BUREAU OF RECLAMATION

Water Year 2021 Seasonal Report for Old and Middle River Flow Management

Central Valley Project, California
California-Great Basin Region

U.S. Department of the Interior **August 2021**

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Water Year 2021 Seasonal Report for Old and Middle River Flow Management

Central Valley Project, California
California-Great Basin Region

prepared by

United States Bureau of Reclamation and
California Department of Water Resources

in coordination with USFWS, NMFS, and CDFW

Cover Photo: A photograph of Mildred Island (Middle River). (Bureau of Reclamation)

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Purpose

The Water Year (WY) 2021 Seasonal Report for Old and Middle River (OMR) Flow Management describes Delta operations and actions and recommends adjustments to the OMR Flow Management Guidance Document (OMR Guidance Document) and the Delta Cross Channel Operations and Fall/Winter Closures Guidance Document (DCC Guidance Document) for WY 2022. While the focus of this report is on OMR flow management, Delta Cross Channel (DCC) operations are included as its operations are related to entrainment performance into the south Delta and the fish salvage facilities. This Seasonal Report fulfills commitments under the Record of Decision (ROD) signed by the Bureau of Reclamation (Reclamation) for the Reinitiation of Consultation on the Coordinated Long-Term Operation (LTO) of the Central Valley Project (CVP) and State Water Project (SWP). It also fulfills the California Department of Water Resources (DWR's) reporting commitments for the smelt and salmon teams to summarize major actions taken to implement the Incidental Take Permit (ITP) Conditions of Approval (COAs) for Long-Term Operation of the SWP in the Sacramento-San Joaquin Delta (Permit No. 2081-2019-066-00, ITP Conditions 8.1.1 and 8.1.2). Additionally, this Seasonal Report will be used to support the development of Reclamation's 2021 Annual Report on the Long-Term Operation of the Central Valley Project and State Water Project (Annual Report), as well as DWR's 2021 Annual Status Report (ITP Condition 7.2). Finally, this document will inform the Four-Year Review Panels adopted under the ROD and identified in the SWP actions (ITP Condition 3.13.8). In January of 2024 and 2028, Reclamation and the DWR will charter an independent panel to review OMR management, among other actions. The purpose of the independent review will be to evaluate the efficacy of actions undertaken under the LTO to reduce the adverse effects on listed species.

Compliance with National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS) 2019 Biological Opinions' Reasonable and Prudent Measures and associated Terms and Conditions adopted by the aforementioned ROD will be documented and discussed in the Annual Report and not in this document. Although this document strives to provide an integrated view of the system and the factors affecting the LTO of the CVP and SWP, evaluation and discussion is focused on actions taken specifically by Reclamation and DWR for OMR flow management and is based on assessments developed through the Salmon Monitoring Team (SaMT) and the Smelt Monitoring Team (SMT). The procedures used by both monitoring teams are described in the Old and Middle River Flow Management Guidance Document (Appendix A).

Background

The Sacramento–San Joaquin River Delta (Delta) is formed by the confluence of the Sacramento and San Joaquin Rivers. Located in the southwestern portion of the Delta are Reclamation's C.W. "Bill" Jones Pumping Plant and DWR's Harvey O. Banks Pumping Plant (hereafter referred to as the CVP and SWP export facilities), which divert water south through the Delta-Mendota Canal and

the California Aqueduct, respectively. The proximity of the CVP and SWP export facilities to the Old and Middle Rivers is shown in Figure 1.

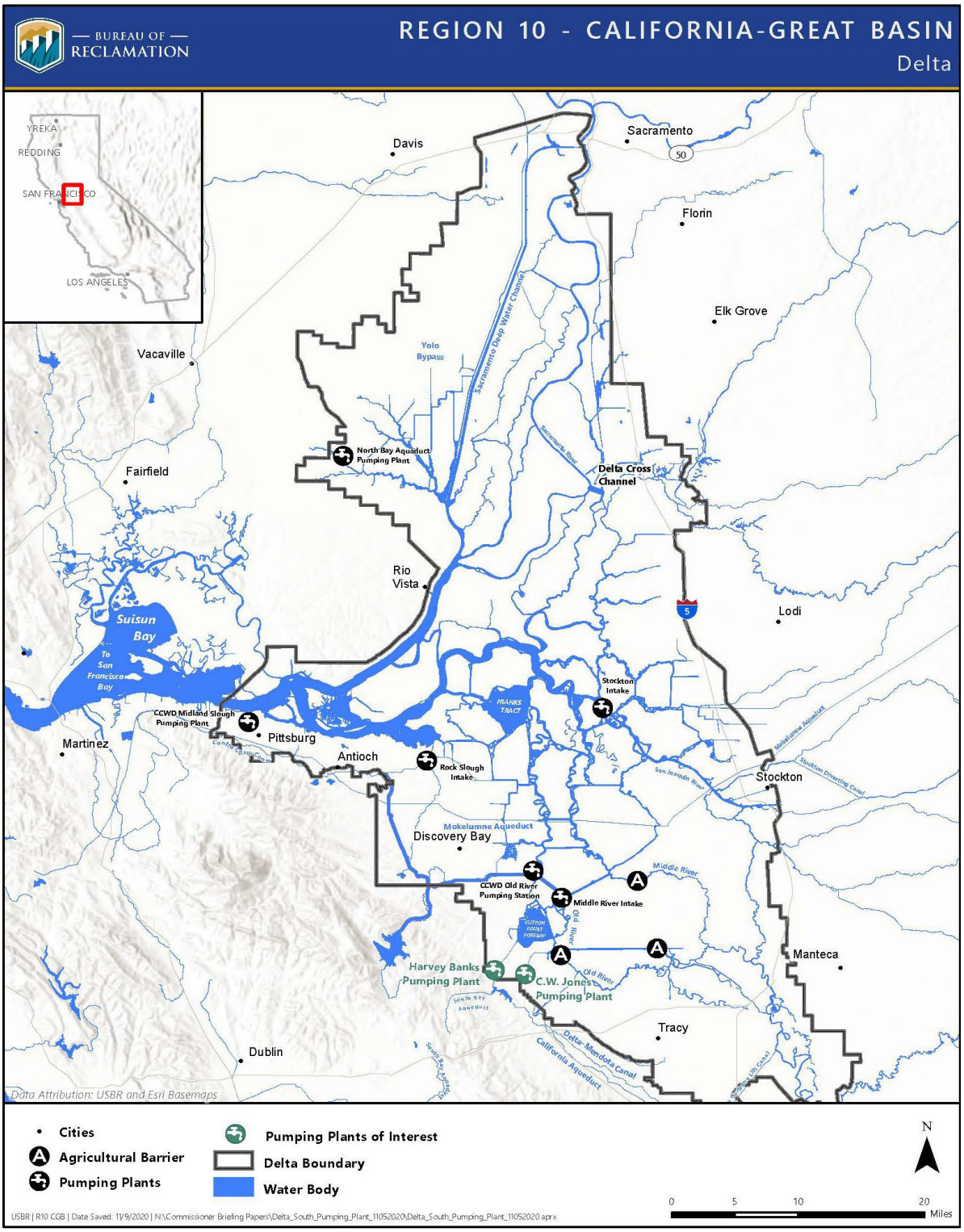


Figure 1. Map of the Delta with CVP and SWP infrastructure.

Net flow within the OMR corridor to the north of the CVP and SWP export facilities provides a surrogate indicator for how export pumping influences hydrodynamics in the South Delta. The management of OMR flow, in combination with other environmental variables, can minimize or avoid the entrainment of fish into the South Delta and at CVP and SWP fish salvage facilities. Reclamation and DWR manage exports by incorporating real-time monitoring of fish spatial distribution, turbidity, water temperature, and current application of hydrodynamic and entrainment models to support decision making for the management of OMR flows to minimize entrainment of fish and protect critical habitat for fish when necessary and provide flexibility when possible. Estimates of species spatial and temporal distribution are described by the two multi-agency Delta-focused technical teams, the SaMT and SMT.

Reclamation consulted under the Endangered Species Act (ESA) with the USFWS and NMFS on potential effects of the Proposed Action on threatened and endangered species and designated critical habitat. The USFWS and NMFS issued their Biological Opinions of the Proposed Action on October 21, 2019. OMR management and DCC operations are a part of the Delta Operations described in the Proposed Action, which requires this Seasonal Report. Reclamation signed the ROD on February 18, 2020, and subsequently began implementing the Proposed Action.

The Proposed Action, adopted in the ROD (hereafter the Proposed Action will be referred to as the ROD when it is described in the context of implementation), included measures that are intended to protect threatened and endangered species. Early Winter Pulse Protection ("First Flush") and net OMR flows no more negative than –5,000 cfs are actions expected to minimize adverse effects to Delta Smelt (*Hypomesus transpacificus*), Sacramento River winter-run Chinook Salmon (*Oncorhynchus tshawytscha*), Central Valley (CV) spring-run Chinook Salmon (O. *tshawytscha*) and California Central Valley (CCV) steelhead (*O. mykiss*). Other OMR management actions expected to reduce or minimize negative effects to Delta Smelt include protections for adult Delta Smelt based on turbidity (Turbidity Bridge Avoidance) and protections for recruitment of larvae and juveniles based on proportional entrainment loss from the Delta Smelt Life Cycle Model. The Turbidity Bridge Avoidance action also is expected to reduce or minimize negative effects to juvenile Delta Smelt. Another OMR management action expected to benefit winter-run Chinook Salmon, and steelhead/rainbow trout is the management of OMR to avoid exceeding single-year and cumulative loss thresholds for natural and hatchery winter-run Chinook Salmon, Sacramento River origin steelhead, and San Joaquin River origin steelhead.

Under the California Endangered Species Act (CESA), DWR consulted with the California Department of Fish and Wildlife (CDFW) to obtain a separate Incidental Take Permit (ITP) for Long-Term Operation of the SWP. DWR submitted an application to CDFW in December 2019 and, on March 31, 2020, CDFW issued an ITP (2081-2019-066-00) to DWR that covers four CESA-listed species: Longfin Smelt (*Spirinchus thaleichthys*), Delta Smelt, CV spring-run Chinook Salmon, and Sacramento River winter-run Chinook Salmon. The project description in the ITP application and Conditions of Approval listed in the ITP included many of the same measures identified in the federal ESA consultation for the management of OMR to reduce the risk of entrainment of listed fish species, as well as some additional measures.

State Water Resources Control Board's (SWRCB) Decision 1641(D-1641) influences operations of the CVP and SWP export facilities, including OMR management. Obligations under D-1641 include protections for fish and wildlife, Municipal and Industrial (M & I) water quality, agricultural water

quality, and Suisun Marsh salinity. Under the ROD, DCC gates are closed when fish triggers are met in October and November, and closed on December 1 unless water quality concern criteria are exceeded in the Delta in December and January which allow limited gate operations. The ROD includes D-1641 requirements including gates closures from February 1 through mid-May, and gates closures up to 45 days from November 1 through January.

Seasonal Operations

This Seasonal Operations section describes DCC Operations and OMR Flow Management during WY 2021. Reclamation and DWR have included a discussion on winter-run Chinook Salmon, CV spring-run Chinook Salmon, CCV steelhead, Longfin smelt, and Delta Smelt. Reclamation does not have actions related to OMR Management in the Proposed Action for green sturgeon in the Delta. However, the NMFS Biological Opinion ITS requires monitoring salvage at the Delta fish collection facilities for this species. In WY 2021 there was no salvage of green sturgeon. Fall-run Chinook Salmon are not an ESA-listed species but are relevant because they comprise a large portion of the Southern Resident killer whale diet, which is an ESA-listed species. Young-of-year (YOY) spring-run Chinook Salmon, steelhead, and YOY fall-run Chinook Salmon have considerable overlap in migration timing, residency, and migration through the Delta. Therefore, an OMR value of no more negative than -5,000 cfs and other actions benefiting spring-run Chinook Salmon and steelhead should also benefit fall-run Chinook Salmon. Additionally, there is overlap between winter-run Chinook Salmon and fall-run Chinook Salmon residency and migration.

All data used to create figures in this report are provided in Appendix C. As a note, natural winter-run Chinook Salmon reported in these data have not been genetically identified and are defined as winter-run Chinook Salmon by length-at-date (LAD) measurements.

Drought Conditions in WY 2021

Water Year (WY) 2021 is the driest on record since 1977. This year offered weak winter storms yielding extremely low precipitation totals, reduced snowpack which was heavier at lower elevations, dry watershed soils, poor runoff, and below normal reservoir storage conditions at the beginning of WY 2021 due to dry conditions in WY 2020. The extremely dry conditions in the Sacramento – San Joaquin Bay-Delta (Delta) watershed pose challenges to the effective management of the CVP and SWP including ability to meet Delta water rights requirements for outflow and water quality.

While WY 2021 started out with dry conditions, the hydrology in late April 2021 deteriorated with significant and uncharacteristic deficits in watershed runoff, especially for the Sacramento River. Runoff conditions at the end of April 2021 unexpectedly deviated from forecasts when expected reservoir inflow from snowmelt failed to materialize, as much of the snowmelt was absorbed into the parched soils or sublimated into the atmosphere. The unimpaired Sacramento Four River Index 90 percent runoff exceedance water year forecast decreased by 685 thousand acre-feet (TAF) between April and May 2021. A combination of factors created poor conditions including May 2021 runoff reductions greater than recent norms, extremely low rainfall, dry soils, continued dry and warm air temperature conditions, and suppressed reservoirs with limited available water supplies to

support outflow and water quality requirements in the Delta. The CVP and SWP were challenged in meeting Delta water right standards under D-1641 in April, and as a result of existing hydrology adjustment criteria, Delta water right requirements for outflow were relaxed in May as part of the existing hydrology adjustment criteria under D-1641 for poor or critical water year types. Delta water right requirements were also relaxed from June through August 15th through a Temporary Urgent Change Petition and resulting Order from the SWRCB.

As announced by the Governor of California in the May 10, 2021, Emergency Proclamation on drought conditions for the Delta and other watersheds, the continuation of extremely dry conditions in the Delta watershed meant there was not an adequate water supply to meet water right permit obligations for instream flows and water quality under D-1641. Thus, Reclamation and DWR submitted a 2021 Temporary Urgency Change Petition (TUCP) requesting the SWRCB approve modification to certain terms of the CVP and SWP water rights permits under D-1641 from June 1, 2021 to August 15, 2021. The SWRCB granted the TUCP on June 1, 2021, which relaxed Delta outflow and water quality requirements. Outflow requirements were relaxed for the months of June and July 2021 from 4,000 cfs to 3,000 cfs and water quality requirements were relaxed from June through August 15, 2021 by changing the Western Delta agricultural salinity objective compliance location at Emmaton to Threemile Slough on the Sacramento River. Relaxation of the standards allowed for a rebalancing of upstream and downstream impacts.

As of August 2021, critically dry conditions in the Delta watershed persist, and Reclamation and DWR, through a team of managers from their agencies, continue to meet with SWRCB staff to consider additional modifications of D-1641 water quality and flow objectives and to coordinate management of water supplies through the course of the declared drought emergency. Although multiple adjustments were made or pursued to accommodate drought conditions, OMR management as described in the ROD was not modified as a result of poor hydrologic conditions.

Delta Cross Channel Operations

Figure 2. Delta Cross Channel Gates (Reclamation/Todd Plain).

The DCC operation schedule is described in the ROD, which includes the D-1641 operations requirement. During the winter and early spring, Reclamation performed construction for critical repairs of the DCC gates. Reclamation completed memos to file with technical assistance from both NMFS and USFWS regarding the February and May testing events. Testing on the DCC gates occurred on February 16, 2021, February 17, 2021, and May 5, 2021. In WY 2021, there were no closures triggered by the Knight's Landing Catch Index (KLCI) or Sacramento Index (SCI) from the ROD. Due to on-going drought conditions and difficulty meeting D-1641 requirements, the DCC gates were opened briefly from June 4, 2021 to June 7, 2021.The requirements, now at Three Mile Slough and Jersey Point, were met under the TUCP leading up to and during this time period. The goal of the operation was to take advantage of the tidal cycle and improve the long-term goal of Jersey Point water quality improvement. The DCC gates were opened again June 16, 2021. (Figure 3). DCC gate openings allow fresh Sacramento River water to flow into central Delta and improve water quality. Opening and closing of the DCC gates in WY 2021 helped to balance the water quality at multiple stations throughout the delta, such as Sacramento River at Emmaton (relaxed to Three Mile Slough by the TUCP) and San Joaquin River at Jersey Point.

The brief openings of the DCC gates on February 16th and 17th occurred while natural winter-run and hatchery winter-run Chinook Salmon, as well as natural CV spring-run Chinook Salmon and

steelhead, were present in the vicinity of the DCC gates. Remaining emigrating Salmonids of Sacramento River Basin origin passing by the DCC gates on May 5, 2021 and after June 4, 2021 when the gates were cycled open on the weekends had the potential to be diverted into the interior Delta; however, the likelihood of this occurring was small for juvenile natural winter-run Chinook Salmon based on historical monitoring data. Average migration timing characteristics of juvenile winter-run Chinook Salmon at Chipps Island Trawls (2006 – 2019) show the average last detection date is March 20th and the median last detection date is March 30th of any given year. During WY 2021 the earliest catch of juvenile winter-run Chinook Salmon in the Sacramento River Trawl at Sherwood Harbor was February 8, 2021 and the latest date was April 9, 2021. Additionally, it is unlikely juvenile natural winter-run Chinook Salmon experienced changes in behavior (rearing, foraging, sheltering, or migrating) in the western Delta and Sacramento River corridor due to DCC gate testing. Adult spring-run Chinook Salmon may have been attracted into the lower Mokelumne River system by Sacramento River flows passing through the open DCC gates during spring testing, which has the potential to delay their upstream migration into the Sacramento River basin. Late emigrating juvenile spring-run Chinook Salmon from the Sacramento River basin would also potentially be in the vicinity of the DCC gates during these periods of open gate configuration and risk entrainment into the Delta interior. Juvenile steelhead loss that occurs between December 1 and June 15 is split into two time-periods: December 1 through March 30 and April 1 through June 15. This is to ensure protection for both Sacramento River Basin and San Joaquin River Basin origin steelhead (NMFS 2019 Biological Opinion, Table 11). The majority of Sacramento River Basin steelhead out-migrate earlier in the season, while the DCC gates are closed. However, late emigrating natural steelhead from the Sacramento River basin are still expected to be in the vicinity of the DCC gates during their operations in May and June. San Joaquin River Basin steelhead out-migrate later in the season, and while the route they follow would not lead them past the DCC gates, migrating fish may overlap with operations in May and June.

During WY 2021, Sacramento River winter-run Chinook Salmon presence was highest at the Knights Landing rotary screw trap in January (15 percent of season observations) and February (59 percent of season observations) (Figure 3); however, the DCC gates were closed for the season on December 1, 2020. Therefore, there was reduced potential for fish to be routed into the Central and South Delta regions. The DCC gates were opened on February 16 and February 17, 2021 when 7.4 percent of total unmarked winter-run Chinook salmonid observations for WY 2021 (October 1, 2020 through May 30, 2021) occurred at Knights Landing. Also, during those two days 0.6 percent of WY 2021 total unmarked spring-run Chinook salmonid observations and 0 percent of total unmarked steelhead observations occurred at Knights Landing. However, observations upstream of the DCC gates may not reflect the actual percentage of fish at the location of the gates, as fish could have moved downstream prior to the date of gate operations. The DCC gates were again opened briefly on May 5, 2021. SaMT distribution estimates of natural winter-run Chinook Salmon in the Delta during the May 4, 2021 meeting was 5 – 20 percent (79 – 95 percent exited past Chipps Island).

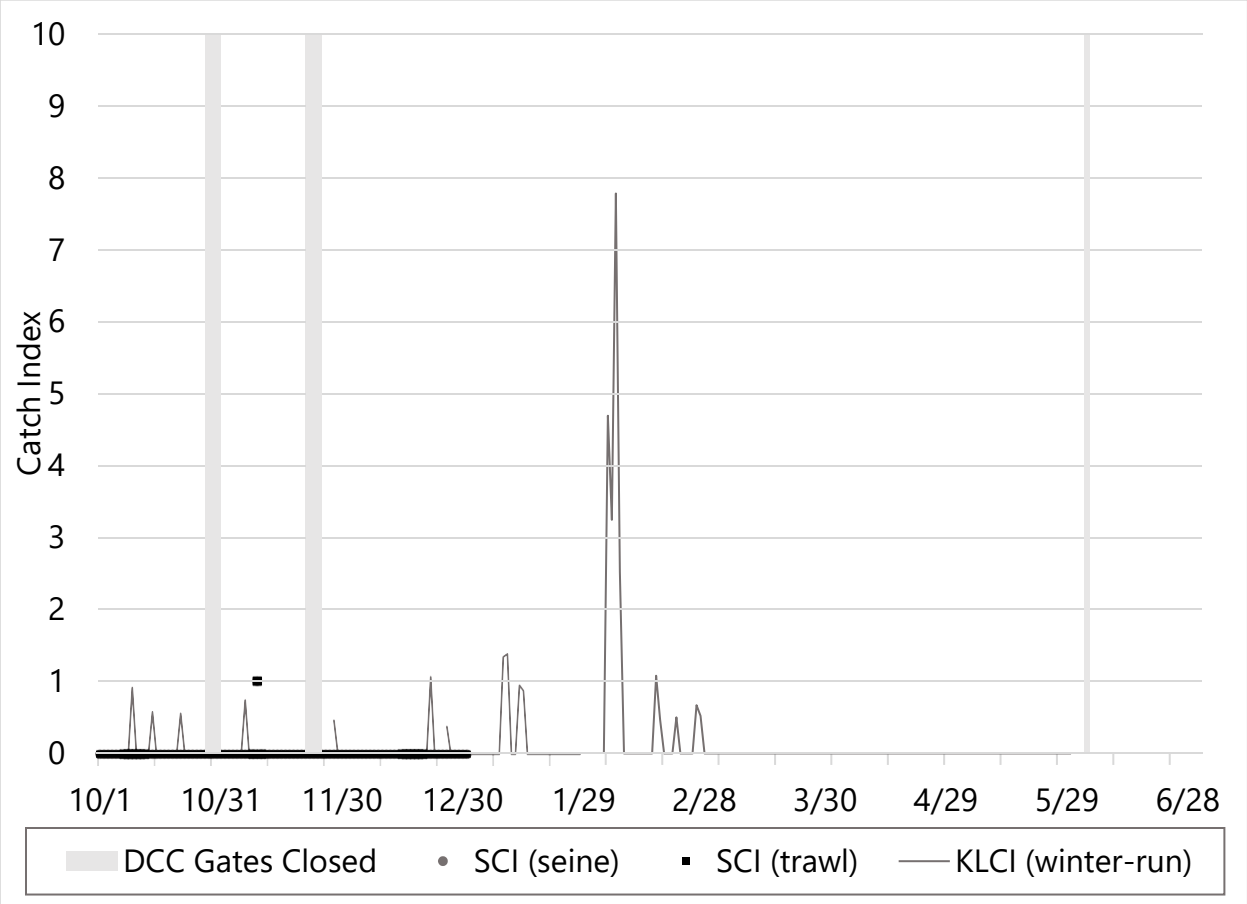


Figure 3. DCC Gate closures, Knights Landing Catch Index (KCLI) and Sacramento Catch Index at beach seines (SCI - seine) and Sacramento Catch Index trawl (SCI – trawl) for natural winter-run Chinook Salmon. On February 16, 2021, February 17, 2021, and May 5, 2021 the gates were opened for an hour for testing.

Old and Middle River Flow Management

Old and Middle River Flow Management is summarized in this section for the WY 2021 management season. OMR index values (1-day, 5-day, and 14-day) for WY 2021 are plotted in Figure 4. The Biological Opinion and ITP have requirements to meet OMR flows no more negative than -5,000 cfs on a 14-day moving average. While OMR management requirements were in effect during WY 2021, they were not necessarily controlling from January through June (Figure 6, Appendix C). Although this time frame could be controlled by OMR, sometimes other D-1641 Delta requirements (possibly more stringent given the conditions) were operated to instead. Between January 1, 2021 and June 21, 2021, OMR 1-day index was more positive than -5,000 cfs 170 out of 172 days (Figure 4; mean: -1,695 cfs; range of -244 cfs to -5,051 cfs).

