Agenda Item G.4.a
SRWG Report 1
November 2025

SACRAMENTO RIVER FALL CHINOOK WORKGROUP PROGRESS REPORT

The Sacramento River Fall Chinook (SRFC) Workgroup (SRWG) met remotely on January 29-30, 2025 to consider the outcome of the 2024 salmon methodology review and feedback received in November 2024 from the Council, SSC, STT, and public comment; on June 30-July 1, 2025 to discuss questions raised during salmon methodology topic selection in April 2025 and to plan and evaluate further work and potential timelines; and briefly on October 6, 2025 to finalize this report. In the material that follows, we highlight important points in bold text.

The SRWG acknowledges the interconnection of the various pieces of the harvest management framework and is aware of the Council's desire to see the full framework prior to final decision making to understand how the components work together. The SRWG also notes that it is necessary to be able to model the relationship between escapement and future production using methods that are considered Best Scientific Information Available (BSIA) to quantify costs and benefits to the fishery and to conservation of alternative scenarios, it is necessary to have tools for considering constraints imposed by other stocks in mixed-stock ocean fisheries when evaluating the effects of changing allowable exploitation rates for SRFC, and it is necessary to know what reference points are considered BSIA to evaluate the risk of overfished status, duration of rebuilding, or the frequency with which *de minimis* fishery provisions are expected to be triggered. In recognition that a Salmon Fishery Management Plan (FMP) amendment process is needed in order to see the full framework and that this process can be lengthy, the Workgroup reminds that greater conservative measures could be taken during the interim period of management.

Following from the TOR and Council guidance, so far the Workgroup has prioritized reference points and the conservation objective over the control rule or other tasks, and recognizes the importance of both National Standards and Council priorities in guiding its work. Previously, the workgroup has:

- re-affirmed that the status quo conservation objective and S_{MSY} reference point are outdated and determined from flawed assumptions
- completed an update of the F_{MSY} reference point, which was adopted by the Council after methodology review.
- recommended routine implementation of a cohort reconstruction, the methodology for which was approved by the Council for phased implementation after methodology review.

In this progress report, the SRWG continues moving forward with development of the larger framework through updates to reference points and the conservation objective. Work has focused on methods for determining S_{MSY}, the conservation objective, and illustrating resultant changes to the harvest control rule.

In response to the first item identified in November 2024 guidance to "use the F_{MSY} value adopted under Agenda Item F.2 Salmon Methodology Review to derive an updated S_{MSY} value per the formula described in Agenda Item F.2, Attachment 2", the SRWG derived natural-area S_{MSY} values using four different approaches, identified its preferred approach and reasons for preferring it, wrote a report documenting all four alternatives, and proposed it for methodology review. The topic was added to the preliminary list of methodology review topics in April 2025, but in September 2025 the Council did not select this item for methodology review.

To address the second element of the guidance to "develop options for an updated conservation objective based on total escapement (natural and hatchery areas combined) and based on an S_{MSY} based on natural-area spawners", the SRWG identified a framework for combining a natural-area production goal and hatchery needs into a conservation objective based on total spawners (Satterthwaite 2023). The SRWG also proposed that framework for methodology review, while noting that some inputs to the model may need further updating, which the SRWG also pursued. At the June 30-July 1 meeting, the SRWG received updated hatchery escapement goals derived by CDFW staff and evaluated models of the probability of meeting those goals at different levels of total escapement. The topic was added to the preliminary list of methodology review topics in April 2025, but in September 2025 the Council did not select this topic for methodology review.

Finally, the SRWG discussed ways to address the third point of Council guidance to "work towards modifying the current harvest control rule to account for potential updates to the S_{MSY} and in terms of an updated conservation objective". The SRWG identified an important set of tools for evaluating the potential effects of changes in control rules, which it proposed for methodology review in April 2025, but the Council did not add the topic to its preliminary list of topics. The SRWG also identified several considerations around the control rule it wishes to bring to the Council's attention.

The SRWG realizes that both the S_{MSY} value and the conservation objective resulting from its preferred analyses are higher than recent returns. The SRWG notes that under the formula used as directed by the Council ($S_{MSY} = F_{MSY} \times S_{MP}$), S_{MSY} is sensitive to both capacity (S_{MP}, the escapement that maximizes production) and F_{MSY} (linked to productivity, i.e., the higher productivity is the higher F_{MSY} is and the closer S_{MSY} is to S_{MP}). For the framework for combining a natural-area production goal and hatchery needs (the workgroup's suggested option for an updated conservation objective) it is important to note that substantial increases in planned hatchery production, increase the needed number of eggs and thus the number of adult

broodstock needed in the hatchery component. This influences the resulting conservation objective based on total escapement.

It has been suggested that the Sacramento Basin may have experienced a "regime shift" that has permanently lowered the productivity and/or capacity of the system for fall Chinook, relative to the earlier years included in the fry recruitment index, which extends back to brood year 1999 in the SRWG's preferred analysis. While it seems plausible that productivity may be persistently lower now than it was prior to the return year 2008-2009 "collapse" (Lindley et al. 2009), this generally lower productivity in recent years may largely be the result of poor flow-dependent downstream migrant survival (Michel 2019) that should be reflected in the preferred model's inclusion of flow covariate (measuring conditions during rearing and outmigration) affecting productivity (Dettman et al. 1987). Use of such a covariate is common in spawner-recruit analyses informing PFMC management, for example STT (2005) and Confer and Falcy (2014).

It is unclear whether any of the recent changes hypothesized to reduce productivity would have reduced capacity as well (i.e. there is still a lot of habitat available when flow and temperature conditions allow its full use). Simulations have demonstrated that attempting to model time-dependent capacity is extremely challenging and "rarely reliable" (Wor et al. 2025), with the authors of that paper recommending "Time-varying capacity models should only be explored when there is strong corroborating evidence, with plausible mechanisms, suggesting that capacity has changed." Simply disregarding data from earlier years is not recommended (Holt and Michielsens 2020). There are examples of past declarations of permanently lower capacity that have not borne out in this system (e.g., based on then-recent declines PFMC [1984] predicted returns to the Upper Sacramento would stabilize around 50,000 adults after the mid-1980s but instead averaged just over 150,000 for 1985-2005 [Satterthwaite 2022]) and other systems (e.g., Terceiro 2011). When identifying plausible hypotheses for changes in productivity and/or capacity, **it is important to consider whether the proposed mechanism is likely to have a density-dependent effect. If density-dependence is hypothesized, it is further necessary to consider whether the relevant density would include hatchery-origin fish**.

