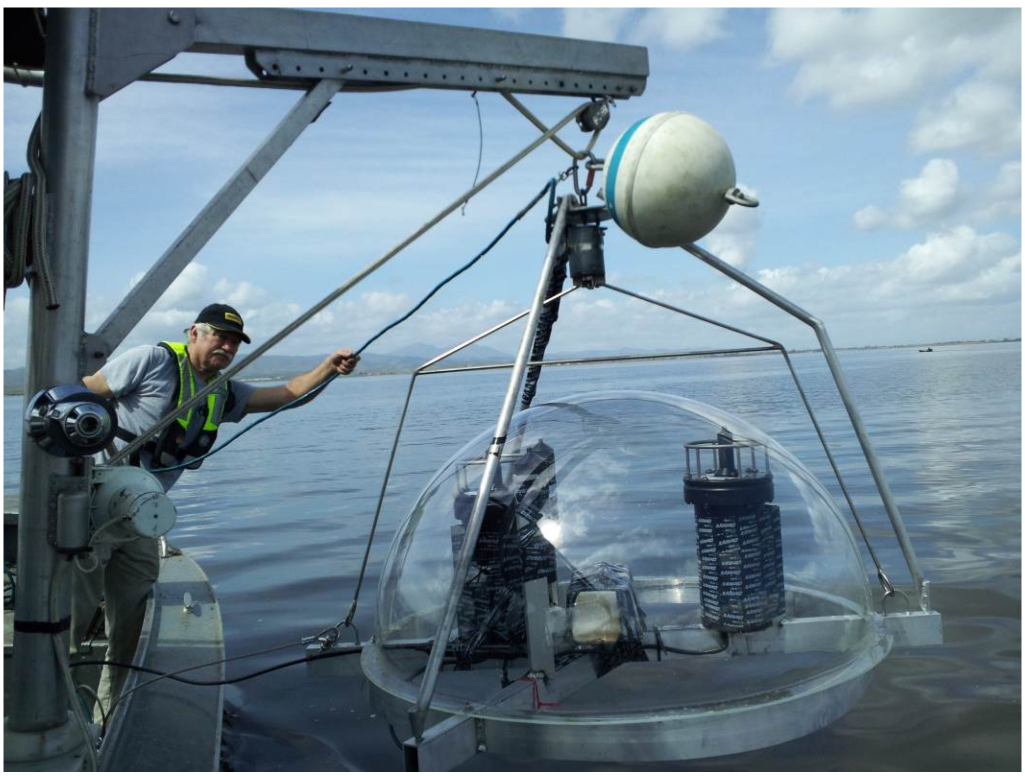
RECLAMATION
*Managing Water in the West*

**NMFS Biological Opinion RPA IV.2.2**

# 2012 Six-Year Acoustic Telemetry Steelhead Study



## NMFS Biological Opinion RPA IV.2.2

# 2012 Six-Year Acoustic Telemetry Steelhead Study

*Contributions by:*
*Rebecca Buchanan[2]; Pat Brandes[3]; and, Joshua Israel[1]*

*Compiled and Edited by*
*Elissa Buttermore[1] and Pat Brandes[3]*

*[1] U.S Department of the Interior*
*U.S. Bureau of Reclamation*
*801 I Street, Suite 100*
*Sacramento, CA 95626*

*[2]University of Washington*
*Columbia Basin Research*
*1325 Fourth Street, Suite 1820*
*Seattle WA 98101-2509*

*[3]U.S Department of the Interior*
*U.S. Fish and Wildlife Service*
*Lodi Fish and Wildlife Office*
*850 Guild Ave, Suite 105*
*Lodi, CA 95240*

## MISSION STATEMENTS

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

______________________

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

## SUGGESTED CITATION:

U.S. Bureau of Reclamation (USBR). 2018. NMFS Biological Opinion RPA IV.2.2: 2012 Six-Year Acoustic Telemetry Steelhead Study. Contributions by Buchanan, P. Brandes, R., J. Israel, E. Buttermore. Reclamation Bay-Delta Office, Mid-Pacific Region, Sacramento, CA. FINAL REPORT May 16, 2018, 172p.

## Bay-Delta Office

David Mooney, Manager

Josh Israel, Science Division Chief

## COVER

Receiver deployment. Photograph by J. Israel

## DISCLAIMER

## Acknowledgments

Several individuals from a variety of agencies made this project possible.  Those agencies and individuals who participated in the tagging and release components of the project were; USFWS: Amber Aguilera, Denise Barnard, Crystal Castle, Dustin Dinh, David Dominguez, Kyle Fronte, J. Scott Foot, Garrett Giannetta, Jack Ingram, Carlie Jackson, Joseph Kirsch, David LaPlante, Jerrica Lewis, Mike Marshall, Louanne McMartin, Greg Nelson, Jacob Osborne, Lori Smith, Brent Trim, and Rob Wilson; California Department of Water Resources: Roxanne Kesler, Bryce Kozak , and Matt Silva; AECOM: Curtis Yip; and USBR: Raymond Bark. USGS provided training for the surgeons (Theresa [Marty] Liedtke) and was responsible for the deployment, maintenance and retrieval of the receiver array (Jon Burau, Chris Vallee, Jim George and Norbert VandenBranden).  Mike Simpson, retired from USGS, processed the tag observation data prior to giving it to the University of Washington for analysis.

# Table of Contents

# Introduction

The NOAA National Marine Fisheries Service's (NMFS) Biological Opinion (BO) on Long-term Coordinated Operation of the Central Valley Project (CVP) and State Water Project (SWP) includes a Reasonable and Prudent Alternative (RPA) action to undertake experiments utilizing acoustic-tagged salmonids to identify 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 2009a). This study is to coincide with different periods of operations and focus on clipped hatchery steelhead (*Oncorhynchus mykiss*), but may include fall run Chinook (*O. tshawytscha*) as surrogate fish or wild steelhead smolts from tributaries for comparative purposes, when appropriate and permitted.

The study period of interest is between March 1 and June 15, which coincides with a majority of *O. mykiss* outmigration from the Stanislaus River (USBR 2018) and recoveries of steelhead smolts in the Mossdale fish monitoring efforts (USBR 2018). This period also includes changes in CVP/SWP operations including reductions in exports, reductions in reverse flows in Old and Middle rivers (OMR), and San Joaquin River pulse outflows.

Salmonids in the San Joaquin River basin were once abundant and widely distributed, but currently face numerous limiting factors. The NMFS Central Valley Recovery Plan identified that some of the most important stressors for juvenile steelhead outmigration on the San Joaquin River include habitat availability, changes in hydrology, water temperature, reverse flow conditions, contaminants, habitat degradation, and entrainment (NMFS 2014). It is possible that reduced survival of emigrating smolts may be the greatest management concern to preserving anadromy in *O. mykiss* (Satterthwaite et al. 2010). The impacts of these stressors can be studied using acoustic telemetry, and an updated conceptual model, developed by the South Delta Salmonid Research Collaborative (SDSRC), demonstrates how experimental variables of interest to the Six-Year Study (i.e. Delta water operations, tributary water operations, and habitat) are influential in survival and behavior of emigrating smolts (Figure 1). This conceptual model has guided specific hypotheses and investigations of the Six-Year Study.

Recent advances in acoustic technology have allowed investigators to evaluate the influence of behavior, species interactions, and physiology on reach-specific survival of salmonids in the Sacramento-San Joaquin river basins (Perry 2010, Vogel 2010). Water operations for fish protection in the San

Joaquin River include increasing river flows for salmonid emigration, reducing export diversions and reverse flows, and directing fish away from the south delta water project facilities via nonphysical or physical barriers. NMFS (2009a) identified flow at Vernalis, export volume, and the ratio of Vernalis flow-to-export as variables to test during this study as priority variables. Separating the effects of these covariates is difficult because the variables are likely to be correlated.

Steelhead in the San Joaquin River belong to the Southern Sierra Nevada Diversity Group of the Central Valley steelhead Distinct Population Segment (DPS). Significant variation in juvenile size and age at outmigration, river residency, and reproductive age has been noted in Central Valley steelhead. Steelhead spawn in Central Valley tributaries during the winter and spring. Steelhead smolts emigrate during the winter and spring high flows, and use the lower San Joaquin River and delta for rearing and migration. On the Sacramento River, acoustic-tagged juvenile hatchery steelhead smolts can take days to over a month to emigrate from the upper Sacramento River through the delta. Recent monitoring has detected small, non-hatchery origin steelhead populations in the Stanislaus, Tuolumne, and Merced rivers (Zimmerman et al 2009, McEwan 2001). Genetic studies have not observed significant genetic divergence among hatchery and natural steelhead or *O. mykiss* populations below dams on the Sacramento and San Joaquin rivers (Garza and Pearse 2009). Because naturally emigrating *O. mykiss* are rare, this study used the closest hatchery stock of steelhead, found at the Mokelumne River Fish Hatchery. Recent review panels have suggested that Chinook salmon are a poor surrogate for steelhead (DSP 2009), thus simultaneous survival studies of juvenile Chinook salmon and steelhead smolts occurred in 2011 and 2012.

The NMFS Biological Opinion includes two actions that influence CVP/SWP export and discharges through the San Joaquin River and Old and Middle River corridor during the study period. Action IV.2.1 identifies targeted levels of export dependent on San Joaquin inflow at Vernalis, which may increase with higher San Joaquin inflow during wetter periods (i.e. inflow to export (I/E) ratio) (NMFS 2009a). This action is calendar based and occurs between April 1 and May 31. The action hypothesizes to increase survival of emigrating salmonids by reducing fishes' vulnerability to entrainment into the south Delta and at the CVP/SWP facilities by increasing the San Joaquin inflow to export ratio. Action IV.2.3 identifies targeted flow through the Old and Middle River corridor (NMFS 2009a). Similar to Action IV.2.1, this action attempts to increase survival of emigrating Sacramento and San Joaquin origin ESA-listed salmonids by reducing their vulnerability to entrainment into the south Delta and pumps. The initial level of -5,000 cfs through Old and Middle rivers is calendar-based and runs between January 1 and June

15, but increased entrainment of ESA-listed salmonids ESUs and steelhead can require modifying hydraulic conditions in the Old and Middle River corridor so that the net downstream flow is greater than -5,000 cfs and meets targets of -3,500 cfs and -2,500 cfs.

In 2011, the Six-Year Study was coordinated with the VAMP and South Delta Temporary Barriers fish monitoring studies to simultaneously release juvenile steelhead and fall-run Chinook salmon to examine questions concerning surrogacy and species-specific route selection and survival estimates. In 2012, the Six-Year Study funded the deployment of the receiver array throughout the Delta which detected tagged fish from other studies, such as Reclamation's San Joaquin Flow Modification Project (SJFMP) and the U.S. Fish and Wildlife Service's Chinook salmon survival Study. In 2012, the Six-Year Study changed tag technology to VEMCO to support the integrated fish survival and behavioral studies funded by Reclamation and USFWS for the San Joaquin River Restoration Program, and the salmonid survival studies being undertaken by East Bay Municipal Utility District. Finally, in 2012, the acoustic telemetry study implemented as part of the "Joint Stipulation Regarding CVP and SWP Operations in 2012" was also coordinated with the Six-Year Study. In combination with the Six-Year Study steelhead releases, that study attempted to provide finer-scale information on steelhead route entrainment and survival in the Old and Middle River (OMR) corridor and adaptive management of OMR flows, to test hypotheses about fish distribution and the ability to manage residence times to reduce exposure to degraded habitat and direct take at the export facilities (Delaney et al 2014). The 2012 Six-Year Study used the same receiver array deployment, tagging and release SOPs as in the 2011 Six-Year Study (USBR 2018), and included three releases between early April and mid-May.

## Project Objectives

It is unknown what increased level of steelhead survival would be targeted by the various operational conditions required by the RPA; this question is one objective of the study. In addition, relevant fish management objectives identified in NMFS Opinion Action IV.2.2 include:

a) Determine survival of emigrating smolts from the tributaries into the mainstem of the San Joaquin River.
b) Determine survival of emigrating smolts through the mainstem San Joaquin River downstream into the Delta.
c) Determine survival of emigrating smolts through the Delta to Chipps Island.
d) Assess the role and influence of flow and exports on survival in these migratory reaches.

e) Identify reach-specific mortality and/or export loss of tagged fish.

f) Assess the influence of flows and exports on route entrainment and selections by tagged fish.

g) Test effectiveness of experimental technologies on route entrainment and selection by tagged fish.

## Uncertainties and Assumptions

### O. MYKISS RESIDENCY

One complexity of working with *O. mykiss* is their residency in San Joaquin Basin tributaries. It is unknown what proportion of *O. mykiss* may remain as a resident or residualize following tagging. It is anticipated that after the first three years of the study (2011-2013), movement data will be available to quantify residency and develop a survival model that includes residency as a parameter influencing the accuracy of observations.

### SURROGACY OF FALL-RUN CHINOOK

Given the rarity of *O. mykiss* smolts originating from San Joaquin basin tributaries, this study used fall run Chinook salmon as a surrogate in 2010 to evaluate relevant issues concerning tributary survival of steelhead smolts. As noted by the 2010 VAMP Review Panel (Dauble et al, 2010), life history differences between Chinook salmon and steelhead are striking and it is likely that Chinook salmon surrogates do not provide a reliable basis for inference concerning flows and steelhead survival. The differences between the targeted study species, juvenile steelhead, and surrogate species, juvenile Chinook salmon, can be evaluated by comparing the influence of measured environmental parameters (e.g. flow, exports, and temperature) on survival of both species.

### USE OF HATCHERY CLIPPED STEELHEAD

The 2010 VAMP Review Panel suggested that hatchery steelhead are a reasonable source, although complementary studies with juvenile Chinook salmon were suggested to be paired with investigations using hatchery steelhead to examine the issues of inference between species. While using hatchery steelhead provides a critical benefit, it includes the potential risk of straying of hatchery steelhead back into the San Joaquin River tributaries. The genetic threat of straying is likely very low, based on recent genetics studies (Garza and Pearse 2009) that characterized populations of naturally spawning *O. mykiss* below tributary dams with non-native hatchery broodstocks (i.e. Nimbus hatchery). These studies suggest that all below-barrier *O. mykiss* have introgressed across the Central Valley and thus, it may be assumed straying impacts from this study would be minimal because no below-barrier native populations exist on the San Joaquin River tributaries. Additionally, potential study survival rates were considered in an integrated demographic risk evaluation of potential straying individuals caused by the study; it was determined that with the proposed sample sizes during the 2012 (n = 1500), very high ocean survival would be necessary for fish surviving through the Delta and Bay, to return.

# Methods

A total of 1,435 acoustic-tagged steelhead were released into the San Joaquin River at Durham Ferry in April and May of 2012: 477 in early April, 478 in early May, and 480 in mid-May. Acoustic tags were detectable on hydrophones located at 26 stations throughout the lower San Joaquin River and Delta to Chipps Island (i.e., Mallard Slough). In 2012, the Head of Old River Barrier (HORB) was installed, beginning on March 15 and completed on April 11. Removal of HORB began on June 1 and was completed on June 20. Personnel from the Stockton Fish and Wildlife Office were tasked with the tagging, transport, holding and release components of the Six-Year Study, while receiver deployment and maintenance were tasks of the U.S. Geological Survey. Rebecca Buchanan of University of Washington conducted the survival analysis. The report was jointly developed.

## Sample Size Analysis

Modeling of juvenile salmon survival in the San Joaquin River for the 2011 VAMP study (SJRGA 2013) was used to determine the minimum number of fish released at Durham Ferry for the 2011-2013 releases (Buchanan 2010). Buchanan (2010) derived release size estimates for two overall survival values while leaving route selection proportions at Head of Old River constant with a high detection probability at Chipps Island. Given these assumptions, Buchanan (2010) recommended a sample size of 475 for estimating survival to Chipps down the Old River and San Joaquin routes if survival in the Old River route was low (0.05). Additionally, if survival between Durham Ferry and Chipps Island was higher (0.15) and survival between Durham Ferry and the Old River junction was high (0.9), a release of 475 at Durham Ferry would be able to detect a 50% difference between survival in the San Joaquin River and Old River routes. Thus, a release group of 475 at Durham Ferry was expected to provide accurate information about route entrainment and survival for examining biotic and abiotic factors influencing juvenile steelhead survival.

## Tagging Transport, Release, and Fish Health Methods

### Study Fish

A total of 2,500 steelhead trout (*O. mykiss*) from the Mokelumne River Hatchery (MKRH) were requested for use from the California Department of Fish and Game for the 2012 Six-Year Study. Fish were used for the acoustic telemetry releases, tag retention studies, dummy tag studies, and fish health studies.

The fish were tagged at the MKRH with support from CDFW and EBMUD. Fish used for the study (1,435) weighed on average 131.2 g (SD = 52.1 g) and ranged between 36.1 and 373.9 g. Fish length averaged 233.6 mm (SD = 24.5 mm) and ranged between 115 and 316 mm.

## TAGS

VEMCO V6-180 khz tags were used for tagging. Four hundred and forty-eight tags from the last tagging week were weighed, and had a mean weight of 1.05 grams (SD = 0.01 g) in air. The percentage of tag weight to body weight averaged 0.7% (SD = 0.26%) for the 448 steelhead that contained tags that had been weighed. This sub-sample of fish had tag burdens much lower than the 5% recommended.

Tags were custom programmed with three codes: a traditional Pulse Position Modulation (PPM) style coding along with a new hybrid PPM/High Residence (HR) coding. The HR component of the coding allowed for detection at high residence receivers. High residence receivers were placed in locations where high densities of tags and tag signal collisions (i.e. many tags emitting signals at the same time to the same receiver) were anticipated (CVP, Clifton Court Forebay). The transmission of the PPM identification code was followed by a 25-35 second delay, followed by the PPM/HR code, followed by a 25-35 second delay, and then back to the PPM code, etc. The PPM code consisted of 8 pings approximately every 1.2 to 1.5 seconds. This sequence of 8 pings was transmitted every 50 to 70 seconds. The PPM/HR code also consisted of 8 pings transmitted within 1.2 to 1.5 seconds every 50-70 seconds. Each of the 8 pings of the PPM/HR transmission also contained an HR code that was the same for each transmitter. The PPM and PPM/HR transmissions were alternated such that a tag transmitted on average every 30 seconds.

Tags were soaked in saline water for at least 24 hours prior to tag activation. Tags were activated using a VEMCO tag activator (Figure 2) approximately 24 hours prior to tag implantation.

## SURGERY TRAINING

U.S. Geological Survey's Columbia River Research Laboratory (CRRL) lead a tagging training session during the week of March 19, 2012, at Mokelumne River Hatchery using steelhead reared at the facility. Four surgeons were trained and used for the study. In addition, four assistants, three runners, and a tagging coordinator participated in the training and tagging. Three surgeons from USFWS (two of whom were experienced) and one from DWR were used during the study. Training of tagging staff was conducted by the US Geological Survey's (USGS) Columbia River Research Lab (CRRL) following methods similar to 2011 and incorporated into a Standard Operating Procedure (SOP) (Appendix A). Five taggers were trained in order to provide an alternate, capable tagger that could be available if one of the four main taggers was not available.

All tagger trainees were required to meet established tagging goals (standards) by the end of the training period in order to be eligible for participation in the study tagging phase of the operation. The returning taggers received a practical refresher on surgical tagging and were required to tag a minimum of 35 fish. New taggers received in-depth instruction on surgical techniques and were required to tag a minimum of 75 fish during the training period (Appendix A). The training combined classroom and hands-on practical lessons. Training included sessions on knot tying, tagging bananas, tagging dead fish and finally tagging live fish, holding them overnight and necropsying them to evaluate techniques and provide feedback. As technique improved, taggers were encouraged to work toward faster implantation times. The goal was to be able to implant fish within 3-4 minutes, on average, so as to limit the amount of time that fish were out of the water on the tagging platform, thereby limiting the stress response. Taggers learned to balance speed and proper execution. The surgery time was recorded for training fish as a quantitative measure of proficiency. Lastly, a mock tagging session was held on March 23 to practice logistic procedures and to identify potential problems and discuss solutions.

## TAGGING

Training and tagging operations occurred at the DWR Collection, Handling, Transport and Release (CHTR) Laboratory for tagging steelhead using standard operating procedures (SOP) developed by the CRRL (Appendix A) and refined during the training week. Steelhead tagging occurred between April 3, 2012 and May 21, 2012 (Table 1). Feed was withheld from study fish for 24 hours prior to transmitter implantation. During each tagging session, fish were surgically implanted with a V6 VEMCO acoustic transmitter into the fish's peritoneal cavity (Figure 3), following procedures bases on a standard operation procedure (SOP) develop by the USGS's Columbia River Research Laboratory (Appendix A).

The SOP directed all aspects of the tagging operation and several quality assurance checks were made during each tagging session to ensure compliance with the SOP guidelines (Appendix A).

Prior to implantation, fish were anesthetized in 70mg/L tricane methanesulfonate buffered with an equal concentration of sodium bicarbonate until they lost equilibrium. Fish were removed from anesthesia, and were measured (fork length (FL) to the nearest mm) and weighed (the nearest 0.1g). No minimum or maximum fish weight criteria were used.

Two sutures were used to close the incision (Figure 4); typical surgery times were less than 3 minutes. Fish were then placed into 19L (5 gal) buckets with aerators following recovery from anesthesia to ensure survival and normal swimming behavior. Each bucket was labeled with a unique code.

### Transmitter Validation

A VEMCO VR100 receiver (Figure 5) with a 180 khz hydrophone (Figure 6) was placed into each recovery bucket to confirm that tags were emitting the correct code immediately after tagging. Hydrophones were covered with material to reduce the electronic interference (multi-path) of detecting fish in a small bucket.

### Transport to Release Site

After transmitter validation, pairs of buckets containing one or two fish each were combined into a perforated 68 L (18 gallon) tote within a 68 L non-perforated tote (sleeve)(Figure 7), for a total of three fish in each tote. A lid was placed on the tote and then it was moved into a transport tank on a large 8 m (26 foot) flat-bed truck (Figure 8). Immediately prior to loading, all fish were visually inspected for mortality or signs of poor recovery from tagging (e.g. erratic swimming behavior). Fish that died or were not recovering from surgery were replaced with new tagged fish.

In order to minimize the stress associated with moving fish and for tracking small groups of individually tagged fish, three specially designed transport tanks were used to move steelhead from the MKRH, where the tagging occurred, to the release site at Durham Ferry. The transport tanks for steelhead were designed to securely hold 24 68-L perforated totes. The transport tanks had an internal frame that held 24 totes in individual compartments to minimize contact between buckets and to prevent tipping (Figure 9). Water levels in the transport tanks were 3 to 4 inches below the top of the totes, to allow the fish access to air for reestablishing neutral buoyancy after the handling during the tagging process. Totes were covered in the transport tanks with stretched cargo nets to assure totes did not tip over and lids did not come off (Figure 10).

Each transport tank was outfitted with an oxygen system (Figure 10) allowing dissolved oxygen (DO) levels to be regulated, maintaining fish health. The oxygen system consisted of two oxygen tanks mounted to a metal frame. A Weldmark (Model # RC250-80-540) medium-duty regulator was used to regulate pressure from the tank to a Victor (Model # 1000-0189) 7LPM flow meter. The oxygen flow rate was maintained at 2LPM during transport. If DO levels were above 10 mg/L (100% saturated), the oxygen flow rate was reduced. A YSI Pro DO meter was used to measure DO and temperature.

Water temperature and DO in the transport tanks were recorded after loading totes into transport tanks and before leaving the MKRH and at the release site after transport. Water temperatures were continuously monitored in the transport tanks during transport using an Onset TidbiT v2 temperature logger. Transport time from the MKRH to Durham Ferry took approximately 75 minutes. Temperature loggers were usually downloaded at the end of each transport period. Three separate trips to the release site were made each tagging day.

### Transfer to Holding Containers

Once the transport truck reached the holding site, temperature and dissolved oxygen (DO) were measured and recorded. If the difference between the temperature of the transport tank water and the river was >5˚C, the fish required tempering. Tempering consisted of adding river water to the 68 L tote in 11 L (three gallon) increments. Once the water was added the fish were allowed to acclimate for a period of 15 minutes at which time the temperature was taken again. If the difference in temperature between tote water and river water was <5˚C, the fish were ready to be placed into the holding containers. If additional tempering were required, the process of adding three gallons of river water to the tote was repeated. Tempering was required on only one day during the study (May 21; all three truckloads).

Once totes were ready to be transferred to the holding containers, totes were moved from the transport truck to the river using a pick-up truck. Eight non-perforated totes (sleeves), placed into the bed of a pick-up truck, were filled 1/4 full of river water, and then the pick-up was driven up the levee and parked next to the transport truck. Perforated totes were then lifted out of the transport tank by the transport truck driver and another crew member, handed to crew in the back of the pick-up, and placed into the partially filled tote sleeves (Figure 11). Once the pick-up truck was filled with approximately 8 totes, the pick-up truck was driven a short distance to the river's edge. Perforated totes were then unloaded from their sleeves in the pick-up truck and given to crew on the ground for carrying to the river's edge and to perforated holding cans anchored in the river. Multiple trips were made with the pick-up truck until all perforated totes were unloaded from the transport tank.

Steelhead were loaded into in 166 L (44-gallon) perforated holding cans (Rubbermaid, Commercial Brute Plastic Vented Utility Container, round, 61 cm [24"] diameter x 80 cm [31.5"] height). These holding containers were held in the river, attached to a tether line (Figure 12). Holding containers had perforated hole sizes of 1.24 cm in diameter. Four totes containing three fish each were usually emptied into each holding container, but occasionally the number in the holding container was less (4, 6, 8 or 11). Twelve steelhead were generally moved into each of 12 or 13 166-L holding cans, with 1 or 2 cans having fewer steelhead per day. Once fish were placed into a holding container, the lid was secured using four bolts and wingnuts. Each tote and holding can was labeled to track the specific tag codes.

A total of 157 to 162 steelhead and 12 to 24 dummy tagged steelhead were transported to the holding site every other day during the tagging period (Table 1). Three transport trips were required daily to transport all tagged steelhead to the holding site. Each transport tank accommodated 56 steelhead at a time. Two transport trucks were used to transport the fish from the MKRH to the holding site at Durham Ferry. The first truck made two deliveries each day (the first and third deliveries). Clean waders or hip boots (frozen for 24 hours) were required on the flatbed of the transport trucks to prevent contamination of organisms from the river back to the hatchery.

After transfer to the 166-L holding containers, the 68-L totes were collected and placed on a clean tarp (4.3 m [14'] square) and allowed to dry. At the end of the day, all 68-L totes were transported back to the Stockton Fish and Wildlife Office. These totes were then transported to the MKRH where they were placed into a -20˚C freezer for a period of at least 24 hours prior to reuse. All fish were held in-river for a period of at least 24 hours prior to release. For more information on holding and release standard operating procedures see Appendix B.

## Fish Releases

At release, the juvenile steelhead, held in perforated holding cans, were transported downstream by boat to the release location, which was in the middle of the channel downstream of the holding location. The fish were released downstream of the holding site to reduce potential initial predation of tagged fish immediately after release, under the assumption that predators may congregate near the holding location. Releases were made every 4 hours after the 24 hour holding period, at approximately 1500, 1900, 2300 (the day after tagging), and 0300, 0700, and 1100 hours (2 days after tagging) (Table 1). Fish releases were made at these 4-hour increments throughout the 24-hour period to spread the fish out and to better represent naturally produced fish that may migrate downstream throughout the 24 hour period.

A STFWO research vessel (16 ft. aluminum boat with 25 hp Honda outboard motor, tiller steer) was used to transport the holding containers to the specified release site. During each release, two to three holding containers were unclipped from the tether line and clipped to the gunnel of the research vessel. These holding containers were then transported to the specified release site; located mid-channel approximately 150 meters downstream of the holding location.

Immediately prior to release, each holding container was checked for any dead or impaired fish. At the release time, the lid was removed and the holding container was rotated to look for mortalities. The container was then inverted to allow the fish to be released into the river. After the holding container was inverted, the time was recorded. As the holding containers were flipped back over, they were inspected to make sure that none of the released fish had swum back into the container. The holding container was then brought into the vessel to be returned to the tether line.

Once the release was completed, the information on any dead fish was recorded and the tags removed. The tags were bagged and labeled and returned to the office for tag code identification. A total of 1,435 juvenile steelhead were released with VEMCO V6 acoustic tags into the San Joaquin River at Durham Ferry on April 4 to 7 (477), May 1 to 6 (478), and May 17 to 23 (480) (Table 1).

### DUMMY TAGGED FISH

In order to evaluate the effects of tagging and transport on the survival of the tagged fish, several groups of steelhead were implanted with inactive ("dummy") transmitters. Dummy tags in 2012 were systematically interspersed into the tagging order for each release group. For each day of tagging and transport, at least 12 fish were implanted with dummy transmitters and included in the tagging process (Table 1). Procedures for tagging these fish, transporting them to the release site, and holding them at the release site were the same as for fish with active transmitters. Dummy fish were kept separately from live tagged juvenile steelhead while being held in the river, but held at the same general density

(12 fish per 166-L holding container). Dummy-tagged fish were evaluated for condition and mortality after being held at the release site for approximately 48 hours, or used to assess fish health (see next section).

At the time of assessment, field crew moved the holding container, filled with dummy tagged steelhead, to the shore so it would dewater to half full of water. The lid of the holding container was then removed to observe if there were any dead or dying fish. After a majority of the water had drained from the holding container, crew poured the fish and remaining water into a 19-L bucket containing a lethal concentration of MS-222. After being euthanized, fish were assessed qualitatively for percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration (Table 2). All tags were returned to the Stockton Fish and Wildlife Office, for reuse in the following tagging session.

### Fish Health Assessment

The U.S. Fish and Wildlife Service's CA-NV Fish Health Center (CNFHC) conducted a general pathogen screening and smolt physiological assessment on some of the dummy-tagged fish held at the release site at San Joaquin River at Durham Ferry for 48 hours (Appendix C). The objectives of this element of the project were to evaluate the juvenile steelhead used for the studies for specific fish pathogens and assess smolt development from gill Na+ - K+- ATPase activity to determine potential differences in health between groups. Sampling was conducted at three time points in the study period (April 6, May 7 and May 23, 2012). Fish were euthanized at the release site and examined for external or internal abnormalities, and tissue samples (kidney, spleen, and gill) were collected. Kidney tissue was inoculated onto brain-heart infusion agar. Bacterial isolates were screened by standard microscopic and biochemical tests (USFWS and AFS-FHS 2010).

These screening methods would not isolate *Flavobacterium columnare*; however, no columnaris lesions were observed in the steelhead. *Renibacterium salmoninarum* (the bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test (FAT) of kidney imprints. Two to four fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 at 15°C as described in the AFS Bluebook (USFWS and AFS-FHS 2010) with the exception that no blind pass was performed. On April 6, a suspected parasite infection of the gill was examined by histology (Davidson's fixative, standard H&E processing). Gill Na+/K+-Adenosine Triphosphatase (ATPase) activity was assayed by the method of McCormick (1993).

### Tag Life Tests

Two tag life studies were conducted in 2012. The first tag life study was conducted between April 5 and June 25 with 48 tags and was combined with the tag retention study. The 48 steelhead were tagged with the activated tags on April 6. The tags had been activated the evening before on April 5. Tags were split evenly between two tanks at the Tracy Fish Collection Facility (TFCF; tank 5 and 6 in row 2), resulting in each tank having 24 tagged fish in them. On May 29, 2012 tank water and oxygen were cutoff, resulting in the death of 44 of the 48 tagged steelhead. Live tags were then dissected from the dead fish in each tank and placed into mesh bags, and returned to the tanks to complete the assessment of the tag life for these tags. This first tag life study ended on June 25.

The second tag life study was conducted between May 24 and August 20 with 45 tags. One of the tags from this second tag life study was never recorded by the receiver so it was removed from the tag life study. Tags were activated on May 24, put into mesh bags and held in three holding tanks, starting on May 25. The holding tanks (row 3, tanks 4, 5 and 6) each held 15 tags and one VR2W receiver and contained ambient Delta water at the TFCF.

Receivers recorded detections of each individual tag. Files of detections were reviewed to identify the date and time of tag failure for each individual tag used in the tag life study. Tags used for the tag life study were systematically chosen among the tags shipped from VEMCO.

### Tag Retention Study

To monitor the effects of surgical implantation of acoustic tags on fish mortality, fish were tagged on April 6 at the MKRH and moved to the TFCF later the same day. Surgical implantation of tags into the tag retention fish was completed following the same SOP as for fish that were tagged and released as part of the study. Forty-eight steelhead with live tags were split evenly between two tanks at the TFCF (tanks 5 and 6 in row 2), resulting in each tank having 24 tagged fish in them. Ten control fish that had not been tagged were also added to each tank.

### Receiver Deployment, Retrieval, and Receiver Database

This study used receivers at 26 locations in the lower San Joaquin River and South Delta and as far west as Chipps Island (i.e. Mallard Slough) for detecting juvenile steelhead as they migrated through the Delta (Figure 13, Table 3). These receivers were placed at key locations throughout the south Delta and similar to those used in VAMP in 2010 and 2011 and for the South Delta Chinook Salmon Study in 2012 (Figure 13). The USBR funded the USGS to deploy, maintain and remove all of the receivers in the array to estimate survival of juvenile salmonids from Durham Ferry and Mossdale to Chipps Island.

## Statistical Methods

### Data Processing for Survival Analysis

The University of Washington received the database of tagging and release data from the US Fish and Wildlife Service. The tagging database included the date and time of tag activation and tagging surgery for each tagged steelhead released in 2012, as well as the name of the surgeon (i.e., tagger), and the date and time of release of the tagged fish to the river.  Fish size (length and weight), tag size, and any notes about fish condition were included, as well as the survival status of the fish at the time of release. Tag serial number and two unique tagging codes were provided for each tag, representing codes for various types of signal coding. Tagging data were summarized according to release group and tagger, and were cross-checked with Pat Brandes (USFWS) and Josh Israel (USBR) for quality control.

Acoustic tag detection data collected at individual monitoring sites (Table 3) were transferred to the US Geological Survey (USGS) in Sacramento, California. A multiple-step process was used to identify and verify detections of fish in the data files and produce summaries of detection data suitable for converting to tag detection histories. Detections were classified as valid if two or more pings were recorded within a 30 minute time frame on the hydrophones comprising a detection site from any of the three tag codes associated with the tag. The University of Washington received the primary database of autoprocessed detection data from the USGS.  These data included the date, time, location, and tag codes and serial number of each valid detection of the acoustic steelhead tags on the fixed site receivers. The tag serial number indicated the acoustic tag ID, and were used to identify tag activation time, tag release time, and release group from the tagging database.

The auto-processed database was cleaned to remove obviously invalid detections.  The University of Washington identified potentially invalid detections based on unreasonable travel times or unlikely transitions between detections, and queried the USGS processor about any discrepancies. All corrections were noted and made to the database. All subsequent analysis was based on this cleaned database.

The information for each tag in the database included the date and time of the beginning and end of each detection event when a tag was detected. Unique detection events were distinguished by detection on a separate hydrophone or by a time delay of 30 minutes between repeated hits on the same receiver. Separate events were also distinguished by unique signal coding schemes (e.g., PPM vs. hybrid PPM/HR). The cleaned detection event data were converted to detections denoting the beginning and end of receiver "visits," with consecutive visits to a receiver separated either by a gap of 12 hours or more between detections on the receiver, or by detection on a different receiver. Detections from receivers in dual or redundant arrays were pooled for this purpose, as were detections using different tag coding schemes.

### Distinguishing between Detections of Steelhead and Predators

The possibility of predatory fish eating tagged study fish and then moving past one or more fixed site receivers complicated analysis of the detection data. The steelhead survival model depended on the assumption that all detections of the acoustic tags represented live juvenile steelhead, rather than a mix of live steelhead and predators that temporarily had a steelhead tag in their gut. Without removing the detections that came from predators, the survival model would produce potentially biased estimates of survival of actively migrating juvenile steelhead through the Delta. The size of the bias would depend on the amount of predation by predatory fish and the spatial distribution of the predatory fish after eating the tagged steelhead. In order to minimize bias, the detection data were filtered for predator detections, and detections assumed to come from predators were identified.

The predator filter used for analysis of the 2012 data was based on the predator filter designed and used in the analysis of the 2011 data (USBR 2018). That predator filter in turn was based on predator analyses presented by Vogel (2010, 2011), as well as conversations with fisheries biologists familiar with the San Joaquin River and Delta regions. The filter was applied to all detections of all tags. Two data sets were then constructed: the full data set including all detections, including those classified as coming from predators (i.e., "predator-type"), and the reduced data set, restricted to those detections classified as coming from live juvenile steelhead (i.e., "steelhead-type"). The survival model was fit to both data sets separately. The results from the analysis of the reduced "steelhead-type" data set are presented as the final results of the 2012 tagging study. Results from analysis of the full data set including “predator-type” detections were used to indicate the degree of uncertainty in survival estimates arising from the predator decision process.

The predator filter used for steelhead tagging data must account for both the possibility of extended rearing by steelhead in the Delta before eventual outmigration, and the possibility of residualization. These possibilities mean that some steelhead may have long residence or transition times, or they may move upstream either with or against the flow. Nevertheless, it was assumed that steelhead could not move against very high flow, and that their upstream excursions would be limited after entering the Delta at the head of Old River. Maximum residence times and transition times were imposed for most regions of the Delta, even allowing for extended rearing.

Even with these flexible criteria for steelhead, it was impossible to perfectly distinguish between a residualizing or extended rearing steelhead and a resident predator. A truly residualizing steelhead that is classified as a predator should not bias the overall estimate of successfully leaving the Delta at Chipps Island, because a residualizing steelhead would not be detected at Chipps Island. However, the case of a steelhead exhibiting extended rearing or delayed migration before finally outmigrating past Chipps Island is more complicated. Such a steelhead may be classified as a predator based on long residence times, long transition times, atypical movements within the Delta, or a combination of all three. Such a classification would negatively bias the overall estimate of true survival out of the Delta for steelhead. On the other hand, the survival model assumes common survival and detection probabilities for all steelhead, and thus is implicitly designed for actively migrating steelhead. With that understanding, the “survival” parameter estimated by the survival model is more properly interpreted as the joint probability of migration and survival, and its complement includes both mortality and extended rearing or residualization. The possibility of classifying steelhead with extended rearing times in the Delta as predators does not bias the survival model under this interpretation of the model parameters, and in fact is more likely to improve model performance (i.e., fit) with these non-actively migrating steelhead detections removed. In short, it was necessary either to limit survival analysis to actively migrating steelhead, or to assume that all detections came from steelhead. The first approach used the outcome of the predator filter described here for analysis. The second approach used all detection data.

The predator filter was based on assumed behavioral differences between actively migrating steelhead smolts and predators such as striped bass and white catfish. All detections were considered when implementing the filter, including detections from acoustic receivers that were not otherwise used in the survival model. As part of the decision process, environmental data including river flow, river stage, and water velocity were examined from several points throughout the Delta (Table 4), as available, downloaded from the California Data Exchange Center website (http://cdec.water.ca.gov/selectQuery.html) and the California Water Data Library (www.water.ca.gov/waterdatalibrary/) on 27 September 2013. Environmental data were reviewed for quality, and obvious errors were omitted.

For each tag detection, several steps were performed to determine if it should be classified as predator or steelhead. Initially, all detections were assumed to be of live steelhead. A tag was classified as a predator upon the first exhibition of predator-type behavior, with the acknowledged uncertainty that the steelhead smolt may actually have been eaten sometime before the first obvious predator-type detection. Once a detection was classified as coming from a predator, all subsequent detections of that tag were likewise classified as predator detections. The assignment of predator status to a detection was made conservatively, with doubtful detections classified as coming from live steelhead.

A tag could be given a predator classification at a detection site on either arrival or departure from the site. A tag classified as being in a predator because of long travel time or movement against the flow was generally given a predator classification upon arrival at the detection site. On the other hand, a tag classified as being in a predator because of long residence time was given a predator classification upon departure from the detection site. Because the survival analysis estimated survival within reaches between sites, rather than survival during detection at a site, the predator classifications on departure from a site did not result in removal of the detection at that site from the reduced data set. However, all subsequent detections were removed from the reduced data set.

Criteria for distinguishing between steelhead detections and predator detections were partially based on observed behavior of tags in fish that were assumed to have been transported from the holding tanks at either the State Water Project (SWP) or the Central Valley Project (CVP) to release sites in the lower San Joaquin River or Sacramento River, upstream of Chipps Island, under the assumption that such tags must have been in steelhead smolts rather than in steelhead predators. Tags assumed to have been transported from either SWP or CVP were used to identify the range of possible steelhead movement through the rest of the Delta. This was most helpful for detection sites in the western portion of the study area. This method mirrors that used for the 2011 predator filter (USBR 2018).

Acoustic receivers were stationed inside the holding tanks at CVP, and tags that were observed in the holding tanks and then next observed at either Chipps Island (i.e., Mallard Island), Jersey Point, or

False River were assumed to have been transported. Acoustic receivers were not placed in the holding tanks at SWP, and so fish transported from SWP were identified with less certainty. It was assumed that tags were transported from SWP if they were detected either inside or outside the radial gates at the entrance to the Clifton Court Forebay (CCFB; the final receivers encountered before the SWP holding tank) and next detected at either Chipps Island, Jersey Point, or False River. This group may include tagged fish that migrated from the CCFB entrance to the Jersey Point/False River/Chipps Island area inriver, evading detection at the multiple Old River and Middle River receivers north of the CCFB. While this pathway was possible, it was deemed less likely than the SWP transport pathway for fish with no detections between CCFB and the downstream sites (Jersey Point, etc.).

The predator filter used various criteria that addressed several spatial and temporal scales and fit under several categories (see USBR 2018 for more details): fish speed, residence time, upstream transitions, other unexpected transitions, travel time since release, and movements against flow. The criteria used in the 2011 study were updated to reflect river conditions and observed tag detection patterns in 2012 (Table 5**Error! Reference source not found.**). The predator scoring and classification method used for the 2011 study was used again for the 2012 study, resulting in tags being classified as in either a predator or a steelhead upon arrival at and departure from a given receiver site and visit; for more details, see USBR 2018. All detections of a tag subsequent to its first predator designation were classified as coming from a predator, as well.

The criteria used in the predator filter were spatially explicit, with different limits defined for different receivers and transitions (Table 5). The overall approach to various regions is described here.

DFU, DFD = Durham Ferry Upstream (A0) and Durham Ferry Downstream (A2): ignore flow and velocity measures, allow long residence and transition times and multiple visits.

BCA, MOS, and HOR = Banta Carbona (A3), Mossdale (A4), and Head of Old River (B0): allow longer residence time if next transition is directed downstream; may have extra visits at BCA if arrival flow is low.

SJL = San Joaquin River near Lathrop (A5): allow longer travel time if low flow during transition; upstream transitions from Stockton sites are not allowed.

ORE = Old River East (B1): allow longer residence time if arrive at low velocity.

SJG = San Joaquin River at Garwood Bridge (A6): repeat visits or transitions from upstream require arrival flow/velocity to be opposite direction from flow/velocity on previous departure.

SJNB = San Joaquin River at Navy Bridge Drive (A7): fast transitions moving downstream require positive water velocity.

MAC = MacDonald Island (A8): allow more flexibility (longer residence time, transition time) if transition water velocity was low and positive for downstream transitions, or low and negative for upstream transitions.

MFE/MFW = Medford Island (A9): allow more flexibility (longer residence time, transition time) if transition water velocity was low and positive for downstream transitions, or low and negative for upstream transitions; transitions from interior Delta sites (B3, B4, C2, C3) must have departed interior Delta sites with very low or positive flow/velocity; transitions from Radial Gates (D) not allowed.

TCE/TCW = Turner Cut (F1): should not move against flow.

ORS = Old River South (B2): allow longer transition times from ORE if mean water velocity during transition was low.

MRH = Middle River Head (C1): shorter residence times than ORS; repeat visits are not allowed.

MR4 = Middle River at Highway 4 (C2): should not move against flow on repeat visits; should arrive on negative/low water velocity if arriving from San Joaquin (Stockton); should not have left water export facilities against high pumping (E1) or reservoir inflow (D).

MRE = Middle River at Empire Cut (C3): should not move against flow on repeat visits or on transitions from San Joaquin or Old River.

CVP = Central Valley Project (E1): allow multiple visits; transitions from downstream Old River should not have departed Old River site against flow or arrived during low pumping.

CVPtank = Central Valley Project holding tank (E2): assume that steelhead can leave tank and return (personal communication, Brent Bridges, USBR).

OR4 = Old River at Highway 4 (B3): allow many visits; should not arrive against flow or water velocity.

OLD = Old River near Empire Cut (B4): should not move against flow on repeat visits or on transitions from Turner Cut or Old River.

RGU/RGD = Radial Gates (D1, D2 = D):

- Assume juvenile steelhead can move from D2 back to D1
- No distinction between near-field and mid-field visit (i.e., gap in detection does not define new visit)
- Residence time may include time spent in river between first arrival at RG and final departure from RG (with no detection elsewhere during "visit")
- Maximum residence time = 80 hours (3.3 days), accounting for gaps in detection, unless:
- if detected at D2 before D1:
    - if the large majority (>80%) of residence time was spent inside CCFB (i.e., at D2, allowing for gaps in detection), then maximum combined residence time = 336 hours (14 days); these tags appear to have spent long time inside CCFB before returning to Old River, look like predators
    - otherwise maximum combined residence time = 800 hours (33 days); these tags spent some time in CCFB, then returned to the entrance channel or river, and eventually returned to radial gates; allow longer residence time than those that spent most of visit inside CCFB.

JPE/JPW and FRE/FRW = Jersey Point (G1) and False River (H1): no flow/velocity restrictions; allowed for transition from Threemile Slough (TMS/TMN)

TMS/TMN = Threemile Slough (T1): should not move against flow on departing from interior Delta or San Joaquin River sites

In addition, detections in the San Joaquin River after previous entry to the Interior Delta (e.g., Old and Middle River sites or export facilities) from Stockton or sites farther downstream in the San Joaquin River were generally not allowed. The exception was at MacDonald Island (A8) and Turner Cut (F1). Detections at sites other than CVP (E1) and the radial gates (D1/D2) after arriving at either CVP or the radial gates from the lower San Joaquin River were not allowed. These restrictions were based on the assumption that juvenile steelhead that leave the lower San Joaquin River for the Interior Delta are not expected to return to the San Joaquin River, and those that leave the lower San Joaquin River for the water export facilities are not expected to subsequently leave the facilities other than through salvage and transport. Maximum travel times were imposed on transitions in the Interior Delta and at the facilities for steelhead observed leaving the lower San Joaquin River for these regions.

### Constructing Detection Histories

For each tag, the detection data summarized on the "visit" scale were converted to a detection history (i.e., capture history) that indicated the chronological sequence of detections on the fixed site receivers throughout the study area. In cases in which a tag was observed passing a particular receiver or river junction multiple times, the detection history represented the final route of the tagged fish past the receiver or river junction. Detections from the receivers comprising certain dual arrays were pooled, thereby converting the dual arrays to redundant arrays: the San Joaquin River near Mossdale Bridge (MOS), Lathrop (SJL), and Garwood Bridge (SJG); Old River East near the head of Old River (ORE); the Central Valley Project trash racks (CVP); and the radial gates just outside of Clifton Court Forebay (RGU). For some release groups, a better model fit was found by pooling detections from dual arrays into redundant arrays at the Durham Ferry Downstream site (D2), MacDonald Island (A8), Old River South (ORS), and/or Jersey Point (G1). Unlike in the 2011 analysis (USBR 2018), the status of the radial gates (opened or closed) upon detection at the receivers just outside the radial gates (RGU) was not included in the detection history because the sparseness of the detection data at this site precluded incorporating gate status into the survival model.

### Survival Model

A two-part multi-state statistical release-recapture model was developed and used to estimate perceived juvenile steelhead survival and migration route parameters throughout the study area. The release-recapture model is a slightly simplified version of the model used in the 2011 steelhead analysis (USBR 2018), and similar to the model developed by Perry et al. (2010) and the model developed for the 2009 – 2011 VAMP studies (SJRGA 2010, 2011, 2013). Figure 13 shows the layout of the receivers using both descriptive labels for site names and the code names used in the survival model (Table 3). The survival model represents movement and perceived survival throughout the study area to the primary exit point at Chipps Island (i.e., Mallard Island) (Figure 13, Figure 14). Individual receivers comprising dual arrays were identified separately, using “a” and “b” to represent the upstream and downstream receivers, respectively. Most sites used in 2012 were also used in 2011, although some site names changed, and some sites were added and others removed from 2011 (Figure 13,Table 3). The Paradise Cut sites from 2011 were not used in 2012 because flows were too low for fish to enter Paradise Cut. Additional detection sites were installed in 2012 in the San Joaquin River just upstream of the head of Old River (HOR = B0), and in Old and Middle rivers north of Highway 4 (OLD = B4 and MRE = C3). Some sites were omitted from the survival model, but all were used in the predator filter.

