# Development of the 2023 Pacific halibut (*Hippoglossus stenolepis*) stock assessment

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## PURPOSE

To provide the IPHC's Scientific Review Board (SRB) with a response to recommendations and requests made during SRB021 (IPHC-2022-SRB021-R) and to provide the Commission with an update of the 2023 stock assessment development.

## INTRODUCTION

In 2022 the International Pacific Halibut Commission (IPHC) undertook its annual coastwide stock assessment of Pacific halibut (*Hippoglossus stenolepis*). That assessment represented a full analysis, following the previous full assessment conducted in 2019, updated in 2020 and again in 2021. Changes from the 2021 assessment were developed and reviewed by the IPHC's SRB, in June (SRB020; IPHC-2022-SRB020-07, IPHC-2022-SRB020-R) and September 2022 (SRB021; IPHC-2022-SRB021-08, IPHC-2022-SRB021-R). Changes that were included in the 2022 stock assessment and new data included:

1. Updating the version of the stock synthesis software used for the analysis (3.30.19).
2. Expanding the treatment of natural mortality (*M*) to include an informative prior based on longevity and assign increased values at the youngest ages based on meta-analysis of other flatfish species.
3. Improving the basis for data weighting via use of bootstrapped effective sample sizes as model inputs based on the FISS and fishery sampling programs, rather than the raw number of sets/trips used in previous assessments.
4. Estimating *M* in the short time-series Areas-As-Fleets (AAF) model.
5. Including standard updates to mortality estimates from all fisheries, directed commercial fishery and FISS (fishery-independent setline survey) biological and trend information, and other sources including data collected in 2022.

A summary of stock assessment results (IPHC-2023-AM099-11) was provided for the IPHC's Annual Meeting (AM099). In addition, the input data files are archived each year on the stock assessment page of the IPHC's website, along with the full assessment (IPHC-2023-SA-01) and data overview (IPHC-2023-SA-02) documents. All previous stock assessments dating back to 1978 are also available at that location.

For 2023, the Secretariat plans to conduct an updated stock assessment, consistent with the schedule for conducting a full assessment and review approximately every three (3) years. Standard data sources are expected to remain unchanged.

## TIME-SERIES AND SOFTWARE UPDATES

In order to provide comparability between preliminary results and all subsequent steps working toward the final 2023 stock assessment (the annual bridging analysis), this evaluation began with the final 2022 models. First, each of the four assessment models was extended by one year, including projected 2023 mortality from all sources based on the mortality limits set during AM099 (IPHC-2023-AM099-R). Extending the time-series without adding any new data does not affect the historical time-series' estimates, but allows for a simple stepwise evaluation of the effects of adding data and other making any other changes to the models prior to the final version used for management.

Next, the Stock Synthesis (SS) software was updated from the version used for the 2022 stock assessment (3.30.19) to the most recent release (10 February 2023), 3.30.21. The changes to the software between these two versions were unimportant to the Pacific halibut stock assessment (the results were identical to the final 2022 assessment). However, maintaining a current version (when possible and efficient) reduces the likelihood of compatibility issues with plotting and other auxiliary software and reduces the cumulative transitional burden when future changes are added. Encouragingly, model run-times were similar or slightly faster than those for final 2022 models. Further, memory allocation appeared to have improved, removing the need to allocate more temporary memory to model runs to avoid writing to disk and dramatically slowing computational speed; AD Model Builder (ADMB), the computational engine for SS, was also updated between these versions, and it is unclear whether improvements in SS or ADMB were responsible for the improved performance. Although there are some new features being added to SS, none of these has been specifically explored in the preliminary analyses reported here.

The IPHC has relied on a variety of model platforms for implementing its stock assessment, many of which have been developed specifically for Pacific halibut (e.g., Clark and Hare 2006; Deriso et al. 1985; Quinn et al. 1990). From 2012 to 2014, the IPHC transitioned from a single stock assessment model to an ensemble of models including alternative structural assumptions. At the same time, the software platform was also transitioned from the previous halibut-specific model implemented directly in ADMB to models using SS. This transition was made in order to speed the evaluation of a wide range of alternative models, facilitate quantitative summary of multiple models, reduce the potential for undiagnosed coding errors, and provide for more tranparent review. The benefits of using a generalized platform for the Pacific halibut stock assessment come with costs, which include lack of some parameterizations that might be desirable, delayed development of new approaches, and in some cases run times that are inflated due to unused model features. These pros and cons have been discussed previously by the SRB and were noted in the 2019 external review (Stokes 2019). Although stock synthesis currently meets the assessment modelling needs for the IPHC, several features would be useful for further development of our assessment models. These include implementation of random effects for time-varying processes (e.g., recruitment and selectivity), more flexible movement and tagging parameterizations for spatially-explicit models, and alternative likelihoods such as the logistic-normal. Similar to other institutions, the IPHC will continue to monitor development of and seek involvement in alternative modelling platforms and whether they provide a sufficient suite of options to support the Pacific halibut stock assessment.

The independently-programmed MSE operating model (generally based on the structure of the current stock assesment) has and will continue to refine the Secretariat's understanding of key biological processes and technical modelling needs. There is an important feedback loop between the assessment modelling and the MSE development fostering increased data and structural testing, as well as exploration and prioritization of hypotheses and research priorities.

Ultimately, the choice of a medium- to long-term assessment platform may depend on the type of MP selected by the Commission. The current compressed stock assesment analysis conducted each fall in order to provide annual management information is based on the current year's data and must be stable and simple enough to be completed in less than two weeks. If a management procedure based on modelled survey trends, or a multi-year procedure is adopted, it may be uneccesary to conduct annual stock assessments. That type of procedure and timeline could allow for the development of more complex stock assessment ensembles/models (including fully Bayesian analyses), given extended development time between assessments. Therefore, the MSE, adoption of a management procedure by the IPHC and strategic planning for the stock assessment modelling platform should be considered together and the long-term focus should be on selecting the most efficient tools to meet management needs as they continue to evolve.

### COMMISSION AND SRB REQUESTS AND RESULTS

During 2022 there were a number of management-supporting analyses requested by the Commission. However, there were no requests made at AM099 specifically relating to the 2023 stock assessment. In 2022, the SRB made the following assessment recommendations and requests during SRB021:

1) SRB021-Rec.07 (para. 34):

   *"The SRB **RECOMMENDED** not implementing MASE weighting for the 2022 stock assessment advice and, instead, continuing to use the equal weighting approach to the ensemble components."*

2) SRB021-Rec.08 (para. 35):

   *"**NOTING** the integration between the stock assessment and biological research in evaluating the impact of genetic sex composition data (and the one-year lag in providing these data) on assessment results along with the resourcing implications, the SRB **RECOMMENDED** continued evaluation of the impact on stock assessment output of analyzing this genetic sex composition data on 1, 2, or 3 year intervals."*

3) SRB021-Req.03 (para. 32):

   *"The SRB **RECALLED** SRB020–Rec.02 (para. 23) and SRB020-Rec.04 (para. 25) (shown below), and **REQUESTED** an update at SRB022:*

