INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC-2022-MSAB017-09

IPHC Secretariat MSE Program of Work (2022–2023) and an update on progress

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PURPOSE

To provide the Management Strategy Advisory Board (MSAB) with results for the Management Strategy Evaluation (MSE) simulations of size limit and multi-year stock assessment management procedures (MPs).

1 INTRODUCTION

The current interim management procedure at the International Pacific Halibut Commission (IPHC) is shown in Figure 1.

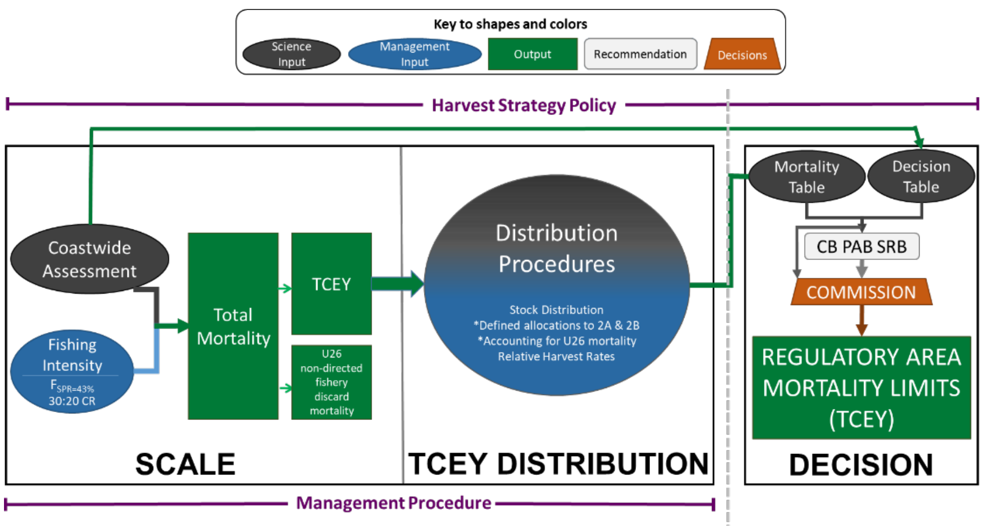

Figure 1. Illustration of the Commission interim IPHC harvest strategy policy (reflecting paragraph ID002 in IPHC-2020-CR-007) showing the coastwide scale and TCEY distribution components that comprise the management procedure. Items with an asterisk are interim agreements in place through 2022. The decision component is the Commission decision-making procedure, which considers inputs from many sources.

The Management Strategy Evaluation (MSE) at the IPHC completed an evaluation in 2021 of management procedures relative to the coastwide scale and distribution of the Total Constant Exploitation Yield (TCEY) to IPHC Regulatory Areas for the Pacific halibut fishery using a recently developed closed-loop simulation framework. Descriptions of those MPs evaluated, and simulation results are presented in Hicks et al. (2021). Additional tasks were identified at the 11th Special Session of the IPHC (IPHC-2021-SS011-R) to supplement and extend this analysis for future evaluation (Table 1). Document IPHC-2021-MSE-02 contains details of the current MSE Program of Work.

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

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

This document provides simulation results for size limits and multi-year stock assessment elements of the IPHC harvest strategy policy. These results are compared and contrasted across assumptions of estimation error and decision-making variability.

2 Management Procedures

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

2.1 Size limits

Since 1973, IPHC has restricted the directed commercial fishery for Pacific halibut with a 32 inch (81.3 cm) minimum size limit, although other forms of size limits have been in place since 1940 (Myhre 1973). Many investigations of size limits have been completed since then including IPHC (1960), Clark & Parma (1995), Parma (1999), Valero & Hare (2012), Martell et al. (2015a), Martell et al. (2015b), Stewart & Hicks (2018), and Stewart et al (2021). Most of these analyses have focused on short-term effects or effects on reference points. The novelty of this analysis using the MSE framework was to examine long-term effects of different size limits in relation to defined conservation and fishery objectives. Additionally, long-term changes to the stock and fishery distribution as well as changes in productivity were examined.

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

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

It is uncertain how selectivity of the directed commercial fisheries may change with the implementation of a different size limit than the current 32 inches. Fisheries may choose to target smaller fish to increase efficiency, they may maintain current practices, or they may target larger fish if that provides improved economic gains. Some sensitivities to changes in selectivity (e.g. alternative scenarios) may be investigated.

An important concept to bring into the evaluation of size limits is market considerations. Stewart et al. (2021) used the ratio between the U32 price and O32 price for Pacific halibut to determine what ratio is necessary for the fishery to break even economically. It is unknown what prices will be for U32 Pacific halibut if a size limit was removed, but the FISS has recently begun selling U32 fish, which may be an indicator for future market conditions of small fish. Regardless, a performance metric related to economics will be important to consider in this evaluation.

2.2 Multi-year assessments

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

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

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

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

a. The same TCEY from the previous year for each IPHC Regulatory Area.

b. Updating the coastwide TCEY proportionally to the change in the coastwide FISS O32 WPUE and updating the distribution of the TCEY using FISS results and the applied distribution procedure.

c. Maintaining the same coastwide TCEY as the previous year but updating the distribution of the TCEY using FISS results and the applied distribution procedure.

