2014 Six-Year Acoustic Telemetry Steelhead Study: Statistical Methods and Results

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Executive Summary

A total of 1,432 acoustic-tagged steelhead were released into the San Joaquin River at Durham Ferry in March, April, and May of 2014: 474 in late March, 480 in late April, and 478 in late May. Detection data were also available from 150 acoustic tags implanted into several species of predatory fish released in the Delta in April – May 2014. Acoustic tags were detectable on VEMCO hydrophones located at 38 stations throughout the lower San Joaquin River and Delta to Chipps Island (i.e., Mallard Slough) and Benicia Bridge. A rock barrier was installed at the head of Old River in early April 2014. Tagging and observation data were processed to construct detection histories, and data were passed through a predator filter to identify and remove detections thought to come from predators. Detection history data were analyzed using a multi-state release-recapture model to estimate survival, route selection, and transition probabilities throughout the Delta; receiver station detection probabilities were estimated concurrently from the release-recapture model. The survival and transition probabilities were adjusted for premature tag failure based on modeled tag survival for the April and May release groups. No attempt was made to adjust survival estimates from the March release group for premature tag failure because a manufacturing error turned off the March tags after approximately 7–28 days of battery use; the survival estimates from the March release group should be interpreted as the joint probability of fish and tag survival, and are minimum estimates of steelhead survival. For all release groups, survival estimates included both the probability of migrating downriver and surviving, so that the complement included the probability of residualization as well as mortality.

Using only those detections classified as coming from juvenile steelhead by the predator filter, the estimates of total survival from Mossdale to Chipps Island, S_{Total}, ranged from 0.06 ($\widehat{SE} = 0.02$) for the May release group, to 0.43 ($\widehat{SE} = 0.03$) for the April release group; the overall population estimate for the April and May releases (i.e., all those fish with functioning tags) was 0.24 ($\widehat{SE} = 0.02$). The joint probability of both the fish and tag surviving from Mossdale to Chipps Island was estimated at 0.18 ($\widehat{SE} = 0.03$) for the March release group; this estimate represents a minimum point estimate for the probably of steelhead Delta survival for that group, and is likely an underestimate of true steelhead survival. The estimated probability of entering Old River at its head was high for the March release (0.91, $\widehat{SE} = 0.02$), when the barrier was not installed, and considerably lower for the April and May releases, which passed mostly after the barrier was in place (April and May population estimate = 0.08, $\widehat{SE} = 0.02$). Estimates of survival from Mossdale to Chipps Island via the San Joaquin River route (S_A)

ranged from 0 for March (95% upper bound = 0.21) to 0.43 ($\widehat{SE} = 0.03$) for April; the population estimate, averaged over the April and May release group, was 0.25 ($\widehat{SE} = 0.02$) overall. The March estimate was confounded with premature tag loss. In the Old River route, estimates of survival from Mossdale to Chipps Island (S_B) ranged from 0.07 ($\widehat{SE} = 0.07$; 95% upper bound = 0.29) for the May release to 0.31 ($\widehat{SE} = 0.09$) for the April release (April and May population average = 0.19, $\widehat{SE} = 0.06$). The joint fish-tag estimate of S_B was 0.19 ($\widehat{SE} = 0.03$) for the March release group. The route-specific survival to Chipps Island was significantly different between routes only for the March release group, when survival was higher in the Old River route than in the San Joaquin River route (P<0.0001); however, the survival estimates in that case represented the joint probability of both fish and tag survival.

Travel time from release at Durham Ferry to Chipps Island ranged from 4.4 days to 29.0 days, and averaged 9.77 days ($\widehat{SE} = 0.32$ days) for tagged steelhead released in April and May. Travel time from release averaged approximately 2 days to the Mossdale receivers, and approximately 6 days to the Turner Cut junction (i.e., either Turner Cut receivers or MacDonald Island receivers) for the April and May release groups. Travel times for the March release group were confounded with premature tag failure.

A barrier was in place at the head of Old River for most of the 2014 tagging study. Of the tagged steelhead that arrived at the head of Old River before the barrier closure during installation, all but 4 entered Old River, so no route selection analysis was performed for the head of Old River. At the Turner Cut junction, tagged steelhead were predicted to have a higher probability of entering Turner Cut if they arrived when river flow was directed into Turner Cut from the San Joaquin River, and on a rising (incoming or flood) tide. Associations between route selection at Turner Cut and measures of exports were not significant (P=0.5678 for SWP, P=0.8112 for CVP).

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Introduction

A total of 1,432 acoustic-tagged steelhead were released into the San Joaquin River at Durham Ferry in March, April, and May of 2014: 474 in late March, 480 in late April, and 478 in late May. Each steelhead was surgically implanted with a VEMCO V5 microacoustic tag. Each acoustic tag was custom-programmed with two coding schemes that incorporated three separate tag codes: a traditional Pulse Position Modulation (PPM) code that pulsed every 60 s (mean), and two hybrid PPM/HR (High Residence) tag codes that pulsed every 60 s (mean). The acoustic tags were detectable on hydrophones located at 38 stations throughout the lower San Joaquin River and Delta to Chipps Island (i.e., Mallard Slough) and Benicia Bridge. Detection data were also available from 150 acoustic tags implanted into several species of predatory fish released in the Delta in April – May 2014. A rock barrier was installed at the head of Old River in early April 2014.

VEMCO acoustic hydrophones and receivers were installed at 38 stations throughout the lower San Joaquin River and Delta in 2014 (Figure 1, Table 1). Most of the receiver sites used in the 2013 steelhead tagging study (USBR 2018c) were also used in 2014. As in 2012 and 2013, the Paradise Cut sites used in 2011 were not used in 2014 because flows were too low for fish to enter Paradise Cut. Sites from 2013 that were omitted from the 2014 study were the San Joaquin River Shipping Channel receivers (SJS), and Middle River near Empire Cut (MRE) (USBR 2018c). Twelve new receiver stations were used in 2014: in West Canal, just north of the entrance channel to Clifton Court Forebay (WCL); in northern Old River near its mouth into the San Joaquin River (OSJ); in Middle River near Mildred Island (MID); in Montezuma and Spoonbill sloughs (MZT, SBS), located just upstream of Chipps Island; and seven receivers (RS4–RS10) in the San Joaquin River between the Lathrop and Garwood Bridge receivers. The RS4–RS10 receivers were installed for use in a concurrent predator removal study (Smith et al. 2016).

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 2014, 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. Additionally, some tags were deactivated after initial activation, and then reactivated before being implanted in a steelhead and released to the river. For these tags, a “virtual activation date” was computed that accounted for the entire time the tag battery was active before the fish implanted with the tag was released. The virtual activation date was used as the basis for taglife adjustments to fish survival estimates (see “Analysis of Tag Failure”).

Acoustic tag detection data collected at individual monitoring sites (Table 1) 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 autoprocessed database was cleaned to remove obviously invalid detections. The University of Washington identified potentially invalid detections based on unexpected travel times or unexpected 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;” consecutive visits to a receiver were separated either by a gap of at least 12 hours 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.

The same data structure and data processing procedure were used to summarize detections of the acoustic-tagged predatory fish. Detections of the predatory fish were compared to detections of the steelhead tags to assist in distinguishing between detections of steelhead and detections of predators (see below).

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 2014 data was based on the predator filter designed and used in the analysis of the 2011, 2012, and 2013 data (USBR 2018a, 2018b, 2018c). The 2011 predator filter 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 2011 predator filter served as the basis for construction of the predator filters used in later years. The 2014 filter was applied to all detections of all tags implanted in steelhead. Two datasets were then constructed: the full dataset of all detections, including those classified as coming from predators (i.e., “predator-type”), and the reduced dataset, restricted to those detections classified as coming from live juvenile steelhead (i.e., “steelhead-type”). The survival model was fit to both datasets separately. The results from the analysis of the reduced “steelhead-type” dataset are presented as the final results of the 2014 Six-Year Steelhead tagging study. Results from analysis of the full dataset 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, or atypical movements within the Delta. 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 likely to improve model performance (i.e., fit) when these non-actively migrating steelhead detections are 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 juvenile steelhead and predators such as striped bass, largemouth bass, channel catfish, and white catfish. For each steelhead tag, 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 2). The environmental data were downloaded from the

California Data Exchange Center website (http://cdec.water.ca.gov/selectQuery.html) on 14 September 2016, and from the California Water Data Library (www.water.ca.gov/waterdatalibrary/) on 18 July 2016. Environmental data were reviewed for quality, and obvious errors were omitted. Daily pumping rates at the CVP and CCFB reservoir inflow rates were also used, downloaded from CDEC on 14 September 2016.

