SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON FINAL METHODOLOGY REVIEW

The Scientific and Statistical Committee (SSC) received a report summarizing reviews of salmon methodology topics conducted by the SSC Salmon Subcommittee (SSCSS) via webinar on October 20-21, 2021 (SSCSS report appended). The SSCSS received presentations and documents on four topics:

1. Complete the documentation of the Chinook Fishery Regulation Assessment Model (FRAM) program and the development of the new Chinook base period, including algorithms and User Manual.
2. Evaluate post-season metrics of FRAM performance.
3. Provide documentation of the abundance forecast approach used for Willapa Bay natural coho.
4. Review Oregon Production Index Hatchery forecast.

Complete the documentation of the Chinook Fishery Regulation Assessment Model (FRAM) program and the development of the new Chinook base period, including algorithms and User Manual.

The SSC appreciates the new FRAM documentation provided by the FRAM analysts. The new, online, "living document" format of the FRAM user manual and associated documents is a significant step forward and will enable managers, scientists, and the public to better understand and critically evaluate the model. The SSC supports ongoing efforts to make the source code publicly available and provide a venue for future improvements to code and documentation. Overall, the SSC considers the FRAM documentation sufficient, though there remain components of the documentation that need additional detail, including further description of the estimation algorithms and the distinction between data and parameters within the model. Additionally, documentation for the Chinook and coho base periods should be completed and undergo methodology review. Over the long term, the SSC encourages moving from FRAM's current deterministic framework to a likelihood-based framework that can inform the uncertainty around model outputs.

Evaluate post-season metrics of FRAM performance

The SSC reviewed a report comparing exploitation rates calculated using the Exploitation Rate Analysis (ERA) conducted by the Pacific Salmon Commission's Chinook Technical Committee with exploitation rates derived by FRAM. The ERA and FRAM analyses share many similarities, relying on the same basic cohort-reconstruction structure and base data type (coded-wire tags [CWTs]), but make many different assumptions about the biological and statistical attributes of the Chinook salmon data. Overall, exploitation rate estimates between the two methods were moderately related for the 2009-2018 period but unrelated for 1999-2008, demonstrating the importance of the model assumptions in determining estimates of exploitation rates.

The SSC commends and thanks the analysts for their exploratory comparative analyses and looks forward to future analyses that may help direct improvements in each method. The SSC identified

four areas in particular that would be productive for improving exploitation rate analyses: 1) Genetic analysis to get CWT-independent estimates of catch by stock, including non-tagged stocks (often the case for wild stocks); 2) analysis of the benefit of updating the base period more often and determining the ideal update time interval; 3) updated analyses that include uncertainty estimates; and 4) pre- and post-season comparison of FRAM fishery impact estimates. The SSC also looks forward to future work aimed at validating model estimates of coho exploitation rates, exploitation rates on unmarked Chinook, and quantifying impacts of mark-selective fisheries.

Provide documentation of the abundance forecast approach used for Willapa Bay natural coho

During the SSCSS meeting, Dr. Dan Auerbach (Washington Department of Fish and Wildlife; WDFW) and Mr. Thomas Buehrens (WDFW) presented the proposed forecast methodology for natural-origin Willapa Bay coho. The Willapa Bay natural coho forecast is needed to set the annual Acceptable Biological Catch (ABC). The proposed approach is based upon a recent publication (DeFillippo et al. 2021) that developed a spatiotemporal integrated population model for coho management units in Washington state excluding Columbia River coho. The analysts extended and tailored the DeFillippo et al. model to make predictions for Willapa Bay natural coho. The model showed considerable forecast skill and provided uncertainty bounds on predictions. The SSC appreciates the comprehensive analyses presented by the analysts and endorses the forecast method for determining the ABC for Willapa Bay natural coho. The SSC also appreciates the open and reproducible approach to the data and statistical code adopted by the analysts including the publication of publicly accessible data and code repositories on GitHub.