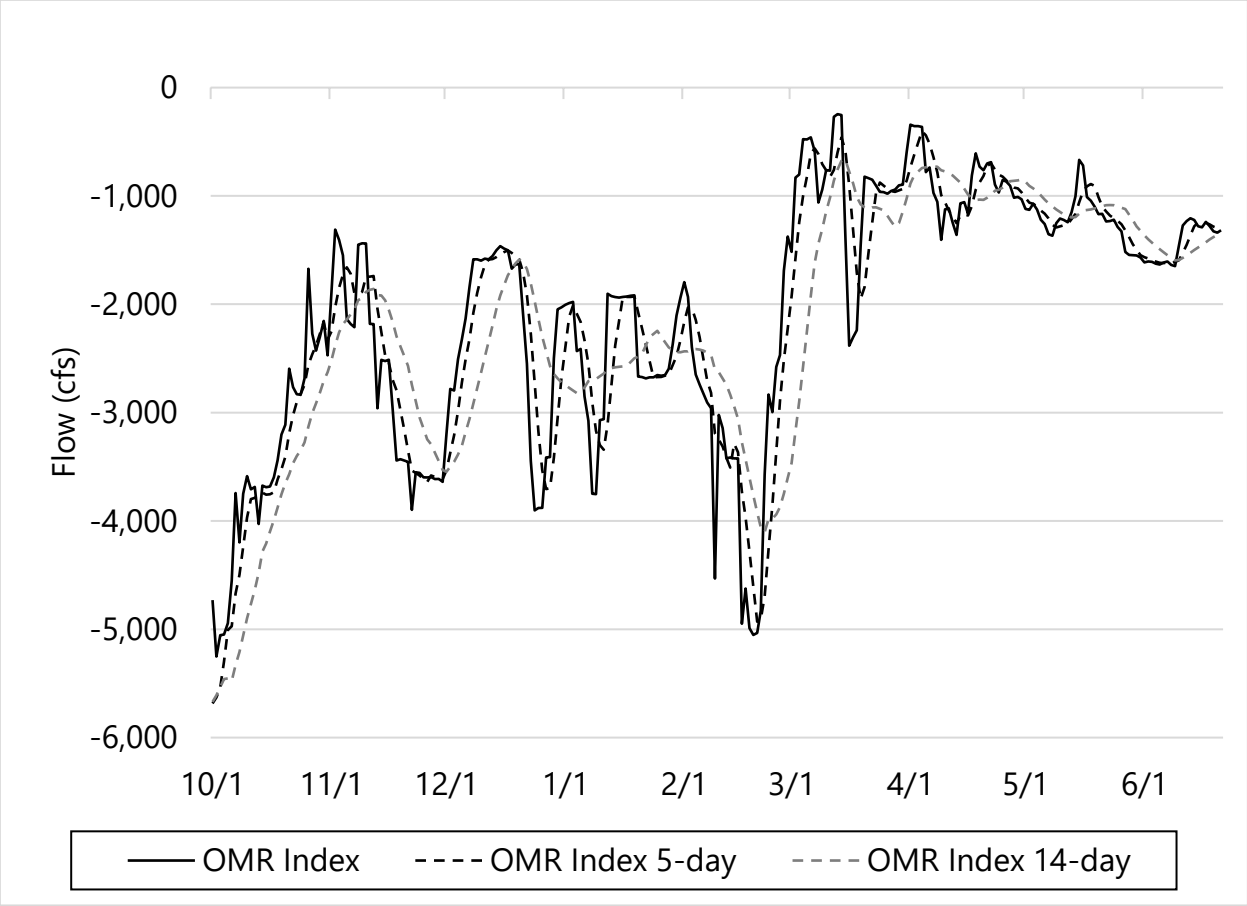


Figure 4. OMR index values measured in cubic feet per second [cfs] (1-day, 5-day, and 14-day) in WY 2021.

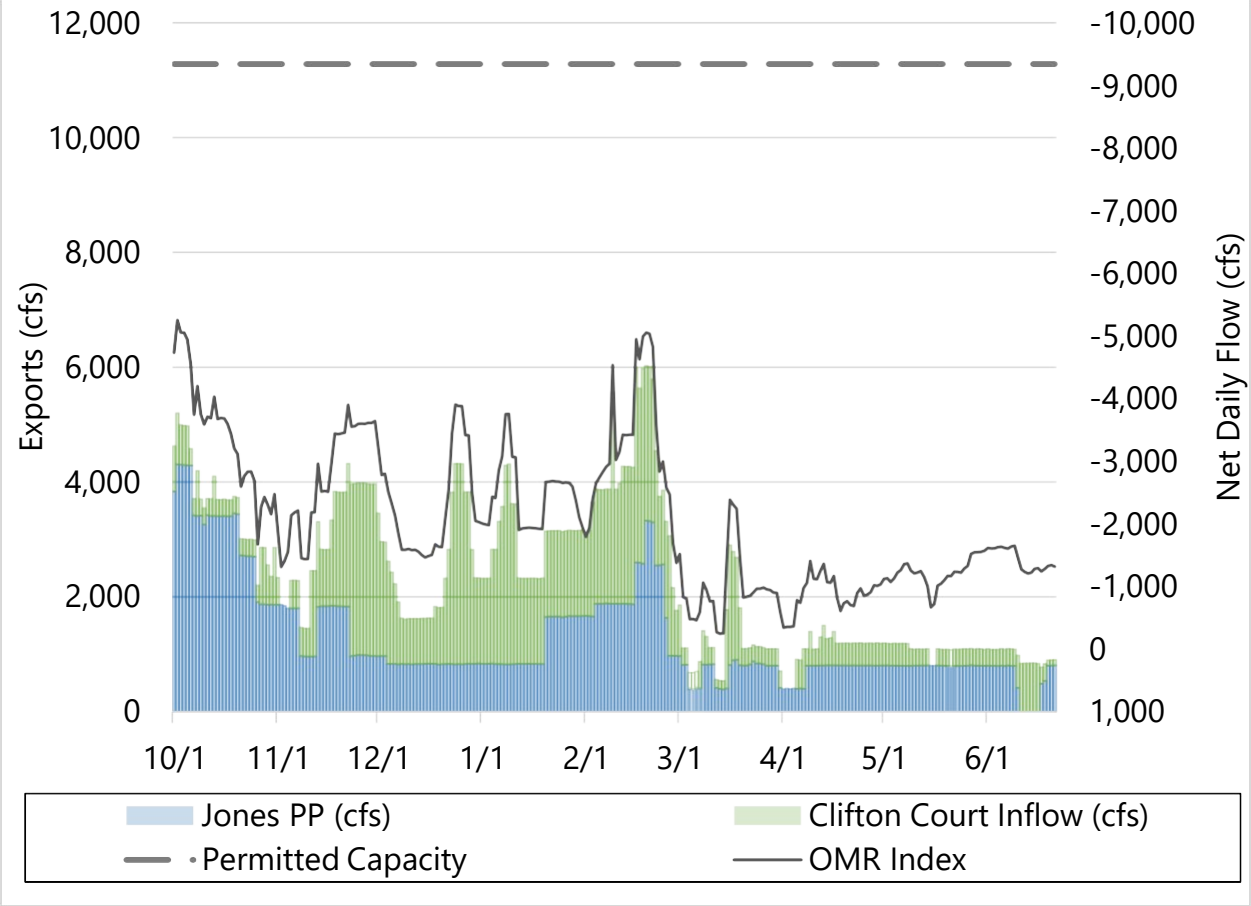


Figure 5. Exports from Clifton Court Forebay Index (for the SWP) and Jones PP (for the CVP) plotted over 1-day OMR index values for WY 2021. Maximum capacity is the combination of the maximum capacity for both facilities (CVP: 4,600 cfs; SWP: 6,680 cfs).

Seasonal operations to manage OMR occur in conjunction with additional controlling factors that change throughout the season. Controlling factors can also overlap in time and may only occur for short periods. Seasonal changes in controlling factors are summarized in Figure 6. The factors controlling export operations at the start of WY 2021 were generally to meet D-1641 outflow and water quality requirements, including fall Rio Vista outflow standards. With the exception of a few late winter storm events, poor hydrology influenced much of the flexibility of export operations, and OMR only potentially controlled operations in February and March (Figure 6) alongside D-1641 Delta Water Quality and Delta Outflow. Spring and summer export operations were again controlled by outflow and water quality as a result of poor hydrology in a Critical year. Exports were limited to minimum pumping continuously from late March through the end of June. Delta hydrologic conditions also change throughout the season, which can be characterized as either Balanced or Excess conditions, and this impacted management of export operations. WY 2021 only experienced approximately half of February in Excess conditions (Figure 7).

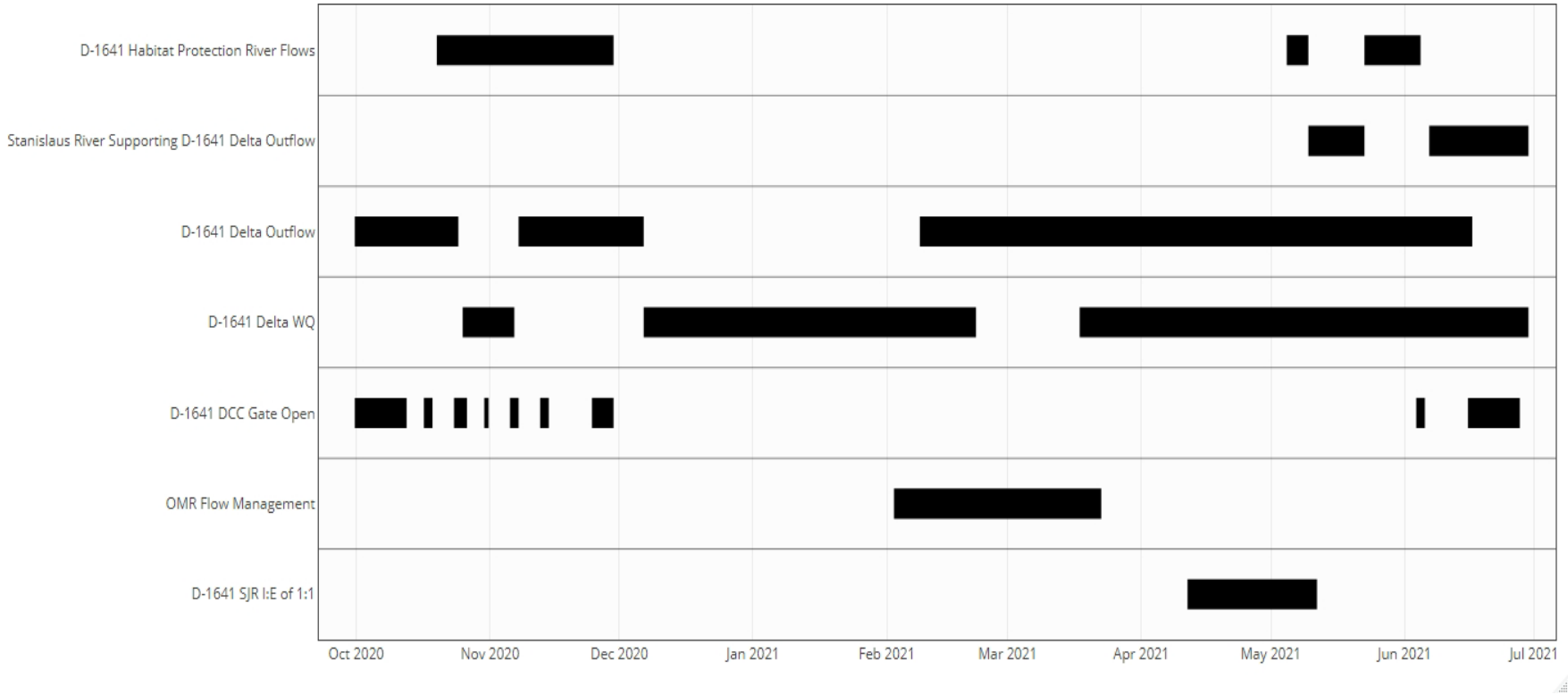


Figure 6. Daily Delta controlling factors for WY 2021. A detailed breakdown of the controlling factors for WY 2021 are provided in Appendix C.

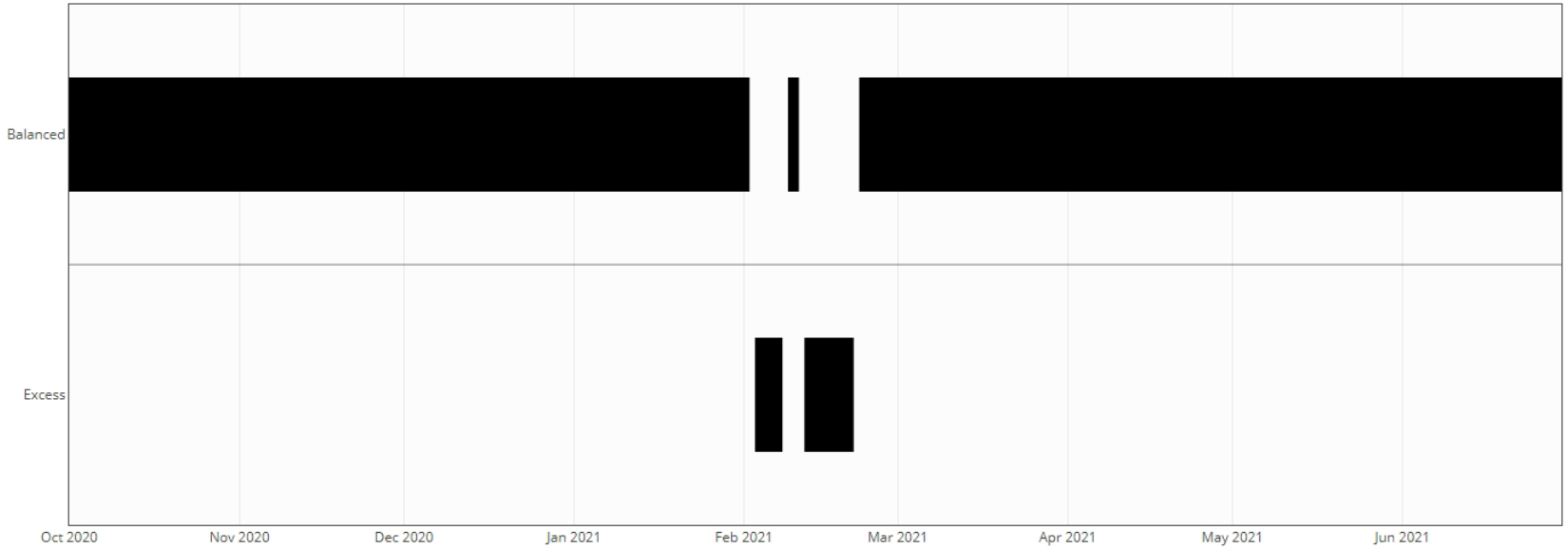


Figure 7. Balanced versus Excess conditions in the Delta for WY 2021.

Onset of OMR Flow Management

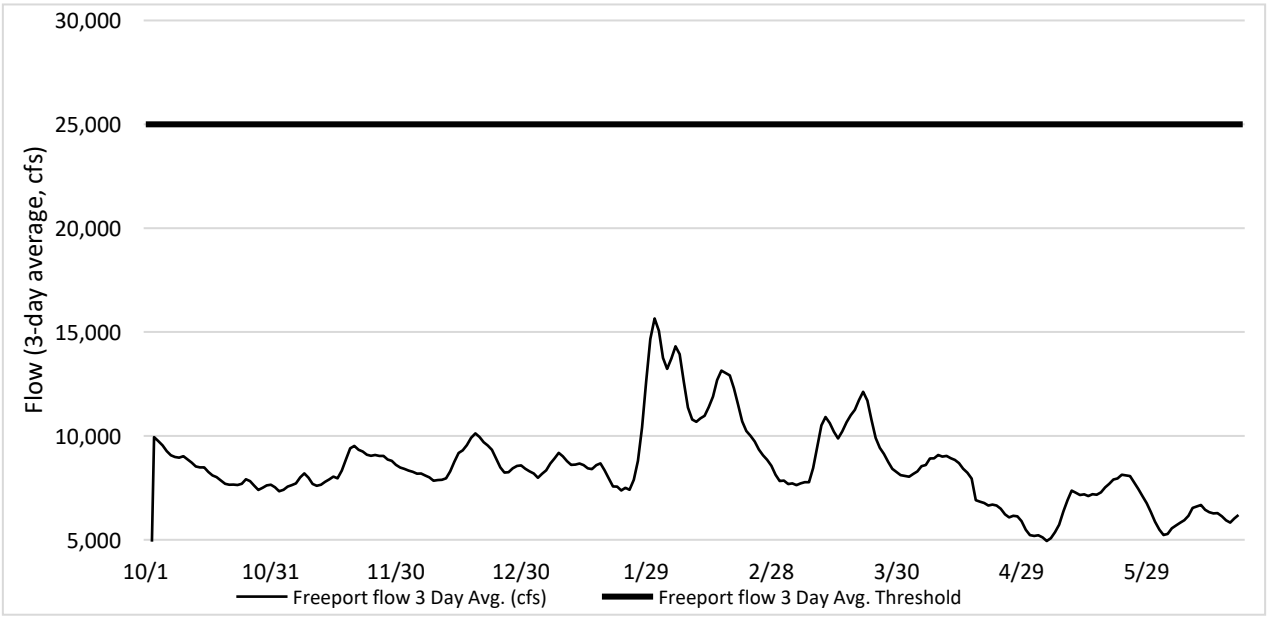
Integrated Early Winter Pulse Protection ("First Flush" Turbidity Event)

The onset of OMR flow management can be triggered by 'First Flush' conditions, which include a 3-day daily average flow at Freeport greater than 25,000 cfs and a 3-day daily average turbidity at Freeport equal to or greater than 50 Nephelometric Turbidity Unit (NTU) between December 1 and January 31. As shown in Figure 7A and 7B, neither the flow nor the turbidity triggers were met in WY 2021. The SWP has an additional option for OMR management to begin if the SMT determines that real time monitoring of biotic and abiotic factors indicates a high risk of Delta Smelt migration and dispersal into areas at high risk of future entrainment (ITP COA 8.3.1).

In the absence of first flush conditions and few Delta Smelt detections during the integrated early winter pulse protection period, the SMT relied upon estimations of the 2 parts per thousand salinity (X2) position. In cases where the position of X2 was upstream of 81 km (distance measured from the Golden Gate Bridge), X2 was estimated using the DWR X2_EC_Graph.xlsm tool, which calculates the position of X2 above the confluence of both the Sacramento and San Joaquin Rivers, individually. To support assumptions made about Delta Smelt distribution, the SMT used either the average of both rivers, or a single river when X2 could only be calculated for one river due to water quality monitoring station outages. Historically, Delta Smelt catch is closely correlated to X2 position during the December through January period (Sommer et al 2011). Subsequently, the SMT used this information each week to approximate the centroid of the distribution of Delta Smelt around X2 when assessing operations.

A precipitation event with notably high South to south Southwest winds (greater than 40 mph up to 50 mph) elevated turbidity across the central Delta and elevated turbidity at Old River at Bacon Island (OBI) water quality monitoring station from January 27 through 31, 2021. The turbidity event was assessed in an out of cycle meeting (January 29, 2021) and the SMT reached consensus that there is no regulatory mechanism for a Turbidity Bridge Avoidance action until February 1st. Further discussion of turbidity is covered in the Turbidity Bridge Avoidance section.

A.



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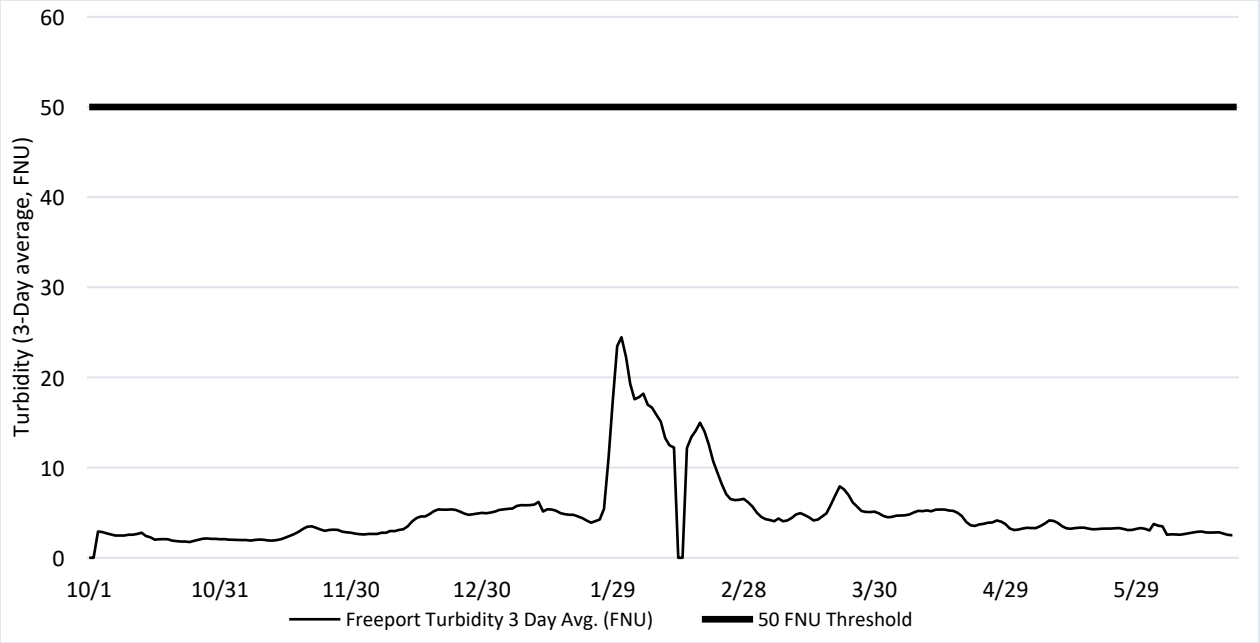


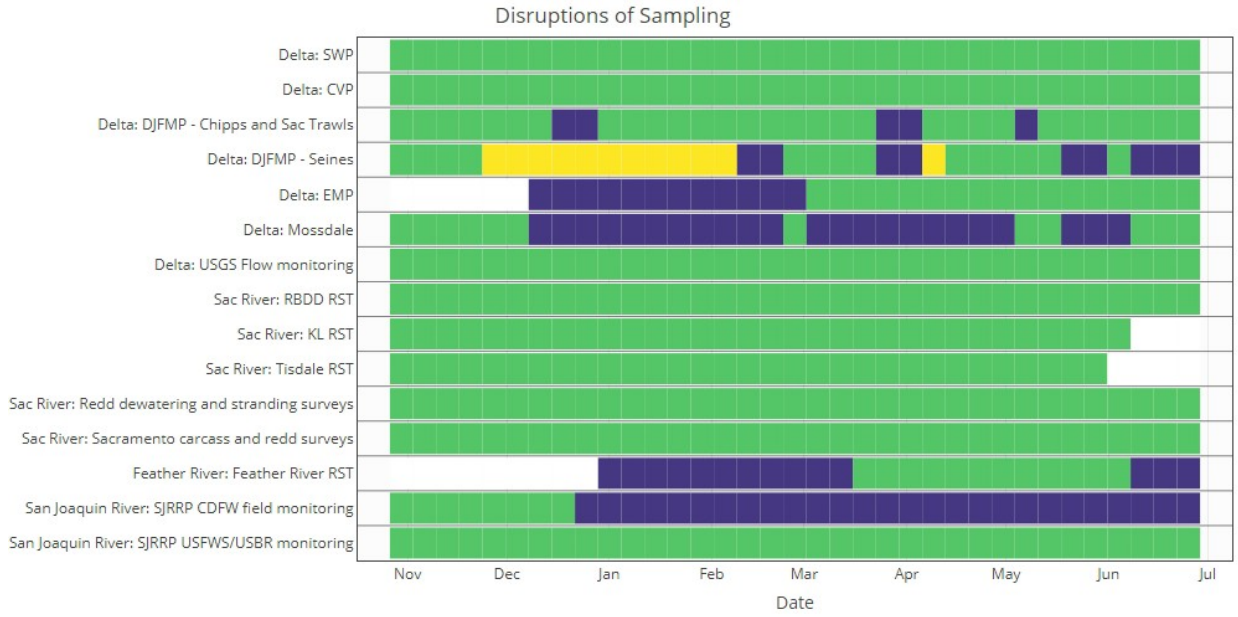
Figure 8. 'First Flush' conditions in WY 2021; **A.** 3-day running average flow (cfs) at Freeport. **B.** 3-day running average turbidity (Formazin Nephelometric Unit, FNU) at Freeport.

Salmonid Presence: Distribution Estimates

Distribution estimates of salmonids are discussed and agreed upon weekly by SaMT members. The first distribution estimates for WY 2021 were made on October 6, 2020, for natural young-of-year spring-run and winter-run Chinook Salmon and natural steelhead. The first distribution estimates for hatchery winter-run Chinook Salmon were made on February 2, 2021, coinciding with the first releases of hatchery winter-run Chinook Salmon.

Multiple sources are considered to produce distribution estimates including catch at targeted locations (e.g., Feather River rotary screw trap (RST), GCID RST, Tisdale Weir RST, Knight's Landing RST, Sacramento regional Beach Seines, lower American River RST, Caswell RST, Sacramento trawls, Chipps Island trawls, and Mossdale Kodiak trawl), historic and current water year salvage numbers, movements of acoustic tagged fish from the current water year, and historic migration patterns at targeted locations (see Proposed Action U.S. Bureau of Reclamation 2019a). In WY 2021, SaMT weekly distribution estimates were derived primarily from inference based on historical migration patterns because of limited detection of listed salmonids from the aforementioned sampling locations, and other concurrent regional surveys more typically used to inform distribution estimates for the listed salmonids (Appendix C, see Supporting Information section). Although some monitoring surveys were disrupted during periods in WY 2021, mainly due to Covid-19 social distancing restrictions (Appendix F, Figure 9), extremely low detection of salmonids was the primary reason for this lack of information. It is uncertain to what extent low detections were caused by low catch efficiency during drought conditions (low flow, low turbidity) versus low numbers of salmonids passing monitoring locations during sampling (i.e., poor survival).

A.



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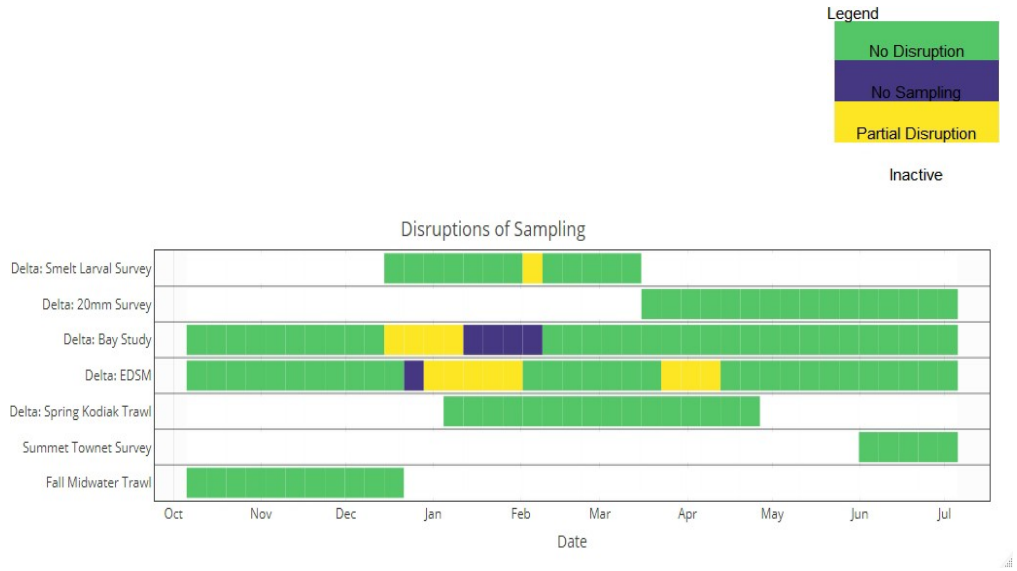

Figure 9. WY 2021 sampling disruptions by monitoring team for **A**. SaMT and **B**. SMT. Partial disruptions represent interruptions such as only a single boat being off the water or partial surveys. See Appendix F for weekly tables of sampling interruptions and cancelations.

