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Introduction and Packet Overview for Spring-run Chinook Salmon Juvenile Production Estimate Modeling Approach

Authors

Kimberly Horndeski, Community Consulting; Brett Harvey, California Department of Water Resources; Ashley Vizek, FlowWest; Liz Stebbins, FlowWest; Erin Cain, FlowWest

Acknowledgments

The data used in this modeling effort are rich and extensive—in some cases, data collection has been ongoing since the late 1990s. This work would not have been possible without the field staff that collected daily rotary screw trap data over many years, and the data stewards who managed that data. We specifically acknowledge the current data collectors and stewards Anna Allison, Nicolas Bauer, Drew Huneycutt, Jeanine Phillips, and Corey Fernandez who assisted in this effort, curating and making compatible data used in analysis, and providing valuable insights that contribute to the modeling process.

Work by Kimberly Horndeski and FlowWest on this project was supported by the California Department of Water Resources.

Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

Term	Definition
CDFW	California Department of Fish and Wildlife
Delta	Sacramento–San Joaquin River Delta
DWR	California Department of Water Resources
EDI	Environmental Data Initiative
JPE	juvenile production estimate
MWD	Metropolitan Water District
NMFS	National Marine Fisheries Service
Reclamation	U.S. Bureau of Reclamation
RST	rotary screw trap
Science Plan	*Incidental Take Permit Spring-Run Chinook Salmon Juvenile Production Estimate Science Plan 2020–2024*
SDM	structured decision-making
spring-run	spring-run Chinook salmon

1 Project Initiation Juvenile Production Estimate Core Team

As part of California Endangered Species Act and federal Endangered Species Act consultations on the long-term operations of the state and federal water projects, the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) agreed to support development and implementation of an approach for forecasting an annual spring-run Chinook salmon (*Oncorhynchus tshawytscha*) (spring-run) juvenile production estimate (JPE) for the Sacramento River and its tributaries upstream of the Sacramento–San Joaquin Delta (Delta) (California Department of Fish and Wildlife [CDFW] 2024; Reclamation 2024). The production of an annual spring-run JPE forecast is intended to support development of new potential measures to minimize the loss of spring-run caused by water operations, and is also intended to contribute to development of a spring-run life cycle model to support improved management of spring-run.

The spring-run JPE Science Program was initiated as a condition of a prior permit issued to DWR in 2020 (CDFW 2020). Under this prior agreement, a process for JPE approach development was outlined in the *Incidental Take Permit Spring-Run Chinook Salmon Juvenile Production Estimate Science Plan 2020–2024* (Science Plan) (DWR et al. 2020), which was later adopted under the 2024 permits with an extended deadline for development and implementation. The Science Plan called for the establishment of six teams with responsibilities listed in Table 1. A seventh Model Review Team with specific expertise in modeling was later established. Although the teams had specific responsibilities, teams are highly interactive, with individuals contributing to work across multiple teams. Among these teams, the JPE Core Team, which is comprised of 15 active members representing six agencies (CDFW, DWR, the National Marine Fisheries Service [NMFS], Reclamation, the U.S. Fish and Wildlife Service [USFWS], and Metropolitan Water District [MWD]) is tasked with guiding technical development of the JPE approach. As a framework for guiding model development, the Core Team used structured decision-making (SDM) tools and processes.

The JPE Core Team has decision authority in one primary area of the SDM process: defining the objectives for JPE approach development. The Core Team provided modelers with nine objectives to guide model development, with objectives reflecting both the range of interests across represented agencies, and the JPE's ability to support development of minimization measures and a life cycle model. The Core Team is also responsible for approving a final recommendation for the JPE approach, and monitoring to support the approach.

It is important to note that recommendation of a modeling and monitoring approach by the Core Team does not ensure those recommendations will be implemented. The implementation decision lies with the consulting agencies (i.e., DWR, Reclamation, CDFW, and NMFS). Also, the Core Team is not tasked with development of new minimization measures based on the JPE approach. Minimization measure development will occur under a separate adaptive management process.