The analysts discussed several possible extensions to their existing model that may be added in the coming years including 1) adding environmental covariates to improve prediction of marine survival and smolt production; 2) adding information from additional proximate coho stocks to the model; and 3) accounting for the contribution of natural-spawning hatchery fish to coho production. The SSC suggests that the addition of such model components generally should not require a full methodology review for use in future forecasts, but the use of any such alternate models should be contingent on the availability of documentation for the proposed model including metrics of forecast skill justifying the use of a new model. The analysts should notify the SSC by the September Council meeting prior to the year in which the forecast is to be used if changes to the Willapa Bay forecast are anticipated, and the appropriate level of further review, if any, can be assessed at that time.

Review Oregon Production Index Hatchery forecast

During the SSCSS meeting, Mr. Erik Suring (Oregon Department of Fish and Wildlife; ODFW) presented an overview of the Oregon Production Index Hatchery (OPIH) coho forecast methodology. The current model structure and data streams have been in use since 2008 and are now publicly available on a GitHub repository.

The SSC recommends continuing to use the current model structure for forecasting this stock as it is currently the only available forecast model for OPIH. However, there should be a high priority placed on investigating alternative models to compete against the current model. The OPIH forecast is particularly influential for properly modeling fishery impacts to less abundant natural

stocks and therefore improved forecast performance for OPIH will likely improve management of many coho stocks.

In comparison to eight natural coho stocks (those included in Figures III-1a and III-1b of Preseason Report 1), the OPIH forecast performed relatively well – though OPIH is a hatchery stock, not a natural stock. Furthermore, across all stocks considered, a majority of forecasts were biased high, and some forecasts performed more poorly than simply using the previous year's abundance as a forecast. The SSC suggests that there is considerable value in compiling and reporting metrics of forecast performance as a component of Preseason Report 1, to identify forecasts in need of review and improvement.

Additional topics

Across the topics discussed, the SSC noted the increased use of non-permanent public repositories as a method for sharing code and data. This is an encouraging and commendable step toward transparency and reproducibility. At present, many code and data repositories are maintained on personal accounts that do not have long-term archiving capabilities, making it difficult to ensure data and methods are preserved. The SSC suggests that identifying a centralized platform or method that can be used to archive information used in Pacific Fishery Management Council (PFMC, Council) applications be a priority for development in the near future.

SCIENTIFIC AND STATISTICAL COMMITTEE'S
SALMON SUBCOMMITTEE REPORT ON
SALMON MEHODOLOGY REVIEW

Pacific Fishery Management Council
Via Webinar

October 20 – 21, 2021

The Scientific and Statistical Committee's Salmon Subcommittee (SSCSS) held an online meeting on October 20 and 21, 2021 with the Model Evaluation Workgroup (MEW), and the Salmon Technical Team (STT) to review salmon methodologies and to discuss planning for potential future salmon review topics. We discussed the four topics that were chosen at the September 2021 Council meeting for the methodology review: (1) Documentation of the Chinook Fishery Regulation Assessment Model (FRAM) program, including algorithms and the User Manual; (2) Evaluate post-season metrics of FRAM model performance; (3) Documentation of the abundance forecast approach used for Willapa Bay natural coho; and (4) Review the Oregon Production Index Hatchery coho forecast methodology. In addition, Ms. Angelika Hagen-Breaux (MEW) gave a FRAM tutorial at the end of the first day.

1. Documentation of the Chinook Fishery Regulation Assessment Model (FRAM) program, including algorithms and the User Manual

Mr. Jeremiah Shrovnal (Washington Department of Fish and Wildlife; WDFW) presented the updated overview portion of the FRAM model documentation. A FRAM User Manual was published previously, but since the documentation was last revised, FRAM has incorporated a number of changes including new algorithms, re-parameterization of the Chinook model base period, and re-coding the model using VisualStudio.Net to work with MS Access databases. The new documentation exists on a website (https://framverse.github.io/fram_doc/) with plans for continued updating and the capability to integrate comments from interested model users.

The SSCSS finds the online FRAM user's manual and overview portion of the documentation to be well organized and user friendly and do not require further review. The SSCSS would like opportunities to review technical details such as the specific equations and data processes used in the model in the future. The documentation should clarify the relationship between "data" inputs and fixed "parameters", including additional details on how fixed parameter values are generated. The documentation should also note any exceptions to the documented algorithms that are hard coded into the program. Documentation of the Chinook and Coho base period construction should also be completed and undergo methodology review in the future.