   *SRB020–Rec.02 (para. 23) "The SRB **NOTED** that most models within the ensemble produced reasonable and well-constrained estimates of natural mortality (M) and **RECOMMENDED** that estimation of M should be adopted in the short AAF assessment model with consideration in other models as part of the stock assessment research program."*

   *SRB020–Rec.04 (para. 25) "The SRB **NOTED** apparent discrepancies in marine mammal prevalence among anecdotal reports, FISS observations, and preliminary evaluation of logbook data, and therefore **RECOMMENDED** further investigation of methods to better estimate marine mammal prevalence and impacts on the fishery."*

4) SRB021-Req.04 (para. 33):

   *"**NOTING** the substantial interannual variation in MASE weightings of the four assessment models, the SRB **AGREED** that one-step-ahead predictive skill is a potentially promising basis for model weighting, and **REQUESTED** continued research into MASE weightings*

*averaged over longer time periods as well as comparing these to alternative weighting metrics, for example, via cross-validation."*

5) SRB021-Req.09 (para. 45):

   *"**NOTING** the Secretariat's interest in identification of evidence for spatial population structure, and given the IPHC manages stocks on the basis of biological reporting regions, the SRB **REQUESTED** clarification on how the Secretariat may alter assessments if 'functionally isolated components of the population are found'."*

***Recommendation – Use of MASE in 2022***

Equal model weights for all four stock assessment models were retained for the final 2022 stock assessment. Additional exploration of updated MASE statistics using the final 2022 stock assessment models and potential model weighting is described below.

***Recommendation – Evaluation of the frequency of sex-specific fishery data***

In order to explore the relative effect of adding sex-specific directed commercial fishery age composition data to the assessment models a series of sensitivity analyses were run starting from the final 2022 stock assessment. That assessment included sex-specific age data from the commercial fishery for the years 2017 through 2021; 2022 data were unavailable due to the standard one-year lag in processing. Three alternative assessments were run, each incrementally replacing the sex-specific age compositions available for the 2022 stock assessment (data from 2017 through 2021) with the sex-aggregated data that would have been available without the genetic assays. For each of these, the beginning of year (2023) spawning biomass (SB) and terminal year (2022) SPR were calculated, along with the 95% credible interval range of each. Each of the estimates and credible ranges was then compared with the actual estimate and interval range to evaluate the relative importance of this additional information and the effect on management-informing quantities.

The results of this analysis showed that removing one, two, or three years of sex-specific information had little effect on the terminal (beginning of the year 2023) estimates of spawning biomass and SPR (2022), and generally caused a small (<7%) underestimate in the credible interval range (Figure 1). This indicates that model predictions are quite robust to missing sex-specific information and/or that changes in sex-ratio-at-age have been relatively small over the last three years.

The commercial fishery age data collected in 2022 showed a shift in the mode from older year classes to the emerging 2012 year class (IPHC-2023-SA-01). This shift is expected to be accompanied by an increased proportion of females in the aggregate landings as dimorphic growth interacts more strongly with younger year-classes, from which fewer males are above the current 32" (82 cm) minimum size limit. As such, the 2022 sex-specific commercial fishery age data may have a larger relative influence on the stock assessment than recent years where the tracking of the aging 2005 cohort has occurred consistent with model predictions.

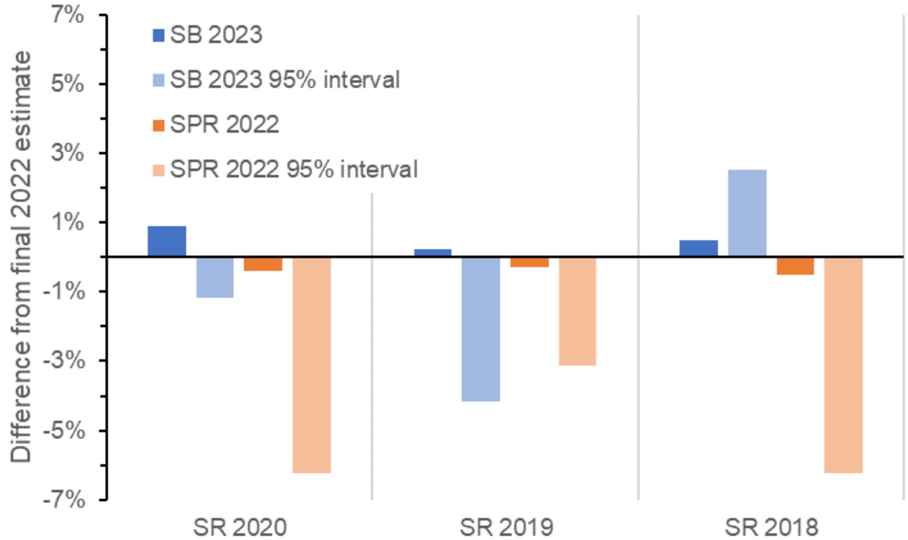


**Figure 1**. Change in key management quantities as a function of removing 1 year (SR 2020), 2 years (SR 2019) or 3 years (SR 2018) of sex-specific commercial fishery age composition data from the 2022 stock assessment. Percentages represent the difference from the final 2022 stock assessment results.

Commercial fishery sex-ratio-at-age data via genetic analysis from the 2022 fishery are currently being processed and are anticipated to be available and included in preliminary models presented at SRB023, 19-21 September 2023. Based on the results of the analysis presented here, it appears that the Commission could in the near future, consider could pausing the processing of commercial fishery sex-ratio data for a period of 1-3 years with little effect on the assessment results and subsequent management decisions. It would make sense to continue to collect the genetic samples from the fishery, as these fish are already being handled for collection of length, weight and otoliths, and the tissue samples could be retrospectively analyzed if needed and also used for other genetic analyses. Potential reduction in processing specific to the sex-ratio analysis may provide the opportunity to focus additional resources on other high-priority Commission research.

***Request – Estimation of natural mortality and continued investigation of marine mammal***

The 2022 full stock assessment relied on the same four stock assessment models used in recent years. The most important change made occurred in the short time-series Areas-As-Fleets (AAF) model, where the natural mortality rate for female Pacific halibut was estimated using the available data and a prior based on longevity rather than fixed at an arbitrary value (IPHC-2022-SRB020-07). As part of that decision, likelihood profiles were evaluated to determine the strength of information on natural mortality in the available data (and prior), convergence of the model was assessed and general plausibility of the estimate was considered. All of these indicated that it was reasonable to estimate natural mortality for female Pacific halibut (males were already estimated) in that preliminary model.

As a further evaluation of this modeling choice, the estimates of natural mortality from the AAF short time-series model were compared among the preliminary stock assessment presented at SRB020, the final 2022 stock assessment including data through 2022, as well as over a 5-year retrospective analysis sequentially removing the terminal year of data from the final 2022 stock assessment for 1 through 5 years. Comparison of these results indicated that the estimates of both female and male natural mortality were robust to recent data added to the model, and that there were no strong trends observed in those estimates (Figure 2). The estimate of female natural mortality from the final 2022 assessment was 0.213, the preliminary assessment 0.211 and the one-year retrospective 0.213. Similarly for males the estimates were 0.177, 0.177 and 0.178. Retrospective results removing years 2-5 were slightly lower (0.209 to 0.200 for females and 0.178 to 0.173 for males); however, these comparisons represented removal of up to all but a single year (2017) of sex-specific commercial fishery age data. In aggregate, this analysis supports the conclusion that the current estimate of natural mortality for both female and male Pacific halibut is robust and not being substantially updated with each new year of information.