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

The coastwide TCEY set in the assessment year also can be calculated using different methods. The coastwide TCEY may simply be determined from the one-year projection of the stock assessment without any consideration of the projections beyond one year. This is the method assumed in the above empirical rules. An alternative method would be to take an average of the coastwide TCEYs, given a defined fishing intensity, projected for all years before the next assessment. This would account for potential changes in the population and may maintain the stock closer to target biomass levels and the fishing intensity closer to reference SPR levels. Alternative methods of averaging projected TCEYs were not considered.

Alternative approaches that would not require the current stock assessment for setting mortality limits in any year would be to use a simpler estimation model that is tuned to achieve the performance desired (i.e. meet primary objectives) or to adopt an empirical-based MP as the method for setting annual mortality limits. The stock assessment would be used at a defined interval to verify that management is effective, determine status of the stock, and to potentially tune the MSE OM and existing MP (Cox and Kronlund 2008). This concept was a request of the SRB

> **IPHC-2022-SRB020-R, para 20** The SRB REQUESTED that the MSE not attempt to implement a Stock Synthesis estimation procedure as part of the management procedure and, instead, to integrate a simpler assessment modelling approach into the management procedure via tuning

The Commission has realized that there are benefits to multi-year assessments, including stability and transparency in mortality limits for multiple rather than single years, additional time during the Interim/Annual meeting process to focus on topics other than setting mortality limits, time for development/improvement of the stock assessment, and the potential for increased collaborative research across branches within the IPHC Secretariat. However, there may be some costs associated with multi-year assessments. For example, performance in meeting conservation and fishery objectives may be reduced depending on the interval for multi-year assessments and the specifics of the selected management procedure.

The Commission has asked the SRB to assist the Secretariat in identifying potential costs and benefits of not conducting an annual stock assessment.

> **IPHC-2022-AM098-R, para 63:** *The Commission REQUESTED that the IPHC Secretariat work with the SRB and others as necessary to identify potential costs and benefits of not conducting an annual stock assessment. This will include a prioritized list of work items that could be accomplished in its place.*

The SRB provided some insight at SRB020 and the Secretariat will continue to work with the SRB in identifying costs and benefits.

> **IPHC-2022-SRB020-R, para 27**. *The SRB NOTED that assessment research activities (e.g. paras. 23-26) are examples of work that could be done more extensively in non-assessment years within a multi-year assessment schedule. Other work could include investigating optimal sub-sampling designs for ages, sex-ratio, annual assessment methods to use within the MPs, and well as any of the several topics listed under Stock Assessment Research. The quantifiable costs of multi-year assessments could be estimated within the MSE, for example, of potentially lower average yield for longer assessment cycles to achieve the same levels of risk associated with annual assessments.*

It may be premature to begin identifying detailed costs and benefits of multi-year assessments until an evaluation has been done to determine whether multi-year assessments may meet the Commission objectives already defined. An evaluation of multi-year assessments using Commission conservation and fishery objectives will be presented at the 99th IPHC Annual Meeting, after which a discussion of detailed costs and benefits would be informative.

2.3 Modelling distribution

The fisheries in the OM are specified by IPHC Regulatory Area because many of the Commission objectives used to evaluate MPs are specific to IPHC Regulatory Areas and the OM is spatially structured by Biological Region. This makes it necessary to distribute the TCEY across the fisheries to appropriately remove biomass from each Biological Region and allow for the calculation of necessary performance metrics. Distribution procedures have been evaluated (Hicks et al. 2021), but a specific MP has not been implemented. Even though distribution procedures are not currently being evaluated and there is no specific agreement on a single distribution procedure, they are part of the MP and need to be included in the simulations. Therefore, the Commission has recommended five different distribution procedures representing a practicable range to provide a robust analysis of size limits and multi-year assessments.

> **IPHC-2022-SS012-R, para 11**: *The Commission RECOMMENDED the following five distribution procedures to be used in the management strategy evaluation of size limits and multi-year assessments, noting that these distribution procedures are for analytical purposes only and are not endorsed by both parties, thus would be reviewed in the future if the Commission wishes to evaluate them for implementation.*
>
> > *a) Baseline based on recent year O32 FISS results, relative harvest rates of 1.0 for IPHC Regulatory Areas 2-3A, relative harvest rates of 0.75 for IPHC Regulatory Areas 3B-4, and no application of the current interim agreements for 2A and 2B;*

b) Baseline based on recent year O32 FISS results, relative harvest rates of 1.0 for IPHC Regulatory Areas 2-3A, relative harvest rates of 0.75 for IPHC Regulatory Areas 3B-4, and current interim agreements for 2A and 2B;

c) Baseline based on recent year O32 FISS results with 1.65 Mlbs to 2A and 20% of the coastwide TCEY to 2B;

d) Baseline based on recent year O32 FISS results, relative harvest rates of 1.0 for IPHC Regulatory Areas 2-3, 4A, and 4CDE, a relative harvest rate of 0.75 for IPHC Regulatory Area 4B, and no agreements for 2A and 2B;

e) Baseline based on recent year O32 FISS results, relative harvest rates of 1.0 for IPHC Regulatory Areas 2-3, 4A, and 4CDE, a relative harvest rate of 0.75 for IPHC Regulatory Area 4B, and current interim agreements for IPHC Regulatory Areas 2A and 2B

Three of the five distribution procedures contain agreements for IPHC Regulatory Areas 2A and 2B (b, c, and e). Decision-making variability for these two areas is set to zero when agreements are in place.

