SACRAMENTO RIVER FALL CHINOOK AD HOC WORKGROUP PROGRESS REPORT

The Sacramento River Fall Chinook (SRFC) ad-hoc Workgroup (SRWG) met remotely on June 25-26, 2024 to consider the feedback received in June 2024 from the Pacific Fishery Management Council (Council), Scientific and Statistical Committee (SSC), Salmon Technical Team (STT), and Salmon Advisory Subpanel (SAS); and on August 6-7, September 3, and October 2-3, 2024 to plan and evaluate further work. The SRWG has identified preferred paths forward for:

- the exploitation rate corresponding to MSY (F_{MSY})
- most steps in the derivation of the corresponding spawning escapement (S_{MSY})
- considerations for developing a conservation objective and escapement target using S_{MSY} as a starting point
- use of cohort reconstructions accounting for hatchery- and natural-origin fish (Chen et al. 2024).

The SRWG has also held informative discussions of risk tables and looks forward to the further discussions called for under Items 4 and 6 of Council action on Agenda Item H.1 from the September 2024 meeting. We summarize progress on each of these items below, with additional details on some items provided in Technical Appendices.

The SRWG has also identified tools for potentially modifying the control rule, evaluating forecast accuracy and the potential for improved forecasts, and methods for quantifying the costs and benefits of different actions in terms of harvest and conservation metrics. However, most of the proposed analytical methods for those topics depend on tools described in the Satterthwaite and Shelton (2023) paper that was proposed for methodology review, but was not moved forward by the Council for 2024 review. Thus, the SRWG has paused work on these topics due to uncertainty whether the SRWG has suitable tools for those tasks or can achieve further progress on them.

The SRWG regrets the challenges in accessing the Satterthwaite and Shelton (2023) paper caused by including links in our June 2024 report for both the paywalled journal article and the public domain version on the NOAA Institutional Repository. Thus, in the interest of an open and transparent process, the SRWG asked Council staff to provide the public domain version of Satterthwaite and Shelton (2023) as Agenda Item F.6, Attachment 1 at this November 2024 Council meeting. For future reference, the intellectual content of any journal article prepared by federal government employees is in the public domain in the United States, and can be obtained by emailing the author(s) if attempts to locate it on the NOAA Institutional Repository are unsuccessful.

The SRWG reports progress and recommendations on specific items as follows:

S_{MSY}

S_{MSY} should be based on a spawner-recruit analysis where spawners are adult SRFC spawning in natural areas, and recruits are some metric of natural-origin production. This does not necessarily mean that S_{MSY} would be expressed in units of natural-area spawners, but the SRWG did not think it was defensible to fit a single spawner-recruit relationship for spawners in both hatcheries and natural areas combined. This is because the reproductive success of individual spawners in different areas would not be equal, and preliminary fits to models where total escapement was used to predict the Sacramento Index (SI) three years later generally had extremely poor fit[1].

If sufficient data were available, the preferred metric of recruits would be potential natural-origin escapement in the absence of fishing for each brood year as derived from a cohort reconstruction (CR), and this would be consistent with the technical recommendations of the STT and SSC. Although a CR for SRFC has not yet been approved for use in management, this will be a topic of the 2024 salmon methodology review. The SRWG does not know the outcome of that review as of the submission deadline for this document, and the CR available to date (Chen et al. 2024) does not yet cover a sufficient number of years over a sufficient range of escapements and environmental conditions. It is important to note that the informational value of a CR would be expected to increase with an increasing number of years analyzed.

None of these analyses would allow direct estimation of S_{MSY} due to the mismatch in the units of spawners and recruits, and the fact that future spawners would not simply be unfished recruits (due to hatchery-origin fish spawning in natural areas). If S_{MP} (the escapement that maximizes production) can be identified, the STT suggested that S_{MSY} could be set equal to S_{MP} times a typical S_{MSY}/S_{MP} ratio, and the 2024 Salmon Methodology Review will evaluate the SRWG's analysis to derive that ratio (SRWG 2024).

