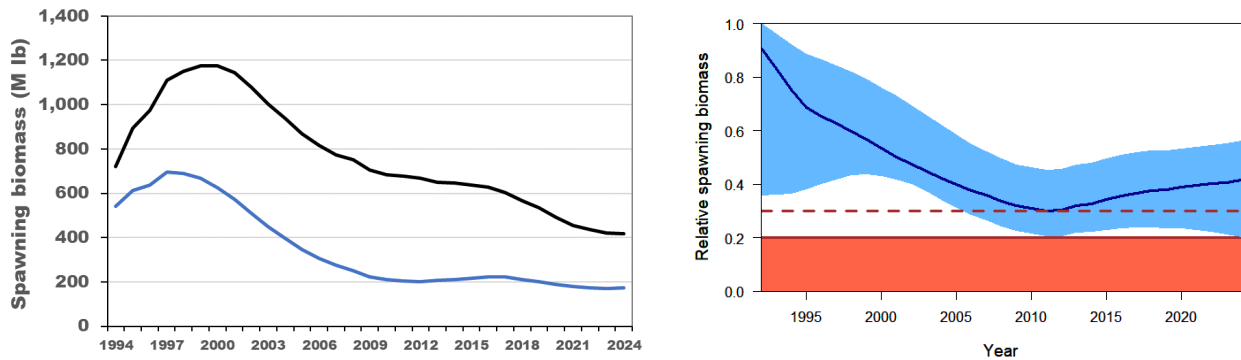


Figure 2. Dynamic unfished spawning biomass (black line) and current spawning biomass (blue line) from the 2023 stock assessment (left) and dynamic relative spawning biomass (right) with an approximate 95% credible interval in light blue and the control rule limit ($B_{20\%}$) and trigger ($B_{30\%}$)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

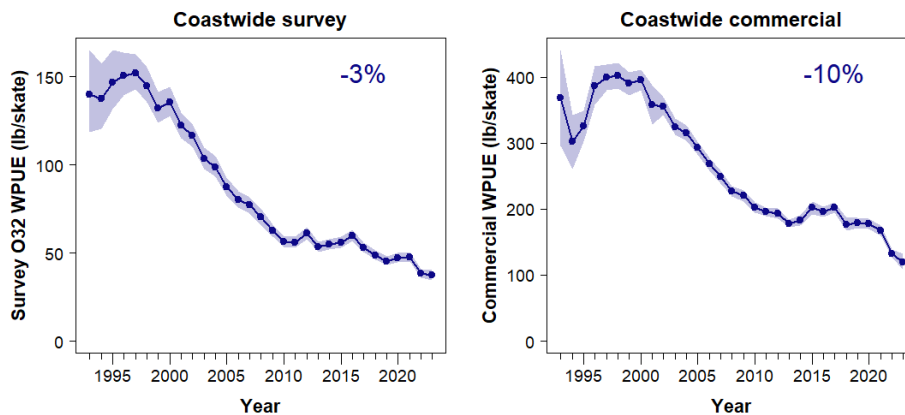


Figure 3. The coastwide FISS O32 WPUE index (left) and coastwide commercial WPUE (right) showing the percent change in the last year (from [IPHC-2024-SA-02](#)). Based on past calculations, additional logbooks collected in 2024 will likely further reduce the decline in commercial WPUE to -12%.

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

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

In actual practice, capital is accumulated in order that interest may be secured from it, and an accumulated stock of fish may also be profitable. The most obvious gain is the greater economy of effort in obtaining a catch from a larger accumulated stock. [...] It not only means less effort, but also less time at sea before the catch is landed. (William F. Thompson, International Fisheries Commission, 1937)

An objective to maintain the absolute spawning biomass above a threshold may be a useful objective for several reasons. First, the level of spawning biomass likely correlates with catch-rates in the fishery, and a higher spawning biomass would likely result in a more efficient and economically viable fishery. Second, current priority conservation objectives use dynamic relative spawning biomass which may result in a low absolute spawning biomass with a satisfactory stock status. Third, a minimum absolute coastwide spawning biomass may be necessary to ensure successful reproduction (such a level is currently unknown for Pacific halibut). Lastly, an observed reference stock level may have concrete meaning to stakeholders. For example, the recent estimated spawning biomass may be near or below the lowest spawning biomass estimated since the mid-1970’s and 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 limit reference point for relative spawning biomass ($SB_{20\%}$) and add a fishery biomass limit reference point for which dropping below would result in serious hardships to the fishery. The fishery biomass limit reference point could be defined using an absolute metric in units of spawning biomass, fishery CPUE, FISS WPUE, or some other estimable quantity. A fishery limit reference point differs importantly from a fishing intensity limit, where the former is a threshold used to maintain catch-

rates and the latter is a threshold used to indicate the potential for overfishing. A fishery absolute spawning biomass limit may also add extra protection for the stock by further reducing the probability of breaching existing limit and threshold reference points. A new objective related to fishery performance could be phrased as:

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

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

The Secretariat will summarize all recommendations from the MSAB and SRB related to these objectives and present them to the Commission at the 100th Interim Meeting of the IPHC and the 101st Annual Meeting of the IPHC.

4 MANAGEMENT PROCEDURES

The MSAB made two requests at MSAB020, which coincides 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%.*

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

- *A static coastwide TCEY determined from the stock assessment;*
- *FISS O32 WPUE;*
- *Incorporation of commercial and FISS age data with FISS O32 WPUE.*

Elements of MPs that were evaluated included assessment frequency, the empirical rule for non-assessment years, 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, as described below.