2.4 MP combinations

The simulation time for a single MP may be days, therefore it is useful to identify a minimal set of runs that will provide insight into the performance of each element of the MP of interest. There are six main elements of MPs to evaluate which include the three size limits and three empirical rules for biennial assessments, as presented above, and are combined as shown in Table 2. For each MP, an SPR of 43% was used, with some specific combinations using SPR values of 40% and 46% to further investigate the effects of fishing intensity.

Table 2. Primary MPs to be evaluated. The multi-year assessment specifies the frequency of the stock assessment and the procedure for years without a stock assessment (see Section 2.2).

MP ID	Multi-year assessment	Size Limit (inches)
MP-A32	Annual	32
MP-A26	Annual	26
MP-A0	Annual	0
MP-Ba32	Biennial, constant TCEY	32
MP-Bb32	Biennial, empirical rule	32
MP-Bc32	Biennial, update distribution	32

Additional factors are often useful to investigate to understand how sources of variability affect the outcomes. We examine estimation error (with or without) and decision-making variability (none and two options) to further examine the specific effects of these sources of variability. Evaluation of the main elements of the MPs under consideration (i.e. size limits and multi-year assessments, Table 2) should be done with estimation error and an appropriate specification of decision-making variability. However, an appropriate specification of decision-making variability is difficult to know. Therefore, we will compare results using the two decision-making variability options presented in IPHC-2022-MSAB017-07 with each other as well as with no decision-making variability. Results only for no decision-making variability and option 1 (distribution only) were available to report in this document, but results for option 2 will be available at MSAB017.

A secondary set of MPs may be developed based on the performance of the primary set. This may include crossing size limits with biennial assessments, tuning SPR values to best meet objectives, examining different levels of estimation error, and incorporating various forms of implementation variability. This secondary set will not be a full factorial, but instead a specific investigation of relevant factors, and to refine the best performing MPs relative to stock and fishery objectives.

Furthermore, a set of sensitivities will be done using alternative scenarios (see Section 2.3 in IPHC-2022-MSAB017-07). These will be performed on a small set of the best performing MPs.

3 Results and Evaluation

The MPs were integrated across the distribution procedures, resulting in the six MPs in Table 2 as distribution is considered an uncertainty in this evaluation. However, any interesting differences between distribution procedures may be reported.

Improvement of the methods to evaluate simulation results and present those for decision-making are ongoing. Current tasks specifically include updates to the MSE Explorer tool, improving the ranking procedure to identify best performing management procedures, determining new methods to identify best performing management procedures, and providing new types of plots and tables that effectively communicate the results. This task will benefit from interactions with stakeholders and management agencies, including MSAB017.

3.1 Projections

The improvements to the MSE framework, including the updated OM, resulted in some different outcomes compared to the previous OM. However, general conclusions were consistent with previous analyses. The additional years at the end of the historical time-series in the OM resulted in immediate optimistic trends in the spawning biomass (Figure 2) due to a possibly large 2012 year class, a positive PDO regime, and increasing trends in weight-at-age. Therefore, short-term results from this analysis are likely more optimistic than previous analyses.

3.2 Size limits

Applying the three size limits resulted in little change to the biological sustainability performance metrics, but short-term fishery sustainability performance metrics showed some improvements when lowering the size limit (Table 3). The TCEY, on average, was 2.8% higher with a 26-inch size limit and 3.3% higher with no size limit. Annual variability in the TCEY was slightly reduced with lower size limits but above 15%.