Table 1. Juvenile Production Estimate Science Program Teams and Team Responsibilities

JPE Team	Team Responsibilities
Guidance Team	Provide guidance for overall Science Plan and inter-team coordination.
Core Team	Provide guidance for and review of JPE approach development, and approve final JPE approach to recommend implementation.
Stream Teams	Collect, organize, and report life-stage-specific data. Contribute to development of the data management system.
Run ID Team	Establish and run genetics sampling, analysis, and modeling program to assign run-type to sampled salmon.
Data Management Team	Curate and process historical data for modeling. Establish a data management system to ensure rapid reporting and compatibility of future collected data.
Modeling Team	Develop JPE modeling approach.
Model Review Team	Review models and provide recommendations for improving models.

2 Decision Statement

The current decision statement was drafted collaboratively by the JPE Core Team members with iterative reviews by the Guidance Team and Executives of both DWR and CDFW. This process allowed for the decision statement to capture information relevant to the JPE Core Team, to be aligned with the expectations of management, and to stay within the intended scope of JPE approach development:

> "By September 2025, the JPE Core Team will develop, evaluate, and recommend a suite of potential approaches to estimate the abundance of springrun Chinook Salmon juveniles in the Sacramento River and its tributaries upstream of the Delta and support the potential development of a life cycle model and minimization measure as described in 2024 ITP COA 7.9.3, 7.9.4, and Attachment 4. In this process, the JPE Core Team understands that they will not know what form the life cycle model and/or minimization measure would take. The JPE Core Team also recognizes the importance of developing an estimate/forecast of spring-run Chinook Salmon juveniles at the point of Delta entry in this process."

The key constraint identified in the decision statement is that "the JPE Core Team understands that they will not know what form the life cycle model and/or minimization measure would take." This means the Core Team and the Modeling Team were tasked with developing a JPE model without consideration of a specific minimization measure or measures for which it might be used, or a specific use or purpose for a life cycle model that the JPE might inform.

This also means that minimization measure development is expected to occur after development of the JPE approach. Although the lack of specificity in the exact nature of a minimization measure provided challenges in model development, this order of operation is expected to allow greater flexibility in objective development by the Core Team and in model development to meet these objectives. In turn, it is expected that a more flexible model will allow greater flexibility and creativity in the minimization measure development.

3 Objectives

A practical set of objectives needs to strike a balance between being complete (i.e., representing all the things that matter) and concise (i.e., a manageable number). The set of objectives must also balance representing fundamental objectives and means objectives, avoid duplication across objectives, and focus on what the decision can influence.

The JPE Core Team identified nine objectives and four sub-objectives. The objectives were developed through an interactive process, and were reviewed and updated as needed in 2021, 2023 and 2024 to ensure they were an accurate reflection of JPE Core Team values. The final set of objectives provided by the Core Team are described in this section. These objectives guide model development for the JPE approach. Note that the objectives text has been adapted from the original JPE Core Team version to enhance clarity and readability for the independent peer review process.

3.1 Maximize Confidence that the Predicted Juvenile Production Estimate is an Accurate Reflection of the True Number of Juveniles at Delta Entry

Recognizing the true number of juvenile salmon entering the Delta is difficult to monitor and cannot ever be known. This objective describes the degree to which an alternative maximizes confidence that the predicted JPE is an accurate reflection of the true number of juveniles based on alternative indicators. Maximizing confidence is important because it enhances the reliability of using the spring-run JPE for minimization measures, conservation actions, and other management decisions. The JPE output may be broken out in several ways, including by tributary, life stage, and timing; because confidence may be different for each of these, we have included these as the following sub-objectives:

- **Single JPE at Delta Entry:** This sub-objective captures the difference between the predicted and true total number of spring-run juveniles entering the Delta each year.
- **Tributaries at Delta Entry:** This sub-objective captures the difference between the predicted and true number of spring-run produced in each tributary that enter the Delta each year.
- **Young-of-Year/Yearling at Delta Entry:** This sub-objective captures the difference between the predicted and true number of juveniles following different life-history types that enter the Delta each year. In practice, the Core Team agreed to delineate life-history type as yearling or young-of-year outmigrants.