If S_{MP} cannot be estimated reliably or methodology review does not endorse the value calculated for F_{MSY} and therefore also the S_{MSY}/S_{MP} ratio, it may be necessary to identify an "optimal" level of production to target. The SRWG noted that in its investigation of spawner-recruit relationships for SRFC, there was little to no statistical evidence for a Ricker spawner-recruit relationship as opposed to alternative forms such as the Beverton-Holt (where there is no peak in the recruitment function). Even assuming a Ricker, estimates of S_{MP} can be highly uncertain and sensitive to the choice of time periods analyzed and covariates considered. At the same time, spawner-recruit relationships fit using different functional forms or to different time periods were often highly similar in their shape at the low to moderate range of escapements, diverging substantially only at the high escapement levels where few observations are available. The SRWG noted this challenge

[1] $R^2<0$ for most time periods explored, implying a worse fit (on the arithmetic scale) than assuming recruitment was constant at its mean value.

is not unique to SRFC, for example Hasbrouck et al. (2020) showed similar results for six model formulations applied to two time periods for an Alaskan sockeye population. Thus, the SRWG recommends continuing to consider options for identifying an "optimal" level of production, which might be done qualitatively based on a sense of diminishing returns, or more quantitatively using the methodology proposed in Satterthwaite (2023). The SRWG particularly welcomes insight from the SSC into the scientific merits of alternative approaches to this challenge, and from the STT on the precedents for how this challenge has been addressed for other stocks.

Switching to an S_{MSY} metric based on natural-area spawners could pose challenges for pre-season planning models and control rule that are currently designed around total escapement (including to hatcheries), although post-season status determinations could still be made easily because postseason escapement estimates are broken out by area. Using a conservation objective based on total escapement (see below) in place of S_{MSY} in the control rule is one potential solution but would not be the only option. See Technical Appendix A for further discussion of the preseason challenges a natural-area S_{MSY} would pose, and potential solutions. The SRWG welcomes feedback from the STT and SSC on these potential solutions.

F_{MSY}

The F_{MSY} proxy used for SRFC should be updated based on analyses scheduled for salmon methodology review. The SRWG identified several more recent analyses and proposed an emphasis on stocks with ocean distributions and inland conditions more like SRFC that could be useful in updating the F_{MSY} proxy value (SRWG 2024).

At the time this document was prepared, the SRWG did not know the outcome of the methodology review. Regardless of the outcome of the review, the SRWG recommends that the value of this and other reference points be periodically reviewed via a prioritized, scheduled process; as recommended by the Salmon Amendment Committee (SAC) when reference points for salmon were first being formalized (SAC 2009) and more recently by the SSC (SSC 2021, SSC 2022, SSC 2024). Keeping reference points up to date is particularly important in the light of climate change and its effects on food webs and other environmental drivers of productivity (Schindler and Hilborn 2015), as well as increasing variability and nonstationarity of these drivers and their relationships to biology.

Conservation Objective

The SRWG considers the S_{MSY} analyses described above as only a starting point for derivation of the conservation objective. National Standard 1 defines Optimum Yield (OY) as MSY reduced[2] by considerations that include "benefits of recreational opportunities reflect the quality of both the recreational fishing experience and non-consumptive fishery uses", "maintaining viable

[2] when considered as a harvest level, meaning the resulting escapement S_{OY} should be an increase from S_{MSY}

populations", "maintaining adequate forage", "maintaining evolutionary and ecological processes", and "maintaining the evolutionary potential of species and ecosystems". The SRWG noted the importance of ensuring adequate broodstock at hatcheries and that in-river harvest is a function of total river run size, not just natural-area river run size. Consequently, the SRWG also discussed ideas for setting a conservation objective based on a total (natural and hatchery area combined) escapement that would be expected to have a high probability of yielding a natural-area escapement at least as high as S_{MSY}, provide for the other ecological and evolutionary considerations highlighted in National Standard 1, ensure adequate broodstock for hatcheries, and provide for quality inland recreational fishing opportunities.

To evaluate the consequences of different escapement goals for river harvest opportunity, the SRWG has analyzed the relationship between river run size and river harvest, allowing the identification of the river run size and ultimate escapement needed to yield a desired level of river harvest given typical river harvest rates. To incorporate hatchery considerations, the SRWG is working toward updating the analyses of hatchery "success" as a function of escapement presented in Satterthwaite (2023) to use juvenile production rather than escapement to the hatchery as the metric of hatchery "success", while accounting for causes of production shortfalls unrelated to broodstock supply (e.g. disease, equipment malfunctions, etc.).