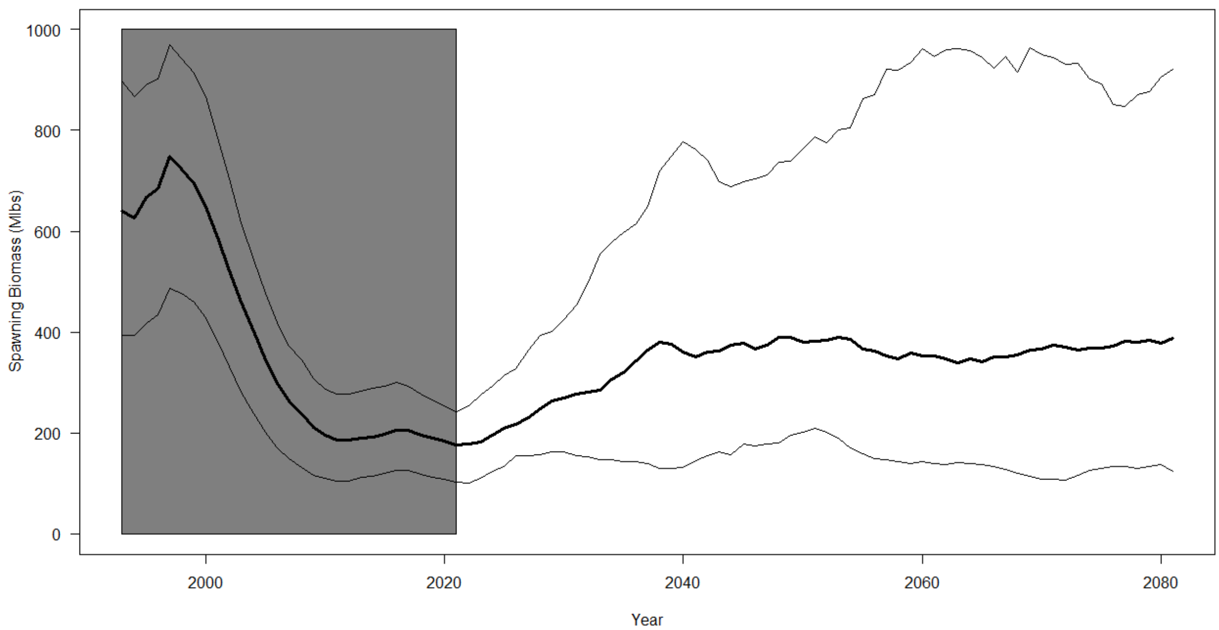

Figure 2. Projected spawning biomass with MP-A32, an SPR of 43%, and no estimation error. The shaded area is the historical region with fixed data and fishing mortality. The thick line is the median and the thin lines are the 5th and 95th percentiles.

The percentage gain in the TCEY is variable across years and is higher in the short-term given starting conditions of the projections (Figure 3) There is a very small probability that the TCEY is less without a size limit. The high percent gain in recent projected years is due to starting conditions, which declines as recruitment, weight-at-age, and environmental regimes become more integrated across the range of possible values. Therefore, the gains in yield due to lowering the size limit are likely dependent on the current size-at-age and incoming recruitment.

The patterns were similar for performance metrics calculated for each IPHC Regulatory Area (Table 4). The median average TCEY in the IPHC Regulatory Areas increased between 4.3% and 5.8% except for IPHC Regulatory Area 2A (no change since three of the five distribution procedures had a fixed 1.65 Mlbs) and IPHC Regulatory Area 2B (3.5%). Even though the TCEY in IPHC Regulatory Area 3A showed a modest percent increase without a size limit (4.3%), the absolute increase in the TCEY was over 1 million pounds. Annual variability in the TCEY for each IPHC Regulatory Area decreased when removing the size limit, but remained above 15.7% for all areas except 2A.

The majority of the gain in median average TCEY and the reduction in annual variability of the TCEY was achieved when lowering the size limit from 32 inches to 26 inches. This is because the directed commercial gear has a low selectivity for Pacific halibut less than 26 inches.

Table 3. Performance metrics related to primary objectives for size limit MPs with estimation error and decision-making variability option 1. Biological sustainability metrics are long-term and fishery sustainability are short-term (4–13 years).

MP name	**MP-A0**	**MP-A26**	**MP-A32**
Decision-making variability	**Option1**	**Option1**	**Option1**
Estimation Error	**Sim**	**Sim**	**Sim**
Assessment Frequency	**Annual**	**Annual**	**Annual**
Size Limit	**0**	**26**	**32**
SPR	**0.43**	**0.43**	**0.43**
Median average SPR	43.9%	44.0%	44.0%
Biological Sustainability			
Median average RSB	38.9%	38.9%	38.9%
P(any RSB_y<20%)	0	0	0
P(all RSB<36%)	0.14	0.14	0.15
Fishery Sustainability			
Median average TCEY	60.08	59.80	58.16
P(any3 change TCEY > 15%)	0.932	0.942	0.958
Median AAV TCEY	18.0%	18.2%	18.5%