Distribution estimates made by SaMT in WY 2021 for natural winter-run Chinook Salmon, natural Steelhead, natural young-of-year spring-run Chinook Salmon, and hatchery winter-run Chinook Salmon are depicted in Figure 10, Figure 11, Figure 12, and Figure 13.

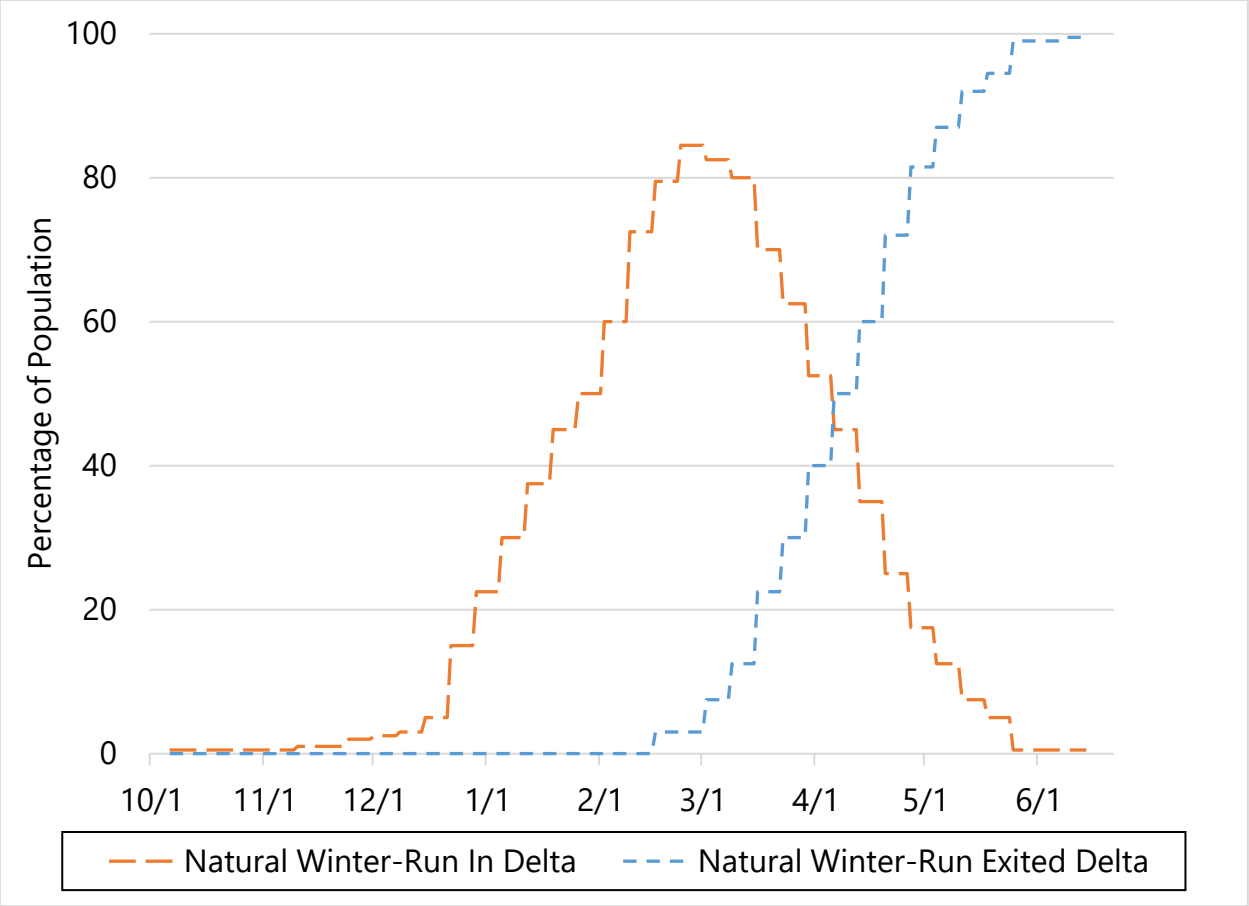

Figure 10. Distribution estimates for natural winter-run Chinook Salmon in WY 2021.

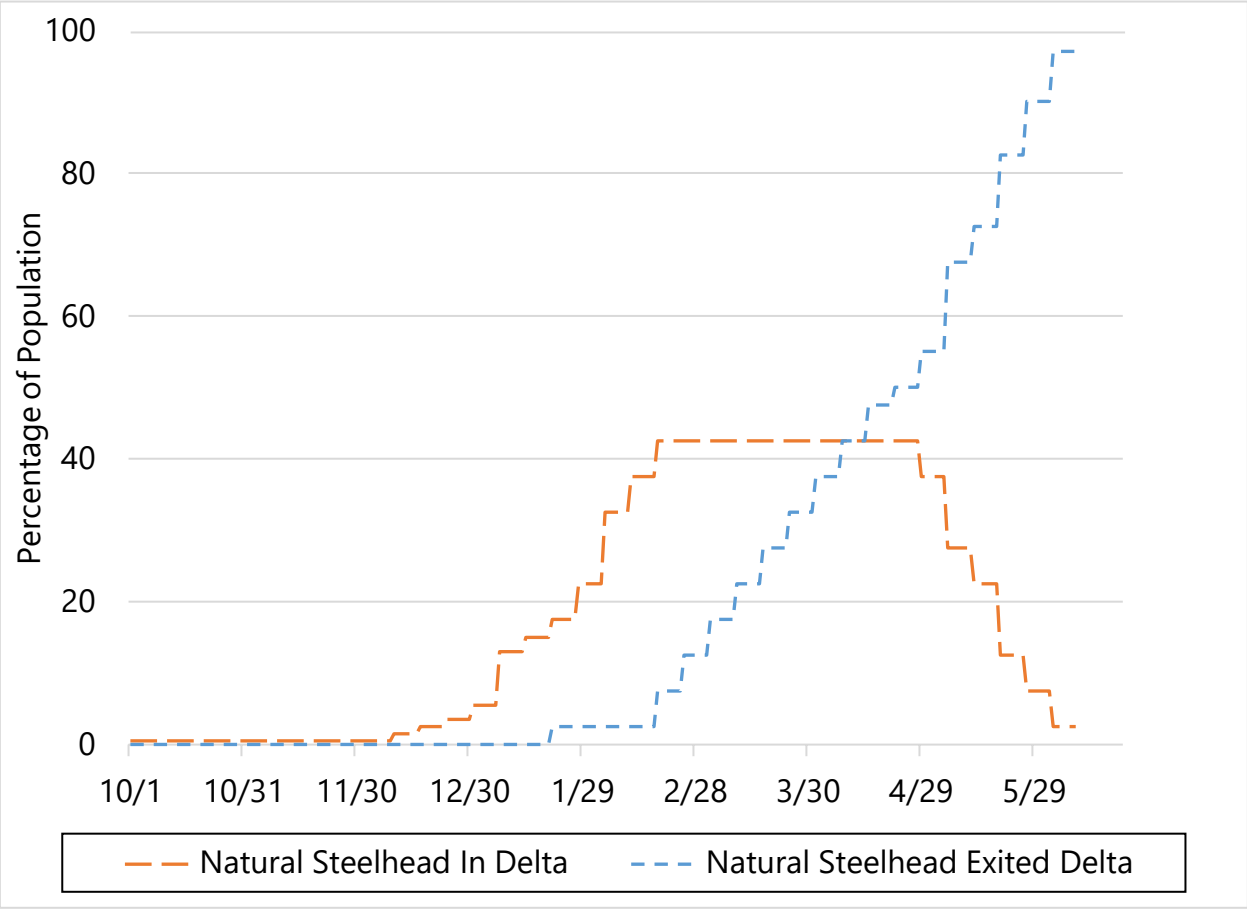

Figure 11. Distribution estimates for natural steelhead in WY 2021.

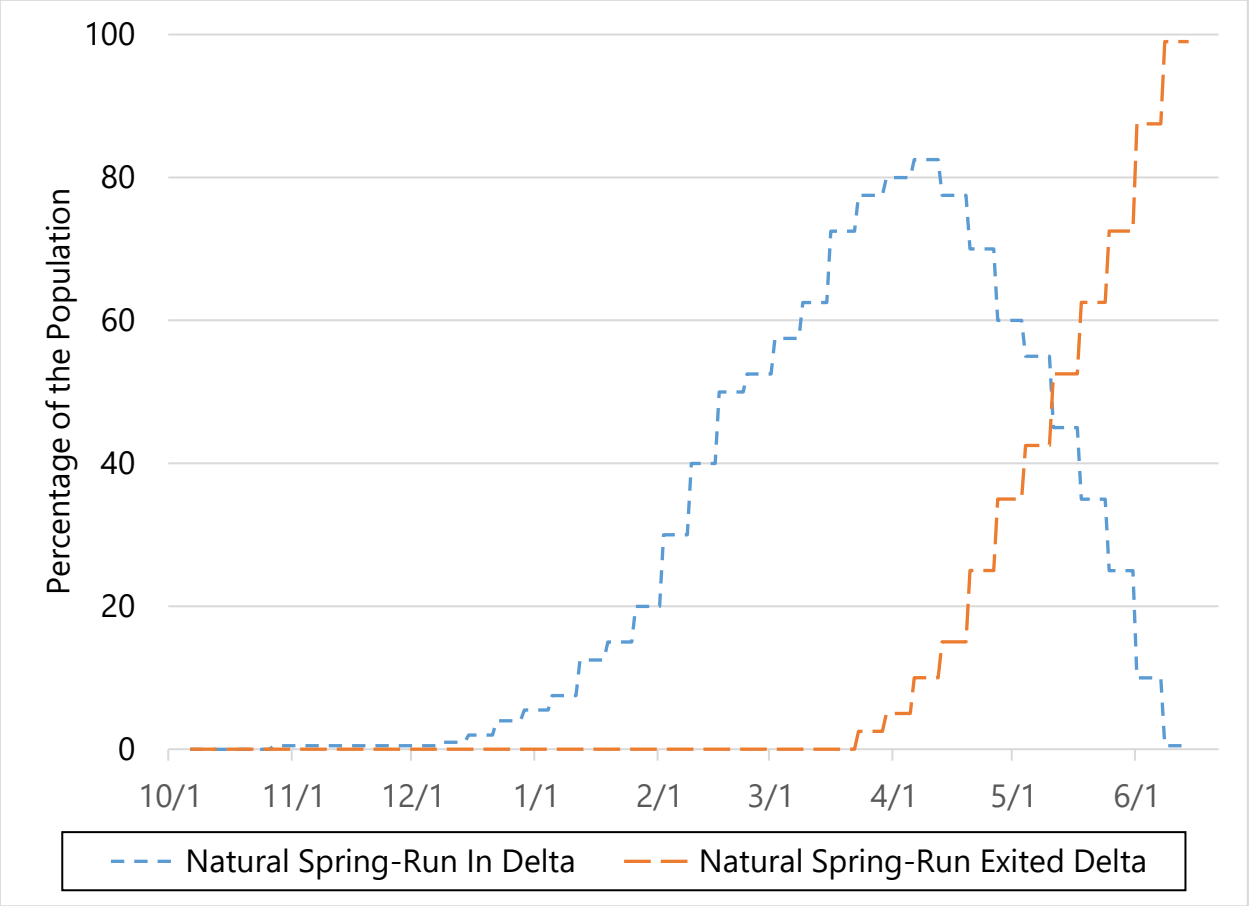

Figure 12. Distribution estimates for natural spring-run Chinook Salmon in WY 2021.

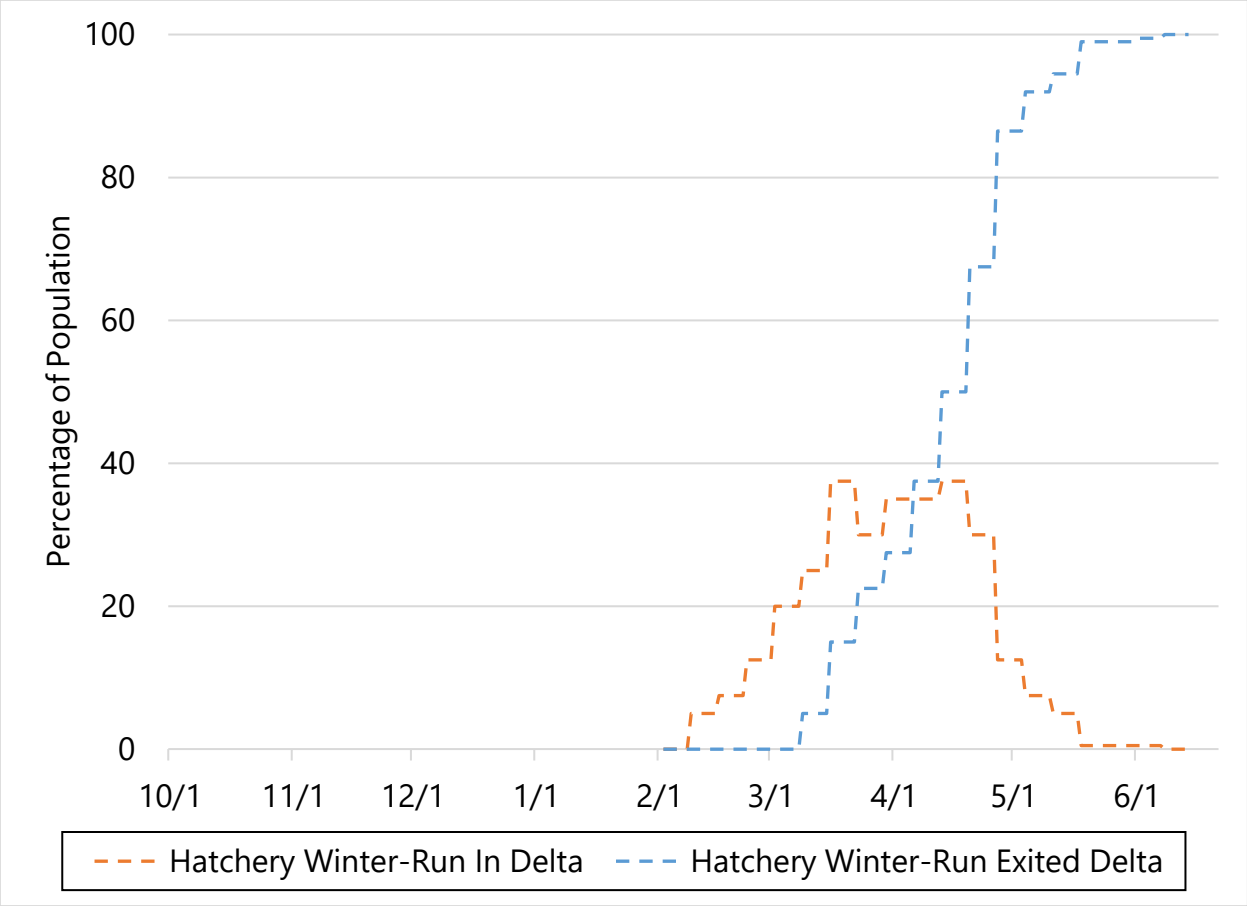

Figure 13. Distribution estimates for hatchery winter-run Chinook Salmon in WY 2021. SaMT began providing estimates beginning 2/2/2021.

Adult Longfin Smelt Entrainment Protection

The SWP includes a third action triggering the onset of OMR management. After December 1, if cumulative combined Longfin Smelt expanded salvage exceeds a threshold or real-time monitoring of abiotic and biotic factors indicates Longfin Smelt movement into areas at high risk for future entrainment, DWR reduces south Delta exports to maintain a 14-day average OMR index no more negative than 5000cfs (ITP COA 8.3.3). The salvage threshold is calculated based on the Fall Mid Water Trawl (FMWT) index for Longfin Smelt. For WY 2021, the threshold was 3, based on a 2021 FMWT index of 28. No adult Longfin Smelt were salvaged during WY 2021 operations, so the salvage threshold was not exceeded.

The SMT evaluated real-time monitoring data for biotic and abiotic factors to assess risk of Longfin Smelt migratory movement into areas of high entrainment risk. Adult Longfin Smelt catch of ≥60 mm (fork length) from the Chipps Island Survey (Figure 14) and hydrologic data were used as an early warning for migration into the south and central Delta. For the Chipps Island Survey, Longfin Smelt detections in WY 2021 began in the fall, with consistent detections from November through April, after which detections ended in May (Figure 14). Abiotic factors used in the evaluation of risk for this COA include OMR flows (Figure 4), OBI turbidity (Figure 15), QWEST (Figure 16), and Clifton Court Forebay (CCF) water temperature (Figure 24). The SMT did not make any

recommendations to Water Operations Management Team (WOMT) during this period regarding the need for adult Longfin Smelt protections.

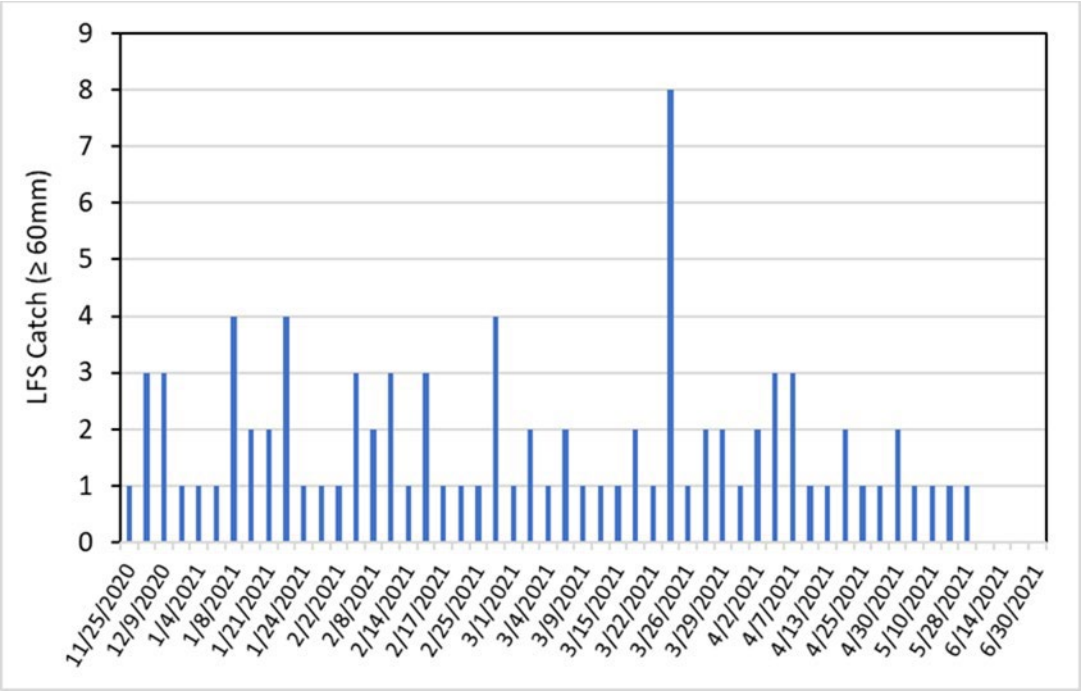

Figure 14. Adult Longfin Smelt (≥60mm) catch from the Chipps Island Trawl from October 2020 through June 2021. May 28 was the last day and adult Longfin Smelt (>60mm) was detected.

Additional Real-time OMR Restrictions and Performance Objectives

Delta Smelt

Adult Delta Smelt Protections

The purpose of Turbidity Bridge Avoidance ("South Delta Turbidity") is to minimize the risk of adult Delta Smelt entrainment in the Old and Middle rivers into the south Delta export facilities. During this period, Reclamation and DWR operate to maintain a daily average turbidity at OBI at a level of less than 12 NTU (currently using FNU values due to instrumentation capabilities). For the CVP, this action continues until April 1, or until a ripe or spent female is detected, whichever is first (see Proposed Action U.S. Bureau of Reclamation 2019c). For the SWP, this action continues until April 1 (ITP COA 8.5.1). Turbidity Bridge Avoidance ("South Delta Turbidity") began on February 1, 2021 because the 'First Flush' trigger did not occur this water year. This action continued until April 1 because no ripe or spent females were detected. The SMT clarified that the daily average turbidity at OBI would be calculated beginning on February 1, 2021, functionally making the first daily average turbidity at OBI available on February 2, 2021 at 12:00 am. Turbidity conditions are always considered by the SMT in developing the assessments of fish distribution and risk of entrainment.

Forecasted wind conditions in the Delta are considered at each meeting of the SMT because of its potential to temporarily increase turbidity within waterways of the Delta. Typically, these wind

driven increases are isolated to only a few of the water quality stations, but large widespread increases in turbidity can occur and may potentially influence the distribution of Delta Smelt. As stated above, the only period where turbidity at OBI exceed the 12 FNU threshold was just prior to the start of the Turbidity Bridge Avoidance period. There were no other instances in which the daily average turbidity at OBI exceeded 12 FNU. Increases in turbidity in the Delta were observed over the course of the season by the SMT and are always considered when assessing the likelihood of entrainment. Under the drought conditions of WY 2021, nearly all notable increases in turbidity observed at OBI were driven by wind events rather than large precipitation events or runoff during the Turbidity Bridge avoidance period (Figure 15).

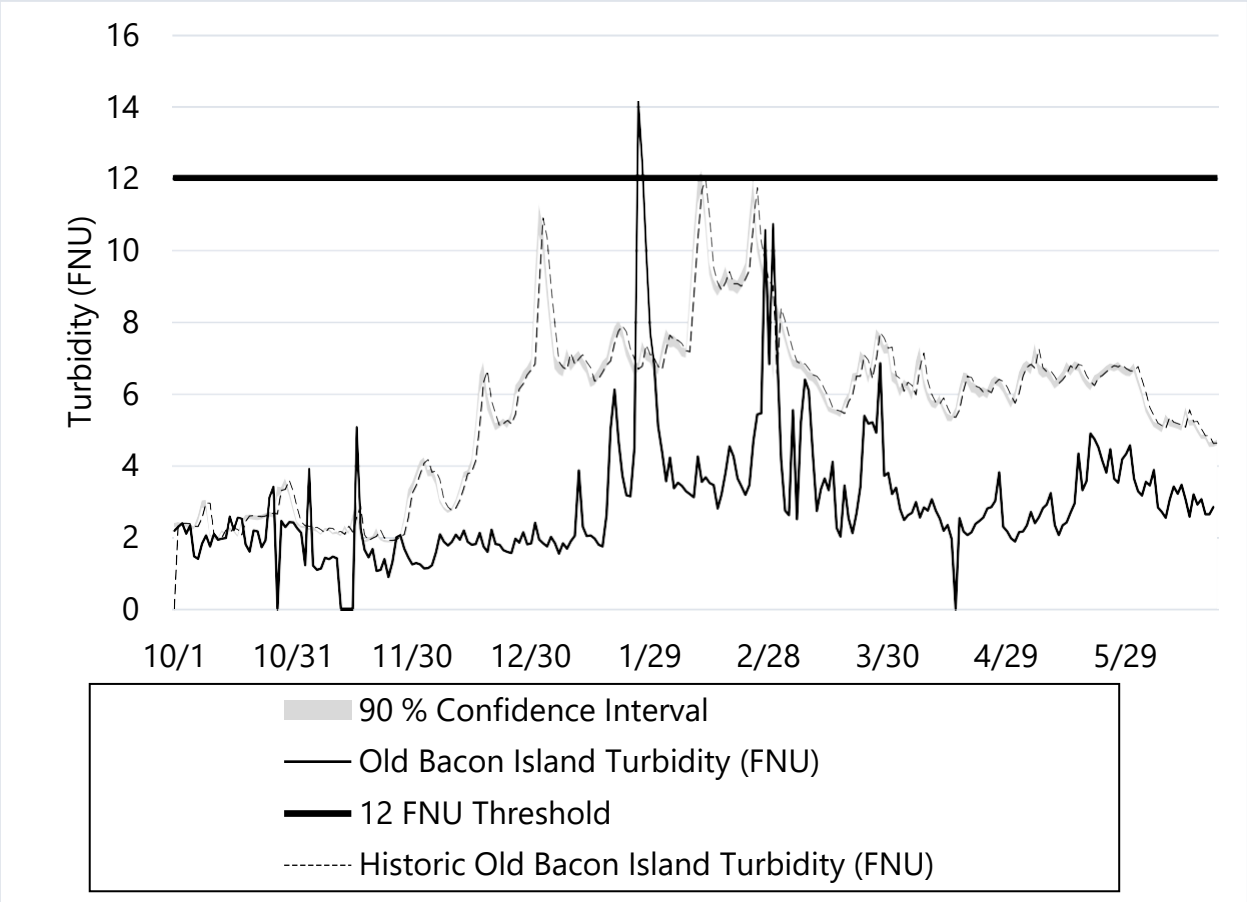

Figure 15. Daily average turbidity (FNU) at Old River at Bacon Island (OBI) in WY 2021 and over the historic period of record (2009-2021) with 90% confidence intervals in gray.

Larval and Juvenile Delta Smelt Protections

The Larval and Juvenile Delta Smelt Protection period began on March 15, 2021, for the CVP and continued until off ramp criteria were met on June 6, 2021 (Figure 24). Within the larval and juvenile Delta Smelt protection period, if QWEST was negative, Delta Smelt were detected within the entrainment zone of the CVP and SWP export facilities, and widespread changes in turbidity are observed by the SMT, the CVP would have operated to an OMR no more negative than -3,500 cfs. The severe drought conditions limited operations during all the Larval and Juvenile Delta Smelt Protection period, which maintained a more protective OMR Index range than -3500 cfs. While at

times some of the environmental conditions were met, no Delta Smelt were ever observed in the central or south Delta.