- **Timing at Delta Entry:** This sub-objective captures the difference between the predicted and true number of juveniles in the temporal component of JPEs (i.e., the difference between the predicted and true distribution of outmigration timing at Delta Entry).

3.2 Maximize the Ability to Incorporate Life-History Diversity in the Juvenile Production Estimate

We know that spring-run have a remarkably diverse life history; by incorporating outmigrant life-history diversity in the JPE, we can protect that diversity, which is important for species resilience. Also, incorporating life-history diversity in the JPE could increase the ability to protect more vulnerable life histories. This objective refers to the different life-history strategies for which a specific JPE is produced.

3.3 Maximize Inclusion of All Spring-Run Populations

Spatial diversity is important to species resilience, both in terms of the genetics of different populations and in terms of stochastic events affecting one population but not others. Capturing different populations in the JPE could give us the ability to target protections and interventions based on vulnerability, and the importance of a particular tributary to the overall spring-run population, avoiding disproportionate effects on one population versus another. The Core Team discussed population diversity as a function of tributary or diversity group. Note: the current JPE as outlined by the Decision Statement requires accounting for only Sacramento River basin spring-run, and not spring-run produced in the San Joaquin River basin.

3.4 Maximize the Timing of Output

The timing, or availability, of a JPE can inform management decisions. JPEs released earlier may provide opportunities for more fish conservation and better planning across regulatory requirements. Because we do not know the specifics about how the JPE will be used, it is difficult to say what the ideal timing would be, although giving managers the ability to make decisions before fish get to the Delta is clearly desirable.

3.5 Minimize Take of Listed Species

The focus of this objective is take associated with monitoring required to support a particular JPE approach. This objective is not concerned with take associated with implementation of the JPE as a minimization measure.

3.6 Minimize Cost of Producing the Juvenile Production Estimate

This objective accounts for the total additional costs incurred as a result of JPE modeling efforts reported in dollars, which are necessary to support the required monitoring and modeling for each approach, in labor, equipment, and other expenditures. This does not include costs for activities and expenses that were dedicated as part of ongoing programs before initiation of the spring-run JPE Science Program.

3.7 Maximize the Likelihood That Monitoring Occurs as Planned

This objective recognizes the reality that monitoring is not always carried out as planned for a range of reasons (e.g., floods, drought, or wildfire). Given that a JPE approach's performance on many other objectives (such as confidence, ability to account for life-history diversity, and spatial diversity) is affected by the availability and consistency of data, developing a modeling and monitoring approach that is robust to the vagaries of monitoring is preferred.

3.8 Maximize the Ability to Compare the Juvenile Production Estimate Forecast to Observed Timing at Delta Entry

This objective accounts for whether model approaches include monitoring that allow the temporal distribution of spring-run outmigration to be characterized. This performance measure assumes that the Delta Entry rotary screw traps (RSTs) constitute "Delta Entry" monitoring. This is scored as a binary variable: either Delta Entry RST data are collected (yes) or are not collected (no) for a given alternative

3.9 Maximize the Ability to Compare the Juvenile Production Estimate Forecast to the Measured Abundance at Delta Entry

This objective accounts for whether a model alternative requires monitoring of spring-run entering the Delta sufficient to make an abundance estimate of spring-run that can be compared to the forecast at the end of each migration season. This performance measure assumes that the Delta Entry RST constitute "Delta Entry" monitoring. This is scored as a binary variable: either the Delta Entry RST data are collected (yes) or the data are not collected (no) for a given alternative.

4 How Objectives Informed the Model

In 2021, the JPE Core Team began an SDM process with a decision sketch and development of JPE model objectives. Through this process, the initial decision statement was revised to the current decision statement (refer to Section 2.1) based on feedback from executive management. The revised decision statement specifically acknowledges that the JPE Core Team would not know what form the life cycle model or minimization measure would take and that the primary interest was on developing a forecast or estimate of juvenile spring-run outmigrant abundance at the point of Delta Entry.