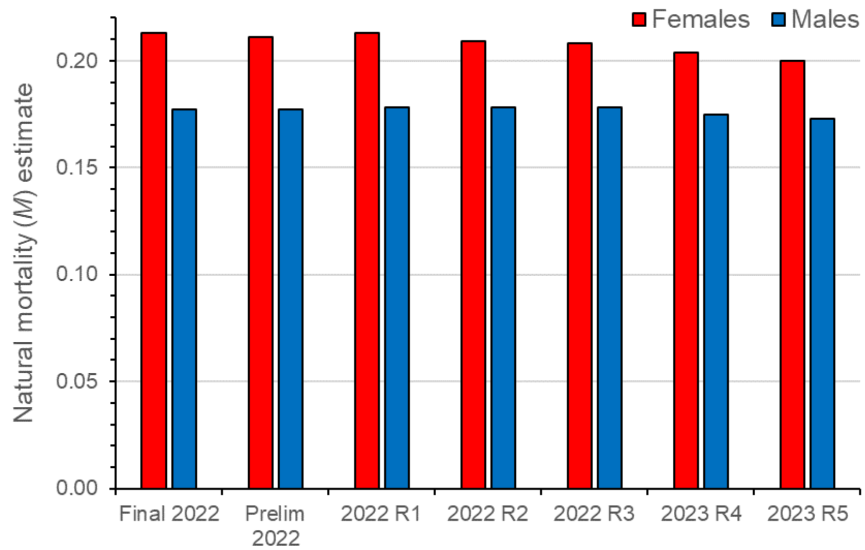


**Figure 2**. Estimates of female and male natural mortality in the AAF short model conducted during 2022. “Prelim 2022” represents the model presented during SRB020, R1 to R5 the retrospective analyses sequentially excluding 1 to 5 years of terminal data.

The second part of this request from SRB021 recommended further work on marine mammal depredation, following the very preliminary analysis presented at SRB020 (IPHC-2022-SRB020-07). That analysis identified a number of inconsistencies among anecdotal reports and verified logbook information but represented the first attempt to filter and evaluate the logbook information available from the commercial fishery. Subsequent to that analysis, the Commission has undertaken an assessment of data collection efforts by field staff, including a clarification of how to record missing information vs. unclear information (e.g., no information recalled/provided by the vessel compared to reporting that whales were present but the species and/or number was unknown). In tandem, a number of codes were reconciled in the Commission database tables leading to a much large number of records (a record in this case is a single longline ‘set’ that resulted in at least one halibut retained, including a reported target of that set: either Pacific halibut or ‘mixed’ targeting of Pacific halibut and sablefish, *Anoplopoma fimbria*) that were determined to be ambiguous in the preliminary 2022 analysis now able to be assigned accurately to either an encounter that could have included depredation or one that did not. This resulted in a relatively large proportion of the total fishing effort available for analysis in most IPHC Regulatory Areas (Figure 3) for the period 2018-2022 (with few records available at this time for 2023).

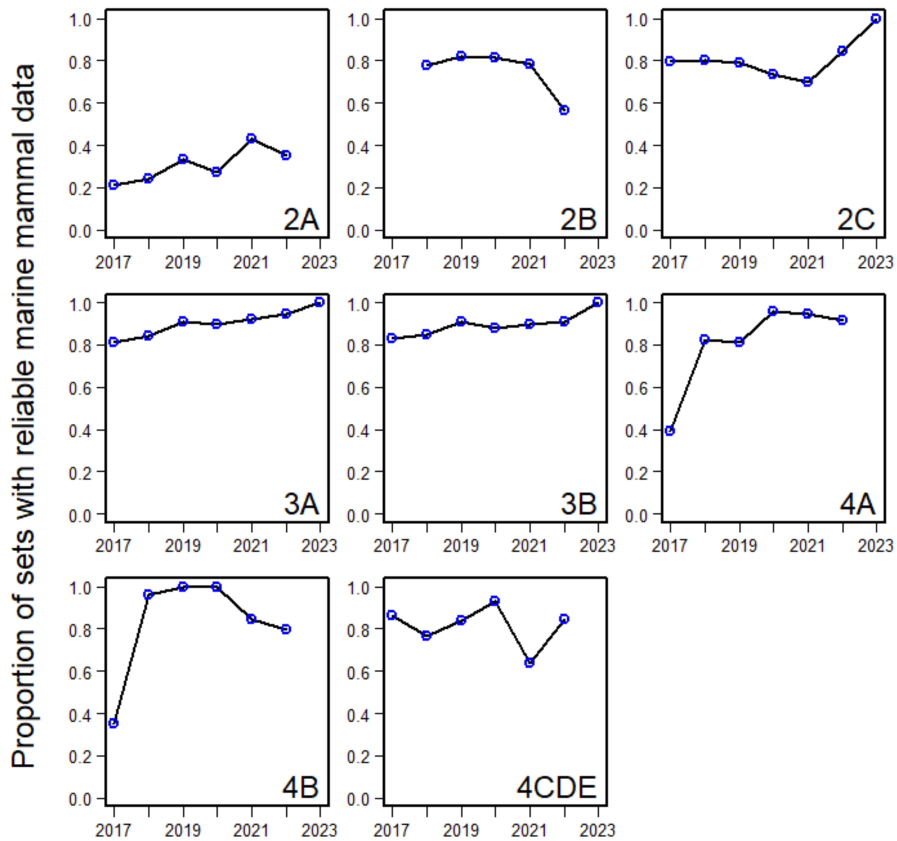


**Figure 3**. Proportion of logbook sets with complete information on species target and whale interactions. Note that during 2017 not all logbooks or field interviews included marine mammal interactions and that data for 2023 are still very sparse.

We used an approach intended to represent the 'worst case' estimate of potential marine mammal depredation, identifying sets where the presence of the two most common depredating species (Orca whales, *Orcinus orca*, and sperm whales, *Physeter macrocephalus*) was positively confirmed during hauling of the gear. We did not require any reported damage to the gear or catch, as field staff reported that this information was often omitted and evaluation of IPHC's Fishery Independent Setline Survey (FISS) has suggested increases in damaged gear (bent, broken or missing hooks and gangions) may be small enough to be unobserved during normal fishing operations (unpublished analysis). Once these complete records were identified each was assigned to a target species (halibut or mixed) and a marine mammal interaction (orca whales present, sperm whales present, or no whales present during hauling of the gear). Orca whale interactions were generally more common on mixed target sets than halibut target sets, consistent with the anecdotally reported preference for sablefish over Pacific halibut and the highest rate of interaction occurred in IPHC Regulatory Area 4A (Figure 4). This pattern was even more pronounced for sperm whale interactions, likely reflecting the preferential use of deeper water areas where mixed target fishing is more likely to occur (Figure 5). Although the rate of depredation was higher for mixed target sets, the majority of commercial halibut landings came from sets targeting only halibut (Figure 6).