The SRWG also held general discussions of progress on other items identified in the draft SRWG Terms of Reference (TOR) and possible timelines for addressing those remaining tasks.

S_{MSY} value

Direct estimation of MSY-based reference points using standard methods is not appropriate for SRFC (SRWG 2024a) due to the large contribution of hatchery-origin spawners in natural areas, meaning there is no way to define spawners and recruits such that spawners are the only source of recruits, recruits are the only source of potential harvest, and unfished recruits are the only source of future spawners. Previous SRWG reports noted that estimating S_{MP}, the natural area escapement that maximizes production of recruits (as opposed to maximizing yield), is possible. Under a Ricker spawner-recruit relationship, as is commonly assumed for PFMC-managed salmon stocks, $S_{MSY}=F_{MSY}xS_{MP}$. Thus, given the adoption of an F_{MSY} proxy value for SRFC in

November 2024, derivation of an S_{MSY} proxy could be possible if an estimate of S_{MP} can be developed. Both the Scientific and Statistical Committee (SSC 2024a) and Salmon Technical Team (STT 2024a) have noted the importance of accounting for origin (natural versus hatchery) when estimating recruitment in a spawner-recruit relationship.

The SRWG discussed four approaches (Appendices A-L) that might inform estimation of S_{MP} for SRFC. Each varies in the brood years for which estimates can be made (Figure 1) and has strengths and weaknesses, as described below. The SRWG previously (SRWG 2024b) identified estimates from a cohort reconstruction as the preferred long-term alternative, but noted the **limited number of estimates currently available, covering a limited range of escapements and environmental conditions, with severe confounding between escapement and flow** (i.e. very low flow during rearing and outmigration for the offspring produced from the highest escapement year, low escapements in the years with high flow for offspring, see Figure 2). The SRWG continues to hold this view, and so still sees merit in revisiting spawner-recruit relationships using outputs from a cohort reconstruction in the future, but our currently preferred option would be based on the juvenile production index first developed by Munsch et al. (2020), as presented in Appendix A. Table 1 summarizes the pros and cons of each recruitment metric for the purpose of estimating a spawner-recruit relationship at this time.

Table 1. Pros and cons of each recruitment metric for estimating a spawner-recruit relationship at this time. NOR = natural-origin. HOR = hatchery-origin.

Natural production estimate	Best brood years (see Figure 1)	Pros	Cons	Reference
Fry passing through lower Sacramento River (preferred method)	1999-2020	• Long time series • **Accounts for all natural area sources of NOR juveniles** • Minimal confounding by HOR fish • Geographically and temporally matched to flow covariate • **Parent escapement not confounded with flow conditions during subsequent rearing and outmigration** • **Includes years with high escapement accompanied by high flow for ensuing rearing and outmigration period** • Peer reviewed	• Additional density dependence possible downstream • Poorer prediction in years with larger-sized outmigrants • Some confounding with spring- and winter-run (but note that there are instances where natural-area spring run spawners in the Feather River could be counted as SRFC)	Munsch et al. (2020)
Pre-harvest adults from cohort reconstruction	2007-2016	• Run reconstruction: **Preferred method to estimate recruitment for cohorts with sufficient data** • Endorsed by methodology review, established method for Klamath River Fall Chinook	• Lowest number of data points • **Limited range of escapement** • **Escapement confounded with subsequent flow conditions for offspring** • Contribution of marine life stage to density dependence • Need to account for fry releases in recent years if extended	Chen et al. (2024)

SI * pr(natural-origin spawners)	2007-2018	• Less demanding of data than cohort reconstruction, may be easier to continue into future	• Relatively short time series **• Limited range of escapement** **• Escapement confounded with subsequent flow conditions for offspring** • Contribution of marine life stage to density dependence **• Inaccuracies of SI** • No contribution of multiple adult age classes • Assumes escapement composition of HOR and NOR is the same as ocean harvest	O'Farrell et al. (2013), annual CWT recovery reports
Natural-origin migrants at Red Bluff Diversion Dam	1998-2020	• Long time series • Better sampling of fall run juvenile timing? • Includes years with high flow/ escapement • Deemed suitable to inform rebuilding plan (PFMC 2019)	**• NOR production from Upper Sac only** • Additional possible density dependence downstream • Likely stronger effects of flow downstream	Voss and Poytress (2022)

Figure 1. Brood years for which each of the natural production indices can be estimated based on data currently available to the SRWG. Dark fill indicates estimates can be made, no fill indicates estimates cannot be made (based on the data in hand), and light fill indicates that estimates can be made, with year-specific caveats that do not apply to the years with dark fill.