The statistical model depended on the assumption that all tagged steelhead in the study area were actively migrating, and that any residualization occurred upstream of the Durham Ferry release site. If, on the contrary, tagged steelhead residualized downstream of Durham Ferry, and especially within the study area (downstream of the Mossdale receiver, A4), then the multi-state statistical release-recapture model estimated perceived survival rather than true survival, where perceived survival is the joint probability of migrating and surviving. The complement of perceived survival includes both the probability of mortality and the probability of halting migration to rear or residualize. Unless otherwise specified, references to “survival” below should be interpreted to mean “perceived survival.”

Fish moving through the Delta toward Chipps Island may have used any of several routes. The two primary routes modeled were the San Joaquin River route (Route A) and the Old River route (Route B). Route A followed the San Joaquin River past the distributary point with Old River near the town of Lathrop and past the city of Stockton. Downstream of Stockton, fish in the San Joaquin River route (route A) may have remained in the San Joaquin River past its confluence with the Sacramento River and on to Chipps Island. Alternatively, fish in Route A may have exited the San Joaquin River for the interior Delta at any of several places downstream of Stockton, including Turner Cut, Columbia Cut (just upstream of Medford Island), and the confluence of the San Joaquin River with either Old River or Middle River, at Mandeville Island. Of these four exit points from the San Joaquin River between

Stockton and Jersey Point, only Turner Cut was monitored and assigned a route name (F, a subroute of route A). Fish that entered the interior Delta from any of these exit points may have either moved north through the interior Delta and reached Chipps Island by returning to the San Joaquin River and passing Jersey Point and the junction with False River, or they may have moved south through the interior Delta to the state or federal water export facilities, where they may have been salvaged and trucked to release points on the San Joaquin or Sacramento rivers just upstream of Chipps Island. All of these possibilities were included in both subroute F and route A.

For fish that entered Old River at its distributary point on the San Joaquin River just upstream of Lathrop (route B), there were several pathways available to Chipps Island. These fish may have migrated to Chipps Island either by moving northward in either the Old or Middle rivers through the interior Delta, or they may have moved to the state or federal water export facilities to be salvaged and trucked. The Middle River route (subroute C) was monitored and contained within Route B. Passage through the State Water Project via Clifton Court Forebay was monitored at the entrance to the forebay and assigned a route (subroute D). Likewise, passage through the federal Central Valley Project was monitored at the entrance trashracks and in the facility holding tank and assigned a route (subroute E). Subroutes D and E were both contained in subroutes C (Middle River) and F (Turner Cut), as well as in primary routes A (San Joaquin River) and B (Old River). All routes and subroutes included multiple unmonitored pathways for passing through the Delta to Chipps Island.

Several exit points from the San Joaquin River were monitored and given route names for convenience, although they did not determine unique routes to Chipps Island. The first exit point encountered was False River, located off the San Joaquin River just upstream of Jersey Point. Fish entering False River from the San Joaquin River entered the interior Delta at that point, and would not be expected to reach Chipps Island without subsequent detection in another route. Thus, False River was considered an exit point of the study area, rather than a waypoint on the route to Chipps Island. It was given a route name (H) for convenience. Likewise, Jersey Point and Chipps Island were not included in unique routes. Jersey Point was included in many of the previously named routes (in particular, routes A and B, and subroutes C and F), whereas Chipps Island (the final exit point) was included in all previously named routes and subroutes except route H. Thus, Jersey Point and Chipps Island were given their own route name (G). Three additional sets of receivers located in Old River (Route B) and Middle River (Subroute C) north of Highway 4 and in Threemile Slough (Route T) were not used in the survival model. The routes, subroutes, and study area exit points are summarized as follows:

A = San Joaquin River: survival

B = Old River: survival

C = Middle River: survival

D = State Water Project: survival

E = Central Valley Project: survival

F = Turner Cut: survival

G = Jersey Point, Chipps Island: survival, exit point

H = False River: exit point

T = Threemile Slough: not used in survival model

The release-recapture model used parameters that denote the probability of detection ($P_{hi}$), route selection ("route entrainment", $\psi_{hl}$), perceived steelhead survival (the joint probability of migrating and surviving; $S_{hi}$), and transition probabilities equivalent to the joint probability of directed movement and survival ($\phi_{kj,hi}$) (Figure 13, Figure 14, Table F1). Unique detection probabilities were estimated for the individual receivers in a dual array: $P_{hia}$ represented the detection probability of the upstream array at station $i$ in route $h$, and $P_{hib}$ represented the detection probability of the downstream array.

The model parameters are:

$P_{hi}$ = detection probability: probability of detection at telemetry station $i$ within route $h$, conditional on surviving to station $i$, where $i$ = $ia$, $ib$ for the upstream, downstream receivers in a dual array, respectively.

$S_{hi}$ = perceived survival probability: joint probability of migration and survival from telemetry station $i$ to $i$+1 within route $h$, conditional on surviving to station $i$.

$\psi_{hl}$ = route entrainment probability: probability of a fish entering route $h$ at junction $l$ ($l$ =1, 2), conditional on fish surviving to junction $l$.

$\phi_{kj,hi}$ = transition probability: joint probability of migration, route entrainment, and survival; the probability of migrating, surviving, and moving from station $j$ in route $k$ to station $i$ in route $h$, conditional on survival to station $j$ in route $k$.

The sparse detection data at the receivers outside the Clifton Court Forebay (site D1, RGU) did not allow classification of transitions by status of the radial gates (open or closed) upon tag arrival at D1. This was a change from the 2011 survival model.

The full survival model used detections at sites B1 (ORE), B2 (ORS), and C1 (MRH) to estimate survival between the head of Old River and the head of Middle River $\left(S_{B1}\right)$, the probability of remaining in Old River at the head of Middle River $\left(\psi_{B2}\right)$, and the probability of entering Middle River at its head $\left(\psi_{C2}=1-\psi_{B2}\right)$. Only three tags were detected at the C1 site indicating entry to Middle River: one tag was later observed upstream of the head of Old River, and so its C1 detection was not used in the survival model, and the other two tags (both from the third release group) were classified as in predators before reaching MRH. Thus, for all results for tags deemed to be in steelhead, and for most cases in general, no detections at C1 were used in the survival model. In these cases, it was not possible to separately estimate the survival parameter $S_{B1}$ and route selection probability $\psi_{B2}$, but instead only their product was estimable: $\phi_{B1,B2} = S_{B1}\psi_{B2}$. Under the assumption that no fish passed the C1 receivers without detection, then in these cases $\psi_{B2} = 1$ and $\phi_{B1,B2} = S_{B1}$. However, these was no way to test that assumption. For the single release group in which predator-type detections at C1 were available for use in the survival model, detections at C1 were too sparse and were omitted from analysis. In this case (third release group), it is acknowledged that $\phi_{B1,B2} < S_{B1}$.

A variation on the parameter naming convention was used for parameters representing the transition probability to the junction of False River with the San Joaquin River, just upstream of Jersey Point (Figure 14). This river junction marks the distinction between routes G and H, so transition probabilities to this junction are named $\phi_{kj,GH}$ for the joint probability of surviving and moving from station $j$ in route $k$ to the False River junction. Fish may arrive at the junction either from the San Joaquin River or from the interior Delta. The complex tidal forces present in this region prevent distinguishing between smolts using False River as an exit from the San Joaquin and smolts using False River as an entrance to the San Joaquin from Frank's Tract. Regardless of which approach the fish used to reach this junction, the $\phi_{kj,GH}$ parameter (e.g. $\phi_{A9,GH}$ or $\phi_{C2,GH}$ ) is the transition probability to the junction of False River with the San Joaquin River via any route; $\psi_{G1}$ is the probability of moving downstream toward Jersey Point from the junction; and $\psi_{H1} = 1 - \psi_{G1}$ is the probability of exiting (or re-exiting) the San Joaquin River to False River from the junction (Figure 13, Figure 14).

For fish that exited the San Joaquin River for the interior Delta downstream of Stockton, CA, the parameters $\phi_{B3,D1}$, $\phi_{B3,E1}$, $\phi_{C2,D1}$, and $\phi_{C2,E1}$ represent the joint probabilities of moving from either site B3 or C2 toward to the export facilities and surviving. Similar parameters were not estimated for fish that reached the B3 or C2 sites via Old River within Route B, but rather transition to the export facilities within route B was estimated directly from the head of Middle River (sites B2 and C1) using parameters $\phi_{B2,D1}$, $\phi_{B2,E1}$, $\phi_{C1,D1}$, and $\phi_{C1,E1}$. Both routes A and B were used to estimate northward transition probabilities from sites B3 and C2 in the interior Delta to the junction with Jersey Point and False River: $\phi_{B3,GH}$ and $\phi_{C2,GH}$. Likewise, both routes A and B were used to estimate transitions at or within the export facility sites (i.e., $\phi_{D1,D2}$ and $\phi_{E1,E2}$), as well as transition probabilities from the interior receivers at these sites to Chipps Island (i.e., $\phi_{D2,G2}$ and $\phi_{E2,G2}$).

For fish that reached the interior receivers at the State Water Project (D2) or the Central Valley Project (E2), the parameters $\phi_{D2,G2}$ and $\phi_{E2,G2}$, respectively, represent the joint probability of migrating and surviving to Chipps Island, including survival during and after collection and transport (Figure 13). Some salvaged and transported smolts were released in the San Joaquin River between Jersey Point and Chipps Island, and others were released in the Sacramento River upstream of the confluence with the San Joaquin River. Because salvaged fish were not required to pass Jersey Point and the False River junction, it was not possible to estimate the transition probability to Chipps Island via Jersey Point for salvaged fish. Thus, only the overall probability of making the transition to Chipps Island was estimated for fish passing through the water export facilities.

Because of the complexity of routing in the vicinity of MacDonald Island (referred to as "Channel Markers" in previous reports [USBR 2018, SJRGA 2010, 2011, 2013]) on the San Joaquin River, Turner Cut, and Medford Island, and the possibility of reaching the interior Delta via either route A or route B, the full survival model that represented all routes was decomposed into two submodels for analysis, as in the 2011 analysis (USBR 2018). Submodel I modeled the overall migration from release at Durham Ferry to arrival at Chipps Island without modeling the specific routing from the lower San Joaquin River (i.e., from the Turner Cut Junction) through the interior Delta to Chipps Island, although it included detailed subroutes in route B for fish that entered Old River at its upstream junction with the San Joaquin River (Figure 14). In Submodel I, transitions from MacDonald Island (A8) and Turner Cut (F1) to Chipps Island were interpreted as survival probabilities ( $S_{A8,G2}$ and $S_{F1,G2}$ ) because they represented all possible pathways from these sites to Chipps Island. Submodel II, on the other hand, focused entirely on Route A, and used a virtual release of tagged fish detected at the San Joaquin River receiver array near Lathrop (A5, SJL) to model the detailed routing from the lower San Joaquin River near MacDonald Island and Turner Cut through or around the interior Delta to Jersey Point and Chipps Island (Figure15). Submodel II included the Medford Island detection site (A9), which was omitted from Submodel I because of complex routing in that region.

The two submodels I and II were fit concurrently using common detection probabilities at certain shared receivers: B3 (OR4), C2 (MR4), D1 (RGU), D2 (RGD), E1 (CVP), E2 (CVP holding tank), G1 (JPE/JPW), and H1 (FRE/FRW). While submodels I and II both modeled detections at these receivers, actual detections modeled at these receivers came from different tagged fish in the two submodels, with detections coming from Route B fish in Submodel I and from Route A fish in Submodel II. Detections at all other sites included in Submodel II either included the same fish as in Submodel I (i.e., sites SJG [A6], SJNB [A7], MAC [A8], TCE/TCW [F1], and MAE/MAW [G2]), or else were unique to Submodel II (i.e., site MFE/MFW [A9]); detection probabilities at these sites were estimated separately for submodels I and II to avoid "double-counting" tags used in both submodels. In the previous year of this study (USBR 2018), unique transition parameters through the water export facility sites (i.e., $\phi_{D1,D2}$, $\phi_{D2,G2}$, $\phi_{E1,E2}$, and $\phi_{E2,G2}$) were estimated for Submodels I and II, under the assumption that fish that arrive outside the CVP or the Clifton Court Forebay coming from the head of Old River might have a different likelihood of reaching the interior receivers than fish that came from the lower San Joaquin River. Because of the sparse detection data at these sites in 2012, the models were fit first using unique parameters for the two submodels, and then using common transition parameters for the two submodels. The significance of submodel-specific (i.e., route-specific) effects on these four transition parameters was assessed using a Likelihood Ratio Test ($\alpha$=0.05; Sokal and Rohlf, 1995); results were reported from the most parsimonious model that fit the data.

In addition to the model parameters, derived performance metrics measuring migration route probabilities and survival were estimated as functions of the model parameters. Both route selection probabilities and route-specific survival were estimated for the two primary routes determined by routing at the head of Old River (routes A and B). Route selection and route-specific survival were also estimated for the major subroutes of routes A and B. These subroutes were identified by a two-letter code, where the first letter indicates routing used at the head of Old River (A or B), and the second letter indicates routing used at the next river junction encountered: A or F at the Turner Cut Junction, and B or C at the head of Middle River. Thus, the route selection probabilities for the subroutes were:

$\psi_{AA}=\psi_{A1}\psi_{A2}$: probability of remaining in the San Joaquin River past both the head of Old River and the Turner Cut Junction,

$\psi_{AF}=\psi_{A1}\psi_{F2}$: probability of remaining in the San Joaquin River past the head of Old River, and exiting to the interior Delta at Turner Cut,

$\psi_{BB}=\psi_{B1}\psi_{B2}$: probability of entering Old River at the head of Old River, and remaining in Old River past the head of Middle River,

$\psi_{BC}=\psi_{B1}\psi_{C2}$: probability of entering Old River at the head of Old River, and entering Middle River at the head of Middle River,

where $\psi_{B1} = 1-\psi_{A1}$, $\psi_{F2} = 1-\psi_{A2}$, and $\psi_{C2} = 1-\psi_{B2}$. In cases with no detections in Middle River near its head (site C1, MRH), the estimates of route selection in the B and C subroutes ($\psi_{BB}$ and $\psi_{BC}$) depend on the assumption that no fish actually entered Middle River without detection (i.e., $\psi_{B2} = 1$ and $\psi_{C2} = 0$).

The probability of surviving from the entrance of the Delta near Mossdale (site A4, MOS) through an entire migration pathway to Chipps Island was estimated as the product of survival probabilities that trace that pathway:

$S_{AA} = S_{A4}S_{A5}S_{A6}S_{A7}S_{A8,G2}$: Delta survival for fish that remained in the San Joaquin River past the head of Old River and Turner Cut,

$S_{AF} = S_{A4}S_{A5}S_{A6}S_{A7}S_{F1,G2}$: Delta survival for fish that entered Turner Cut from the San Joaquin River,

$S_{BB} = S_{A4}S_{B1}S_{B2,G2}$: Delta survival for fish that entered Old River at its head, and remained in Old River past the head of Middle River,

$S_{BC} = S_{A4}S_{B1}S_{C1,G2}$: Delta survival for fish that entered Old River at its head, and entered Middle River at its head.

In cases where no tags were detected at the Middle River site near its head (MRH, site C1), the parameter $S_{B1}$ in $S_{BB}$ was replaced by $\phi_{B1,B2}$ under the assumption that $\psi_{B2} = 1$, and the parameter $S_{BC}$ was not estimable.

The parameters $S_{A8,G2}$ and $S_{F1,G2}$ represent the probability of getting to Chipps Island (i.e., Mallard Island, site MAE/MAW) from sites A8 and F1, respectively. Both parameters represent multiple pathways around or through the Delta to Chipps Island (Figure 13). Fish that were detected at the A8 receivers (MacDonald Island) may have remained in the San Joaquin River all the way to Chipps Island, or they may have entered the interior Delta downstream of Turner Cut. Fish that entered the interior Delta either at Turner Cut or farther downstream may have migrated through the interior Delta to Chipps Island via Frank's Tract or Fisherman's Cut, False River, and Jersey Point; returned to the San Joaquin River via its downstream confluence with either Old or Middle River at Mandeville Island; or gone through salvage and trucking from the water export facilities. All such routes are represented in the $S_{A8,G2}$ and $S_{F1,G2}$ parameters, which were estimated directly using Submodel I.

Survival probabilities $S_{B2,G2}$ and $S_{C1,G2}$ represent survival to Chipps Island of fish that remained in the Old River at B2 (ORS), or entered the Middle River at C1 (MRS), respectively. Fish in both these routes may have subsequently been salvaged and trucked from the water export facilities, or have migrated through the interior Delta to Jersey Point and on to Chipps Island (Figure 13). Because there were many unmonitored river junctions within the "reach" between sites B2 or C1 and Chipps Island, it was impossible to separate the probability of taking a specific pathway from the probability of survival along that pathway. Thus, only the joint probability of movement and survival could be estimated to the next receivers along a route (i.e., the $\phi_{kj,hi}$ parameters defined above and in Figure 13). However, the overall survival probability from B2 ($S_{B2,G2}$) or C1 ($S_{C1,G2}$) to Chipps Island was defined by summing products of the $\phi_{kj,hi}$ parameters:

$$S_{B2,G2} = \phi_{B2,D1}\phi_{D1,D2}\phi_{D2,G2} + \phi_{B2,E1}\phi_{E1,E2}\phi_{E2,G2} + \left(\phi_{B2,B3}\phi_{B3,GH} + \phi_{B2,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}$$

$$S_{C1,G2} = \phi_{C1,D1}\phi_{D1,D2}\phi_{D2,G2} + \phi_{C1,E1}\phi_{E1,E2}\phi_{E2,G2} + \left(\phi_{C1,B3}\phi_{B3,GH} + \phi_{C1,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}$$

The parameter $S_{C1,G2}$ is not estimable in cases with no detections at C1.

Fish in the Old River route that successfully bypassed the water export facilities and reached the receivers in Old River or Middle River near Highway 4 (sites B3 or C2, respectively) may have used any of several subsequent routes to reach Chipps Island. In particular, they may have remained in Old or Middle rivers until they rejoined the San Joaquin downstream of Medford Island, and then migrated in the San Joaquin, or they may have passed through Frank's Tract and False River or Fisherman's Cut to rejoin the San Joaquin River. As described above, these routes were all included in the transition probabilities $\phi_{B3,GH}$ and $\phi_{C2,GH}$, representing the probability of moving from site B3 or C2, respectively, to the False River junction with the San Joaquin.

Both route selection probabilities and route-specific survival were estimated on the large routing scale, as well, focusing on routing only at the head of Old River. The route selection probabilities were defined as:

$\psi_A = \psi_{A1}$: probability of remaining in the San Joaquin River at the head of Old River

$\psi_B = \psi_{B1}$: probability of entering Old River at the head of Old River.

The probability of surviving from the entrance of the Delta (site A4, MOS) through an entire large-scale migration pathway to Chipps Island was defined as a function of the finer-scale route-specific survival probabilities and route selection probabilities:

$S_A = \psi_{A2}S_{AA} + \psi_{F2}S_{AF}$: Delta survival (from Mossdale to Chipps Island) for fish that remained in the San Joaquin River at the head of Old River, and

$S_B = \psi_{B2}S_{BB} + \psi_{C2}S_{BC}$: Delta survival for fish that entered Old River at the head of Old River.

In cases with no detections at site C1 (MRH, Middle River at its head), the Old River survival probability through the delta is simply $S_B = S_{BB}$, which already includes the parameter $\psi_{B2}$ (assumed to be 1). Using the estimated migration route probabilities and route-specific survival for these two primary routes (A and B), survival of the population from A4 (Mossdale) to Chipps Island was estimated as:

$$S_{Total} = \psi_A S_A + \psi_B S_B.$$

Survival was also estimated from Mossdale to the Jersey Point/False River junction, both by route and overall. Survival through this region ("Mid-Delta" or MD) was estimated only for fish that migrated entirely inriver, without being trucked from either of the water export facilities. Thus, the route-specific Mid-Delta survival for the large-scale San Joaquin River and Old River routes was defined as follows:

$S_{A(MD)} = \psi_{A2} S_{AA(MD)} + \psi_{F2} S_{AF(MD)}$: Mid-Delta survival for fish that remained in the San Joaquin River past the head of Old River, and

$S_{B(MD)} = \psi_{B2} S_{BB(MD)} + \psi_{C2} S_{BC(MD)}$: Mid-Delta survival for fish that entered Old River at its head, where

$$S_{AA(MD)} = S_{A4} S_{A5} S_{A6} S_{A7} \left[ \phi_{A8,GH} + \phi_{A8,A9}\phi_{A9,GH} + \left( \phi_{A8,B3} + \phi_{A8,A9}\phi_{A9,B3} \right)\phi_{B3,GH} + \left( \phi_{A8,C2} + \phi_{A8,A9}\phi_{A9,C2} \right)\phi_{C2,GH} \right],$$

$$S_{AF(MD)} = S_{A4} S_{A5} S_{A6} S_{A7} \left[ \phi_{F1,GH} + \phi_{F1,B3}\phi_{B3,GH} + \phi_{F1,C2}\phi_{C2,GH} \right],$$

$$S_{BB(MD)} = S_{A4} S_{B1} \left( \phi_{B2,B3}\phi_{B3,GH} + \phi_{B2,C2}\phi_{C2,GH} \right), \text{ and}$$

$$S_{BC(MD)} = S_{A4} S_{B1} \left( \phi_{C1,B3}\phi_{B3,GH} + \phi_{C1,C2}\phi_{C2,GH} \right).$$

In cases with no detections in Middle River near its head (site C1, MRH), the B subroute Mid-Delta survival probability is estimated as $S_{BB(MD)} = S_{A4} \phi_{B1,B2} \left( \phi_{B2,B3}\phi_{B3,GH} + \phi_{B2,C2}\phi_{C2,GH} \right)$. In such cases, the subroute C survival probability $S_{BC(MD)}$ was not estimable, because no tags were observed taking that route.

Total Mid-Delta survival (i.e., from Mossdale to the Jersey Point/False River junction) was defined as $S_{Total(MD)} = \psi_A S_{A(MD)} + \psi_B S_{B(MD)}$. Mid-Delta survival was estimated only for those release groups with sufficient tag detections to model transitions through the entire south Delta and lower San Joaquin River and to the Jersey Point/False River junction.

Survival was also estimated through the southern portions of the Delta ("Southern Delta" or SD), both within each primary route and overall:

$$S_{A(SD)} = S_{A4}S_{A5}S_{A6}S_{A7}, \text{ and}$$

$$S_{B(SD)} = S_{A4}S_{B1}\left(\psi_{B2}S_{B2(SD)} + \psi_{C2}S_{C1(SD)}\right),$$

where $S_{B2(SD)}$ and $S_{C1(SD)}$ are defined as:

$$S_{B2(SD)} = \phi_{B2,B3} + \phi_{B2,C2} + \phi_{B2,D1} + \phi_{B2,E1}, \text{ and}$$

$$S_{C1(SD)} = \phi_{C1,B3} + \phi_{C1,C2} + \phi_{C1,D1} + \phi_{C1,E1}.$$

In cases with no detections in Middle River near its head (site C1), Southern Delta survival within route B is defined as

$$S_{B(SD)} = S_{A4}\phi_{B1,B2}S_{B2(SD)}.$$

Total survival through the Southern Delta was defined as:

$$S_{Total\ (SD)} = \psi_A S_{A(SD)} + \psi_B S_{B(SD)}.$$

The probability of reaching Mossdale from the release point at Durham Ferry, $\phi_{A1,A4}$, was defined as the product of the intervening reach survival probabilities:

$$\phi_{A1,A4} = \phi_{A1,A2}S_{A2}S_{A3}.$$

This measure reflects a combination of mortality and residualization upstream of Old River.

Individual detection histories (i.e., capture histories) were constructed for each tag as described above. More details and examples of detection history construction and model parameterization are available in USBR 2018. Under the assumptions of common survival, route entrainment, and detection probabilities and independent detections among the tagged fish in each release group, the likelihood function for the survival model for each release group is a multinomial likelihood with individual cells denoting each possible capture history.

## Parameter Estimation

The multinomial likelihood model described above was fit numerically to the observed set of detection histories according to the principle of maximum likelihood using Program USER software, developed at the University of Washington (Lady et al. 2009). Point estimates and standard errors were computed for each parameter. Standard errors of derived performance measures were estimated using the delta method (Seber 2002: 7-9). Sparse data prevented some parameters from being freely estimated for some release groups. Transition, survival, and detection probabilities were fixed to 1.0 or 0.0 in the USER model as appropriate, based on the observed detections. The model was fit separately for each release group. For each release group, the complete data set that included possible detections from predatory fish was analyzed separately from the reduced data set restricted to detections classified as steelhead detections. Population-level estimates of parameters and performance measures, representing all three release groups, were estimated as weighted averages of the release-specific estimates, using weights proportional to release size.

For each release group, the significance of route (A or B) on estimates of transition probabilities at the Central Valley Project and the radial gates at Clifton Court Forebay to Chipps Island (i.e., $\phi_{D1,D2}$, $\phi_{D2,G2}$, $\phi_{E1,E2}$, and $\phi_{E2,G2}$) were tested using a Likelihood Ratio Test ($\alpha$=0.05; Sokal and Rohlf, 1995). In the event that the effect of route on these parameter estimates and model fit was negligible, common transition probabilities through these regions were used in the two submodels representing the different routes. Otherwise, unique transitions based on route through these facilities were estimated. For each model, goodness-of-fit was assessed visually using Anscombe residuals (McCullagh and Nelder 1989). The sensitivity of parameter and performance metric estimates to inclusion of detection histories with large absolute values of Anscombe residuals was examined for each release group individually.

For each release group, the effect of primary route (San Joaquin River or Old River) on estimates of survival to Chipps Island was tested with a two-sided *Z*-test on the log scale:

$$\mathrm{Z} = \frac{\ln\left(\hat{S}_A\right) - \ln\left(\hat{S}_B\right)}{\sqrt{\hat{V}}},$$

where

$$V = \frac{Var\left(\hat{S}_A\right)}{\hat{S}_A^2} + \frac{Var\left(\hat{S}_B\right)}{\hat{S}_B^2} - \frac{2Cov\left(\hat{S}_A, \hat{S}_B\right)}{\hat{S}_A \hat{S}_B}.$$

The parameter $V$ was estimated using Program USER. Estimates of survival to Jersey Point and False River (i.e., $S_{A(MD)}$ and $S_{B(MD)}$ ) were also compared in this way. Also tested was whether tagged steelhead showed a preference for the San Joaquin River route using a one-sided *Z*-test with the test statistic:

$$\mathrm{Z} = \frac{\hat{\psi}_A - 0.5}{SE\left(\hat{\psi}_A\right)}.$$

Statistical significance was tested at the 5% level ($\alpha$=0.05).

### Analysis of Tag Failure

The first of two tag-life studies began on April 5, 2012 with the last failure recorded on June 25, 2012. The second tag-life study began on May 24, 2012, and the last tag failure was recorded on August 20, 2012. A single tag in the May study was omitted from analysis because it was malfunctioning at the time of tag activation. This left data on 48 tags from the April study, and 44 tags from May study.

Observed tag survival was modeled using the 4-parameter vitality curve (Li and Anderson 2009). In both tag-life studies, the majority of the tags failed on day 80, with only a few premature failures. Because of the concurrent failure of so many tags, it was necessary to right-censor the failure times at day 80 for both studies in order to adequately fit the tag-survival model. Despite having censored the failure times, a good fit to the tag-failure data was achieved. Stratifying by tag-life study (April or May) versus pooling across studies was assessed using the Akaike Information Criterion (AIC; Burnham and Anderson 2002).

The fitted tag survival model was used to adjust estimated fish survival and transition probabilities for premature tag failure using methods adapted from Townsend et al. (2006). In Townsend et al. (2006), the probability of tag survival through a reach is estimated based on the average observed travel time of tagged fish through that reach. For this study, travel time and the probability of tag survival to Chipps Island were estimated separately for the different routes (e.g., San Joaquin route vs. Old River route). Subroutes using truck transport were handled separately from subroutes using only inriver travel. Standard errors of the tag-adjusted fish survival and transition probabilities were estimated using the inverse Hessian matrix of the fitted joint fish-tag survival model. The additional uncertainty introduced by variability in tag survival parameters was not estimated, with the result that standard errors may have been slightly low. In previous studies, however, variability in tag-survival parameters has been observed to contribute little to the uncertainty in the fish survival estimates when compared with other, modeled sources of variability (Townsend et al., 2006); thus, the resulting bias in the standard errors was expected to be small.

### Analysis of Surgeon Effects

Surgeon effects (i.e., "tagger effects") were analyzed in several ways. The simplest method used contingency tests of independence on the number of tag detections at key detection sites throughout the study area. Specifically, a lack of independence (i.e., heterogeneity) between the detections distribution and surgeon was tested using a chi-squared test ($\alpha$=0.05; Sokal and Rohlf 1995). Detections from those downstream sites with sparse data were omitted for this test in order to achieve adequate cell counts, and the chi-squared test was performed via Monte Carlo simulations to accommodate remaining low cell counts.

Lack of independence may be caused by differences in survival, route entrainment, or detection probabilities. A second method visually compared estimates of cumulative survival throughout the study area among surgeons. A third method used Analysis of Variance to test for a surgeon effect on individual reach survival estimates, and an F-test to test for a surgeon effect on cumulative survival throughout each major route (routes A and B). Surgeon effects on estimates of individual parameters were also assessed using an F-test. Finally, the nonparametric Kruskal-Wallis rank sum test (Sokal and Rohlf 1995, ch. 13) was used to test for whether one or more surgeons performed consistently poorer than others, based on individual reach survival or transition probabilities through key reaches. In the event that survival was different for a particular surgeon, the model was refit to the pooled release groups without tags from the surgeon in question, and the difference in survival estimates due to the surgeon was tested using a two-sided Z-test on the lognormal scale. The reduced data set (without predator detections), pooled over release groups, was used for these analyses.

### Analysis of Travel Time

Travel time was measured from release at Durham Ferry to each detection site. Travel time was also measured through each reach for tags detected at the beginning and end of the reach, and summarized across all tags with observations. Travel time between two sites was defined as the time delay between the last detection at the first site and the first detection at the second site. In cases where the tagged fish was observed to make multiple visits to a site, the final visit was used for travel time calculations. When possible, travel times were measured separately for different routes through the study area. The harmonic mean was used to summarize travel times.

### Route Entrainment Analysis

A physical barrier was installed at the head of Old River in 2012. The barrier was designed to keep fish from entering Old River, but included culverts that allowed limited fish passage. Only 58 of the 1,435 (4%) tags released in juvenile steelhead in 2012 were detected entering the Old River route in 2012, while 776 (54% of 1,435) were detected in the San Joaquin River route (Table 8). Because of the barrier and the low number of tags detected in the Old River route, no effort was made to relate route entrainment (i.e., route selection) at the head of Old River to hydrologic conditions in 2012. A route entrainment analysis was performed for the Turner Cut junction instead.

The effects of variability in hydrologic conditions on route entrainment at the junction of Turner Cut with the San Joaquin River were explored using statistical generalized linear models (GLMs) with a binomial error structure and logit link (McCullagh and Nelder, 1989). The acoustic tags used in this analysis were restricted to those detected at either of the acoustic receiver dual arrays located just downstream of the Turner Cut junction: site MAC (model code A8) or site TCE/TCW (code F1). Tags were further restricted to those whose final pass of the Turner Cut junction came from either upstream sites or from the opposite leg of the junction; tags whose final pass of the junction came either from downstream sites (e.g., MFE/MFW) or from a previous visit to the same receivers (e.g., multiple visits to the MAC receivers) were excluded from this analysis. Tags were restricted in this way in order to limit the delay between initial arrival at the junction, when hydrologic covariates were measured, and the tagged fish's final route selection at the junction. Only one steelhead was observed moving from one junction leg to the other (i.e., from Turner Cut to the San Joaquin at MacDonald Island). Predator-type detections were also excluded. Detections from a total of 505 tags were used in this analysis: 169, 208, and 124 from release groups 1, 2, and 3, respectively.

Hydrologic conditions were represented in several ways, primarily total river flow (discharge), water velocity, and river stage. These measures were available at 15-minute intervals from the TRN gaging station in Turner Cut, maintained by the USGS (Table 4). The Turner Cut acoustic receivers (TCE and TCW) were located 0.15 – 0.30 km past the TRN station in Turner Cut. No gaging station was available in the San Joaquin River close to the MAC receivers. The closest stations were PRI (13 km downstream from the junction), and SJG (18 km upstream from the junction) (Table 4). These stations were considered too far distant from the MAC receivers to provide measures of flow, velocity, and river stage sufficiently accurate for describing localized conditions at the Turner Cut junction for the route entrainment analysis. Thus, while measures of hydrologic conditions were available in Turner Cut, measures of flow proportion into Turner Cut were not available.

Additionally, there was no measure of river conditions available just upstream of the junction that might inform about the environment as the fish approached the junction. Instead, gaging data from the SJG gaging station (18 km upstream of the junction) were used as a surrogate for conditions upstream of the junction. Because of the distance between the SJG station and the Turner Cut junction, and the fact that the San Joaquin River becomes considerably wider between the SJG station and the junction, conditions at SJG were used only as an index of average conditions during the time when the fish was in this reach. In particular, no measure of tidal stage or flow direction was used at SJG. Instead, the analysis used the average magnitude (measured as the root mean square, RMS) of flow and velocity at SJG during the tag transition from the time of tag departure from the SJG acoustic receiver (model code A6) to the time of estimated arrival at the Turner Cut junction.

Conditions at the TRN gaging station were measured at the estimated time of arrival at the Turner Cut junction. The location (named TCJ for Turner Cut Junction) used to indicate arrival at the junction was located in the San Joaquin River 1.23 km from the TCE receiver and 2.89 km upstream of the MACU receiver. Time of arrival at TCJ $(t_i)$ was estimated for tag $i$ by a linear interpolation from the observed travel time from the SJNB or SJG acoustic receivers upstream to detection on either the MAC or TCE/TCW receivers just downstream of the junction. Linear interpolation is based on the first-order assumption of constant movement during the transition from the previous site. In a tidal area, it is likely that movement was not actually constant during the transition, but in the absence of more precise spatiotemporal tag detection data, the linear interpolation may nevertheless provide the best estimate of arrival time.

The TRN gaging station typically recorded flow, velocity, and river stage measurements every 15 minutes. Some observations were missing during the time period when tagged steelhead were passing the junction. Linear interpolation was used to estimate the flow, velocity, and river stage conditions at the estimated time of tag arrival at TCJ:

$$x_i = w_i x_{t_{1(i)}} + (1 - w_i) x_{t_{2(i)}}$$

where $x_{t_{1(i)}}$ and $x_{t_{2(i)}}$ are the metric $x$ ($x = Q$ [flow], $V$ [velocity], or $C$ [stage]) at the TRN gaging station nearest in time to the time $t_i$ of tag $i$ arrival such that $t_{1(i)} \le t_i \le t_{2(i)}$. The weights $w_i$ were defined as

$$w_i = \frac{t_{2(i)} - t_i}{t_{2(i)} - t_{1(i)}},$$

and resulted in weighting $x_i$ toward the closest flow, velocity, or stage observation.

In cases with a short time delay between consecutive flow and velocity observations (i.e., $t_{2(i)} - t_{1(i)}$ $\le 60$ minutes), the change in conditions between the two time points was used to represent the tidal stage (Perry 2010):

$$\Delta x_i = x_{t_{2(i)}} - x_{t_{1(i)}}$$

for $x = Q, V,$ or $C$, and tag $i$.

Negative flow measured at the TRN gaging station was interpreted as river flow being directed into the interior Delta, away from the San Joaquin River (Cavallo et al. 2013). Flow reversal (i.e., negative flow at TRN) was represented by the indicator variable $U$ (Perry 2010):

$$U_i = \begin{cases} 1, & for\ Q_i < 0 \\ 0, & for\ Q_i \ge 0 \end{cases}$$

Prevailing flow and velocity conditions in the reach from the SJG acoustic receiver to arrival at the Turner Cut junction were represented by the root mean square (RMS) of the time series of observed conditions measured at the SJG gaging station during the estimated duration of the transition:

$$x_{RMS(i)} = \sqrt{\frac{1}{n_i} \sum_{j=T_{1(i)}}^{T_{2(i)}} x_j^2},$$

where $x_j$ = observed covariate $x$ at time $j$ at the SJG gaging station $(x = Q \text{ or } V)$, $T_{1(i)}$ = closest observation time of covariate $x$ to the final detection of tag $i$ on the SJG acoustic receivers, and $T_{2(i)}$ = closest observation time of covariate $x$ to the estimated time of arrival of tag $i$ at TCJ. If the time delay between either $T_{1(i)}$ and final detection of tag $i$ on the SJG acoustic receivers, or $T_{2(i)}$ and estimated time of arrival of tag $i$ at TCJ, was greater than 1 hour, then no measure of covariate $x$ from the SJG gaging station was used for tag $i$.

Daily export rate for day of arrival of tag $i$ at TCJ was measured at the Central Valley Project $(E_{iCVP})$ and State Water Project $(E_{iSWP})$ (data downloaded from DayFlow on November 5, 2013). Fork length at tagging $L_i$ and release group $RG_i$ were also considered. Finally, arrival time (day vs. night) at the Turner Cut Junction site (TCJ) was measured based on whether the tagged steelhead first arrived at TCJ between sunrise and sunset $(day_i)$.

All continuous covariates were standardized, i.e.,

$$\tilde{x}_{ij} = \frac{x_{ij} - \overline{x}_j}{s(x_j)}$$

for the observation $x$ of covariate $j$ from tag $i$. The indicator variables $U$, $RG$, and $day$ were not standardized.

The form of the generalized linear model was

$$\ln\left(\frac{\psi_{iA}}{\psi_{iF}}\right) = \beta_0 + \beta_1(\tilde{x}_{i1}) + \beta_2(\tilde{x}_{i2}) + \cdots + \beta_p(\tilde{x}_{ip})$$

where $\tilde{x}_{i1}, \tilde{x}_{i2}, \ldots, \tilde{x}_{ip}$ are the observed values of standardized covariates for tag $i$ (covariates 1, 2, …, $p$, see below), $\psi_{iA}$ is the predicted probability that the fish with tag $i$ selected route A (San Joaquin River route), and $\psi_{iF} = 1 - \psi_{iA}$ (F = Turner Cut route). Route choice for tag $i$ was determined based on detection of tag $i$ at either site A8 (route A) or site F1 (route F). Estimated detection probabilities for the three release groups were 0.97 – 1.00 for site A8 and 0.58 – 1.00 for site F1 (Appendix E; Table E2). The estimated detection probability at site F1 was 0.58 for the first release group (April), and 1.00 for the latter two release groups (May). If tag detections at site F1 from the first release group were missing completely at random, then these missing detections should not bias results from the route entrainment analysis because the analysis is restricted to those tags that had detections at F1 (or A8). However, if detections from F1 were missing because of a factor that may also have influenced route choice at the Turner Cut junction, then the missing detections produced by low detectability may bias results of this analysis. Thus, the analysis was performed both with and without tag detections from the first release group.

Single-variate regression was performed first, and covariates were ranked by P-values from the appropriate F-test (McCullagh and Nelder 1989). Covariates found to be significant alone ($\alpha \leq 0.05$) were then analyzed together in a series of multivariate regression models. Because of high correlation between flow and velocity measured from the same site, and to a lesser extent, correlation between flow or velocity and river stage, the covariates flow, velocity, and river stage were analyzed in separate models. The exception was that the flow index in the reach from SJG to TCJ $\left(Q_{SJG}\right)$ was included in the river stage model. Exports at CVP and SWP had low correlation over the time period in question, so CVP and SWP exports were considered in the same models. The general forms of the three multivariate models were:

Flow model: $Q_{TRN} + Q_{SJG} + \Delta Q_{TRN} + U + day + E_{CVP} + E_{SWP} + L + RG$

Velocity model: $V_{TRN} + V_{SJG} + \Delta V_{TRN} + U + day + E_{CVP} + E_{SWP} + L + RG$

Stage model: $C_{TRN} + Q_{SJG} + \Delta C_{TRN} + U + day + E_{CVP} + E_{SWP} + L + RG.$

Backwards selection with F-tests was used to find the most parsimonious model in each category (flow, velocity, and stage) that explained the most variation in the data (McCullagh and Nelder 1989). Main effects and two-way interaction effects were considered. The model that resulted from the backwards selection process in each category (flow, velocity, or stage) was compared using an F-test to the full model from that category to ensure that all significant main effects were included. AIC was used to select among the flow, velocity, and stage models. Model fit was assessed by grouping data into discrete classes according to the independent covariate, and comparing predicted and observed frequencies of route entrainment into the San Joaquin using the Pearson chi-squared test (Sokal and Rohlf 1995).

### SURVIVAL THROUGH FACILITIES

A supplemental analysis was performed to estimate the probability of survival of tagged fish from the interior receivers at the water export facilities through salvage to release on the San Joaquin or Sacramento rivers. Overall salvage survival from the interior receivers at site $k2$, $S_{k2(salvage)}$ $(k = D, E)$, was defined as

$$S_{k2(salvage)} = \phi_{k2,GH} + \phi_{k2,G2},$$

where $\phi_{k2,G2}$ is as defined above, and $\phi_{k2,GH}$ is the joint probability of surviving from site $k2$ to the Jersey

Point/False River junction and not going on to Chipps Island. The subset of detection histories that included detection at site $k2$ ($k = D, E$) were used for this analysis. Detections from the full data set were used to estimate the detection probability at sites G1, G2, and H1, although only data from tags detected at either D2 or E2 were used to estimate salvage survival. Profile likelihood was used to estimate the 95% confidence intervals for both $S_{D2(salvage)}$ and $S_{E2(salvage)}$.

# Results

## Transport to Release Site

No mortalities were observed after transport and prior to release at the release site (Table 6). Water temperatures ranged from 11.8°C to 13.7°C after loading, prior to transport (Table 6). Water temperatures ranged from 12.4°C to 16.0°C after transport and before unloading at the release site (Table 6). Water temperature in the river at the release site ranged from 14.7°C to 20.7°C, with the average during the first week being lower (17.4°C) than for the second week (19.2°C) (Table 6). Water temperatures did not change substantially during transport (maximum of 2.8°C; Table 6, Appendix D). Water temperatures in the transport tanks when arriving at the release site were usually within 6.3°C of the water temperature in the river. Holding temperatures were colder than the river. Dissolved oxygen levels ranged between 5.5 and 17.2 mg/l for all measurements in the transport tanks or in the river (Table 6).

## Fish Releases

Four mortalities were observed immediately prior to release—one each on April 4 and 5 and May 2 and 4 (Table 6).

## Dummy Tagged Fish

Of the 72 steelhead examined, all survived until the evaluation day. All fish had normal gill coloration, normal eye quality and body coloration and no fin hemorrhaging, with the exception of one fish on May 21, 2012, that had abnormal gill color (i.e., grey to light red colored gill filaments; Table 7). Mean scale loss for all fish examined ranged from 7.4 to 17.9% (Table 7). Eight had stitched organs (Figure 16), one had a broken stitch, one other had swelling on the stitch, and one had bleeding from the incision.

## Fish Health

The U.S. Fish and Wildlife Service California-Nevada Fish Health Center conducted a fish health assessment (Appendix C). A total of 71 steelhead were evaluated for mortality and condition after being held for 48 hours at Durham Ferry (Table C1). No significant fish pathogen or disease condition was detected in these steelhead sampled on three collection dates (April 6, May 7, and May 23, 2012). One mortality was observed in the holding containers on May 7, 2012. All remaining fish were found swimming vigorously, had normal gill coloration, normal eye quality and body coloration and no fin hemorrhaging with the exception of April 6 group.

Aeromonas-Pseudomonas (AP) bacteria were commonly isolated from the kidney, however, no clinical signs of septicemia were observed in the trout. All gill Na-K-ATPase samples were lost during processing. The ADP standard curve was normal which indicates that the majority of enzymes and co-factors were operating normally. The pH and magnesium conditions were also normal for the assay. We suspect that the recently purchased Sigma Chemical Adenosine TriPhosphate was faulty as this nucleotide is the substrate for the ouabain-sensitive gill Na-K-ATPase enzyme. On April 6, an opaque focal region was seen in the gill of one steelhead and determined to be an amoeba infection by histology (Figure C1). Epithelial hyperplasia or necrosis was not associated with the parasites and it is unlikely that the fish was affected by the infection. One fish, assessed on April 6, demonstrated unique coloration (Figure C2). No gonads were apparent in this immature fish. No assessment of suture condition was conducted.

## Tag Retention

All steelhead survived as part of the combined tag life/tag retention study until the water and oxygen were mistakenly turned off at the TFCF on May 29, 2012. Twenty-one tagged and nine control fish were killed in tank 5, and 23 tagged and eight control fish were killed in tank 6. Four tagged fish (3 from tank 5 and 1 from tank 6) survived this event and were subsequently necropsied on July 10, 2012. Of the 20 control fish initially placed into the tanks, three (one in tank 5 and two in tank 6) survived the dewatering event on May 29th. All four surviving tagged steelhead had no signs of expelling their tag and none had signs of inflammation. One tagged steelhead had organ adhesion to the incision with the tag imbedded into organs, but no stitched organs, and none had signs of disease or fungus.

## Detections of Acoustic-Tagged Fish

There were 1,435 tags released in juvenile steelhead at Durham Ferry in 2012. Of these, 1,187 (83%) were detected on one or more receivers either upstream or downstream of the release site (Table 8), including any predator-type detections. A total of 1,104 tags (77%) were detected at least once downstream of the release site, and 840 (59%) were detected in the study area from Mossdale to Chipps Island (Table 8). A smaller proportion of the last release group (39%) was detected in the study area than of the earlier release groups (67% - 70%).

Overall, there were 776 tags detected on one or more receivers in the San Joaquin River route downstream of the head of Old River (Table 8). In general, tag detections decreased within each migration route as distance from the release point increased. Of these 776 tags, 776 were detected on the receivers near Lathrop; 724 were detected on one or both of the receivers near Stockton (SJG or SJNB); 606 were detected on the receivers in the San Joaquin River near MacDonald Island or in Turner Cut; and 326 were detected at Medford Island (Table 9). Not all of the 776 tags detected in the San Joaquin River downstream of the head of Old River were assigned to that route for the survival model, because some were subsequently detected in the Old River route or upstream of Old River.

Overall, 751 tags were assigned to the San Joaquin River route for the survival model (Table 8). Of these 751 tags, 138 were observed exiting the San Joaquin River at Turner Cut, 183 were observed at the Old or Middle River receivers near Empire Cut, 94 were observed at the Old or Middle River receivers near Highway 4, and 68 were observed at the water export facilities receivers (including the radial gates at the entrance to the Clifton Court Forebay) (Table 9, Table 10). A total of 297 San Joaquin River route tags were detected at the Jersey Point/False River receivers, including 112 detections on the False River receivers (Table 9). However, the majority of the tags detected at False River were later detected either at Jersey Point or Chipps Island, and so only 10 San Joaquin River tags were used in the survival model at False River (Table 10). A total of 252 San Joaquin River route tags were eventually detected at Chipps Island, including predator-type detections (Table 9).

Only 58 tags were detected in the Old River route (Table 8). All 58 of these tags were detected at the Old River East receivers near the head of Old River, while 51 were detected near the head of Middle River, and 32 were detected either at the receivers at the water export facilities, or at the Old or Middle River receivers near Highway 4 in the interior Delta (Table 8, Table 9). Only 3 tags were detected on the Middle River receivers near the head of Middle River. Also, only 3 of the tags detected in the Old River route were ever detected at the receivers in the Old and Middle rivers near Empire Cut (omitting a single tag that was eventually detected at Durham Ferry after detection in the northern Middle River), and only 1 of these 3 tags entered the Old River route via the head of Old River. Similarly, few tags appear to have reached either the Old River receivers (6 tags) or the Middle River receivers (2 tags) at Highway 4 via the Old River route (Table 9).

