Updates to the IPHC MSE and a review of coastwide management procedures

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PURPOSE

To provide the MSAB with an overview work done since the 20th meeting of the Management Strategy Advisory Board (MSAB020) using the IPHC Management Strategy Evaluation (MSE) framework.

1 INTRODUCTION

Rapid investigation of different questions is possible with the fully developed MSE framework. The operating models (OMs) in this framework were conditioned using the 2022 stock assessment and will be reconditioned after the 2025 full stock assessment to reflect new understanding of the Pacific halibut population and fishery dynamics. The MSAB made three requests for further investigation, which are reported here. Additionally, an investigation into the effects of weight-at-age and recruitment regimes is provided.

2 MSAB020 REQUESTS

The 20th meeting of the Management Strategy Advisory Board (MSAB020) took place the 29th and 30th of October 2024. Three requests were made at this meeting for additional investigation. Outcomes of these additional investigations are shown below.

2.1 Additional understanding of patterns

The MSE results presented at MSAB020 showed many interesting outcomes, but some of the complex outcomes were not fully understood. The MSAB was interested in how different fishing intensities affected the range of TCEYs and made this request.

> **IPHC-2024-MSAB020-R, para 27**. *The MSAB **NOTED** that lower fishing intensities (i.e. higher SPR values) resulted in higher absolute spawning biomass but reduced the median coastwide TCEY. There is a greater than 1-in-3 chance that the short-term absolute spawning biomass will be less than the 2023 spawning biomass when fishing at a reference SPR=43%. The chance was approximately 1-in-4 for long-term spawning biomass. Fishing at an SPR=52% reduced these chances to approximately 1-in-4 and 1-in-6 for the short- and long-terms, respectively. However, lower fishing intensities did not realize high TCEYs seen at higher fishing intensities, and did result in lower TCEYs more often than seen at higher fishing intensities, over the short-term.*

> **IPHC-2024-MSAB020-R, para 28**. *The MSAB **REQUESTED** more exploration into understanding the patterns presented in paragraph 27.*

Figure 1 shows the spawning biomass increasing with lower fishing intensity and Figure 2 shows the TCEY declining with lower fishing intensity. The long-term showed higher spawning biomass and higher TCEYs at a specific fishing intensity. The change in the TCEY relative to the change in spawning biomass at different SPR values was different for the short- and long-term (Figure 3). The TCEY showed larger changes across fishing intensities than the spawning biomass in the short-term. The protracted and lower range of spawning biomass in the short-term resulted in the control rule reducing the realized SPR more often (Figure 4). Smaller spawning biomass and the control rule reducing the realized fishing intensity results in only a slight reduction in the TCEY at high fishing intensities or low SPR (Figure 2). Increasing fishing intensity resulted in higher probabilities that the spawning biomass was below the spawning biomass in 2023 for both the short- and long-term (Figure 5). These probabilities were lower in the long-term due the spawning biomass being typically larger, as noted at MSAB020.

The range of TCEYs was large for all SPR values simulated, but was reduced at lower fishing intensity (Figure 2). The high range declined faster than the lower range. A useful metric is the probability that the TCEY is less than a specific amount, with a desire to minimise the chance of being below any amount. As shown in Figure 6, the chance that the TCEY is less than a specific amount is minimised at higher fishing intensities (lower SPR), except for low thresholds like 20 Mlb and 30 Mlb where the chance of being less than these values is minimised near SPR values of 45%. Narrowing this down to two performance metrics, the chance that the TCEY is less than 20 Mlbs and the chance that the TCEY is less than 80 Mlbs, the trade-offs between avoiding very low TCEYs and achieving very high TCEYs become clear (Figure 7).

Jointly minimising the chance that the TCEY is less than 20 Mlb and the chance that the TCEY is less than 80 Mlb is possible for low fishing intensities, but at SPR values near 45% and lower, these two performance metrics cannot be minimised at the same time. Increasing fishing intensity beyond SPR=45% results in a higher chance of realizing TCEYs greater than 80 Mlb, but a higher chance of realizing TCEYs less than 20 Mlb. The higher fishing intensities take advantage of high biomass with high TCEYs but at a higher risk of realizing lower TCEYs in poor conditions. There is not a single optimal solution for these two performance metrics and the trade-offs are important to consider when making a decision.

The minimum TCEY across simulations in each IPHC Regulatory Area shows a similar pattern where the minimum is highest at intermediate values of SPR (Figure 8). This pattern is consistent across all IPHC Regulatory Areas.

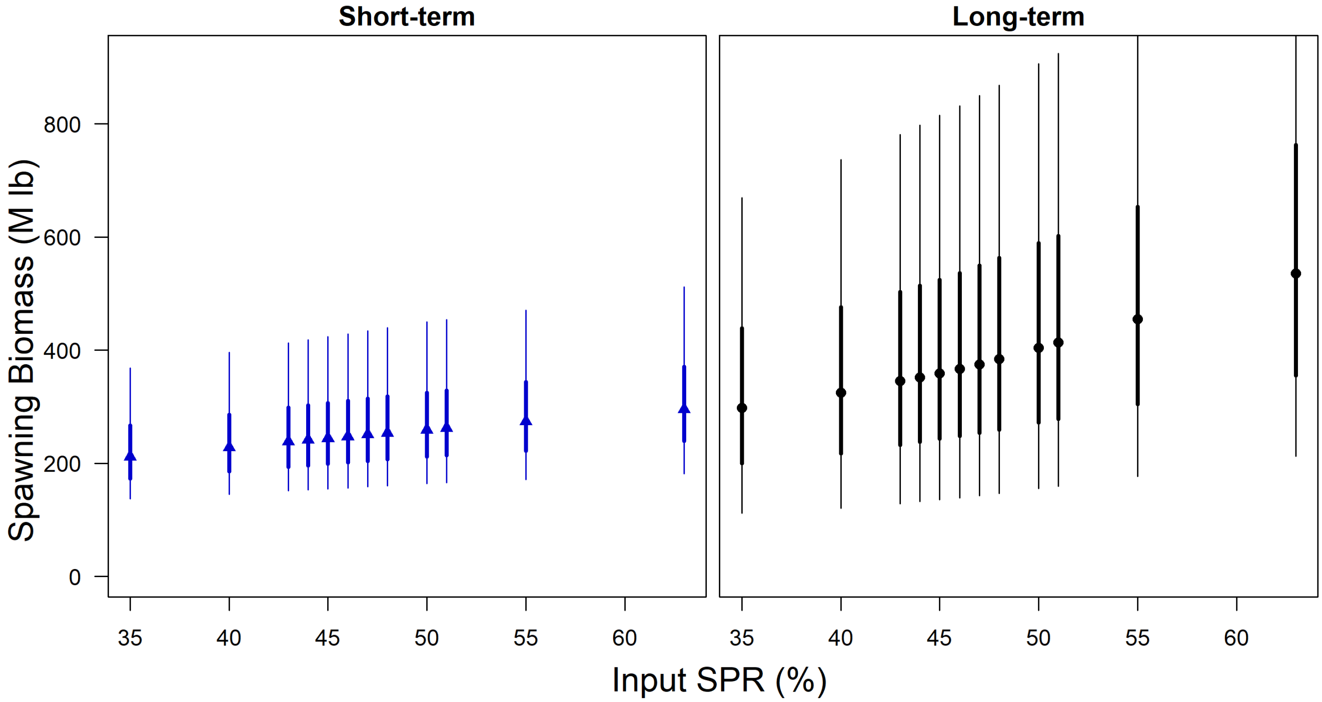

Figure 1. Spawning biomass at different SPR values over the short- and long-term. The thick lines show the 25th and 75th percentiles. The thin lines show the 5th and 95th percentiles.