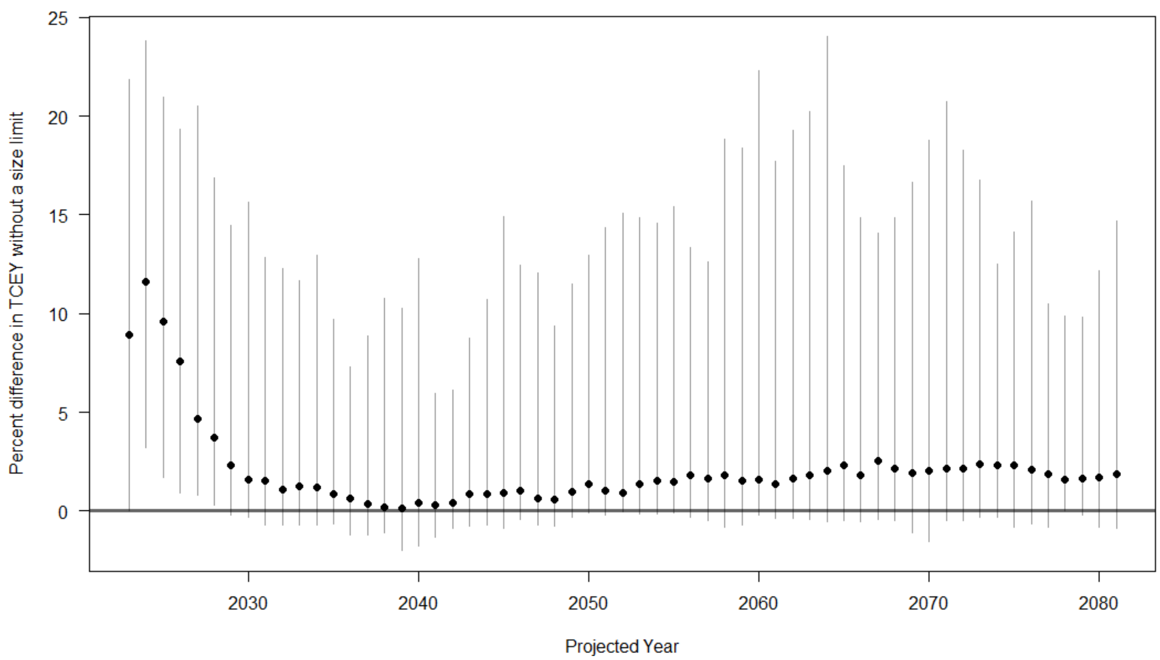

Figure 3. Percent difference in the TCEY without a size limit compared to a 32-inch size limit for each projected year when simulating estimation error and using an input SPR equal to 43%. The points are the median and the vertical lines connect the 5th and 95th percentiles.

Table 4. Performance metrics related to area-specific primary objectives for size limit MPs with no decision-making variability. Fishery sustainability metrics are short-term (4–13 years).

MP name	**MP-A0**	**MP-A26**	**MP-A32**
Decision-making variability	**Option1**	**Option1**	**Option1**
Estimation Error	**Sim**	**Sim**	**Sim**
Assessment Frequency	**Annual**	**Annual**	**Annual**
Size Limit	**0**	**26**	**32**
SPR	**0.43**	**0.43**	**0.43**
Median average TCEY-2A	1.63	1.63	1.63
Median average TCEY-2B	9.09	9.03	8.78
Median average TCEY-2C	6.79	6.77	6.47
Median average TCEY-3A	24.41	24.14	23.32
Median average TCEY-3B	7.48	7.45	7.17
Median average TCEY-4A	3.63	3.6	3.43
Median average TCEY-4CDE	4.25	4.22	4.04
Median average TCEY-4B	2.95	2.89	2.79
P(any3 change TCEY 2A > 15%)	0.262	0.266	0.294
P(any3 change TCEY 2B > 15%)	0.690	0.674	0.734
P(any3 change TCEY 2C > 15%)	0.748	0.768	0.786
P(any3 change TCEY 3A > 15%)	0.758	0.780	0.790
P(any3 change TCEY 3B > 15%)	0.758	0.778	0.788
P(any3 change TCEY 4A > 15%)	0.854	0.834	0.870
P(any3 change TCEY 4CDE > 15%)	0.612	0.624	0.610
P(any3 change TCEY 4B > 15%)	0.834	0.826	0.856
Median AAV TCEY 2A	2.30%	2.30%	2.50%
Median AAV TCEY 2B	16.80%	17.50%	18.00%
Median AAV TCEY 2C	18.40%	18.70%	19.20%
Median AAV TCEY 3A	19.90%	20.10%	20.40%
Median AAV TCEY 3B	20.80%	21.50%	21.50%
Median AAV TCEY 4A	21.50%	21.60%	22.30%
Median AAV TCEY 4CDE	15.70%	16.00%	15.80%
Median AAV TCEY 4B	21.90%	21.80%	22.50%

3.2.1 Effects of estimation error and decision-making variability

Simulated estimation error resulted in a lower average fishing intensity (i.e. higher SPR) but a slightly lower average relative spawning biomass when using an input SPR equal to 43%. The lower portion of the distribution of average relative spawning biomass was more compact than without estimation error as shown by the lower probability of being less than 36%. The upper portion of the distribution of average RSB was wider with estimation error (Figure 4).

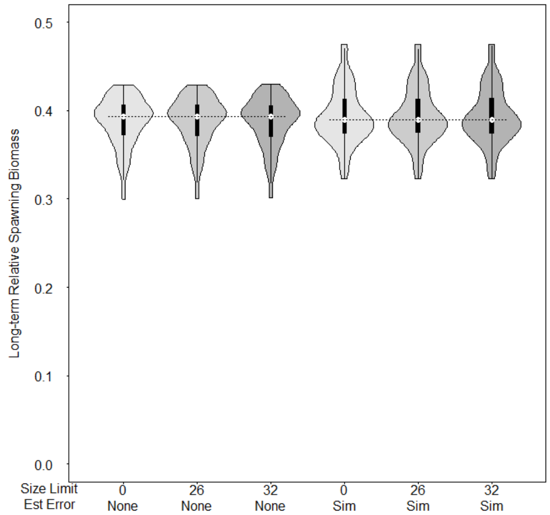

Figure 4. Violin plots of long-term relative spawning biomass for the three size limits (different shades of grey) and no estimation error (left) or simulated estimation error (right) and an input SPR equal to 43%. A dashed line is drawn at the median for the 32 inch size limit of each estimation error type.

