BUREAU OF RECLAMATION

Long-Term Operation – Biological Assessment

Appendix I – Old and Middle River Flow Management

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Contents

Tables

Figures

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Appendix I Old and Middle River Flow Management

I.1 Introduction

This appendix analyses the management of exports for Old and Middle River (OMR) reverse flows to reduce entrainment stressors on winter-run and spring-run Chinook salmon, steelhead, and Delta smelt.

Within the area of the Sacramento–San Joaquin Delta (Delta) affected by exports, survival and behavior of fish depend, in part, on actions by many parties, including the United States Department of the Interior, Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR), the State Water Resources Control Board (Water Board), in-Delta diverters, flood projects, and non-project upstream releases. Export operations at the C.W. "Bill" Jones Pumping Plant (Jones Pumping Plant) and Harvey O. Banks Pumping Plant (Banks Pumping Plant are anticipated to entrain fish into the central and south Delta. The Central Valley Project (CVP) operates the Tracy Fish Collection Facility (TFCF) and the State Water Project (SWP) operates the Skinner Delta Fish Protection Facility (collectively "Salvage Facilities") to monitor entrainment and salvage fish before they reach the pumps. The effectiveness of capturing and the survival of fish through salvage (salvage efficiency) can be high for salmonids, but very low or zero for smelt. Net flows in OMRs provide a surrogate for how exports influence hydrodynamics in the Delta. Negative flow rates in OMRs indicate a net direction towards export facilities, and positive flow rates indicate a net direction towards exiting the Delta from the South Delta. The management of exports for OMRs reverse flows, in combination with other environmental variables, can minimize or avoid adverse effects on the migration of fish and reduce or avoid entrainment at the export facilities.

I.2 Initial Alternatives Report

The 2021 Initial Alternatives Report (IAR) developed potential options for the long-term operation of the CVP and SWP to inform alternative formulation by seeking the bounds of potential decisions and a contrast between approaches. Initial alternative options generally considered flow actions, non-flow actions, and the use of real-time information. Management questions, analyses, and findings provided information for further evaluation in the public draft Environmental Impact Statement (EIS) alternatives.

I.2.1 Management Questions

Reclamation's management questions for the formulation of an alternative include:

- Should the onset of OMR management be based on real-time conditions, or does a fixed schedule based on the historical migration timing protect species with limited impacts on water supply?
- How does the magnitude of different OMR restrictions change the relative risk of species entrainment at the export facilities and in the central and/or south Delta?
- How does the duration of temporary OMR restrictions change the entrainment of species within the influence of export facilities?
- Does an offramp of OMR management based on real-time conditions protect species and improve water supply performance, or does a fixed schedule protect species with limited impacts on water supply?
- What is the effect of different levels of near- and far-field entrainment on population viability?

I.2.2 Initial Analyses

Reclamation solicited input for the knowledge base paper, *Old and Middle River Reverse Flow Management–Smelt, Chinook Salmon, and Steelhead Migration and Survival*.

Reclamation completed an exhaustive literature and data review to consider on-ramp and offramp strategies for OMR reverse flow management. It evaluated loss and entrainment processes and mechanisms using various relationships between loss and operational and environmental covariates.

Reclamation conducted Delta Simulation Model II (DSM2) simulations for Initial Alternative 1, Initial Alternative 2, Initial Alternative 3, followed by Particle Tracking Models (PTM) for two types of particle behaviors: larval and adult fish. It also used these DSM2 simulations to model juvenile salmonid survival under a broad range of OMR reverse flow conditions. Model assumptions and results of these initial alternatives are summarized in IAR Attachment I.1, *Delta Particle Tracking Modeling under Varying OMR Conditions*.

I.2.3 Initial Findings

Should the onset of OMR management be based on real-time conditions, or does a fixed schedule based on the historical migration timing protect species with limited impacts on water supply?

- Monitoring data indicate that >5% of winter-run sized Chinook salmon have passed real-time Delta entry or salvage much more frequently than a calendar-based schedule starting January 1st (IAR: Section 4.2, *Historical, Presence-Based, and Model-Based OMR On-Ramp Analysis*) See:

    - At Knights Landing, 5% of fish observed occurred as early as September 16, with 17 of 19 (89%) years showing >5% of passage before January 1
    - In the Sacramento Trawl, >5% of fish observed there occurred as early as October 8, with 22 of 25 (88%) years showing >5% of passage before January 1
    - At Chipps Island 5% of fish observed in monitoring are detected as early as December 6, with 9 of 25 (36%) years showing >5% passage before January 1
    - The triggers for integrated early winter pulse protections (IEWPPs) were observed as early as December 7 in the past 25 years, with 3 of 6 (50%) years when these triggers were exceeded occurring before January 1
    - Onset of OMR management based on >5% salvage occurred as early as December 6 (prior to the 2009 National Marine Fisheries Service (NMFS) Biological Opinion), with 9 of 25 (36%) years showing >5% passage before January 1
- Using a fixed schedule based on the historical migration timing for Delta entry at Knights Landing or Sacramento Trawl rather than one based on real-time conditions may reduce OMR management flexibility prior to January 1 (IAR: Section 4.2)
- A schedule based on >5% presence at Chipps Island or salvage rather than a fixed January 1 onset may increase OMR management impacts on winter-run Chinook salmon entrainment

How does the magnitude of different OMR restrictions change the relative risk of species entrainment at the export facilities and into the central and/or south Delta?

Delta PTM under varying OMR conditions: range of particle fates and particle export fates (IAR Attachment I.1).

- Under most circumstances in December, the overall percentage of particles entrained at the export facilities varies by OMR flow condition specified by a sensitivity analysis.
    - As OMR reverse flow decreases, the percentage of particles entrained at the exports incrementally decreases (IAR Attachment I.1: Figure I.1-2).
    - The percentage of particles that exit the Delta decreases as the OMR reverse flow condition incrementally increases (IAR Attachment I.1: Figure I.1-10).
- Under most circumstances in December, regions close to the export facility (Central Delta) observed varying percentage of particles entrained at the export facilities or passing Chipps Island regardless of OMR flow conditions. This result is different compared to regions further away from the export facilities (Sacramento River) (IAR Attachment I.1: Figure I.1-6).
- Overall, the location of particle injection can provide limits on the entrainment and residence times of particles.

    - As OMR flow decreases, the percentage of particles entrained at the exports or exiting Chipps overlap (IAR Attachment I.1: Section I.2.2, *Results*:49–57).
    - The percentage of particles that are entrained is different than the percent of particles exiting the Delta for regions further away (Sacramento River vs Central Delta) (IAR Attachment I.1: Section I.2.2:49–57).

Delta PTM under varying OMR conditions: conclusions

- No Action Alternative particle entrainment at exports is most similar to the OMR flow condition of -5,000 cubic feet per second (cfs) in December
- The No Action Alternative particle entrainment is between the OMR flow condition of -4,000 cfs and -5,000 cfs in January and February
- The No Action Alternative particle entrainment is similar to the OMR flow condition of -3,000 cfs in March

Zone of Influence

- Gaussian Kernel Density Estimation (KDE) plots used to assess the effect of pumping for varying OMR flow conditions and proportional overlap maps illustrate the estimated effects of pumping under a range of OMR flow conditions (IAR Attachment I.2, *Zone of Influence Analysis*: Sections I.2.4.2, *Velocity KDE Plots*, and I.2.4.3, *Zone of Influence Maps*).
- Multiple factors affect the proportional overlap and velocity differential values (e.g., proximity to the pumps, orientation of flow relative to the pumps, influence of riverine flow, preexisting flow and/or velocity patterns).
- Increasingly negative OMR flows increase the spatial extent of the zone of influence 0.75 contour in a nested manner for the months of March through June. This pattern does not hold in earlier months (January and February) (IAR Attachment I.2: Section I.2.4.4, *Contour Maps*).
- Biological implications of varying OMR flow conditions are not reflected in results because the water velocity threshold that alters fish movements is unknown.

Does the duration of temporary OMR restrictions change the entrainment of species within the influence of export facilities?

- Based on the expanded salvage autocorrelation analysis and other studies (Tillotson et al. 2022), it seems likely that a change in fish observations in salvage due to changes in OMR would not be instantaneous and may take up to seven days.
- It is unclear how long temporary OMR restrictions based on species loss triggers need to be for re-routing fish out of the central and south Delta. We have no evidence that the duration of a temporary OMR restriction changes farfield effects. To reduce routing of fish species into the interior Delta requires a proactive approach.

Does an offramp of OMR management based on real-time conditions protect species and improve water supply performance, or does a fixed schedule protect species with limited impacts on water supply?

- Real-time fish monitoring data indicates 100% of winter-run Chinook salmon and steelhead have exited the Delta earlier than June 30 (calendar-based offramp)
- Temperature-based offramp criteria at Mossdale and Prisoner's Point are met by June 30th in some years, but not all.
    - In the years since 2012, the Mossdale temperature-based offramp criteria was not met in 2017 and was not reached in 2019 until July 15th
    - The Prisoner's Point temperature record began in 2020. In the years 2020–2022, the Prisoner's Point temperature-based offramp criteria was met in each year
- Using a fixed schedule based on the historical migration timing for Delta exit at Chipps Island rather than a June 30 offramp may increase OMR management flexibility with similar fish protection
- A schedule-based temperature criteria rather than a real-time fishery monitoring offramp may increase water supply impacts without benefiting steelhead entrainment protection

What is the effect of different levels of near- and far-field entrainment on population viability?

There is not a tool to evaluate this.

I.2.4 Subsequent Considerations

Subsequent review of the PTM in the IAR for larval smelt found that the injection point of particles was more significant than OMR at -5,000 cfs or more positive on the amount of entrainment at the facilities. Particles entering the Delta from the San Joaquin region arrive at the facility in similar large quantities regardless of OMR level. Particles entering the Delta from the Sacramento Region arrive at the facilities in similar quantities regardless of OMR level. For central Delta injection points, variation across OMR -3,000 cfs to -7,000 cfs results in a change of ~10% in fish arriving at the facilities or exiting the Delta.

The Salmon Scoping Team Report found juvenile salmon and steelhead survival in different regions of the Delta is variable. The Salmonid Scoping Team found a relationship between inflow and survival, but did not find a relationship between OMR and through-Delta survival. At OMR levels less than -5,000 cfs where the changes in hydrodynamics as a result of exports are small relative to tides and inflow, the effects on survival are small. Inflow, tides, and export hydrodynamics vary by region within the Delta. The influence of exports on fish survival depends on the hydraulic footprint of the facilities. Results for the Delta Passage Model (DPM) for Sacramento origin fish also found survival to be linked to inflows, not OMR between -3,000 cfs and -7,000 cfs. Additional analyses were done to review outmigration period protection for steelhead by evaluating weekly and seasonal loss, presence of steelhead, and environmental variables influencing steelhead presence and loss.

I.3 Public Draft Environmental Impact Statement Scenarios

Under the National Environmental Policy Act (NEPA), Reclamation compares action alternatives to a "no action" alternative. Under the Endangered Species Act, Reclamation's discretionary actions over an environmental baseline determine the effects on listed species. No single environmental baseline to evaluate the effects under the Endangered Species Act (ESA) or impacts under NEPA. ESA requires a comparison to the environmental baseline which is informed by ROR and Alternative 1. NEPA requires a comparison to NA.

I.3.1 Exploratory 1

No OMR restrictions, no exports, Delta Cross Channel (DCC) gate closed.

I.3.2 Exploratory 3

No OMR restrictions, no Delta exports, DCC gate closed.

I.3.3 No Action

OMR restrictions per 2020 Record of Decision (ROD) and 2020 Incidental Take Permit (ITP), Delta exports, DCC gate operations per 2020 ROD, Water Right Decision 1641(D-1641) outflow.

I.3.4 Alternative 1 – Water Quality Control Plans

D-1641 export/inflow (E/I) ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. No OMR restriction, no additional DCC gate fish protection closures.

I.3.5 Alternative 2 – Multi-Agency Consensus

D-1641 E/I ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. OMR restriction based on environmental surrogate and fish salvage criteria, additional DCC gate fish protection closures.

I.3.5.1 Winter-run Early Season Loss Threshold

Genetically confirmed winter-run Chinook salmon have been observed in the Delta during the months of November and December (Brandes et al. 2021), though November and December observations of genetically verified winter-run Chinook salmon at the salvage facilities have not occurred in over a decade (Kevin Reece, pers. comm.). In the 2020 ITP for the SWP, a static daily loss threshold for winter-run sized Chinook salmon and larger fish was set for the months of November and December to reduce entrainment of these early migrating fish towards the pumping facilities (ITP 2020). These daily thresholds were loss of 6 juvenile winter-run sized Chinook salmon or larger at the salvage facilities for November, and 26 juvenile winter-run sized Chinook salmon or larger for December. These November and December thresholds were determined based on data of winter-run sized or larger juvenile Chinook salmon, and as such, were not necessarily based on true genetic winter-run Chinook salmon (Harvey et al. 2014). To calculate these thresholds in the ITP, historical salvage daily data with zero Chinook salmon observations were also removed and the November loss threshold was based on data from a single date in November of 2010 in which two juvenile Chinook Salmon were observed at salvage. There was no consideration as to how these thresholds link back to the winter-run

Chinook salmon population number and the portion of these larger Chinook salmon that are true genetic winter-run. To develop limits that are more responsive to interannual changes in juvenile production or population, November-December winter-run Chinook salmon data from upstream of the Delta can potentially be used. Furthermore, as with the annual loss threshold, new genetic markers can be used to produce genetic information of salvaged Chinook salmon in near real-time during the months of November and December.

Research has been conducted looking into loss of Chinook salmon and other populations of native estuarine species to diversions in the San Francisco Bay-Delta and to the State and Federal fish facilities. Jahn and Kier (2020) concluded estimates of loss to diversions and the fish facilities may not reliable and recommend both an improvement to currently existing loss estimation equations and studies (e.g., predation near the fish facilities) to increase accuracy and precision of estimates. Alternative 2 was developed using the California Department of Fish and Wildlife (CDFW) (2020) calculation method for loss.

I.3.5.2 Winter-run Total Annual Loss Threshold

The purpose of the total annual loss threshold is to avoid loss exceeding a level that may impact the number of juveniles existing the Delta and potentially affecting the number of adults returning to spawn. This threshold is a fraction of the juvenile production estimate (JPE) calculated by NMFS annually. It is uncertain whether the level of facility loss may affect through Delta survival, but it is hypothesized that higher mortality associated with interior routing of juvenile salmonid, predation, and poor habitat that influence rearing, sheltering, and outmigrating juvenile salmonids are reflected by the magnitude of facility loss. Thus, it is hypothesized total annual loss is an indicator of overall entrainment effects on juvenile outmigration survival.

I.3.5.3 Steelhead Loss Threshold

The purpose of steelhead loss threshold is to avoid loss exceeding a level that may impact the number of juveniles existing the Delta and potentially affecting the number of adults returning to spawn. The is uncertainty about what level of loss may be appropriate to protect abundance, life history diversity, and distribution.

A hypothesis that weekly distributed loss threshold may reduce impacting juvenile steelhead outmigration was examined. Weekly proportions of Delta entrance at Sacramento and San Joaquin monitoring locations and exit at Chipps Island were examined (Table I-1).

Table I-1. Historical Cumulative Percent Presence of Genetically Verified Winter-run Chinook Salmon Entering the Delta, Exiting the Delta, Remaining to Pass Chipps Island, and Present in the Delta, Water Years 2017–2021

Week	Historical Cumulative Percent Presence			
	Entering the Delta [a]	Exiting the Delta [b]	Remaining to Pass Chipps [c]	Present in Delta [d]
1/1–1/7	1%	1%	99%	0%
1/8–1/14	2%	1%	99%	1%

Week	Historical Cumulative Percent Presence			
	Entering the Delta [a]	Exiting the Delta [b]	Remaining to Pass Chipps [c]	Present in Delta [d]
1/15–1/21	3%	3%	97%	1%
1/22–1/28	4%	3%	97%	2%
1/29–2/4	7%	4%	96%	3%
2/5–2/11	10%	8%	92%	2%
2/12–2/18	14%	11%	89%	3%
2/19–2/25	17%	13%	87%	4%
2/26–3/4	19%	18%	82%	2%
3/5–3/11	20%	21%	79%	-1%
3/12–3/18	23%	23%	77%	0%
3/19–3/25	24%	28%	72%	-4%
3/26–4/1	25%	35%	65%	-10%
4/2–4/8	31%	40%	60%	-9%
4/9–4/15	37%	47%	53%	-10%
4/16–4/22	48%	52%	48%	-3%
4/23–4/29	57%	59%	41%	-3%
4/30–5/6	65%	66%	34%	0%
5/7–5/13	81%	79%	21%	2%
5/14–5/20	88%	86%	14%	2%
5/21–5/27	94%	93%	7%	1%
5/28–6/4	98%	96%	4%	3%
6/5–6/11	99%	97%	3%	1%
6/12–6/18	100%	100%	0%	0%

[a] Sherwood Harbor Trawl and Mossdale Trawl; based on Mossdale and Sacramento counts.
[b] Chipps Island Trawl.
[c] 100% minus exiting the Delta.
[d] Entering the Delta minus exiting the Delta.
Data are grouped by week starting on January 1st, with steelhead presence in monitoring occurring before January 1st included in the first week of the cumulative presence.

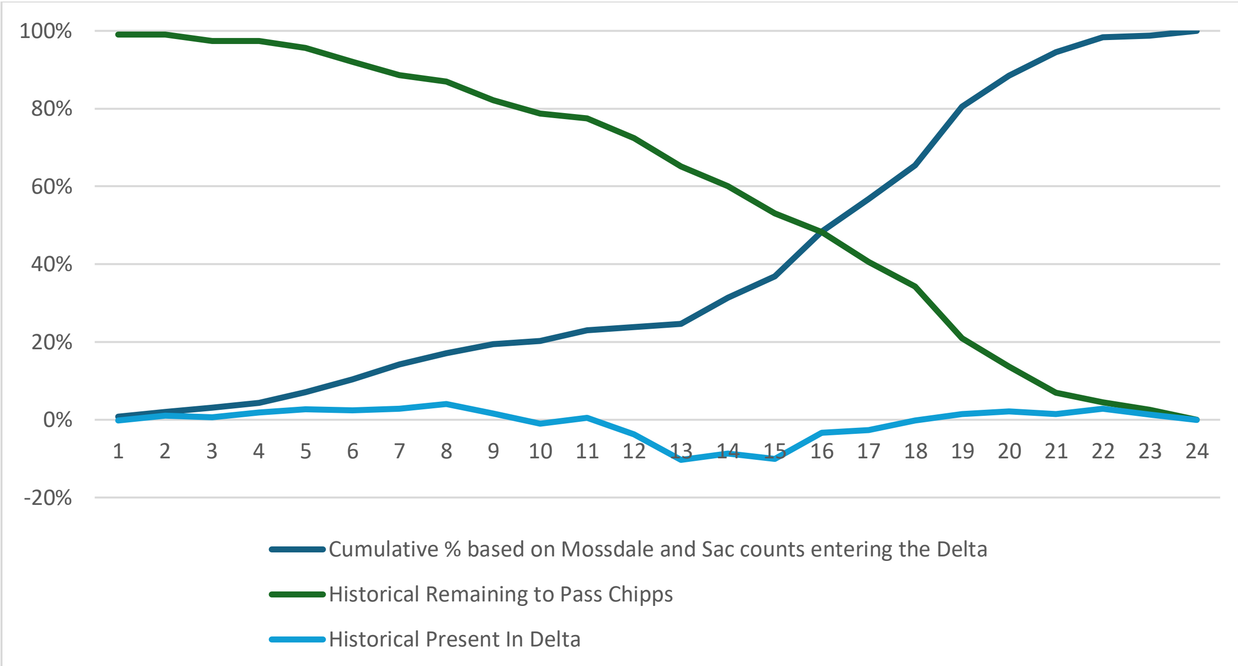


Figure I-1. Cumulative Percent of Juvenile Steelhead Entering, Exiting, and Present in the Delta

When the proportion of the outmigration period that is present in the Delta is considered (Figure I-1), periods where more fish have left the Delta than are reported remaining the Delta results in a negative presence in the Delta. This suggest that juvenile steelhead salvage and loss management cannot be based on our monitoring of the outmigration period in the Delta. Since steelhead outmigration does not seem to be reflected. To evaluate other potential drivers of steelhead salvage, weekly loss across 2009–2019 was looked at (Figure I-2).

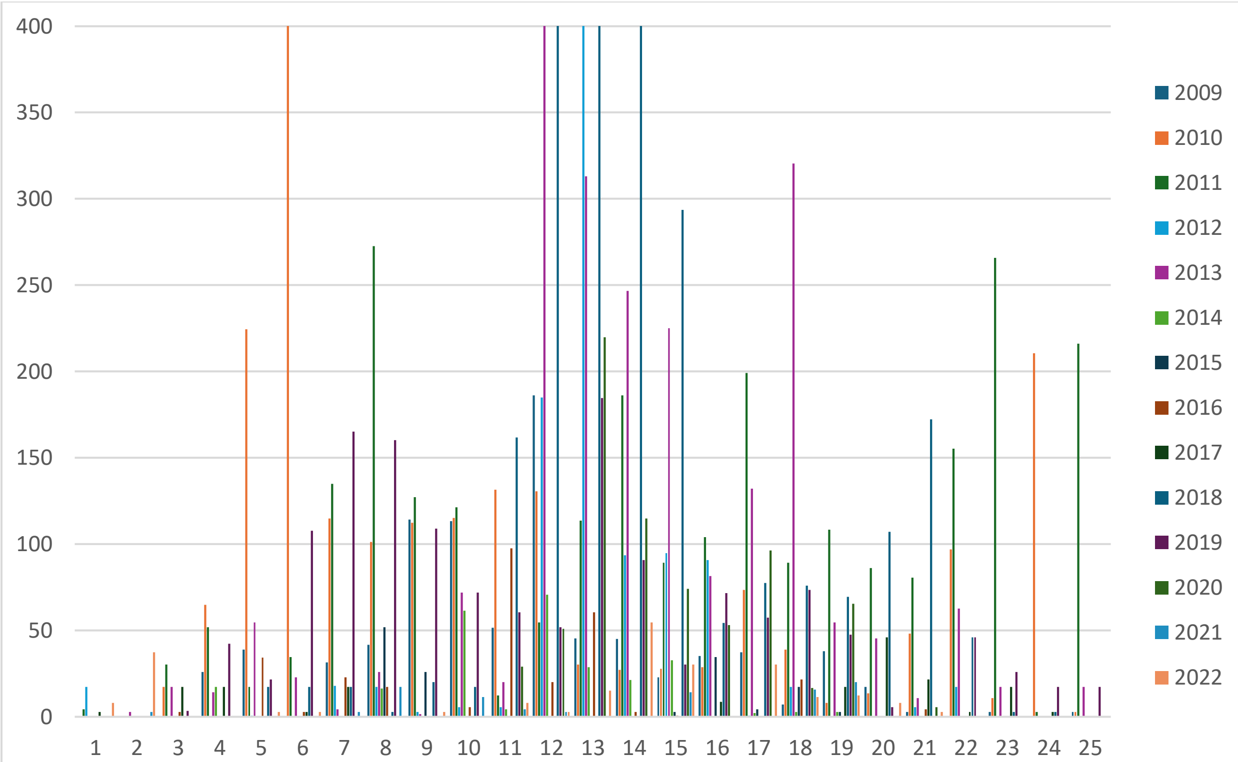
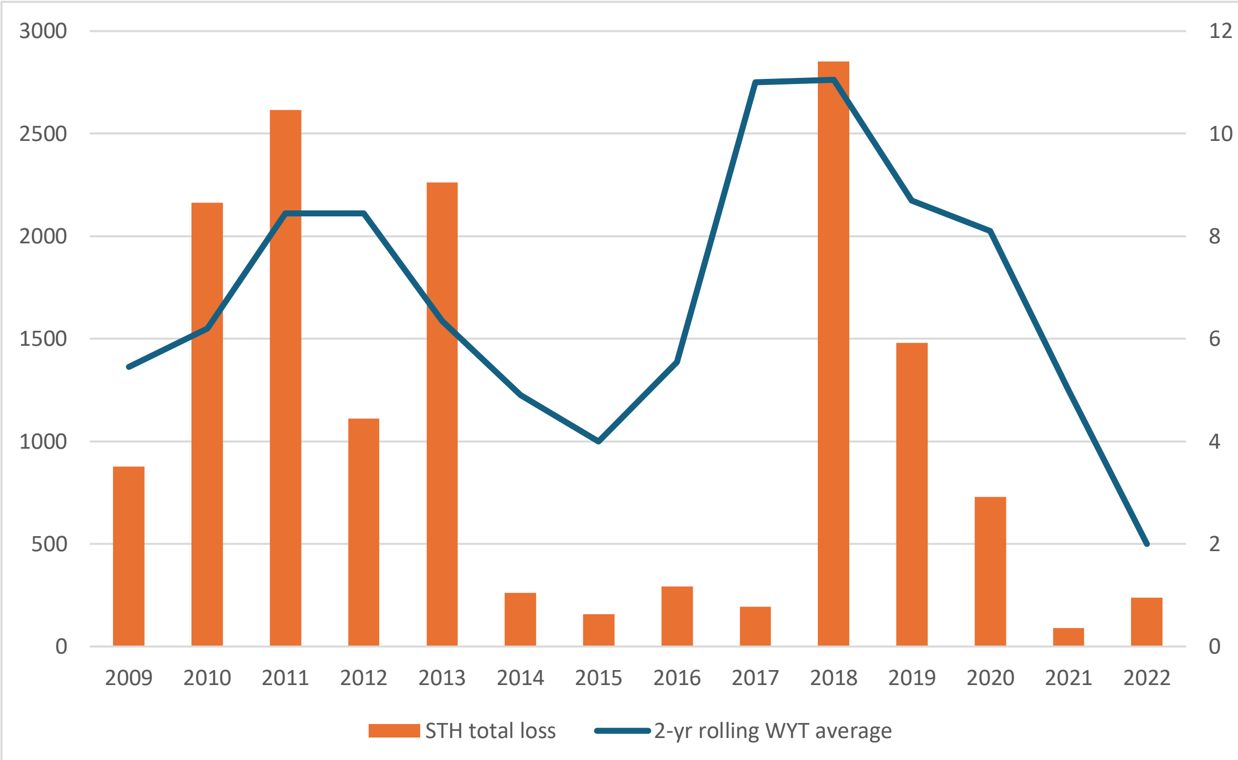


Figure I-2. Steelhead Loss by Julian Week

Although steelhead salvage is greatest and less variable in the middle of their outmigration period, there can be moderate-to-high loss early and late in the period.

There is not a clear pattern between presence in the Delta and loss. This could be due to sampling and/or outmigration behavior and long migration and rearing times in Delta, but we have limited information about these hypotheses. We assume steelhead are not sampled as well in trawls as Chinook salmon, but all trawls likely catch steelhead equally. We know that steelhead do spend longer migrating through the Delta than juvenile Chinook, but do not know how this would result in affecting salvage patterns. To consider other factors influencing the loss of steelhead, we looked at if annual loss may be related to other correlations. We hypothesized current and previous water year indices may be indicative of steelhead abundance. For instance, higher water year indices may support better temperatures and flows for rearing survival and winter releases for outmigration survival. Loss generally followed the 2-year water year type (WYT) rolling average, which suggests that estimated loss may be related to conditions when fish are rearing and outmigrating and not the week during the outmigration window (Figure I-3). If this is the case, weekly steelhead loss minimization may provide similar protection to distributed loss thresholds during the outmigration window of steelhead.



STH = steelhead; WYT = water year type.

Figure I-3. Average of Current and Previous Sacramento River Index and Annual Steelhead Loss

I.3.6 Alternative 3 – Modified Natural Flow Hydrograph

D-1641 E/I ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. OMR restriction based on environmental surrogate and fish salvage criteria, Additional DCC gate fish protection closures. Spring Delta outflow following D-1641 and consistent with modeling for storage requirements.

I.3.7 Alternative 4 – Reservoir Flexibility

D-1641 E/I ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. OMR restriction based on environmental surrogate and fish salvage criteria, Additional DCC gate fish protection closures.

I.4 Performance Metrics

Performance metrics describe criteria that can be measured, estimated, or calculated relevant to informing trade-offs for alternative management actions. Additional performance metrics were considered in the IAR; however, only the performance metrics below were included to evaluate the effects of Delta operations. Performance metrics include measures or estimates related to water supply, NEPA Resource Areas, and fish. These performance metrics are associated with methods that are available, accessible, peer-reviewed, repeatable, and transparent which are further described in Section I.5, *Methods Selection*.

I.4.1 Fish Performance Metrics

- **Salmonids: Winter-run and Spring-run Chinook Salmon, Steelhead**
  - Routing probability into DCC, Georgiana Slough, Sutter/Steamboat Slough, Sacramento and San Joaquin Rivers
  - Survival probability to Chipps Island
  - Estimated seasonal loss
  - Predicted seasonal salvage
  - Estimated first entrainment date (useful for on-ramping to OMR)
  - Zone of entrainment
- **Delta Smelt**
  - Estimated Larval Entrainment Risk
  - Population Growth Rate
  - Zone of entrainment
- **Longfin Smelt**
  - Estimated Larval Entrainment Risk
  - Zone of entrainment

I.4.2 Water Supply

Water supply performance metrics include:

- South of Delta agricultural deliveries (average and critical/dry years)
- San Joaquin River Exchange and Settlement Contracts and Central Valley Project Improvement Act (CVPIA) Refuge deliveries
- Frequency of when OMR is controlling exports

I.4.3 National Environmental Policy Act Resource Areas

Considerations under the NEPA will include changes in multiple resource areas. Key resources are anticipated to include surface water supply, water quality, groundwater resources, power, aquatic resources, terrestrial biological resources, regional economics, land use and agricultural resources, recreation, cultural resources, socioeconomics, environmental justice, and climate change.

I.5 Methods Selection

Reclamation solicited input from agencies and interested parties for the knowledge base paper *Old and Middle River Reverse Flow Management–Smelt, Chinook Salmon, and Steelhead Migration and Survival*. Knowledge base papers compile potential datasets, literature, and models for analyzing potential effects from the operation of the CVP and SWP on species, water supply, and power generation. From the knowledge base papers, Reclamation and DWR organized the best available information for evaluating the impacts of OMR management as described below:

I.5.1 Literature

I.5.1.1 History of Old and Middle River and Outflow Effects by Regulatory Regime

1950s–Early 1970s: Onset of Central Valley Project Operations

The Jones Pumping Plant was constructed from 1947 to 1951. The TFCF was constructed shortly there-after. The facility was completed in 1956 and operations began in 1957. During this era, regulatory mandates required changes to TFCF operations including the 1957 Memorandum of Agreement, Water Right Decisions 990 (D-990) and 1275 (D-1275). During the 1960s, exports primarily served as delivery for agriculture during the summer months.

- **1957 Memorandum of Agreement:** Reclamation and the U.S. Fish and Wildlife Service (USFWS) entered an agreement in 1957, before TFCF came online, which lasted two years. During these two years, the agreement's intent was to evaluate TFCF operations and provide monthly progress reports including biological phases of the program.
- **D-990:** D-990 was adopted in February of 1961. During the early 1960's, this Water Right Decision did not provide guidance on export rates. Protections were in place for operations of Shasta and Keswick Dam (D-990:42) but no fish-related flow requirements at the Delta pumping facilities.
- **D-1275:** D-1275 was adopted in May of 1967. This Water Right Decision did not provide criteria for protections for listed species at the Delta pumping facilities.

1978: Water Right Decision D-1485

Unlike the 1960s, during the 1970s exports began to occur year-round and were increasing in volume. Water Right Decision 1485 (D-1485) was the first Water Right Decision to consider monthly Delta outflow, pumping, and protections for fish and wildlife at and near the Delta pumping facilities. D-1485 was adopted in 1978 to establish water quality standards, including flows to be maintained for the protection of fish and wildlife, imposed as a condition to all of the CVP and SWP permits. The two documents adopted by the Water Board (a water quality control plan and a Water Right Decision) represent a unified effort by the Water Board to develop and implement under its full authority a single comprehensive set of water quality standards to protect beneficial uses of Delta water supplies (D-1485:6).

1990s and Early 2000s: Central Valley Project Improvement Act, D-1641, CALFED

By the early 1990s, agreements were in place allowing the CDFW to monitor TFCF salvage operations providing further monitoring of fish. During this era, requirements were set to address standards for fish and wildlife protection with written intent to restore the Bay-Delta ecosystem and improve water management. Among these requirements was consideration of the export rate restriction standard (E/I ratio). CVPIA passed mandating changes in CVP management specifically for "protection, restoration, and enhancement of fish and wildlife" (Section [b] [4] of CVPIA). There was organization of Federal and State agencies through CALFED. D-1641 outlined a long-term plan, incorporating seasonal and water-year specific criteria, to limit pumping to protect juvenile Chinook salmonids.

- **Central Valley Project Improvement Act:** In 1992, Congress included fish and wildlife actions through the CVPIA. Physical improvements to facilities (e.g., fish recovery and protections) and management practices were among the included mitigations. After implementation of D-1641 (discussed below), the Department of Interior Decision on Implementation of Section 3406(b)(2) of the CVPIA increased export curtailment and directly reduced exports by the CVP for fishery management.
- **CALFED:** CALFED was organized in 1994, a partnership between Federal and State agencies with management and regulatory responsibilities in the Delta. The lead CALFED agencies released a Final Programmatic EIS/Environmental Impact Report and the Preferred Alternative on July 21, 2000. This was followed by the signing of the ROD on August 28, 2000, which formally approved a long-term plan to restore the Bay-Delta ecosystem and improve water management.
- **D-1641:** In 2000, through adoption of D-1641, the SWP and CVP were mandated to comply with the objectives in the 1995 Bay-Delta Plan. The requirements in D-1641 address standards for fish and wildlife protection, municipal and industrial water quality, agricultural water quality, and Suisun Marsh salinity. D-1641 also authorizes SWP and CVP to jointly use each other's points of diversion in the southern Delta, with conditional limitations and required response coordination plans. An important component of D-1641 was the E/I ratio, an export rate restriction standard, generally occurring during winter and spring months when hydrologic conditions are such that exports are not supported by reservoir storage releases. Another important component of D-1641 was the month-long San Joaquin River pulse flow requirement and CVP-SWP export limitation with the intent to improve river flows and reduce export potential for outmigrating juvenile salmonids from the San Joaquin River watershed. The Vernalis Adaptive Management Program was developed because of technical and legal disagreements over the spring pulse requirements.
- **Environmental Water Account:** Fishery management agencies (USFWS, National Oceanic and Atmospheric Administration, and California Department of Fish and Game) and action agencies (Reclamation, DWR) shared responsibility in implementing and managing the Environmental Water Account. Management agencies were responsible for recommending biological judgement on the operations of the SWP and CVP to provide benefits to the Bay-Delta system.

Late 2000s and 2010s: 2008/2009 Reasonable and Prudent Alternatives

USFWS and NMFS issued Biological Opinions in 2008 and 2009, respectively, for the operation of TFCF to minimize take of listed species. The fishery management agencies recognized operations of the CVP and SWP were likely to adversely modify critical habitat for listed species and jeopardize some species' continued existence. Protections were put in place including controlling the OMR flows. The NMFS 2009 Biological Opinion included measures implemented specific to entrainment of salmonids and green sturgeon, and management actions for listed fish protections.

- **2009 Biological Opinion:** The 2009 NMFS Biological Opinion suggested reasonable and prudent alternatives to enable the project to move forward in compliance with the ESA. There were six actions to be taken in the Delta Division (p. 630), two of which were directly related to the history of OMR: *Action IV.2* and *IV.3*. This suite of actions incorporated studies and a refined understanding of the relationships between inflows, exports, and native fish distribution and behavior. OMR management was "dialed in" and measures were put in place specific to entrainment risk.
    - *Action IV.2* reads "Control the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento River into the southern or central Delta." Within Action IV.2 Delta Flow Management there were a suite of three actions directed related to informing OMR and entrainment: *Action IV.2.1* San Joaquin River Inflow to Export Ratio (SJR I:E, p. 641), *Action IV.2.2* Six-Year Acoustic Tag Experiment (p. 645), and *Action IV.2.3* Old and Middle River Flow Management (p. 648). The suite of actions within Action IV.2 were developed to provide Delta flow management through the lens of protecting listed native fish.
    - *Action IV.2.1* San Joaquin River Inflow to Export Ratio was developed to reduce vulnerability of emigrating Central Valley (CV) steelhead within the lower San Joaquin River. This sub-action increased the inflow to export ratio to include greater net downstream flows to enhance likelihood of survival to Chipps Island. The underlying rationale for Action IV.2.1 came from coded-wire tagged (CWT) Chinook smolt survival estimates from the Vernalis Adaptive Management Program experiments to spring flows to provide benefit salmonids (Chinook and steelhead).
    - *Action IV.2.2* Six-Year Acoustic Tag Experiment was developed to quantify proportional causes of mortality to tagged steelhead smolts outmigrating from the San Joaquin basin (flows, exports, project- and non-project-related effects). The implementation of this 6-year study yielded results that were used in the development of the 2020 ROD and 2020 ITP. The study was designed to allow exports to vary in relation to inflows from the San Joaquin River to test varying flow to export ratios.

- *Action IV.2.3* Old and Middle River Flow Management was developed to reduce vulnerability of listed fish within the lower Sacramento and San Joaquin rivers to entrainment into the Delta fish collection facilities. Combined exports were managed to provide for a flow in OMR of -5,000 cfs, tidally filtered over 14-days between January 1 and June 15. A 5-day running average was set to be no more than 25% more negative than the targeted requirement flow for the 14-day average (National Marine Fisheries Service 2009:648). PTM simulations and results from acoustic tagging studies were used to craft protections for fish.

- **2008 Biological Opinion:** The USFWS 2008 Biological Opinion included measures implemented specific to entrainment of Delta smelt, and management actions for listed fish protections.

  - *Action 1*: Adult Migration and Entrainment (First Flush) is a fixed duration action that was developed to protect pre-spawning adult Delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period. The action occurs during two time-periods (December 1 to December 20 and after December 20) and calls for limiting exports so that the average daily OMR flow[6] is no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25 percent).

Present Day: 2019 Reasonable and Prudent Measures, 2020 Record of Decision and 2020 Incidental Take Permit

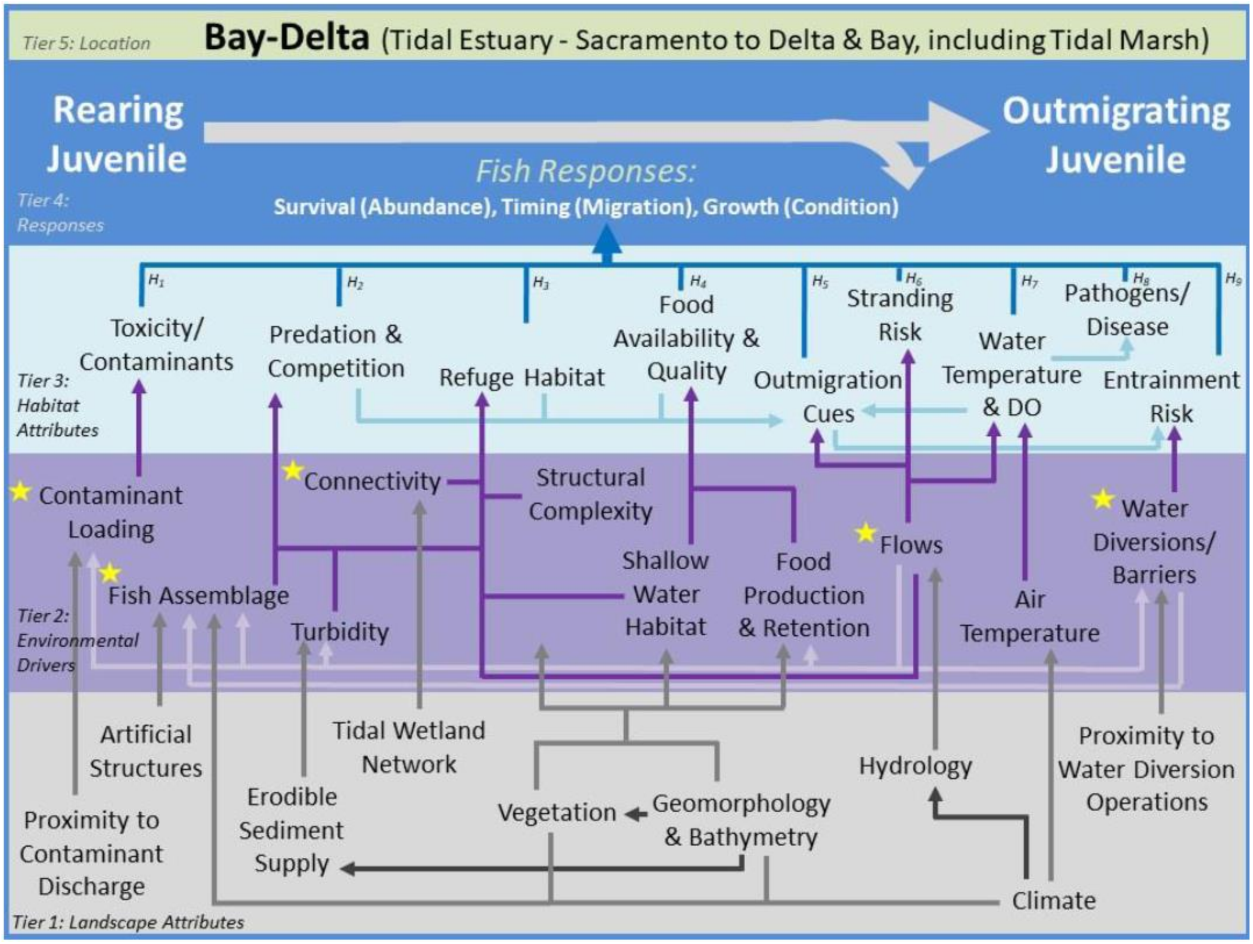
Currently, continued measures are in place to provide protections for listed fish and to minimize the amount or extent of incidental take including OMR management. Reclamation's 2020 Proposed Action via the 2020 ROD and DWR's 2020 ITP both include "OMR Management" sections with subsections to on-ramp and off-ramp along with real-time limits (e.g., 2020 Proposed Action Single-Year Loss thresholds 4.10.5.1.2 Additional Real-Time OMR Restrictions and Performance Objectives; 2020 ITP 3.5 Salmonid Cumulative Entrainment Loss Thresholds).

- **2019 Biological Opinion:** The 2019 NMFS Biological Opinion suggests reasonable and prudent measures (RPMs) to minimize the impact of the amount or extent of incidental take. The 2019 Biological Opinion calls for one RPM in the Bay-Delta Division directly related to the history of OMR (p. 817), RPM 5. *RPM 5* reads "Reclamation and DWR shall minimize the impact of the amount or extent of incidental take of listed species during operations of the Bay-Delta Division". In conjunction with RPM 5, the 2019 Biological Opinion has Section 8.6.9, *Old and Middle River Flow Management*, which calls for seasonal operations that "maximizes exports while minimizing entrainment of fish and protecting critical habitat" (p. 476).

- Data from the Six Year Acoustic Tag Experiment (National Marine Fisheries Service 2009 Biological Opinion) refined understanding of the relationship of flows and entrainment. Studies on migration through the Delta providing data on how Delta inflow affects survival to define relationship of Freeport flow and survival but also routing on migratory success. The DPM was used to integrate operational effects to understand the influence of survival based on operating scenarios. The Winter-run Chinook Salmon Lifecycle Model (WR-LCM) was used to estimate survival of emigrating winter-run to Chipps that have reared in different Sac River habitats. The Survival, Travel time, and Routing Simulation (STARS) model estimated the relationship between Sacramento inflows on reach-specific parameters such as travel time, survival, and routing.
- **2020 Record of Decision/Proposed Action and 2020 Incidental Intake Permit:** *4.10.5.10 OMR Management* (2020 Proposed Action:4-66) and *3.1 OMR Management* (2020 ITP:22), in combination with other environmental variables, was implemented to minimize or avoid the entrainment of fish in the Delta salvage facilities. Operations attempted to maximize exports by incorporating real-time monitoring of environmental and fish parameters into decisions to management of OMR. Actions in OMR Management include "First Flush" and "Salmonids Presence" to guide the onset of the OMR Management season, real-time restrictions, and performance objects during the OMR Management season (e.g., single year loss thresholds for salmonids, turbidity bridge avoidance for smelt), Storm-related OMR flexibility, and criteria for off ramping the OMR Management season (e.g., by date, fish presence, or environmental conditions).

I.5.1.2 Winter-run and Spring-run Chinook Salmon

Studies have shown that juvenile outmigrants from the Sacramento River experience higher survival when riverine inflows are higher (Kjelson et al 1982; Buchanan et al. 2021, 2017). Also, studies have shown that juvenile outmigrants from the Sacramento River experience lower survival when they route through the central and south Delta instead of remaining in the mainstem Sacramento River, which is hypothesized to be linked to CVP and SWP diversion rates (Brandes and McLain 2001, Newman and Brandes 2010). A negative correlation between water exports and survival probabilities have been demonstrated, although the mechanism is not well documented (Newman and Brandes 2010). The reversed tidal flows in the central and south Delta due to the pumping facilities is hypothesized to slow outmigration for juvenile Chinook salmon towards the ocean, which may reduce survival due to the unfavorable Delta habitat conditions (high densities of predators, lower density of food, and suboptimal water quality). Another hypothesis is that juvenile Chinook salmon may experience a diminished ability to navigate out of the south Delta due to confusing navigational cues from altered hydrology and water quality gradients, the highly altered channel network configuration, and impairments to sensory systems from contaminants (Windell et al. 2017).

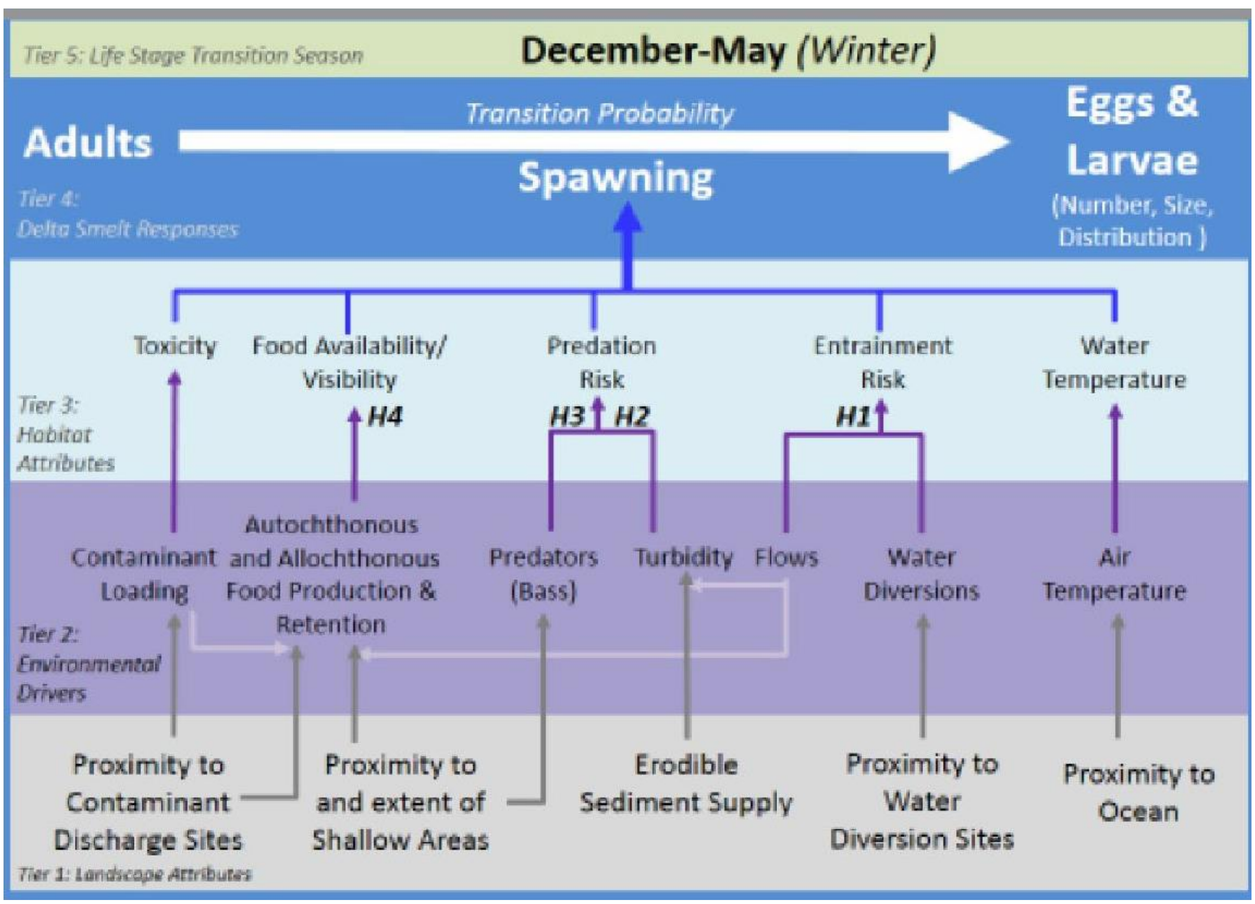


Source: Windell et al. 2017.

Figure I-4. Conceptual Model of Winter-run Chinook Salmon in the Bay-Delta

I.5.1.3 Delta Smelt

The operation of the CVP and SWP pumping plants can potentially entrain Delta smelt in all post-hatch life stages. Upon hatching, Delta smelt begin a pelagic larval life stage and are distributed primarily by water current direction due to minimal swimming ability. Flows due to the operations of the CVP and SWP may entrain these early life stages into lower quality habitats in the South Delta or as loss at the facilities. Delta smelt become more proficient at swimming at approximately 20 millimeters (mm) (Wang 2007) and are assumed to seek out suitable habitat with turbid water (>12 Formazin Nephelometric Units [FNU]), suitable water temperatures (< 25 degrees Celsius [°C]), and low salinity (< 6 practical salinity units). The subadult Delta smelt rear until the fall when inflows and turbidity from seasonal rains initiate a migration to the low salinity zone (<0.2 parts per thousand) where they stage until moving upstream into freshwater to spawn. The increases in inflows and turbidity that initiate migration may increase the likelihood of entraining adults if they migrate into the central and south Delta toward the CVP and SWP pumping plants. After the initial migration, Delta smelt are hypothesized to remain in areas of high turbidity, and CVP and SWP operations are adjusted to minimize turbidity in the south Delta. Delta smelt adults typically do not live long after spawning and two-year-old adults are rare.