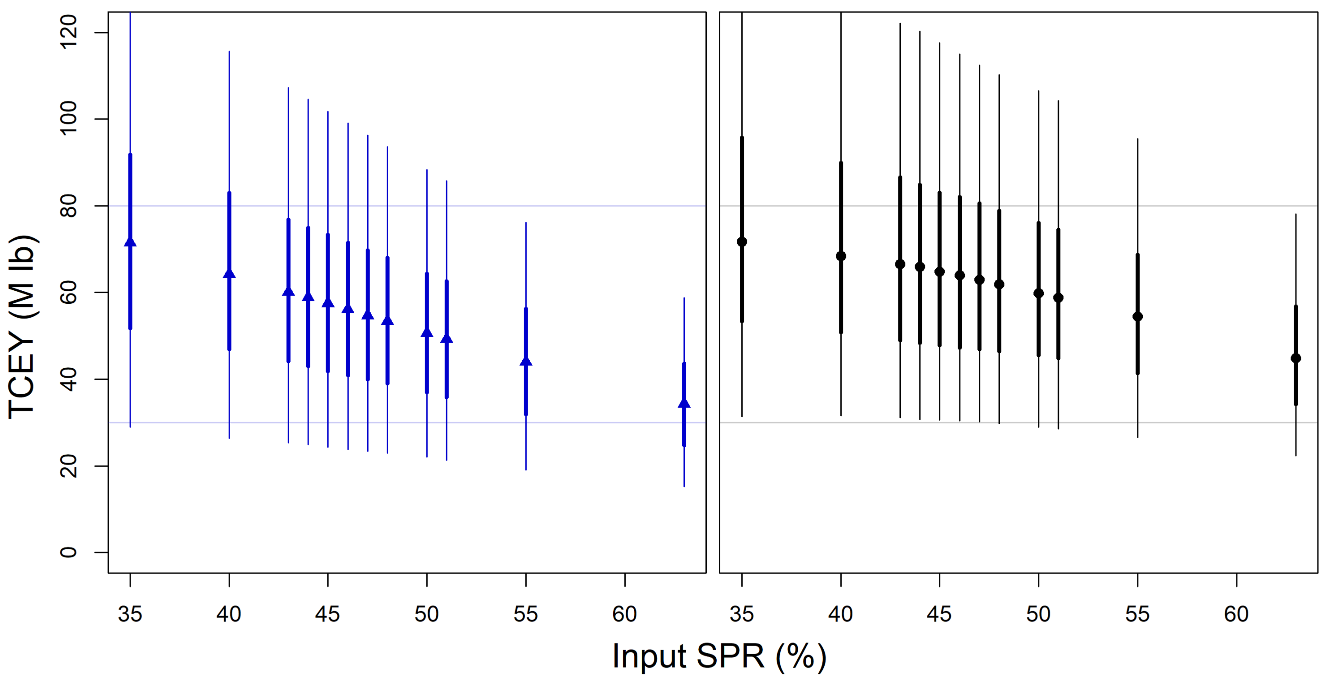

Figure 2. TCEY at different SPR values over the short- and long-term. The thick lines show the 25th and 75th percentiles. The thin lines show the 5th and 95th percentiles.

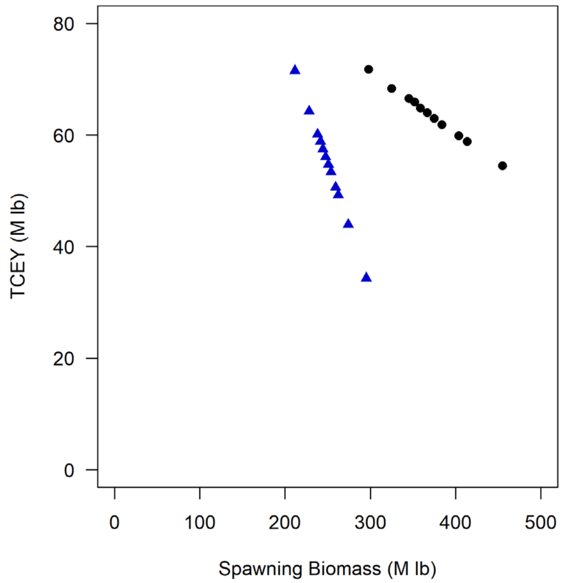

Figure 3. TCEY vs spawning biomass for short- (blue triangles) and long-term (black circles) results.

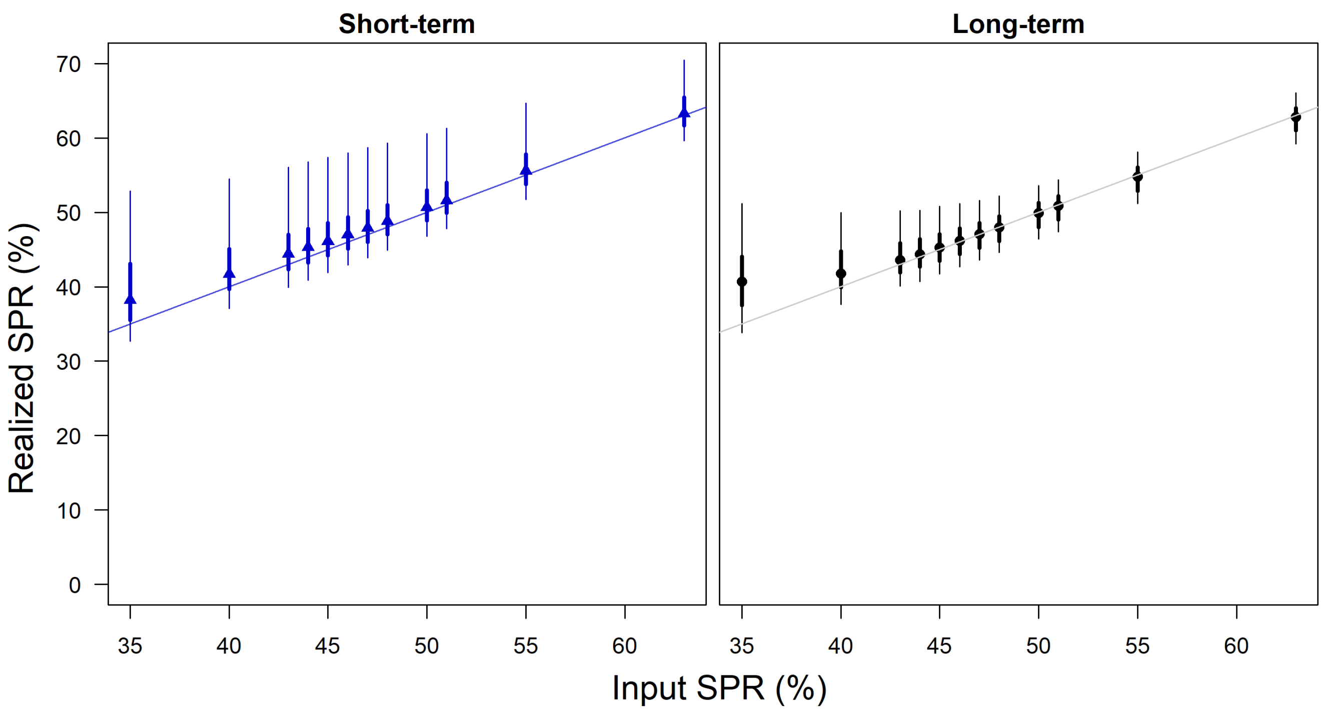

Figure 4. The realized SPR in the short- and long-term for different input fishing intensities. The thick lines show the 25th and 75th percentiles. The thin lines show the 5th and 95th percentiles.