Particle tracking models were not run specifically for Delta Smelt in WY 2021, and with no detections of larval Delta Smelt in the southern or central Delta, the selection of insertion points would have been informed only by historic distribution patterns. During this period, OMR management was less negative than the -3,500 cfs threshold and CVP operated to maintain that criteria in conjunction with SWP due to drought conditions and further limited the applicability of PTM to Delta Smelt. In combination, the SMT determined that circumstances for all weeks during this period reduced benefits of running a particle tracking model for Delta Smelt below the level of effort required to produce it. See additional information on particle tracking models for Longfin Smelt.

For the SWP, cumulative salvage of juvenile Delta Smelt can also trigger South Delta export restrictions and further OMR recommendations (ITP COA 8.5.2). During WY 2021, no larval or juvenile Delta Smelt were detected at either the SWP or CVP in regular salvage or qualitative larval sampling.

Additionally, from March 1 through June 30 of dry and critical water years, DWR operates the Barker Slough Pumping Plant to protect larval Delta Smelt (ITP COA 8.12). For WY 2021, no larval Delta Smelt were detected in either Smelt Larva Survey or 20mm Survey sampling at station 716, so no Barker Slough Pumping Plant restrictions were implemented for the purpose of Delta Smelt protection.

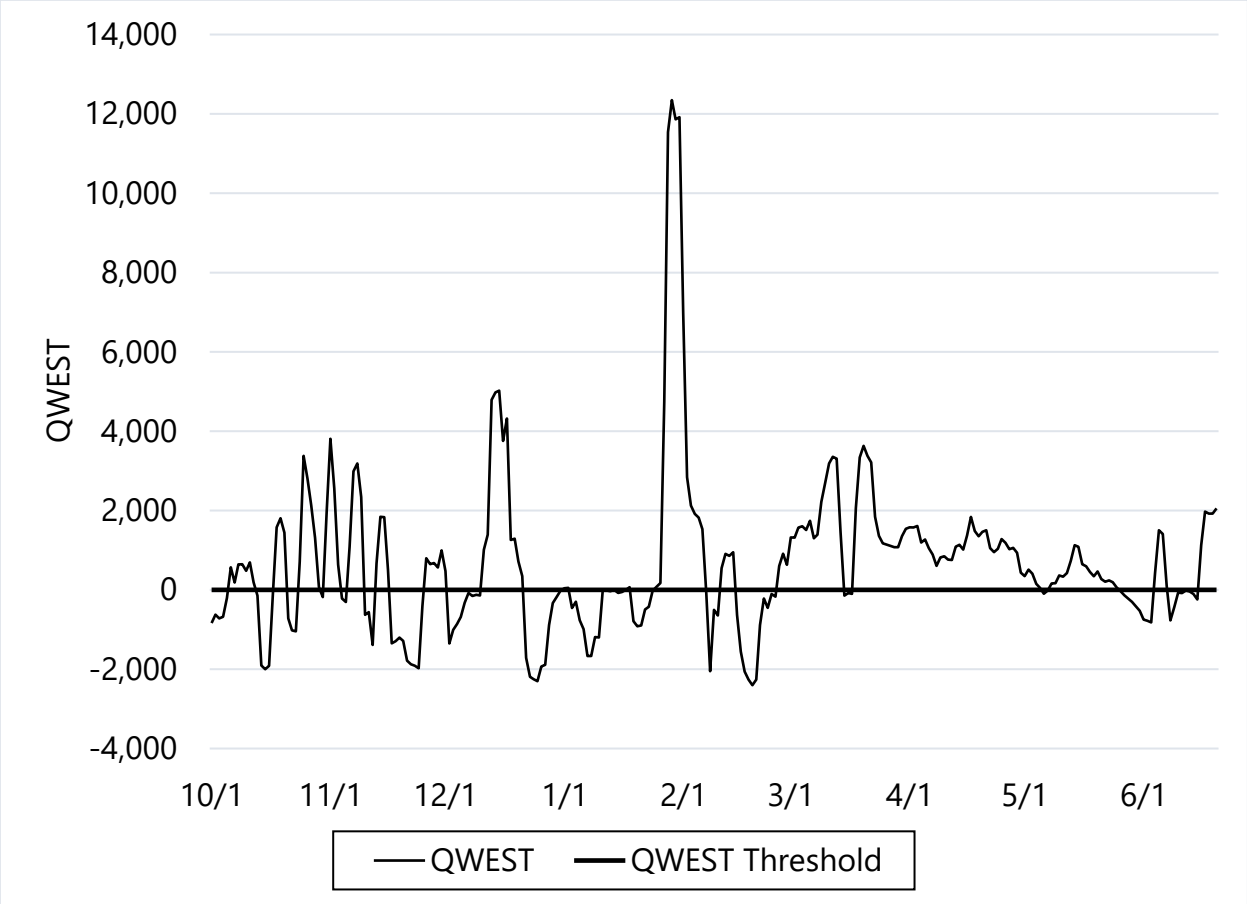

Figure 16. QWEST (cfs) in WY 2021.

Delta Smelt Detections

All Delta Smelt catch data were reported to the SMT (catch and salvage locations shown in Figure 17) and considered each week. In WY 2021, only 14 Delta Smelt were observed by all surveys and Fish Conservation and Culture Lab (FCCL) Broodstock Collections, which was the lowest catch of Delta Smelt ever recorded. Among the surveys, Enhanced Delta Smelt Monitoring Program (EDSM) caught eleven, FCCL Broodstock Collections caught two and the 20 mm Survey caught one. The detections were nearly all in the Sacramento Deepwater Ship Channel and those individuals provide limited information that inform planning for South Delta operations (Figure 17).

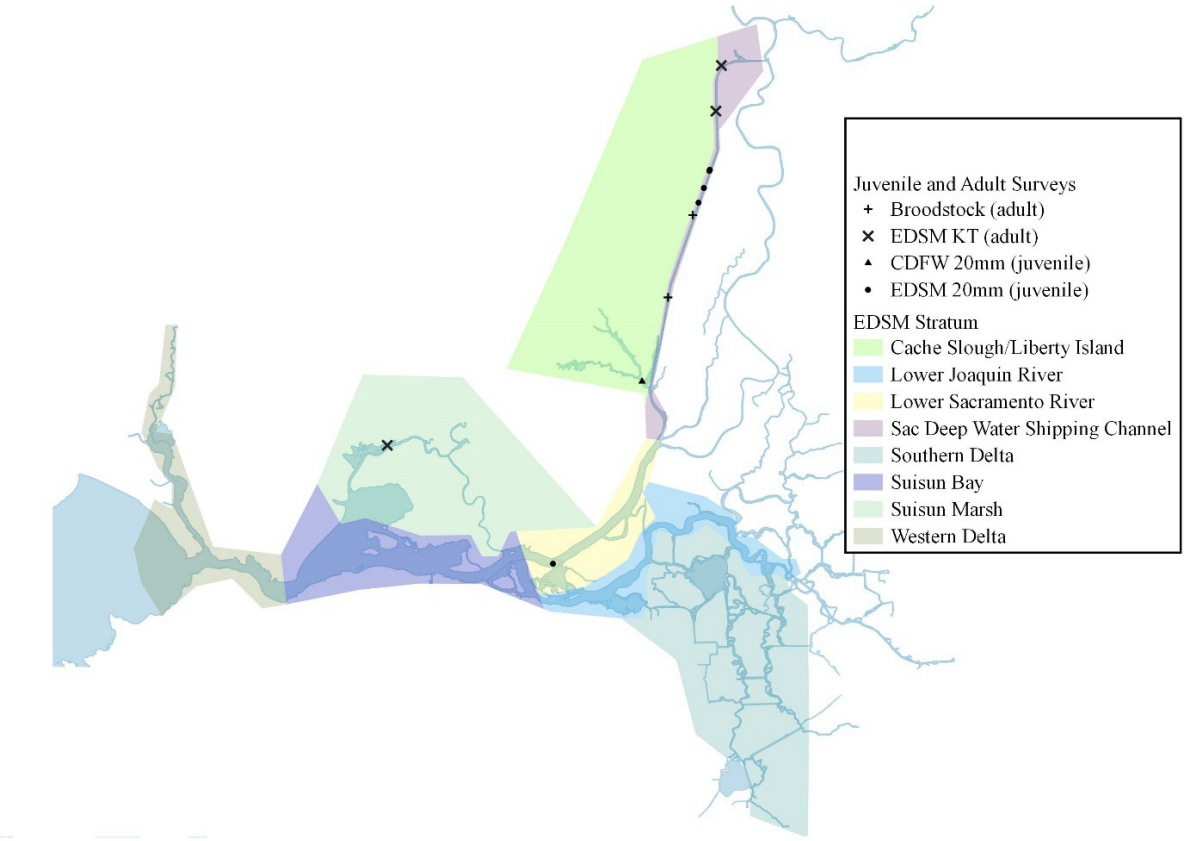

Figure 17. Delta Smelt seasonal catch locations in WY 2021 (all reported between November 1, 2020 - June 21, 2021). EDSM: 20mm and KT (Kodiak Trawl), and the CDFW 20mm Survey caught Delta Smelt in WY 2021(14 individuals total). EDSM 20 mm caught multiple fish on April 27, 2021 (2 fish), and May 4, 2021 (3 fish), all other catches were single individuals. The UC Davis Fish Conservation and Culture Laboratory broodstock collections are also included since such low catch occurred. EDSM Stratum shown as colored polygons. Life stages targeted by surveys are included in the figure legend.

Longfin Smelt

Adult Longfin Smelt Protections

SWP includes protections for adult Longfin Smelt from the onset of OMR management through February 28 (ITP COA 8.4.1). However, during WY 2021, the SMT did not make recommendations for OMR management based on COA 8.4.1. The opportunity for 8.4.1 to be activated offramped on December 29, 2020, prior to the onset of OMR management, with the detection of three Longfin Smelt larvae at Jersey Point in the December Smelt Larva Survey (ITP COA 7.6.1).

Larval and Juvenile Longfin Smelt Protections

Between January 1 and June 30, when Longfin Smelt surveys reach thresholds for detection of larvae and juveniles, DWR implements ITP COA 8.4.2. COA 8.4.2 distribution and/or density triggers were exceeded in SLS surveys #2, #4, #5, & #6 and 20mm Survey #1 (Figure 18A). Following SLS #4, the SMT made a recommendation to WOMT for an OMR index no more negative than –2,500

CFS under the guidance of 8.4.2. This recommendation was made during the February 23, 2021 SMT meeting, and this advice was lifted during the March 23, 2021 meeting. During the period of this advice, Longfin Smelt OMR management only controlled south Delta operations for a very brief period, as concurrent Delta water quality standards and dry hydrology were generally keeping OMR flows more positive than -2,500 cfs.

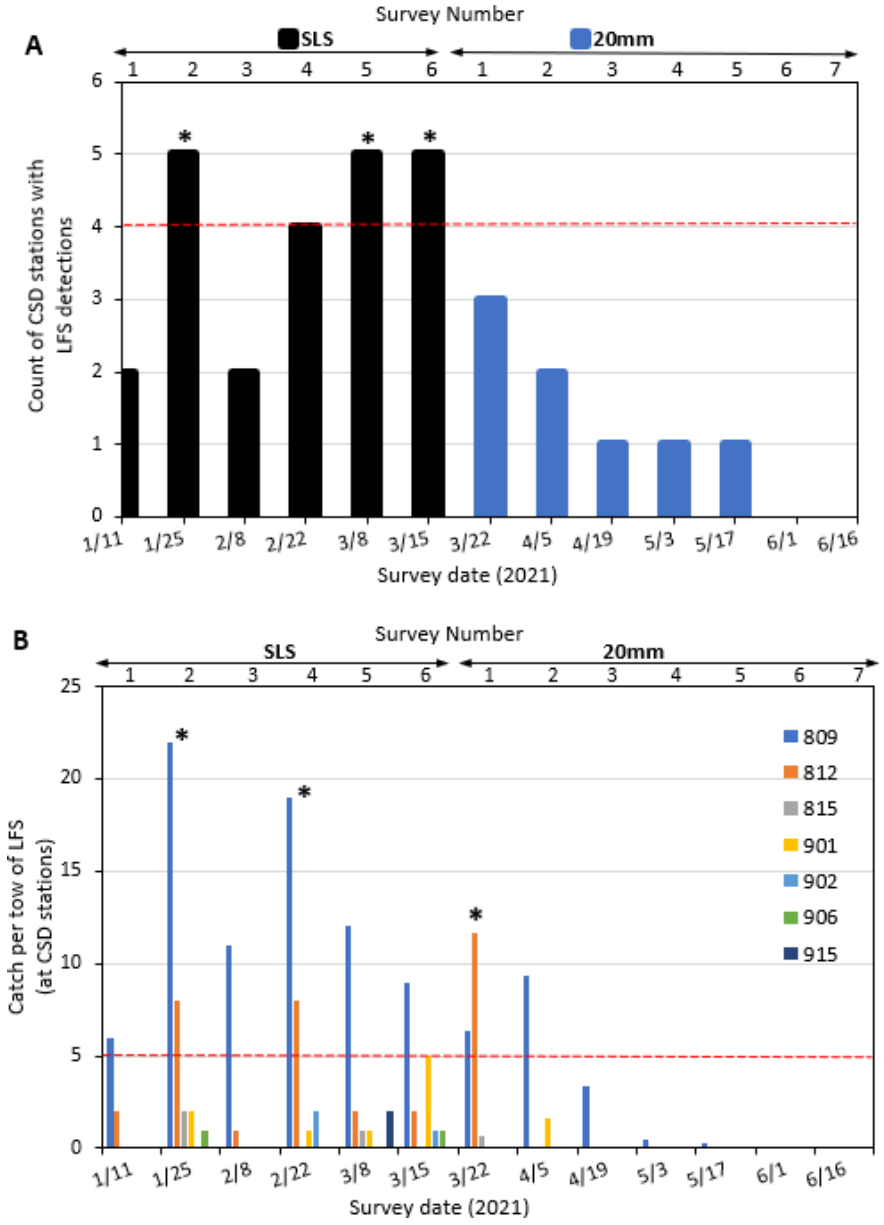

Figure 18. **A.** Number of Central and South Delta (CSD) stations with Longfin Smelt detections from the Smelt Larva Survey (SLS) and 20mm Survey (20mm), and **B.** catch per tow of Longfin Smelt at relative 12 CSD stations (809, 812, 815, 901, 902, 906, and 915). The red dashed lines indicate thresholds (ITP COA 8.4.2) of **A** 4 of 12 CSD station Longfin Smelt detections or **B** for 5 Longfin Smelt catch per tow at 2 CSD stations (as the average of three tows), with asterisks representing surveys that exceeded triggers.

Additionally, from January 15-March 31 of dry and critical water years, DWR operates the Barker Slough Pumping Plant to protect larval Longfin Smelt (ITP COA 8.12). COA 8.12 for BSPP was in effect from January 15, 2021 to March 31, 2021 for Longfin Smelt, and April 1, 2021 to June 30, 2021 for Delta Smelt. During this period, three Longfin Smelt were detected at Station 716, triggering BSPP restrictions to <60 cfs on January 19, 2021, February 2, 2021, and March 2, 2021 (Figure 18B). No Delta Smelt were detected at station 716 during this period.

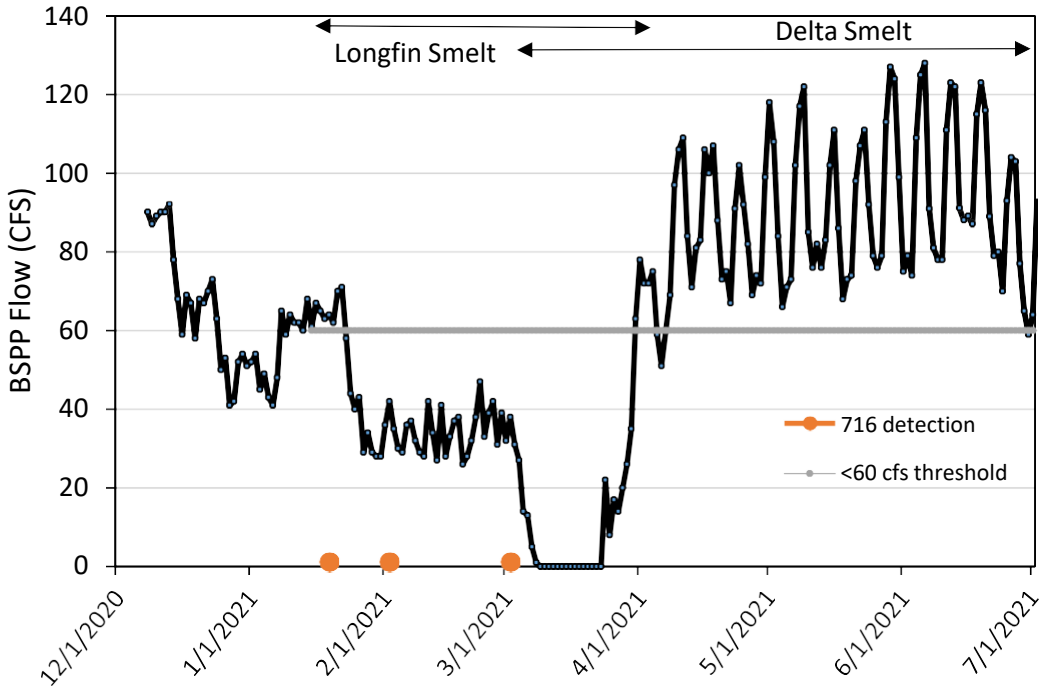

Figure 19. Flow (cfs) at Barker Slough Pumping Plant for WY 2021. Periods of Longfin Smelt and Delta Smelt protections are indicated (ITP COA 8.12), with dates of SLS or 20mm detections at station 716 (orange points). The gray dashed line indicates the pumping threshold of <60 cfs when detections at 716 occurred. BSPP ceased operations from March 9, 2021 to March 26, 2021 to conduct annual maintenance.

Larval Longfin Smelt Detections

During WY 2021, larval Longfin Smelt sampling started on December 13, 2020, in compliance with ITP COA 7.6.1, which directed DWR to fund additional Smelt Larva Surveys (SLS) in the Central and South Delta in December. This additional sampling is meant to more completely cover the period of larval Longfin Smelt presence, as SLS previously did not begin until the first week in January. This December sampling did detect larval Longfin Smelt, highlighting the potential that the initiation of hatching may have been missed in previous years. Throughout the WY 2021 Longfin Smelt spawning season, the majority of larvae detected in regular monitoring were in Sacramento River stations, with Suisun Bay and marsh being the second most prevalent region for catch (Figure 20). Despite substantial detection in salvage (Figure 26), regular larval fish monitoring detected the lowest numbers of Longfin Smelt catch in the Central and South Delta, compared with other regions of the estuary (Figure 20). April and May saw the highest catches of larval Longfin Smelt in regular monitoring, with catch significantly dropping off in June with warming water temperatures.

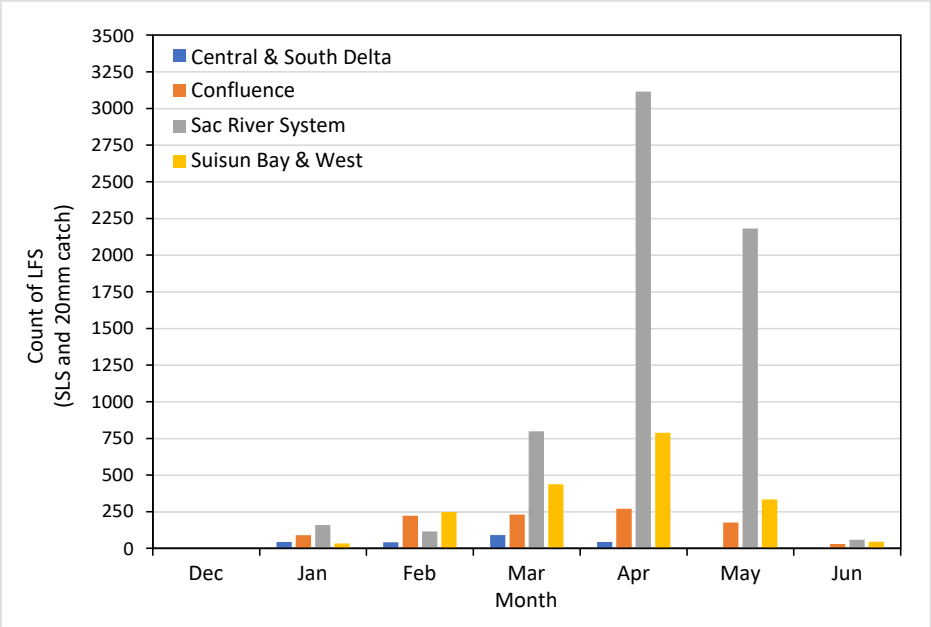

Figure 20. Catch of larval Longfin Smelt in the Smelt Larva Survey and 20mm Survey during WY 2021 sampling. Note that three Longfin Smelt were caught in December in the Central & South Delta.

Winter-run Chinook Salmon

Daily Loss

SWP includes a separate daily loss threshold for winter-run Chinook Salmon for each month of the migratory season from November through May, described in COAs 8.6.2 and 8.6.3. The November and December Early-season daily thresholds are set discrete thresholds, and the January through May Mid- and Late-season daily thresholds are newly calculated each year as set percentages of the winter-run Juvenile Production Estimate (JPE) for that management season.

The SWP Early-season thresholds are intended to minimize water project operations impact on the earliest migrating juvenile winter-run to preserve life history diversity at the leading edge of the migration timing distribution. The SWP Mid- and Late-season Natural winter-run Chinook Salmon daily loss thresholds are intended to minimize entrainment, salvage, and take of natural winter-run Chinook Salmon during the peak and end of their migration through the Delta. Exceedance of a daily threshold requires that DWR restrict south Delta exports for five days to achieve a five-day average OMR index no more negative than -5,000 cfs for Early-season thresholds, and -3,500 cfs for Mid- and Late-season thresholds. In WY 2021, no daily loss thresholds were triggered for winter-Run Chinook.

Single Year Loss

The ROD and SWP (ITP COA 8.6.1) set the same single-year threshold loss values for natural and hatchery winter-run Chinook Salmon. These values are the same for both the ROD and SWP and are calculated as 1.17 percent of the JPE for natural origin winter-run, equal to 3,862 for WY 2021, and 0.12 percent of the JPE for each hatchery production group, equal to 117 for the Sacramento River release and 45 for the Battle Creek release in WY 2021.

Total natural winter-run Chinook Salmon (LAD) loss for WY 2021, (October 1, 2020 – July 1, 2021) was 8.2 fish. This loss equaled 0.43 percent of 50 percent of the single-year loss threshold; 0.21 percent of the single-year loss threshold. Total loss of hatchery winter-run Chinook Salmon was zero. In WY 2021, neither LAD natural winter-run Chinook Salmon (Figure 21, Figure 22) nor the hatchery winter-run Chinook Salmon single-year loss threshold was triggered.

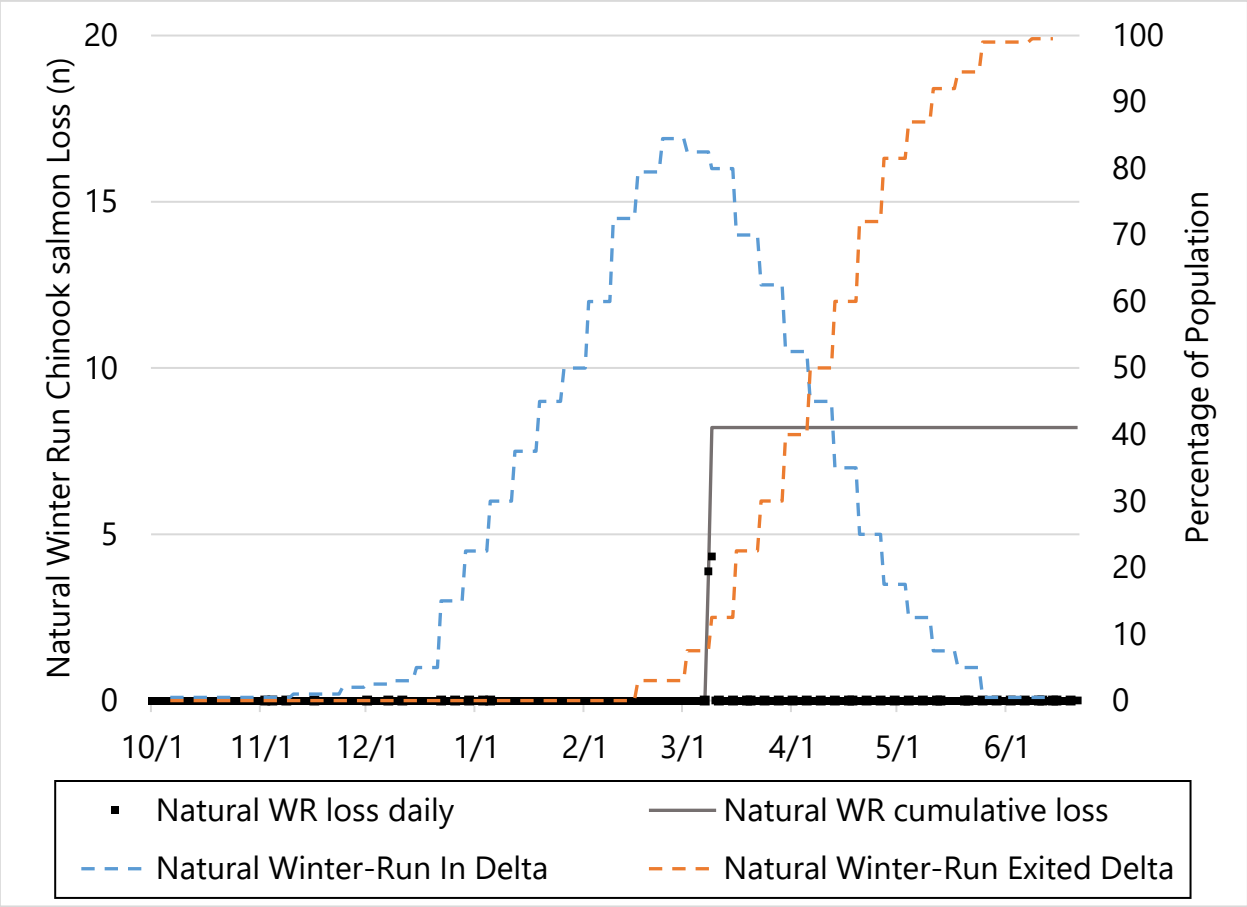

Figure 21. Total loss of natural winter-run Chinook Salmon in WY 2021 (53% occurred at SWP, 47% occurred at CVP).