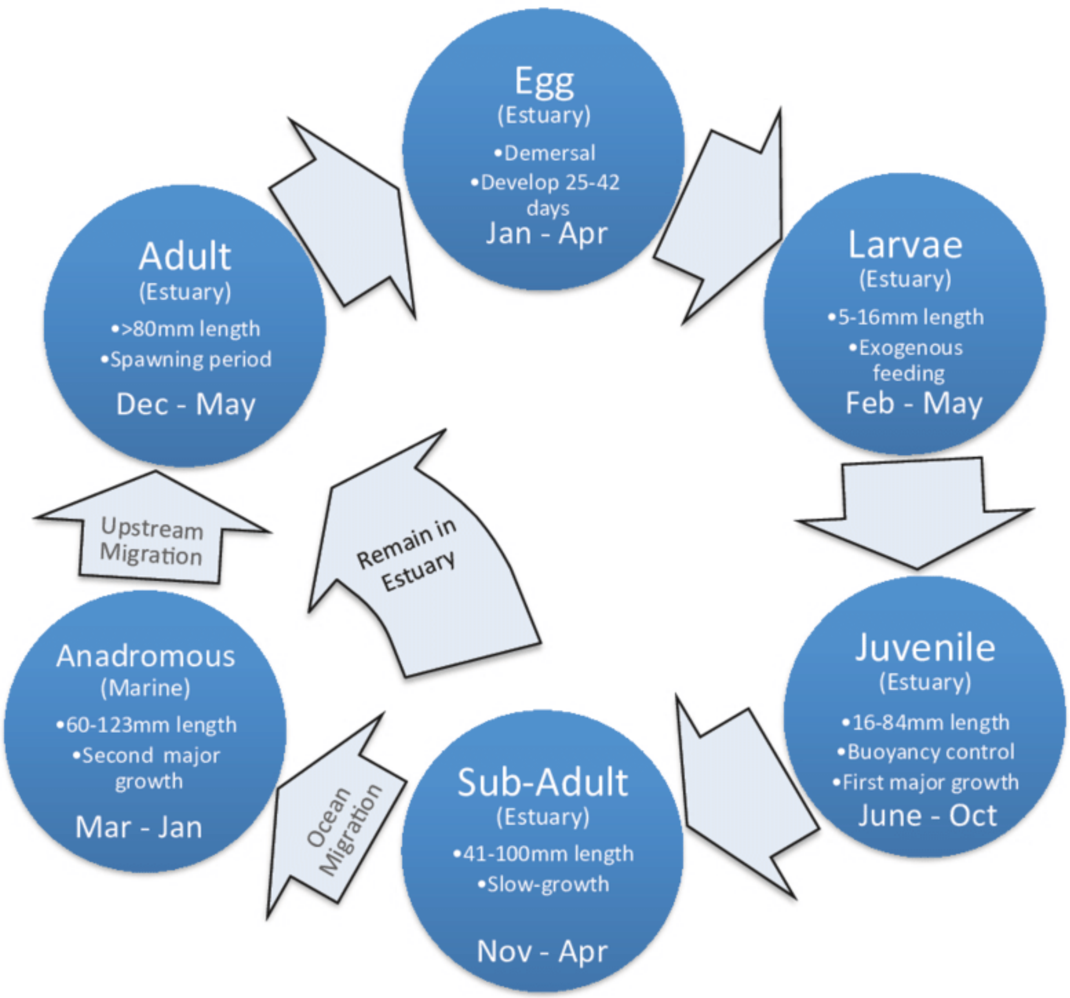


Source: Baxter et al. 2015.

Figure I-5. Conceptual Model of Delta Smelt in the Delta

I.5.1.4 Longfin Smelt

The operation of the CVP and SWP pumping plants can potentially entrain longfin smelt in post-hatch life stages. The Delta pumps can directly entrain longfin smelt into the facilities, resulting in salvage, or influence flows in OMR, which can route longfin smelt to sub-optimal habitats within the Delta. Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017; Lewis et al. 2019), and through PTMs (Gross et al. 2022) to suggest spawning extends farther seaward than previously estimated (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017:11), in tidal wetlands of South San Francisco Bay (Lewis et al. 2020:3), and in San Pablo and lower South Bay during wet years (Grimaldo et al. 2020:10). Longfin smelt migrate from areas of high salinity to either brackish or fresh water for spawning from winter to the spring, and spawn by the spring (Rosenfield 2010:4; Lewis et al. 2019:5). Since longfin smelt can spawn farther seaward than previously thought, entrainment from the SWP and CVP pumps do not appear to have a substantial effect on the population (Gross et al. 2022:189). Kimmerer and Gross (2022:2741) indicate that larval abundance is not related to outflow effects, and that the relationship of longfin smelt with freshwater flow may be more important after March/ early larval development. The spatial distribution of these larvae reflects the year-to-year variation in the geographic location of the low-salinity zone (Dege and Brown 2004:57, Figure 3; Grimaldo et al. 2020:10, Figure 6). Within the low-salinity zone and adjacent waters, larvae have been commonly collected in both littoral (nearshore) and pelagic (offshore) habitats. Upon hatching, the larvae may swim toward the water surface which would facilitate relatively rapid seaward transport (California Department of Fish and Game 2009:8). However, it is not clear that such a behavior would facilitate retention in the low-salinity zone, especially when Delta outflow is high (Kimmerer et al. 2014:910, Figure 5). Modeling by Gross et al. (2022) found early stage longfin smelt larvae would be rapidly transported seaward and suggests larval longfin smelt undergo from a passive to directional behavior transition which may include tidal vertical migration and depth seeking behavior to retain position in the low-salinity zone.



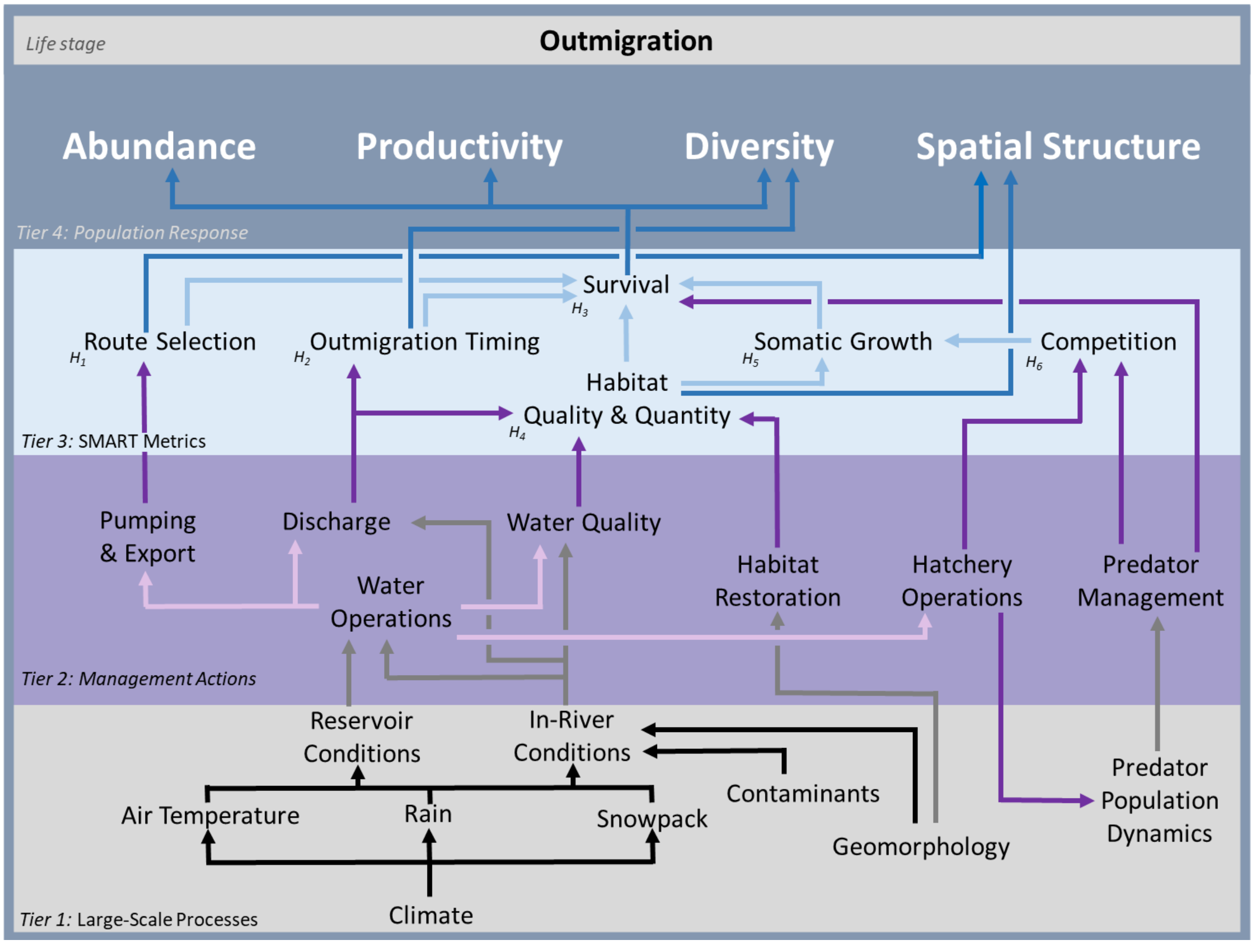
Source: Merz et al. 2013. Adapted from the Delta Regional Ecosystem Restoration Implementation Plan Conceptual Models.

Figure I-6. Lifecycle of Longfin Smelt

I.5.1.5 Steelhead

Steelhead, or *Oncorhynchus mykiss* expressing anadromous life history, pass through the Delta as they outmigrate towards the Pacific Ocean. However, unlike Chinook salmon, the age at which steelhead conduct their outmigration may vary by multiple years. Steelhead are also iteroparous and may pass through the Delta more than twice (juvenile outmigration and return as adults) within their lifetime (Moyle 2002). In the Delta, there are many pathways that outmigrating steelhead may take to reach the Pacific Ocean. Delta inflow, tidal flows, and diversions influence outmigrating steelhead route selection by altering hydrodynamics around channel junctions along the lower San Joaquin River (Anchor QEA 2022). These changes in flows can attract fish entering the Delta out of the San Joaquin River (with low-moderate survival) into the interior Delta (with extremely low survival) and pumping facilities (with low-moderate survival; Buchanan et al. 2021). Thus, changes in the flow regime due to inflow and diversions can have effects on route selection and ultimately survival (Figure I-3).

Additionally, the duration of the migration, and therefore timing of ocean entry, are also likely impacted by water management in the Delta through changes in the flow patterns and route selection of outmigrating juveniles. Assuming *O. mykiss* smolts travel time in the Delta is comparable to juvenile Chinook salmon, we would expect a rapid migration during periods of high flow entering the Delta. Oppositely, under low flow conditions, we would expect slower outmigration for *O. mykiss* smolts.



Source: Beakes et al. 2022.

Figure I-7. Steelhead Smolt Outmigration Conceptual Model Linking Large-Scale Processes to Management Actions, SMART Metrics, and Desired Population Responses (i.e., VSP criteria)

I.5.1.6 Green Sturgeon

Green sturgeon (*Acipenser medirostris*) is an anadromous species, spawning in the upper Sacramento River from January through November. Juveniles outmigrate from the Sacramento River to the Delta through San Francisco Bay starting in late August; however, juveniles are present in the central Delta in all months, except January (Miller et al. 2020). Subadults are in the Delta and San Francisco Bay in all months, with greater presence from April through October (Miller et al. 2020; Colborne et al. 2022).

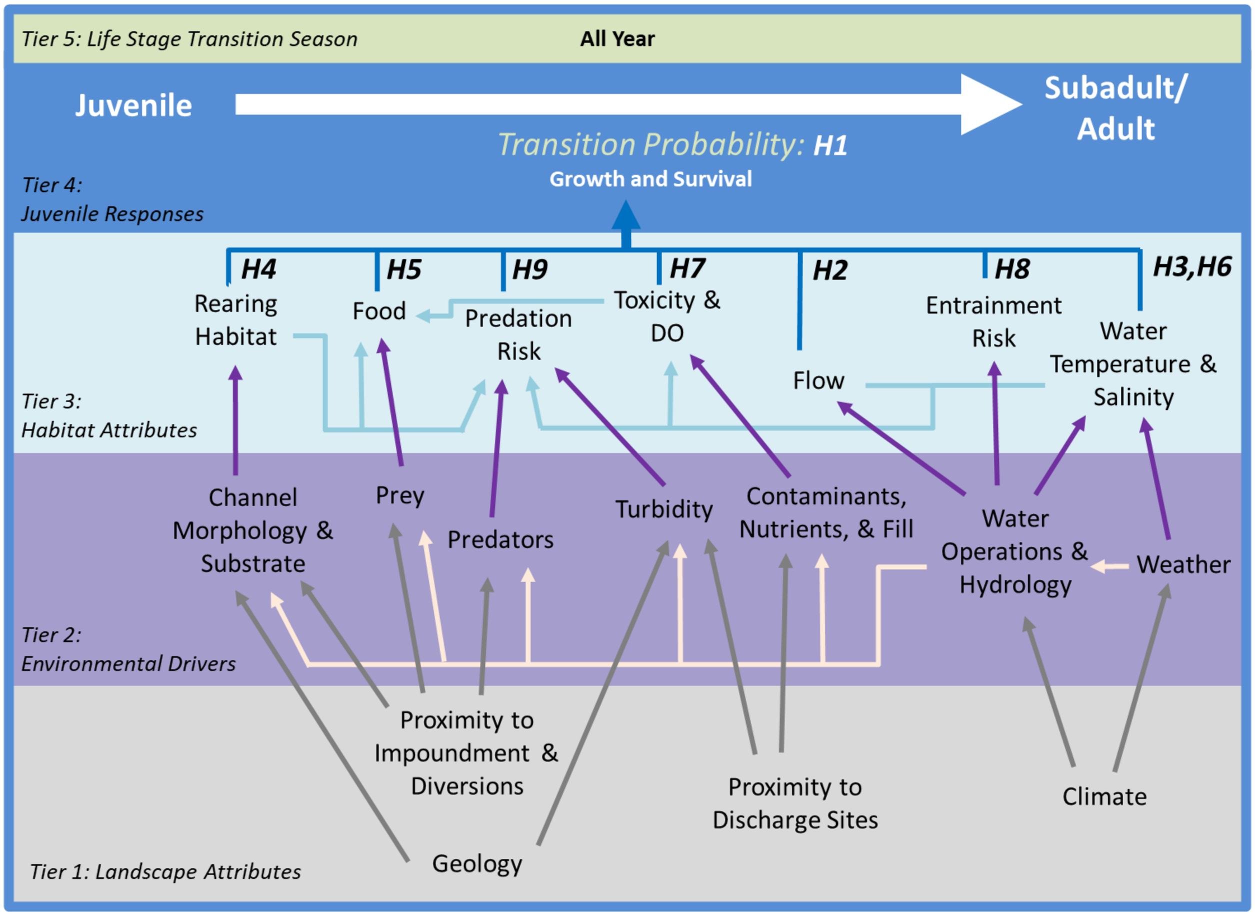


Figure I-8. Conceptual Model of Green Sturgeon Juvenile to Subadult Transition in the Delta

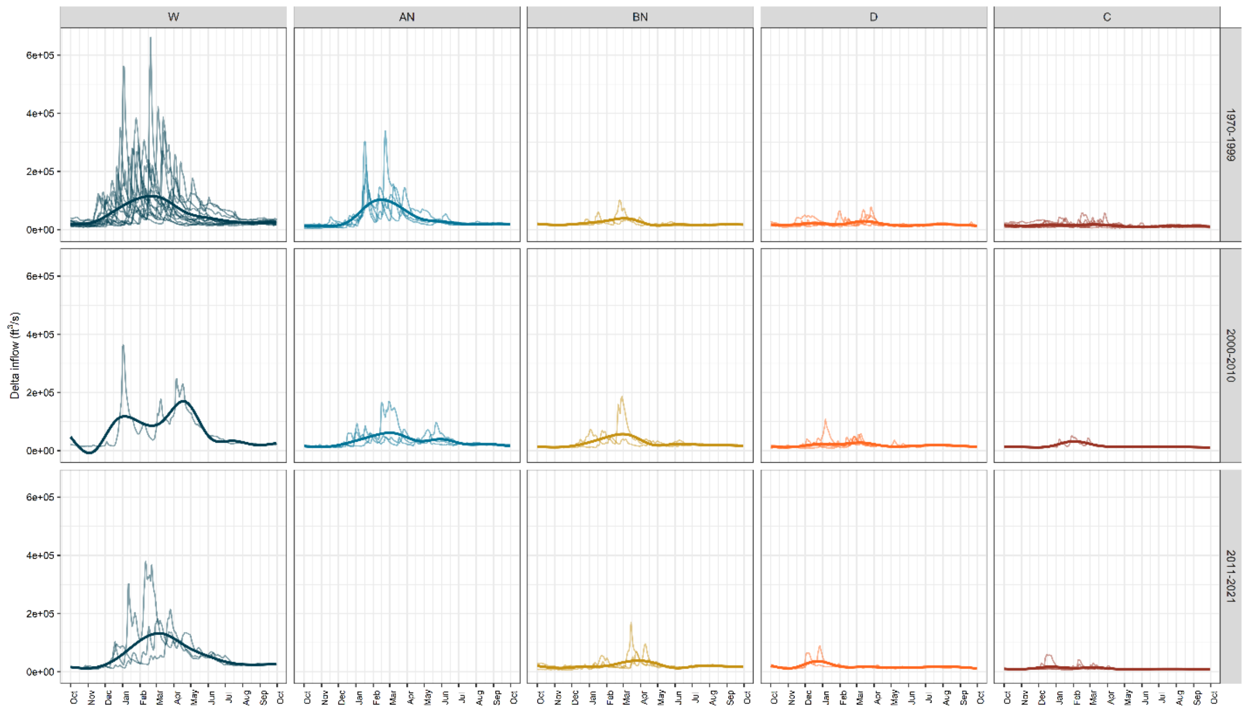
I.5.2 Datasets

Entrainment stressors on federally-listed native fish species are influenced by multiple factors, including hydrology, water quality, facilities operations, and fish population abundance and distribution. Monitoring of hydrodynamics, water quality, and fish populations has been ongoing for over forty years for some datasets and covers the full spatial extent of the Bay-Delta. These data, in the following plots serve as a foundation to illustrate patterns of interannual variability in historical hydrology and exports and trends in water quality. They also provide data and visualizations of trends in federally listed native fish population abundances, distribution, and losses to the CVP and SWP facilities.

Presented in this section are three themes of empirical data: Bay-Delta hydrodynamics, Bay-Delta water quality parameters, and Bay-Delta fish observations for Federally listed native fish species. Hydrodynamics datasets (Section I.5.2.1, *Hydrodynamics*) include five decades of Delta inflow and SWP and CVP exports, 1970–2021. Water quality parameters (Section I.5.2.2, *Water Quality Parameters*) include monitoring data for turbidity, flow, salinity, and temperature at locations throughout the Bay-Delta representing a broad spatial and temporal range. Fish observations (Section I.5.2.3, *Fish Observations in Salvage*) include Delta Smelt abundance indices and estimates from multiple surveys and loss at the SWP and CVP fish facilities for Federally listed salmonids (natural and CWT), Delta smelt, and green sturgeon and state of California listed longfin smelt. Delta migration timing is documented in Appendix C, *Species Spatial and Temporal Domains*.

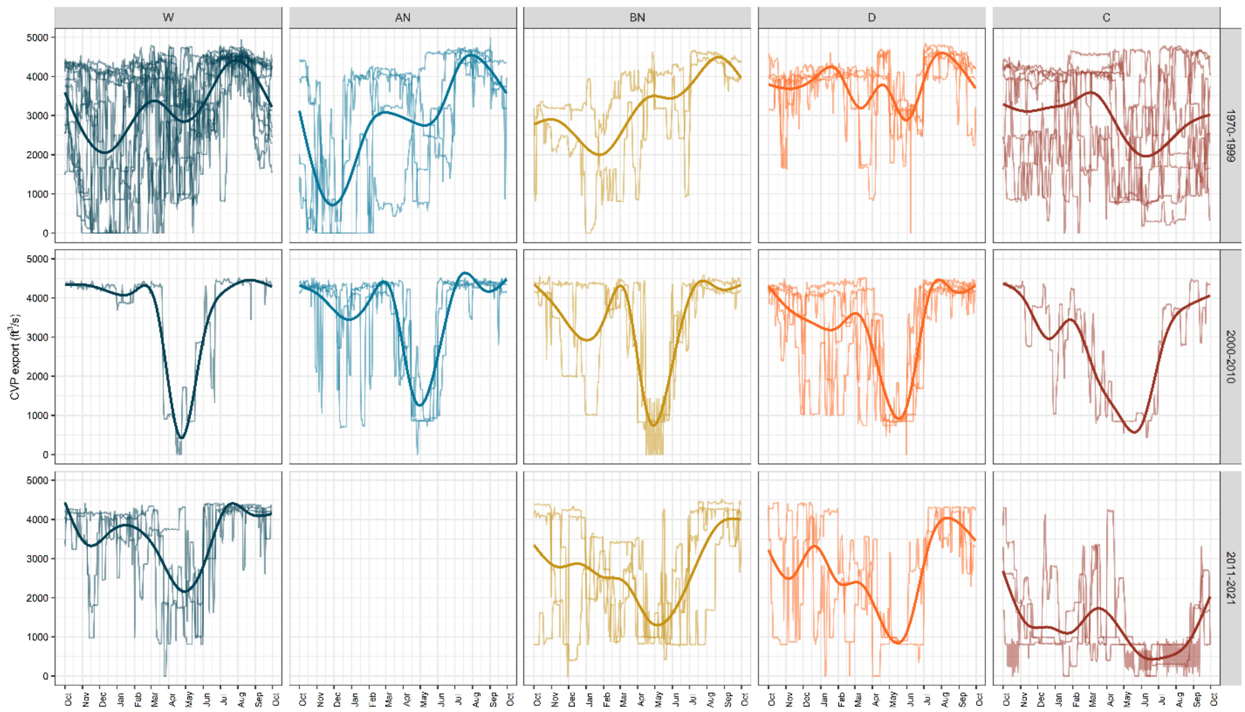
While some datasets include data gaps or shorter sampling efforts than others, overall a large body of historic monitoring data within the Bay-Delta is available. These data sets, in conjunction with modeled data (i.e., CalSim 3, DSM2, USRDOM), serve as inputs for models that can be used to understand and predict the effects of CVP and SWP operations on environmental conditions and fish distributions and loss. Each data set is incorporated into one or multiple lines of evidence used to inform conclusions about both the magnitude and direction of differences among alternatives regarding Delta hydrology and listed native fish populations abundance and loss at state and federal facilities.

I.5.2.1 Hydrodynamics



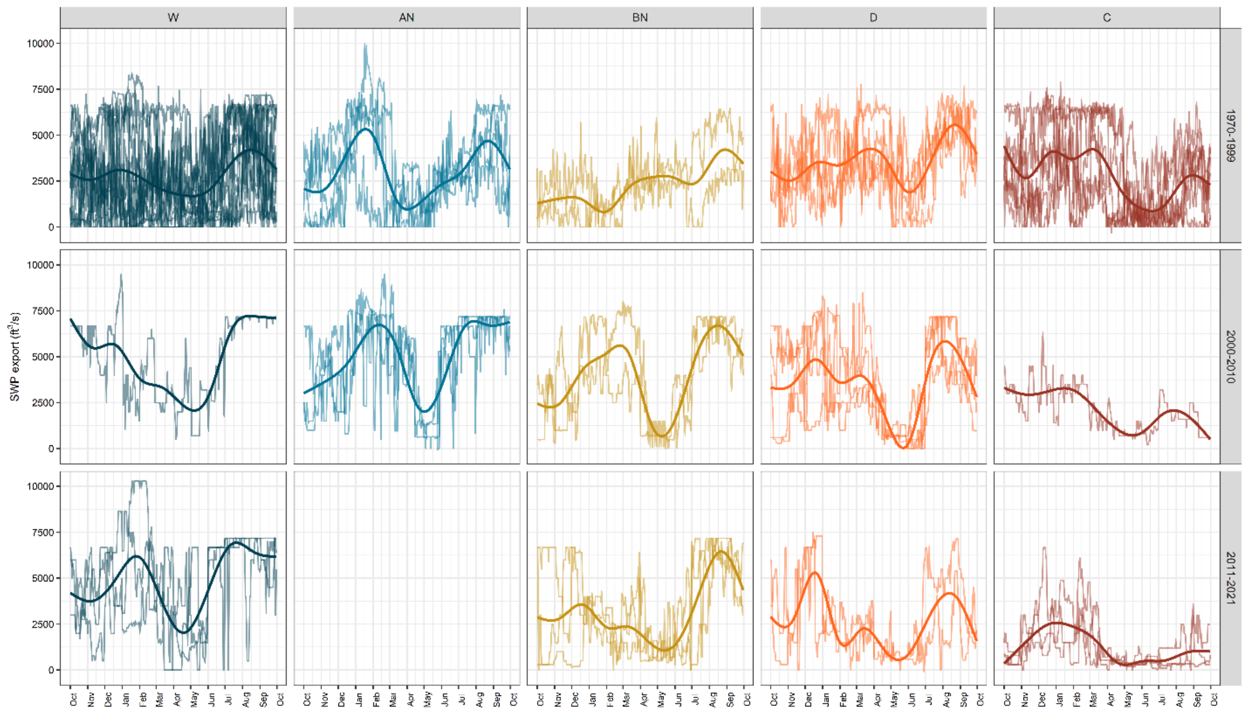
Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic feet per second; W = wet; AN = above normal; BN = below normal = D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era; 2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

Figure I-9. Daily Delta Inflow Data, 1970–2021, by Water Year Type and Time Period



Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic feet per second; W = wet; AN = above normal; BN = below normal = D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era; 2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

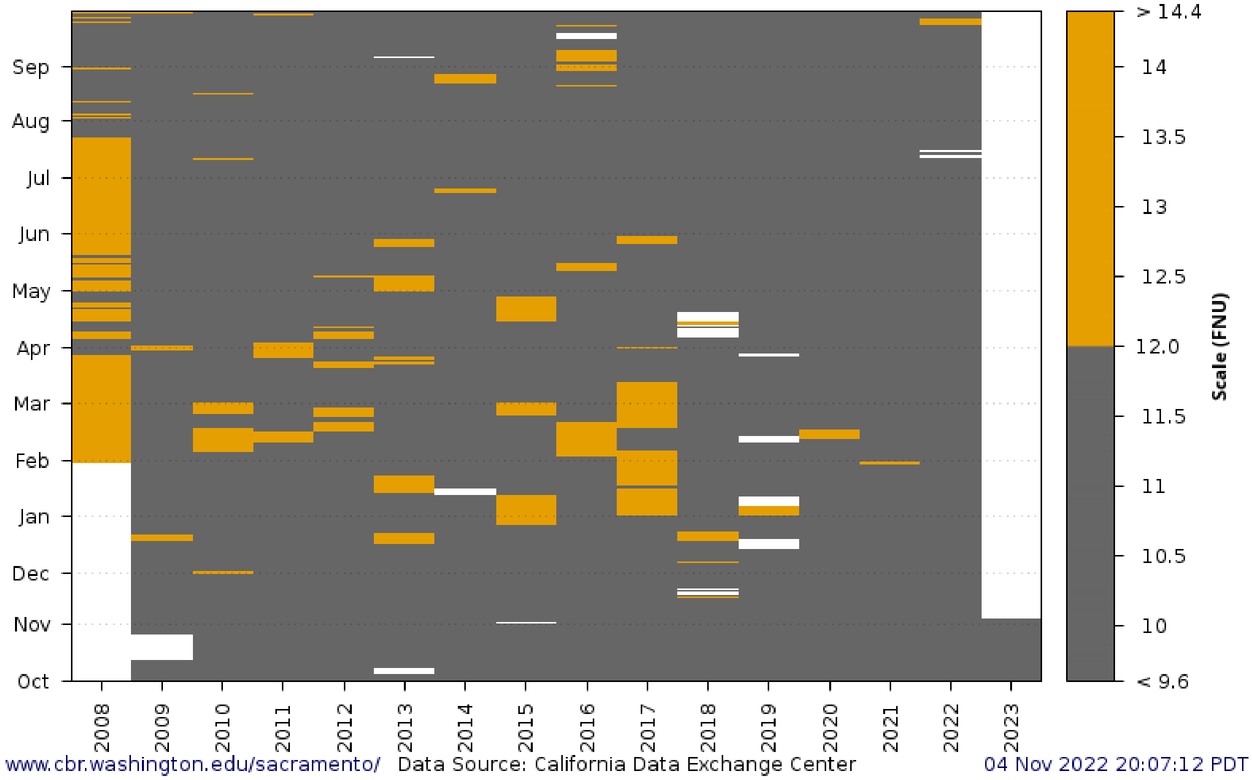
Figure I-10. Central Valley Project Delta Export Data , 1970–2021, by Water Year Type and Time Period



Source: DAYFLOW Model (https://data.cnra.ca.gov/dataset/dayflow).
ft^3/s = cubic feet per second; W = wet; AN = above normal; BN = below normal = D = dry; C = critical;
1970–1999 = pre-D-1641 and CALFED era; 2000–2010 = D-1641 and CALFED era;
2011–2021 = post-2008/2009 Biological Opinions.
Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

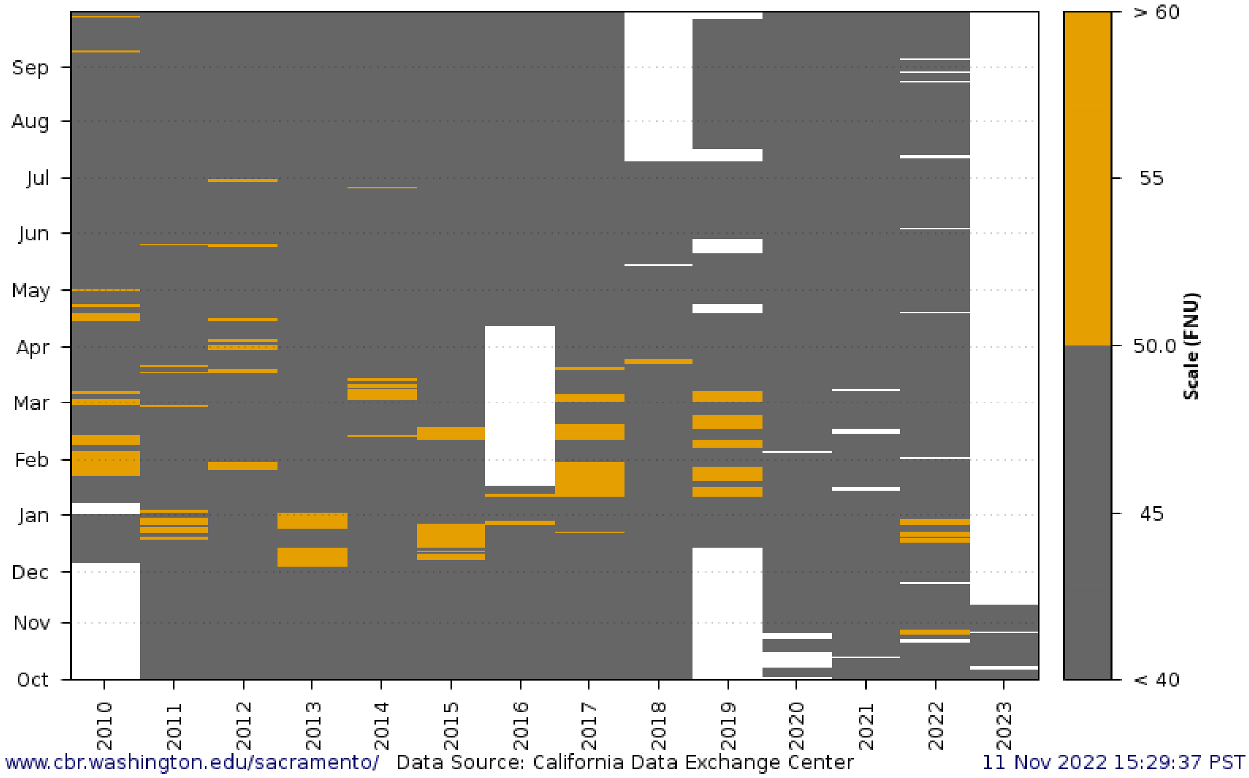
Figure I-11. State Water Project Delta Export Data, 1970–2021, by Water Year Type and Time Period

I.5.2.2 Water Quality Parameters



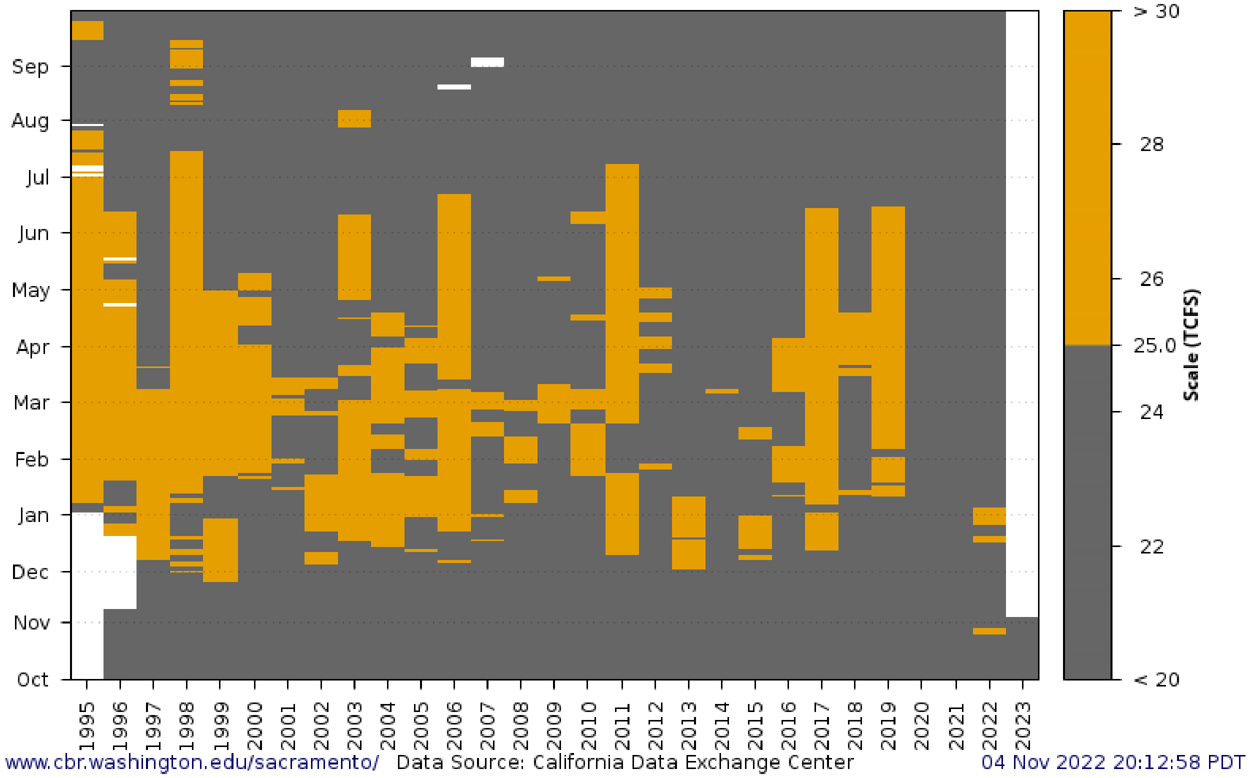
Source: California Data Exchange Center (www.cbr.washington.edu/sacramento). Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).
FNU = Formazin Nephelometric Unit.
Gray shading represents turbidity values below a 12.0 FNU threshold, orange shading represents turbidity values above a 12.0 FNU threshold. Observed range is 0.57 FNU–99.05 FNU.

Figure I-12. Daily Average Turbidity (FNU) Values Observed at Old River at Bacon Island, Water Years 2008–2023



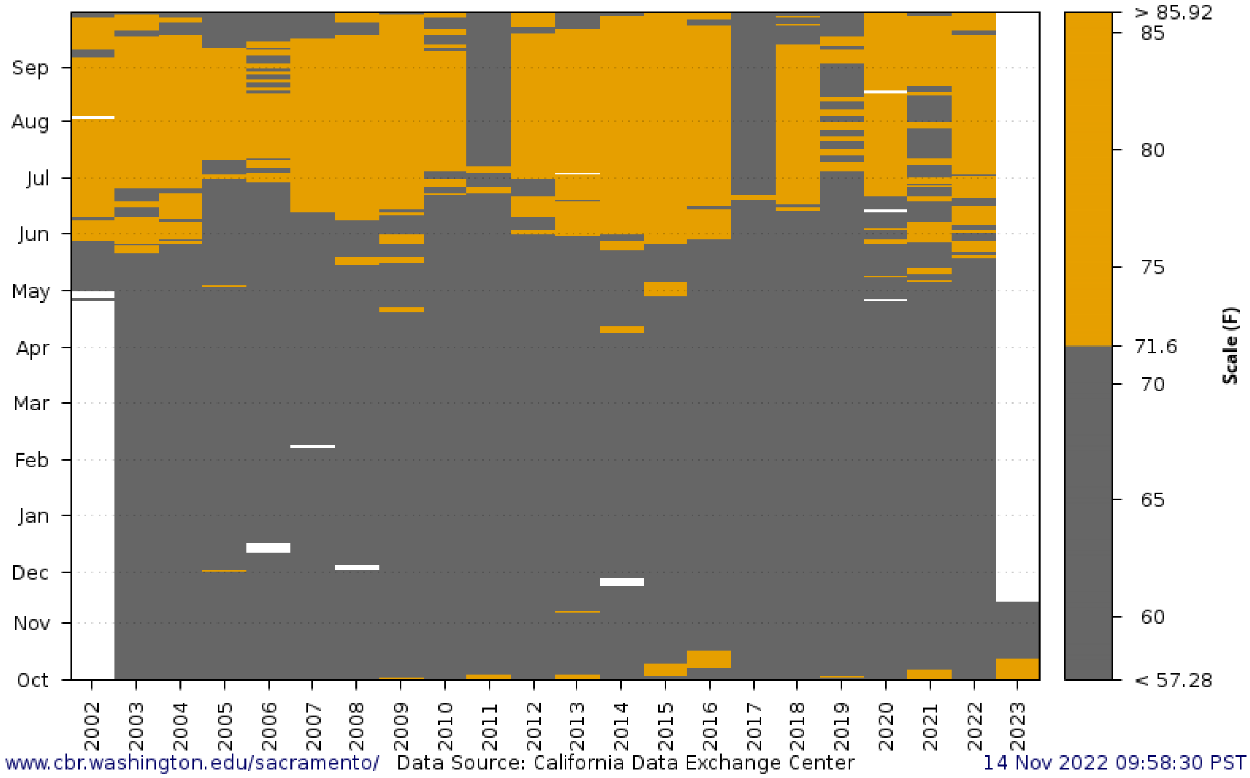
Source: California Data Exchange Center (www.cbr.washington.edu/sacramento). Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).
FNU = Formazin Nephelometric Unit.
Gray shading represents turbidity values below a 12.0 FNU threshold, orange shading represents turbidity values above a 12.0 FNU threshold. Observed range is 0.45 FNU–407.33 FNU.

Figure I-13. Daily Average Turbidity (FNU) Values Observed at Sacramento River at Freeport, Water Years 2010–2023



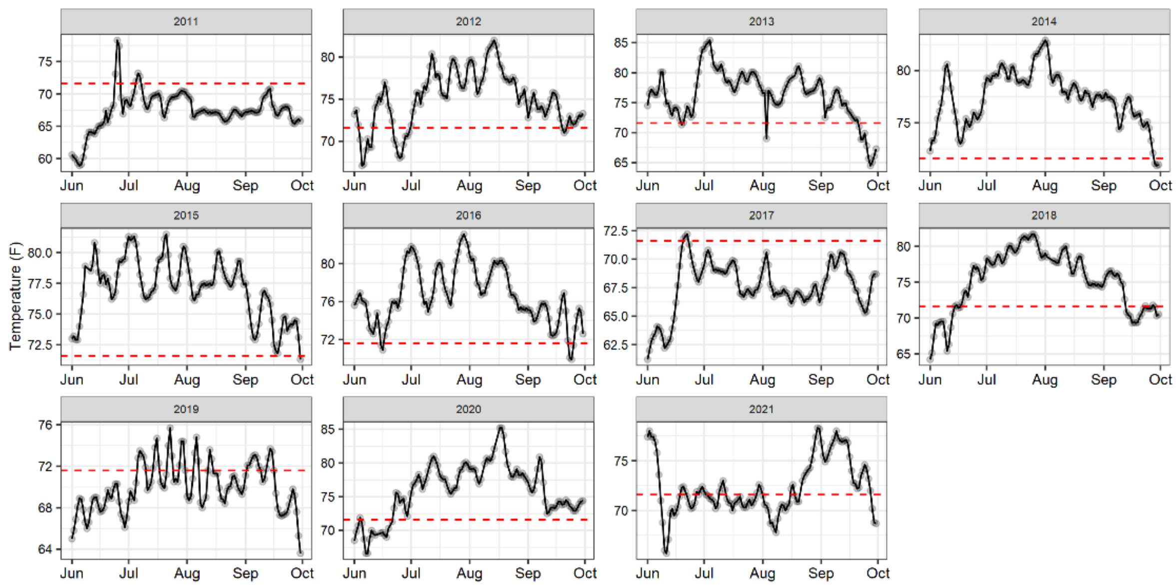
Source: California Data Exchange Center (www.cbr.washington.edu/sacramento). Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).
TCFS = total cubic feet per second.
Gray shading represents flow values below a 25.0 TCFS threshold, orange shading represents flow values above a 25.0 TCFS threshold. Observed range is -12.41 TCFS–113.20 TCFS.

Figure I-14. Daily Average River Discharge Flow (TCFS) Values Observed at Sacramento River at Freeport, Water Years 1995–2023



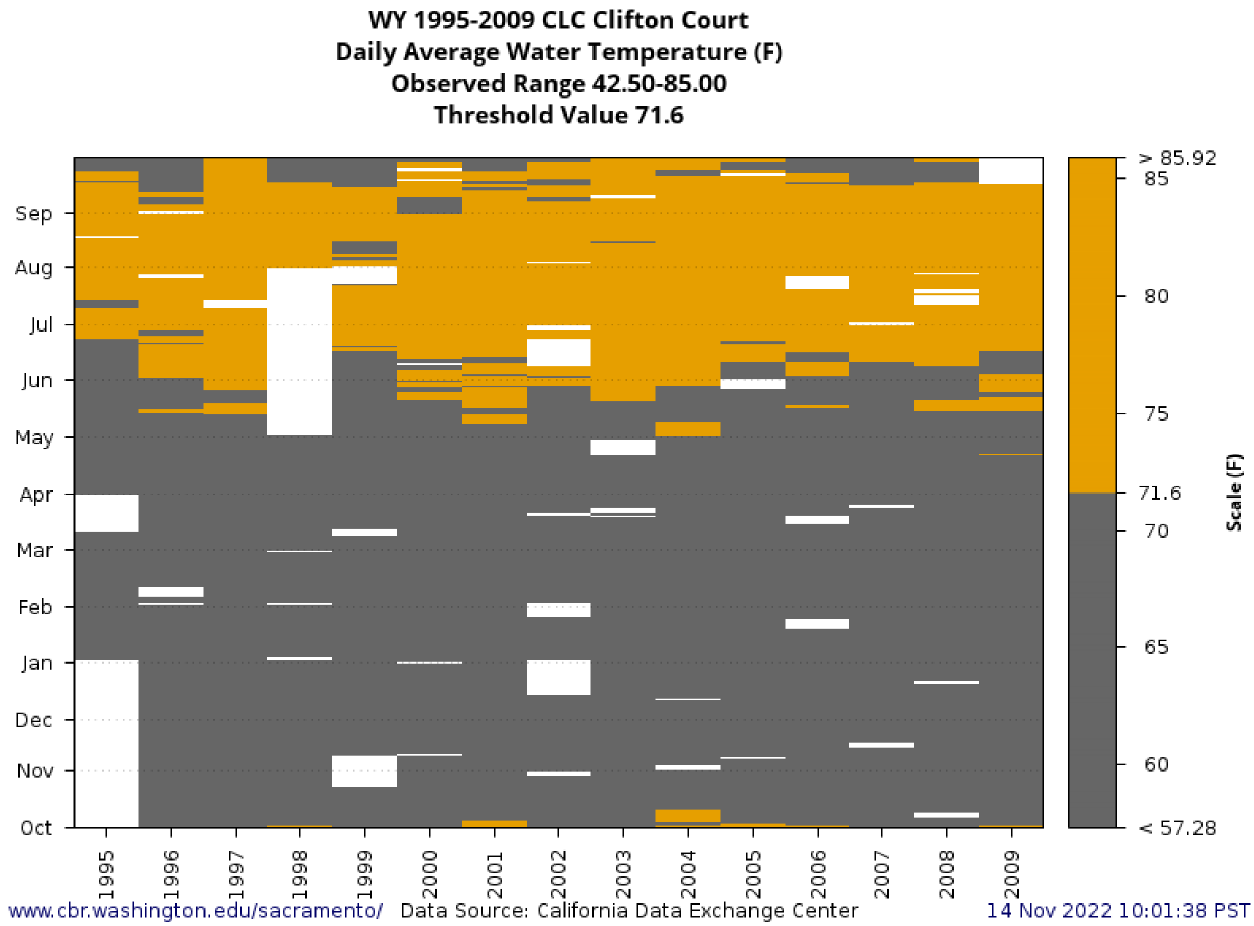
Source: California Data Exchange Center (www.cbr.washington.edu/sacramento). Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).
°F = degrees Fahrenheit.
Gray shading represents temperature values below a 71.6°F threshold, orange shading represents temperature values above a 71.6°F threshold. Observed range is 32.52°F–84.97°F.

Figure I-15. Daily Average Water Temperature (°F) Values Observed at San Joaquin River at Mossdale Bridge, Water Years 2002–2023



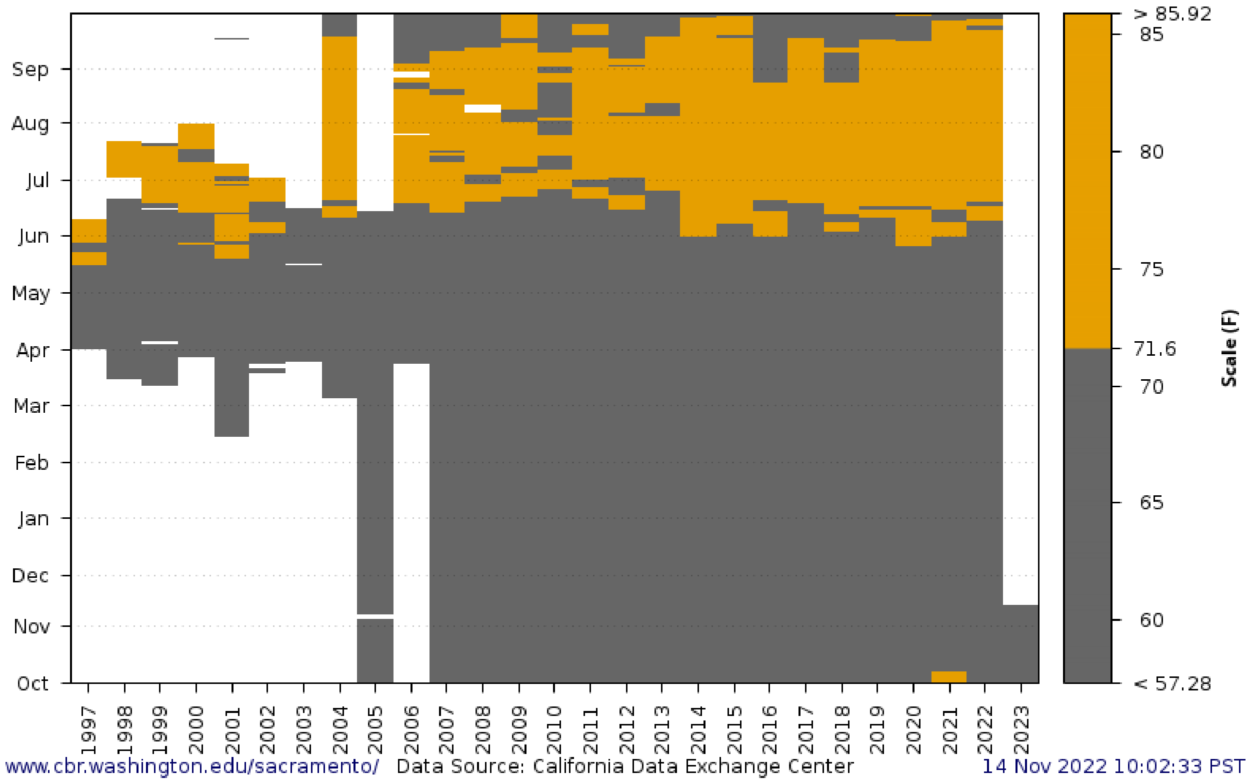
°F = degrees Fahrenheit.
The red dashed line represents a temperature threshold of 71.6°F.

Figure I-16. Daily Average Water Temperature (°F) Values Observed at Mossdale Station (MSD), Water Years 2011–2021



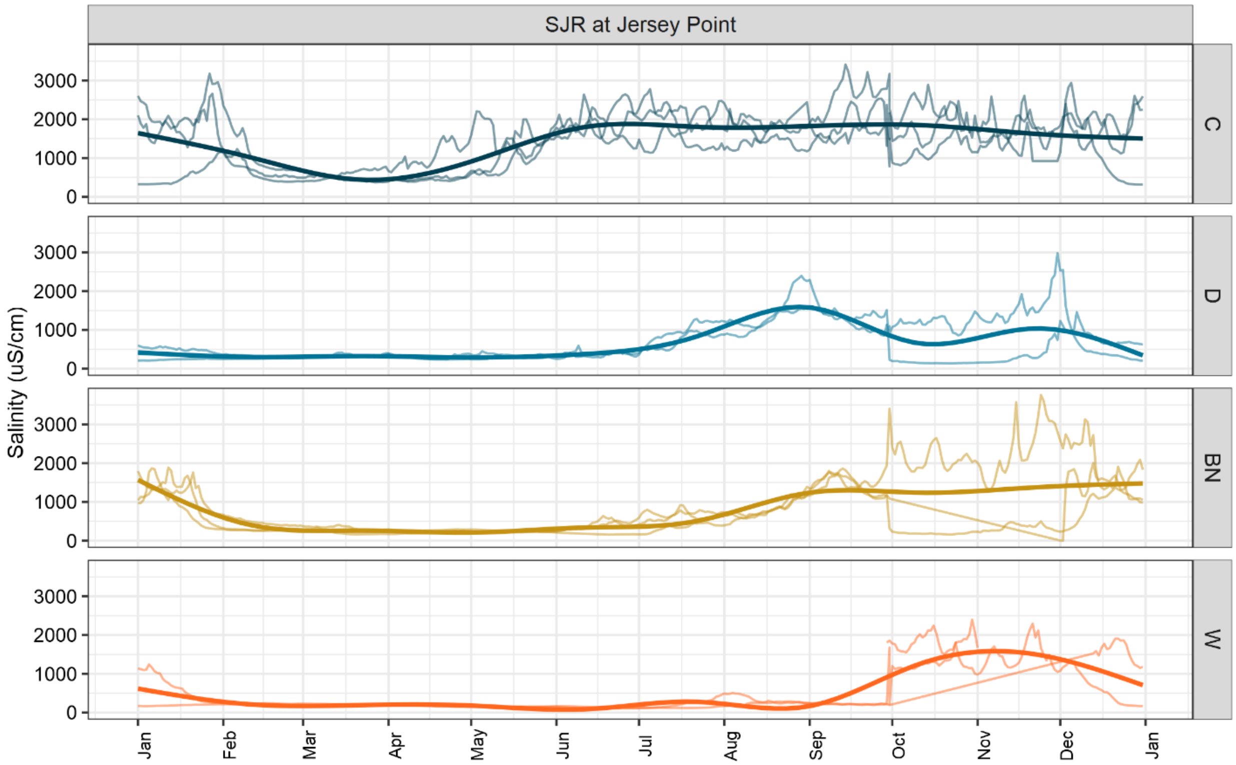
Source: California Data Exchange Center (www.cbr.washington.edu/sacramento). Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).
°F = degrees Fahrenheit.
Gray shading represents temperature values below a 71.6°F threshold, orange shading represents temperature values above a 71.6°F threshold. Observed range is 42.50°F–85.00°F.

Figure I-17. Daily Average Water Temperature (°F) Values Observed at Clifton Court, Water Years 1995–2023



Source: California Data Exchange Center (www.cbr.washington.edu/sacramento). Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).
°F = degrees Fahrenheit.
Gray shading represents temperature values below a 71.6°F threshold, orange shading represents temperature values above a 71.6°F threshold. Observed range is 43.67°F–79.71°F.