Estimation error had a minor effect on the short-term TCEY but had a greater effect on the range of TCEY in the long-term (Figure 5). There was a clear lower bound on the TCEY, which was slightly lower in the long-term and with estimation error. The gain in TCEY when removing the size limit was reduced when simulating estimation error.

The biggest difference between no estimation error and simulated estimation error was seen in the variability metrics for the TCEY. The short-term coastwide AAV was greater than 18% (Table 3) and the short-term coastwide AAV was near 5% without estimation error. The probability of the change in TCEY for any 3 years out of 10 being greater than 15% was above 0.90 without estimation error (Table 3) and below 0.10 without estimation error. With or without estimation error, the removal of the size limit resulted in a very slight decrease in variability metrics.

Decision-making variability (option1) showed very little difference when compared to results not simulating decision-making variability. Results using option 2 for decision-making variability (departures from the coastwide TCEY) were not available for this document, but may show more of a difference.

3.2.2 Effects of fishing intensity (SPR)

Increasing fishing intensity resulted in higher average TCEY and higher variability in the TCEY (Table 5). Short-term median average TCEYs without a size limit and an input SPR of 40% increased by 4.6% compared to the short-term median average TCEY with a size limit of 32 inches and an input SPR of 40%. The short-term increase in yield was 2.4% without a size limit and an input SPR of 46%. Long-term yields showed a similar pattern with less increase (Table 6). Long-term probabilities of relative spawning biomass being less than 36% were around 42% with an input SPR of 40%.

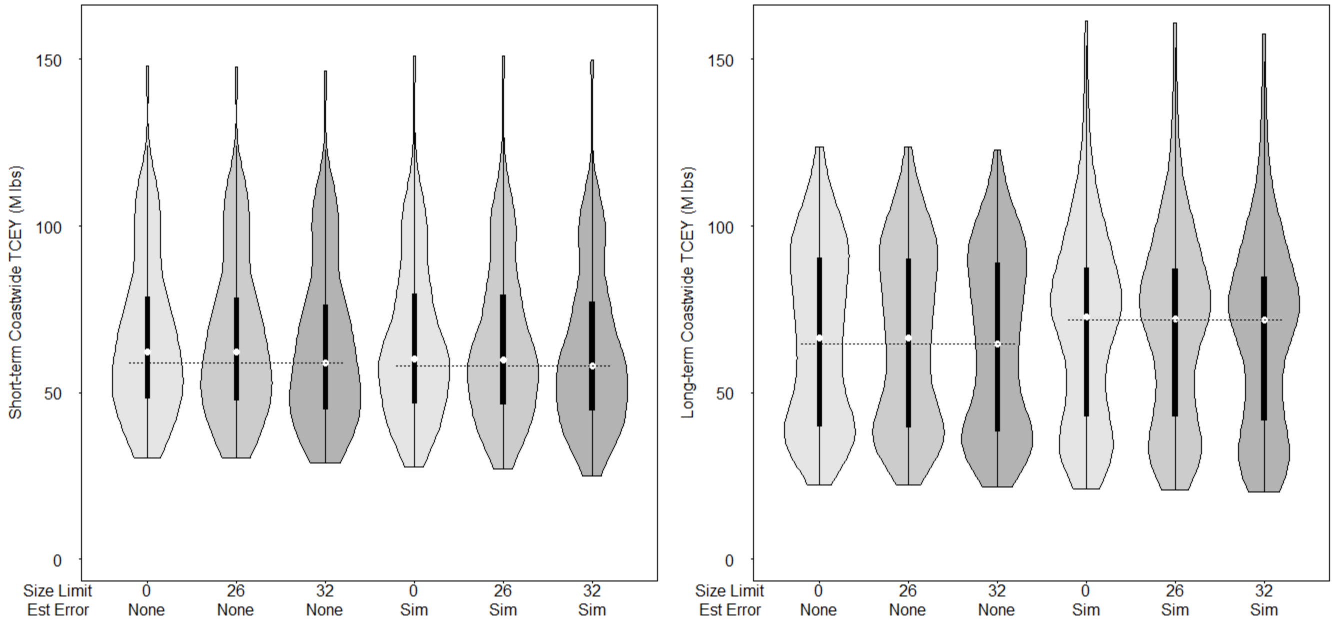

Figure 5. Short-term coastwide TCEY (left) and long-term coastwide TCEY (right) for the three size limits with (Sim) and without (None) simulated estimation error and an input SPR equal to 43%.

Table 5. Performance metrics related to primary objectives for no size limit and 32 inch size limit MPs with estimation error and decision-making variability option 1. Three different input SPR values (40%, 43%, and 46%) are used.