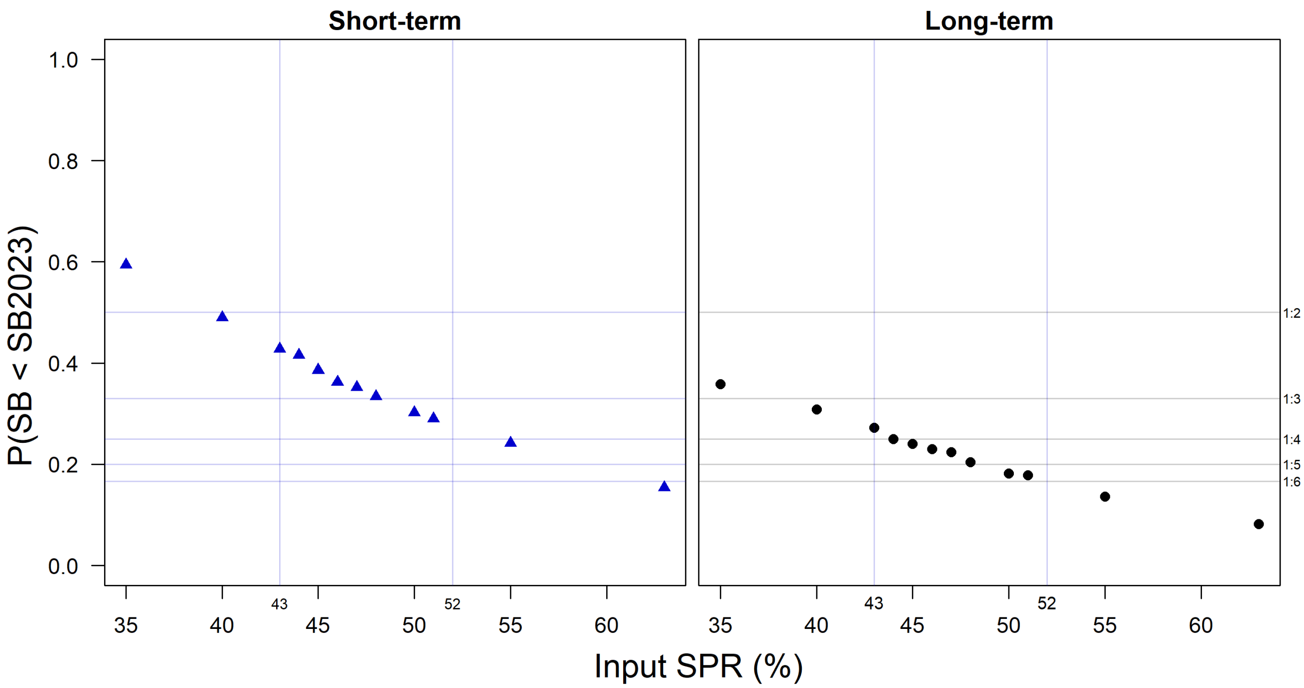

Figure 5. The probability that the short-term and long-term spawning biomass is less than the spawning biomass in 2023. Horizontal lines show the 1 in 2, 1 in 3, up to a 1 in 6 chance. The vertical lines show 43% and 52% SPR values.

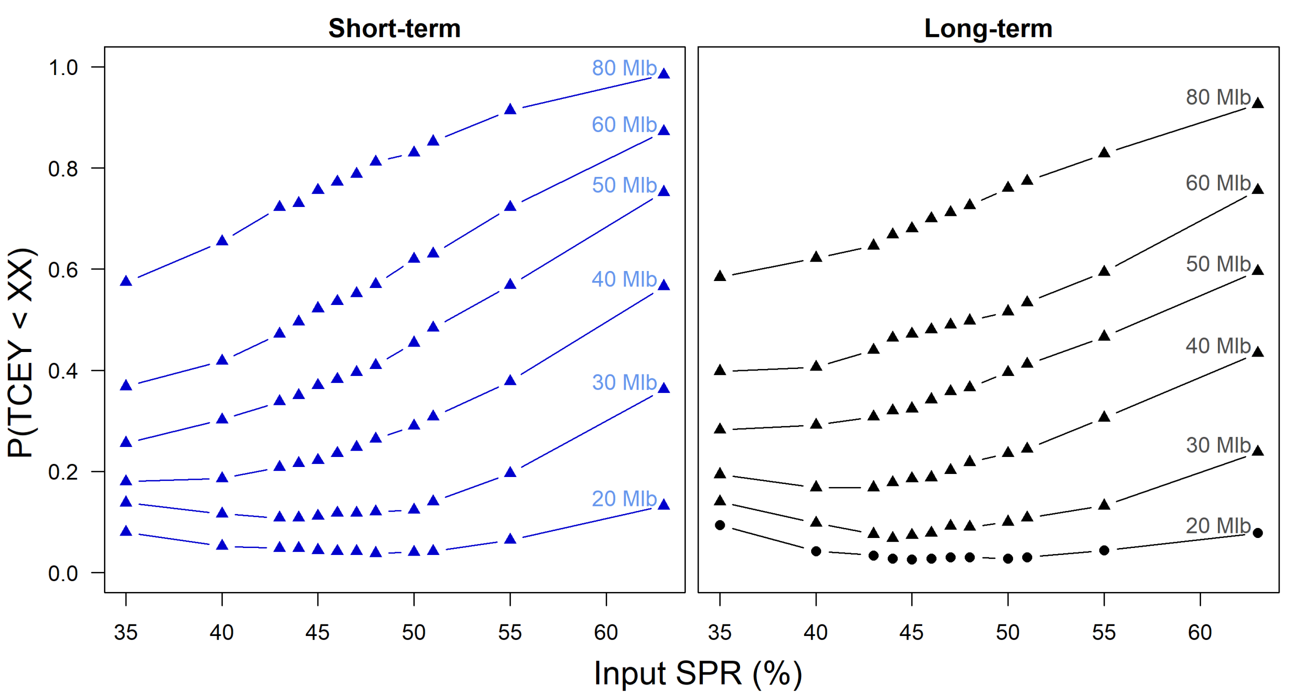

Figure 6. The probability that the TCEY is less than a specific amount (shown at the right of each curve) for various SPR values.

