Scientific and Statistical Committee Salmon Subcommittee Report: Salmon Methodology Review

Pacific Fishery Management Council
Online Meeting

October 4, 2024

The Scientific and Statistical Committee's Salmon Subcommittee (SSC-SSC) met online on October 4, 2024, to conduct a Salmon Methodology Review with the Salmon Technical Team (STT) of two topics submitted by the Sacramento River fall Chinook Workgroup (SRWG). Will Satterthwaite (Southwest Fisheries Science Center [SWFSC], SSC-SSC[1], SRWG) presented "Derivation of proxy S_{MSY}/S_{MSP}[2] ratio and F_{MSY}[3] value suitable for use in Sacramento River Fall Chinook (SRFC)" and Emily Chen (University of California Berkeley) presented "SRFC cohort reconstruction (CR) and comparison to the Sacramento Index (SI)" for review and discussion by the SSC-SSC and the STT. The meeting was co-chaired by Mike O'Farrell (SWFSC, STT) and Galen Johnson (Northwest Indian Fisheries Commission, SSC-SSC). Members of the SRWG and the public were also present, and public comments were given prior to and following the presentations.

The SSC-SSC supports the adoption of the updated FMSY proxy of 0.58 for SRFC and the updated cohort reconstruction methodology, and finds them to be the best scientific information available.

Derivation of proxy S_{MSY}/S_{MSP} ratio and F_{MSY} value suitable for use in Sacramento River Fall Chinook (SRFC)

Will Satterthwaite provided a document, "Updated F_{MSY} Proxy and S_{MSY}/S_{MP} Ratio", a presentation summarizing the document, and answered questions from the SSC-SSC and STT. The SRWG recommended in June 2024 that high priority should be given to updating the F_{MSY} proxy for SRFC. The current F_{MSY} proxy, used for most Chinook stocks with no stock-specific estimate, is based on an average F_{MSY} from 20 stocks using data from 1946 to 2000. The SSC recommended updating the reference point, and the STT supported the suggestion of the SRWG that a "typical" ratio between S_{MSY} and S_{MP} might be found in the literature which could be used to indirectly estimate S_{MSY} for SRFC as data may be available to estimate S_{MP} for the stock.

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[1] Will Satterthwaite recused himself from SSC-SSC decisions on both Methodology Review items, as he was the lead author on the first and a co-author on the second.

[2] S_{MSY} is the escapement corresponding to maximum sustainable yield. S_{MP} (also called S_{MSP}) is the escapement maximizing production, however unlike with yield, the 'sustainable" qualifier is not necessary because maximum production cannot be even temporarily exceeded.

[3] F_{MSY} is the exploitation rate corresponding to maximum sustainable yield.

Subsequently, it was recognized that for salmon, $F_{MSY} = S_{MSY}/S_{MP}$, so these two recommendations were in fact one task.

The SRWG reviewed the literature for new and updated analyses of F_{MSY} for Chinook stocks used in the original F_{MSY} proxy, as well as for Chinook stocks that have a stock-specific F_{MSY} developed since that original proxy was developed. The SRWG developed criteria for inclusion of analyses in a new proxy, such as the use of recent data and similarity to SRFC in ocean distribution and life history traits. The SSC-SSC agrees with the decision of the SRWG to use Klamath and Rogue Fall Chinook stocks for the new F_{MSY} proxy. The mean and median F_{MSY} and S_{MSY}/S_{MP} ratio are the same, 0.58, but if more than two stocks are considered, the SSC-SSC supports using the median as it is the more risk neutral measure.

The SSC-SSC is supportive of this review and the SRWG recommendation of a new F_{MSY} proxy of 0.58, and suggests a similar exercise be carried out for all the Chinook salmon stocks using the older F_{MSY} proxy, either on a stock-by-stock basis or perhaps developing a proxy for north-migrating stocks and using the SRFC F_{MSY} proxy for southern-migrating stocks. Some of the stocks in the Pacific Coast Salmon Fishery Management Plan (FMP) that use the older F_{MSY} proxy now have direct estimates available; it is also worth considering whether a proxy based on multiple stocks might be better than a stock-specific estimate, given sources of uncertainty in individual estimates.