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 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 assigned a predator classification upon arrival at the detection site. A tag classified as being in a predator because of long residence time was assigned 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.

The predator filter used various criteria that addressed several spatial and temporal scales and fit under several categories (see USBR 2018a for more details): fish speed, residence time, upstream transitions, other unexpected transitions, travel time since release, and movements against flow. A predator score of at least 2 (i.e., failure to meet criteria of two or more predator filter components) was required to classify a tag as in a predator for a given transition if all previous detections had been classified as steelhead (USBR 2018a). If a previous detection had been classified as a predator, then all subsequent detections were classified as predators, also. The criteria used in the 2011–2013 studies were updated to reflect river conditions and observed tag detection patterns in 2014, and to represent transitions observed among the 2014 detection sites (Table 3). There were several new receiver sites installed in 2014 that were added to the predator filter: WCL (B3) = West Canal, OSJ (B5) = Old River at the San Joaquin River (i.e., Old River mouth), MZT (T2) = Montezuma Slough, SBS (T3) = Spoonbill Slough, BBR (G3) = Benicia Bridge, and seven receiver sites used for the NMFS predator removal study (RS4–RS10, model codes N1–N7) (Table 1). Sites MRE and SJS from 2013 were not used in 2014 (USBR 2018c).

Criteria for distinguishing between steelhead detections and predator detections were partially based on observed behavior of tags in fish that were presumed 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 juvenile steelhead rather than in steelhead predators. More weight was given to data from tags that were presumed to have passed through the SWP than through the CVP, because steelhead predators can enter the CVP holding tank but are thought to be too large to pass through the louvers at the SWP (personal communication, Kevin Clark, California Department of Water Resources). Tags presumed 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, 2012, and 2013 predator filters (USBR 2018a, 2018b, 2018c).

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), Benicia Bridge, Jersey Point, False River, or Montezuma or Spoonbill sloughs (i.e., JPE/JPW–BBR) 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 presumed 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 one of the JPE/JPW–BBR sites. This group may include tagged fish that migrated from the CCFB entrance to the JPE/JPW–BBR region in-river, 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 (i.e., JPE/JPW–BBR).

Additionally, in 2014, six acoustic-tagged steelhead were recaptured after release: 3 in the Mossdale trawl, and 3 via electrofishing as part of a complementary study. The tags recaptured in the

Mossdale trawl occurred 7–11 days after initial release at Durham Ferry; the electrofishing recaptures occurred near the head of Old River and between sites RS6 and RS7 approximately 9–11 days after initial release at Durham Ferry. The recapture events provided evidence that the steelhead acoustic tag was still in a live steelhead at the time of recapture, rather than in a predator's gut. The fixed site receiver detections of the recaptured steelhead tags that occurred prior to the recapture event provided information on the range of steelhead behavior, and were used to calibrate the predator filter for the regions represented by pre-recapture detections. In particular, the total score from the predator filter for each pre-recapture detection was required to be either 0 or 1, so that each pre-recapture detection was classified as coming from a likely steelhead rather than a likely predator. There was no limit placed on the predator score for detections of recaptured tags that occurred after the recapture event.

The criteria used in the predator filter were spatially explicit, with different limits defined for different receivers and transitions (Table 3). The overall approach used in the 2013 study was also used for the 2014 study; no new criteria were developed for the 2014 study. A change from the predator filter in previous years was removal of the requirement that upstream-directed transitions have migration rate or body length per second (BLPS) travel rate that was no greater than that observed on the downstream transition through the same reach. Components of the filter that are broadly applicable are described below, along with general criteria and/or exceptions for individual detection sites. This information largely complements that in Table 3, which provides detailed information on criteria for individual transitions. Only those transitions actually observed among either steelhead tags or predator tags (described below) are addressed. More information on the predator filter structure can be found in reports on the 2011, 2012, and 2013 studies in USBR (2018a, 2018b, 2018c).

The criteria newly developed for the 2013 study were retained for the 2014 study, including the maximum total visit length at a site (combined over multiple visits), time between visits to the same site, and large-scale movements from different regions of the study area. The maximum allowed time for detections anywhere since release at Durham Ferry was 1,000 hours. The default maximum total visit length at a site was 500 hours (approximately 21 days), although it was considerably longer upstream of the head of Old River and at the radial gates (D1, D2). The maximum total visit length was further limited to the maximum of either the mid-field residence time (i.e., duration from the first detection at a site without intervening detections elsewhere) or the far-field (i.e., regional) residence time, if less than the default limit for the site. The maximum regional residence time that was allowed for transitions depended on the values allowed for the mid-field residence time, travel time for the transition, and the regional residence time at previously detected sites in the region, if the tagged fish was coming from a site in the same region (see Table 4 for a description of the regions); if the tagged fish was coming from a different region, then the maximum allowed regional residence time was determined based only on the maximum mid-field residence time. More generally, regional residence times were limited to 1,000 hours upstream of the head of Old River and at the CVP (E1, E2), 800 hours in the vicinity of WCL (B3), OR4 (B4), and RGU/RGD (D1, D2), and 500 hours elsewhere in the study area; exceptions to this rule are indicated in Table 3. Unless otherwise specified, the maximum allowed length of an upstream foray (i.e., upstream directed movement that is uninterrupted by detections that indicated downstream movement between sites) was 20 km. The other criteria are specified below and in Table 3.

Detections in the San Joaquin River or near the heads of Old and Middle Rivers (B1, B2, C1) after previous entry to the Interior Delta (sites B3, B4, C2, C3, D1, D2, E1, and E2) from near Stockton or sites farther downstream in the San Joaquin River ("lower San Joaquin River"; sites N6, N7, A6–A9, R1, F1, and B5) were generally not allowed. The exceptions were at MacDonald Island (A8), Turner Cut (F1), and Medford Island (A9). Once fish had been detected arriving at either the CVP or the radial gates from the lower San Joaquin River, subsequent detection was allowed only at CVP (E1), the radial gates (D1/D2), Jersey Point (G1), False River (H1), Old River at its mouth (B5), Threemile Slough (T1), and the other sites downstream of Threemile Slough (T2, T3, G2, and G3). An exception was for West Canal (B3), for which post-facility transitions were allowed coming from the radial gates and Old River at Highway 4 (B4) for fish previously detected in the lower San Joaquin River. These restrictions were based on the assumption that juvenile steelhead that leave the lower San Joaquin River for the Interior Delta were not expected to return to the San Joaquin River, and those that leave the lower San Joaquin River for the water export facilities were 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. In general, travel time in the Interior Delta after entry to that region from the lower San Joaquin River was limited to 120 hours. For fish that entered the Interior Delta from the lower San Joaquin River and were then detected at the facilities, travel time in the Interior Delta after leaving the facilities was further limited to 100 hours. Transitions from the northern Delta sites (G1, G2, H1, T1) or western Delta sites (B2, B3, B4, C1, C2, D, E1, E2) back to the regions of the San Joaquin River near Stockton and farther upstream were not allowed. Finally, transitions from ORS (B2) or the head of Middle River (C1) upstream to the head of Old River (B1) were not expected following detection in the lower San Joaquin River, whether the tagged fish used the Interior Delta or the head of Old River to move from the lower San Joaquin River to the B2/C1 region. More site-specific details and exceptions to these general rules are described below, and in Table 3.

DFU, DFD = Durham Ferry Upstream (A0) and Durham Ferry Downstream (A2): allow long residence and transition times and multiple visits, maximum total visit length (summed over all visits to the site) = 1,000 hours.

