MEMORANDUM

TO: Collaborative Adaptive Management Team (CAMT)
FROM: CAMT Salmon Technical Working Group (TWG)
DATE: April 26, 2024
RE: Final TWG Report

In 2022, the Collaborative Adaptive Management Team (CAMT) sought to update the 2017 Salmon Scoping Team Report by formulating five charge questions related to salmon survival, routing, and behavior through the South Delta. A Salmon Technical Working Group (STWG) was formed and charged with answering these questions through a review of recent research. The STWG invited researchers to share their findings with the group, then synthesized the information conveyed within the context of answering the five questions. The STWG's review considered analyses of survival and behavior of acoustically tagged, hatchery-origin juvenile salmon and steelhead released into the San Joaquin River upstream of the Delta for the years currently available (2008-2017). The findings shared in this document represent 11 years of studies and >20,000 tagged and tracked fish.

The report is divided into the following sections:

- Introduction
- Methods
- Framing
- Results
- Conclusion

The Results section provides responses to each of the charge questions, first by presenting findings and then by sharing the STWG's interpretation. The STWG did not seek to achieve consensus but rather to highlight differences in perspectives. While there was little disagreement related to the findings themselves, there was a wide array of perspectives regarding the significance of the findings based on the context described in the Framing section. The following is a summary of key points the STWG would like to communicate to the reader:

- While higher survival of juvenile salmonids is observed with higher San Joaquin River flows and cooler temperatures, overall survival has consistently been very low (likely too low to support San Joaquin River populations) regardless of water export rate, environmental conditions during release, or route taken.

- Earlier migrating spring-run Chinook salmon appear to have higher survival compared to fall-run and may be a promising life history strategy for supporting recovery. There is a need for more spring run data and for incorporation of existing spring run data into models.

- Export regulations were implemented to reduce harm caused by exports (i.e., improve survival) such that the viability of affected, ESA-listed stocks would not be appreciably reduced by water project operations. After many years of intensive scientific investigation, we have not observed significant survival improvements for San Joaquin River-origin salmonids, nor have we seen an adverse impact from water export rates on survival under the range of regulatory and environmental conditions studied (e.g., OMR no more negative than -5,000 cfs. See Framing section for more detail). This raises questions about whether export regulations are yielding benefits which were presumably expected and what additional actions are needed to improve survival.

- Though considerable uncertainties remain, the lack of a detectable trend between exports and survival of San Joaquin River-origin salmonids challenges the current conceptual model that assumes a strong negative relationship between the two. To move beyond the current impasse in our learning, we will need to refine our conceptual model around the effects of export and include other factors impacting survival.

- Additional next steps might include:
    - Reorganizing the Delta into component sub-regions and exploring patterns of survival and distinct management issues in each sub-region
    - Developing hypothesis-based experiments at smaller spatial scales that address specific management questions associated with each sub-region (linked to a larger adaptively managed framework for improving survival)
    - Once testable hypotheses have been clearly identified, consider applying multivariate statistics and/or incorporating covariates directly into multistate mark-recapture models as tools for better evaluating experimental results.

A Review of Recent Science to Improve Our Understanding and the Application of Life Cycle and Decision Support Models to Salmon Management in the South Delta

Report by Salmon Technical Working Group to the Collaborative Adaptive Management Team

INTRODUCTION

In 2022, the Collaborative Adaptive Management Team (CAMT) formulated the following charge questions related to salmon survival, routing, and behavior through the South Delta:

1. What does analysis post the 2017 Salmon Scoping Team (SST) report have to tell us about how exports influence salmon and steelhead survival through the South Delta (i.e., now that telemetry data for more years has been analyzed and processed)?
2. Are any of the conclusions of the SST related to survival changed or strengthened because we have additional data? If not, what study results would allow new/different/firmer conclusions to be reached?
3. What is the impact of exports relative to other factors influencing juvenile salmonid survival in the Delta? (e.g., what does acoustic telemetry data tell us about how foraging/sheltering/migrating behavior may be impacted by export altered hydrodynamics?)
4. How do juveniles respond (survival, behavior, growth) to the different operations based on flow dynamics in different water year types?
5. For each question, does the Science Integration Team (SIT) model take into account this new information and are tools reflective of what we are seeing in the science (e.g., will changes in operations based on water year type be reflected in juvenile response)?

In order to address these five charge questions, the Salmon Technical Working Group (STWG) focused on results published since the SST report was issued in 2017 related to: (1) reach-specific survival based on complete sets of acoustic telemetry data for steelhead and fall-run Chinook salmon; (2) the behavior of steelhead and fall-run Chinook salmon at distributary junctions; and (3) new information on spring-run Chinook salmon survival through the Delta and behavior at the Head of Old River junction. This report summarizes the STWGs approach and findings regarding their charge.

Please note: given its narrower scope, the STWG report should be viewed as an updated version of the 2017 SST report only for questions with overlapping subject matter. [As a reminder: Volume 1 of the SST report reviewed information related to the application of hydrodynamic simulation models used to assess local and regional changes in flow direction and water velocities in Delta channels, and juvenile salmonid migration behavior and survival based on partial sets of acoustic data available for fish originating from both the Sacramento and San Joaquin rivers; and Volume 2 addressed eight specific questions identified by CAMT, including: 1) export effects on flows and velocities in the Delta; 2) effects of exports and inflows on San Joaquin River juvenile salmonid survival; 3) January 1 onset of OMR reverse flow management; 4) salvage-density-based export restrictions; 5) alternative flow metrics; 6) biological response metrics; 7) use of available hydrodynamic models; and 8) tests using hatchery-reared fall-run Chinook salmon]. Further context and limitations of the STWG's review is discussed in the framing section, below.

ACKNOWLEDGMENTS

The STWG would like to acknowledge the following contributors to this effort:

- External researchers who prepared presentations, discussed their findings and reviewed drafts of this report
- John Ferguson and Brad Cavallo who took pen to paper and are the primary authors of this report
- Rafael Silberblatt who facilitated the STWG through this effort

METHODS

CAMT member agencies were asked to select representatives to serve on the STWG tasked with addressing these charge questions. STWG members who contributed to this effort include:

- Alison Collins (The Metropolitan Water District of Southern California)
- Amanda Cranford (NOAA Fisheries)
- Brad Cavallo (Cramer Fish Sciences)
- Bryan Matthias (U.S. Fish and Wildlife Service)
- Dan Kratville (CDFW)
- Erica Meyers (CDFW)
- Elissa Buttermore (USBR)
- Heidi Williams (Santa Clara Valley Water District)
- John Ferguson (Anchor QEA)
- John Kelly (CDFW)
- Kate Spear (NOAA Fisheries)
- Pascale Goertler (DWR, DSP)
- Rene Henery (Trout Unlimited)
- Tracy Grimes (CDFW)

STWG members conducted a review of literature published since the SST report was issued related to salmon and steelhead in the San Joaquin River (SJR) and invited the following guest presenters to share their findings based on the fully processed acoustic telemetry data sets for both Chinook salmon and steelhead and the effects of exports and water management metrics (Inflow: Export (I:E) ratio and Old and Middle River flow restrictions (OMR)) on salmon and steelhead routing and survival:

- Rebecca Buchanan (University of Washington): Updated understanding of effects of operations on survival of salmon and steelhead in the South Delta.
- Towns Burgess (USBR): San Joaquin River Restoration Program
- Colby Hause and Gabe Singer (Rypel Laboratory at U. C. Davis (UCD)): Outmigration survival of juvenile spring-run Chinook Salmon in the San Joaquin River and South Delta, 2017-2019.
- Sydney Gonsalves (Anchor QEA): Evaluation of Juvenile Steelhead Behavioral Responses to Hydrodynamic Conditions in the Sacramento-San Joaquin Delta.
- Rusty Holleman (UCD): Swimming behavior of emigrating Chinook salmon smolts.
- Simone Olivetti (U.C. Santa Cruz): Merging computational fluid dynamics and machine learning to reveal animal migration strategies.
- Mike Dodrill (U.S. Geological Survey (USGS)): Quantifying the effects of tides, river flow, and barriers on movements of Chinook Salmon smolts at junctions in the Sacramento – San Joaquin River Delta using multistate models.

- Brandon Wu (USBR): Use of Predation Detection Acoustic Tags to Estimate Juvenile Chinook Salmon Salvage Efficiency and Loss at the Tracy Fish Collection Facility (TFCF).
- Javier Miranda (California Department of Water Resources (DWR)): State Water Project (SWP) Salmonid Loss and Predator Studies.

The STWG discussed each presentation and the accompanying publications or research reports, summarized its findings, and noted areas of agreement or disagreement related to the interpretation of results. The STWG did not seek to reach consensus regarding its findings.

FRAMING

The STWG endorses the findings shared in this report while also acknowledging the context and limitations outlined below related to water project effects, spatial and temporal scope, acoustic data availability, regulatory setting and controls, data limitations and other factors not considered within this report. This framing is critical to understanding the STWG members' divergent perspectives regarding the significance, uncertainty and overall interpretation of the findings - as evidenced by the nature of the STWG's disagreements throughout this undertaking which were more concerned with the implications of the findings as opposed to their veracity.

Water Project Effects on Juvenile Salmonids of the San Joaquin River Basin

Water Project Effects: Background

This report attempts to describe the effects of water exports and SJR inflow on SJR-origin juvenile salmonids under 2009-2019 water project operations, including management of Old and Middle River Flows (OMR) and the Import/Export ratio (I:E) as required by the 2009 Biological Opinions (NMFS 2009). Based on their review of I:E regulations, Buchanan and Whitlock (2022) describe the conceptual model underlying our current regulatory framework as one that predicts higher through-Delta survival being associated with (1) higher SJR discharge, (2) lower total exports, and (3) fish using the mainstem river route and avoiding the interior Delta. These predicted outcomes were based on conceptions for how hydrodynamic conditions would affect juvenile salmonids and how management actions involving SJR inflow and exports would influence hydrodynamic conditions in different regions of the Delta. Briefly, the expectation was that greater net flows—provided by increased SJR discharge and/or decreased exports-- would reduce mortality experienced by juvenile salmonids.

Efforts to quantify export and inflow effects on SJR-origin juvenile salmonid survival in the Delta began in the 1970's with the use of coded-wire-tags (CWT). Results of these studies with regard to export effects were ambiguous, and this ambiguity was attributed to the Delta's environmental heterogeneity. Acoustic tags were recognized to provide superior resolution and were expected to be able to discern environmental noise from the "signal" of water project operation effects on juvenile salmonids. A six-year acoustic tagging study was conceived, planned and conducted with the specific expectation that it would demonstrate: 1) how exports influence juvenile steelhead to exit the San Joaquin River mainstem and to enter channels of the south Delta, and 2) how more favorable hydraulic conditions provided by reduced exports and/or higher San Joaquin River flows would improve survival of juvenile salmonids from Delta entry at Mossdale to exit at Chipps Island (NMFS 2009; Appendix 5). The six-year acoustic tagging study was identified as a "vehicle to monitor the efficacy of the [I:E] RPA in achieving its objectives" that would be used to adaptively manage the lower SJR and Delta to benefit steelhead and other listed fish (NMFS 2009; Appendix 5, p. 77).

Water Project Effects: Complications

Multiple controlling factors: Studying the efficacy of I:E regulations is complicated by the regulatory setting under which the survival studies take place (see "Regulatory Setting," below), which includes operational controls for the CVP and SWP export facilities to protect water supply, fisheries, and the environment. With so many factors working together to control SJR flows, exports, and/or OMR during the study periods, it is difficult to determine the effects of an individual factor. Furthermore, the absence of an observable survival trend can be interpreted in very different ways, for example it could mean that there is no trend in survival, or it could mean that the measures we have in place to protect migrating salmonids have worked, or at least minimized the impacts of exports enough that a trend is not observable.

Detecting statistically significant change: One of the Question 1 findings states that there was no evidence of a negative export effect on the survival of acoustically tagged fall-run Chinook salmon through-Delta (from the Head of Old River to Chipps Island). This was based on results of post-hoc analyses of acoustic telemetry data, where authors of the publication that was cited applied a single-variable regression to model through-Delta survival while accounting for other factors. In our responses to Question 1 we report where there was no evidence of a negative export effect but not the level of effect required for a difference to be significant. The STWG reviewed publications that provided results of studies but not study plan development that included estimating differences in survival that could be detected given a certain sample size (i.e., the power of the tests conducted). The STWG recognizes that salmon recovery actions may be ecologically important even if statistically significant thresholds are not achieved (Bisson et al. 2023). This is important to keep in mind when interpreting study results where survival is low, and differences may be small and ecologically meaningful but not statistically detectable. Detecting measurable changes in fish parameters is oftentimes challenging. For example, Buchanan (2010) conducted modeling of juvenile salmon survival in the San Joaquin River for the 2011 VAMP study (SJRGA 2013). Based on these results, USBR (2018) estimated that if survival between Durham Ferry and Chipps Island was 0.15 and survival between Durham Ferry and HOR was 0.9, a sample size of 475 tagged fish released at Durham Ferry would be needed to detect a 50% difference in survival between San Joaquin River and Old River routes. In 2012, a total of 1,435 tagged juvenile steelhead were released into the San Joaquin River at Durham Ferry (USBR 2018) indicating the number of fish used that year was sufficient to detect expected differences in survival.

Direct, indirect, and systemic effects: The impact of water project operations on survival of juvenile salmonids in the Delta has traditionally distinguished between direct and indirect effects (SST 2017). Direct effects occur in close proximity to the export diversion facilities. For example, juvenile salmonids which suffer mortality after entering Clifton Court Forebay or after passing through the CVP trash racks are considered to be direct losses, regardless of how mortality occurs (e.g. predation, impingement, louver pass-through). In contrast, indirect effects refer to the potential of exports (alone or in combination with regulated SJR flows) to contribute to juvenile salmonid mortality even when fish are not near the diversion facility intakes. Changes in hydrodynamic conditions that delay migration and/or elevate predation risk have been suggested as the primary sources of indirect mortality. Regulations that restrict exports in April and May—for example—are expected to yield contemporaneous benefits to juvenile salmonids by increasing net flows through the lower SJR, thereby reducing indirect effects. While the scientific investigations reviewed by the STWG were primarily focused on evaluating the effectiveness of management actions intended to reduce indirect effects to SJR-origin salmon and steelhead, the STWG also identified and discussed a third category of systemic effects (i.e., stressors present in the Delta that have, over many years, contributed to habitat degradation and ecosystem changes that likely affect salmonid survival). Some of these stressors have been present since before the water projects, but others like contaminants, invasive species, and non- CVP/SWP hydrodynamic alteration have been amplified in recent decades. While the STWG acknowledges these systemic impacts are real and significant, management strategies to address systemic effects would be broader in scope and larger in magnitude than the seasonal operational regulations the STWG was asked to review.

Spatial and Temporal Scope of Report

This review considered acoustically tagged, hatchery-origin juvenile salmon and steelhead released into the San Joaquin River upstream of the Delta. Acoustically tagged juvenile salmonids originating from the Sacramento River basin were not considered because the STWG was charged with evaluating patterns of survival and behavior of San Joaquin River-origin salmonids as they are more likely to be exposed to the effects of the water export operations than Sacramento River originating salmonids. All acoustic tagging studies have included a dual-receiver array just downstream of the Head of Old River (HOR) junction in the San Joaquin River mainstem and in the Old River route. Though juvenile salmonids were released upstream of this point, the STWG only considered patterns of survival from the HOR junction to points downstream. Through-Delta survival was considered to be from HOR junction to Chipps Island (Delta exit). Between the HOR junction and Chipps Island, we grouped available analyses into four regions (see Figure 1 through Figure 4). These regions were selected for several reasons. First, the regions are most relevant to STWG charge questions as each is exposed to differing water project operation effects. Second, at least six years of acoustic tagging data were available for each region. Lastly, the regions were generally compatible with the geographic scale of analyses provided by acoustic tagging studies reviewed by the STWG. Some studies focused on specific channel junctions, or areas of the Delta - in those instances, the specific area targeted by the study is identified in the body of this report.