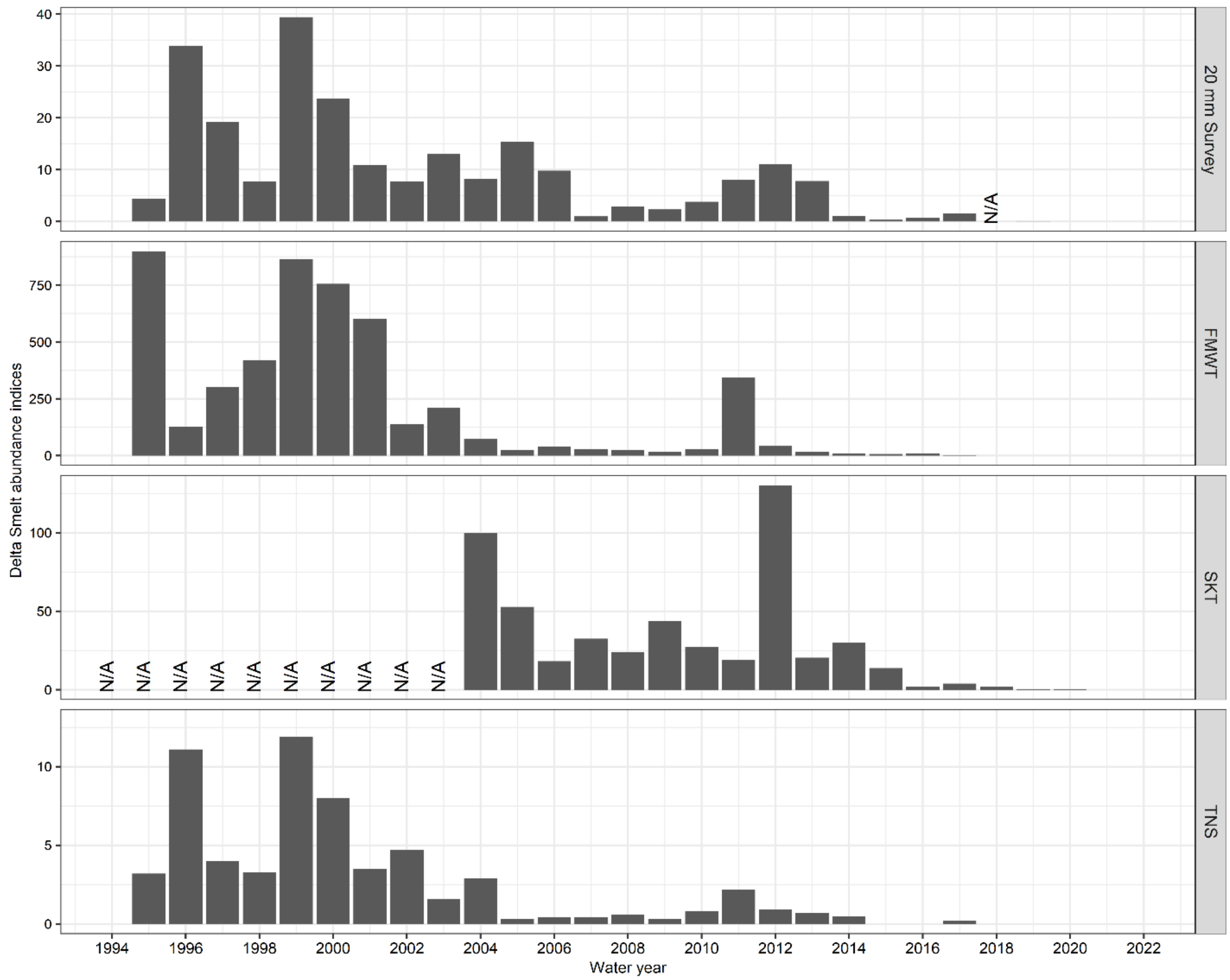
Figure I-18. Daily Average Water Temperature (°F) Values Observed at Prisoner's Point, Water Years 1997–2023



µS/cm = microsiemens per centimeter; SJR = San Joaquin River; C = critical; D = dry; BN = below normal; W = wet. Event data downloaded from the California Data Exchange Center and then averaged. Minor QA/QC applied (filtered between 0 and 10,000 µS/cm; minor outlier removal).

Figure I-19. Daily Average Salinity (uS/cm) Observed at Jersey Point (SJJ), 2009–2021

I.5.2.3 Fish Observations in Salvage



20-mm Survey = 20-mm Larval Delta Smelt Survey; FMWT = Fall Midwater Trawl Survey; SKT = Spring Kodiak Trawl Survey; TNS = Summer Townet Survey.
For more information on each survey, see Tempel et al. (2021).

Figure I-20. Indices of Delta Smelt Abundance from Long-Running Fish Surveys in the Delta

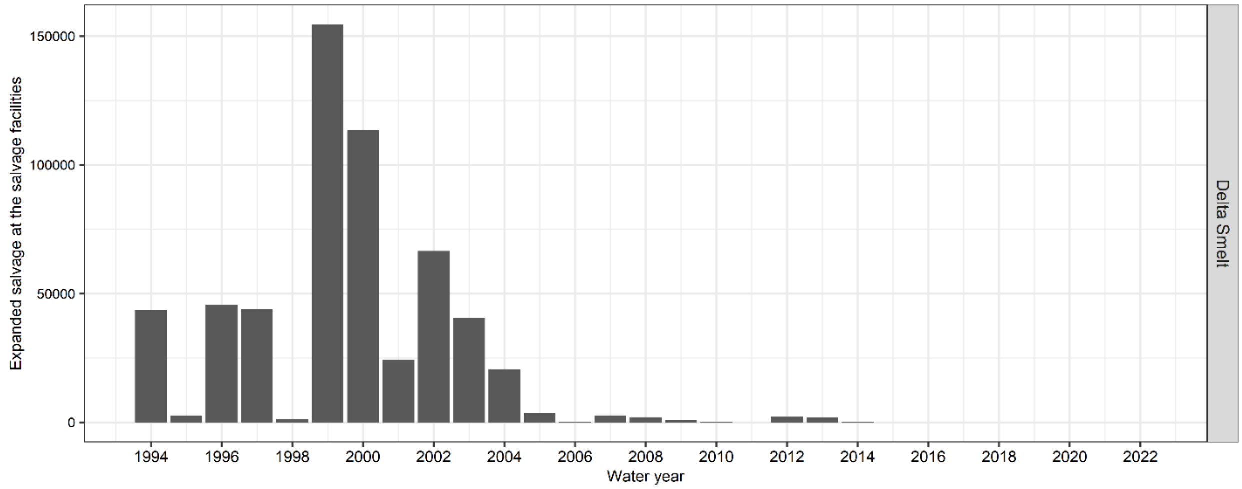
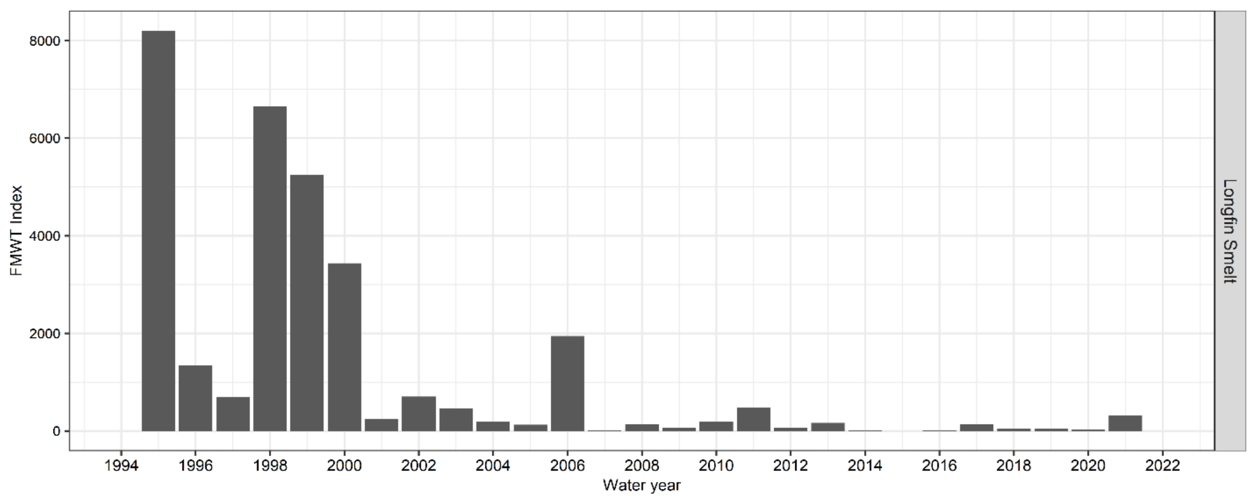


Figure I-21. Annual Delta Smelt Expanded Salvage Numbers at the Central Valley Project and State Water Project Export Facilities, 1994–2022



FMWT = Fall Midwater Trawl Survey.

Figure I-22. Longfin Smelt Abundance Index Time Series from the Fall Midwater Trawl Survey, 1994–2022

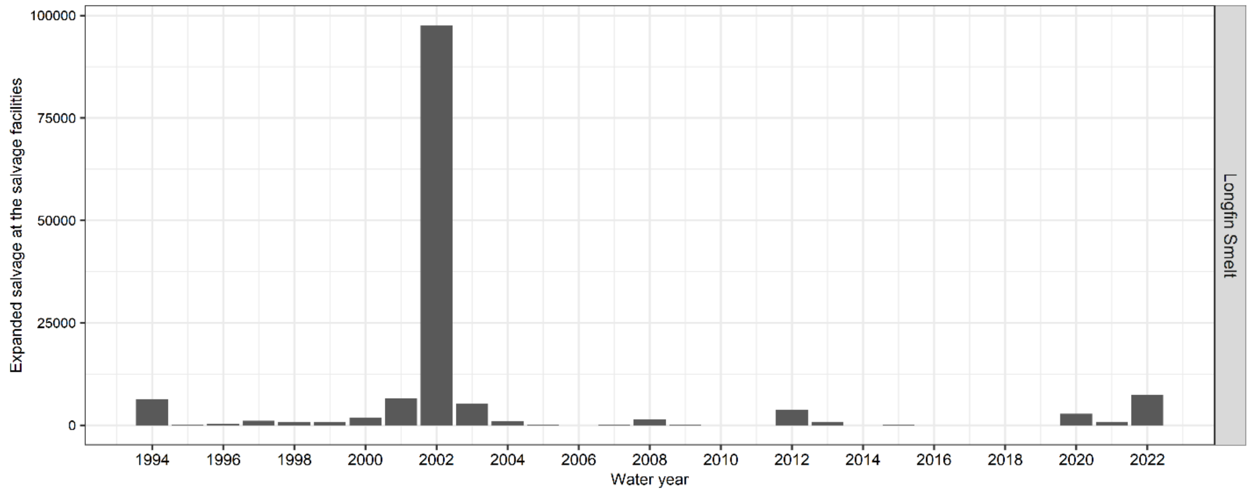


Figure I-23. Total Annual Longfin Smelt Expanded Salvage Numbers at the Central Valley Project and State Water Project Export Facilities, 1994–2022

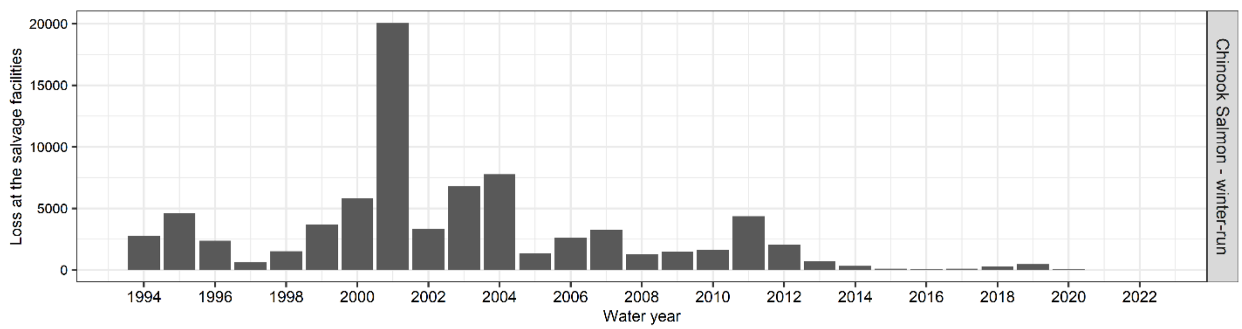


Figure I-24. Summary of Chinook Salmon Metrics Related to Old and Middle River Management: Annual Total Loss of Unclipped Winter-run Length-at-Date Chinook Salmon at the Central Valley Project and State Water Project Export Facilities, 1994–2022

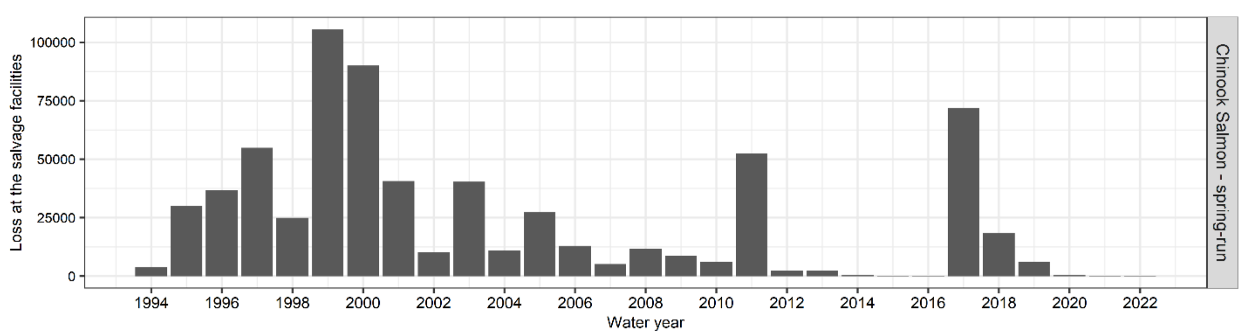
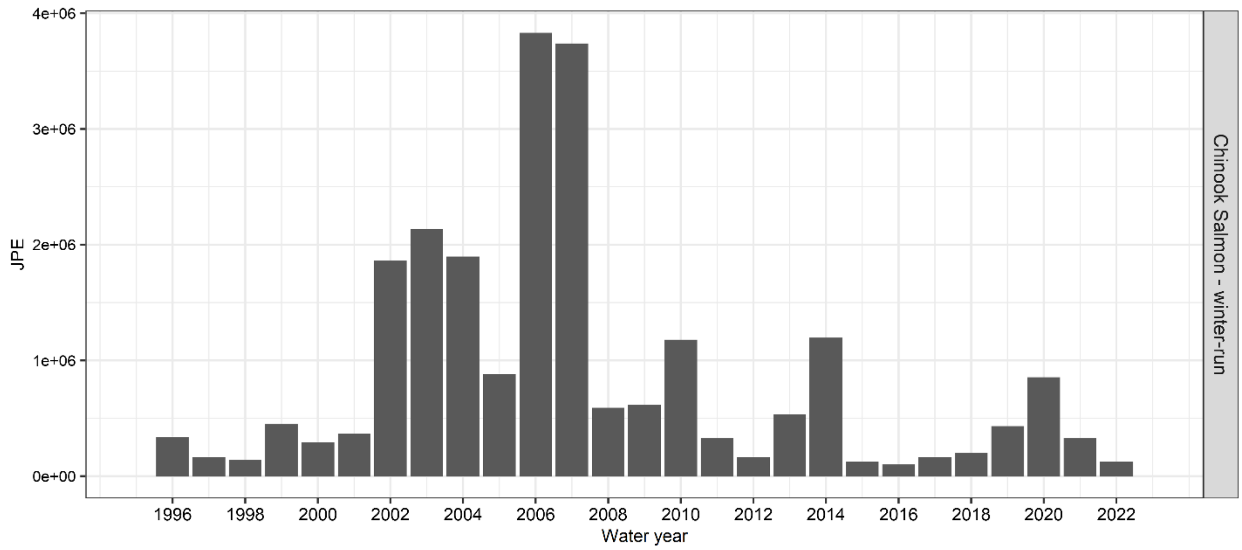


Figure I-25. Summary of Chinook Salmon Metrics Related to Old and Middle River Management: Annual Total Loss of Unclipped Spring-run Length-at-Date Chinook Salmon at the Central Valley Project and State Water Project Export Facilities, 1994–2022



JPE = juvenile production estimate.

Figure I-26. Annual Winter-run Chinook Salmon Juvenile Production Estimates, 2009–2022

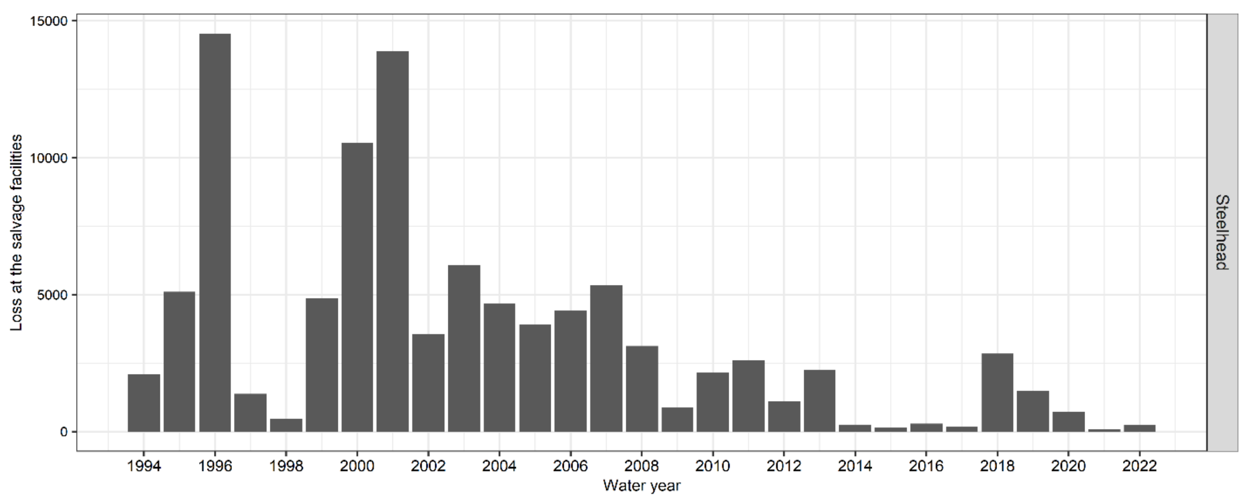


Figure I-27. Annual Total Loss of Unclipped Steelhead/Rainbow Trout at the Central Valley Project and State Water Project Export Facilities, 1994–2022

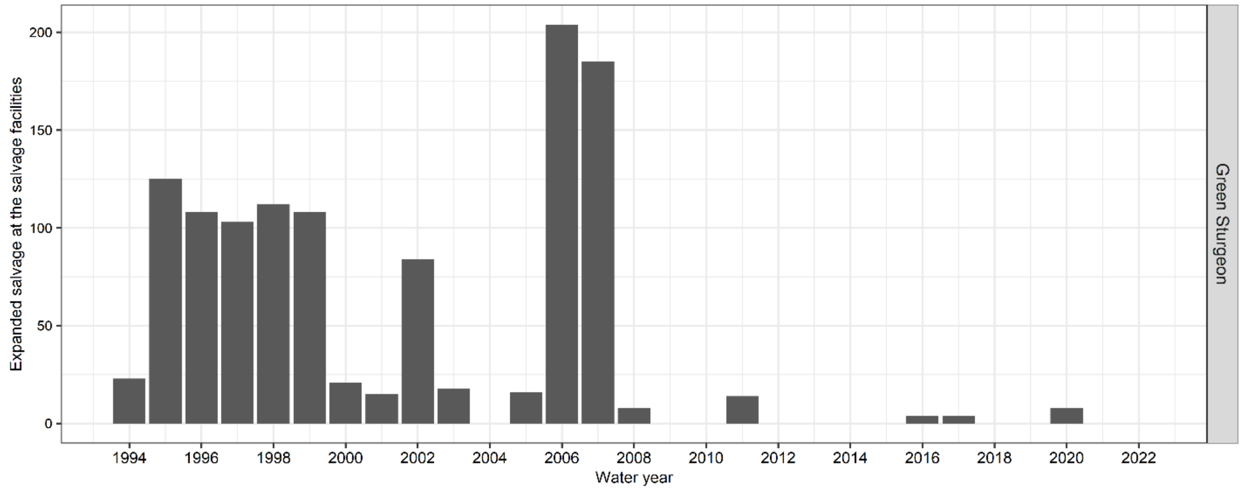


Figure I-28. Annual Green Sturgeon Expanded Salvage Numbers at the Central Valley Project and State Water Project Export Facilities, 1994–2022

I.5.2.4 Loss of Coded Wire Tagged Salmonids

Between 2009 and 2022, 369 batches of Sacramento River basin CWT fall-run (n = 311) and late fall-run (n = 58) Chinook salmon were released at Coleman National Fish Hatchery (Table I-2). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to almost 30% (2018) (Table I-2).

Table I-2. Coded Wire Tag Information for Sacramento River Basin Tagged Fall-run and Late Fall-run Chinook Salmon, 2009–2022

Year	Groups with Observed Salvage	Total Number of CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT Groups Salvaged, Non-Zero (min, max)
2009		34	0.0	
2010		27	0.0	
2011		27	0.0	
2012	10	36	27.8	0.096 (0.009–0.281)
2013	3	13	23.1	0.073 (0.047–0.121)
2014	1	14	7.1	0.005 (0.005–0.005)
2015		1	0.0	
2016	1	29	3.4	0.244 (0.244–0.244)
2017		29	0.0	
2018	7	24	29.2	0.015 (0.003–0.065)
2019	1	31	3.2	0.323 (0.323–0.323)
2020	1	34	2.9	0.029 (0.029–0.029)

Year	Groups with Observed Salvage	Total Number of CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT Groups Salvaged, Non-Zero (min, max)
2021	6	41	14.6	0.013 (0.006–0.024)
2022	1	29	3.4	0.048 (0.048–0.048)

CWT = coded wire tag.

Between 2009 and 2020, 27 batches of American River basin CWT fall-run Chinook salmon from Nimbus Fish Hatchery were released at a few locations along the American River (Table I-3). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to 66.7% (2012) (Table I-3).

Table I-3. Coded Wire Tag Information for American River Basin Tagged Fall-run Chinook Salmon, 2009–2020

Year	Groups with Observed Salvage	Total Number of CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT Groups Salvaged, Non-Zero (min, max)
2009		1	0	
2010		1	0	
2011		1	0	
2012	2	3	66.7	0.003 (0.003–0.004)
2013		3	0	
2016		4	0	
2017		4	0	
2018		2	0	
2019		4	0	
2020	1	4	25	0.016 (0.016–0.016)

CWT = coded wire tag.

Between 2009 and 2022, 62 batches of Feather River basin CWT spring-run (n = 55) and fall-run (n = 7) Chinook salmon from Feather River Hatchery were released at a few locations along the Feather River (Table I-4). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to 50% (2018) (Table I-4).

Table I-4. Coded Wire Tag Information for Feather River Basin Tagged Spring-run and Fall-run Chinook Salmon, 2009–2022

Year	Groups with Observed Salvage	Total Number of CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT Groups Salvaged, Non-Zero (min, max)
2009		5	0	
2010		1	0	
2011		2	0	
2012		2	0	
2013		1	0	
2014		4	0	
2015		7	0	
2016		6	0	
2017		10	0	
2018	1	2	50	0.032 (0.032–0.032)
2019		9	0	
2020	1	7	14.3	0.010 (0.010–0.010)
2021		4	0	
2022		2	0	

CWT = coded wire tag.

Between 2011 and 2023, 40 batches of San Joaquin River basin CWT spring-run (n = 39) and fall-run (n = 1) Chinook salmon from Feather River Hatchery and the San Joaquin River Conservation Hatchery were released at a few locations along the San Joaquin River (Table I-5). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to 100% (2011, 2016, 2017, 2018. and 2021) (Table I-5).

Table I-5. Coded Wire Tag Information for San Joaquin River Basin Tagged Spring-run and Fall-run Chinook Salmon, 2011–2023

Year	Groups with Observed Salvage	Total Number of CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT Groups Salvaged, Non-Zero (min, max)
2011	1	1	100	0.325 (0.325–0.325)
2014		1	0	
2015		1	0	
2016	2	2	100	7.021 (1.127–12.914)

Year	Groups with Observed Salvage	Total Number of CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT Groups Salvaged, Non-Zero (min, max)
2017	3	3	100	7.715 (6.701–7.672)
2018	4	4	100	3.888 (1.069–7.730)
2019	4	7	57.1	2.432 (0.080–3.595)
2020	7	10	70.0	2.362 (0.155–4.393)
2021	4	4	100	0.374 (0.003–0.615)
2022	2	5	40.0	0.028 (0.015–0.042)
2023	1	2	50	0.016 (0.016–0.016)

CWT = coded wire tag.

I.5.3 Models

Numerous quantitative models can be used to evaluate the environmental impacts of the CVP and SWP on listed fishes. A standardized set of criteria was applied to identify the suite of models used in our effects analysis. The necessary criteria include: (1) models are accessible and model output can be reproduced by an independent party, (2) model structure is well documented including model assumptions, (3) model functions are responsive to changing operations such as flow, and (4) model output informs performance metrics. In addition, models also preferably include: (1) focus on target species and/or run-timing group, (2) data collected after 2008, (3) an open and participatory development process, and (4) recent application in regulatory context (e.g., Biological Assessment, Biological Opinions).

I.5.3.1 Salvage Models

Salvage Density Model Documentation (National Marine Fisheries Service 2019 Biological Opinion, Appendix C)

- **Input Data and Preprocessing:** Historic monthly export data and expanded salvage data for all species were used for water years 1994–2020. The combined datasets were used as basic estimates of fish density (fish salvaged / volume of water exported) multiplied by simulated export data for the 1922–2021 (CalSim 3) CalSim modeling period to assess differences between scenarios. The use of expanded salvage estimates has a known associated statistical error caused by the expansion of subsamples. This statistical error has not been accounted for in the current salvage-density method though this is consistent with analyses using these data. The method assumes a linear relationship between entrainment and export flows due to a lack of information on how salvage would increase with increasing flows. The method does not account for spatial distribution of fish populations. Juvenile Chinook were assigned a race using length-at-date (LAD) method. There is a large overlap in size distributions among races which can lead to false race assignments and LAD has been shown to be inaccurate for both winter-run and spring-run Chinook salmon when compared with genetic identification assignment. Salvage by race should be interpreted with caution.

- **Normalization to Population Size:** Salvage and loss data were normalized where possible (e.g., winter-run Chinook salmon estimates normalized by JPE) to account for population abundance. No normalization occurred for spring-run Chinook salmon, fall- / late fall-run Chinook salmon, steelhead, or green sturgeon.
- **Salvage Index Calculation:** For each species at each month at each facility, density (fish per thousand acre-feet) was calculated as total monthly loss or expanded salvage for the facility divided by total monthly volume of exported water. Assuming a linear relationship between entrainment and flow may be an oversimplification so the method "functions as a description of changes in export flows weighted by seasonal changes in salvage density of covered species." Mean monthly entrainment indices for each month of each WYT is calculated as salvage or loss density multiplied by CalSim modeled export value for the same month for all years with the same WYT.

  This method can be used to compare the salvage index calculated from one export scenario to another and relies on historical salvage data to estimate changes in entrainment at the SWP/CVP export facilities providing a description of "changes in export flows weighted by seasonal changes in salvage density of covered species."

Machine Learning

A new model to predict winter-run Chinook salmon occurrence at the salvage facilities is currently being developed by Jeremy Gaeta (CDFW), Trinh Nguyen (CDFW), and Brian Mahardja (Reclamation). This model (hereinafter, Salvage Machine-Learning Tool) takes a machine learning approach (extreme gradient boosting dropout multiple additive regression trees) to predict winter-run Chinook salmon salvage as a function of various potential environmental drivers. Whereas previously developed machine learning salvage prediction tool (Tillotson et al. 2022) can estimate the number of winter-run Chinook salmon with high accuracy after salvage has occurred, the Salvage Machine-Learning Tool is designed to predict winter-run Chinook salmon occurrence prior to any salvage (one-week and three-week ahead models are currently being refined) and, thus, may be useful for on-ramping of OMR management season.

The Salvage Machine-Learning Tool can be used to evaluate the seasonal loss and first entrainment date performance metrics for winter-run Chinook salmon. This model can incorporate daily flow data from the Sacramento and San Joaquin Rivers as well as export level values from the pumping facilities (combined). CalSim output is in a monthly timestep and because using the same value across all days within the month for the Salvage Machine-Learning Tool may yield highly biased or misleading results, Reclamation will not use this model for evaluating different OMR alternatives.

Tillotson et. al. (2022)

Tillotson et al. (2022) developed a hurdle quantile regression forest model that predicts winter-run Chinook salmon and natural CV steelhead numbers at the salvage facilities one week in advance. This model was built to be a risk forecasting tool that can inform adjustments of water export in the Delta based on real-time conditions. This model is currently accessible through SacPAS and provides a robust and conservative estimate of entrainment risk, as overpredictions were uncommon in the testing dataset. However, because the previous week's entrainment loss was found to be the strongest predictor for the model, it complicates the use of this model for evaluating alternatives. A fish behavior component or model that predicts fish response to changing environmental conditions will likely be required in order to properly estimate expected salvage numbers across alternatives. Because there is currently no means to incorporate such effect in the model, Reclamation will not use this model for evaluating different OMR alternatives.

Negative Binomial Model of Loss

To evaluate potential changes to the number of LAD winter-run and spring-run Chinook salmon salvaged at the CVP and SWP pumping facilities based on the alternatives, Reclamation analyzed historical salvage data via negative binomial regression. Negative binomial regression requires estimation of a dispersion parameter rather than assuming the variance is equal to the mean. In doing so, negative binomial regression can account for overdispersion, which is common in ecological data (e.g., the salvage dataset), as well as reduce the likelihood of biased coefficient estimation.

Longfin Smelt Salvage Old and Middle River

The longfin smelt salvage OMR relationship is a model of salvage at South Delta facilities as a function of flow based on historical salvage data. The results are a quantitative analysis of loss differences between operating scenarios (including the Proposed Action). The method uses data from 1993-2005, reflective of historically high periods of juvenile salvage at the CVP and SWP collection facilities and OMR flows. This period represents conditions prior to the 2009 Biological Opinion and conditions under the 2019 Biological Opinion.

I.5.3.2 Hydrodynamic Models

DSM2

DSM2 is a one-dimensional hydrodynamic and water quality simulation model for the Delta, developed by DWR. The state and federal agencies, through the Salmon Monitoring Team (SaMT), model impacts of OMR scenarios associated with changes in operations of the Delta projects on behavior of sheltering, migrating, foraging, and rearing salmonids. DSM2 can simulate flows, velocities, and stage, and these data can be used to compare differences in flow conditions reflecting distinct inputs (i.e., no exports, specific inflows), which allows for visualizing the zone of influence of different releases and diversions in Delta regions. Reclamation conducted a DSM2 scenario sensitivity exercise. This was a collaboration between Reclamation and DWR's operations modeling teams to determine what difference in OMR flows resulted in differences in distribution of velocities and flow. Kolmogorov-Smirnov test statistic results demonstrated that if the difference in modeled OMR scenarios is less than 500 cfs (possibly even less than 1,000 cfs), then a comparison of DSM2 model runs outputs are not different. This finding is likely due to the dominant control of velocity, flow, and stage due to tides.

UnTRIM Bay-Delta Model

UnTRIM is a three-dimensional hydrodynamic model developed for San Francisco Bay-Delta boundary conditions used to test hypotheses and evaluate impacts of varying management actions, climate scenarios, and hydrology. The model provides predictions of water level, tidal flows, current speed, and salinity. Use of an unstructured mesh grid at varying resolutions allows for individual cells to be wetted and dried in both horizontal and vertical directions by solving Navier-Stokes equations in the horizontal plane. Varying grid size allows for flexibility in a single model: localized model predictions while still incorporating estuary-wide hydrodynamics. The model incorporates high-resolution bathymetric data varying from 10-meter to 90-meter resolution within different Bay regions (e.g., San Pablo Bay derived from 30-meter, Suisun Bay derived from 10-meter). Calibration includes water level, flow, and salinity observations from the San Francisco Bay and Delta (Casulli and Zanolli 2002; MacWilliams et al 2015). Model calibration and validation show UnTRIM provides accurate predictions of flow, stage, and salinity.

Resource Management Associates Bay-Delta Model

The Resource Management Associates Bay-Delta model is a two-dimensional hydrodynamic model developed for the San Francisco Bay-Delta and includes one-dimensional representations of some Delta and Suisun March channels in a single model (MacWilliams et al. 2016). The model provides predictions of flow, velocity, depth, electrical conductivity, residence time, and particle tracking. Flexibility in grid size allows for flexibility and ability to represent different scenarios. Bathymetric inputs are updated as new bathymetry data becomes available. Calibration includes observed stage, flow, and salinity time series data from San Francisco Bay locations.

I.5.3.3 Salmonid Delta Survival and Routing

This study (Buchanan et al. 2021) investigated factors influencing survival of acoustically telemetered juvenile hatchery *O. mykiss* from 2011 to 2016. Juvenile steelhead survival through Delta varied considerably both within years and between years. In general, survival through the San Joaquin route was greater than survival through the Old River Route, but not notably so. Survival was higher for the San Joaquin River route compared to the Old River Route for 16 of 19 release groups; however, the differences were sometimes very small and not statistically significant when year, barrier status, and fork length were accounted for. It would be expected that if the San Joaquin route was the superior route, then a positive effect on survival would have been observed by fish using this route.

Low steelhead survival was observed through the Turner Cut route. One would expect that entering the interior Delta at Turner Cut junction would lower survival by increasing risk of entrainment into the water export facilities. 67% of the fish that used Old River route entered the facilities compared to only 8 percent of the fish that took the San Joaquin River at the head of Old River. While increased entrainment into the facilities was observed for *O. mykiss* using the Old River route markedly lower survival was not observed. This study did not find a relationship between exports and survival head of Old River to Chipps. A complete range of exports was not evaluated (around 6100 cfs).

STARS

The STARS model is an individual-based simulation that predicts fish parameters (survival, travel time, entrainment) of juvenile salmonids migrating through the Delta. The fish parameters are related to movement of individual acoustically tagged late-fall and winter-run Chinook salmon connected to daily data (DCC gate status and Sacramento River flow at Freeport). The implementation of the simulation model currently available for use is calibrated to acoustically tagged late-fall fish released from 2007 to 2011. Data inputs to the model can be obtained by assigning monthly CalSim output to daily values within each month. Results are for individuals in cohorts, or fish who enter the model's "system" daily at Freeport. The use of the STARS model can inform the migrating behavior of juvenile salmonids (i.e., route selection) and total survival in the Delta. It is constructed to understand the space outside the interior Delta, but interpolation could be used to identify possible behavior of fish once they take a specific route away from the Sacramento River (i.e., DCC or Georgiana Slough). STARS provides overall survival and travel time, route-specific survival and travel time, and proportion of fish on a daily timestep that would use individual migration pathways or routes. An application of the STARS models run in real time is available here: https://oceanview.pfeg.noaa.gov/shiny/FED/CalFishTrack/. The code and supporting document are available from the U.S. Geological Survey (USGS) (Russ Perry, USGS, pers. comm.). The model structure and assumptions are documented in peer-reviewed literature (Perry et al. 2018). Model development is not currently open and participatory.

The STARS model can be applied to assess the performance metric of routing probability for winter-run Chinook salmon and possibly also spring-run Chinook salmon. The STARS model was applied to the 2019 NMFS Biological Opinion.

Delta Passage Model

The DPM is based on migratory pathways and reach-specific mortality as Chinook Salmon smolts travel through a simplified network of reaches and junctions. The biological functionality of the DPM is based on releases of acoustically tagged Chinook salmon performed between 2007 and 2017. The current model is based on acoustically tagged winter run, spring run, fall run and late fall–run individuals (≥ 80 mm) released in the upper reaches of the Sacramento River and within the Delta. These releases are primarily comprised of hatchery fish. However, wild spring and fall run are included in the dataset. These releases cover a wide range of environmental conditions, including extreme drought in 2014 and 2015 and high flow years. Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available. The major model functions in the DPM are as follows: (1) Delta entry timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon, (2) fish behavior at junctions, which models fish movement as they approach river junctions, (3) migration speed, which models reach-specific smolt migration speed and travel time, (4) route-specific survival, which models route-specific survival response to non-flow factors, (5) flow-dependent survival, which models reach-specific survival response to flow, and (6) export-dependent survival, which models survival response to water export levels in the interior Delta reach. The DPM model can be used to assess the survival of smolts from Delta entry to Chipps Island performance metrics for winter-run or spring-run Chinook salmon. Model documentation for previous iterations of the model is available in an accompanying report (Cavallo et al. 2011). The model was applied in the NMFS 2019 Biological Opinion. Model development and current application is not fully open and participatory.

The DPM operates on a daily timestep using simulated daily average flows and south Delta exports as model inputs. Water movement through the Delta as input to the DPM is derived from daily (tidally averaged) flow output produced by the hydrology module of the DSM2 (DSM2-HYDRO; http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/) or from CalSim II.

Particle Tracking Model

The PTM component of DSM2 computes the location of an individual particle at any time step within a channel based on velocity, flow and water level information provided by HYDRO. The longitudinal movement is based on transverse and vertical velocity profiles computed from mean channel velocity provided by HYDRO. PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae. PTM is publicly available from DWR at CADWRDeltaModeling/dsm2: Delta Simulation Model 2 (github.com).

ECO-PTM

The Ecological Particle Tracking Model (ECO-PTM) was developed by DWR, in collaboration with USGS, and applies to juvenile Chinook Salmon migration. Currently built upon data from acoustically tagged late fall–run Chinook salmon (2006–2014), the ECO-PTM estimates routing through Georgiana Slough, DCC route, the Sutter / Steamboat slough complex, or remaining in the Sacramento River. Development of the model is still ongoing and currently focused on the south Delta. This model was recently used in evaluating the biological effects of the spring 2022 Temporary Urgency Change Petition (TUCP), and code is available from DWR at https://data.cnra.ca.gov/dataset/ecological-particle-tracking-model-eco-ptm.

ECO-PTM can be used to evaluate survival, travel time, and routing probabilities, and thus apply to the seasonal loss and zone of entrainment performance metrics for winter-run and spring-run Chinook salmon. This model can incorporate CalSim or DSM2 data as model input. Development of this model is in progress.

I.5.3.4 Lifecycle Models

Winter-run Chinook Salmon Lifecycle Model

The WR-LCM is a spatially and temporally explicit stage-structured simulation model that estimates the number of winter-run Chinook salmon at each geographic area and timestep for all stages of their lifecycle. The first version of the WR-LCM was developed in 2014. In 2015, the WR-LCM underwent a model review by the Center for Independent Experts, which contributed to improvements in more recent versions of the model. See https://oceanview.pfeg.noaa.gov/wrlcm/intro.

In the 2019 NMFS Biological Opinion, the WR-LCM uses the Newman model (Newman 2003), which is a nonlinear hierarchical juvenile Chinook salmon Delta survival model that incorporates biotic covariates, environmental covariates, and random effects. Covariates include fish length, log transformed median river flow during the outmigration period, water salinity, river water temperature and hatchery water temperature at release, magnitude of the tide, median volume of exports during the outmigration period, DCC gate position, and water turbidity. The Enhanced Particle Tracking Model (ePTM) has been developed to improve the lifecycle model estimates for survival effects from Delta flows.

The Newman model compares survival of juvenile hatchery CWT fall-run Chinook salmon released upstream (lower Sacramento River, cities of Sacramento Courtland and Ryde) and downstream (west of Chipps Island) of the Delta. Releases represent two scenarios where fish either had to transit the Delta or not before reaching the ocean. The relative difference in survival between release groups (upstream: CWT recoveries from Chipps Island Midwater Trawl; upstream and downstream: CWT recoveries from commercial and recreational fisheries) allows for Delta-specific survival estimates. The Newman model results are based on environmental data from 1979–1995. The model is developed using fall-run hatchery Chinook released in April and May (later than winter-run peak outmigration). Model results should be considered as an assumption of how smolt survival rates vary with changes in scenarios.

The ePTM was developed as joint collaboration between the University of California, Santa Cruz and National Marine Fisheries Service's Southwest Fisheries Science Center. It is a data-driven model of juvenile salmonid migration through the Delta built off of behavioral fish decisions based on local environmental variables. The model uses acoustically tagged late fall–run Chinook salmon data with plans to use fall-run Chinook salmon in the future. It is currently still in development but has a downloadable, working version at GitHub: The ePTM Version 2.0 (https://github.com/cvclcm/ePTM_v2). Attempts to use the model for the lifecycle model were limited by documentation and program versioning.

Oncorhynchus Bayesian Analysis

The winter-run Chinook salmon Oncorhynchus Bayesian Analysis (OBAN) model has been developed from the conceptual WR-LCM and coded into Windows-based software with graphic output capability. The Bayesian estimation of model coefficients was coded into WinBUGS. The software finds a statistical "best fit" to empirical trends by matching model predictions to empirically observed juvenile and adult abundances. The model is capable of fitting any number of abundance data sources and estimating any number of coefficient values to find the best statistical prediction. This model code is not available for Reclamation's use, so it does not inform the initial alternative analyses.

Central Valley Project Improvement Act Winter-run and Spring-run Lifecycle Models

CVPIA Science Integration Team (SIT) Decision Support Model lifecycle models can be used to compare natural production and demographic rates of winter-run and spring-run Chinook salmon. The CVPIA SIT Decision Support Models were developed by the CVPIA SIT as part of a Structured Decision Making process, and the models, as implemented in R, are open source and publicly available. See: https://cvpia.scienceintegrationteam.com/cvpia-sit/resources/dsm-r-packages. Analyses using a version of the Decision Support Model have been published (Peterson and Duarte 2020). These models can incorporate CalSim flow and HEC-5Q temperature data from the Sacramento River and tributaries. The original purpose of these Decision Support Models was to compare outcomes of different restoration scenarios, but they would also be appropriate for comparisons of different flow and temperature scenarios. These models can inform multiple performance metrics for Chinook salmon, including Delta routing and survival probabilities.

Delta Smelt Individual-Based Model

Delta Smelt Individual-Based Model (IBM) can potentially be used to evaluate the population growth, entrainment mortality, and survival probability between life stages for Delta smelt (Rose et al. 2013a, 2013b). However, some key issues precluded the use of the Delta Smelt IBM by Reclamation. The Delta Smelt IBM would not be able to directly incorporate any flow variables from CalSim into the simulation aside from OMR, whereas the Delta Smelt Lifecycle Model

(Smith et al. 2021; see below) contains a summer Delta outflow component. Delta Smelt IBM-simulated movement is also not mechanistic. Relevant to this application for OMR management, the entrainment submodel lacks any effect causing simulated fish to occupy the San Joaquin River or South Delta, such as turbidity.

Delta Smelt Lifecycle Model (2021 Version)

Polansky et al. (2020) developed a stage-structured state-space lifecycle model for Delta smelt. State-space models are useful as ecological modeling tool because they allow separate descriptions of state and observation processes and because they permit integration of disparate data sets. This Delta smelt lifecycle model was later expanded from four to seven different life stages and to include a component that describes the entrainment process into the Delta export facilities (Smith et al. 2021). This model produces expected values for larval recruitment and survival at the subsequent life stages. The best model in Smith et al. (2021) also used OMR values at a monthly scale and therefore, CalSim output for the alternatives can be directly incorporated into the analysis. As such, Reclamation can use this model to calculate expected annual population growth rate (λ). The metric of interest will be geometric mean of λ for a specified time period (e.g., 1995–2015), which will be compared across alternatives.

I.6 Lines of Evidence

From the full list of quantitative models outlined in Section I.5.3, *Models*), a subset of tools was selected to evaluate the environmental impacts of the CVP and SWP operations on listed fishes. These tools are included as lines of evidence. Additionally, observations from the literature and datasets can be incorporated to understand management concepts regarding OMR effects on fish and the environment as lines of evidence.

I.6.1 First Flush Conditions

The frequency of first flush conditions are summarized below. Results will provide an evaluation of the first flush criteria for the Proposed Action and each of the alternatives.

First flush conditions, when flows and turbidity in the Delta initially increases occurs in winter when large precipitation events occur within the Sacramento and San Joaquin River basins. These conditions are the cue for the seasonal prespawn migration of adult Delta smelt to reach tidal freshwater habitats where they spawn in later months (Bennet 2005). The reduction of exports by the CVP and SWP was hypothesized to reduce entrainment of migrating adult Delta smelt (Grimaldo et al. 2009). After the first flush event, adult Delta smelt show little movement (Polansky et al 2018).

Under the 2020 ROD, first flush conditions were contained in the IEWPP action in which Reclamation and DWR would reduce exports for 14 consecutive days so that the 14-day averaged OMR index for the period will not be more negative than -2,000 cfs, in response to “First Flush” conditions in the Delta. The IEWPP could be triggered between December 1 and January 31 when the follow environmental criteria occurs:

- Running 3-day average of the daily flows at Freeport is greater than 25,000 cfs; and
- Running 3-day average of the daily turbidity at Freeport is 50 Nephelometric turbidity units (NTU) or greater; or
- Real-time monitoring indicates a high risk of migration and dispersal into areas at high risk of future entrainment.

The Proposed Action includes a First Flush Action as the start of OMR management, similar to the First Flush Action in the 2020 ROD. During the Proposed Action's First Flush Action, Reclamation and DWR will reduce CVP and SWP exports for 14 consecutive days, anytime between December 1 and the last day of February, to maintain a 14-day average OMR index no more negative than -2,000 cfs within three days of when the following criteria are met:

- Three-day running average of daily flows at Freeport is greater than, or equal to, 25,000 cfs, and
- Three-day running average of daily turbidity at Freeport is greater than, or equal to, 50 FNU

These conditions were exceeded in Water Years 2022 and 2023. Analysis of historical water quality and flow data between Water Year 2010 and Water Year 2021 showed that these conditions were exceeded in Water Years 2019, 2017, 2014, and 2012.

I.6.2 Old and Middle River South Delta Turbidity Sources, Conditions, and Frequency of Delta Smelt Adult, Larvae, and Juvenile Entrainment Protection

The frequency of alternative South Delta entrainment protection criteria is summarized below. Results will provide an evaluation of the OMR management related to turbidity for the Proposed Action and each of the alternatives.

Under the 2020 ROD, injury and mortality of adult, larval, and juvenile Delta smelt are anticipated to be minimized due to active real-time management of OMR flow and turbidity in the south Delta:

- **Adult Protection:** During the winter and early spring, after a First Flush event or February 1 (whichever comes first) net negative OMR flows are held at levels no more negative than a 14-day averaged OMR of -2000 cfs, for at least 5 days, when turbidity at the Old River at Bacon Island monitoring station (OBI) is a daily average of 12 NTU or greater.
- **Juvenile/Larval Protection:** On or after March 15 of each year, if QWEST is negative and larval or juvenile Delta smelt are within the entrainment zone of the pumps based on real-time sampling of spawning adults or young of year life stages, Reclamation and DWR will manage exports to limit entrainment of larval and juvenile Delta smelt. When secchi depth in the south Delta is less than 1m, Reclamation will operate to OMR no more negative than -3500 cfs. When secchi depth in the south Delta is greater than 1m, Reclamation and DWR and DWR will operate to OMR no more negative than -5000 cfs.

Entrainment protections under the Proposed Action include:

- **Adult Protection:** If after a First Flush Action and until larval and juvenile protections are applicable, Reclamation and DWR propose to manage exports to maintain daily average turbidity in OBI at a level of less than 12 FNU. If the daily average turbidity at Bacon Island cannot be maintained less than 12 FNU, Reclamation and DWR will manage exports to achieve an OMR no more negative than -2,000 cfs until the daily average turbidity at Bacon Island drops below 12 FNU. However, if five consecutive days of OMR less negative than -2,000 cfs do not reduce turbidity at Bacon Island below 12 FNU in a given month, Reclamation and will instead operate to OMR no more negative than -3,500 cfs until OBI less than 12 FNU.
- **Juvenile/Larval Protection:** Larval and juvenile Delta smelt protections start when larval or juvenile Delta smelt are detected withing the entrainment zone based on real-time sampling of spawning adults or young of year life stages, Reclamation and DWR will restrict exports to OMR no more negative than -5,000 cfs. When the secchi depth in the south Delta is less than 1 meter, as determined by weekly monitoring, Reclamation and DWR will restrict exports to OMR no more negative than -3,500 cfs.

The purpose of these actions is to minimize entrainment risk to Delta smelt in the OMR Corridor and South Delta, since these regions are associated with low-quality habitat, high predation risk, and can lead to salvage at export facilities.

Analysis of historical turbidity data indicates that between Water Years 2012 and 2023, turbidity bridge conditions were met in eight years under the 2020 ROD and in six years under the Proposed Action.

Analysis of historical secchi depth and dayflow data indicates that between Water Years 2010 and 2019, larval and juvenile protection conditions were met in seven years under the 2020 ROD, and in all years under the Proposed Action.

I.6.3 Adult Delta Smelt Salvage Off-ramp Analysis

In the Proposed Action, adult Delta smelt protection off-ramp criteria include when San Joaquin River flows at Vernalis are greater than 10,000 cfs, the Adult Delta Smelt Entrainment Protection Action (Turbidity Bridge) is offramped. While offramped, the OMR Index will be managed to no more negative than -5,000 cfs on a 14-day average. The Adult Delta Smelt Entrainment Protection Action (Turbidity Bridge) would be immediately reinstated when San Joaquin River flows at Vernalis drop below 8,000 cfs.

USFWS (2008) included an off-ramp criterion that required Rio Vista flow at 100,000 cfs and Vernalis flow at 10,000 cfs. Adult Delta smelt salvage can remain high even with high Rio Vista flows when Vernalis flow remained low, likely because OMR is influenced largely by San Joaquin River instead of Sacramento River. This is observed in the data, and although adult salvage between January and March has been low since 2008 (Figure I-29), it follows similar trends from prior to 2008 (Figure I-30) in relationship to Sacramento and San Joaquin rivers inflow. Sacramento River at Rio Vista flow was proxied from DAYFLOW by summing Yolo Bypass flow and Sacramento River flow at Freeport. San Joaquin River flow at Vernalis was acquired directly from DAYFLOW variable SJR.