Control Rule

The current control rule is designed to target escapement equal to S_{MSY} over a wide range of forecasted abundance. As noted above, the SRWG's clearest path toward deriving S_{MSY} would be a spawner-recruit analysis based on natural-area spawners, resulting in different units for S_{MSY} than are used by the current forecasting and harvest modeling tools. In addition, the SRWG identified several reasons why the conservation objective and thus desired escapement should likely be higher than S_{MSY}, and include consideration of escapement to both natural areas and hatcheries. Therefore, the SRWG recommends re-parameterizing the control rule in terms of the conservation objective rather than S_{MSY} (and similarly, revising language in the FMP [PFMC 2024, p. 32] around de minimis fisheries to apply with respect to targeting escapement less than the conservation objective rather than S_{MSY}).

In addition, the SRWG discussed the effects of forecast error on successful application of the control rule, and discussed the "nuances" raised by the STT (STT 2024) in evaluating the recent performance of the SI forecast. The SRWG agrees that forecasting of salmon is always challenging for any stock, and there are limits to the amount of improvement we can reasonably expect (Ward et al. 2014, Schindler and Hilborn 2015, Wainwright 2021). The SRWG also notes the importance of focusing on proportional errors in forecasts rather than errors in numbers of fish, as well as the consequences of those errors for management advice (SSC 2023). For example, one of the forecasts that the STT described as "overforecast by a modest amount" resulted in twice the

allowable exploitation rate compared to what the postseason estimate would have allowed[3], and one of the forecasts described as "very close" failed to trigger the de minimis conservation considerations that would have been triggered by the postseason estimate[4] and would have led to investigation of factors related to the viability and resilience of SRFC and co-occurring stocks.

Cohort Reconstruction

The SRWG strongly supports continued development and routine application of a cohort reconstruction (CR) for SRFC that considers both hatchery- and natural-origin components. Both the SSC and STT emphasized the importance of accounting for origin in analyses informing the derivation of reference points. The CR, and a comparison of the CR with the Sacramento Index (SI), is scheduled as a topic for the 2024 salmon methodology review, but that review had not yet taken place at the time of writing. Thus, the SRWG largely defers to reports from the methodology review for further discussion of this item. The SRWG highlights its expectations that the methodology review will confirm the value of a CR in better capturing abundance and evaluating status, of direct importance to PFMC management. For example, if the CR provides a better estimate of ocean abundance than the SI, this could substantially affect quota setting for inseason management. A CR could also be used for multiple purposes outside direct Council needs. For example, there are plans to use a CR in evaluating the performance of individual hatchery releases, contributing to improved hatchery practices going forward, which could support increased harvest opportunity.

Historically, the CR method has depended on coded-wire tags (CWT) since all hatchery releases were at least fractionally marked and tagged. In order to perform CR into the future, the SRWG highlights the importance of continued collection, processing, and timely reporting of CWT[5] data throughout ocean and freshwater areas where SRFC are encountered and scale ages throughout freshwater. Whenever unmarked (i.e., not adipose fin clipped) but genetically tagged fry are released from hatcheries, it is crucial that adequate genetic sampling take place throughout relevant ocean and freshwater areas for all the years that these fry could be encountered as adults; and unmarked releases should always be genetically tagged.

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[3] In 2022, the preseason forecast of 396,458 allowed an exploitation rate of 55% given the Council guidance to target an escapement of 180,000 compared to the 28% that would have been allowed based on the postseason estimate of 251,191.

[4] In 2023, the preseason forecast of 169,767 was just above the 162,667 value that would have triggered the "de minimis" considerations (PFMC 2024, p. 32):
"The potential for critically low natural spawner abundance, including considerations for substocks that may fall below crucial genetic thresholds; Spawner abundance levels in recent years; The status of co-mingled stocks; Indicators of marine and freshwater environmental conditions; Minimal needs for Tribal fisheries; Whether the stock is currently in an approaching an overfished condition; Whether the stock is currently overfished; Other considerations as appropriate." Thus, while the exploitation rate targeted in 2023 was not directly affected by the forecast error, our state of knowledge around the stock and co-occurring stocks was.