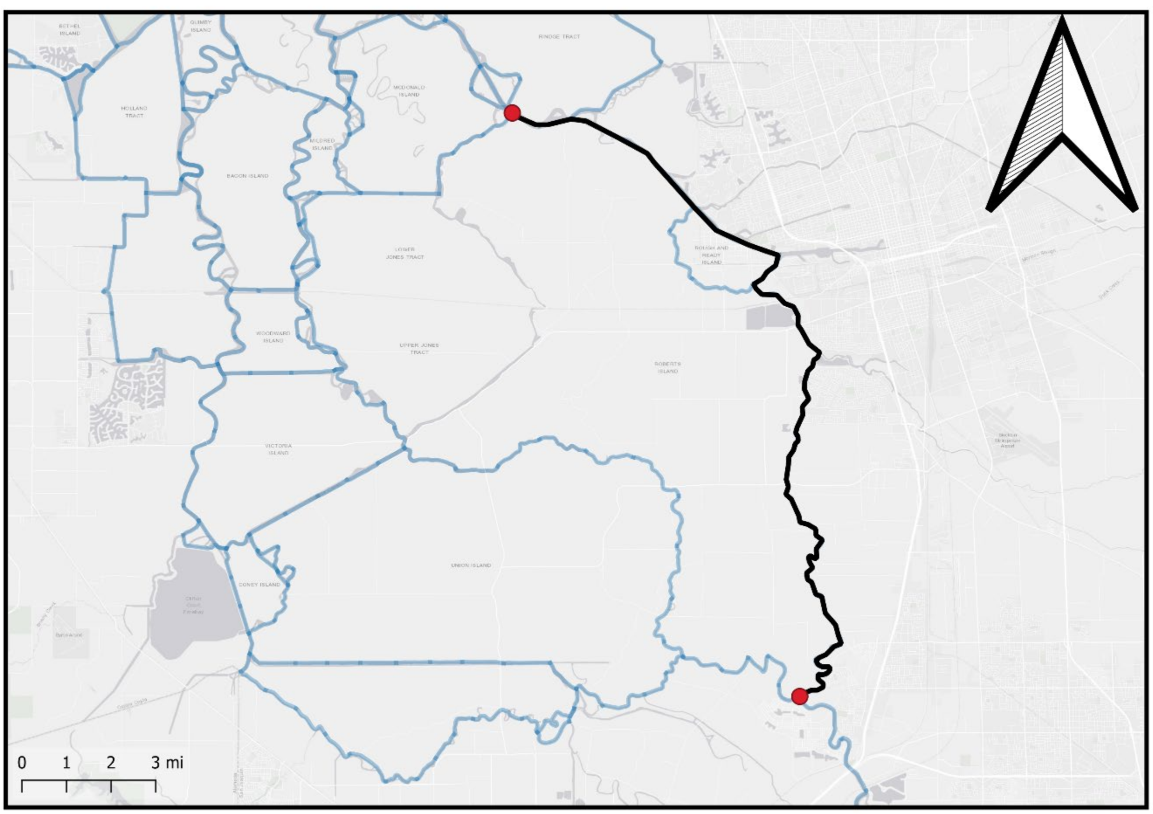

Figure 1. Region 1: the mainstem San Joaquin River from the Head of Old River to Turner Cut.

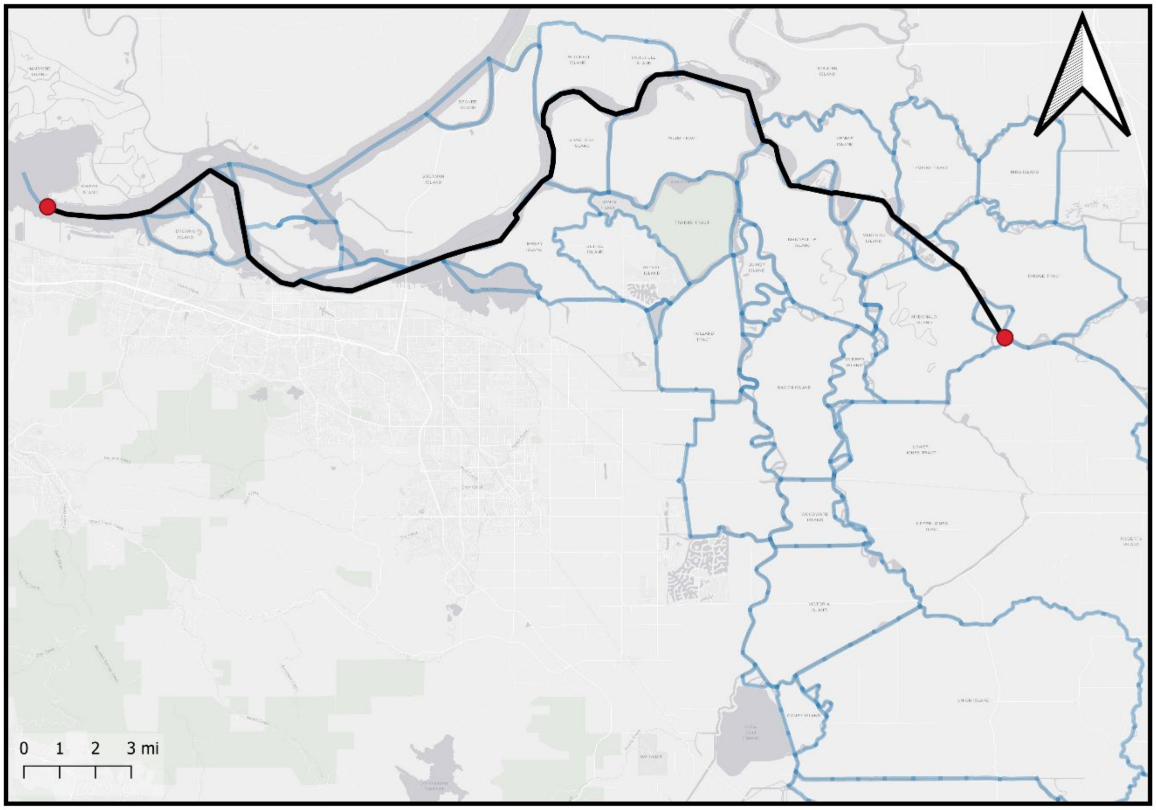

Figure 2. Region 2: the mainstem San Joaquin River from Turner Cut to Chipps Island.

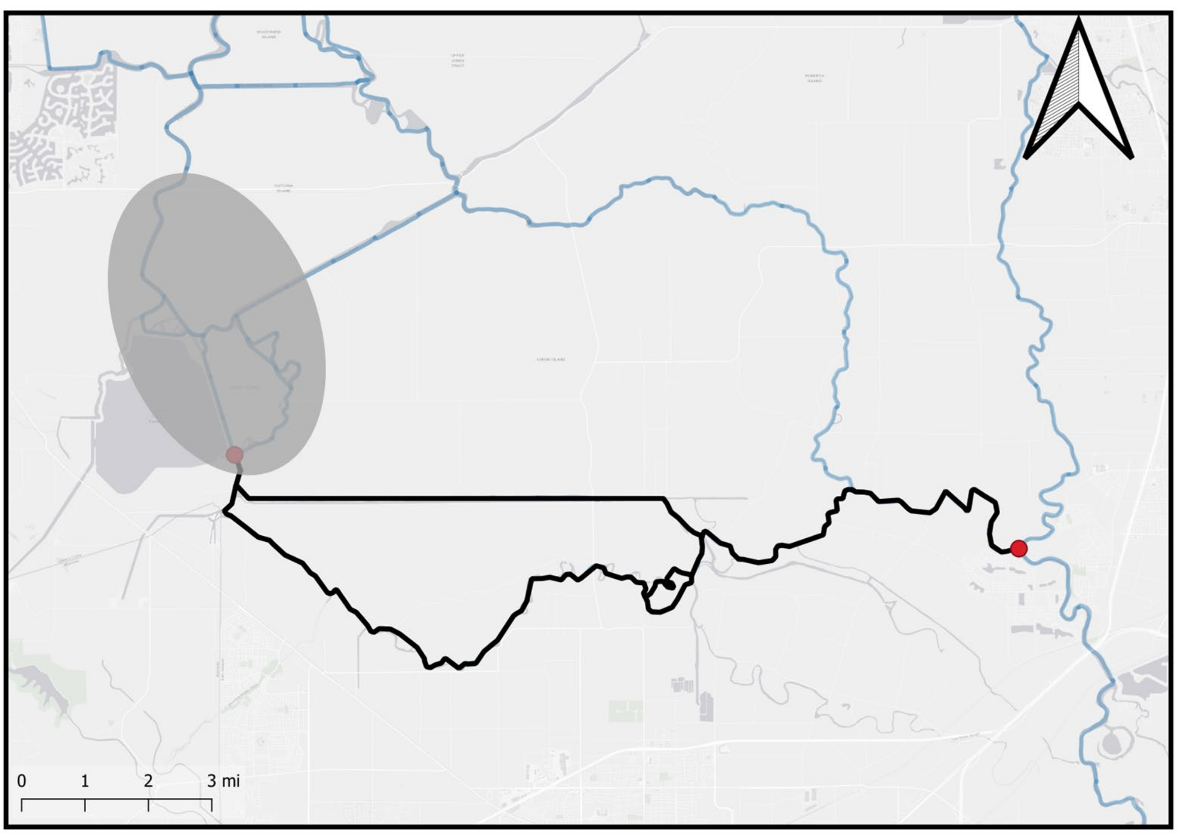

Figure 3. Region 3: the Old River route from Head of Old River to CVP/SWP intake facilities (black line) and/or channels north of the facilities to the Hwy 4 crossing (grey shading).

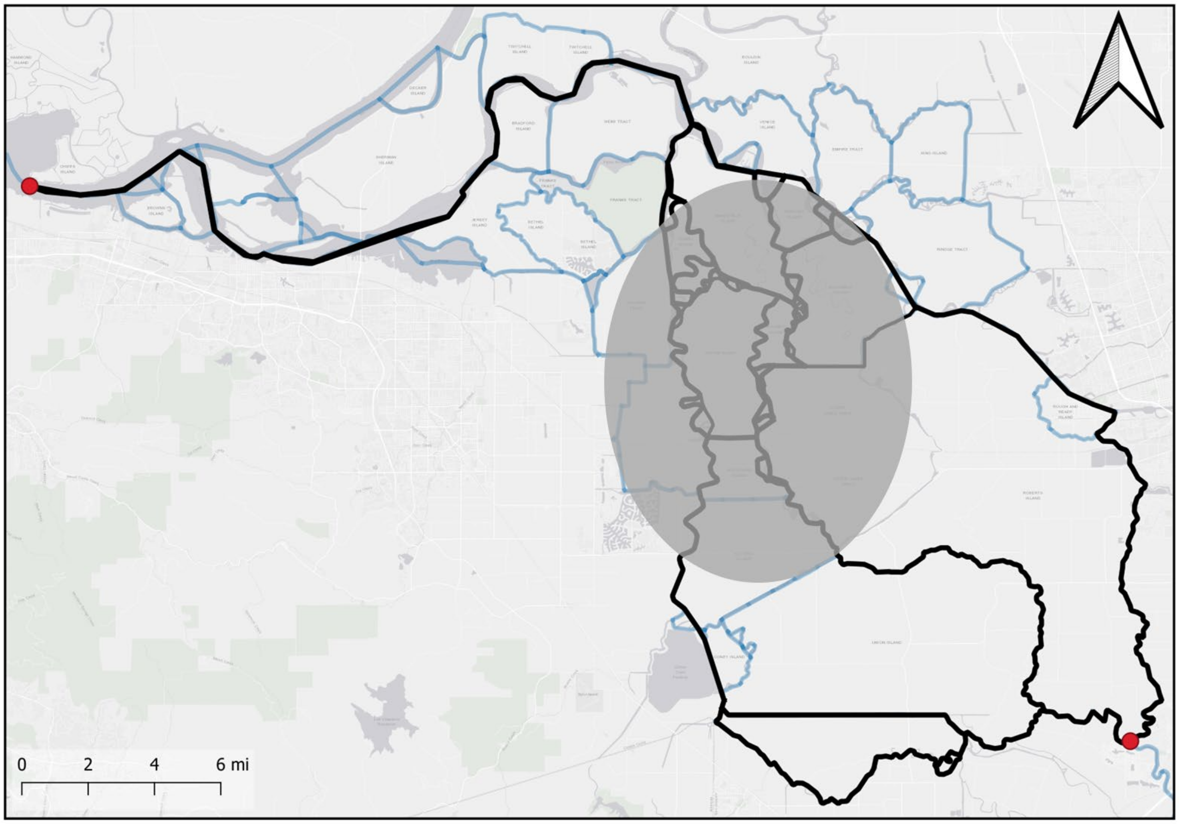

Figure 4. Region 4: the Old Middle River corridor (grey shaded area only). Juvenile salmonids may enter this area after passing north of the CVP/SWP intake facilities, from Turner Cut, or from one of the other junctions which occurs downstream of Turner Cut.

Acoustic Data Analyses Reviewed by the STWG

Analyses of acoustically tagged, actively migrating juvenile salmonids released into the San Joaquin River were available for 2009-2019 (Table 1), though available years differed between Chinook salmon runs and steelhead. Relative to the 2017 SST review, the STWG review included four additional years of steelhead smolt analyses, five additional years of fall-run Chinook analyses, and for the first time, three years of spring-run Chinook analyses.

Table 1. Summary of Telemetry data and Water Year (WY) reviewed in SST (2017) indicated by X, additional data reviewed by the STWG indicated by √. No data were available on spring-run Chinook salmon for inclusion in the SST (2017) report.

Year	WY Class – San Joaquin River[1]	Steelhead data reviewed	Fall-run Chinook salmon data reviewed	Spring-run Chinook salmon data reviewed
2009	Below Normal		X	
2010	Above Normal		X	
2011	Wet	X	X	
2012	Dry	X	X	
2013	Critical	√	√	
2014	Critical	√	√	
2015	Critical	√	√[2]	
2016	Dry	√	√	
2017	Wet		√	√
2018	Below Normal			√
2019	Wet			√

1. http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST
2. The 2015 study was omitted from Buchanan and Whitlock (2022) analyses because extreme drought during that year compromised the fish release at Durham Ferry, but these data were included in other analyses reviewed by the STWG.

Regulatory Setting and Layered Controls

Operations of the Delta export facilities are controlled by a complicated mosaic of overlapping requirements to protect water supply, the environment, and threatened and endangered species. During the months and years when the survival studies we describe were completed, various regulations were in place (e.g., Water Rights Decisions and Orders, Biological Opinions, Army Corps Permits) and may have been controlling flows and/or exports through OMR, I:E, or other mechanisms. Determining which regulations may have been controlling exports at the time of each fish release is beyond the scope of this report, and the effects of individual regulatory measures cannot be decoupled.

This section describes some of the regulatory documents that were in place and affecting operations of the Delta export facilities during the study periods, but should not be considered a complete list. State Water Board Decision 1641 (D-1641) includes requirements for net delta outflow, export limits during certain months of the year, and salinity requirements which can control the amount of water that can be pumped at the CVP and SWP export facilities at any time of year. The requirements of D-1641 are required for exercising water rights and are therefore considered as part of "baseline" for other permits and regulations.

The 2009 National Marine Fisheries Service's Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (NMFS 2009) included a Reasonable and Prudent Alternative (RPA) to protect ESA-listed species. The RPA prescribed a list of actions to protect and reduce the vulnerability of listed salmonids, a few of which affected operations at the delta export facilities. For example, Action IV.2.3 restricted reverse flows in OMR in January through June 15 to no more negative than –5,000 cfs to reduce the vulnerability of emigrating juvenile winter-run Chinook salmon, spring-run Chinook salmon, and California Central Valley steelhead within the lower Sacramento and San Joaquin rivers to entrainment into the channels of the south Delta or into the export facilities themselves. Additional triggers were included to further reduce negative OMR flows if listed salmonids were observed in salvage. To further protect steelhead migrating out of the San Joaquin River basin from export-related changes to hydrodynamics, the RPA also included Action IV.2.1. Phase 1 (2010 and 2011) of Action IV.2.1 established minimum San Joaquin River flows at Vernalis and associated export limits. Phase 2 (beginning 2012, except as modified by the joint stipulation in 2012) implemented the SJR I:E ratio based on water year type. Action IV.2.2 required a six-year acoustic tag experiment to "confirm proportional causes of mortality due to flows, exports, and other project and non-project adverse effects on steelhead smolts out-migrating from the San Joaquin basin and through the southern Delta" (NMFS 2009).

While not focused on salmonids, the 2008 U.S. Fish and Wildlife Service's Biological Opinion included measures in its RPA that prescribe management of OMR flows to protect Delta Smelt (*Hypomesus transpacificus*) which were in place and affected operations and exports at times during the study periods. OMR management for Delta Smelt ranged from –5,000 to –1,250 cfs, depending on environmental conditions and observation of adults in surveys or at the CVP and SWP fish salvage facilities.

It should be noted that the regulatory environment surrounding operations of the CVP and SWP export facilities changed in 2019 and 2020 with issuance of new Biological Opinions for winter-run and spring-run Chinook Salmon, Central Valley steelhead, Green Sturgeon (*Acipenser medirostris*) and Southern Resident Killer Whales (*Orcinus orca*)(NMFS 2019); and Delta Smelt (FWS 2019); and an Incidental Take Permit for winter-run and spring-run Chinook Salmon, Delta Smelt, and Longfin Smelt (*Spirinchus thaleichthys*)(CDFW 2020). Therefore, the studies summarized in this report and some of the conclusions may no longer represent "current" export operations and management of OMR and I:E in the Delta.

Attributes and Limitations of Available Data

Relative to the SST report, the STWG reviewed results of analyses that were conducted on a more extensive set of acoustic telemetry data and that included more rigorous statistical analyses of covariate influences on survival. In total, more than 20,000 acoustically tagged juvenile salmonids and 46 releases were included in analyses considered by the STWG (Table 2). Additional years of data for steelhead, spring-run and fall-run Chinook salmon have been collected since 2019, but results are not yet available.