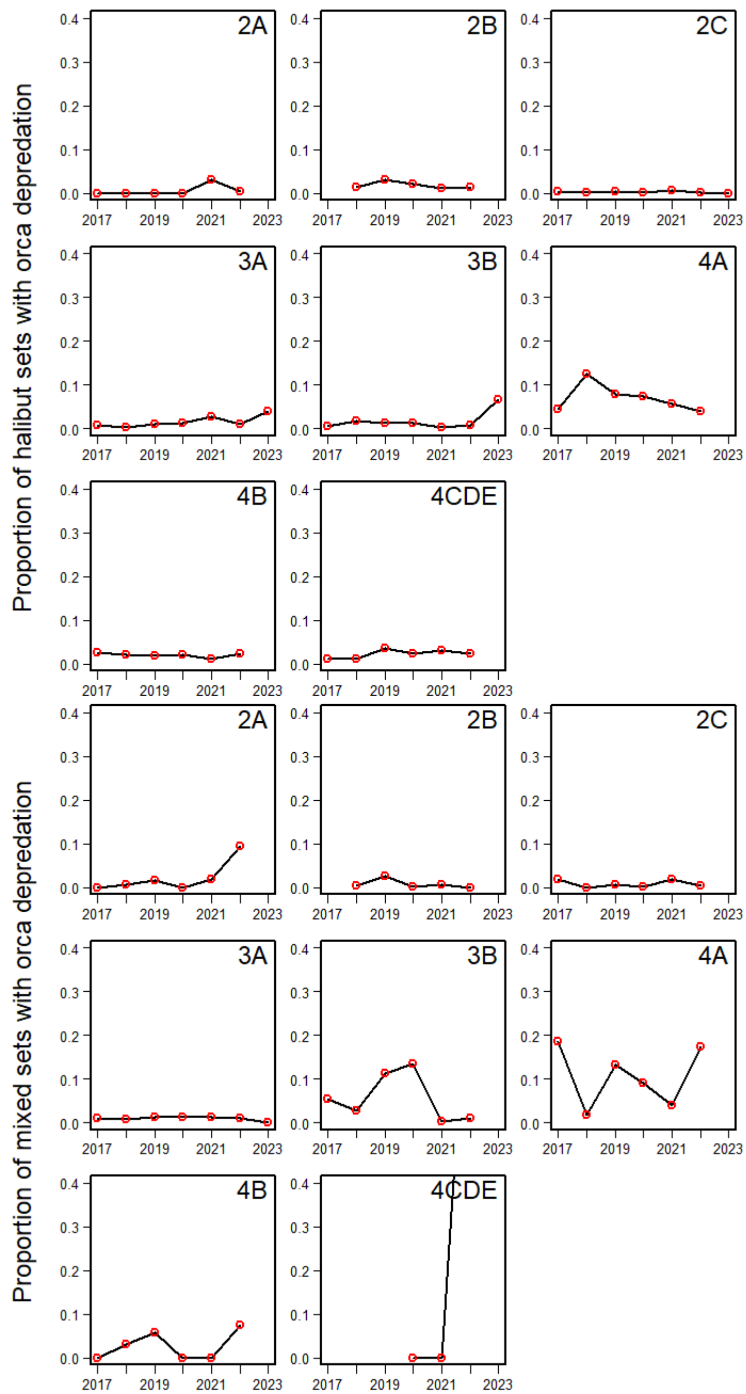


**Figure 4**. Proportion of commercial fishing sets reported to have orca whale interactions by IPHC Regulatory Area and set target. Upper panels represent halibut target sets and lower panels mixed halibut and sablefish target sets.

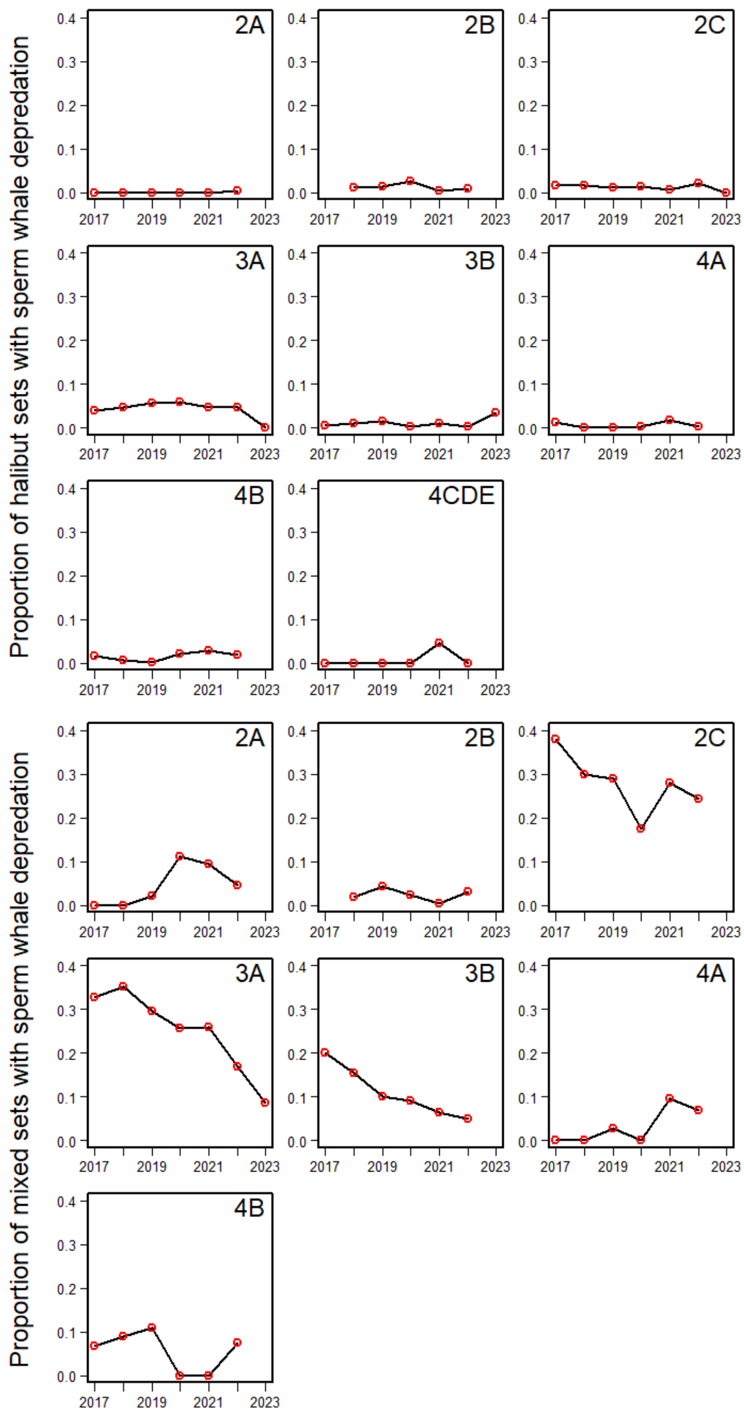


**Figure 5**. Proportion of commercial fishing sets reported to have sperm whale interactions by IPHC Regulatory Area and set target. Upper panels represent halibut target sets and lower panels mixed halibut and sablefish target sets.