The SSCSS commends the workgroup responsible for creating the documentation. The FRAM user manual and other documentation is a significant step forward and will enable managers, scientists, and the public to better understand and critically evaluate the model. The SSCSS also appreciates the steps that the workgroup has taken to make the source code publicly available and consider comments from interested parties to improve the code and documentation. Over the long term, the SSCSS encourages moving from the current FRAM deterministic projection framework to one that incorporates uncertainty around point estimates and documenting this well.

2. Evaluate post-season metrics of FRAM model performance

Mr. Jon Carey (National Marine Fisheries Service, West Coast Regional Office) presented work on the evaluation of post-season FRAM performance. The evaluation was based upon comparison of FRAM exploitation rate estimates and static maturity rate estimates to those estimated by the Exploitation Rate Analysis (ERA) undertaken by the Chinook Technical Committee, for the years 1999-2018.

While both analyses are based upon data from coded wire tags (CWTs), they are derived independently from each other using markedly different analyses. FRAM is a deterministic single pool, multi-stock model designed to assess the effects of multiple mixed-stock fisheries on individual stocks, uses a base period, currently from 2005-2008, to estimate relative fishing rates of each fishery across stocks, and is used primarily for pre-season predictive analysis, although it can be used post-season as well. ERA is used only for post-season analysis for a calendar year and produces independent estimates for each year and stock.

FRAM and ERA use the same adult natural mortality assumptions and have stock definitions that can be matched up (or nearly so) for 25 of the 39 FRAM Chinook stocks. The time scales they use are not the same, however, with FRAM being run from October to September, in three time steps (although standard FRAM ERs are calculated May to April), and the ERA covering a full calendar year in a single time step. Only marked fish were used in this comparison, as ERA does not currently account for impacts of mark-selective fisheries on unmarked fish. For comparability, age 2 fish were included in the escapement for all ER computations, which is a deviation from standard practice when computing FRAM based ERs.

One would expect FRAM exploitation rate estimates to be less variable across years for each stock than those from ERA due to the constant relative exploitation rate assumption for each fishery within FRAM, along with the expected larger effect of sampling error in single-year datasets. While there was some evidence of this, it was also true that the mean exploitation rate estimate for each stock differed between the two methods. For both methods, the mean exploitation rate was between 0.2 and 0.5 for all stocks except for one outlier, which was close to 0.1 for both methods. For the period 1999-2008, there was no apparent relationship between the average rates for the

two methods across stocks when not including that low outlier. For 2009-2018, there was a correlation between the means of the two methods, though, even then, the relationship was not especially tight.

The ERA analyses demonstrated a pattern of decreasing age at maturity (maturity rate for ages 2-4 increasing across time). In contrast, the maturity rates in FRAM are fixed according to the years used for the base period. This maturity pattern could lead to biases (high or low) outside the base period years. The ERA maturation rate estimates depend on assumed values for adult natural mortality (an assumption shared with FRAM), and variation in maturation rates (and/or exploitation rates) could be confounded with changes in natural mortality.

The SSCSS would like to emphasize the importance of adequate CWT tagging and recovery efforts to support both methods.

The SSCSS commends and thanks the authors for their comprehensive analyses and looks forward to seeing future analyses to help direct improvements in each method. These might include:
(1) Genetic analysis to get CWT-independent estimates of catch by stock, including non-tagged stocks (often the case for wild stocks); (2) analysis of the benefit of updating the base period more often and determining the ideal update time interval; (3) updated analyses that include uncertainty estimates; and (4) pre- and post-season comparison of FRAM fishery impact estimates.

3. Documentation of the abundance forecast approach used for Willapa Bay natural coho

Dr. Dan Auerbach (WDFW) and Mr. Thomas Buehrens (WDFW) presented the proposed forecast methodology for natural-origin Willapa Bay. The Willapa Bay natural coho forecast is needed to set the annual Acceptable Biological Catch (ABC). The data, statistical approach, and model evaluation framework in the proposed methodology to forecast Willapa Bay natural coho are all substantial departures from previous analyses. Since full documentation for the previous approach(s) is not available, it is not possible to detail all the differences from the previous methods that were used to make forecasts.