Some of the 58 tags detected in the Old River route were assigned to a different route for the survival model because they were subsequently detected in the San Joaquin River after their Old River route detections. In all, 48 tags were assigned to the Old River route at the head of Old River based on the full sequence of tag detections (Table 8). Of these 48 tags, 22 were detected at the CVP trashracks, although only 15 of these CVP detections were used in the survival model because the others were later detected either at the radial gates or farther north in Old or Middle rivers (Table 9, Table 10). No Old River route tags were detected at the Jersey Point/False River receivers; while some tags were observed to reach the Jersey Point/False River junction coming from the northern Old and Middle river receivers, these tags had all remained in the San Joaquin River at the head of Old River, and entered the interior Delta downstream of the city of Stockton. Of the 48 tags assigned to the Old River route at the head of Old River, 4 were detected at Chipps Island, including predator-type detections (Table 9,Table 10).

In addition to the Old and Middle river receivers located near Empire Cut, the Threemile Slough receivers recorded detections of tags but were purposely omitted from the survival model. Fifty- two (52) tags were detected on the Threemile Slough receivers: 37 tags came directly from the San Joaquin River receivers (MacDonald and Medford islands), 13 from Jersey Point or False River, and 1 each from Turner Cut and the Old River receiver near Empire Cut.

The predator filter used to distinguish between detections of juvenile steelhead and detections of predatory fish that had eaten the tagged steelhead classified 265 of the 1,435 tags (18%) released as being detected in a predator at some point during the study (Table 11). Of the 840 tags detected in the study area (i.e., at Mossdale or points downstream), 122 tags (15%) were classified as being in a predator, although some had been identified as a predator before entering the study area. A total of 103 tags (12%) were classified as a predator within the study area. The region upstream of Mossdale had a larger percentage of tags classified as in a predator at some point, with 181 of 781 tags (23%) detected in that region classified as in a predator. Nineteen of those 181 tags were classified as a predator downstream of Mossdale, and then returned to the upstream regions (Table 11).

Within the study area, the detection sites with the largest number of first-time predator-type detections were Garwood Bridge (14 of 724, 2%), Navy Drive Bridge (11 of 693, 2%), and the CVP trashracks (10 of 76, 13%) (Table 11). Most predator classifications were assigned to tags on arrival at the detection site in question because of unexpected travel time and unexpected transitions between detection sites, with the result that predator-type detections at those sites were removed from the survival model. Predator classifications on departure from a detection site were typically because of long residence times, and were most prevalent at Garwood Bridge, Navy Drive Bridge, and the receivers at the Clifton Court Forebay radial gates entrance channel.

When the detections classified as coming from predators were removed from the detection data, somewhat fewer detections were available for survival analysis (Table 12, Table 13, Table 14). With the predator-type detections removed, 1,045 of the 1,435 (73%) tags released were detected downstream of the release site, and 821 (57% of those released) were detected in the study area from Mossdale to Chipps Island (Table 12). The final release group had a lower percentage (37%) of total tags subsequently detected within the study area than the earlier release groups (65% to 70%). The final release group also had the lowest percentage of tags detected anywhere after release (70% vs. 79% - 88% for previous releases).

Many more steelhead were observed using the San Joaquin River route at the head of Old River (759) than the Old River route (42) (Table 12). As observed from the full data set including the predator-type detections, the reduced data set with only steelhead-type detections showed that the majority of the tags detected at the receivers in the western and northern portions of the study area, including the water export facilities, Jersey Point, and Chipps Island, used the San Joaquin River route at the head of Old River rather than the Old River route (Table 13). No tagged steelhead from the Old River route were detected at the Old and Middle river receivers near Empire Cut (OLD and MRE, respectively), although 50 tagged steelhead from the San Joaquin River route were detected at OLD, and 175 were detected at MRE (Table 13). Thus, using a barrier to keep steelhead out of Old River at its head does not necessarily prevent them from entering the interior Delta farther downstream. While there were more San Joaquin River route steelhead detected at the receivers near the export facilities than Old River route steelhead, the differences between routes was not as marked at those locations as at the northern Old and Middle river receivers. Of the 42 steelhead assigned to the Old River route at the head of Old River, 12 were detected at the radial gates receivers and 18 were detected at the Central Valley Project. Only 3 of the Old River route steelhead were eventually detected at Chipps Island (Table 13). At most sites in the San Joaquin River route, considerably fewer steelhead were detected from the third release group (mid-May) than from either of the first two release groups (Table 13). For the Old River route, however, detection counts were similar between the second and third release groups, and tended to be lower than for the first release group (early April) (Table 12). Detection counts used in the survival model follow a similar pattern (Table 14).

## Tag-Survival Model and Tag-Life Adjustments

The Akaike Information Criterion (AIC) indicated that pooling data from both tag-life studies (AIC = 8.9) was preferable to stratifying by study month (AIC = 17.6). Thus, a single tag survival model was fitted and used to adjust fish survival estimates for premature tag failure. The estimated mean time to failure from the pooled data was 77.7 days ($\widehat{SE} = 10.8$ days) (Figure 17).

The complete set of detection data, including any detections that may have come from predators, contained some detections that occurred after the tags began dying, although before the precipitous drop in tag survival at day 80 (Figure18, Figure 19). The sites with the latest detections were the Durham Ferry site located just downstream of the release site, Banta Carbona, the San Joaquin River receiver near Medford Island, and Lathrop. Some of these late-arriving detections may have come from predators, or from residualizing steelhead. Tag-life corrections were made to survival estimates to account for the premature tag failure observed in the tag-life studies. All estimates of reach survival for the acoustic tags were greater than 0.97 (out of a possible range of 0 – 1), and cumulative tag survival to Chipps Island was estimated at 0.98 or above with or without predator-type detections. Thus, there was very little effect of either premature tag failure or corrections for tag failure on the estimates of steelhead reach survival.

## Surgeon Effects

Fish in the release groups were fairly evenly distributed across surgeons, with 11-14 more fish tagged by surgeons C or D than by surgeons A or B in each release group (Table 15). For each surgeon, the number tagged was distributed evenly across the three release groups. A chi-squared test found no evidence of lack of independence of surgeon across release groups ( $\chi^2$ =0.0184, df=6, P=1.0000). The distribution of tags detected at various key detection sites was well-distributed across surgeons and showed no evidence of a surgeon effect on survival, route selection, or detection probabilities at these sites ( $\chi^2$ = 36.7316, df = 39, P = 0.5738; Table 16).

Estimates of cumulative survival throughout the San Joaquin River route to Chipps Island showed similar patterns of survival across all surgeons. Although surgeons A and C had consistently higher cumulative survival through much of the San Joaquin River route, there was no significant difference in overall survival to Chipps Island among surgeons (Figure 20). Analysis of variance found no effect of tagger on reach survival (P=0.6649). Larger differences in cumulative survival by surgeon were observed in the Old River route, with surgeon B showing relatively low survival to the South Delta exit points in the Old River route (Figure 21) compared to the other surgeons. However, there was no effect of surgeon on cumulative survival via the Old River route either to the South Delta exits points (P=0.7735) or to Chipps Island (P=0.6840). Rank tests found no evidence of consistent differences in reach survival across fish from different surgeons either upstream of the Head of Old River (P=0.9932), or in either the San Joaquin River route (P=0.9932) or the Old River route (P=0.9363).

## Survival and Route Entrainment Probabilities

For each release group, likelihood ratio tests indicated that transition probabilities through the Central Valley Project and Clifton Court Forebay did not significantly depend on the route taken to those sites (i.e., the San Joaquin River route versus the Old River route) (P ≥ 0.4005 without the predator-type detections, and P ≥ 0.2301 with the predator-type detections). Thus, common transition probabilities through those regions were estimated, regardless of route.

Some parameters were unable to be estimated because of sparse data. In particular, only 3 tags were detected at the receiver at the head of Middle River (MRH, model code C1). Two of these were classified as a predator prior to arrival at site C1, and they were both last observed at site C1. The third tag was observed making over 20 visits to site C1, and finally ended its detection history at Banta Carbona; because it was classified as a predator on departure from its first visit to C1, the first C1 detection was available to be used in analysis excluding the predator-type detections. However, having only 1-3 detections at C1 made estimation of detection and transition probabilities at that site untractable. Thus, no detections of C1 were used in the survival analysis for any release group. This prevented estimation of all transition parameters starting at C1: $\phi_{C1,B3}$, $\phi_{C1,C2}$, $\phi_{C1,D1}$, and $\phi_{C1,E1}$. It was also necessary to combine the survival probability from ORE (site B1) to the Middle River junction with Old River $(S_{B1})$ and the route selection probability for Old River at that junction $(\psi_{B2})$ to yield the transition probability $\phi_{B1,B2} = S_{B1}\psi_{B2}$. This transition probability may be interpreted as equal to the survival parameter from the head of Old River to the head of Middle River only under the assumption that no fish actually entered Middle River (i.e., $\psi_{B2} = 1$). In the absence of Middle River detections and under the assumption that the Middle River receivers were actually working, this may be a reasonable assumption. In cases such as the first release group using steelhead-type detections and the third release group using all detections (steelhead-type and predator-type), in which there were detections at Middle River but too few to estimate parameters there, it must be noted that estimates of $\phi_{B1,B2}$ are only minimum estimates of survival from the head of Old River to the head of Middle River.

There were very few tags observed moving to the Jersey Point and False River receivers from the northern Old and Middle River receivers (i.e., those near Highway 4, OR4 [B3] and MR4 [C2]). Of the fish coming from the Old River route at the head of Old River, none were observed moving from the Highway 4 receivers to Jersey Point and False River, and of the fish coming from the San Joaquin River route, only 4 tags were observed moving to Jersey Point and False River from OR4, and none from MR4. Thus, estimates of $\phi_{B3,GH}$ and $\phi_{C2,GH}$ were both 0 for Old River route fish, and $\phi_{C2,GH}$ was also estimated at 0 for San Joaquin River route fish. Furthermore, no estimates of $\phi_{G1,G2}$ or $\psi_{G1}$ were available for Old River route fish.

In some cases, detections were at a particular site were too sparse to include the site in the model. There were too few detections at the False River receivers (site H1) from the first and second release groups to estimate the detection probability at that site. Site H1 was omitted from the model in these cases, and the parameters $\phi_{x,G1} = \phi_{x,GH}\psi_{G1}$ were estimated for *x* = A8, A9, B3, C2, and F1. In many cases analysis of model residuals showed that incorporating certain detection sites or the full dual array at certain sites in the model reduced the quality of the model fit to the data. In such cases where it was possible to simplify the data structure and still attain useful and valid parameter estimates, the problematic sites were either omitted (e.g., site A2 at Durham Ferry Downstream for the second and third release groups) or detections from the dual array were pooled (e.g., site A8 at MacDonald Island for the second release group) to improve model fit. In cases where site A2 was removed, the model used the composite parameter $\phi_{A1,A3} = \phi_{A1,A2}S_{A2}$ in place of $\phi_{A1,A2}$ and $S_{A2}$.

Using only those detections classified as coming from juvenile steelhead and excluding the predator-type detections, the estimates of total survival from Mossdale to the receivers at Chipps Island, $S_{total}$, ranged from 0.26 ($\widehat{SE} = 0.02$) for the first release group (released in early April) to 0.35 ($\widehat{SE} = 0.03$) for the second release group (released in early May) (Table 17). The overall population estimate for all fish in the tagging study was 0.32 ($\widehat{SE} = 0.02$). Estimates of the probability of remaining in the San Joaquin River at the junction with Old River $(\psi_A = \psi_{A1})$ were high, ranging from 0.92 ($\widehat{SE} = 0.02$) for the third release group to 0.97 ($\widehat{SE} = 0.01$) for the second release group; the population estimate was 0.94 ($\widehat{SE} = 0.01$) (Table 17). For each release group, there was a significant preference for the San Joaquin River route (P<0.0001 for each group). Estimates of survival from Mossdale to Chipps Island via the San Joaquin River route $\left(S_A\right)$ ranged from 0.28 ($\widehat{SE} = 0.03$) for the early April release group to 0.36 ($\widehat{SE} = 0.04$) for the mid-May release group; the overall population estimate was 0.33 ($\widehat{SE} = 0.02$). In the Old River route, estimates of survival from Mossdale to Chipps Island were considerably lower, ranging from 0.05 ($\widehat{SE} = 0.03$) for the mid-May release group, to 0.10 ($\widehat{SE} = 0.07$) for the early May release group; the overall population estimate was 0.07 ($\widehat{SE} = 0.03$) (Table 17). For all release groups, the estimate of survival to Chipps Island was significantly higher in the San Joaquin River route than in the Old River route (P≤0.0405).

Survival was estimated to the Jersey Point/False River junction for fish that did not pass through the holding tanks at the CVP or the SWP. This survival measure ( $S_{total(MD)}$ ) had estimates ranging from 0.30 ($\widehat{SE} = 0.03$) for the early April release group to 0.45 ($\widehat{SE} = 0.03$) for the early May release group, averaging 0.39 ($\widehat{SE} = 0.02$) over all release groups (Table 17). All of the tagged steelhead observed at the Jersey Point/False River junction came via the San Joaquin River route; none had taken the Old River route at the head of Old River. Many of the Old River route fish were observed at the receivers closest to the salvage facilities at Central Valley Project (i.e., the holding tank) and the State Water Project (i.e., the radial gates receivers); the survivors of these fish would not have contributed to survival to Jersey Point/False River. Because $S_{total(MD)}$ does not reflect survival to downstream regions via salvage, it is not necessarily indicative of overall survival to Chipps Island ( $S_{total}$ ). In all, very few tags were observed leaving the San Joaquin River for False River (Table 14, and $\widehat{\Psi}_{H1(A)}$ in Table E2 in Appendix E).

Survival was estimated through the South Delta ( $S_{A(SD)}$ , $S_{B(SD)}$ , and $S_{total(SD)}$ ) for all release groups. The "South Delta" region corresponded to the region studied for Chinook Salmon survival in the 2009 VAMP study (SJRGA 2010). Estimates of survival in the San Joaquin River from Mossdale to MacDonald Island (MAC) or Turner Cut (TCE/TCW) ( $S_{A(SD)}$ ) ranged from 0.78 ($\widehat{SE} = 0.04$) for the first release group to 0.89 ($\widehat{SE} = 0.03$) for the last release group, yielding a population estimate of 0.83 ($\widehat{SE} = 0.02$) (Table 17). In the Old River route, estimated survival from Mossdale to the entrances of the water export facilities (CVP, RGU) or the northern Old River and Middle River receivers near Highway 4 (OR4, MR4) ( $S_{B(SD)}$ ) ranged from 0.23 ($\widehat{SE} = 0.11$) for the last release group to 0.80 ($\widehat{SE} =$

$0.08$) for the first release group; the population-level estimate was 0.55 ($\widehat{SE} = 0.07$) (Table 17). The larger standard errors on the Old River route estimates reflect the relatively small numbers of fish using the Old River route in 2012 compared to the San Joaquin River route. Total estimated survival through the entire South Delta region ( $S_{total(SD)}$ ) ranged from 0.78 ($\widehat{SE} = 0.04$) for the first release group to 0.84 ($\widehat{SE} = 0.03$) for the last release group, yielding a population estimate of 0.81 ($\widehat{SE} = 0.02$) over all three release groups (Table 17).

Including predator-type detections in the analysis produced little change in the estimates of survival on any of the spatial scales considered, including survival to Chipps Island, survival to the Jersey Point/False River region, or survival through the South Delta (Table 17, Table 18). The largest difference was in estimates of survival through the South Delta region in the Old River route, which increased from 0.80 ($\widehat{SE} = 0.08$) without the predator-type detections for the April release group to 0.89 ($\widehat{SE} = 0.07$) with the predator-type detections (Table 17, Table 18). The increase may be due to the typically high density of predators at the CVP trashracks and radial gates. Overall survival to Chipps Island showed essentially no change (difference ≤ 0.02) when predator-type detections were included (Table 18). Survival from Mossdale to the Jersey Point/False River region (without salvaged fish) showed similarly negligible changes when predator-type detections were included. The small effect of removing the predator detections on survival estimates over the larger spatial scales may reflect limitations of the spatial range of the predators, or similarities in behavior between steelhead and the predatory fish targeted in the predator filter (Table 17, Table 18).

## Travel Time

For tags classified as being in steelhead, average travel time through the system from release at Durham Ferry to Chipps Island was 9.41 days ($\widehat{SE} = 0.25$ days) (Table 19a). Travel time to Chipps Island tended to decrease for later release groups: the first release group (early April) took an average of 13.64 days ($\widehat{SE} = 0.51$), while the final release group (mid-May) took an average of 7.93 days ($\widehat{SE} = 0.37$) (Table 19a). The large majority of tags reaching Chipps Island came via the San Joaquin River route; the 3 tags that arrived at Chipps Island via the Old River route had a slightly longer travel time (average = 13.00 days; ($\widehat{SE} = 2.57$ days). While most tags that were observed at Chipps Island arrived within 15 days of release at Durham Ferry, there were several tags that took longer, and 4 tags that took 25–40 days to get to Chipps Island. All of the very slow tags had remained in the San Joaquin River at the head of Old River.

Travel time from release to Mossdale Bridge receivers averaged approximately 2–3 days throughout the study, and travel time to the Turner Cut junction receivers (i.e., at Turner Cut and MacDonald Island) averaged approximately 5–9 days over all release groups (Table 15). Travel time from release to the receivers near or at the water export facilities (Central Valley Project and Clifton Court Forebay radial gates) tended to be longer for fish taking the San Joaquin River route rather than the Old River route. This pattern was not consistent throughout the season, however; Old River route fish from the final release group took considerably longer than their counterparts in the San Joaquin River route (Table 19a). However, few fish took the Old River route at the head of Old River, and few Old River fish were detected at the facilities from the last release group, so the results for the Old River route may be skewed by the small sample size. Pooled over all three release groups, there was little difference in total travel time to the radial gate receivers at the Clifton Court Forebay by route (approximately 9–10 days), and San Joaquin River route fish took approximately 2 extra days to reach the Central Valley Project than Old River route fish (Table 19a). Very few fish reached the receivers in the interior Delta (i.e., Middle River and Old River receivers near Highway 4) via the Old River route, and they tended to take just over two weeks from the release at Durham Ferry. Most fish that were observed at those receivers came from the San Joaquin River route, and took an average of 9–10 days from Durham Ferry, averaged over all release groups. Fish from the first release group tended to have longer travel times to the Highway 4 receivers (12–13 days) than fish from later release groups (7–9 days) (Table 19a). All fish observed at the Jersey Point or False River receivers came via the San Joaquin River route, and average travel times were approximately 7–8 days (averaged over all releases). The first release group generally took longer to reach these receivers (12 days) than fish released later (6–8 days) (Table 19a).

Including detections from tags classified as predators tended to lengthen average travel times, but the general pattern across routes and release groups stayed the same (Table 19b). The average travel time from release to Chipps Island via all routes, including the predator-type detections, was 9.52 days ($\widehat{SE} = 0.26$ days) (Table 19b). Increases in travel time with the predator-type detections reflect the travel time criteria in the predator filter, which assumes that predatory fish may move more slowly through the study area than migrating steelhead. Travel time increases may also reflect multiple visits to a site by a predator, because the measured travel time reflects time from release to the start of the final visit to the site.

Average travel time through reaches for tags classified as being in steelhead ranged from 0.01–0.09 days (20–130 minutes) from the entrance channel receivers at the Clifton Court Forebay (RGU) to the interior forebay receivers (RGD) to over 5 days from the head of Old River (ORE) to the head of Middle

River (MRH) and from Old River South (ORS) to Old River near Highway 4 (OR4) (Table 20a). However, of those tags classified as in steelhead, only one tag was observed moving from ORE to MRH and only two tags moving from ORS to OR4. The reach from the exterior to the interior radial gate receivers (RGU to RGD) was the shortest, so it is not surprising that it would have the shortest travel time, as well. However, travel time did not always reflect travel distance. For example, average travel time from Lathrop (SJL) to Garwood Bridge (SJG) was approximately 0.8 days through a distance of about 18 rkm, while average travel time from the Old River South receivers (ORS) to the Central Valley Project trash rack receivers (CVP) was about 3 days, also through a distance of approximately 18 rkm. Travel times within the San Joaquin River tended to be shorter than travel times that involved the interior Delta. For example, the average travel time from the MacDonald Island receivers to the Jersey Point/False River receivers (~26 rkm) was 1.61 $(\widehat{SE} = 0.05)$ days, while the average travel time from the MacDonald Island receivers to the receivers in Old River near Highway 4 (~27 rkm) was 3.73 $(\widehat{SE} = 0.36)$ days (Table 20a). The comparable distances but widely different travel times suggest that travel in the interior Delta may be prolonged by the complexity of the routing and hydrologic environment in that region.

Reach travel times tended to be longer in the first release group than in the later groups, although this was not consistent throughout the study area. This was most apparent in the San Joaquin River reaches, in particular from the Navy Drive Bridge (SJNB) to MacDonald Island and Turner Cut, and from MacDonald or Medford islands to points downstream (Table 20a). Including the predator detections tended to increase reach travel times, although not consistently across all reaches and release groups (Table 20b).

## Route Entrainment Analysis

River flow (discharge) at the TRN gaging station in Turner Cut ranged from -4,646 cfs to 3,363 cfs (average = -1,117 cfs) during the estimated arrival time of the tagged steelhead at the Turner Cut junction location (TCJ) in 2012. Water velocity in Turner Cut was highly correlated with river flow (r=0.999), and velocity values ranged from -0.8 ft/s to 0.7 ft/s (average = -0.2 ft/s). The flow in Turner Cut was negative (i.e., directed to the interior Delta) upon arrival at TCJ for approximately 65% (326 of 505) tags in this analysis. River stage measured in Turner Cut was moderately correlated with both river flow and velocity (r=-0.73), and ranged from 6.7 ft to 11.3 ft (average = 9.2 ft). Changes in river stage in the 15-minute observation period, during which the tagged steelhead arrived at the Turner Cut junction (TCJ), ranged from -0.2 ft to 0.2 ft (average = 0 ft). Changes in river stage were not correlated with stage (r=-0.08). The index of river flow in the reach from Stockton to Turner Cut was uncorrelated with flow and velocity in Turner Cut upon arrival at TCJ (r=0.14), and only moderately correlated with river stage at Turner Cut (r=-0.30). The flow index in the Stockton-Turner Cut reach ranged from 765 cfs to 4,018 cfs (average = 2,702 cfs).

The daily export rate at CVP ranged from 821 cfs to 4,263 cfs (average = 1,048 cfs), with exports generally low early in the study and peaking in mid-May. The daily export rate at the State Water Project (SWP) ranged from 507 cfs to 3,699 cfs (average = 1,604 cfs). SWP exports were more variable than CVP exports but also peaked in mid-May. Exports from CVP and SWP were uncorrelated (r=-0.06). Neither CVP nor SWP exports was correlated with either flow (r=0.07 for CVP, r=-0.08 for SWP) or river stage (r=-0.22 for CVP, r=0.01 for SWP) in Turner Cut.

The single-variate analyses using all three release groups found significant effects ($\alpha$=5%) of several covariates on the probability of remaining in the San Joaquin River at Turner Cut: river stage and change in river stage at TRN, change in flow and velocity at TRN, release group, exports at CVP, fork length at tagging, and reverse flow at TRN (Table 21) Exports at SWP and total flow and velocity at TRN were significant at the 10% level (Table 21). When tags were limited to the second and third release group, which passed Turner Cut during periods of high detection probability at all receivers in the region, the effects of fork length and reverse flow at TRN were no longer significant at the 5% level, although fork length was significant at the 10% level (Table 22). SWP exports, flow, and velocity in Turner Cut were no longer significant at the 10% level without the first release group. The fact that flow and velocity at TRN were (marginally) significant only when the first release group was included, during a time of deficient detection probability at the Turner Cut acoustic receivers, suggests that the effects of flow and velocity were confounded with the effects of non-detection at site F1. This may produce a bias in the results. For example, if the detection probability at the F1 receivers was lower during periods of high flow through Turner Cut during the first release group, then the regression model might indicate an effect of increased flow on the route entrainment probability when in fact the effect was instead on the detection probability. For this reason, further results are limited to the second and third release groups, for which detection probabilities were high at all acoustic receivers downstream of the Turner Cut junction.

When limited to the second and third release groups, the single-variate regression models found significant effects on the probability entering Turner Cut of change in flow and velocity at TRN (P<0.0001 for both), river stage and change in river stage at TRN (P<0.0001 for both), release group

(P=0.0087), and CVP exports (P=0.0093). Fork length was significant at the 10% level, but not the 5% level (P=0.0866). Neither of the measures of river conditions in the reach from SJG to the Turner Cut junction was significant (P≥0.3324), nor was the direction of flow in Turner Cut (P=0.3678) or SWP exports (P=0.3892). Arrival during daylight was non-significant (P=0.7659). As mentioned above, neither flow nor velocity at TRN was significant (P≥0.8370) when restricted to the later release groups (Table 22).

Several covariates had strong effects based on the single-variate models (Table 22). However, while the single-variate models may suggest possible relationships, confounding among the independent covariates and the possibility of a causal relationship with an unobserved factor both make it impossible to conclude that changes in any of the significant single-variate measures directly produce changes in route selection at Turner Cut. Multiple regression may shed more light on which covariates are worthy of further study, but causal relationships will not be discernable.

Multiple regression using data from the second and third release groups found significant effects of river stage and change in river stage at the TRN gaging station, as well as changes in flow and velocity at the TRN station (Table 23). Release group was also significant for each of the flow, velocity, and stage models (P≤0.0038), reflecting a difference in the underlying propensity to enter Turner Cut for the mid-May release group relative to the early May release group. Exports at CVP were significant (P=0.0008) for the flow and velocity models but not for the stage model (Table 23). All three models (flow, velocity, and stage) adequately fit the data (P>0.99); the stage model accounted for more variation in route entrainment than either flow ($\Delta$AIC=5.2) or water velocity ($\Delta$AIC=5.4) (Table 23).

The stage model predicted the probability of entering Turner Cut from its junction with the San Joaquin River according to:

$\hat{\Psi}_f = [1 + \exp(-3.55 + 0.54 C_{TRN} - 4.76 \Delta C_{TRN})]^{-1}$ for fish from the second release group, and

$\hat{\Psi}_f = [1 + \exp(-4.35 + 0.54 C_{TRN} - 4.76 \Delta C_{TRN})]^{-1}$ for fish from the third release group,

where $C_{TRN}$ and $\Delta C_{TRN}$ represent the river stage and 15-minute change in river stage upon tag arrival at the Turner Cut junction. If $\Delta C_{TRN}$ is interpreted as a partial indicator of the tidal cycle in Turner Cut, this model of route entrainment indicates that at a given point in the tidal cycle, steelhead that arrive at a higher river stage have a lower probability of entering Turner Cut than fish that arrive at a lower river stage (Figure 22). Although river stage and river discharge (flow) are moderately correlated in Turner Cut such that higher river stages are associated with negative river flows (r=-0.73), river flow was not significantly correlated with the probability of entering Turner Cut (P= 0.8370 from a single-variate model,Table 22). This suggests that it is the tidal component of river stage, rather than the inflow component, that may be influencing entry into Turner Cut. This route entrainment model suggests that for a given level of river stage, steelhead that arrive on an ebb tide ($\Delta C_{TRN}$ <0) are less likely to enter Turner Cut than fish that arrive on a flood tide ($\Delta C_{TRN}$ >0) (Figure 23). However, the actual modeled probability of entry into Turner Cut depends on the level of river stage upon arrival at the junction (Figure 23 and Figure 24). Overall, steelhead from the third release group were more likely to enter Turner Cut than those from the second release group.

### Survival through Facilities

Survival through the water export facilities was estimated as the overall probability of reaching either Chipps Island, Jersey Point, or False River after being last detected in the CVP holding tank (site E2, for the federal facility) or the interior receivers at the radial gates at the entrance to Clifton Court Forebay (site RGU, D2, for the receivers closest to the state facility). Thus, survival for the federal facility is conditional on being entrained in the holding tank, while survival for the state facility is conditional on entering (and not leaving) the Clifton Court Forebay, and includes survival through the Forebay to the holding tanks. Results are reported for the individual release groups, and also for the full set of data from all three release groups combined (population estimate).

Estimated survival from the CVP holding tanks to Chipps Island ranged from 0.50 ($\widehat{SE} = 0.18$) for the second release group (early May), with a 95% profile likelihood interval of (0.19, 0.81), to 0.68 ($\widehat{SE} = 0.28$) (95% CI = (0.16, 0.99)) for the third release group (mid-May). The population estimate, found from pooling across release groups, was 0.57 ($\widehat{SE} = 0.12$) (95% CI = (0.33, 0.79)) (Table 24). For the state facility, estimated survival from the radial gates to Chipps Island, Jersey Point, and False River ranged from 0 for the first release group (April) to 0.30 ($\widehat{SE} = 0.15$)(95% CI = (0.09, 0.62)) for the third release group. The population estimate for the state facility was 0.17 ($\widehat{SE} = 0.08$), with a 95% confidence interval of (0.06, 0.36) (Table 24).

## Discussion

Numerous objectives were developed as part of the Six-Year Study in its requirements in the 2009 National Marine Fisheries Service Biological Opinion on the Long term Operation of the CVP and SWP, but given the limited sample size from the first and second year, these analyses are reserved for consideration until completion of three years of the multi-year study. Management implications will be discussed in subsequent reports.

## References


Buchanan, R. A. 2010. Sample Size for VAMP 2011: Preliminary Analysis. Prepared for: Pat Brandes, U.S. Fish and Wildlife Service, Stockton CA. 12 August 2010. Included as Appendix E in SJRGA (2013).

Burnham, K. P., and D. R. Anderson (2002). Model selection and multimodel inference: A practical information-theoretic approach. 2nd edition. Springer. New York, NY. 488 pp.

Cavallo, B., P. Gaskill, and J. Melgo (2013). Investigating the influence of tides, inflows, and exports on sub-daily flow in the Sacramento-San Joaquin Delta. Cramer Fish Sciences Report. 64 pp. Available online at: http://www.fishsciences.net/reports/2013/Cavallo_et_al_Delta_Flow_Report.pdf.

Dauble, D., D. Hankin, J. Pizzimenti, P. Smith 2010. The Vernalis Adaptive Management Program (VAMP) Report of the 2010 Review Panel. Prepared for the Delta Science Program. May 13, 2010. 45 pgs.

Delaney, D., P. Bergman, B. Cavallo, and J. Melgo (2014). Stipulation Study: Steelhead Movement and Survival in the South Delta with Adaptive Management of Old and Middle River Flows. Prepared under the direction of Kevin Clark, Bay-Delta Office, Biotelemetry and Special Investigations Unit. California Department of Water Resources. 150 pgs.

DSP (Delta Science Program). 2009. The Vernalis Adaptive Management Program (VAMP): report of the 2010 review panel. May 13, 2010. Prepared for the Delta Science Program, 45 p.

Garza, J.C., D.E. Pearse (2009) Population genetic structure of *Oncorhynchus* mykiss in the California Central Valley. Final report for the California Department of Fish and Game Contract #PO485303.

Lady, J. M., and J. R. Skalski (2009). USER 4: User-Specified Estimation Routine. School of Aquatic and Fishery Sciences. University of Washington. Available from http://www.cbr.washington.edu/paramest/user/.

Li, T., and J. J. Anderson (2009). The Vitality model: A Way to understand population survival and demographic heterogeneity. Theoretical Population Biology 76: 118-131.

McCullagh, P., and J. Nelder (1989). Generalized linear models. 2nd edition. Chapman and Hall, London.

McEwan, D (2001) Central Valley steelhead. In R .L. Brown (editor), Contributions to the Biology of Central Valley Salmonids, Volume 1, pages 1-44. California Department of Fish and Game, Fish Bulletin 179.

National Marine fisheries Service (NMFS). 2009a. Biological Opinion on long-term operations of the Central Valley Project and State Water Project. June 4. NMFS Southwest Region, Long Beach, California. Available from: http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/nmfs_biological_and_conference_opinion_on_the_long-term_operations_of_the_cvp_and_swp.pdf.

National Marine Fisheries Service. 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the

Distinct Population Segment of California Central Valley Steelhead. California Central Valley Area Office. July 2014.

U.S. Bureau of Reclamation (USBR). 2018. NMFS Biological Opinion RPA IV.2.2: 2011 Six-Year Acoustic Telemetry Steelhead Study. Contributions by Buchanan, R., J. Israel, P. Brandes. E. Buttermore. Reclamation Bay-Delta Office, Mid-Pacific Region, Sacramento, CA. FINAL REPORT May 14, 2018, 144p.

Perry, R. W. (2010). Survival and migration dynamics of juvenile Chinook salmon (Oncorhynchus tshawytscha) in the Sacramento-San Joaquin River Delta. Doctoral Dissertation, University of Washington.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, and B. MacFarlane (2010). Estimating survival and migration route probabilities of juvenile Chinook salmon in the Sacramento-San Joaquin River Delta. North American Journal of Fisheries Management 30: 142-156.

San Joaquin River Group Authority (SJRGA) (2010). 2009 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board.

San Joaquin River Group Authority (SJRGA) (2011). 2010 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board.

San Joaquin River Group Authority (SJRGA) (2013). 2011 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board.

Satterthwaite, W.H., M.P. Beakes, E.M. Collins, D.R. Swank, J.E. Merz, R.G. Titus, S.M. Sogard, M. Mangel (2010) State-dependent life history models in a changing (and regulated) environment: steelhead in the California Central Valley. Evolutionary Applications 3: 221-243.

Seber, G. A. F. (2002). The estimation of animal abundance. Second edition. Blackburn Press, Caldwell, New Jersey.

Sokal, R. R., and Rohlf, F. J. (1995). Biometry, 3rd ed. W.H. Freeman and Co., New York, NY, USA.

Townsend, R. L., J. R. Skalski, P. Dillingham, and T. W. Steig (2006). Correcting Bias in Survival Estimation Resulting from Tag Failure in Acoustic and Radiotelemetry Studies. Journal of Agricultural, Biological, and Environmental Statistics 11: 183-196.

Vogel, D. A. (2010). Evaluation of acoustic-tagged juvenile Chinook salmon movements in the Sacramento-San Joaquin delta during the 2009 Vernalis Adaptive Management Program. TechnicalReport for San Joaquin River Group Authority. 72 p. Available http://www.sjrg.org/technicalreport/ (accessed 13 December 2011).

Vogel, D. A. (2011). Evaluation of acoustic-tagged juvenile Chinook salmon and predatory fish movements in the Sacramento-San Joaquin Delta during the 2010 Vernalis Adaptive Management Program. Technical report for San Joaquin River Group Authority. Available http://www.sjrg.org/technicalreport/ (accessed 13 December 2011).

USFWS and AFS-FHS (American Fisheries Society-Fish Health Section). 2010. FHS blue book: suggested procedures for the detection and identification of certain finfish and shellfish pathogens, 2010 edition. AFS-FHS, Bethesda, Maryland.

McCormick SD.  1993.  Methods for Nonlethal Gill Biopsy and Measurement of Na+, K+-ATPase Activity.  Canadian Journal of Fisheries and Aquatic Sciences.  50: 656-658

Zimmerman, C.E., G.W. Edwards, K. Perry (2009) Maternal origin and migratory history of steelhead and rainbow trout captured in rivers of the Central Valley, California. Transactions of the American Fisheries Society 138: 280-291.

## Figures

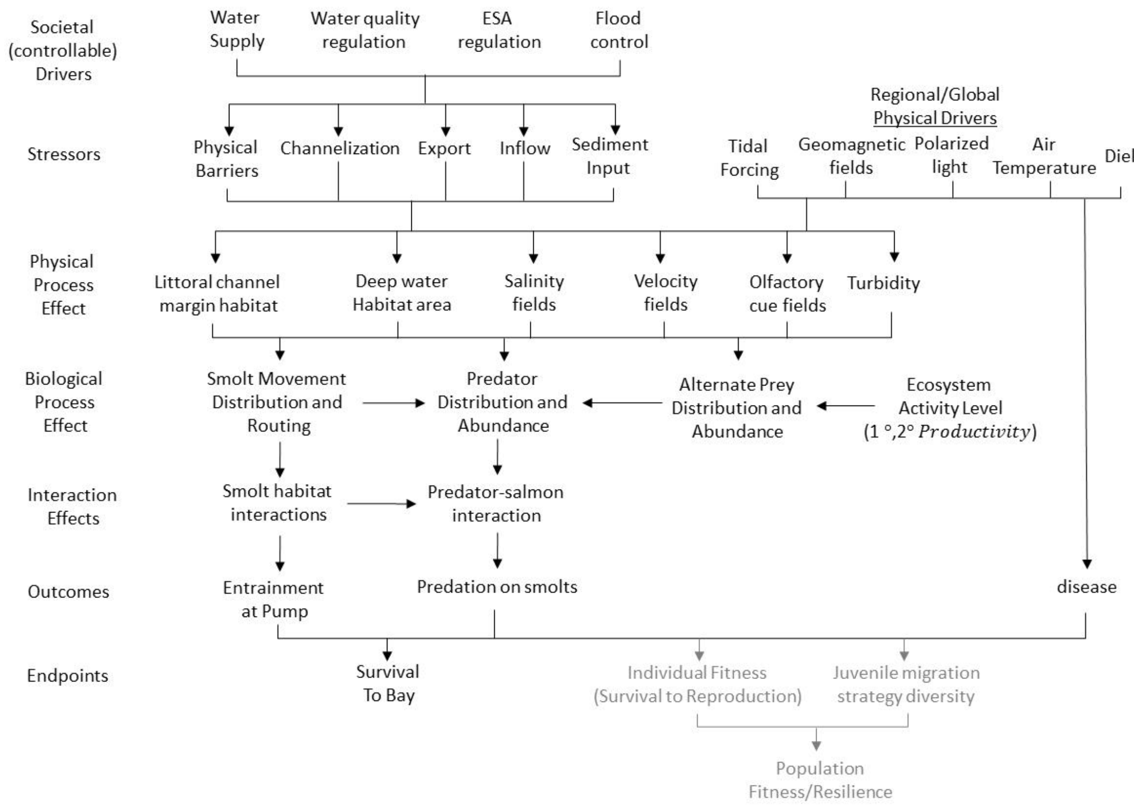



**Figure 1: Conceptual model of how Delta water operations, tributary water operations, and habitat control biotic and abiotic ecosystem variables influencing survival of steelhead smolts in a reach along the San Joaquin River and south Delta.**


**Figure 2: Tag activator for activating tags in the 2012 Six-Year Study. Photo credit: Jake Osborne/USFWS**

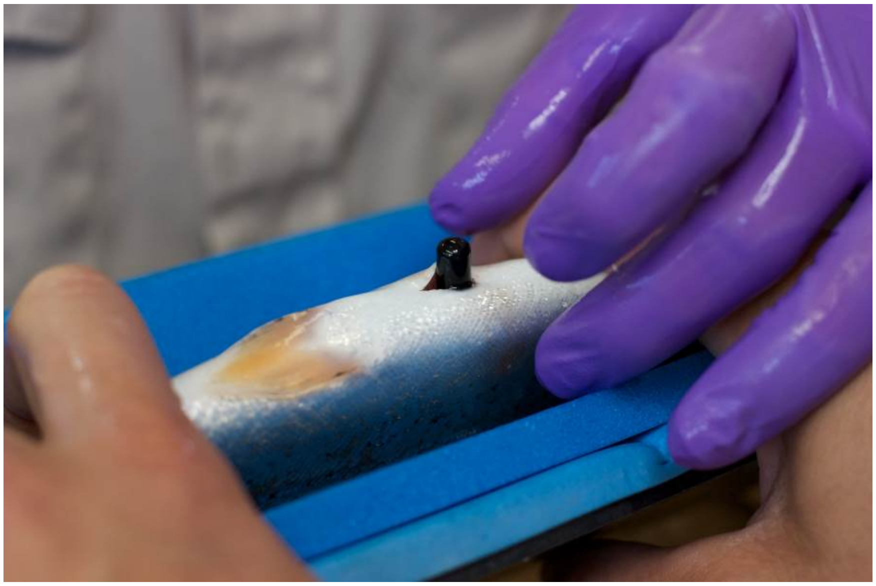


Figure 3: Insertion of V6 VEMCO acoustic tag placed into the body cavity of the juvenile steelhead for the Six-Year Study in 2012. Photo credit: Jake Osborne/ USFWS

Figure 4: Two sutures closing incision after acoustic tag insertion in a steelhead used in the 2012 Six-Year Study. Photo credit: Jake Osborne/ USFWS


**Figure 5: Two VR100 receivers for decoding tag codes from steelhead tagged with VEMCO V6 tags for the 2012 Six-Year Study. Photo Credit: Jake Osborne/USFWS**

**Figure 6: Hydrophone, covered with foam material to reduce multi-path electronic signal, being removed from recovery bucket after verifying tag code in tagged fish. Photo credit: Jake Osborne/USFWS**

**Figure 7: Steelhead in recovery buckets being transferred to 68 L (18 gallon) perforated tote held within a "sleeve" (non-perforated tote), prior to being loaded on the transport truck. Photo credit: Jake Osborne/USFWS**


**Figure 8: Loading steelhead in a perforated tote onto the transport tank for the 2012 Six-Year Study. Photo credit: Jake Osborne/USFWS**

**Figure 9: Perforated totes, containing 3 steelhead each, in one of the transport tanks with flow-through water piped in from the raceway during the 2012 Six-Year Study. Photo Credit: Jake Osborne/USFWS**

**Figure 10: Oxygen tanks on the flat-bed truck for supplying oxygen to steelhead being transported in transport tanks. Photo credit: Jake Osborne/ USFWS**

**Figure 11: Unloading perforated totes into "sleeves" containing river water in a pick-up truck at the holding site (Durham Ferry). Photo credit: Pat Brandes/USFWS**

**Figure 12: Holding cans for steelhead in the San Joaquin River at Durham Ferry. Photo Credit: Josh Israel/USBR**

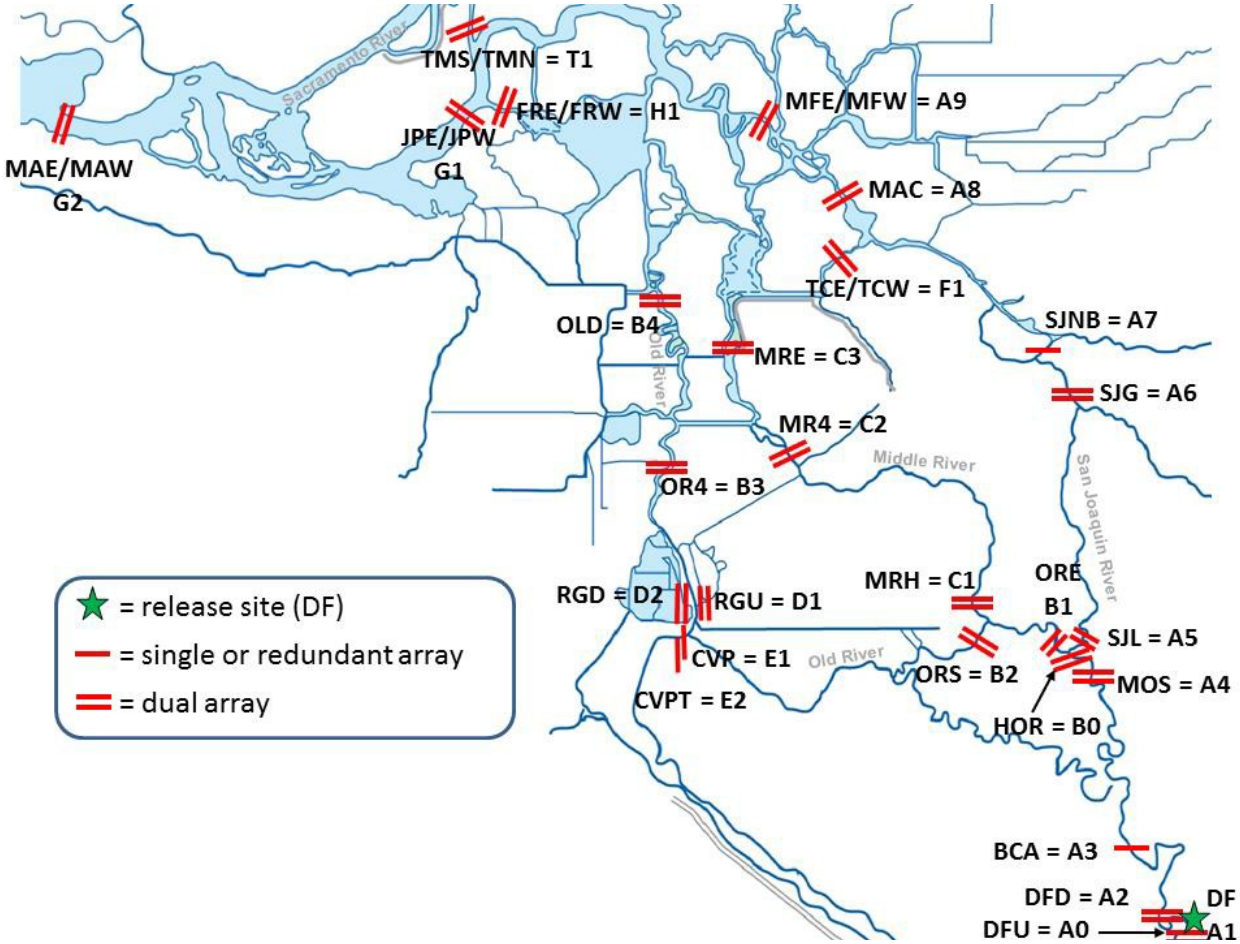



**Figure 13. Locations of acoustic receivers and release site used in the 2012 steelhead study, with site code names (3- or 4-letter code) and model code (letter and number string). Site A1 is the release site at Durham Ferry. Sites B0, B4, C3, and T1 were excluded from the survival model.**

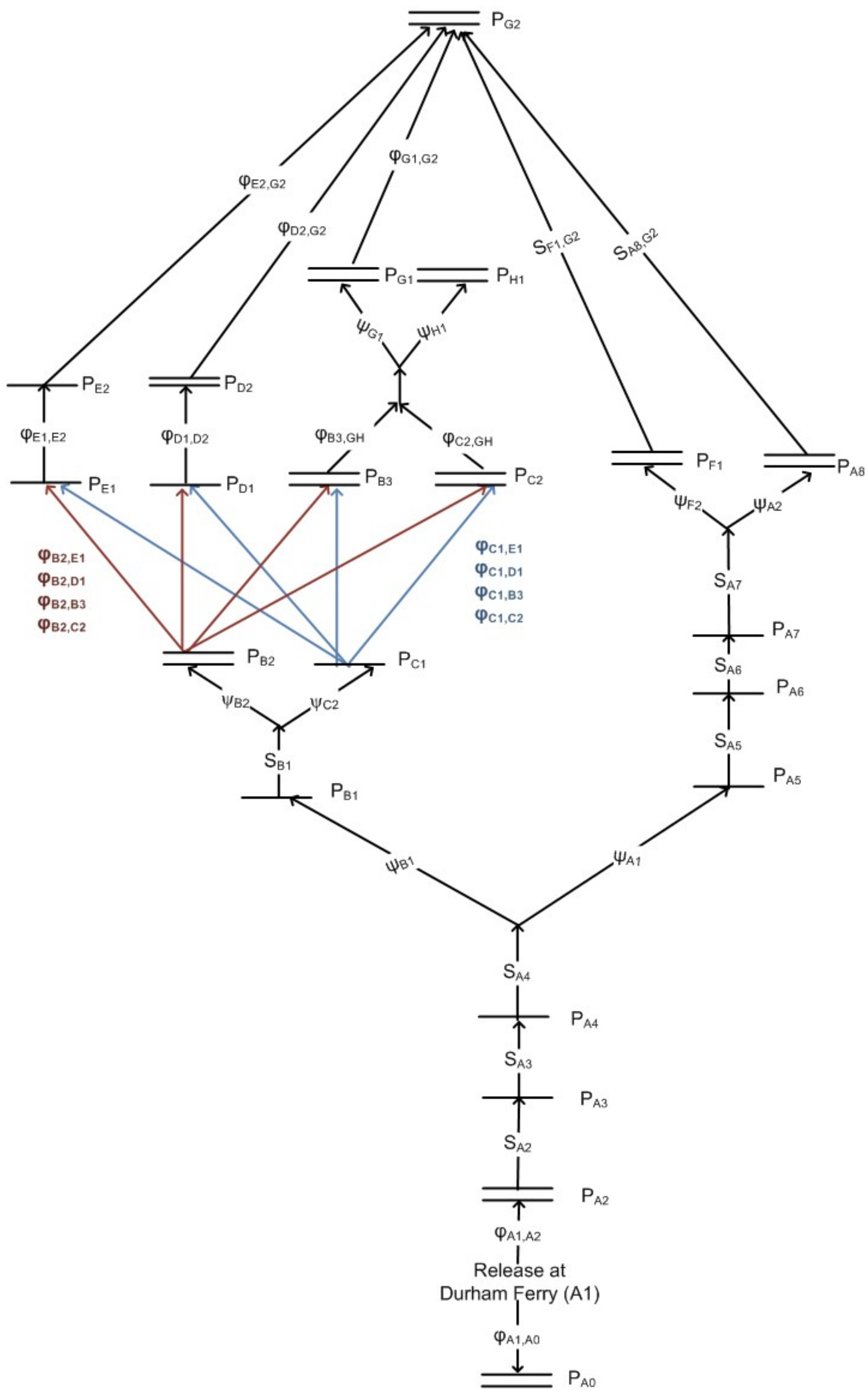



**Figure 14. Schematic of 2012 mark-recapture Submodel I with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 13. Migration pathways to sites B3 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.**