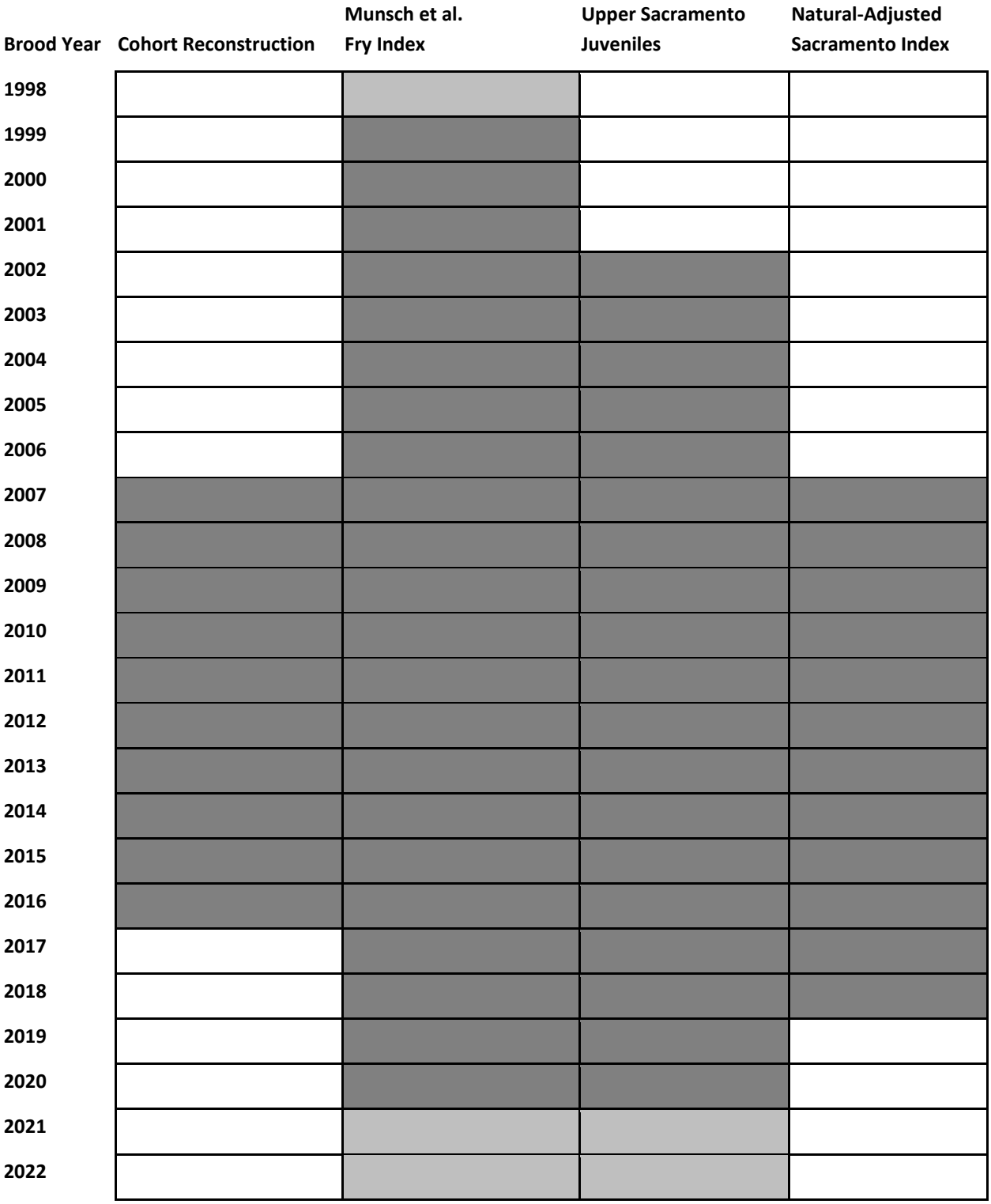
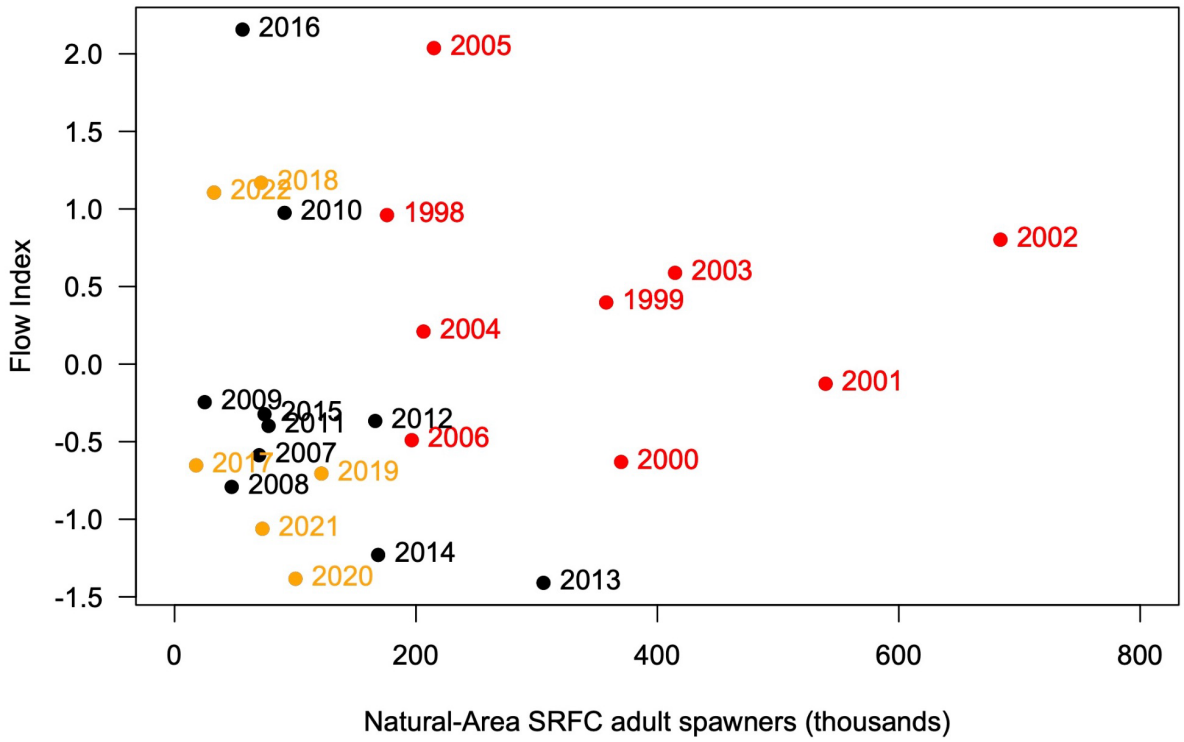


Figure 2. Brood years plotted by natural-area parent escapement (x-axis) and a metric of flow (Munsch et al. 2020) during rearing and outmigration (y-axis). Brood years in red lack, and always will lack (due to a lack of sufficient tagging and scale reading) the data required for a cohort reconstruction, but allow estimation of a juvenile production index. Brood years in orange have juvenile production index estimates but have not had complete cohort reconstructions performed yet, and may face challenges related to a 2020 gap in ocean fisheries sampling due to COVID-19 and unmarked fry releases increasing from low levels beginning with brood year 2021.