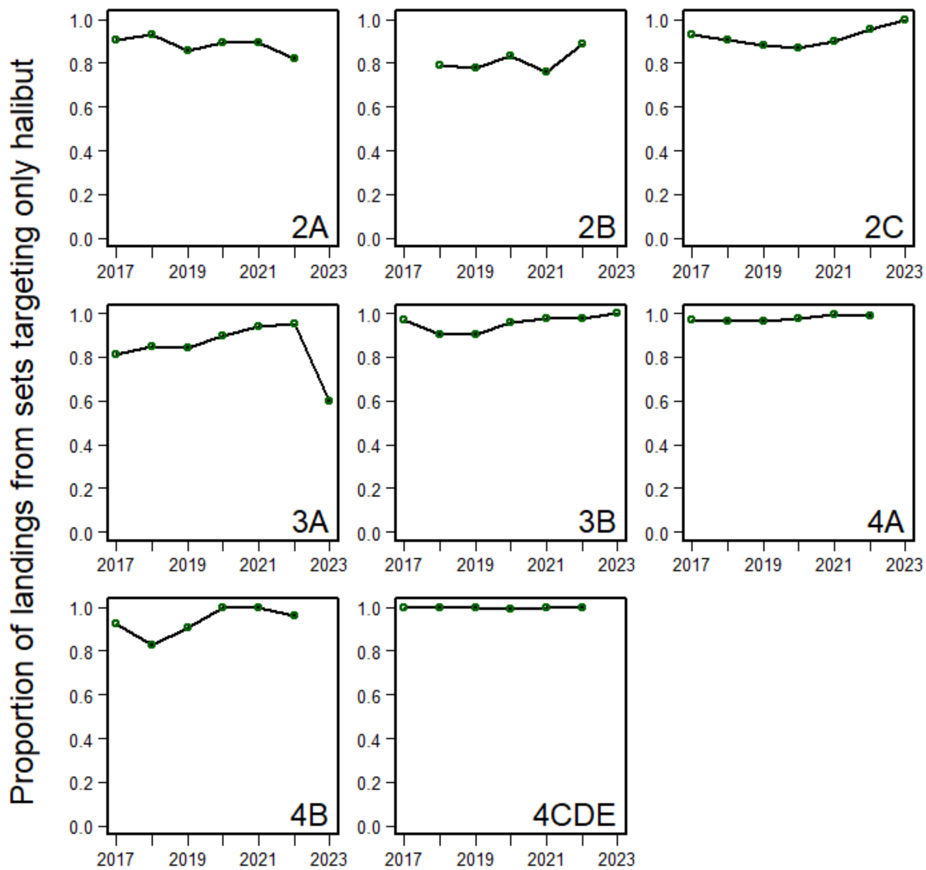


**Figure 6**. Proportion of commercial landings from halibut target sets. Note that few data were available for 2023 at the time of this analysis.

In order to approximate the effect on catch-rate of whale depredation we relied on estimates from the Commission's spatiotemporal model based on the FISS catches in the presence and absence of observed marine mammal depredation. The coefficients for relative catch when depredation occurred were: 84% (68-104% credible interval) for orca whales estimated in IPHC Regulatory Area 3A, 51% (43-60%) for orca whales in IPHC Regulatory Area 4A and 86% (75-99%) for sperm whales in IPHC Regulatory Area 3A (IPHC-2021-SRB019-05). These values were extrapolated as follows: all sperm whale depredation was assumed to occur at the 3A rate regardless of IPHC Regulatory Area, the orca whale depredation rate for 3A was applied to IPHC Regulatory Areas 2A-3B, and the rate estimated for IPHC Regulatory Area 4A was applied to 4A-4CDE. These coefficients were applied to the proportion of sets for each target type, the target-specific proportion of sets depredated and the landings for each target type by IPHC Regulatory area.

Recent estimates of depredation produced by this analysis ranged from very low values in IPHC Regulatory Area 2A to much higher values in IPHC Regulatory Area 3A, up to a high of 123 thousand net pounds in 2019 (Figure 7). Because the landings in each IPHC Regulatory Area differ, the highest average depredation as a percentage of area-specific landings occurred in IPHC Regulatory Area 4A, peaking at 5.9% in 2018 (Figure 7).

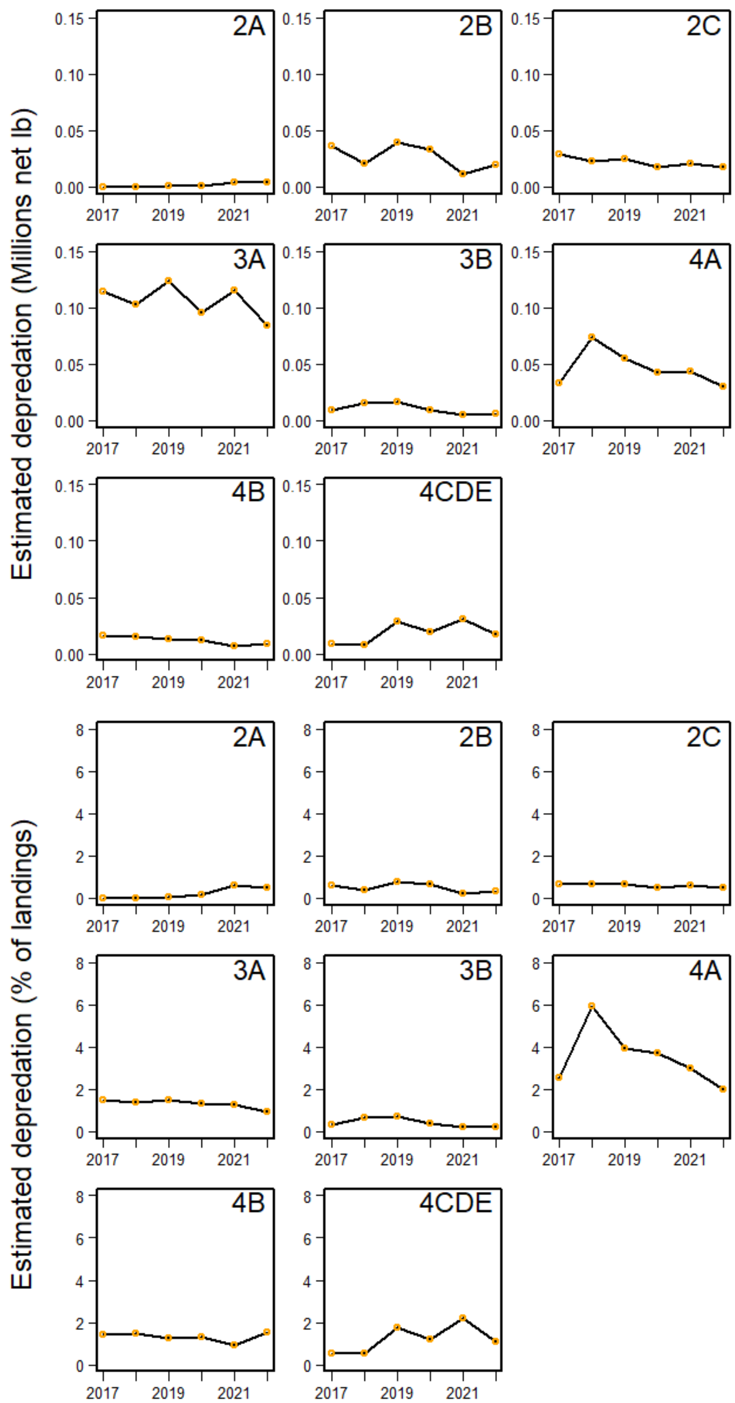


**Figure 7**. Estimated whale depredation by IPHC Regulatory Area (upper panels) and as a percentage of the annual landings (lower panels).