Table 2. Annual total of acoustically tagged fall-run Chinook (FRC), spring-run Chinook (SRC), and steelhead smolts (STH) released into the San Joaquin River between 2009 and 2019 which were used for data analysis considered by the STWG. Though FRC releases in 2015 were omitted from Buchanan and Whitlock (2022), they had been included in some prior analyses (e.g. Buchanan et al. 2018) considered by the STWG and so are included here.

Year	FRC	SRC	STH	**Total**
2009	933			933
2010	504			504
2011	1895		2196	4091
2012	959		1435	2394
2013	950		1425	2375
2014	1275		958	2233
2015	1290		1427	2717
2016	648		1440	2088
2017	647	700		1347
2018		700		700
2019		700		700
Total	9101	2100	8881	20082

When interpreting the findings outlined in this report it is critical to keep in mind the conditions under which these tests were conducted, we therefore provide a description of the conditions evaluated in greater detail:

Water project operations related to the STWG's charge questions include combined CVP and SWP exports (total exports) and San Joaquin River inflows. Regulatory metrics Old and Middle River flow (OMR) and the San Joaquin River inflow to export ratio (I:E) are functions of total exports and SJR inflows which are intended to integrate these factors and index hydrodynamic conditions experienced by fish in the South Delta. A substantial fraction of FRC and STH releases occurred when both SJR inflows and exports were low, but many observations are available that represent variation in exports while SJR inflows remained within a narrower range (Figure 5, Table 3). For FRC, such observations were for exports between 1,500 and 3,250 cfs while SJR inflows were ~2,500 cfs (Figure 5, Table 3). This small export variation is caused in part by regulations controlling OMR and I:E during the study periods. For example, with SJR inflows at 2,500 cfs, a change in exports from 1,500cfs to 3,250 cfs is the difference between an I:E ratio of 1.7 and an I:E ratio of 0.8; a difference that is hypothesized to affect juvenile salmonid survival. For STH, observations are available for a larger range of exports, between 1,000 and 6,000 with SJR inflows at ~1,500 cfs, and with exports between 1,750 and 6,500 cfs with SJR inflows at ~3,000cfs (Figure 6, Table 3). These observations represent I:E ratios ranging between 1.5 and 0.2, and OMR index values (Hutton 2008) between negative 98 and negative 5,109. STH and FRC releases were also exposed to variable exports at higher SJR inflows. For FRC, with SJR inflows at ~10,000 cfs, two releases each were available for exports at ~2,500 cfs and exports at ~9,750 cfs (Figure 6). For STH, with SJR inflows at 10,000, two releases were available for exports at 2,500 cfs and one release with exports at ~9,500 cfs (Figure 6). These observations represent I:E ratios ranging between 4 and 1, and OMR index values between positive 2,463 and negative 4,142. The STWG recommends caution when extrapolating the results of these studies to other unobserved flow and export scenarios.

OMR index values for FRC releases were centered near zero or at slightly negative values (Figure 7), but eleven releases occurred during positive OMR conditions while only two releases occurred with OMR flows more negative than minus 2,500 cfs. STH releases relative to OMR were similar to FRC, except with five observations at OMR flows more negative than minus 2,500 cfs. Only three SRC releases were available with OMR values ranging from negative

2,000 to positive 5,000 cfs. The I:E ratio ranged from ~0.75 to ~4.25 for FRC releases, though most releases with larger sample sizes occurred between values of 1 and 2 (Figure 8). The I:E ratio ranged from ~0.25 to ~7 for STH releases, though most releases occurred between ~0.25 and ~1.5 (Figure 8). I:E ratios for SRC ranged from 1 to >3, but were represented by only three releases.

All acoustic tagging studies reviewed by the STWG relied on hatchery origin juvenile salmonids. Fork lengths of FRC averaged 102mm (range: 85-140), SRC averaged 79mm (range: 70-98), and STH averaged 242mm (range: 97-396). Fish of these sizes are representative of smolt-sized emigrants for each of these species. However, juvenile Chinook salmon will enter the South Delta at smaller sizes (fry or parr), particularly during wet winters (Zeug et al. 2014). Therefore, acoustic tagging studies reviewed by the STWG are not representative of smaller-sized juvenile Chinook emigrants that can contribute substantially to recruitment in years where hydrologic conditions and adult salmon returns result in large pulses of salmon fry being produced (Sturrock et al. 2020).

Hatchery produced juvenile salmonids are used in tagging studies because adequate numbers and comparable sizes of wild origin fish are rarely available—particularly for ESA-listed stocks. While hatchery fish can differ from wild fish in their migration behavior (Roper and Scarnecchia 1996) and in their survival (Buchanan et al. 2010) they are commonly used as surrogates (Buchanan et al. 2010; Adams et al. 2014). Comparisons of behavior and survival for wild and hatchery juvenile salmonids migrating through the Delta are not currently available. This being the case, studies of tagged hatchery fish in the Central Valley provide the best available measure of wild stock performance and water project operation effects. Tagging studies based on hatchery salmon are routinely relied upon to guide ESA-related management decisions on topics including Sacramento River flows (Michel et al. 2021; Hassrick et al. 2021), Delta operational effects (Sridharan et al. 2023), and ocean harvest impacts (O'Farrell and Satterthwaite 2015). Therefore, it is appropriate that the same standard be applied to acoustic tagging studies reviewed by the STWG.

Factors Not Addressed by the STWG

This review focused on the survival and behavior of acoustically tagged, hatchery-origin juvenile salmon and steelhead released into the San Joaquin River upstream of the Delta. However, several factors that influence salmonid survival through the Delta were not included in the review. For example, although the STWG discussed predation as being a likely cause of mortality within the Delta, it did not undertake a review of recent predation-related research. Since the focus of this review was on the South Delta and acoustically tagged fish released in the San Joaquin River, the review did not include data on fish entering the Delta from the Sacramento River. Nor did the review include data on CVP/SWP entrainment rates for fish entering the Delta based on count or genetic data, or systemic effects such as the potential for climate change to affect water resources and operations, and thus, the survival of juvenile salmon through the Delta under future conditions. The STWG did review presentations by DWR and Reclamation on predator and survival studies associated with CVP and SWP facilities, which were limited in scope to actions taken to address direct mortality within these facilities. The CVP presentation described that salvage efficiencies are not consistently achieving performance measures of overall survival to be greater than 75% through the facility. However, recent research conducted using tags that identify predation events suggests that in theory reducing predation as a source of loss could result in salvage efficiencies that meet this requirement. The SWP presentation indicated that survival among fall-run and late fall-run Chinook salmon and steelhead releases through the entire SWP was highly variable within years and relatively consistent across years but was low overall (generally <0.25). Predator relocation techniques have been tested at SWP and the abundance and biomass removed each year varied. To date, DWR's salmonid survival data and analyses show no evidence of any clear correlation between salmonid survival and the predator removal/relocation effort (i.e., quantity of fish/biomass removed).

RESULTS

Question 1:

What does analysis post the SST report have to tell us about how exports influence salmon and steelhead survival through the South Delta (i.e., now that telemetry data for more years has been analyzed and processed)?

Q1 Findings

Overall through-Delta survival: Analysis of juvenile salmonid survival under the conditions observed from the Head of Old River (HOR) to Chipps Island has shown no evidence of a negative export effect. For acoustically tagged fall-run Chinook salmon (2010-2017), Buchanan and Whitlock (2022) provide the most comprehensive analysis. The authors applied a single-variable regression to model through-Delta survival while accounting for migration route selection at the HOR junction, the presence of a physical barrier at the HOR, and fork length of individual fish. Among the nine candidate, single covariate models considered, the root mean square of flow measured at Bacon Island on Old River (ORB.3rms) best explained observed variation in survival (Cite 1). As a root mean square metric, ORB.3rms represents the volume of water moving near Bacon Island, but not the direction of that movement. Higher ORB.3rms values can occur from higher SJR inflow, from stronger tides, from higher exports, or from the combined effects of these factors. Therefore, this finding is not consistent with an adverse effect of higher exports on survival. Alternative covariates evaluated included exports (without SJR inflows), SJR inflows (without exports), I:E ratio, and OMR flow analogues (MID.3net and OMR.3net), but each of these explained substantially less variation in Chinook salmon through-Delta survival estimates than ORB.3rms.

For acoustically tagged steelhead smolts (2011-2016, Buchanan et al. 2021), SJR inflow was the single factor that best explained observed variation in through-Delta survival estimates—survival improved with higher SJR inflow (Cite 2). Exports and other flow metrics (I:E ratio, net flow) were considered as alternative models, but had much less support in explaining variation in survival estimates. For example, the I:E ratio model had an AIC value 68 points higher than the model that included only inflow. According to Buchanan et al. (2021), "When SJR inflow was included in the model, no other covariates had statistically significant added effects." As noted in Buchanan et al. (2021), total export levels in the analysis did not exceed 6,100 cfs, and "different survival patterns might be exhibited under unrestricted (i.e. higher) exports."

Relative to fall-run Chinook salmon, juvenile spring-run exhibited higher through-Delta survival (Cite 3). In 2017 and 2019, when SJR inflow exceeded 12,000 cfs, survival to Chipps Island among spring-run juveniles was 0.22 and 0.13, respectively. In contrast, the highest through-Delta survival observed among fall-run Chinook salmon was 0.05. Fork lengths of FRC averaged 102mm (range: 85-140), SRC averaged 79mm (range: 70-98). Spring-run were released in March whereas Chinook salmon were released in May and June. Total exports ranged from 4,000 cfs (2018) to 6,800 cfs (2017) during three spring-run Chinook salmon releases, and the limited observations were insufficient to support assessment of export effects.

Region-specific effects: Factors influencing survival of juvenile salmonids vary across the Delta. A better understanding of these effects, including the effect of exports, is provided by reviewing region-specific results. In **Region 1**-- the SJR mainstem from HOR to TC (see Figure 1) —analyses of acoustic tagging studies suggest either no effect of exports or a positive effect. For juvenile Chinook salmon, water temperature had the strongest support among all the models considered-- higher survival was associated with colder water temperatures (Cite 4). SJR inflow was the second ranked model (with a large increase in AIC relative to water temperature), but SJR inflow as a covariate had more support relative to models representing exports and other flow metrics (exports, I:E ratio, net flow). Export effects for Chinook in Region 1 were associated with negative coefficients but explained substantially less variation (change in AIC>90) relative to the top ranked covariate, water temperature (Cite 4). For steelhead smolts, SJR inflow was strongly supported over other models (Cite 5). Poorer performing models for describing steelhead survival in Region 1 included I:E ratio, water temperature, exports and net flow. Export effects for steelhead in Region 1, yielded a positive coefficient for pCVP.5 and a negative coefficient for SWP.5, but export covariates explained substantially less variation (change in AIC>115) relative to the top ranked covariate, SJR inflow (Cite 5).

In **Region 2**—the SJR mainstem from TC to Chipps Island (see Figure 2) ---survival to and through this region has been consistently very poor for Chinook salmon released between April and June under a variety of export and SJR inflow conditions (Cite 6). This pattern of low survival from TC has yielded insufficient data (i.e., the number of tagged fish surviving) to support statistical analyses of factors influencing survival in this region. Steelhead smolt survival was higher in this region relative to Chinook salmon, but statistical analysis indicates that the null model (route + year + fork length) explains observed variation as well as alternative models which included single environmental covariates (Cite 7). Therefore, survival of steelhead smolts in this region appears to be relatively insensitive to exports but also insensitive to SJR inflow, the I:E ratio, and net flow.

In **Region 3**---Old River route between Head of Old River to the export facilities area (Figure 3)—higher survival of juvenile fall-run Chinook salmon was associated with colder water temperatures and higher SJR inflow—models that included covariates including exports, I:E ratio and net flow metrics were not well supported (Cite 8). Patterns of survival for acoustically tagged steelhead smolts suggest a positive effect of SJR inflow on survival and no discernble influence of exports in the region (Cite 9), but a statistical analysis comparable to that conducted for Chinook salmon was not available.

Patterns of survival in Region 3 described above are based on detections in the vicinity of the export facilities (Figure 3), but do not account for how export operations may influence subsequent survival. Buchanan and Whitlock (2022) found a positive relationship between CVP exports and survival to Chipps Island (Cite 10) which they attributed to entrainment and salvage of acoustically tagged Chinook salmon in Region 3. For acoustically tagged fall-run Chinook releases between 2010 and 2014, Buchanan and Skalski (2018) reported that of the relatively small number of fish that survived to be detected at Chipps Island (77 individuals), 65% had passed through Region 3 and been subjected to entrainment and salvage (Cite 11).

In **Region 4**--- the interior Delta including the Old and Middle River corridor north of the export facility intakes (see Figure 4) —less information from acoustic tagging studies is available in this region because the Head of Old River Barrier prevents entry in some years, acoustic receiver arrays have been sparse in this region, and relatively few fish enter at Turner Cut. Additionally, survival for salmonids in this region has been poor for Chinook salmon and highly variable for steelhead. In contrast to Region 1 and Region 2, exports can strongly influence hydrodynamic conditions in this region (SST 2017).

Junction Routing. Exports have the potential to influence routing of juvenile salmonids at two junctions which have been subject to acoustic tagging study: Head of Old River (HOR) and Turner Cut (TC). Analyses reviewed by STWG did not directly evaluate if or how much exports might increase routing into these junctions; some information on routing was evaluated in SST 2017. However, analyses for juvenile Chinook salmon suggest routing into HOR decreases with higher SJR discharge measured near the HOR junction (Cite 12), which is consistent with another analysis (see Cite 14). Relative to HOR, a smaller proportion of Chinook salmon and steelhead are routed through TC (Cite 13). Analyses suggest routing into TC is associated with flood tides and net flows (Cite 14). Though exports can influence net flows at TC (Cite 15), the magnitude of this effect on routing probability has not been quantified.

Q1 Interpretation of Findings

The STWG reviewed analyses representing forty-six separate release groups and more than twenty-thousand acoustically tagged juvenile salmonids released into the San Joaquin River upstream of entry to the south Delta. A variety of export and SJR inflow conditions were represented by these releases (Figure 5 and Figure 6). While there is a tendency for total exports to be positively correlated with higher SJR inflow, observations with both lower export/higher SJR flow and higher export/lower SJR flow were available. Over the range of exports observed in the regions of the Delta where adequate data were available (Region 1, Region 2 and Region 3), analyses reviewed by the STWG did not find that survival of SJR-origin juvenile salmonids were negatively associated with exports. For steelhead smolts (the only species where such observations are available), total exports ranging from 1,000 and 6,500 cfs while SJR inflows were <3,000 cfs were not associated with any detectable adverse export effect on survival. With SJR inflows >10,000 cfs, six releases of FRC and five releases of STH were available and split between low-medium exports (2,500 to 4,000 cfs) and high exports (>8,000 cfs). Since these releases contrast low and high exports under higher SJR flow conditions, a survival improvement with lower exports should have been apparent. However, no such effect was observable within the range of exports included in the analyses reviewed by the STWG. It is important to note that steelhead smolts are particularly relevant for the assessment of export effects. By design, steelhead smolt releases were associated with greater variation in exports relative to SJR inflow because the releases occurred earlier in the season (note: 2009 NMFS BiOp I:E regulations pertaining to San Joaquin steelhead occurred in April through May). In addition, steelhead smolts are larger and survive at higher rates, thus hypothesized indirect effects should have been more detectable among steelhead smolts than among poor surviving fall-run Chinook juveniles.

In contrast to evidence lacking for export effects, higher SJR inflows were positively associated with survival of juvenile salmonids in Region 1 and Region 3, but not in Region 2. This finding appears to be consistent with more riverine hydrodynamic conditions (e.g. velocity and flow direction) benefiting survival of juvenile salmonids. Specifically, hydrodynamic conditions in Region 1 and Region 3 can change dramatically with higher SJR inflow, while Region 2 is tidally-dominated and therefore comparatively insensitive to SJR inflow. Thus, where water project operations produce a strong hydrodynamic signal (e.g. SJR inflow effects in Region 1 and Region 3), acoustic tagging studies can detect its effect on survival. An effect of exports on survival may not be observed because the hydrodynamic signal of exports in Region 1, Region 2 and Region 3 is comparatively weak, or because the range of operations is limited (e.g., we have no data for OMR flow more negative than -5000 cfs). It is important to note that hydrodynamic conditions in Region 4 (i.e., from the end of Region 3 to Chipps Island through the OMR corridor) are strongly influenced by exports, but few survival analyses are available for this region.

Collectively, analyses reviewed by the STWG indicate exports rates within the range of exports currently studied (Figure 5 and Figure 6) do not negatively affect survival of juvenile salmonids emigrating from the SJR through the south Delta (acknowledging the context described in the Framing section). This result does not necessarily support an inference that existing regulatory tools that limit exports are ineffective but does suggest exports are not the primary factor negatively affecting survival of San Joaquin origin salmonids.

Acoustic tagging studies suggest that higher San Joaquin River flows in months when water temperatures are cooler (<16^{o}C) would yield the greatest water project operation-related survival benefit to juvenile salmonids. While additional experimental evaluation may be warranted, analyses currently available suggest exports as high as 6,000 cfs when SJR inflows are <3,000 cfs did not appear to adversely affect survival of juvenile salmonids migrating from the SJR.