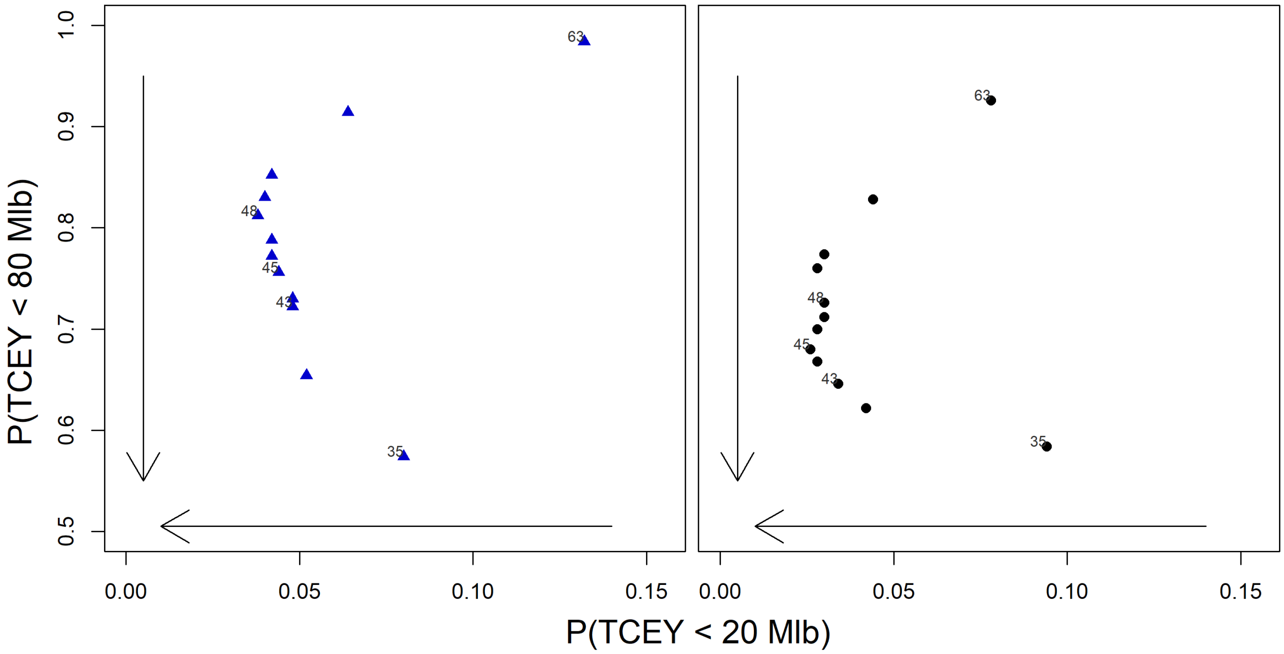

Figure 7. The probability that the TCEY is less than 80 Mlb plotted against the probability that the TCEY is less than 20 Mlb for various SPR values. The arrows indicate the desired direction (to minimise the chance) for each metric.

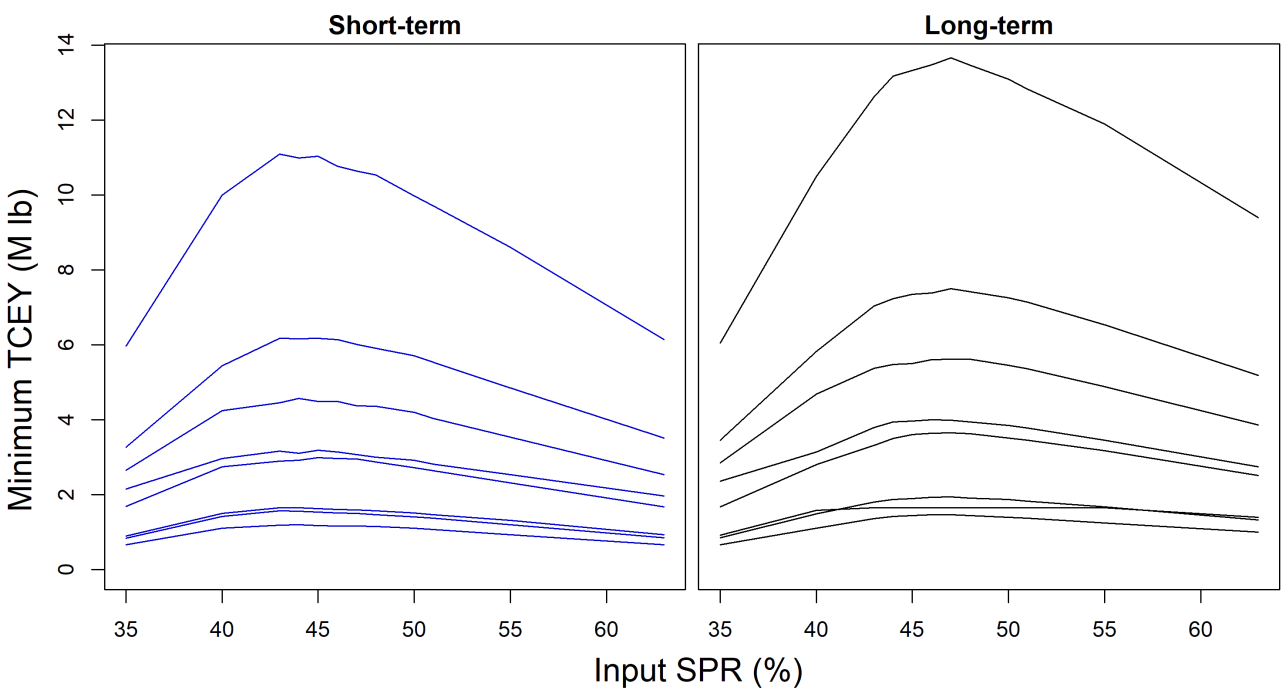

Figure 8. Minimum TCEY by IPHC Regulatory Area across fishing intensity. The individual IPHC Regulatory Areas are not labeled because the general shape of the curves is of interest.

2.2 Triennial assessment frequency performance metrics

The stock assessment undergoes a full examination every third year and is subject to smaller changes in the intervening years. This has sparked interest in examining a triennial assessment frequency using the MSE framework where the two years between full assessments do not use an assessment to determine stock status, risks (e.g. decision table), and a reference coastwide TCEY, but instead use FISS observations to determine only the reference coastwide TCEY. The current priority objectives were used to evaluate this triennial assessment frequency with an empirical harvest rule (IPHC-2025-AM101-12), but it was difficult to fully compare the interannual variability in the TCEY because it was not known what the change in the assessment year was. This was challenging when comparing a biennial assessment frequency with a triennial assessment frequency because there are fewer assessments in a ten-year period to compare with these two periods, and other factors, such as changes in the population, are confounding without consistent years with an assessment for comparison.

Document IPHC-2024-MSAB020-06 presented additional performance metrics to compare annual, biennial, and triennial assessment frequencies (partially reproduced in Table 1), but none were adopted for evaluation. The performance metrics for maximum change and maximum duration less than a 15% change from year to year were of interest and showed a longer period with a change in the TCEY less than 15% but larger maximum changes within a 10-year period. The MSAB, therefore, requested to continuing research into useful performance metrics to compare MPs with different assessment frequencies.

> **IPHC-2025-MSAB020-R, para 31.** The MSAB **REQUESTED** more research into performance metrics that may be informative of changes in the TCEY for non-assessment years and changes in the TCEY for assessment years when using a triennial assessment frequency.

If the Commission preferred to focus on only annual and triennial assessment frequencies, it would be possible to compare the years with an assessment to the years without an assessment. Choosing a ten-year period that begins with an assessment would result in four years with an assessment occurring triennially and six years without an assessment. The annual change (AC) could be calculated for the assessment and non-assessment set of years corresponding to the triennial assessment frequency (compared to the previous year). The probability that the AC exceeds a threshold could also be calculated for the assessment and non-assessment years. A similar approach could be taken with a biennial assessment, but the comparisons would only be meaningful when comparing the same assessment years. Figure 9 shows the percent AC over all 10-years of the short and long-term. The triennial assessment frequency has a lower percent AC on average, but there are high values at lower fishing intensities that are similar to the annual assessment frequency. Figure 10 shows the percent AC for only the years with an assessment in the triennial assessment frequency. The assessment years have a higher percent AC in the triennial assessment frequency compared to the annual assessment frequency. Figure 11 shows the percent AC for the years without an assessment in the triennial assessment frequency. The percent AC is lower for the triennial assessment frequency.

Table 1. 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. Partially reproduced from IPHC-2024-MSAB020-06.