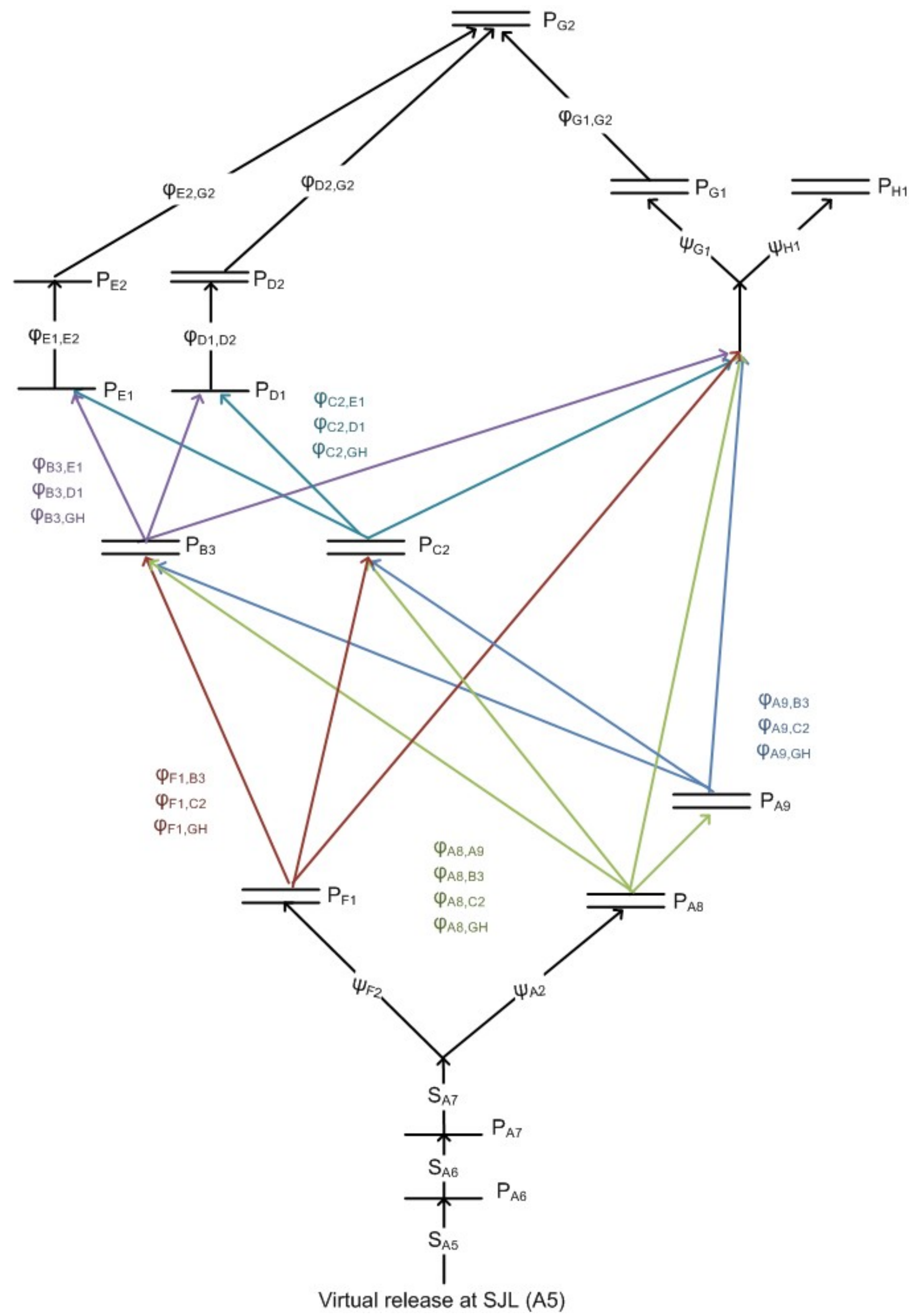



**Figure 15. Schematic of 2012 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 13. Migration pathways to sites B3 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.**

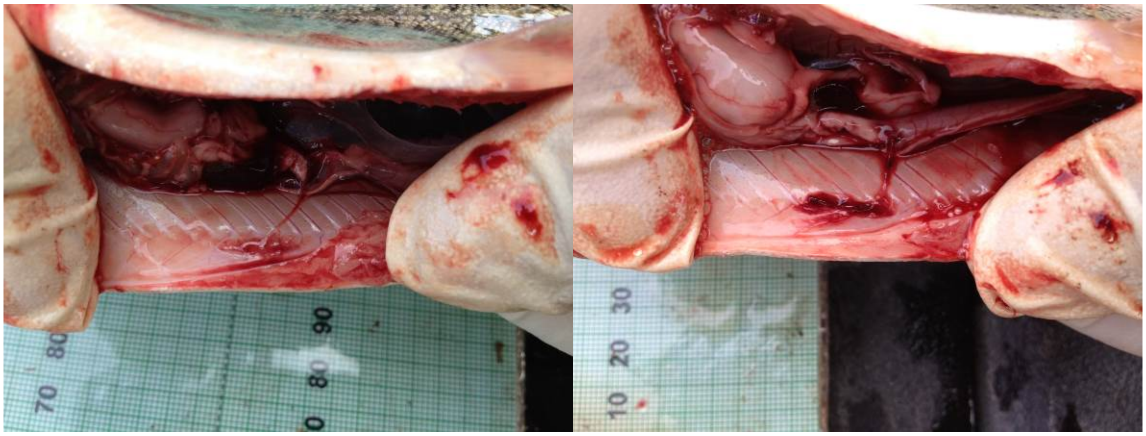


**Figure 16: Examples of stitched organs in juvenile steelhead held for 48 hours prior to assessment for the 2012 Six-Year Study.**

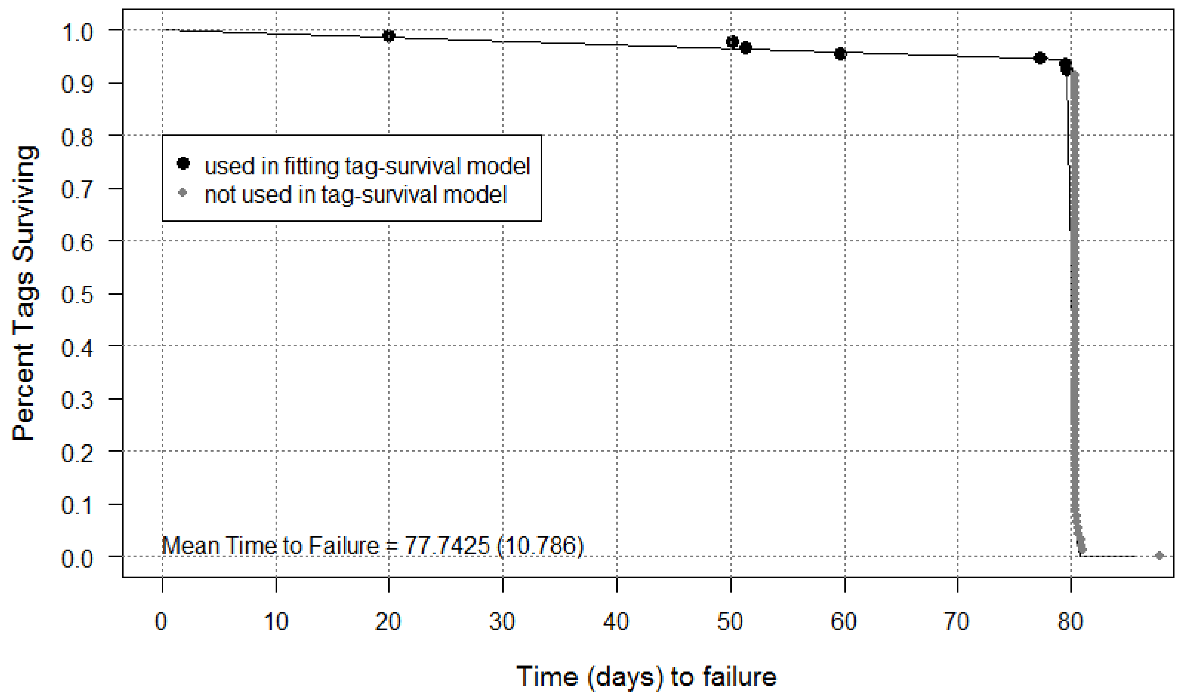



**Figure 17. Observed tag failure times from the 2012 tag-life studies, pooled over the April and May studies, and fitted four- parameter vitality curve. Failure times were censored at day 80 to improve fit of the model.**

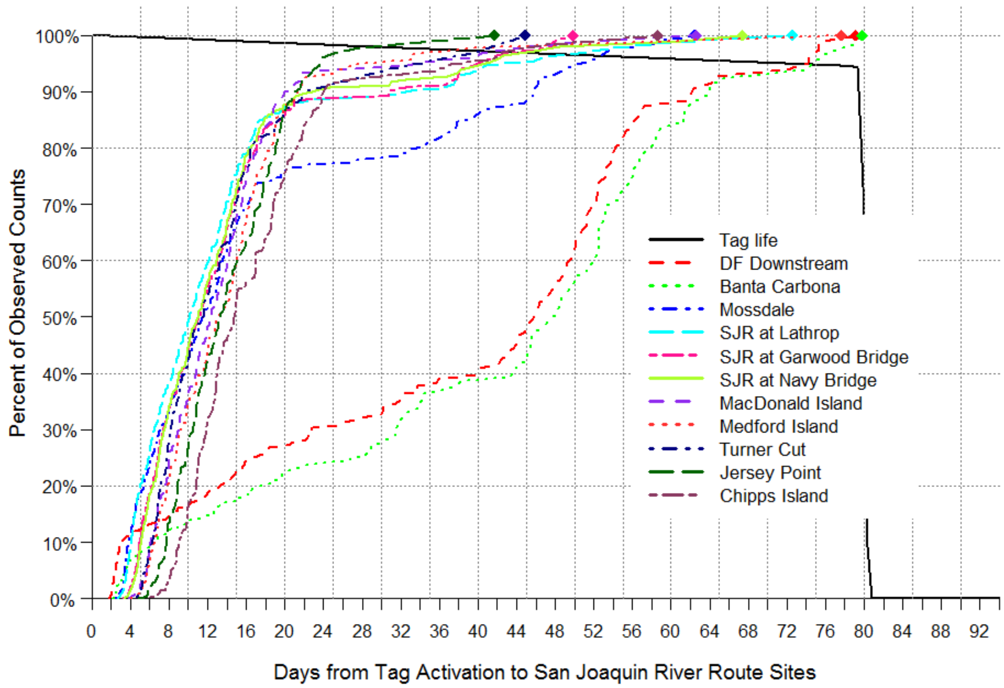



**Figure 18. Four-parameter vitality survivorship curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile steelhead at receivers in the San Joaquin River route to Chipps Island in 2012, including detections that may have come from predators.**

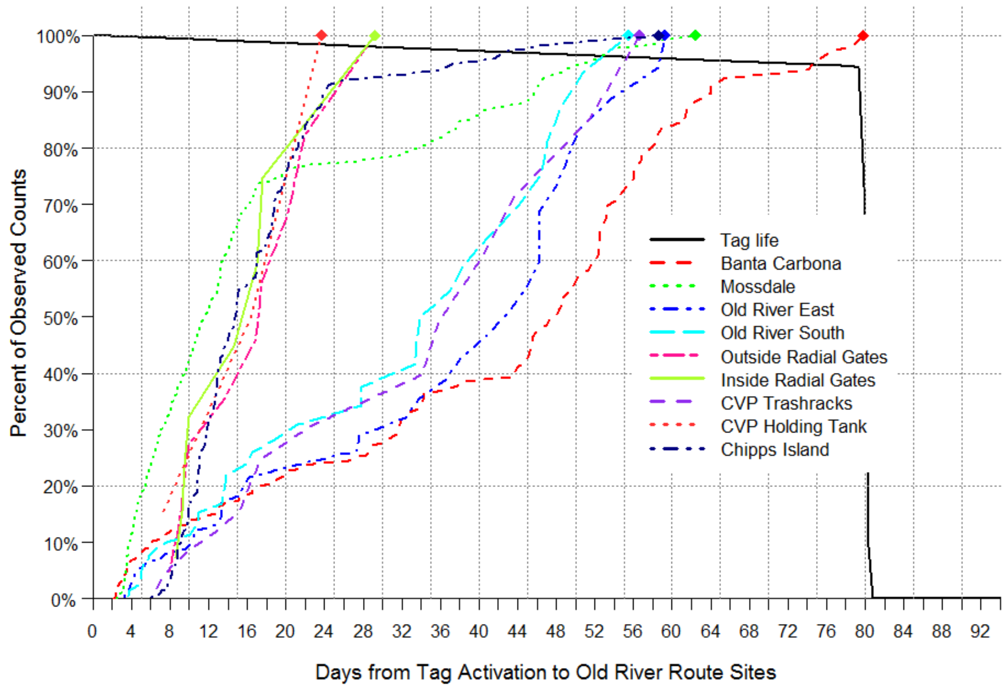



**Figure 19. Four-parameter vitality survivorship curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile steelhead at receivers in the Old River route to Chipps Island in 2012, including detections that may have come from predators.**

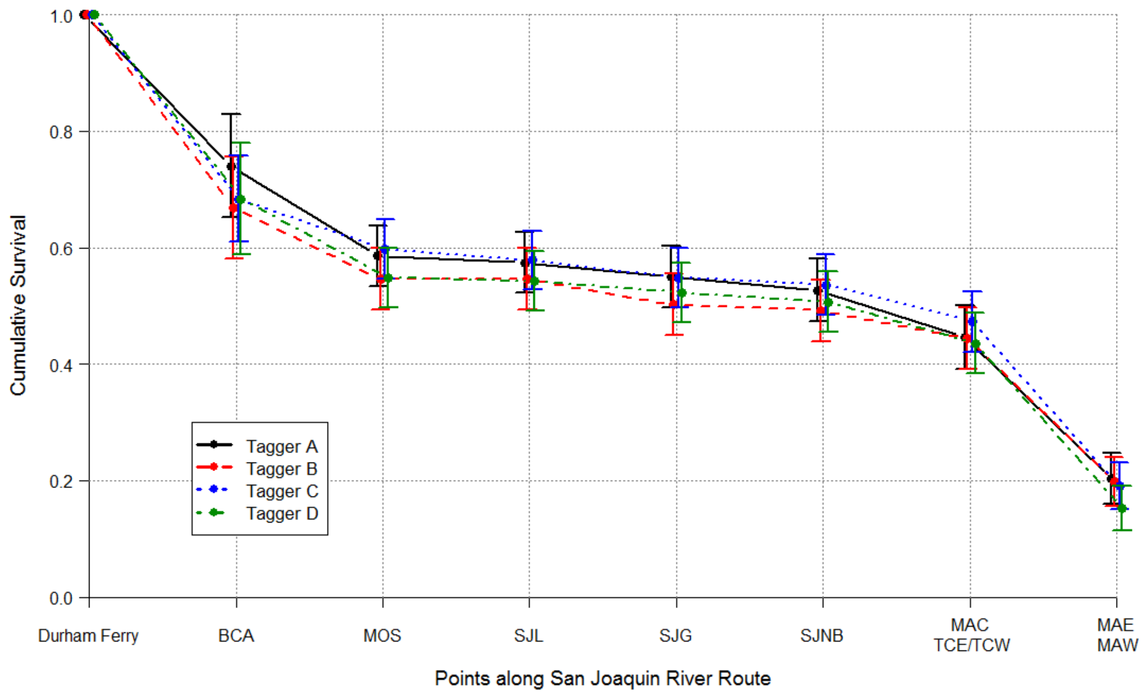



**Figure 20. Cumulative survival from release at Durham Ferry to various points along the San Joaquin River route to Chipps Island, by surgeon. Error bars are 95% confidence intervals.**

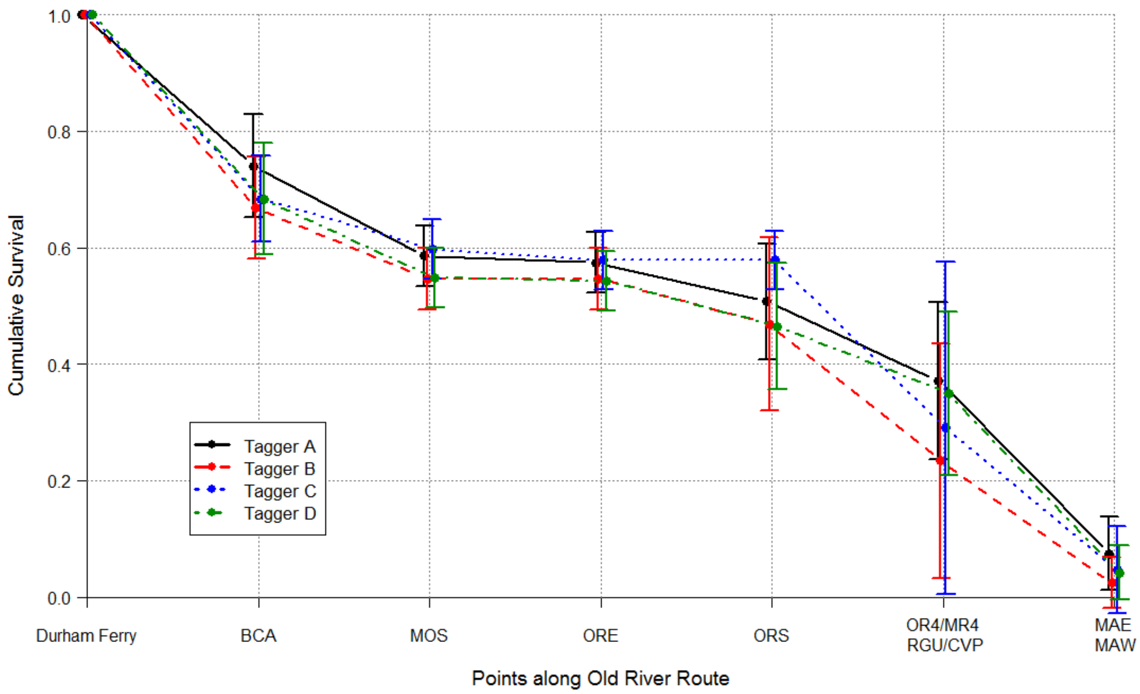



**Figure 21. Cumulative survival from release at Durham Ferry to various points along the Old River route to Chipps Island, by surgeon. Error bars are 95% confidence intervals.**

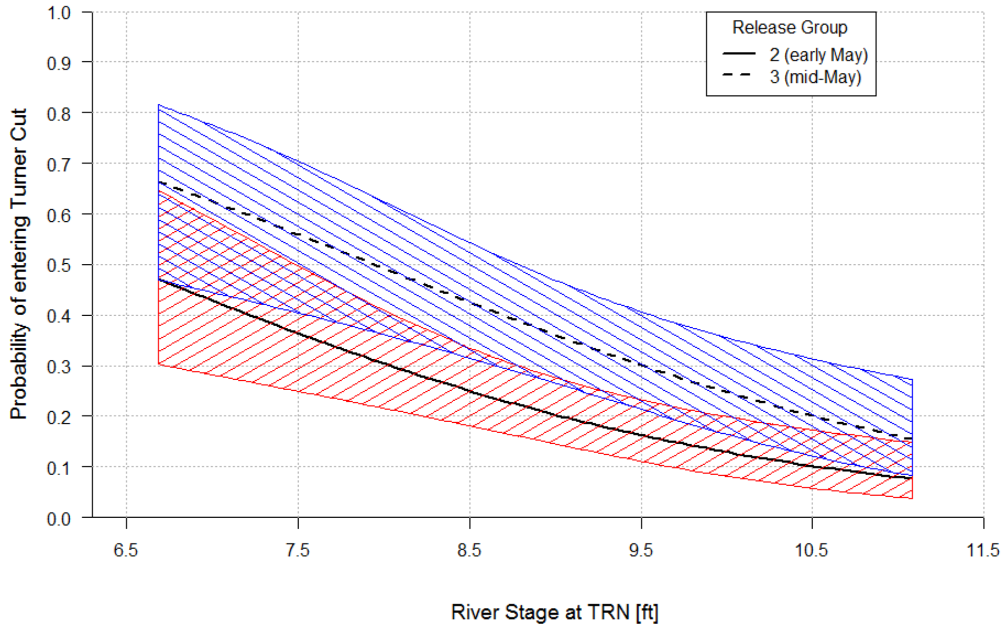



**Figure 22. Fitted probability of entering Turner Cut at its junction with the San Joaquin River versus river stage measured at the TRN gaging station in Turner Cut, for change in stage ($\Delta C_{TRN}$) = 0 ft/s, with 95% confidence bands, in 2012.**

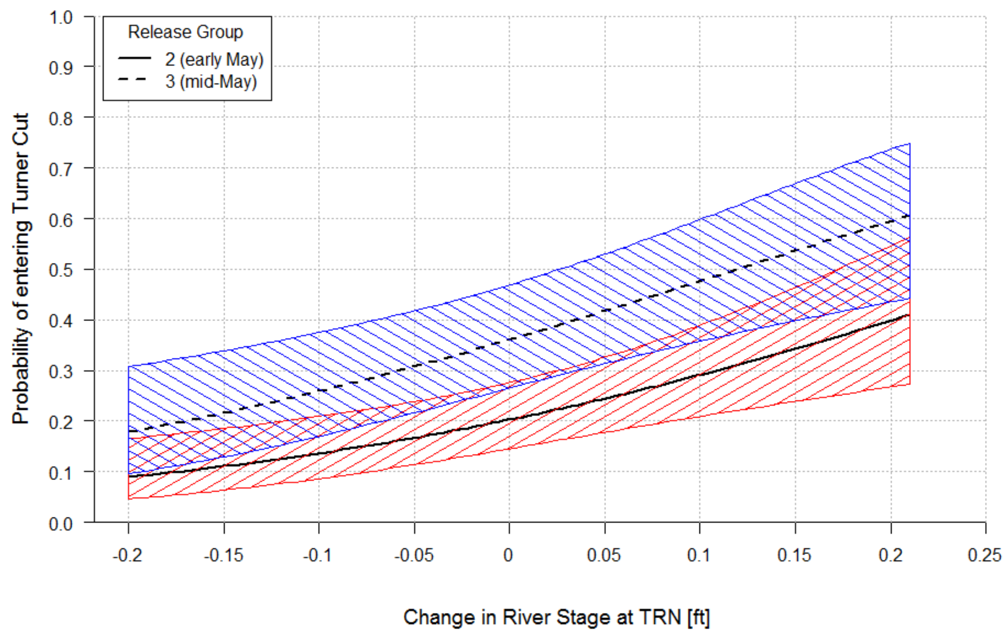



**Figure 23. Fitted probability of entering Turner Cut at its junction with the San Joaquin River versus 15-minute change in river stage ($\Delta C_{TRN}$) measured at the TRN gaging station in Turner Cut, for stage = 9 ft on arrival at the junction, with 95% confidence bands, in 2012.**

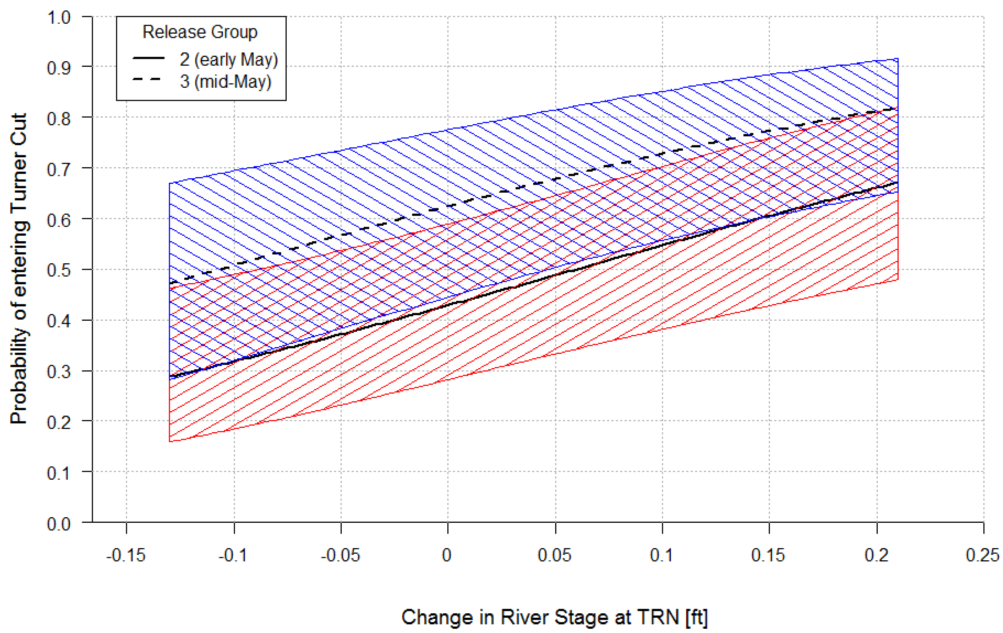



**Figure 24. Fitted probability of entering Turner Cut at its junction with the San Joaquin River versus 15-minute change in river stage ($\Delta C_{TRN}$) measured at the TRN gaging station in Turner Cut, for stage = 7 ft on arrival at the junction, with 95% confidence bands, in 2012.**

# Tables

**Table 1: Tagging, transport and holding date and times, and the number released for Steelhead as part of 2012 Six-Year Study. Mortalities are in parentheses.**

| | | | | Release A | | Release B | | Release C | | Release D | | Release E | | Release F | | Fish Health |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tagging Date | Transport Date/ Time | Start Holding time | Total released (A+B+C+D+E+F) | Date/Time | Number released | Date/Time | Number released | Date/Time | Number released | Date/time | Number released | Date/Time | Number released | Date/time | Number released | Dummy tagged |
| 4/3/12 | 4/3/12; 1130 - 1250<br>4/3/12; 1410 - 1525<br>4/3/12; 1730 - 1840 | 4/3/12; 1337<br>4/3/12; 1615<br>4/3/12; 1930 | 161 | 4/4; 1500, 1501 | 24 | 4/4; 1900, 1902,1910<br>4/4; 1910 | 29<br>6 | 4/4; 2301, 2302 | 24 | 4/5; 0257, 0258, | 24 | 4/5; 0659, 0700, 0704 | 36 | 4/5; 1100 | 18 | 12 |
| 4/4/12 | 4/4/12; 1131 - 1240<br>4/4/12; 1408 - 1520<br>4/4/12; 1715 - 1823 | 4/4; 1323<br>4/4; 1600<br>4/4; 1920 | 161 (1) | 4/5; 1500,1501 | 24 | 4/5; 1910,1911 | 24 | 4/5; 2306,<br>4/5; 2306, 2308,2316 | 5(1)<br>30 | 4/6; 0259, 0300 | 24 | 4/6; 0659, 0700, 0704 | 36 | 4/6; 1100, 1101 | 18 | 12 |
| 4/5/12 | 4/5/12; 1055 - 1158<br>4/5/12; 1340 - 1450<br>4/5/12; 1624 - 1729 | 4/5; 1249<br>4/5; 1535<br>4/5; 1820 | 155 (1) | 4/6; 1502, | 24 | 4/6; 1859 | 24 | 4/6; 2257,<br>4/6; 2257, 2258, 2306 | 4<br>27(1) | 4/7; 0259, 0300 | 24 | 4/7; 0700 | 24 | 4/7; 1101, 1102 | 28 | 24* |
| 4/30/12 | 4/30/12; 1150 - 1300<br>4/30/12; 1425 - 1527<br>4/30/12; 1725 - 1847 | 4/30; 1350<br>4/30; 1614<br>4/30; 1938 | 162 | 5/1; 1504, 1505 | 24 | 5/1; 1859, 1900, 1908<br>5/1; 1908 | 30<br>6 | 5/1; 2301, | 24 | 5/2; 0300, | 24 | 5/2; 0702, 0703 | 36 | 5/2; 1101, 1102 | 18 | 12 |
| 5/2/12 | 5/2/12; 1050-1200<br>5/2/12; 1320 - 1421<br>5/2/12; 1630 - 1740 | 5/2; 1300<br>5/2; 1513<br>5/2; 1837 | 161 (1) | 5/3; 1504, 1505 | 23 (1) | 5/3; 1859, 1900 | 24 | 5/3; 2257<br>5/3; 2257, 2258, 2307 | 6<br>30 | 5/4; 0300 | 24 | 5/4; 0700 | 24 | 5/4; 1104 | 30 | 12 |
| 5/4/12 | 5/4/12; 1025-1137<br>5/4/12; 1225-1327<br>5/4/12; 1610-1717 | 5/4; 1224<br>5/4; 1410<br>5/4; 1755 | 155 (1) | 5/5; 1457, | 24 | 5/5; 1857, 1858,1904<br>5/5; 1904 | 28<br>4 | 5/5; 2300, 2301 | 23 (1) | 5/6; 0300<br>5/6; 0259 | 24<br>12 | 5/6; 0700, | 24 | 5/6; 1100, 1101 | 16 | 24* |
| 5/17/12 | 5/17/12; 1050 - 1200<br>5/17/12; 1300-1410<br>5/17/12; 1633 - 1740 | 5/17; 1250<br>5/17; 1502<br>5/17; 1824 | 162 | 5/18; 1457, 1458 | 24 | 5/17; 1859, | 24 | 5/18; 2330<br>5/18; 2330,2331 | 6<br>33 | 5/19; 0300 | 21 | 5/19; 0700 | 24 | 5/19; 1100 | 30 | 12 |

Table 1 (Continued)

| | | | | Release A | | Release B | | Release C | | Release D | | Release E | | Release F | | Fish Health |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tagging Date** | **Transport Date/ Time** | **Start Holding time** | **Total released (A+B+C+D+E+F)** | **Date/Time** | **Number released** | **Date/Time** | **Number released** | **Date/Time** | **Number released** | **Date/time** | **Number released** | **Date/Time** | **Number released** | **Date/time** | **Number released** | **Dummy tagged** |
| | 5/19/12; 1025 - 1140 | 5/18; 1220 | | 5/20; 1501, 1503 | 24 | 5/20; 1858, 1859 | 24 | 5/20; 2302 | 6 | | | | | | | |
| 5/19/12 | 5/19/12; 1240-1348 | 5/18; 1421 | 162 | | | | | 5/20; 2300, 2301, 2302 | 30 | 5/21; 0259; 0300 | 24 | | | | | 12 |
| | 5/19/12; 1608-1709 | 5/18; 1740 | | | | | | | | | | 5/21; 0700 | 24 | 5/21; 1101, 1102, 1103 | 30 | |
| | 5/21/12; 1045 - 1151 | 5/21; 1236 | | 5/22; 1503 | 24 | 5/22; 1856, 1857, 1858 | 28 | | | | | | | | | |
| 5/21/12 | 5/21/12; 1317-1423 | 5/21; 1506 | 156 | | | 5/22; 1856 | 4 | 5/22; 2256, 2257 | 24 | 5/23; 0300 | 24 | | | | | 24* |
| | 5/21/12; 1555-1705 | 5/21; 1740 | | | | | | | | 5/23; 0300 | 12 | 5/23; 0701 | 24 | 5/23; 1101 | 16 | |

**Table 2. Characteristics Assessed for Steelhead Smolt Condition and Short-term Survival**

| Characteristic | Normal | Abnormal |
|---|---|---|
| **Percent Scale Loss** | Lower relative numbers based on 0-100% | Higher relative numbers based on 0-100% |
| **Body Color** | High contrast dark dorsal surfaces and light sides | Low contrast dorsal surfaces and coppery colored sides |
| **Fin Hemorrhaging** | No bleeding at base of fins | Blood present at base of fins |
| **Eyes** | Normally shaped | Bulging or with hemorrhaging |
| **Gill Color** | Dark beet red to cherry red colored gill filaments | Grey to light red colored gill filaments |
| **Vigor** | Active swimming (prior to anesthesia) | Lethargic or motionless (prior to anesthesia) |

**Table 3: Names and descriptions of receivers and hydrophones used in the 2012 steelhead tagging study, with receiver codes used in Figure 13, the survival model (Figures 14, 15), and in data processing by the United States Geological Survey (USGS). The release site was located at Durham Ferry.**

| Individual Receiver Name and Description | Hydrophone Location | | Receiver Code | Survival Model Code | Data Processing Code |
|---|---|---|---|---|---|
| | Latitude (°N) | Longitude (°W) | | | |
| San Joaquin River near Durham Ferry upstream of the release site, upstream node | 37.685806 | 121.256500 | DFU1 | A0a | 300856 |
| San Joaquin River near Durham Ferry upstream of the release site, downstream node | 37.686444 | 121.256806 | DFU2 | A0b | 300857 |
| San Joaquin River near Durham Ferry; release site (no acoustic hydrophone located here) | 37.687011 | 121.263448 | DF | A1 | |
| San Joaquin River near Durham Ferry downstream of the release site, upstream node | 37.688222 | 121.276139 | DFD1 | A2a | 300858 |
| San Joaquin River near Durham Ferry downstream of the release site, downstream node | 37.688333 | 121.276139 | DFD2 | A2b | 300859 |
| San Joaquin River near Banta Carbona | 37.727722 | 121.298917 | BCA | A3 | 300860 |
| San Joaquin River near Mossdale Bridge, upstream node | 37.792194 | 121.307278 | MOSU | A4a | 300861 |
| San Joaquin River near Mossdale Bridge, downstream node | 37.792356 | 121.307369 | MOSD | A4b | 300862 |
| San Joaquin River upstream of Head of Old River, upstream node (not used in survival model) | 37.805528 | 121.320000 | HORU | B0a | 300863 |
| San Joaquin River upstream of Head of Old River, downstream node (not used in survival model) | 37.805000 | 121.321306 | HORD | B0b | 300864 |
| San Joaquin River near Lathrop, upstream | 37.810875[a] | 121.322500[a] | SJLU | A5a | 300869/300870 |
| San Joaquin River near Lathrop, downstream | 37.810807[a] | 121.321269[a] | SJLD | A5b | 300871/300872 |
| San Joaquin River near Garwood Bridge, upstream | 37.934972 | 121.329333 | SJGU | A6a | 300877 |
| San Joaquin River near Garwood Bridge, downstream | 37.935194 | 121.329833 | SJGD | A6b | 300878 |
| San Joaquin River at Stockton Navy Drive Bridge | 37.946806 | 121.339583 | SJNB | A7 | 300879 |
| San Joaquin River at MacDonald Island, upstream | 38.018022[a] | 121.462758[a] | MACU | A8a | 300899/300901 |
| San Joaquin River at MacDonald Island, downstream | 38.023877[a] | 121.465916[a] | MACD | A8b | 300900/300902 |
| San Joaquin River near Medford Island, east | 38.053134[a] | 121.510815[a] | MFE | A9a | 300903/300904 |
| San Joaquin River near Medford Island, west | 38.053773[a] | 121.513315[a] | MFW | A9b | 300905/300906 |
| Old River East, near junction with San Joaquin, upstream | 37.811653[a] | 121.335486[a] | OREU | B1a | 300865/300866 |

a = Average latitude and longitude given for sites with multiple hydrophones or for sites with multiple locations throughout the study

**Table 3. (Continued)**

| Individual Receiver Name and Description | Hydrophone Location | | Receiver Code | Survival Model Code | Data Processing Code |
|---|---|---|---|---|---|
| | Latitude (°N) | Longitude (°W) | | | |
| Old River East, near junction with San Joaquin, downstream | 37.812284[a] | 121.335558[a] | ORED | B1b | 300867/300868 |
| Old River South, upstream | 37.819583 | 121.378111 | ORSU | B2a | 300873 |
| Old River South, downstream | 37.820028 | 121.378889 | ORSD | B2b | 300874 |
| Old River at Highway 4, upstream | 37.893864[a] | 121.567083[a] | OR4U | B3a | 300882/300883 |
| Old River at Highway 4, downstream | 37.895125[a] | 121.566403[a] | OR4D | B3b | 300884/300885 |
| Old River near Empire Cut, upstream receiver (not used in survival model) | 37.967125[a] | 121.574514[a] | OLDU | B4a | 450022 |
| Old River near Empire Cut, downstream receiver (not used in survival model) | 37.967375[a] | 121.574389[a] | OLDD | B4b | 450023 |
| Middle River Head, upstream | 37.824744 | 121.380056 | MRHU | C1a | 300875 |
| Middle River Head, downstream | 37.824889 | 121.380417 | MRHD | C1b | 300876 |
| Middle River at Highway 4, upstream | 37.895750 | 121.493861 | MR4U | C2a | 300881 |
| Middle River at Highway 4, downstream | 37.896222 | 121.492417 | MR4D | C2b | 300880 |
| Middle River at Empire Cut, upstream receiver (not used in survival model) | 37.941685[a] | 121.533250[a] | MREU | C3a | 300898/450021 |
| Middle River at Empire Cut, downstream receiver (not used in survival model) | 37.942861[a] | 121.532370[a] | MRED | C3b | 300897/450030 |
| Radial Gate at Clifton Court Forebay, upstream (in entrance channel to forebay), array 1 | 37.830086 | 121.556594 | RGU1 | D1a | 300888 |
| Radial Gate at Clifton Court Forebay, upstream, array 2 | 37.829606 | 121.556989 | RGU2 | D1b | 300889 |
| Radial Gate at Clifton Court Forebay, downstream (inside forebay), array 1 in dual array | 37.830147[a] | 121.557528[a] | RGD1 | D2a | 300890/300892/ 460009/460011 |
| Radial Gate at Clifton Court Forebay, downstream, array 2 in dual array | 37.829822[a] | 121.557900[a] | RGD2 | D2b | 300891/460010 |
| Central Valley Project trashracks, upstream | 37.816900[a] | 121.558459[a] | CVPU | E1a | 300894/460012 |
| Central Valley Project trashracks, downstream | 37.816647 | 121.558981 | CVPD | E1b | 300895 |
| Central Valley Project holding tank (all holding tanks pooled) | 37.815844 | 121.559128 | CVPtank | E2 | 300896 |
| Turner Cut, east (closer to San Joaquin) | 37.991694 | 121.455389 | TCE | F1a | 300887 |
| Turner Cut, west (farther from San Joaquin) | 37.990472 | 121.456278 | TCW | F1b | 300886 |
| San Joaquin River at Jersey Point, east (upstream) | 38.056351[a] | 121.686535[a] | JPE | G1a | 300915 - 300922 |
| San Joaquin River at Jersey Point, west (downstream) | 38.055167[a] | 121.688070[a] | JPW | G1b | 300923 - 300930 |

a = Average latitude and longitude given for sites with multiple hydrophones or for sites with multiple locations throughout the study

**Table 3. (Continued)**

| Individual Receiver Name and Description | Hydrophone Location | | Receiver Code | Survival Model Code | Data Processing Code |
|---|---|---|---|---|---|
| | Latitude (°N) | Longitude (°W) | | | |
| False River, west (closer to San Joaquin) | 38.056834[a] | 121.671403[a] | FRW | H1a | 300913/300914 |
| False River, east (farther from San Joaquin) | 38.057118[a] | 121.669673[a] | FRE | H1b | 300911/300912 |
| Chipps Island (aka Mallard Island), east (upstream) | 38.048772[a] | 121.931198[a] | MAE | G2a | 300931 - 300942 |
| Chipps Island (aka Mallard Island), west (downstream) | 38.049275[a] | 121.933839[a] | MAW | G2b | 300943, 300979 - 300983, 300985 - 300990 |
| Threemile Slough, south (not used in survival model) | 38.107771[a] | 121.684042[a] | TMS | T1a | 300909/300910 |
| Threemile Slough, north (not used in survival model) | 38.111556[a] | 121.682826[a] | TMN | T1b | 300907/300908 |

a = Average latitude and longitude given for sites with multiple hydrophones or for sites with multiple locations throughout the study

**Table 4. Environmental monitoring sites used in predator decision rule and route entrainment analysis. Database = CDEC (http://cdec.water.ca.gov/) or Water Library (http://www.water.ca.gov/waterdatalibrary/).**

| Environmental Monitoring Site | | | Detection Site | Data Available | | | | | Database |
|---|---|---|---|---|---|---|---|---|---|
| Site Name | Latitude (°N) | Longitude (°W) | | River Flow | Water Velocity | River Stage | Pumping | Reservoir Inflow | |
| CLC | 37.8298 | 121.5574 | RGU, RGD | No | No | No | No | Yes | CDEC |
| FAL | 38.0555 | 121.6672 | FRE/FRW | Yes | Yes | Yes | No | No | CDEC |
| GLC | 37.8201 | 121.4497 | ORS | Yes | Yes | Yes | No | No | CDEC |
| MAL | 38.0428 | 121.9201 | MAE/MAW | No | No | Yes | No | No | CDEC |
| MDM | 37.9425 | 121.534 | MR4, MRE | Yes | Yes | Yes | No | No | CDEC[a] |
| MSD | 37.7860 | 121.3060 | HOR, MOS | Yes | Yes | Yes | No | No | Water Library |
| ODM | 37.8101 | 121.5419 | CVP | Yes | Yes | Yes | No | No | CDEC |
| OH1 | 37.8080 | 121.3290 | ORE | Yes | Yes | Yes | No | No | CDEC |
| OH4 | 37.8900 | 121.5697 | OR4 | Yes | Yes | Yes | No | No | CDEC |
| ORI | 37.8280 | 121.5526 | RGU, RGD | Yes | Yes | No | No | No | Water Library |
| PRI | 38.0593 | 121.5575 | MAC, MFE/MFW | Yes | Yes | Yes | No | No | CDEC |
| RMID040 | 37.8350 | 121.3838 | MRH | No | No | Yes | No | No | Water Library |
| ROLD040 | 37.8286 | 121.5531 | RGU, RGD | No | No | Yes | No | No | Water Library |
| SJG | 37.9351 | 121.3295 | SJG, SJNB | Yes | Yes | Yes | No | No | CDEC |
| SJJ | 38.0520 | 121.6891 | JPE/JPW | Yes | Yes | Yes | No | No | CDEC |
| SJL | 37.8100 | 121.3230 | SJL | Yes | Yes | Yes | No | No | Water Library |
| TRN | 37.9927 | 121.4541 | TCE/TCW | Yes | Yes | Yes | No | No | CDEC |
| TRP | 37.8165 | 121.5596 | CVP | No | No | No | Yes | No | CDEC |
| TSL | 38.1004 | 121.6866 | TMS/TMN | Yes | Yes | Yes | No | No | CDEC |
| VNS | 37.6670 | 121.2670 | DFU, DFD, BCA | Yes | No | Yes | No | No | CDEC |
| WCI | 37.8316 | 121.5541 | RGU, RGD | Yes | Yes | No | No | No | Water Library |

a = California Water Library was used for river stage

**Table 5a. Cutoff values used in predator filter in 2012. Observed values past cutoff or unmet conditions indicate a predator. Time durations are in hours unless otherwise specified. See Table 5b for Flow, Water Velocity, Extra Conditions, and Comment. Footnotes refer to both this table and Table 5b.**

| Detection Site | Previous Site | Residence Time[a] (hr) Near Field | Residence Time[a] (hr) Mid-field | Residence Time[a] (hr) Interior Delta/Facilities[b] | Migration Rate[c, d] (km/hr) | | BLPS (Magnitude) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum |
| DFU | DF | 500 | 1,000 | | 0 | 4 | | 1 | 0 |
| | DFU, DFD, BCA | 500 | 1,000 | | 0 | 4 | | 3 | 2 |
| DFD | DF | 500 | 1,000 | | 0 | 4.5 | | 1 | 0 |
| | DFU, DFD | 500 | 1,000 | | 0 | 4.5 | | 10 (15[g]) | 0 (2[g]) |
| | BCA | 500 | 1,000 | | 0.2 | 4 | | 3 | 2 |
| BCA | DF | 20 (1000[g]) | 40 (1000[g]) | | 0 | 4.5 | 4 | 1 | 0 |
| | DFU, DFD | 20 (1000[g]) | 40 (1000[g]) | | 0.1 | 4.5 | 4 | 3 | 0 |
| | BCA | 60 (1000[g]) | 350 (1000[g]) | | | | | 8 | 1 |
| | MOS | 1 | 2 | | 0.1 | 4 | 4 | 2 | 2 |
| MOS | DFU | 50 (100[g]) | 100 (200[g]) | | 0.1 | 6 | 4.5 | 2 (1[g]) | 0 |
| | DF, DFD | 50 (100[g]) | 100 (200[g]) | | 0.1 | 6 | 4.5 | 1 | 0 |
| | BCA | 50 (100[g]) | 100 (200[g]) | | 0 | 6 | 4.5 | 2 | 0 |
| | MOS | 25 | 250 | | | | | 3 | 1 |
| | HOR | 50 | 100 | | 0.1 | 6 | 4.5 | 2 | 1 |
| SJL | MOS, HOR | 24 | 48 | | 0.2 (0.1[g]) | 6 | 4.5 | 2 | 0 |
| | SJL | 2 | 236 (86[g]) | | | | | 2 | 1 |
| | ORE | 1 | 2 | | 0.4 | 6 | | 0 | 0 |
| | SJG | 0.1 | 10 | | 1.5 | 4 | 4.5 | 2 | 0 |
| SJG | SJL | 30 | 60 | | 0.2 | 6 | 4.5 | 1 | 0 |
| | SJG | 15 | 89 | | | | | 5 | 1 |

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Interior Delta residence time (Facilities residence time in parentheses) after leaving first site in Interior Delta (or Facilities, respectively)

c = Approximate migration rate calculated on most direct pathway

d = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

g = See comments for alternate criteria

**Table 5a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (hr) | | | Migration Rate[c, d] (km/hr) | | BLPS (Magnitude) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|
| | | Near Field | Mid-field | Interior Delta/Facilities[b] | | | | | |
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum |
| SJG | SJNB | 10 | 20 | | 0.2 | 4 | 4.5 | 2 | 3 |
| SJNB | SJG | 30 | 60 | | 0.03 (0.13[g]) | 6 | 4.5 | 1 | 0 |
| | SJNB | 15 | 135 | | | | | 2 | 4 |
| | MAC, TCE/TCW | 6 | 12 | | 1.3 (1.1[g]) | 4 | 4.5 | 2 | 4 |
| MAC | SJG, SJNB | 30 (20[g]) | 70 (40[g]) | | 0.1 (0.4[g]) | 6 | 4.5 | 1 | 0 |
| | MAC | 30 (15[g]) | 500 | | | | | 3 | 4 |
| | MFE/MFW | 15 | 30 | | 0.5 | 4 | 4.5 | 3 | 4 |
| | TCE/TCW | 15 | 30 | | 0.1 | 6 | | 3 | 1 |
| | MRE | 15 | 30 | | 0.1 | 4.5 | | 1 | 1 |
| MFE/MFW | SJG, SJNB, MAC, TCE/TCW | 35 (20[g]) | 70 (40[g]) | | 0.1 (0.4[g]) | 6 | 4.5 | 1 | 0 |
| | MFE/MFW | 10 | 150 | | | | | 2 | 4 |
| | MRE | 35 | 70 | | 0.1 | 4.5 | | 1 | 0 |
| | OLD | 10 | 20 | | 0.1 | 4.5 | | 0 | 0 |
| | JPE/JPW, TMN/TMS | 10 | 20 | | 1.9 | 4 | 4.5 | 1 | 0 |
| HOR | MOS | 12 (100[g]) | 24 (200[g]) | | 0 | 6 | 4.5 | 2 | 0 |
| | HOR | 12 | 250 | | | | | 2 | 1 |
| | SJL, ORE | 5 | 10 | | 0.1 (0.2[g]) | 6 | 4.5 | 2 | 1 |
| ORE | HOR | 15 (10[g]) | 30 (20[g]) | | 0.1 | 6 | 4.5 | 1 | 0 |
| | ORE | 3 | 88 | | | | | 3 | 1 |
| | SJL | 3 | 6 | | 0.4 | 6 | | 1 | 1 |
| | ORS, MRH | 1 | 2 | | 0.3 | 4 | 4.5 | 0 | 0 |