To reflect the revised decision statement, the JPE Core Team developed a revised set of objectives, although the importance of an accurate and precise model (per the maximize confidence objective, Section 3.1) remained the primary modeling objective for the JPE Core Team. Recognizing that the data available for modeling would be a key determinant in the ability of a model to achieve the objectives, the JPE Core Team directed the Modeling Team to draft an initial set of alternative modeling frameworks that would illuminate how data availability from different monitoring elements could influence the ability to meet modeling objectives and tradeoffs between objectives.

Specifically, the Core Team asked the Modeling Team to build models to assess three conditions of spatially constrained data availability crossed with three conditions of temporally constrained data availability. Three spatial constraints were to model using monitoring data:

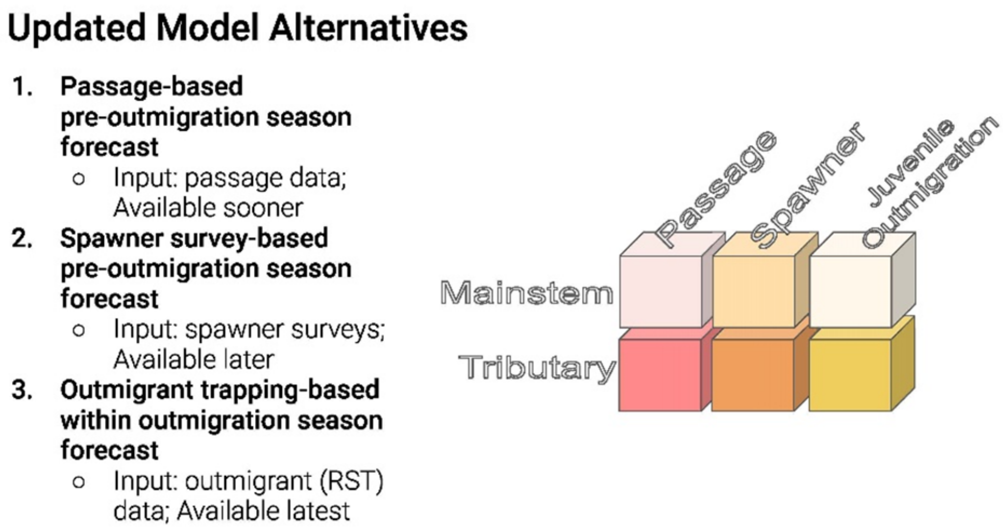
- Only from tributaries
- Only from the two dominant spring-run-producing tributaries (Butte Creek and Feather River)
- Only from mainstem Sacramento RST monitoring coupled with tributary spawner and redd surveys

These spatial constraints determined which RST site data could be used as the response variable for predicting juvenile outmigrant abundance at RST sites. The three temporal data constraints reflected predictor data that would be available at different points in time during annual monitoring, which were:

- Video passage monitoring data, which would theoretically be available earliest
- Adult spawner and redd survey data
- Initial early-season juvenile outmigrant data at RSTs, which could be used as a predictor of subsequent annual outmigrant abundance but would be the last data available for making JPE forecasts each year

From a modeling perspective, the modeling framework for the dominant tributary constraint was considered a subset of the all-tributaries constraint (i.e., it would simply require a subset of models built for the all-tributaries constraint), which meant there were six scenarios of data availability and six alternative modeling approaches to construct (Figure 1).

Figure 1. Initial Set of Six Scenarios of Data-Availability Constraints



In 2024, the Modeling Team completed a preliminary set of alternative modeling frameworks comprised of different configurations of the submodels described in Chapters 4 through 9 of this materials package (refer to Table 2). However, during this period of model development, the Core Team decided to drop alternatives constrained to using adult passage data as the key predictor variable because uncertainty in passage estimates and uncertainty in future environmental conditions affecting pre-spawn mortality and egg-to-fry survival could lead to poorly informed management actions.