Exports as high as 10,000 cfs when SJR inflows were of approximately equal magnitude (that is, an I: E ratio of 1) were also not associated with decreased survival relative to equivalent SJR inflows with much lower exports (<3,000 cfs). It is also important to note that a large proportion of the small number of juvenile Chinook salmon surviving to Chipps Island are fish that utilized the Old River route and appear to have been salvaged at the export facilities. Reducing exports may reduce entrainment of SJR-origin salmonids to the export facilities, but does not appear to reduce indirect effects in the broader Delta and therefore may not improve survival to Chipps Island for fish that are not entrained.

Question 2A:

Are any of the conclusions of the SST related to survival changed or strengthened because we have additional data?

Q2A Findings

As noted in the Introduction, the STWG reviewed a narrower set of questions than was originally considered by the SST. For topics covered by both the STWG and the SST, conclusions that were strengthened include the following:

- Through-Delta survival for juvenile Chinook migrating through the South Delta remains very poor. Survival rates of 10 to 30% have been observed for some routes in wet water years (Cite 16), but most Chinook releases survived at 5% or less. Even the highest rates of survival observed among juvenile Chinook salmon may be inadequate to support self-sustaining salmon populations in the San Joaquin Basin.
- Steelhead smolts survive at a higher rate than juvenile Chinook salmon.
- Survival of juvenile salmonids in the SJR mainstem from HOR to Turner Cut (Region 1) is positively associated with higher SJR inflow.
- Survival of juvenile Chinook entering the interior Delta at Turner Cut is very poor.
- The effect of water project operations on environmental conditions and how those conditions affect juvenile salmonids vary by region and route. These effects cannot be generalized across the South Delta.

For topics covered by both the STWG and the SST, conclusions that changed, or where new insights were revealed, include the following:

- Higher SJR inflows were not associated with improved survival of FRC or STH from Turner Cut to Chipps Island (Region 3). Though this is a new finding, it is consistent with the driver-linkage-outcome model described by the SST. Specifically, effects on survival of juvenile salmonids are most likely to occur where water project operations alter velocities or flow direction and are therefore less likely in tidally dominated reaches (as in Region 3).
- Statistical analysis among FRC and STH releases consistently found that exports alone and metrics that combine exports and SJR inflows (i.e. OMR and I:E) were poorly supported relative to models that considered just SJR inflows or water temperature. This finding applies to Region 1, Region 2 and Region 3.
- Spring-run Chinook juveniles (SRC) released in the SJR in March demonstrated higher survival to Chipps Island than FRC released in later months.
- Water temperatures can strongly influence survival of juvenile Chinook salmon in the South Delta. This conclusion is supported by statistical analysis of FRC survival, but temperature effects may also explain relatively high survival observed among juvenile SRC released in March, rather than between April and June as has been typical for FRC.
- Paradise Cut is an alternative route between the SJR mainstem and Old River that becomes available only when SJR flows exceed 17,000 cfs. In 2017, 45% of SRC juveniles using the Paradise Cut route survived to

Chipps Island. Survival in the mainstem SJR and in Old River (via the HOR) in 2017 was 31% and 20%, respectively-- also relatively high, but lower than for fish utilizing the Paradise Cut route.

- Researchers analyzed the behavior of acoustically tagged steelhead in the area directly outside the SWP/CVP entrances in Old River and West Canal using data collected during 2014, 2015, and 2016. Test fish displayed long residence times and non-directional movement. Ninety percent of the test fish spent 6.5 days or less in the export facility area (as compared to 1.6 days or less at head of Old River and 1.3 days or less at Turner Cut junctions off the mainstem San Joaquin River). How this delay may influence survival and entrainment and salvage rates is uncertain and could be the subject of future study.
- Despite considerable study on fish routing and survival in the Delta, we still have a poor understanding of routing and survival for fish that approach the CVP and SWP facility intakes. This is a result of several factors: limited acoustic tag receivers near the export facilities; small sample sizes due to poor survival of tagged fish generally; and the HORB reducing the number of tagged fish reaching the export facilities area when in place.
- A large proportion of juvenile Chinook salmon surviving to Chipps Island are fish that utilized the Old River route and appear to have been salvaged at the export facilities. Reducing exports may reduce entrainment to the export facilities but may not improve survival to Chipps Island for fish that are not entrained.

Question 2B:

If not, what study results would allow new/different/firmer conclusions to be reached?

Q2B Findings

Articulating specific studies that can best resolve remaining uncertainties regarding water project operation effects on juvenile salmonid is challenging and time-consuming. Frequently such efforts undertaken by interagency groups produce lists of study topics built around methodologies—often with inadequate consideration for how management-related questions would be firmly and effectively addressed. The STWG did not undertake this type of research program development. We instead articulate attributes of a study design process that would have the greatest potential to substantially advance our understanding of water project operation effects on juvenile salmonids in the South Delta.

If the desired objective is to make more definitive conclusions regarding export effects, then a rigorous framework for study design along the following lines is needed:

- Step 1: Identify a clear mechanism for how exports are hypothesized to affect survival or behavior of juvenile salmonids
  - e.g. Loss of SJR chemical navigation cues caused by exports
- Step 2: Determine where in the Delta and what export rates are needed to produce a strong signal of the hypothesized mechanism
- Step 3: Specify the magnitude and direction of the hypothesized biological response that will be evaluated
- Step 4: Develop an experimental design capable of detecting the hypothesized effect

Following these steps requires considerable effort, but a rigorous and structured approach is warranted given the complexity and significance of underlying management issues. Flawed study concepts would fail at one step or another, and corrective revisions might be infeasible. Such an outcome would suggest the study topic is unsuitable for scientific investigation, and very likely the underlying hypothesized impacts provides an inadequate basis for managing water project operations. Even promising study concepts would require a series of iterations and adjustments to meet each step.

Providing examples of promising study concepts to illustrate how steps could be satisfied is beyond the scope of the STWG and would also bias concepts that would hopefully be proposed by researchers.

The framework for identifying and evaluating study designs to address the indirect effects of exports on juvenile salmonid behavior and survival could also utilize existing tools to help address some types of mechanisms. For example, existing hydrodynamic models could be incorporated into Step 2 of the framework to identify export rates and locations where a strong signal of a hypothesized hydrodynamic mechanism is estimated to occur. Also, simulation models have been developed for the North Delta to represent the effects of water project operations actions on juvenile salmon (e.g., STARS, ePTM and the DPM). At least one such model (see Wohner et al. 2022) has been developed for fall-run Chinook entering the South Delta from the San Joaquin basin. This or other models could be expanded to include the South Delta and used in support of Step 3.

Other approaches for increasing rigor should be discussed. This includes asking more specific questions and addressing the questions through modeling. To date the analyses have largely focused on the use of single-variate analysis to address complex issues with confounding variables. The focus has been on biological responses of routing and survival over generally large reaches (e.g., what is the effect of exports on through-Delta survival?). While this approach is useful, there is a potential lack of congruence in the results presented in this report. Namely, few export effects have been documented yet overall survival remains low. This lack of congruence raises questions as to whether the conceptual model underlying current analytical models needs to be updated. For example, export effects may be negative, but relative to factors like river inflow, water temperature, and predation pressure are too small to detect. Alternatively, maybe exports are having an effect via a different mechanism. One potential approach for continuing to investigate the hydrodynamic-export effect hypothesis would be to incorporate travel time into future analyses. If travel time is influenced by tidally-averaged flows, there will still be covariation between inflow and exports, but it might be easier to detect changes in travel time associated with inflow and exports than a survival effect. If travel time in the tidal Delta is linked to survival, and if travel time is in turn strongly correlated with a hydrodynamic condition that can be modeled (e.g., tidally-averaged flow), then this might provide a basis for quantifying the effects of water project operation on survival, even in the absence of a direct survival-export relationship from acoustic tagging studies.

Another potential analytical approach is to take relationships supported by the existing data and use the current biological and hydrodynamic models to estimate the level of biological response associated with management scenarios. For example, determine the level of habitat restoration or flow action required in Region 1 (the SJR mainstem from HOR to TC) to produce a desired biological response (e.g., a change in survival of X percent). This does not require that specific test conditions and export operations be established and maintained, but rather, it uses existing tools to investigate potential ways to improve the observed low survival, and the magnitude of change needed to achieve that survival target.

The approaches described above include a framework for evaluating hypothesized mechanisms, developing alternative response variables based on those hypothesized mechanisms, and using existing models to explore management actions to improve survival. Further collaborative discussion could identify additional approaches.

Question 3:

What is the impact of exports relative to other factors influencing juvenile salmonid survival in the Delta? (e.g., what does acoustic telemetry data tell us about how foraging/sheltering/migrating behavior may be impacted by export altered hydrodynamics?)

Q3 Findings

Results previously reviewed in response to charge questions 1 & 2 suggest that within the range of conditions observed, and regions studied, survival of SJR-origin juvenile salmonids is more strongly influenced by San Joaquin River inflow and water temperature than by exports.

The STWG believes systemic impacts like habitat degradation, proliferation of non-native fish species, and poor water quality, along with San Joaquin River inflows and water temperatures, are the factors contributing most to poor survival of San Joaquin-origin juvenile salmonids in the Delta. Though water project facilities and operations (along with other human activities) have contributed to long-term habitat degradation, reducing exports in months when juvenile salmonids are present in the Delta does not on its own offset these impacts.

Available studies suggest indirect export effects do not appreciably influence survival of juvenile salmonids relative to other factors, but it's important to note that the observed combinations of exports and SJR inflow do not represent all conditions that might occur under a different regulatory framework. For example, combined exports greater than 6,500cfs were represented by a single release of acoustically tagged steelhead. Higher exports do lead to more fish being entrained into the South Delta diversion facilities—i.e., direct export effects. A management priority on minimizing or avoiding entrainment assumes implicitly that survival outcomes will be better for juvenile salmonids that can avoid entrainment and volitionally emigrate from the South Delta. However, in years when exports have been low enough (relative to SJR inflows) for fish to avoid entrainment and begin migrating northward in Old and Middle River corridor, survival to Chipps Island has been close to zero (Table 4). Conversely, survival of juvenile salmon to Delta exit was frequently higher for fish utilizing the Old River route (relative to the SJR mainstem route) and this outcome has been attributed to entrainment and salvage at the CVP (Buchanan and Whitlock 2022), not to volitional migration. Though counter-intuitive, these study results suggest managing exports to reduce entrainment risk may negatively impact survival of juvenile Chinook salmon utilizing the Old River route. Because the estimated loss of entrained salmonids is considerably greater at the SWP (compared to the CVP), and the SWP has greater export capacity (and thus entrainment potential) than the CVP, it is important to consider that survival effects attributed to salvage differ between the two facilities. More studies and analyses of fates of juvenile Chinook salmon and steelhead near the diversion facility intakes and northward in the OMR corridor are needed to determine what operational conditions (if any) can improve survival outcomes relative to entrainment and salvage.

Year	WY Class	OMR	OR4	CHP
2010	AN	+	58	1
2011	W	+	103	0
2012	D	-	1	0
2013	C	-	15	0
2014	C	-	0	0
2016	D	-	3	0
2017	W	+	44	0

Table 4. Acoustic tag detection data from Buchanan and Whitlock (2022). OMR indicates whether positive (+) or negative (-) Old and Middle River flows prevailed when the study was conducted. OR4 is the receiver array located on Old River at Highway 4, 8km north of Clifton Court Forebay intake canal. CHP is the estimated number of fish detected at OR4 which were subsequently detected at Chipps Island.

Question 4:

How do juveniles respond (survival, behavior, growth) to the different operations based on flow dynamics in different water year types?

Q4 Findings

Survival results are covered in the responses to Questions 1 to 3 above, including any relationship to water year type. Growth studies have not been conducted since the SST report was issued. However, Sydney Gonsalves (Anchor QEA analyst) noted when evaluating steelhead behavior that juvenile steelhead that reached the export facility area when the Head of Old River barrier was installed (and presumably took the longer route down the mainstem San Joaquin River before migrating to the facilities), had significantly longer fork lengths than fish that reached the facilities area when the barrier was out and presumably took a more direct route on Old River. The data have not been cross-checked with the final routes developed by Rebecca Buchanan for the tags observed at the export facilities from 2014-2016 that were used in the study, nor has a release group effect been ruled out, but the tenuous observation of growth associated with a longer routing was interesting.

Regarding behavior, there is now limited information regarding juvenile behavior at distributary junctions and at the export facilities in response to different operations and flow conditions, but the results were not related to specific water year types. Behavioral observations at the three locations studied are summarized as follows:

- Head of Old River:
  - Steelhead behavior was grouped into two categories: active migrators that moved through the area quickly and non-migrators that did not. Also, there was more variability in the percentage of fish classified as active migrators when the barrier was not installed. Steelhead generally stayed in the San Joaquin River when the barrier was in place and moved into Old River when it was not installed. Fish were more likely to move downstream on the San Joaquin River rather than into Old River when net flows were high (generally during high water years), even when the barrier was not installed. During low flow years, tidal flow had the most influence, with fish generally moving downstream with the ebb tide and “backtracking” on the flood tide (Anchor QEA 2022).
  - For fall-run Chinook salmon, the barrier effect on movement from upstream San Joaquin River into Old River was significant and strong, indicating that when the barrier was absent, smolts have a much higher movement rate into Old River and decreased movements from the upstream to downstream in the San Joaquin River (Dodrill et al. 2022).
  - Spring-run Chinook salmon expended more energy (e.g., swimming against the flow, swimming laterally) during high flows at head of Old River (Holleman et al. 2022).
- Turner Cut:
  - Few steelhead entered Turner Cut, but those that did were more likely to enter during flood tide flow into Turner Cut. The tidal component of flow had the strongest influence on fish transitions at this junction. Fish previously designated as “actively migrating” at Head of Old River continued to move through Turner Cut at approximately the same rate. Net flow was the strongest predictor of upstream-to-downstream movement. Exports influenced net flow through Turner Cut. During low flow years, tidal flow had more influence on the probability of transitioning with fish generally moving downstream with the ebb tide and “backtracking” on the flood tide (Anchor QEA 2022).
  - Regarding fall-run Chinook salmon, the findings were similar to those of steelhead (e.g., flood tides decreased seaward movement rates of fall-run Chinook salmon (Dodrill et al. 2022)).
- Export facilities:

    - Steelhead displayed longer residence time and a lack of directional movement compared to Head of Old River and Turner Cut. Also, fish had higher probabilities of transitioning in the direction of tidal flows. Of the total fish detected, 30.7% ended up in the CVP salvage tank, and the probability of this happening increased with high reverse net flow. Since net flow was reversed for the entire study period evaluated (2014 to 2016), all test fish experienced some level of reverse net flow. Fish were more likely to move away (either direction) from the entrance to SWP (i.e., the radial gates) when net flow in West Canal was low, probably because the radial gates are generally closed when net flow is low. Temperature, source water, and tidal flows are highly dynamic in this area. Data were only available in critical or below normal water years. Fish released into the SJR after the HOR barrier was installed (i.e., later release day) were more likely to transition toward CVP in the export facility area, potentially a result of taking a longer route down the SJR and generally moving in a southward direction through the Inner Delta (Anchor QEA 2022).
- Travel time was not included as a covariate in the analyses reviewed, but was discussed as follows:
    - Based on analysis of steelhead presented in Buchanan et al. (2021), the median travel time from the head of Old River to Chipps Island was approximately 5.6 days, travel time ranged from 1.4 to 34.9 days, and neither the San Joaquin River route nor the Old River route had a consistently shorter travel time (Buchanan et al. 2021). Travel time from Mossdale through the Delta to Chipps Island varied from 1.5 to 35.0 days; the median travel time each year ranged from 5.8 to 8.0 days.
    - Based on analysis of fall-run Chinook salmon presented in Buchanan and Whitlock (2022), median travel time through the San Joaquin River route was 5.7 days compared to 2.6 days through the Old River route. Based on Buchanan et al. (2018), median travel time from Mossdale to Chipps Island was approximately 3 to 4 days in 2010, 2011, and 2013 and 5.2 days in 2012. No fish with tags passing Mossdale in 2015 were detected at Chipps Island. WY 2015 was characterized as critical. Both the shortest (1.1 day) and the longest (12.4 day) travel times through the study area to Chipps Island occurred in 2011. Travel time through the Delta (i.e., Mossdale to Chipps Island) was significantly longer on average in 2012 than in the other 3 years that have estimates ($P = 0.0045$). WY 2012 was characterized as dry.