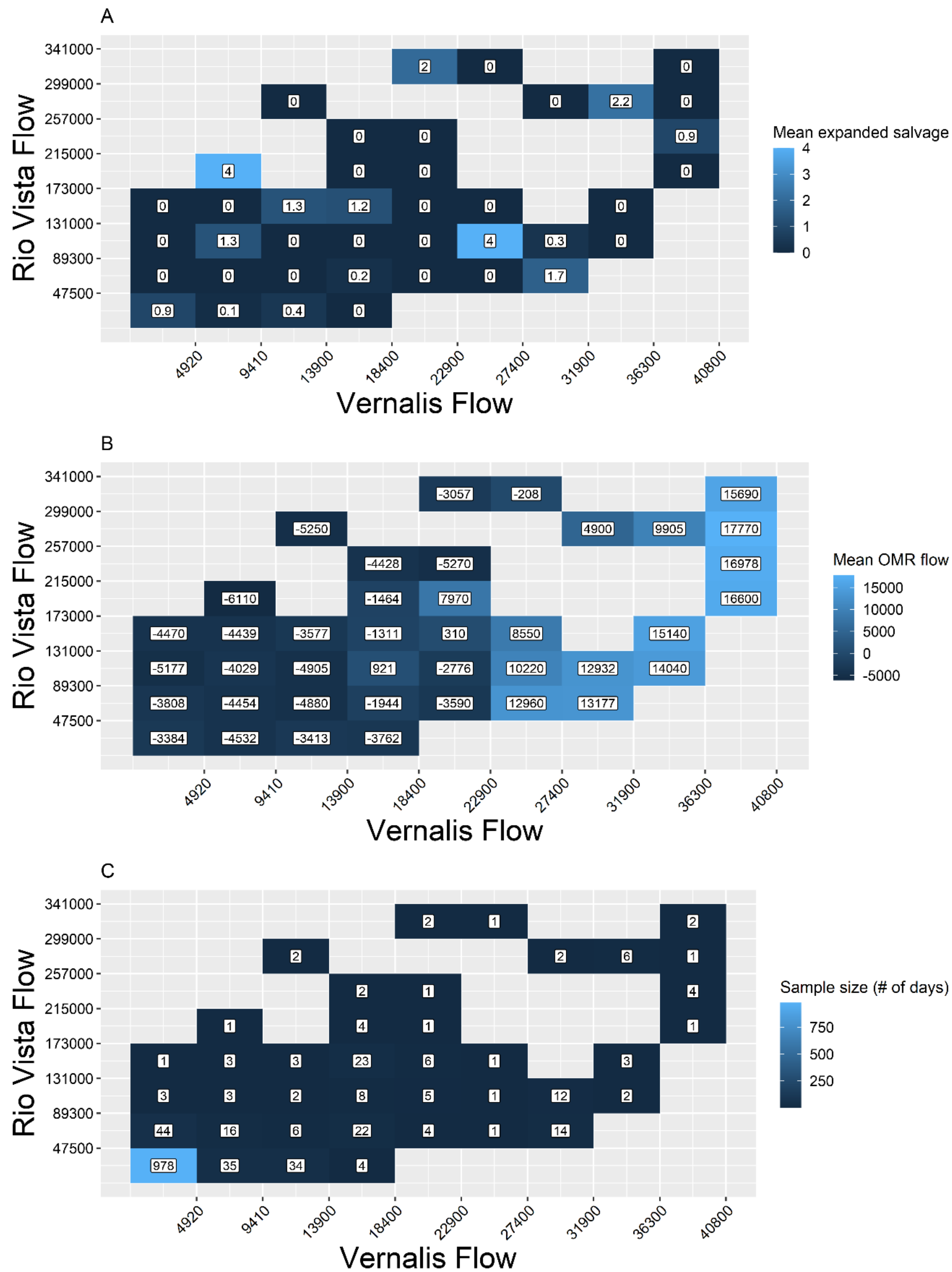


Figure I-29. Mean Daily Delta Smelt Expanded Salvage Data (A), Mean Old and Middle River Flow (B), and Sample Size/Number of Days (C) Binned by Sacramento River Flow at Rio Vista and San Joaquin River Flow at Vernalis Flow Values, 2008–2022, January–March

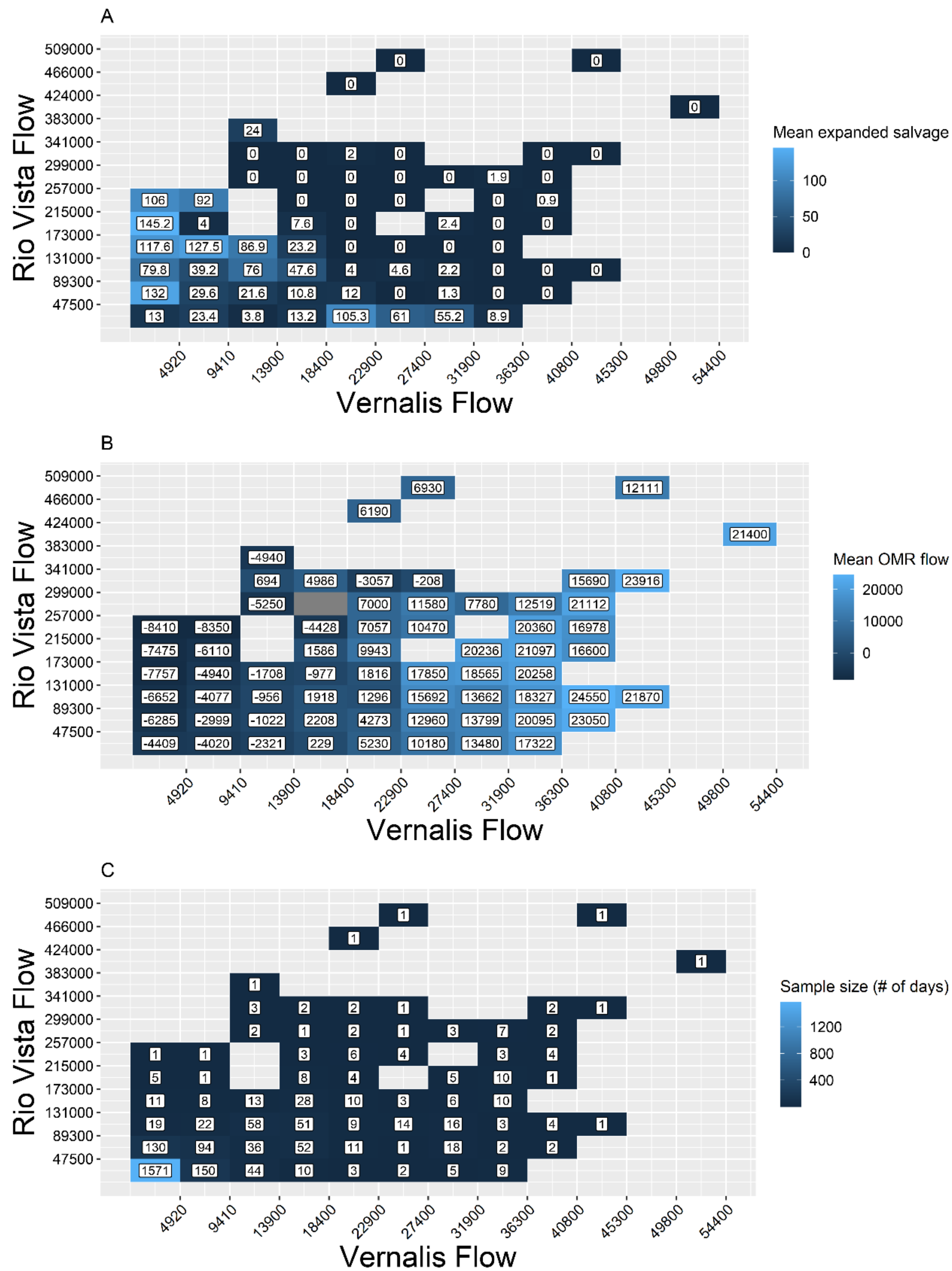


Figure I-30. Mean Daily Delta Smelt Expanded Salvage Data (A), Mean Old and Middle River Flow (B), and Sample Size/Number of Days (C) Binned by Sacramento River Flow at Rio Vista and San Joaquin River Flow at Vernalis Flow Values, 1993–2022, January–March

I.6.4 Use of Genetic Data for Old and Middle River Management

Genetic data have been collected from Chinook salmon captured within the Delta and the Central Valley for over two decades. Through this genetic information, it is now well understood that the LAD criteria used to assign Chinook salmon to runs are flawed and can be highly inaccurate (Harvey et al. 2014, Johnson et al. 2017). As such, using LAD criteria do not accurately describe the effects of CVP and SWP on listed Chinook salmon runs (i.e., winter-run and spring-run). However, it has been commonly used to assign Chinook salmon runs in surveys, studies, and regulatory context due to its practicality (ITP 2020, 2020 Biological Opinions), as processing for genetic analysis can be costly and time intensive. Reclamation and DWR have demonstrated that rapid genetic protocol to report run assignment of salvaged Chinook salmon within two days can be done (Bureau of Reclamation Letter 2019). Through this process, if salvaged LAD winter-run or spring-run Chinook salmon triggered pumping reductions, but were later discovered to be not genetically ESA-listed Evolutionarily Significant Units (ESUs), then these pumping restrictions will be rescinded. Through recent advancements in genetic technology, genetic assay that produces results in near real-time (i.e., hours) at a low cost is now a possibility (Baerwald et al. 2023). In Water Year 2023, the genetic methods and field procedures to identify runs of Chinook salmon within hours is being piloted, and it should be available as part of the 2021 Consultation. This use of genetic data can replace the inaccurate LAD criteria for identifying Chinook salmon runs at the salvage facilities and be used for more effective OMR management to protect winter-run and spring-run Chinook salmon populations.

In the Proposed Action, genetic identification of juvenile salmon will be implemented to improve accuracy of OMR management including winter-run Chinook salmon early migration protection, annual threshold, and weekly distributed loss threshold real-time adjustment for OMR management.

I.6.5 Historical, Presence-Based, and Model-Based Old and Middle River On-Ramp Analysis

The frequency of alternative OMR management on-ramp strategies is summarized below.

One component to consider regarding OMR flow management is when to initiate the OMR management season (when OMR flow is managed to be more positive than what would normally be operated for if fish species of concern were not an issue). Results will provide an evaluation of the on-ramp criteria for the Proposed Action and each of the alternatives.

I.6.5.1 Calendar-Based

Under the 2020 ROD, OMR flow no more negative than -5,000 cfs is initiated if after January 1 more than 5% of any salmonid species are determined to be present in the Delta by the SaMT. Unless preceded by a First Flush Action for Delta smelt, January 1 has typically been the start date for OMR management season. As such, the 2020 ROD has a combination of calendar-based and presence-based starting criteria for OMR management season. An alternative for OMR management may be using a fixed earlier or later calendar (date-based) start for OMR management or in combination with other on-ramping criteria as described below.

Under the Proposed Action, OMR flows no more negative than -5,000 cfs is initiated by January 1. Between 2009–2022, 5% of the total LAD winter-run Chinook salmon were salvage prior to January 1 in 4 of 13 years.

I.6.5.2 Presence-Based

In the 2020 ROD, OMR management at no more negative than -5,000 cfs is initiated after January 1 when the SaMT has determined that more than five percent of any salmonid species are present in the Delta. Although the percentage of salmonid distribution as determined by the SaMT can be somewhat subjective, they often rely on real-time monitoring data. In lieu of forming a team of salmonid experts to determine start dates for OMR flow management season, historical data from commonly used salmonid surveys can be used to identify dates when five percent of each species are believed to have entered the Delta. This was done by calculating the date at which five percent of winter-run Chinook salmon total catch has been reached for the water year (as winter-run Chinook salmon is typically the taxon that initiates OMR management season for salmonids). Note that LAD criteria were used to define winter-run Chinook salmon (Fisher 1992). WYT based on the Sacramento Valley and in water years when it occurred the date at which the turbidity and flow conditions were met to trigger IEWPP are included.

I.6.5.3 Model-Based

Models with the ability to forecast salvage events of winter-run Chinook salmon have been produced (Tillotson et al. 2022), and more are being developed (see Section I.6.7, *Winter-run Chinook Salmon Salvage Machine-Learning Tool*). Because winter-run Chinook salmon is typically the species that initiates the OMR management season, these predictive models can be used to on-ramp the OMR management season. Complex machine learning models may be able to incorporate complex information and various interacting factors that determine the timing and number of winter-run Chinook salmon entering the Delta. For example, date of first model-predicted entrainment event or certain probability of salvage can be used to initiate the start of OMR management at -5,000 cfs OMR flow or other thresholds.

I.6.6 Historical, Environmental Surrogate, and Calendar-Based Old and Middle River Offramp Analysis

The frequency of alternative OMR management on-ramp strategies is summarized below. Results will provide an evaluation of the off-ramp criteria for the Proposed Action and each of the alternatives.

The final variable component to consider is the offramp criteria for OMR flow management season. Warm conditions during late-summer and fall would presumably preclude Delta smelt and salmonids from the south Delta and the vicinities of the CVP and SWP pumping facilities. As such, the 2020 ROD and ITP have a combination of criteria that would signify the end of OMR management. These criteria include those based on real-time monitoring data (temperature threshold and SaMT distribution estimates) and a calendar-based cut-off (e.g., June 30).

I.6.6.1 Presence-Based

Under the 2020 ROD, OMR management may end when more than 95 percent of salmonids have migrated past Chipps Island, as determined by the SaMT.

I.6.6.2 Temperature-Based

- **Salmonids:** Under the 2020 ROD, OMR management may also end after daily average water temperatures at Mossdale exceed 72.0 degrees Fahrenheit (°F) (22°C) for 7 days during June (the 7 days do not need to be consecutive). Under the new Proposed Action, OMR management may end when daily mean water temperatures at Mossdale (MSD) and Prisoner's Point (PPT) have exceeded 72.0°F (22.2°C) for 7 non-consecutive days. Mossdale temperature exceeded 72.0°F (22°C) and Prisoner's Point temperature exceeded 72.0°F (22°C) for 7 non-consecutive days prior to June 30 in 6 of 11 years (2011–2021).
- **Delta Smelt:** Under the 2020 ROD, OMR management may end when the daily mean water temperature at Clifton Court Forebay reaches 77°F (25°C) for 3 consecutive days. This criterion occurred prior to June 30 in 8 of 11 years.

  Under the new Proposed Action, Adult Delta Smelt Entrainment Protection Action ends when the three-day continuous average water temperature at Jersey Point or Rio Vista reaches 53.6°F (12°C).

I.6.6.3 Calendar-Based

Under the 2020 ROD, OMR management may end June 30 (for Delta smelt and Chinook salmon) or June 15 (for steelhead) if real-time criteria have not been met. In addition, Turbidity Bridge Avoidance is offramped under the 2020 ROD when a ripe or spent female was detected or April 1, whichever is first.

Historical data from water year 2010 to water year 2021 was used to identify the date when 95% of each salmonid species of interest exited the Delta, based on Chipps Trawl. This date was compared to June 30 and the temperature exceedance date to determine when OMR management to reduce entrainment would end. Historical data were also used to identify the data when temperature offramp criteria would occur under the new Proposed Action.

Historical data indicate that in all years between 2011–2021, date when 100% salmonids were past Chipps Island occurred sooner than the date when temperature criteria were met, and both criteria typically (in all years but 2019) occurred prior to June 30.

Historical data indicate that in all years between 2011-2021, the date when adult Delta smelt entrainment protection met temperature criteria was consistently earlier than April 1, the date specified in the 2020 ROD. Meanwhile, the date when temperatures met OMR management season offramp temperature criteria was usually earlier than the calendar date threshold of June 30.

I.6.7 Winter-run Chinook Salmon Salvage Machine-Learning Tool

,Results from the winter-run Chinook salmon salvage machine learning tool are summarized below. Results will provide an evaluation of the seasonal loss and first entrainment date performance metrics for winter-run Chinook salmon for the Proposed Action and applicable alternatives.

A new model to predict winter-run Chinook salmon occurrence at the salvage facilities is currently being developed by Jeremy Gaeta (CDFW), Trinh Nguyen (CDFW), and Brian Mahardja (Reclamation). This model (hereinafter, Salvage Machine-Learning Tool) takes a machine learning approach (extreme gradient boosting dropout multiple additive regression trees) to predict winter-run Chinook salmon salvage as a function of various potential environmental drivers. Whereas previously developed machine learning salvage prediction tool (Tillotson et al. 2022) can estimate the number of winter-run Chinook salmon with high accuracy after salvage has occurred, the Salvage Machine-Learning Tool is designed to predict winter-run Chinook salmon occurrence prior to any salvage (one-week and three-week ahead models are currently being refined) and, thus, may be useful for on-ramping of OMR management season (Section 4.2). The model can incorporate daily flow data from the Sacramento and San Joaquin Rivers as well as export level values from the pumping facilities (combined).

I.6.8 Volumetric Influence Analysis

- When grouped by water year, the observed lowest (non-zero) mean percent Delta inflow exported was in Alternative 3 and observed in an above normal year at 10%, the lowest minimum (non-zero) value was observed in Alternative 3 in wet years at 0.35%, and the greatest maximum value of 65% was observed in all alternatives in wet, above normal, dry and critically dry year types except in Alternative 3, Alternative 4, Exploratory 1 and Exploratory 3.
- When grouped by inflow group, the observed lowest (non-zero) mean percent Delta inflow exported was in Alternative 3 and observed in the hihi inflow group at 6.7%, the lowest minimum (non-zero) value was observed in Alternative 3 in the hihi inflow group at 0.35%, the greatest maximum value of 65% was observed in all alternatives in the lolo, medmed, medlo, lohi inflow groups except in Alternative 3, Alternative 4, Exploratory 1 and Exploratory 3.
- In both groupings, the distribution of the percent Delta inflow exported is explained in part by operational constraints of the CVP and SWP. No more than 65% of Delta inflow may be exported at any time per D-1641 and in critically dry years operations to meet human health and safety are maximized to meet that need when Delta inflow would be at its lowest.
- Based on the assumption that lower percent Delta inflow exported is better for fish and their habitat, alternatives with low percent Delta inflow exported would exert the least influence over the natural hydrodynamics of the Delta. Alternative 3 has the highest frequency of low percent Delta inflow exported and should exert the least influence among the alternatives within the context of CalSim 3 model inflow and export values.

Table I-6. Monthly (December–June) Mean Percent Delta Inflow Exported Values and Percent Difference from the No Action Alternative for Each Alternative by Water Year Type

Water Year Type	Month	NAA Monthly Mean %	Alt1 Monthly Mean %	Alt1 % Diff	Alt2 wTUCP woVA Monthly Mean %	Alt2 wTUCP woVA % Diff	Alt2 woTUCP woVA Monthly Mean %	Alt2 woTUCP woVA % Diff	Alt2 woTUCP DeltaVA Monthly Mean %	Alt2 woTUCP DeltaVA % Diff	Alt2 woTUCP AllVA Monthly Mean %	Alt2 woTUCP AllVA % Diff	Alt3 Monthly Mean %	Alt3 % Diff	Alt4 Monthly Mean %	Alt4 % Diff	EXP1 Monthly Mean %	EXP1 % Diff	EXP3 Monthly Mean %	EXP3 % Diff
AN	12	38.0	43	13.0	38	0.20	38	0.099	38	-0.843	37.7	-0.8781	16.6	-56	35	-7.672	0	-100	0	-100
AN	1	16.9	28	66.2	17	-2.19	17	-2.101	17	-2.237	16.5	-2.6677	9.6	-44	16	-3.911	0	-100	0	-100
AN	2	12.9	19	48.7	13	0.73	13	0.254	13	0.396	12.9	0.0045	10.2	-21	14	9.308	0	-100	0	-100
AN	3	12.3	19	57.5	12	1.63	13	2.929	10	-18.861	10.0	-18.1755	7.4	-40	13	6.255	0	-100	0	-100
AN	4	13.4	19	39.7	18	33.58	18	33.536	10	-25.509	9.5	-29.4360	5.3	-61	18	33.669	0	-100	0	-100
AN	5	19.1	26	35.8	25	29.33	25	29.341	23	21.733	21.6	12.8968	4.9	-74	25	29.716	0	-100	0	-100
AN	6	30.9	35	12.1	28	-7.94	28	-7.936	29	-7.162	29.1	-5.6840	18.8	-39	28	-7.909	0	-100	0	-100
BN	1	25.0	41	63.2	24	-2.62	24	-2.394	25	-1.402	24.6	-1.5022	14.7	-41	24	-2.753	0	-100	0	-100
BN	2	23.3	30	27.8	22	-4.86	22	-4.827	22	-4.884	22.2	-4.9142	13.4	-43	24	4.326	0	-100	0	-100
BN	3	20.7	31	48.3	21	-0.69	21	-0.635	14	-34.297	13.6	-34.4377	12.2	-41	21	-0.182	0	-100	0	-100
BN	4	16.5	22	32.1	20	23.15	20	23.199	16	-2.828	14.6	-11.3564	7.7	-53	20	23.580	0	-100	0	-100
BN	5	17.8	25	38.1	23	30.27	23	27.882	22	26.233	20.8	16.9508	7.1	-60	23	31.866	0	-100	0	-100
BN	6	32.1	33	2.1	29	-9.20	29	-8.440	29	-8.544	30.1	-6.2555	16.7	-48	29	-9.121	0	-100	0	-100
BN	12	25.5	36	42.7	25	-0.57	25	-2.836	26	1.620	24.8	-2.8011	15.0	-41	24	-6.003	0	-100	0	-100
CD	1	33.7	47	39.5	30	-10.71	31	-9.346	31	-8.219	31.5	-6.3893	24.5	-27	33	-2.710	0	-100	0	-100
CD	2	29.1	37	27.1	31	7.44	28	-2.348	29	-0.532	28.8	-0.8812	24.0	-17	34	18.326	0	-100	0	-100
CD	3	29.3	26	-10.3	28	-4.75	23	-22.013	22	-23.331	22.4	-23.5150	17.5	-40	29	-1.156	0	-100	0	-100
CD	4	19.3	20	3.1	21	6.55	19	0.592	19	0.069	18.9	-2.1414	9.1	-53	21	7.028	0	-100	0	-100
CD	5	21.3	23	8.4	23	6.11	22	4.889	22	4.999	21.4	0.4520	9.6	-55	22	3.114	0	-100	0	-100
CD	6	17.9	19	4.1	17	-4.86	17	-7.611	17	-7.081	16.1	-10.2008	10.6	-41	16	-8.884	0	-100	0	-100
CD	12	36.3	42	15.4	36	-0.83	40	9.009	39	7.022	36.0	-0.8505	11.5	-68	32	-10.734	0	-100	0	-100
D	1	35.6	50	39.8	33	-7.87	33	-7.919	33	-6.694	33.2	-6.7645	17.9	-50	36	-0.029	0	-100	0	-100
D	2	23.3	32	37.1	22	-7.33	22	-7.272	21	-7.847	22.2	-4.9755	16.4	-30	24	3.650	0	-100	0	-100
D	3	25.0	32	29.0	25	-1.32	25	-1.363	19	-23.008	19.1	-23.4760	18.2	-27	25	-0.382	0	-100	0	-100
D	4	16.8	21	22.2	19	13.19	19	13.095	15	-8.831	14.3	-15.2592	6.1	-64	19	13.585	0	-100	0	-100
D	5	18.2	24	30.0	21	16.78	21	16.753	20	7.852	18.5	1.4406	7.2	-61	21	16.956	0	-100	0	-100
D	6	30.5	31	2.5	28	-8.70	28	-8.734	28	-9.939	27.7	-9.1789	9.2	-70	28	-8.059	0	-100	0	-100
D	12	22.0	37	68.1	23	4.23	22	0.694	22	0.680	22.3	1.0947	13.3	-39	22	-1.648	0	-100	0	-100
W	1	11.7	18	57.7	11	-3.05	11	-3.110	11	-2.352	11.4	-2.3383	9.4	-19	11	-5.272	0	-100	0	-100

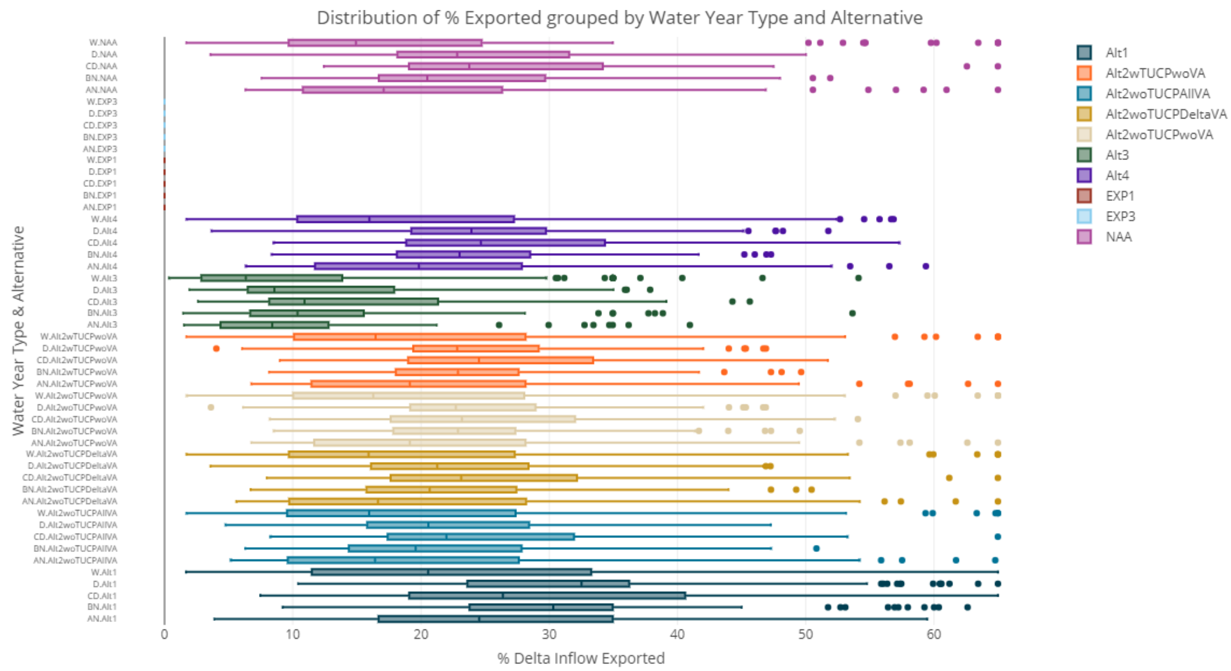
Water Year Type	Month	NAA Monthly Mean %	Alt1 Monthly Mean %	Alt1 % Diff	Alt2 wTUCP woVA Monthly Mean %	Alt2 wTUCP woVA % Diff	Alt2 woTUCP woVA Monthly Mean %	Alt2 woTUCP woVA % Diff	Alt2 woTUCP DeltaVA Monthly Mean %	Alt2 woTUCP DeltaVA % Diff	Alt2 woTUCP AllVA Monthly Mean %	Alt2 woTUCP AllVA % Diff	Alt3 Monthly Mean %	Alt3 % Diff	Alt4 Monthly Mean %	Alt4 % Diff	EXP1 Monthly Mean %	EXP1 % Diff	EXP3 Monthly Mean %	EXP3 % Diff
W	2	9.9	13	32.4	10	3.43	10	3.379	10	3.866	10.3	3.8753	6.2	-38	11	7.195	0	-100	0	-100
W	3	11.8	15	28.5	12	5.79	12	5.678	12	0.799	11.9	0.9373	4.8	-60	13	13.092	0	-100	0	-100
W	4	13.2	16	18.1	16	19.43	16	19.640	14	3.513	13.5	2.4140	3.8	-71	16	19.434	0	-100	0	-100
W	5	18.5	23	26.9	24	28.04	24	27.918	24	28.265	23.6	27.5001	3.7	-80	23	26.963	0	-100	0	-100
W	6	30.9	33	5.5	30	-2.34	30	-2.357	30	-2.261	30.3	-1.9933	26.0	-16	30	-3.047	0	-100	0	-100
W	12	36.7	42	13.2	37	-0.14	37	-0.120	36	-1.712	36.0	-1.7374	19.9	-46	33	-8.999	0	-100	0	-100

AN = above normal; BN = below normal; CD = critically dry; D = dry; W = wet.

Table I-7. Mean Percent Delta Inflow Exported Values and Percent Difference from the No Action Alternative for Each Alternative by Inflow Group

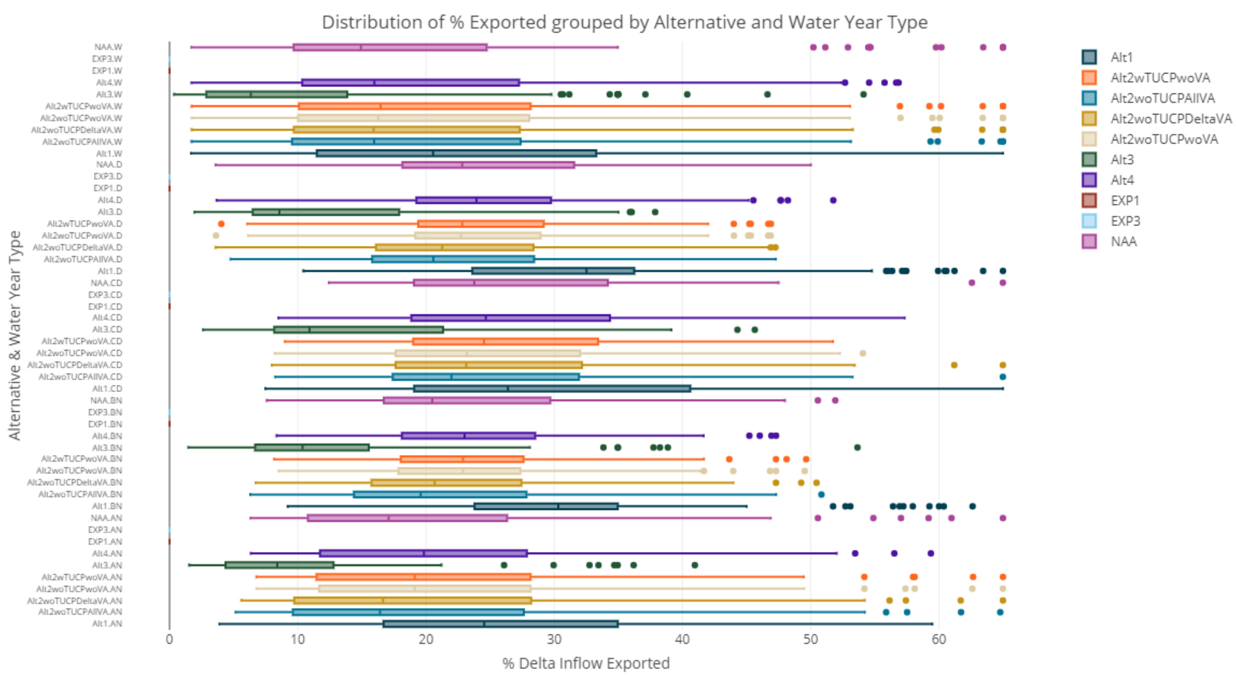
Inflow Group	NAA	Alt1	Alt1 % Diff	Alt2wTUCP woVA	Alt2wTUCP woVA % Diff	Alt2woTUCP woVA	Alt2woTUCP woVA % Diff	Alt2woTUCP DeltaVA	Alt2woTUCP DeltaVA % Diff	Alt2woTUCP AllVA	Alt2woTUCP AllVA % Diff	Alt3	Alt3 %% Diff	Alt4	Alt4 % Diff
hihi	12	14.6	24.9	12	6.32	12	6.4	12	0.67	12	1.18	6.7	-42.5	13	8.36
hilo	16	29.6	90.6	16	0.98	16	1.1	16	2.09	16	1.18	11.2	-27.5	15	-0.71
himed	14	24.5	79.6	14	2.23	14	2.5	13	-3.19	13	-3.98	10.0	-26.4	14	2.56
lohi	29	32.1	12.1	32	11.56	31	8.8	31	7.22	31	9.11	26.1	-8.8	31	8.63
lolo	29	32.6	10.6	29	-1.10	29	-2.9	29	-1.32	28	-3.78	15.4	-47.6	30	0.37
lomed	26	28.3	8.2	27	2.72	26	1.2	24	-6.92	24	-6.95	14.9	-42.9	28	5.63
medhi	21	28.6	33.2	26	20.13	26	19.7	23	8.85	24	10.11	10.0	-53.4	26	20.33
medlo	32	43.5	35.4	31	-2.95	31	-2.7	31	-2.84	32	-0.99	15.1	-53.0	30	-6.56
medmed	25	34.7	40.8	25	2.49	25	1.9	22	-9.79	22	-12.11	11.1	-54.9	25	3.13
NA	NA	9.6	NA	33	NA	NA	NA	NA	NA	NA	NA	9.2	NA	NA	NA

See Table I-8 for a description of the inflow groups.



W = wet; AN = above normal; BN = below normal; CD = critically dry; D = dry.

Figure I-31. Boxplots of Percent Delta Inflow Exported Grouped by Water Year Type and Alternative



W = wet; AN = above normal; BN = below normal; CD = critically dry; D = dry.

Figure I-32. Boxplots of Percent Delta Inflow Exported Grouped by Alternative and Water Year Type

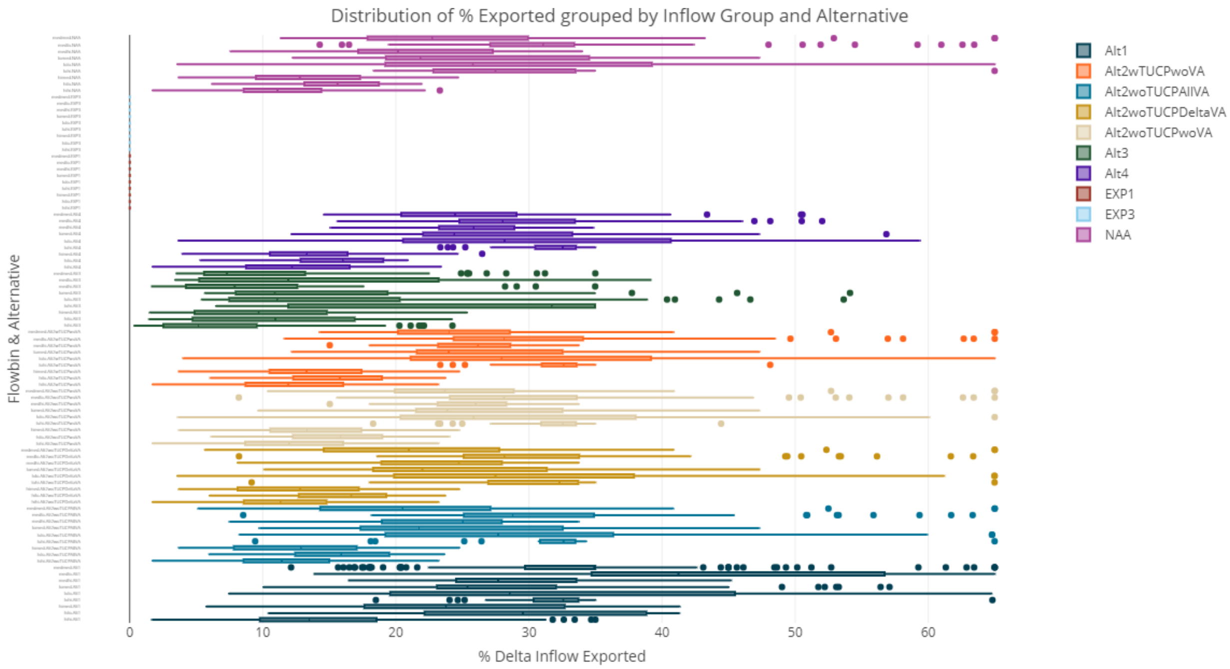


Figure I-33. Boxplot of the Full Distribution of the Each Alternatives' Percent Delta Inflow Exported from All Years Grouped by Inflow Group and Alternative

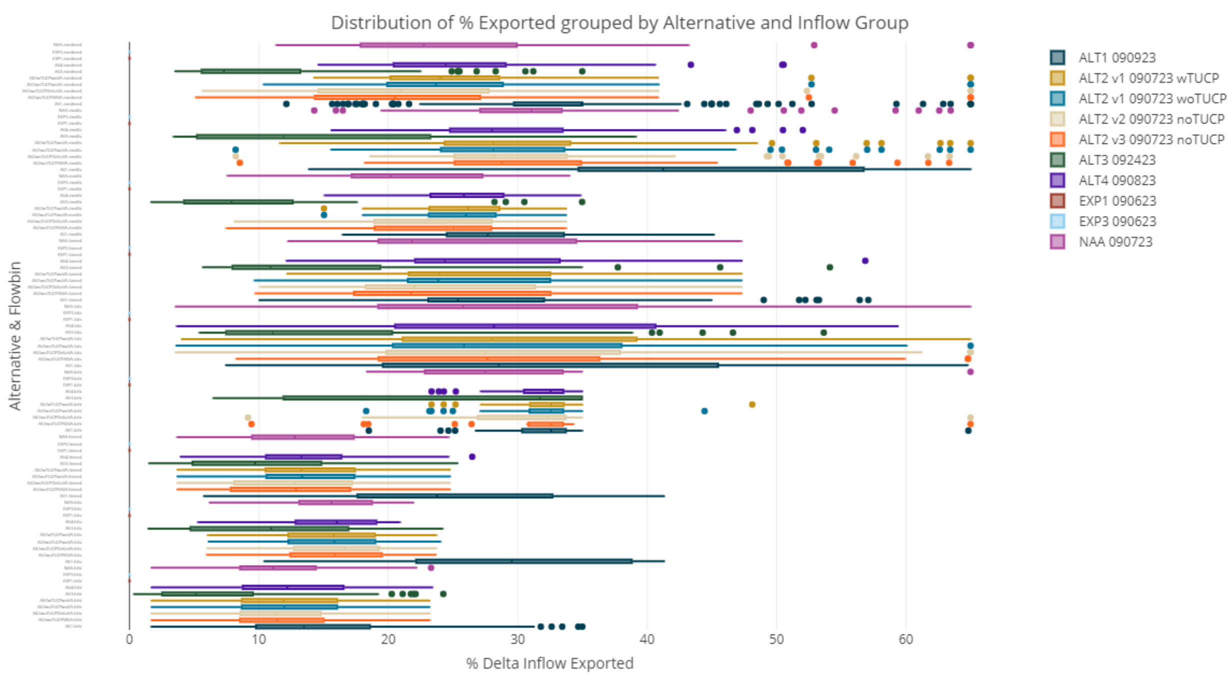


Figure I-34. Box Plot of the Full Distribution of the Each Alternatives' Percent Delta Inflow Exported from All Years Grouped by Alternative and Inflow Group

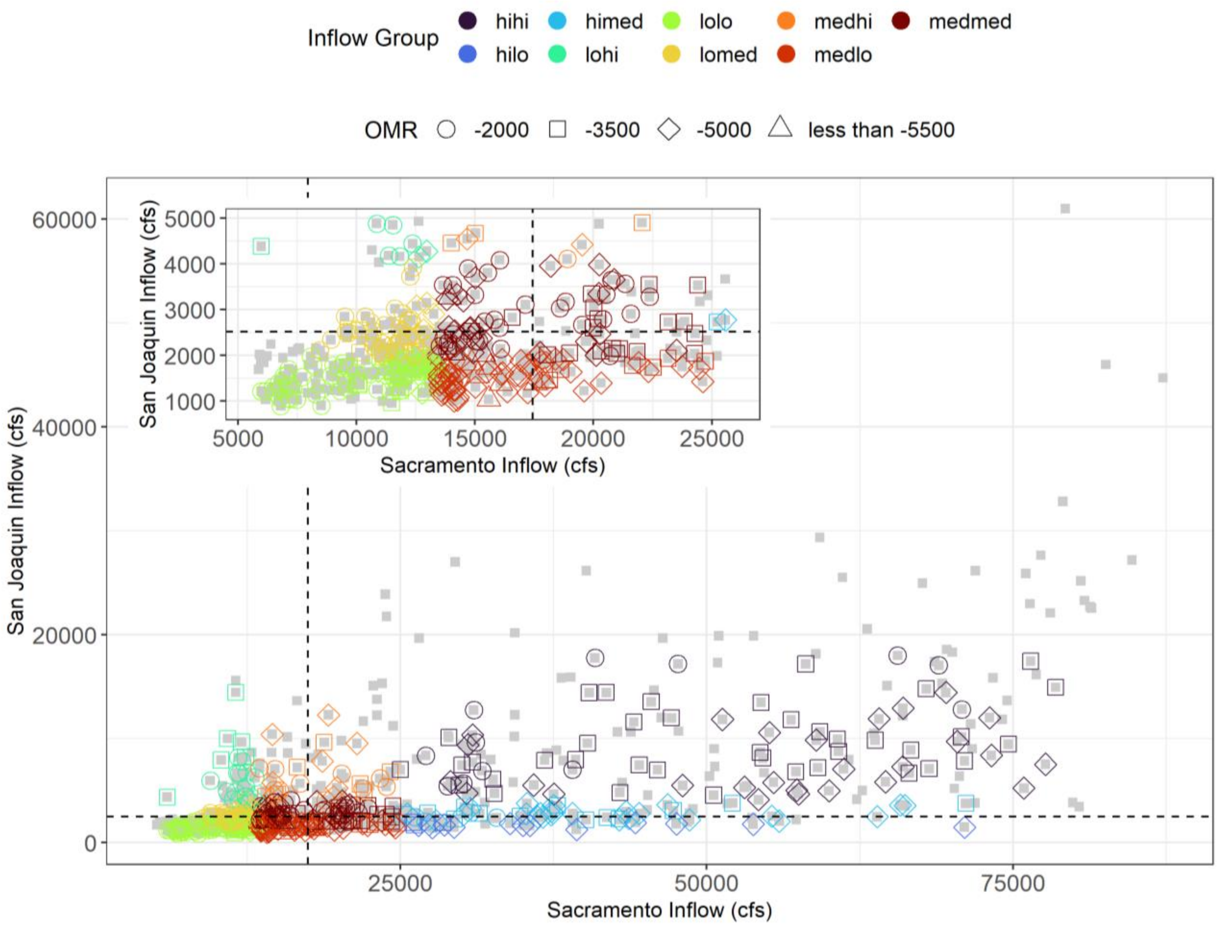
I.6.9 Delta Export Zone of Influence

Several lines of evidence are influenced by variations in inflow. To standardize results across San Joaquin (Vernalis) and Sacramento (Freeport) inflows, representative combinations of average monthly San Joaquin River and Sacramento River inflow were identified (Table I-8). For zone of influence analysis, data are also assigned OMR bins based on average monthly OMR, with data falling within +/-500 cfs of -2000 cfs, -3500 cfs, and -5000 cfs assigned to the respective -2000, -3500, and -5000 OMR bin categories, and data with OMR less than -5500 cfs assigned to the less than -5500 bin (Figure I-35). These values (-2000, -3500, -5000) were selected to reflect values used for real-time management during OMR season.

Table I-8. December–June Zone of Influence Flow Groups based on CalSim 3 Sacramento (Freeport) and San Joaquin (Vernalis) River Inflows under the No Action Alternative

Inflow Group	Description	SR Inflow Range (cfs)	SJR Inflow Range (cfs)	Mean OMR (cfs)	Mean Exports (cfs)
lolo	Low SR Low SJR	5117–13415	890–1983	-3049	3745
medmed	Med SR Med SJR	13416–24725	1984–4096	-3758	5328
hihi	High SR High SJR	24726–87222	4097–61005	-2005	9227
himed	High SR Med SJR	24726–87222	1984–4096	-4242	6548
medhi	Med SR High SJR	13416–24725	4097–61005	-2506	6271
lomed	Low SR Med SJR	5117–13415	1984–4096	-2805	3864
medlo	Med SR Low SJR	13416–24725	890–1983	-5070	6069
lohi	Low SR High SJR	5117–13415	4097–61005	-2916	5713
hilo	High SR Low SJR	24726–87222	890–1983	-4562	6158

SR = Sacramento River; SJR = San Joaquin River; OMR = Old and Middle River; cfs = cubic feet per second.
Values have been rounded to the nearest integer.



OMR = Old and Middle River; cfs = cubic feet per second.
See Table I-8 for a description of the inflow groups. Gray points represent all data. Points outlined in color indicate data points falling within OMR groupings, and used in subsequent modeling. Inset plot zooms in on lower inflow values for greater resolution. Points and inflow grouping are based CalSim 3 results from the No Action Alternative.

Figure I-35. Data Categorized into Sacramento and San Joaquin River Inflow Groupings

Takeaways:

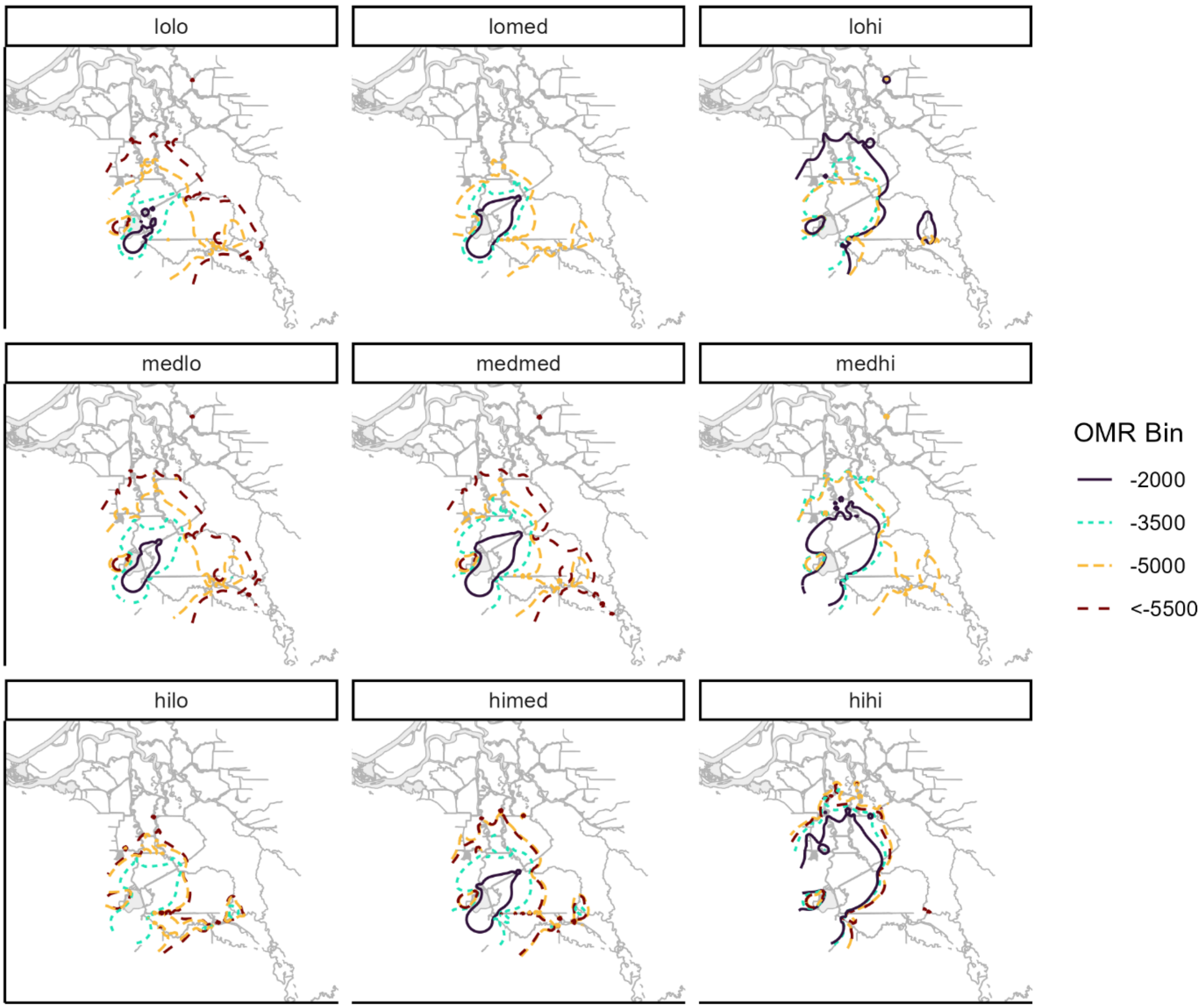
- **Drivers of Variation:** The Delta export zone of influence is influenced by Sacramento River and to a greater extent San Joaquin River inflow, as well as export level.

  Delta export zone of influence is calculated using a metric comparing the proportional overlap between a pumping and no pumping scenario for each alternative and DSM2 node. The results are represented with contour maps (Figure I-35) and the metrics of summed channel length altered and proportional channel length altered (channel length divided by the total DSM2 grid channel length).

  Sacramento and San Joaquin inflow are represented by inflow groups.

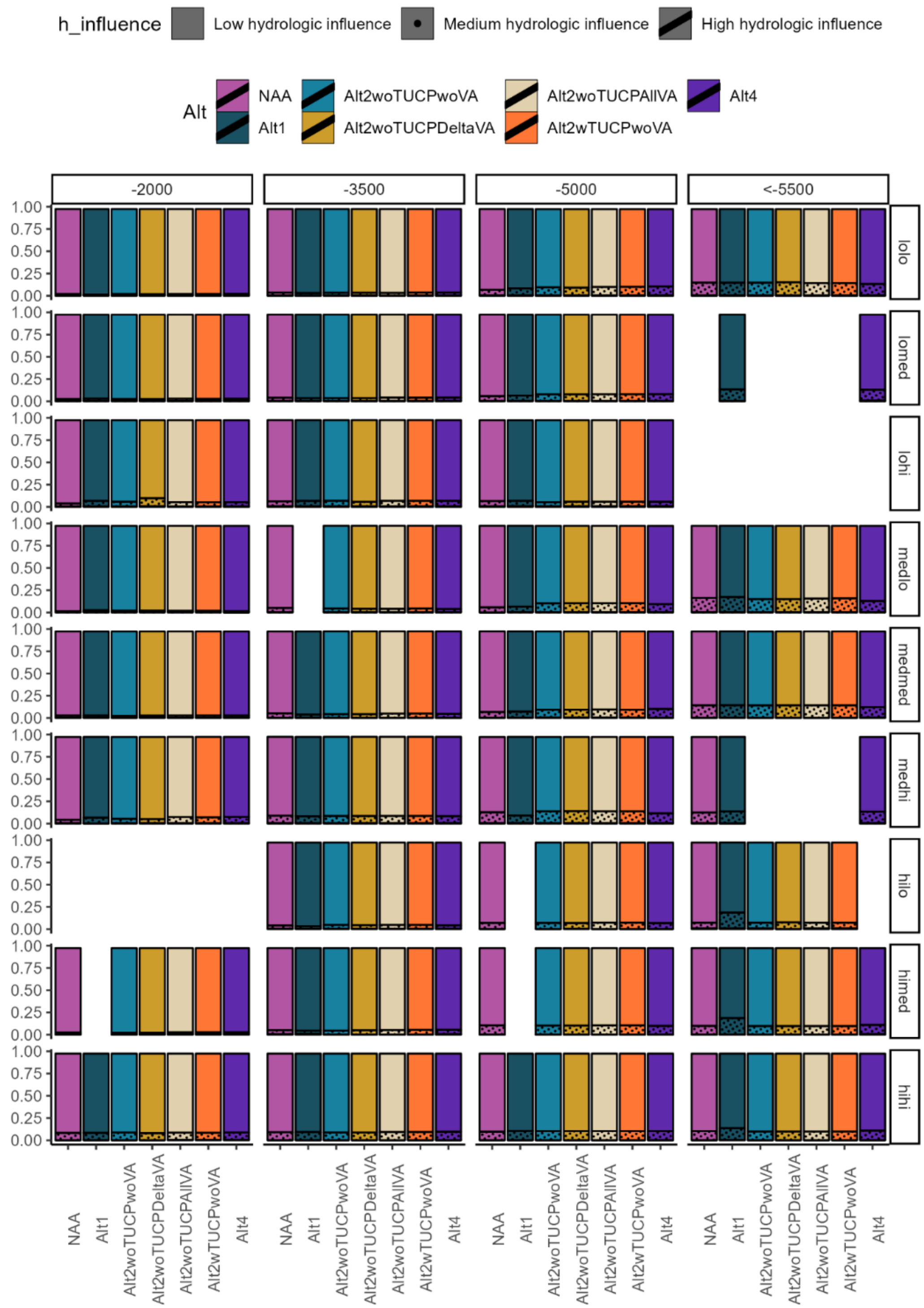
  Exports are represented by OMR.

- **Calibration:** Inflow groups were created using CalSim 3-modeled No Action Alternative results from December to June of 1921 to 2021. DSM2-Hydro hourly velocity results from 1922–2021 were used to generate proportional overlap values used to evaluate and visualize zone of influence.
- **Uncertainties:** The analysis does not take into account several variables that may influence results, including: seasonal tidal influence, channel depth and width, number of pumping hours in the "pumping" scenarios, and the magnitude of velocity difference between pumping and no pumping scenarios. Contour maps have been mapped across land to visualize the relative spatial extent of the Delta export zone of influence at each OMR flow but do not assume that channels constructed in those areas would experience the same impacts of pumping. Regarding sample sizes, the inflow groups and OMR bins exclude several samples (months) from analysis, and sample sizes vary greatly among different inflow groups and OMR bins (between 0 and 65 months per combination), thus the amount of certainty and variability in a given result may differ widely. It is also important to note that differences noted were not evaluated statistically.
- **Takeaways (General):** Across all alternatives, most of the nodes experience low hydrologic influence (greater than 0.75 overlap) and very few experience high hydrologic influence (Figure I-36). With increasingly negative OMR, proportional overlap at selected locations generally decreases. Changes to proportional overlap are more subtle at distances further from pumping facilities. Channel length altered generally increases with higher San Joaquin inflow and more negative OMR.
- **Performance Measure Comparisons (Biological Assessment):** Alternatives experience very similar amounts of channel length altered across inflow group and OMR (Figure I-37, Figure I-38. Table I-9). Both the lowest and highest amount of channel length altered under medium hydrologic variation (27,647 feet or 0.7% of the DSM2 grid to 606,560 feet or 15.7% of the DSM2 grid) occurred under the No Action Alternative (Table I-9).
- **Performance Measure Comparisons (Environmental Impact Statement):** The greatest difference in summed channel length, when compared with the No Action Alternative, was observed in Alternative 1, which experienced 182% greater channel length altered at <-5500 OMR in the hilo inflow group (Table I-10). A large difference (89%) was also seen for Alternative 1 at the <-5500 OMR in the himed inflow group. These differences may occur because Alternative 1 has different DCC gate operations, and because Alternative 1 does not include OMR management. Other than Alternative 1, all alternatives experience very similar amounts of channel length altered across inflow group and OMR (Figure I-39, Figure I-40, Table I-10).