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 to BCA, MOS, and HOR or longer travel times to MOS and HOR if arrival flow is low. Transitions from Old River East (B1) are not allowed if the HOR barrier is installed. Maximum total visit length to any of these sites = 1000 hours.

SJL = San Joaquin River near Lathrop (A5): transitions from Old River East (B1) are not allowed if the HOR barrier is in place. Maximum total visit length = 500 hours.

RS4–RS10 = Removal Study 4 (N1) through Removal Study 10 (N7): generally increasing regional residence times allowed for sites further downstream. Maximum total visit length = 55 hours.

SJG = San Joaquin River at Garwood Bridge (A6): repeat visits require arrival flow/velocity to be opposite direction from flow/velocity on previous departure. Maximum total visit length = 55 hours.

SJNB and RRI = San Joaquin River at Navy Bridge Drive (A7) and Rough and Ready Island (R1): fast transitions moving downstream require positive water velocity. Maximum total visit length = 45 hours. No previous detection in the northwestern region of the Delta.

MAC = San Joaquin River at MacDonald Island (A8): allow more flexibility (longer residence time, transition time) if transition water velocity was low and positive for downstream transitions. Maximum total visit length = 60 hours.

MFE/MFW = Medford Island (A9): allow more flexibility (longer transition time) if transition water velocity was low and positive for downstream transitions; transitions from interior Delta sites (MID) must have departed interior Delta sites with very low or positive flow/velocity. Maximum total visit length = 500 hours. If coming from MID, no prior transition to the Interior Delta from the lower San Joaquin River.

ORE = Old River East (B1): require fewer transitions and shorter residence times if the HOR barrier is in place; maximum total visit length = 280 hours. For transitions from ORS and MRH, no prior detections in the lower San Joaquin River.

ORS = Old River South (B2): maximum total visit length = 500 hours. If coming from ORE, no prior detection in the northwest Delta.

WCL = West Canal (B3): allow many visits; should not arrive against flow or water velocity, or have departed RGU/RGD against strong inflow or CVP against strong pumping. Maximum total visit length = 30 hours. No prior transition to facilities from the lower San Joaquin River if coming from CVP, ORS, or MR4; no prior transition to Interior Delta from the lower San Joaquin River if coming from CVP or ORS.

OR4 = Old River at Highway 4 (B4): should not arrive against flow or water velocity; maximum total visit length = 60 hours.

OSJ = Old River at the San Joaquin (B5): should not move against flow; repeat visits require arrival flow/velocity to be opposite direction from flow/velocity on previous departure. Maximum total visit length = 138 hours. If coming from MAC, MFE/MFW, or TCE/TCW, no prior transition to the facilities from the lower San Joaquin River, and no prior detection in the northwest Delta (allowed for transitions from MFE/MFW). If coming from OR4, no prior transition to the Interior Delta from the lower San Joaquin River via the head of Old River.

MRH = Middle River Head (C1): shorter residence times than at ORS; repeat visits are not allowed; maximum total visit length = 46 hours. If coming from ORE, no prior detection in the northwest Delta.

MR4 = Middle River at Highway 4 (C2): maximum total visit length = 60 hours. If coming from ORS, MRH, OR4, WCL, or RGU/RGD, no prior detections in the lower San Joaquin River.

MID = Middle River near Mildred Island (C3): should not move against flow; maximum total visit length = 134 hours. If coming from OR4, no prior detection in the lower San Joaquin River; if coming from MAC, MFE/MFW, or TCE/TCW, no prior detection in northwest Delta.

RGU/RGD = Radial Gates (D1, D2 = D): see USBR (2018c) for a general description of the residence time criteria at the radial gates. Maximum total visit length = 800 hours. Should not have moved against strong flow or CVP pumping. No prior transition to Interior Delta or facilities from the lower San Joaquin River if coming from ORS.

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. Maximum total visit length = 500 hours. Maximum cumulative upstream foray length = 23 km. If coming from ORS, no prior transition to Interior Delta or facilities from the lower San Joaquin River. Maximum travel time in the Interior Delta after entering that region from the lower San Joaquin River = 180 hours for consecutive CVP transitions (i.e., CVP–CVP) and for transitions from WCL and RGU/RGD, and 120 hours otherwise.

CVPtank = Central Valley Project holding tank (E2): assume that steelhead can leave tank and return (personal communication, Brent Bridges, USBR). Maximum total visit length = 1000 hours. Maximum cumulative upstream foray length = 23 km.

TCE/TCW = Turner Cut (F1): should not move against flow. Maximum total visit length = 60 hours. If coming from SJNB, RRI, or MAC, no prior transition to the Interior Delta from the lower San Joaquin River.

JPE/JPW and FRE/FRW = Jersey Point (G1) and False River (H1): no flow/velocity restrictions; maximum total visit length = 140 hours for JPE/JPW, and 73 hours for FRE/FRW. Maximum cumulative upstream foray length = 25 km if coming from JPE/JPW, FRE/FRW, SBS, or BBR. No prior transition to facilities from the lower San Joaquin River if coming from MAC, MFE/MFW, MID, OR4, or TCE/TCW; no prior detection in northwest Delta if coming from MAC, MFE/MFW, or TCE/TCW.

TMS/TMN = Threemile Slough (T1): should not move against flow on departing from San Joaquin River sites. Maximum total visit length = 47 hours. Maximum cumulative upstream foray length = 25 km.

No prior transition to facilities from the lower San Joaquin River or prior detection in northwest Delta if coming from MFE/MFW.

MTZ, SBS = Montezuma Slough (T2) and Spoonbill Slough (T3): No flow or velocity restrictions. Maximum total visit length = 10 hours for MTZ, and 4 hours for SBS; maximum cumulative upstream foray = 25 km.

MAE/MAW, BBR = Chipps Island (G2) and Benicia Bridge (G3): should not arrive from upstream against strong negative water velocity/flow (MAE/MAW). Maximum total visit length = 50 hours; maximum cumulative upstream foray = 25 km. No prior transition to facilities from the lower San Joaquin River if coming from MFE/MFW.

Fixed-site receiver detections were available from 150 predatory fish that had been implanted with acoustic tags as part of a predation study conducted by NMFS: 37 Striped Bass *Morone saxatilis*, 66 Largemouth Bass *Micropterus salmoides*, 29 White Catfish *Ameiurus catus*, and 18 Channel Catfish *Ictalurus punctatus*. Releases of tagged predatory fish took place in April and May of 2014, in reaches of the San Joaquin River between MOS (A4) and RS9 (N6) (Smith et al. 2016). The predator detections were used to assess the sensitivity (i.e., true positive rate) of the predator filter. A "positive" outcome was a predator score of 2 or more on at least one detection on the visit spatiotemporal scale during the detection history; earning a predator score ≥ 2 on every detection of the predator tag was not required. Filter sensitivity was measured as the proportion of the predator tags that were classified as in a predator at some point during their detection history within 2014. Only predator tags that were detected on at least one fixed site receiver were used in the sensitivity assessment. Some components of the predator filter use information from multiple detections, with the result that tags that have more observations are more likely to be classified as in a predator. Thus, the filter sensitivity was measured first using all detected predator tags, and then using only those that had at least five detections on the "visit" spatiotemporal scale. A sensitivity of 100% indicates a perfect ability to classify predators correctly, although it is still possible that live steelhead may be erroneously classified as predators.

The filter specificity (true negative rate) is the ability of the filter to correctly classify detections of steelhead as coming from steelhead rather than predatory fish. Assessing the filter specificity requires tags that are known to be in steelhead at some point after their initial release. There were 6 steelhead tags recaptured after initial release in 2014. These 6 tags were used in calibrating the filter, however, and so it was not appropriate to use them also for assessing the filter specificity. No attempt was made to monitor filter specificity.