Q4 Interpretation of Findings

- Head of Old River: Installing the barrier has a strong effect on fish behavior and operates as expected to decrease movement into Old River and increase movement downstream on the mainstem San Joaquin River, especially during high inflows. Hydrodynamic conditions at the junction are affecting fish behavior by delaying migration, and potentially increasing predation potential. Reclamation is implementing a project to reduce the predation intensity at the scour hole at the Head of Old River through modifications to the channel geometry and associated habitats. Holleman et al. (2022) suggest that potentially altering one bank of the river to draw fish laterally to the habitat on that bank might also affect routing at this junction. Tidal influences are less here compared to Turner Cut but are strongest in low flow years.
- Turner Cut: Few fish entered Turner Cut, but those that did were more likely to enter during flood tides. Exports influenced net flow through Turner Cut. Therefore, adjusting the timing of water project operations during daytime such that net flow during ebb tides is enhanced and exports do not coincide with flood tide flows would increase the proportion of fish staying on the mainstem San Joaquin River and may allow fish to move through the area more quickly (i.e., increase the probability of upstream fish transitioning downstream). These changes would result in higher survival (Buchanan et al. 2021).
- Export facilities: Steelhead displayed longer residence time and a lack of directional movement during the 2014-2016 studies during critical or below normal water years. Temperature, source water, and tidal flows

are highly dynamic in this area and the influence of these interacting variables requires further investigation. Fish released after the Head of Old River barrier was installed (i.e., later release day) were more likely to move toward the CVP. Buchanan et al. (2021) conducted a preliminary analysis showing that the salvage subroute may increase survival because it shortens route length. If trucking of salvaged fish has a higher route survival than other longer routes through the Inner Delta, this might be a positive factor (Anchor QEA 2022).

- Travel times: Vary considerably between species and water years, with some fish taking up to 35 days to transit the Delta. Higher flows that result in faster water velocities and shorter travel times may reduce exposure to the risk of mortality (Anderson et al. 2005).

Question 5:

For each question, do existing life cycle models take into account this new information and are tools reflective of what we are seeing in the science (e.g., will changes in operations based on water year type be reflected in juvenile response)?

Q5 Findings

The SIT model incorporates available information regarding routing and survival of fall-run Chinook salmon in the South Delta, including the effect of SJR inflow and water temperature covariates (see Wohner et al. 2022). However, the SIT model does not currently incorporate findings from studies of steelhead smolts or spring-run Chinook salmon. Incorporating spring-run Chinook results into the SIT model, particularly as more years of analyzed data become available, would greatly improve the model's ability to represent conditions earlier in the juvenile Chinook emigration season. An area of improvement for the SIT model would be to provide a more detailed accounting of survival and entrainment for fish utilizing the Old River route. Accomplishing this will require that acoustically tagged fish more consistently reach the vicinity of the water project intake facilities and that receiver arrays are placed such that probability of entrainment to the SWP and CVP can be estimated separately, and more definitively distinguished from volitional emigration of fish northward in the OMR corridor.

Other simulation models have been developed to represent the effects of water project operations and other management actions on juvenile salmon in the Delta. These models include STARS, ePTM and the DPM. However, these models are focused on the North Delta and do not currently represent juvenile salmon entering the Delta from the San Joaquin River basin.

CONCLUSION

In summary, this report reflects the STWG's review and synthesis of the most relevant information available to respond to the charge questions. Numerous constraints (as outlined in the Framing section), including the regulatory context under which the studies took place and data limitations associated with not being able to observe all conditions mean this is necessarily a rather narrow response to the questions posed.

There are now 11 years of tagged release data (comprising >20,000 total tags and 46 separate release groups) that have been analyzed. As outlined in the response to Question 2, many of the key findings from the 2017 SST report have been affirmed. Taking a step back, the STWG considered what this data suggests about our current regulatory framework:

The current regulatory framework associates high survival with…	STWG conclusion
Higher SJR discharge during outmigration	Confirmed
Lower total export rates during outmigration	No significant adverse effect observed under the conditions studied
Fish using the mainstem river route and avoiding the interior Delta	Confirmed for steelhead; Fall-run Chinook have higher survival through Old River (due to being salvaged); however, survival through Turner Cut is almost zero

The STWG's conclusion regarding lower export pumping rates not showing an adverse effect on survival of San Joaquin-origin salmonids is one that will doubtless cause some consternation and elicit interest in further dialog and research. To develop more definitive conclusions regarding export effects, a different study approach would be required as outlined in response to Question 2b. For example, to date the analyses have largely focused on the use of single-variate analysis to address complex issues with confounding variables. The focus has been on biological responses of routing and survival over generally large reaches (e.g., what is the effect of exports on through-Delta survival?). While this approach is useful, there is a potential lack of congruence in the results presented in this report. Namely, few export effects have been documented yet overall survival remains low. This lack of congruence raises questions as to whether the conceptual model underlying current analytical models needs to be updated. Also, the STWG hypothesizes there are other factors contributing to poor survival of juvenile salmonids in the Delta (e.g., habitat degradation, proliferation of non-native fish species, poor water quality, lower inflows and higher water temperature, etc.), only some of which are directly or indirectly related to exports. Therefore, the STWG recommends pivoting from studying exports as we have been to focusing on improving survival at various scales by identifying, recreating, testing, and building upon the conditions where/when salmonids have had success (i.e., higher survival). Next steps might include collaboratively revisiting the conceptual model and/or defining the hypotheses/conditions to investigate.

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Appendix

Table 3

Species	Year	Release Date	N	SJR Flow	Exports	OMR Index	I to E Ratio
FRC	2009	4/22/2009	311	2,098	1,673	-435	1.3
FRC	2009	4/29/2009	311	2,457	2,260	-804	1.1
FRC	2009	5/13/2009	311	2,340	2,384	-970	1.0
FRC	2010	4/27/2010	72	5,285	1,534	1164	3.4
FRC	2010	4/30/2010	72	5,406	1,531	1223	3.5
FRC	2010	5/4/2010	72	5,802	1,526	1410	3.8
FRC	2010	5/7/2010	72	5,686	1,520	1362	3.7
FRC	2010	5/11/2010	72	4,998	1,499	1064	3.3
FRC	2010	5/14/2010	72	4,572	1,500	866	3.0
FRC	2010	5/18/2010	72	4,689	1,774	670	2.6
FRC	2011	5/17/2011	474	11,013	2,593	2846	4.2
FRC	2011	5/22/2011	474	10,540	2,892	2355	3.6
FRC	2011	6/7/2011	474	10,980	9,130	-3124	1.2
FRC	2011	6/15/2011	474	10,213	9,937	-4215	1.0
FRC	2012	5/2/2012	480	3,516	2,279	-331	1.5
FRC	2012	5/17/2012	480	2,467	3,219	-1673	0.8
FRC	2013	5/1/2013	475	3,851	2,304	-200	1.7
FRC	2013	5/15/2013	475	1,231	1,535	-709	0.8
FRC	2014	4/30/2014	638	2,307	1,663	-329	1.4
FRC	2014	4/15/2014	638	2,682	2,617	-1025	1.0
FRC	2016	4/13/2016	324	1,848	1,514	-405	1.2
FRC	2016	4/20/2016	324	2,776	2,187	-590	1.3
FRC	2017	4/12/2017	324	23,508	5,470	7885	4.3
FRC	2017	4/26/2017	324	23,875	8,225	5545	2.9

STH	2011	3/22/2011	479	22,278	3,088	9287	7.2
STH	2011	5/3/2011	474	14,160	3,858	3147	3.7
STH	2011	5/17/2011	478	11,013	2,593	2846	4.2
STH	2011	5/22/2011	480	10,540	2,892	2355	3.6
STH	2011	6/15/2011	285	10,214	9,857	-4141	1.0
STH	2012	4/4/2012	477	2,457	2,491	-1014	1.0
STH	2012	5/1/2012	478	3,374	2,306	-422	1.5
STH	2012	5/18/2012	480	2,446	2,972	-1458	0.8
STH	2013	3/7/2013	476	1,580	4,566	-3309	0.3
STH	2013	4/3/2013	477	1,425	1,493	-582	1.0
STH	2013	5/8/2013	472	2,870	1,901	-286	1.5
STH	2014	4/24/2014	480	2,839	2,843	-1158	1.0
STH	2014	5/21/2014	478	647	1,123	-604	0.6
STH	2015	3/4/2015	480	529	4,106	-3376	0.1
STH	2015	3/25/2015	478	998	1,532	-815	0.7
STH	2015	4/22/2015	469	467	1,447	-983	0.3
STH	2016	2/24/2016	480	805	5,741	-4738	0.1
STH	2016	3/16/2016	480	2,459	6,320	-4501	0.4
STH	2016	4/27/2016	480	2,745	2,594	-975	1.1
SRC	2017	3/5/2017	700	21,725	6,833	5390	3.2
SRC	2018	3/2/2018	700	4,278	4,026	-1571	1.1
SRC	2019	2/28/2019	700	12,526	5,639	770	2.2

Table 3. Acoustically tagged fall-run Chinook (FRC), steelhead (STH) and spring-run Chinook (SRC) release groups included in analyses evaluated by the STWG. SJR Flow is the seven-day average at Vernalis beginning on the release date. Exports is seven-day average total exports (CVP+SWP) beginning on the release date. OMR Index is the seven-day average beginning on the release date calculated from Hutton (2008). I to E Ratio is seven-day average beginning on the release date. These data provide general information regarding conditions during tagged fish releases. Analyses considered by the STWG may have grouped releases differently or used different covariates calculated for different time periods (e.g. 5-day average rather than 7-day average).

Cite 1

Table 6. Single-variable regression results for survival from the SJL/ORE telemetry stations to Chipps Island (HOR-CHP), adjusted for fixed water year effects, migration route selection at the head of Old River (OR), the physical barrier at the head of OR, and fork length at tagging, 2010–2017. See Table 4 for definition of covariates. Sign refers to the estimated regression coefficient. *P* = P-value from F-test with 1 and 105 degrees of freedom. AUC = area under the curve for the Receiver Operating Characteristic curve.

Name	Type	Sign	*P*	ΔAIC	AUC
ORB.3rms	Flow	+	0.046	0.00	0.78
OMT.3rms	Flow	+	0.064	4.76	0.77
CVP.2	Exports	+	0.095	10.56	0.76
VNS.2	Delta inflow ($\log_e$ scale)	+	0.124	14.33	0.76
SWP.2	Exports	+	0.312	26.62	0.74
IE.2	I:E ratio ($\log_e$ scale)	-	0.475	31.32	0.72
MID.3net	Flow	-	0.535	32.47	0.72
OMT.3net	Flow	-	0.543	32.60	0.72
Tslt.2	Temperature	-	0.817	35.54	0.73

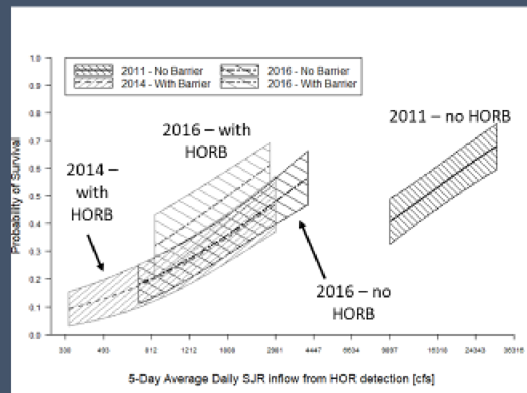
Cite 1. Model selection results for covariates evaluated for their ability to account for variation in observed survival of acoustically tagged Chinook salmon using either the mainstem San Joaquin River route or the Old River route. Among the nine candidate single covariate models considered, the root mean square of flows measured at Bacon Island on Old River (ORB.3rms) best explained observed variation in survival. As a root mean square metric, ORB.3rms represents the volume of water moving near Bacon Island, but not the direction of that movement. The AIC value for the second ranked model (OMT.3rms)– the root mean square of flows measured at a different location in the Delta-- was >4 points higher, suggesting it is a weaker model but somewhat competitive with ORB.3rms. All lower ranked models were not competitive with ORB.3rms. For more information about multi-model inference and the interpretation of model selection results, see Hobbs and Hilborn (2006). Source: Buchanan and Whitlock (2022).

Cite 2

Head of Old River to Chipps Island: Steelhead Results (2011 – 2016)

Name	Type	Sign	P	ΔAIC	AUC
VNS.5[a]	Inflow	+	<0.001	0.00	0.72
Tmsd.7dadm	Temp.	-	<0.001	31.87	0.72
IE.5[a]	I:E Ratio	+	0.001	68.18	0.71
OMT.1net	Flow	+	0.005	73.21	0.71
SAC.5	Inflow	+	0.012	84.20	0.71
pCVP.5	Exports	+	0.020	89.35	0.71
SWP.5	Exports	-	0.223	104.37	0.70
CVP.5	Exports	+	0.487	109.42	0.70
CVPSWP.5	Exports	-	0.638	109.55	0.70
OHT.1rms	Flow	+	0.909	124.93	0.70

a = $\log_e$ scale



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Cite 2. Model selection results for covariates evaluated for their ability to account for variation in observed survival of acoustically tagged steelhead smolts in the mainstem San Joaquin River route. SJR inflows (VNS.5a) had the lowest AIC score. The AIC value for the second ranked model (water temperatures, Tmsd.7dadm) was >30 points higher, suggesting it and all lower ranked models were not competitive with SJR inflows. For more information about multi-model inference and the interpretation of model selection results, see Hobbs and Hilborn (2006). Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

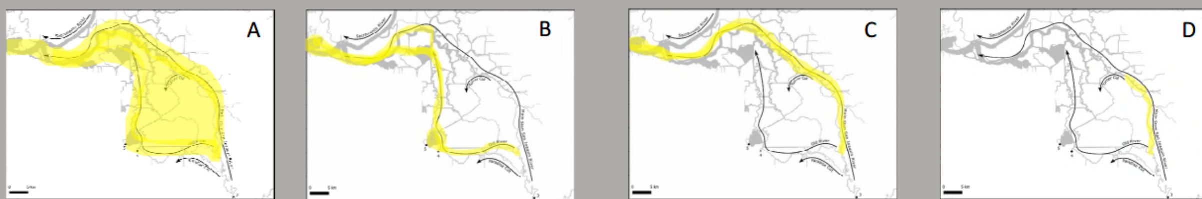
Cite 3

Survival

- How are patterns of survival from your study similar or different from those reported by Buchanan for Chinook salmon?

	Fall-run Chinook (Buchanan et al 2018)						Spring-run Chinook (Singer et al. in prep, Hause et al. 2022-in press)		
Region	2010	2011	**2012**	2013	**2014**	**2015**	2017	2018*	2019
A) Cumulative through Delta survival (Moss to Chipps)	0.05	0.02	0.03	0.01	0 (n = 0)	0 (n = 0)	0.22 ± 0.02	0.04 ± 0.01	0.13 ± 0.02
B) S Moss to Chipps- OR route	0.07	0.04	0.11	0.01	0	0	0.2 ± 0.04	0.12 ± 0.03	0.03 ± 0.01
C) S Moss to Chipps- SJ route	0.04	0.01	0.03	0.01	0	0	0.31 ± 0.04	0.02 ± 0.03	0.1 ± 0.02
D) S Moss to TC junction	0.32	0.48	0.24	0.02	0.01	0.05	0.43 ± 0.03	0.14 ± 0.02	0.35 ± 0.05

Bold years indicate temporary rock barrier present



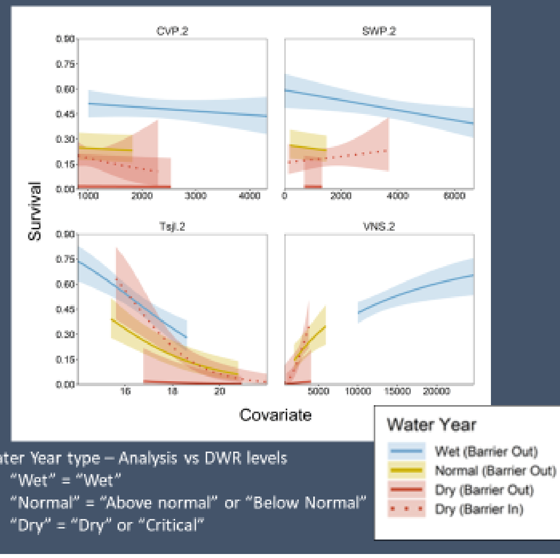
Cite 3. Patterns of survival for acoustically tagged juvenile spring-run Chinook and fall-run Chinook salmon. From Slide 17 of Singer, Hause and Agosta presentation to the STWG.