Munsch et al. (2020) juvenile production index (with flow covariate)

Munsch et al. (2020) developed an index of natural-origin juvenile (fry, defined here as <55mm) Chinook abundance passing through the lower Sacramento River, which they modeled as a function of natural-area spawners (including fall, spring, and winter-runs; but fall run dominates numerically by a large margin) as well as a covariate characterizing flow levels during rearing and outmigration. The published paper spanned brood years 1998-2015, and further work has extended the index through brood year 2022. Thus, this analysis spans a much wider range of escapements and conditions than currently-available cohort reconstructions, while capturing production throughout the Sacramento basin. Although the SRWG acknowledges the potential

for density-dependence after the fry stage, and notes a modest (r=0.34) correlation between the fry index and recruitment (assessed here as natural-origin ocean age-2 abundance) estimates from the cohort reconstruction for common brood years, the SRWG nevertheless finds the peer-reviewed Munsch et al. (2020) fry index a sound metric of natural production, and notes that when escapement (re-parameterized for these purposes to include adult SRFC in natural areas only) and the flow covariate are both included in a spawner-recruit relationship, the explanatory power is acceptable (R^2=0.53).

Thus, the SRWG's preferred approach to derive a natural-area S_{MSY} at this time in is to estimate S_{MP} using an extended version of the Munsch et al. (2020) fry index and flow covariate to model recruitment as a function of natural-area adult SRFC escapement, and multiply the resulting S_{MP} by F_{MSY} to derive S_{MSY}. Due to the potential for the cohort reconstruction to provide better estimates of year-specific recruitment, but its currently limited temporal coverage, the SRWG recommends revisiting the S_{MSY} analysis once cohort reconstruction results are available from a sufficient number of years covering a range of escapements and environmental conditions, particularly higher flow conditions. It is difficult to identify in advance when sufficient data from a sufficient range of conditions will accumulate, but the cohort reconstruction's coverage should be periodically re-assessed, and then S_{MSY} revisited when appropriate.

Although the Munsch et al. (2020) index can be extended further back in time than the cohort reconstruction, **continuing to develop the index for future years will require a way of accounting for unmarked hatchery fry releases when they are recovered in juvenile sampling efforts.**

Cohort reconstruction

The newly completed cohort reconstruction for SRFC (Chen et al. 2024) likely provides the highest-quality estimates of natural-origin SRFC recruitment possible from existing data sources. The SRWG views these estimates as the "gold standard" for SRFC recruitment estimates (especially when recruitment is defined as potential escapement in the absence of fishing), and thinks the cohort reconstruction has considerable short- and long-term potential for informing multiple aspects of management. However, currently the cohort reconstruction only covers brood years 2007-2016. For the purpose of estimating a spawner-recruit relationship, this is a modest sample size with statistical power on the low end compared to typical recommendations (e.g. SSC [2024b] recommended 10-15 years minimum, and Adkison [2022] notes that "for short time series, high values of recruitment tend to be overrepresented at low spawner abundances, and vice versa"), and this range of years is also lacking in high escapement years (only one with natural-area escapement above 200,000) and the only high escapement year was accompanied by

very low flow during rearing and outmigration (and overall the correlation between spawners and flow for these brood years was -0.49, versus 0.11 for brood years 1999-2020). The combination of small sample size, low contrast in the range of escapements covered, and strong confounding between parent escapement and the flow faced by resultant offspring makes statistical inference from this severely limited dataset unreliable. Therefore, **the SRWG recommends revisiting S_{MSY} based on a spawner-recruit analysis using the cohort reconstruction once estimates are available from a larger number of years covering a broader range of conditions, but does not recommend its use for estimating a spawner-recruit relationship at this time**.

Although the value of the cohort reconstruction is expected to increase over time as additional data become available, this will take considerable time. It is difficult to predict when the next high escapement year might be, and **current management does not generally target high escapements, such that even a strong recruitment event may not lead to high escapement. Even once a high escapement year occurs, there will be a 4-5 year lag before the cohort produced from that high escapement year can be reconstructed**. In addition, there will need to be a commitment to ongoing collection and processing of the required data, including developing new methods to **sample for unmarked fry releases that can only be identified through genetic sampling, which needs to take place wherever SRFC might be recovered (e.g., ocean fisheries along the U. S. West Coast, river harvest, natural spawning areas, and hatcheries).**

Sacramento Index (SI) times Proportion Natural-Origin Escapement

Prior to the availability of cohort reconstruction results, members of the SRWG explored a crude index of natural-origin production based on the Sacramento Index (SI, O'Farrell et al. [2013], an index of potential escapement in the absence of fishing that includes both natural and hatchery-origin fish) times the proportion of escapement that was of natural-origin three years after parent spawning. This suffers from all of the inaccuracies of the SI relative to the cohort reconstruction (Chen et al. 2024) and also relies on the assumption that the composition (hatchery- versus natural-origin) of harvest is the same as the composition of escapement, which would not be the case if hatchery- and natural-origin fish differ in their maturation rates or other aspects of their behavior affecting exposure to the fishery. Given that Chen et al. (2024) estimated natural-origin SRFC age-3 maturation rates ranging from 0.53 to 0.90 with median 0.69, **assuming that potential recruitment from a brood year in the absence of fishing can be fully characterized by returns three years later is not supported**.

Because the estimates of the proportion of escapement that is natural-origin depend on the same constant fractional marking program that enabled the cohort reconstruction, this approach is

largely restricted to the same set of years as the cohort reconstruction, with the same resulting limitations in terms of escapements and environmental conditions covered, and therefore is less informative than the Munsch et al. index that covers a wider range of escapements and flows.

In practice, the natural-adjusted SI and the recruitment estimates from the cohort reconstruction were well correlated (i.e. both high in high abundance years, both low in low abundance years) and gave similar results for S_{MP}. The cohort reconstruction approach would be preferred based on first principles because it provides more accurate year-specific estimates, and the SI was developed as an interim measure due to data deficiencies at the time. However, if data deficiencies persist, it might be easier to extend the SI-based approach into the future (and indeed, with the publication of White et al. [2025], it is possible to extend the SI-based approach to two more brood years than those covered by the Chen et al. [2024] cohort reconstruction). Both approaches would require a way of accounting for hatchery-origin fish in the escapement, including unmarked fry releases, but an SI-based approach would not depend on scale aging and might be able to accommodate a lack of genetic sampling of ocean harvest. The SRWG recommends further consideration of this approach only in the event that future data streams are insufficient for cohort reconstructions but sufficient to estimate the SI and the proportion of escapement that is natural-origin.