The proposed approach is based upon a recent publication (DeFillippo et al. 2021) that developed a spatiotemporal integrated population model (ST-IPM) for all coho management units in Washington state except Columbia River coho. This state-space model integrates smolt, escapement, harvest, and coded wire tag (CWT) data from 36 coho salmon management units in Washington, including Willapa Bay, to estimate Beverton-Holt stock-recruitment relationships for each coho stock. The hierarchical structure of the model allows for information about stock productivity and marine survival to be shared spatially.

The proposed method builds off DeFillippo et al. (2021) in three ways. First, they updated the data to include information from 34 management units beginning in 1998, including use of marine survival data through 2018, smolt trapping through 2020, and harvest rate estimates from the Coho Technical Committee FRAM model runs through 2019. Second, they developed two parallel models in a Bayesian framework, a ST-IPM and a lag-one autoregressive (AR1) model for the time series. Third, they constructed a structure for evaluating forecast performance using one-step ahead evaluation methods and a range of forecast performance metrics. Due to the lag in data becoming available for use in forecasting, they investigated forecast skill using only data collected three years before the forecast year (lag-3, a conservative scenario), and data lags of two years (lag-2, an intermediate scenario) and one year (lag-1, an aspirational scenario).

The proposed methods (ST-IPM and AR1) improved the performance of forecasts of pre-fishery ocean abundance relative to the forecasts previously used and a forecast based upon a simple trailing mean. Forecasts that included more recent data (i.e., lag-one) outperformed forecasts without recent data (lag-three). The analysts noted that all forecast methods considered were relatively imprecise. The new methods provide estimates of forecast uncertainty, which were not available using the previous methods.

The SSCSS and analysts agree that there are several future avenues of research worth investigating to improve forecast skill. Three specific areas were discussed by the SSCSS: 1) adding environmental covariates to improve prediction of marine survival and smolt production; 2) adding information from lower Columbia River coho stocks to gain information from proximate populations; and 3) explicitly accounting for the contribution of natural-spawning hatchery fish to coho production. The SSCSS suggests that the addition of such model components generally should not require a full methodology review for use in future forecasts, but the use of any such alternate models is contingent on the availability of documentation for the proposed model including metrics of forecast skill justifying the use of a new model. The analysts should notify the SSC by the September Council meeting prior to the year in which the forecast is to be used if changes to the Willapa Bay forecast are anticipated, and the need for, and appropriate level of further review can be assessed at that time.

The SSCSS appreciates the comprehensive analyses presented by the analysts and endorses the forecast method for determining the ABC for Willapa Bay natural coho. The SSCSS endorses using the single model with the highest forecast skill as measured by median symmetric accuracy (MSA) or mean absolute scale error (MASE) or using an ensemble of the ST-IPM and AR1 models with model weights determined by forecast skill. The SSCSS also appreciates the open and reproducible approach to the data and statistical code adopted by the analysts including the publication of publicly accessible data and code repositories on GitHub.

4. Review the Oregon Production Index Hatchery coho forecast methodology

Mr. Erik Suring (Oregon Department of Fish and Wildlife; ODFW) presented an overview of the Oregon Production Index Hatchery (OPIH) coho forecast methodology. The current model structure and data streams have been in use since 2008 and are now publicly available at https://github.com/ErikSuring/OPIH_Evaluation.

The forecast model is a multiple linear regression that uses total jack (age-2 adult coho) returns to all OPIH facilities and a delayed smolt release ratio to predict total adult abundance from all OPIH facilities. To explore model performance through time, this model was fit to data from 1970-2020 in 30-year blocks (i.e., 1970-1999, 1971-2000, etc.) and showed a trend of better fits for early blocks than for latter blocks. Relative long-term model performance for the OPIH forecast was comparable to or better than a select group of natural coho forecasts. OPIH coho is a large stock and consequently, OPIH forecast error may be more meaningful for Council management.