MP name	**MP-A0**	**MP-A0**	**MP-A0**	**MP-A32**	**MP-A32**	**MP-A32**
Decision-making variability			**Option1**			
Estimation Error			**Sim**			
Assessment Frequency			**Annual**			
Size Limit	**0**	**0**	**0**	**32**	**32**	**32**
SPR	**0.40**	**0.43**	**0.46**	**0.40**	**0.43**	**0.46**
Median average SPR	41.50%	43.70%	46.10%	41.60%	43.70%	46.30%
Biological Sustainability						
Median average RSB	36.50%	38.90%	41.70%	36.60%	38.90%	41.70%
P(any RSB_y<20%)	0	0	0	0	0	0
P(all RSB<36%)	0.43	0.14	0.05	0.42	0.15	0.06
Fishery Sustainability						
Median average TCEY	63.85	60.08	56.16	61.04	58.16	54.85
P(any3 change TCEY > 15%)	0.952	0.932	0.928	0.982	0.958	0.956
Median AAV TCEY	22.30%	18.00%	16.80%	22.40%	18.50%	17.20%

Table 6. Percent change in short-term and long-term yield of MPs with no size limit compared to MPs with a 32 inch size limit using three levels of input SPR**.**

SPR	**0.40**	**0.43**	**0.46**
Short-term	4.6%	3.3%	2.4%
Long-term	2.8%	1.9%	0.7%

3.3 Multi-year assessments

Simulations of an MP with a biennial assessment frequency were done using three options for non-assessment years: option a) used the same TCEY in each IPHC Regulatory from the previous assessment year, option b) updated the coastwide TCEY proportional to the change in the coastwide FISS index and updated distribution using FISS results, and option c) used a constant coastwide TCEY in non-assessment years but updated distribution using FISS observations. Long-term biological sustainability metrics were very similar across the four MPs of an annual assessment and three options for a biennial ssessment (Table 7). The long-term probability that the relative spawning biomass would be less than 36% differed slightly between MPs, with the biennial assessment frequency having a slightly higher probability. Differences in short-term median average TCEY were almost negligible, although the biennial MPs that did not update the coastwide TCEY in non-assessment years were slightly smaller and the biennial MP that used the FISS observations to update the coastwide TCEY was slightly larger. The annual variability of the TCEY was less for the biennial assessments that did not update the coastwide TCEY in non-assessment years, which is likely due to the fact that 5 of the 10 years had zero change. It is not known how much change occurred every other year when the TCEY was able to change, and there are no current objectives that would indicate whether a stable 2-year period with a larger biennial change is preferable to possibly smaller annual changes in the TCEY. The patterns in TCEY across MPs were similar for each IPHC Regulatory both in the short-term (Table 7) and the long-term (not shown).

3.3.1 Effects of estimation error and decision-making variability

Simulations with estimation error showed a lower probability of the relative spawning biomass being less than 36%, slightly lower short-term median average TCEY, and much higher short-term variability in the TCEY. Option 1 decision-making variability had little effect on the results for biennial assessment MPs. Results using option 2 for decision-making variability (departures from the coastwide TCEY) were not available for this document but may show more of a difference.

Table 7. Performance metrics related to primary objectives for annual and biennial MPs with a size limit of 32 inches simulated with estimation error and option 1 decision-making variability. Biological sustainability metrics are long-term and fishery sustainability are short-term (4–13 years). Long-term fishery sustainability metrics (not shown here) suggested a slightly larger median average TCEY in the biennial assessment MPs and slightly lower variability in the TCEY for biennial assessment MPs.

MP name	**MP-A32**	**MP-Ba32**	**MP-Bb32**	**MP-Bc32**
Decision-making variability	**Option1**	**Option1**	**Option1**	**Option1**
Estimation Error	**Sim**	**Sim**	**Sim**	**Sim**
Assessment Frequency	**Annual**	**Biennial**	**Biennial**	**Biennial**
Size Limit	**32**	**32**	**32**	**32**
SPR	**0.43**	**0.43**	**0.43**	**0.43**
Median average SPR	44.0%	43.3%	43.7%	43.3%
Biological Sustainability				
Median average RSB	38.9%	38.9%	38.8%	38.9%
P(any RSB_y<20%)	0.00	0.00	0.00	0.00
Fishery Sustainability				
P(all RSB<36%)	0.15	0.18	0.16	0.18
Median average TCEY	58.16	57.93	58.32	57.94
P(any3 change TCEY > 15%)	0.958	0.768	0.900	0.770
Median AAV TCEY	18.5%	14.6%	18.9%	14.6%

3.3.2 Effects of fishing intensity (SPR)

A higher fishing intensity (SPR=40%) showed higher long-term probabilities of the relative spawning biomass being below 36%, which were highest in the biennial assessment MPs (Table 9). Surprisingly, though, the long-term median average SPR for the biennial assessment MPs were higher, indicating a lower fishing intensity. It is uncertain why this occurs. The TCEY is similar across MPs and although the variability of the TCEY is higher due to higher fishing intensity, the pattern is the same as with SPR=43%.