Cite 4

Head of Old River to Turner Cut: Chinook Results (2009 – 2017)

	Name	Type	Sign	P	ΔAIC	AUC
	Tsjl.2	Temp.	-	<0.001	0.00	0.74
	VNS.2[a]	Delta inflow	+	<0.001	41.89	0.72
	IE.2[a]	I:E ratio	+	<0.001	52.49	0.73
*	OMT.1net	Flow	+	<0.001	61.50	0.73
	SJG.1net[b]	Flow	+	0.002	NA	0.70
*	SWP.2	Exports	-	0.022	94.37	0.72
*	CVPSWP.2	Exports	-	0.045	98.61	0.72
*	CVP.2	Exports	-	0.291	108.96	0.72
*	pCVP.2	Exports	-	0.800	112.68	0.70

a = $\log_e$ scale
b = omits 2014 (missing data)
* = results depend on 2011



Water Year type – Analysis vs DWR levels
- "Wet" = "Wet"
- "Normal" = "Above normal" or "Below Normal"
- "Dry" = "Dry" or "Critical"

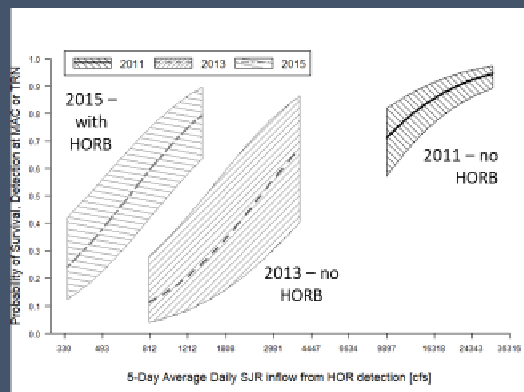
Cite 4. Model selection results for covariates evaluated for their ability to account for variation in observed survival of acoustically tagged juvenile Chinook salmon in Region 1. Water temperature had the strongest support among all the models considered-- higher survival was associated with colder water temperatures. SJR inflow was the second ranked model (with a large increase in AIC relative to water temperature), but SJR inflow as a covariate had more support relative to models representing exports and other flow metrics (exports, I:E ratio, net flow). For more information about multi-model inference and the interpretation of model selection results, see Hobbs and Hilborn (2006). Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

Cite 5

San Joaquin at Lathrop to Turner Cut: Steelhead Results (2011 – 2016)

Name	Type	Sign	P	ΔAIC	AUC
VNS.5[a]	Delta inflow	+	<0.001	0.00	0.74
IE.5[a]	I:E ratio	+	<0.001	80.54	0.73
Tmsd.7dadm	Temp.	-	<0.001	85.45	0.71
CVP.5	Exports	Mixed	0.001	115.78	0.69
CVPSWP.5	Exports	Mixed	0.005	131.07	0.69
pCVP.5	Exports	+	0.023	134.23	0.71
OMT.1net	Flow	+	0.093	142.08	0.69
SWP.5	Exports	-	0.197	147.17	0.70
OMT.1rms	Flow	-	0.379	151.78	0.68

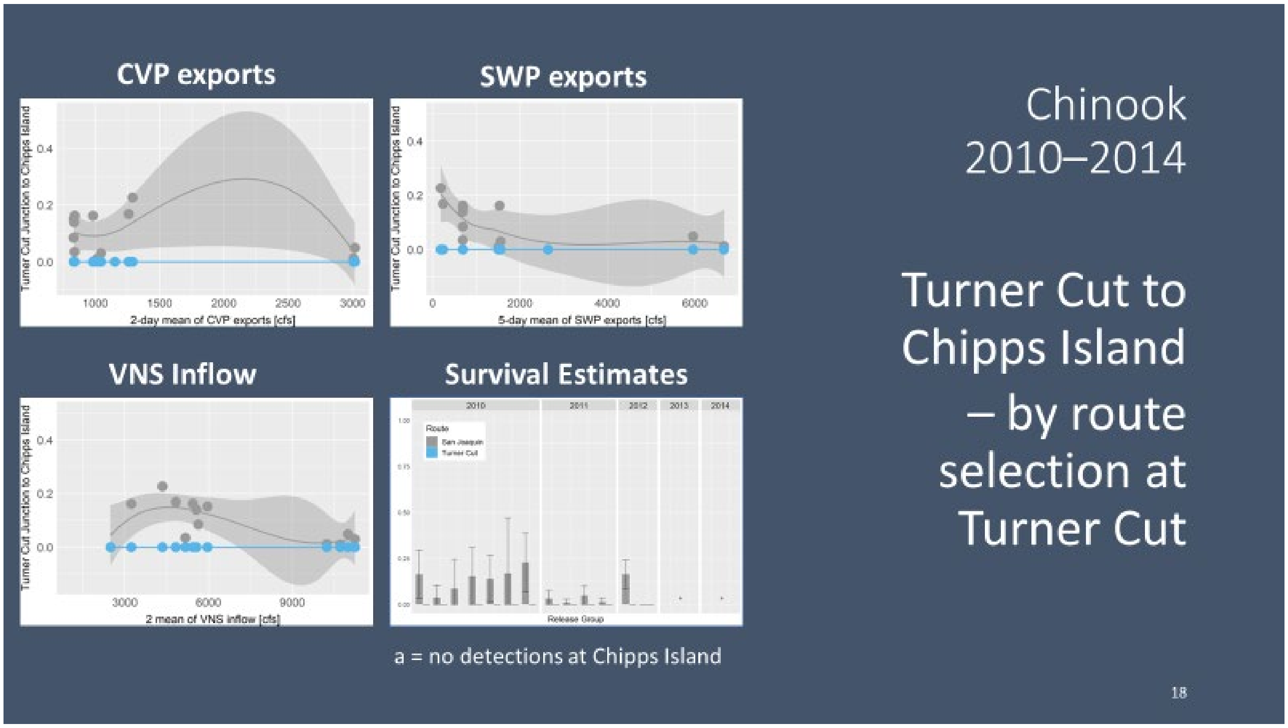
a = $\log_e$ scale



24

Cite 5. Model selection results for covariates evaluated for their ability to account for variation in observed survival of acoustically tagged steelhead smolts in Region 1. SJR inflows (VNS.5a) had the lowest AIC score. The AIC value for the second ranked model (I:E ratio) was >80 points higher, suggesting it and all lower ranked models were not competitive with SJR inflows. For more information about multi-model inference and the interpretation of model selection results, see Hobbs and Hilborn (2006). Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

Cite 6



Cite 6. Patterns of juvenile Chinook salmon survival in Region 2 (grey points and grey bars). Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

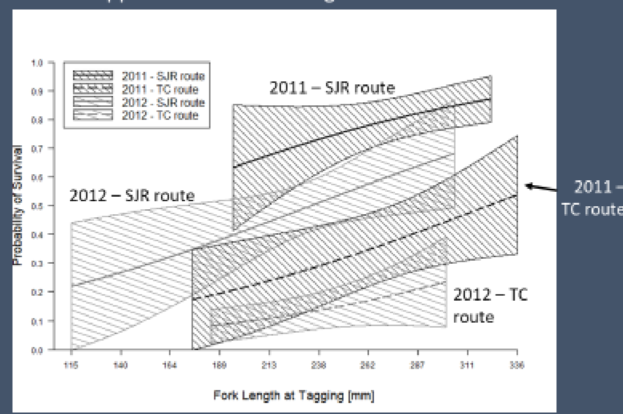
Cite 7

Turner Cut to Chipps Island: Steelhead Results (2011 – 2016)

Name	Type	Sign	P	ΔAIC	AUC
IE.1[a]	I:E Ratio	+	0.228	0.00	0.76
VNS.1[a]	Inflow	+	0.271	0.91	0.76
pCVP.1	Exports	+	0.347	2.42	0.76
SWP.1	Exports	-	0.574	4.73	0.76
OMT.1net	Flow	+	0.434	3.45	0.76
Tmsd.7dadm	Temp.	-	0.662	5.57	0.75
CVPSWP.1	Exports	-	0.706	5.50	0.75
SAC.1	Inflow	+	0.815	5.89	0.75
CVP.1	Exports	-	0.994	6.17	0.75

a = $\log_e$ scale

Survival from Turner Cut Junction to Chipps Island vs. Fork Length and Route



Route Effect: P<0.001

AUC of null model (Route + Year + Fork length) = 0.75

26

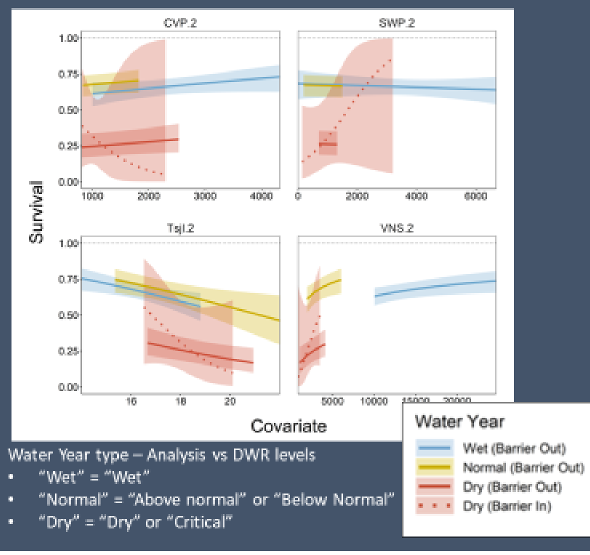
Cite 7. Model selection results for covariates evaluated for their ability to account for variation in observed survival of acoustically tagged steelhead smolts in Region 2. Small differences in AIC between candidate models and the null model (Route + Year + Fork length), along with high p-value suggest that none of the covariates considered have support in explaining patterns of steelhead survival in Region 2. For more information about multi-model inference and the interpretation of model selection results, see Hobbs and Hilborn (2006). Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

Cite 8

Head of Old River to CVP/CCFB/Highway 4: Modeling Results (2009 – 2017)

	Name	Type	Sign	P	ΔAIC	AUC
	Tsjl.2	Temp.	-	0.014	0.00	0.67
*	VNS.2[a]	Delta inflow	+	0.022	2.89	0.68
	OMT.1net	Flow	+	0.157	15.29	0.67
	OMT.1rms	Flow	+	0.158	15.35	0.67
	IE.2[a]	I:E ratio	+	0.173	15.86	0.67
	CVP.2	Exports	+	0.180	16.08	0.67
	pCVP.2	Exports	+	0.287	18.65	0.67
*	SWP.2	Exports	-	0.676	22.37	0.66
*	CVPSWP.2	Exports	+	0.824	22.85	0.66

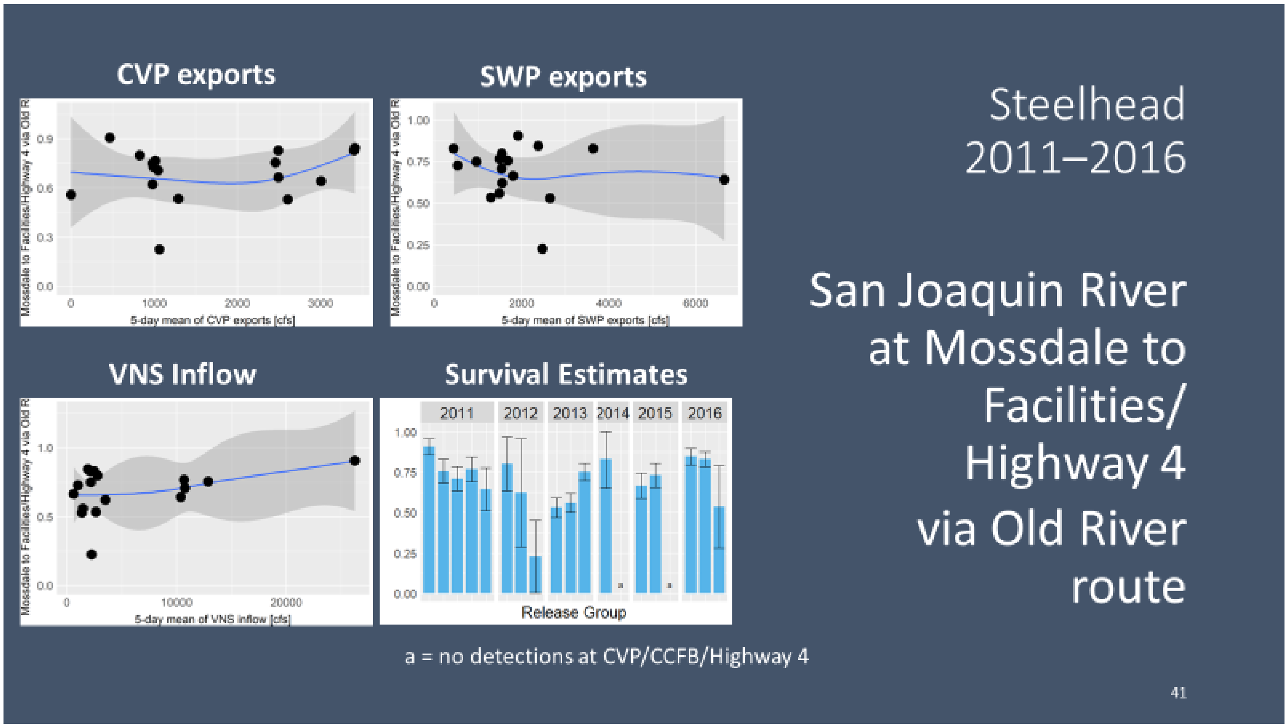
a = $\log_e$ scale
* = results depend on 2011



Water Year type – Analysis vs DWR levels
- "Wet" = "Wet"
- "Normal" = "Above normal" or "Below Normal"
- "Dry" = "Dry" or "Critical"

Cite 8. Model selection results for covariates evaluated for their ability to account for variation in observed survival of acoustically tagged juvenile Chinook salmon in Region 3. Higher survival of juvenile fall-run Chinook salmon was associated with colder water temperatures and higher SJR inflow—models that included covariates including exports, I:E ratio and net flow metrics were not well supported. For more information about multi-model inference and the interpretation of model selection results, see Hobbs and Hilborn (2006). Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

Cite 9



Cite 9. Patterns of steelhead smolt survival in Region 3. Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

Cite 10

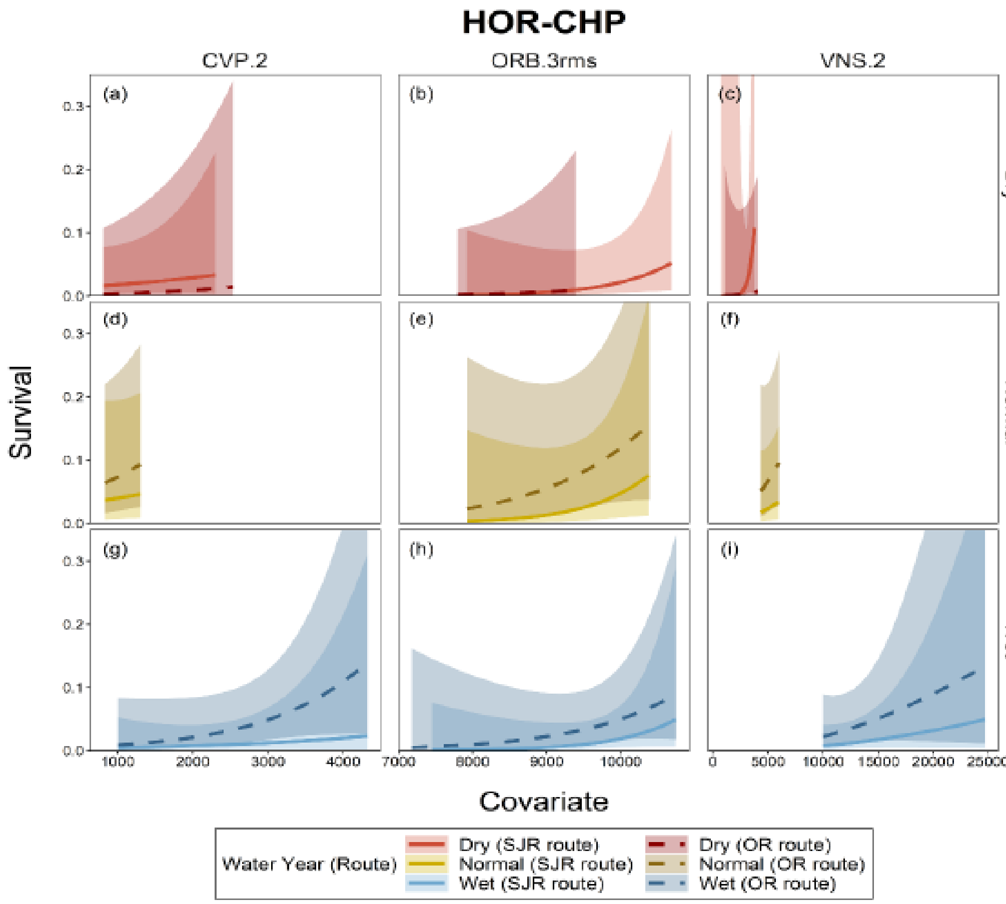


Figure 4. Predicted survival and 95% confidence interval band for survival from the head of Old River (HOR = SJL, ORE telemetry stations) to Chipps Island (CHP) as a function of the 2-day average Central Valley Project export rate (CVP.2), the 3-day root mean square of Old River (OR) flow at Bacon Island (ORB.3rms), and the 2-day average Delta inflow measured at the VNS station (VNS.2). Solid lines represent modeled relationship for the San Joaquin River (SJR) route from the head of OR, and dashed lines represent the relationship for the OR route. Survival predictions for the dry water year type are shown with the physical barrier in place for the SJR route and without the physical barrier for the OR route. Survival was predicted for fish of average fork length at tagging, 107 mm.

Cite 10. Patterns of Chinook salmon survival to Chipps Island as a function of CVP exports in three different water year types (left column of plot above). As described in Buchanan and Whitlock (2022), juvenile salmon surviving to Chipps Island when CVP exports are higher are primarily fish from Region 3.