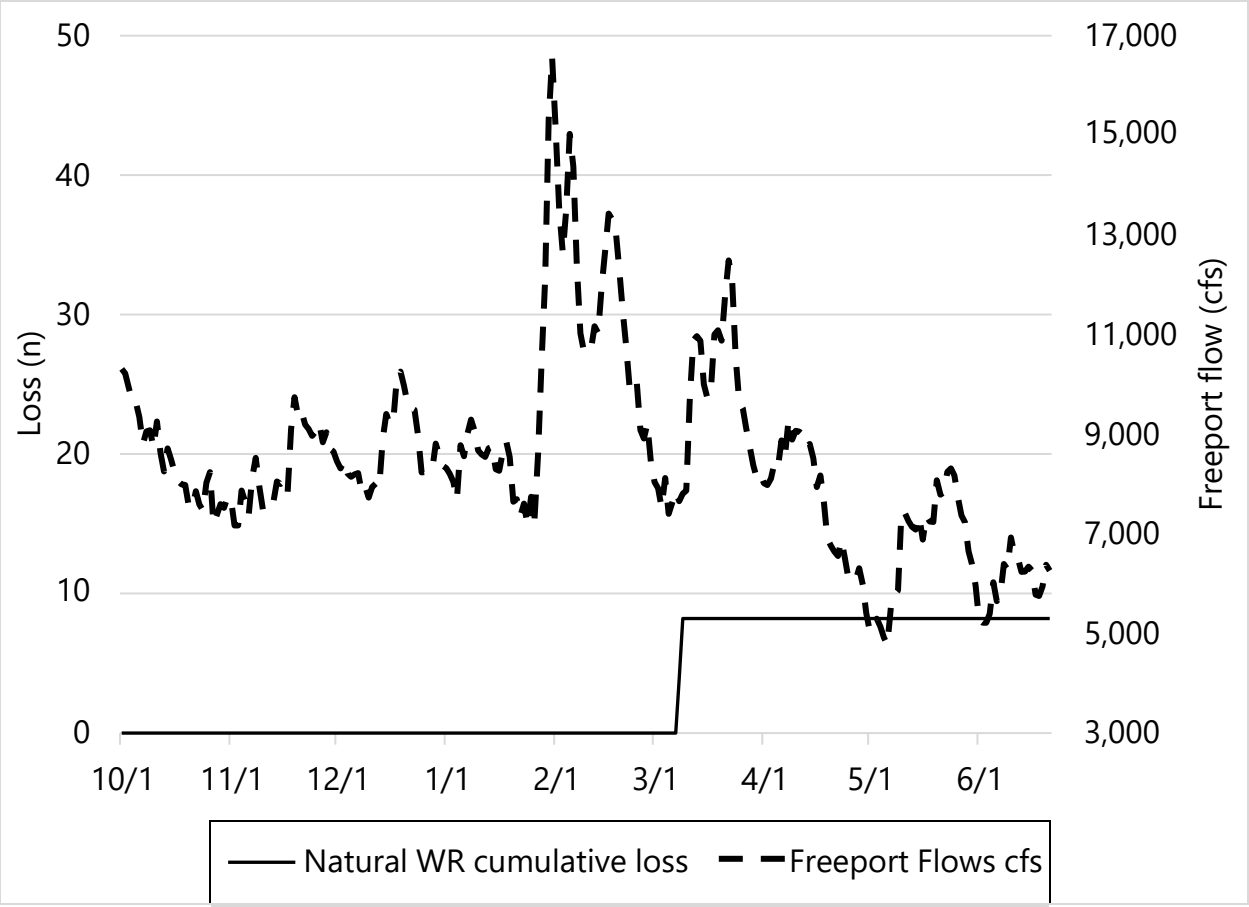

Figure 22. Freeport flows (cfs) and combined natural winter-run Chinook Salmon loss at the CVP and SWP fish salvage facilities for WY 2021.

Cumulative Loss

The cumulative loss threshold for natural winter-run Chinook Salmon over the duration of the ROD and the SWP (ITP COA 3.5) is 8,738 fish. Total cumulative loss to date of natural winter-run Chinook Salmon over the duration of the ROD is 191.2 fish, or 2.19 percent of the threshold (Figure 28). The cumulative loss threshold for hatchery winter-run Chinook Salmon over the duration of the ROD and the SWP is 5,356 fish. Neither cumulative loss thresholds were triggered in WY 2021.

Spring-Run Chinook Salmon

ROD Spring-Run Surrogates

As part of the NMFS 2019 Biological Opinion, the incidental take statement's cumulative loss threshold for late fall-run hatchery release groups serving as yearling spring-run surrogates should not exceed 0.5% of each release group (Section 13.3.5.3). During WY 2021, three groups of brood year 2020 late-fall Chinook Salmon were released into Battle Creek from the Coleman National Fish Hatchery. The first group of 66,912 fish was released on January 8, 2021 (loss threshold =334.6). The second group of 57,357 fish was released on January 22, 2021 (loss threshold = 286.8). The third group of 64,807 fish was released on January 29, 2021 (loss threshold = 324.0). The only

observed loss was from the second release group which had a cumulative loss of 6.4 fish (2.2% of the loss threshold). Therefore, during WY 2021 no spring-run loss thresholds were exceeded and no OMR restrictive action was required (Table 1).

Table 1. Confirmed SWP and CVP hatchery (adipose-fin clipped) Chinook loss for WY 2021.

Release Date	CWT Tag Race	Hatchery	Release Site	Release Type	Loss	CWT Number Released	% CWT Marked of Total Number Released	% Loss CWT number released	First Loss	Last Loss
1/22/2021	Late-Fall	Coleman National Fish Hatchery	Battle Creek	Spring Surrogate	6.401	57,357	100	0.011	2/10/21	2/21/21

ITP Spring-Run Surrogates

To minimize entrainment of emigrating natural juvenile spring-run Chinook Salmon from the Sacramento River and tributaries the SWP (ITP COA 8.6.4) requires surrogate releases of hatchery spring-run and fall-run in addition to those required by the ROD. Initially, DWR and CDFW agreed to and planned for two Coleman National Fish Hatchery fall-run surrogate releases into the upper Sacramento River during March, two Feather River Fish Hatchery spring-run releases into the Feather River during March and April, and two Nimbus Fish Hatchery fall-run releases into the American River during April and May. The first group of 322,538 fish was released from Coleman National Fish Hatchery on March 10, 2021 (loss threshold = 806.35). The second Coleman National Fish Hatchery release group of 372,072 fish was released on March 24 and 26, 2021 (loss threshold = 930.18). The first group of 514,027 Feather River fish was released on March 3, 2021 (loss threshold = 1285.07). The second group of 500,312 Feather River fish was released on April 1, 2021 (loss threshold= 1250.78). Due to drought induced low flow and high-water temperatures in the American River, the two intended release groups from Nimbus Fish Hatchery were released directly into the Bay, and could not serve as surrogates. Therefore, a third group of 1,347,465 hatchery fall-run Chinook Salmon was released from Coleman National Fish Hatchery on April 8, 2021 (loss threshold = 3,368.66) as a replacement for the American River releases from Nimbus Fish Hatchery.

Loss at the CVP and SWP was detected for only one of the ten surrogate release groups, and that was for only a single juvenile Salmon. In so far as spring-run surrogate salvage and loss reflects the performance of OMR management toward minimizing the impact of CVP and SWP operations on spring-run Chinook Salmon, the near complete lack of spring-run loss indicates daily loss thresholds did not fail to protect spring-run. Given that OMR was not controlled by spring-run Chinook Salmon protective measures at any time during WY 2021 and, given the low detections of spring-run Chinook Salmon throughout the migration route network, it was not possible to evaluate the efficacy of ROD and SWP surrogate loss thresholds as protective measures, or how OMR levels in general contribute to protection of the spring-run population from direct entrainment loss.

Steelhead

There are two single-year loss thresholds set for natural steelhead under OMR flow management conditions: December 1 – March 31 and April 1 – June 15 (see Proposed Action U.S. Bureau of Reclamation 2019c, Section 4.10.5.10.2). Since steelhead out-migrate from both the Sacramento and San Joaquin River basins, this split in the season was created to capture those that out-migrate earlier (Sacramento River Basin) and those that out-migrate later (San Joaquin River Basin). The single-year loss thresholds for natural steelhead under the ROD's OMR flow management are set at 90 percent of the greatest annual loss from 2010 through 2018. The single-year loss threshold under the ROD for December 1 – March 31 is equal to 1,414 fish. The ROD's single-year loss threshold for April 1 – June 15 is equal to 1,552 fish. The ROD sets a cumulative (which lasts the duration of the Proposed Action) threshold loss value for steelhead. The cumulative loss threshold over the duration of the ROD (i.e., ten years) is equal to 6,038 fish for the December 1 - March 31 time period, and 5,826 fish for the April 1 - June 15 time period.

Between December 1, 2020 and March 31, 2021, a total of 41.2 natural steelhead were lost. This loss equals 5.8 percent of 50 percent of the single-year loss threshold under the Proposed Action; 2.9 percent of the single-year loss threshold; and 7.3 percent of the cumulative loss threshold over the duration of the ROD (Figure 23). Between April 1, 2021 and June 15, 2021, an estimated total of 49.8 natural steelhead were lost. This loss equals 6.4 percent of 50 percent of the single-year loss threshold; 3.2 percent of the single-year loss threshold; and 6.4 percent of the cumulative loss threshold over the duration of the ROD (Figure 30). Loss did not exceed 50 percent of either of the single-year loss thresholds during WY 2021. Exports were not decreased as a result of a threshold trigger exceedance for natural steelhead during either the early or later periods of migration.

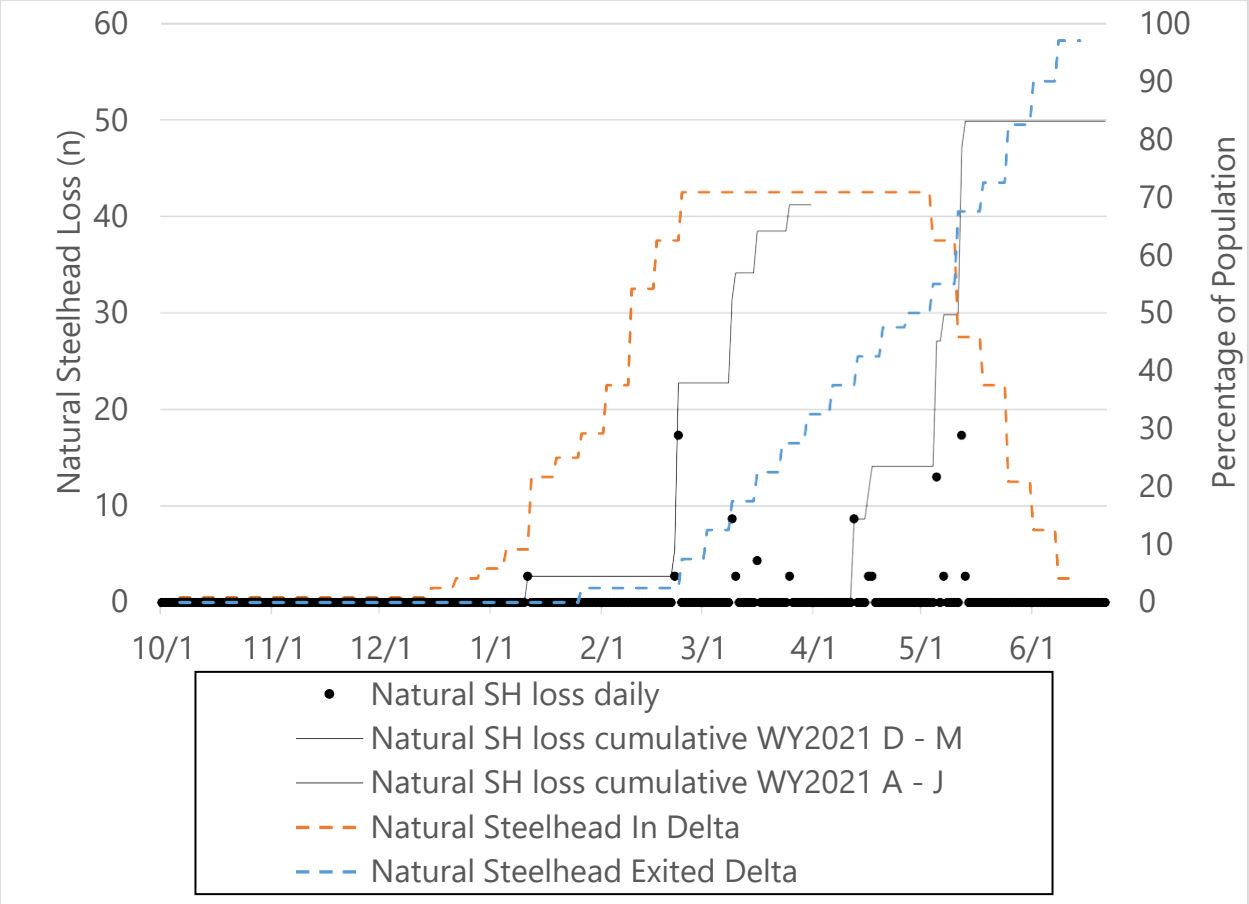

Figure 23. Estimated total loss of natural steelhead loss for WY 2021 (76% at SWP, 24% at CVP).

Storm-Related OMR Flexibility

The CVP and SWP can increase exports during OMR management season to capture peak flows in the Delta during storm-related events (see Proposed Acton U.S. Bureau of Reclamation 2019c, ITP COA 8.7). Reclamation and DWR determined that the Delta outflow index did not increase in response to a storm-related event such that it would indicate a higher level of flow available for export. In WY 2021 there were no storm-related events that prevented or precluded operations.

End of OMR Management

OMR criteria may be in effect until June 30th or when species-specific off-ramps have occurred. The ROD and SWP have the same species-specific criterion for Delta Smelt, which also applies to the SWP for Longfin Smelt (ITP COA 8.8): OMR management season ends when daily mean water temperature at CCF reaches 25°C/77°F for 3 consecutive days (ITP COA 8.8). Similarly, the ROD and SWP (ITP COA 8.8) have similar off-ramp criterion for Salmon, which also applies to the ROD for steelhead: OMR management season ends when average daily temperatures at both Mossdale and Prisoner's Point) exceed 22.0°C/71.6°F for seven non-consecutive days and the SaMT determines that 95% of winter-run and spring-run have migrated past Chipps Island. The CCF criterion for Delta Smelt and Longfin Smelt was met on June 21, 2021 (Figure 24), and thus ended the OMR flow management season for these species. Daily average water temperature at Mossdale and Prisoner's Point met offramp criteria for Chinook Salmon and steelhead on June 8, 2021 (Figure

24) and SaMT estimated that more than 95 percent of natural winter-run and YOY spring-run Chinook Salmon had exited the Delta by June 8, 2021, ending the OMR management season for these species.

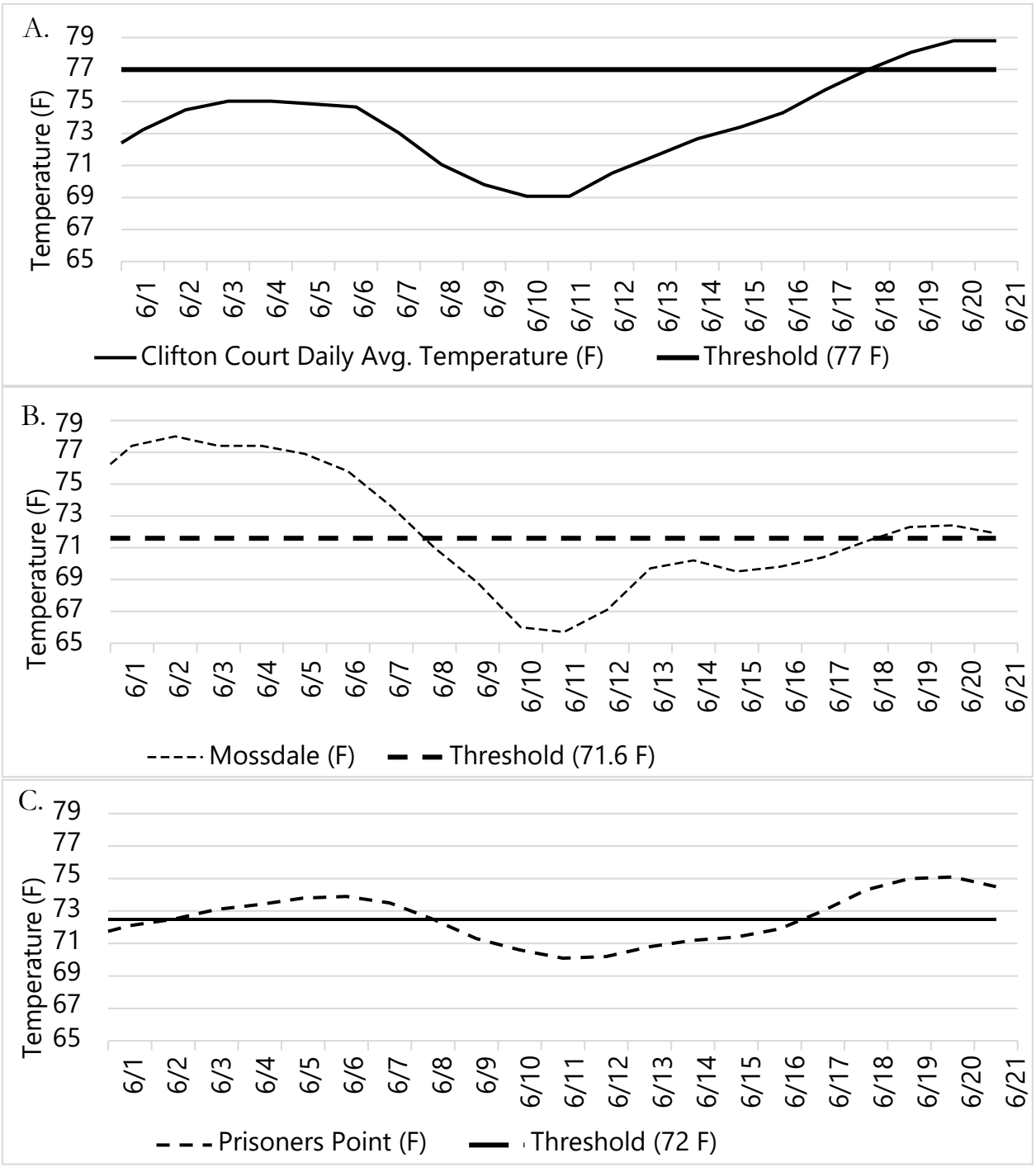

Figure 24. Average daily temperatures (F) at **A.** Clifton Court Forebay, **B.** Mossdale, and **C.** Prisoner's Point in June 2021.

South Delta Agricultural Barriers

Figure 25. Agricultural barrier on Old River near Tracy, California. (DWR)

During WY 2021 the South Delta agricultural barriers were installed. Agricultural barriers have the potential to effect fish movement and hydrology. Construction of the Middle River barrier started on May 1, 2021 and ended May 8, 2020. The barrier was partially closed and all gates were tied open May 12, 2021. The barrier was fully closed and all gates were released to tidal operations May 15, 2021. On Old River near Tracy, the in-water work began May 10, 2021. The boat ramp was completed on May 21, 2021. The barrier was closed on May 27, 2021 with one flap gate tied open and the rest operating tidally. The completion date was June 1, 2021. Mobilization to install the Grant Line Barrier in-water work began May 3, 2021. The boat ramp was completed May 24, 2021 and the closure of the weir started May 27, 2021. The completion date was June 2, 2021.

Export Curtailments for Spring Outflow

The daily export rate for the SWP is the daily inflow to CCF minus the daily Byron Bethany Irrigation District (BBID) diversion from the CCF. For 2021, the BBID diversion varied daily, but the monthly average was approximately 60 cfs/day in April and 70 cfs/day in May.

SWP exports are scheduled based upon a 3-day running averaging period for both the San Joaquin River flow at Vernalis and SWP exports, in consideration of daily short-term flow fluctuations. This provides operators with a reasonable methodology for calculating scheduled SWP exports and is aligned with SWRCB's compliance methodology for D-1641 regarding exports during the 31-day April-May pulse flow period.

The SWRCB's D-1641 specifies (see footnotes [17] and [18] on page 186 of the document) that within the months of April and May, there shall be a 31-day continuous pulse flow period, scheduled in coordination with USFWS, NMFS and CDFW. During the "pulse flow" period, combined CVP (Jones pumping plant exports) and SWP (CCF inflow) diversions are not to exceed either: (1) 1500 cfs, or (2) the 3-day running average of Vernalis flow, whichever of these is greater. For April and May days falling outside of the 31-day pulse flow period, the combined exports are limited to 35% of the total Delta inflow.

The Incidental Take Permit issued by the CDFW (ITP COA 8.17) for SWP operations specifies that "Permittee shall reduce exports from April 1 to May 31 each year to achieve the SWP proportional share of export reductions established by the ratio of Vernalis flow(cfs) to combined CVP and SWP exports, scaled by water year type…In a critically dry year, the ratio of Vernalis flow to CVP and SWP combined exports shall be 1 to 1." However, ITP Section 3.8 specifies that "…combined CVP and SWP export rates will not be required to drop below 1,500 cfs and SWP exports will not be required to drop below 600 cfs."

During the 2021 Water Year (classified as Critically Dry), the 31-day pulse flow period was from April 13 – May 13. As Appendix D shows, combined CVP and SWP exports never exceeded 1500 cfs throughout April and May. Therefore, both the CVP and SWP were in compliance with D-1641 requirements and the SWP was in compliance with the ITP requirements.

WOMT Elevation to Directors

No WOMT member elevated OMR flow management concerns to directors during WY 2021 (See Supporting Information Section).

Performance

Delta Cross Channel Closures

The Delta Cross Channel was operated consistent with the ROD during the OMR flow management season (Figure 6) except for required maintenance. During WY 2021 there was construction and testing of the DCC gates during periods when the gates were required to be closed. Gate openings and closures for testing were short in duration and their operations were evaluated as part of weekly assessments by the SaMT. As measured by the California Data Exchange Center

water quality station (Station ID: DLC) located in Snodgrass Slough, the cycling of the DCC gates resulted in a small change in water elevation and velocity; however, it did not result in a measurable change to Sacramento River flow. The short duration of the urgent maintenance required of the DCC gates resulted in an insignificant or discountable hydrological alteration and did not expose federally-listed fish species to stressors identified in the NMFS 2019 Biological Opinion.

For winter-run Chinook Salmon, Figure 3 shows the Knights Landing Catch Index (KLCI) from October 1, 2020 through May 30, 2021 and the Sacramento Catch Index (SCI) seine data and trawl data for October 1, 2020 through December 31, 2020. Trapping ended on May 30, 2021 at Knights Landing due to river temperatures reaching 70°F. During WY 2021, Sacramento River winter-run Chinook Salmon presence was highest at the Knights Landing rotary screw trap in January and February; however, the DCC gates had been closed on December 1, 2020. Therefore, fish were protected from routing through the DCC into the Central and South Delta regions except for the two brief openings in February for testing of the gates. Salmonid presence was evaluated by the SaMT and is addressed in the Seasonal Operations section above. Additionally, a process was implemented between CDFW (KLCI indices), USFWS (SCI indices), and SacPAS (University of Washington) staff for daily reporting of indices for agency biologists and the interested public. During WY 2021 there were no DCC gate closures due to exceeding the KLCI or SCI catch triggers.

Salvage and Loss Performance

Delta Smelt Salvage

Adult and Juvenile Salvage

No adult or juvenile Delta Smelt were salvaged during the OMR flow management season.

Qualitative Larval Sampling

Larval Delta Smelt sampling methods began at the CVP on February 15, 2021 and at the SWP on February 22, 2021. No larval Delta Smelt were detected at the TFCF or the Skinner Delta Fish Protection Facility. On June 1, 2021, the SMT began evaluating if the labor-intensive process of the larval sampling would continue every week. The TFCF ended larval sampling methods on June 2, 2021, and the Skinner Delta Fish Protection Facility ended larval sampling methods on June 1, 2021.

Longfin Smelt Salvage

Adult and Juvenile Salvage

Across the entire water year, there was zero salvage of adult Longfin Smelt. Salvage of juvenile (>20mm) Longfin Smelt began in March at the SWP fish salvage facility (Figure 26). Once salvage at the SWP began, it rapidly increased until early May. Salvage of Longfin Smelt then slowed in May until May 31, when the last Longfin Smelt salvage was observed. For WY 2021, total Longfin Smelt salvage was 677 fish for the SWP and 188 fish for CVP and was lower compared to WY 2020 with 1,360 fish for the SWP and 1,326 fish for the CVP.