4.1 Distribution of the TCEY

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

For these simulations, we implemented the approach recommended by the SRB.

[IPHC-2024-SRB024-R](#), para 24. *NOTING that the Operating Model (OM) requires a distribution of harvest across the IPHC Regulatory Areas even though distribution of the TCEY is not a recommended part of the MP, the SRB **RECOMMENDED capturing uncertainty in future TCEY distribution via the approach described in IPHC-2024-SRB024-07, where the TCEY is distributed similar to what is done annually as part of the decision table construction process in the stock assessment.***

We used the observed distribution of the TCEY in recent years to define the simulated percentage of TCEY in each IPHC Regulatory Area. For the last six years, the TCEY in IPHC Regulatory Area 2A has been 1.65 M lbs ([Table 1](#)). Over the last twelve years, the adopted TCEY in IPHC Regulatory Area 2B has ranged from 17.1% to 20.8% of the coastwide TCEY with the three most recent years equal to 18.3% and no relationship with the coastwide TCEY ([Table 2](#) and [Figure 4](#)).

Table 1. Adopted TCEYs (millions of pounds) for each IPHC Regulatory Area from 2013 to 2024.

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

Table 2. Adopted percentage of the coastwide TCEY (millions of pounds) for each IPHC Regulatory Area from 2013 to 2024.

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

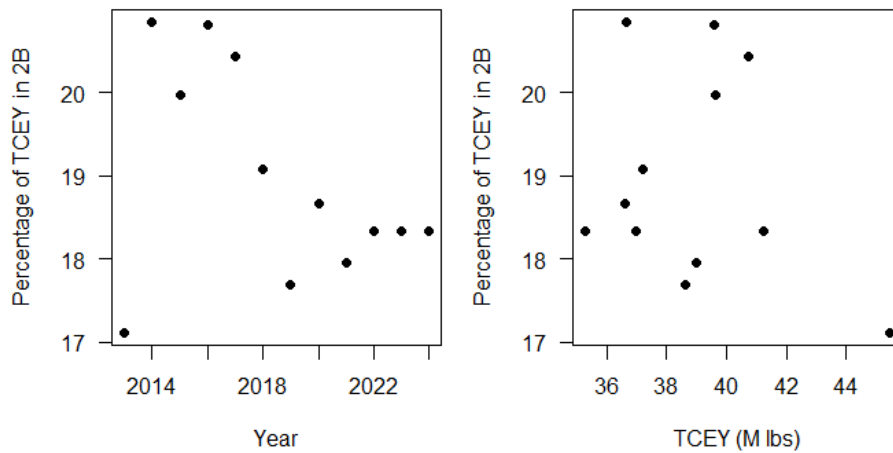


Figure 4. The percentage of the coastwide TCEY in IPHC Regulatory Area 2B plotted against year (left) and the coastwide TCEY (right).

The simulated distribution of the TCEY to IPHC Regulatory Areas 2A and 2B was therefore simply 1.65 Mlbs for 2A and a randomly drawn percentage from a triangle distribution with percentages ranging from 17% to 21% for 2B with the mode of the distribution at 18.3%. The simulated TCEY in IPHC Regulatory Areas in Alaska was distributed after the TCEY had been distributed to IPHC Regulatory Areas 2A and 2B. A year was randomly sampled, and the observed percentages in only Alaskan areas were used (Table 3).

Table 3. Percentage of the adopted TCEY for Alaskan IPHC Regulatory Areas only in each Alaskan IPHC Regulatory Area. IPHC Regulatory Areas 2A and 2B are omitted.

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

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

- a. A multi-year TCEY set constant until a stock assessment is available.
- b. Update the coastwide TCEY proportionally to the change in the coastwide FISS O32 WPUE.

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

- a. Update the coastwide TCEY proportionally to the change in the coastwide FISS all-sizes WPUE.
- b. Use projected TCEY's from the stock assessment with the reference SPR and control rule. This method is common among other fisheries management organizations.
- c. Incorporate commercial fishery catch-rates into the empirical rule.

Further collaboration between the Secretariat and the SRB to develop empirical rule options will occur in the future.

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.

4.3 Fishing intensity

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

4.4 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 4](#)). 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 ([Figure 5](#)). 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 4](#) & [Figure 5](#)). 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 4. 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%

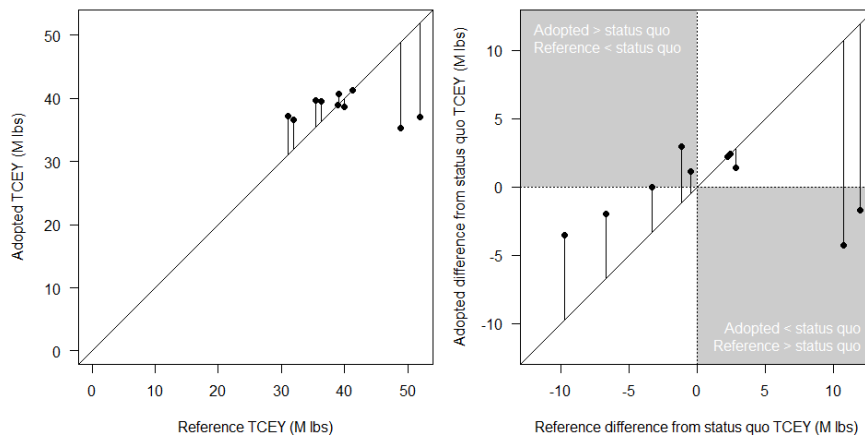


Figure 5. The adopted TCEY vs the reference TCEY (left) and the adopted difference from the status quo TCEY vs the reference difference from the status quo TCEY (right) for the last ten years (2015–2024). The 1:1 line shows when the two are equal. The grey quadrants in the right plot show when the adopted and reference TCEY differences from the status quo are opposite.

