SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON WILLAPA BAY COHO FORECAST METHODOLOGY REVIEW – FINAL ACTION

The Scientific and Statistical Committee (SSC) received a report from the SSC Salmon Subcommittee (SSCSS, subcommittee report appended to the end of this statement) regarding the February 26, 2020 joint webinar of the SSCSS and the Salmon Technical Team (STT), and reviewed an earlier draft of "Willapa Bay Coho – Supporting Documentation of Abundance Forecasting Approach" (Agenda Item E.2, Supplemental Attachment 1). The SSC did not have sufficient time to review the changes between the draft document and the supplemental briefing book version.

The SSC agrees with the SSCSS's finding that the Willapa Bay natural coho forecast is much more thoroughly documented now than it has been in the past. Clarification is needed in the draft documentation on how outliers are identified and how their exclusion is justified. A clearer description of how competing models are chosen among when model evaluation metrics disagree is needed. The SSC supports attempts to quantify uncertainty and appreciates progress toward quantifying and reporting uncertainty in the models used for salmon management.

The SSC recommends using the output of the forecast model as presented for this year. Caution may be warranted in applying the 2020 forecast due to the unprecedented low value of maximum summer flow, as well as lower marine survival forecasted by a competing model with higher support according to some model evaluation metrics. The unprecedented flow value is worrisome both because it suggests extreme environmental conditions and because the smolt production forecast depends on extrapolating a linear regression beyond the range of the input data, which leads to greatly increased uncertainty.

The SSC agrees with the SSCSS that the proposed forecast model likely outperforms naïve models based on short- or long-term mean returns, and that no clearly superior basis for forecasting abundance or specifying acceptable biological catch (ABC) for this stock is currently available. The SSC also agrees that there are several places where the theoretical basis of the forecast could be improved, including less ad hoc methods of scaling smolt densities between watersheds, alternative treatments of putative "outliers," and more robust model selection or model averaging. There was not sufficient time to properly evaluate these alternative approaches. The SSC recommends further analysis of these alternatives in the future, potentially this year, following the standard methodology review timeline.

SSC Salmon Subcommittee Report on
Joint SSCSS/STT webinar reviewing Willapa Bay natural coho forecast

The SSC Salmon Subcommittee (SSCSS) and Salmon Technical Team (STT) held a webinar on February 26, 2020 to discuss the Willapa Bay coho natural forecast methodology. Dr. Marisa Litz (Washington Department of Fish and Wildlife, WDFW) presented the forecast methods, and WDFW staff answered questions about local data collection. The review was based on the document "2_Willapa Bay Natural Forecast_FINAL 2.10.2020.pdf" (hereafter "the document"). The document was circulated to the SSCSS on February 11, 2020 and distributed to the full SSC via email by John DeVore dated 2/18/20 with subject line "Willapa Bay coho forecasting material." The document is an earlier draft of Agenda Item E.2, Supplemental Attachment 1 in the March 2020 Briefing book. WDFW submitted the supplemental briefing book version based on inputs received during the February 26 webinar. The SSCSS did not receive the supplemental briefing book version in time to review it.

The natural-origin component of the Willapa Bay coho run size forecast was calculated by multiplying forecasts of natural-origin smolt production and natural-origin marine survival. The performance of the run size forecast was evaluated in a hindcasting exercise. The run size forecast method used for 2020 is planned for use in future years. The webinar addressed each component of the run-size forecast and its evaluation.

Smolt forecast

Natural-origin smolt production is not measured for Willapa Bay coho, rather a proxy based on the Chehalis River (the major river basin of the neighboring Grays Harbor management unit) was used. Direct measures of smolt abundance cannot be used for the forecast as smolt abundances in the Chehalis basin are not estimated until adults return. Instead, multiple linear regressions were fitted to historical estimates of smolt abundance. Potential covariates based on various metrics of flow were considered. Each year a single model was selected via AICc and used to forecast the current year's smolt production. The forecasted Chehalis smolt abundance is converted to a forecasted smolt density (smolts per square mile of watershed). The Chehalis smolt density is converted to a (usually lower) Willapa Bay smolt density using a stair-step relationship (Table 2 of the document). The forecasted Willapa Bay smolt density is then multiplied by the watershed area to forecast the Willapa Bay natural coho smolt production.