OMR = Old and Middle River.
See Table I-8 for a description of the inflow groups. The contours identify where there is up to 75% overlap in velocity distribution with and without Central Valley Project exports. Results apply to Alt2woTUCPDeltaVA.

Figure I-36. Faceted Contour Maps Delineating Delta Export Zone of Influence Under Varying Inflows and Old and Middle River Flows



High = <25% proportional overlap; Medium = 25-75% proportional overlap; Low = >75% proportional overlap.
See Table I-8 for a description of the inflow groups.

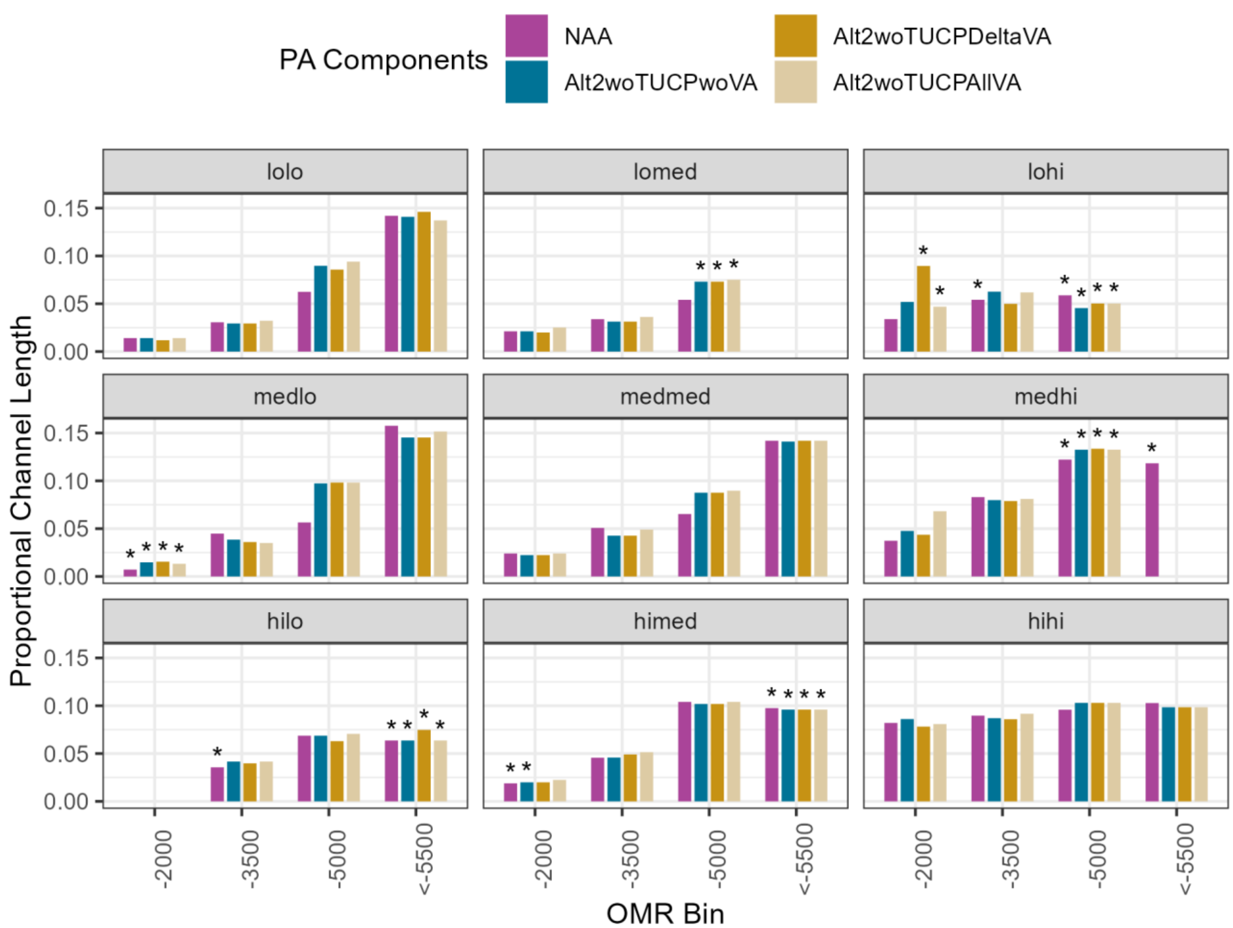
Figure I-37. Proportion of Total Channel Length in the Delta (DSM2 grid) that Experiences High, Medium, and Low Hydrologic Influence Across Inflow Groups, Alternatives, and Old and Middle River Bins

Table I-9. Channel Length (feet) Altered by Pumping for the No Action Alternative and Three Components of the Proposed Action Across Inflow Groups and Old and Middle River Bins

Inflow Group	Old and Middle River Bin	NAA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
lolo	-2000	54189 (0%)	54189 (0%)	45576 (-16%)	54189 (0%)
lolo	-3500	117806 (0%)	113044 (-4%)	113044 (-4%)	124055 (5%)
lolo	-5000	240433 (0%)	345257 (44%)	329891 (37%)	361840 (50%)
lolo	<-5500	546547 (0%)	542342 (-1%)	562344 (3%)	527855 (-3%)
lomed	-2000	81465 (0%)	81465 (0%)	76711 (-6%)	96978 (19%)
lomed	-3500	130344 (0%)	120549 (-8%)	120549 (-8%)	139432 (7%)
lomed	-5000	208217 (0%)	281435 (35%)	281435 (35%)	289043 (39%)
lomed	<-5500	NA	NA	NA	NA
lohi	-2000	130552 (0%)	199749 (53%)	344641 (164%)	180584 (38%)
lohi	-3500	208428 (0%)	241111 (16%)	191942 (-8%)	238045 (14%)
lohi	-5000	226351 (0%)	175053 (-23%)	193470 (-15%)	193470 (-15%)
medlo	-2000	27647 (0%)	56798 (105%)	59520 (115%)	50971 (84%)
medlo	-3500	172490 (0%)	148289 (-14%)	138590 (-20%)	134670 (-22%)
medlo	-5000	217383 (0%)	374670 (72%)	377919 (74%)	377919 (74%)
medlo	<-5500	606560 (0%)	559302 (-8%)	559302 (-8%)	583403 (-4%)
medmed	-2000	92454 (0%)	86009 (-7%)	86009 (-7%)	92454 (0%)
medmed	-3500	195201 (0%)	164174 (-16%)	164174 (-16%)	188699 (-3%)
medmed	-5000	251330 (0%)	337165 (34%)	337165 (34%)	345232 (37%)
medmed	<-5500	546334 (0%)	543002 (-1%)	546334 (0%)	546334 (0%)
medhi	-2000	143735 (0%)	183314 (28%)	167915 (17%)	262475 (83%)
medhi	-3500	319355 (0%)	307325 (-4%)	303468 (-5%)	311986 (-2%)
medhi	-5000	470418 (0%)	510174 (8%)	514154 (9%)	510385 (8%)
medhi	<-5500	455531 (0%)	NA	NA	NA
hilo	-3500	137049 (0%)	160217 (17%)	153086 (12%)	160217 (17%)
hilo	-5000	264382 (0%)	264382 (0%)	242315 (-8%)	271698 (3%)
hilo	<-5500	245068 (0%)	245068 (0%)	287645 (17%)	245068 (0%)
himed	-2000	72558 (0%)	76711 (6%)	76711 (6%)	86402 (19%)
himed	-3500	175651 (0%)	176405 (0%)	188818 (7%)	197951 (13%)
himed	-5000	400448 (0%)	392039 (-2%)	392039 (-2%)	400448 (0%)
himed	<-5500	375420 (0%)	369417 (-2%)	369417 (-2%)	369417 (-2%)

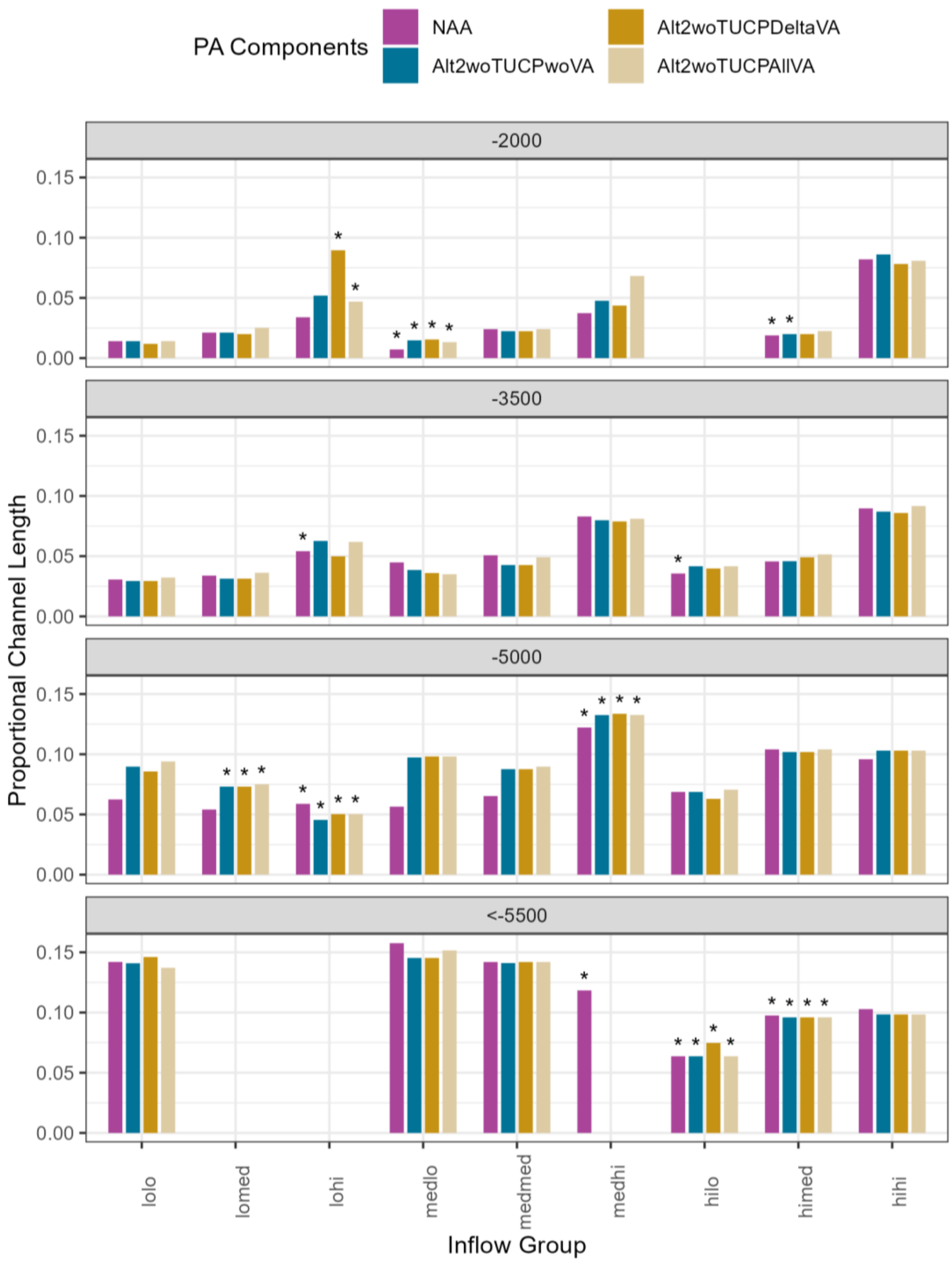
Inflow Group	Old and Middle River Bin	NAA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
hihi	-2000	315738 (0%)	331338 (5%)	300952 (-5%)	311077 (-1%)
hihi	-3500	345153 (0%)	334832 (-3%)	330569 (-4%)	352728 (2%)
hihi	-5000	368941 (0%)	396491 (7%)	396491 (7%)	396491 (7%)
hihi	<-5500	395764 (0%)	378812 (-4%)	378812 (-4%)	378812 (-4%)

See Table I-8 for a description of the inflow groups. Values represent total summed channel length between nodes experiencing 0.25-0.75 proportional overlap, or medium hydrologic influence. Absolute values are rounded.



OMR = Old and Middle River; cfs = cubic feet per second; Medium = 25–75% proportional overlap.
See Table I-8 for a description of the inflow groups. Results are displayed across alternatives. Stars indicate combinations with five or less samples (months).

Figure I-38. Proportion of Total Channel Length in the Delta (DSM2 grid) that Experiences Medium Hydrologic Influence at Standardized Inflow Groups and Across Old and Middle River Bins of -2000, -3500, -5000, and Less Than -5500 cfs



OMR = Old and Middle River; cfs = cubic feet per second; Medium = 25–75% proportional overlap.
See Table I-8 for a description of the inflow groups. Results are displayed across alternatives. Stars indicate combinations with five or less samples (months).

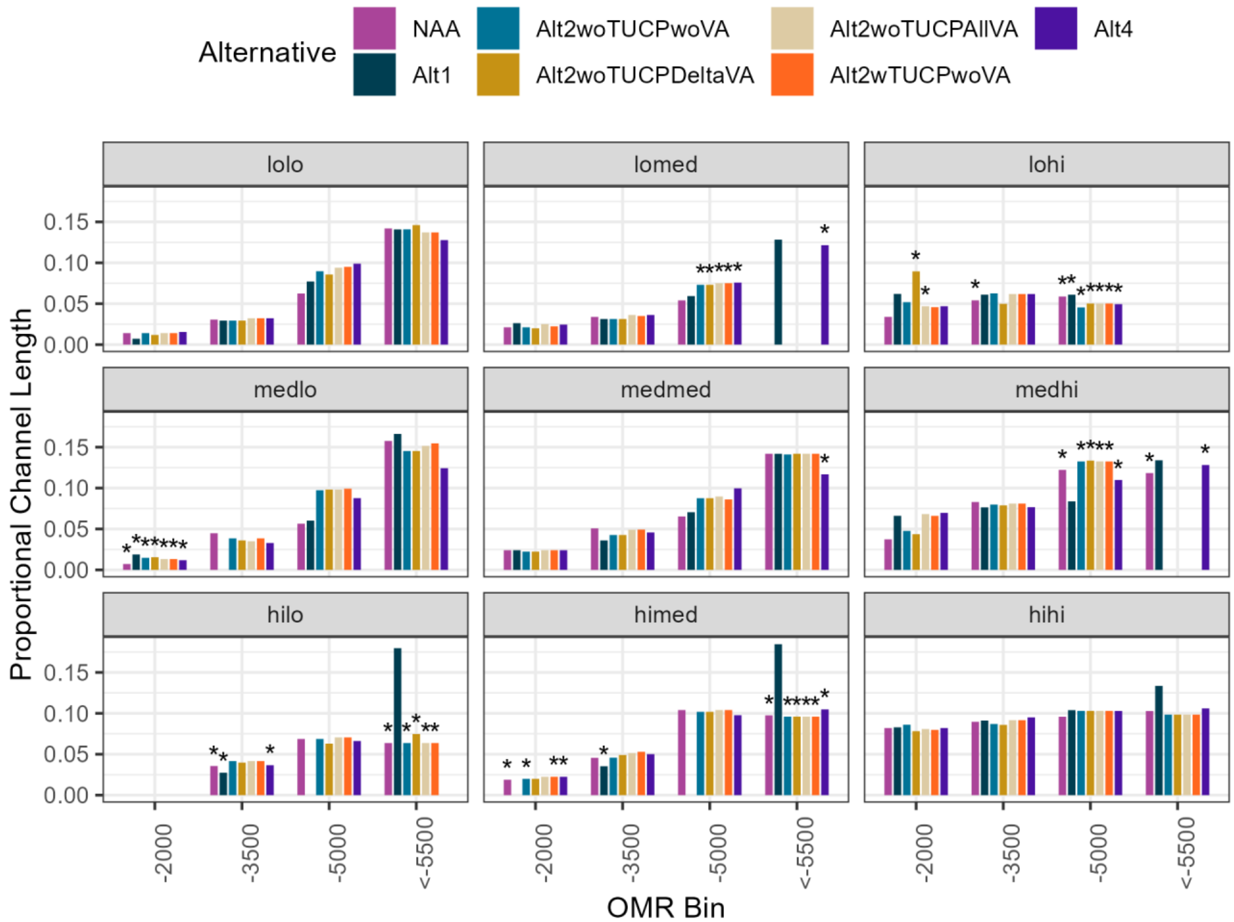
Figure I-39. Proportion of Total Channel Length in the Delta (DSM2 grid) that Experiences Medium Hydrologic Influence at Standardized Inflow Groups and Across Old and Middle River Bins of -2000, -3500, -5000, and Less Than -5500 cfs

Table I-10. Channel Length (feet) Altered by Pumping for the No Action Alternative, Alternative 1, Four Runs of Alternative 2, and Alternative 4 Across Inflow Groups and Old and Middle River Bins

Inflow Group	Old and Middle River Bin	NAA	Alt1	Alt2woTUCP woVA	AltwoTUCP DeltaVA	Alt2woTUCP AllVA	Alt2wTUCP woVA	Alt4
lolo	-2000	54,189 (0%)	27,647 (-49%)	54,189 (0%)	45,576 (-16%)	54,189 (0%)	54,189 (0%)	59,520 (10%)
lolo	-3500	117,806 (0%)	113,044 (-4%)	113,044 (-4%)	113,044 (-4%)	124,055 (5%)	124,055 (5%)	124,055 (5%)
lolo	-5000	240,433 (0%)	297,005 (24%)	345,257 (44%)	329,891 (37%)	361,840 (50%)	365,872 (52%)	380,800 (58%)
lolo	<-5500	546,547 (0%)	541,978 (-1%)	542,342 (-1%)	562,344 (3%)	527,855 (-3%)	527,855 (-3%)	491,719 (-10%)
lomed	-2000	81,465 (0%)	101,000 (24%)	81,465 (0%)	76,711 (-6%)	96,978 (19%)	86,009 (6%)	94,255 (16%)
lomed	-3500	130,344 (0%)	120,549 (-8%)	120,549 (-8%)	120,549 (-8%)	139,432 (7%)	134,670 (3%)	139,432 (7%)
lomed	-5000	208,217 (0%)	228,476 (10%)	281,435 (35%)	281,435 (35%)	289,043 (39%)	289,043 (39%)	291,861 (40%)
lomed	<-5500	NA	493,876 (NA%)	NA	NA	NA	NA	467,873 (NA%)
lohi	-2000	130,552 (0%)	238,535 (83%)	199,749 (53%)	344,641 (164%)	180,584 (38%)	176,161 (35%)	180,584 (38%)
lohi	-3500	208,428 (0%)	235,111 (13%)	241,111 (16%)	191,942 (-8%)	238,045 (14%)	238,045 (14%)	238,045 (14%)
lohi	-5000	226,351 (0%)	234,862 (4%)	175,053 (-23%)	193,470 (-15%)	193,470 (-15%)	193,470 (-15%)	190,404 (-16%)
medlo	-2000	27,647 (0%)	72,558 (162%)	56,798 (105%)	59,520 (115%)	50,971 (84%)	50,971 (84%)	45,576 (65%)
medlo	-3500	172,490 (0%)	NA	148,289 (-14%)	138,590 (-20%)	134,670 (-22%)	148,289 (-14%)	126,424 (-27%)
medlo	-5000	217,383 (0%)	231,821 (7%)	374,670 (72%)	377,919 (74%)	377,919 (74%)	381,951 (76%)	337,552 (55%)
medlo	<-5500	606,560 (0%)	639,690 (5%)	559,302 (-8%)	559,302 (-8%)	583,403 (-4%)	595,220 (-2%)	478,383 (-21%)
medmed	-2000	92,454 (0%)	92,454 (0%)	86,009 (-7%)	86,009 (-7%)	92,454 (0%)	92,454 (0%)	92,454 (0%)
medmed	-3500	195,201 (0%)	138,575 (-29%)	164,174 (-16%)	164,174 (-16%)	188,699 (-3%)	189,671 (-3%)	176,161 (-10%)
medmed	-5000	251,330 (0%)	271,281 (8%)	337,165 (34%)	337,165 (34%)	345,232 (37%)	331,544 (32%)	383,716 (53%)
medmed	<-5500	546,334 (0%)	546,215 (0%)	543,002 (-1%)	546,334 (0%)	546,334 (0%)	546,334 (0%)	449,589 (-18%)
medhi	-2000	143,735 (0%)	254,409 (77%)	183,314 (28%)	167,915 (17%)	262,475 (83%)	254,229 (77%)	268,199 (87%)
medhi	-3500	319,355 (0%)	294,142 (-8%)	307,325 (-4%)	303,468 (-5%)	311,986 (-2%)	311,986 (-2%)	294,946 (-8%)

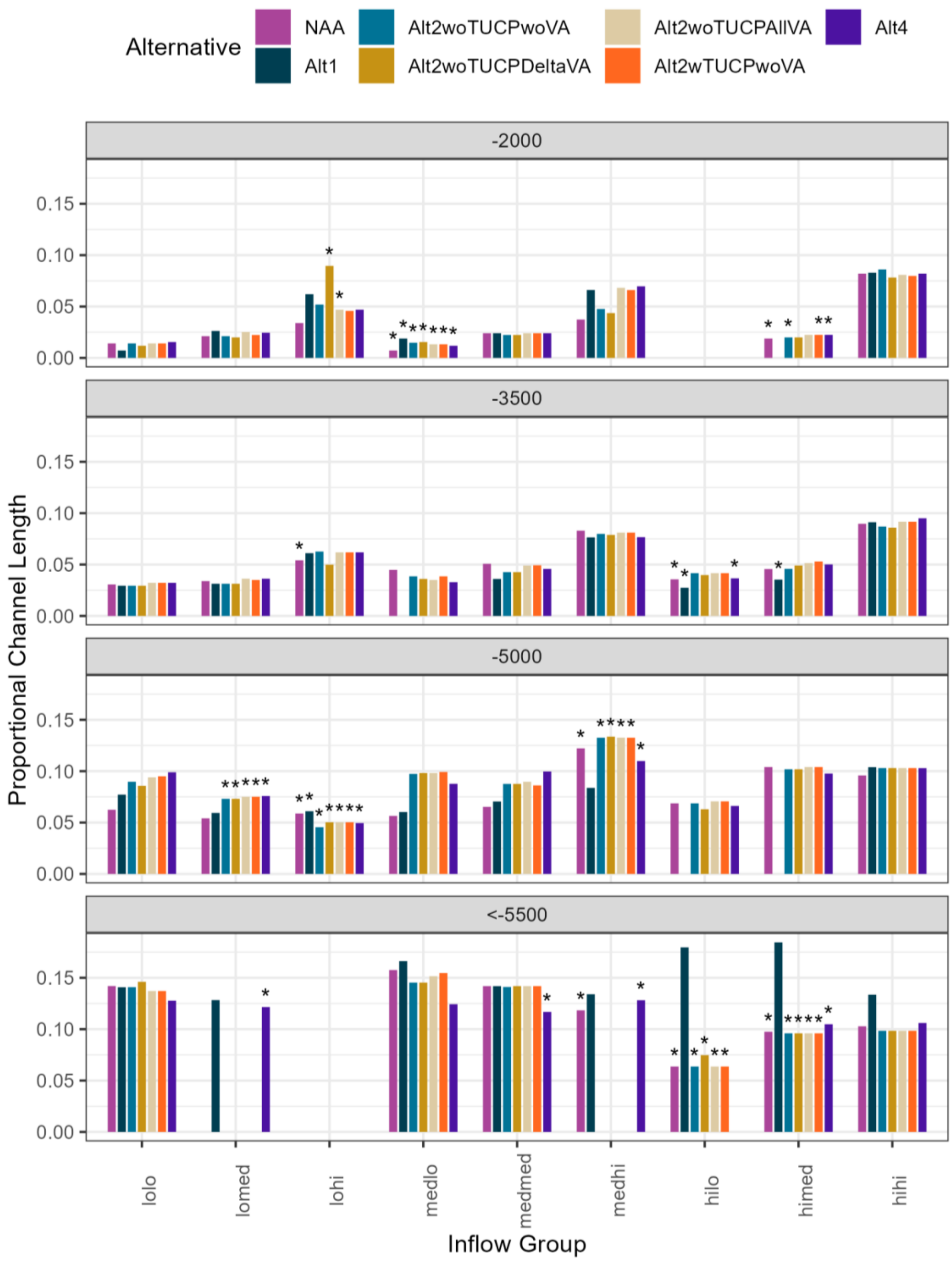
Inflow Group	Old and Middle River Bin	NAA	Alt1	Alt2woTUCP woVA	AltwoTUCP DeltaVA	Alt2woTUCP AllVA	Alt2wTUCP woVA	Alt4
medhi	-5000	470,418 (0%)	322,374 (-31%)	510,174 (8%)	514,154 (9%)	510,385 (8%)	510,174 (8%)	422,974 (-10%)
medhi	<-5500	455,531 (0%)	515,663 (13%)	NA	NA	NA	NA	493344 (8%)
hilo	-3500	137,049 (0%)	105,506 (-23%)	160,217 (17%)	153,086 (12%)	160,217 (17%)	160,217 (17%)	140,818 (3%)
hilo	-5000	264,382 (0%)	NA	264,382 (0%)	242,315 (-8%)	271,698 (3%)	271,698 (3%)	254,721 (-4%)
hilo	<-5500	245,068 (0%)	691,451 (182%)	245,068 (0%)	287,645 (17%)	245,068 (0%)	245,068 (0%)	NA
himed	-2000	72,558 (0%)	NA	76,711 (6%)	76,711 (6%)	86,402 (19%)	86,402 (19%)	86,402 (19%)
himed	-3500	175,651 (0%)	135,964 (-23%)	176,405 (0%)	188,818 (7%)	197,951 (13%)	203,970 (16%)	192,852 (10%)
himed	-5000	400,448 (0%)	NA	392,039 (-2%)	392,039 (-2%)	400,448 (0%)	400,448 (0%)	376,014 (-6%)
himed	<-5500	375,420 (0%)	710,057 (89%)	369,417 (-2%)	369,417 (-2%)	369,417 (-2%)	369,417 (-2%)	403,479 (7%)
hihi	-2000	315,738 (0%)	319,078 (1%)	331,338 (5%)	300,952 (-5%)	311,077 (-1%)	307,097 (-3%)	315,738 (0%)
hihi	-3500	345,153 (0%)	351,039 (2%)	334,832 (-3%)	330,569 (-4%)	352,728 (2%)	352,728 (2%)	365,763 (6%)
hihi	-5000	368,941 (0%)	399,903 (8%)	396,491 (7%)	396,491 (7%)	396,491 (7%)	396,491 (7%)	396,192 (7%)
hihi	<-5500	395,764 (0%)	514,124 (30%)	378,812 (-4%)	378,812 (-4%)	378,812 (-4%)	378,812 (-4%)	408,122 (3%)

See Table I-8 for a description of the inflow groups. Values represent total summed channel length between nodes experiencing 0.25–0.75 proportional overlap, or medium hydrologic influence. Values in parentheses represent percent difference between each alternative and No Action Alternative. Absolute values are rounded.



OMR = Old and Middle River; cfs = cubic feet per second; Medium = 25–75% proportional overlap.
See Table I-8 for a description of the inflow groups. Results are displayed across alternatives. Stars indicate combinations with five or less samples (months).

Figure I-40. Proportion of Total Channel Length in the Delta (DSM2 grid) that Experiences Medium Hydrologic Influence at Standardized Inflow Groups and Across Old and Middle River Flows of -2000, -3500, -5000, and Less Than -5500 cfs



OMR = Old and Middle River; cfs = cubic feet per second; Medium = 25–75% proportional overlap.
See Table I-8 for a description of the inflow groups. Results are displayed across alternatives. Stars indicate combinations with five or less samples (months).

Figure I-41. Proportion of Total Channel Length in the Delta (DSM2 grid) that Experiences Medium Hydrologic Influence at Standardized Inflow Groups and Across Old and Middle River Flows of -2000, -3500, -5000, and Less Than -5500 cfs

I.6.10 Flow Into Junctions

This section will summarize results from Attachment I.10, *Flow Into Junctions Analysis*. This line of evidence was not used in the Initial Alternative Report. Results will provide an evaluation of the fraction of flows entering junctions that may be hydrologically altered under different pumping conditions created by the CVP and SWP exports facilities for each of the alternatives.

I.6.11 Particle Tracking/Fate Modeling

This section will summarize results from Attachment I.8, *Particle Tracking Fate Modeling of Larval Smelt Entrainment*. This line of evidence was used in the Initial Alternative Report. Results will provide an evaluation of the area hydrodynamically influenced by exports for the Proposed Action and each of the alternatives.

I.6.12 ECO-PTM

This section will summarize results from Attachment I.7, *ECO-PTM*. This line of evidence was used in the Initial Alternative Report. Results will provide an evaluation of through-Delta survival influenced by exports for the Proposed Action and each of the alternatives.

I.6.13 STARS Model

This section summarizes results from Attachment I.5, *Survival, Travel time, And Routing Simulation (STARS) Model*. This line of evidence was used in the Initial Alternative Report. Results provide an evaluation of juvenile salmonid through-Delta survival and routing probability for the Proposed Action and each of the alternatives.

Reclamation analyzed monthly CalSim 3 flows for each alternative to evaluate long-term operations (e.g., releases, exports, and DCC gate closures) effects on juvenile salmonids migrating through the Delta. Using inflow groups and a combination of WYT and month, through-Delta survival, travel time through the Delta, and probability of entering the interior Delta was described.

Summarized results for the performance metrics of routing proportions to the Interior Delta migratory survival to Chipps Island (i.e., through-Delta survival) are provided in Table I-11 through Table I-14 and Figure I-42 through Figure I-45 for the EIS (i.e., No Action Alternative, Alternative 1, all four phases of Alternative 2, Alternative 3, and Alternative 4).

Summarized results for the same two performance metrics are provided in Table I-15 through Table I-18 and Figure I-46 through Figure I-49 for the Biological Assessment.

- **Driver of Variation:** The STARS model is responsive to modeled Sacramento River flow at Freeport and daily operations of the DCC gates, both obtained from CalSim 3.
- **Calibration and Calibration Period:** The STARS model was calibrated to data obtained from acoustically tagged late-fall-run, hatchery Chinook salmon smolts released from 2007 and 2011.

- **Uncertainties:** The STARS model assumes only Sacramento River flow and operations of the DCC gates affect through-Delta routing and survival, but other factors including exports, OMR, and inflow from the San Joaquin have the potential to influence both. Additionally, STARS was calibrated using data from hatchery fish and may not fully represent realized behavior of natural-origin juveniles. For additional uncertainties, refer to Attachment I.5.
- **Explanation of Performance Measures:** Relevant fish performance metrics from STARS include the proportion of migrating juvenile Chinook salmon routed to the Interior Delta (i.e., through either the DCC or Georgiana Slough) and overall migratory survival through the Delta to Chipps Island.

Mean Interior Delta routing proportions for unique combinations WYT and month had a narrow range, from a low of 0.206 (Alternative 3) to a high 0.240 (No Action Alternative). The greatest expected proportions occurred in December or April, depending on WYT, and proportions were lowest and least variable across water years in February. Fewer Chinook salmon can be expected to be routed to the Interior Delta in above normal and wet water years than below normal, dry, or critical water years. Lower proportions of fish routed to the Interior Delta in February were accompanied by the highest expected Delta inflows from the Sacramento River, and higher routing proportions in December and April were associated with lower Delta inflows (Appendix B, *Water Operations and Ecosystem Analyses*). Alternative 1 resulted in increased proportions of fish routed to the Interior Delta relative to the No Action Alternative, particularly in December and January (6.0 and 13.6% increases in routing). Alternative 3 resulted in slightly decreased proportions of routed fish (between 0.5 and 3.4% decreases in routing), and Alternative 4 resulted in no meaningful changes in fish routing proportions. The four components of Alternative 2 generally resulted in decreased routing to the Interior Delta across months, although Alt2wTUCPwoVA resulted in the smallest changes (between -0.5 and 0.3% percent differences relative the No Action Alternative). The Alternative 1 was the only alternative with DCC operations meeting D-1641 requirements only.

Proportions of migrating juvenile Chinook salmon routed to the Interior Delta varied across inflow groups (i.e., ranging from low Sacramento River inflow and low San Joaquin River inflow, or lolo, to high Sacramento and San Joaquin River inflow, or hihi; Attachment I.3, *Delta Export Zone of Influence Analysis*). The lowest and least variable routing proportions across water years occurred for inflow groups with high Sacramento River inflow (i.e., hilo, himed, hihi). Across all different inflow groups, the Alternative 1 alternative generally resulted in greater proportions of fish routed to the Interior Delta than the No Action Alternative (between -1.0 and 14.4% differences relative to the No Action Alternative). The four components of Alternative 2 generally resulted in decreased routing to the Interior Delta under low Sacramento River inflow and increased routing for moderate and high inflow, although differences relative to the No Action Alternative were small. The Alternative 3 and Alternative 4 resulted in no consistent changes in routing proportions within inflow groups.

The mean overall survival of migrating juvenile Chinook salmon migrating through the Delta, calculated across all WYTs for each month and alternative, had a wider range, from a low of 0.470 (Alternative 1) to a high 0.583 (Alternative 3). The greatest expected survival values occurred in January, February, and March, which corresponded to months with greater Delta inflows. Greater survival is expected in above normal and wet water years than below normal, dry, or critical water years. The Alternative 1 resulted in variable but generally decreased fish survival relative to the No Action Alternative, particularly in December and January (2.6 and 7.6% decreases in survival). Alternative 3 resulted in consistently higher survival (between 0.7 and 3.5% increases in survival) and Alternative 4 showed no meaningful changes in survival. The four components generally resulted in increased survival relative to the No Action Alternative, with Alt2woTUCPwoVA resulting in the most consistent increased survival relative to the No Action Alternative (between 0 and 1.2% increases in survival), although differences were small. Again, the Alternative 1 was the only alternative with DCC operations meeting D-1641 requirements only.

Mean overall survival also varied among inflow groups. The highest survival values occurred for inflow groups with high Sacramento River inflow (i.e., hilo, himed, hihi). Across all differ inflow groups, the Alternative 1 alternative generally resulted in more variable and lower survival than the No Action Alternative (between -9.8 and 1.4% differences relative to the No Action Alternative). The four components of Alternative 2 generally resulted in increased survival under low Sacramento River inflow and decreased survival for moderate and high inflow, relative to the No Action Alternative, although differences relative to the No Action Alternative were small. The Alternative 3 and Alternative 4 resulted in no consistent changes in survival within inflow groups.

Table I-11. Predicted Mean Proportion of Particles Routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), Averaged by Water Year Type and Month

Water Year Type	Month	NAA	Alt1	Alt2 wTUCP wo VA	Alt2 woTUCP wo VA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	1	0.218	0.232 (6.0)	0.217 (-0.5)	0.218 (-0.1)	0.219 (0.1)	0.219 (0.2)	0.216 (-1.1)	0.218 (0.0)
All	2	0.207	0.207 (-0.3)	0.208 (0.3)	0.207 (-0.0)	0.208 (0.2)	0.207 (0.1)	0.206 (-0.5)	0.207 (0.0)
All	3	0.215	0.215 (-0.2)	0.216 (0.0)	0.214 (-0.6)	0.214 (-0.6)	0.214 (-0.8)	0.211 (-1.9)	0.216 (0.0)
All	4	0.240	0.236 (-1.5)	0.239 (-0.3)	0.236 (-1.7)	0.236 (-1.4)	0.231 (-3.7)	0.232 (-3.4)	0.239 (-0.3)
All	12	0.235	0.267 (13.6)	0.234 (-0.2)	0.235 (0.0)	0.235 (0.2)	0.235 (0.2)	0.233 (-1.0)	0.235 (0.0)
W	1	0.187	0.188 (0.7)	0.187 (0.1)	0.187 (-0.1)	0.187 (0.0)	0.187 (0.0)	0.186 (-0.4)	0.187 (0.0)

Water Year Type	Month	NAA	Alt1	Alt2 wTUCP wo VA	Alt2 woTUCP wo VA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
W	2	0.182	0.182 (0.0)	0.182 (0.1)	0.182 (0.0)	0.182 (0.0)	0.182 (0.0)	0.181 (-0.3)	0.181 (-0.1)
W	3	0.187	0.187 (0.0)	0.187 (-0.1)	0.187 (-0.1)	0.187 (-0.2)	0.187 (-0.2)	0.187 (-0.4)	0.187 (-0.1)
W	4	0.199	0.201 (0.7)	0.199 (-0.1)	0.199 (-0.1)	0.199 (-0.1)	0.198 (-0.4)	0.195 (-2.2)	0.199 (-0.1)
W	12	0.196	0.205 (4.6)	0.196 (-0.2)	0.196 (-0.2)	0.196 (0.1)	0.196 (0.0)	0.193 (-1.6)	0.196 (0.0)
AN	1	0.197	0.202 (2.6)	0.196 (-0.4)	0.196 (-0.2)	0.197 (-0.1)	0.197 (0.1)	0.194 (-1.2)	0.197 (-0.1)
AN	2	0.190	0.189 (-0.8)	0.191 (0.2)	0.190 (-0.1)	0.190 (0.1)	0.191 (0.2)	0.187 (-1.8)	0.190 (-0.3)
AN	3	0.187	0.188 (0.2)	0.187 (-0.4)	0.187 (-0.2)	0.187 (-0.4)	0.187 (-0.3)	0.184 (-1.7)	0.186 (-0.6)
AN	4	0.219	0.220 (0.3)	0.219 (0.0)	0.219 (-0.1)	0.220 (0.2)	0.214 (-2.4)	0.207 (-5.5)	0.218 (-0.3)
AN	12	0.233	0.264 (13.3)	0.233 (0.2)	0.233 (0.1)	0.234 (0.4)	0.234 (0.5)	0.230 (-1.2)	0.235 (0.8)
BN	1	0.217	0.228 (5.1)	0.217 (-0.1)	0.216 (-0.2)	0.218 (0.4)	0.218 (0.4)	0.213 (-1.8)	0.217 (-0.1)
BN	2	0.206	0.206 (-0.4)	0.206 (0.0)	0.207 (0.1)	0.207 (0.4)	0.206 (-0.3)	0.206 (-0.2)	0.206 (-0.1)
BN	3	0.211	0.210 (-0.8)	0.211 (-0.2)	0.211 (0.0)	0.211 (0.1)	0.211 (-0.2)	0.205 (-2.8)	0.212 (0.1)
BN	4	0.236	0.237 (0.3)	0.235 (-0.4)	0.235 (-0.4)	0.237 (0.2)	0.227 (-4.1)	0.224 (-5.2)	0.236 (0.1)
BN	12	0.251	0.295 (17.6)	0.252 (0.4)	0.253 (0.8)	0.251 (0.4)	0.252 (0.6)	0.251 (0.1)	0.253 (1.0)
D	1	0.244	0.269 (10.5)	0.244 (0.1)	0.244 (0.1)	0.244 (0.2)	0.244 (0.1)	0.242 (-0.6)	0.245 (0.5)
D	2	0.225	0.223 (-0.9)	0.225 (0.1)	0.225 (0.1)	0.224 (-0.2)	0.225 (0.1)	0.221 (-1.4)	0.224 (-0.4)
D	3	0.234	0.236 (0.8)	0.235 (0.2)	0.233 (-0.6)	0.233 (-0.5)	0.232 (-0.8)	0.225 (-3.8)	0.235 (0.2)
D	4	0.260	0.258 (-0.7)	0.260 (0.0)	0.259 (-0.2)	0.262 (0.7)	0.252 (-3.1)	0.254 (-2.1)	0.260 (0.1)
D	12	0.247	0.291 (18.0)	0.245 (-0.6)	0.246 (-0.4)	0.247 (0.0)	0.247 (-0.1)	0.243 (-1.6)	0.246 (-0.2)

Water Year Type	Month	NAA	Alt1	Alt2 wTUCP wo VA	Alt2 woTUCP wo VA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
C	1	0.263	0.291 (10.5)	0.257 (-2.4)	0.263 (-0.3)	0.264 (0.1)	0.265 (0.6)	0.258 (-2.2)	0.262 (-0.4)
C	2	0.246	0.247 (0.3)	0.249 (1.1)	0.245 (-0.4)	0.248 (0.7)	0.247 (0.4)	0.248 (0.6)	0.249 (1.0)
C	3	0.270	0.267 (-1.3)	0.272 (0.6)	0.265 (-1.9)	0.265 (-1.9)	0.264 (-2.3)	0.267 (-1.1)	0.271 (0.2)
C	4	0.309	0.285 (-7.5)	0.306 (-0.9)	0.285 (-7.7)	0.285 (-7.6)	0.282 (-8.7)	0.298 (-3.5)	0.305 (-1.1)
C	12	0.274	0.318 (16.1)	0.272 (-0.3)	0.273 (-0.3)	0.275 (0.3)	0.274 (0.3)	0.273 (-0.3)	0.269 (-1.7)

W = wet; AN = above normal; BN = below normal; D = dry; C = critical.
Parentheses indicate % difference from NAA (negative values indicate a decrease in routing to the Interior Delta, which is considered beneficial).

Table I-12. Predicted Mean Proportion of Particles Routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), Averaged by Inflow Grouping

Inflow Group	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	0.223	0.231 (3.6)	0.223 (-0.1)	0.222 (-0.5)	0.222 (-0.3)	0.221 (-0.8)	0.220 (-1.6)	0.223 (-0.1)
lolo	0.279	0.311 (11.3)	0.279 (-0.3)	0.278 (-0.7)	0.278 (-0.6)	0.279 (-0.2)	0.278 (-0.5)	0.278 (-0.5)
lomed	0.279	0.278 (-0.4)	0.280 (0.4)	0.274 (-1.8)	0.274 (-1.7)	0.272 (-2.7)	0.270 (-3.1)	0.280 (0.3)
lohi	0.276	0.273 (-1.0)	0.274 (-0.6)	0.272 (-1.2)	0.274 (-0.6)	0.277 (0.5)	0.282 (2.4)	0.272 (-1.3)
medlo	0.231	0.264 (14.4)	0.234 (1.3)	0.234 (1.2)	0.233 (1.1)	0.235 (1.8)	0.232 (0.5)	0.232 (0.5)
medmed	0.229	0.236 (3.2)	0.229 (0.1)	0.230 (0.4)	0.229 (0.1)	0.229 (-0.1)	0.228 (-0.5)	0.229 (0.2)
medhi	0.230	0.230 (-0.1)	0.230 (-0.1)	0.230 (-0.1)	0.230 (0.0)	0.229 (-0.5)	0.224 (-2.7)	0.230 (-0.2)
hilo	0.192	0.194 (1.1)	0.193 (0.4)	0.193 (0.6)	0.194 (1.2)	0.193 (0.6)	0.191 (-0.5)	0.193 (0.6)
himed	0.188	0.189 (0.3)	0.189 (0.5)	0.189 (0.5)	0.189 (0.3)	0.189 (0.3)	0.190 (0.7)	0.189 (0.3)
hihi	0.182	0.182 (0.0)	0.182 (0.1)	0.182 (0.0)	0.182 (0.0)	0.182 (0.0)	0.182 (-0.1)	0.182 (0.1)

Parentheses indicate % difference from NAA (negative values indicate a decrease in routing to the Interior Delta, which is considered beneficial). The Inflow Grouping ‘All’ excludes water year and month combinations that did not map into the listed inflow groupings and the values may differ from those reported in Table I-11.

Table I-13. Predicted Through-Delta Survival of Particles Across All Routes, Averaged by Water Year Type and Month

Water Year Type	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	1	0.550	0.536 (-2.6)	0.552 (0.4)	0.551 (0.1)	0.550 (0.0)	0.549 (-0.1)	0.556 (1.2)	0.550 (0.1)
All	2	0.579	0.581 (0.3)	0.579 (-1.1)	0.580 (0.1)	0.579 (-0.1)	0.579 (0.0)	0.583 (0.7)	0.579 (0.0)
All	3	0.558	0.559 (0.0)	0.558 (-0.1)	0.560 (0.3)	0.560 (0.2)	0.561 (0.4)	0.568 (1.7)	0.558 (0.0)
All	4	0.499	0.504 (1.0)	0.500 (0.2)	0.505 (1.2)	0.504 (0.9)	0.514 (3.0)	0.517 (3.5)	0.500 (0.3)
All	12	0.509	0.470 (-7.6)	0.510 (0.2)	0.509 (0.0)	0.508 (-0.1)	0.508 (-0.1)	0.517 (1.5)	0.509 (0.0)
W	1	0.644	0.644 (0.0)	0.645 (0.1)	0.645 (0.1)	0.644 (0.0)	0.644 (0.0)	0.649 (0.7)	0.645 (0.1)
W	2	0.664	0.664 (0.0)	0.664 (0.0)	0.664 (0.0)	0.664 (0.0)	0.664 (0.0)	0.665 (0.2)	0.664 (0.0)
W	3	0.643	0.642 (-0.1)	0.643 (0.0)	0.643 (0.0)	0.643 (0.0)	0.643 (0.0)	0.645 (0.3)	0.643 (0.0)
W	4	0.600	0.598 (0.5)	0.601 (0.0)	0.601 (0.0)	0.601 (0.0)	0.603 (0.4)	0.613 (2.0)	0.601 (0.0)
W	12	0.606	0.597 (-1.6)	0.607 (0.2)	0.607 (0.2)	0.607 (0.1)	0.607 (0.2)	0.619 (2.0)	0.607 (0.1)
AN	1	0.605	0.601 (-0.8)	0.607 (0.2)	0.606 (0.2)	0.606 (0.1)	0.607 (0.2)	0.612 (1.1)	0.607 (0.2)
AN	2	0.628	0.632 (0.6)	0.629 (0.1)	0.629 (0.1)	0.628 (0.0)	0.628 (0.0)	0.637 (1.5)	0.629 (0.1)
AN	3	0.635	0.632 (-0.4)	0.635 (0.1)	0.634 (-0.1)	0.633 (-0.2)	0.633 (-0.2)	0.643 (1.3)	0.635 (0.1)
AN	4	0.535	0.534 (-0.1)	0.535 (0.0)	0.535 (0.0)	0.534 (-0.2)	0.547 (2.4)	0.565 (5.7)	0.535 (0.1)
AN	12	0.506	0.469 (-7.3)	0.505 (-0.2)	0.505 (-0.2)	0.504 (-0.4)	0.504 (-0.4)	0.515 (1.7)	0.503 (-0.6)
BN	1	0.539	0.528 (-2.0)	0.541 (0.3)	0.540 (0.3)	0.538 (-0.2)	0.538 (-0.1)	0.550 (2.0)	0.540 (0.2)
BN	2	0.574	0.577 (0.5)	0.575 (0.2)	0.574 (0.1)	0.574 (-0.1)	0.576 (0.3)	0.578 (0.8)	0.575 (0.3)

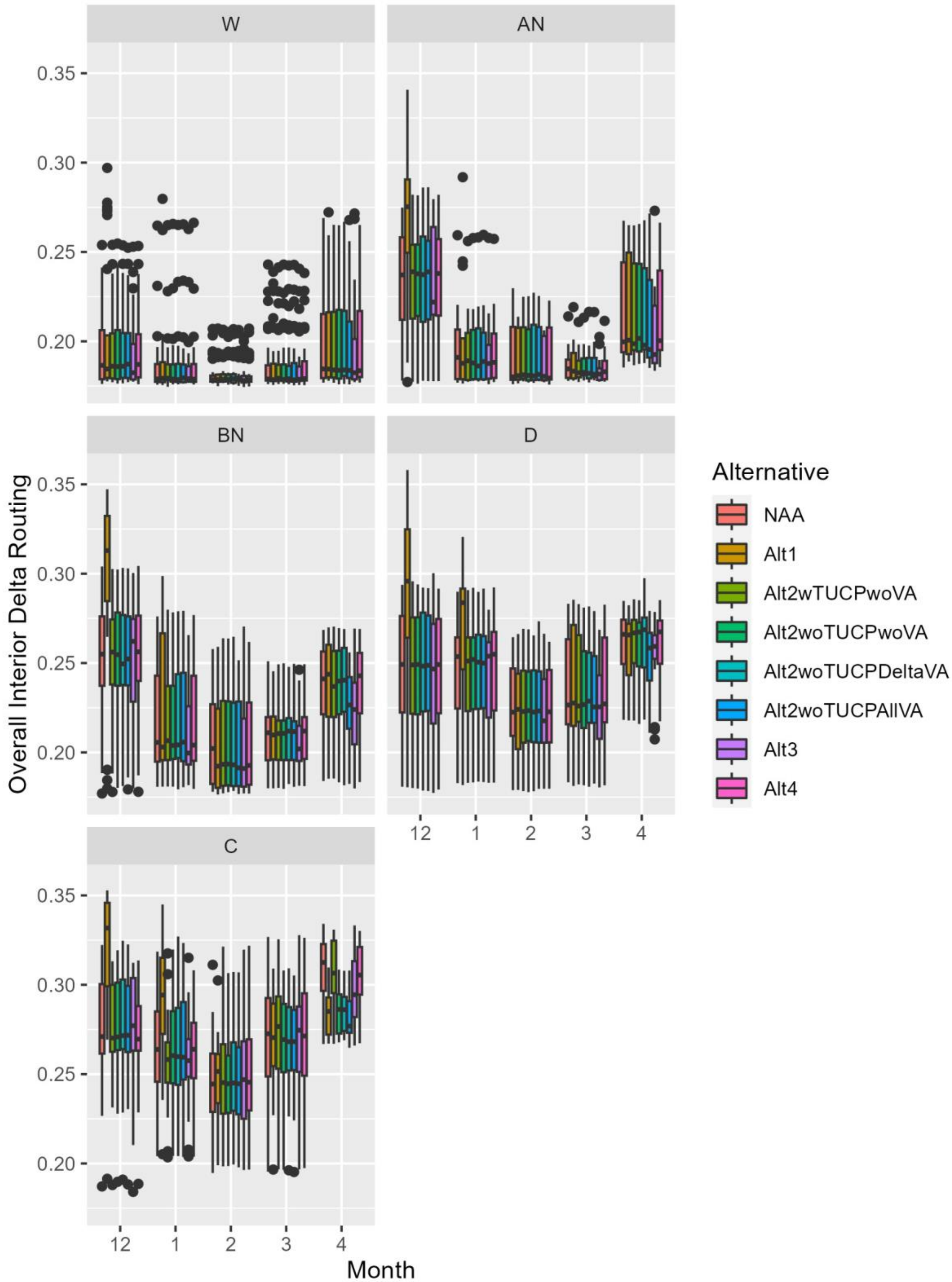
Water Year Type	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
BN	3	0.550	0.554 (0.9)	0.550 (0.1)	0.550 (0.1)	0.550 (0.0)	0.551 (0.2)	0.568 (3.3)	0.550 (0.1)
BN	4	0.491	0.490 (0.0)	0.492 (0.3)	0.492 (0.2)	0.490 (-0.2)	0.510 (4.0)	0.518 (5.6)	0.491 (0.1)
BN	12	0.468	0.415 (-11.4)	0.467 (-0.3)	0.465 (-0.7)	0.466 (-0.4)	0.466 (-0.5)	0.470 (0.4)	0.464 (-0.9)
D	1	0.476	0.447 (-6.2)	0.477 (0.1)	0.477 (0.1)	0.477 (0.1)	0.477 (0.0)	0.480 (0.7)	0.475 (-0.3)
D	2	0.519	0.524 (1.0)	0.519 (0.1)	0.519 (0.1)	0.520 (0.2)	0.519 (0.0)	0.526 (1.5)	0.521 (0.4)
D	3	0.499	0.496 (-0.7)	0.498 (-0.2)	0.501 (0.4)	0.501 (0.3)	0.503 (0.7)	0.517 (3.5)	0.498 (-0.2)
D	4	0.442	0.446 (0.8)	0.442 (0.0)	0.443 (0.2)	0.440 (-0.5)	0.456 (3.2)	0.453 (2.5)	0.443 (0.1)
D	12	0.474	0.417 (-12.1)	0.476 (0.4)	0.475 (0.3)	0.474 (0.0)	0.474 (0.1)	0.484 (2.0)	0.473 (-0.1)
C	1	0.441	0.410 (-7.1)	0.450 (2.0)	0.442 (0.2)	0.441 (-0.1)	0.438 (-0.6)	0.450 (1.9)	0.443 (0.5)
C	2	0.471	0.468 (-0.7)	0.467 (-0.9)	0.472 (0.2)	0.468 (-0.6)	0.468 (-0.6)	0.469 (-0.4)	0.467 (0.8)
C	3	0.430	0.434 (0.8)	0.427 (-0.7)	0.437 (1.7)	0.437 (1.6)	0.439 (2.0)	0.434 (1.0)	0.429 (-0.3)
C	4	0.369	0.401 (8.9)	0.373 (1.3)	0.402 (8.9)	0.401 (8.7)	0.406 (10.1)	0.383 (4.0)	0.374 (1.6)
C	12	0.425	0.372 (-12.5)	0.428 (0.7)	0.426 (0.1)	0.424 (-0.3)	0.424 (-0.4)	0.428 (0.7)	0.431 (1.4)

W = wet; AN = above normal; BN = below normal; D = dry; C = critical.
Parentheses indicate % difference from NAA (negative values indicate a decrease in survival).