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.

Additional constraints will be evaluated in the future.

- A maximum 15% change in the coastwide TCEY only when the TCEY is increasing. There is no constraint when the TCEY is decreasing.
- A maximum 20% change in the coastwide TCEY in either direction from one year to the next.
- A weighted average of last year's and the MP's TCEYs.

4.5 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. FISS uncertainty is not currently modelled with an effect on decision-making variability.

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.

Four FISS designs were simulated, representing increasing observation and assessment error ([Table 5](#)). A few simulations assuming no observation error were also included for comparison. The Base FISS design represents an ideal sampling approach with a random selection of stations occurring in all areas. 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.

Table 5. Assumptions of observation and estimation error for four FISS designs.

FISS Design	Frequency	Coastwide WPUE CV	Coastwide WPUE Bias	Assessment Uncertainty	Assessment Bias
Base	Every year	3%	None	15%	None
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%

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.

Core FISS design

- Frequency
 - When the spawning biomass is less than the spawning biomass in 2020 other areas are surveyed every 5th year and bias is reduced by one-half.
 - When the spawning biomass is greater than the spawning biomass in 2020 other areas are surveyed every 3rd year and bias is reduced by one-half.
- FISS bias
 - Bias depends on recent 3-year coastwide trend and the number of years without a block design surveying non-core areas
 - 0-5%: $\pm 0.5\%$ bias added to current bias. Sign chosen randomly.
 - 5-15%: annual increase of 1% bias opposite direction of trend
 - 15-30%: annual increase of 2% bias opposite direction of trend
 - >30%: annual increase of 3% bias opposite direction of trend
- Assessment bias
 - Bias depends on recent 3-year coastwide trend and the number of years without a block design surveying non-core areas
 - 0-5%: $\pm 0.25\%$ bias added to current bias. Sign chosen randomly.
 - 5-15%: annual increase of 0.5% bias opposite direction of trend
 - 15-30%: annual increase of 1% bias opposite direction of trend
 - >30%: annual increase of 2% bias opposite direction of trend

Reduced Core FISS design

- Frequency
 - When the spawning biomass is less than the spawning biomass in 2020 other areas are surveyed every 5th year and bias is reduced by one-half.
 - When the spawning biomass is greater than the spawning biomass in 2020 other areas are surveyed every 3rd year and bias is reduced by one-half.
- FISS bias
 - Bias depends on recent 3-year coastwide trend and the number of years without a block design surveying non-core areas:
 - 0-5%: $\pm 0.5\%$ bias added to current bias. Sign chosen randomly.
 - 5-15%: annual increase of 2% bias opposite direction of trend
 - 15-30%: annual increase of 3% bias opposite direction of trend
 - >30%: annual increase of 4% bias opposite direction of trend
- Assessment bias
 - Bias depends on recent 3-year coastwide trend and the number of years without a block design surveying non-core areas:
 - 0-5%: $\pm 0.25\%$ bias added to current bias. Sign chosen randomly.
 - 5-15%: annual increase of 0.75% bias opposite direction of trend
 - 15-30%: annual increase of 1.5% bias opposite direction of trend
 - >30%: annual increase of 2.5% bias opposite direction of trend

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.

4.6 Summary of MSE simulations

The Base Block FISS design was used to compare other elements of the MPs such as assessment frequency, constraints, and depensation (Table 6). Annual, biennial, and triennial assessment frequencies were simulated with an empirical rule proportional to FISS O32 WPUE and for some cases as fixed in non-assessment years. No constraint was contrasted with a constraint on the coastwide TCEY of 15% in both directions (15% u/d) and a 15% constraint only when increasing.

Simulations with the Core and Reduced Core FISS designs were done with only the annual assessment frequency and four levels of fishing intensity from 43% to 52%. Simulations using the Base FISS design and simulations without estimation, observation, and decision-making variability were done only with a fishing intensity of 43%.

Table 6. MSE simulations using the Base Block FISS design and decision-making variability.

Empirical Rule		Proportional to FISS O32			NA	NA	NA
Depensation		None			None	None	$\delta=2$
Constraint		None			15% u/d	15% u	None
Assessment		Annual	Biennial	Triennial	Annual	Annual	Annual
SPR	35						
	40						
	43						
	46						
	49						
	52						

Performance metrics associated with Commission priority objectives are presented and any additional performance metrics of interest are provided. The average annual variability (AAV) performance metric is calculated over 10- and 15-year periods, each starting in year 4 of the projection. All performance metrics and MPs are available on the [MSE Explorer](#).

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 7](#). 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).

Additional performance metrics provide insight into the variability in the TCEY from the biennial and triennial assessment frequencies ([Table 8](#)). The AAV calculated over a 15-year period was similar to the AAV calculated over a 10-year period. The probability that the annual change (AC) was greater than 15% for 3 year or more years increase for a 15-year period because there were more chances for the AC to be greater than 15%. The maximum change in a 10-year period was reported as the absolute change in the TCEY (in millions of pounds) and increased from Annual to Triennial assessment frequencies and higher fishing intensities. The mean maximum duration of the AC less than 15% (i.e. the run of years where the TCEY changed by less than 15%) was near 3 years and increased with less frequent assessments. A less frequent assessment resulted in lower average variability and more often the changes in the TCEY was less than a 15% change from the previous year. However, occasionally, a less frequent assessment had a larger change than an annual assessment, suggesting that the biennial and triennial MPs may

have to make a correction when an assessment is done. The choice of assessment frequency depends on the trade-off between a lower average variability over a range of years vs. the chance of a slightly larger absolute change in the TCEY. Lastly, there is a greater than 25% chance that the spawning biomass is less than the spawning biomass in 2023 when fishing at an SPR=40% and a near 20% chance when fishing at an SPR=49% in the long-term. These probabilities increase to 51% and 34% in the short-term.