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Interior Delta residence time (Facilities residence time in parentheses) after leaving first site in Interior Delta (or Facilities, respectively)

c = Approximate migration rate calculated on most direct pathway

d = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

g = See comments for alternate criteria

**Table 5a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (hr) Near Field Maximum | Mid-field Maximum | Interior Delta/Facilities[b] Maximum | Migration Rate[c, d] (km/hr) Minimum | Maximum | BLPS (Magnitude) Maximum | No. of Visits Maximum | No. of Cumulative Upstream Forays Maximum |
|---|---|---|---|---|---|---|---|---|---|
| ORS | ORE | 12 | 24 | | 0.02 (0.06[g]) | 6 | 4.5 | 1 | 0 |
| | ORS | 12 | 220 | | | | | 8 | 1 |
| | MRH | 12 | 24 | | 0.2 | 6 | | 1 | 0 |
| | RGU, CVP | 12 | 24 | | 0.3 | 4 | 4.5 | 2 | 1 (2[g]) |
| OR4 | ORS | 100 | 200 | 120 (10) | 0.2 | 4.5 | 4 | 2 | 0 |
| | RGU | 100 | 200 | 120 (10) | 0 | 4.5 | 4 | 15 | 4 |
| | CVP | 100 | 200 | 120 (10) | 0.1 | 4.5 | 4 | 15 | 4 |
| | OR4 | 100 | 700 | 120 (10) | | | | 15 | 4 |
| | OLD, MRE | 30 | 60 | 120 (10) | 0.1 (0[g]) | 4 (4.5[g]) | 4 (NA[g]) | 15 | 4 |
| | MR4 | 100 | 200 | 120 (10) | 0.1 | 4.5 | | 4 | 4 |
| OLD | SJNB | 100 | 200 | | 0.2 | 4.5 | | 1 | 0 |
| | MAC, MFE/MFW | 100 | 200 | | 0.1 | 4.5 | | 1 | 0 |
| | OR4 | 100 | 200 | 120 (10) | 0.1 | 4.5 | 4 | 2 | 0 |
| | OLD | 100 | 700 | 120 (10) | | | | 4 | 0 |
| | MRE | 100 | 200 | 120 (10) | 0.1 | 4.5 | | 1 | 0 |
| | TCE/TCW | 100 | 200 | | 0.1 | 4.5 | | 1 | 0 |
| MRH | ORE | 10 | 20 | | 0.03 | 6 | | 1 | 0 |
| | ORS | 1 | 2 | | 0.2 | 6 | | 1 | 1 |
| | MRH | 1 | 22 | | | | | 0 | 0 |
| MR4 | ORS | 15 | 30 | 120 (10) | 0.1 | 4.5 | 4 | 1 | 0 |
| | OR4, OLD | 15 | 30 | 120 (10) | 0.1 | 4.5 | NA (4[g]) | 1 | 0 (1[g]) |

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Interior Delta residence time (Facilities residence time in parentheses) after leaving first site in Interior Delta (or Facilities, respectively)

c = Approximate migration rate calculated on most direct pathway

d = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

g = See comments for alternate criteria

**Table 5a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (hr) Near Field Maximum | Residence Time[a] (hr) Mid-field Maximum | Residence Time[a] (hr) Interior Delta/Facilities[b] Maximum | Migration Rate[c, d] (km/hr) Minimum | Migration Rate[c, d] (km/hr) Maximum | BLPS (Magnitude) Maximum | No. of Visits Maximum | No. of Cumulative Upstream Forays Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | MR4 | 10 | 75 | 120 (10) | | | | 2 | 0 |
| | MRE | 15 | 30 | 120 (10) | 0.1 | 4 | 4 | 1 | 1 |
| | RGU | 15 | 30 | 120 (10) | 0.1 | 4.5 | | 1 | 0 |
| | CVP | 15 | 30 | 120 (10) | 0.1 | 4.5 | | 1 | 0 |
| | TCE/TCW | 15 | 30 | | 0.1 | 4.5 | | 1 | 0 |
| MRE | SJL, SJG, SJNB | 50 | 100 | | 0.2 (0.3[g]) | 4.5 | | 1 | 0 |
| | MAC, MFE/MFW | 50 | 100 | | 0.1 | 4.5 | | 1 | 0 |
| | OR4, OLD | 30 | 60 | 120 (10) | 0.1 | 4.5 | | 1 | 0 |
| | MR4 | 50 | 100 | 120 (10) | 0.1 | 4.5 | 4 | 1 | 0 |
| | MRE | 30 | 160 | 120 (10) | | | | 4 | 0 |
| | TCE/TCW | 50 | 100 | | 0.1 | 4.5 | | 1 | 0 |
| | TMN/TMS | 30 | 60 | 120 (10) | 0.2 | 4 | 4 | 1 | 1 |
| RGU/RGD | ORS | 80 (336[i]; 800[j]) | | 120 (100) | 0.08 | 4.5 | 4 | 1 | 0 |
| | CVP | 80 (336[i]; 800[j]) | | 120 (100) | 0.02 | 4.5 | 4 | 2 | 0 |
| | OR4 | 80 (336[i]; 800[j]) | | 120 (100) | 0 | 4 | 4 | 2 | 2 |
| | MR4 | 10 (336[i])[k] | | 120 (100) | 0.06 | 4.5 | | 1 | 0 |
| CVP | ORS | 150 | | 300 | 120 (100) | 0.2 | 4.5 | 4 | 1 |
| | CVP | 100 | | 510 | 180 (100) | | | | 4 |

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Interior Delta residence time (Facilities residence time in parentheses) after leaving first site in Interior Delta (or Facilities, respectively)

c = Approximate migration rate calculated on most direct pathway

d = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

g = See comments for alternate criteria

i = If returned to Old River from Clifton Court Forebay and most detections were at RGU (not RGD)

j = If known presence at gates < 80 hours, or if present at RGU < 80% of total residence time and returned to Forebay entrance channel from RGD

k = Maximum residence time is 100 hours if known presence at gates < 10 hours, or 800 hours if present at RGU < 80% of total residence time and returned to Forebay entrance channel from RGD

**Table 5a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (hr) Near Field | | | Migration Rate[c, d] (km/hr) | | BLPS (Magnitude) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|
| | | Near Field | Mid-field | Interior Delta/Facilities[b] | | | | | |
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum |
| CVP | RGU | 100 (150[g]) | 200 (300[g]) | 180 (100) | 0 | 4 | 4 | 10 (1[g]) | 9 (3[g]) |
| | OR4 | 100 (150[g]) | 200 (300[g]) | 180 (100) | 0.1 | 4 | 4 | 10 (1[g]) | 9 (3[g]) |
| | MR4 | 150 | 300 | 180 (100) | 0.1 | 4.5 | | 1 | 0 |
| CVPtank | CVP | 20 | 150 | 120 (10) | 0 | NA | | 2 | 3 |
| TCE/TCW | SJNB | 12 | 24 | | 0.1 | 6 | 4.5 | 1 | 0 |
| | TCE/TCW | 12 | 106 | | | | | 3 | 4 |
| | MAC | 12 | 24 | | 0.2 | 6 | | 1 | 4 |
| | MRE | 12 | 24 | | 0.2 | 4.5 | | 1 | 4 |
| JPE/JPW | MAC, MFE/MFW, TCE/TCW, OLD | 40 | 80 | | 0.2 | 4.5 | 4 | 1 | 0 |
| | TMN/TMS | 40 | 80 | | 0.2 | 4.5 | 4 | 2 | 4 |
| | CVPtank | 40 | 80 | | 0.2 | 3.4 | 4.5 | 1 | 0 |
| | RGU | 40 | 80 | | 0 | 0.8 | 4.5 | 1 | 0 |
| | JPE/JPW | 20 | 80 | | | | | 3 | 0 |
| | FRE/FRW | 20 | 80 | | 0.1 | 7 | | 3 | 4 |
| MAE/MAW | MAC, MFE/MFW, TCE/TCW, MRE | 40 | 200 | | 0.2 | 7 | | 1 | 0 |
| | CVP, CVPtank | 40 | 200 | | 0.2 | 3 | | 1 | 0 |
| | RGU/RGD | 40 | 200 | | 0 | 2 | | 1 | 0 |
| | JPE/JPW, FRE/FRW, TMN/TMS | 40 | 200 | | 0.2 | 7 | | 2 | 0 |
| | MAE/MAW | 40 | 160 | | | | | 2 | 0 |
| FRE/FRW | SJNB | 30 | 80 | | 0.2 | 4.5 | 4 | 1 | 0 |

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Interior Delta residence time (Facilities residence time in parentheses) after leaving first site in Interior Delta (or Facilities, respectively)

c = Approximate migration rate calculated on most direct pathway

d = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

g = See comments for alternate criteria

**Table 5a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (hr) Near Field Maximum | Residence Time[a] (hr) Mid-field Maximum | Residence Time[a] (hr) Interior Delta/Facilities[b] Maximum | Migration Rate[c, d] (km/hr) Minimum | Migration Rate[c, d] (km/hr) Maximum | BLPS (Magnitude) Maximum | No. of Visits Maximum | No. of Cumulative Upstream Forays Maximum |
|---|---|---|---|---|---|---|---|---|---|
| FRE/FRW | MAC, MFE/MFW, TCE/TCW, OR4, OLD, MRE | 30 | 80 | | 0.1 | 4.5 | 4 | 1 | 0 |
| | TMN/TMS | 30 | 80 | | 0.2 | 4.5 | 4 | 1 | 0 |
| | JPE/JPW | 30 | 80 | | 0.1 | 7 | | 2 | 0 |
| | FRE/FRW | 10 | 80 | | | | | 3 | 0 |
| TMN/TMS | MAC, MFE/MFW | 20 | 100 | | 0.2 | 4.5 | 4 | 1 | 0 |
| | TCE/TCW | 20 | 100 | | 0.2 | 4.5 | 4 | 1 | 0 |
| | OLD | 20 | 100 | | 0.2 | 4.5 | 4 | 1 | 0 |
| | TMN/TMS | 10 | 64 | | | | | 2 | 0 |
| | JPE/JPW, FRE/FRW | 20 | 100 | | 0.2 | 4.5 | 4 | 2 | 4 |
| | MAE/MAW | 20 | 100 | | 0.2 | 4.5 | 4 | 1 | 4 |

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Interior Delta residence time (Facilities residence time in parentheses) after leaving first site in Interior Delta (or Facilities, respectively)

c = Approximate migration rate calculated on most direct pathway

d = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

g = See comments for alternate criteria

**Table 5b. Cutoff values used in predator filter in 2012. Observed values past cutoff or unmet conditions indicate a predator. Time durations are in hours unless otherwise specified. Footnotes, Extra Conditions and Comment refer to both this table and Table 5a.**

| | | Flow[e] (cfs) | | Water Velocity[e] (ft/sec) | | | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| Detection Site | Previous Site | At arrival | At departure[f] | At arrival | At departure[f] | Average during transition | | |
| DFU | DF | | | | | | | |
| | DFU, DFD, BCA | | | | | | Travel time < 600 hours from DFU | |
| DFD | DF | | | | | | Transition from MOS not allowed | |
| | DFU, DFD | | | | | | Travel time < 400 from DFD | Alternate values if coming from DFD |
| | BCA | | | | | | | |
| BCA | DF | | | | | | | Alternate values if next transition is downstream |
| | DFU, DFD | | | | | | If coming from DFU: Maximum of 1 visit if next transition is downstream; Travel time < 200 | Alternate values if next transition is downstream |
| | BCA | <12000 | | | | | Maximum of 3 visits if arrival flow > 12000 cfs; Travel time < 200 (500[g]) | Alternate values and known presence in detection range < 30 hours if next transition is downstream |
| | MOS | | <5000 | | | | | |
| MOS | DFU | | | | | | | Alternate values if next transition is downstream |
| | DF, DFD | >11000 | | | | | Allow 2 visits, no minimum migration rate if arrival flow < 11000 cfs | Alternate values if next transition is downstream |
| | BCA | <11000 | | | | | Allow 1 visit if arrival flow > 11000 cfs | Alternate values if next transition is downstream |
| | MOS | <14000 | | | | <2.7 | Travel time < 35 | |
| | HOR | <14000 | | | | <3 | | |
| SJL | MOS, HOR | | | | | | | Alternate value if coming from HOR |

e = Flow or velocity condition, if any, must be violated for predator classification

f = Condition at departure from previous site

g = See comments for alternate criteria

**Table 5b. (Continued)**

| | | Flow[e] (cfs) | | Water Velocity[e] (ft/sec) | | | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| Detection Site | Previous Site | At arrival | At departure[f] | At arrival | At departure[f] | Average during transition | | |
| SJL | MOS, HOR | | | | | | | Alternate value if coming from HOR |
| | SJL | | | | | <1.9 | Travel time < 200 (50[g]) | Alternate values if average transition water velocity outside range |
| | ORE | | | | | | | Not allowed because of barrier |
| | SJG | | | | | <1 | | Not allowed |
| SJG | SJL | | | | | | Known presence in detection range < 12 | |
| | SJG | <1000 (>-1000)[h] | >-1000 (<1000)[h] | <0.5 (>-0.5)[h] | >-0.5 (<0.5)[h] | <0.8 | Known presence in detection range < 9 | |
| | SJNB | <3500 | <3500 | <1.1 | <1.1 | <1.1 | Known presence in detection range < 6 | |
| SJNB | SJG | <2000 (>2000)[h] | <0.7 (>0.5)[h] | | | | Maximum migration rate is 2 if average water velocity < -0.15 and arrival flow < 2000; known presence in detection range < 12 | Alternate values for alternate flow, velocity conditions |
| | SJNB | | | | | | Travel time < 50; known presence in detection range < 9 | |
| | MAC, TCE/TCW | | | | | | | Alternate value if coming from TCE/TCW |
| MAC | SJG, SJNB | | | | | -0.1 to 0.4 | | Alternate values if average transition water velocity outside range; alternate minimum migration rate = 0.5 if coming from SJG |
| MAC | MAC | | | | | <0.1 | Travel time < 60 | Alternate values if average transition water velocity outside range |

e = Flow or velocity condition, if any, must be violated for predator classification

f = Condition at departure from previous site

g = See comments for alternate criteria

h = High flow/velocity on departure requires low values on arrival (and vice versa)

**Table 5b. (Continued)**

| Detection Site | Previous Site | Flow[e] (cfs) At arrival | Flow[e] (cfs) At departure[f] | Water Velocity[e] (ft/sec) At arrival | Water Velocity[e] (ft/sec) At departure[f] | Water Velocity[e] (ft/sec) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| MAC | MFE/MFW | | | -0.8 to 0.8 | | | Known presence in detection range < 15 (8[g]) | Alternate values if arrival water velocity outside range |
| | TCE/TCW | | | | | | | |
| | MRE | | | | | | | |
| MFE/MFW | SJG, SJNB, MAC, TCE/TCW | | | | | -0.1 to 0.4 | Maximum of 2 visits if coming from MAC | Alternate values if average transition water velocity outside range |
| | MFE/MFW | | | | | | Travel time < 60 | |
| | MRE | | >-1500 | | >-0.1 | | | |
| | OLD | | >-1500 | | >-0.5 | | | Not allowed |
| | JPE/JPW, TMN/TMS | <5000 | | <0.1 | | <0.1 | | Not allowed |
| HOR | MOS | <11000 | | | | | Travel time < 700; 1 visit allowed and travel time < 200 if arrival flow outside range | Alternate values if next transition is downstream |
| | HOR | <14000 | | | | <2.7 | Travel time < 35 | |
| | SJL, ORE | <14000 | | | | <2.7 (3[g]) | | Alternate values if coming from ORE |
| ORE | HOR | | | <0.8 | | | | Alternate values if arrival water velocity outside range |
| | ORE | | | | | | Travel time < 60 | |
| | SJL | >500 | | | | | | |
| | ORS, MRH | <3000 | | | | | | Not allowed because of barrier |
| ORS | ORE | | | | | <1.8 | | Alternate value if average transition water velocity outside range |
| | ORS | | | | | | Travel time < 200 | |
| | MRH | | | | | | | |

e = Flow or velocity condition, if any, must be violated for predator classification

f = Condition at departure from previous site

g = See comments for alternate criteria

**Table 5b. (Continued)**

| Detection Site | Previous Site | Flow[e] (cfs) At arrival | Flow[e] (cfs) At departure[f] | Water Velocity[e] (ft/sec) At arrival | Water Velocity[e] (ft/sec) At departure[f] | Water Velocity[e] (ft/sec) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| ORS | RGU, CVP | | | | | <1.5 | Not allowed if came from lower SJR | Alternate value if coming from CVP |
| OR4 | ORS | >-1500 | | >-0.5 | | | | |
| | RGU | >-1500 | | >-0.5 | | | CCFB inflow < 3000 cfs on departure[f] | |
| | CVP | >-1500 | >-1000 | >-0.5 | >-0.6 | | CVP pumping < 1500 cfs on departure[f] | |
| | OR4 | <1500 (>-1500)[h] | >-1500 (<1500)[h] | <0.5 (>-0.5)[h] | >-0.5 (<0.5)[h] | | Travel time < 500 | |
| | OLD, MRE | <1500 | NA (<1500[g]) | <0.5 | NA (<0.1[g]) | | Known presence in detection range < 10 hours | Alternate values if coming from MRE |
| | MR4 | | | | | | | |
| OLD | SJNB | | | | | | | |
| | MAC, MFE/MFW | | | | | | | |
| | OR4 | >-2000 | >-1500 | >-0.1 | >-0.5 | | | |
| | OLD | <1500 (>-1500)[h] | >-1500 (<1500)[h] | <0.5 (>-0.5)[h] | >-0.5 (<0.5)[h] | | Travel time < 500 | |
| | MRE | | | | | | | |
| | TCE/TCW | | <200 | | <0.05 | | | |
| MRH | ORE | | | | | | Transition from MRH not allowed | |
| | ORS | | | | | | | |
| | MRH | | | | | | Travel time < 15 | Not allowed |
| MR4 | ORS | | | | | | | |
| | OR4, OLD | <0 (2500[g]) | | <0 (0.25[g]) | | | | Alternate values if coming from OLD |

e = Flow or velocity condition, if any, must be violated for predator classification

f = Condition at departure from previous site

g = See comments for alternate criteria

h = High flow/velocity on departure requires low values on arrival (and vice versa)

**Table 5b. (Continued)**

| Detection Site | Previous Site | Flow[e] (cfs) At arrival | Flow[e] (cfs) At departure[f] | Water Velocity[e] (ft/sec) At arrival | Water Velocity[e] (ft/sec) At departure[f] | Water Velocity[e] (ft/sec) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| MR4 | MR4 | <-5500 (>-6000)[h] | >-6000 (<-5500)[h] | <-0.5 (>-0.5)[h] | >-0.5 (<-0.5)[h] | | Travel time < 30 | |
| | MRE | <2500 | <1500 | <0.25 | <0.1 | <0.1 | | |
| | RGU | | | | | | CCFB inflow < 3000 cfs on departure[f] | |
| | CVP | | | | | | CVP pumping < 4000 cfs on departure[f] | |
| | TCE/TCW | | | <0.15 | <0.1 | | | |
| MRE | SJL, SJG, SJNB | <1500 | | <0.1 | | | No previous entry to Interior Delta from lower SJR if coming from SJL | Alternate value if coming from SJL |
| | MAC, MFE/MFW | <1500 | | <0.1 | | | | |
| | OR4, OLD | >-1500 (NA[g]) | >-1500 (NA[g]) | >-0.1 (NA[g]) | >-0.5 (NA[g]) | | Known presence in detection range < 10 hours | Alternate values of coming from OLD |
| | MR4 | >-1500 | | >-0.1 | | >0 | | |
| | MRE | <1500 (>-1500)[h] | >-1500 (<1500)[h] | <0.1 (>-0.1)[h] | >-0.1 (<0.1)[h] | | Travel time < 100 | |
| | TCE/TCW | <1500 | <200 | <0.1 | <0.05 | | | |
| | TMN/TMS | <1500 | | <0.1 | | <0.25 | Known presence in detection range < 10 hours | |
| RGU/RGD | ORS | | | | | | | |
| | CVP | | >-1000 | | >-0.6 | | CVP pumping < 4000 cfs at departure[f] | |
| | OR4 | | <2000 | | <0.8 | | | |
| | MR4 | | | | | | | |
| CVP | ORS | | | | | | | |
| | CVP | | | | | | CVP pumping > 1500 cfs on arrival; travel time < 100 | |

e = Flow or velocity condition, if any, must be violated for predator classification

f = Condition at departure from previous site

g = See comments for alternate criteria

h = High flow/velocity on departure requires low values on arrival (and vice versa)

**Table 5b. (Continued)**

| Detection Site | Previous Site | Flow[e] (cfs) At arrival | Flow[e] (cfs) At departure[f] | Water Velocity[e] (ft/sec) At arrival | Water Velocity[e] (ft/sec) At departure[f] | Water Velocity[e] (ft/sec) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| CVP | RGU | <3000 | | <1.5 | | | Travel time < 200 | Alternate values if came via lower SJR |
| | OR4 | <3000 | <2000 | <1.5 | <0.8 | | CVP pumping > 1500 cfs on arrival | Alternate values if came from lower SJR |
| | MR4 | | | | | | | |
| CVPtank | CVP | | | | | | Travel time < 100 | |
| TCE/TCW | SJNB | | | <0.1 | | | | |
| | TCE/TCW | <1500 (>-1500)[h] | >-1500 (<1500)[h] | <0.3 (>-0.3)[h] | >-0.3 (<0.3)[h] | | Travel time < 60 | |
| | MAC | | | <0.1 | | <0.1 | | |
| | MRE | >-500 | >-1000 | >-0.1 | >-0.1 | >-0.2 | | |
| JPE/JPW | MAC, MFE/MFW, TCE/TCW, OLD | | | | | | | |
| | TMN/TMS | | | | | | | |
| | CVPtank | | | | | | Maximum travel time is 2 from CVPtank | Trucking release sites are downstream of JPE/JPW |
| | RGU | | | | | | Maximum travel time is 300 from RGU | Trucking release sites are downstream of JPE/JPW |
| | JPE/JPW | | | | | | Travel time < 50 | |
| | FRE/FRW | | | | | | | |
| MAE/MAW | MAC, MFE/MFW, TCE/TCW, MRE | | | | | | Not allowed if prior entry to Interior Delta from lower SJR | |
| | CVP, CVPtank | | | | | | | |
| | RGU/RGD | | | | | | | |
| | JPE/JPW, FRE/FRW, TMN/TMS | | | | | | | |
| | MAE/MAW | | | | | | Travel time < 40 | |

e = Flow or velocity condition, if any, must be violated for predator classification

f = Condition at departure from previous site

h = High flow/velocity on departure requires low values on arrival (and vice versa)

**Table 5b. (Continued)**

| Detection Site | Previous Site | Flow[e] (cfs) At arrival | Flow[e] (cfs) At departure[f] | Water Velocity[e] (ft/sec) At arrival | Water Velocity[e] (ft/sec) At departure[f] | Water Velocity[e] (ft/sec) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| FRE/FRW | SJNB | | | | | | Not allowed if prior entry to Interior Delta from lower SJR | |
| | MAC, MFE/MFW, TCE/TCW, OR4, OLD, MRE | | | | | | | |
| | TMN/TMS | | | | | | | |
| | JPE/JPW | | | | | | | |
| | FRE/FRW | | | | | | | |
| TMN/TMS | MAC, MFE/MFW | | >-50000 | | > -1 | | Not allowed if prior transition to facilities from lower SJR | |
| | TCE/TCW | | | | | | Not allowed if prior transition to facilities from lower SJR | |
| | OLD | | > 0 | | > 0 | | Not allowed if prior transition to facilities from lower SJR | |
| | TMN/TMS | <0 (>0)[h] | >0 (<0)[h] | <0 (>0)[h] | >0 (<0)[h] | | | |
| | JPE/JPW, FRE/FRW | | | | | | | |
| | MAE/MAW | | | | | | | |

e = Flow or velocity condition, if any, must be violated for predator classification

f = Condition at departure from previous site

h = High flow/velocity on departure requires low values on arrival (and vice versa)

**Table 6. Water temperature and dissolved oxygen in the transport tank after loading prior to transport, after transport, and in the river at the Durham Ferry release site just prior to placing fish in holding containers, and the number of mortalities after transport and prior to release for steelhead as part of the Six-Year Study.**

| Transport | | Tank after loading | | Tank after transport | | | River | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Loading time | Temp (˚C) | DO (mg/L) | Temp (˚C) | DO (mg/L) | # morts after transport | Temp (˚C) | DO (mg/L) | Mortalities just prior to release |
| 4/3/2012 | 920 | 12.6 | 10.05 | 13.0 | 16.7 | 0 | 16.8 | 10.44 | 0 |
| 4/3/2012 | 1232 | 13.6 | 9.6 | 13.3 | 8.8 | 0 | 17.6 | 11.36 | 0 |
| 4/3/2012 | 1535 | 12.6 | 10.0 | 12.9 | 17.2 | 0 | 17.7 | 11.8 | 0 |
| 4/4/2012 | 926 | 11.8 | 10.3 | 13.0 | 16.4 | 0 | 16 | 10.31 | 1 |
| 4/4/2012 | 1210 | 12.2 | 8.4 | 12.4 | 16.5 | 0 | 16.8 | 10.9 | 0 |
| 4/4/2012 | 1520 | 12.0 | 10.1 | 12.8 | 15.6 | 0 | 16.9 | 11.4 | 0 |
| 4/5/2012 | 914 | 12.3 | 10.8 | 12.40 | 14.0 | 0 | 14.7 | 10.27 | 0 |
| 4/5/2012 | 1140 | 12.2 | 10.1 | 12.9 | 14.6 | 0 | 15.9 | 10.94 | 1 |
| 4/5/2012 | 1440 | 12.8 | 10.6 | 13.2 | 15.4 | 0 | - | - | 0 |
| 4/30/2012 | 958 | 12.6 | 10.6 | 14.0 | 11.2 | 0 | 19.1 | 6.03 | 0 |
| 4/30/2012 | 1244 | 13.2 | 10.6 | 16.0 | 12.8 | 0 | 20.0 | 5.7 | 0 |
| 4/30/2012 | 1535 | 12.3 | 10.7 | 14.5 | 10.9 | 0 | 19.9 | 5.5 | 0 |
| 5/2/2012 | 920 | 12.5 | 10.8 | 13.3 | 11.5 | 0 | 18.1 | 9.5 | 1 |
| 5/2/2012 | 1140 | 13.1 | 10.7 | 14.7 | 13.6 | 0 | 19.4 | 9.7 | 0 |
| 5/2/2012 | 1456 | 12.9 | 10.7 | 13.7 | 11.1 | 0 | 19.1 | 10.0 | 0 |
| 5/4/2012 | 857 | 12.2 | 10.9 | 12.8 | 11.2 | 0 | 17.4 | 9.0 | 0 |
| 5/4/2012 | 1100 | 13.2 | 11.2 | 14.7 | 13.6 | 0 | 18.0 | 9.4 | 1 |
| 5/4/2012 | 1420 | 12.5 | 10.9 | 13.5 | 10.9 | 0 | 18.5 | 9.7 | 0 |
| 5/17/2012 | 920 | 12.6 | 10.8 | 14.8 | 10.8 | 0 | 19.0 | 8.5 | 0 |
| 5/17/2012 | 1127 | 13.1 | 10.9 | 14.7 | 10.2 | 0 | 19.8 | 9.12 | 0 |
| 5/17/2012 | 1446 | 13.2 | 10.5 | 15.2 | 10.7 | 0 | 20.0 | 9.07 | 0 |
| 5/19/2012 | 910 | 12.8 | 11.0 | 13.7 | 10.9 | 0 | 18.7 | 8.08 | 0 |
| 5/19/2012 | 1112 | 13.4 | 10.8 | 15.8 | 10.9 | 0 | 19.5 | 7.77 | 0 |
| 5/19/2012 | 1425 | 13.2 | 10.8 | 15.2 | 10.3 | 0 | 20.2 | 8.1 | 0 |
| 5/21/2012 | 907 | 12.7 | 11.1 | 13.8 | 10.6 | 0 | 19.6 | 9.34 | 0 |
| 5/21/2012 | 1118 | 13.7 | 10.4 | 14.6 | 10.2 | 0 | 20.5 | 9.88 | 0 |
| 5/21/2012 | 1434 | 12.9 | 10.9 | 14.4 | 11.0 | 0 | 20.7 | 10.6 | 0 |

**Table 7: Results of dummy tagged fish evaluated after being held at the Durham Ferry holding site for 48 hours as part of Six-Year Study in 2012.**

| Examination Date, Time | Mean (sd) Forklength (mm) | Mortality | Mean (sd) scale loss | Normal Body Color | No Fin Hemorrhaging | Normal Eye Quality | Normal Gill Color |
|---|---|---|---|---|---|---|---|
| 4/05/12, 1133 | 209.7 (35.5) | 12/12 | 17.9 (12.5) | 12/12 | 12/12 | 12/12 | 12/12 |
| 4/06/12, 1116 | 211.8 (35.2) | 12/12 | 13.3 (10.3) | 12/12 | 12/12 | 12/12 | 12/12 |
| 5/02/12, 1100 | 229.1 (12.3) | 12/12 | 13.3 (10.1) | 12/12 | 12/12 | 12/12 | 12/12 |
| 5/04/12, 1100 | 231.7 (19.1) | 12/12 | 7.4 (5.2) | 12/12 | 12/12 | 12/12 | 12/12 |
| 5/19/12, 1100 | 224.8 (32.9) | 12/12 | 13.3 (13.5) | 12/12 | 12/12 | 12/12 | 12/12 |
| 5/21/12, 1100 | 243.9 (37.9) | 12/12 | 16.4 (8.9) | 12/12 | 12/12 | 12/12 | 11/12 |

**Table 8: Number of tags from each release group that were detected after release in 2012, including predator-type detections and detections omitted from the survival analysis.**

| Release Group | 1 | 2 | 3 | Total |
|---|---|---|---|---|
| Number Released | 477 | 478 | 480 | 1,435 |
| Number Detected | 425 | 392 | 370 | 1,187 |
| Number Detected Downstream | 408 | 372 | 324 | 1,104 |
| Number Detected Upstream of Study Area | 323 | 144 | 314 | 781 |
| Number Detected in Study Area | 333 | 318 | 189 | 840 |
| Number Detected in San Joaquin River Route | 306 | 306 | 164 | 776 |
| Number Detected in Old River Route | 21 | 11 | 26 | 58 |
| Number Assigned to San Joaquin River Route | 304 | 297 | 150 | 751 |
| Number Assigned to Old River Route | 20 | 11 | 17 | 48 |

**Table 9. Number of tags observed from each release group at each detection site in 2012, including predator-type detections. Routes (SJR = San Joaquin River, OR = Old River) represent route assignment at the head of Old River. Pooled counts are summed over all receivers in array and all routes. Route could not be identified for some tags.**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Release site at Durham Ferry | | | 477 | 478 | 480 | 1,435 |
| Durham Ferry Upstream | DFU | A0 | 32 | 35 | 152 | 219 |
| Durham Ferry Downstream | DFD | A2 | 288 | 84 | 159 | 531 |
| Banta Carbona | BCA | A3 | 71 | 52 | 178 | 301 |
| Mossdale | MOS | A4 | 333 | 318 | 189 | 840 |
| Head of Old River | HOR | B0 | 332 | 313 | 177 | 822 |
| Lathrop | SJL | A5 | 306 | 306 | 164 | 776 |
| Garwood Bridge | SJG | A6 | 288 | 286 | 150 | 724 |
| Navy Drive Bridge | SJNB | A7 | 273 | 278 | 142 | 693 |
| MacDonald Island Upstream | MACU | A8a | 198 | 197 | 94 | 489 |
| MacDonald Island Downstream | MACD | A8b | 194 | 188 | 89 | 471 |
| MacDonald Island | MAC | A8 | 202 | 198 | 96 | 496 |
| Medford Island East | MFE | A9a | 125 | 130 | 67 | 322 |
| Medford Island West | MFW | A9b | 121 | 131 | 68 | 320 |
| Medford Island (Pooled) | MFE/MFW | A9 | 126 | 132 | 68 | 326 |
| Turner Cut East | TCE | F1a | 25 | 64 | 54 | 143 |
| Turner Cut West | TCW | F1b | 14 | 61 | 56 | 131 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 32 | 64 | 56 | 152 |
| Old River East | ORE | B1 | 21 | 11 | 26 | 58 |
| Old River South Upstream | ORSU | B2a | 21 | 10 | 18 | 49 |
| Old River South Downstream | ORSD | B2b | 21 | 3 | 0 | 24 |
| Old River South (Pooled) | ORS | B2 | 21 | 10 | 18 | 49 |
| Old River at Highway 4, Upstream | OR4U | B3a | 38 | 16 | 18 | 72 |
| Old River at Highway 4, Downstream | OR4D | B3b | 38 | 15 | 18 | 71 |
| Old River at Highway 4, SJR Route | OR4 | B3 | 33 | 15 | 17 | 65 |
| Old River at Highway 4, OR Route | OR4 | B3 | 5 | 1 | 0 | 6 |
| Old River at Highway 4 (Pooled) | OR4 | B3 | 38 | 16 | 18 | 72 |
| Old River near Empire Cut, Upstream | OLDU | B4a | 29 | 16 | 10 | 55 |
| Old River near Empire Cut, Downstream | OLDD | B4b | 0 | 0 | 0 | 0 |
| Old River near Empire Cut, SJR Route | OLD | B4 | 29 | 16 | 9 | 54 |
| Old River near Empire Cut, OR Route | OLD | B4 | 0 | 0 | 1 | 1 |
| Old River near Empire Cut (Pooled) | OLD | B4 | 29 | 16 | 10 | 55 |
| Middle River Head | MRH | C1 | 1 | 0 | 2 | 3 |
| Middle River at Highway 4, Upstream | MR4U | C2a | 11 | 19 | 11 | 41 |
| Middle River at Highway 4, Downstream | MR4D | C2b | 13 | 21 | 11 | 45 |

**Table 9. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Middle River at Highway 4, SJR Route | MR4 | C2 | 12 | 21 | 9 | 42 |
| Middle River at Highway 4, OR Route | MR4 | C2 | 1 | 0 | 1 | 2 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 13 | 21 | 11 | 45 |
| Middle River near Empire Cut, Upstream | MREU | C3a | 71 | 60 | 46 | 177 |
| Middle River near Empire Cut, Downstream | MRED | C3b | 1 | 59 | 41 | 101 |
| Middle River near Empire Cut, SJR Route | MRE | C3 | 71 | 60 | 44 | 175 |
| Middle River near Empire Cut, OR Route | MRE | C3 | 0 | 0 | 1 | 1 |
| Middle River near Empire Cut (Pooled) | MRE | C3 | 71 | 60 | 46 | 177 |
| Radial Gates Upstream: SJR Route | RGU | D1 | 7 | 8 | 11 | 26 |
| Radial Gates Upstream: OR Route | RGU | D1 | 7 | 4 | 1 | 12 |
| Radial Gates Upstream | RGU | D1 | 14 | 12 | 13 | 39 |
| Radial Gates Downstream #1 | RGD1 | D2a | 8 | 8 | 11 | 27 |
| Radial Gates Downstream #2 | RGD2 | D2b | 7 | 7 | 11 | 25 |
| Radial Gates Downstream: SJR Route | RGD | D2 | 5 | 4 | 10 | 19 |
| Radial Gates Downstream: OR Route | RGD | D2 | 3 | 4 | 1 | 8 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 8 | 8 | 11 | 27 |
| CVP Trashrack: SJR Route | CVP | E1 | 21 | 19 | 13 | 53 |
| CVP Trashrack: OR Route | CVP | E1 | 14 | 4 | 4 | 22 |
| Central Valley Project Trashrack | CVP | E1 | 35 | 23 | 18 | 76 |
| CVP tank: SJR Route | CVPtank | E2 | 4 | 9 | 2 | 15 |
| CVP tank: OR Route | CVPtank | E2 | 2 | 0 | 1 | 3 |
| Central Valley Project Holding Tank | CVPtank | E2 | 6 | 9 | 3 | 18 |
| Threemile Slough South | TMS | T1a | 20 | 24 | 6 | 50 |
| Threemile Slough North | TMN | T1b | 18 | 25 | 3 | 46 |
| Threemile Slough (Pooled) | TMS/TMN | T1 | 21 | 25 | 6 | 52 |
| Jersey Point East | JPE | G1a | 101 | 121 | 57 | 279 |
| Jersey Point West | JPW | G1b | 96 | 112 | 57 | 265 |
| Jersey Point: SJR Route | JPE/JPW | G1 | 103 | 125 | 62 | 290 |
| Jersey Point: OR Route | JPE/JPW | G1 | 0 | 0 | 0 | 0 |
| Jersey Point (Pooled) | JPE/JPW | G1 | 103 | 125 | 62 | 290 |
| False River West | FRW | H1a | 37 | 46 | 23 | 106 |
| False River East | FRE | H1b | 36 | 39 | 19 | 94 |
| False River: SJR Route | FRE/FRW | H1 | 40 | 49 | 23 | 112 |
| False River: OR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River (Pooled) | FRE/FRW | H1 | 40 | 49 | 23 | 112 |

**Table 9. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Chipps Island East | MAE | G2a | 86 | 105 | 47 | 238 |
| Chipps Island West | MAW | G2b | 89 | 103 | 51 | 243 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 88 | 109 | 55 | 252 |
| Chipps Island: OR Route | MAE/MAW | G2 | 3 | 1 | 0 | 4 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 91 | 110 | 55 | 256 |

**Table 10. Number of tags observed from each release group at each detection site in 2012 and used in the survival analysis, including predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags.**

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Release site at Durham Ferry | | | 477 | 478 | 480 | 1,435 |
| Durham Ferry Upstream | DFU | A0 | 21 | 27 | 92 | 140 |
| Durham Ferry Downstream | DFD | A2 | 281 | 77 | 107 | 465 |
| Banta Carbona | BCA | A3 | 71 | 51 | 157 | 279 |
| Mossdale | MOS | A4 | 329 | 315 | 173 | 817 |
| Lathrop | SJL | A5 | 304 | 297 | 150 | 751 |
| Garwood Bridge | SJG | A6 | 288 | 284 | 144 | 716 |
| Navy Drive Bridge | SJNB | A7 | 273 | 271 | 134 | 678 |
| MacDonald Island Upstream | MACU | A8a | 185 | 176 | 82 | 443 |
| MacDonald Island Downstream | MACD | A8b | 186 | 176 | 79 | 441 |
| MacDonald Island | MAC | A8 | 194 | 181 | 84 | 459 |
| Medford Island East | MFE | A9a | 116 | 126 | 65 | 307 |
| Medford Island West | MFW | A9b | 113 | 126 | 66 | 305 |
| Medford Island (Pooled) | MFE/MFW | A9 | 118 | 127 | 66 | 311 |
| Turner Cut East | TCE | F1a | 24 | 58 | 48 | 130 |
| Turner Cut West | TCW | F1b | 13 | 57 | 50 | 120 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 30 | 58 | 50 | 138 |
| Old River East | ORE | B1 | 20 | 11 | 17 | 48 |
| Old River South Upstream | ORSU | B2a | 20 | 9 | 13 | 42 |
| Old River South Downstream | ORSD | B2b | 20 | 2 | 0 | 22 |
| Old River South (Pooled) | ORS | B2 | 20 | 9 | 13 | 42 |
| Old River at Highway 4, Upstream | OR4U | B3a | 33 | 13 | 16 | 62 |
| Old River at Highway 4, Downstream | OR4D | B3b | 33 | 12 | 16 | 61 |
| Old River at Highway 4, SJR Route | OR4 | B3 | 31 | 13 | 16 | 60 |
| Old River at Highway 4, OR Route | OR4 | B3 | 2 | 0 | 0 | 2 |
| Old River at Highway 4 (Pooled) | OR4 | B3 | 33 | 13 | 16 | 62 |
| Middle River Head | MRH | C1 | 0 | 0 | 2 | 2 |
| Middle River at Highway 4, Upstream | MR4U | C2a | 6 | 17 | 8 | 31 |
| Middle River at Highway 4, Downstream | MR4D | C2b | 7 | 18 | 7 | 31 |
| Middle River at Highway 4, SJR Route | MR4 | C2 | 7 | 18 | 8 | 33 |
| Middle River at Highway 4, OR Route | MR4 | C2 | 1 | 0 | 1 | 2 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 7 | 18 | 8 | 33 |
| Radial Gates Upstream: SJR Route | RGU | D1 | 6 | 4 | 10 | 20 |

**Table 10. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Radial Gates Upstream: OR Route | RGU | D1 | 6 | 4 | 1 | 11 |
| Radial Gates Upstream | RGU | D1 | 12 | 8 | 11 | 31 |
| Radial Gates Downstream #1 | RGD1 | D2a | 8 | 8 | 11 | 27 |
| Radial Gates Downstream #2 | RGD2 | D2b | 7 | 7 | 11 | 25 |
| Radial Gates Downstream: SJR Route | RGD | D2 | 5 | 4 | 10 | 19 |
| Radial Gates Downstream: OR Route | RGD | D2 | 3 | 4 | 1 | 8 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 8 | 8 | 11 | 27 |
| CVP Trashrack: SJR Route | CVP | E1 | 14 | 17 | 9 | 40 |
| CVP Trashrack: OR Route | CVP | E1 | 9 | 2 | 4 | 15 |
| Central Valley Project Trashrack | CVP | E1 | 23 | 19 | 13 | 55 |
| CVP tank: SJR Route | CVPtank | E2 | 4 | 9 | 2 | 15 |
| CVP tank: OR Route | CVPtank | E2 | 2 | 0 | 1 | 3 |
| Central Valley Project Holding Tank | CVPtank | E2 | 6 | 9 | 3 | 18 |
| Jersey Point East | JPE | G1a | 90 | 112 | 55 | 257 |
| Jersey Point West | JPW | G1b | 87 | 102 | 56 | 245 |
| Jersey Point: SJR Route | JPE/JPW | G1 | 94 | 116 | 61 | 271 |
| Jersey Point: OR Route | JPE/JPW | G1 | 0 | 0 | 0 | 0 |
| Jersey Point (Pooled) | JPE/JPW | G1 | 94 | 116 | 61 | 271 |
| False River West | FRW | H1a | 2 | 6 | 1 | 9 |
| False River East | FRE | H1b | 0 | 3 | 1 | 4 |
| False River: SJR Route | FRE/FRW | H1 | 2 | 7 | 1 | 10 |
| False River: OR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River (Pooled) | FRE/FRW | H1 | 2 | 7 | 1 | 10 |
| Chipps Island East | MAE | G2a | 85 | 104 | 46 | 234 |
| Chipps Island West | MAW | G2b | 89 | 101 | 51 | 241 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 88 | 108 | 55 | 251 |
| Chipps Island: OR Route | MAE/MAW | G2 | 3 | 1 | 0 | 4 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 91 | 109 | 55 | 255 |

**Table 11. Number of tags from each release group in 2012 first classified as in a predator at each detection site, based on the predator filter.**

| Detection Site and Code | | | Durham Ferry Release Groups | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Classified as Predator on Arrival at Site | | | | Classified as Predator on Departure from Site | | | |
| Detection Site | Site Code | Survival Model Code | 1 | 2 | 3 | Total | 1 | 2 | 3 | Total |
| Durham Ferry Upstream | DFU | A0 | 4 | 12 | 46 | 62 | 0 | 0 | 6 | 6 |
| Durham Ferry Downstream | DFD | A2 | 7 | 10 | 39 | 56 | 0 | 0 | 0 | 0 |
| Banta Carbona | BCA | A3 | 2 | 9 | 22 | 33 | 0 | 1 | 4 | 5 |
| Mossdale | MOS | A4 | 2 | 2 | 1 | 5 | 0 | 0 | 0 | 0 |
| Head of Old River | HOR | B0 | 2 | 2 | 4 | 8 | 1 | 0 | 0 | 1 |
| Lathrop | SJL | A5 | 2 | 1 | 0 | 3 | 3 | 0 | 1 | 4 |
| Garwood Bridge | SJG | A6 | 2 | 4 | 2 | 8 | 1 | 3 | 2 | 6 |
| Navy Drive Bridge | SJNB | A7 | 0 | 4 | 2 | 6 | 4 | 0 | 1 | 5 |
| MacDonald Island | MAC | A8 | 1 | 0 | 0 | 1 | 3 | 1 | 0 | 4 |
| Medford Island | MFE/MFW | A9 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| Old River East | ORE | B1 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| Old River South | ORS | B2 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| Old River at Highway 4 | OR4 | B3 | 5 | 1 | 0 | 6 | 1 | 0 | 0 | 1 |
| Old River near Empire Cut | OLD | B4 | 3 | 1 | 0 | 4 | 0 | 0 | 0 | 0 |
| Middle River Head | MRH | C1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Middle River at Highway 4 | MR4 | C2 | 1 | 1 | 2 | 4 | 0 | 0 | 0 | 0 |
| Middle River near Empire Cut | MRE | C3 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 |
| Radial Gates Upstream | RGU | D1 | 0 | 0 | 1 | 1 | 3 | 4 | 0 | 7 |
| Radial Gates Downstream | RGD | D2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Central Valley Project Trashrack | CVP | E1 | 4 | 1 | 2 | 7 | 0 | 2 | 1 | 3 |
| Central Valley Project Holding Tank | CVPtank | E2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Turner Cut | TCE/TCW | F1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| Jersey Point | JPE/JPW | G1 | 1 | 1 | 0 | 2 | 1 | 0 | 0 | 1 |
| Chipps Island | MAE/MAW | G2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| False River | FRE/FRW | H1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Threemile Slough | TMS/TMN | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Tags | | | 39 | 52 | 128 | 219 | 18 | 12 | 16 | 46 |

**Table 12. Number of tags from each release group that were detected after release in 2012, excluding predator-type detections, and including detections omitted from the survival analysis.**

| Release Group | 1 | 2 | 3 | Total |
|---|---|---|---|---|
| Number Released | 477 | 478 | 480 | 1,435 |
| Total Number Detected | 422 | 380 | 337 | 1,139 |
| Total Number Detected Downstream | 405 | 360 | 280 | 1,045 |
| Total Number Detected Upstream of Study Area | 319 | 133 | 278 | 730 |
| Total Number Detected in Study Area | 333 | 312 | 176 | 821 |
| Number Detected in San Joaquin River Route | 306 | 301 | 161 | 768 |
| Number Detected in Old River Route | 21 | 8 | 13 | 42 |
| Number Assigned to San Joaquin River Route | 306 | 300 | 153 | 759 |
| Number Assigned to Old River Route | 21 | 8 | 13 | 42 |