Table I-14. Predicted Through-Delta Survival Across All Routes, Averaged by Inflow Grouping

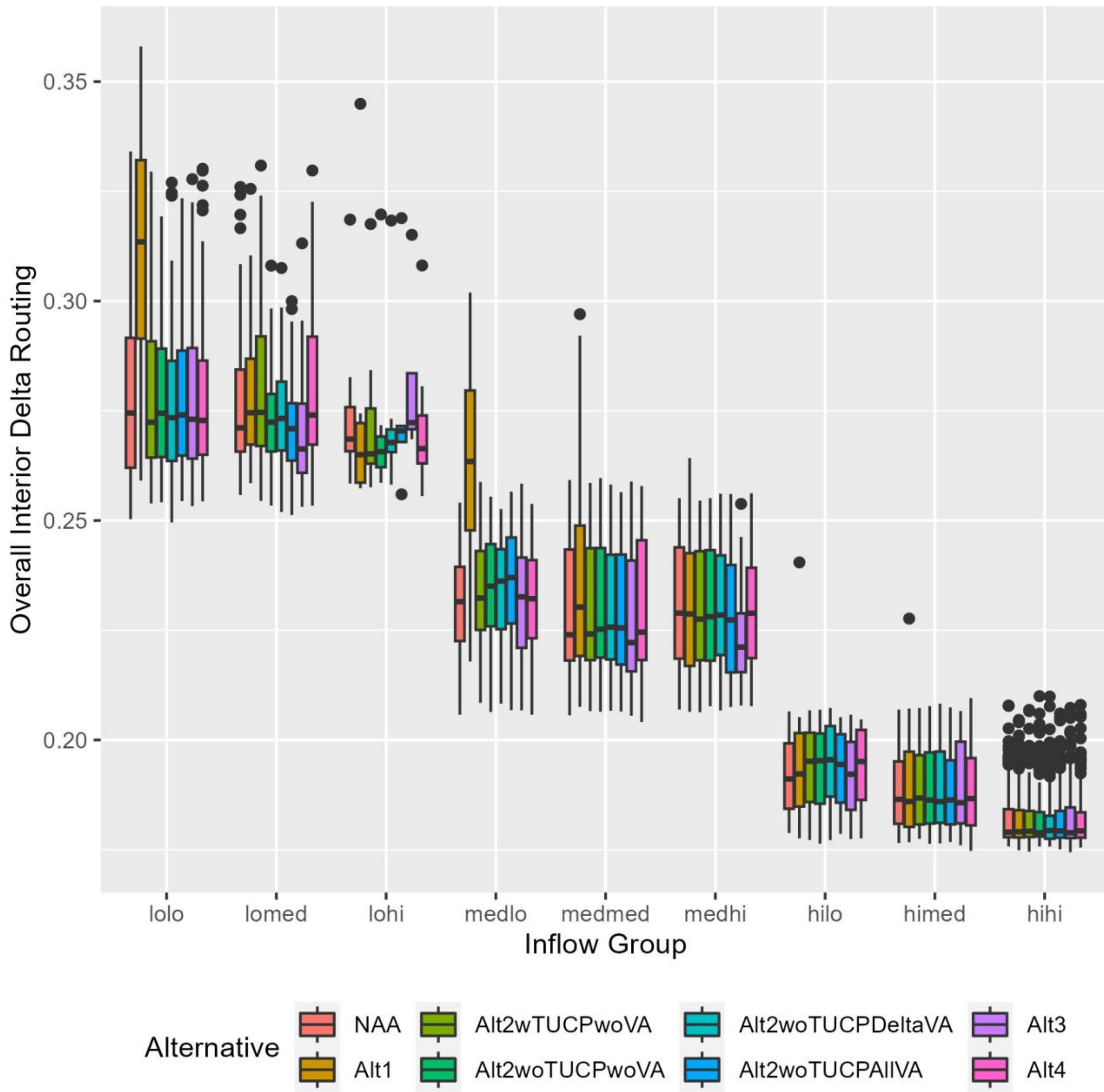
Inflow Group	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	0.539	0.530 (-1.7)	0.540 (0.1)	0.541 (0.3)	0.540 (0.2)	0.542 (0.6)	0.548 (1.7)	0.539 (0.1)
lolo	0.411	0.374 (-9.0)	0.412 (0.3)	0.413 (0.6)	0.413 (0.6)	0.411 (0.1)	0.413 (0.5)	0.413 (0.5)
lomed	0.410	0.414 (0.8)	0.409 (-0.4)	0.418 (1.8)	0.417 (1.7)	0.422 (2.8)	0.424 (3.2)	0.409 (-0.2)
lohi	0.416	0.422 (1.4)	0.418 (0.4)	0.420 (0.9)	0.419 (0.6)	0.414 (-0.5)	0.407 (-2.1)	0.420 (0.9)
medlo	0.498	0.449 (-9.8)	0.491 (-1.3)	0.491 (-1.2)	0.492 (-1.1)	0.489 (-1.7)	0.495 (-0.5)	0.495 (-0.6)
medmed	0.502	0.492 (-1.9)	0.500 (-0.3)	0.499 (-0.5)	0.501 (-0.2)	0.502 (0.0)	0.504 (0.5)	0.501 (-0.2)
medhi	0.499	0.501 (0.6)	0.499 (0.1)	0.499 (0.1)	0.499 (0.0)	0.501 (0.5)	0.512 (2.7)	0.499 (0.2)
hilo	0.608	0.604 (-0.8)	0.604 (-0.7)	0.604 (-0.8)	0.601 (-1.2)	0.604 (-0.7)	0.611 (0.5)	0.604 (-0.7)
himed	0.625	0.624 (-0.2)	0.621 (-0.6)	0.621 (-0.7)	0.622 (-0.5)	0.623 (-0.3)	0.619 (-0.9)	0.623 (-0.3)
hihi	0.657	0.657 (0.0)	0.657 (0.0)	0.657 (0.0)	0.657 (0.0)	0.656 (-0.1)	0.658 (0.1)	0.656 (-0.1)

Parentheses indicate % difference from NAA (negative values indicate a decrease in survival). The Inflow Grouping ‘All’ excludes water year and month combinations that did not map into the listed inflow groupings and the values may differ from those reported in Table I-13.



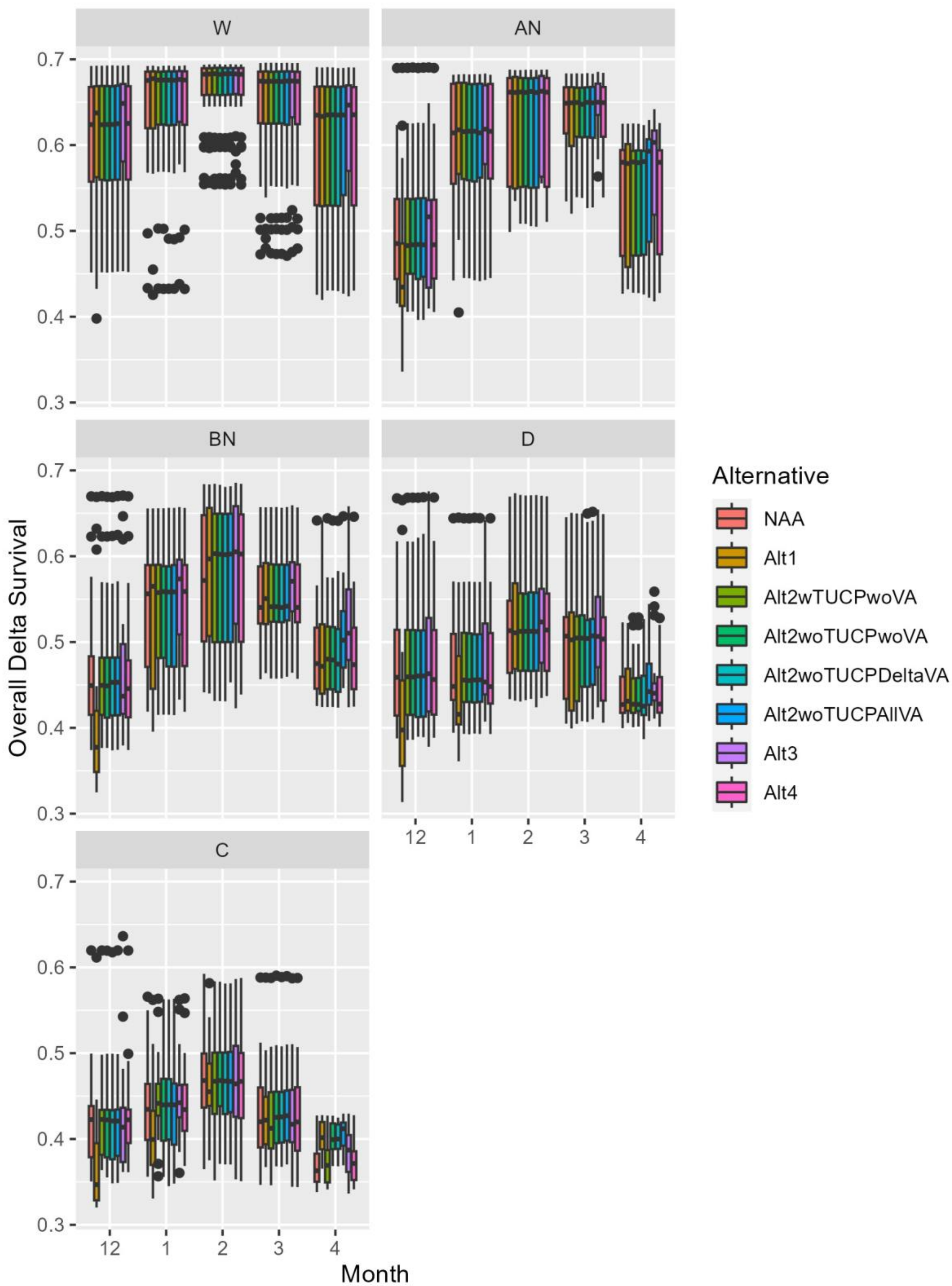
The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-42. Boxplots of Predicted Routing Proportions to the Interior Delta, Separated by Water Year Type



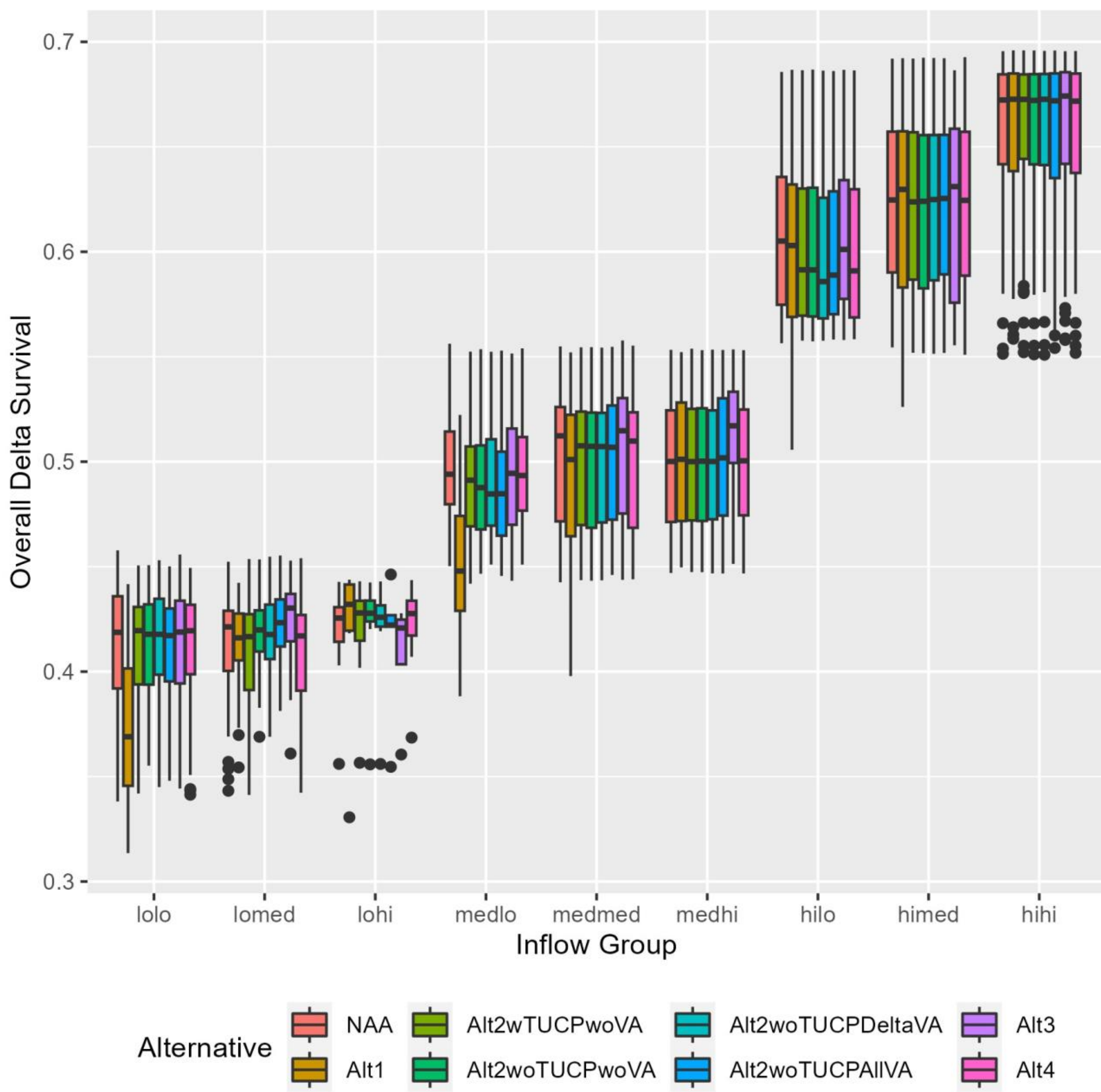
The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-43. Boxplots of Predicted Routing Proportions to the Interior Delta, Separated by Inflow Grouping



The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-44. Boxplots of Predicted Mean Survival Across All Routes, Separated by Water Year Type



The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-45. Boxplots of Predicted Mean Survival Across All Routes, Separated by Inflow Grouping

Table I-15. Predicted Proportion of Particles Routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), Averaged by Water Year Type and Month

Water Year Type	Month	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
All	1	0.212	0.216	0.218	0.217	0.218	0.219	0.219
All	2	0.199	0.207	0.207	0.208	0.207	0.208	0.207
All	3	0.199	0.213	0.215	0.216	0.214	0.214	0.214
All	4	0.220	0.247	0.240	0.239	0.236	0.236	0.231
All	12	0.230	0.220	0.235	0.234	0.235	0.235	0.235
W	1	0.184	0.185	0.187	0.187	0.187	0.187	0.187
W	2	0.180	0.181	0.182	0.182	0.182	0.182	0.182
W	3	0.182	0.188	0.187	0.187	0.187	0.187	0.187
W	4	0.187	0.201	0.199	0.199	0.199	0.199	0.198
W	12	0.189	0.187	0.196	0.196	0.196	0.196	0.196
AN	1	0.190	0.192	0.197	0.196	0.196	0.197	0.197
AN	2	0.183	0.185	0.190	0.191	0.190	0.190	0.191
AN	3	0.180	0.184	0.187	0.187	0.187	0.187	0.187
AN	4	0.193	0.219	0.219	0.219	0.219	0.220	0.214
AN	12	0.223	0.211	0.233	0.233	0.233	0.234	0.234
BN	1	0.204	0.210	0.217	0.217	0.216	0.218	0.218
BN	2	0.199	0.206	0.206	0.206	0.207	0.207	0.206
BN	3	0.191	0.205	0.211	0.211	0.211	0.211	0.211
BN	4	0.205	0.242	0.236	0.235	0.235	0.237	0.227
BN	12	0.251	0.230	0.251	0.252	0.253	0.251	0.252
D	1	0.234	0.241	0.244	0.244	0.244	0.244	0.244
D	2	0.209	0.222	0.225	0.225	0.225	0.224	0.225
D	3	0.207	0.228	0.234	0.235	0.233	0.233	0.232
D	4	0.239	0.283	0.260	0.260	0.259	0.262	0.252
D	12	0.238	0.228	0.247	0.245	0.246	0.247	0.247
C	1	0.265	0.265	0.263	0.257	0.263	0.264	0.265
C	2	0.234	0.252	0.246	0.249	0.245	0.248	0.247
C	3	0.246	0.273	0.270	0.272	0.265	0.265	0.264
C	4	0.295	0.314	0.309	0.306	0.285	0.285	0.282
C	12	0.279	0.268	0.274	0.272	0.273	0.275	0.274

W = wet; AN = above normal; BN = below normal; D = dry; C = critical.

Table I-16. Predicted Mean Proportion of Particles Routed to the Interior Delta (i.e., via either Georgiana Slough or Delta Cross Channel), Averaged by Inflow Grouping

Inflow Group	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
All	0.212	0.221	0.223	0.223	0.222	0.222	0.221
lolo	0.283	0.284	0.279	0.279	0.278	0.278	0.279
lomed	0.292	0.281	0.279	0.280	0.274	0.274	0.272
lohi	NA	0.272	0.276	0.274	0.272	0.274	0.277
medlo	0.234	0.232	0.231	0.234	0.234	0.233	0.235
medmed	0.234	0.224	0.229	0.229	0.230	0.229	0.229
medhi	0.220	0.226	0.230	0.230	0.230	0.230	0.229
hilo	0.193	0.193	0.192	0.193	0.193	0.194	0.193
himed	0.189	0.189	0.188	0.189	0.189	0.189	0.189
hihi	0.181	0.182	0.182	0.182	0.182	0.182	0.182

The Inflow Grouping 'All' excludes water year and month combinations that did not map into the listed inflow groupings and the values may differ from those reported in Table I-15.

Table I-17. Predicted Survival of Particles Across All Routes, Averaged by Water Year Type and Month

Water Year Type	Month	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
All	1	0.571	0.560	0.550	0.552	0.551	0.550	0.549
All	2	0.605	0.584	0.579	0.579	0.580	0.579	0.579
All	3	0.603	0.567	0.558	0.558	0.560	0.560	0.561
All	4	0.551	0.489	0.499	0.500	0.505	0.504	0.514
All	12	0.527	0.549	0.509	0.510	0.509	0.508	0.508
W	1	0.657	0.652	0.644	0.645	0.645	0.644	0.644
W	2	0.672	0.665	0.664	0.664	0.664	0.664	0.664
W	3	0.661	0.642	0.643	0.643	0.643	0.643	0.643
W	4	0.643	0.598	0.600	0.601	0.601	0.601	0.603
W	12	0.630	0.642	0.606	0.607	0.607	0.607	0.607
AN	1	0.630	0.620	0.605	0.607	0.606	0.606	0.607
AN	2	0.654	0.644	0.628	0.629	0.629	0.628	0.628
AN	3	0.664	0.646	0.635	0.635	0.634	0.633	0.633
AN	4	0.611	0.538	0.535	0.535	0.535	0.534	0.547

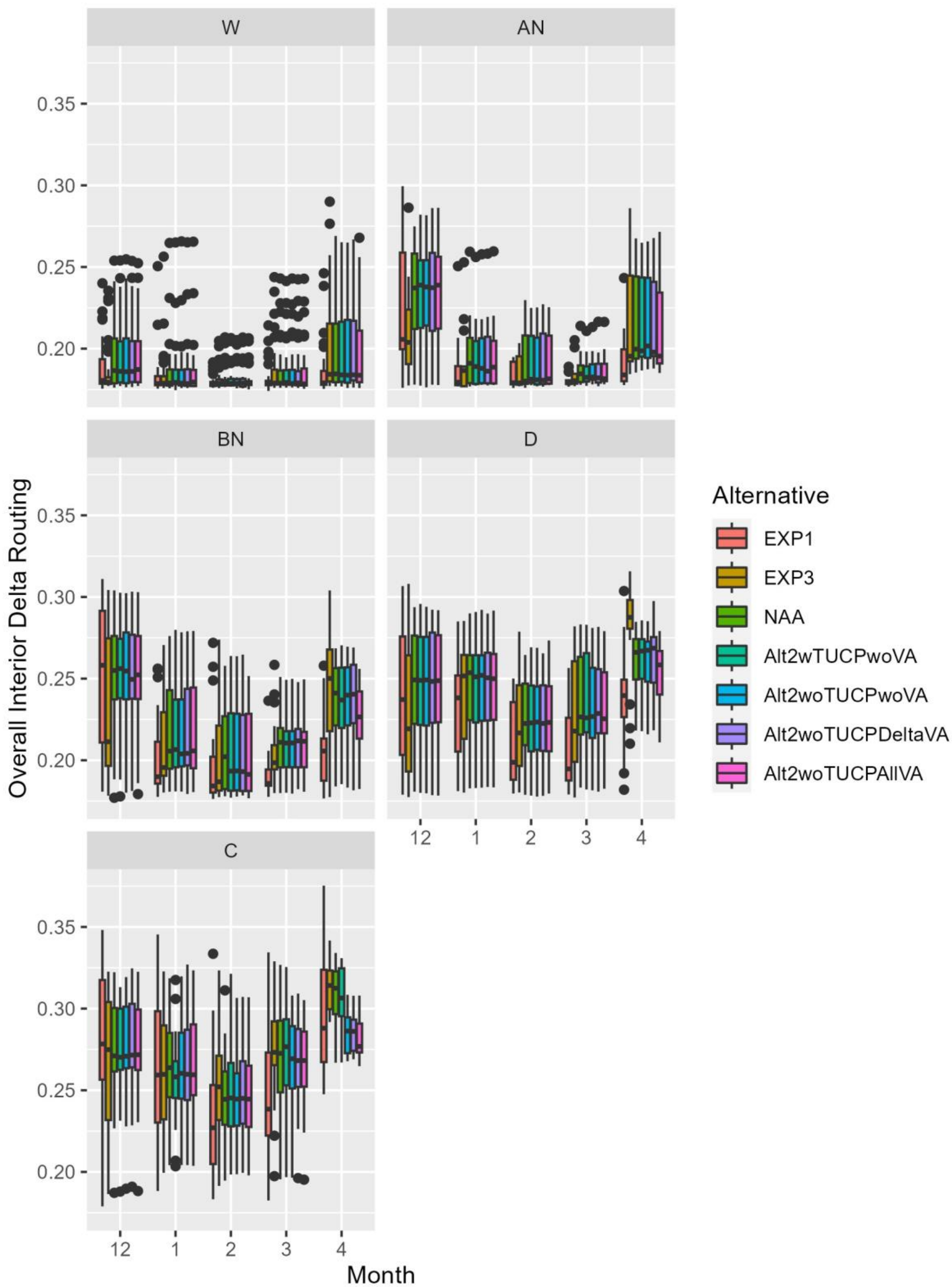
Water Year Type	Month	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
AN	12	0.533	0.559	0.506	0.505	0.505	0.504	0.504
BN	1	0.579	0.559	0.539	0.541	0.540	0.538	0.538
BN	2	0.600	0.583	0.574	0.575	0.574	0.574	0.576
BN	3	0.614	0.569	0.550	0.550	0.550	0.550	0.551
BN	4	0.573	0.486	0.491	0.492	0.492	0.490	0.510
BN	12	0.475	0.519	0.468	0.467	0.465	0.466	0.466
D	1	0.500	0.485	0.476	0.477	0.477	0.477	0.477
D	2	0.563	0.528	0.519	0.519	0.519	0.520	0.519
D	3	0.568	0.518	0.499	0.498	0.501	0.501	0.503
D	4	0.488	0.408	0.442	0.442	0.443	0.440	0.456
D	12	0.499	0.520	0.474	0.476	0.475	0.474	0.474
C	1	0.448	0.441	0.441	0.450	0.442	0.441	0.438
C	2	0.502	0.463	0.471	0.467	0.472	0.468	0.468
C	3	0.478	0.425	0.430	0.427	0.437	0.437	0.439
C	4	0.391	0.362	0.369	0.373	0.402	0.401	0.406
C	12	0.426	0.439	0.425	0.428	0.426	0.424	0.424

W = wet; AN = above normal; BN = below normal; D = dry; C = critical.

Table I-18. Predicted Through-Delta Survival Across All Routes, Averaged by Inflow Grouping

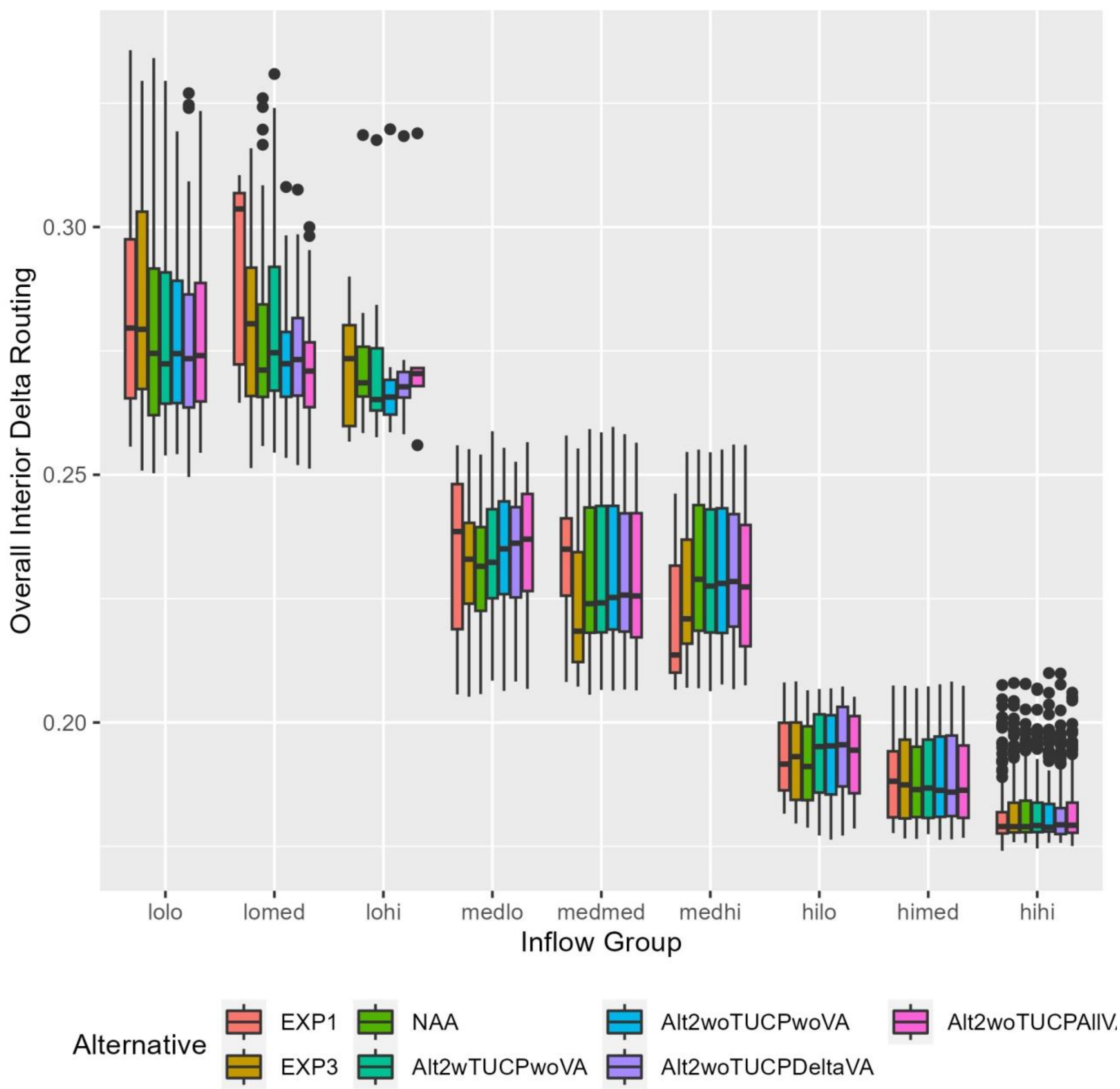
Inflow Group	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
All	0.571	0.550	0.539	0.540	0.541	0.540	0.542
lolo	0.407	0.404	0.411	0.412	0.413	0.413	0.411
lomed	0.394	0.408	0.410	0.409	0.418	0.417	0.422
lohi	NA	0.421	0.416	0.418	0.420	0.419	0.414
medlo	0.493	0.495	0.498	0.491	0.491	0.492	0.489
medmed	0.491	0.512	0.502	0.500	0.499	0.501	0.502
medhi	0.521	0.509	0.499	0.499	0.499	0.499	0.501
hilo	0.600	0.605	0.608	0.604	0.604	0.601	0.604
himed	0.622	0.622	0.625	0.621	0.621	0.622	0.623
hihi	0.662	0.659	0.657	0.657	0.657	0.657	0.656

The Inflow Grouping 'All' excludes water year and month combinations that did not map into the listed inflow groupings and values may differ from those reported in Table I-17.



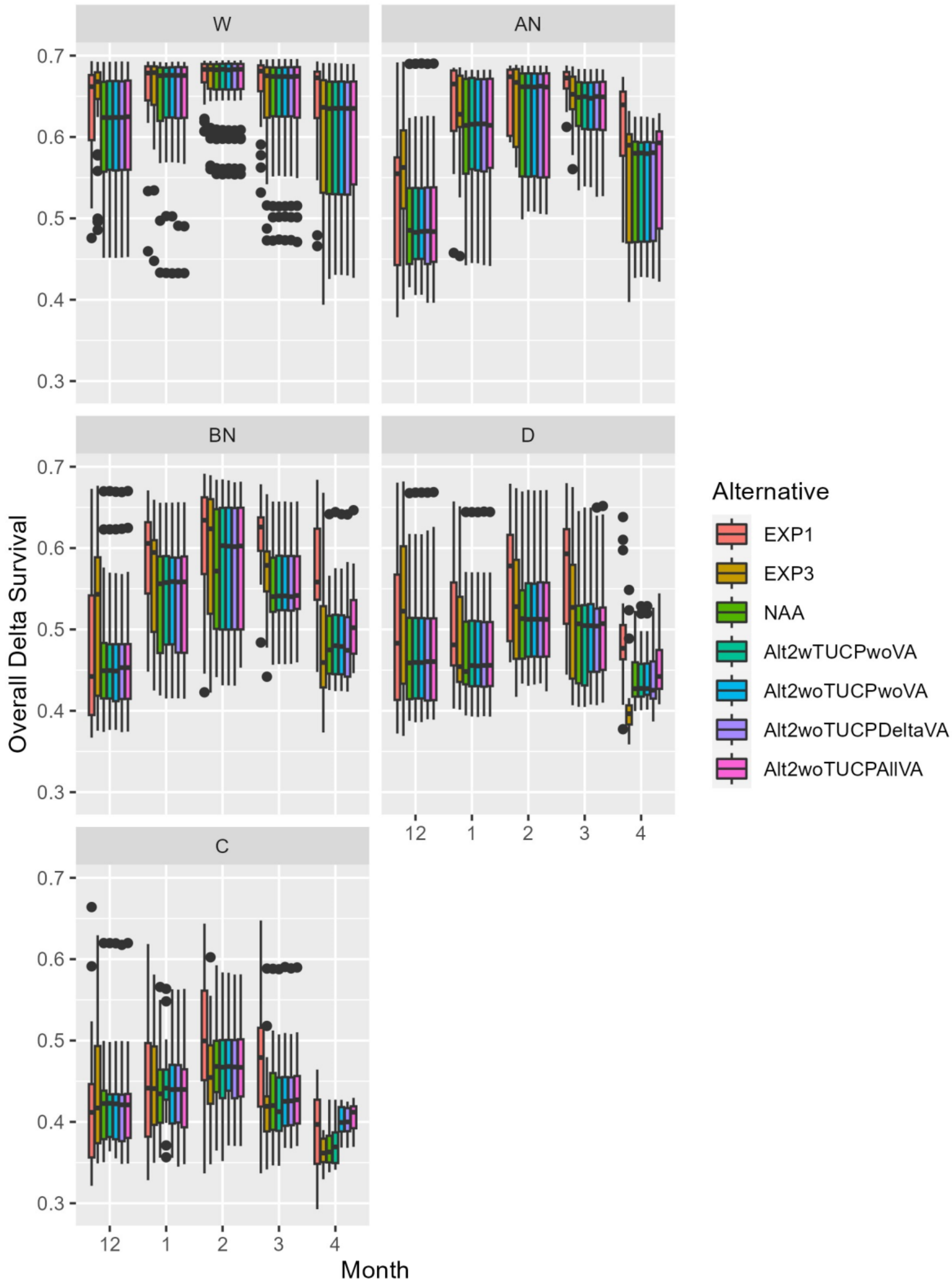
The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-46. Boxplots of Predicted Routing Proportions to the Interior Delta, Separated by Water Year Type



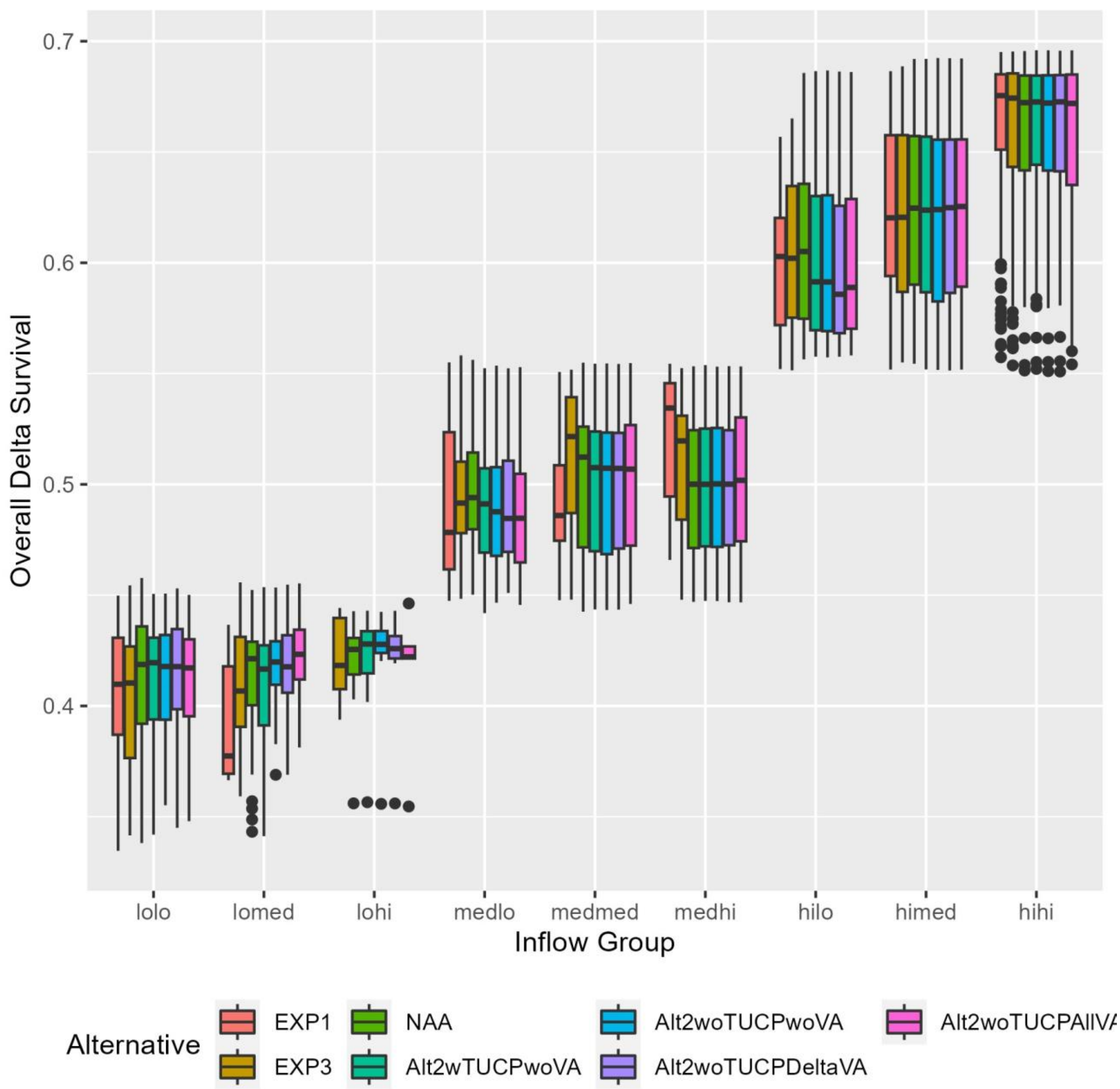
The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-47. Boxplots of Predicted Routing Proportions to the Interior Delta, Separated by Inflow Grouping



The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-48. Boxplots of Predicted Mean Survival Across All Routes, Separated by Water Year Type



The box edges represent 25th and 75th percentiles, and whiskers are the product of the interquartile range and 1.5.

Figure I-49. Boxplots of Predicted Mean Survival Across All Routes, Separated by Inflow Grouping

I.6.14 Negative Binomial Model Loss Simulation

This section summarizes results from Attachment I.1, *Negative Binomial Salvage Model*. This line of evidence was not used in the Initial Alternative Report. Results provide an evaluation of potential changes to the predicted number of LAD winter-run Chinook salmon, LAD spring-run Chinook salmon, and steelhead salvaged at the Delta fish collection facilities (Jones and Banks Pumping Plants) combined for each of the alternatives. Modeled predictions should not be treated as predictions of future entrainment.

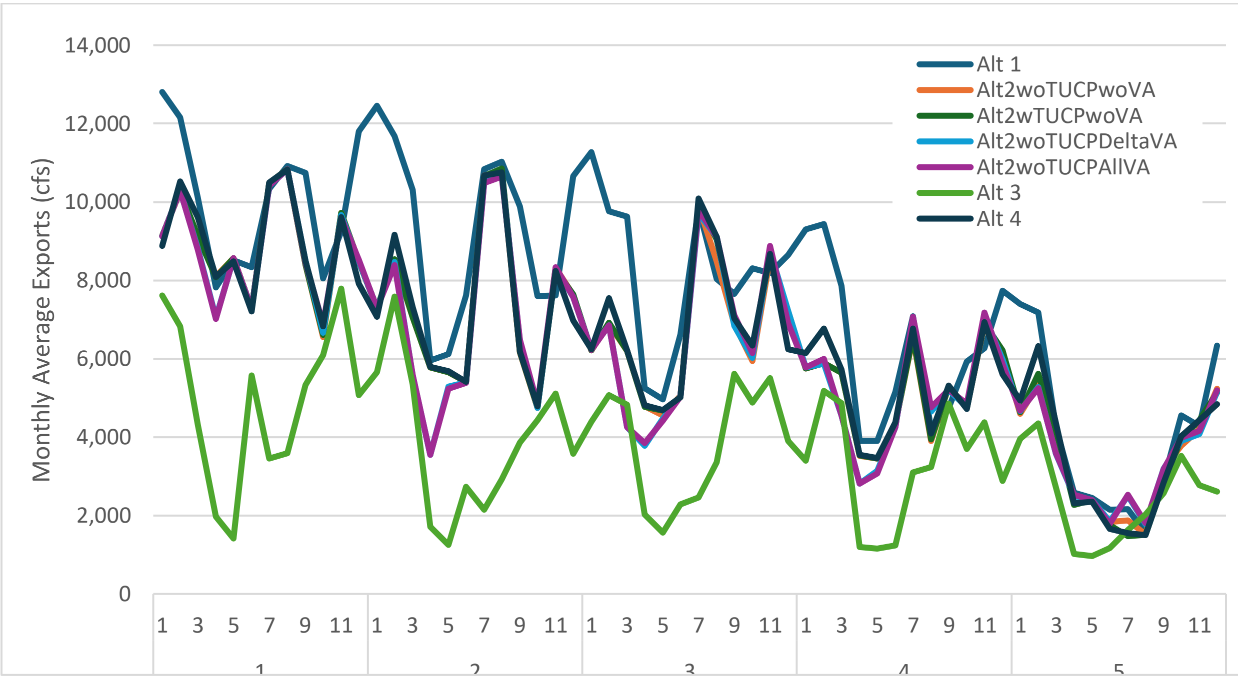
Reclamation analyzed historical salvage data via negative binomial regression. Negative binomial regression requires estimation of a dispersion parameter rather than assuming the variance is equal to the mean. In doing so, negative binomial regression can account for overdispersion, which is common in ecological data (e.g., the salvage dataset), as well as reduce the likelihood of biased coefficient estimation.

I.6.14.1 Biological Assessment Key Takeaways

Length-at-Date Winter-run Chinook Salmon

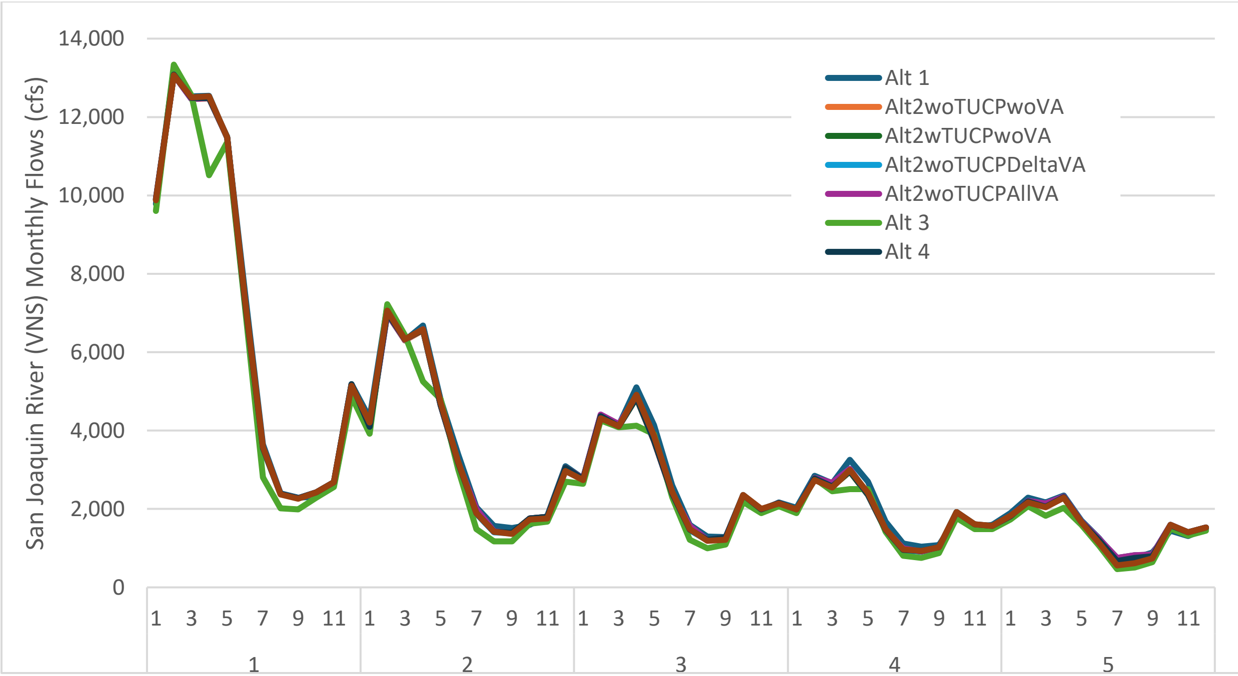
- **Driver of Variation:** The Negative Binomial analysis was used to predict average monthly salvage for LAD winter-run Chinook salmon. The analysis includes three variables: monthly CalSim 3 exports, monthly historic Sacramento Trawl Catch, and monthly CalSim 3 San Joaquin River flows. Variation in those variables are the drivers of variation in model results.
- **Calibration and Calibration Method:** Models were developed using historic salvage, catch per unit effort (CPUE), and hydrodynamic variables. A full negative binomial regression model with all predictor variables was constructed for winter-run Chinook salmon, followed by an assessment of variance inflation factor (VIF) values. Model selection process included 26 possible models and top performing model was determined by Akaike Information Criterion for small sample size (AICc). Leave-one-out cross validation (LOOCV) was used to provide a measure for model predictive performance.
- **Uncertainties:** Historic Sacramento Trawl CPUE records from 1993–2020 is assumed to be representative of recent patterns. Monthly historic values were used to generate a monthly average winter-run Chinook salmon CPUE. For more text on assumptions and uncertainty, refer to Attachment I.1.
- **Explanation of Performance Measures:** There are three variables in the Negative Binomial analysis: historic Sacramento Trawl CPUE, monthly CalSim 3 exports, and monthly CalSim 3 San Joaquin River flows. Historic CPUE in part drives the higher predictions in certain months. Modeled CalSim 3 exports also in part drive salvage predictions and the average monthly exports by WYT could explain trends in salvage among modeled scenarios. Average monthly CalSim 3 exports under Alternative 1 are consistently higher than other scenarios, both at Banks and Jones Pumping Plants, particularly in non-wet water years. Average monthly CalSim 3 exports under Alternative 3 are often lower than other scenarios, both at Banks and Jones Pumping Plants. Finally, there is less variation in average monthly CalSim 3 export values among the remaining scenarios (No Action Alternative, the four components of Alternative 2, and Alternative

4). Modeled CalSim 3 San Joaquin River flows are less likely drive salvage predictions and average monthly flows by WYT are similar. Alternative 3 flows are consistently slightly lower than the other alternatives. Alternative 1 flows are slightly higher than the other alternatives, particularly in above normal, below normal, and dry water years. There is little variation in average monthly CalSim 3 flow values among the remaining scenarios (No Action Alternative, the four components of Alternative 2, and Alternative 4).



cfs = cubic feet per second.

Figure I-50. Monthly Average Exports (cfs), CalSim 3 1922–2021, by Water Year Type and Alternative



cfs = cubic feet per second.

Figure I-51. Monthly Average San Joaquin River at Vernalis (VNS) Flows, CalSim 3 1922–2021, by Water Year Type and Alternative

Across all alternatives except Exploratory 1 and Exploratory 3, the highest predicted salvage of LAD winter-run Chinook salmon occurred in March followed by February, in all WYTs. This may reflect the months when the largest proportion of the juvenile winter-run Chinook salmon population are expected to be in the Delta. Predicted average salvage values in Table I-19 and Table I-20 are calculated for all WYTs using the months developed for the model: December through April.

The greatest predicted salvage of LAD winter-run Chinook salmon occurred during above normal and wet water years for all alternatives (Table I-19 and Table I-20). Within both above normal and wet water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 3. Predicted average monthly salvage had a wide range among WYTs (e.g., 28 Alternative 1 above normal compared with 7 Alternative 1 critical) but a narrower range within WYTs (e.g., critical Alternative 1 7 compared with 2 Alternative 3).

The lowest predicted salvage of LAD winter-run Chinook salmon occurred during dry and critical water years for all alternatives and the No Action Alternative (Table I-19 and Table I-20). Within dry water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 2 without TUCP Delta VA, Alternative 2 without TUCP All VA, and Alternative 3. Within critical water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 3.

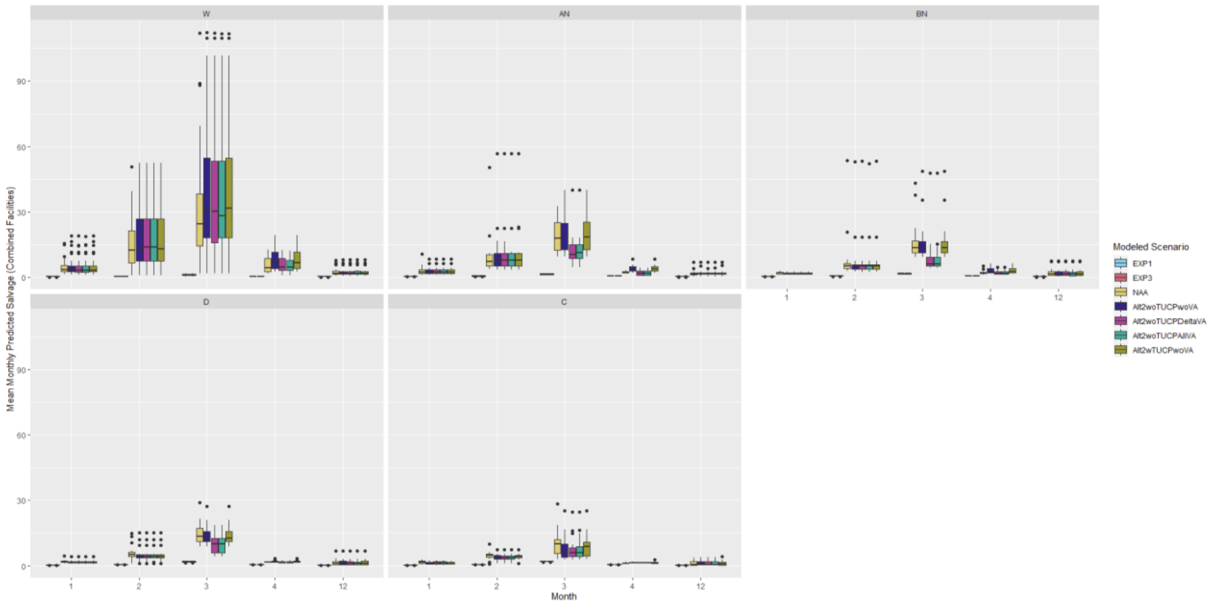
The average monthly exports by WYT could explain trends in salvage of LAD winter-run Chinook salmon among modeled scenarios. CalSim exports under Alternative 1 are consistently higher average monthly exports, particularly in December–April. CalSim exports under Alternative 3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (No Action Alternative, four components of Alternative 2, Alternative 4). The months of highest predicted winter-run Chinook salvage at the facilities temporally coincides with when the largest proportion of the juvenile winter-run Chinook salmon population is expected to be in the Delta. Generally, across all WYTs, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, *Seasonal Operations*, Figure 4-66.) Monthly Sacramento River flows below Keswick Dam, across all WYTs, increase across the same months and seasons (Chapter 4, Figure 4-3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the DCC.