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. In particular, if a fish was observed even far downstream in one route but then returned to the river junction and finally selected the other route, then survival and detection in the later route were modeled. Detections from the receivers comprising certain dual arrays were pooled, thereby converting the dual arrays to redundant arrays: the San Joaquin River receivers from Banta Carbona (A3) downstream to Garwood Bridge (A6); the Central Valley Project trash racks (E1); and the radial gates just outside of Clifton Court Forebay (D1). The model fit was improved by also pooling dual array detections to redundant arrays at Jersey Point (G1) and Chipps Island (G2); treating the Chipps Island receivers as a redundant array rather than a dual array was possible because of the Benicia Bridge receivers (G3). 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), and Middle River at its head (C1). The status of the radial gates (opened or closed) upon detection at the receivers just outside the radial gates (D1) was included in the detection history. Detections on receivers at the Head of Old River site (B0), the predator removal study sites (N1–N7), Threemile Slough (T1), Montezuma Slough (T2), and Spoonbill Slough (T3) were used in determining the detection history, but were omitted from the survival model. Detections at West Canal (B3) were included in the model for the Old River from the head of Old River, but excluded from the San Joaquin River route.

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 was a modified version of the models used in the 2011–2013 steelhead analyses (USBR 2018a, 2018b, 2018c), 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 1 shows the layout of the receivers using both descriptive labels for site names and the code names used in the survival model (Table 1). The survival model represented movement and perceived survival throughout the study area to the primary exit point at Chipps Island (i.e., Mallard Island) (Figure 2, Figure 3). Individual receivers comprising dual arrays were identified separately, using "a" and "b" to represent the upstream and downstream receivers, respectively. Of the twelve new receiver stations introduced in 2014 (see *Introduction*), only the West Canal receiver (WCL = site B3) was used in the survival model, and it was used only in the Old River route. Unlike in 2013, the 2014 survival model used the receivers in Burns Cutoff around Rough and Ready Island near Stockton, CA (RRI = R). As in the past, the receivers located just upstream of the head of Old River (HOR = B0) and in Threemile Slough (TMS/TMN = T1) were omitted from the survival model.

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, CA, and past the city of Stockton, CA. 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 and the Old River mouth were monitored (TCE/TCW and OSJ, respectively). Turner Cut was used in the survival model, and was assigned route F, and treated as a subroute of route A. The Old River mouth route was not distinguished in the survival model from the mainstem San Joaquin River route, and site OSJ was omitted from the survival model. Fish that entered the interior Delta from the lower San Joaquin River 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. Another subroute of route A was Burns Cutoff around Rough and Ready Island, near Stockton, assigned subroute R.

For fish that entered Old River at its distributary point on the San Joaquin River just upstream of Lathrop, CA (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). Benicia Bridge was monitored in 2014; located downstream of Chipps Island, it was considered to be outside the study area, but facilitated in estimating survival to Chipps Island; Benicia Bridge was also assigned route G. Several additional sets of receivers located in the San Joaquin

River upstream of Stockton (Route A), Middle River (Subroute C) near Mildred Island, and in Threemile, Montezuma, and Spoonbill sloughs (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, Benicia Bridge: survival, exit point

H = False River: exit point

N = Predator Removal Study: not used in survival model

R = Rough and Ready Island: survival

T = Threemile, Montezuma, and Spoonbill sloughs: not used in survival model

The release-recapture model used parameters that denote the probability of detection (P_{hi}), route selection ("route entrainment", ψ_{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 2, Figure 3, Table A1). For each dual array, unique detection probabilities were estimated for the individual receivers in the 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. A new parameter was used in the 2014 model: the "last reach" parameter $\lambda = \phi_{G2,G3} P_{G3}$, representing the joint probability of successfully moving from Chipps Island to Benicia Bridge, and detection at Benicia Bridge. The complement of the last reach parameter, $1-\lambda$, includes the possibility of survival to Benicia Bridge but evading detection there, as well as mortality upstream of Benicia Bridge.

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.

ψ_{hl} = route selection probability: probability of a fish entering route h at junction l (l =1, 2, 3), conditional on fish surviving to junction l.

$\phi_{kj,hi}$ = transition probability: joint probability of migration, route selection, 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.

λ = joint transition and detection probability: joint probability of moving downstream from Chipps Island, surviving to Benicia Bridge, and detection at Benicia Bridge, conditional on survival to Chipps Island.

The transition parameters involving the receivers outside Clifton Court Forebay (site D1, RGU) depended on the status of the radial gates upon tag arrival at D1. Although fish that arrive at D1 when the gates are closed cannot immediately enter the gates to reach site D2 (RGD), they may linger in the area until the gates open. Thus, the parameters $\phi_{kj,D1O}$ and $\phi_{D1O,D2}$ represent transition to and from site D1 when the gates are open, and parameters $\phi_{kj,D1C}$ and $\phi_{D1C,D2}$ represent transition to and from D1 when the gates are closed. It was not possible to estimate unique detection probabilities at site D1 for open and closed gates, so a common probability of detection, P_{D1}, was assumed at that site regardless of gate status upon arrival. This assumption was reasonable in light of high detection probabilities at this site for most release groups ($\hat{P}_{D1}$ = 1 for all release groups with estimates) (Tables A1, A2, and A3).

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 1). 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 individuals using False River as an exit from the San Joaquin and individuals 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. $\phi_{A9,GH}$) is the transition probability to the junction of False River with the San Joaquin River via any route; ψ_{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 2).

Although the full survival model provides separate estimates for the transition probabilities to the Jersey Point/False River junction ($\phi_{kj,GH}$) and the route selection probability at that junction $\left(\psi_{G1}\right)$, it was not possible to estimate these two parameter separately in 2014. Of the 43 steelhead tags observed on the False River receivers, all but two of them were later detected at either Jersey Point, Chipps Island, or Threemile Slough, or had been detected at False River after salvage and release from the CVP, for which route False River is not a modeled way point or exit. There were too few detections available in the modeled detection histories at False River to reliably estimate the detection probability at that site. This meant that it was not possible to separately estimate the survival transition parameters $\phi_{kj,GH}$ from the route selection probability ψ_{G1}, for transitions from station j in route k. Instead, only their product was estimable: $\phi_{kj,G1} = \phi_{kj,GH}\psi_{G1}$. Because there were some detections at the H1 receivers, it is known that the route selection parameter $\psi_{G1} < 1$, and that the estimable parameter $\phi_{kj,G1}$ is not equal to $\phi_{kj,GH}$. However, it was not possible to estimate the difference between these parameters.

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 2).

Some salvaged and transported fish 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, and in particular those released in the Sacramento River, 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 2018a, 2018b; 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 2011–2013 analyses (USBR 2018a, 2018b, 2018c). 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 2). 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 (Figure 3). 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: B4 (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: detections from Route B fish were used in Submodel I, and detections from Route A fish were used 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. Following similar reasoning, the "last reach" parameter (λ), representing the joint probability of transition from Chipps Island to Benicia Bridge and detection at Benicia Bridge, was estimated separately in the two submodels. In the 2011 study (USBR 2018a), 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. In 2014, however, sparse detections at the radial gates required using common transition parameters from the radial gates in the two submodels, regardless of the route used to arrive at the gates.

In addition to the model parameters, 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, when possible from the available data. 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:

$\psi_{AA} = \psi_{A1}\psi_{A3}$: probability of remaining in the San Joaquin River past both the head of Old River and the Turner Cut Junction,

$\psi_{AF} = \psi_{A1}\psi_{F3}$: 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 $\psi_{B1} = 1 - \psi_{A1}$, $\psi_{F3} = 1 - \psi_{A3}$, and $\psi_{C2} = 1 - \psi_{B2}$. In cases where there were too few detections in the Route A to model detections downstream of site A6 (i.e., for the first release group), route selection probabilities were not available for the subroutes within route A, and only $\psi_A = \psi_{A1}$ was estimated for route A.

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

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

$S_{AF} = S_{A4} S_{A5} S_{A6,TCJ} S_{F1,G2}$: 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.

The measure $S_{A6,TCJ}$ is the probability of surviving from Garwood Bridge (A6) to the receivers just downstream of the Turner Cut junction (A8, F1), and includes both passing Rough and Ready Island via the San Joaquin River (ψ_{A2}) and passing it via Burns Cutoff (ψ_{R2}):

$$S_{A6,TCJ} = S_{A6} \left(\psi_{A2} S_{A7} + \psi_{R2} S_{R1} \right).$$

In cases where detections were sparse downstream of either site A5 in route A or site B1 in route B, Delta survival could not be estimated for the individual subroutes in the affected primary route.