The SSCSS found the description of the smolt forecast methods clear and near complete, and raised the following concerns about the methods:

For the multiple regression model, four out of nineteen ocean entry years potentially informing the smolt forecast were dropped as outliers identified "by observing residual plots and evaluating Cook's distances." Instead of excluding 21 percent of the dataset as outliers, it may be appropriate to consider nonlinear models or robust regression techniques. The four ocean entry years that were dropped also had the four lowest smolt abundance observations, creating concern that a positive bias was being introduced.

The general approach of adjusting Chehalis smolt densities downward to predict Willapa Bay smolt densities seemed sensible to local experts from WDFW. However, when evaluated in the context of relative adult returns to the two systems, the SSCSS finds this inconsistent with the assumption of equivalent marine survival. Willapa Bay has approximately 40 percent the area of the Chehalis basin, so given equivalent marine survivals this would lead to adult returns approximately 40 percent of the Chehalis return if smolt densities were equal. In fact, adult returns to Willapa Bay were on average 72 percent of returns to the Chehalis basin and very rarely less than 40 percent (Table 3 of document 2). The basis for assuming lower smolt densities in Willapa Bay is therefore unclear, and the downward adjustment to smolt densities may introduce a negative bias. The staircase form of the assumed relationship (Table 2 of the document) has an undesirable consequence that sometimes small changes in the input (Chehalis smolt density) can cause a relatively large change in the forecasted output (Willapa Bay smolt density), while at other times moderate changes in the inputs cause no change in the forecasted output.

The maximum summer flow (one of the covariates retained in the final smolt forecast model) informing the 2020 forecast is the lowest on record (Figure 2c of the document.). It is generally not best practice to extrapolate predictions from a linear regression outside the range of the input data and doing so can create highly uncertain predictions. A model using average incubation flow instead of maximum summer flow received very nearly equivalent support (ΔAICc=0.18, Table 5 of document), and would not require extrapolating outside the range of the input data. However, the relative support for different covariates would be different if the “outlier” years were retained.

The SSCSS requested a report on what the smolt forecast would be using average incubation flow rather than maximum summer flow as a predictor, and what the smolt forecast would have been for the chosen model if the four “outliers” had not been excluded. The SSCSS realized that time constraints would preclude full evaluation (e.g., looking at hindcast performance of the revised models, or repeating model comparison with outliers included) for these alternatives.

Marine survival forecast

Although survival estimates for hatchery-origin Willapa Bay coho are made, they are not used in forecasting (and would not be available in time for current-year forecasts). Instead, a marine survival forecast based on CWT-tagged Bingham Creek wild coho (part of the Chehalis River basin) is used. Bingham Creek survival estimates are not available for the year being forecasted, hence marine survival is forecasted based on a model relating environmental covariates to past survival estimates.

Numerous environmental covariates (Appendix A of document 2) were considered in multiple linear regressions modeling marine survival. Preliminary model comparison involved a backwards stepwise regression approach from different candidate starting points that excluded highly correlated variables. Remaining candidate models after the backwards stepwise regressions, along with a model based on PC1 of a principal component analysis of salmon ocean indicators produced by the NWFSC, were compared using leave-one-out cross validation and evaluated based on mean raw error (MRE), mean absolute error (MAE), root mean square error (RMSE), mean percent error (MPE), and mean absolute percent error (MAPE). The highlighted model in Table 7 of the document was chosen over the second model in the table, despite similar performance metrics, based on a likelihood ratio test. The chosen model predicts higher marine survival for the current forecast year than the similarly-performing alternative model.