Table 7. 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	0.2870	0.1338	0.0526	0.0094
Median TCEY	65.50	60.46	56.96	53.57	49.11
AAV	20.7%	20.2%	20.0%	20.5%	21.0%

Table 8. Additional performance metrics 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. All performance metrics are short-term with 10-year being 4-13 years and 15-years being 4-18 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
AAV 10-year	25.3%	24.2%	23.5%	23.5%	23.7%
AAV 15-year	26.4%	24.5%	23.9%	24.0%	24.6%
P(AC3>15%) 10-year	0.992	0.988	0.986	0.988	0.986
P(AC3>15%) 15-year	1.000	1.000	1.000	1.000	1.000
Max Change (10-yr, absolute Mlbs)	47.7	40.3	36.1	32.7	30.2
Mean Max Duration < 15% AC (10-yr)	2.53	2.55	2.52	2.48	2.45
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
AAV 10-year	23.3%	22.6%	22.5%	22.8%	23.5%
AAV 15-year	23.0%	22.9%	22.4%	22.6%	22.7%
P(AC3>15%) 10-year	0.972	0.980	0.978	0.974	0.976
P(AC3>15%) 15-year	0.998	1.000	1.000	0.996	0.996
Max Change (10-yr, absolute Mlbs)	48.2	42.6	38.5	34.9	32.5
Mean Max Duration < 15% AC (10-yr)	3.00	3.02	2.95	2.84	2.79
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
AAV 10-year	20.7%	20.2%	20.0%	20.5%	21.0%
AAV 15-year	23.0%	21.6%	21.6%	21.7%	22.0%
P(AC3>15%) 10-year	0.914	0.906	0.926	0.932	0.940
P(AC3>15%) 15-year	0.988	0.986	0.986	0.992	0.992
Max Change (10-yr, absolute Mlbs)	49.5	43.8	40.4	37.8	34.6
Mean Max Duration < 15% AC (10-yr)	3.26	3.29	3.31	3.22	3.12

Results with no observation error, no estimation error, and no decision-making variability show a slightly higher median TCEY and a much lower AAV (Table 9). Some variability remains in the interannual change in the TCEY due to the annual assessment tracking changes in the population. However, the AAV was near 12% for the biennial and triennial assessment frequencies because the TCEY is proportional to the FISS O32 WPUE which is a different demographic of the population than is tracked using SPR, and when the assessment occurred it resulted in a large correction to maintain the SPR. Using all sizes FISS WPUE may result in a reduced AAV for biennial and triennial assessment frequencies.

Table 9. Performance metrics for an SPR of 43% 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 **no observation error, no estimation error, and no 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.

Empirical Rule	Fixed		FISS O32 WPUE
	Annual	Triennial	Triennial
Assessment Frequency			
P(RSB<20%)	<0.001	<0.001	<0.001
P(RSB<36%)	0.2438	0.2728	0.2652
Median TCEY	60.34	60.23	61.69
AAV 10-year	6.2%	4.7%	12.0%
AAV 15-year	6.1%	5.1%	11.4%
P(AC3>15%) 10-year	0.176	0.108	0.606
P(AC3>15%) 15-year	0.216	0.360	0.790
Max Change (10-yr, absolute Mlbs)	10.7	17.8	22.2
Mean Max Duration < 15% AC (10-yr)	11.62	8.50	6.50

Including a constraint of 15% when the TCEY goes up or down in the MP reduced the AAV, but the AAV remained above 15% with decision-making variability (Table 10). With a constraint, the median TCEY was less, resulting 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 6).

Without decision-making variability, the AAVs were less for the annual and triennial assessment frequencies and the median TCEY was slightly larger (Table 10). However, the AAVs remained above 15% due to observation and assessment error.

Table 10. Performance metrics associated with priority objectives for an SPR of 43%, a triennial assessment without a constraint, an annual assessment with and without a 15% constraint on the change in the TCEY, and with and without decision-making variability. 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.

	Annual	Triennial	Annual	Annual	Triennial	Annual	Annual
Decision-making variability	No	No	No	Yes	Yes	Yes	Yes
Constraint	None	None	15% up/down	None	None	15% up/down	15% up
P(RSB<20%)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P(RSB<36%)	0.2420	0.2634	0.0564	0.2466	0.2870	0.0506	0.0528
Median TCEY	59.92	61.00	52.30	60.11	60.46	49.51	51.55
AAV	20.8%	17.2%	14.5%	24.2%	20.2%	16.6%	16.7%

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.