Table 8. Short-term fishery-sustainability performance metrics for each IPHC Regulatory Area related to primary objectives for annual and biennial MPs with a size limit of 32 inches simulated with estimation error and option 1 decision-making variability.

MP name	**MP-A32**	**MP-Ba32**	**MP-Bb32**	**MP-Bc32**
Decision-making variability	**Option1**	**Option1**	**Option1**	**Option1**
Estimation Error	**Sim**	**Sim**	**Sim**	**Sim**
Assessment Frequency	**Annual**	**Biennial**	**Biennial**	**Biennial**
Size Limit	**32**	**32**	**32**	**32**
SPR	**0.43**	**0.43**	**0.43**	**0.43**
Median average TCEY-2A	1.63	1.63	1.63	1.63
Median average TCEY-2B	8.78	8.67	8.7	8.69
Median average TCEY-2C	6.47	6.31	6.42	6.39
Median average TCEY-3A	23.32	22.89	23.27	22.82
Median average TCEY-3B	7.17	7.05	7.16	7.06
Median average TCEY-4A	3.43	3.44	3.47	3.40
Median average TCEY-4CDE	4.04	4.03	4.04	4.02
Median average TCEY-4B	2.79	2.75	2.76	2.71
P(any3 change TCEY 2A > 15%)	0.958	0.768	0.900	0.770
P(any3 change TCEY 2B > 15%)	0.294	0.128	0.244	0.184
P(any3 change TCEY 2C > 15%)	0.734	0.454	0.624	0.492
P(any3 change TCEY 3A > 15%)	0.786	0.492	0.698	0.512
P(any3 change TCEY 3B > 15%)	0.790	0.532	0.778	0.560
P(any3 change TCEY 4A > 15%)	0.788	0.518	0.772	0.594
P(any3 change TCEY 4CDE > 15%)	0.870	0.516	0.754	0.580
P(any3 change TCEY 4B > 15%)	0.610	0.298	0.556	0.396
Median AAV TCEY 2A	2.5%	1.9%	2.3%	2.0%
Median AAV TCEY 2B	18.0%	13.8%	17.8%	15.0%
Median AAV TCEY 2C	19.2%	15.2%	19.4%	16.7%
Median AAV TCEY 3A	20.4%	15.5%	21.0%	16.6%
Median AAV TCEY 3B	21.5%	16.7%	21.9%	18.1%
Median AAV TCEY 4A	22.3%	17.0%	22.0%	19.6%
Median AAV TCEY 4CDE	15.8%	11.9%	16.0%	14.0%
Median AAV TCEY 4B	22.5%	16.3%	21.4%	19.7%

3.4 Additional results anticipated for the 99th IPHC Annual Meeting

Additional results and comparisons will be provided at the 99th IPHC Annual Meeting. Option 2 for decision-making variability with estimation error will be simulated and contrasted to runs without this source of variability. Additional performance metrics will also be examined, including the age/size composition of landings, the amount of fish discarded and discard mortality in the directed commercial fisheries, and other sector-specific metrics.

Table 9. Performance metrics related to primary objectives for annual and biennial MPs with a size limit of 32 inches and SPR equal to 40%, simulated with estimation error and option 1 decision-making variability. Biological sustainability metrics are long-term and fishery sustainability are short-term (4–13 years).

MP name	**MP-A32**	**MP-Ba32**	**MP-Bb32**	**MP-Bc32**
Decision-making variability	**Option1**	**Option1**	**Option1**	**Option1**
Estimation Error	**Sim**	**Sim**	**Sim**	**Sim**
Assessment Frequency	**Annual**	**Biennial**	**Biennial**	**Biennial**
Size Limit	**32**	**32**	**32**	**32**
SPR	**0.40**	**0.40**	**0.40**	**0.40**
Median average SPR	41.7%	42.5%	42.3%	42.4%
Biological Sustainability				
Median average RSB	36.6%	36.4%	36.3%	36.4%
P(any RSB_y<20%)	0.00	0.00	0.00	0.00
Fishery Sustainability				
P(all RSB<36%)	41.8%	45.1%	44.3%	45.1%
Median average TCEY	61.04	61.03	61.74	60.97
P(any3 change TCEY > 15%)	0.982	0.824	0.934	0.822
Median AAV TCEY	22.4%	17.8%	22.9%	17.7%

RECOMMENDATION/S

That the MSAB:

a) **NOTE** paper IPHC-2022-MSAB017-09 describing size limits and biennial assessment management procedures with simulation results to evaluate.

b) **RECOMMEND** additional scenarios or additional MPs to be presented at IM098 and AM099.

c) **RECOMMEND** additional performance metrics that may be useful for evaluation of size limit and biennial assessment MPs.

d) **RECOMMEND** MPs to evaluate beyond 2023.

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Appendices

Appendix A: Supplementary material

APPENDIX A
SUPPLEMENTARY MATERIAL

In addition to this document, an MSE technical document is available electronically. This is document IPHC-2022-MSE-01 and is available on the IPHC MSE page (https://www.iphc.int/management/science-and-research/management-strategy-evaluation). Additional updates will be made as time allows.

The MSE Explorer will also be updated as additional results.

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