Cite 11

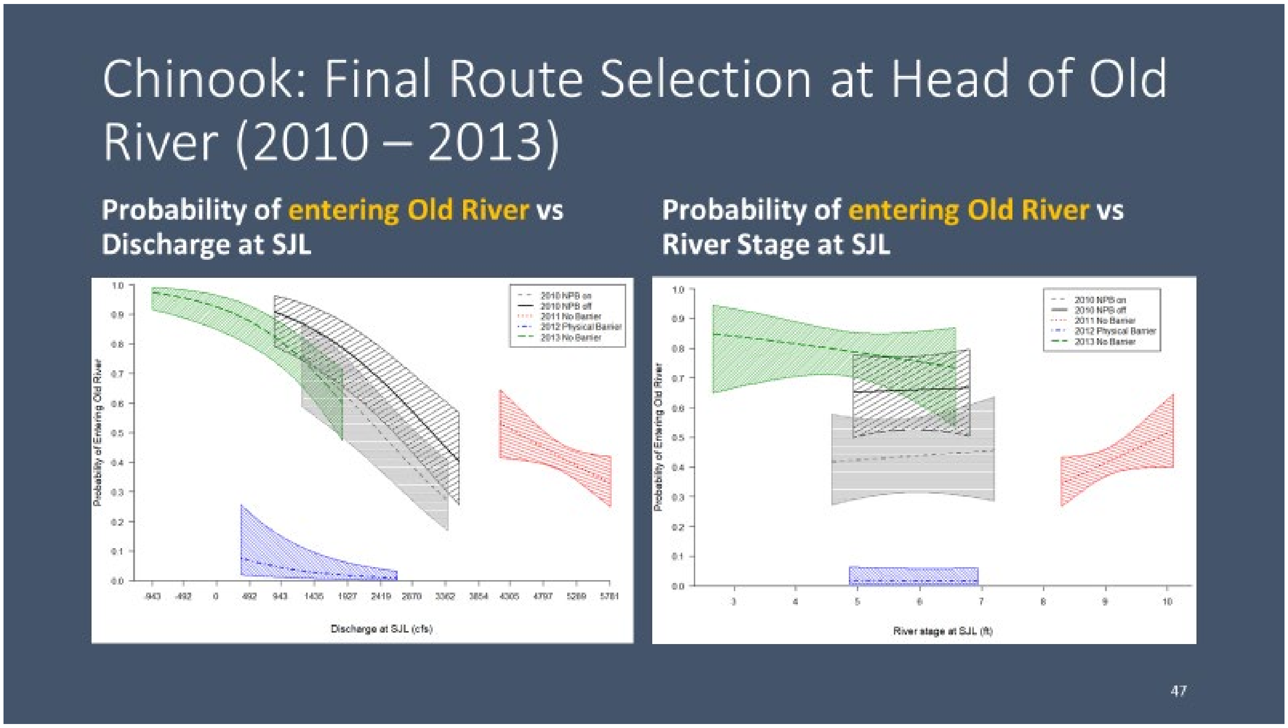
Table 3 Counts of tag detections at SJL and ORE and subsequent detections at Chipps Island (CHP), MacDonald Island (MAC), and Turner Cut (TRN)

Year	Upstream Site		CHP			MAC	TRN
	Station	Count	*11*	*10*	*01*		
2010	SJL	202	9	0	0	75	6
	ORE	228	17	2	0		
2011	SJL	919	5	1	0	348	95
	ORE	656	19	5	1		
2012	SJL	444	14	0	0	97	12
	ORE	9	1	0	0		
2013	SJL	106	0	0	1	2	0
	ORE	341	2	0	0		
2014	SJL	102	0	0	0	1	2
	ORE	9	0	0	0		
Total	SJL	1773	28	1	1	523	115
	ORE	1243	39	7	1		

Detection histories at CHP indicated detection (1) or non-detection (0) at the two parallel lines of acoustic receivers that formed the telemetry station. Detections at MAC and TRN were modeled only for tags detected at SJL

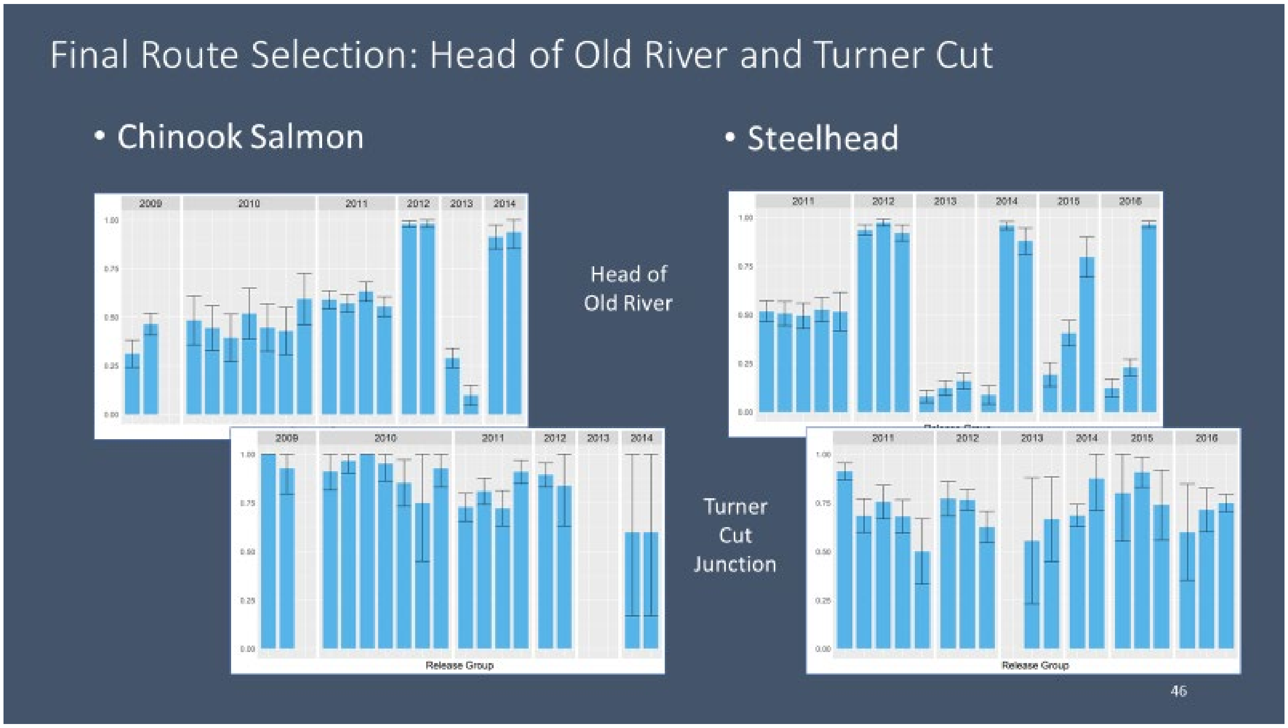
Cite 11. Detections of acoustically tagged Chinook at the entry point of the San Joaquin River route (SJL) and at the entry of the Old River route (ORE) and subsequent detections at Chipps Island. Across all five years, 70 fish were detected at Chipps Island and 47 of those (65%) had passed though Region 3. The authors indicate that these Chipps Island detections are attributable to entrainment and salvage at the export facilities. Source: Buchanan and Skalski (2018)

Cite 12



Cite 12. Effect of San Joaquin River discharge near the HOR junction on the probability of routing into Old River. Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

Cite 13



Cite 13. Proportion of Chinook salmon (left plots) and steelhead (right plots) remaining in the mainstem San Joaquin River at the Head of Old River junction (top plots) and at Turner Cut (bottom plots). Source: Rebecca Buchanan presentation (June 9, 2022) to the STWG.

Cite 14

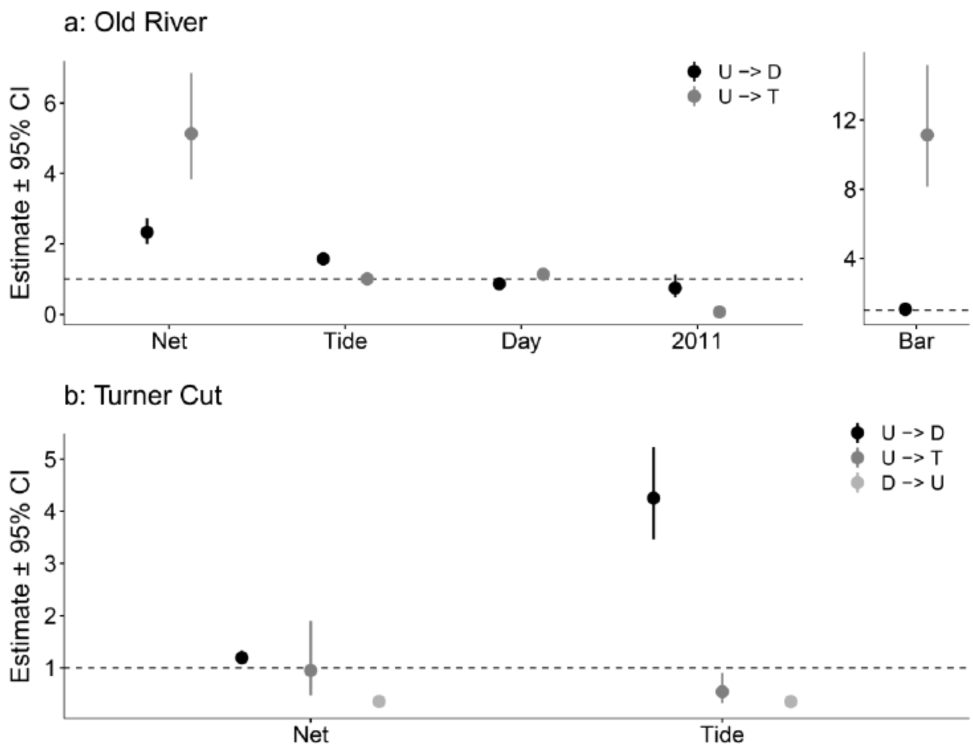
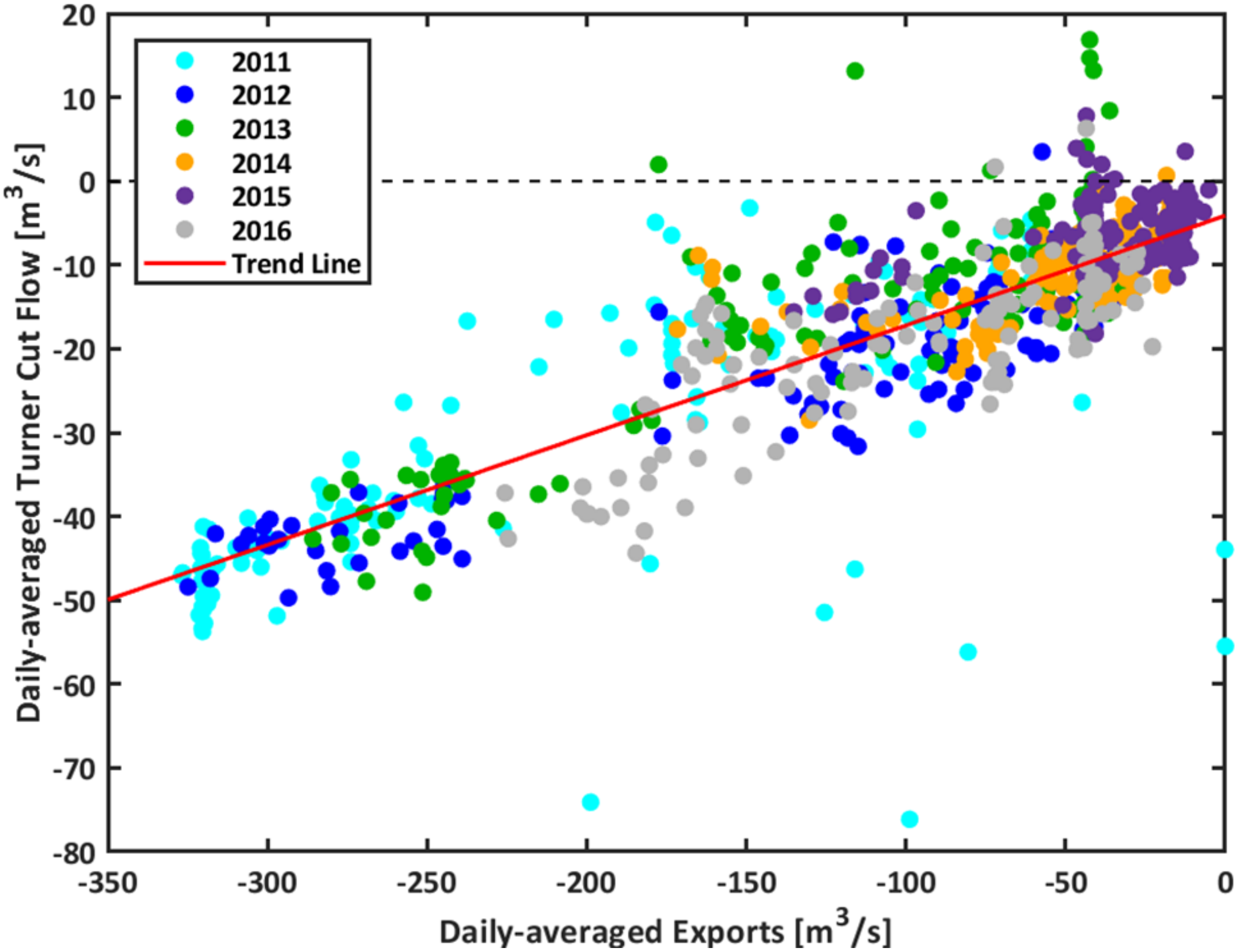


Fig. 5 Coefficient estimates and 95% confidence intervals from the most highly supported model at head of Old River (Panel a) and Turner Cut (Panel b). Note the separate y-axis for the barrier effect. For discrete covariates, Day represents the effect of daytime ($Day = 1$), 2011 represents the year 2011 and Bar represents the effect of the barrier being absent ($Bar = 1$) at the head of Old River. States are defined as San Joaquin Upstream (U), San Joaquin Downstream (D), and Head of Old River or Turner Cut (T).

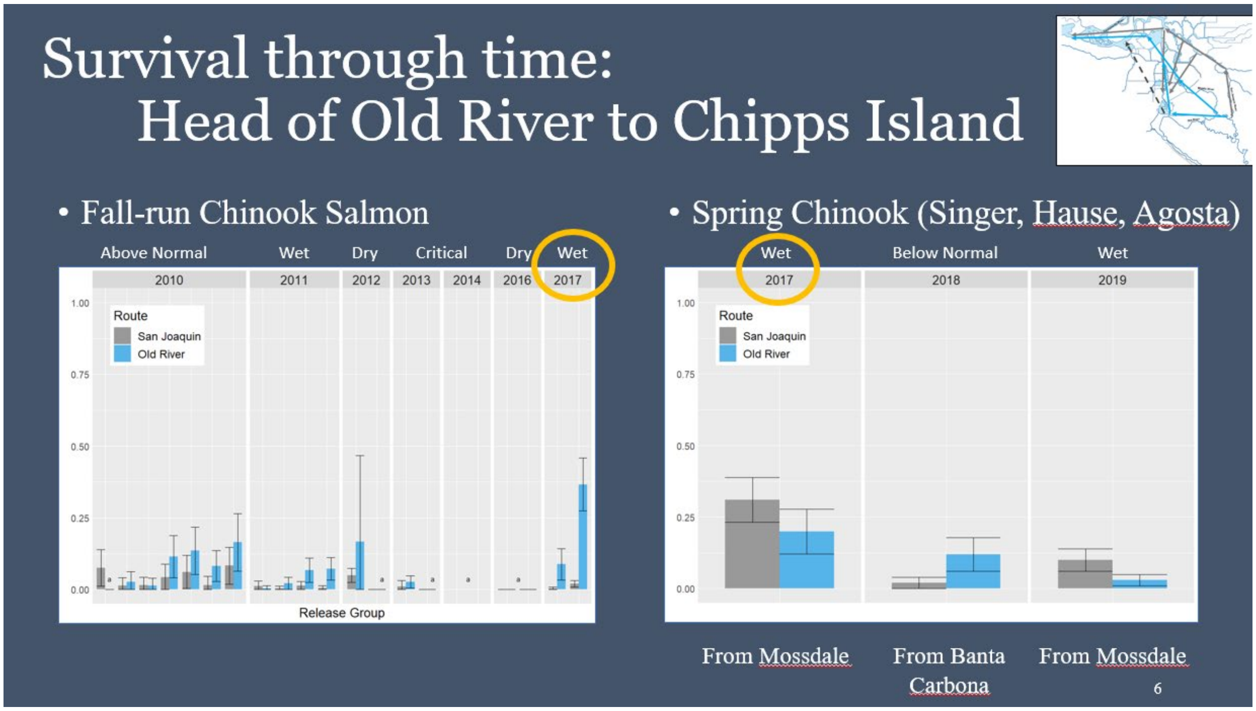
Cite 14. Factors associated with remaining in San Joaquin River at Old River (upper panel) and at Turner Cut (lower panel). Source: Dodrill et al. 2022.