The parameters $S_{A8,G2}$ and $S_{F1,G2}$ represent the probabilities 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 1). 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 (Figure 2).

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 (MRH), 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 1). 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 to the next receivers along a route (i.e., the $\phi_{kj,hi}$ parameters defined above and in Figure 2) could be estimated. However, the overall survival probability from B2 ($S_{B2,G2}$) or C1 ($S_{C1,G2}$) to Chipps Island was estimable by summing products of the $\phi_{kj,hi}$ parameters:

$$\begin{aligned} S_{B2,G2} \quad = \quad & \left(\phi_{B2,D1O}\phi_{D1O,D2} + \phi_{B2,D1C}\phi_{D1C,D2}\right)\phi_{D2,G2} + \phi_{B2,E1}\phi_{E1,E2}\phi_{E2,G2} + \\ & \left(\phi_{B2,B3}\phi_{B3,B4}\phi_{B4,GH} + \phi_{B2,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2} \end{aligned}$$

and

$$\begin{aligned} S_{C1,G2} \quad = \quad & \left(\phi_{C1,D1O}\phi_{D1O,D2} + \phi_{C1,D1C}\phi_{D1C,D2}\right)\phi_{D2,G2} + \phi_{C1,E1}\phi_{E1,E2}\phi_{E2,G2} + \\ & \left(\phi_{C1,B3}\phi_{B3,B4}\phi_{B4,GH} + \phi_{C1,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}. \end{aligned}$$

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 B4 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 $\phi_{B4,GH}$ and $\phi_{C2,GH}$, which represent the probability of moving from site B4 or C2, respectively, to the False River junction with the San Joaquin.

Both route selection 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 parameters 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:

$S_A = \psi_{A3} S_{AA} + \psi_{F3} S_{AF}$: 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 where the subroute-specific survival probabilities could not be estimated, the primary route-specific survival probabilities were defined as $S_A = S_{A4} S_{A5,G2}$ or $S_A = S_{A4} S_{A5} S_{A6,G2}$ for route A, and $S_B = S_{A4} S_{B1,G2}$ for route B, where $S_{A5,G2}$, $S_{A6,G2}$, and $S_{B1,G2}$ were estimated directly from a simplified Submodel I. 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, because trucked fish were not required to pass the Jersey Point/False River junction in order to reach Chipps Island. The route-specific Mid-Delta survival for the large-scale San Joaquin River and Old River routes was defined as follows:

$S_{A(MD)} = \psi_{A3} S_{AA(MD)} + \psi_{F3} S_{AF(MD)}$: 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

$$S_{AA(MD)} = S_{A4} S_{A5} S_{A6,TCJ} \left[\phi_{A8,GH} + \phi_{A8,A9} \phi_{A9,GH} + \left(\phi_{A8,B4} + \phi_{A8,A9} \phi_{A9,B4} \right) \phi_{B4,GH} + \left(\phi_{A8,C2} + \phi_{A8,A9} \phi_{A9,C2} \right) \phi_{C2,GH} \right],$$

$$S_{AF(MD)} = S_{A4} S_{A5} S_{A6,TCJ} \left[\phi_{F1,GH} + \phi_{F1,B4} \phi_{B4,GH} + \phi_{F1,C2} \phi_{C2,GH} \right],$$

$$S_{BB(MD)} = S_{A4} S_{B1} \left(\phi_{B2,B3} \phi_{B3,B4} \phi_{B4,GH} + \phi_{B2,C2} \phi_{C2,GH} \right), \text{ and}$$

$$S_{BC(MD)} = S_{A4} S_{B1} \left(\phi_{C1,B3} \phi_{B3,B4} \phi_{B4,GH} + \phi_{C1,C2} \phi_{C2,GH} \right).$$

In cases where detections were too sparse at the Highway 4 receiver sites (B4 and C2) from Old River route fish to estimate transition probabilities from those sites (i.e., first and third release groups), no estimates were available of Mid-Delta survival for either the Old River route or its subroutes.

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. Because detections at False River were too sparse to be modeled for all release groups, all available estimates of survival through the Mid-Delta region should be interpreted as survival to Jersey Point, rather than 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:

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

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

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

$$S_{B2(SD)} = \phi_{B2,B3}\phi_{B3,B4} + \phi_{B2,C2} + \phi_{B2,D1O} + \phi_{B2,D1C} + \phi_{B2,E1}, \text{ and}$$

$$S_{C1(SD)} = \phi_{C1,B3}\phi_{B3,B4} + \phi_{C1,C2} + \phi_{C1,D1O} + \phi_{C1,D1C} + \phi_{C1,E1}.$$

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 (2018a). Under the assumptions of common survival, route selection, 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 the possible capture histories.

Modifications for March Release Group

The temporary barrier at the head of Old River was not yet installed by the time fish from the March release group were passing that region, and the large majority of tagged steelhead that were detected downstream of the head of Old River were observed taking the Old River route. Detection data were too sparse in the San Joaquin River route to fit the reach-specific survival model to those data. Instead, only the overall probability of survival from SJL (site A5) to Chipps Island (G2) could be estimated for the Old River route: $S_{A5,G2}$. This parameter was estimated directly, without attempting to decompose it into reach-specific survival and subroute selection probabilities. Submodel II was omitted completely for analysis of the March detection data.

No steelhead tags were detected at either Jersey Point (G1) or False River (H1) from the March release group, so both sites were removed from the model for that release group. Instead, the transition probabilities from the Highway 4 sites (OR4 = B4, and MR4 = C2) to Chipps Island (G2) were included directly in the model. However, because only two tags were detected at B4 and only one tag was detected at C2, robust estimates of these transition probabilities were not available. Sites B4 and C2 were not omitted from the model, however, because their removal would have also required the removal of the water facility sites (E1, E2, D1, D2), where there were more detections. The overall probabilities of survival to Chipps Island from the Old River South (B2) and Middle River Head (C1) receivers ($S_{B2(D)}$ and $S_{C1(D)}$) were estimated separately using the CJS model (Skalski et al. 1998) together with virtual releases at B2 and C1, respectively, to confirm the derived survival probabilities estimated from the full Old River route component of Submodel I (Figure 2). No attempt was made to adjust the joint fish-tag survival estimates for premature tag failure, because a tag manufacturing error and high rate of tag failure meant that the observed travel time and estimated tag survival probabilities were likely to be biased for this release group.

Modifications for April Release Group

The head of Old River barrier was installed by the time the tagged steelhead from the April release group passed that river junction, and most tags detected in the study area were observed taking the San Joaquin River route. This resulted in sparse detection data in the Old River route, especially at MRH (C1), RGU/RGD (D1, D2), WCL (B3), OR4 (B4), and MR4 (C2). Of the fish taking the San Joaquin River route, although 27 were subsequently observed at the Highway 4 receivers (OR4 and MR4), few were detected at the radial gates sites (D1, D2). Only two tags were detected at the interior radial gates receivers (RGD = D2), regardless of route; it was necessary to remove that site from the survival model, and estimate directly the transition probability from the exterior radial gates receivers (RGU = D1) to Chipps Island. No attempt was made to model the effect of the radial gate status (open or closed) on transitions to or from RGU. Only one tag was detected at the WCL receivers (B3) in the Old River route, and so that site was removed from the survival model, as well, and the transition probabilities from the ORS (B2) and MRH (C1) receivers to OR4 (B4) were estimated directly. However, because only one tag was detected at the MRH receiver, no transition probabilities from that receiver to downstream sites could be estimated. The detection probability at MRH was assumed to be 1 (100%) based on data from all release groups; while a questionable practice in general because of potential seasonal changes on detection probability, this approach was deemed acceptable for MRH because the Middle River channel is narrow in that location (< 25 m), there were two receiver lines (i.e., a dual array), and all of the (predator-filtered) tags detected at the closest upstream site (ORE = B1) were detected either at MRH or at ORS, leaving little room or effect of imperfect detection probabilities. The detection probability at the exterior radial gates receivers (RGU) was also assumed to be 1 based on the full set of detections at RGU and RGD from all release groups. Detection probabilities have been estimated at > 0.9 at that site in previous years (0.92 in 2011, and 1.0 in 2012 and 2013; USBR 2018a, 2018b, 2018c). Detection probabilities at OR4 and MR4 were estimated by pooling detections from both routes. The estimate of the total Delta survival in route B, S_B, was confirmed using a simplified model that omitted all reach-specific survival and transition probabilities downstream of ORE (B1). It was necessary to equate transition probabilities from the two routes for sites involving OR4, MR4, and RGU: $\phi_{x,y}$ for x = B4 and C2 and y = G1, D1, and E1, and $\phi_{D1,G2}$. As with the other release groups, the False River (FRE/FRW = H1) site was removed from the model. The estimated probabilities of tag survival to the various detection sites were incorporated into the model, so that the resulting survival and transition probability estimates are unbiased for premature tag failure.