Several extensions to this analysis are possible, ranging from additional reporting of results to potential direct inclusion in the stock assessment and management process. It would be possible to quantify some of the uncertainty in the estimates by reporting the range of potential depredation based on the credible interval for coefficients estimated from the FISS instead of only the point estimates. However, it is likely that the greatest sources of uncertainty are related to observation/reporting by the fleet and the definition of which sets to include as 'depredated', both of which are currently impossible to quantify.

The stock assessment for sablefish explicitly includes marine mammal depredation in the fishery mortality, both for the historical period as well as projected for setting of mortality limits (Goethel et al. 2022). A similar approach could be taken for Pacific halibut, with the benefit of making the effect of marine mammal depredation more transparent, and potentially accounting for the differential affects among IPHC Regulatory Areas. The cost of this approach would be an increase in complexity associated with an additional 'fleet' in each stock assessment model, and the need to include another step in projected mortality limits. Based on previous sensitivity analyses (IPHC-2022-SA-01), increasing the fishery mortality by a small amount of whale depredation will increase the estimated scale of the population which would result in slightly larger mortality limits that are then decremented by the projection of whale depredation. This is the same general result that occurred in the sablefish stock assessment, which uses an average of the depredation rate estimated for the most recent three years for yield projections (Goethel et al. 2022). Due to the relatively small magnitude of whale depredation currently estimated for Pacific halibut and the substantial uncertainties associated with the estimates it may make sense to explore fisheries observer and other information and consider how to extrapolate farther back in time before adding this source of mortality to the stock assessment. Whale depredation is hypothesized to have begun increasing into a larger problem after the fisheries in Alaska and Canada moved from 'derby' style management to a quota system in 1995 and 1991, allowing fishing throughout most of the calendar year and the development of this marine mammal behavior. At present it is unclear how recent estimates would be extrapolated prior to 2017 when the quota fisheries were operating but marine mammal interactions were not reliably reported in IPHC logbooks. The IPHC Secretariat has initiated the process to obtain recent self-reported depredation information from Fisheries and Oceans Canada and detailed at-sea fisheries observer data for fisheries in Alaska, the latter would include information at least as far back as 2013.

### *Request – Model weighting*

The primary focus on model weighting has been 'hindcast' predictive performance. This approach removes data from the assessment models and evaluates their skill in predicting subsequent observations. An increasingly common measure of model skill is the Mean Absolute Standardized Error (MASE; Hyndman and Koehler 2006). Because of the correlated time-series nature of observations used in stock assessment models, the hindcasting method is more appropriate than standard statistical cross-validation.

The MASE statistic has been used as a diagnostic tool for stock assessment models (Carvalho et al. 2021; Kell et al. 2021), but it's use has ignored the heterogeneous variance associate with each year's observations. Therefore, as presented at SRB020 and SRB021, we employed a 'standardized' MASE, calculated as

$$MASE = \frac{\frac{1}{n}\sum_{t=1}^{n} \left| \frac{O_t - E_t}{\sigma_t} \right|}{\frac{1}{n}\sum_{t=1}^{n} \left| \frac{O_t - O_{t-1}}{\sigma_t} \right|}$$

Where *O* indicates the observation at time *t*, *E* the prediction (or expected value) and $\sigma_t$ is the standard deviation of the observation. The calculation can be averaged over any number of years (lags) relevant to the predictive problem. As defined, MASE estimates must be positive, and the range of values is interpreted as:

>1: model predictive skill is worse than the naïve prediction (last year's index)

1: model predictive skill is exactly equal to the naïve prediction

<1: model predictive skill exceeds that of the naïve prediction

0: model predictions perfectly match subsequent observations

In order to turn the MASE statistic into a model weight we need to specify the scale of the weighting and the behavior at the end-points. In this case, for model (*m*) within the set of models (*M*; limited to those models with MASE values <1):

$$MASE\ weight_m = \frac{1 - MASE_m}{\sum_{m=1}^{M} 1 - MASE_m}$$

Models that do not outperform the naïve prediction (MASE >= 1) over the set of years included get assigned zero weight. At the other extreme, a set of models all perfectly predicting the subsequent observations (MASE = 0) will receive equal weights.

The current set of four stock assessment models all fit the index of abundance generated from the FISS very well (Figure 8, upper panel). Further, despite large differences in the structure of these models and the parameter estimates on which they are based (e.g., differences in estimated natural mortality), all four predicted the decline in the index observed in 2022 nearly as well as the fit when those data were included in the likelihood (Figure 8, lower panel).

Because the sex-ratio of the commercial fishery landings is unavailable prior to 2017, hindcasting skill cannot be explored prior to 2018 without making major changes to the current model structure which would make reasonable comparison with more recent model performance skill impossible. However, over the period from 2018 through 2022, change in the index has included both negative and positive trends, as well as one year (2020) when the index remained virtually identical from the previous year (Figure 8). Prior to computing the MASE weights, it is useful to compare the deviations between the observed index, the naïve prediction (the previous year's index) and each of the four models for each year of hindcast prediction (Table 1). Notably, the 2020 observation was predicted better by the previous year's observation than by any of the four models. The increase in 2021 and the subsequent decrease in 2022 were both predicted well by all four models, with the short coastwide model performing most poorly in all but 2018 and 2022.

It is unclear how long a period is optimal for averaging model performance. On one end of the spectrum, as was noted in the 2022 analysis, using only 1- or 2-year periods likely reflects the most current model skill, but leads to highly volatile weighting. At the other extreme, longer term averages would generate more stable weights, at the cost of a slower response to real changes in model skill as data and population dynamics change over time. Simulation analysis seems like a promising approach for investigating this trade-off. The Secretariat has begun collaboration with University of Washington researchers on exactly this topic. For the current analysis, weights were calculated based on 2- to 5-year averages, with 5 years being the longest period possible for evaluation. Results generally show lower weight assigned to the coastwide short model, and similar weights assigned to the other three (Figure 9).