Assessment Frequency			**Annual**		
SPR	**40**	**43**	**46**	**49**	**52**
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**
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**
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

Assessment years in the triennial assessment tend to have a higher percent change in the TCEY when compared to the annual assessment, but the non-assessment years have a lower percent change. Table 2 shows the probability that the percent AC is greater than 15%. The annual assessment frequency is the same for years with and without a triennial assessment because an assessment is done every year. This probability is higher in triennial assessment years and lower in triennial non-assessment years. With more non-assessment years in the triennial assessment frequency, the overall percent AC over the entire 10-year period is lower for the triennial assessment frequency. The effect of this difference depends on the assumed estimation error (accuracy of the stock assessment) and the error in the FISS because the non-assessment years use the trend in the FISS WPUE. These simulations used a single assumption based on a retrospective analysis of stock assessment results and a single assumption of the FISS error (although the FISS design analysis used different assumptions). Furthermore, the usefulness of these performance metrics depends on the objectives related to variability in the TCEY. If the objective is to reduce the variability in any year, then looking at the assessment and non-assessment years is important. However, if the objective is to reduce the variability in yield over time, then the performance metric over the entire 10-year period would be more appropriate.

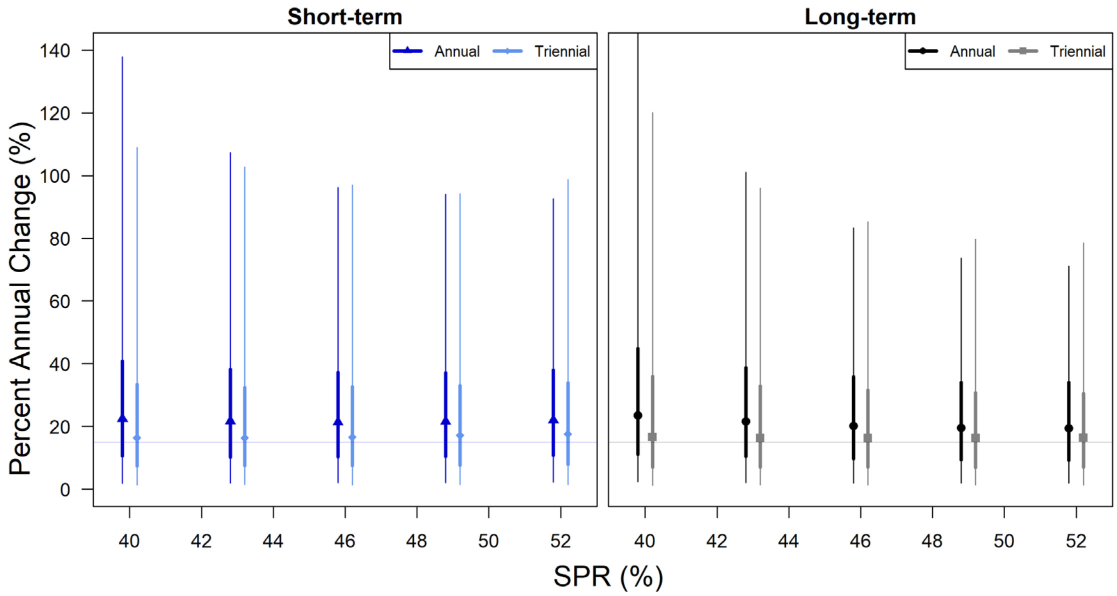

Figure 9. The percent annual change calculated over an entire 10-year period in the short- and long-term for different fishing intensities. The annual assessment frequency is shown by the darker lines. A horizontal line is shown at 15%.

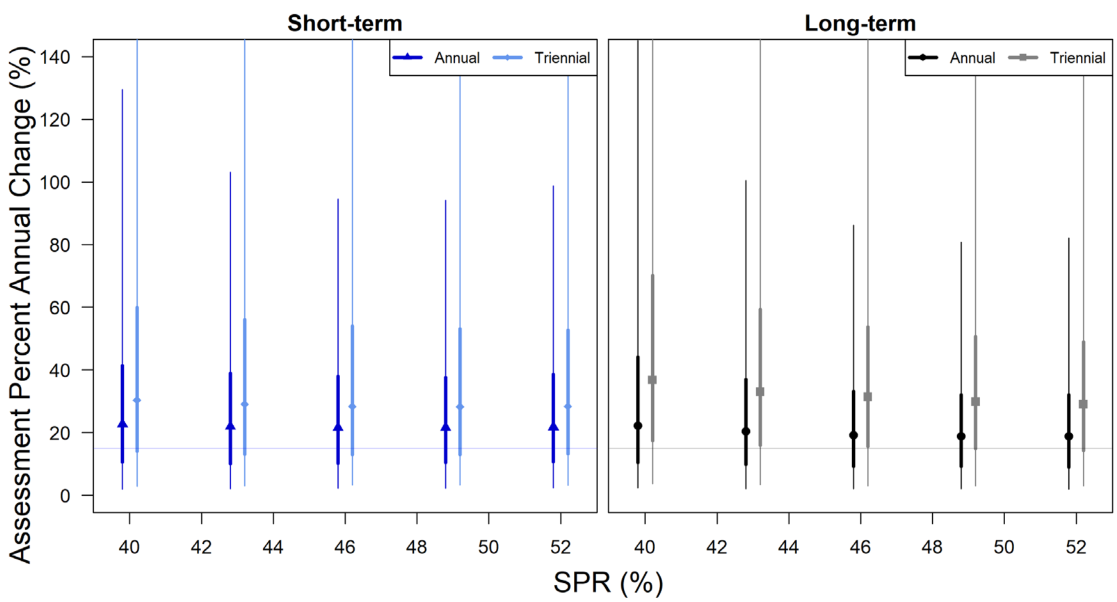

Figure 10. The percent annual change calculated over triennial assessment years only within an entire 10-year period in the short- and long-term for different fishing intensities. The annual assessment frequency is shown by the darker lines. A horizontal line is shown at 15%.

Table 2. Additional performance metrics highlighting the differences between changes in the TCEY in assessment years and non-assessment years. The percent Annual Change (AC) is calculated as the percentage change in the TCEY from the previous year.

Assessment Frequency			**Annual**		
SPR	**40**	**43**	**46**	**49**	**52**
P(AC>15%) assessment years (triennial)	0.649	0.636	0.634	0.640	0.644
P(AC>15%) non-assessment years (triennial)	0.653	0.648	0.640	0.645	0.648
Assessment Frequency			**Triennial**		
SPR	**40**	**43**	**46**	**49**	**52**
P(AC>15%) assessment years	0.728	0.713	0.703	0.710	0.715
P(AC>15%) non-assessment years	0.402	0.410	0.418	0.428	0.448

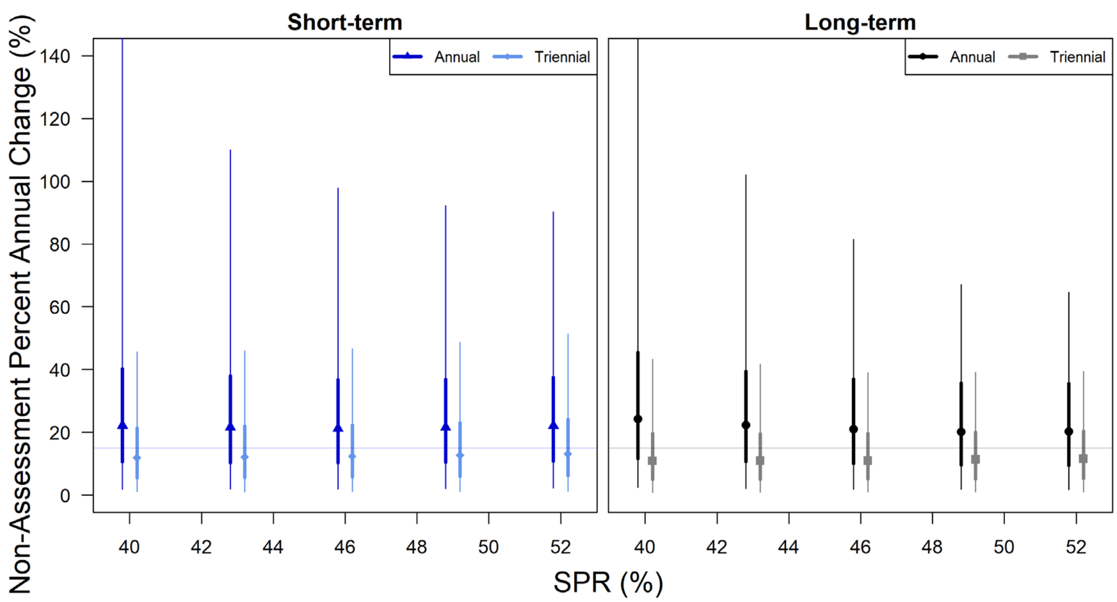

Figure 11. The percent annual change calculated over triennial non-assessment years only within an entire 10-year period in the short- and long-term for different fishing intensities. The annual assessment frequency is shown by the darker lines. A horizontal line is shown at 15%.