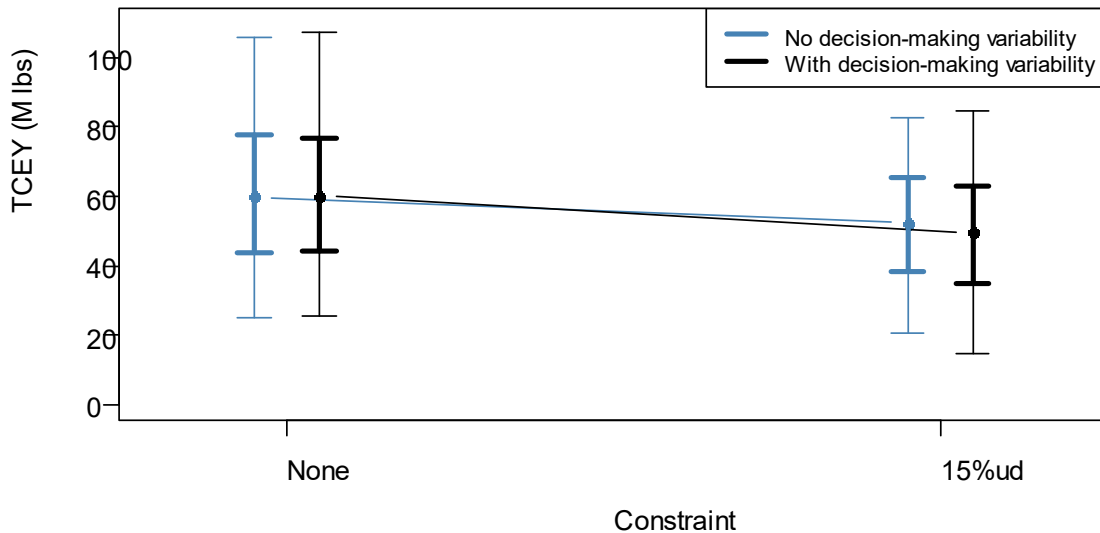


Figure 6. The TCEY (M lbs) for simulations with and without a constraint (15% maximum change up or down) and with and without decision-making variability. All simulations assumed the Base Block FISS design, an annual assessment, and an SPR of 43%. Light whiskers show the 5-95% interval, dark whiskers the 25-75% interval and the dot the median.

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 11). 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 7).

With an SPR of 43%, the median TCEY declined by 450,000 lbs moving to the Core FISS design from the Base Block FISS design, and another 450,000 lbs 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.

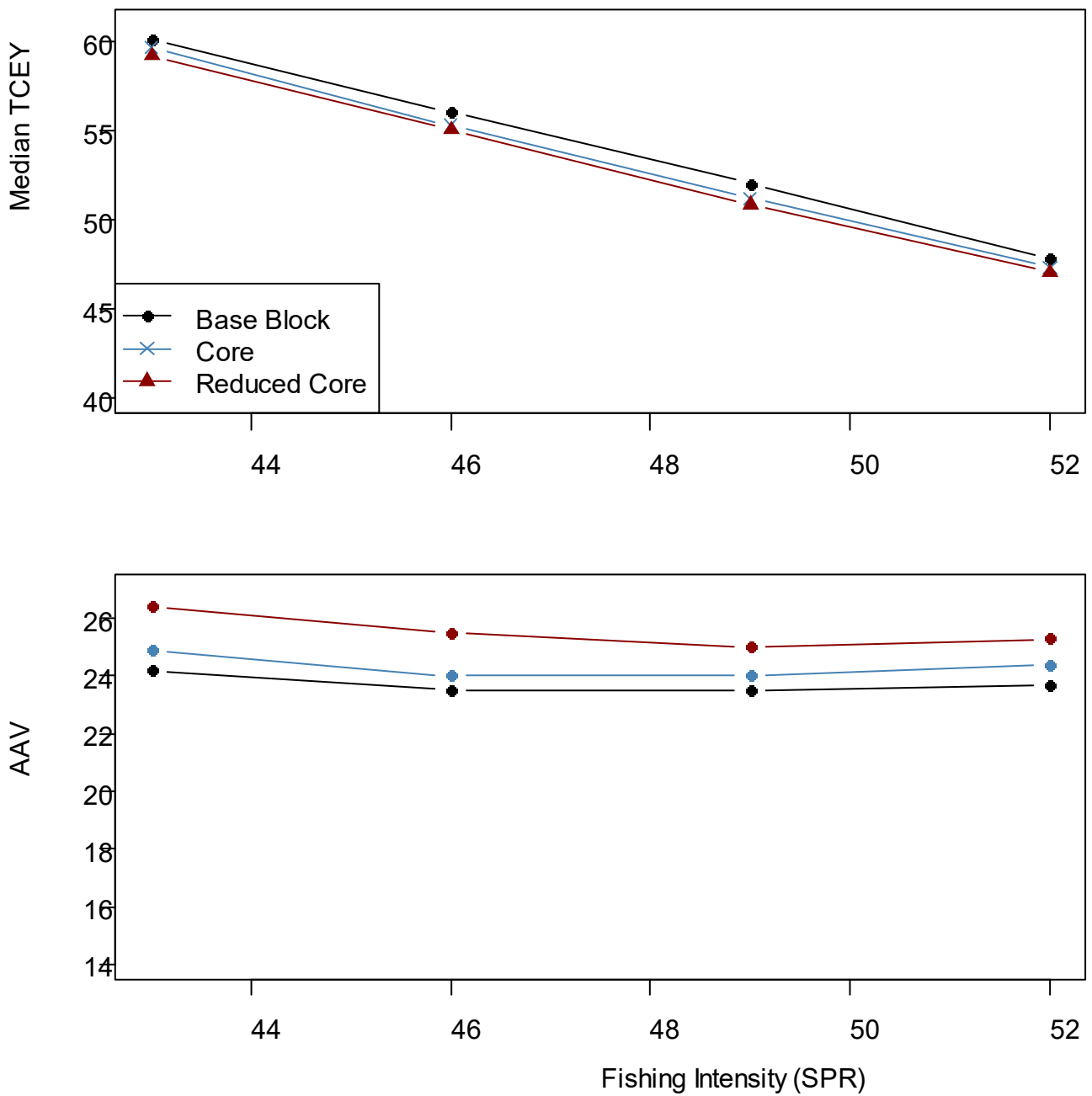


Figure 7. Median TCEY (top) and AAV (bottom) for different fishing intensities (SPR) and FISS designs.