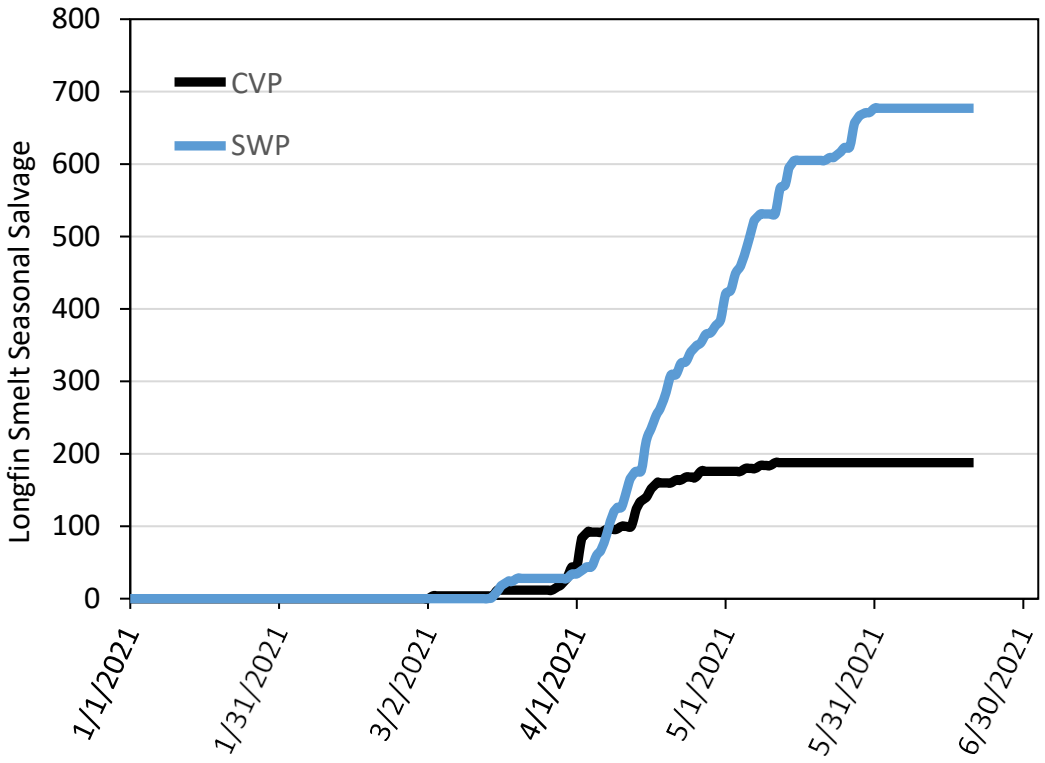

Figure 26 Cumulative young of year Longfin Smelt salvage. Salvage is shown for SWP (blue) and CVP (black) separately.

Qualitative Larval Sampling

Larval Longfin Smelt sampling methods began at the CVP on February 15, 2021 and at the SWP on February 22, 2021. Larval Longfin Smelt were detected at the TFCF on 13 days between February 28, 2021 and May 2, 2021 and at the Skinner Delta Fish Protection Facility on two days between March 1, 2021 and April 30, 2021. On May 18, 2021, the SMT began evaluating if the labor-intensive process of the larval sampling would continue every week. The TFCF ended larval sampling methods on June 2, 2021 and the Skinner Delta Fish Protection Facility ended larval sampling methods on June 1, 2021.

Winter-run Chinook Salmon

Daily Loss

The early-season Natural Winter-run Chinook Salmon Discrete daily loss threshold for the SWP was not met in November and December of 2020, nor was the Mid- and Late-season Natural Winter-run Chinook Salmon daily loss threshold exceeded at either the SWP or CVP fish salvage facilities between January and May 2021.

Single Year Loss

In WY 2021 none of the single-year loss thresholds (50 percent, 75 percent, 90 percent, and 100 percent) for natural winter-run were exceeded. Zero hatchery winter-run Chinook Salmon were lost in WY 2021. Total natural winter-run Chinook Salmon (LAD) loss for WY 2021 (October 1, 2020 through July 1, 2021) was 8.2 fish which represents 0.43 percent of the 50 percent single-year loss threshold (1,931 fish) (Figure 27). Weekly, SacPAS produced plots which incorporate both current and historic loss data: current cumulative WY 2021 loss to the creation date of the plot and historic loss added to the current cumulative loss to visualize historic loss from the creation date of the plot to the end of the season. There was no historic loss rate (2009 – 2020) that caused concern to SaMT members leading to the exceedance of the 50 percent single-year loss threshold in WY 2021. As the season progressed, loss numbers (both current and historic) became more static thus these plots are most useful early in the season. In WY 2021, all loss of natural winter-run Chinook Salmon salvage occurred on March 8, 2021 and March 9, 2021.

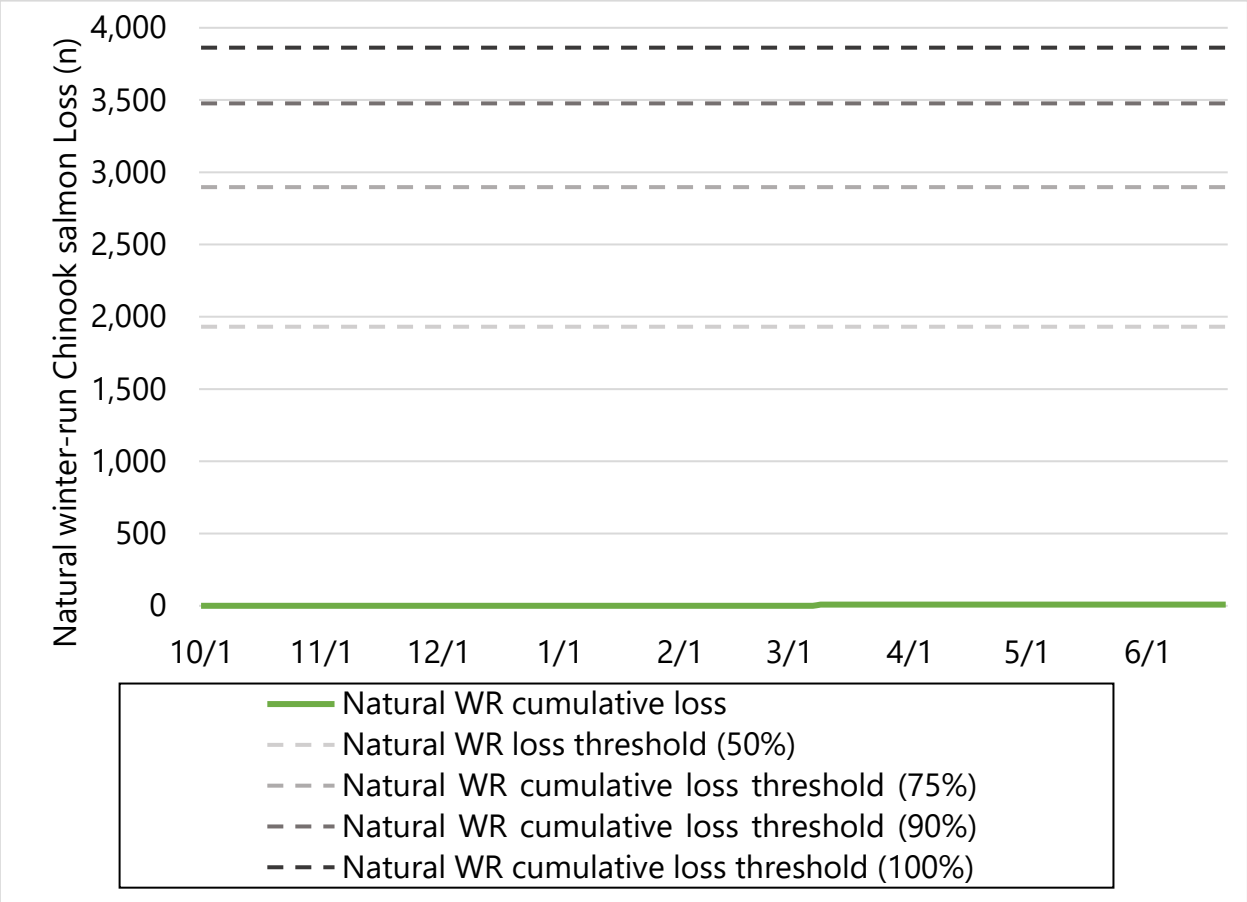

Figure 27. Total natural winter-run Chinook Salmon (LAD) loss for WY 2021.

Cumulative

A total of 8.2 natural winter-run Chinook Salmon were lost in WY 2021. The cumulative loss threshold for natural winter-run Chinook over the duration of the ROD is 8,738 fish. At the end of WY 2021, current loss is 2.19 percent of total allowed loss over the duration of the ROD (Figure 27,

Figure 28). A 45-degree line is superimposed to track the trajectory of natural winter-run Chinook Salmon loss over the duration of the ROD, assuming each year's natural winter-run Chinook Salmon loss is equal.

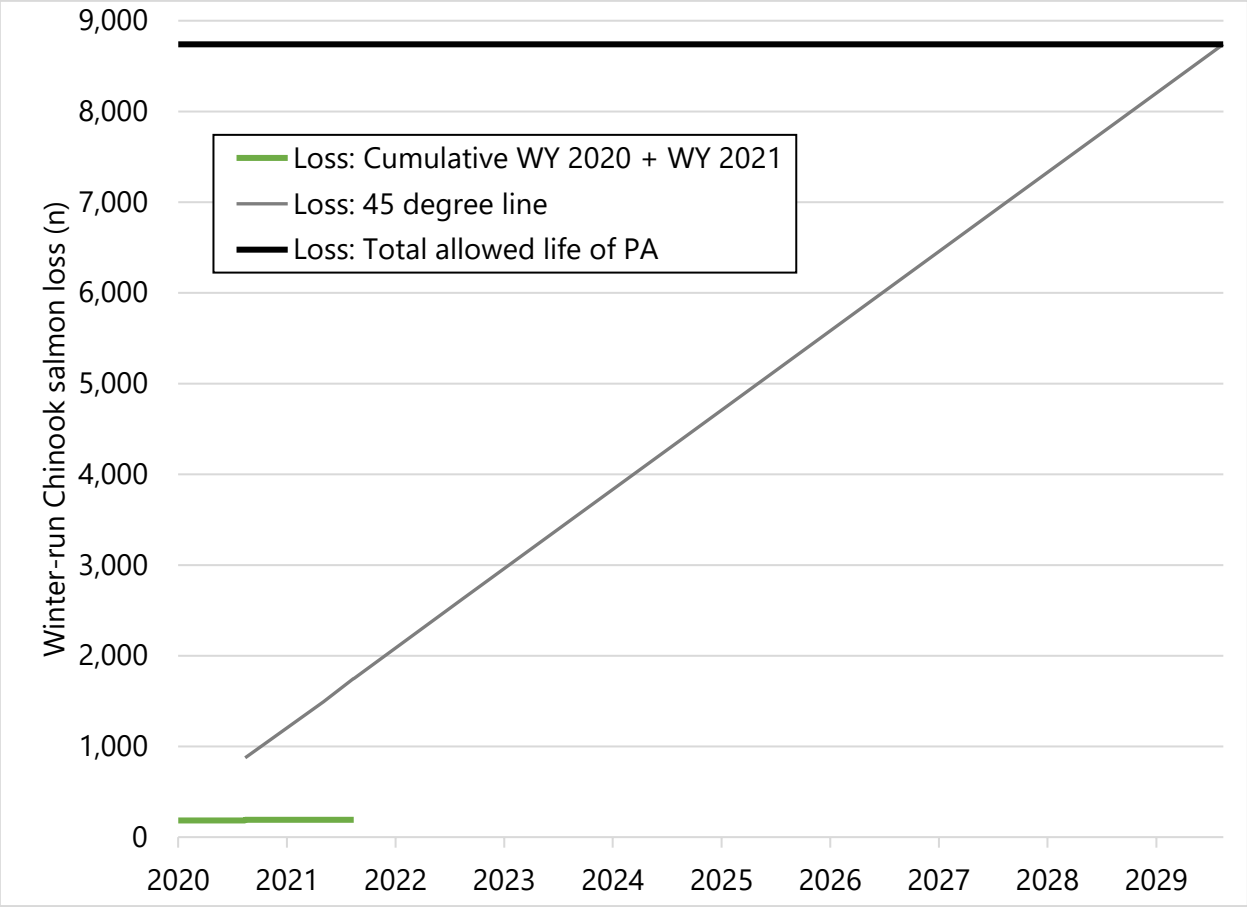

Figure 28. Cumulative loss threshold for natural winter-run Chinook Salmon in WY 2021. A 45-degree line is superimposed to track the trajectory of natural winter-run Chinook Salmon loss over the duration of the ROD.

Steelhead

Total natural steelhead loss for WY 2021 (October 1, 2020 through June 15, 2021) did not exceed any of the single-year loss thresholds (Figure 23). Total natural steelhead loss was 41.2 fish between December 1 and March 31 which represents 5.8 percent of the 50 percent single-year loss threshold (707 fish). Total natural steelhead loss for WY 2021 was 49.8 between April 1 and June 15 which represents 6.4 percent of the 50 percent single-year loss threshold (776 fish). In WY 2021, 45.2 percent of natural steelhead loss occurred by March 31, 2021 and 54.8 percent of natural steelhead loss occurred after that date, until the end of the OMR flow management season on June 7, 2021. On March 30, 2021, the SaMT estimated the distribution of natural steelhead within the Delta to be 35-50 percent, and distribution of natural steelhead that had exited past Chipps Island to be 30-35 percent. More than half the season's steelhead loss occurred at the CVP and SWP fish salvage

facilities by April 12, 2021 (54.8 percent) before more than half the population was estimated to have migrated past Chipps Island.

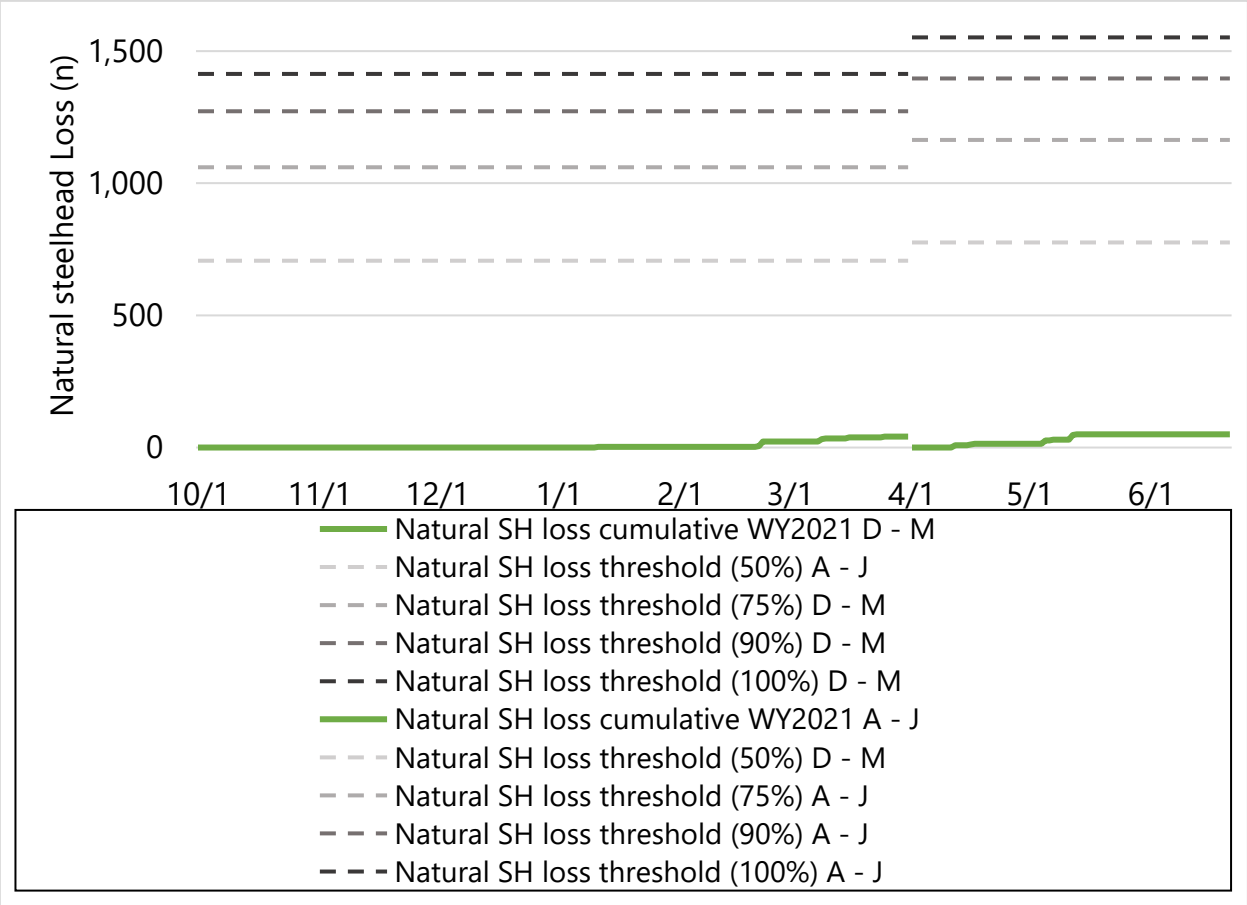

Figure 29. Single-year loss for natural steelhead for WY 2021.A total of 41.2 natural steelhead fish were lost in WY 2021 from December 1, 2020 through March 31, 2021. The cumulative loss threshold for steelhead over the 10-year duration of the ROD for the period from December 1 to March 31 is 6,038 fish. At the end of WY 2021, the loss for the first two "seasons" is 7.3 percent of the 10-year duration cumulative total loss for this period (Figure 29, Figure 30). A total of 49.9 natural steelhead fish were lost in WY 2021 from April 1, 2020 to June 15, 2020. The cumulative loss threshold for steelhead over the 10-year duration of the ROD for the period between April 1 and June 15 is 5,826 fish. At the end of WY 2021, the loss for the second two "seasons" is 6.4 percent of the cumulative total loss for this period (Figure 29, Figure 30). 45-degree lines are superimposed to track the trajectories of natural steelhead loss over the duration of the ROD, assuming each year's natural steelhead loss is equal.

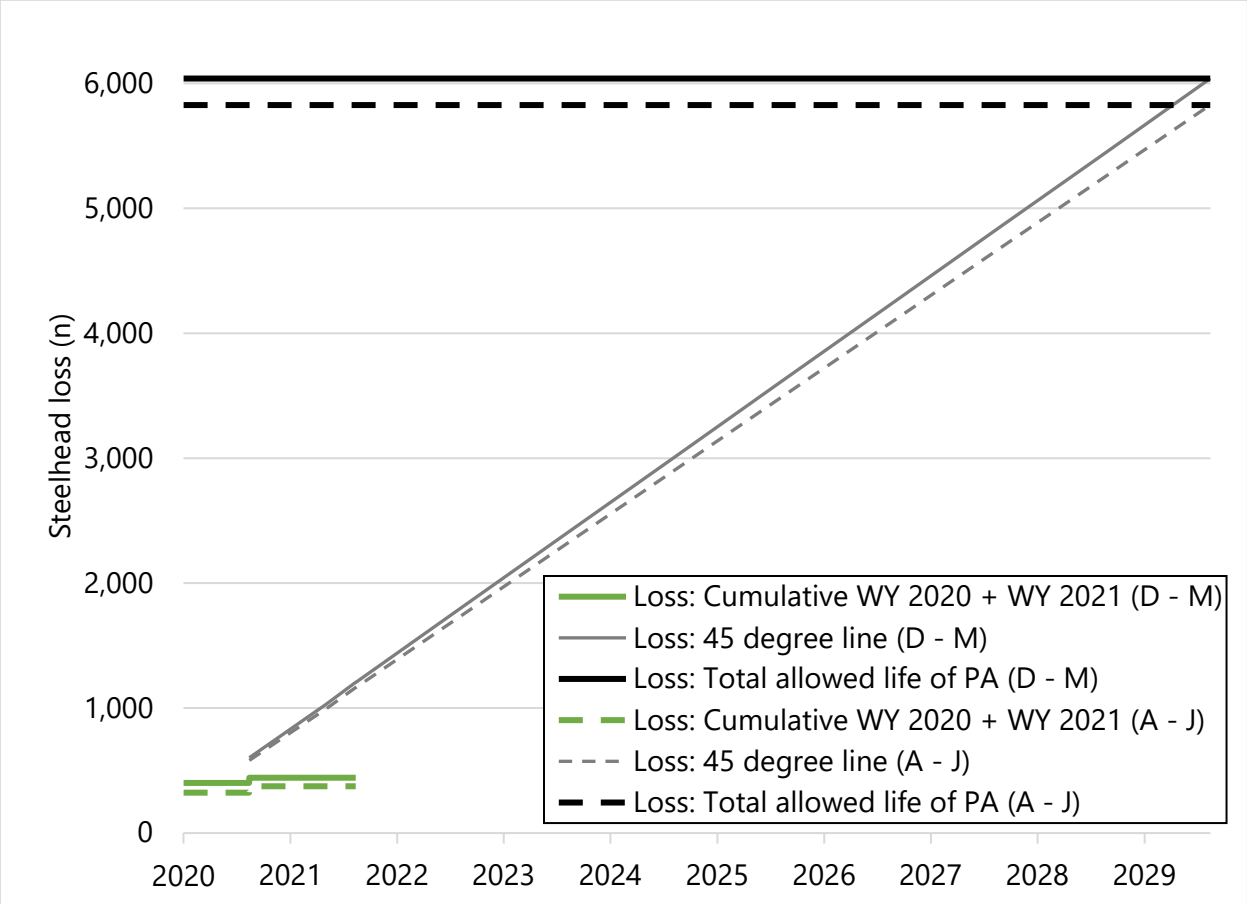

Figure 30. Cumulative loss for natural steelhead in WY 2021 for December 1 – March 30 and April 1 and June 15. 45-degree lines are superimposed to track the trajectories of natural steelhead loss over the duration of the ROD.

Salmonids and Historic Performance

Historic natural winter-run Chinook Salmon LAD loss by month by year (2009 – 2020), with loss shown as percentage of total water year loss, is shown in Figure 31. The highest percentage of historic loss occurs in March. In WY 2021, 100 percent of loss occurred in March. Between 2009 and 2020, between 4.1 and 92.9 percent of loss occurred during March. There have been no other years where natural winter-run Chinook Salmon LAD loss occurred solely in March; however, in WY 2009 and WY 2014 high percentages of loss occurred in March (91.6 percent and 92.9 percent, respectively; Figure 31).

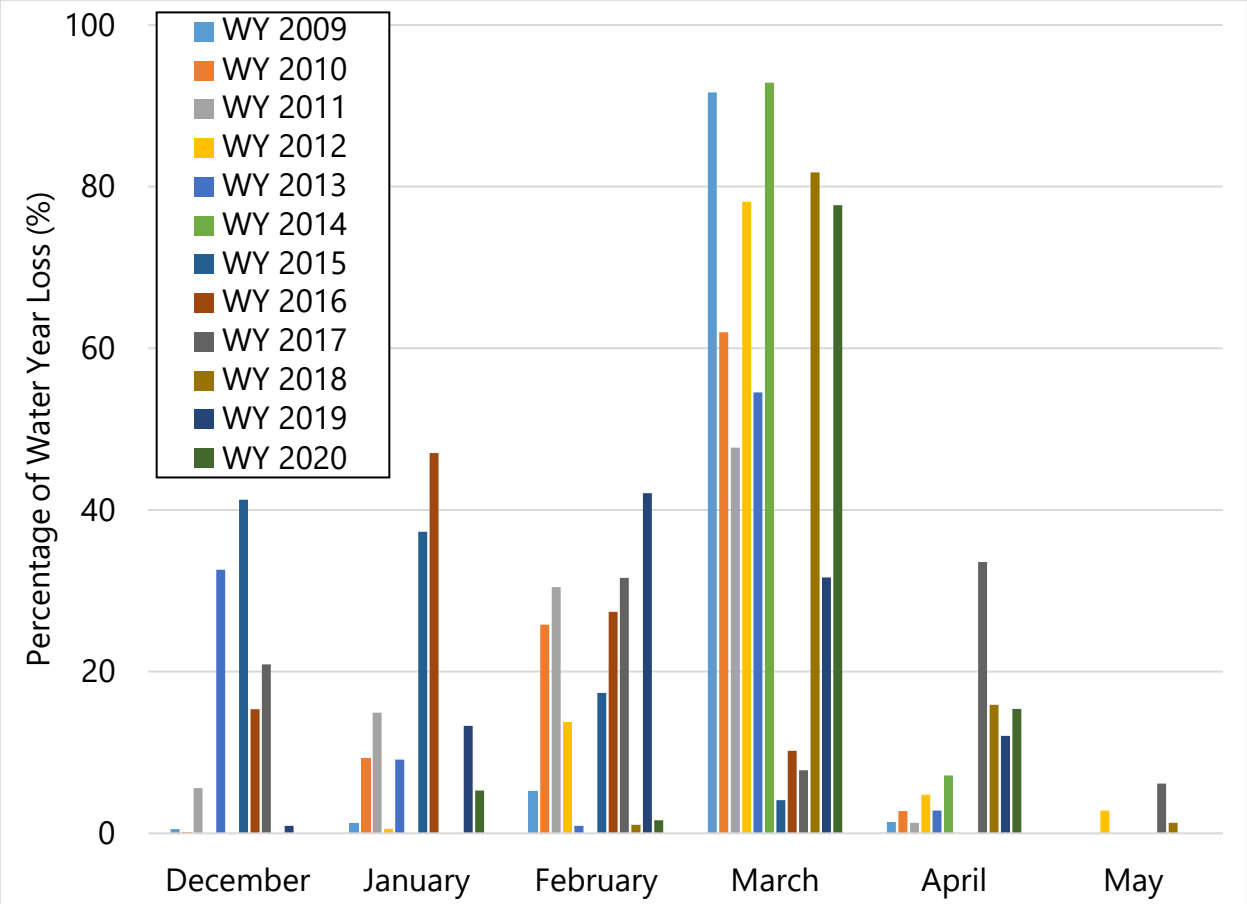

Figure 31. Historic natural winter-run Chinook Salmon loss by month by WY (2009 - 2020).