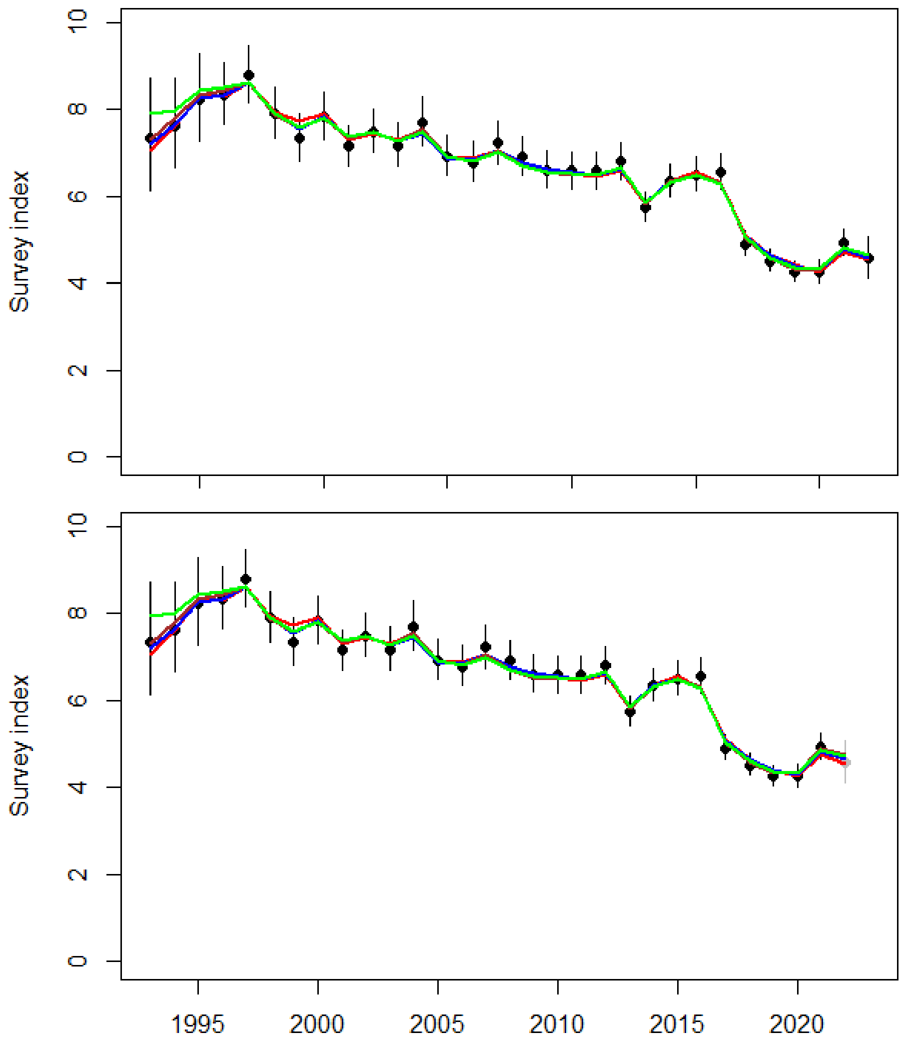


**Figure 8**. Fit to FISS index from the final models used for 2022 (upper panel) and hindcast projection based only on data through 2021 (lower panel).

**Table 1.** Scaled deviations ($\frac{O-E}{\sigma}$) between survey predictions and subsequent observations used in calculating MASE weights. Note that none of the four models had a smaller deviation than the naïve prediction (the previous year's observation) in 2020.

| | Model | | | | |
|---|---|---|---|---|---|
| Year | Naive | CW short | CW long | AAF short | AAF long |
| 2018 | 3.08 | 0.52 | 0.39 | 1.10 | 1.00 |
| 2019 | 2.02 | 1.17 | 0.16 | 0.80 | 0.80 |
| 2020 | 0.07 | 2.19 | 0.45 | 0.14 | 0.15 |
| 2021 | 4.25 | 3.86 | 1.12 | 1.76 | 0.72 |
| 2022 | 1.53 | 0.06 | 0.33 | 0.60 | 0.76 |

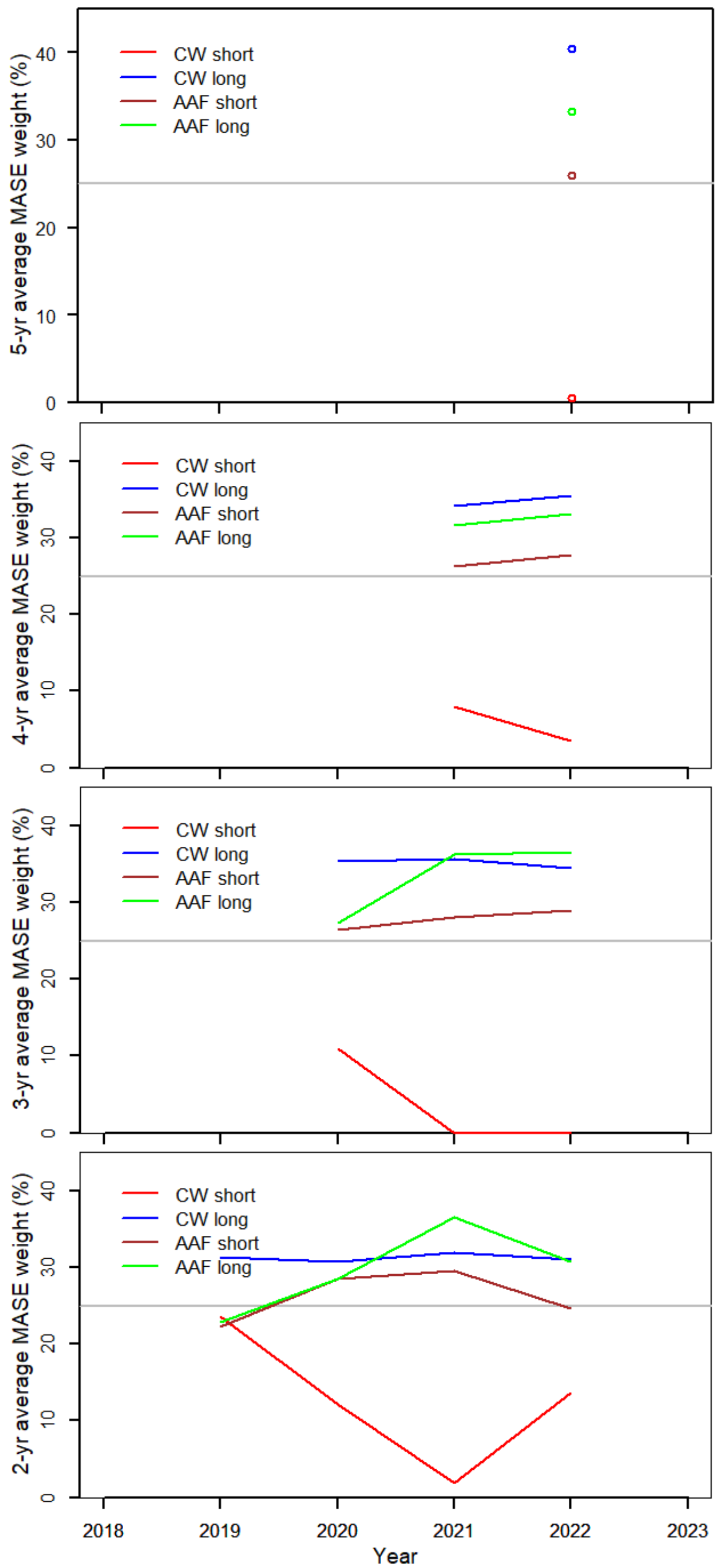


**Figure 9**. MASE weights for each year calculated based on the most recent 5, 4, 3, or 2-year period (panels from top to bottom).