Upper Sacramento Juvenile Production

The SRWG discussed spawner-recruit relationships fit to fry equivalents (with larger fish included using a correction for expected survival differences) passing downstream of the Red Bluff Diversion Dam rotary screw trap (Voss and Poytress 2022) as a function of females spawning in natural areas above it, as done previously in the SRFC rebuilding plan (PFMC 2019). However, similar to the Munsch et al. index, there is the potential for density dependence after the fry stage, and in this case additional lower river mortality (that might have a density-dependent component) going unmeasured as well. This also represents only a portion of the Sacramento basin, albeit an important one that has had recent escapement shortfalls. Therefore, this data source is not the SRWG's preferred approach for developing S_{MSY}.

Conservation objective approach

Council direction was to focus on a natural-area S_{MSY} along with a conservation objective that included fish returning to both hatcheries and natural areas combined (which would be consistent with the units used in the existing forecast, harvest model, and control rule). In determining the appropriate analytical approach to derive a conservation objective given Council guidance to consider a natural area S_{MSY} and hatchery needs, the SRWG concluded that it should consider

both factors in its analysis**.** Given Council guidance to adhere to National Standard 1, the SRWG also discussed the potential utility of explicitly accounting for river harvest (a component of "benefits of recreational opportunities reflect[ing] the quality of both the recreational fishing experience and non-consumptive fishery uses" called out in National Standard 1) and/or escapement to specific sub-areas within the Sacramento basin (potentially relevant to multiple points of National Standard 1 guidance including "maintaining viable populations", "maintaining evolutionary and ecological processes", and "maintaining the evolutionary potential of species and ecosystems").

The SRWG ultimately decided against building consideration of river harvest into the conservation objective, to avoid the perception of encroaching upon matters of allocation. The SRWG did not reach consensus on the utility of considering escapements to sub-areas within the overall SRFC natural-area escapement, but noted a current lack of defined sub-areas of importance or numerical goals for those sub-areas. Nevertheless, the SRWG also noted the potential need for such definitions and goals, regardless of the conservation objective, if and when the "de minimis" provisions of the FMP (PFMC 2024, p. 32) requiring "potential for critically low natural spawner abundance, including considerations for substocks that may fall below crucial genetic thresholds" were ever invoked for SRFC, as they have been for Klamath River Fall Chinook (KRFC). Although these "de minimis" provisions have never been invoked for SRFC as of this writing, they would have been necessary in 2025 if the 2024 jack escapement estimate had been 3% lower (PFMC 2025).

In the near term, the SRWG discussed the utility of the approach described by Satterthwaite (2023) for deriving an escapement goal (expressed in terms of total spawners) that has a desired probability of simultaneously achieving natural-area escapement sufficient to produce a desired fraction of the maximum possible natural production (which could be replaced with achieving a natural-area S_{MSY}, once available) along with meeting pre-defined escapement goals for each hatchery in the system. The SRWG recommended a methodology review for this general framework, noting that the inputs could be readily updated to incorporate a new S_{MSY} estimate, new hatchery goals (those used in Satterthwaite [2023] reflect Table B-1 of the Review of Ocean Fisheries but may be out of date), and/or escapement goals for specific sub-areas within the basin (e.g., Satterthwaite [2023] presented analyses based on achieving desired levels of production in just the Upper Sacramento) as they become available. Notably, this approach does rely on past patterns of how fish are distributed across the watershed at different abundances being representative into the future, and has many conceptual parallels with the approach used when de minimis considerations are triggered for KRFC (PFMC 2007, their Appendix D) requiring an assessment of the probability of any key substock falling below a critically low escapement threshold. Application of this approach to updated hatchery goals is documented in Appendix M.

Control rule

The SRWG interpreted November 2024 Council guidance as prioritizing S_{MSY} and the conservation objective over the control rule, and has focused most of its efforts accordingly. Nevertheless, the SRWG wishes to highlight several points around the control rule that may merit attention even before S_{MSY} and the conservation objective have been fully addressed.

Most crucially, the SRWG notes that if a natural-area S_{MSY} value is adopted but no other changes to the control rule and forecast are made, there will be a mismatch because the control rule is defined in terms of S_{MSY} rather than the conservation objective, and applying the control rule requires a prediction of potential escapement in the absence of fishing as an input. The current SRFC forecast is expressed in units of total spawners, not natural-area spawners. A relatively simple near-term fix would be to re-parameterize the control rule in terms of the conservation objective in place of S_{MSY}, although the conservation objective would need to take on a discrete value rather than a range (noting that the current range reflects an "interim" adjustment [PFMC 1984][1]). Alternately, tools to forecast natural area escapement would be needed. The STT (2024b) noted that "While the Sacramento Harvest Model does not currently have a module that projects escapement to natural areas only, the Klamath Ocean Harvest Model (KOHM) has this capability, and the method used for Klamath River fall Chinook could be modified for use with SRFC." Alternatively, the approach used in the Amendment 16 Environmental Assessment to convert total escapement to natural- versus hatchery-area escapement based on the mean proportion over the past ten years could be used (PFMC and NMFS 2011, p. 115).

The SRWG also notes that multiple lines of evidence support an updated S_{MSY} and/or conservation objective larger than the existing values. An updated S_{MSY} and/or conservation objective could lead to increased likelihood of triggering "de minimis" considerations (PFMC 2024, p. 32) to allow fisheries to proceed even if they were not expected to yield escapement above S_{MSY} or the conservation objective. **Allowing de minimis fisheries to proceed would require consideration of factors such as potential for critically low natural spawner abundance, including considerations for substocks that may fall below crucial genetic thresholds, along with the status of co-mingled stocks" and "indicators of marine and freshwater environmental conditions, that have not previously been formally assessed for SRFC.** The SRWG recommends prioritizing the development of tools to do so. The SRWG notes considerable progress on risk tables (Leising et al. 2025), and potential for risk tables to address some of these considerations.

[1] As has been previously noted by the workgroup, the minimum spawner escapement floor of 122,000 hatchery and natural area adults for SRFC was developed as an "interim" value for the lower bound of the conservation objective pending the permanent opening of the Red Bluff Diversion Dam gates (PFMC 1984). Escapement data shows the first and second lowest observed returns of SRFC to the Upper Sacramento River were realized post removal of RBDD highlighting likely changes in the spawner recruit relationship since its development.

The SRWG wishes to highlight the potential for some very restrictive allowable exploitation rates in the "de minimis" zone of the control rule, and suggests there could be merit in reconsidering appropriate levels of "de minimis" exploitation rates and analyzing their likely consequences for both conservation and fishery performance.