2.3 Additional FISS design investigations

Three FISS designs were investigated at MSAB020, and reductions in the amount of area surveyed showed a reduction in the short-term TCEY, on average (Figure 12). The MSAB made the following request to further investigate these trends.

> **IPHC-2025-MSAB020-R, para 37.** ***NOTING*** *that increased uncertainty due to reductions in the FISS design resulted in only declines in the median coastwide TCEY, the MSAB* ***REQUESTED*** *further exploration into the causes of this, especially since there is a monetary value being attributed to the FISS design.*

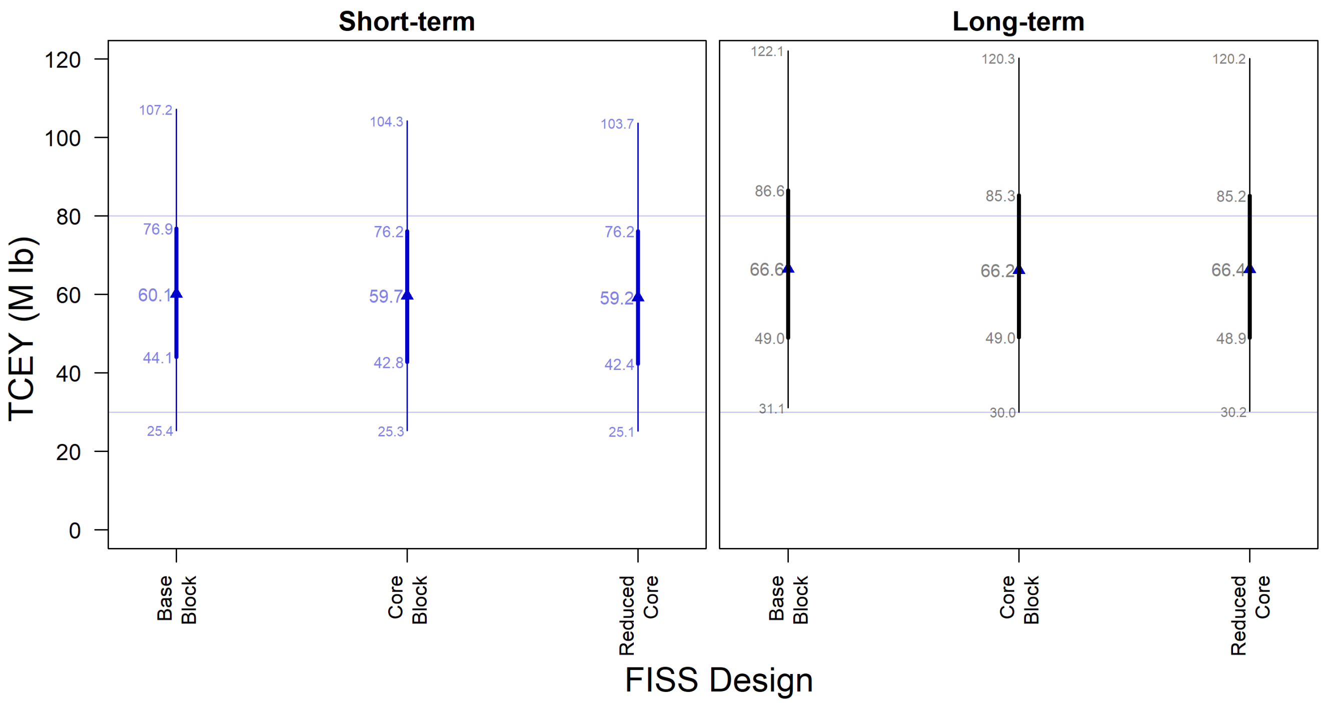

Figure 12. The distribution of simulated short- and long-term TCEY (M lb) for each FISS design. The points are the medians, the thick lines show the 25th and 75th percentiles, and the thin lines show the 5th and 95th percentiles. Actual values are shown for convenience.

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.

Three FISS designs were simulated, representing increasing observation and assessment error (Table 3). The Base Block FISS design includes sampling in all Biological Regions and IPHC Regulatory Areas each year and is considered the status quo, although it has not been fully realized since 2019. 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 3. 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%

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 base block design surveys 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 the recent 3-year coastwide trend and the number of years without a block design surveying non-core areas
        - 0-5%: ±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 the recent 3-year coastwide trend and the number of years without a block design surveying non-core areas
    - 0-5%: ±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 the recent 3-year coastwide trend and the number of years without a block design surveying non-core areas
    - 0-5%: ±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 the recent 3-year coastwide trend and the number of years without a block design surveying non-core areas
    - 0-5%: ±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

These assumptions determine the overall bias in the short- and long-term. There was no FISS bias in the Base Block design, and the FISS bias was more often negative than positive in the short-term for the Core Block and Reduced Core designs (Figure 13). The FISS bias for the long-term was on average near zero, but showed a wider range. This difference between short- and long-term occurred because the trend was more often increasing in the short-term when starting from the current low spawning biomass. The long-term TCEY was slightly reduced with the Core Block and Reduced Core designs, but less than the short-term TCEY (Figure 12). Occasional TCEYs larger than the true TCEY for a given fishing intensity have longer term effects than TCEYs smaller than the true TCEY.