Historic natural steelhead loss by month by year (2009 – 2020) is shown in Figure 32, with loss shown as percentage of total water year loss. Historic loss occurred more frequently from December 1 to March 30 than from April 1 to June 15 in 7 of the last 11 years (2009 – 2020).

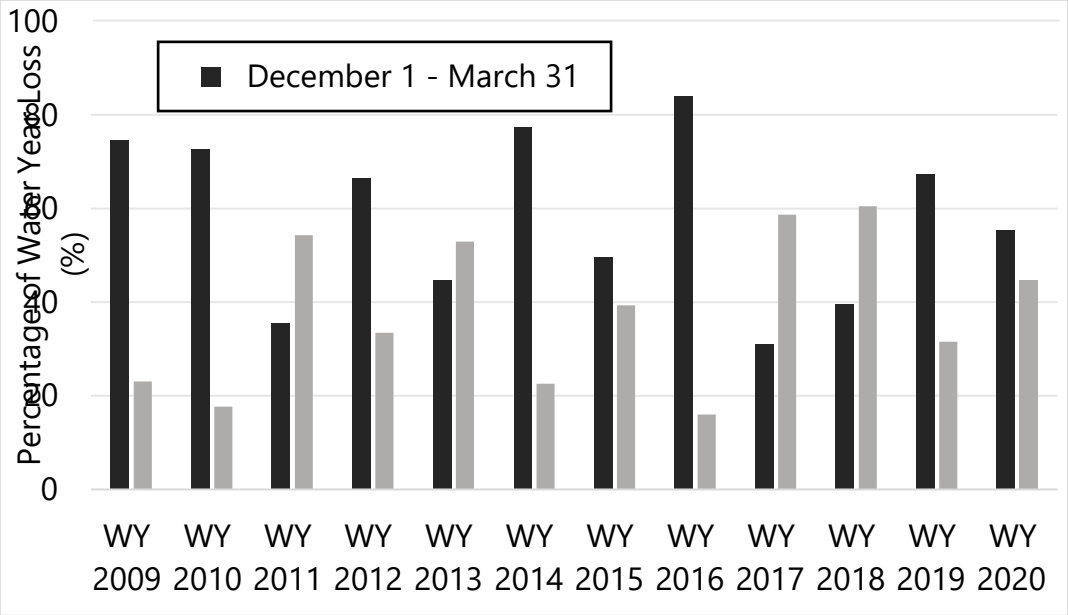

Figure 32. Historic natural steelhead loss by action period "season" (December 1 – March 31, April 1 – June 15) by year (2009 – 2020). Loss shown as percentage of total water year loss.

Discussion

Delta Cross Channel

Out-migrating Sacramento River Basin origin salmonids traveling downstream through the Sacramento River have the potential to encounter the junction with the DCC gates. When the DCC gates are open salmonids are vulnerable to entrainment into the interior Delta and potentially farther into the South Delta. Survival within the South Delta, as estimated from tagged fish studies, is less than survival through the Sacramento River to Chipps Island. Throughout the OMR flow management season, the DCC gates remained closed per the ROD during time periods of highest risk for juvenile salmonids except for two brief openings in February to inform urgent maintenance. Historic migration patterns at Knights Landing RST show an average of 50 percent of natural winter-run Chinook Salmon by December 26th and an average of 75 percent of natural winter-run Chinook Salmon by January 7th (2006 – 2019). In WY 2021 the first natural winter-run Chinook Salmon was observed at Knights Landing on September 21, 2020 and the last on February 27, 2021. The action of closing the DCC gates on December 1, 2020 provided a high level of protection for juvenile salmonids out-migrating down the Sacramento River. At no point during WY 2021 were the KLCI and SCI trigger thresholds exceeded and, as such, there were no resulting operational actions (Figure 3).

Integrated Early Winter Pulse Protection ("First Flush")

The flow and turbidity thresholds of the First Flush action were not met in WY 2021. Given the acknowledged drought conditions, precipitation driven changes in turbidity and flow have been rare throughout the season (Figure 7A and B). Only four Delta Smelt were detected during the Integrated Early Winter Pulse Protection period: one in November in Suisun Marsh and three in January in the Sacramento Deepwater Ship Channel. Those fish observed in the Sacramento Deepwater Ship Channel may also have a freshwater resident life history and have a lower likelihood to migrate (Hobbs 2019). Thus, the SMT struggled to assess the likelihood of entrainment due to adult migration during this period.

Turbidity Bridge Avoidance ("South Delta Turbidity")

Turbidity data at Old River at Bacon Island (OBI) is used to assess the formation of a turbidity bridge within the Old River corridor between the San Joaquin River shipping channel and the CVP and SWP fish salvage facilities. The threshold for determining the conditions necessary for the formation of a turbidity bridge, 12 FNU at Old River at Bacon Island, did not occur within the period of the Turbidity Bridge Avoidance Action (Figure 15). Wind driven turbidity was frequently considered in the weather forecast each week, but only one wind event ever actually elevated turbidity above the OBI threshold prior to the start of the Turbidity Bridge Avoidance Action period. This event occurred on January 27, 2021, where OBI daily turbidity reached 14 FNU in response to a wind event on the January 26th. Turbidities at OBI fell below 12 FNU the following day and the SMT considered these circumstances in an off-cycle meeting and did not make any recommendations in response to this event. Methods for analyzing turbidity and the formation of a turbidity bridge due to wind driven turbidity events are under consideration for a potential topic in the Four-Year Review.

Delta Smelt Protections

During the period of Larval and Juvenile Delta Smelt protection, the SMT examined QWEST, the DWR Delta Turbidity Conditions Report, and available catch data each week to assess the likelihood of larval and juvenile entrainment. Drought operations influenced QWEST (Figure 16), and as expected in such low flow conditions, turbidity also remained relatively stable across the south Delta and any observed change was not deemed significant enough for the SMT to consider it likely to increase the risk of entrainment under the operational plans each week. The same drought requirements also maintained the OMR index at levels more protective than those operated to under Larval and Juvenile Delta Smelt protection. No Delta Smelt larvae or juveniles were detected in the South Delta during this period.

Longfin Smelt Protections

During the period of adult Longfin Smelt entrainment protections, no salvage of adult Longfin Smelt was observed and no adults were detected in regular monitoring in the Central and South Delta (though the later presence of larvae indicate adults were present in the area for spawning).

For larval and juvenile Longfin Smelt entrainment protections, substantial salvage occurred at both export facilities, particularly the SWP, despite the full implementation of the 2020 ITP. However, a general upstream distribution of Longfin Smelt is to be expected during dry conditions experienced in 2021, and thus a generally higher risk of entrainment is to be expected. It is notable that salvage was substantially reduced from the WY 2020 season, which saw only partial implementation of the 2020 ITP. It is possible that advice from the SMT provided from February 23, 2021 to March 23, 2021 may have helped to reduce the magnitude of salvage in WY 2021 compared to WY 2020, though OMR flows in WY 2021 were generally lower than WY 2020 due to drought conditions (Figure 36) and this would also function to reduce entrainment. Additional years of data will be necessary to analyze the full effectiveness of these actions over a broad range of OMR flows and hydrologies. Additionally, Barker Slough Pumping Plant restrictions (ITP COA 8.12) were triggered three times for the protection of Longfin Smelt in WY 2021 (Figure 19).

Qualitative Larval Fish Sampling at Salvage Facilities

During the WY 2021 season, qualitative larval fish sampling at the SWP and CVP fish salvage facilities began approximately one month earlier than was typically done in previous years. This earlier start was in response to the 2020 ITP and in recognition of the earlier larval entrainment period for Longfin Smelt relative to Delta Smelt. Despite the early start to qualitative larval sampling, and the presence of Longfin Smelt spawning in the Central and South Delta, the first two weeks of qualitative larval sampling did not detect any Longfin Smelt larvae. However, by the beginning of March 2021, larval Longfin Smelt were detected at both the SWP and CVP, weeks ahead of when they would have been detected in previous years with a qualitative larval sampling start date around mid-March. Given the life history of Longfin Smelt, proper management of larval entrainment would benefit from earlier data relative to Delta Smelt. However, during WY 2022 a new pilot larval entrainment monitoring program will begin (ITP COA 7.6.2) that will sample near the SWP and CVP beginning in January and will be designed to also help meet this information need in a more quantitative way. It is possible that in the future, initiation of qualitative larval sampling at the SWP and CVP could be tied to detections in this new monitoring program, or otherwise be coordinated, to make most efficient use of monitoring resources and meet the needs of real time OMR management for the protection of Longfin Smelt and Delta Smelt.

Salmonid Presence-Based OMR Onramp and Offramp

OMR management season ended on June 8, 2021 for steelhead and Chinook Salmon due to meeting the temperature off-ramp criteria. The last natural winter-run Chinook Salmon was salvaged on March 9, 2021. The last natural steelhead was salvaged on May 13, 2021. Salvage occurrences were relatively well distributed throughout the season (45 percent from December 1, 2020 through March 31, 2021, and 55 percent from April 1, 2021 through June 15, 2021). The last juvenile winter-run Chinook Salmon and steelhead were salvaged well before the end of the OMR flow management season. During the OMR flow management season under the ROD, losses stayed within the annual and cumulative limits described in the Proposed Action as well as the annual take limits from the ITS in the NMFS Biological Opinion for natural steelhead and natural winter-run Chinook Salmon.

The CVP and SWP export facilities operated OMR to be more positive than -5,000 cfs during the period when the majority of salmonids were estimated by the SaMT to be present in the Central and South Delta regions. Operations were not constrained by fishery-related loss restrictions, but other factors such as D-1641 (Figure 6).

Average daily water temperatures are tracked at three sites (CCF, Mossdale, and Prisoner's Point) to evaluate the end of the OMR flow management season. Daily average water temperature to meet offramp criteria at Mossdale (72° F in the NMFS 2019 Biological Opinion and 71.6° F in Reclamation's ROD) was met on June 8, 2021 in WY 2021 (Figure 24). Daily average water temperature to meet offramp criteria at Clifton Court Forebay (77° F) was met on June 21, 2021 in WY 2021 (Figure 24). The distribution estimates of greater than 95 percent for both natural winter-run and natural YOY spring-run Chinook Salmon juveniles exited past Chipps Island was met by June 8, 2021. On June 8, 2021 the SaMT provided a distribution estimate range for natural steelhead exited past Chipps Island of 94 to 100 percent.

Real-Time Decision-Making Tools

The SaMT and SMT utilize real-time data and various modeling tools to provide information for consideration by Reclamation for OMR flow management. These real-time decision-making tools are discussed in this section.

Salmonids

Distribution estimates of salmonids change weekly from projections provided by the SaMT. The distributions are grounded in real-time operations data (i.e., KLCI, Mossdale Trawl, salvage and loss numbers, acoustically-tagged juveniles, etc.) and modeling tools (Delta Simulation Model II (DSM2) model runs, STARS model predictions, entrainment model predictions). During WY 2021 before the DCC gate closures on December 1, 2020, weekly reports of KLCI and SCI values were received from CDFW and USFWS and Reclamation.

DSM2

Throughout the OMR flow management season, weekly DSM2 runs were modeled (Appendix E). During WY 2021, drought conditions often affected the ability to run one or two scenarios to compare with a baseline OMR scenario. For weeks when two OMR scenarios representing an operational range were available, they were compared to a baseline OMR using a Kolmogorov–Smirnov (K-S) statistical test. The effect of the CVP and SWP export facilities' hydraulic footprint was discussed at the SaMT meetings. To assess the effects of operations, the Delta was subdivided into several regions: (1) the Central Delta from the Sacramento River to the Western Delta; (2) the South Delta from the San Joaquin River to the Central Delta; and (3) facilities in the South Delta. Within each of these regions, fish presence and behavior was considered. DSM2 modeling of potential operational changes indicated hydraulic changes close to the export facilities, however the likelihood of listed fish presence in those regions was low throughout the water year based on concurrent salvage information, thus, no operational changes were supported by SaMT members to inform WOMT decisions.

Based on a special study exercise conducted prior to the WY 2021 OMR Management Season, DSM2 flow and velocity for each OMR scenario were displayed in daily-averaged time-series plots

which allow for easier interpretation compared to previous ECDF plots (empirical cumulative distribution function) as a second visualization tool for DSM2 modeling in WY 2021.

SacPAS

SacPAS is a website that provides monitoring, evaluation, and web-based data products for management of Salmon and smelt. The SaMT and SMT rely on this publicly accessible, web-based query system to provide data support for real-time decision making during the DCC Gate operation and OMR flow management season. SacPAS has included data queries and alerts used by multiple work groups and teams on topics including, but not limited to, catch indices, water temperature, salvage, river conditions, escapement, and juvenile monitoring. This season, in addition to previously available tools, species distribution estimates plots and daily natural winter-run Chinook Salmon and natural steelhead loss at the Delta fish facilities were developed. Adult Salmon weir and spawner surveys and juvenile Salmon rotary screw trapping on CVP and SWP tributaries were reported during the SaMT meetings but remained inaccessible through open data repositories. This required biologists to undertake the time-intensive activities of aggregating, formatting, and visualizing for sharing with SaMT these monitoring data via email in WY 2021.

An entrainment estimation modeling tool (SacPAS Loss and Salvage Predictor, http://www.cbr.washington.edu/sacramento/lossandsalvage/) has been developed and is available on SacPAS. SacPAS produced weekly figures for salvage of natural winter-run Chinook Salmon and steelhead layered onto historic loss data (2009 – 2020). Using these figures, the SaMT evaluated on a weekly basis if the 50 percent single-year loss threshold (natural winter-run Chinook Salmon or natural steelhead) was likely to be exceeded. During WY 2021 OMR flow management season, none of the plots raised concerns that historic loss would cause WY 2020 loss of natural winter-run Chinook Salmon or steelhead to exceed the 50 percent of single-year threshold.

Salmonid Distribution Estimates and Cumulative Salvage

The SaMT provides weekly distribution estimates for three categories: (1) species yet to enter the Delta; (2) species within the Delta; and (3) species that have exited the Delta past Chipps Island. These weekly estimates are made by incorporating the best available real-time data (salvage, hatchery releases, catch at important monitoring sites, DSM2 hydrodynamic modeling, etc.). In WY 2021, estimating fish distribution was made challenging since many surveys for real-time fish distribution data were not being completed after the statewide COVID shelter-in-place order, which resulted in a few of these surveys being reduced or cancelled from March to June (Figure 9). Reclamation and DWR provided fish salvage monitoring throughout WY 2021 distributing daily sampling to the SaMT to track the percentage of the annual loss thresholds in conjunction with percentage of fish estimates to be within the Delta and percentage of fish estimated to have exited the Delta. Considering these two pieces of information, historical trends in distribution and salvage, fish behavior and salvage, in conjunction with export levels and hydrodynamic modeling (e.g., DSM2) allowed SaMT to consider risk for fish being routed into the interior Delta from the Sacramento River or entrained into the fish salvage facilities once in the South Delta (e.g., 15 percent of 50 percent of single year threshold and 40 percent of the population within the Delta would result in less risk than 40 percent of 50 percent of single year threshold and 80 percent of the population within the Delta).

In WY 2021, there were low detections of salmonids at locations considered by SaMT to produce distribution estimates (e.g., Knights Landing and other sampling stations sampled few winter-run

Chinook Salmon). Given observations of large number of spawning adults and high number of juvenile winter-run Chinook Salmon migrating past Red Bluff Diversion Dam, historic trends would suggest higher numbers of winter-run Chinook Salmon were expected at all locations, including the CVP and SWP fish salvage facilities. The challenge of the continued shelter-in-place and social distancing restrictions associated with Covid-19 on monitoring was compounded with other potential sources of uncertainty in WY 2021 (See Figure 9 for monitoring survey suspensions). Some other possible causes for low detection of juvenile salmonids in WY 2021 include assumptions about sampling bias and effort at each survey location, potential impacts due to thiamine-deficient early life stages (Appendix G), and different and unique hydrologic conditions. Hydrology in WY 2021 including but not limited to dry river conditions throughout the system, lack of any substantial rainfall events leading to higher flows, and low Delta outflows may have had a compounding impact on Salmon, resulting in increased mortality of out-migrating juvenile Salmon. A decreased number of juveniles in the system due to high mortality is one potential cause of the low observation rate in key downstream and estuarine monitoring locations including the Delta salvage facilities.

Delta STARS Model

The Delta STARS model (survival, travel time, and routing simulation) predicts survival, travel time, and routing of migrating juvenile Salmon through the Delta. Simulated fish enter the Delta on a given day at Freeport and the model examines conditions fish were likely to encounter. STARS accounts for DCC gates opening and closings and Delta inflow at Freeport and produces estimates of route specific survival through the Delta. STARS does not evaluate potential changes to export operations or changes to OMR. The model is used as a tool similar to historical data providing predictions on fish parameters (survival, travel time, and routing) based on what happened to late-fall Chinook Salmon that migrated through the Delta November through mid-March 2007 – 2011. Results help guide SaMT on what might be expected of out-migrating juveniles based on the past.

Acoustic Tagging

Acoustically tagged salmonids were tracked throughout the Delta in WY 2021 (https://calfishtrack.github.io/real-time/index.html, Table 2). Real-time detections of tagged fish inform routing, entrainment, and survival. Information at critical junctions (Delta fish facilities, Georgiana Slough, Tower Bridge, Old River, Benicia Bridge) helps inform management decisions. The SaMT used tagging project data, along with other datasets (salvage, RST catch at locations, etc.), to provide weekly distribution estimates for hatchery winter-run Chinook Salmon.

In WY 2021 hatchery-origin winter-run Chinook Salmon survival to Benicia from Caldwell Park and North Fork Battle Creek) was low, 3.6 percent and 0.2 percent respectively (Table 2 and Table 3). The projected survival rate used for development of the hatchery-origin winter-run Chinook Salmon JPE was 31.48 percent (Appendix G). Additionally, measured travel times for fish were longer than in previous years, suggesting longer residence time in the river than typical. Feather River hatchery origin spring-run Chinook Salmon survival to Benicia from Boyd's Landing on the Feather River was low, 2.2 percent (Table 2 and Table 3).

Table 2. 2021 Acoustic Tagging: project details.

Project	Release Date(s)	Fish Released	Groups (n) and description	Release Location(s)
Hatchery-origin winter-run Chinook Salmon	1/30/2021	556	*n* = 3 thiamine boost, thiamine control; release 3	Caldwell Park
Hatchery-origin Battle Creek winter-run Chinook Salmon	3/8/2021 – 3/18/2021	900	*n* = 3 release groups 1 – 3	North Fork Battle Creek
Feather River Hatchery Spring-run Chinook Salmon	3/19/2021, 4/1/2021	590	*n* = 2 release groups 1 – 2	Feather River Boyds
6-Year Study San Joaquin River Steelhead - March	3/23/2021 – 3/26/2021	400	*n* = 3 Durham Ferry, Stockton, HOR	Durham Ferry, Stockton, HOR
6-Year Study San Joaquin River Steelhead - April	4/13/2021 – 4/16/2021	500	*n* = 3 Durham Ferry, Stockton, HOR	Durham Ferry, Stockton, HOR
Mill and Deer Creek wild steelhead, Spring Releases	3/16/2021 – 5/7/2021	96	*n* = 2 Deer Creek, Mill Creek	Deer Creek, Mill Creek
Butte Creek wild spring-run Chinook Salmon	4/7/2021 – 4/23/2021	99	*n* = 2 upstream, downstream	Laux Road (up), Parrot-Phelan Diversion Dam (down)
Hatchery-origin fall-run Chinook Salmon May Release	4/30/2021 – 5/14/2021	961	*n* = 2 RBDD	Red Bluff Diversion Dam
Natural-origin Red Bluff RST captured Chinook Salmon	4/29/2021 – 5/7/2021	61	*n* = 2 release groups 1 – 2	Altube Island
6-Year Study San Joaquin River Steelhead - May	5/4/2021 – 5/7/2021	598	*n* = 3 Durham Ferry, Stockton, HOR	Durham Ferry, Stockton, HOR

Table 3. 2021 Acoustic Tagging: minimum survival, SE, 90 percent confidence intervals (CI) to Benicia Bridge East Span and minimum through-Delta survival (City of Sacramento to Benicia) estimated using a Cormack-Jolly-Seber (CJS) survival model. Updated 6/11/21.

	Benicia Bridge				Through-Delta			
Project	**Survival (%)**	**SE**	**95% lower CI**	**95% upper CI**	**Survival (%)**	**SE**	**95% lower CI**	**95% upper CI**
Hatchery-origin winter-run Chinook Salmon	3.6	0.8	2.3	5.5	35.7	6.4	24.3	49.0
Hatchery-origin Battle Creek winter-run Chinook Salmon	0.2	0.2	0.1	0.9	6.7	4.6	1.7	23.1
Feather River Hatchery Spring-run Chinook Salmon	2.2	0.6	1.3	3.8	7.7	2.0	4.5	12.8
6-Year Study San Joaquin River Steelhead - March Releases	3	0.9	1.7	5.2				
6-Year Study San Joaquin River Steelhead - April	5.0	1.0	3.4	7.3				
Mill and Deer Creek wild steelhead, Spring Releases	17.1	3.7	11.1	25.6	77.3	8.9	55.6	90.2
Butte Creek wild spring-run Chinook Salmon	No detections yet	NA	NA	NA	Not enough detections	NA	NA	NA
Hatchery-origin fall-run Chinook Salmon May Release	No detections yet	NA	NA	NA	Not enough detections	NA	NA	NA
Natural-origin Red Bluff RST captured Chinook Salmon	No detections yet	NA	NA	NA	Not enough detections	NA	NA	NA
6-Year Study San Joaquin River Steelhead - May	3.0	0.7	1.9	4.8				

Salmonid Distribution Uncertainty: Drivers & Empirical vs Model Results

In previous years, data have been used to validate SaMT's weekly distribution estimates and provide confidence in those estimates. In 2021, monitoring observations did not provide clear evidence of winter-run Chinook Salmon presence and thus SaMT relied heavily on historic migration patterns. In WY 2021, due to low observations, this validation was not possible, leaving SaMT members with questions (e.g., are current sampling methods/gear suitable to catch salmonids during drought conditions, were there not significant numbers of salmonids due to low survival or different migration behavior during drought conditions?).

A qualitative assessment of STARS model projections and acoustic data can be used to compare empirical with modeled results. Figure 33 and Figure 34 show routing probability at the Georgiana Slough junction for two hatchery-origin winter-run Chinook Salmon releases. The 95% confidence intervals for the study period empirical estimate overlapped with the 90% confidence intervals for STARS daily predictions.

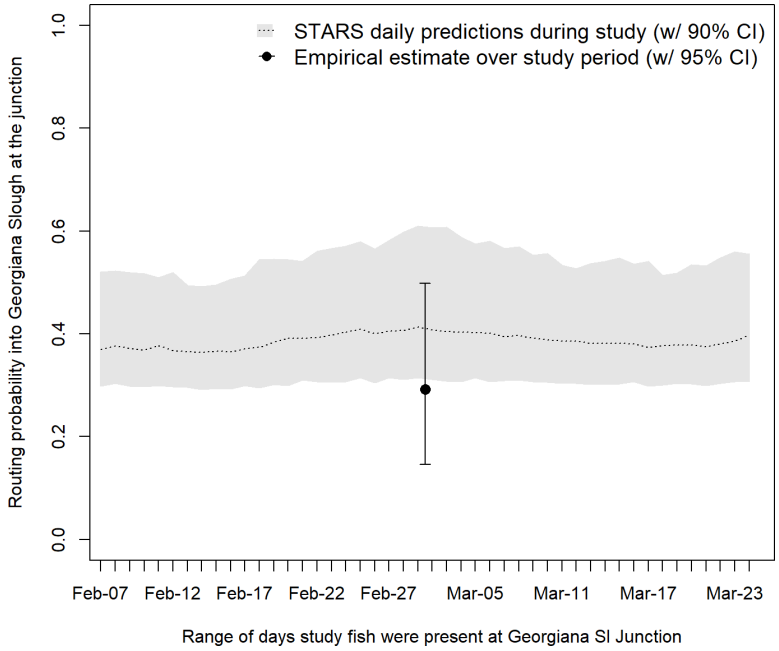

Figure 33. STARS prediction vs empirical estimate of routing probability at the Georgiana Slough junction for hatchery-origin winter-run Chinook Salmon tagged January 30, 2021 and released at Caldwell Park (more data available Table 2 and Table 3 in acoustic tagging section). Figure courtesy of CalFishTrack Central Valley Enhanced Acoustic Tagging Project (CalFishTrack (noaa.gov)).

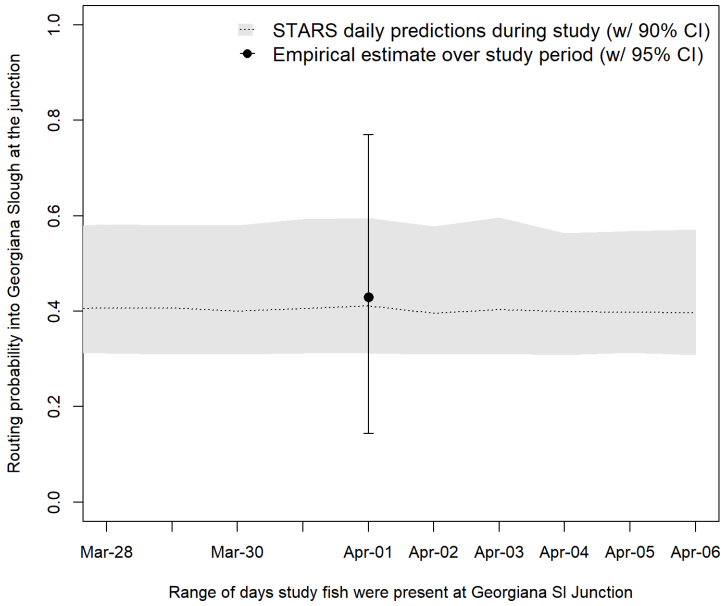

Figure 34. STARS prediction vs empirical estimate of routing probability at the Georgiana Slough junction for hatchery-origin Battle Creek winter-run Chinook Salmon tagged March 8, 2021 through March 18, 2021 and released at Battle Creek (more data available in Table 2 and Table 3 in acoustic tagging section). Figure courtesy of CalFishTrack Central Valley Enhanced Acoustic Tagging Project (CalFishTrack (noaa.gov)).