Table 11. 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 DEPENDATION STRESS TEST

6.1 A background on depensation

The Pacific halibut population has shown a high amount of variability in spawning biomass over 100 years of commercial fishing, sometimes increasing to high levels quickly after a low period. However, if a population experiences a very low number of spawners, it may have reduced reproductive success. Depensation occurs if the per-capita rate of growth decreases as the density or abundance decreases to low levels (Liermann and Hilborn 2001). In other words, it is inverse density dependence at low population sizes (reduced spawning potential) and is also referred to as the Allee effect (Dennis 2002).

There are many mechanisms that may result in depensation (Liermann and Hilborn 2001), such as increased adult mortality observed in Northwest Atlantic cod (*Gadus morhua*) stocks (Kuparinen and Hutchings 2014). It is not known if Pacific halibut may experience depensation, but MSE is a useful tool to examine the effects on the population and management outcomes if depensation was present. The SRB recommended examining the effects of possible depensation in the Pacific halibut stock using the MSE framework.

IPHC-2024-SRB024-R, para 29. *The SRB NOTED the analysis of depensation presented in paper IPHC-2024-SRB024-07, and RECOMMENDED:*

- a) *fitting a depensatory stock-recruitment model to estimate the depensation parameter value;*

b) operating model stress tests in the MSE with and without depensation across a range of plausible fishing intensities.

The stock-recruitment elements of the operating model were updated to allow for a depensation parameter following Liermann and Hilborn (1997).

$$R_t = \frac{\alpha S_t^\delta}{\beta^\delta + S_t^\delta}$$

where R_t is the number of recruits at time t , S_t is the spawning biomass at time t , α is the maximum number of predicted recruits (asymptote), β is the level of spawners that produces $\alpha/2$ recruits, and δ is the depensation parameter. A value greater than 1 for δ indicates depensation. The Pacific halibut stock assessment (and many other stock assessments from around the world) use the steepness parameterization (Mace and Doonan 1998) and use steepness (h), R_0 , and B_0 to calculate the α and β parameters. Steepness is defined as the proportion of unfished recruitment that occurs when the spawning biomass is at 20% of its unfished level. An example Beverton-Holt stock-recruit curve is shown in Figure 8 with these various parameters and concepts labeled.

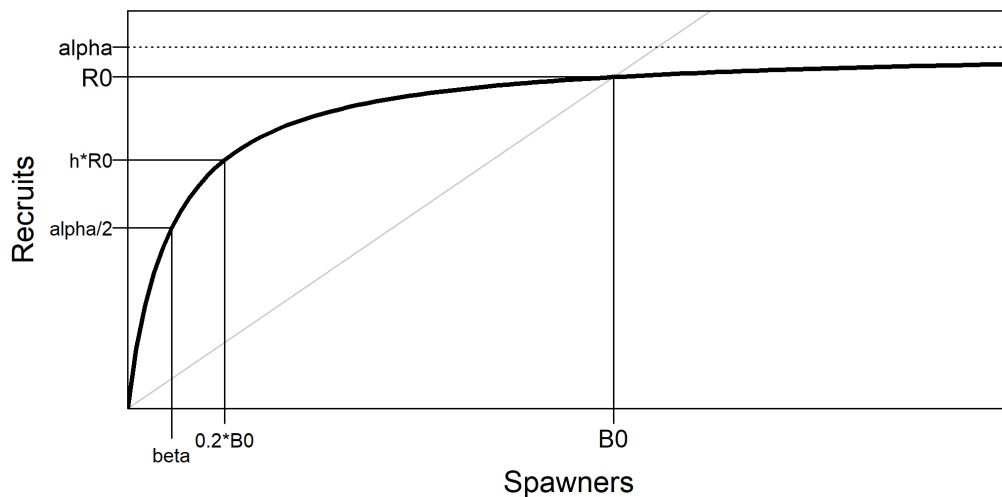


Figure 8. An example Beverton-Holt stock-recruit curve with various parameters and concepts labeled.

Environmental effects may change R_0 , which changes the stock-recruit curve. For example, the Pacific halibut stock assessment assumes a steepness of 0.75 and estimates R_0 (and thus B_0) for two different environmental regimes related to periods of low or high Pacific Decadal Oscillation (PDO). Figure 9 shows the estimated Beverton-Holt stock-recruit curves for the two regimes within the two ‘long’ models of the Pacific halibut stock assessment ensemble.