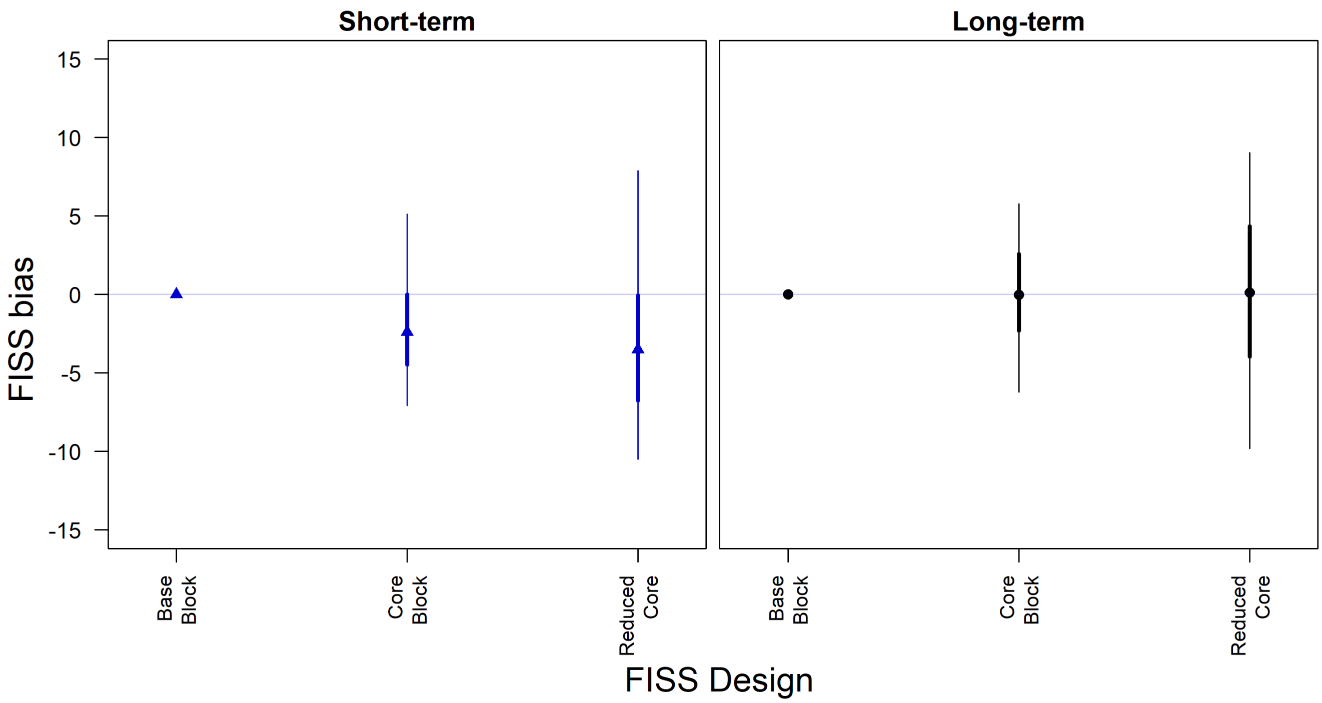

Figure 13. Simulated short- and long-term bias for the Core Block and Reduced Core designs.

3 EFFECTS OF WEIGHT-AT-AGE AND RECRUITMENT REGIMES

Pacific halibut exhibit high variability in weight-at-age and recruitment. Over the past 100 years, the average weight of an age 12 Pacific halibut has ranged from below 20 pounds in recent years to near 40 pounds in the mid-1970's (Figure 14). In the last ten years, the weight of the oldest fish has been declining or stable, but the weight of younger fish has been increasing. Recruitment is variable as well, and 1987 was one of the largest recruitments on record, as estimated in both 'long' assessment models (Figure 15). The two "long time-series" models in the IPHC stock assessment (IPHC-2025-SA-01) estimated a link between the Pacific Decadal Oscillation (PDO, Mantua et al. (1997)) and average unfished equilibrium recruitment (R_0), with an estimated average recruitment more than 50% greater during a positive PDO . Previous analyses (Clark and Hare 2002; Stewart and Martell 2016) have also shown that a positive PDO phase is correlated with enhanced productivity, while productivity decreases in negative PDO phases. Although the PDO is strongly correlated with historical recruitments, it is unclear whether the effects of climate change and other recent anomalous conditions in both the Bering Sea and Gulf of Alaska are comparable to those observed in previous decades (Litzow et al. 2020).

To investigate the effects of these low and high weight-at-age and recruitment regimes, different scenarios were defined from past observations and the population was projected 70 years with an SPR of 43%, assuming constant weight-at-age and average recruitment defined by the scenario. Three levels were developed for weight-at-age: low weight-at-age was defined from a five-year period in the 2010s, high weight-at-age was defined from a five-year period in the 1970s, and current weight-at-age was defined as the most recent five-years (Figure 14). These three weight-at-age levels show different patterns and although the low weight-at-age and current weight-at-age scenarios were both low in general, they differed between the weight of young fish and older fish. The current weight-at-age scenario had larger young fish but smaller older fish. High and low recruitment regimes were defined based on the stock assessment estimates of average recruitment in positive and negative PDO regimes. That resulted in six scenarios.

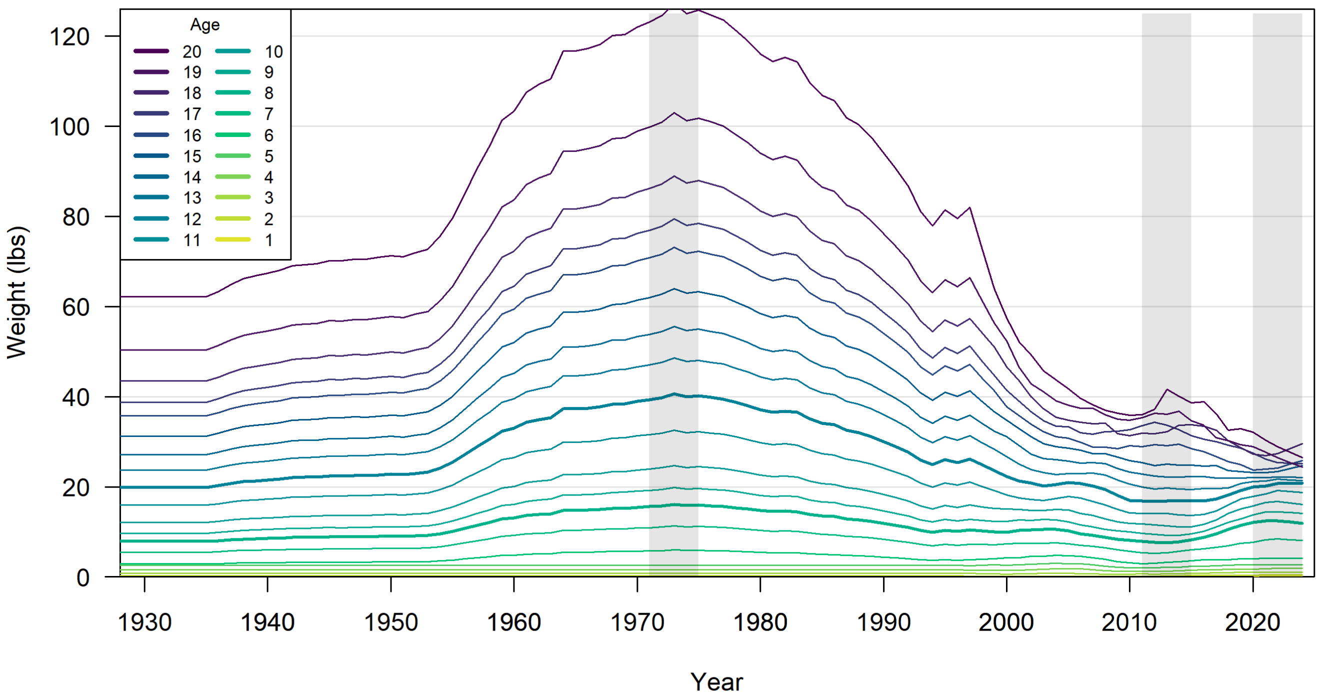

Figure 14. Average historical weight of Pacific halibut for ages one to twenty. Gray bands show three blocks of five years classified as high (1970s), low (2010s) and current (recent).