**Table 13. Number of tags observed from each release group at each detection site in 2012, excluding predator-type detections. Routes (SJR = San Joaquin River, OR = Old River) represent route assignment at the head of Old River. Pooled counts are summed over all receivers in array and all routes. Route could not be identified for some tags.**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Release site at Durham Ferry | | | 477 | 478 | 480 | 1,435 |
| Durham Ferry Upstream | DFU | A0 | 30 | 27 | 118 | 175 |
| Durham Ferry Downstream | DFD | A2 | 285 | 78 | 109 | 472 |
| Banta Carbona | BCA | A3 | 67 | 44 | 144 | 255 |
| Mossdale | MOS | A4 | 333 | 312 | 176 | 921 |
| Head of Old River | HOR | B0 | 332 | 308 | 167 | 807 |
| Lathrop | SJL | A5 | 306 | 301 | 161 | 768 |
| Garwood Bridge | SJG | A6 | 283 | 285 | 150 | 718 |
| Navy Drive Bridge | SJNB | A7 | 269 | 275 | 139 | 683 |
| MacDonald Island Upstream | MACU | A8a | 191 | 196 | 92 | 479 |
| MacDonald Island Downstream | MACD | A8b | 188 | 187 | 87 | 462 |
| MacDonald Island | MAC | A8 | 195 | 197 | 94 | 486 |
| Medford Island East | MFE | A9a | 121 | 130 | 66 | 317 |
| Medford Island West | MFW | A9b | 117 | 131 | 67 | 315 |
| Medford Island (Pooled) | MFE/MFW | A9 | 122 | 132 | 67 | 321 |
| Turner Cut East | TCE | F1a | 25 | 63 | 53 | 141 |
| Turner Cut West | TCW | F1b | 14 | 60 | 55 | 129 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 32 | 63 | 55 | 150 |
| Old River East | ORE | B1 | 21 | 8 | 13 | 42 |
| Old River South Upstream | ORSU | B2a | 20 | 8 | 10 | 38 |
| Old River South Downstream | ORSD | B2b | 20 | 3 | 0 | 23 |
| Old River South (Pooled) | ORS | B2 | 20 | 8 | 10 | 38 |
| Old River at Highway 4, Upstream | OR4U | B3a | 34 | 15 | 18 | 67 |
| Old River at Highway 4, Downstream | OR4D | B3b | 34 | 14 | 18 | 66 |
| Old River at Highway 4, SJR Route | OR4 | B3 | 29 | 14 | 18 | 61 |
| Old River at Highway 4, OR Route | OR4 | B3 | 5 | 1 | 0 | 6 |
| Old River at Highway 4 (Pooled) | OR4 | B3 | 34 | 15 | 18 | 67 |
| Old River near Empire Cut, Upstream | OLDU | B4a | 26 | 15 | 9 | 50 |
| Old River near Empire Cut, Downstream | OLDD | B4b | 0 | 0 | 0 | 0 |
| Old River near Empire Cut, SJR Route | OLD | B4 | 26 | 15 | 9 | 50 |
| Old River near Empire Cut, OR Route | OLD | B4 | 0 | 0 | 0 | 0 |
| Old River near Empire Cut (Pooled) | OLD | B4 | 26 | 15 | 9 | 50 |
| Middle River Head | MRH | C1 | 1 | 0 | 0 | 1 |
| Middle River at Highway 4, Upstream | MR4U | C2a | 11 | 18 | 8 | 37 |
| Middle River at Highway 4, Downstream | MR4D | C2b | 12 | 20 | 8 | 40 |

**Table 13. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Middle River at Highway 4, SJR Route | MR4 | C2 | 11 | 20 | 8 | 39 |
| Middle River at Highway 4, OR Route | MR4 | C2 | 1 | 0 | 0 | 1 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 12 | 20 | 8 | 40 |
| Middle River near Empire Cut, Upstream | MREU | C3a | 71 | 59 | 45 | 175 |
| Middle River near Empire Cut, Downstream | MRED | C3b | 1 | 58 | 40 | 99 |
| Middle River near Empire Cut, SJR Route | MRE | C3 | 71 | 59 | 45 | 175 |
| Middle River near Empire Cut, OR Route | MRE | C3 | 0 | 0 | 0 | 0 |
| Middle River near Empire Cut (Pooled) | MRE | C3 | 71 | 59 | 45 | 175 |
| Radial Gates Upstream: SJR Route | RGU | D1 | 7 | 7 | 10 | 24 |
| Radial Gates Upstream: OR Route | RGU | D1 | 7 | 4 | 1 | 12 |
| Radial Gates Upstream | RGU | D1 | 14 | 11 | 11 | 36 |
| Radial Gates Downstream #1 | RGD1 | D2a | 6 | 7 | 10 | 23 |
| Radial Gates Downstream #2 | RGD2 | D2b | 6 | 6 | 10 | 22 |
| Radial Gates Downstream: SJR Route | RGD | D2 | 3 | 3 | 9 | 15 |
| Radial Gates Downstream: OR Route | RGD | D2 | 3 | 4 | 1 | 8 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 6 | 7 | 10 | 23 |
| CVP Trashrack: SJR Route | CVP | E1 | 19 | 19 | 13 | 51 |
| CVP Trashrack: OR Route | CVP | E1 | 13 | 3 | 2 | 18 |
| Central Valley Project Trashrack | CVP | E1 | 32 | 22 | 15 | 69 |
| CVP tank: SJR Route | CVPtank | E2 | 3 | 8 | 2 | 13 |
| CVP tank: OR Route | CVPtank | E2 | 2 | 0 | 1 | 3 |
| Central Valley Project Holding Tank | CVPtank | E2 | 5 | 8 | 3 | 16 |
| Threemile Slough South | TMS | T1a | 18 | 23 | 6 | 47 |
| Threemile Slough North | TMN | T1b | 16 | 24 | 3 | 43 |
| Threemile Slough (Pooled) | TMS/TMN | T1 | 19 | 24 | 6 | 49 |
| Jersey Point East | JPE | G1a | 95 | 120 | 57 | 272 |
| Jersey Point West | JPW | G1b | 91 | 111 | 57 | 259 |
| Jersey Point: SJR Route | JPE/JPW | G1 | 97 | 124 | 62 | 283 |
| Jersey Point: OR Route | JPE/JPW | G1 | 0 | 0 | 0 | 0 |
| Jersey Point (Pooled) | JPE/JPW | G1 | 97 | 124 | 62 | 283 |
| False River West | FRW | H1a | 34 | 46 | 23 | 103 |
| False River East | FRE | H1b | 33 | 39 | 19 | 91 |
| False River: SJR Route | FRE/FRW | H1 | 37 | 49 | 23 | 109 |
| False River: OR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River (Pooled) | FRE/FRW | H1 | 37 | 49 | 23 | 109 |

**Table 13. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Chipps Island East | MAE | G2a | 83 | 104 | 47 | 234 |
| Chipps Island West | MAW | G2b | 86 | 102 | 51 | 239 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 86 | 108 | 55 | 249 |
| Chipps Island: OR Route | MAE/MAW | G2 | 2 | 1 | 0 | 3 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 88 | 109 | 55 | 252 |

**Table 14. Number of tags observed from each release group at each detection site in 2012 and used in the survival analysis, excluding predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags.**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Release site at Durham Ferry | | | 477 | 478 | 480 | 1,435 |
| Durham Ferry Upstream | DFU | A0 | 18 | 22 | 83 | 123 |
| Durham Ferry Downstream | DFD | A2 | 280 | 75 | 82 | 437 |
| Banta Carbona | BCA | A3 | 67 | 44 | 130 | 241 |
| Mossdale | MOS | A4 | 333 | 311 | 170 | 814 |
| Lathrop | SJL | A5 | 306 | 300 | 153 | 759 |
| Garwood Bridge | SJG | A6 | 283 | 285 | 150 | 718 |
| Navy Drive Bridge | SJNB | A7 | 269 | 273 | 137 | 679 |
| MacDonald Island Upstream | MACU | A8a | 178 | 179 | 85 | 442 |
| MacDonald Island Downstream | MACD | A8b | 181 | 179 | 81 | 441 |
| MacDonald Island | MAC | A8 | 187 | 184 | 87 | 458 |
| Medford Island East | MFE | A9a | 114 | 126 | 65 | 305 |
| Medford Island West | MFW | A9b | 110 | 126 | 66 | 302 |
| Medford Island (Pooled) | MFE/MFW | A9 | 115 | 127 | 66 | 308 |
| Turner Cut East | TCE | F1a | 24 | 58 | 50 | 132 |
| Turner Cut West | TCW | F1b | 14 | 57 | 52 | 123 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 31 | 58 | 52 | 141 |
| Old River East | ORE | B1 | 21 | 8 | 13 | 42 |
| Old River South Upstream | ORSU | B2a | 20 | 7 | 10 | 37 |
| Old River South Downstream | ORSD | B2b | 20 | 2 | 0 | 22 |
| Old River South (Pooled) | ORS | B2 | 20 | 7 | 10 | 37 |
| Old River at Highway 4, Upstream | OR4U | B3a | 31 | 14 | 18 | 63 |
| Old River at Highway 4, Downstream | OR4D | B3b | 31 | 13 | 18 | 62 |
| Old River at Highway 4, SJR Route | OR4 | B3 | 29 | 14 | 18 | 61 |
| Old River at Highway 4, OR Route | OR4 | B3 | 2 | 0 | 0 | 2 |
| Old River at Highway 4 (Pooled) | OR4 | B3 | 61 | 14 | 18 | 63 |
| Middle River Head | MRH | C1 | 1 | 0 | 0 | 1 |
| Middle River at Highway 4, Upstream | MR4U | C2a | 6 | 16 | 7 | 29 |
| Middle River at Highway 4, Downstream | MR4D | C2b | 7 | 17 | 7 | 31 |
| Middle River at Highway 4, SJR Route | MR4 | C2 | 6 | 17 | 7 | 30 |
| Middle River at Highway 4, OR Route | MR4 | C2 | 1 | 0 | 0 | 1 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 7 | 17 | 7 | 31 |
| Radial Gates Upstream: SJR Route | RGU | D1 | 6 | 3 | 10 | 19 |
| Radial Gates Upstream: OR Route | RGU | D1 | 6 | 4 | 1 | 11 |
| Radial Gates Upstream | RGU | D1 | 12 | 7 | 11 | 30 |
| Radial Gates Downstream #1 | RGD1 | D2a | 6 | 7 | 10 | 23 |

Table 14. (Continued)

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Radial Gates Downstream #2 | RGD2 | D2b | 6 | 6 | 10 | 22 |
| Radial Gates Downstream: SJR Route | RGD | D2 | 3 | 3 | 9 | 15 |
| Radial Gates Downstream: OR Route | RGD | D2 | 3 | 3 | 9 | 15 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 3 | 4 | 1 | 8 |
| CVP Trashrack: SJR Route | CVP | E1 | 18 | 18 | 10 | 46 |
| CVP Trashrack: OR Route | CVP | E1 | 8 | 1 | 2 | 11 |
| Central Valley Project Trashrack | CVP | E1 | 26 | 19 | 12 | 57 |
| CVP tank: SJR Route | CVPtank | E2 | 3 | 8 | 2 | 13 |
| CVP tank: OR Route | CVPtank | E2 | 2 | 0 | 1 | 3 |
| Central Valley Project Holding Tank | CVPtank | E2 | 5 | 8 | 3 | 16 |
| Jersey Point East | JPE | G1a | 88 | 113 | 55 | 256 |
| Jersey Point West | JPW | G1b | 85 | 103 | 56 | 244 |
| Jersey Point: SJR Route | JPE/JPW | G1 | 92 | 117 | 61 | 270 |
| Jersey Point: OR Route | JPE/JPW | G1 | 0 | 0 | 0 | 0 |
| Jersey Point (Pooled) | JPE/JPW | G1 | 92 | 117 | 61 | 270 |
| False River West | FRW | H1a | 2 | 6 | 1 | 9 |
| False River East | FRE | H1b | 0 | 3 | 1 | 4 |
| False River: SJR Route | FRE/FRW | H1 | 2 | 7 | 1 | 10 |
| False River: OR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River (Pooled) | FRE/FRW | H1 | 2 | 7 | 1 | 10 |
| Chipps Island East | MAE | G2a | 82 | 104 | 46 | 232 |
| Chipps Island West | MAW | G2b | 86 | 101 | 51 | 238 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 86 | 108 | 55 | 249 |
| Chipps Island: OR Route | MAE/MAW | G2 | 2 | 1 | 0 | 3 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 88 | 109 | 55 | 252 |

**Table 15. Number of juvenile steelhead tagged by each surgeon in each release group during the 2012 tagging study.**

| Surgeon | Release Group 1 | Release Group 2 | Release Group 3 | Total Tags |
|---|---|---|---|---|
| A | 116 | 115 | 117 | 348 |
| B | 117 | 117 | 117 | 351 |
| C | 122 | 123 | 123 | 368 |
| D | 122 | 123 | 123 | 368 |
| Total Tags | 477 | 478 | 480 | 1,435 |

**Table 16. Release size and counts of tag detections at key detection sites by surgeon in 2012, excluding predator-type detections. * = omitted from chi-square test of independence because of low counts.**

| | Tagger | | | |
|---|---|---|---|---|
| Detection Site | A | B | C | D |
| Release at Durham Ferry | 348 | 351 | 368 | 368 |
| Mossdale (MOS) | 203 | 191 | 219 | 201 |
| Lathrop (SJL) | 182 | 184 | 208 | 185 |
| MacDonald Island (MAC) | 107 | 113 | 129 | 109 |
| Turner Cut (TCE/TCW) | 31 | 34 | 38 | 38 |
| Medford Island (MFE/MFW) | 75 | 78 | 88 | 67 |
| Old River East (ORE) | 17 | 7 | 4 | 14 |
| Old River South (ORS) | 15 | 6 | 4 | 12 |
| Old River at Highway 4 (OR4) | 15 | 14 | 14 | 20 |
| Middle River at Highway 4 (MR4) | 6 | 6 | 11 | 8 |
| Clifton Court Forebay Interior (RGD)* | 7 | 4 | 4 | 8 |
| Central Valley Project Holding Tank (CVPtank)* | 6 | 3 | 4 | 3 |
| Jersey Point (JPE/JPW) | 72 | 71 | 73 | 54 |
| Chipps Island (MAE/MAW) | 66 | 67 | 68 | 51 |

**Table 17. Performance metric estimates (standard error in parentheses) for tagged juvenile steelhead released in the 2012 tagging study, excluding predator-type detections. South Delta ("SD") survival extended to MacDonald Island and Turner Cut in Route A, and the Central Valley Project trash rack, exterior radial gate receiver at Clifton Court Forebay, and Old River and Middle River receivers at Highway 4 in Route B. (Population-level estimates were weighted averages over the release-specific estimates, using weights proportional to release size.)**

| Parameter | Release Group | | | Population Estimate |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| $\psi_{AA}$ | 0.72 (0.04) | 0.75 (0.03) | 0.58 (0.04) | 0.68 (0.02) |
| $\psi_{AF}$ | 0.21 (0.04) | 0.23(0.03) | 0.34 (0.04) | 0.26 (0.02) |
| $\psi_{BB}$[a] | 0.06 (0.01) | 0.03 (0.01) | 0.08 (0.02) | 0.06 (0.01) |
| $\psi_{BC}$[a] | 0.00 | 0.00 | 0.00 | 0.00 |
| $S_{AA}$ | 0.33 (0.03) | 0.43 (0.03) | 0.45 (0.05) | 0.40 (0.02) |
| $S_{AF}$ | 0.10 (0.04) | 0.14 (0.04) | 0.21 (0.05) | 0.15 (0.03) |
| $S_{BB}$[a] | 0.07 (0.04) | 0.10 (0.07) | 0.05 (0.03) | 0.07 (0.03) |
| $S_{BC}$[a] | NA | NA | NA | NA |
| $\psi_A$[b] | 0.94 (0.01) | 0.97 (0.01) | 0.92 (0.02) | 0.94 (0.01) |
| $\psi_B$[b] | 0.06 (0.01) | 0.03 (0.01) | 0.08 (0.02) | 0.06 (0.01) |
| $S_A$[c] | 0.28 (0.03) | 0.33 (0.03) | 0.36 (0.04) | 0.33 (0.02) |
| $S_B$[c] | 0.07 (0.04) | 0.10 (0.07) | 0.05 (0.03) | 0.07 (0.03) |
| $S_{Total}$ | 0.26 (0.02) | 0.35 (0.03) | 0.33 (0.04) | 0.32 (0.02) |
| $S_{A(MD)}$ | 0.32 (0.03) | 0.46 (0.03) | 0.45 (0.04) | 0.41 (0.02) |
| $S_{B(MD)}$[d] | 0.00 | 0.00 | 0.00 | 0.00 |
| $S_{Total(MD)}$ | 0.30 (0.03) | 0.45 (0.03) | 0.41 (0.04) | 0.39 (0.02) |
| $S_{A(SD)}$ | 0.78 (0.04) | 0.82 (0.02) | 0.89 (0.03) | 0.83 (0.02) |
| $S_{B(SD)}$ | 0.80 (0.08) | 0.62 (0.17) | 0.23 (0.11) | 0.55 (0.07) |
| $S_{Total(SD)}$ | 0.78 (0.04) | 0.81 (0.02) | 0.84 (0.03) | 0.81 (0.02) |
| $\phi_{A1A4}$ | 0.70 (0.02) | 0.65 (0.02) | 0.36 (0.02) | 0.57 (0.01) |

a = No tags were detected in subroute C or insufficient tags were detected to subroute C for use in analysis, so assumed $\Psi_{B2} = 1$, $\Psi_{C2} = 0$, and $S_{B1} = \phi_{B1B2}$. No estimate of survival in subroute C was available.

b = Significant preference for route A (San Joaquin Route) ($\alpha$= 0.05) for all release groups

c = Estimated survival is significantly higher in route A (San Joaquin River) than in route B (Old River) ($\alpha$= 0.05) for all release groups (tested only for Delta survival)

d = No tags from fish that entered Old River at its head were later detected at Jersey Point or False River, although some were detected farther downstream at Chipps Island (presumably transported)

**Table 18. Performance metric estimates (standard error in parentheses) for tagged juvenile steelhead released in the 2012 tagging study, including predator-type detections. South Delta ("SD") survival extended to MacDonald Island and Turner Cut in Route A, and the Central Valley Project trash rack, exterior radial gate receiver at Clifton Court Forebay, and Old River and Middle River receivers at Highway 4 in Route B. (Population-level estimates were weighted averages over the release-specific estimates, using weights proportional to release size.)**

| | Release Group | | | |
|---|---|---|---|---|
| Parameter | 1 | 2 | 3 | Population Estimate |
| $\psi_{AA}$ | 0.77 (0.04) | 0.74 (0.03) | 0.56 (0.04) | 0.69 (0.02) |
| $\psi_{AF}$ | 0.17 (0.04) | 0.23 (0.03) | 0.33 (0.04) | 0.25 (0.02) |
| $\psi_{BB}$[a] | 0.06 (0.01) | 0.04 (0.01) | 0.10 (0.02) | 0.07 (0.01) |
| $\psi_{BC}$[a] | 0.00 | 0.00 | 0.00 | 0.00 |
| $S_{AA}$ | 0.33 (0.03) | 0.43 (0.03) | 0.45 (0.05) | 0.40 (0.02) |
| $S_{AF}$ | 0.11 (0.05) | 0.14 (0.04) | 0.2116 (0.05) | 0.15 (0.03) |
| $S_{BB}$[a] | 0.14 (0.05) | 0.08 (0.05) | 0.05 (0.03) | 0.09 (0.03) |
| $S_{BC}$[a] | NA | NA | NA | NA[a] |
| $\psi_A$[b] | 0.94 (0.01) | 0.96 (0.01) | 0.90 (0.02) | 0.93 (0.01) |
| $\psi_B$[b] | 0.06 (0.01) | 0.04 (0.01) | 0.10 (0.02) | 0.07 (0.01) |
| $S_A$[ac] | 0.29 (0.03) | 0.36 (0.03) | 0.36 (0.04) | 0.34 (0.02) |
| $S_B$[c] | 0.14 (0.05) | 0.08 (0.05) | 0.05 (0.03) | 0.09 (0.03) |
| $S_{Total}$ | 0.28 (0.02) | 0.35 (0.03) | 0.33 (0.04) | 0.32 (0.02) |
| $S_{A(MD)}$ | 0.33 (0.03) | 0.46 (0.03) | 0.45 (0.04) | 0.41 (0.02) |
| $S_{B(MD)}$[d] | 0.00 | 0.00 | 0.00 | 0.00 |
| $S_{Total(MD)}$ | 0.31 (0.03) | 0.44 (0.03) | 0.31 (0.04) | 0.39 (0.02) |
| $S_{A(SD)}$ | 0.79 (0.03) | 0.81 (0.02) | 0.86 (0.03) | 0.82 (0.02) |
| $S_{B(SD)}$ | 0.89 (0.07) | 0.53 (0.15) | 0.34 (0.11) | 0.59 (0.07) |
| $S_{Total(SD)}$ | 0.80 (0.03) | 0.80 (0.02) | 0.81 (0.03) | 0.80 (0.02) |
| $\phi_{A1A4}$ | 0.69 (0.02) | 0.66 (0.02) | 0.36 (0.02) | 0.57 (0.01) |

a = No tags were detected in subroute C or insufficient tags were detected to subroute C for use in analysis, so assumed $\Psi_{B2} = 1$, $\Psi_{C2} = 0$, and $S_{B1} = \phi_{B1B2}$. No estimate of survival in subroute C was available

b = Significant preference for route A (San Joaquin Route) ($\alpha$= 0.05) for all release groups

c = Estimated survival is significantly higher in route A (San Joaquin River) than in route B (Old River) ($\alpha$ = 0.05) for all release groups (tested only for Delta survival)

d = No tags from fish that entered Old River at its head were later detected at Jersey Point or False River, although some were detected farther downstream at Chipps Island (presumably transported)

**Table 19a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile steelhead from release at Durham Ferry during the 2012 tagging study, without predator-type detections. Standard errors are in parentheses. See Table 19b for travel time from release with predator-type detections.**

| | Without Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| Detection Site and Route | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry Upstream (DFU) | 13 | 1.74 (0.53) | 18 | 0.35 (0.12) | 22 | 3.37 (1.87) | 83 | 6.72 (2.18) |
| Durham Ferry Downstream (DFD) | 437 | 0.07 (<0.01) | 280 | 0.05 (<0.01) | 75 | 0.11 (0.02) | 82 | 0.25 (0.06) |
| Banta Carbona (BCA) | 241 | 0.89 (0.07) | 67 | 0.56 (0.06) | 44 | 0.78 (0.14) | 130 | 1.37 (0.16) |
| Mossdale (MOS) | 814 | 2.09 (0.07) | 333 | 2.71 (0.15) | 311 | 1.67 (0.08) | 170 | 2.14 (0.15) |
| Lathrop (SJL) | 759 | 2.57 (0.08) | 306 | 3.55 (0.18) | 300 | 2.09 (0.09) | 153 | 2.35 (0.13) |
| Garwood Bridge (SJG) | 718 | 3.95 (0.10) | 283 | 5.27 (0.23) | 285 | 3.35 (0.13) | 150 | 3.46 (0.16) |
| Navy Drive Bridge (SJNB) | 679 | 4.17 (0.11) | 269 | 5.62 (0.24) | 273 | 3.51 (0.13) | 137 | 3.70 (0.17) |
| MacDonald Island (MAC) | 458 | 5.64 (0.16) | 187 | 7.95 (0.39) | 184 | 4.64 (0.18) | 87 | 4.83 (0.265) |
| Turner Cut (TCE/TCW) | 141 | 5.79 (0.25) | 31 | 7.08 (0.81) | 58 | 6.24 (0.42) | 52 | 4.886 (0.29) |
| Medford Island (MFE/MFW) | 308 | 5.98 (0.21) | 115 | 8.86 (0.63) | 127 | 5.03 (0.22) | 66 | 4.99 (0.29) |
| Old River East (ORE) | 42 | 3.54 (0.54) | 21 | 2.68 (0.45) | 8 | 2.59 (0.65) | 13 | 13.53 (6.35) |
| Old River South (ORS) | 37 | 4.70 (0.69) | 20 | 3.83 (0.65) | 7 | 3.41 (0.80) | 10 | 16.56 (7.18) |
| Old River at Highway 4 (OR4), SJR Route | 61 | 9.51 (0.54) | 29 | 12.73 (0.89) | 14 | 8.38 (0.75) | 18 | 7.30 (0.63) |
| Old River at Highway 4 (OR4), OR Route | 2 | 15.39 (4.36) | 2 | 15.39 (4.36) | 0 | NA | 0 | NA |
| Middle River Head (MRH) | 1 | 12.98 (NA) | 1 | 12.98 (NA) | 0 | NA | 0 | NA |
| Middle River at Highway 4 (MR4), SJR Route | 30 | 9.70 (0.82) | 6 | 12.94 (1.34) | 17 | 9.26 (1.20) | 7 | 8.82 (0.82) |
| Middle River at Highway 4 (MR4), OR Route | 1 | 15.23 (NA) | 1 | 15.23 (NA) | 0 | NA | 0 | NA |
| Radial Gates Upstream (DFU), SJR Route | 19 | 9.97 (1.03) | 6 | 15.99 (1.89) | 3 | 10.49 (0.60) | 10 | 8.04 (0.97) |
| Radial Gates Upstream (DFU), OR Route | 11 | 9.66 (1.45) | 6 | 10.57 (2.53) | 4 | 7.50 (0.83) | 1 | 26.70 (NA) |
| Radial Gates Downstream (DFD), SJR Route | 15 | 8.82 (0.81) | 3 | 14.00 (2.30) | 3 | 10.69 (0.65) | 9 | 7.47 (0.71) |
| Radial Gates Downstream (DFD), OR Route | 8 | 9.56 (1.49) | 3 | 10.85 (3.04) | 4 | 7.65 (0.94) | 1 | 26.70 (NA) |
| Central Valley Project Trashrack (CVP), SJR Route | 46 | 11.24 (0.78) | 18 | 14.55 (1.33) | 18 | 10.05 (1.19) | 10 | 9.40 (0.98) |
| Central Valley Project Trashrack (CVP), OR Route | 11 | 9.18 (1.77) | 8 | 7.65 (1.43) | 1 | 13.25 (NA) | 2 | 26.16 (7.66) |
| Central Valley Project Holding Tank (CVPtank), SJR Route | 13 | 11.03 (0.97) | 3 | 12.17 (1.83) | 8 | 10.66 (1.31) | 2 | 11.04 (2.90) |
| Central Valley Project Holding Tank (CVPtank), OR Route | 3 | 9.03 (4.20) | 2 | 7.00 (3.43) | 0 | NA | 1 | 21.47 (NA) |

**Table 19a. (Continued)**

| Detection Site and Route | Without Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Jersey Point (JPE/JPW), SJR Route | 270 | 7.66 (0.23) | 92 | 11.94 (0.49) | 117 | 6.58 (0.26) | 61 | 6.25 (0.27) |
| Jersey Point (JPE/JPW), OR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| False River (FRE/FRW), SJR Route | 10 | 7.97 (0.86) | 2 | 12.04 (1.55) | 7 | 7.67 (0.91) | 1 | 5.69 (NA) |
| False River (FRE/FRW), OR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| Chipps Island (MAE/MAW), SJR Route | 249 | 9.38 (0.25) | 86 | 13.59 (0.51) | 108 | 8.13 (0.27) | 55 | 7.93 (0.37) |
| Chipps Island (MAE/MAW), OR Route | 3 | 13.00 (2.57) | 2 | 16.19 (0.66) | 1 | 9.33 (NA) | 0 | NA |
| Chipps Island (MAE/MAW) | 252 | 9.41 (0.25) | 88 | 13.64 (0.51) | 109 | 8.14 (0.27) | 55 | 7.93 (0.37) |

**Table 19b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile steelhead from release at Durham Ferry during the 2012 tagging study, with predator-type detections. Standard errors are in parentheses. See Table 19a for travel time from release without predator-type detections.**

| | With Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| Detection Site and Route | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry Upstream (DFU) | 140 | 2.25 (0.77) | 21 | 0.42 (0.16) | 27 | 5.24 (3.55) | 92 | 13.76 (4.11) |
| Durham Ferry Downstream (DFD) | 465 | 0.07 (<0.01) | 281 | 0.05 (<0.01) | 77 | 0.11 (0.02) | 107 | 0.33 (0.08) |
| Banta Carbona (BCA) | 279 | 1.04 (0.08) | 71 | 0.60 (0.07) | 51 | 0.90 (0.17) | 157 | 1.68 (0.21) |
| Mossdale (MOS) | 817 | 2.13 (0.07) | 329 | 2.73 (0.15) | 315 | 1.70 (0.08) | 173 | 2.20 (0.15) |
| Lathrop (SJL) | 751 | 2.59 (0.08) | 304 | 3.57 (0.18) | 297 | 2.11 (0.09) | 150 | 2.34 (0.13) |
| Garwood Bridge (SJG) | 716 | 3.98 (0.10) | 288 | 5.36 (0.24) | 284 | 3.38 (0.13) | 144 | 3.39 (0.16) |
| Navy Drive Bridge (SJNB) | 678 | 4.20 (0.11) | 273 | 5.72 (0.25) | 271 | 3.51 (0.13) | 134 | 3.68 (0.17) |
| MacDonald Island (MAC) | 459 | 5.70 (0.17) | 194 | 8.14 (0.40) | 181 | 4.63 (0.18) | 84 | 4.77 (0.26) |
| Turner Cut (TCE/TCW) | 138 | 5.73 (0.25) | 30 | 7.12 (0.84) | 58 | 6.20 (0.42) | 50 | 4.75 (0.28) |
| Medford Island (MFE/MFW) | 311 | 6.07 (0.21) | 118 | 9.00 (0.64) | 127 | 5.09 (0.23) | 66 | 4.99 (0.29) |
| Old River East (ORE) | 48 | 4.07 (0.67) | 20 | 2.60 (0.44) | 11 | 3.48 (1.05) | 17 | 18.03 (8.80) |
| Old River South (ORS) | 42 | 5.30 (0.83) | 20 | 3.87 (0.67) | 9 | 4.29 (1.22) | 13 | 19.55 (7.82) |
| Old River at Highway 4 (OR4), SJR Route | 60 | 9.78 (0.61) | 31 | 14.24 (1.11) | 13 | 8.07 (0.67) | 16 | 6.81 (0.51) |
| Old River at Highway 4 (OR4), OR Route | 2 | 15.39 (4.36) | 2 | 15.39 (4.36) | 0 | NA | 0 | NA |
| Middle River Head (MRH) | 2 | 45.00 (2.22) | 0 | NA | 0 | NA | 2 | 45.00 (2.22) |
| Middle River at Highway 4 (MR4), SJR Route | 31 | 9.74 (0.80) | 6 | 13.27 (1.51) | 18 | 9.30 (1.14) | 7 | 8.82 (0.82) |
| Middle River at Highway 4 (MR4), OR Route | 2 | 23.00 (11.74) | 1 | 15.23 (NA) | 0 | NA | 1 | 46.96 (NA) |
| Radial Gates Upstream (DFU), SJR Route | 20 | 9.98 (0.98) | 6 | 17.71 (2.96) | 4 | 10.79 (0.54) | 10 | 7.73 (0.74) |
| Radial Gates Upstream (DFU), OR Route | 11 | 9.66 (1.45) | 6 | 10.57 (2.53) | 4 | 7.50 (0.83) | 1 | 26.70 (NA) |
| Radial Gates Downstream (DFD), SJR Route | 19 | 9.82 (0.97) | 5 | 17.88 (3.71) | 4 | 10.95 (0.55) | 10 | 7.75 (0.74) |
| Radial Gates Downstream (DFD), OR Route | 8 | 9.56 (1.49) | 3 | 10.85 (3.04) | 4 | 7.65 (0.94) | 1 | 26.70 (NA) |
| Central Valley Project Trashrack (CVP), SJR Route | 40 | 12.19 (1.13) | 14 | 16.26 (2.22) | 17 | 10.58 (1.46) | 9 | 11.05 (2.11) |
| Central Valley Project Trashrack (CVP), OR Route | 15 | 11.82 (2.59) | 9 | 8.54 (1.84) | 2 | 20.83 (11.93) | 4 | 33.49 (7.59) |
| Central Valley Project Holding Tank (CVPtank), SJR Route | 15 | 12.23 (1.36) | 4 | 14.87 (3.81) | 9 | 11.59 (1.70) | 2 | 11.04 (2.90) |
| Central Valley Project Holding Tank (CVPtank), OR Route | 3 | 9.03 (4.20) | 2 | 7.00 (3.43) | 0 | NA | 1 | 21.47 (NA) |

**Table 19b. (Continued)**

| Detection Site and Route | With Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Jersey Point (JPE/JPW), SJR Route | 271 | 7.69 (0.23) | 94 | 12.04 (0.49) | 116 | 6.56 (0.26) | 61 | 6.25 (0.27) |
| Jersey Point (JPE/JPW), OR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| False River (FRE/FRW), SJR Route | 10 | 8.47 (1.20) | 2 | 12.04 (1.55) | 7 | 8.35 (1.49) | 1 | 5.698 (NA) |
| False River (FRE/FRW), OR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| Chipps Island (MAE/MAW), SJR Route | 251 | 9.46 (0.26) | 88 | 13.75 (0.53) | 108 | 8.18 (0.28) | 55 | 7.93 (0.37) |
| Chipps Island (MAE/MAW), OR Route | 4 | 15.41 (3.82) | 3 | 19.68 (4.28) | 1 | 9.33 (NA) | 0 | NA |
| Chipps Island (MAE/MAW) | 255 | 9.52 (0.26) | 91 | 13.89 (0.53) | 109 | 8.19 (0.28) | 55 | 7.93 (0.37) |

**Table 20a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile steelhead through the San Joaquin River Delta river reaches during the 2012 tagging study, without predator-type detections. Standard errors are in parentheses. See Table 20b for travel time through reaches with predator-type detections.**

| Reach | | Without Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry (Release) | BCA | 241 | 0.89 (0.07) | 67 | 0.56 (0.06) | 44 | 0.78 ().14) | 130 | 1.37 (0.16) |
| BCA | MOS | 198 | 0.60 (0.03) | 59 | 0.76 (0.10) | 34 | 0.46 (0.06) | 105 | 0.59 (0.04) |
| MOS | SJL | 759 | 0.19 (<0.01) | 306 | 0.22 (0.01) | 300 | 0.18 (0.01) | 153 | 0.19 (0.01) |
| | ORE | 42 | 0.29 (0.03) | 21 | 0.27 (0.03) | 8 | 0.26 (0.06) | 13 | 0.35 (0.08) |
| SJL | SJG | 718 | 0.76 (0.01) | 283 | 0.77 (0.02) | 285 | 0.71 (0.02) | 150 | 0.83 (0.03) |
| SJG | SJNB | 679 | 0.08 (<0.01) | 269 | 0.08 (<0.01) | 273 | 0.08 (<0.01) | 137 | 0.08 (<0.01) |
| SJNB | MAC | 444 | 1.02 (0.03) | 182 | 1.18 (0.06) | 181 | 0.96 (0.04) | 81 | 0.87 (0.05) |
| | TCE/TCW | 139 | 1.01 (0.06) | 31 | 1.42 (0.17) | 58 | 1.04 (0.09) | 50 | 0.83 (0.08) |
| MAC | MFE/MFW | 304 | 0.18 (0.01) | 114 | 0.24 (0.02) | 125 | 0.18 (0.01) | 65 | 0.13 (0.01) |
| | JPE/JPW/FRE/FRW | 253 | 1.61 (0.05) | 88 | 2.05 (0.10) | 111 | 1.58 (0.07) | 54 | 1.23 (0.08) |
| | OR4 | 21 | 3.73 (0.36) | 12 | 5.03 (0.46) | 7 | 2.74 (0.35) | 2 | 2.91 (0.76) |
| | MR4 | 10 | 2.57 (0.29) | 3 | 2.01 (0.34) | 4 | 2.60 (0.42) | 3 | 3.51 (0.47) |
| MFE/MFW | JPE/JPW/FRE/FRW | 211 | 1.19 (0.05) | 77 | 1.52 (0.08) | 89 | 1.20 (0.07) | 45 | 0.87 (0.09) |
| | OR4 | 10 | 3.84 (0.52) | 6 | 5.32 (0.68) | 2 | 2.83 (0.47) | 2 | 2.61 (0.49) |
| | MR4 | 2 | 1.90 (0.83) | 0 | NA | 1 | 3.36 (NA) | 1 | 1.33 (NA) |
| TCE/TCW | JPE/JPW/FRE/FRW | 17 | 2.04 (0.31) | 2 | 2.06 (1.16) | 7 | 1.70 (0.49) | 8 | 2.45 (0.17) |
| | OR4 | 34 | 2.33 (0.27) | 11 | 3.77 (0.33) | 7 | 2.68 (0.35) | 16 | 1.76 (0.28) |
| | MR4 | 16 | 1.72 (0.24) | 1 | 4.12 (NA) | 11 | 1.86 (0.25) | 4 | 1.27 (0.39) |
| ORE | ORS | 35 | 0.47 (0.05) | 20 | 0.49 (0.07) | 7 | 0.44 (0.09) | 10 | 0.46 (0.13) |
| | MRH | 1 | 5.41 (NA) | 1 | 5.41 (NA) | 0 | NA | 0 | NA |
| ORS | OR4 | 2 | 5.20 (1.53) | 2 | 5.20 (1.53) | 0 | NA | 0 | NA |
| | MR4 | 1 | 2.07 (NA) | 1 | 2.07 (NA) | 0 | NA | 0 | NA |
| | RGU | 11 | 3.13 (0.57) | 6 | 4.50 (0.80) | 4 | 2.72 (0.72) | 1 | 1.41 (NA) |
| | CVP | 11 | 2.93 (0.69) | 8 | 3.63 (0.99) | 1 | 9.03 (NA) | 2 | 1.39 (0.23) |

**Table 20a. (Continued)**

| Reach | | Without Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| OR4 via OR | JPE/JPW/FRE/FRW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| OR4 via SJR | JPE/JPW/FRE/FRW | 3 | 2.48 (1.74) | 1 | 11.87 (NA) | 2 | 1.77 (1.28) | 0 | NA |
| | RGU | 12 | 0.40 (0.09) | 5 | 0.80 (0.22) | 0 | NA | 7 | 0.29 (0.07) |
| | CVP | 30 | 0.54 (0.11) | 16 | 0.76 (0.15) | 7 | 0.48 (0.17) | 7 | 0.35 (0.16) |
| MRH | anywhere downstream[a] | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| MR4 via OR | JPE/JPW/FRE/FRW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| MR4 via SJR | JPE/JPW/FRE/FRW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | RGU | 7 | 1.03 (0.11) | 1 | 1.23 (NA) | 3 | 1.21 (0.21) | 3 | 0.86 (0.12) |
| | CVP | 16 | 0.79 (0.12) | 2 | 0.91 (0.61) | 11 | 0.70 (0.12) | 3 | 1.28 (0.42) |
| RGU via OR | RGD | 8 | 0.01 (<0.01) | 3 | 0.01 (<0.01) | 4 | 0.05 (0.03) | 1 | <0.01 (NA) |
| RGU via SJR | RGD | 15 | 0.01 (<0.01) | 3 | 0.01 (0.01) | 3 | 0.09 (0.04) | 9 | 0.01 (<0.01) |
| CVP via OR | CVPtank | 3 | 0.23 (0.12) | 2 | 0.16 (0.06) | 0 | NA | 1 | 1.23 (NA) |
| CVP via SJR | CVPtank | 13 | 0.18 (0.06) | 3 | 0.15 (0.12) | 8 | 0.20 (0.10) | 2 | 0.16 (0.09) |
| JPE/JPW | MAE/MAW (Chipps Island) | 209 | 0.89(0.04) | 76 | 0.94 (0.10) | 92 | 0.88 (0.05) | 41 | 0.84 (0.08) |
| MAC | | 217 | 2.87 (0.07) | 79 | 3.53 (0.13) | 95 | 2.77 (0.08) | 43 | 2.28 (0.14) |
| MFE/MFW | | 180 | 2.42 (0.07) | 66 | 2.89 (0.11) | 76 | 2.32 (0.08) | 38 | 2.03 (0.14) |
| TCE/TCW | | 25 | 4.04 (0.41) | 3 | 3.22 (1.98) | 10 | 3.87 (0.49) | 12 | 4.49 (0.35) |
| OR4 | | 2 | 2.40 (1.48) | 0 | NA | 1 | 1.49 (NA) | 1 | 6.24(NA) |
| MR4 | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| RGD | | 4 | 1.91 (0.22) | 0 | NA | 1 | 2.43 (NA) | 3 | 1.79 (0.22) |
| CVPtank | | 9 | 1.26 (0.14) | 3 | 1.45 (0.18) | 4 | 1.27 (0.23) | 2 | 1.04 (0.33) |

a = all detections at Middle River Head (MRH) used in the survival model were final detections for the tag, so no travel time is reported for reaches starting at MRH

**Table 20b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile steelhead through the San Joaquin River Delta river reaches during the 2012 tagging study, with predator-type detections. Standard errors are in parentheses. See Table 20a for travel time through reaches without predator-type detections.**

| Reach | | With Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry (Release) | BCA | 279 | 1.04 (0.08) | 71 | 0.60 (0.07) | 51 | 0.90 (0.17) | 157 | 1.68 (0.21) |
| BCA | MOS | 208 | 0.63 (0.04) | 60 | 0.76 (0.10) | 37 | 0.853 (0.07) | 111 | 0.62 (0.04) |
| MOS | SJL | 751 | 0.20 (<0.01) | 304 | 0.21 (0.01) | 297 | 0.18 (0.01) | 150 | 0.20 (0.01) |
| | ORE | 48 | 0.26 (0.03) | 20 | 0.26 (0.03) | 11 | 0.27 (0.06) | 17 | 0.27 (0.05) |
| SJL | SJG | 716 | 0.77 (0.01) | 288 | 0.79 (0.02) | 284 | 0.72 (0.02) | 144 | 0.82 (0.03) |
| SJG | SJNB | 678 | 0.08 (<0.01) | 273 | 0.08 (<0.01) | 271 | 0.08 (<0.01) | 134 | 0.08 (<0.01) |
| SJNB | MAC | 445 | 1.02 (0.03) | 189 | 1.17 (0.06) | 178 | 0.96 (0.04) | 78 | 0.89 (0.05) |
| | TCE/TCW | 136 | 1.02 (0.06) | 30 | 1.43 (0.18) | 58 | 1.04 (0.09) | 48 | 0.85 (0.08) |
| MAC | MFE/MFW | 307 | 0.18 (0.01) | 117 | 0.24 (0.02) | 125 | 0.18 (0.01) | 65 | 0.13 (0.01) |
| | JPE/JPW/FRE/FRW | 253 | 1.61 (0.05) | 89 | 2.05 (0.10) | 110 | 1.58 (0.07) | 54 | 1.23 (0.08) |
| | OR4 | 23 | 3.99 (0.44) | 15 | 5.38 (0.67) | 6 | 2.61 (0.34) | 2 | 2.91 (0.76) |
| | MR4 | 10 | 2.65 (0.32) | 2 | 1.71 (0.02) | 5 | 2.84 (0.48) | 3 | 3.51 (0.47) |
| MFE/MFW | JPE/JPW/FRE/FRW | 209 | 1.19 (0.05) | 76 | 1.51 (0.08) | 88 | 1.19 (0.07) | 45 | 0.87 (0.09) |
| | OR4 | 11 | 4.33 (0.68) | 7 | 6.54 (0.65) | 2 | 2.83 (0.47) | 2 | 2.61 (0.49) |
| | MR4 | 2 | 1.90 (0.83) | 0 | NA | 1 | 3.36 (NA) | 1 | 1.33 (NA) |
| TCE/TCW | JPE/JPW/FRE/FRW | 17 | 2.04 (0.31) | 2 | 2.06 (1.16) | 7 | 1.70 (0.49) | 8 | 2.45 (0.17) |
| | OR4 | 30 | 2.18 (0.27) | 9 | 3.97 (0.61) | 7 | 2.31 (0.31) | 14 | 1.65 (0.27) |
| | MR4 | 17 | 1.81 (0.26) | 2 | 5.72 (2.22) | 11 | 1.86 (0.25) | 4 | 1.27 (0.39) |
| ORE | ORS | 42 | 0.40 (0.04) | 20 | 0.49 (0.07) | 9 | 0.45 (0.09) | 13 | 0.35 (0.05) |
| | MRH | 2 | 0.53 (0.26) | 0 | NA | 0 | NA | 2 | 0.53 (0.26) |
| ORS | OR4 | 2 | 5.20 (1.53) | 2 | 5.20 (1.53) | 0 | NA | 0 | NA |
| | MR4 | 2 | 2.46 (0.47) | 1 | 2.07 (NA) | 0 | NA | 1 | 3.04 (NA) |
| | RGU | 11 | 3.13 (0.57) | 6 | 4.50 (0.80) | 4 | 2.72 (0.72) | 1 | 1.41 (NA) |
| | CVP | 15 | 3.19 (0.65) | 9 | 3.42 (0.82) | 2 | 4.53 (2.26) | 4 | 2.46 (1.13) |

Table 20b. (Continued)

| Reach | | With Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | All Releases | | Release 1 | | Release 2 | | Release 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| OR4 via OR | JPE/JPW/FRE/FRW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| OR4 via SJR | JPE/JPW/FRE/FRW | 4 | 2.33 (1.10) | 2 | 3.42 (2.43) | 2 | 1.77 (1.28) | 0 | NA |
| | RGU | 14 | 0.46 (0.11) | 6 | 0.86 (0.21) | 1 | 1.66 (NA) | 7 | 0.30 (0.08) |
| | CVP | 24 | 0.46 (0.09) | 12 | 0.65 (0.13) | 6 | 0.43 (0.15) | 6 | 0.31 (0.14) |
| MRH | anywhere downstream[a] | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| MR4 via OR | JPE/JPW/FRE/FRW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| MR4 via SJR | JPE/JPW/FRE/FRW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | RGU | 6 | 1.01 (0.12) | 0 | NA | 3 | 1.21 (0.21) | 3 | 0.86 (0.12) |
| | CVP | 16 | 1.09 (0.27) | 2 | 0.91 (0.61) | 11 | 0.89 (0.23) | 3 | 14.00 (7.40) |
| RGU via OR | RGD | 8 | 0.01 (<0.01) | 3 | 0.01 (<0.01) | 4 | 0.05 (0.03) | 1 | <0.01 (NA) |
| RGU via SJR | RGD | 19 | 0.01 (<0.01) | 5 | 0.01 (0.01) | 4 | 0.03 (0.02) | 10 | 0.01 (<0.01) |
| CVP via OR | CVPtank | 3 | 0.23 (0.12) | 2 | 0.16 (0.06) | 0 | NA | 1 | 1.23 (NA) |
| CVP via SJR | CVPtank | 15 | 0.19 (0.06) | 4 | 0.17 (0.11) | 9 | 0.22 (0.11) | 2 | 0.16 (0.09) |
| JPE/JPW | MAE/MAW (Chipps Island) | 210 | 0.88(0.04) | 77 | 0.92 (0.09) | 92 | 0.88 (0.05) | 41 | 0.84 (0.08) |
| MAC | | 218 | 2.88 (0.07) | 80 | 3.51 (0.13) | 95 | 2.78 (0.08) | 43 | 2.28 (0.14) |
| MFE/MFW | | 180 | 2.43 (0.07) | 66 | 2.89 (0.11) | 76 | 2.34 (0.09) | 38 | 2.03 (0.14) |
| TCE/TCW | | 26 | 4.19 (0.45) | 4 | 4.18 (2.66) | 10 | 3.87 (0.49) | 12 | 4.49 (0.45) |
| OR4 | | 2 | 2.40 (1.48) | 0 | NA | 1 | 1.49 (NA) | 1 | 6.24 (NA) |
| MR4 | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| RGD | | 4 | 1.91 (0.22) | 0 | NA | 1 | 2.43 (NA) | 3 | 1.79 (0.22) |
| CVPtank | | 10 | 1.16 (0.14) | 4 | 1.12 (0.26) | 4 | 1.27 (0.23) | 2 | 1.04 (0.33) |

a = all detections at Middle River Head (MRH) used in the survival model were final detections for the tag, so no travel time is reported for reaches starting at MRH