The SSCSS expressed concern that repeating the model selection process every year may result in chasing noise. Model averaging may be more robust than picking a single model. This could apply to the smolt forecast as well.

The SSCSS notes that there are marine survival estimates available for Willapa Bay hatchery coho, and they are not well correlated with Bingham Creek wild coho marine survival estimates. Concerns were expressed during the webinar about the precision of Willapa Bay hatchery coho survival estimates due to low tag recoveries and sampling challenges.

Hindcast performance of run size forecast

Performance of the model that was chosen for the 2020 run size forecast was evaluated in a leave-one-out hindcasting exercise. This may provide an overly optimistic assessment of model performance since it uses more data than would have been available to parameterize the forecast model in earlier years and does not repeat the covariate selection process each year. The hindcasted model outperformed alternative methods of basing the run size forecast on a 3- or 10-year recent average mean of observed returns, when evaluated over the past nine years.

The SSCSS noted that hindcast model performance was notably worse in particular years (2011 and 2015, Figure 4A of the document), and it may be fruitful to investigate whether this error seems attributable to error in the smolt abundance hindcast or the marine survival hindcast.

WDFW response to SSCSS smolt forecast request

Dr. Marisa Litz was able to provide the SSCSS with the results of the multiple regression models for forecasting natural origin smolt abundances in the Chehalis basin that included outliers on February 27, 2020. She provided results from two models: (1) the maximum summer flow and minimum overwinter flow (the WDFW preferred model) and (2) the average incubation flow and minimum winter flow model. She used these results to forecast the Willapa Bay natural run-size using the previously discussed methods.

With the outliers removed, using the maximum summer flow with incubation flow did not change the final run size forecast of 17,850 (due to the binning of smolt densities). Including the four "outlier" years in the models changed the forecasted adult run size from 17,850 (WDFW preferred model) to 15,300.

Quantifying Uncertainty

Several of the intermediate calculations informing the run size forecast are accompanied by estimates of uncertainty. The SSCSS supports attempts to quantify uncertainty and appreciates progress toward quantifying and reporting uncertainty in the models used for salmon management. However, no attempt was made to propagate uncertainty through the final run size forecast product, and some of the uncertainty calculations were not completely documented.

SSCSS Recommendation

The SSCSS appreciates the work that has been done to document the Willapa Bay natural coho run size forecast at a level that allows for review. The current run size forecast method likely outperforms naïve approaches based on recent or mean returns. The SSCSS could not identify a better currently-available basis for S_{ABC} determination than the proposed run size forecast methodology, although several points of potential improvement to the theoretical basis of the forecast were noted, including less ad hoc methods of scaling smolt densities between watersheds, alternative treatments of putative "outliers," and model averaging rather than repeating the model selection process each year. There was not sufficient time to fully evaluate or implement these alternatives.

A number of factors suggest that the current year's forecast may have additional uncertainty relative to the years in the hindcast exercise, including the unprecedented low value of maximum summer flow, lower marine survival forecasted by a competing model with higher support according to some model evaluation metrics, and potential bias introduced by excluding the four lowest smolt estimates on record from the input data.

Hatchery-origin forecast

Natural-area spawners also include some hatchery-origin fish that stray to natural areas, and this has been accounted for in the past in setting the ABC. The hatchery-origin run size forecast uses the same marine survival as the natural-origin forecast, and hatchery smolt production is enumerated at the hatchery as described in the document. The document provided limited information on how hatchery strays in natural areas are quantified, and no information on how stray rates (i.e., the proportion of hatchery-origin fish returning that stray into natural area, as opposed to the proportion of natural-area spawners that are of hatchery origin) are calculated. Hatchery-origin strays to natural areas need to be accounted for in setting the Willapa Bay natural coho S_{ABC}. How strays are enumerated will need to be addressed by the STT and SSC at the March 2020 Council meeting.

PFMC
03/04/20