Modifications for May Release Group

The head of Old River barrier was installed by the time the tagged steelhead from the May release group reached that river junction, and most tags that were detected in the study area were observed taking the San Joaquin River route. Compared to the previous two release groups, relatively few of the tagged steelhead released in May were detected in the study area, and there were sparse detections at the export facilities and Old and Middle river receivers. There were too few detections to model detection probabilities and transition probabilities for MRH (C1), CVP (E1, E2), RGU/RGD (D1, D2), WCL (B3), OR4 (B4), and MR4 (C2), whether for fish that took the Old River route at the head of Old River, or for fish that took the San Joaquin River route. It was necessary to omit those sites in both Submodel I and Submodel II. In the Old River route, only two transition probabilities were estimated: $\phi_{B1,B2}$ from ORE (site B1) to ORS (site B2), and $\phi_{B2,G2}$ from ORS to Chipps Island (G2). The transition probability $\phi_{B1,B2}$ is defined as $\phi_{B1,B2} = S_{B1}\psi_{B2}$; however, because the detection probability could not be estimated at C1, the individual parameters S_{B1} and ψ_{B2} could not be estimated separately. Under the assumption that the detection probability at C1 was 100%, $\phi_{B1,B2}$ is equal to S_{B1}. The estimate of Delta survival via the Old River route was estimated as $S_B = S_{A4}\phi_{B1,B2}S_{B2,G2}$; this formulation has the potential to underestimate survival from B1 to G2 if the detection probability at C1 was < 100%, so the estimate of S_B computed in this way was confirmed using a simplified Submodel I that estimated $S_{B1,G2}$ directly. In the San Joaquin River route, no tags were detected moving from MAC (A8), MF (A9), or TCE/TCW (F1) into the Interior Delta; the only transition probabilities estimated from these sites in Submodel II were $\phi_{A8,A9}$, $\phi_{A8,G1}$, $\phi_{A9,G1}$, and $\phi_{F1,G1}$, assumed to represent the only potentially successful pathway from the Turner Cut junction to Chipps Island. Although included in the model, there were too few detections at either RRI (R1) or Turner Cut (F1) to estimate the survival and transition probabilities arising from those sites: S_{R1} and $\phi_{F1,G1}$ or $\phi_{F1,G2}$. Although these parameters were included in the model, their estimates were reported as NA. The estimate of the overall probability of Delta survival in route, S_A, was confirmed using a simplified model that omitted reach-specific survival and transition probabilities from downstream of SJL (A5). The estimated probabilities of tag survival to the various detection sites were incorporated into the model, so that the resulting survival and transition probability estimates were unbiased for premature tag failure.

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, detection, route selection, and last reach probabilities were fixed to 1 or 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 that was restricted to detections classified as steelhead detections. Population-level estimates of parameters and performance measures were estimated as weighted averages of the release-specific estimates, using weights proportional to release size; only results from the April and May release groups were used in the population estimates, because data from the March release group reflected a tag manufacturing error that turned the tag battery off prematurely.

In cases in which a key survival parameter was estimated at 0 or was estimated on the basis of only 0 or 1 detections, the 95% upper bound on survival was estimated using a binomial error structure

(Louis 1981); correction for tag failure was calculated using an assumed travel time that was based either on travel time from other release groups, or from previous years, together with the fitted tag survival model. Likewise, in cases in which a survival parameter was estimated at 1, the 95% lower bound on survival was estimated.

The significance of the radial gates status on arrival at the outside receiver (RGU, site D1) was assessed for the each release group separately using a likelihood ratio test (α = 0.05) to indicate a significant difference in model fit (Sokal and Rohlf 1995). If the effect of the gates was found to be insignificant using this criterion, then a simplified model was used for parameter estimation in which $\phi_{B2,D1O}=\phi_{B2,D1C}$, $\phi_{C1,D1O}=\phi_{C1,D1C}$, $\phi_{B4,D1O}=\phi_{B4,D1C}$, $\phi_{C2,D1O}=\phi_{C2,D1C}$, and $\phi_{D1O,D2}=\phi_{D1C,D2}$. For the April release group, sparse detection data at the radial gate at the Clifton Court Forebay required using common transition probabilities from the radial gate receivers to Chipps Island (i.e., $\phi_{D1O,D2}$, $\phi_{D1C,D2}$, and $\phi_{D2,G2}$) regardless of the primary route used at the head of Old River (route A or route B) to reach the radial gates. For the transition probabilities at the CVP, a likelihood ratio test was used to compare the model fit using either common or route-specific CVP transition probabilities (i.e., $\phi_{E1,E2}$ and $\phi_{E2,G2}$) (α = 0.05). 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:

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

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:

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

Statistical significance was tested at the 5% level (α=0.05).

Estimates of key survival parameters were compared between the April and May release groups. The hypothesis that the April release had higher survival was tested at the family-wise 10% level, using the Bonferroni correction for multiple comparisons (Sokal and Rohlf, 1995).

Analysis of Tag Failure

Three in-tank tag-life studies of VEMCO V5 tags were planned for the 2014 steelhead survival study. The first (March) study indicated a high rate of premature tag failure, which the manufacturer attributed to an error in programming of the tag's kill-time counter; the March release group of tags also had this programming error. The programming error was corrected for the April and May releases of tags and the May tag-life study. However, the tags in the April tag-life study had the programming error, and so did not represent the tags released in April; the data from the April tag-life study were discarded. Two additional tag-life studies were implemented in May to compensate for the lost data from the April tag-life study. The early May tag-life study used tags whose kill-time counters had been reset, and the two late May tag-life studies used tags whose kill-time counters had been extended to 200 days. Likewise, the late April release group used tags whose kill-time counters had been reset, while the late May release group used tags whose kill-time counters had been extended.

There were 33 tags in the March tag-life study, but one tag did not activate; thus, 32 tags were available for the March tag-life study, which began on 24 March 2014 and ended 21 April 2014. The early May study used 30 tags, but two tags did not activate and the final detection was not observed for one tag. Thus, the early May study used data from 27 tags; it ran from 5 May through 24 July 2014. The two late-May tag-life studies used 33 and 22 tags, respectively; each ran from 30 May through 18 August 2014. Several (eight) tags in the tag-life studies had originally been used in steelhead to be released in the survival study, and were removed from pre-release mortalities. These tags were deactivated upon removal from the dead steelhead, and reactivated for the tag-life study. Total time of battery activation was used in the tag-life study. Tags were monitored in tanks using fixed-site hydrophones and receivers, and were pooled across tanks for analysis.

For each tag-life study, the observed tag survival was modeled using the 4-parameter vitality curve (Li and Anderson, 2009). Because tags from the March tag-life study had the programming error and tags from the May tag-life studies did not, separate tag survival models were fit for the March and May studies. For the three May studies, tag failure times were right-censored at day 79 to improve model fit (USBR 2018b). Also for the three May studies, stratifying by study and by the type of correction to the tag programming error (i.e., reset vs extended counter) was assessed using the Akaike Information Criterion (AIC; Burnham and Anderson, 2002).