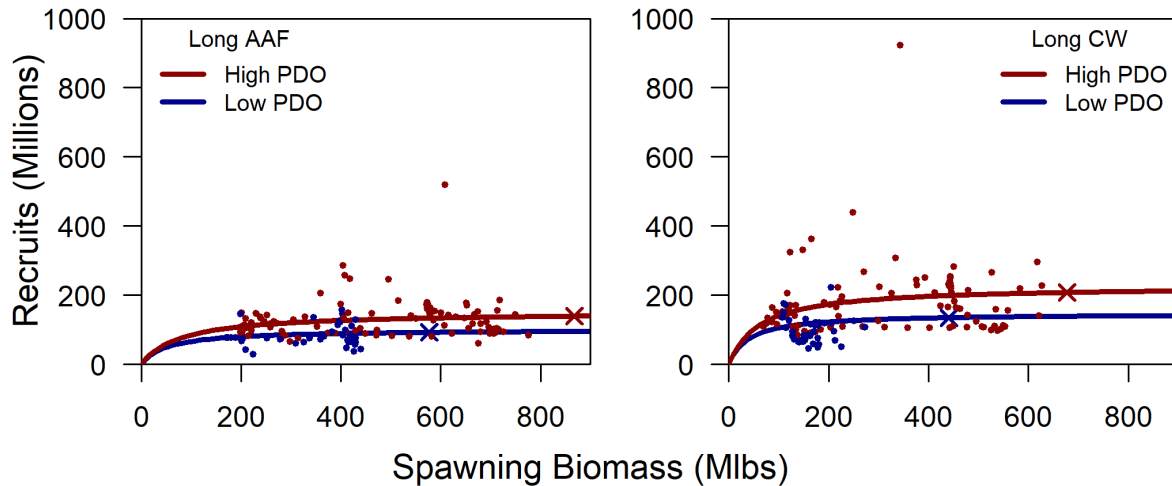


Figure 9. Beverton-Holt stock-recruit curves for two regimes as estimated in the two long models of the stock assessment ensemble. Points are estimated recruits at spawning biomass and the Xs mark the unfished equilibrium R_0 and B_0 .

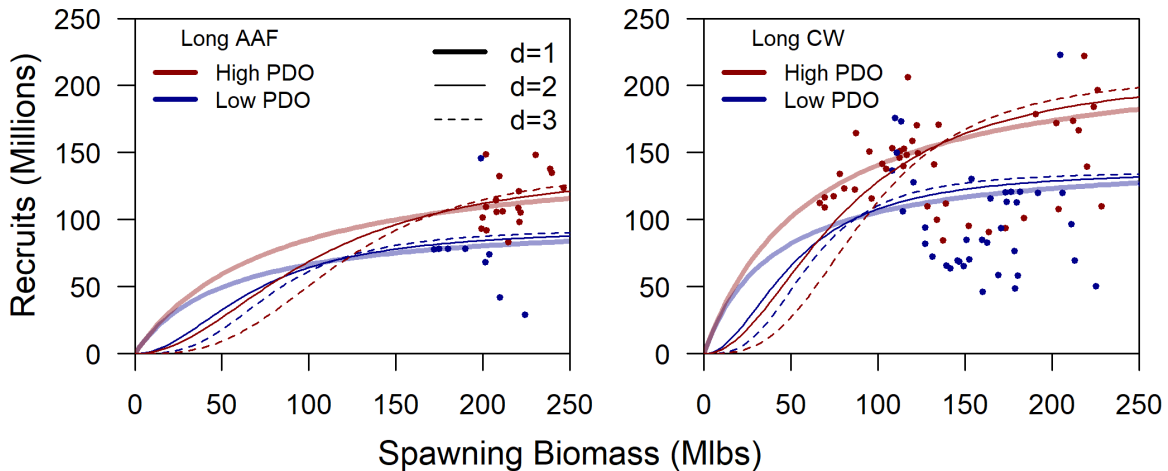


Figure 10. Beverton-Holt stock-recruit curves for the two regimes as estimated in the two long models of the stock assessment ensemble with three different values for depensation. Points are estimated recruits at spawning biomass. Axes have been truncated to focus on the change in the curve at low spawning biomass.

Using the above formulation, depensation with δ at values greater than 1 shows a steepening of the curve at low spawning biomass with a resulting increase in recruits above the curve to meet the consistent R_0 .

6.1.1 Estimates of depensation in the Pacific halibut population

Estimates of recruitment and estimates of spawning biomass from the two ‘long’ models in the 2023 stock assessment ensemble were treated as data in a Beverton-Holt stock-recruit model to estimate three parameters, including depensation.

For each long model (LongAAF and LongCW) three analyses were done: 1) all data were combined into a single analysis to estimate the stock-recruit parameters, 2) only recruits and spawning biomass from years with a positive PDO were used, and 3) only recruits and spawning biomass from years with a negative PDO were used.

From these results, there is not a clear indication of depensation over the observed range of spawning biomass and the value of δ is highly uncertain (Table 12). Analyzing only recruits from high PDO years showed potential depensation, but was uncertain. Low PDO years had fewer observations, especially at low spawning biomass. The uncertainty in the estimate of depensation is due to variable recruitment and the lack of observations at low spawning biomass.

The purpose of this analysis was to determine a reasonable level of depensation for a stress test using the MSE framework. Given no clear indication of depensation, a value of $\delta = 2$ was chosen. Other values may be reasonable but were not tested at this time. Applying depensation only in a specific environmental regime is also possible but was not attempted here because the OM does not change the stock-recruit function in separate environmental regimes, but simply multiplies recruitment by a factor for the high PDO regime. Future improvements to the OM are expected where tested management outcomes with depensation on specific environmental regimes would be appropriate.

Table 12. Estimated depensation parameter for the LongAAF and LongCW model observations combined or separated by PDO regime. The lower and upper 95% confidence interval determined from the likelihood profile is also shown (An NA indicates that the confidence limit could not be determined over the range tested).

Model	Data	Depensation (δ)	Lower	Upper
Long AAF	All	0.35	0.22	1.75
	Positive PDO	4.49	1.35	20.85
	Negative PDO	0.92	NA	NA
Long CW	All	0.36	0.24	0.81
	Positive PDO	2.9	0.70	9.43
	Negative PDO	13	5	29

6.1.2 MSE simulations with depensation

From the investigation of depensation (results reported below) MSE simulations were done using two levels of depensation, three fishing intensities (with a 30:20 control rule), and the base block FISS design (Table 13). Additionally, the highest fishing intensity was simulated without a control rule to increase the realized fishing intensity. Models were not reconditioned by incorporating depensation.