Table I-19. Predicted Average Monthly Salvage of Juvenile Winter-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, December through April

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	13	25 (99%)	15 (20%)	15 (20%)	14 (13%)	14 (11%)	6 (-53%)	16 (28%)
Above Normal	8	28 (267%)	9 (13%)	8 (11%)	6 (-16%)	6 (-17%)	8 (4%)	9 (22%)
Below Normal	6	22 (251%)	6 (1%)	6 (1%)	5 (-25%)	5 (-25%)	6 (-11%)	7 (3%)
Dry	5	16 (224%)	5 (-6%)	5 (-6%)	4 (-23%)	4 (-23%)	4 (-14%)	5 (4%)
Critical	4	7 (88%)	3 (-8%)	3 (-14%)	3 (-17%)	3 (-17%)	2 (-40%)	4 (6%)

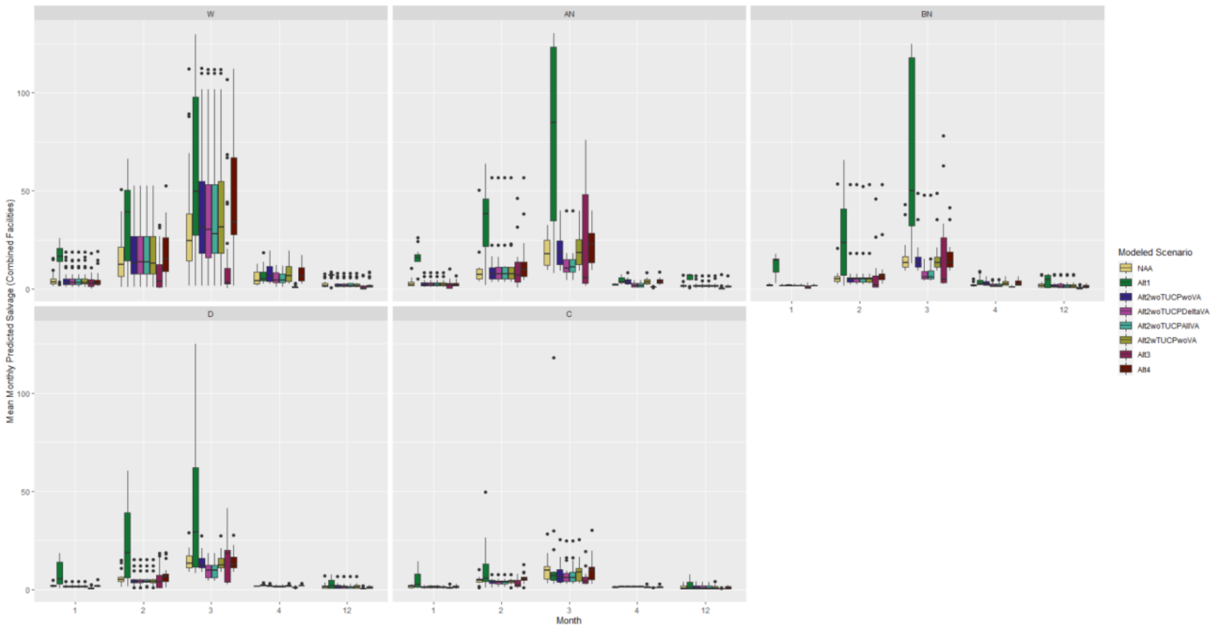
Table I-20. Predicted Average Monthly Salvage of Juvenile Winter-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, December through April

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	0	0	13	15	15	14	14
Above Normal	1	1	8	9	8	6	6
Below Normal	1	1	6	6	6	5	5
Dry	1	1	5	5	5	4	4
Critical	1	1	4	3	3	3	3



Note the y-axis scale is fixed.

Figure I-52. Predicted Average Monthly Salvage of Winter-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type and Month, based on the Negative Binomial Salvage Method



Note the y-axis scale is fixed.

Figure I-53. Predicted Average Monthly Salvage of Winter-run Chinook Salmon at the Delta fish Collection Facilities by Water Year Type and Month, based on the Negative Binomial Salvage Method

Length-at-Date Spring-run Chinook Salmon

- **Driver of Variation:** The Negative Binomial analysis was used to predict average monthly salvage for spring-run Chinook salmon. The analysis includes two variables: monthly CalSim 3 exports and monthly CalSim 3 San Joaquin River flows. Variation in those variables are the drivers of variation in model results.
- **Calibration and Calibration Method:** Models were developed using historic salvage and hydrodynamic variables. A full negative binomial regression model with all predictor variables was constructed for spring-run Chinook salmon, followed by an assessment of VIF values. Model selection process included 26 possible models and top performing model was determined by the AICc. LOOCV was used to provide a measure for model predictive performance.
- **Uncertainties:** For more text on assumptions and uncertainty, refer to Attachment I.1.
- **Explanation of Performance Measures:** There are two variables in the Negative Binomial analysis: monthly CalSim 3 exports and monthly CalSim 3 San Joaquin River flows. Modeled CalSim 3 exports in part drives salvage predictions and the average monthly exports by WYT could explain trends in salvage among modeled scenarios. Average monthly CalSim 3 exports under Alternative 1 are consistently higher than other scenarios, both at Banks and Jones Pumping Plants, particularly in non-wet water years. Average monthly CalSim 3 exports under Alternative 3 are often lower than other scenarios, both at Banks and Jones Pumping Plants. Finally, there is less variation in

average monthly CalSim 3 export values among the remaining scenarios (No Action Alternative, the four components of Alternative 2, and Alternative 4). Modeled CalSim 3 San Joaquin River flows are less likely drive salvage predictions and average monthly flows by WYT are similar. Alternative 3 flows are consistently slightly lower than the other alternatives. Alternative 1 flows are slightly higher than the other alternatives, particularly in above normal, below normal, and dry water years. There is little variation in average monthly CalSim 3 flow values among the remaining scenarios (No Action Alternative, the four components of Alternative 2, and Alternative 4) (Figure I-50 and Figure I-51).

Across all alternatives except Exploratory 1 and Exploratory 3, the highest predicted salvage of LAD spring-run Chinook salmon occurred between March and May, depending on WYT. This may reflect the months when the largest proportion of the juvenile spring-run Chinook salmon population are expected to be in the Delta. Predicted average salvage values in Table I-21 and Table I-22 are calculated for all WYTs using the months developed for the model: March through June.

The greatest predicted salvage of LAD spring-run Chinook salmon occurred during wet water years for all alternatives (Table I-21 and Table I-22). Within wet water years, the greatest predicted salvage occurred under Alternative 4 and the lowest predicted salvage occurred under Alternative 3. Predicted average monthly salvage had a wide range among WYTs (e.g., 2,212 Alternative 4 wet compared with 36 Alternative 4 critical) but a narrower range within WYTs (e.g., critical Alternative 1 41 compared with 18 Alternative 3).

The lowest predicted salvage of LAD spring-run Chinook salmon occurred during dry and critical water years for all alternatives and the No Action Alternative (Table I-21 and Table I-22). Within dry water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 3. Within critical water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 3.

The average monthly exports by WYT could explain trends in salvage of LAD spring-run Chinook salmon among modeled scenarios. CalSim exports under Alternative 1 are consistently higher average monthly exports, particularly in December–April. CalSim exports under Alternative 3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (No Action Alternative, four components of Alternative 2, Alternative 4). The months of highest predicted spring-run Chinook salvage at the facilities temporally coincides with when the largest proportion of the juvenile spring-run Chinook salmon population is expected to be in the Delta.

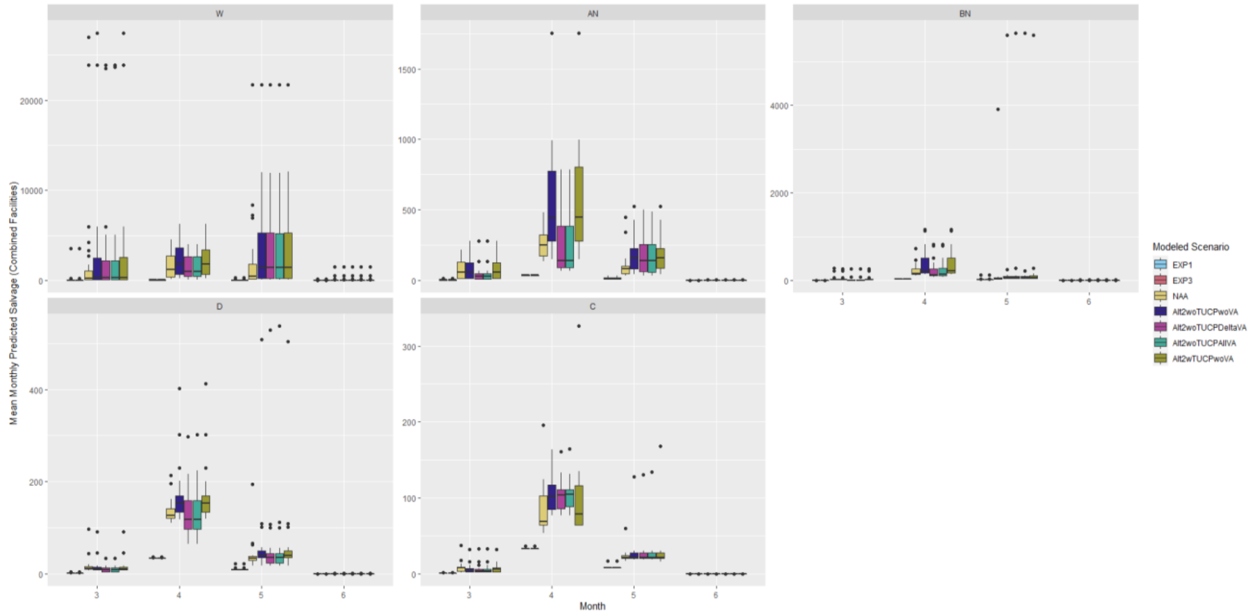
Generally, across all WYTs, combined monthly OMR flows become slightly more positive or consistent from March through May (Chapter 4, Figure 4-66). Monthly Sacramento River flows below Keswick Dam, across all WYTs, decreases from February through April after increasing since November, and begins to increase in May through the summer months (Chapter 4, Figure 4-3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the DCC.

Table I-21. Predicted Average Monthly Salvage of Juvenile Spring-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, March through June

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	1615	1906 (18%)	2183 (35%)	2188 (35%)	1959 (21%)	1940 (20%)	209 (-87%)	2212 (37%)
Above Normal	115	292 (154%)	224 (95%)	223 (94%)	121 (5%)	120 (4%)	55 (-52%)	226 (97%)
Below Normal	134	278 (108%)	207 (55%)	205 (53%)	167 (25%)	168 (26%)	65 (-51%)	201 (50%)
Dry	48	88 (83%)	63 (30%)	63 (29%)	50 (3%)	50 (3%)	23 (-52%)	63 (31%)
Critical	30	41 (34%)	36 (18%)	35 (17%)	35 (16%)	36 (17%)	18 (-42%)	36 (20%)

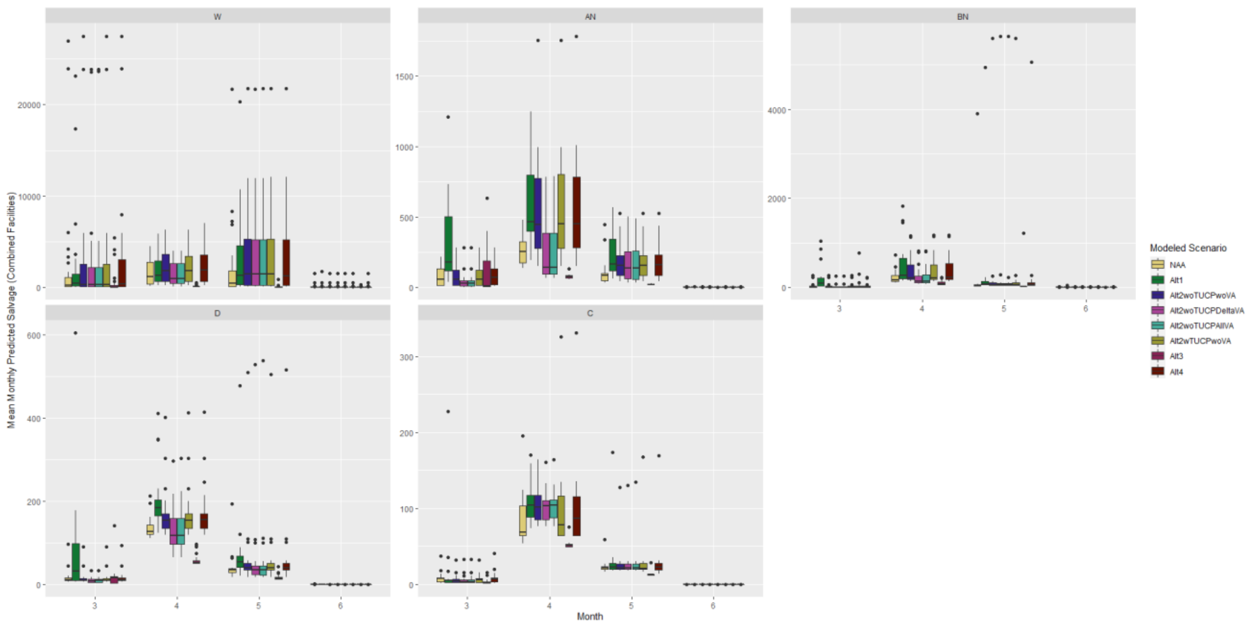
Table I-22. Predicted Average Monthly Salvage of Juvenile Spring-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type, March through June

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	69	69	1615	2183	2188	1959	1940
Above Normal	14	14	115	224	223	121	120
Below Normal	14	14	134	207	205	167	168
Dry	11	11	48	63	63	50	50
Critical	11	11	30	36	35	35	35



Note the y-axis scale is free.

Figure I-54. Predicted Average Monthly Salvage of Spring-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type and Month, based on the Negative Binomial Salvage Method



Note the y-axis scale is free.

Figure I-55. Predicted Average Monthly Salvage of Spring-run Chinook Salmon at the Delta Fish Collection Facilities by Water Year Type and Month, based on the Negative Binomial Salvage Method

Steelhead

- **Driver of Variation:** The Negative Binomial analysis was used to predict average monthly salvage for steelhead. The analysis includes one variable: monthly CalSim 3 exports. Variation in this single variable is the driver of variation in model results.
- **Calibration and Calibration Method:** Models were developed using historic salvage and hydrodynamic variables. A full negative binomial regression model with all predictor variables was constructed for steelhead, followed by an assessment of VIF values. Model selection process included 14 possible models and top performing model was determined by the AICc. LOOCV was used to provide a measure for model predictive performance.
- **Uncertainties:** For more text on assumptions and uncertainty, refer to Attachment I.1.
- **Explanation of Performance Measures:** There is a single variable in the Negative Binomial analysis: monthly CalSim 3 exports. Modeled CalSim 3 exports drives salvage predictions and the average monthly exports by WYT could explain trends in salvage among modeled scenarios. Average monthly CalSim 3 exports under Alternative 1 are consistently higher than other scenarios, both at Banks and Jones Pumping Plants, particularly in non-wet water years. Average monthly CalSim 3 exports under Alternative 3 are often lower than other scenarios, both at Banks and Jones Pumping Plants. Finally, there is less variation in average monthly CalSim 3 export values among the remaining scenarios (No Action Alternative, the four components of Alternative 2, and Alternative 4) (Figure I-50).

Across all alternatives except Exploratory 1 and Exploratory 3, the highest predicted salvage of steelhead occurred in February or march, depending on WYT. This may reflect the months when a large proportion of the juvenile steelhead population are expected to be in the Delta. Predicted average salvage values in Table I-23 and Table I-24 are calculated for all WYTs using the months developed for the model: December through June.

The greatest predicted salvage of steelhead occurred during wet water years for all alternatives (Table I-23 and Table I-24). Within wet water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 3. Predicted average monthly salvage had a wide range among WYTs (e.g., 5,428 Alternative 1 wet compared with 632 Alternative 1 critical.

The lowest predicted salvage of steelhead occurred during dry and critical water years for all alternatives and the No Action Alternative (Table I-23 and Table I-24). Within dry water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 2 without TUCP Delta VA. Within critical water years, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alternative 3.

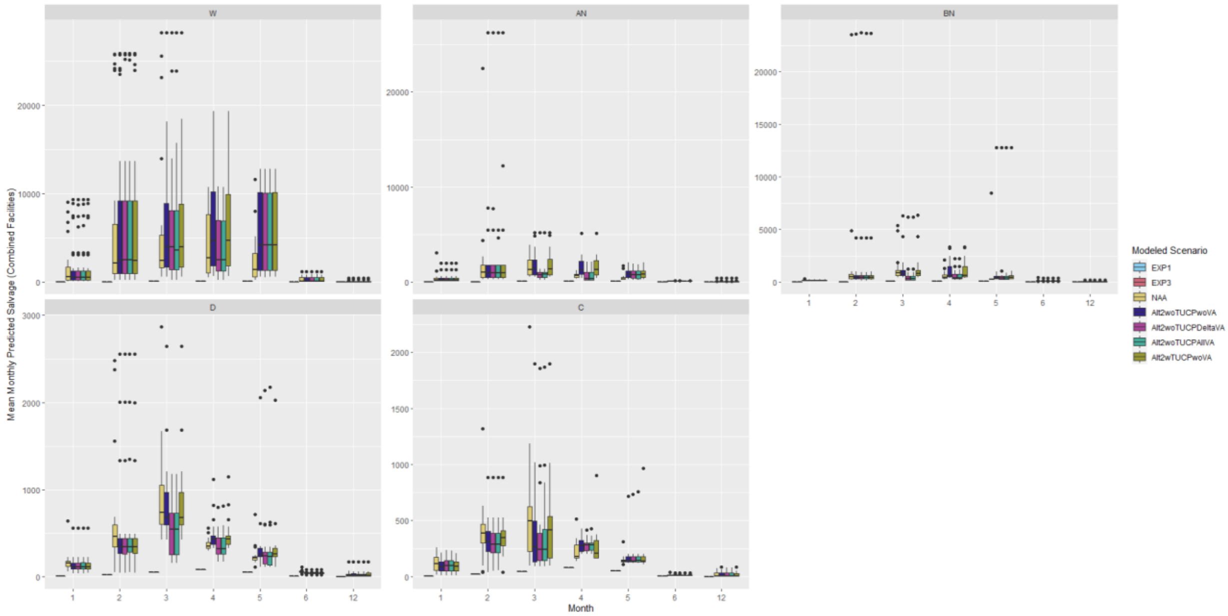
The average monthly exports by WYT could explain trends in salvage of steelhead among modeled scenarios. CalSim exports under Alternative 1 are consistently higher average monthly exports, particularly in December–April. CalSim exports under Alternative 3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (No Action Alternative, four components of Alternative 2, Alternative 4). The months of highest predicted steelhead salvage at the facilities temporally coincides with when the largest proportion of the juvenile steelhead population is expected to be in the Delta. Generally, across all WYTs, combined monthly OMR flows become increasingly more positive from November to February through late fall into winter (Chapter 4, Figure 4-66.) Monthly Sacramento River flows below Keswick Dam, across all WYTs, increase across the same months and seasons (Chapter 4, Figure 4-3). Monthly Stanislaus River flows below Goodwin Dam, across all WYTs, increase from November to February before decreasing in March (Chapter 4, Figure 4-42). This increase of flows in the Sacramento River cues juveniles to outmigrate from the upper Sacramento River through the mainstem. This increase of flows in the Stanislaus River cues juveniles to outmigrate through the San Joaquin River. Fish are present in the South Delta if they become entrained into the Central and Interior Delta at junctions like Georgiana Slough or the DCC, from the Sacramento River route, or at junctions like Head of Old River, from the San Joaquin River route.

Table I-23. Predicted Average Monthly Salvage of Juvenile Steelhead at the Delta Fish Collection Facilities by Water Year Type, December through June

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	3145	5428 (73%)	4287 (36%)	4286 (36%)	3917 (25%)	3844 (22%)	1024 (-67%)	4375 (39%)
Above Normal	921	3909 (324%)	1298 (41%)	1248 (35%)	947 (3%)	915 (-1%)	948 (3%)	1478 (60%)
Below Normal	718	2857 (298%)	838 (17%)	832 (16%)	679 (-5%)	680 (-5%)	620 (-14%)	871 (21%)
Dry	339	1732 (411%)	342 (1%)	342 (1%)	277 (-18%)	278 (-18%)	278 (-18%)	401 (18%)
Critical	218	632 (190%)	209 (-4%)	194 (-11%)	190 (-13%)	191 (-12%)	120 (-45%)	253 (16%)

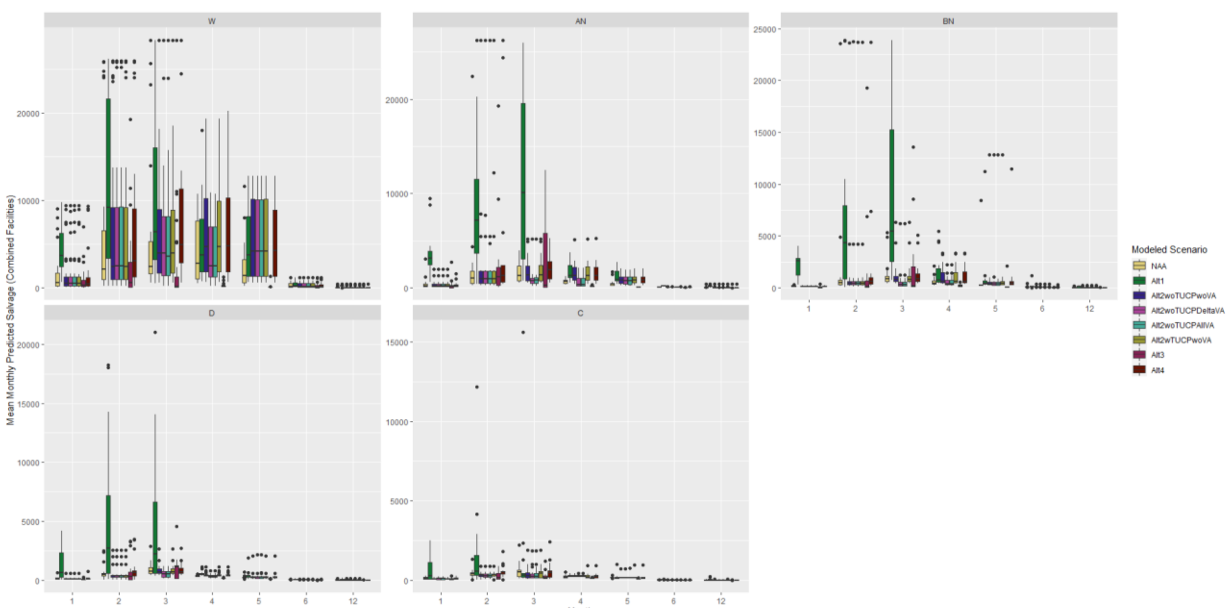
Table I-24. Predicted Average Monthly Salvage of Juvenile Steelhead at the Delta Fish Collection Facilities by Water Year Type, December through June

Water Year Type	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
Wet	30	30	3145	4287	4286	3917	3844
Above Normal	30	30	921	1298	1248	947	915
Below Normal	30	30	718	838	832	679	680
Dry	30	30	339	342	342	277	278
Critical	30	30	218	209	194	190	191



Note the y-axis scale is free.

Figure I-56. Predicted Average Monthly Salvage of Steelhead at the Delta Fish Collection Facilities by Water Year Type and Month, based on the Negative Binomial Salvage Method



Note the y-axis scale is free.

Figure I-57. Predicted Average Monthly Salvage of Steelhead at the Delta Fish Collection Facilities by Water Year Type and Month, based on the Negative Binomial Salvage Method

I.6.14.2 Environmental Impact Statement Key Takeaways

[not yet developed]

I.6.15 Old and Middle River-Salvage Density Model Loss Simulation

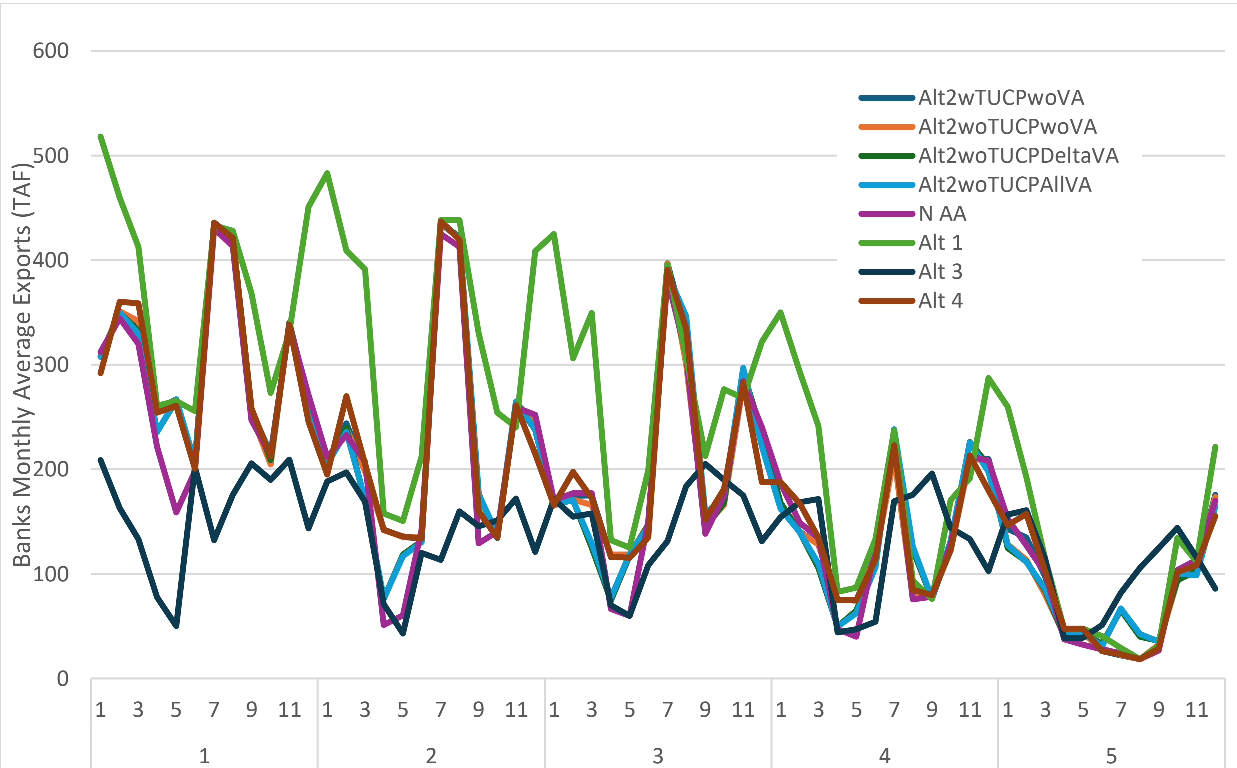
This section summarizes results from Attachment I.2, *OMR Salvage-Density Model Loss Simulation*. This line of evidence was not used in the Initial Alternative Report. Results provide an evaluation of potential changes of estimated seasonal loss of LAD winter-run Chinook salmon, genetic winter-run Chinook salmon, LAD spring-run Chinook salmon, steelhead, and green sturgeon salvaged at each of the Delta fish collection facilities (Jones and Banks Pumping Plants) independently for each of the alternatives. Modeled predictions should not be treated as predictions of future entrainment.

I.6.15.1 Biological Assessment Key Takeaways

The following key takeaways are applicable for all modeled species' predicted loss values, the Salvage-Density analysis uses the same two variables for species: species-specific historic salvage and CalSim 3 exports.

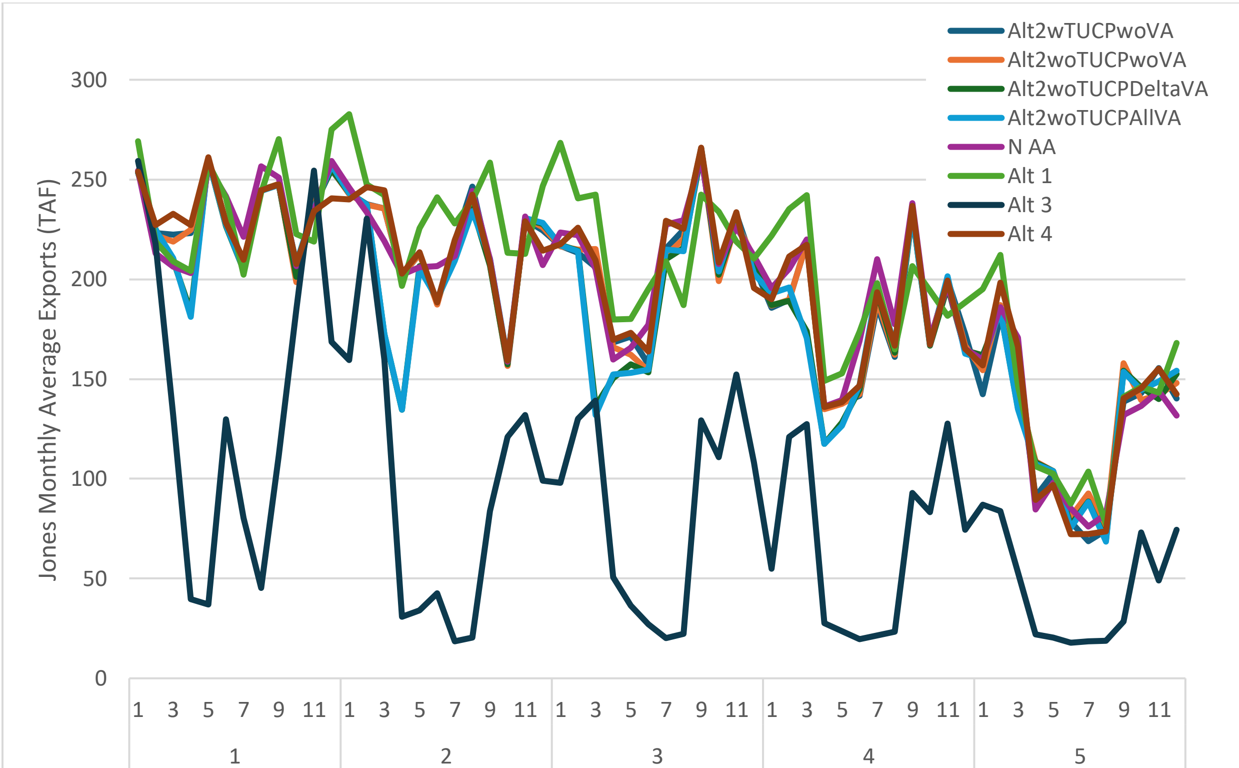
- **Driver of Variation:** The Salvage-Density analysis weights south Delta exports (at Banks and Jones Pumping Plant facilities, independently) by historical salvage per unit volume for each modeled species of interest (e.g., genetic winter-run Chinook salmon, California roach). The analysis includes two variables: monthly CalSim 3 exports and historic monthly salvage for an individual species. Variation in those two variables are the drivers of variation in model results.
- **Calibration and Calibration Method:** Historic salvage records for each species modeled include data from Banks and Jones Pumping Plant facilities, independently, from 14 water years: 2009–2022. Monthly CalSim 3 exports data include October 1921–September 2021.
- **Uncertainties:** Historic salvage records from 2009–2022 is assumed to be representative of recent salvage patterns. There were no above normal water years within that timeframe, so wet was used as a proxy for above normal. Both clipped and unclipped juvenile salmonids were included in the salvage record, assumed to be representative of the ESU. The method assumes a linear relationship between entrainment and export flows. Model predictions from the Salvage-Density analysis should be used as relative difference in loss values between scenarios, as opposed to absolute differences. For more text on assumptions and uncertainty, refer to Attachment I.2.
- **Explanation of Performance Measures:** There are two variables in the Salvage-Density analysis: historic salvage and monthly CalSim 3 exports. Historic salvage in part drives the higher predictions in certain months (e.g., historic salvage of LAD and genetic winter-run Chinook salmon is higher in March, subsequently if CalSim 3 exports follow the same trend among months among scenarios, predicted salvage will be higher in March). Modeled CalSim 3 exports also in part drive loss predictions and the average monthly exports by WYT could explain trends in loss among modeled scenarios. Average monthly CalSim 3 exports under Alternative 1 are consistently higher than other scenarios, both at Banks and Jones Pumping Plants, particularly in non-wet water years

(Figure I-58 and Figure I-59). Average monthly CalSim 3 exports under Alternative 3 are often lower than other scenarios, both at Banks and Jones Pumping Plants. Finally, there is less variation in average monthly CalSim 3 export values among the remaining scenarios (No Action Alternative, the four components of Alternative 2, and Alternative 4).



TAF = thousand acre-feet.

Figure I-58. Monthly Average Exports (TAF), CalSim 3 1922–2021, by Water Year Type and Alternative



TAF = thousand acre-feet.

Figure I-59. Monthly Average Exports (TAF), CalSim 3 1922–2021, by Water Year Type and Alternative

Length-at-Date Winter-run Chinook Salmon

Across the alternatives except Exploratory 1 and Exploratory 3, the highest values of predicted average monthly loss of LAD winter-run Chinook salmon was estimated were in March followed by February at both Banks and Jones Pumping Plant facilities which may reflect the months when the largest proportion of the juvenile winter-run Chinook salmon population are expected to be in the Delta. There are no exports in Exploratory 1 and Exploratory 3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-25 through Table I-28 are calculated using the months where predicted loss is non-zero.

The greatest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss of LAD winter-run Chinook salmon occurred during below normal and wet water years for all alternatives (Table I-25 and Table I-26). Within both below normal and wet water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Predicted average monthly loss at Banks Pumping Plant had a wide range among WYTs (e.g., 584 Alternative 1 below normal compared with 19 Alternative 1 critical) but a narrower range within WYTs (e.g., critical Alternative 1 19 compared with 13 Alternative 2c). The lowest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss occurred during dry and critical water years for all alternatives and the No Action Alternative. Within dry water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Within critical water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3 and Alternative 4. Alternative 1 predicted loss ranged from 584 to 19 in below normal and critical water years, respectively. Alternative 3 predicted loss ranged from 271 to 16 in below normal and critical water years, respectively.

The greatest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss of LAD winter-run Chinook salmon occurred during below normal water years for all alternatives (Table I-27 and Table I-28). Within below normal water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Predicted average monthly loss at Jones Pumping Plant had a wide range among WYTs (e.g., 135 Alternative 1 below normal compared with 9 Alternative 1 critical) but a narrower range within WYTs (e.g., all scenarios except Alternative 3 in critical had predicted loss 8 or 9). The lowest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss occurred during dry and critical water years for all alternatives and the No Action Alternative. Within dry water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Within critical water years, predicted loss for all alternatives was 9 or 9 with the exception of Alternative 3 which was 4. Alternative 1 predicted loss ranged from 135 to 9 in below normal and critical water years, respectively. Alternative 3 predicted loss ranged from 67 to 4 in below normal and critical water years, respectively.

At Banks Pumping Plant, the average monthly exports by WYT could explain trends in loss of LAD winter-run Chinook salmon among modeled scenarios. CalSim exports under Alternative 1 are consistently higher average monthly exports, particularly in December–April. CalSim exports under Alternative 3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (No Action Alternative, four versions of Alternative 2, Alternative 4). At Jones Pumping Plant, the trend is more pronounced for Alternative 1 while Alternative 3 is more similar to the other scenarios (No Action Alternative, four versions of Alternative 2, Alternative 4). This, in combination with lower historic salvage density at Jones Pumping Plant could explain predicted loss at Jones Pumping Plant less than at Banks Pumping Plant. The months of highest predicted winter-run Chinook loss at the facilities (both LAD and genetic) temporally coincides with when the largest proportion of the juvenile winter-run Chinook salmon population is expected to be in the Delta. Generally, across all WYTs, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 4-66.) Monthly Sacramento River flows below Keswick Dam, across all WYTs, increase across the same months and seasons (Chapter 4, Figure 4-3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the DCC.

Table I-25. Predicted Average Monthly Loss of Length-at-Date Winter-run Chinook Salmon at Banks Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	404	548 (36%)	422 (-23%)	424 (0%)	415 (-2%)	414 (0%)	185 (-55%)	434 (135%)	6: Dec–May
Above Normal	266	501 (88%)	271 (2%)	268 (1%)	242 (-9%)	242 (-9%)	214 (-20%)	278 (4%)	6: Dec–May
Below Normal	300	584 (94%)	303 (1%)	294 (-2%)	256 (-15%)	260 (-13%)	271 (-10%)	316 (5%)	6: Dec–May
Dry	140	249 (77%)	136 (-3%)	136 (-3%)	118 (-16%)	120 (-14%)	158 (13%)	142 (1%)	6: Dec–May
Critical	15	19 (25%)	15 (2%)	13 (-12%)	13 (-11%)	14 (-9%)	16 (8%)	16 (8%)	5: Dec–Apr

In wet, above normal, below normal, and dry water years, average across 6 months: December–May. In critical water years, average across 5 months: December–April.

Table I-26. Loss of Juvenile Length-at-Date Winter-run Chinook Salmon at State Water Project Banks Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	404	0	0	424	415	414	6: Dec–May
Above Normal	266	0	0	268	242	242	6: Dec–May
Below Normal	300	0	0	294	256	260	6: Dec–May
Dry	140	0	0	136	118	120	6: Dec–May
Critical	15	0	0	13	13	14	5: Dec–Apr

Absolute values are rounded.

Table I-27. Predicted Average Monthly Loss of Length-at-Date Winter-run Chinook Salmon at Jones Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	52	54 (3%)	54 (4%)	54 (3%)	53 (1%)	53 (2%)	40 (-23%)	55 (6%)	5: Dec–Apr
Above Normal	52	58 (11%)	55 (5%)	55 (5%)	48 (-8%)	48 (-8%)	38 (-27%)	56 (7%)	5: Dec–Apr
Below Normal	117	135 (15%)	116 (-1%)	118 (1%)	98 (-16%)	97 (-17%)	67 (-42%)	119 (1%)	5: Dec–Apr
Dry	45	51 (12%)	44 (-3%)	44 (-3%)	39 (-14%)	39 (-13%)	23 (-49%)	45 (-1%)	5: Dec–Apr
Critical	9	9 (2%)	9 (-7%)	9 (-8%)	8 (-9%)	8 (-9%)	4 (-60%)	9 (-1%)	5: Dec–Apr

In all water year types, average across 5 months: December–April.

Table I-28. Loss of Juvenile Length-at-Date Winter-run Chinook Salmon at Central Valley Project Jones Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	52	0	0	54	53	53	5: Dec–Apr
Above Normal	52	0	0	55	48	48	5: Dec–Apr
Below Normal	117	0	0	118	98	97	5: Dec–Apr
Dry	45	0	0	44	39	39	5: Dec–Apr
Critical	9	0	0	9	8	8	5: Dec–Apr

Absolute values are rounded.

Genetic Winter-run Chinook Salmon

Given all the alternatives aside from Exploratory 1 and Exploratory 3, the highest values of predicted average monthly loss of genetic winter-run Chinook salmon estimated at Banks and Jones Pumping Plants were in March followed by February, in all WYTs, except for the dry and critically dry water years. In the dry and critical water years, the highest predicted loss of winter-run Chinook salmon was in April followed by March at Banks Pumping Plant. At Jones Pumping Plant, the highest predicted loss for genetic winter-run Chinook salmon was in March, followed by December for the dry water years, and March followed by January for the critically dry water years. The timing of the predicted loss for genetic winter-run Chinook salmon at Banks and Jones Pumping Plants may reflect the months when the largest proportion of the juvenile winter-run Chinook salmon population are expected to be in the Delta. There are no exports in Exploratory 1 and Exploratory 3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-29 through Table I-32 are calculated using the months where predicted loss is non-zero.

The greatest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss of genetic winter-run Chinook salmon occurred during below normal and wet water years for all alternatives (Table I-29 and Table I-30). Within both below normal and wet water years, the greatest predicted loss occurred under Alternative 1. The lowest predicted loss for genetic winter-run Chinook salmon at Banks Pumping Plant occurred under Alternative 3, and Alternative 2c, for the wet, and below normal water years, respectively. Predicted average monthly loss at Banks Pumping Plant had a wide range among WYTs (e.g., 179 Alternative 1 wet compared with 2 Alternative 1 critical) but a narrower range within WYTs (e.g., dry Alternative 1 31 compared with 14 Alternative 2c). The lowest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss occurred during dry and critical water years for all alternatives and the No Action Alternative. Within the critically dry water years, predicted loss was low, and the same loss was predicted for all alternatives. Within dry water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 2c, and Alternative 2d. Alternative 1 predicted loss ranged from 179 to 2 in wet and critically dry water years, respectively. Alternative 3 predicted loss ranged from 82 to 2 in below normal and critical water years, respectively.

The greatest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss of genetic winter-run Chinook salmon occurred during below normal water years for all alternatives (Table I-31 and Table I-32). Within below normal water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3, although by just a small margin. Predicted average monthly loss at Jones Pumping Plant had a somewhat narrow range among WYTs (e.g., 39 Alternative 1 below normal compared with 2 Alternative 1 critical) but a narrower range within WYTs (e.g., all scenarios except Alternative 3 in critical had predicted loss 5 or 6). The lowest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss occurred during wet and critical water years for all alternatives and the No Action Alternative. Within dry water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Within the above normal water years, the range of loss was very narrow, 19 to 14 for Alternative 1 and Alternative 3, respectively. Alternative 1 predicted loss ranged from 39 to 5 in below normal and critical water years, respectively. Alternative 3 predicted loss ranged from 22 to 2 in below normal and critical water years, respectively.

At Banks Pumping Plant, the average monthly exports by WYT could explain trends in loss of genetic winter-run Chinook salmon among modeled scenarios. CalSim exports under Alternative 1 are consistently higher average monthly exports, particularly in December–April. CalSim exports under Alternative 3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (No Action Alternative, four versions of Alternative 2, Alternative 4). At Banks Pumping Plant, the trend is more pronounced for Alternative 1. Given the lower historic salvage density seen at Jones Pumping Plant, the model predicted, as expected, less loss at Jones Pumping Plant than at Banks Pumping Plant. The months of highest predicted winter-run Chinook loss at the facilities (both LAD and genetic) temporally coincides with when the largest proportion of the juvenile winter-run Chinook salmon population is expected to be in the Delta. Generally, across all WYTs, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 4-66.) Monthly Sacramento River flows below Keswick Dam, across all WYTs, increase across the same months and seasons (Chapter 4, Figure 4-3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the DCC.

Table I-29. Predicted Average Monthly Loss of Genetic Winter-run Chinook Salmon at Banks Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	138	179 (30%)	146 (6%)	146 (6%)	143 (4%)	142 (3%)	59 (-57%)	152 (10%)	6: Dec–May
Above Normal	86	163 (89%)	89 (3%)	88 (2%)	77 (-10%)	77 (-10%)	72 (-16%)	93 (8%)	6: Dec–May
Below Normal	92	178 (93%)	92 (0%)	88 (-5%)	71 (-23%)	73 (-21%)	82 (-11%)	94 (2%)	6: Dec–May
Dry	17	31 (79%)	17 (0%)	17 (0%)	14 (-19%)	14 (-16%)	22 (26%)	18 (4%)	6: Dec–May
Critical	2	2 (22%)	2 (10%)	2 (-2%)	2 (-2%)	2 (2%)	2 (8%)	2 (17%)	5: Dec–Apr

In wet, above normal, below normal, and dry water years, average across 6 months: December–May. For critical water years, average across 5 months: December–April.

Table I-30. Loss of Juvenile Genetic Winter-run Chinook Salmon at State Water Project Banks Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	138	0	0	146	143	142	6: Dec–May
Above Normal	86	0	0	88	77	77	6: Dec–May
Below Normal	138	0	0	132	107	110	4: Jan–Apr
Dry	52	0	0	52	42	43	2: Mar–Apr
Critical	5	0	0	5	5	5	2: Mar–Apr

Absolute values are rounded.

Table I-31. Predicted Average Monthly Loss of Genetic Winter-run Chinook Salmon at Jones Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	17	17 (2%)	18 (6%)	17 (5%)	17 (2%)	17 (3%)	12 (-25%)	18 (10%)	5: Dec–Apr
Above Normal	17	19 (10%)	18 (6%)	18 (5%)	15 (-13%)	15 (-13%)	14 (-22%)	19 (9%)	5: Dec–Apr
Below Normal	34	39 (15%)	34 (-1%)	35 (3%)	26 (-24%)	25 (-26%)	22 (-36%)	35 (2%)	4: Dec, Feb–Apr
Dry	22	25 (10%)	22 (-1%)	22 (-1%)	18 (-20%)	17 (-22%)	13 (-43%)	22 (-1%)	2: Dec, March
Critical	6	5 (-12%)	5 (-8%)	5 (-15%)	5 (-19%)	5 (-20%)	2 (-68%)	6 (-3%)	2: Jan, March

In wet and above normal water years, average across 5 months: December–April. For below normal water years, average across 4 months: December, February–April. In dry and critical water years, average across 2 months: January and March.

Table I-32. Loss of Juvenile Genetic Winter-run Chinook Salmon at State Water Project Banks Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	17	0	0	17	17	17	5: Dec–Apr
Above Normal	17	0	0	18	15	15	5: Dec–Apr
Below Normal	34	0	0	35	26	25	4: Dec, Feb–Apr
Dry	22	0	0	22	18	17	2: Dec, Mar
Critical	6	0	0	5	5	5	2: Jan, Mar

Absolute values are rounded.

Length-at-Date Spring-run Chinook Salmon

Across the alternatives except Exploratory 1 and Exploratory 3, depending on WYT, the highest values of predicted average monthly loss of LAD spring-run Chinook salmon estimated were in March, April, or May, for both Banks and Jones Pumping Plant facilities, which may reflect the months when the largest proportion of the juvenile spring-run Chinook salmon population are expected to be in the Delta. There are no exports in Exploratory 1 and Exploratory 3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-33 through Table I-36 are calculated using the months where predicted loss is non-zero.

The greatest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss of LAD spring-run Chinook salmon occurred during above normal and wet water years for all alternatives (Table I-33 and Table I-34). Within both above normal and wet water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Predicted average monthly loss at Banks Pumping Plant had a wide range among water years (e.g., 9,463 Alternative 1 wet compared with 105 Alternative 1 critical) but a narrower range within WYTs (e.g., critical Alternative 1 105 compared with 84 No Action Alternative). The lowest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss occurred during dry and critical water years for all alternatives and the No Action Alternative. Within dry water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under the No Action Alternative. Within critical water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred also occurred under the No Action Alternative. Alternative 1 predicted loss ranged from 9,463 to 105 in wet and critical water years, respectively. Alternative 3 predicted loss ranged from 2,308 to 91 in wet and critical water years, respectively.

The greatest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss of LAD spring-run Chinook salmon occurred during wet water years for all alternatives (Table I-35 and Table I-36). Within the wet water years, the greatest predicted loss occurred under Alternative 4 and the lowest predicted loss occurred under Alternative 3. Predicted average monthly loss at Jones Pumping Plant had a wide range among WYTs (e.g., 1,269 Alternative 4 wet compared with 17 Alternative 3 critical) as well as a wide range within WYTs (e.g., 516 Alternative 1 to 109 Alternative 3 dry). The lowest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss occurred during dry and critical water years for all alternatives and the No Action Alternative. Within dry water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Within critical water years, the greatest predicted loss occurred under Alternative 2b, and the lowest predicted loss occurred under Alternative 3. Alternative 1 predicted loss ranged from 1,228 to 63 in wet and critical water years, respectively. Alternative 3 predicted loss ranged from 234 to 17 in below normal and critical water years, respectively.

At Banks Pumping Plant, the average monthly exports by WYT could explain trends in loss of LAD spring-run Chinook salmon among modeled scenarios. CalSim exports under Alternative 1 are consistently higher average monthly exports, particularly in December–April. CalSim exports under Alternative 3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (No Action Alternative, four versions of Alternative 2, Alternative 4). At Banks Pumping Plant, the trend is more pronounced for Alternative 1, but the difference in predicted loss for all alternatives besides Alternative 3 is minimal. The predicted loss under Alternative 3 is notably far less than all other alternatives at both facilities. Given the lower historic salvage density at Jones Pumping Plant, the model predicted, as would be expected, far less loss at Jones Pumping Plant compared to Banks Pumping Plant. The months of highest predicted spring-run Chinook loss at both facilities temporally coincides with when the largest proportion of the juvenile spring-run Chinook salmon population is expected to be in the Delta. Generally, across all WYTs, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 4-66.) Monthly Sacramento River flows below Keswick Dam, across all WYTs, increase across the same months and seasons (Chapter 4, Figure 4-3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the DCC.

Table I-33. Predicted Average Monthly Loss of Length-at-Date Sacramento River at Banks Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	6,425	9463 (47%)	9347 (45%)	9334 (45%)	9110 (42%)	9125 (42%)	2308 (-64%)	9181 (43%)	6: Jan–June
Above Normal	2273	5677 (150%)	4920 (116%)	4914 (116%)	3842 (69%)	3801 (67%)	1995 (-12%)	4929 (117%)	6: Jan–June
Below Normal	1196	2403 (101%)	2015 (68%)	2043 (71%)	1579 (32%)	1616 (35%)	1205 (1%)	2010 (68%)	4: March–June
Dry	900	1675 (86%)	1433 (59%)	1434 (59%)	1043 (16%)	1037 (15%)	922 (2%)	1442 (60%)	3: March–May
Critical	84	105 (24%)	95 (13%)	86 (2%)	86 (2%)	90 (6%)	91 (8%)	102 (21%)	4: Feb–May

In wet and above normal water years, average across 6 months: January–June. For below normal water years, average across 4 months: March–June. In dry water years, average across 3 months: March–May. In critical water years, average across 4 months: February–May.

Table I-34. Loss of Juvenile Length-at-Date spring-run Chinook Salmon at State Water Project Banks Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	7496	0	0	10889	10629	10646	6: Jan–June
Above Normal	2652	0	0	5733	4482	4435	6: Jan–June
Below Normal	1196	0	0	2043	1579	1616	4: Mar–June
Dry	900	0	0	1434	1043	1037	3: Mar–May
Critical	84	0	0	86	86	90	4: Feb–May

Absolute values are rounded.

Table I-35. Predicted Average Monthly Loss of Length-at-Date Sacramento River at Jones Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1,220	1228 (1%)	1259 (3%)	1260 (3%)	1205 (-1%)	1202 (-2%)	227 (-81%)	1269 (4%)	7: Dec–June
Above Normal	1042	1111 (7%)	1062 (2%)	1061 (2%)	946 (-9%)	942 (-10%)	188 (-82%)	1067 (2%)	7: Dec–June
Below Normal	674	757 (12%)	700 (4%)	689 (2%)	606 (-10%)	603 (-11%)	234 (-65%)	707 (5%)	6: Jan–June
Dry	472	516 (9%)	468 (-1%)	467 (-1%)	410 (-13%)	408 (-13%)	109 (-77%)	469 (-1%)	5: Dec, March–June
Critical	60	63 (5%)	60 (0%)	64 (5%)	62 (3%)	62 (2%)	17 (-72%)	61 (1%)	5: Jan–May

In wet and above normal water years, average across 7 months: December–June. For below normal water years, average across 6 months: January–June. In dry water years, average across 5 months: December, and March–June. In critical water years, average across 5 months: January–May.

Table I-36. Loss of Juvenile Length-at-Date Spring-run Chinook Salmon at Central Valley Project Jones Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	1220	0	0	1260	1205	1202	7: Dec–June
Above Normal	1042	0	0	1061	946	942	7: Dec–June
Below Normal	674	0	0	689	606	603	6: Jan–June
Dry	472	0	0	467	410	408	5: Dec, Mar–June
Critical	60	0	0	64	62	62	5: Jan–May

Absolute values are rounded.

Steelhead

Across the alternatives except Exploratory 1 and Exploratory 3, the highest values of predicted average monthly loss of steelhead estimated were in December, January, and February, at both Banks and Jones Pumping Plant facilities which may reflect the months when the largest proportion of the juvenile steelhead are expected to be in the Delta. There are no exports in Exploratory 1 and Exploratory 3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-37 through Table I-40 are calculated using the months where predicted loss is non-zero.