The JPE Core Team also combined the original maximize accuracy objective and maximize precision objective into a single new objective (maximize confidence, Section 3.1), because post-season assessments of juvenile production are subject to the same sources of bias as forecasts, and therefore no clear true JPE value is available to evaluate the potential accuracy of modeling approach.

Finally, through an iterative interagency review process spanning 2024 and 2025, the JPE Core Team recognized that the spatial data-availability constraints used to inform initial model development were not informative for selecting a modeling approach. These spatial data were not informative because constraints on spatial data availability were determined by historical monitoring efforts over the previous decades that produced available datasets, and because agencies had agreed during this period to continue funding the current level of monitoring for the near future (refer to Chapter 2 for current monitoring and data availability).

This meant the key remaining tradeoff between alternative modeling approaches was determined by the day of the year when the JPE forecast would be needed for annual management actions and decisions, the in-season data that would be available by that annual JPE date, and the influence these data availability would have on confidence in the JPE forecast.

Since the Core Team could not know the form the minimization measure or life cycle model would take, and therefore could not know when the JPE would need to be available, the team agreed to move forward with refinement of a flexible modeling framework presented by the Modeling Team (the JPE Integrated Model; refer to Chapter 3). The JPE Integrated Model and its submodels described in this package for peer review provide a flexible and adaptable modeling approach that uses all data available for any given forecast date that may eventually support an annual management action or decision.

5 Materials Packet Overview

The materials packet for review consists of nine chapters including this overview chapter (Table 2). Aside from this overview chapter and Chapter 2, chapters in the materials packet consist of JPE Integrated Model and submodel descriptions that are part of the overarching Integrated Model framework.

Chapter 2 of these materials provides links to Environmental Data Initiative (EDI) repositories, and documentation of dataset assembly and data processing and model code documentation on GitHub, which is not necessary reading for this review panel. Note: this documentation is ongoing and not complete.

Table 2. Materials Packet Chapters Summary

Chapter	Title	Summary
1	*Introduction and Packet Overview for Spring-Run Chinook Salmon Juvenile Production Estimate Modeling Approach*	Overview of JPE Science Program, scope and guidance for model development, and contents of the materials packet chapters.
2	*Overview of Monitoring Data Availability and Processing for the Spring-Run Juvenile Production Estimate Models*	Overview of available monitoring data for modeling and the data management system to support future model updates.
3	*Spring-run Chinook Salmon Juvenile Production Model*	Describes srJPE, the model that integrates all submodels to produce a forecast of spring-run juvenile abundance expected to enter the Delta and Delta entry timing. Also includes suggested processes for updating models at different time scales.
4	*Estimating the Abundance of Outmigrant Juvenile Chinook Salmon from Rotary Screw Traps on Tributaries of the Sacramento River, California*	Describes the submodel that estimates efficiency and abundance of juvenile outmigrants passing tributary RST locations.
5	*Estimating the Abundance of Outmigrant Juvenile Chinook Salmon from Rotary Screw Traps at Knights Landing and Tisdale Sites on the Sacramento River, California*	Describes the submodel that estimates efficiency and abundance of juvenile outmigrants passing mainstem Sacramento River RST locations.
6	*Probabilistic Length-at-Date Model and Application to Spring-run Chinook Salmon on Tributaries of the Sacramento River, California*	Describes the submodel that uses historical genetics data to predict the run-type of juvenile salmon sampled at RST locations.
7	*Forecasting the Abundance of Juvenile Spring-Run Chinook Salmon Outmigrants from Sacramento River Tributaries and the Mainstem Using Spawner-Outmigrant Stock-Recruit Models*	Describes submodels that predict outmigrant abundance passing RST locations on spring-run producing tributaries of the Sacramento River based on adult survey data.