The fitted tag survival model from the May tag-life studies 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.

Adjustments for premature tag failure were made using only the tags without the programming error (i.e., the April and May release groups using tag-life data from the May tag-life studies). The highly accelerated rate of tag failure from the March release group made it inappropriate to attempt to adjust the estimated joint probability of fish survival and tag survival by the estimated tag survival curve from the March tag-life study, for several reasons. First, the travel time distribution estimated using the faulty tags was likely to be biased toward shorter travel times because longer travel times were not observable; thus, any adjustment to the survival estimate would be smaller than was appropriate, and the adjusted survival estimates would remain negatively biased (Holbrook et al. 2013). Additionally, the nature of the tag programming error (i.e., premature initiation of the kill-time counter) meant that tags activated on different days had different probabilities of surviving a given duration since tag activation. In particular, most of the tags that were released in the March release group were activated over a period of 3 days (March 24–26, 2014), and a single tag was activated on a fourth day (March 27, 2014). The tags in the March tag-life study were all activated on March 24, 2014, the first day of tag activation of the released tags; it is thus reasonable to assume that the tag survival curve estimated from the March tag-life study represented the survival of the released tags that were also activated on that day (although the estimated travel time for these tags will remain biased). However, the released tags that were activated after March 24 will have had a different tag survival curve that was not represented by the tag-life study. Thus, no attempt was made to adjust the estimated parameters from the March release group for premature tag failure; the reported estimates represent both fish mortality and tag failure. The survival parameter estimates were mostly likely to have been affected by the premature tag failure. The estimates for total survival through the Delta (S_{Total}) were expected to be negatively biased by the premature tag failure; individual reach survival and transition probability estimates were also expected to be negatively biased, assuming a constant travel rate through the system. However, if some fish delayed migration in certain regions of the Delta or returned upstream after their tags failed, it is possible that some reach-specific survival estimates were positively biased.

Analysis of Surgeon Effects

The potential effects of different surgeons (i.e., taggers) on steelhead survival 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 (α=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.

Lack of independence may be caused by differences in survival, route selection, or detection probabilities. A second method of assessing possible surgeon effects visually compared estimates of cumulative steelhead survival throughout the study area among surgeons; an F-test was used to test for a surgeon effect on cumulative survival through each major route (routes A and B). Although differences in cumulative survival can provide compelling indications of possible surgeon effects on survival, they are inconclusive alone; the reason is that consistent differences in cumulative survival can be driven by differences in the first several reaches, which then persist for the cumulative survival estimates through downstream reaches even if individual reach survival estimates are equal among surgeons in those downstream reaches. Thus, it is necessary to augment the cumulative survival assessment with additional evidence. Accordingly, a third method of assessment used Analysis of Variance to test for a surgeon effect on individual reach survival estimates. 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 more poorly than others, based on individual reach survival or transition probabilities through key reaches. In the event that survival was different for the steelhead tagged by 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. Because surgeons tagged steelhead for all three release groups, using both the faulty tags for the March release group and the properly functioning tags for the April and May release groups, no attempt was made to correct survival estimates for premature tag failure in the estimation of survival for assessment of surgeon effects.

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 Selection Analysis

Head of Old River

A temporary rock barrier was installed at the head of Old River through most of the 2014 tagging study, effectively blocking most access to the upper reaches of Old River. Culverts in the barrier allowed water and fish to pass through the barrier, but few (14) tagged steelhead were observed at the upper Old River detection sites when the barrier was in place in 2014. Analysis of route selection at the head of Old River was tenable only for those fish that passed before the barrier was installed. The barrier closure date during installation was 8 April 2014, so only tag detections from either the San Joaquin River receivers at Lathrop (SJL, site A5) or the Old River receivers at Old River East (ORE, site B1) from before that date were used in the route selection analysis at the head of Old River. Because the estimated detection probabilities at both these sites were 1.0 for all release groups, no detections from downstream sites in either route were needed to augment the route selection data. All tags detected at SJL or ORE before barrier closure date came from the March release group, which suffered from the tag manufacturing error that turned the tags off prematurely. However, the barrier installation closure date was at most 13 days after the tagged fish were released at Durham Ferry, at which time the predicted tag survival was approximately 83%. Thus, the majority of the tags were expected to have been still functioning through the entire time before barrier closure. However, any conclusions that may be drawn from the route selection analysis for the head of Old River are contingent on the assumption of equal tag failure rates for the fish that selected the San Joaquin River as for those that selected the Old River route. That assumption was assessed by comparing the arrival time distribution of fish from the first release group that were detected at either SJL or ORE before the barrier closure date. Only tags that finally arrived at SJL or OH1 coming from either upstream or the opposite leg of the river junction were included in the route selection analysis; those tags whose final pass of the river junction came from either downstream or from a previous visit to the same receivers (e.g., repeated visits to the SJL receivers) were excluded from the analysis. When restricted to this set of the March tags, there were too few (4) tags detected at the San Joaquin River receiver (SJL) to perform a full route selection analysis at the head of Old River. Although many more individuals were detected taking the Old River route (112) from this set of tags, the very low number that selected the San Joaquin River route meant that any analysis would have high uncertainty and low statistical power (at most 4 degrees of freedom). Instead of attempting to fit a model of route selection at the head of Old River, simple data descriptions were reported.

The same set of possible covariates were formatted for the simple route selection analysis at the head of Old River in 2014 as in previous years: measures of flow, water velocity, and river stage at the estimated time of arrival at the head of Old River junction, the 15-minute change in these measures, daily export rates from the Central Valley Project and State Water Project on the day of arrival at the junction, fish fork length at the time of tagging, and time of day at fish arrival at the junction. Methods used to compile and format the data were those used in previous years; see USBR (2018c) for more details. One change in 2014 was the absence of flow or water velocity data from the Lathrop gaging station (SJL) in the San Joaquin River in 2014; this lack of data meant that the flow proportion into the San Joaquin River was also missing for 2014. Simple graphical comparisons of conditions for the two routes selected were constructed.

Turner Cut Junction

Analysis of factors affecting route selection at Turner Cut was performed for the April and May release groups; no tags from the March release group were detected at the receivers (MacDonald Island and Turner Cut) near the San Joaquin River entrance to Turner Cut ("Turner Cut junction"). Acoustic tag detections used in this analysis were restricted to those detected at the acoustic receiver arrays MAC (A8) or TCE/TCW (F1), located 1.2–3.4 km downstream of the Turner Cut junction. Tags were further restricted to those whose final pass of the junction came from either upstream sites or the opposite leg of the junction; tags whose final pass of the junction came from either downstream sites or a previous visit to the same receivers (e.g., multiple visits to the MAC receivers) were excluded from the analysis. This requirement excluded data from six tags from the analysis. Also excluded were tags whose estimated travel time from the Turner Cut junction to the Turner Cut or MacDonald Island receivers exceeded 15 hours; this requirement removed 1 tag. Predator-type detections were excluded. Detections from a total of 211 tags were used in this analysis: 196 from the April release group, and 15 from the May release group.