As the modelling progresses toward the next full stock assessment scheduled for 2025, there will be 2 additional FISS observations to extend these results (2023 and 2024), and to provide a better perspective on the stability/performance trade-off in the number of years to include in the MASE weighting approach. Further, there may be simulation results relevant to this and other stock assessments. In the interim, the Secretariat plans to continue to investigate estimation of natural mortality in the coastwide short assessment model (a potential contributor to poorer performance than other models in the current set) and to annually update these MASE calculations.

### *Request – Potential assessment revision to accommodate stock structure*

Until 2006, demographically separate stock assessments were conducted for each IPHC Regulatory Area (Clark and Hare 2006). This approach was based on the hypothesis that there was little movement of adult Pacific halibut among IPHC Regulatory areas, and therefore the population dynamics could be approximated acceptably with separate assessments regardless of the potential for recruitment and/or juvenile exchange among areas. However, the IPHC's PIT-tagging experiment in the early 2000s indicated appreciable exchange of adult Pacific halibut among IPHC Regulatory areas (Webster et al. 2013), meaning that closed-area assessments would be biased to larger population estimates due to the immigration of older and larger fish. Since 2006, the annual stock assessment has included the entire geographical range of Pacific halibut within the convention waters. This approach makes the implicit assumption that the Russian border comprises a boundary with only a small rate of demographic exchange; this appears reasonable given relatively low densities observed in recent years in the most northern convention waters. Exploration of that boundary may be increasingly important under future climate change, but recent world events have reduced the potential for collaboration and data exchange with Russian scientists.

There are two primary considerations with regard to potential stock structure within the greater Pacific halibut population in the IPHC convention waters: conservation of biological/genetic diversity and optimization of fishery yield. The IPHC has adopted the objective of maintain the spawning biomass in each Biological Region at or above the minimum proportion of the coastwide stock observed in the FISS since 1993. Evidence of unique genetic components of the stock within existing Biological Regions would warrant consideration of refining the management objective to maintain all such components in a similar manner. Genetic isolation would also imply little to no exchange of adults or recruits which would suggest conducting a separate stock assessment for a smaller stock component. Current research priorities for IPHC Regulatory Area 4B have been developed to specifically address whether there is evidence that Area 4B is genetically separated from the rest of the convention waters and therefore warrants development of a separate stock assessment with self-contained dynamics. A separate assessment for IPHC Regulatory Area 4B would allow the Commission to evaluate fishing intensity and spawning biomass reference points specific to that area in both tactical results from the stock assessment and strategic performance of management approaches as part of the MSE.

## OTHER TOPICS

Other assessment development topics are ongoing; updates on progress will be provided if available in time for SRB022.

## RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2023-SRB022-08 which provides a response to requests from SRB021, and an update on model development for 2023.

b) **REQUEST** any further analyses to be provided at SRB023, 19-21 September 2023.

## REFERENCES

Carvalho, F., Winker, H., Courtney, D., Kapur, M., Kell, L., Cardinale, M., Schirripa, M., Kitakado, T., Yemane, D., Piner, K.R., Maunder, M.N., Taylor, I., Wetzel, C.R., Doering, K., Johnson, K.F., and Methot, R.D. 2021. A cookbook for using model diagnostics in integrated stock assessments. Fisheries Research **240**. doi:10.1016/j.fishres.2021.105959.

Clark, W.G., and Hare, S.R. 2006. Assessment and management of Pacific halibut: data, methods, and policy. International Pacific Halibut Commission Scientific Report No. 83, Seattle, Washington. 104 p.

Deriso, R.B., Quinn, T.J., II, and Neal, P.R. 1985. Catch-age analysis with auxiliary information. Canadian Journal of Fisheries and Aquatic Sciences **42**: 815-824.

Goethel, D.R., Rodgveller, C.J., Echave, K.B., Shotwell, S.K., Siwicke, K.A., Hanselman, D., Malecha, P.W., Cheng, M., Williams, M., Omori, K., and Lunsford, C.R. 2022. Assessment of the sablefish stock in Alaska. NPFMC Bering Sea, Aleutian Islands and Gulf of Alaska SAFE. 182 p.

Hyndman, R.J., and Koehler, A.B. 2006. Another look at measures of forecast accuracy. International Journal of Forecasting **22**(4): 679-688. doi:10.1016/j.ijforecast.2006.03.001.

IPHC. 2022a. Report of the 21st session of the IPHC Scientific review board (SRB021). IPHC-2022-SRB021-R.

IPHC. 2022b. Report of the 20th session of the IPHC Scientific Review Board (SRB020). Meeting held electronically, 14-16 June 2022. IPHC-2022-SRB020-R. 19 p.

IPHC. 2023. Report of the 99th session of the IPHC annual meeting (AM099). IPHC-2023-AM099-R. 62 p.

Kell, L.T., Sharma, R., Kitakado, T., Winker, H., Mosqueira, I., Cardinale, M., Fu, D., and Kraak, S. 2021. Validation of stock assessment methods: is it me or my model talking? ICES Journal of Marine Science **78**(6): 2244-2255. doi:10.1093/icesjms/fsab104.

Methot, R.D., and Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research **142**(0): 86-99. doi:http://dx.doi.org/10.1016/j.fishres.2012.10.012.

Quinn, T.J.I., Deriso, R.B., and Neal, P.R. 1990. Migratory catch-age analysis. Canadian Journal of Fisheries and Aquatic Sciences **47**: 2315-2327.

Stewart, I., and Hicks, A. 2022a. Development of the 2022 Pacific halibut (*Hippoglossus stenolepis*) stock assessment. IPHC-2022-SRB020-07. 128 p.

Stewart, I., and Hicks, A. 2022b. Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2021. IPHC-2022-SA-01. 36 p.

Stewart, I., and Hicks, A. 2023. Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2022. IPHC-2023-SA-01. 37 p.

Stewart, I., and Webster, R. 2023. Overview of data sources for the Pacific halibut stock assessment, harvest policy, and related analyses. IPHC-2023-SA-02. 59 p.

Stewart, I., Hicks, A., Webster, R., and Wilson, D. 2023. Summary of the data, stock assessment, and harvest decision table for Pacific halibut (*Hippoglossus stenolepis*) at the end of 2022. IPHC-2023-AM099-11.

Stokes, K. 2019. Independent peer review for the 2019 IPHC stock assessment. August 2019. 31 p. https://www.iphc.int/uploads/pdf/sa/2019/stokes_2019-independent_peer_review_for_the_2019_iphc_stock_assessment.pdf.

Webster, R.A., Clark, W.G., Leaman, B.M., and Forsberg, J.E. 2013. Pacific halibut on the move: a renewed understanding of adult migration from a coastwide tagging study. Canadian Journal of Fisheries and Aquatic Sciences **70**(4): 642-653. doi:10.1139/cjfas-2012-0371.