[5] And/or parentage-based tag, to the extent this technology is deployed as a complement or replacement to coded-wire tags in the future.

Risk Tables

The SRWG has continued their discussion of how risk tables might be applied to SRFC. The Ecosystem Workgroup (EWG) recommended use of risk tables to adjust harvest considerations for groundfish, by documenting levels of uncertainty in stock assessments and ecosystem conditions. These concepts were advocated by the HC to also apply to the stocks for which stoplight charts of ecosystem conditions have been developed (SRFC and Klamath River Fall Chinook [KRFC]). The application of risk tables to salmon stocks was also discussed by the SSC in their review of the CCIEA's report on development of risk tables. At the September 2024 meeting, the Council tasked the EWG with further developing the risk table concept for KRFC and SRFC through meetings with salmon advisory bodies.

The SRWG has drafted an initial concept for a risk table for SRFC, which was shared with STT and SAS at the September 2024 Council meeting. In this initial concept, uncertainty was conceptualized in terms of ecosystem considerations (e.g., variability of different indicators in salmon stoplights), forecasting uncertainties, and post-season retrospective analysis of forecasting performance and other demographic indicators. The SRWG sees potential value in further developing the risk table concept and how it could be used, and looks forward to coordinating with the CCIEA team, EWG, STT, and other advisory bodies to improve the potential to incorporate ecosystem variability via risk tables for SRFC.

Natural-Origin Objectives and Consideration of the Full Stock Complex

The SRWG discussed the SSC's recommendation that the long-term goal should be development of natural-origin objectives – for consistency with the theoretical basis of MSY reference points, to reduce the risk of over-harvest of the natural component, and to reduce the risk of ESA listing that could constrain future fishing opportunities. A fully developed CR would allow tracking natural-origin dynamics and provide tools for forecasting it. Public comment during the second day of the June SRWG meeting also raised considerations around ensuring adequate escapement to each significant area and life-history within the total Central Valley Fall Chinook stock complex, and raised the question of whether managing for the sustainability and resiliency of each component of the Central Valley Fall Chinook stock complex should be an explicit management goal. The SRWG notes that considerations around natural spawner abundance, genetics, substocks, and co-occurring stocks are explicitly triggered when de minimis provisions come into play at low forecasted abundance (PFMC 2024, p. 32) but not otherwise. To date, no SRFC preseason forecast has been low enough to trigger the de minimis provisions. It is possible that natural-origin or natural-area forecasts would have been more likely to predict low abundance of natural spawners and trigger investigation of these factors. The SRWG also notes there would be value in formally evaluating these questions for SRFC even in years of higher forecasted abundance.

The SRWG agrees with the STT and SSC that developing natural-origin objectives could not be accomplished in the short term based on available data, and thus will focus on natural-area escapement for spawner-recruit analyses in the near term.

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Technical Appendix A - Further details on S_{MSY} Units and Effects on Preseason Planning

Currently, S_{MSY} is used in the preseason as an input to the control rule and is typically the goal set for the escapement predictions of the harvest models; and S_{MSY} (and/or the Minimum Stock Size Threshold value that is specified as a fraction of S_{MSY}) is used in the postseason to assess for overfished, rebuilding, or rebuilt status. For the preseason, the current forecast and harvest models used only predict total escapement, not distinguishing by area of return, resulting in a potential incompatibility if S_{MSY} were defined in terms of natural-area escapement. For the postseason status determination, escapement by area is already reported, and so comparing natural-area escapement to a new natural-area S_{MSY} value would be straightforward.

For preseason planning purposes, if the control rule remains parameterized based on S_{MSY} (see "Conservation Objective" section) an S_{MSY} value based on natural-area spawners would require some adjustments to the process. Either the forecast and harvest models would need to be modified to predict natural-area spawners, a separate model would need to be derived for converting across scales, or the S_{MSY} value would need to be rescaled by applying an adjustment to the output of the spawner-recruit analysis to convert it to units of total adult escapement including hatchery returns. Conversion across scales could be as simple as using historical mean or median ratios (Satterthwaite 2022), involve simple linear regression, or involve more sophisticated probability-based models (e.g., PFMC 2007 Appendix D or Satterthwaite 2023). The SRWG will continue to explore the feasibility and pros and cons of these approaches and invites feedback from the STT and SSC.

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