The current control rule depends on F_{MSY} and S_{MSY} as inputs, and thus will change as these reference points are updated. Therefore, the SRWG prepared a set of plots to illustrate the control rule as it existed in 2024, the control rule resulting from the enacted change in F_{MSY} and thus F_{ABC}, and how the control rule would further change in response to a hypothetical change in S_{MSY} (and thus MSST) added on top of the change in F_{MSY} (Fig. 3). The SRWG also prepared plots illustrating the implied targets for each version of the control rule in terms of both harvest (of SRFC, not considering co-occurring ocean harvest of other stocks, Fig. 4) and escapement (Fig. 5). These "implied targets" reflect the escapement and harvest (of SRFC) that would be expected to result from the control rule in the absence of any forecast error, any error in the harvest planning models, and any mixed-stock constraints or other factors leading to targeting an exploitation rate different from control rule output.

Figure 3. SRFC control rule showing allowable exploitation rate as a function of forecasted abundance (potential escapement in the absence of fishing) as it existed in the 2024 preseason (black), as changed by adoption of F_{MSY}=0.58 and the accompanying F_{ABC}=0.52 (blue), and as hypothetically further modified by a hypothetical S_{MSY}=180,000 and resultant MSST=135,000 (red). At forecasts where the black curve is invisible, it is covered by the blue curve. At forecasts where the blue curve is invisible, it is covered by the red curve.

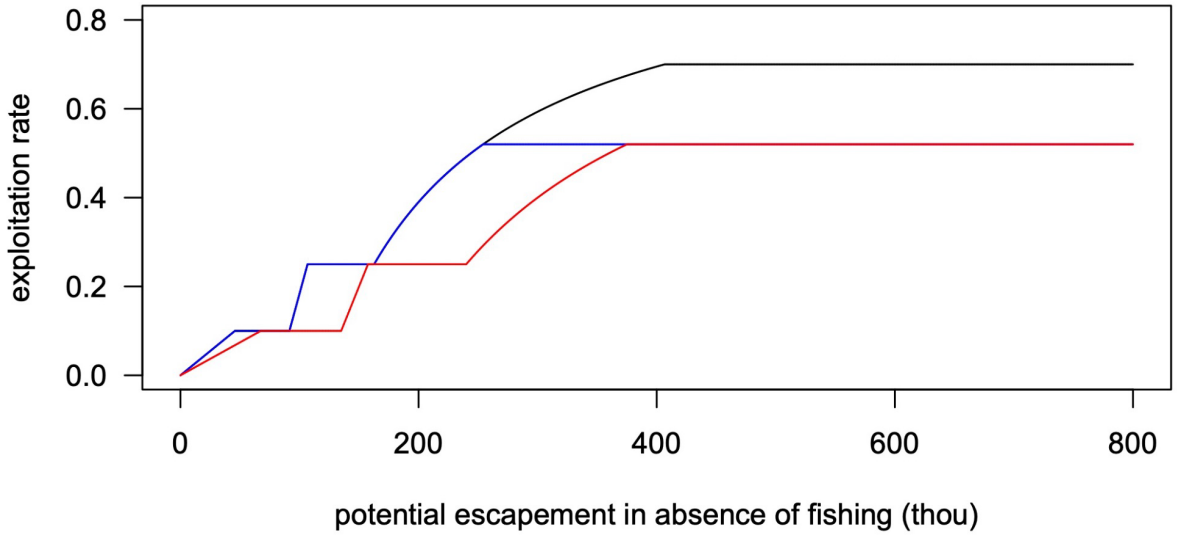


Figure 4. Projected (or implied target) SRFC escapement as a function of potential escapement in the absence of fishing under the control rules described in Figure 1 (black = control rule in effect during 2024 preseason, blue = effect of adopting F_{MSY}=0.58 and the accompanying F_{ABC}=0.52, red = hypothetical effect of also adopting a hypothetical S_{MSY}=180,000 and resultant MSST=135,000). At forecasts where the black curve is invisible, it is covered by the blue curve. At forecasts where the blue curve is invisible, it is covered by the red curve. These projections depend on the assumptions that forecasts are made without error, there are no mixed stock constraints or other reasons the exploitation rate targeted in the preseason would differ from the control rule output, and that exactly the intended exploitation rate is actually achieved.