The greatest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss of steelhead occurred during wet and dry water years, for all alternatives (Table I-37 and Table I-38). Within both wet and dry water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Predicted average monthly loss at Banks Pumping Plant had a wide range among WYTs (e.g., 617 Alternative 1 wet compared with 68 Alternative 3 below normal) also having a wide range within WYTs (e.g., above normal Alternative 1 567 compared with 198 Alternative 3). The lowest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss occurred during below normal and critical water years for all alternatives and the No Action Alternative. Within below normal water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Within critical water years, the greatest predicted loss also occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Alternative 1 predicted loss ranged from 617 to 138 in wet and critical water years, respectively. Alternative 3 predicted loss ranged from 222 to 68 in wet and critical water years, respectively.

The greatest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss of steelhead occurred during wet water years for all alternatives (Table I-39 and Table I-40). Within the wet water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3, albeit by a small margin. Predicted average monthly loss at Jones Pumping Plant had a somewhat narrow range among WYTs (e.g., 61 Alternative 1 wet to 7 Alternative 3 below normal) and a even narrower range within WYTs (e.g., above normal Alternative 1 58 to 26 Alternative 3). The lowest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss occurred during below normal and critical water years for all alternatives and the No Action Alternative. Within below normal, and critical water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Alternative 1 predicted loss ranged from 61 to 17 in wet and below normal water years, respectively. Alternative 3 predicted loss ranged from 43 to 7 in wet and below normal water years, respectively.

At Banks Pumping Plant, the average monthly exports by WYT could explain trends in loss of steelhead among modeled scenarios. CalSim exports under Alternative 1 are consistently higher average monthly exports, particularly in December–April. CalSim exports under Alternative 3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (No Action Alternative, four versions of Alternative 2, Alternative 4). At Banks Pumping Plant, the trend is more pronounced for Alternative 1 while Alternative 3 similarly outperforms all other alternatives at both facilities. The lower historic salvage density at Jones Pumping Plant could explain the lower predicted loss at Jones Pumping Plant compared to Banks Pumping Plant. The months of highest predicted steelhead loss at the facilities temporally coincides with when the largest proportion of the juvenile steelhead population is expected to be in the Delta. Generally, across all WYTs, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 4-66.) Monthly Sacramento River flows below Keswick Dam, across all WYTs, increase across the same months and seasons (Chapter 4, Figure 4-3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the DCC.

Table I-37. Predicted Average Monthly Loss of Steelhead at Banks Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	377	617 (64%)	372 (-1%)	372 (-1%)	372 (-1%)	373 (-1%)	222 (-41%)	351 (-7%)	4: Dec–March
Above Normal	300	567 (89%)	293 (-2%)	291 (-3%)	288 (-4%)	287 (-4%)	198 (-34%)	269 (-10%)	4: Dec–March
Below Normal	81	157 (95%)	78 (-3%)	78 (-3%)	77 (-4%)	76 (-5%)	68 (-15%)	78 (-3%)	5: Dec–April
Dry	359	503 (40%)	360 (0%)	358 (0%)	351 (-2%)	340 (-5%)	182 (-49%)	312 (-13%)	2: Dec–Jan.
Critical	96	138 (43%)	98 (2%)	92 (-5%)	88 (-8%)	89 (-8%)	76 (-21%)	95 (-1%)	5: Dec–April

In wet and above normal water years, average across 4 months: December–March. For below normal water years, average across 5 months: December–April. In dry water years, average across 2 months: December–January. In critical water years, average across 5 months: December–April.

Table I-38. Loss of Juvenile Steelhead at State Water Project Banks Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	377	0	0	372	372	373	4: Dec–Mar
Above Normal	300	0	0	291	288	287	4: Dec–Mar
Below Normal	81	0	0	78	77	76	5: Dec–Apr
Dry	359	0	0	0	0	0	3: Mar–May
Critical	96	0	0	92	88	89	5: Dec–Apr

Absolute values are rounded.

Table I-39. Predicted Average Monthly Loss of Steelhead at Jones Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	58	61 (6%)	57 (-1%)	57 (-1%)	57 (-1%)	58 (-1%)	43 (-25%)	55 (-5%)	5: Oct–Feb
Above Normal	49	58 (18%)	52 (6%)	52 (6%)	52 (7%)	52 (7%)	26 (-47%)	50 (2%)	5: Oct–Feb
Below Normal	14	17 (17%)	14 (-3%)	14 (-3%)	14 (-4%)	14 (-4%)	7 (-53%)	14 (-2%)	5: Dec–April
Dry	42	48 (14%)	43 (3%)	42 (0%)	41 (-1%)	41 (-1%)	18 (-58%)	42 (-1%)	2: Dec–Jan
Critical	29	35 (21%)	27 (-5%)	29 (1%)	30 (4%)	30 (4%)	15 (-47%)	29 (2%)	4: Dec–March

In wet and above normal water years, average across 5 months: October–February. For below normal water years, average across 5 months: December–April. In dry water years, average across 2 months: December–January. In critical water years, average across 4 months: December–March.

Table I-40. Loss of Juvenile Steelhead at Central Valley Project Jones Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	58	0	0	57	57	58	5: Oct–Feb
Above Normal	49	0	0	52	52	52	5: Oct–Feb
Below Normal	14	0	0	14	14	14	5: Dec–Apr
Dry	42	0	0	42	41	41	2: Dec–Jan
Critical	29	0	0	29	30	30	4: Dec–Mar

Absolute values are rounded.

Green Sturgeon

Across the alternatives except Exploratory 1 and Exploratory 3, the highest values of predicted average monthly loss of Green Sturgeon estimated were in January, March, or June depending on the WYT, and facility. The extremely low historic salvage density for Green Sturgeon at both facilities may explain the seemingly random distribution of predicted values both by facility, and by month. It should be further stated that the presence of 1-2 fish at either facility over a calendar year does not speak much to the abundance, movement, or distribution of Green Sturgeon in the Delta. There are no exports in Exploratory 1 and Exploratory 3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-41 through Table I-44 are calculated using the months where predicted loss is non-zero.

The greatest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss of Green Sturgeon occurred during wet and below normal water years for all alternatives (Table I-41 and Table I-42). Within the wet water years, the greatest predicted loss occurred under the No Action Alternative, Alternative 1, all components of Alternative 2, and Alternative 4, the lowest predicted loss occurred under Alternative 3. Predicted average monthly loss at Banks Pumping Plant had a narrow range among WYTs (e.g., 4 Alternative 1 below normal compared with 1, the only other value higher than zero, for all WYTs, and alternatives) but a narrower range within WYTs (e.g., wet Alternative 1 1 compared with 0 Alternative 3). The lowest predicted loss at Banks Pumping Plant across all months with predicted non-zero average monthly loss occurred during above normal water years for all alternatives and the No Action Alternative. Within above normal water years, the greatest predicted loss occurred under the No Action Alternative, Alternative 1, Alternative 2a, Alternative 2b, and Alternative 4, the lowest predicted loss occurred under Alternative 3, Alternative 2c, and Alternative 2d. Within dry, and critical water years, the predicted loss for Green Sturgeon at Banks Pumping Plant was zero for all alternatives. Alternative 1 predicted loss ranged from 4 to 1 in below normal and wet water years, respectively. Alternative 3 predicted loss ranged from 1 to 0 in below normal and all other water years, respectively.

The greatest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss of Green Sturgeon occurred during wet, and above normal water years for all alternatives (Table I-43 and Table I-44). Within the wet water years, the greatest predicted loss occurred under Alternative 1 and the No Action Alternative, the lowest predicted loss occurred under Alternative 3. Similarly, under the above normal water years, the greatest predicted loss occurred under Alternative 1 and the lowest predicted loss occurred under Alternative 3. Predicted average monthly loss at Jones Pumping Plant had a narrow range among WYTs (e.g., 7 Alternative 1 above normal compared with 1 Alternative 4 dry) and a similar range within WYTs (e.g., above normal Alternative 1 7 to 1 Alternative 3). The lowest predicted loss at Jones Pumping Plant across all months with predicted non-zero average monthly loss occurred during the dry water years for all alternatives and the No Action Alternative. Within dry water years, the greatest predicted loss occurred under the No Action Alternative, Alternative 1, all components of Alternative 2, and Alternative 4, with the same value predicted (1), the lowest predicted loss occurred under Alternative 3 (0). Alternative 1 predicted loss ranged from 7 to 1 in wet and above normal water years, and dry water years, respectively. Alternative 3 predicted loss ranged from 4 to 1 in wet, and above normal water years, respectively.

The extremely low historic salvage density for Green Sturgeon at both facilities likely explains the seemingly random trends of predicted loss by WYT and across all alternatives. The distribution and movement of Green Sturgeon in the Delta and importantly, the affect to which exports and OMR flows have on their movements is not well understood. While the model predicts that decreased exports, especially in non-summer months associated with Alternative 3 will have decreased salvage of Green Sturgeon, actual affects will likely vary, this is due to the overlying bias in the model and data currently available.

Table I-41. Predicted Average Monthly Loss of Green Sturgeon at Banks Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	1	1 (29%)	1 (6%)	1 (7%)	1 (4%)	1 (3%)	0 (-58%)	1 (12%)	1: March
Above Normal	1	1 (89%)	1 (-4%)	1 (-4%)	0 (-18%)	0 (-18%)	0 (-18%)	1 (-1%)	1: March
Below Normal	1	4 (149%)	1 (-3%)	1 (-3%)	1 (-3%)	1 (-3%)	1 (1%)	1 (-3%)	1: Jan.
Dry	0	0	0	0	0	0	0	0	No Fish
Critical	0	0	0	0	0	0	0	0	No Fish

In wet and above normal water years, average across 1 month: March. For below normal water years, average across 1 month: January. In dry and critical water years, no predicted loss in all months.

Table I-42. Loss of Green Sturgeon at State Water Project Banks Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	1	0	0	1	1	1	1: Mar
Above Normal	1	0	0	1	0	0	1: Mar
Below Normal	1	0	0	1	1	1	1: Jan
Dry	0	0	0	0	0	0	No Fish
Critical	0	0	0	0	0	0	No Fish

Absolute values are rounded.

Table I-43. Predicted Average Monthly Loss of Green Sturgeon at Jones Pumping Plant by Water Year Type for All Months with Predicted Non-Zero Average Monthly Loss

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4	Months
Wet	7	7 (0%)	6 (-6%)	6 (-6%)	6 (-6%)	6 (-6%)	4 (-46%)	6 (-6%)	1: June
Above Normal	6	7 (17%)	5 (-9%)	5 (-9%)	5 (-8%)	5 (-8%)	1 (-79%)	5 (-9%)	1: June
Below Normal	0	0	0	0	0	0	0	0	No Fish
Dry	1	1 (-1%)	1 (-14%)	1 (-13%)	1 (-12%)	1 (-10%)	0 (-89%)	1 (-11%)	2: June–July
Critical	0	0	0	0	0	0	0	0	No Fish

In wet and above normal water years, average across 1 month: June. For dry water years, average across 2 months: June–July. In below normal and critical water years, no predicted loss in all months.

Table I-44. Loss of Green Sturgeon at Central Valley Project Jones Pumping Plant for Exploratory Runs 1 and 3, the No Action Alternative, and 3 Components of Alternative 2, Averaged by Water Year Type and Month, based on the Salvage-Density Method

Water Year Type	NAA	EXP1	EXP3	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Months
Wet	7	0	0	6	6	6	1: June
Above Normal	6	0	0	5	5	5	1: June
Below Normal	0	0	0	0	0	0	No Fish
Dry	1	0	0	1	1	1	1: June–July
Critical	0	0	0	0	0	0	No Fish

Absolute values are rounded.

I.6.15.2 Environmental Impact Statement Key Takeaways

Length-at-Date Winter-run Chinook Salmon

The descriptive text below considers predicted loss of winter-run Chinook salmon at Banks and Jones Pumping Plants, independently, during the months of January, February, and March for wet and critical water years. These months capture the distribution of predicted values that temporally coincides with juvenile winter-run Chinook presence. These WYTs capture the greatest and least values of predicted loss. Months and water years are applicable to text for both LAD and genetic winter-run Chinook salmon.

At Banks Pumping Plant, in the month of March, Alternative 1 predicted loss of LAD winter-run Chinook salmon is greater than the No Action Alternative, ranging from 29% greater to 14% greater, in wet and critical water years respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of February, Alternative 1 predicted loss is greater than the No Action Alternative, ranging from 33% greater to 51% greater, in wet and critical water years respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of January, Alternative 1 predicted loss is greater than the No Action Alternative, ranging from 66% greater to 70% greater, in wet and critical water years respectively, compared to the No Action Alternative.

At Banks Pumping Plant, in the month of March, Alternative 2 (with TUCP without VA, wTUCPwoVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 6% greater to 4% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of February, Alternative 2 (with TUCP without VA) predicted loss of LAD winter-run Chinook salmon is greater than the No Action Alternative, ranging from 2% greater to 6% greater, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of January, Alternative 2 (with TUCP without VA) predicted loss of LAD winter-run Chinook salmon is less than the No Action Alternative, ranging from 1% less to 6% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Banks Pumping Plant, in the month of March, Alternative 2 (without TUCP without VA, woTUCPwoVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 7% greater to 21% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of February, Alternative 2 (without TUCP without VA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 2% greater to 11% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of January, Alternative 2 (without TUCP without VA) predicted loss of LAD winter-run Chinook salmon is less than the No Action Alternative, ranging from 1% less to 16% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Banks Pumping Plant, in the month of March, Alternative 2 (without TUCP Delta VA, woTUCPDeltaVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 4% greater to 17% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of February, Alternative 2 (without TUCP Delta VA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 2% greater to 12% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of January, Alternative 2 (without TUCP Delta VA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 1% greater to 16% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Banks Pumping Plant, in the month of March, Alternative 2 (without TUCP All VA, woTUCPAllVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 3% greater to 15% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of February, Alternative 2 (without TUCP All VA, woTUCPAllVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 2% greater to 13% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of January, Alternative 2 (without TUCP All VA, woTUCPAllVA) predicted loss of LAD winter-run Chinook salmon is less than the No Action Alternative, ranging from 1% less to 16% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Banks Pumping Plant, in the month of March, Alternative 3 predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 58% less to 13% greater, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of February, Alternative 3 predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 53% less to 15% greater, in wet and critical water years, respectively. At Banks Pumping Plant, in the month of January, Alternative 3 predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 33% less to 3% greater, in wet and critical water years, respectively.

At Banks Pumping Plant, in the month of March, Alternative 4 predicted loss of LAD winter-run Chinook salmon is greater than the No Action Alternative, ranging from 12% greater to 1% greater, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of February, Alternative 4 predicted loss of LAD winter-run Chinook salmon is greater than the No Action Alternative, ranging from 5% greater to 24% greater, in wet and critical water years, respectively, compared to the No Action Alternative. At Banks Pumping Plant, in the month of January, Alternative 4 predicted loss of LAD winter-run Chinook salmon is less than the No Action Alternative, ranging from 7% less to 4% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Jones Pumping Plant, in the month of March, Alternative 1 predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 1% greater to 14% less, in wet and critical water years respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of February, Alternative 1 predicted loss is greater than the No Action Alternative, ranging from 3% greater to 14% greater, in wet and critical water years respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of January, Alternative 1 predicted loss is greater than the No Action Alternative, ranging from 6% greater to 22% greater, in wet and critical water years respectively, compared to the No Action Alternative.

At Jones Pumping Plant, in the month of March, Alternative 2 (with TUCP without VA, wTUCPwoVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 8% greater to 8% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of February, Alternative 2 (with TUCP without VA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 5% greater to 2% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of January, Alternative 2 (with TUCP without VA) predicted loss of LAD winter-run Chinook salmon is equivalent or less than the No Action Alternative, ranging from 0% different to 11% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Jones Pumping Plant, in the month of March, Alternative 2 (without TUCP without VA, woTUCPwoVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 6% greater to 16% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of February, Alternative 2 (without TUCP without VA) predicted loss of LAD winter-run Chinook salmon is greater than the No Action Alternative, ranging from 4% greater to 1% greater, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of January, Alternative 2 (without TUCP without VA) predicted loss of LAD winter-run Chinook salmon is equivalent or less dependent on WYT than the No Action Alternative, ranging from 0% different to 3% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Jones Pumping Plant, in the month of March, Alternative 2 (without TUCP Delta VA, woTUCPDeltaVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 2% greater to 21% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of February, Alternative 2 (without TUCP Delta VA, woTUCPDeltaVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 6% greater to 1% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of January, Alternative 2 (without TUCP Delta VA, woTUCPDeltaVA) predicted loss of LAD winter-run Chinook salmon is equivalent or greater dependent on WYT than the No Action Alternative, ranging from 0% different to 1% greater, in wet and critical water years, respectively, compared to the No Action Alternative.

At Jones Pumping Plant, in the month of March, Alternative 2 (without TUCP All VA, woTUCPAllVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 2% greater to 21% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of February, Alternative 2 (without TUCP All VA, woTUCPAllVA) predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 6% greater to 1% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of January, Alternative 2 (without TUCP All VA, woTUCPAllVA) predicted loss of LAD winter-run Chinook salmon is equivalent to the No Action Alternative, 0% different in both wet and critical water years compared to the No Action Alternative.

At Jones Pumping Plant, in the month of March, Alternative 3 predicted loss of LAD winter-run Chinook salmon is less than the No Action Alternative, ranging from 36% less to 69% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of February, Alternative 3 predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 2% greater to 55% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones Pumping Plant, in the month of January, Alternative 3 predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 2% greater to 46% less, in wet and critical water years, respectively.

At Jones Pumping Plant, in the month of March, Alternative 4 predicted loss of LAD winter-run Chinook salmon is greater or less dependent on WYT than the No Action Alternative, ranging from 13% greater to 3% less, in wet and critical water years, respectively, compared to the No Action Alternative. At Jones, Pumping Plant in the month of February, Alternative 4 predicted loss of LAD winter-run Chinook salmon is greater than the No Action Alternative, at 7% greater in both wet and critical water years, compared to the No Action Alternative. At Jones Pumping Plant, in the month of January, Alternative 4 predicted loss of LAD winter-run Chinook salmon is equivalent or less than the No Action Alternative, ranging from 0% different to 2% less, in wet and critical water years, respectively, compared to the No Action Alternative.

At Banks Pumping Plant, …. genetic winter-run Chinook salmon

Length-at-Date Spring-run Chinook salmon

Steelhead

Green Sturgeon

Fall-run Chinook salmon

Late Fall-run Chinook salmon

Warmwater Species

Native: Hardhead, California Roach, Sacramento Splittail, Hitch

Nonnative: Black Basses (Largemouth Bass, Smallmouth Bass, Spotted Bass), Striped Bass, American Shad, Threadfin Shad

Coldwater Species

Pacific Lamprey, River Lamprey, White Sturgeon, Starry Founder

I.6.16 Longfin Smelt Salvage Old and Middle River Relationship

This section will summarize results from Attachment I.4, *Longfin Smelt Salvage OMR Relationship*. This line of evidence was not used in the IAR. Results provide an evaluation of potential changes of estimated salvage during the period of historically high juvenile presence in April and May. This analysis is meant as a tool to compare mean longfin smelt salvage across different operation scenarios and is not a predictive tool.

The following key takeaways are applicable for longfin smelt estimated salvage by WYT. The model recreates the regression of Grimaldo et al. (2009) for longfin smelt salvage at South Delta facilities as a function of CalSim 3-derived estimates of OMR flow.

- **Driver of Variation:** CalSim 3 exports are the primary driver of variation in the salvage OMR relationship.
- **Calibration and Calibration Period:** Following Grimaldo et al. (2009), longfin smelt salvage data for April and May from 1993–2005 were obtained from the CDFW salvage monitoring website and regressed against historical OMR flow data. CalSim 3 data outputs were used to calculate mean April–May OMR flows for each year of the 1922–2021 simulation and then used to estimate salvage for the modeled scenarios based on the historical regression relationship.
- **Uncertainties:** The historical salvage records used to develop this regression model were from 1993-2005, prior to the USFWS 2008 and 2009 Biological Opinions. Since the model is based solely on OMR flow and was developed using prior operational scenarios, the analysis may not be robust for current operational scenarios.
    - The model only uses a single covariate and assumes a constant population size, and does not take into account other abiotic factors (e.g. turbidity) and biotic factors (e.g. longfin smelt behavior, geographical distribution in wet versus critical water years) that may interact with OMR flows to reduce or increase entrainment.

- **Performance Measures:** Generally, salvage was higher for more negative OMR values. Predicted salvage in the modeled scenarios results were highest in wet years, due to OMR flow. Historically, juvenile longfin smelt salvage was highest in critical years and lowest in wet years.
  - Mean predicted salvage was highest for Alternative 1 in all WYTs, ranging from a 35% increase in critically dry years to a 295% increase in above normal years compared to the No Action Alternative. Alternative 1 mean OMR April–May flows were the most negative across all WYTs.
  - Mean predicted salvage was lowest for Alternative 3 in all WYTs, ranging from a 92% decrease in wet years to a 47% decrease in critically dry years compared to the No Action Alternative. Mean OMR April–May flows for Alternative 3 were positive for the wet and above normal water years and the least negative for all other WYTs.
  - Mean predicted salvage under the Proposed Action phases ranged from 3,712 to 1,110. The four components of Alternative 2 mean OMR values across April–May were most negative for the above normal followed by below normal, then wet, dry and critical water years.
- Mean predicted salvage was higher during wet water years for Alt2woTUCPDeltaVA and Alt2woTUCPAllVA even though mean April-May OMR flows were higher in the above normal water years because OMR flow was more variable and median OMR flow was more negative in wet years.

Table I-45. April–May Predicted Longfin Smelt Salvage by Water Year Type for Modeled Scenarios

Water Year Type	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
Wet	1359	4,032 (197%)	3,712 (173%)	3,706 (173%)	2,764 (103%)	2,697 (98%)	109 (-92%)	3,508 (158%)
Above Normal	1335	5,280 (295%)	3,754 (181%)	3,757 (181%)	1,829 (37%)	1,779 (33%)	265 (-80%)	3,813 (185%)
Below Normal	1451	3,388 (134%)	2,537 (75%)	2,647 (82%)	1,901 (31%)	1,763 (22%)	395 (-73%)	2,700 (86%)
Dry	1464	2,390 (63%)	2,090 (43%)	2,091 (43%)	1,578 (8%)	1,403 (-4%)	449 (-69%)	2,124 (45%)
Critical	905	1,226 (35%)	1,168 (29%)	1,110 (23%)	1,170 (29%)	1,126 (24%)	477 (-47%)	1,114 (23%)

Values are rounded to the nearest integer.

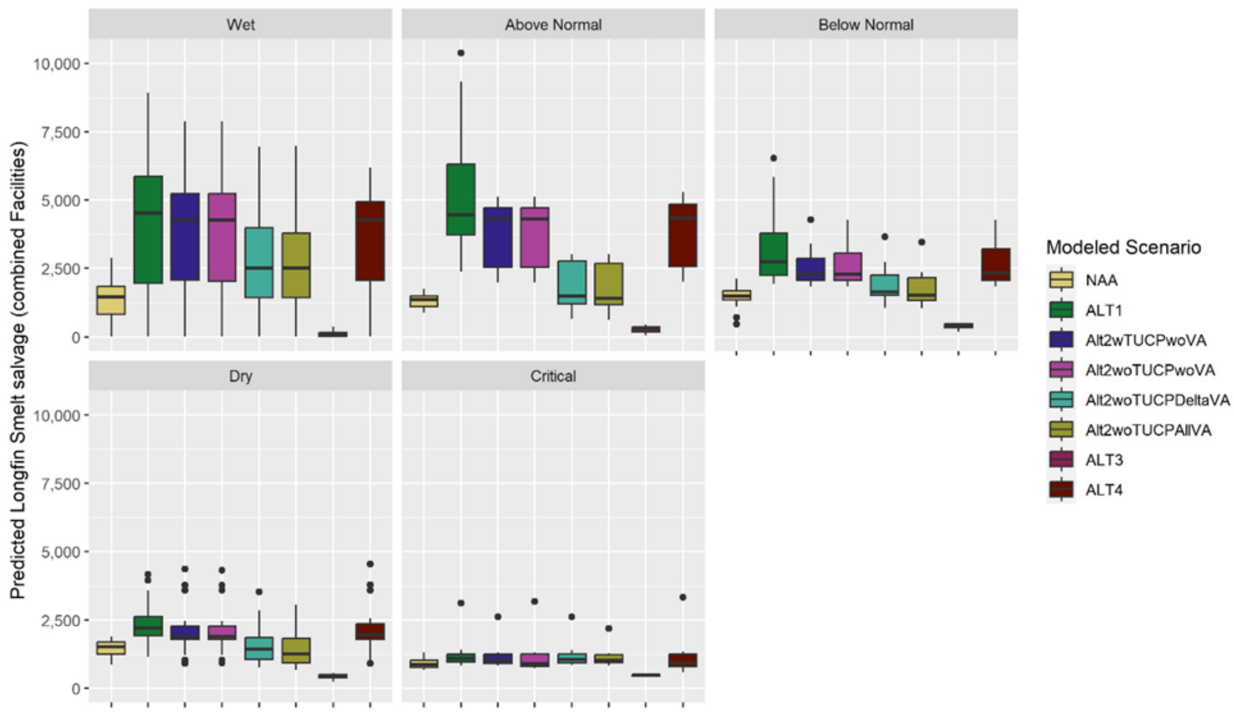


Figure I-60. Total Salvage at Bureau of Reclamation and California Department of Water Resources Facilities, Predicted from Old and Middle River Flows

I.6.17 Expanded Loss Autocorrelation Analysis

This section will summarize results from the expanded loss autocorrelation analysis. This line of evidence was not used in the Initial Alternative Report. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

Temporal autocorrelation is a well-known phenomenon commonly observed in time series data. As such, there are questions regarding the expected lag/response time of fish when daily loss thresholds, such as those in the 2020 ITP, are triggered and OMR is adjusted. Overall, the autocorrelation analysis indicated that autocorrelation is mostly prominent for about a week (~7 days). Because this analysis did not specifically evaluate autocorrelation during times when actions were taken (e.g., OMR shift towards a more positive or negative value), it does not provide a definitive answer on the question of response time for any particular species. Nevertheless, the results do suggest that a lagged response to water operation changes is likely and that there may be a carryover effect for roughly a week. In the Proposed Action, fish loss thresholds are thus set at a weekly or annual timescale for OMR management.

I.6.18 Interactive Object-oriented Simulation

This section will summarize Delta survival results from Attachment F.5, *Interactive Object-oriented Simulation Model*. Estimates can be used as a representation of entrainment risk effects. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

I.6.19 Oncorhynchus Bayesian Analysis

This section will summarize Delta survival results from Attachment F.6, *Oncorhynchus Bayesian Analysis Model*. Estimates cane be used as a representation of entrainment risk effects. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

I.6.20 Central Valley Project Improvement Act Science Integration Team Lifecycle Model

This section will summarizes Delta survival results from Attachment F.2, *CVPIA Winter-run LCM*. Reclamation analyzed monthly flow estimates from CalSim 3 and daily water temperature from HEC-5Q estimates for each alternative to evaluate the effect of long-term operation on population demographics, including migratory survival in the North and South Delta, for winter-run Chinook salmon. Estimates can be used as a representation of entrainment risk effects. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

USFWS and Reclamation have been working to develop lifecycle models for use in Structured Decision Making for CVPIA. Through a participatory process, the SIT has developed a winter-run Chinook Salmon Decision Support Model. The winter-run Decision Support Model, in addition to those created for fall- and spring-run Chinook salmon, were created to compare how habitat restoration actions might improve natural production. The Decision Support Models are stochastic or deterministic stage-based lifecycle models that track the number of Chinook salmon across juvenile size classes and adult stages of natural and hatchery origin. The transitions between stages are estimated with survival, growth, and movement submodels. Reclamation staff updated the model structure from the peer-reviewed, published version to include the following changes: (1) made the model responsive to new flow inputs from CalSim 3 and temperature inputs from new HEC-5Q runs, (2) conducted model re-calibration following correction of two issues in the original model, and (3) modified the model to save new model inputs, including demographic rates like migratory survival in the North and South Delta. Additional details can be found in Attachment F.2.

Summarized results for the performance metrics of migratory survival for smolt-sized fish (i.e., >110 mm) through the North or South Delta to Chipps Island are provided in Table I-46 and Table I-47 and Figure I-61 and Figure I-62 for the EIS (i.e., No Action Alternative, Alternative 1, all four phases of Alternative 2, Alternative 3, and Alternative 4).

Summarized results for the same performance metric are provided in Table I-48 and Table I-49 and Figure I-63 and Figure I-64 for the Biological Assessment.

- Within the context of Reclamation's application of the model for long-term operation purposes, the CVPIA SIT winter-run lifecycle model is responsive to monthly estimates of flow variables throughout the Central Valley and monthly estimates of temperature and temperature exposure in the Upper Sacramento River.
- The model was calibrated to winter-run Chinook salmon spawner abundance data from the Upper Sacramento River for the period 1998–2016.
- Reclamation's application of the CVPIA SIT models to evaluate management alternatives assumes that winter-run Chinook salmon are only responsive to changes in flow as well as temperature in the Upper Sacramento River. Reclamation did not include responsiveness of habitat availability to changing flow, and as such this application assumes habitat availability is constant across all alternatives. The update from CalSim II to CalSim 3 model results also includes possible directional change in flow values due only to how flow variables are defined between the two CalSim models. Reclamation staff note that calibrating the model with numerous parameters to a single dataset has the potential to result in unrealistically high or low parameter values; staff attempted to constrain parameter values to biologically feasible values where appropriate. Finally, several demographic rates in the model are not currently constructed to be responsive to changing flow and temperature inputs, despite possible expectation to the contrary; these include timing of adult arrival to spawning grounds and subsequent spawning, egg-to-fry survival, and juvenile growth rates.
- Presented performance metrics for these models are migratory survival in the North and South Delta.

Expected smolt migratory survival in the North Delta, across all WYTs and for the months of September through May, varied between 0.839 (Alt2woTUCPDeltaVA) and 0.855 (all Alts). Expected migratory survival in the North Delta was greatest in February and March and lowest in September, October, and May. Migratory survival also was lowest in critical water years and greatest in wet water years. Alternative 1 and Alternative 3 produced the most variable survival for individual WYTs and months, relative to the No Action Alternative, while the four phases of Alternative 2 and Alternative 4 produced generally similar survival relative to the No Action Alternative.

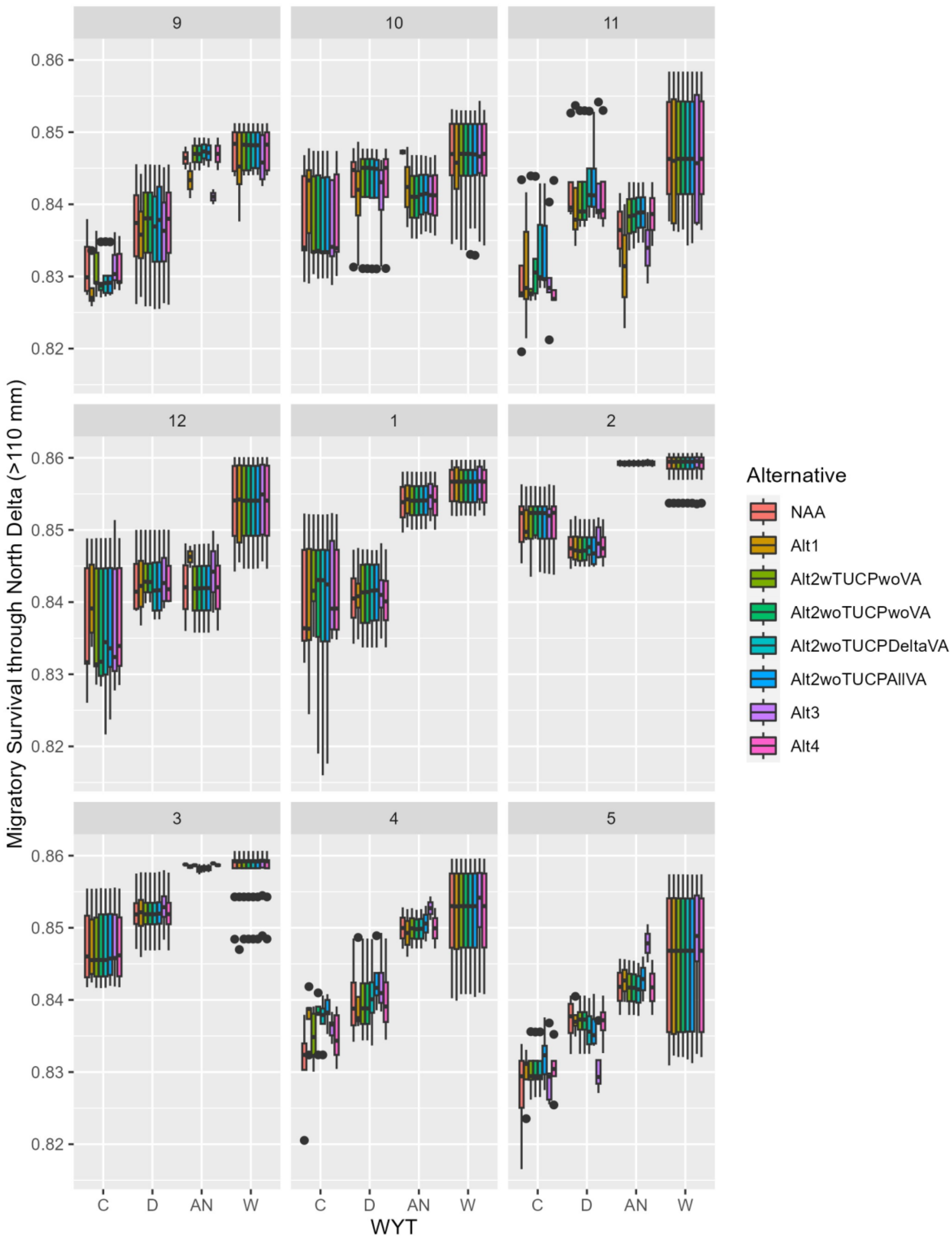
Expected smolt migratory survival in the North Delta, across all WYTs and for the months of September through May, varied between 0.286 (Alternative 3) and 0.473 (Alternative 3). Expected migratory survival in the South Delta was greatest in February and March and lowest in September, October, and November. Expected migratory survival also was consistently highest in wet and above normal years in February and March and consistently lowest in critical years in September, November, April, and May.

Table I-46. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the North Delta, Across All Water Year Types and Faceted by Month

Water Year Type	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	9	0.841	0.839	0.841	0.841	0.841	0.841	0.840	0.841
All	10	0.843	0.843	0.843	0.843	0.842	0.843	0.842	0.843
All	11	0.841	0.840	0.841	0.842	0.842	0.842	0.841	0.841
All	12	0.846	0.847	0.846	0.846	0.846	0.846	0.847	0.846
All	1	0.849	0.849	0.850	0.849	0.849	0.849	0.850	0.849
All	2	0.855	0.855	0.855	0.855	0.855	0.855	0.855	0.855
All	3	0.854	0.854	0.854	0.854	0.854	0.854	0.855	0.854
All	4	0.844	0.846	0.845	0.846	0.846	0.847	0.847	0.845
All	5	0.839	0.840	0.840	0.840	0.839	0.840	0.840	0.840

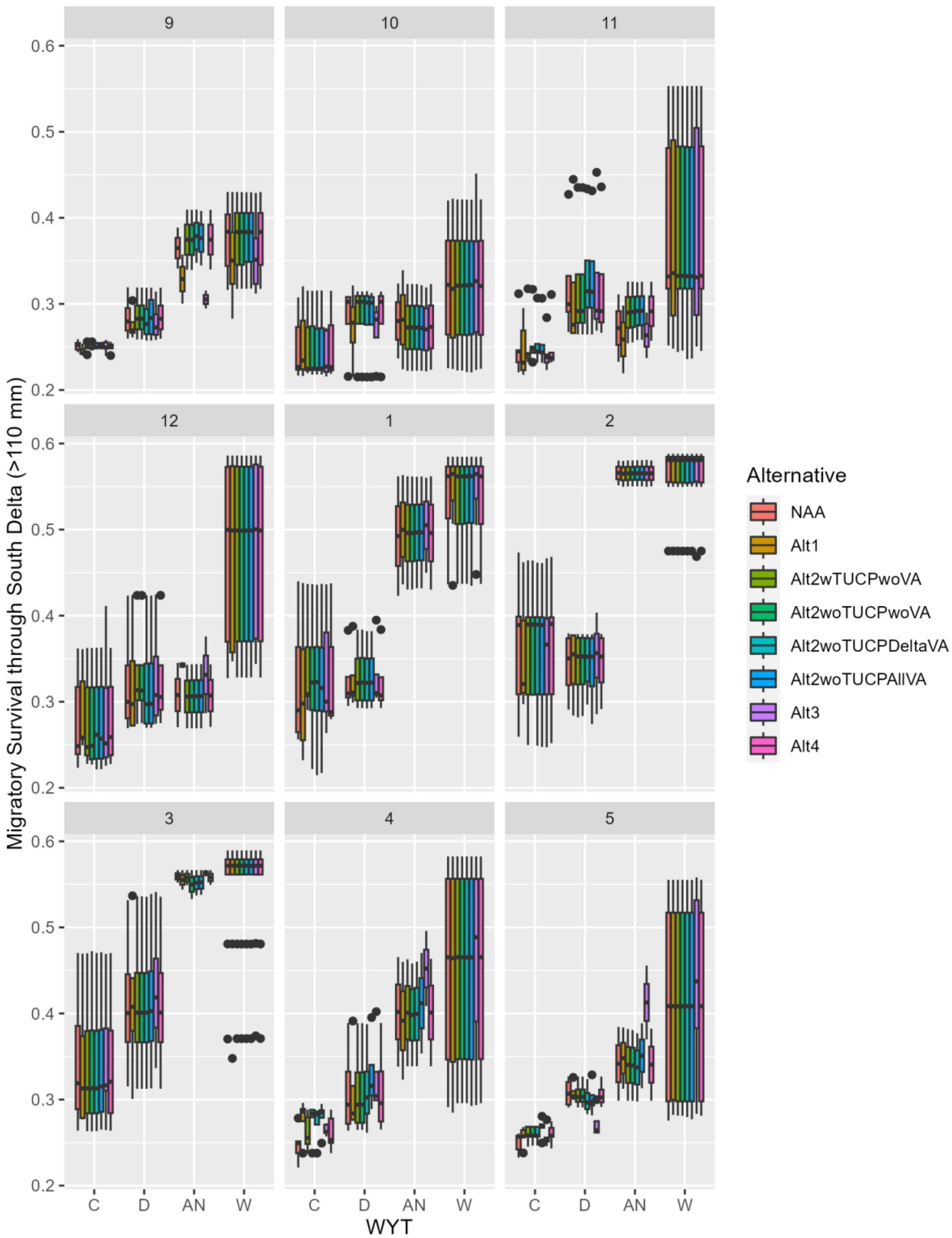
Table I-47. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the South Delta, Across All Water Year Types and Faceted by Month

Water Year Type	Month	NAA	Alt1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt3	Alt4
All	9	0.326	0.308	0.326	0.326	0.327	0.327	0.310	0.327
All	10	0.291	0.287	0.291	0.291	0.290	0.290	0.286	0.291
All	11	0.329	0.323	0.331	0.332	0.333	0.333	0.326	0.331
All	12	0.379	0.387	0.381	0.381	0.379	0.379	0.389	0.381
All	1	0.438	0.439	0.443	0.440	0.439	0.439	0.445	0.439
All	2	0.470	0.468	0.469	0.472	0.470	0.468	0.469	0.470
All	3	0.469	0.466	0.468	0.467	0.467	0.468	0.473	0.468
All	4	0.365	0.370	0.369	0.372	0.372	0.378	0.387	0.369
All	5	0.345	0.348	0.347	0.347	0.345	0.349	0.359	0.347



mm = millimeter; C = critical; D = dry; AN = above normal; W = wet.

Figure I-61. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the North Delta from Deterministic Model Runs, Faceted by Month



mm = millimeter; C = critical; D = dry; AN = above normal; W = wet.

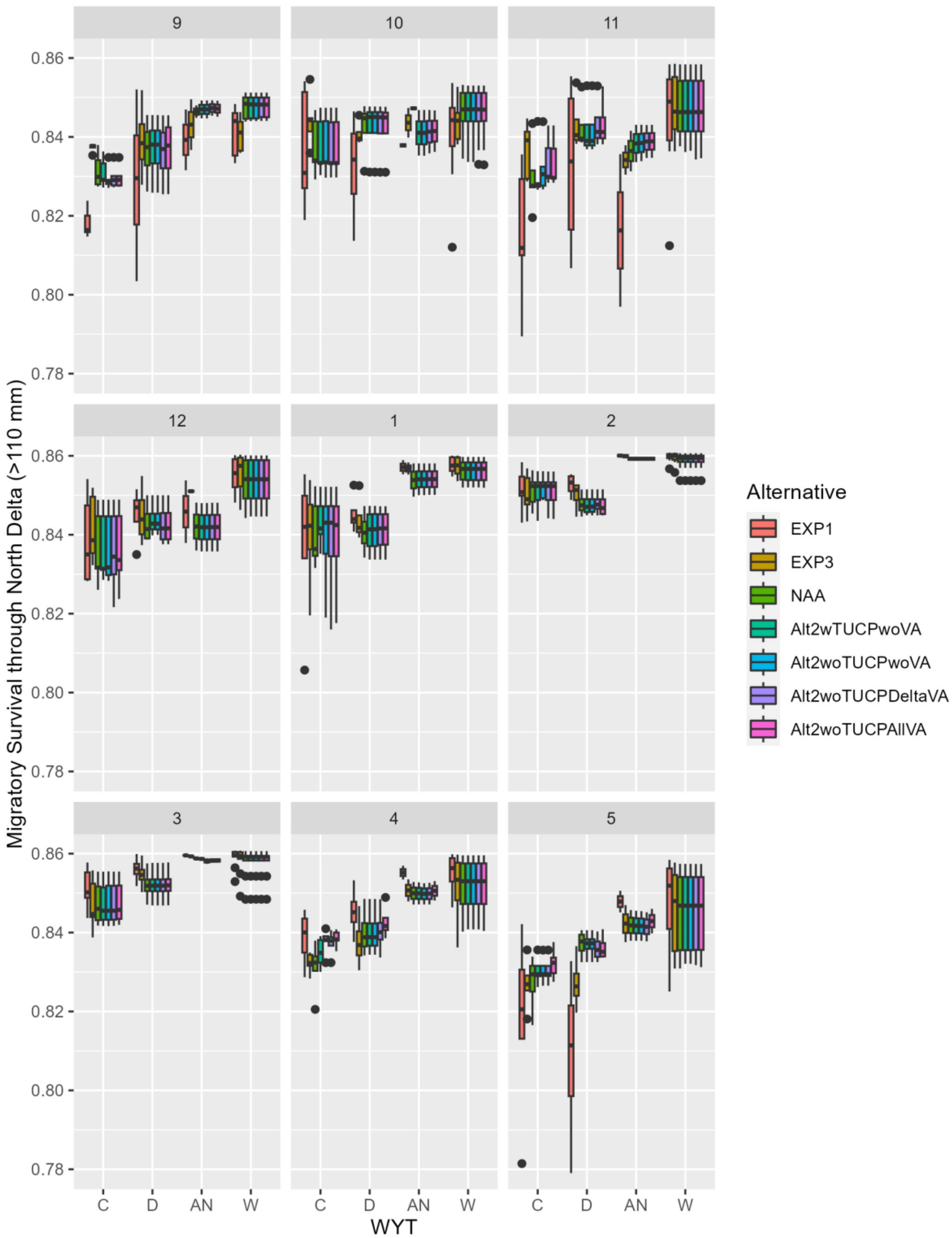
Figure I-62. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the South Delta from Deterministic Model Runs, Faceted by Month

Table I-48. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the North Delta, Across All Water Year Types and Faceted by Month

Water Year Type	Month	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
All	9	0.833	0.840	0.841	0.841	0.841	0.841	0.841
All	10	0.837	0.843	0.843	0.843	0.843	0.842	0.843
All	11	0.832	0.843	0.841	0.841	0.842	0.842	0.842
All	12	0.848	0.849	0.846	0.846	0.846	0.846	0.846
All	1	0.850	0.850	0.849	0.850	0.849	0.849	0.849
All	2	0.856	0.855	0.855	0.855	0.855	0.855	0.855
All	3	0.856	0.855	0.854	0.854	0.854	0.854	0.854
All	4	0.849	0.844	0.844	0.845	0.846	0.846	0.847
All	5	0.833	0.837	0.839	0.840	0.840	0.839	0.840

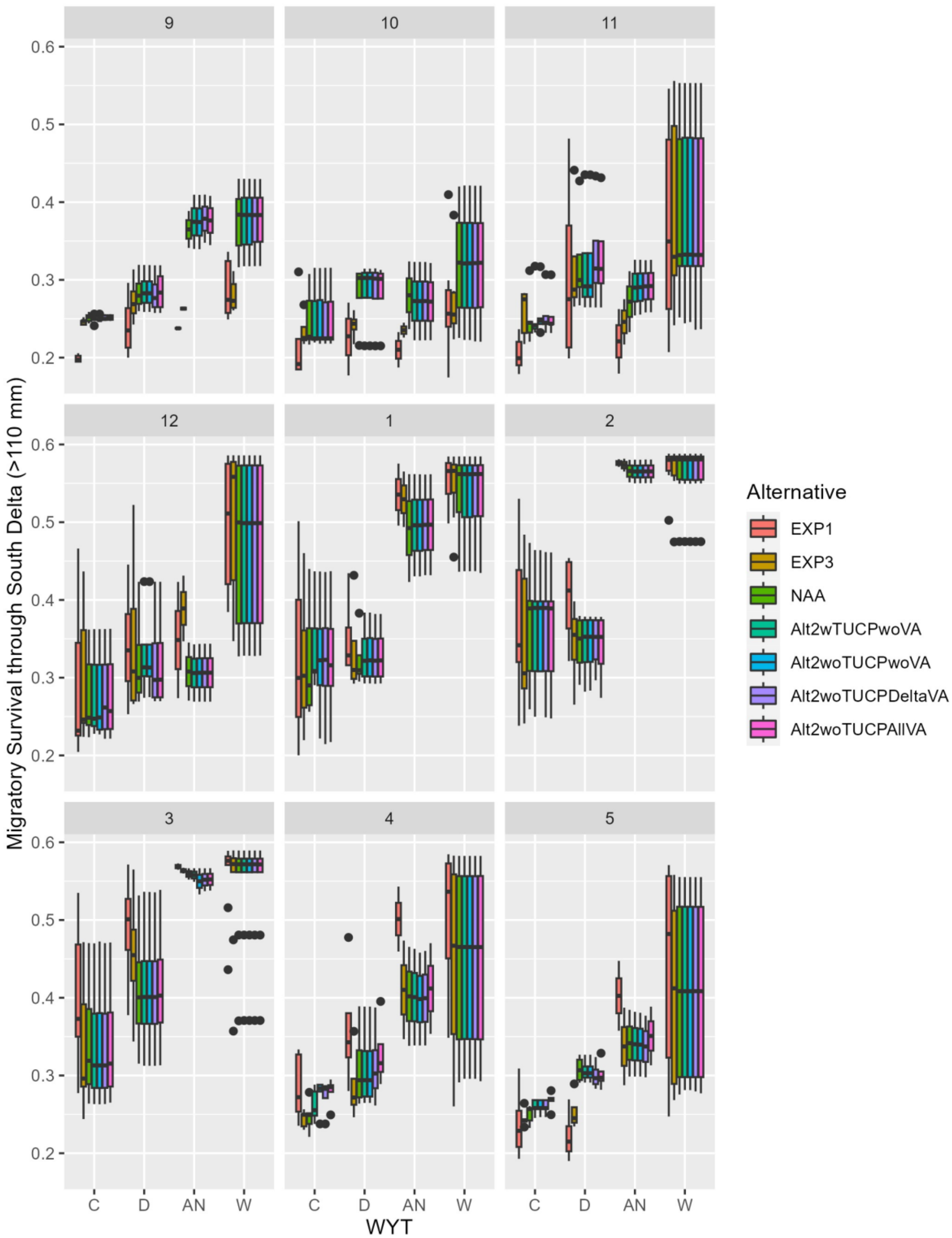
Table I-49. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the South Delta, Across All Water Year Types and Faceted by Month

Water Year Type	Month	EXP1	EXP3	NAA	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA
All	9	0.253	0.269	0.326	0.326	0.326	0.327	0.327
All	10	0.240	0.252	0.291	0.291	0.291	0.290	0.290
All	11	0.301	0.326	0.329	0.331	0.332	0.333	0.333
All	12	0.402	0.411	0.379	0.381	0.381	0.379	0.379
All	1	0.455	0.446	0.438	0.443	0.440	0.439	0.439
All	2	0.487	0.467	0.470	0.469	0.472	0.470	0.468
All	3	0.505	0.475	0.469	0.468	0.467	0.467	0.468
All	4	0.422	0.360	0.365	0.369	0.372	0.372	0.378
All	5	0.343	0.331	0.345	0.347	0.347	0.345	0.349



mm = millimeter; C = critical; D = dry; AN = above normal; W = wet.

Figure I-63. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the North Delta from Deterministic Model Runs, Faceted by Month



mm = millimeter; C = critical; D = dry; AN = above normal; W = wet.

Figure I-64. Predicted Smolt Migratory Survival for Winter-run Chinook Salmon in the South Delta from Deterministic Model Runs, Faceted by Month

I.6.21 Delta Smelt Lifecycle Model with Entrainment

See Attachment F.4, *Delta Smelt Lifecycle Model with Entrainment*, for more details.

- Differences in results across alternatives for the lifecycle model with entrainment were driven by differences in December-June OMR values, June-August outflow value, and aggregated food/prey metric from January to March.
- The lifecycle model with entrainment was constructed using data from cohort years 1995-2015. As such, the model was used to calculate expected annual population growth rate (λ; the abundance of current year divided by abundance from previous year) as a performance measure of Delta seasonal flow operations influence on OMR and outflow over a twenty year time period (1995–2015).
- The general statistical prohibition against extrapolation suggests that model predictions are more uncertain when explanatory variables are outside the range of observations to which the model was fit. Most CalSim-predicted flows and zooplankton predictions were not outside the range of observations to which the Delta smelt lifecycle model with entrainment was fit, but some alternatives did include out-of-range values.
- Geometric mean of population growth rate (λ) from 1995 to 2015 only showed considerable differences from the observed data and/or No Action Alternative for Exploratory 3, Alternative 1, and Alternative 3 scenarios, where Exploratory 3 and Alternative 3 performed better than most scenarios/alternatives (i.e., higher λ) and Alternative 1 performed worse than most alternatives (i.e., lower λ).
- Exploratory 3 and Alternative 3 scenarios likely produced in higher λ due to more positive OMR flows for most months and the relatively high June-August Delta Outflow during dry years.
- The Alternative 1 scenario likely produced lower λ relative to most scenarios due to the more negative OMR flows during most months.
- The No Action Alternative, all components of Alternative 2, and Alternative 4 did not produce considerably higher λ than the empirical data despite OMR restrictions that should reduce entrainment. This may be due to the apparent trade-off between OMR flow and summer Delta outflow that somehow occurred between these alternatives and the empirical data.

I.7 Uncertainty

Hydrodynamics and effects of the CVP and SWP operations on entrainment risk is well documented. Multiple corollary and mechanistic models exists to explain individual effects. Uncertainty remains around how these individual effects, both direct and indirect, from operations, may impact ESA listed species populations.

Future studies of high value that may benefit from special studies include estimating the juvenile production of steelhead in the Delta and studies to evaluate the effect operations has on winter-run Chinook salmon and other migratory ESA listed species seasonal survival through outmigration past Chipps Island. Better understanding for the percentage of winter-run and other ESA species that are influenced by export versus inflow effects of the CVP and SWP may help to better inform Delta management efforts that use OMR flows to influence population dynamics of these species.

These special studies include:

- Winter-run Chinook Salmon Delta Route Selection and Survival
- Steelhead JPE and OMR Management

I.8 References

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I.8.2 Personal Communications

Kevin Reece, pers. comm.

Russ Perry, USGS, pers. comm.