The SSCSC appreciates the work that went into documenting the methodology and providing public access to the data used to parameterize the OPIH coho forecast. The SSCSC recommends continuing to use the current model structure for forecasting this stock. However, there should be a high priority to investigate other models that may perform better and to examine various performance metrics and model selection criteria that would inform the choice of a model that best fits the data and shows the least bias. A forecast for OPIH that performs well is important because its forecasted abundance is influential for properly modeling fishery impacts to less abundant natural stocks.

5. Future Workload and Meeting Planning

The SSCSS and the STT had a discussion about future meeting and workload planning, with specific attention to the three major recommendations outlined in the SSCSS's June 2021 report (https://www.pcouncil.org/documents/2021/06/c-10-a-supplemental-ssc-report-1.pdf/). A summary of the recommendations of the SSC and the major discussion points are below, under the appropriate items. The SSCSS looks forward to working more with the STT on these issues in the future.

1. Clarify the definition of "major stocks." Council Operating Procedure (COP) 15 provides details on the process for conducting salmon methodology reviews and states that "forecasting methods for major PFMC stocks" is an issue that could merit a full review but does not define "major". The SSC proposes that the Council explicitly define which stocks are 'major".

The SSCSS and STT agreed that Council guidance is necessary for any of the advisory bodies to move forward on establishing a definition for "major stocks" and how those major stocks relate to

the “target stocks” in Tables 1-1, 1-2, and 1-3 of the Salmon Fishery Management Plan (FMP). The SSCSS previously suggested that “major stocks” be defined as those salmon stocks for which the PFMC specifies ABCs (Sacramento River Fall Chinook, Klamath River Fall Chinook, and Willapa Bay natural coho), all Chinook and coho stocks considered a fishery target stock in Tables 1-1 and 1-2 of the FMP, and all stocks with harvest control rules. The SSCSS is willing to help staff a working group to develop a definition of major stocks, which could include criteria like abundance, importance to Council fisheries, closely related stocks, and conservation concerns.

2. Establish a database that describes the forecast methodology used for each "major" stock, when that method was adopted, and when it was last reviewed. Ideally the history of all forecast methods and reviews for each stock would be included. The performance of the forecast should be evaluated and reported on each year in Pre-1 and in the database.

The SSCSS and the STT agree that this database would be helpful in the long term, but that in the short term populating the database with historical information on forecast methodology and performance may be time-consuming. The SSCSS recommends as a first step that a repository be established with the documentation of all currently used forecast methodologies, along with a way to track when changes are made to these methodologies going forward and document the reviews of these changes when reviews are performed. As time permits, information on past methodologies and performance metrics could be added. The SSCSS also recommends that the STT add one or more summary metrics of forecast performance and bias to the records of annual forecast performance already present in Preseason I Report (i.e., Tables II-4, II-8, II-9, III-1, III-3, and III-4; and/or the values presented in Figures II-4 and III-1). A number of metrics were discussed during other items at this Methodology Review which would be a helpful starting point for consideration.

3. Establish a process that outlines how and when reference points and conservation objectives are reviewed and updated as appropriate.

The SSCSS notes that in some of the FMP language and COP 15, it appears that there was an intention for reference points and conservation objectives to be periodically reviewed and updated as appropriate, but no firm process or timeline was established for doing so. To make it easier for the Council and other interested parties to see the rationale for the current values and when they were last reviewed the SSCSS recommends compiling all current documentation in a publicly accessible place and noting the year that the current analysis was developed. The current values are available in Table A-1 of Preseason Report 1 and citations are available in Table 3-1 of the FMP, but in many cases the cited documents are not publicly available. In some cases, the documentation cites previous work, so the date of the documentation is not always reflective of the age of the analysis. The SSCSS notes that for reference points and conservation objectives that are identified as possibly needing review or updating, the ideal first step would be for analysts

from the relevant management agencies and/or other parties as necessary to develop reference points/conservation objectives using modern methodologies and updated data. This would allow for a review of alternatives that could lead to an adoption of a new objective(s)/reference point(s) or provide evidence that the current value(s) are still valid. These analyses could then be reviewed by the SSCSS and other advisory bodies and used by the Council for consideration to retain or change the reference points/conservation objectives.

PFMC
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