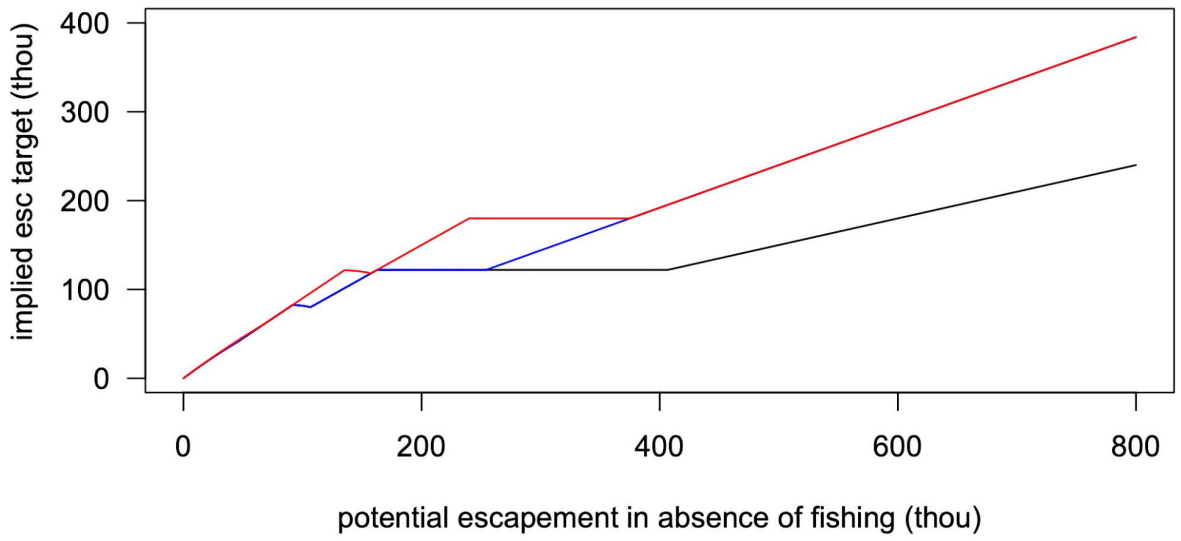
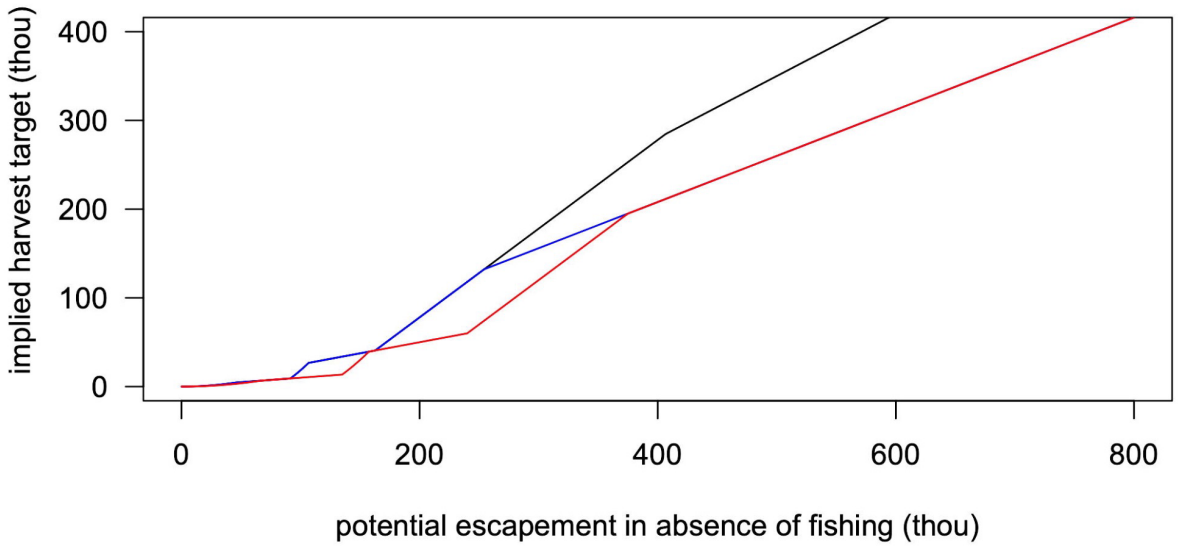


Figure 5. Projected (or implied target) SRFC harvest as a function of potential escapement in the absence of fishing under the control rules described in Figure 1 (black = control rule in effect during 2024 preseason, blue = effect of adopting F_{MSY}=0.58 and the accompanying F_{ABC}=0.52, red = hypothetical effect of also adopting a hypothetical S_{MSY}=180,000 and resultant MSST=135,000). At forecasts where the black curve is invisible, it is covered by the blue curve. At forecasts where the blue curve is invisible, it is covered by the red curve. These projections depend on the assumptions that forecasts are made without error, there are no mixed stock constraints or other reasons the exploitation rate targeted in the preseason would differ from the control rule output, and that exactly the intended exploitation rate is actually achieved. Note that ocean harvest of co-occurring stocks is not included in the harvest amount.



As shown in Figure 3, reducing F_{MSY} from 0.78 to 0.58 and thus F_{ABC} from 0.70 to 0.52 limits the allowable exploitation rate at the highest forecasted abundances (blue curve flattens out lower than the black curve), but has no effect for forecasted abundances that would require an exploitation rate no higher than 0.52 to achieve the target escapement of S_{MSY} (black and blue curves are superimposed, with only blue visible). As a result, the implied target escapements (Figure 4) and harvests (Figure 5) are identical for the black and blue curves at low or moderate forecasted abundances, but at high forecasted abundances the implied target escapement is higher (blue [or red where blue is hidden underneath it] is above black on the right side of Figure 4) and the implied target harvest is lower (blue [or red where blue is hidden underneath it] is below black on the right side of Figure 5).

A hypothetical change of S_{MSY} from 122,000 to 180,000 leaves allowable exploitation rates at high forecasted abundance unchanged (red and blue overlap on the right side of Figure 3), but allowable exploitation rates begin to drop off from F_{ABC} at higher abundances (farther to the right) as the red curve targets escapement of 180,000 while the blue curve targets escapement of 122,000 in the middle portion of Figure 3, resulting in higher escapements (red above blue in Figure 4) and lower harvests (red below blue in Figure 5) at moderate forecasted abundances. An increase in S_{MSY} (and thus MSST) also causes de minimis provisions to begin at higher abundances (red below the overlapping blue and black on the left side of Figure 3). At such low abundances and exploitation rates, the realized magnitude of difference in the already low escapement (left side of Figure 4) and harvest (left side of Figure 5) are small.

The SRWG reiterates that these harvest and escapement projections rely on the assumptions that forecasts are made without error, there are no mixed stock constraints or other reasons the exploitation rate targeted in the preseason would differ from the control rule output, and that exactly the intended exploitation rate is actually achieved. None of these assumptions will be met in practice. Satterthwaite and Shelton (2023) presented a framework for projecting the consequences of different management regimes for escapement and harvest (of the target stock), while accounting for complicating factors like forecast error, harvest planning error, and mixed-stock constraints. A methodology review of Satterthwaite and Shelton (2023) could allow the SRWG to confidently apply those tools to analysis of risks and benefits in the future (or might lead to the identification of better methods).

Other tasks identified in TOR, and associated timelines

In addition to reference points, the conservation objective, and the control rule, the draft TOR mentions several elements relevant to the management of SRFC, as follows:

effect of environmental variables on the stability and accuracy of the management measures listed above

The SRWG is performing spawner-recruit analyses that use flow as a covariate. The SRWG explored alternate metrics of flow (in terms of timing/location of measurements), as well as temperature metrics, and found them highly correlated such that the exact choice of river condition covariates for spawner-recruit relationships was not crucial, but model selection techniques strongly favored spawner-recruit relationships with some sort of flow/temperature metric over those without, and the scientific literature provides strong support for a link between flow and survival during outmigration (e.g., Michel et al. 2015, Michel 2019, Hance et al. 2022). While a single number cannot be expected to capture every detail of freshwater conditions for an entire year (just like using an annual spawner number ignores the effects of age structure, spawning location, and origin), it is generally the case historically that years with more water in the system tended to lead to greater flow and cooler temperatures than years with limited water in the system. Adkison (2022) recommended a cautious approach to including environmental covariates in spawner-recruit relationships, recommending that analysts "test few variables, and restrict to those for which a plausible and literature-supported biological mechanism of action exists. Aggregate the variable over large areas and timespans unless the mechanism specifies a particular time and/or place of action; this aggregate will likely be correlated to that at the unknown time and location of the action, or that of the correlated mechanism it represents".