Table 13. Specifications of MSE simulations investigating depensation.

Parameter	Values
Depensation (δ)	$\delta = 1$ or 2
SPR	35%, 43%, 52%
FISS design	Base block

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

Including depensation in the OM ($\delta = 2$) resulted in an undetectable difference in long-term performance metrics (Table 14) for all fishing intensities investigated (SPR = 35%, 43%, and 52%). There are two explanations for no effect due to depensation. First, a control rule reduces the fishing intensity when RSB is less than 30%, and sets directed fishery mortality to zero when below 20%. This results in a realized fishing intensity that may be lower than implied by the input SPR, especially at an SPR of 35% (the long-term median realized SPR was 36% with an input SPR of 35%). Second, this control rule reduces the chance that the spawning biomass falls to a low enough level where depensation becomes a concern. However, simulations removing the control rule were still similar for the two levels of depensation (Figure 11).

Table 14. Performance metrics for two different levels of depensation and three fishing intensities.

Depensation	$\delta=1$			$\delta=2$		
	35%	43%	52%	35%	43%	52%
P(RSB<20%)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
P(RSB<36%)	0.7106	0.2466	0.0012	0.7102	0.2462	0.0012
Median TCEY	71.78	66.55	57.81	71.78	66.55	57.81

This does not conclude that depensation does not occur for Pacific halibut. Depensation may exist, especially below spawning biomass levels lower than have been observed. However, if it does exist, the use of a 30:20 control rule and recent levels of fishing intensity seem to avoid these low spawning biomass levels where depensation would have an effect.

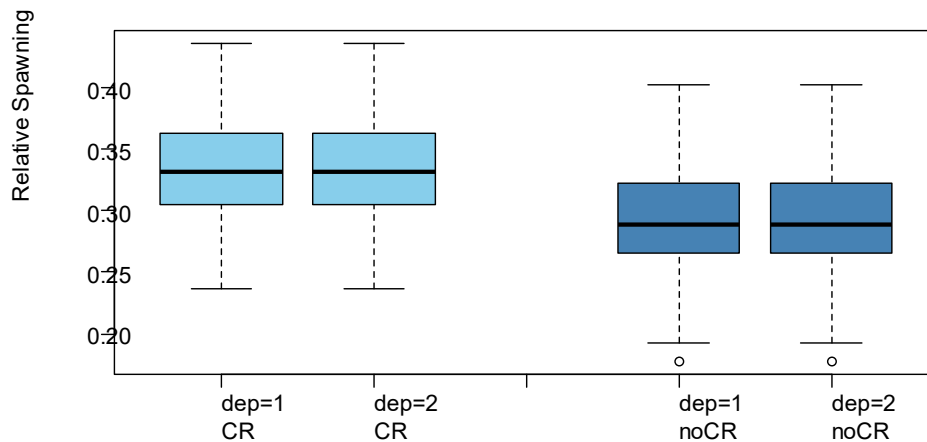


Figure 11. Boxplots of relative spawning biomass using a fishing intensity of SPR=35%, with and without a control rule, and with and without depensation.

7 CONCLUSIONS

Three concepts were evaluated using the MSE: assessment frequency along with harvest control rule elements, FISS designs, and depensation. These simulations show 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 would lower the interannual variability in the TCEY. This would also allow more time to improve assessment and MSE methods, but at the cost of not providing detailed annual information such as stock status. 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. Finally, depensation is likely not a concern for the Pacific halibut stock, given the expected range of fishing intensities.

This work supports the development of the harvest strategy policy ([IPHC-2024-MSAB020-07](#)). 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 MSAB

- 1) **NOTE** paper IPHC-2024-MSAB020-06 presenting recent MSE work including exceptional circumstances; goals and objectives; evaluating assessment frequency, a constraint and fishing intensity; investigating the effects of reduced FISS designs; and simulating a scenario with depensation.
- 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** further analyses to support the development of the harvest strategy policy.
- 4) **REQUEST** any further analyses to be provided to the Commission or at MSAB021.

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APPENDICES

[Appendix A](#): Primary objectives used by the Commission for the MSE

APPENDIX A

PRIMARY OBJECTIVES USED BY THE COMMISSION FOR THE MSE

Table A1. Primary objectives, evaluated over a simulated ten-year period, accepted by the Commission at the 7th Special Session of the Commission (SS07). Objective 1.1 is a biological sustainability (conservation) objective and objectives 2.1, 2.2, and 2.3 are fishery objectives. Priority objectives are shown in green text.

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	MEASURABLE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRIC
1.1. KEEP FEMALE SPAWNING BIOMASS ABOVE A LIMIT TO AVOID CRITICAL STOCK SIZES AND CONSERVE SPATIAL POPULATION STRUCTURE	Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point ($B_{20\%}$) at least 95% of the time	$B < \text{Spawning Biomass Limit } (B_{Lim})$ $B_{Lim}=20\%$ 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	$p_{SB,2} > 5\%$ $p_{SB,3} > 33\%$ $p_{SB,4} > 10\%$ $p_{SB,AB} > 2\%$	Long-term	0.05	$P(p_{SB,R} < p_{SB,R,min})$
2.1 MAINTAIN SPAWNING BIOMASS AT OR ABOVE A LEVEL THAT OPTIMIZES FISHING ACTIVITIES	Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point ($B_{36\%}$) 50% or more of the time	$B < \text{Spawning Biomass Reference } (B_{Thresh})$ $B_{Thresh}=B_{36\%}$ 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 $\left(\frac{TCEY_A}{TCEY}\right)$
	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

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

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