Chapter	Title	Summary
8	*Forecasting Outmigration Timing and Abundance of Juvenile Spring-run Chinook Salmon at Rotary Screw Traps in Sacramento River Tributaries and the Mainstem to Support a Juvenile Production Estimate*	Describes submodels that predict outmigrant abundance passing RST on the mainstem Sacramento River and its spring-run producing tributaries based on within-season catch prior to the prediction date. This model also predicts the timing of outmigration past these sampling locations.
9	*Spring-run Juvenile Survival and Travel Time Model*	Describes submodel that predicts the survival rate and migration duration of outmigrant juveniles between RST sampling locations and the location where the Sacramento River enters the Delta.

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Appendices

A. Science Program Team Members

Guidance Team

Active: Brett Harvey and Pete Nelson (California Department of Water Resources [DWR]); Paige Uttley and Sheena Holley (California Department of Fish and Wildlife [CDFW])

Former: Ted Sommer (DWR); Brooke Jacobs (CDFW)

Core Team

Active: Brett Harvey, Pete Nelson and Jason Kindopp (DWR), Paige Uttley, Sheena Holley, Anna Allison, Ryan Revnak and Tracy Grimes (CDFW); Towns Burgess and Alex Vaisvil (US Bureau of Reclamation [USBR]); Flora Cordoleani and Kyra Fitz (National Oceanic and Atmospheric Administration [NOAA]); Natasha Wingerter (US Fish and Wildlife Service [USFWS]); Corey Phillis (Metropolitan Water District [Metropolitan])

Former: Ted Sommer (DWR); Brooke Jacobs, Mike Harris, Matt Johnson, Ryon Kurth, Jessica Nichols, Morgan Kilgour, and Erica Meyers (CDFW); Barbara Byrne (National Oceanic and Atmospheric Administration [NOAA]); Suzanne Munugian and Mike Beakes (USBR); Alison Collins (Metropolitan); Darcy Austin (State Water Contractors)

Stream Teams Leads and Data Stewards

Active: Anna Allison, Nick Bauer, Grant Henley, Ryan Revnak, Drew Huneycutt, Corey Fernandez, Gabriel Loera and David Custer (CDFW); Jason Kindopp, Kassie Henley and Casey Campos (DWR); Natasha Wingerter, Gabriella Moreno, Sam Provins, Teresa Urrutia and Bill Poytress (USFWS)

Former: Rebecca Stark, Claire Bryant, and Jessica Nichols (CDFW); Mike Shraml (USFWS); Jacob Vander Meulen (Yuba Water Agency)

Run ID Team

Active: Melinda Baerwald, Sarah Brown, Sean Canfield, Scott Meyer, Michelle Pepping, Daphne Gille, Aviva Fiske, Bryan Nguyen, Pachia Lee, Jeff Jenkins, and Sarah Stinson (DWR); David Custer, Bryan Barney, Mallory Bedwell, Sheena Holley, Vanessa Costa, Corey Fernandez, Marelle Arndt and Gabriel Loera (CDFW); Lindsey Carson and Connor Webb (USFWS); Noble Hendrix (QEDA Consulting); Stream Team leads also participate on the Run ID team.

Former: Jeff Rodzen (CDFW); Nicole Kwan (DWR)

Data Management Team

Data Management System: Ashley Vizek, Liz Stebbins, Erin Cain, Jordan Hoang, Emanuel Rodriguez and Badhia Katz (FlowWest); Brett Harvey and Pete Nelson (DWR)

Former: Sadie Gill (FlowWest)

Modeling Team

Modelers: Josh Korman (Ecometrics); Flora Cordoleani (NOAA); Noble Hendrix (QEDA Consulting); Liz Stebbins, Erin Cain and Ashley Vizek (FlowWest); Brett Harvey (DWR)

Interagency Model Review Team

Derek Alcott and Arthur Barros (CDFW); Pete Nelson (DWR); Flora Cordoleani and Cyril Michel (NOAA); Natasha Wingerter (USFWS); Alex Vaisvil (USBR); Corey Phillis (Metropolitan)

Note: listed affiliations reference the time of team membership, not current affiliations