Work on indicators to potentially inform risk tables based on the ability of indicators to predict abundance, productivity, and/or deviations from sibling model forecasts are ongoing (e.g., Leising et al. [2025], p. 101), without a clear timeline for adoption (if any), but this and related work continues to improve our understanding of the system.

The SRWG notes that their member with the most expertise in habitat issues is no longer employed by NWFSC and will not be available to assist the SRWG indefinitely. The USFWS seat on the SRWG is also vacant, removing another potential source of insight on freshwater conditions.

The SAS (2025) recommended "adaptive approaches to managing this stock, rather than just managing to a single value", perhaps implying that the escapement target should vary as a function of anticipated environmental conditions faced by escaping spawners and their offspring. The SRWG (2024a) discussed this approach in its June 2024 progress report, but the STT (2024a) stated that this approach was "not recommended". The Council may wish to provide input on resolving these conflicting positions.

analysis of biological risks and fishery related benefits

The SRWG has not prioritized work on this, given Council direction to focus on reference points and the conservation objective. As described above, the SRWG highlights the need for

conservation-related metrics for key substocks in the event of a need to invoke "de minimis" considerations in the future, and this would be an important element of an analysis of biological risks. Identifying such metrics has not been a focus of the SRWG to date. Once escapement levels corresponding to different levels of biological risk have been identified, Satterthwaite and Shelton (2023) offers a framework for projecting the consequences of different management regimes for escapement and harvest (of the target stock), while accounting for complicating factors like forecast error, harvest planning error, and mixed-stock constraints. A positive outcome from a methodology review of Satterthwaite and Shelton (2023) would allow the SRWG to confidently apply those tools to analysis of risks and benefits in the future, while a negative outcome might lead to the identification of better tools. The establishment of substock goals may be a long-term effort, but should not delay evaluation of tools that already exist and could be applied in the future.

design new, or update existing, abundance forecast methods and harvest models that may incorporate age-structure information, as is done for Klamath River fall Chinook

The SRWG discussed two aspects of revised forecasts and harvest models for SRFC.

First, given the "as is done for Klamath River fall Chinook" language, the SRWG discussed the feasibility and timeline of applying an age-structured forecast and harvest model, as is done for KRFC, to SRFC. Fundamentally, the calculations would be identical, could use the same codebase, and simply require a cohort reconstruction for SRFC covering a sufficient number of years to both train and test the model. The current KRFC forecast model is based on a moving window for inputs, where the relationship between age a river run size in year y and ocean abundance at age a+1 at the start of year y+1 is evaluated based on observed ratios over the last 10 brood years with complete or nearly complete data (PFMC 2025). This implies the need for around ten complete cohorts to train the model in its first year of simulated application, and then a sufficient number of additional years would be needed to perform out-of-sample prediction to test the model performance. Exactly how many years of out-of-sample prediction would be needed to adequately assess model performance is debatable, but the current SRFC cohort reconstruction covering ten brood years is clearly not sufficient to both train and test the model.

Second, the SRWG discussed alternate approaches to forecasting. Methods to adjust for bias, and potentially buffer against uncertainty, based on past performance already exist (Satterthwaite and Shelton 2023), and numerous publications have pointed out the need to develop salmon management frameworks that are robust to the inevitable presence of forecast error (e.g., Haeseker et al. 2005, Haeseker et al. 2008, Wainwright 2021). Winship et al. (2015) compared performance of 13 model variants (some with numerous subvariants) in forecasting the SI based on data from 1983 through 2012, potentially these comparisons could be updated using over a decade worth of additional data. Once a sufficient number of years of cohort reconstruction

estimates are available, even if there is not a move to a fully age-structured forecast, it may be useful to explore forecasting (and evaluating forecast performance relative to) potential adult escapement in the absence of fishing as derived from a cohort reconstruction rather than as approximated by the SI. Finally, ongoing work on ecosystem indicators and their potential to predict abundance or variation in forecast performance (Leising et al. 2025, p. 101) could be informative.

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Appendices

The following appendices are provided in *Agenda Item G.4.a SRWG Report 2.*

Appendices A-L: S_{MSY} Documentation

Appendix A. Derivation of natural-area S_{MSY} for Sacramento River Fall Chinook

Appendix B. Description and updating of Munsch et al. (2020) juvenile production index and associated flow covariate

Appendix C. Code for natural-area SRFC S_{MSY} based on updated Munsch et al fry index

Appendix D. Sensitivity analysis: Spawner-recruit analysis based on cohort reconstruction estimate of potential natural-origin adult escapement in the absence of fishing

Appendix E. R Code for the spawner-recruit analysis based on cohort reconstruction estimate of potential natural-origin adult escapement in the absence of fishing.

Appendix F. Input files for spawner-recruit analysis based on cohort reconstruction estimate of potential natural-origin adult escapement in the absence of fishing.

Appendix G. Sensitivity analysis: Spawner-recruit analysis based on Sacramento Index and proportion natural-origin escapement

Appendix H. R Code for the spawner-recruit analysis based on the SI.

Appendix I. Input files for SI-based spawner-recruit code.

Appendix J. Sensitivity analysis: Spawner-recruit analysis based on RBDD fry passage

Appendix K. R Code for the spawner-recruit analysis based on the Upper Sacramento (RBDD) fry passage index.

Appendix L. Input files for RBDD-based spawner-recruit code.

Appendices M-P: Updated Hatchery Goal Analysis and Effect of Incorporating Natural-Area S_{MSY}

Appendix M. Supplement to Conservation Objective Materials - Updated Hatchery Goals

Sacramento River Fall Chinook Workgroup

Appendix N. Code for logistic regression analysis.

Appendix O. Data for logistic regression analyses. Save as "RefPeriodEscapements.csv" in the directory used to run the code in Appendix N

Appendix P. Effects of incorporating a natural-area S_{MSY}