**Table 21. Results of single-variate analyses of route entrainment at the Turner Cut Junction (all release groups). The values df1, df2 are degrees of freedom for the F-test.**

| Covariate | F-test | | | |
|---|---|---|---|---|
| | *F* | df1 | df2 | *P* |
| Stage at TRN[a] | 34.4221 | 1 | 503 | <0.0001 |
| Change in stage at TRN[a] | 19.7119 | 1 | 500 | <0.0001 |
| Change in flow at TRN[a] | 21.5089 | 1 | 500 | <0.0001 |
| Change in velocity at TRN[a] | 21.2500 | 1 | 500 | <0.0001 |
| Release Group[a] | 11.0050 | 2 | 502 | <0.0001 |
| Exports at CVP[a] | 7.9417 | 1 | 503 | 0.0050 |
| Fork Length[a] | 5.5480 | 1 | 503 | 0.0189 |
| Negative flow at TRN[a] | 5.1778 | 1 | 503 | 0.0233 |
| Exports at SWP | 3.3004 | 1 | 503 | 0.0699 |
| Flow at TRN | 2.8136 | 1 | 503 | 0.0941 |
| Velocity at TRN | 2.7981 | 1 | 503 | 0.0950 |
| Arrive at TCJ during day | 0.5041 | 1 | 503 | 0.4780 |
| Flow during transition from SJG | 0.1434 | 1 | 503 | 0.7051 |
| Velocity during transition from SJG | 0.0286 | 1 | 503 | 0.8657 |

a = Significant at 5% level

**Table 22. Results of single-variate analyses of route entrainment at the Turner Cut Junction (without first release group). The values df1, df2 are degrees of freedom for the F-test.**

| | F-test | | | |
|---|---|---|---|---|
| Covariate | *F* | df1 | df2 | *P* |
| Change in flow at TRN[a] | 20.8085 | 1 | 329 | <0.0001 |
| Change in velocity at TRN[a] | 20.4498 | 1 | 329 | <0.0001 |
| Change in stage at TRN[a] | 20.1618 | 1 | 329 | <0.0001 |
| Stage at TRN[a] | 19.3936 | 1 | 332 | <0.0001 |
| Release Group[a] | 6.9637 | 1 | 332 | 0.0087 |
| Exports at CVP[a] | 6.8495 | 1 | 332 | 0.0093 |
| Fork Length | 2.9545 | 1 | 332 | 0.0866 |
| Flow during transition from SJG | 0.9424 | 1 | 332 | 0.3324 |
| Negative flow at TRN | 0.8134 | 1 | 332 | 0.3678 |
| Exports at SWP | 0.7434 | 1 | 332 | 0.3892 |
| Velocity during transition from SJG | 0.4612 | 1 | 332 | 0.4975 |
| Arrive at TCJ during day | 0.0888 | 1 | 332 | 0.7659 |
| Flow at TRN | 0.0424 | 1 | 332 | 0.8370 |
| Velocity at TRN | 0.0337 | 1 | 332 | 0.8544 |

a = Significant at 5% level

**Table 23. Results of multivariate analyses of route entrainment at the Turner Cut junction in 2012 (without first release group). Modeled response is the probability of selecting the San Joaquin River route.**

| Model Type | Covariate[a] | Estimate | S.E. | *t*-test | | |
|---|---|---|---|---|---|---|
| | | | | *t* | df | *P* |
| Flow | Intercept | 1.5564 | 0.1925 | 8.084 | 327 | <0.0001 |
| | $\Delta Q_{TRN}$ | 0.6253 | 0.1335 | 4.684 | 327 | <0.0001 |
| | CVP | -0.3466 | 0.1028 | -3.371 | 327 | 0.0008 |
| | Release Group 3 | -0.9689 | 0.2748 | -3.527 | 327 | 0.0005 |
| | Goodness-of-fit: $\chi^2$=3.9664, df=13, P=0.9917; AIC = 347.63 | | | | | |
| Velocity | Intercept | 1.5539 | 0.1923 | 8.081 | 327 | <0.0001 |
| | $\Delta V_{TRN}$ | 0.6215 | 0.1332 | 4.666 | 327 | <0.0001 |
| | CVP | -0.3491 | 0.1031 | -3.387 | 327 | 0.0008 |
| | Release Group 3 | -0.9719 | 0.2747 | -3.5375 | 327 | 0.0005 |
| | Goodness-of-fit: $\chi^2$=3.4164, df=13, P=0.9960; AIC = 347.83 | | | | | |
| Stage | Intercept | 1.4796 | 0.1892 | 7.820 | 327 | <0.0001 |
| | $C_{TRN}$ | 0.5690 | 0.1337 | 4.254 | 327 | <0.0001 |
| | $\Delta C_{TRN}$ | -0.5637 | 0.1381 | -4.082 | 326 | 0.0001 |
| | Release Group 3 | -0.7960 | 0.2734 | -2.911 | 327 | 0.0038 |
| | Goodness-of-fit: $\chi^2$=3.0594, df=13, P=0.9977; AIC = 342.43 | | | | | |

a = continuous covariates ($\Delta Q_{TRN}$, CVP, $\Delta V_{TRN}$, $C_{TRN}$, $\Delta C_{TRN}$) are standardized

**Table 24. Estimates of survival from downstream receivers at water export facilities (CVP holding tank or interior of Clifton Court Forebay at radial gates) through salvage to receivers after release from truck, excluding predator-type detections (95% profile likelihood interval in parentheses). Population estimate is based on data pooled from all release groups.**

| Facility | Upstream Model Site Code | Release Group 1 | Release Group 2 | Release Group 3 | Population Estimate |
|---|---|---|---|---|---|
| CVP | E2 | 0.60 (0.20, 0.92) | 0.50 (0.19, 0.81) | 0.68 (0.16, 0.99) | 0.57 (0.33, 0.79) |
| SWP | D2 | 0 (*n* = 6) | 0.14 (0.01, 0.50) | 0.30 (0.09, 0.62) | 0.17 (0.06, 0.36) |

# Appendices

**Appendix A. Standard Operating Procedures for Acoustic Tagging of Steelhead**
**Date : 3/26/12**

# Standard Operating Procedure

# Acoustic Tagging for Steelhead 2012 South Delta Studies

## MATERIALS NEEDED:

- Thermometer
- Dissolved oxygen (DO) meter
- Acoustic tags and acoustic tag activation and monitoring equipment
- Chlorhexidine solution (30mL/L D-$H_2O$)
- Distilled or de-ionized water (D-$H_2O$)
- Tricaine methanesulfonate (MS-222; 100g/L),
- Sodium bicarbonate solution (buffer; 100g/L)
- Stress coat - stock concentration and 25% solution (250mL/L D-$H_2O$)
- Disinfectant solution (Virkon Aquatic or 70% ETOH)
- 19 L bucket(s) marked at 10 L and clearly labeled 'Anesthesia'
- 19 L bucket clearly labeled 'Reject' for fish not selected for tagging procedures
- Two gravity feed containers marked at 10 L, and connected by rubber tubing with in-line shut-off valves (one labeled 'anesthesia' and one labeled 'freshwater')
- Syringes (10 mL) for measuring anesthetic, buffer, and stress coat
- Oxygen delivery system (cylinder, regulator, airline, air diffusers)
- Dip nets
- Nitrile gloves
- Scale measuring to the nearest 0.1 g
- Large plastic weigh boats
- Measuring board with ruler to the nearest millimeter
- Surgical platform
- Trays for holding solutions used to disinfect surgical tools
- Needle drivers
- Forceps
- Scalpel handle and blades
- Sutures: Vicryl plus 4-0 with an RB-1 needle
- Spray bottles for disinfectant solution
- Timer(s)
- Sharps container
- Datasheets and writing tools

*Equipment Set Up:*

- Fill surgical instrument disinfection trays with chlorhexidine (brand name Nolvasan)
    - Autoclave instruments such that each tagging event begins with sterile instruments
- Activate transmitters and confirm operational status
    - Remove labels from the Vemco V6 transmitters and scrub the transmitter surface to ensure that no label residue remains
    - Position the transmitter in an isolated compartment to enable tracking of the transmitter

ID through the implantation process

- Disinfect transmitters in chlorhexidine
    - Ensure at least 20 minutes of contact time with chlorhexidine
    - Following disinfection, thoroughly rinse transmitters in distilled or de-ionized water prior to implantation
    - Following disinfection, transmitters should only be handled by gloved hands or clean surgical instruments such as forceps
- Fill rinse tray with de-ionized or distilled water
- Set up scale, measuring board, and surgical platform or foam
    - Apply stress coat to weigh boat, measuring board, and platform to reduce damage to fish skin or mucus layer
- Fill gravity feed carboys. Add 2 ml of the MS-222 stock solution and 2 ml of the sodium bicarbonate stock solution to the 10 L of water in the MS-222 carboy. Concentration may be increased upon group consensus and in consultation with coordinator.
- Fill anesthesia container to indicated volume line. Set the initial concentration in collaboration with the tagging coordinator. Suggested starting concentration is 70 mg/ L. Concentration may be adjusted upon group consensus and in consultation with coordinator. Concentration changes should be executed for all taggers simultaneously and recorded on the tagging datasheet.
- Prepare recovery containers by filling with water, adding stress coat, and supersaturating with oxygen
    - Immediately following surgery fish will be held in recovery containers that provide 130% to 150% DO for a minimum of 10 minutes
    - Holding time in recovery containers begins when the last fish is added to the container and will be monitored using a timer
- Prepare a reject container for fish that cannot be tagged by filling with water and equipping with a bubbler . These fish will be returned to a separate raceway.
- Start tagging data sheets. Note the time the tagging session was started and complete all appropriate data fields. Start a Daily Fish Reject Tally datasheet to account for fish that are handled but not tagged.
- The tagger should wear medical-grade exam gloves during all fish handling and tagging procedures
- Prepare the transport truck to be able to circulate water through containers
- Remove transport containers from the freezer and prepare them to receive tagged fish
    - Transport containers that leave the hatchery grounds and are delivered to the release site at Durham Ferry must be frozen for 24 h prior to being used again for the tagging operation. These details are outlined in the project biosecurity plan.
    - When removing containers from the freezer, be sure to consult with the tagging coordinator to ensure that all containers undergo the full 24 h of exposure before they are removed and used.

*Surgery*

- Food should be withheld from fish for ~24 h prior to surgical implantation of the transmitter.
- Anesthetize fish

- Net one fish from source tank/raceway and place directly into an anesthesia container. Immediately start a timer to monitor anesthesia exposure time and place a lid on the container.
- Remove the lid after about 1 minute to observe the fish for loss of equilibrium. Keep the fish in the water for an additional 30-60 seconds after it has lost equilibrium. Time to sedation should normally be 2-4 minutes, with an average of about 3 minutes. If loss of equilibrium takes less than 1 minute or if a fish is exposed to anesthesia for more than 5 minutes, reject that fish. If after anesthetizing a few fish they are consistently losing equilibrium in more or less time than typical, the anesthesia concentration may need to be adjusted. Anesthesia concentration should only be adjusted in coordination with all study taggers and the tagging coordinator.
  - Changes to anesthesia concentration should be done at 5 mg/L increments. For example, if the initial dosage was 70 mg/L, an adjusted dose should be 65 mg/L or 75 mg/L.
  - When an anesthesia change is agreed upon, all taggers should drain their anesthesia containers, refill with 10 L of water, and re-mix to the new anesthesia concentration
- If a fish is unacceptable for tagging due to issues with anesthesia, place the fish in the "Reject" container and log it on the reject tally datasheet.
- The anesthesia container should be emptied and remixed at regular intervals throughout the tagging operation to ensure the appropriate concentration and to avoid warming
- The gravity feed containers should be monitored for volume and temperature and changed as needed to avoid inadequate volume to complete a surgery and significant warming

- Recording fish length, weight, and condition
  - Start a timer when a fish is removed from the anesthesia container to record the time the fish is out of water (recorded as "air time").
  - Transfer the fish to the scale and record the weigh to the nearest 0.1g
    - Scales should be calibrated regularly to ensure accuracy
    - Fish must weigh at least 20 g to be selected for tagging so that tag burden does not exceed 5% of the weight of the fish. Transmitters used for this study are Vemco brand V6 models, weighing 1.0 g in air.
  - Transfer the fish to the measuring board and determine forklength to the nearest mm.
  - Check for any abnormalities and descaling. If the fish is abnormal or grossly descaled, note this on the datasheet and place the fish in the reject container.
    - Scale condition is noted as Normal (N), Partial (P), or Descaled (D) and is assessed on the most compromised side of each fish. The normal scale condition is defined as loss of less than 5% of scales on one side of the fish. Partial descaling is defined as loss of 6-19% of scales on one side of the fish. Fish are classified as descaled if they have lost 20% or more of the scales on one side of the fish, and should not be tagged due to compromised osmoregulatory ability.

    - Data must be vocally relayed to the recorder, and the recorder should repeat the information back to the tagger to avoid miscommunication.
    - Any fish dropped on the floor should be rejected.

- Transmitter Implantation
    - Anesthesia should be administered through the gravity feed irrigation system as soon as the fish is on the surgical platform. Use the flow control valves to adjust the flow rate as needed so that the opercular rate of the fish is steady.
        - Note that low-flow or inconsistent irrigation can mimic shallow anesthesia
    - Using a scalpel, make an incision approximately 3-5 mm in length beginning a few mm in front of the pelvic girdle. The incision should be about 3 mm away from and parallel to the mid-ventral line, and just deep enough to penetrate the peritoneum, avoiding the internal organs. The spleen is generally near the incision point so the depth and placement of the incision are critical.
        - There is no exact specification for the selection of a micro scalpel for steelhead. A general recommendation is to use a 5 mm blade for fish larger than about 50 g.
        - The incision should only be long enough to allow entry of the tag.
    - Forceps may be used to open the incision to check for potential organ damage. If you observe damage or note excessive bleeding, reject the fish.
    - Scalpel blades can be used on several fish, but if the scalpel is pulling roughly or making jagged incisions, it should be changed prior to tagging the next fish.
    - Gently insert the tag into the body cavity and position it so that it lies directly beneath the incision and the ceramic head is facing forward. This positioning will provide a barrier between the suture needle and internal organs.
    - Close the incision with two simple interrupted stitches.
        - Vicryl Plus sutures are recommended
        - 4-0 suture size is appropriate for juvenile steelhead or similar fish with weights above about 50 g
        - If the incision cannot effectively be closed with two stitches, a third stitch may be added. The presence of a third suture should be noted on the datasheet.
    - Ideally the gravity feed irrigation system should be switched to fresh water or a combination of sedation and freshwater during the final stages of surgery to begin recovery from anesthesia. Typically a good time to switch to freshwater is when the second suture is initiated.
    - Transfer the fish from the surgical platform to a recovery container and stop the timer recording air time
        - Avoid excessive handling of fish during transfer. Ideally the fish will be moved to the recovery container on the surgical platform to reduce handling.
    - Once a recovery container has been fully stocked, start a timer to monitor the 10 min of exposure to high DO concentrations for recovery.
    - Between surgeries the tagger should place surgical instruments and any partially consumed suture material into the chlorhexidine bath. Multiple sets of surgical

instruments should be rotated to ensure 10 min of contact time with chlorhexidine. Once disinfected, instruments should be rinsed in distilled or de-ionized water. Organic debris in the disinfectant bath reduces effectiveness, so be sure to change the bath regularly.

*Tag Validation*

- Filled recovery containers will be moved to the tag validation station.
    - Recovery containers may be moved from the tagging location to the tag validation station during the 10 min recovery time, but they must not be established on flow-through water exchange. The flow-through exchange will immediately reduce the DO saturation.
- Use the appropriate receiving system to confirm the identity and function of the transmitters in the recovery container. Record validation on the datasheet.
- Following tag validation, recovery containers are loaded onto a truck for transport to the holding and release location.

*Cleanup*

- Both the tagger and assistant must review the full complement of tagging datasheets and initial each sheet to confirm that the set of transmitters they were assigned to implant have been implanted. Use the list of transmitters provided by the tag coordinator to ensure that all transmitters supplied to you were implanted and recorded. Both the tagger and the assistant must initial the header of each of the datasheets. This review step is completed for each tagging session (that is, for each transport truck that is loaded).
- Return tag tray and datasheets to coordinator at end of each tagging session.
- Complete the reject fish tally datasheet and return to the tag coordinator.
- Use a spray disinfectant to disinfect tagging surfaces and supplies, and position them to dry.
- Return any rejected fish to the appropriate raceway where they cannot be selected for future tagging efforts.
- At the completion of the tagging effort each day, package surgical instruments for the autoclave so they can be sterilized prior to the next tagging session.

*Important things to remember:*

- Water containers used for tagging should be filled just prior to tagging to avoid temperature changes and should be changed frequently.
- Fish cannot be transferred between water sources until the difference between the water temperatures of the two sources is less than two degrees Celsius.
- No water sources used in the tagging operation should be more than two degrees different in water temperature from the source water temperature.
- All containers holding fish should have lids in place.
- If a tag is dropped bring it to the tagging coordinator to confirm that it is still functioning before it is implanted. The transmitter may also require disinfection if it fell onto a dirty surface.
- Carefully handle all fish containers to minimize disturbances to fish.
- Containers used to transport fish to the release site cannot be used for tagging operations until they have been held in the freezer for 24 h.

## Standard Operating Procedure

# Holding and Releasing Acoustically Tagged Fish 2012 South Delta Steelhead Studies

### Transport

Prior to loading the driver should take a water temperature and dissolved oxygen reading at the hatchery.

During loading, transport truck drivers will fill out datasheets, and confirm fish in each tote are alive and visually uncompromised. Any mortalities or compromised fish should be taken out of the tote and returned to Jack. Load tote in order, with replacement fish added directly to tote in the truck once they are provided.

After the fish are loaded into the transport tank, the driver takes and records the transport tank water temperature and dissolved oxygen (DO) level on the Transport and Release datasheet. The driver should call the office and let them know they are leaving and relay the temperature information so the crew at Durham Ferry can assess the need for tempering at the release site.

The DO should be between 7 and 10 mg/liter. Please regulate oxygen tanks to maintain a DO's at these levels as closely as possible during transport.

The driver will take the loading and release datasheet for the fish being transported and a copied set of the Surgical Tagging datasheets from the previous day to the release site crew. He should also have a DO meter in the cab.

### Holding site tempering

**Biosecurity Control Point: Once the transport truck has arrived at the gravel driveway at the release site, crews on the ground will loosen and slide transport tank straps onto the bed of the truck, BEING CAREFUL NOT TO LET THEM TOUCH THE GROUND**.

Once the straps are undone, the truck driver will take a temperature and DO reading in the tank prior to unloading.

The field crew will have already taken a water temperature in the river and have 8 buckets, each with 4 gallons of river water in the pick-up truck. Once the fish arrive, the pick-up will be driven over the levee to the transport truck for the transfer of totes.

If the difference in water temperature between the river and transport tank water is less than 5˚C, then river crews does not need to temper the fish at the holding site prior to loading totes into garbage cans. The perforated totes will be quickly transferred one at a time from the transport tank into sleeves in the pick-up truck to keep as much water in tote as possible. Repeat for 8 totes prior to delivering totes to the river holding site.

If the difference in water temperature between the river and transport tank water is greater than 5˚C, then river crews will need to temper the fish at the holding site prior to loading totes into garbage cans. The perforated totes will be transferred one at a time from the transport tank into sleeves in the pick-up truck. After transfer there should be approximately 4 gallons of water in each perforated tote. Once each tote is placed into its sleeve in the pick-up truck, pour one bucket 4/5's full (4 gallons) of river water into each tote, taking care not to have fish jump out. Repeat for 8 totes prior to delivering totes to the river holding site. Once the fish arrive at the river holding site take a temperature in the river and from each of the 8 totes. If the difference between the river and the transport tank is greater than 5˚C and the difference between the river and 8 totes is still greater than 5˚C after adding the initial 4 gallons of river water, then add additional river water at the holding site to each tote to raise the temperature by 1/2˚C every 15 minutes prior to putting totes into the garbage cans.

Refill each of the 8 buckets with 4 gallons of river water and take back to the transport truck for adding water to the next 8 totes after transferring to the pick-up truck. Move remaining fish to the river.

Transport truck returns to the Mokelumne River or the Stockton office. If returning to the Mokelumne River hatchery, the transport tank will be driven to the hatchery cleaning station to hose off truck if needed (if muddy or evidence of vegetation). The truck will then be taken back to raceway for reloading. If returning to Stockton, hose off truck if needed.

Twenty-four sleeves are available at the holding site for use for tempering all totes in the transport tank if necessary. Totes need to be rinsed in the river and put into a clean (no mud or vegetation) pick-up for return to Stockton where they will be driven to Mokelumne River Hatchery by the tagging personnel and placed into the freezers at the hatchery.

**Biosecurity Control Point: After unloading at no point will totes or their lids be put onto the transport truck. Empty totes and lids will be rinsed in the river of any mud or vegetation and returned to the freezer at Mokelumne River hatchery.**

### River transfer of tagged fish

Transfer the fish from totes into their respective in-river holding cans per the delivery schedule.  Do not slide totes in pick-up.  Pick up and move.  Use two people to carry each tote to the river.

If there are any mortalities after transport, retrieve the fish and place the acoustic tag into a zip-loc bag with a premade label (date and time of release and number of tote that it was collected from).  If there are multiple mortalities from the same tote, you can put them into the same bag, but otherwise please use separate bags.  Document on the data sheet which the tote the mortality was in.  Bring tag(s) back to office at the end of the shift and put in Jack's office.  Place carcass(es) in plastic bag and bring it/them back to the office for disposal.

### Releasing Tagged Fish

Field crew will release fish at times provided on the release schedule posted in the field crew trailer.

Release crews should wear all appropriate field gear.  This includes; waders, wading boots, safety belt, appropriate outerwear and PFD with safety strobes when on the boat. Use headlamps at night.

When arriving at the release site, make sure that all of the cans are in place and all are upright.  Also, check to see if there is enough clearance between the bottom of the cans and the substrate.  If the cans are sitting on the substrate, they need to be moved out into deeper water.  This can be accomplished by either pulling the fence stakes and anchors into deeper water, or, if this is not feasible, contact appropriate personnel and they can come out and assist with this process.

Identify which cans are to be released.  Steelhead containers will be marked with a number (1-31); Cans 1-28 are live-tagged fish and cans 29-31 are dummy tagged fish. Each container is equipped with two tethers with two quick-links attached to the main anchor line (fixed between two fence stakes).  Detach the quick-links from the main anchor line and attach to the transport line located near the starboard side gunnel of the release boat. Either two or three cans will be released at a time.

Once you have attached the transport cans to the vessel, board the vessel and start outboard engine.  The outboard is equipped with a key start; make sure that the outboard is in neutral with the throttle set at start.  Once the outboard is running, safely engage the shifter into forward or reverse, depending on the orientation of the vessel and move away from the holding area.

Maintain a slow and steady speed; making sure that the cans are not tipping or submerging.  If cans appear to be tipping or submerging, slow down the rate of speed.

Once the release location has been reached put boat in neutral, remove the wing-nuts holding the lid in position.  Pull the lid off and place into boat.  Once the lid is removed, pull the can slowly up; allowing some of the water to drain. DO NOT DEWATER THE CAN!!

Observe the fish inside of the container; making sure there are no mortalities. If you observe a dead fish, remove it as gently as possible from the can and place it into a zip-loc bag. Record the number of mortalities for each can in your field notebook for transferring to the data sheets kept in the trailer. Once you have retrieved any mortalities from the can, slowly invert and push the can down so that one end of the opening is just under the surface of the water and allow the fish to swim out of the can. If necessary turn the can upside down to empty the contents of the container into the river; making sure that all fish have left the container prior to bringing the container on board. Once the can is empty, place it inside of the vessel. Record the date and actual time of release (to the nearest minute) in your notebook for later transfer to the data sheets in the trailer. (Do not write down the time from the schedule if this is not the actual time of release. Also, remember to change the date if the release is after midnight).

Repeat the procedure for the remaining cans, making sure that you record release date and time for each can of fish.

Return to shore and remove the empty cans from the vessel and place on shore. Make sure that the cans are placed upside down (frame facing ground) so that the containers do not get damaged. You can stack up to four containers inside of each other.

If you encountered any mortalities during the release process, retrieve the acoustic tag and place into a zip-loc bag. Place the tag inside of the bag with all information required on the premade label (date and time of release and number or letter of can that it was collected from). If there are multiple mortalities from the same can, you can put the tags into the same bag. However, if mortalities are from different cans, please use separate bags for each mortality. For all mortalities document which cans the mortalities came from in the comments section of the data sheet. Bring tag(s) back to office at the end of the shift and put in Jack's office. Bag carcasses and bring back to the office for disposal.

Continue to release fish at the scheduled times according to the schedule posted in the field crew trailer. Releases should be every four hours. If cans will be reused please place them back into the river on the quick-links attached to the main anchor line. If cans will no longer be reused during the rest of the week they should be brought back to the office. At the end of your shift, make sure that the next shift of personnel or security guard arrives prior to leaving. The crew making the last release of the each transport day will conduct fish health evaluations. The crew making the last release from each week will check dummy tagged fish for mortality only (by lifting up can to view fish) and keep the fish in the river for Ken Nichols (see release schedule). The last crew of the week will also bring all supplies and trailer back to the office.

## Fish Health Evaluations

### ***Processing Dummy Tagged Fish:***

After the last release for each transport day complete the following steps (refer to release schedule for time and can numbers for fish health):

1. Determine if there are any mortalities in the dummy tagged cans by putting fish into a bucket, being careful not to lose any of the fish into the river, at the time fish health is to be done (see release schedule). Note mortalities on data sheet.
2. Euthanize the six dummy tagged steelhead.
3. Note date, time, species and crew on dummy tag datasheets
4. Measure each fish, check the 5 characteristics of condition and complete datasheets
5. Take picture of each fish showing sutures (turn camera date and time stamp on). Record picture number in comment section on Fish Health Assessment data sheet
6. Put dummy tags in a ziplock bag marked "dummy tags" and bring them back to the office and leave on Jack's desk

- After the noon release on April 7 at 1100 (and other releases noted for Ken on the schedule) check the 24 steelhead for mortalities and **keep them alive** in the river for Ken Nichols of CA/NV Fish Health Center for further evaluation.

***Disposal of MS-222:***

DO NOT dispose of MS-222 into the river or within 100 feet of any water source. Dump MS-222 containers onto dry ground on the other side of the levee; on the pavement.

***Disposal of carcasses:***

Once the tag has been removed from study fish, place the carcass into a Ziploc bag and bring back to the office. Once you arrive at the office, discard all carcasses into the large trash bin that is located back by the Fed parking area.

Data flow and transfer:

Please check over release sheets prior to leaving for the day, to confirm data sheets are complete and all information is correct.

Between releases, please enter in the tagging and transport and Surgical Tagging datasheets into the excel spreadsheet provided on the Toughbook laptop.

Once tagging and transport data sheets have been entered, please QA/QC sheets

Enter data entry information into data entry log form.

**PLEASE SIGN THAT YOU HAVE READ AND WILL FOLLOW THE SOP:**

## Appendix C: 2012 Steelhead Health and Physiology Sampling

United States Department of the Interior
Fish and Wildlife Service

California-Nevada Fish Health Center
24411 Coleman Fish Hatchery Rd
Anderson, CA 96007
530-365-4271 Fax: 530-365-7150

**TECHNICAL MEMORANDUM**

**TO:** **Josh Israel, USBR**

**FROM:** **J. Scott Foott**

**DATE:** **August 13, 2012**

**SUBJECT:** **2012 Steelhead Health and Physiology Sampling**

---

**Summary:** No significant fish pathogen or disease condition was detected in 71 trout sampled on 3 collection dates (6Apr,7May, and 23May) from live cages held at Durham Ferry. One mortality was observed in the live cages on 7May. Gill Na-K-ATPase activity data was inconclusive due to reagent problems and is not recorded.

**Background:** This technical memorandum summarizes the results of microbiological testing and gill Na-K-ATPase activity monitoring in support of the six year acoustic telemetry study (Action IV.2.2) of the NMFS Biological Opinion on the Coordinated Long-term operation of the Central Valley Project and State Water Project. Sampled fish were dummy-tagged control groups which shadowed treatment and handling of acoustic tagged fish used in the study. These control fish were sampled after holding for 48 (±3 hrs.) in the San Joaquin River at Durham Ferry (release site for the acoustic tagged cohorts).

**Methods**: Sampling was conducted at 3 time points in the study period (6 Apr, 7 May and 23 May 2012). Fish were euthanized at the release site, examined for external or internal abnormalities, and tissue samples (kidney, spleen, and gill) collected. Kidney tissue was inoculated onto brain-heart infusion agar. Bacterial isolates were screened by standard microscopic and biochemical tests (USFWS and AFS-FHS 2010). These screening methods would not isolate *Flavobacterium columnare*, however, no columnaris lesions were observed in the trout. *Renibacterium salmoninarum* (the bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test (FAT) of kidney imprints. Two to four fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 at 15°C as described in the AFS Bluebook (USFWS and AFS-FHS 2010) with the exception that no blind pass was performed. On 6 April, a suspect parasite infection of the gill was examined by histology (Davidson's fixative, standard H&E processing). Gill $Na^+/K^+$-Adenosine Triphosphatase (ATPase) activity was assayed by the method of McCormick (1993).

**Results:** No significant viral or bacterial fish pathogen or disease condition was detected in the sampled trout (Table D1). *Aeromonas-Pseudomonas* (AP) bacteria were commonly isolated from the kidney, however, no clinical signs of septicemia were observed in the trout. All gill Na-K-ATPase samples were lost during processing. The ADP standard curve was normal which indicates that the majority of enzymes and co-factors were operating normally. The pH and magnesium conditions were also normal for the assay. We suspect that the recently purchased Sigma Chemical Adenosine TriPhosphate was faulty as this nucleotide is the substrate for the ouabain-sensitive gill Na-K-ATPase enzyme. On 6April, an opaque focal region was seen in the gill of one trout and determined to be an amoeba infection by histology (Fig. D1). Epithelial hyperplasia or necrosis was not associated with the parasites and it is unlikely that the fish was affected by the infection. One 6 April fish demonstrated unique “rainbow” trout coloration (Fig. D2). No gonads were apparent in this immature fish. No assessment of suture condition was done.

Table C1. Mean (SD) fork length in mm, observed mortality in live cage, prevalence of infection for virus assay, bacterial inoculum onto BHI agar, and *Renibacterium salmoninarum* by fluorescent antibody test (Rs-DFAT).

| Date | FL | Mortality | Viral | Bacteria | Rs-DFAT |
|---|---|---|---|---|---|
| 6-Apr | 217(20) | 0/24 | 0/6 [4p] | 1/24 AP | 0 / 24 |
| 7-May | ND | 1/24 | 0/8 [3p] | 3 /24 AP | 0/21 |
| 23-May | 253 (23) | 0/23 | 0/8 [2&3p] | 5/23 AP | 0/23 |

Figure C1. Steelhead trout gill section with presumptive amoeba from 6 April collection.

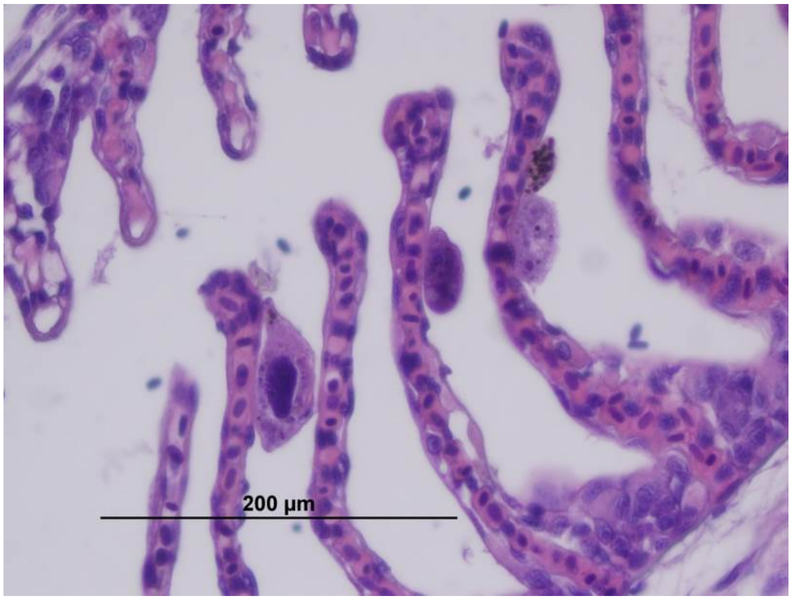


Figure C2.  April 6 trout with unique coloration.

FHC Cases: 12-68, 87, and 99.

References

AFS-FHS (American Fisheries Society-Fish Health Section). 2010. FHS blue book: suggested procedures for the detection and identification of certain finfish and shellfish pathogens, 2010 edition. AFS-FHS, Bethesda, Maryland.

McCormick SD.  1993.  Methods for Nonlethal Gill Biopsy and Measurement of $Na^+$, $K^+$-ATPase Activity.  Canadian Journal of Fisheries and Aquatic Sciences.  50: 656-658.

**Appendix D: Water temperature in the transport tanks for the 2012 Six-Year Study.**

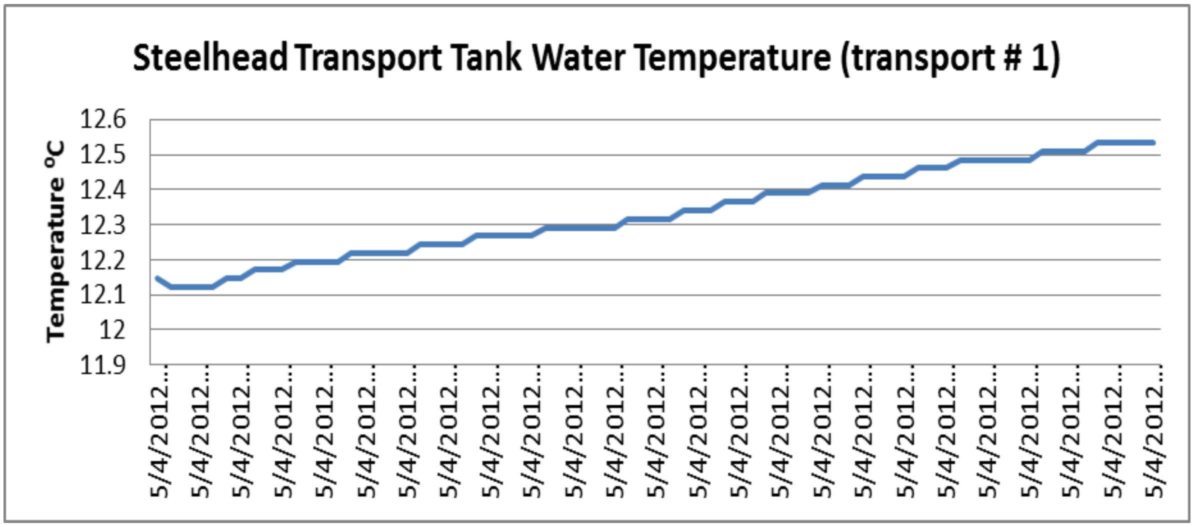



Figure D1. Transport tank water temperature during transport #1 on May 5, 2012.

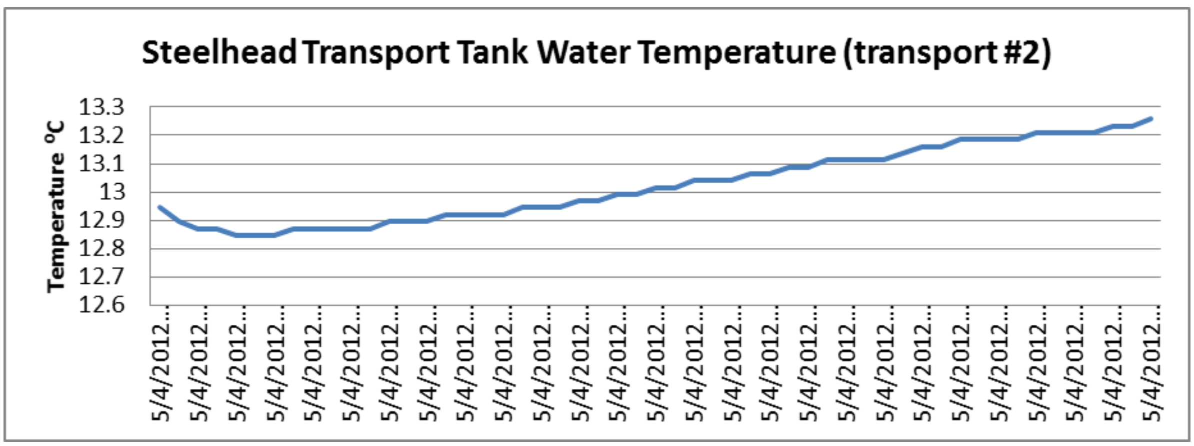



Figure D2. Transport tank water temperature during transport #2 on May 5, 2012.