Cite 15



Cite 15. Relationship between daily-averaged flow at Turner Cut and daily-averaged exports. Source: Anchor QEQ 2022.

Cite 16



Cite 16. Interannual patterns of through-Delta survival for fall-run and spring-run Chinook using the Old River route or the San Joaquin River route: Source: Slide 6 from Rebecca Buchanan's presentation to the SWC I:E Science Symposium held on September 13th 2022.

Figure 5

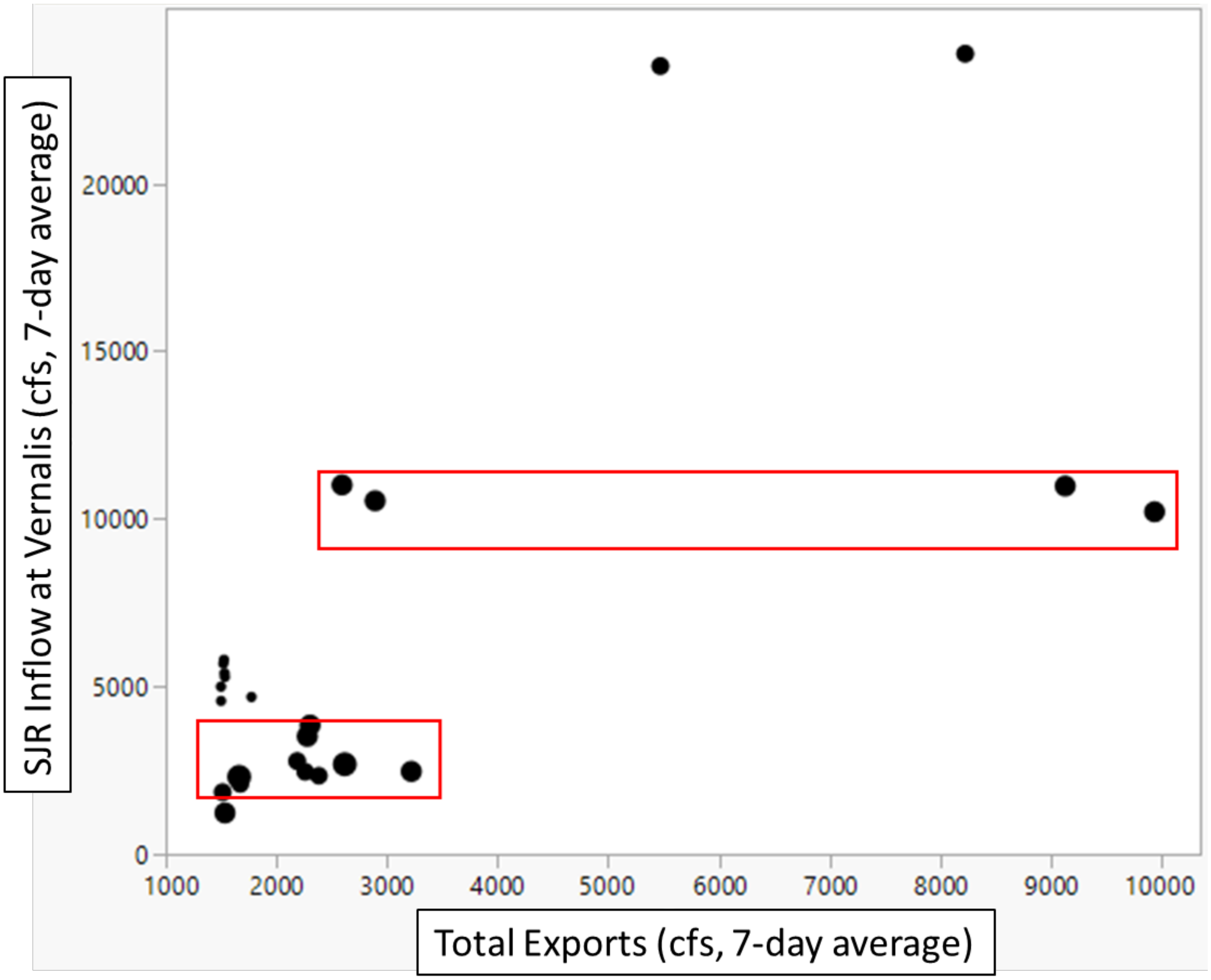


Figure 5. Seven-day average San Joaquin River inflows at Vernalis (y-axis) and total exports (x-axis) for individual release groups of acoustically tagged fall-run Chinook (FRC) considered by the STWG. Size of symbols are scaled to the number of fish in each release group (average: 409 fish, minimum: 72 fish, maximum: 700 fish). Horizontal rectangles (red) highlight range of variable export conditions represented at two levels of San Joaquin River inflow. With low SJR inflow (~2,500cfs), total exports ranged from ~1,500 to ~3,250cfs. With higher SJR inflow (~10,000cfs), two releases each were available for exports at ~2,500cfs and exports at ~9,500cfs.

Figure 6

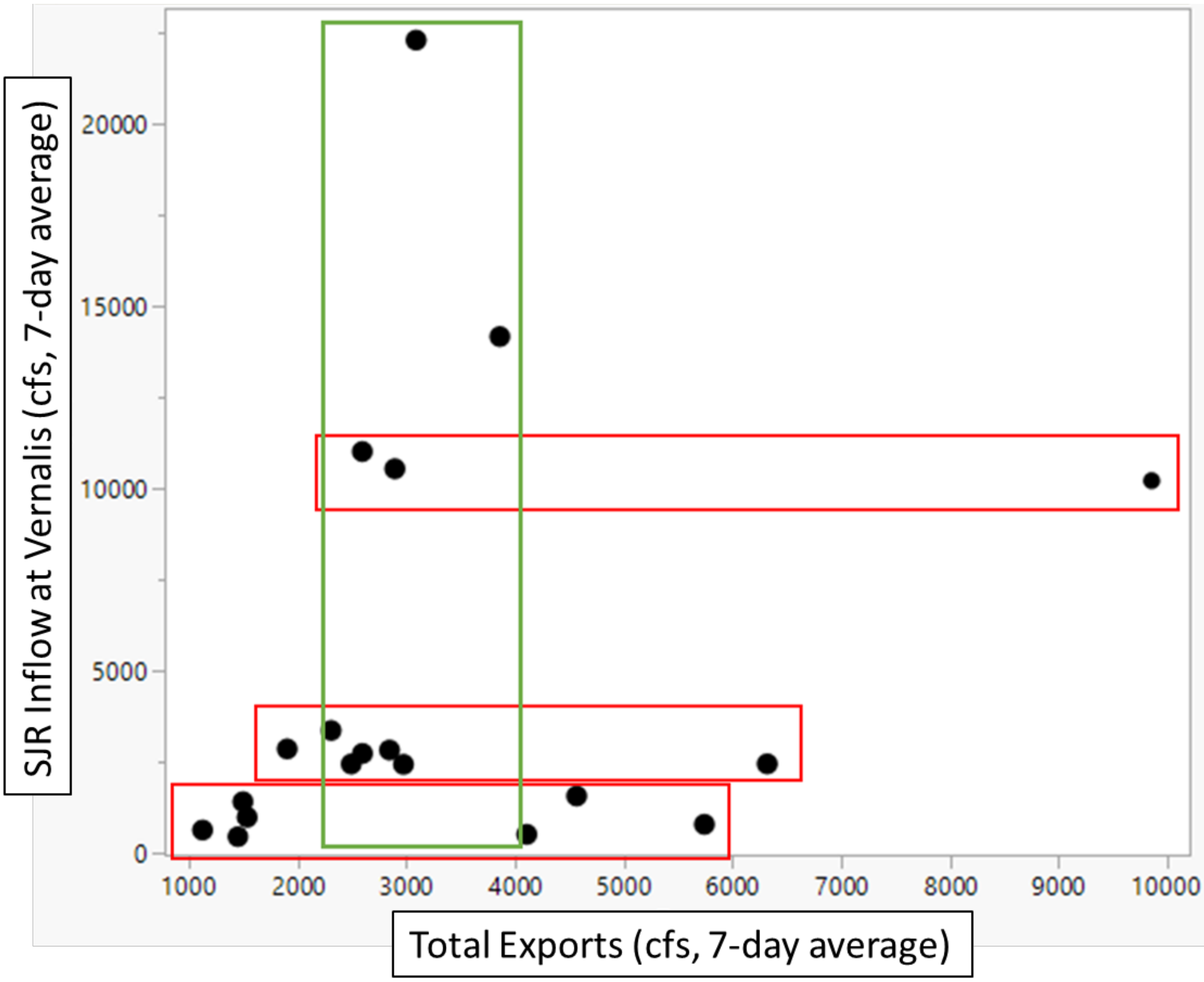


Figure 6. Seven-day average San Joaquin River inflows at Vernalis (y-axis) and total exports (x-axis) for individual release groups of acoustically tagged steelhead smolts (STH) considered by the STWG. Horizontal rectangles (red) highlight range of variable export conditions represented at three levels of San Joaquin River inflow. With low SJR inflow (~1,500cfs), total exports ranged from ~1,000 to ~6,000cfs. With low-med SJR inflow (~3,000cfs), exports ranged from ~1,750 to ~6,500cfs. With higher SJR inflow (~10,000cfs), exports ranged from ~2,500 to ~9,750cfs. Vertical rectangle (green) highlight range of variable SJR inflows (~2,500 to 25,000cfs) represented with exports between ~2,250 and ~4,000cfs.

Figure 7

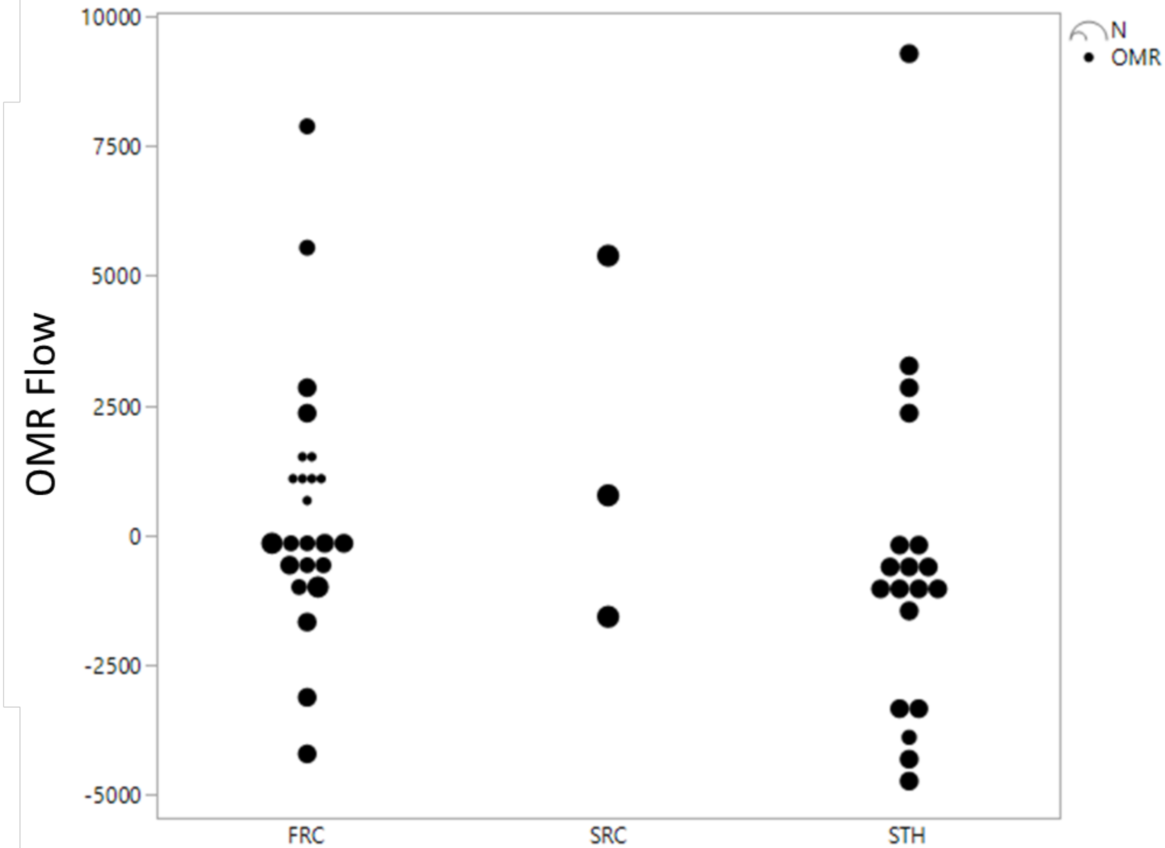


Figure 7. Seven-day average OMR index flows for individual release groups of acoustically tagged fall-run Chinook (FRC), spring-run Chinook (SRC) and steelhead smolts (STH) considered by the STWG. Size of symbols are scaled to the number of fish in each release group (average: 409 fish, minimum: 72 fish, maximum: 700 fish).

Figure 8

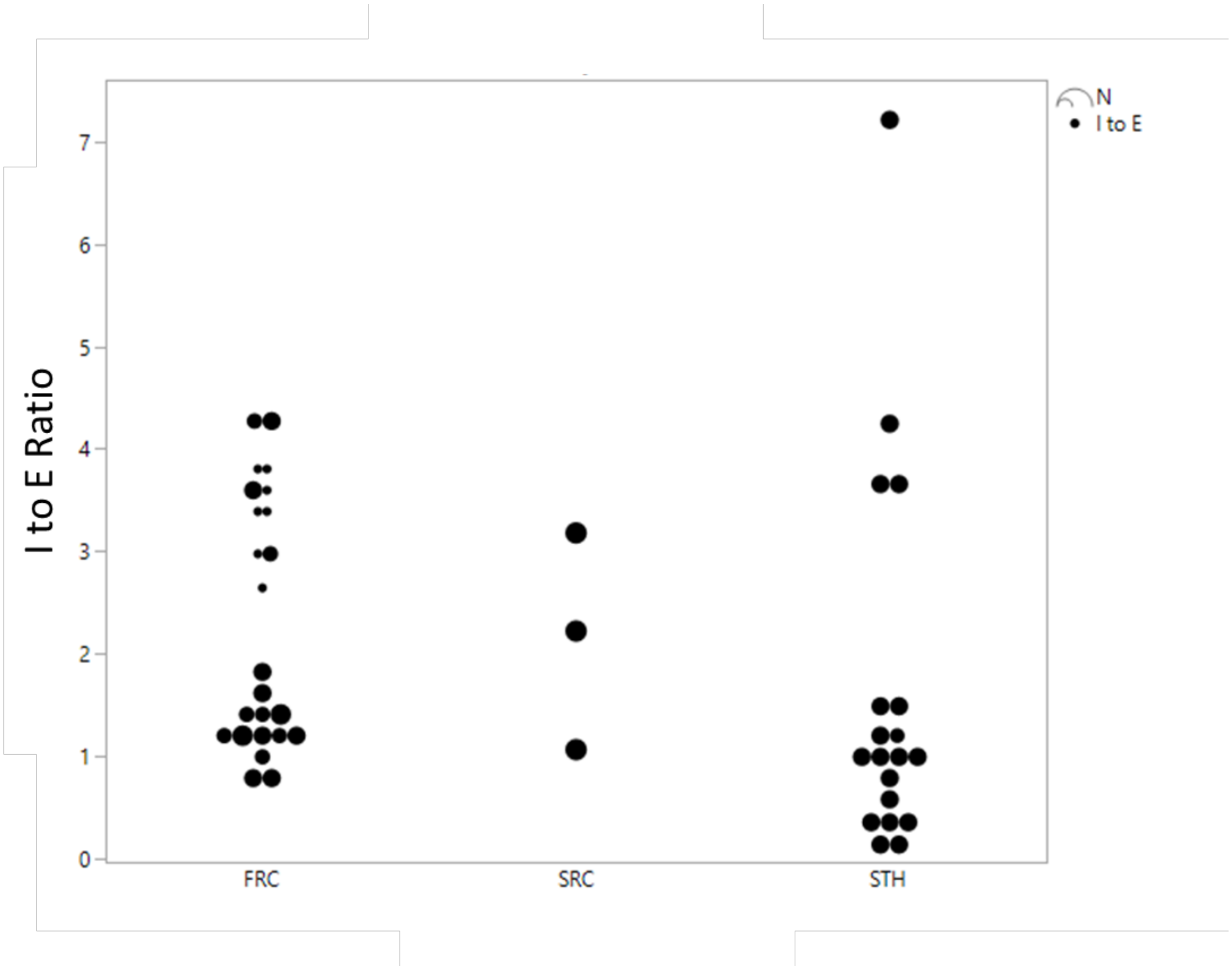


Figure 8. Seven-day average San Joaquin River inflow to total export ratio (I to E) for individual release groups of acoustically tagged fall-run Chinook (FRC), spring-run Chinook (SRC) and steelhead smolts (STH) considered by the STWG. Size of symbols are scaled to the number of fish in each release group (average: 409 fish, minimum: 72 fish, maximum: 700 fish).