The SSC-SSC briefly discussed the use of alpha (α, "productivity") versus alpha prime (α', alpha adjusted for process error) obtained from each report, as the reasoning of the authors of previous analyses and the previous choice of proxy for choosing one or the other were not always clear. However, the larger the variance (ideally, process error), the larger alpha prime, which means the F_{MSY} goes up. If the variance is not adjusted to account for observation error, this has the effect of saying the less you know about a system, the harder you can fish it. Even if observation error is properly accounted for, this says the less stable and predictable a system is and the greater the chance of a low productivity year, the harder it can be fished (due to a small chance of a very high productivity year increasing the mean). The SSC-SSC favors the use of alpha given this counter-intuitive result of using alpha prime. The use of the median as the risk-neutral value matches the approach taken in groundfish management.

If adopted, the new F_{MSY} should be included in the Salmon FMP and in the appropriate tables and text in the stock assessment and fishery evaluation (SAFE) documents. In the production and review of this proxy work, a number of cases were uncovered where the status determination criteria from NOAA Final Rulemaking, Council decisions, the Salmon FMP, and annual SAFE documents were not in full alignment, with no clarity about which status determination criteria should actually be used. The SSC-SSC recommends a thorough review of reference points within each of these documents and processes, to ensure there is constancy and clarity for advisory bodies and the Council.

Cohort reconstruction for Sacramento River fall Chinook salmon and comparison to the Sacramento Index.

The SSC-SSC reviewed and discussed the new methodology for determining the abundance, age-structure, escapement, and harvest rates for Sacramento River fall Chinook salmon (SRFC). Emily Chen presented results from this new cohort reconstruction (CR; Chen et al. 2024) and compared the results of this analysis to the index of abundance (the Sacramento Index, SI) currently used for management of SRFC.

Both the SI and CR are intended to support management by quantifying the ocean abundance of adult (age-3+) Chinook salmon at the start of each fishing season, identifying harvest impacts on adult SRFC, and determining adult escapement predicted to occur in the absence of fishing. The SI achieves this "by summing estimates of adult escapement of SRFC (to hatcheries and natural-areas combined, anywhere in the Sacramento Basin but excluding strays out of the system), adult river harvest, and adult ocean harvest" (Chen et al. 2024). The SI has estimates going back to at least 1983 (see Pacific Fishery Management Council [PFMC] Preseason Report I).

While serving the same basic management needs as the SI, the CR accounts for additional biological processes and incorporates multiple new data sources. Specifically, the CR: 1) models the populations on a monthly rather than an annual time-step, 2) accounts for the age-structure of returning adults, 3) tracks adults by their origin (natural or hatchery), 4) accounts for unobserved mortality associated with fisheries (release and drop-off mortalities), 5) incorporates information about the size-distribution of SRFC in the ocean to adjust ocean harvest impacts, 6) allows for age-specific maturity rates to vary among years, and 7) changes assumptions about the assignment of ocean harvest to SRFC versus non-SRFC Chinook salmon stocks. To account for all of these additional processes requires new data streams that have been developed for SRFC since 2007, including: 1) improved coded-wire tags (CWT) tagging rates of hatchery-origin fish, 2) expanded in-river surveys for CWT and non-CWT fish in the Sacramento Basin to provide estimates of escapement and harvest abundance, and 3) scales collected from spawner carcass surveys to provide age-structure of both hatchery- and natural-origin adults. In addition, the CR incorporates two components of uncertainty (the sampling uncertainty associated with expanding CWT recoveries from ocean harvest, in-river, and at hatcheries and the uncertainty associated with sampling and aging of scale samples) to provide uncertainty bounds on estimates of abundance and harvest. In all cases, the SSC-SSC finds that the changes introduced in the CR represent significant improvements over the SI.

Both the SI and CR work backward from the observed escapement of each cohort accounting sequentially for maturation, harvest impacts (both in-river and ocean), and natural mortality. Comparisons of the SI and CR between run years 2010 and 2019 showed that broadly they generate similar estimates of abundance and ocean harvest (Table 1, Chen et al. 2024), and years of relatively high and low abundance are coincident between the methods. However, within each year, the CR generally provides lower estimates of potential escapement than the SI. This is largely due to the CR acknowledging that some age-3 SRFC will remain in the ocean and mature the following year as age-4 adults. This effect on the estimate of potential escapement is partially

offset by incorporating release and drop-off mortalities in ocean fisheries. Generally, the CR produced lower estimates of ocean harvest in areas south of Cape Falcon, Oregon than the SI (8 of 11 years; Table 1; Chen et al 2024). This is predominantly a result of the SI assigning a smaller portion of ocean harvest south of Point Arena, California to non-SRFC stocks. Overall ocean impacts from the CR, which includes the effects of harvest, release, and drop-off mortality, were larger than estimated SI ocean harvest in 7 of 11 years (Table 1; Chen et al 2024).