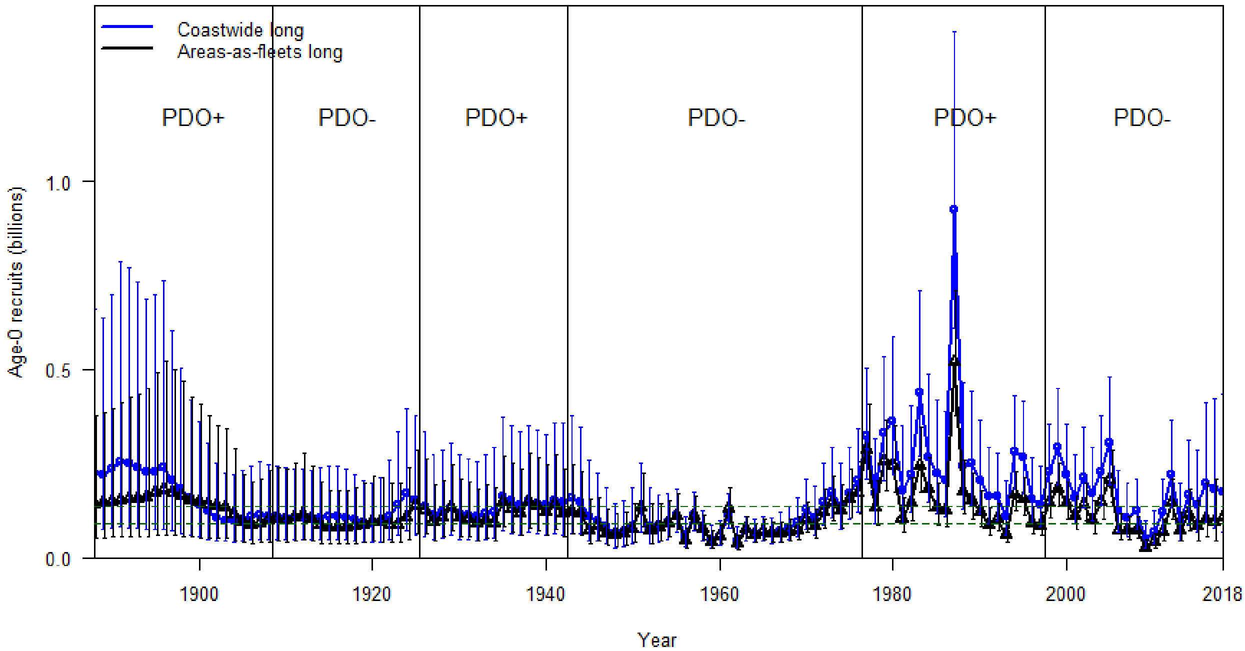

Figure 15. Trend in historical recruitment strengths (by birth year) estimated by the two long time-series stock assessment models, including the effects of the Pacific Decadal Oscillation (PDO) regimes. Figure reproduced from IPHC-2025-SA-01.

The spawning biomass differed substantially across different scenarios, but the high weight-at-age scenarios showed a considerable higher spawning biomass than the others (Figure 16). The sudden increase in the spawning biomass when the projections began indicates that weight-at-age is an important driver to the spawning biomass in the current year and future years. Average recruitment had a significant effect as well, but affected the spawning biomass in the longer term since the fish must age into the spawning biomass and was more prevalent with higher weight-at-age. For a given recruitment regime, the current weight-at-age scenario resulted in a smaller spawning biomass than the low weight-at-age scenario. This indicates the importance of the older fish in the spawning biomass.

Simulated TCEYs showed the same pattern for high weight-at-age, but different patterns for low and current weight-at-age scenarios. Weight-at-age and recruitment both had a profound effect on the TCEY with the high weight-at-age and high recruitment scenario supporting TCEYs near 120 Mlb and the high weight-at-age and low recruitment scenario supporting TCEYs near 75 Mlb. The low and current weight-at-age scenarios resulted in TCEYs in the range of 30 to 60 Mlb, on average. The TCEY showed a different pattern in the low and current weight-at-age scenarios when compared to the spawning biomass. The TCEY was higher for the current weight-at-age scenario while the spawning biomass was higher for the low weight-at-age scenario. Young Pacific halibut are more influential to the TCEY than to the spawning biomass because some are selected by the fishery before they become mature.

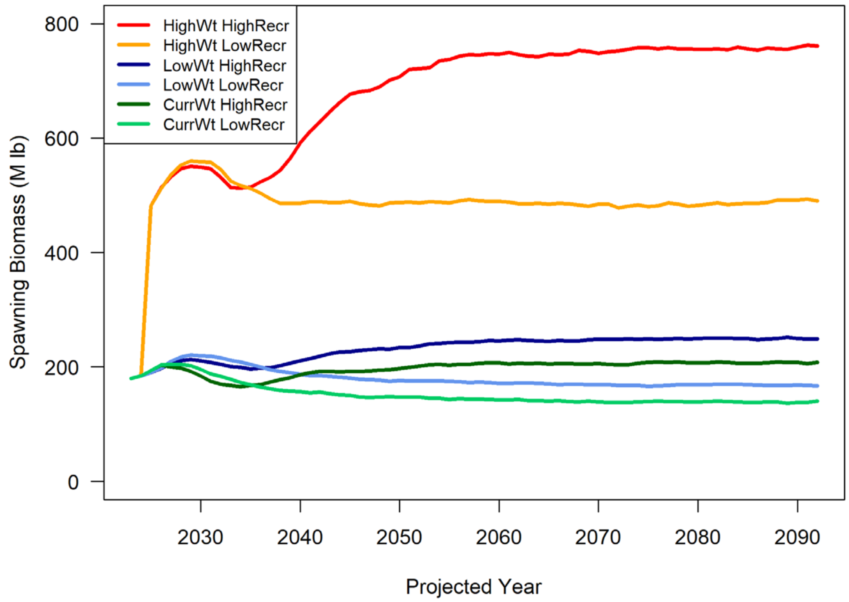

Figure 16. Simulated projections of spawning biomass assuming six different regimes for combinations of weight-at-age and recruitment and an SPR of 43%. Each projection held the weight-at-age and average recruitment at the defined level for all projected years.

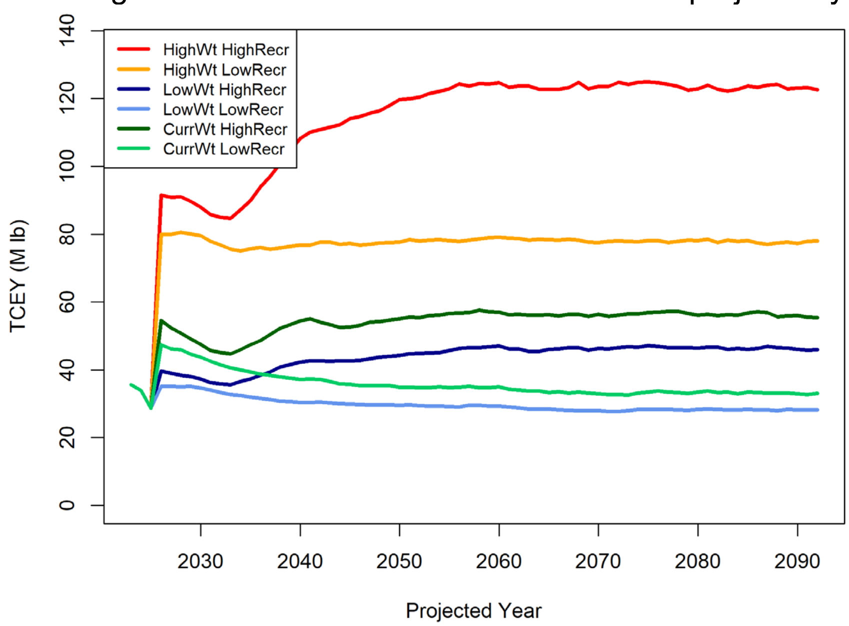

Figure 17. Simulated projections of the TCEY assuming six different regimes for combinations of weight-at-age and recruitment and an SPR of 43%. Each projection held the weight-at-age and average recruitment at the defined level for all projected years.

RECOMMENDATION/S

That the MSAB:

1) **NOTE** paper IPHC-2025-MSAB021-07 which details responses to requests of the MSAB and other work done using the management strategy evaluation framework.

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