A qualitative assessment of the Delta facilities entrainment models and observed loss at the Delta fish facilities can be used to compare empirical with modeled results. For example, in weeks 23 and 24 of WY 2021 (March) the SacPAS Loss and Salvage Predictor tool and observed loss data differed (Table 4 and Figure 35).

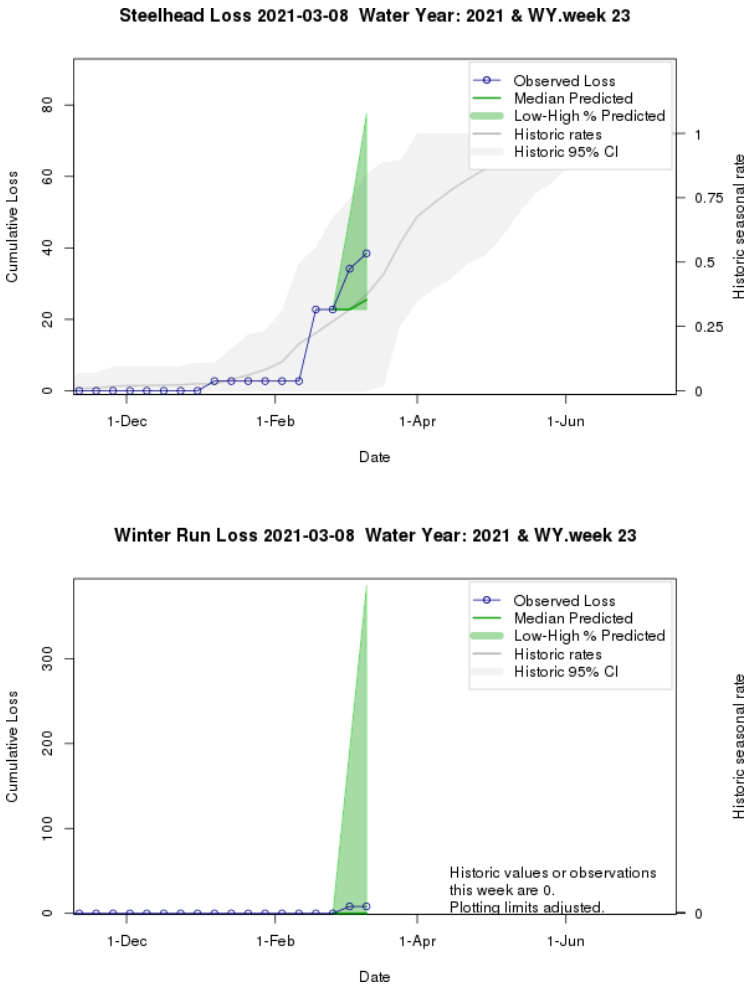

Figure 35. SacPAS Loss and Salvage Predictor tool prediction vs empirical observed loss for natural winter-run Chinook Salmon and natural steelhead in WY 2021. Figure courtesy of SacPAS (SacPAS Loss and Salvage Predictor (washington.edu)).

Table 4. WY 2021 Week 23 and 24 modeled loss and observed loss for natural winter-run Chinook Salmon and steelhead. Data courtesy of SacPAS (SacPAS Loss and Salvage Predictor (washington.edu)).

Week	23	24
Model loss		
Steelhead (low)	0	0
Steelhead (median)	0	3
Steelhead (high)	26	29
Winter-run Chinook Salmon (low)	0	0
Winter-run Chinook Salmon (median)	0	0
Winter-run Chinook Salmon (high)	193	193
Observed loss		
Steelhead (observed)	11	4
Winter-run Chinook Salmon (observed)	8	0

Juvenile Production Estimate (JPE)

Annually natural and hatchery-origin winter-run Chinook Salmon JPEs are calculated by the IEP winter-run Chinook Salmon Project Work Team (WR PWT) after considering the effects of multiple factors (Appendix G). Recent improvements in the accuracy and precision of JPE estimates are assumed to have occurred by incorporating key monitoring surveys, and survival estimates from acoustically tagged salmonids. These data are typically evaluated during the annual WR PWT review of the JPE methodology and any new recommendations considered. As a recommendation to achieve further improvements, the WR PWT could meet in the summer to conduct a post-season analysis comparing and validating its annual JPE estimate modeling approach from the previous season to the empirical monitoring survey data. For example, the JPE approach in WY 2021 predicted a relatively high JPE compared to the last ten years, while empirical observations in the Delta, acoustic tag fish studies (e.g., survival, travel time), and low salvage (independent of low export rates) suggested far fewer winter-run entered the Delta than predicted, which would indicate that the predicted JPE was biased high.

The JPE varies considerably by water year type (Table 5) suggesting many abiotic and biotic processes affect its value through their influence on both survival (actual Salmon abundance) and the efficiency of sampling gear (apparent Salmon abundance). As discussed in the Salmonids and Historic Performance section of this report, annual loss values vary widely by water year type. In WY 2021 the JPE estimate was likely biased high due to over-estimated river survival. It is uncertain whether the LTO actions multi-mechanism multi-season OMR strategy, including DCC gate closure, integrated early winter pulse flow protection, turbidity bridge avoidance--which all improve survival of juvenile salmonids and reduce entrainment of these fish into the South and Central Delta--may have had a similar or higher level of loss if exports had not been controlled by water quality and if export levels were higher.

Since the drought conditions that apparently caused the JPE to be biased high also resulted in non-Salmon related OMR restrictions, it is difficult to assess whether such a bias would lead to reduced protection of Salmon under alternative conditions because it is uncertain whether such a bias would occur under these alternative conditions. Nevertheless, the suggestion that the JPE has the potential

to be highly biased raises the question of whether some form of correction should or could be devised based on empirical observations later in the season after the initial JPE calculation.

There are many potential factors that may have caused low juvenile survival for the Delta, low observations in key Delta monitoring locations, and low salvage in WY 2021. There are observations to support some of these including flow-mediated increase travel times (see "Delta STARS Model", "Acoustic Tagging", and "Salmonid Distribution Uncertainty: Drivers & Empirical vs Model Results" sections above), higher thiamine deficiency in 2020 hatchery broodstock, and monitoring survey suspensions due to Covid-19. In addition, other factors may also reduce survival in the Delta, such as low turbidity resulting in higher predation.

Table 5 Winter-run Chinook Salmon JPE by brood year (BY) and water year type (WYT, 2009 – 2021).

Year	WRCH BY	WR JPE	Sac Basin WYT
2009	2008	JPE: 617,783 Hatchery JPE:82,050	Dry
2010	2009	JPE: 1,179,633 Hatchery JPE: 108,725	Below Normal
2011	2010	JPE 332,012 Hatchery JPE: 66,734	Wet
2012	2011	JPE: 162,051 Hatchery JPE: 96,525	Below Normal
2013	2012	JPE: 532,809 Hatchery JPE: 96,525	Dry
2014	2013	JPE: 1,196,387 Hatchery JPE: 30,880	Critical
2015	2014	JPE: 124,521 Hatchery JPE: 188,500	Critical
2016	2015	JPE: 101,716 Hatchery JPE: 155,400	Below Normal
2017	2016	JPE: 166,189 Hatchery JPE: 58,188	Wet
2018	2017	JPE: 201,409 Hatchery JPE 92,904 Battle Creek JPE: 90,924	Below Normal
2019	2018	JPE: 433,176 Hatchery JPE: 86,699 Battle Cr JPE: 82366	Wet
2020	2019	JPE: 854,941 Hatchery JPE: 94,528 Battle Cr JPE: 67,257	Dry
2021	2020	JPE: 330,130 Hatchery JPE: 117 Battle Cr JPE: 45	Critical

Particle Tracking Models

Delta Smelt environmental surrogates, such as turbidity and OMR flows, are now used in conjunction with Particle Tracking Models (PTM) because it is impossible to accurately quantify and monitor the amount or number of individuals that are incidentally taken, due to the variability associated with the declining population size of Delta Smelt, and the difficulty in detecting individuals (USFWS 2019 Biological Opinion, p 394). PTMs are used to plot the flow of neutrally buoyant particles from an insertion point in the Delta and estimate the percentage that will be entrained by the operational scenario used in the model. The SMT typically requests a scenario with the expected upper and lower limits for the next weeks operations. The insertion points used for the buoyant particles within are informed by the latest catch information collected by either SLS or 20 mm surveys. Thus, the absence of larval Delta Smelt catch in the South Delta in this season contributed to no PTM runs being conducted specifically for Delta Smelt.

The Smelt Monitoring Team requested PTM runs for the purpose of evaluating the risk of Longfin Smelt larval entrainment on three occasions in WY 2021. All runs were conducted after the onset of spawning, so detections of larvae in Central and South Delta monitoring were used to identify insertion points. The results from these PTM runs were then used in SMT discussions regarding OMR advice for the protection of larval and juvenile Longfin Smelt under ITP COA 8.4.2.

Effects of Operation

Longfin Smelt Salvage Trends

Salvage of larval and juvenile Longfin Smelt occurred in both WY 2020 and WY 2021 (Figure 36). Notably, ITP COA 8.4.2 was not fully in effect for the whole of the WY 2020 OMR management season as the ITP was not signed until March 31, 2020. While Longfin Smelt salvage was significantly less in WY 2021 compared to WY 2020, there is insufficient data at this time to properly analyze whether this is due, in whole or in part, to the protections put in place by the ITP. Nevertheless, it is promising that, despite record dry conditions, Longfin Smelt salvage in WY 2021 was relatively moderate compared to WY 2020.

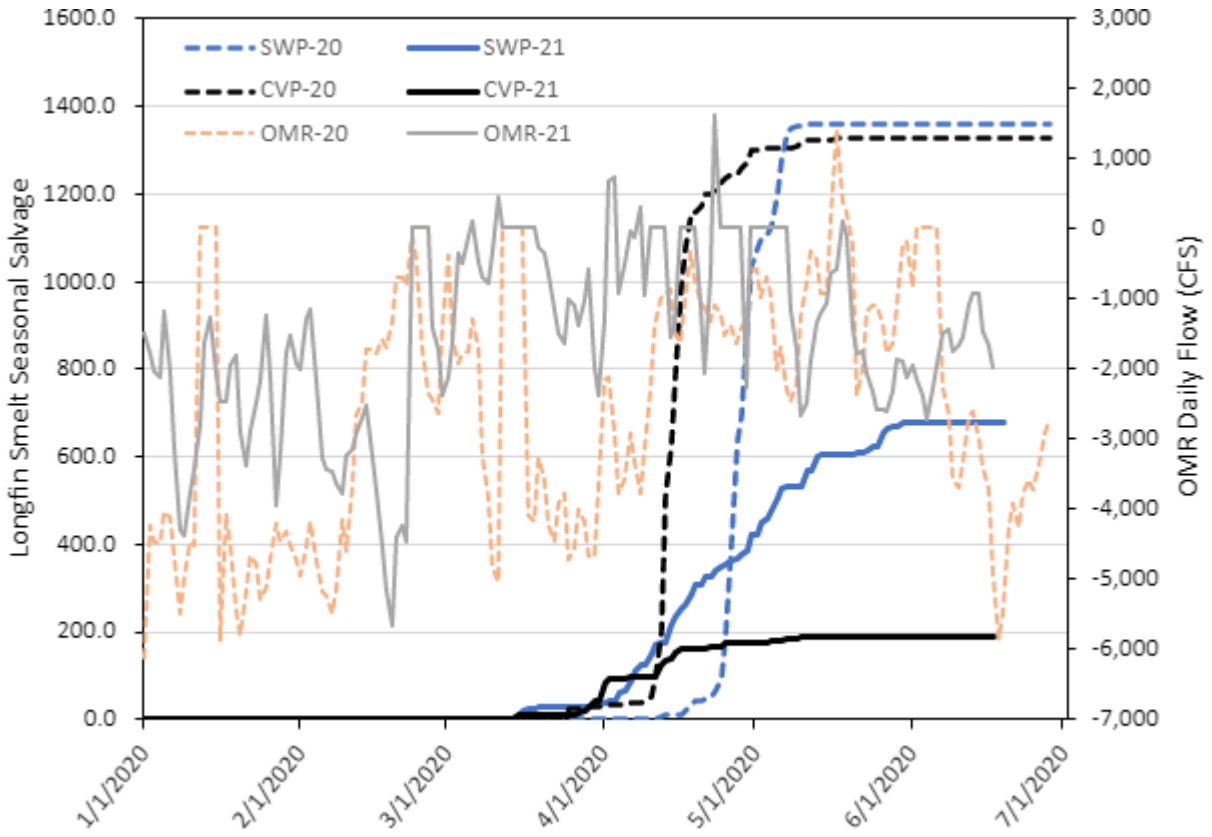

Figure 36. Comparison of Longfin Smelt salvage trends for WY 2020 and WY 2021. Blue and black lines are Longfin Smelt cumulative salvage, and gray and orange lines representing OMR flow levels. Dashed lines are for WY 2020 and solid lines are WY 2021.

Velocity Density Modeling/ Exposure

Weekly DSM2 hydrodynamic modeling was conducted to assess the effects of different OMR scenarios within certain selected channels throughout the Delta region (see text above, see Appendix E). Behavior of fish in different Delta locations (e.g., Western Delta, Central Delta, and South Delta) was considered weekly in light of the hydrologic alteration modeled in the DSM2 modeling. Overall, velocity changes were very small. Rearing salmonids are unlikely to be transported since they spend their time holding and seeking food, but migrating salmonids move with the water. If migrating salmonids move the same amount as passive particles, they would move this distance per day in the South and Central Delta migration corridors. Enhanced particle tracking models are likely to better reflect the biological consequences of hydrologic alteration due to exports, yet these estimates provide one measurement for the modification of travel rates along these corridors toward the South Delta export facilities. Increased travel times exposes juvenile salmonids to increased predation throughout their Delta residency and potentially suboptimal water quality conditions during the spring. None of the model runs during OMR flow management season caused the SaMT concern or identified issues that needed to be elevated to WOMT.

Pre-screen loss (predation rate within the primary channel)

Staff at the Tracy Fish Collection Facility (TFCF) completed a "proof of concept" study using Predation Detection Acoustic Tags (PDAT). Chinook Salmon with PDAT were released at the trash boom upstream of the TFCF and then tracked to estimate participation, facility efficiencies (whole facility efficiency, primary louver efficiency, and secondary screen efficiency), total predation, predation in the primary channel, pre-facility loss to predation, and passage time of salvaged fish under a range of pumping conditions at the CVP export facility (Jones Pumping Plant, JPP). The study showed that juvenile Chinook Salmon salvage efficiency and participation significantly increased with increased pumping at the JPP. Primary channel louver efficiency averaged 72.2–100 percent and was not significantly influenced by the number of pumps in operation at the JPP. Secondary channel screen efficiency was 100 percent throughout the experiment. Passage time of salvaged Chinook Salmon and pre-facility predation estimates significantly decreased with increased pumping at the JPP, while total predation loss estimates potentially decreased significantly with increased pumping. Predation in the primary channel and predation in the secondary channel were not significantly influenced by the number of JPP pumps in operation. Predation in the secondary channel was minimal during all JPP pump operations. Results were published in May 2021 as a Tracy Series Report (Tracy Series Volume 56; https://www.usbr.gov/mp/TFFIP/docs/tracy-reports/tracy-series-vol-56-full-report-wu-etal-may-2021.pdf). Additional efficiency testing is being planned using PDAT, as well as developing a more extensive hydrophone array and/or mobile tracking technology. To obtain greater sample sizes and higher test power, it may be prudent to release externally marked fish along with PDAT-tagged fish during future research efforts to investigate salvage efficiency at the TFCF. A larger-scale experiment is currently being discussed by the TFCF biology staff and will likely be proposed for FY2023 through the Tracy Fish Facility Improvement Program. This action is subject to its own non-flow action charter and guidelines, but it was included in this report as it may impact salvage in future management years.

Tracy/Skinner Fish Salvage

The TFCF used dry ice placed into the waters of the primary channel to increase the level of dissolved carbon dioxide (CO_2) for removing predators in the bypasses and downstream secondary channel on a monthly basis throughout WY 2021. For the larger primary channel, CO_2 is used once a year to remove predators due to the necessary coordination with the CVP export facility operations for curtailing pumping to one pump. In 2020, the Technical Service Center/Denver was funded to develop a hydrodynamic model of the primary channel and included investigating CO_2 bubblers for anesthetizing fish. Although large random eddies with reverse flows complicated the flow in the primary channel, the model showed effective removal of predators at the primary channel given an even distribution of CO_2. Vertical distribution of CO_2 dissolution, i.e. dissolving from gas bubbles to dispersed molecules, into the water column is roughly being approximated. Analysis after the completion of the model will determine confidence for the proposed CO_2 injector for adequate predator removal. A final report for the primary channel hydrodynamic model is planned to be released towards the end of 2021. This action is subject to its own non-flow action charter and guidelines, but it was included in this report as it may impact salvage in future management years. Full study results will be described in the final report.

Improvements

Improvements listed in this section may be evaluated as potential future updates to OMR flow management, including the OMR Guidance Document and DCC Guidance Document, which could assist operations in upcoming OMR flow management seasons. Updated versions of the OMR Guidance Document (Appendix A, dated December 1, 2020) and the DCC Guidance Document (Appendix B, dated April 1, 2020) are attached. Improvements may also be considered or evaluated by the four-year independent review panels.

Delta Smelt Larval and Juvenile Entrainment Improvements

Revisions made to the WY 2021 Guidance Document changed the assessment questions language to address more general patterns in turbidity which are available online in near real-time on Bay Delta Live, summarized as daily averages values by both SacPAS, and provided by DWR for most SMT meetings in the Delta Turbidity Report. In combination, the SMT is capable of examining Delta turbidity in real-time and at a wide range of scales to address the likelihood of Delta Smelt entrainment.

Additionally, efforts to standardize and streamline the running of weekly PTM scenarios, for both Delta Smelt and Longfin Smelt, would facilitate more meaningful integration of PTM outputs into SMT discussions and would reduce the lag time currently experienced when PTM runs are requested. This effort would require the SMT to standardize on fixed insertion points and OMR levels, which would then be coupled with real-time hydrology and forecasting weekly during larval entrainment season. Having consistent OMR levels and insertion points would assist the SMT in evaluating changes to entrainment risk over the course of the season and would aid in maintaining consistency in OMR recommendations.

DCC Improvements

Decisions about DCC gate operations frequently occur rapidly. Reclamation is currently in the process of modernizing and improving the DCC gates. Reclamation will increase coordination between area offices to ensure gates are operated in a timely manner and will require a test run of the closure protocol prior to the beginning of each OMR flow management season. A daily notification in the fall with catch index information, provided by the USFWS and CDFW monitoring survey is emailed to Reclamation's Central Valley Operations office (CVO) and Reclamation's Bay Delta office (BDO). This notification will allow CVO real-time information on catch index exceedance to schedule a DCC gates closure. This information is also available to agency biologists and the public on SacPAS.

Proposed Drought Actions

To address reducing uncertainty regarding Salmon distributions presumably due to poor survival and/or low detection efficiency in current monitoring during drought conditions, DWR has proposed to add Drought Toolkit items which will augment ongoing monitoring with Environmental DNA (eDNA) monitoring at the point of Delta entry. This information is intended to improve understanding of whether Salmon are present but undetected in current monitoring, or simply not present. Currently eDNA monitoring cannot distinguish between Salmon races, and monitoring will have to be interpreted cautiously until models are developed to characterize the relationship between eDNA detection distribution and probable Salmon distributions.

Ecological particle tracking: ePTM and ECO-PTM

Several models are in development for modeling juvenile salmonid survival and migration patterns, ECO-PTM (California DWR) and ePTM (NMFS SWFSC). Unlike DSM2 which tracks neutrally buoyant particles, particle models which incorporates fish behavior can be a more effective tool for quantitatively assessing fish parameters. These models have been calibrated and validated with acoustic tagged fish data. When available, pilot implementation of these models with weekly DSM2 runs may provide additional information of important biological response prediction such as fish reaching Chipps Island, the Central Delta, South Delta, and/or fish collection facilities to the SaMT to provide more realistic information regarding effects on migratory juvenile salmonids.

Winter-run Chinook Salmon salvage machine-learning tool

A new winter-run Chinook salvage tool is currently in development which differs from the tool available on SacPAS. This tool takes a machine learning approach (specifically extreme gradient boosting dropout multiple additive regression trees) to predicting winter-run Chinook salvage as a function of numerous potential environmental drivers. This approach is different in that it is specifically interested in early-warning indicators to provide information prior to winter-run Chinook Salmon detection in salvage whereas previous models have been shown to estimate salvage after winter-run Chinook Salmon are detected. Predictor variables may include, but are not limited to exports, Chipps Island catch, water temperature at multiple locations, zooplankton, and brood day-of-year (DOY). This model may be implemented weekly and provide the SaMT with additional information regarding entrainment and loss predictions for juvenile salmonids in the Central Delta, South Delta, and/or fish collection facilities.

Monitoring Team Assessment Improvements

The Proposed Action Assessment was developed in the WY 2021 OMR flow management season as a means of reporting the conclusions and providing supporting information about the range of weekly OMR operations to WOMT. The contents of the document are reviewed annually at the close of the season and recommendations from the WY 2021 season as changes to the Proposed Action Assessment document are included below.

- Include a section at the end of the Proposed Action Assessment on issues that were recommended for discussion at WOMT / Director Elevation. This section would be similar to the "Recommendations to WOMT" section in the weekly SaMT notes. (Note: This improvement was incorporated into the WY 2021 OMR Guidance Document).
- Evaluate whether the format of the Weekly Assessment could be modified in the future to better inform the writing of future Seasonal OMR flow management reports. Once a format is finalized, the OMR Guidance Document should be updated, as appropriate.

Conclusion and Management Summary

Exports at the CVP and SWP export facilities and operations of the Delta Cross Channel Gates, with the few exceptions noted, were consistent with the ROD and within the effects anticipated by the 2019 USFWS and NMFS Biological Opinions. The CVP and SWP did not exceed the amount of annual take specified in the incidental take statement of listed fish species described in the 2019 USFWS and NMFS Biological Opinions. As detailed above, salmonid entrainment levels did not trigger OMR reverse flow reductions and losses did not exceed thresholds. As detailed above, due to dry conditions, difficult hydrology controlled CVP and SWP operations and exports, as well as DCC operations throughout WY 2021. OMR flow management was not primarily controlling. OMR flows did not exceed those prescribed by the incidental take statement in the 2019 USFWS Biological Opinion. No need was identified by the agencies for an independent panel review for WY 2021.

The SMT submitted the items below for consideration and development as part of the Guidance Document review prior to the WY2022 OMR Management Season:

- Regarding the ITP Risk Assessment:
    - CDFW will lead the SMT in developing bullet points of the key ideas to be incorporated into the ITP Risk Assessment.
    - CDFW will seek consensus on the executive summary as well as any advice to WOMT via live editing these sections of the ITP Risk Assessment.
- SMT members will identify supporting data, references, and other pertinent information to support their assessments of low, medium, or high risk.
- Regarding information received outside of SMT meetings:
    - SMT members will share data corrections or new data via email with a subject line highlighting the new information.
    - SMT members will memorialize new or corrected data in the meeting notes as a post-meeting update.
- SMT members noted that the current critically dry conditions could lead to low Fall Midwater Trawl Survey (FMWT) catches this autumn. SMT members requested clarification on the following:
    - If the FMWT Index for Longfin Smelt is zero, does the SMT need an alternative method to establish a cumulative take threshold for ITP COA 8.3.3 (Adult Longfin Smelt Entrainment Protection)?

The SaMT submitted the items below for consideration and development as part of the guidance document review prior to the WY2022 OMR Management Season:

- Geographic boundaries for fish distribution table
- Hatchery winter run Chinook Salmon estimate for fish distribution table
- Notification process for exceeding relevant action thresholds
- Develop decision tree for hitting a salvage-based threshold (e.g., ITP daily loss threshold for natural winter-run Chinook Salmon)
    - Develop a communication plan for salvage-based trigger
    - Timeline for implementation of response if threshold is exceeded (e.g., if a trigger is exceeded over the weekend.
    - Probably best as a separate product from the OMR Guidance Document as it will likely need to be updated more frequently.
- Changes to JPE- consider reconvening the IEP winter-run Chinook JPE project work team to iteratively evaluate the season's estimate using empirical data (e.g., observations in monitoring locations, acoustic tagged fish)

Recommendations adopted in WY 2021 from WY 2020

- Guidance Document revisions for Larval Delta Smelt Protection questions to address turbidity and likelihood of entrainment in more real-time context.
- DCC gate closure protocol was developed and adopted.
- The Proposed Action Assessment includes a section specific to non-consensus concerns to be elevated to WOMT each week.

Supporting Information

- Salmon Monitoring Team Notes and Proposed Action Assessments: https://www.usbr.gov/mp/bdo/salmon-monitoring-team.html
- Salmon Monitoring Team webpage: http://www.cbr.washington.edu/sacramento/workgroups/salmon_monitoring.html
- Smelt Monitoring Team Notes: https://www.usbr.gov/mp/bdo/smelt-monitoring-team.html
- Smelt Monitoring Team webpage: http://www.cbr.washington.edu/sacramento/workgroups/delta_smelt.html
- Smelt and Salmon Monitoring Teams ITP Risk Assessments: https://wildlife.ca.gov/Conservation/Watersheds/Water-Operations
- Water Operations Management Team Notes: https://www.usbr.gov/mp/bdo/water-operations-management.html
- Bay Delta Live Webpage: https://www.baydeltalive.com/current_conditions/turbidityReferences

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