Because the CR is age-structured it can produce two different measures of exploitation rate. First, the spawner reduction rate (SRR) measures the proportional reduction in abundance of a given cohort over the course of multiple years, which can be indexed by brood year or calendar year. There is not an equivalent quantity currently provided for SRFC in the current management system. SRR is the appropriate measurement for cumulative harvest and is appropriate to compare to harvest management reference points (e.g. F_{MSY}). The second measure of harvest is the terminal spawner reduction rate in a given year (SRR_y) which is the ratio of observed escapement relative to the estimated escapement in the absence of fishing in the current year only. SRR_y is comparable to SI exploitation rates currently used in the PFMC process.

The current SI approach does not include harvest from north of Cape Falcon in its calculation despite a small and variable number of SRFC CWTs that are recovered from this area annually. Results from the CR showed that including harvest data from north of Cape Falcon would increase estimated ocean harvest by an average of 4.8% (range among years 1.6-13%) and estimated ocean abundance by an average of 1.9% (range: 0.6-3.9%). The SSC-SSC agreed that including harvest information from north of Cape Falcon was advisable to accurately represent ocean harvest for SRFC in both the SI and the CR.

Overall, the CR for SRFC is an approach broadly similar to approaches used for other Chinook populations along the U.S. west coast including Klamath River fall Chinook. The addition of new CWT and scale age data sources from the Sacramento Basin starting in 2007 enabled the development of this new CR, and the SSC-SSC commends the California Department of Fish and Wildlife for their work in producing the necessary data.

The additional information provided by the CR is a substantial advance over current methods and the SSC-SSC recommends the use of the CR in management. Several aspects of the CR should improve SRFC management. Two in particular deserve mention. First, the spawner reduction rate (SRR_y) using improved measures of ocean harvest provides an improved annual postseason measure of exploitation of SRFC. Second, the separation of SRFC into hatchery- and natural-origin components greatly improves assessment of SRFC natural-origin abundance and status relative to natural-origin SRFC stock size objectives.

The SSC-SSC and STT discussed how gathering and processing the data and implementing the CR may stretch the resources of responsible analysts and the STT. Of particular concern was whether data from CWT and scale ages could reasonably be processed in time to meet annual management needs. The SSC-SSC agreed that workload concerns were significant and it may be necessary to produce multiple outputs from the CR as data becomes available. For example,

initial estimates of annual fisheries impact (SRR) might be quickly calculated using only hatchery-origin CWT fish that are then updated as additional information about scale age data from natural-origin fish become available. These logistical uncertainties mean that practical implementation of the CR may not mirror exactly its current implementation and will require testing and experimentation by the STT and partners.

The inclusion of some components of uncertainty (e.g. sampling and expansion of CWT recoveries, scale-age uncertainty) but not others (e.g. escapement estimate uncertainty) produces a cohort reconstruction with a mix of deterministic and stochastic elements. While having such a mix is not fundamentally a problem, the description did not describe why some components of CR were implemented as uncertain while others were assumed to be fixed and known. The SSC-SSC appreciates the inclusion of some components of uncertainty into the cohort reconstruction and considers it a substantial improvement over previous deterministic projections. The SSC-SSC also recognizes that the CR is an ongoing process that can be refined and improved over time. Future work should consider how uncertainty in additional model components, including but not limited to those listed above, may affect point estimates and uncertainty bounds of abundance and harvest metrics used in management.

A downstream outcome of switching from the SI to the CR are the impacts to the Sacramento harvest model (SHM), which is used to predict SRFC spawner escapement and overall exploitation rate given proposed ocean and river fishery management measures. The SSC-SSC supports re-parameterizing the SHM to allow for results from the CR to be used in the SHM.

Citations

Chen, E.K, W.H. Satterthwaite, M.R. O'Farrell, S.M. Carlson. 2024 Cohort Reconstruction for Sacramento River Fall Chinook salmon and Comparison with the Sacramento Index. Report prepared for PFMC Salmon Methodology Review.

Appendix A.
SSC Salmon Subcommittee Member Participants

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