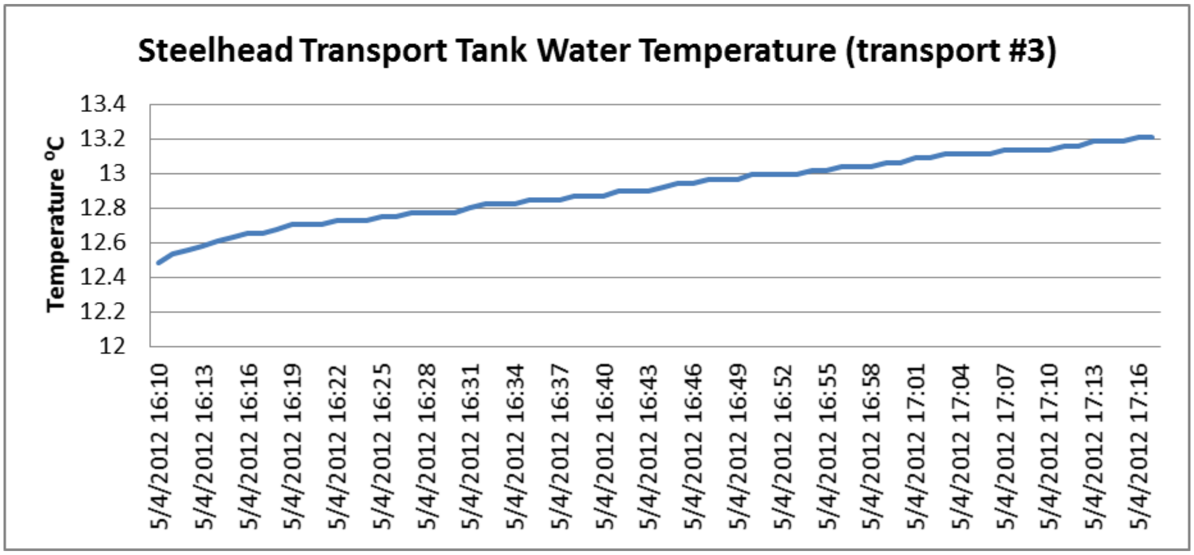



**Figure D3. Transport tank water temperature during transport #3 on May 5, 2012.**

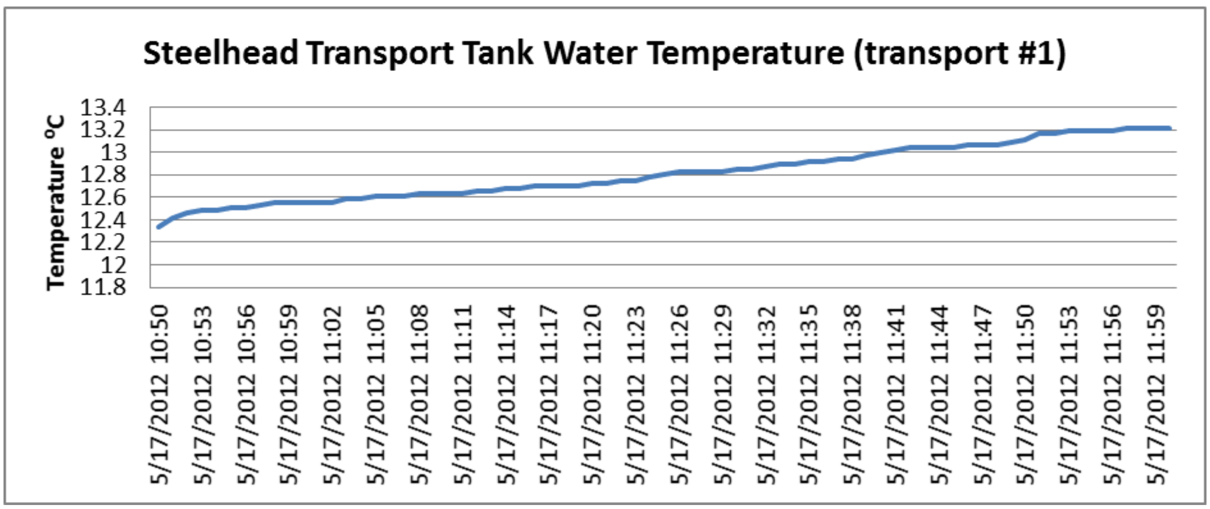



**Figure D4. Transport tank water temperature during transport #1 on May 17, 2012**

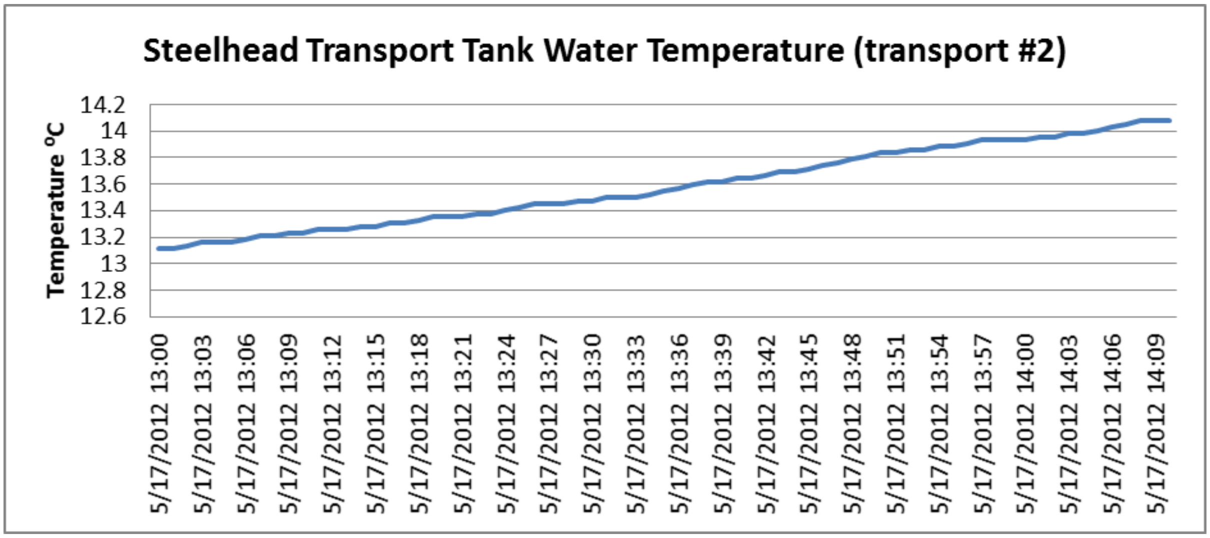



**Figure D5. Transport tank water temperature during transport #2 on May 17, 2012.**

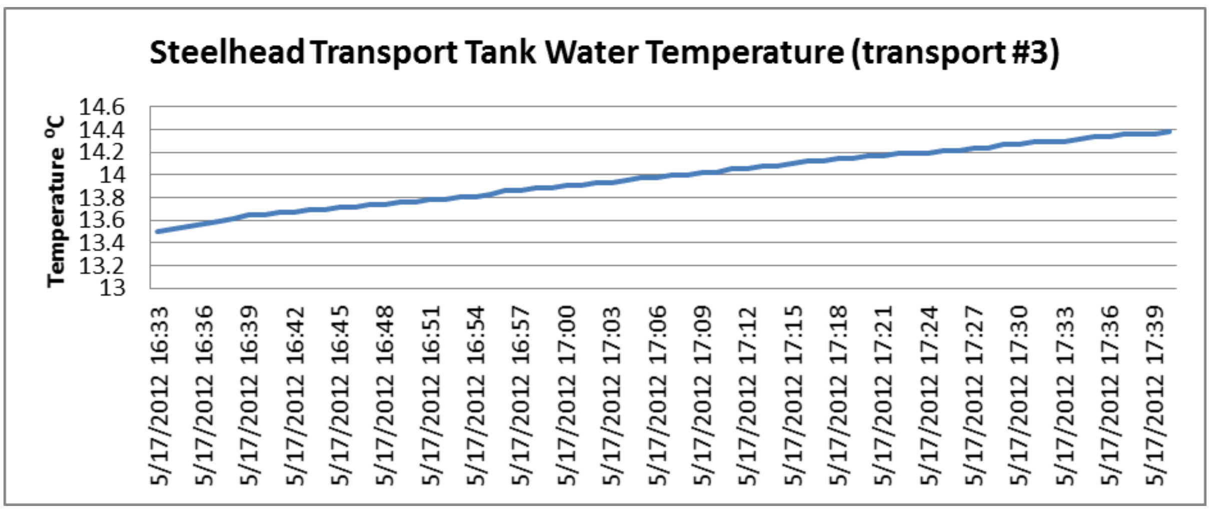



**Figure D6. Transport tank water temperature during transport #3 on May 17, 2012.**

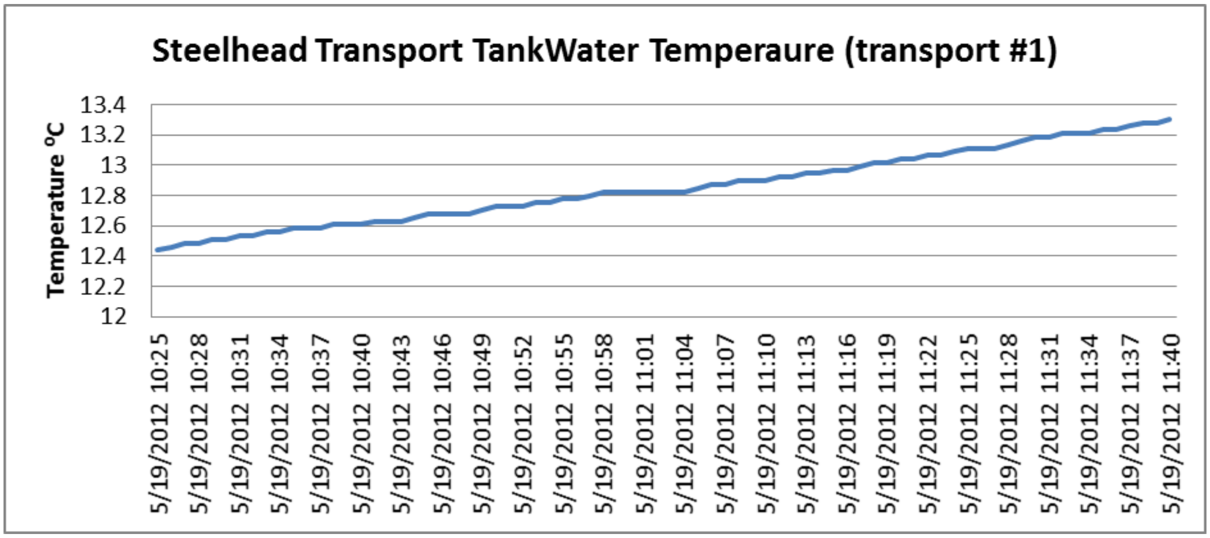



**Figure D7. Transport tank water temperature during transport #1 on May 19, 2012.**

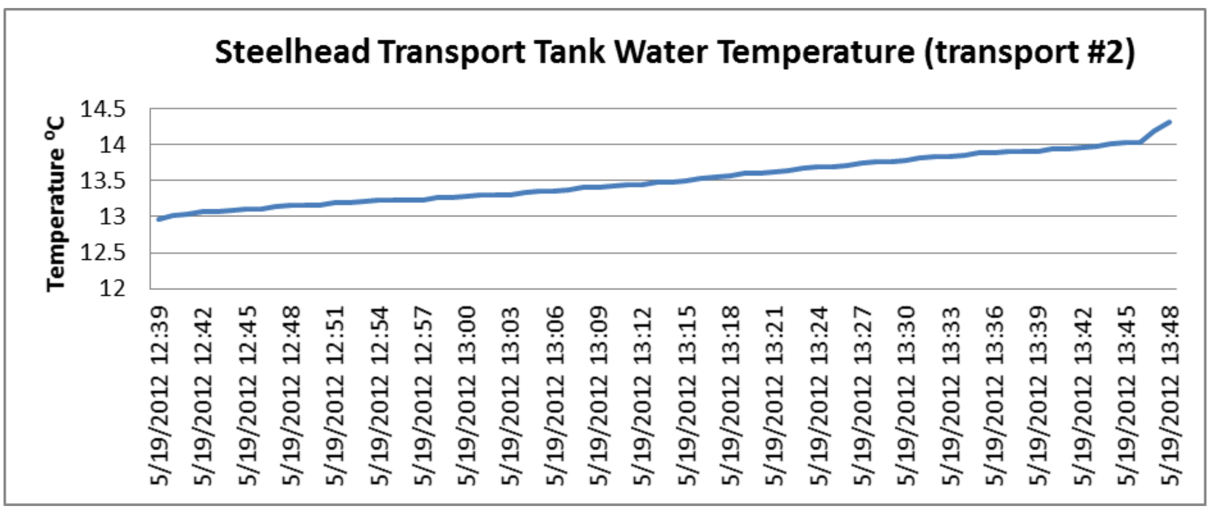



**Figure D8. Transport tank water temperature during transport #2 on May 19, 2012.**

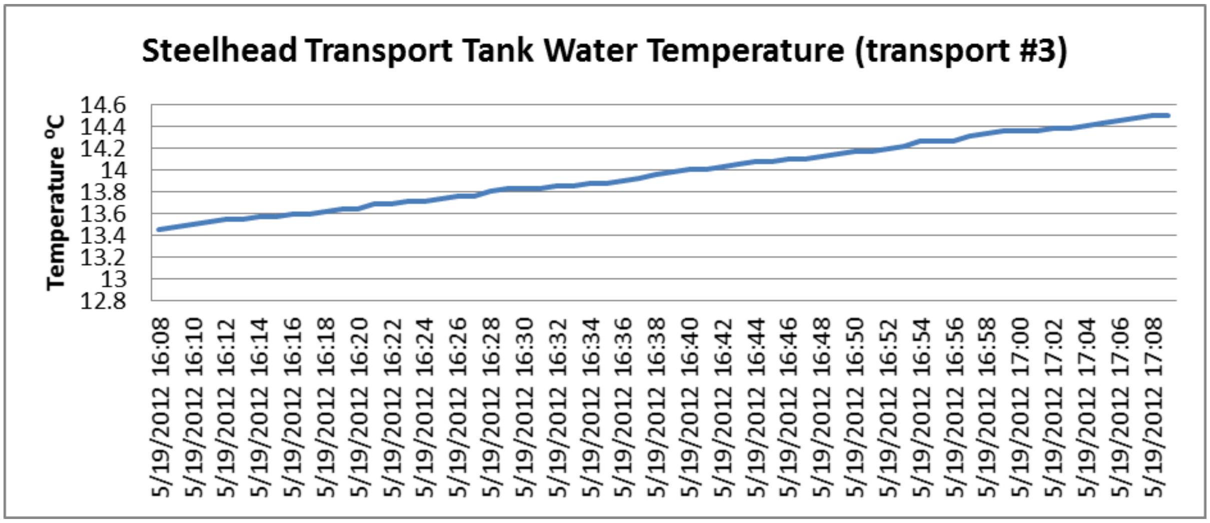



**Figure D9. Transport tank water temperature during transport #3 on May 19, 2012.**

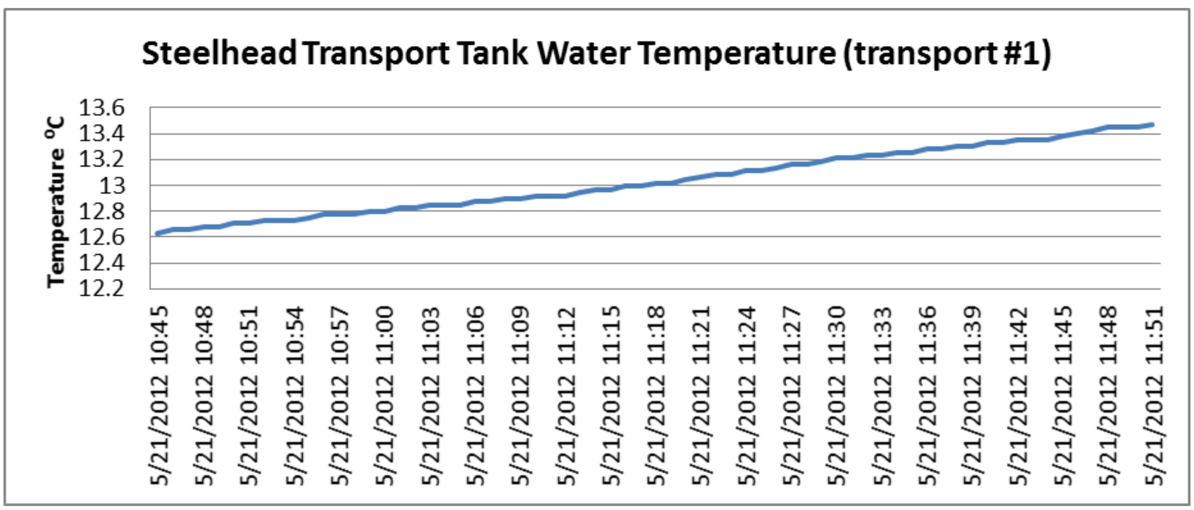



**Figure D10. Transport tank water temperature during transport #1 on May 21, 2012.**

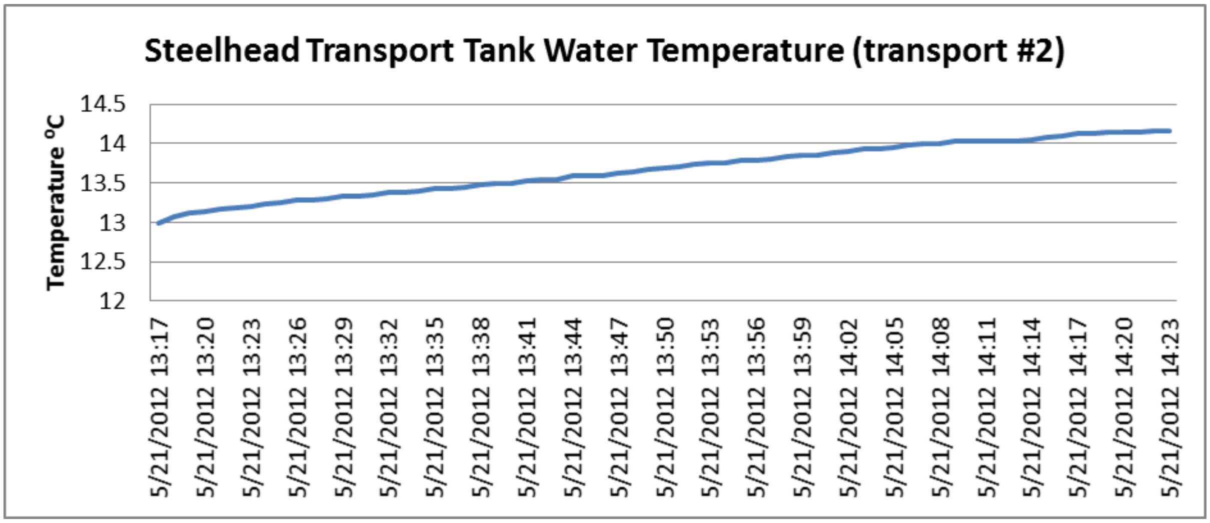



**Figure D11. Transport tank water temperature during transport #2 on May 21, 2012.**

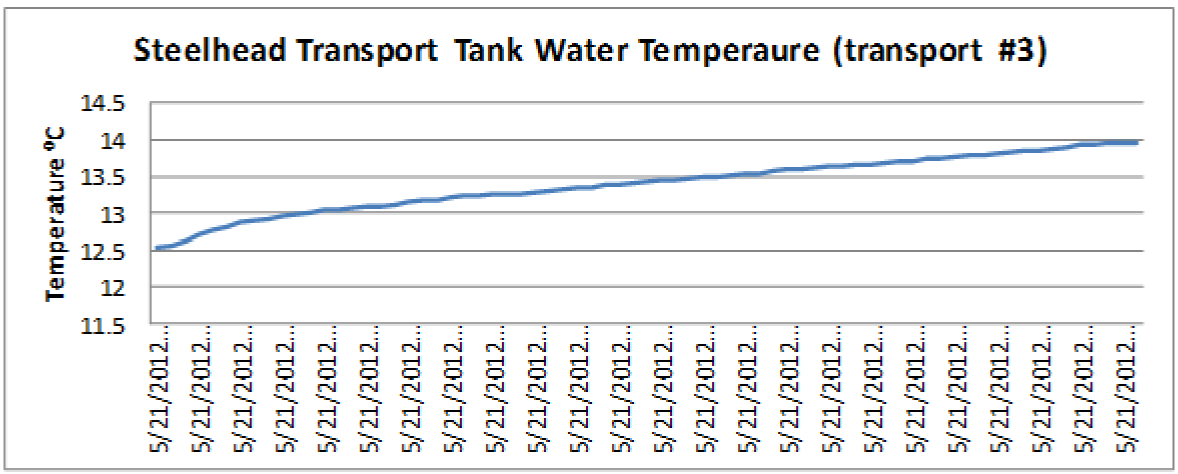



**Figure D12. Transport tank water temperature during transport #3 on May 21, 2012.**

## Appendix E. Survival Model Parameters

**Table E1. Definitions of parameters used in the release-recapture survival model. Parameters used only in particular submodels are noted.**

| Parameter | Definition |
|---|---|
| $S_{A2}$ | Probability of survival from Durham Ferry Downstream (DFD) to Banta Carbona (BCA) |
| $S_{A3}$ | Probability of survival from Banta Carbona (BCA) to Mossdale (MOS) |
| $S_{A4}$ | Probability of survival from Mossdale (MOS) to Lathrop (SJL) or Old River East (ORE) |
| $S_{A5}$ | Probability of survival from Lathrop (SJL) to Garwood Bridge (SJG) |
| $S_{A6}$ | Probability of survival from Garwood Bridge (SJG) to Navy Drive Bridge (SJNB) |
| $S_{A7}$ | Probability of survival from Navy Drive Bridge (SJNB) to MacDonald Island (MAC) or Turner Cut (TCE/TCW) |
| $S_{A7,G2}$ | Overall survival from Navy Drive Bridge (SJNB) to Chipps Island (MAE/MAW) (derived from Submodel I) |
| $S_{A8,G2}$ | Overall survival from MacDonald Island (MAC) to Chipps Island (MAE/MAW) (Submodel I) |
| $S_{B1}$ | Probability of survival from Old River East (ORE) to Old River South (ORS) |
| $S_{B2,G2}$ | Overall survival from Old River South (ORS) to Chipps Island (MAE/MAW) (derived from Submodel I) |
| $S_{B2(SD)}$ | Overall survival from Old River South (ORS) to the exit points of the Route B Southern Delta Region: OR4, MR4, RGU, CVP (derived from Submodel I) |
| $S_{C1,G2}$ | Overall survival from head of Middle River (MRH) to Chipps Island (MAE/MAW) (derived from Submodel I) |
| $S_{C1(SD)}$ | Overall survival from head of Middle River (MRH) to the exit points of the Route B Southern Delta Region: OR4, MR4, RGU, CVP (derived from Submodel I) |
| $S_{F1,G2}$ | Overall survival from Turner Cut (TCE/TCW) to Chipps Island (MAE/MAW) (Submodel I) |
| $\phi_{A1,A0}$ | Joint probability of moving from Durham Ferry release site upstream toward DFU, and surviving to DFU |
| $\phi_{A1,A2}$ | Joint probability of moving from Durham Ferry release site downstream toward DFD, and surviving to DFD |
| $\phi_{A1,A3}$ | Joint probability of moving from Durham Ferry release site downstream toward BCA, and surviving to BCA; = $\phi_{A1,A2} S_{A2}$ |
| $\phi_{A8,A9}$ | Joint probability of moving from MAC toward MFE/MFW, and surviving from MAC to MFE/MFW (Submodel II) |
| $\phi_{A8,B3}$ | Joint probability of moving from MAC toward OR4, and surviving from MAC to OR4 (Submodel II) |
| $\phi_{A8,C2}$ | Joint probability of moving from MAC toward MR4, and surviving from MAC to MR4 (Submodel II) |
| $\phi_{A8,GH}$ | Joint probability of moving from MAC directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving JPE/JPW or FRE/FRW (Submodel II) |
| $\phi_{A8,G1}$ | Joint probability of moving from MAC directly toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{A8,GH}\psi_{G1(A)}$ |
| $\phi_{A9,B3}$ | Joint probability of moving from MFE/MFW toward OR4, and surviving from MFE/MFW to OR4 (Submodel II) |
| $\phi_{A9,C2}$ | Joint probability of moving from MFE/MFW toward MR4, and surviving from MFE/MFW to MR4 (Submodel II) |
| $\phi_{A9,GH}$ | Joint probability of moving from MFE/MFW directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving to JPE/JPW or FRE/FRW (Submodel II) |
| $\phi_{A9,G1}$ | Joint probability of moving from MFE/MFW directly toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{A9,GH}\psi_{G1(A)}$ |
| $\phi_{B1,B2}$ | Joint probability of moving from ORE toward ORS, and surviving from ORE to ORS; = $S_{B1}\psi_{B2}$ |
| $\phi_{B2,B3}$ | Joint probability of moving from ORS toward OR4, and surviving from ORS to OR4 |
| $\phi_{B2,C2}$ | Joint probability of moving from ORS toward MR4, and surviving from ORS to MR4 |
| $\phi_{B2,D1}$ | Joint probability of moving from ORS toward RGU, and surviving from ORS to RGU |
| $\phi_{B2,E1}$ | Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP |
| $\phi_{B3,D1}$ | Joint probability of moving from OR4 toward RGU and surviving from OR4 to RGU conditional on coming from lower San Joaquin River (Submodel II) |
| $\phi_{B3,E1}$ | Joint probability of moving from OR4 toward CVP, and surviving from OR4 to CVP, conditional on coming from lower San Joaquin River (Submodel II) |
| $\phi_{B3,GH(A)}$ | Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from OR4 to JPE/JPW or FRE/FRW (Submodel II [route A]) |

**Table E1. (Continued)**

| Parameter | Definition |
|---|---|
| $\phi_{B3,GH(B)}$ | Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from OR4 to JPE/JPW or FRE/FRW (Submodel I [route B]) |
| $\phi_{B3,G1(A)}$ | Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) and surviving from OR4 to JPE/JPW (Submodel II [route A]); = $\phi_{B3,GH(A)}\psi_{G1(A)}$ |
| $\phi_{B3,G1(B)}$ | Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) and surviving from OR4 to JPE/JPW (Submodel I [route B]); = $\phi_{B3,GH(B)}\psi_{G1(B)}$ |
| $\phi_{C1,B3}$ | Joint probability of moving from MRH toward OR4, and surviving from MRH to OR4 |
| $\phi_{C1,C2}$ | Joint probability of moving from MRH toward MR4, and surviving from MRH to MR4 |
| $\phi_{C1,D1}$ | Joint probability of moving from MRH toward RGU, and surviving from MRH to RGU |
| $\phi_{C1,E1}$ | Joint probability of moving from MRH toward CVP, and surviving from MRH to CVP |
| $\phi_{C2,D1}$ | Joint probability of moving from MR4 toward RGU and surviving from MR4 to RGU conditional on coming from lower San Joaquin River (Submodel II) |
| $\phi_{C2,E1}$ | Joint probability of moving from MR4 toward CVP, and surviving from MR4 to CVP, conditional on coming from lower San Joaquin River (Submodel II) |
| $\phi_{C2,GH(A)}$ | Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from MR4 to JPE/JPW or FRE/FRW (Submodel II [route A]) |
| $\phi_{C2,GH(B)}$ | Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from MR4 to JPE/JPW or FRE/FRW (Submodel I [route B]) |
| $\phi_{C2,G1(A)}$ | Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) and surviving from MR4 to JPE/JPW (Submodel II [route A]); = $\phi_{C2,GH(A)}\psi_{G1(A)}$ |
| $\phi_{C2,G1(B)}$ | Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) and surviving from MR4 to JPE/JPW (Submodel I [route B]); = $\phi_{C2,GH(B)}\psi_{G1(B)}$ |
| $\phi_{D1,D2}$ | Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD (equated between submodels I and II) |
| $\phi_{D2,G2}$ | Joint probability of moving from RGD toward Chipps Island (MAE/MAW) and surviving from RGU to MAE/MAW (equated between submodels I and II) |
| $\phi_{D1,G2}$ | Joint probability of moving from RGU toward Chipps Island (MAE/MAW) via CCFB and surviving to MAE/MAW (equated between submodels I and II); = $\phi_{D1,D2}\phi_{D2,G2}$ |
| $\phi_{E1,E2}$ | Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank (equated between submodels I and II) |
| $\phi_{E2,G2}$ | Joint probability of moving from CVPtank toward Chipps Island (MAE/MAW) and surviving from CVPtank to MAE/MAW (equated between submodels I and II) |
| $\phi_{F1,B3}$ | Joint probability of moving from TCE/TCW toward OR4, and surviving from TCE/TCW to OR4 (Submodel II) |
| $\phi_{F1,C2}$ | Joint probability of moving from TCE/TCW toward MR4, and surviving from TCE/TCW to MR4 (Submodel II) |
| $\phi_{F1,GH}$ | Joint probability of moving from TCE/TCW directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving to JPE/JPW or FRE/FRW (Submodel II) |
| $\phi_{F1,G1}$ | Joint probability of moving from TCE/TCW directly toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{F1,GH}\psi_{G1(A)}$ |
| $\phi_{G1,G2(A)}$ | Joint probability of moving from JPE/JPW toward Chipps Island (MAE/MAW), and surviving to MAE/MAW (Submodel II [route A]) |
| $\phi_{G1,G2(B)}$ | Joint probability of moving from JPE/JPW toward Chipps Island (MAE/MAW), and surviving to MAE/MAW (Submodel I [route B]) |
| $\psi_{A1}$ | Probability of remaining in the San Joaquin River at the head of Old River; = 1 - $\psi_{B1}$ |
| $\psi_{A2}$ | Probability of remaining in the San Joaquin River at the junction with Turner Cut; = 1 - $\psi_{F2}$ |
| $\psi_{B1}$ | Probability of entering Old River at the head of Old River; = 1 - $\psi_{A1}$ |
| $\psi_{B2}$ | Probability of remaining in Old River at the head of Middle River; = 1 - $\psi_{C2}$ |
| $\psi_{C2}$ | Probability of entering Middle River at the head of Middle River; = 1 - $\psi_{B2}$ |
| $\psi_{F2}$ | Probability of entering Turner Cut at the junction with the San Joaquin River; = 1 - $\psi_{A2}$ |

**Table E1. (Continued)**

| Parameter | Definition |
|---|---|
| $\psi_{G1(A)}$ | Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction (Submodel II [route A]); = 1 - $\psi_{H1(A)}$ |
| $\psi_{G1(B)}$ | Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction (Submodel I [route B]); = 1 - $\psi_{H1(B)}$ |
| $\psi_{H1(A)}$ | Probability of entering False River at the Jersey Point/False River junction (Submodel II [route A]); = 1 - $\psi_{G1(A)}$ |
| $\psi_{H1(B)}$ | Probability of entering False River at the Jersey Point/False River junction (Submodel I [route B]); = 1 - $\psi_{G1(B)}$ |
| $P_{A0a}$ | Conditional probability of detection at DFU1 |
| $P_{A0b}$ | Conditional probability of detection at DFU2 |
| $P_{A2a}$ | Conditional probability of detection at DFD1 |
| $P_{A2b}$ | Conditional probability of detection at DFD2 |
| $P_{A2}$ | Conditional probability of detection at DFD (either DFD1 or DFD2) |
| $P_{A3}$ | Conditional probability of detection at BCA |
| $P_{A4}$ | Conditional probability of detection at MOS |
| $P_{A5}$ | Conditional probability of detection at SJL |
| $P_{A6}$ | Conditional probability of detection at SJG |
| $P_{A7}$ | Conditional probability of detection at SJNB |
| $P_{A8a}$ | Conditional probability of detection at MACU |
| $P_{A8b}$ | Conditional probability of detection at MACD |
| $P_{A8}$ | Conditional probability of detection at MAC (either MACU or MACD) |
| $P_{A9a}$ | Conditional probability of detection at MFE |
| $P_{A9b}$ | Conditional probability of detection at MFW |
| $P_{B1}$ | Conditional probability of detection at ORE |
| $P_{B2a}$ | Conditional probability of detection at ORSU |
| $P_{B2b}$ | Conditional probability of detection at ORSD |
| $P_{B2}$ | Conditional probability of detection at ORS (either ORSU or ORSD) |
| $P_{B3a}$ | Conditional probability of detection at OR4U |
| $P_{B3b}$ | Conditional probability of detection at OR4D |
| $P_{C1a}$ | Conditional probability of detection at MRHU |
| $P_{C1b}$ | Conditional probability of detection at MRHD |
| $P_{C1}$ | Conditional probability of detection at MRH |
| $P_{C2a}$ | Conditional probability of detection at MR4U |
| $P_{C2b}$ | Conditional probability of detection at MR4D |
| $P_{D1}$ | Conditional probability of detection at RGU (either RGU1 or RGU2) |
| $P_{D2a}$ | Conditional probability of detection at RGD1 |
| $P_{D2b}$ | Conditional probability of detection at RGD2 |
| $P_{D2}$ | Conditional probability of detection at RGD (either RGD1 or RGD2) |
| $P_{E1}$ | Conditional probability of detection at CVP |
| $P_{E2}$ | Conditional probability of detection at CVPtank |
| $P_{F1a}$ | Conditional probability of detection at TCE |
| $P_{F1b}$ | Conditional probability of detection at TCW |

**Table E1. (Continued)**

| Parameter | Definition |
|---|---|
| $P_{F1}$ | Conditional probability of detection at TCE/TCW |
| $P_{G1a}$ | Conditional probability of detection at JPE |
| $P_{G1b}$ | Conditional probability of detection at JPW |
| $P_{G1}$ | Conditional probability of detection at JPE/JPW |
| $P_{G2a}$ | Conditional probability of detection at MAE |
| $P_{G2b}$ | Conditional probability of detection at MAW |
| $P_{G2}$ | Conditional probability of detection at MAE/MAW |
| $P_{H1a}$ | Conditional probability of detection at FRW |
| $P_{H1b}$ | Conditional probability of detection at FRE |
| $P_{H1}$ | Conditional probability of detection at FRE/FRW |

**Table E2. Parameter estimates (standard errors in parentheses) for tagged juvenile steelhead released in 2012, excluding predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are weighted averages of the release-specific estimates. Some parameters were not estimable because of sparse data.**

| Parameter | Release Group 1 | Release Group 2 | Release Group 3 | Population Estimate |
|---|---|---|---|---|
| $S_{A2}$ | 0.86 (0.04) | | | |
| $S_{A3}$ | 0.88 (0.04) | 0.77 (0.06) | 0.81 (0.03) | 0.82 (0.03) |
| $S_{A4}$ | 0.98 (0.01) | 0.99 (0.01) | 0.98 (0.01) | 0.98 (< 0.01) |
| $S_{A5}$ | 0.93 (0.02) | 0.95 (0.01) | 0.98 (0.01) | 0.95 (0.01) |
| $S_{A6}$ | 0.97 (0.01) | 0.97 (0.01) | 0.97 (0.01) | 0.97 (0.01) |
| $S_{A7}$ | 0.88 (0.05) | 0.90 (0.02) | 0.96 (0.02) | 0.91 (0.02) |
| $S_{A7,G2}$ | 0.31 (0.03) | 0.39 (0.03) | 0.39 (0.04) | 0.36 (0.02) |
| $S_{A8,G2}$ | 0.42 (0.04) | 0.52 (0.04) | 0.50 (0.05) | 0.48 (0.03) |
| $S_{B1}$ | | | | |
| $S_{B2,G2}$ | 0.08 (0.04) | 0.11 (0.08) | 0.06 (0.04) | 0.08 (0.03) |
| $S_{B2(SD)}$ | 0.85 (0.08) | 0.72 (0.17) | 0.30 (0.14) | 0.62 (0.08) |
| $S_{C1,G2}$ | | | | |
| $S_{C1(SD)}$ | | | | |
| $S_{F1,G2}$ | 0.12 (0.05) | 0.17 (0.05) | 0.24 (0.06) | 0.18 (0.03) |
| $\phi_{A1,A0}$ | 0.10 (0.08) | 0.06 (0.01) | 0.22 (0.03) | 0.12 (0.03) |
| $\phi_{A1,A2}$ | 0.92 (0.02) | | | |
| $\phi_{A1,A3}$ | 0.79 (0.04) | 0.85 (0.07) | 0.44 (0.03) | 0.69 (0.03) |
| $\phi_{A8,A9}$ | 0.61 (0.04) | 0.66 (0.03) | 0.75 (0.05) | 0.67 (0.02) |
| $\phi_{A8,B3}$ | 0.03 (0.01) | 0.03 (0.01) | 0 | 0.02 (0.01) |
| $\phi_{A8,C2}$ | 0.02 (0.01) | 0.03 (0.01) | 0.02 (0.02) | 0.02 (0.01) |
| $\phi_{A8,GH}$ | | 0.16 (0.03) | | |
| $\phi_{A8,G1}$ | 0.07 (0.02) | 0.15 (0.13) | 0.10 (0.03) | 0.11 (0.02) |
| $\phi_{A9,B3}$ | 0.05 (0.02) | 0.02 (0.01) | 0.03 (0.02) | 0.03 (0.01) |
| $\phi_{A9,C2}$ | 0 | 0.01 (0.01) | 0.02 (0.02) | 0.01 (0.01) |
| $\phi_{A9,GH}$ | | 0.79 (0.04) | | |
| $\phi_{A9,G1}$ | 0.69 (0.04) | 0.74 (0.04) | 0.80 (0.05) | 0.74 (0.03) |
| $\phi_{B1,B2}$ | 0.95 (0.05) | 0.88 (0.12) | 0.77 (0.12) | 0.87 (0.06) |
| $\phi_{B2,B3}$ | 0.10 (0.07) | 0 | 0 | 0.03 (0.02) |
| $\phi_{B2,C2}$ | 0.05 (0.05) | 0 | 0 | 0.02 (0.02) |
| $\phi_{B2,D1}$ | 0.30 (0.10) | 0.57 (0.19) | 0.10 (0.09) | 0.32 (0.08) |
| $\phi_{B2,E1}$ | 0.40 (0.11) | 0.14 (0.13) | 0.20 (0.13) | 0.25 (0.07) |
| $\phi_{B3,D1}$ | 0.17 (0.07) | 0 | 0.39 (0.12) | 0.19 (0.05) |
| $\phi_{B3,E1}$ | 0.55 (0.09) | 0.50 (0.13) | 0.39 (0.11) | 0.48 (0.07) |
| $\phi_{B3,GH(A)}$ | | 0.15 (0.10) | | |
| $\phi_{B3,GH(B)}$ | | | | |
| $\phi_{B3,G1(A)}$ | 0.03 (0.03) | 0.14 (0.09) | 0.06 (0.05) | 0.08 (0.04) |
| $\phi_{B3,G1(B)}$ | 0 | | | |

**Table E2. (Continued)**

| Parameter | Release Group 1 | Release Group 2 | Release Group 3 | Population Estimate |
|---|---|---|---|---|
| $\phi_{C1,B3}$ | | | | |
| $\phi_{C1,C2}$ | | | | |
| $\phi_{C1,D1}$ | | | | |
| $\phi_{C1,E1}$ | | | | |
| $\phi_{C2,D1}$ | 0.17 (0.15) | 0.18 (0.09) | 0.43 (0.19) | 0.26 (0.09) |
| $\phi_{C2,E1}$ | 0.33 (0.19) | 0.65 (0.12) | 0.43 (0.19) | 0.47 (0.10) |
| $\phi_{C2,GH(A)}$ | | 0 | | |
| $\phi_{C2,GH(B)}$ | | | | |
| $\phi_{C2,G1(A)}$ | 0 | 0 | 0 | 0 |
| $\phi_{C2,G1(B)}$ | 0 | | | |
| $\phi_{D1,D2}$ | 0.50 (0.14) | 1 | 0.91 (0.09) | 0.80 (0.05) |
| $\phi_{D2,G2}$ | 0.00 | 0.14 (0.13) | 0.31 (0.15) | 0.15 (0.07) |
| $\phi_{D1,G2}$ | 0.00 | 0.14 (0.13) | 0.28 (0.14) | 0.14 (0.06) |
| $\phi_{E1,E2}$ | 0.32 (0.12) | 0.42 (0.11) | 0.25 (0.13) | 0.33 (0.07) |
| $\phi_{E2,G2}$ | 0.60 (0.22) | 0.50 (0.18) | 0.68 (0.28) | 0.59 (0.13) |
| $\phi_{F1,B3}$ | 0.32 (0.07) | 0.12 (0.04) | 0.31 (0.06) | 0.25 (0.04) |
| $\phi_{F1,C2}$ | 0.06 (0.03) | 0.19 (0.05) | 0.08 (0.04) | 0.11 (0.02) |
| $\phi_{F1,GH}$ | | 0.13 (0.04) | | |
| $\phi_{F1,G1}$ | 0.11 (0.05) | 0.12 (0.04) | 0.16 (0.05) | 0.13 (0.03) |
| $\phi_{G1,G2(A)}$ | 0.84 (0.04) | 0.79 (0.04) | 0.72 (0.06) | 0.78 (0.03) |
| $\phi_{G1,G2(B)}$ | | | | |
| $\psi_{A1}$ | 0.94 (0.01) | 0.97 (0.01) | 0.92 (0.02) | 0.94 (0.01) |
| $\psi_{A2}$ | 0.77 (0.04) | 0.77 (0.03) | 0.63 (0.04) | 0.72 (0.02) |
| $\psi_{B1}$ | 0.06 (0.01) | 0.03 (0.01) | 0.08 (0.02) | 0.06 (0.01) |
| $\psi_{B2}$ | | | | |
| $\psi_{C2}$ | | | | |
| $\psi_{F2}$ | 0.23 (0.04) | 0.23 (0.03) | 0.37 (0.04) | 0.28 (0.02) |
| $\psi_{G1(A)}$ | | 0.94 (0.03) | | |
| $\psi_{G1(B)}$ | | | | |
| $\psi_{H1(A)}$ | | 0.06 (0.03) | | |
| $\psi_{H1(B)}$ | | | | |
| $P_{A0a}$ | 0.06 (0.06) | 0.56 (0.12) | 0.65 (0.07) | 0.42 (0.05) |
| $P_{A0b}$ | 0.33 (0.27) | 0.60 (0.13) | 0.47 (0.06) | 0.47 (0.10) |
| $P_{A2a}$ | [pooled] | | | |
| $P_{A2b}$ | [pooled] | | | |
| $P_{A2}$ | 0.64 (0.03) | | | |
| $P_{A3}$ | 0.18 (0.02) | 0.11 (0.02) | 0.62 (0.04) | 0.30 (0.02) |
| $P_{A4}$ | 1 | 1 | 1 | 1 |
| $P_{A5}$ | 1 | 1 | 1 | 1 |
| $P_{A6}$ | 1 | 1 | 1 | 1 |

**Table E2. (Continued)**

| Parameter | Release Group 1 | Release Group 2 | Release Group 3 | Population Estimate |
|---|---|---|---|---|
| $P_{A7}$ | 0.98 (0.01) | 0.99 (0.01) | 0.94 (0.02) | 0.97 (0.01) |
| $P_{A8a}$ | 0.95 (0.02) | [pooled] | 0.98 (0.02) | |
| $P_{A8b}$ | 0.97 (0.01) | [pooled] | 0.93 (0.03) | |
| $P_{A8}$ | 1.00 (< 0.01) | 0.97 (0.02) | 1.00 (< 0.01) | 0.99 (0.01) |
| $P_{A9a}$ | 0.99 (0.01) | 0.99 (0.01) | 0.98 (0.02) | 0.99 (0.01) |
| $P_{A9b}$ | 0.96 (0.02) | 0.99 (0.01) | 1 | 0.98 (0.01) |
| $P_{B1}$ | 1 | 1 | 1 | 1 |
| $P_{B2a}$ | 1 | 1 | [pooled] | |
| $P_{B2b}$ | 1 | 0.29 (0.17) | [pooled] | |
| $P_{B2}$ | 1 | 1 | 1 | 1 |
| $P_{B3a}$ | 1 | 1 | 1 | 1 |
| $P_{B3b}$ | 1 | 0.93 (0.07) | 1 | 0.98 (0.02) |
| $P_{C1a}$ | | | | |
| $P_{C1b}$ | | | | |
| $P_{C1}$ | | | | |
| $P_{C2a}$ | 0.86 (0.13) | 0.94 (0.06) | 1 | 0.93 (0.05) |
| $P_{C2b}$ | 1 | 1 | 1 | 1 |
| $P_{D1}$ | 1 | 1 | 1 | 1 |
| $P_{D2a}$ | 1 | 1 | 1 | 1 |
| $P_{D2b}$ | 1 | 0.86 (0.13) | 1 | 0.95 (0.04) |
| $P_{D2}$ | 1 | 1 | 1 | 1 |
| $P_{E1}$ | 1 | 1 | 1 | 1 |
| $P_{E2}$ | 0.60 (0.22) | 1 | 1 | 0.87 (0.07) |
| $P_{F1a}$ | 0.43 (0.11) | 1 | 0.96 (0.03) | 0.80 (0.04) |
| $P_{F1b}$ | 0.25 (0.08) | 0.98 (0.02) | 1 | 0.75 (0.03) |
| $P_{F1}$ | 0.58 (0.11) | 1 | 1 | 0.86 (0.04) |
| $P_{G1a}$ | 0.89 (0.03) | [pooled] | 0.77 (0.05) | |
| $P_{G1b}$ | 0.86 (0.04) | [pooled] | 0.79 (0.05) | |
| $P_{G1}$ | 0.98 (0.01) | 0.88 (0.03) | 0.95 (0.02) | 0.94 (0.01) |
| $P_{G2a}$ | 0.93 (0.03) | 0.95 (0.02) | 0.82 (0.05) | 0.90 (0.02) |
| $P_{G2b}$ | 0.98 (0.02) | 0.92 (0.03) | 0.91 (0.04) | 0.94 (0.02) |
| $P_{G2}$ | 1.00 (< 0.01) | 1.00 (< 0.01) | 0.98 (0.01) | 0.99 (< 0.01) |
| $P_{H1a}$ | | 0.67 (0.27) | | |
| $P_{H1b}$ | | 0.33 (0.19) | | |
| $P_{H1}$ | | 0.78 (0.22) | | |

**Table E3. Parameter estimates (standard errors in parentheses) for tagged juvenile steelhead released in 2012, including predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are weighted averages of the release-specific estimates. Some parameters were not estimable because of sparse data.**

| Parameter | Release Group 1 | Release Group 2 | Release Group 3 | Population Estimate |
|---|---|---|---|---|
| $S_{A2}$ | 0.89 (0.05) | | | |
| $S_{A3}$ | 0.84 (0.04) | 0.72 (0.06) | 0.70 (0.04) | 0.75 (0.03) |
| $S_{A4}$ | 0.99 (0.01) | 0.98 (0.01) | 0.97 (0.01) | 0.98 (0.01) |
| $S_{A5}$ | 0.95 (0.01) | 0.96 (0.01) | 0.96 (0.02) | 0.96 (0.01) |
| $S_{A6}$ | 0.97 (0.01) | 0.97 (0.01) | 0.99 (0.01) | 0.98 (0.01) |
| $S_{A7}$ | 0.87 (0.04) | 0.89 (0.02) | 0.94 (0.02) | 0.90 (0.02) |
| $S_{A7,G2}$ | 0.32 (0.03) | 0.40 (0.03) | 0.39 (0.04) | 0.37 (0.02) |
| $S_{A8,G2}$ | 0.41 (0.04) | 0.53 (0.04) | 0.52 (0.06) | 0.49 (0.03) |
| $S_{B1}$ | | | | |
| $S_{B2,G2}$ | 0.14 (0.06) | 0.10 (0.06) | 0.07 (0.04) | 0.10 (0.03) |
| $S_{B2(SD)}$ | 0.90 (0.07) | 0.67 (0.16) | 0.46 (0.14) | 0.68 (0.07) |
| $S_{C1,G2}$ | | | | |
| $S_{C1(SD)}$ | | | | |
| $S_{F1,G2}$ | 0.13 (0.06) | 0.17 (0.05) | 0.24 (0.06) | 0.18 (0.03) |
| $\phi_{A1,A0}$ | 0.07 (0.03) | 0.07 (0.01) | 0.21 (0.02) | 0.12 (0.01) |
| $\phi_{A1,A2}$ | 0.93 (0.02) | | | |
| $\phi_{A1,A3}$ | 0.82 (0.04) | 0.92 (0.08) | 0.52 (0.03) | 0.75 (0.03) |
| $\phi_{A8,A9}$ | 0.60 (0.04) | 0.67 (0.03) | 0.78 (0.05) | 0.68 (0.02) |
| $\phi_{A8,B3}$ | 0.04 (0.01) | 0.02 (0.01) | 0 | 0.02 (0.01) |
| $\phi_{A8,C2}$ | 0.01 (0.01) | 0.03 (0.01) | 0.02 (0.02) | 0.02 (0.01) |
| $\phi_{A8,GH}$ | | 0.17 (0.03) | | |
| $\phi_{A8,G1}$ | 0.08 (0.02) | 0.15 (0.03) | 0.11 (0.03) | 0.11 (0.02) |
| $\phi_{A9,B3}$ | 0.06 (0.02) | 0.02 (0.01) | 0.03 (0.02) | 0.04 (0.01) |
| $\phi_{A9,C2}$ | 0 | 0.01 (0.01) | 0.02 (0.02) | 0.01 (0.01) |
| $\phi_{A9,GH}$ | | 0.79 (0.04) | | |
| $\phi_{A9,G1}$ | 0.66 (0.04) | 0.73 (0.04) | 0.80 (0.05) | 0.73 (0.03) |
| $\phi_{B1,B2}$ | 1 | 0.82 (0.12) | 0.76 (0.10) | 0.86 (0.05) |
| $\phi_{B2,B3}$ | 0.10 (0.07) | 0 | 0 | 0.03 (0.02) |
| $\phi_{B2,C2}$ | 0.05 (0.05) | 0 | 0.08 (0.07) | 0.04 (0.03) |
| $\phi_{B2,D1}$ | 0.30 (0.10) | 0.44 (0.16) | 0.08 (0.07) | 0.27 (0.07) |
| $\phi_{B2,E1}$ | 0.45 (0.11) | 0.22 (0.14) | 0.31 (0.13) | 0.33 (0.07) |
| $\phi_{B3,D1}$ | 0.19 (0.07) | 0.08 (0.07) | 0.44 (0.12) | 0.24 (0.05) |
| $\phi_{B3,E1}$ | 0.39 (0.09) | 0.46 (0.14) | 0.38 (0.12) | 0.41 (0.07) |
| $\phi_{B3,GH(A)}$ | | 0.16 (0.10) | | |
| $\phi_{B3,GH(B)}$ | | | | |
| $\phi_{B3,G1(A)}$ | 0.06 (0.04) | 0.15 (0.10) | 0.06 (0.06) | 0.09 (0.04) |
| $\phi_{B3,G1(B)}$ | 0 | | | |
| $\phi_{C1,B3}$ | | | | |

### Table E3. (Continued)

| Parameter | Release Group 1 | Release Group 2 | Release Group 3 | Population Estimate |
|---|---|---|---|---|
| $\phi_{C1,C2}$ | | | | |
| $\phi_{C1,D1}$ | | | | |
| $\phi_{C1,E1}$ | | | | |
| $\phi_{C2,D1}$ | 0 | 0.17 (0.09) | 0.43 (0.19) | 0.20 (0.07) |
| $\phi_{C2,E1}$ | 0.33 (0.19) | 0.61 (0.12) | 0.44 (0.19) | 0.46 (0.10) |
| $\phi_{C2,GH(A)}$ | | 0 | | |
| $\phi_{C2,GH(B)}$ | | | | |
| $\phi_{C2,G1(A)}$ | 0 | 0 | 0 | 0 |
| $\phi_{C2,G1(B)}$ | 0 | | 0 | |
| $\phi_{D1,D2}$ | 0.67 (0.14) | 1 | 1 | 0.89 (0.05) |
| $\phi_{D2,G2}$ | 0.00 | 0.13 (0.12) | 0.28 (0.14) | 0.13 (0.06) |
| $\phi_{D1,G2}$ | 0.00 | 0.13 (0.12) | 0.28 (0.14) | 0.13 (0.06) |
| $\phi_{E1,E2}$ | 0.46 (0.13) | 0.47 (0.11) | 0.23 (0.12) | 0.39 (0.07) |
| $\phi_{E2,G2}$ | 0.67 (0.19) | 0.44 (0.17) | 0.68 (0.28) | 0.60 (0.13) |
| $\phi_{F1,B3}$ | 0.30 (0.07) | 0.12 (0.04) | 0.28 (0.06) | 0.23 (0.03) |
| $\phi_{F1,C2}$ | 0.08 (0.04) | 0.19 (0.05) | 0.08 (0.04) | 0.12 (0.02) |
| $\phi_{F1,GH}$ | | 0.13 (0.04) | | |
| $\phi_{F1,G1}$ | 0.11 (0.05) | 0.12 (0.04) | 0.16 (0.05) | 0.13 (0.03) |
| $\phi_{G1,G2(A)}$ | 0.83 (0.04) | 0.80 (0.04) | 0.72 (0.06) | 0.78 (0.03) |
| $\phi_{G1,G2(B)}$ | | | | |
| $\psi_{A1}$ | 0.94 (0.01) | 0.96 (0.01) | 0.90 (0.02) | 0.93 (0.01) |
| $\psi_{A2}$ | 0.82 (0.04) | 0.76 (0.03) | 0.63 (0.04) | 0.74 (0.02) |
| $\psi_{B1}$ | 0.06 (0.01) | 0.04 (0.01) | 0.10 (0.02) | 0.07 (0.01) |
| $\psi_{B2}$ | | | | |
| $\psi_{C2}$ | | | | |
| $\psi_{F2}$ | 0.18 (0.04) | 0.24 (0.03) | 0.37 (0.04) | 0.26 (0.02) |
| $\psi_{G1(A)}$ | | 0.94 (0.03) | | |
| $\psi_{G1(B)}$ | | | | |
| $\psi_{H1(A)}$ | | 0.06 (0.03) | | |
| $\psi_{H1(B)}$ | | | | |
| $P_{A0a}$ | 0.24 (0.10) | 0.63 (0.11) | 0.79 (0.05) | 0.55 (0.05) |
| $P_{A0b}$ | 0.50 (0.18) | 0.60 (0.11) | 0.71 (0.05) | 0.60 (0.07) |
| $P_{A2a}$ | [pooled] | | | |
| $P_{A2b}$ | [pooled] | | | |
| $P_{A2}$ | 0.64 (0.03) | | | |
| $P_{A3}$ | 0.18 (0.02) | 0.12 (0.02) | 0.64 (0.04) | 0.31 (0.02) |
| $P_{A4}$ | 1 | 1 | 1 | 1 |
| $P_{A5}$ | 1 | 1 | 1 | 1 |
| $P_{A6}$ | 1 | 1 | 1 | 1 |
| $P_{A7}$ | 0.98 (0.01) | 0.99 (0.01) | 0.94 (0.02) | 0.97 (0.01) |

**Table E3. (Continued)**

| Parameter | Release Group 1 | Release Group 2 | Release Group 3 | Population Estimate |
|---|---|---|---|---|
| $P_{A8a}$ | 0.92 (0.02) | [pooled] | 0.95 (0.02) | |
| $P_{A8b}$ | [pooled] | [pooled] | 0.98 (0.02) | |
| $P_{A8}$ | [pooled] | [pooled] | 0.94 (0.03) | |
| $P_{A9a}$ | 0.97 (0.03) | 0.97 (0.02) | 1.00 (< 0.01) | 0.98 (0.01) |
| $P_{A9b}$ | 0.98 (0.01) | 0.99 (0.01) | 0.98 (0.02) | 0.99 (0.01) |
| $P_{B1}$ | 1 | 1 | 1 | 1 |
| $P_{B2a}$ | 1 | 1 | [pooled] | |
| $P_{B2b}$ | 1 | 0.22 (0.14) | [pooled] | |
| $P_{B2}$ | 1 | 1 | 1 | 1 |
| $P_{B3a}$ | 1 | 1 | 1 | 1 |
| $P_{B3b}$ | 1 | 0.92 (0.07) | 1 | 0.97 (0.02) |
| $P_{C1a}$ | | | | |
| $P_{C1b}$ | | | | |
| $P_{C1}$ | | | | |
| $P_{C2a}$ | 0.86 (0.13) | 0.94 (0.05) | 1 | 0.93 (0.05) |
| $P_{C2b}$ | 1 | 1 | 1 | 1 |
| $P_{D1}$ | 1 | 1 | 1 | 1 |
| $P_{D2a}$ | 1 | 1 | 1 | 1 |
| $P_{D2b}$ | 0.87 (0.12) | 0.87 (0.12) | 1 | 0.92 (0.06) |
| $P_{D2}$ | 1 | 1 | 1 | 1 |
| $P_{E1}$ | 1 | 1 | 1 | 1 |
| $P_{E2}$ | 0.57 (0.19) | 1 | 1 | 0.86 (0.06) |
| $P_{F1a}$ | 0.54 (0.14) | 1 | 0.96 (0.03) | 0.83 (0.05) |
| $P_{F1b}$ | 0.29 (0.09) | 0.98 (0.02) | 1 | 0.76 (0.03) |
| $P_{F1}$ | 0.67 (0.13) | 1 | 1 | 0.89 (0.04) |
| $P_{G1a}$ | 0.89 (0.03)0.81 (0.04) | [pooled] | 0.77 (0.05) | |
| $P_{G1b}$ | 0.86 (0.03) | [pooled] | 0.79 (0.05) | |
| $P_{G1}$ | 0.98 (0.01) | 0.88 (0.03) | 0.95 (0.02) | 0.94 (0.01) |
| $P_{G2a}$ | 0.93 (0.03) | 0.95 (0.02) | 0.82 (0.05)0.90 (0.05) | 0.90 (0.02) |
| $P_{G2b}$ | 0.98 (0.02) | 0.92 (0.03) | 0.91 (0.04) | 0.94 (0.02) |
| $P_{G2}$ | 1.00 (< 0.01) | 1.00 (< 0.01) | 0.98 (0.01) | 0.99 (<0.01) |
| $P_{H1a}$ | | 0.67 (0.27) | | |
| $P_{H1b}$ | | 0.33 (0.19) | | |
| $P_{H1}$ | | 0.78 (0.22) | | |

# Appendix F. Update on 2011 Survival through Facilities

Survival through the water export facilities was estimated for the 2011 steelhead tagging study (USBR 2018). However, results presented in the 2011 OCAP report represented only those tagged steelhead that arrived at the interior receivers in or closest to the facilities via the Old River route, excluding those that arrived via the San Joaquin River route. In 2011, the majority of the steelhead detected at the radial gates at the Clifton Court Forebay (194 of 233) and at the CVP trashracks (66 of 80) came via the Old River route, but some steelhead arrived via the San Joaquin River route. Average estimated survival from the CVP holding tank to Chipps Island, Jersey Point, or False River was 0.94 ($\widehat{SE} = 0.03$) for Old River route fish alone, and 0.92 ($\widehat{SE} = 0.03$) for both the Old River route and the San Joaquin River route combined (Table G1). Average survival from the interior receivers at the radial gates at the Clifton Court Forebay to Chipps Island, Jersey Point, or False River was 0.73 ($\widehat{SE} = 0.03$) for fish from the Old River route alone, and 0.70 ($\widehat{SE} = 0.03$) for both routes combined (Table G1). In each case, the difference observed by including the San Joaquin River route was not significant at the 5% level (P≥0.4205).

**Table F1. Estimates of survival in 2011 from the CVP holding tank or interior radial gates receiver to Chipps Island, Jersey Point, and False River for tagged steelhead that arrived at CVP or radial gates via only the Old River route, or via either the Old River route or the San Joaquin River route. Standard errors are in parentheses.**

| | From CVP holding tank | | From Radial Gates (Interior) | |
|---|---|---|---|---|
| Release Group | OR Route | OR and SJR Route | OR Route | OR and SJR Route |
| 1[a] | 0.88 (0.16) | 0.88 (0.16) | 0.72 (0.08) | 0.72 (0.88) |
| 2 | 0.90 (0.07) | 0.88 (0.07) | 0.74 (0.06) | 0.70 (0.06) |
| 3 | 0.91 (0.09) | 0.87 (0.09) | 0.73 (0.06) | 0.71 (0.06) |
| 4 | 1 (0) (n=22) | 0.98 (0.05) | 0.79 (0.08) | 0.76 (0.06) |
| 5 | 0.93 (0.07) | 0.93 (0.07) | 0.38 (0.17) | 0.31 (0.13) |
| 2-5 | 0.95 (0.03) | 0.92 (0.03) | 0.73 (0.04) | 0.69 (0.03) |
| 3-4 | 0.98 (0.04) | 0.93 (0.05) | 0.76 (0.05) | 0.73 (0.04) |
| Pooled | 0.94 (0.03) | 0.92 (0.03) | 0.73 (0.03) | 0.70 (0.03) |

a = No tagged steelhead from this release group were detected at the CVP holding tank or the radial gates coming from the San Joaquin River route.