As in previous years (USBR 2018a, 2018b, 2018c), the effects of variability in hydrologic conditions on route selection at Turner Cut were explored using statistical generalized linear models (GLMs) with a binomial error structure and logit link (McCullagh and Nelder, 1989). The same set of covariates were used as in previous years: measures of river discharge (flow), river velocity, and river stage measured at the TRN gaging station, the 15-minute change in flow, velocity, and stage at TRN, measures of the average magnitude (i.e., the Root Mean Square, or RMS) of flow and velocity at the SJG gaging station (Table 2) during the tagged individual's transition from the SJG acoustic receiver (model code A6) to the Turner Cut or MacDonald Island receivers, daily export rates at the CVP and SWP upon tag detection at the Turner Cut junction, fork length at tagging, release group, and time of day of arrival at the junction. The covariates considered were:

- Q_{TRN}, ΔQ_{TRN} = TRN river flow (i.e., discharge) and the 15-minute change in TRN flow at the time of tag detection at either the TCE/TCW or MAC acoustic receivers;
- V_{TRN}, ΔV_{TRN} = TRN water velocity and 15-minute change in TRN velocity at the time of tag detection at either TCE/TCW or MAC acoustic receivers;
- C_{TRN}, ΔC_{TRN} = TRN river stage and 15-minute change in the river stage at the time of tag detection at either TCE/TCW or MAC acoustic receivers;

- Q_{SJG} = Root Mean Square (RMS) of San Joaquin River flow measured at the SJG gaging station at Garwood Bridge, from the time of the final tag detection at the SJG acoustic receiver (site A6) until the time of detection at either the TCE/TCW or MAC acoustic receivers;
- V_{SJG} = Root Mean Square (RMS) of San Joaquin River water velocity at the SJG gaging station from the time of final tag detection at the SJG receiver until the time of detection at the TCE/TCW or MAC receivers;
- U = Indicator variable defined to be 1 if flow at TRN was negative, and 0 otherwise
- E_{CVP}, E_{SWP} = Daily export rate at the CVP and SWP at the time of tag detection at TCE/TCW or MAC receivers, as reported by Dayflow (https://www.water.ca.gov);
- day = Indicator variable defined to be 1 if tag was detected at TCE/TCW or MAC receivers during the day, and 0 otherwise;
- L = Fork length at tagging;
- RG = Release group (categorical variable).

The TRN gaging station was located 0.13–0.20 km northeast of the TCE and TCW receivers (i.e., between the Turner Cut junction with the San Joaquin River and the TCE/TCW receivers (Table 2). Negative flow at the TRN station was interpreted as being directed into the interior Delta, away from the San Joaquin River (Cavallo et al. 2013). No gaging station was available in the San Joaquin River close to the MAC receivers. Thus, while measures of hydrologic conditions were available in Turner Cut, measures of flow proportion into Turner Cut were not available. The SJG gaging station was approximately 14 km upstream from the Turner Cut junction. More details on the definition and construction of the covariates are available in the report for the 2012 study, USBR (2018b). One change was made in the data formatting procedure from the 2012 analysis. In the 2012 analysis, environmental conditions were measured at the estimated time of arrival at the Turner Cut junction, based on observed travel time and travel distance to the TCE/TCW or MAC receivers. For the 2014 analysis, environmental conditions were measured instead at the observed time of detection at the TCE/TCW or MAC receivers, which was expected to provide a more accurate depiction of conditions when the tagged steelhead selected the route at the junction.

As in 2012, 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. Categorical variables (e.g., release group, time of day) were not standardized.

The form of the generalized linear model was

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

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), ψ_{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 were 1.0 for both sites A8 and A9 for the April and May release groups, without predator-type detections (Appendix Table A2).

Single-variate regression was performed first, and covariates were ranked by P-values from the appropriate F-test (if the model was over-dispersed) or χ-square test otherwise (McCullagh and Nelder 1989). Significance was determined at the family-wise level of 5%; the Bonferroni correction for multiple comparisons was used within each step of the stepwise regression (Sokal and Rohlf 1995). Covariates 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 the TCE/TCW or MAC receivers $\left(Q_{SJG}\right)$ was included in the river stage model. Exports at CVP and SWP had only moderate correlation (r=0.56) 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 were considered using the full model; two-way interaction effects were considered using the reduced model found from backwards selection on the main effects model. The model that resulted from the selection process in each category (flow, velocity, or stage) was compared using an F-test to the full model (or a χ^2-test if the data were not overdispersed from the 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 (Burnham and Anderson 2002). Model fit was assessed by grouping data into discrete classes according to the independent covariate, and comparing predicted and observed frequencies of route selection 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 $k2$ $(k = D, E)$ was used for this analysis; predator-type detections were excluded. 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. Because there were many tags detected at H1 that were later detected elsewhere and thus were not used in the survival model, all tags ever detected at H1 were used to estimate the detection probability at H1; only detections from the final visit to H1 were used for detection probability estimation. Profile likelihood was used to estimate the 95% confidence intervals for both $S_{D2(salvage)}$ and $S_{E2(salvage)}$ when those parameters were estimated freely; in the event that the parameter estimates were on the boundary of the permissible interval (i.e., either 0 or 1), the sample size and the 95% upper bound (for a point estimate of 0) or the 95% lower bound (for a point estimate of 1) were reported.

Results

Detections of Acoustic-Tagged Fish

A total of 1,432 tags were released in juvenile steelhead at Durham Ferry in 2014 and used in the survival study. Of these, 1,200 (84%) were detected on one or more receivers either upstream or downstream of the release site (Table 5), including any predator-type detections. A total of 1,074 (75%) were detected at least once downstream of the release site, and 643 (45%) were detected in the study area from Mossdale to Chipps Island (Table 5). Two hundred forty-seven (247) tags were detected upstream of the release site; 121 of these were also detected downstream of the release site.

Overall, there were 491 tags detected on one or more receivers in the San Joaquin River route downstream of the head of Old River, including possible predator detections (Table 5). In general, tag detections decreased within each migration route as distance from the release point increased. Of these 491 tags, all 491 were detected on the receivers near Lathrop, CA; 329 were detected on one or more receivers near Stockton, CA (SJG, SJNB, or RRI); 283 were detected on the receivers near the Turner Cut (MAC or TCE/TCW), and 163 were detected at Medford Island (Table 6). The majority of the tags from the March release group that were detected in the San Joaquin River downstream of the head of Old River were not assigned to the San Joaquin River route for the survival model, because they were subsequently detected in the Old River route or upstream of Old River (Table 5). However, most of the tags detected in the San Joaquin River route from the April and May releases were also assigned to that route for survival analysis (Table 5). Overall, 394 tags were assigned to the San Joaquin River route for the survival model, mostly from the April and May release groups (Table 5). Two additional tags were last detected at the Lathrop receivers and would have been assigned to the San Joaquin River route, but they were recaptured in the Mossdale trawl or in electro-fishing, and their detection histories were right-censored at site A5 (SJL); these two tags were not included in the total 394 tags assigned to the San Joaquin River route. Of the 394 tags, 97 were detected at the receivers in Turner Cut, although 12 of those tags were subsequently detected in the San Joaquin River at either MacDonald or Medford Islands (Table 6). A total of 25 of the tags assigned to the San Joaquin River route were observed at the northern Middle River receivers (MID, site C3), 17 were observed at the northern Old River receivers (OSJ, site B5), 27 were observed at the Old or Middle River receivers near Highway 4 (OR4 and MR4, sites B4 and C2), 21 at West Canal (WCL, site B3), and 18 at the water export facilities (including the radial gates at the entrance to the Clifton Court Forebay) (Table 6). A total of 153 San Joaquin River route tags were detected at the Jersey Point/False River receivers, including 42 on the False River receivers (Table 6). However, most of the tags detected at False River were later detected either at Jersey Point or Chipps Island, and so only two tags detected at False River were available for use in the survival model, both from the San Joaquin river route (Table 7). A total of 152 San Joaquin River route tags were eventually detected at Chipps Island, including predator-type detections, mostly from the April release group (Table 6).

The majority of the tags from the March release group that were detected downstream of the head of Old River were detected in the Old River route (127 tags); relatively few were detected in the Old River route from the April and May releases (19 and 14 tags, respectively) (Table 5). All 160 tags detected in the Old River route were detected at the Old River East receivers near the head of Old River; 148 were detected near the head of Middle River, 94 at the receivers at the water export facilities, 25 at West Canal, and 7 at the Old or Middle River receivers near Highway 4 in the interior Delta (Table 6). None of the tags observed entering Old River at its head were detected at the northern Middle River receivers (MID) or the northern Old River receivers (OSJ) (Table 6). The majority of the tags detected at the Old or Middle River receivers in the interior Delta (WCL, OR4, MR4, MID) entered the interior Delta from the San Joaquin River downstream of Stockton (Table 6).

Some of the 160 tags detected in the Old River route were assigned to the San Joaquin River route for the survival model because they were subsequently detected in the San Joaquin River after their Old River detections. In all, 153 tags were assigned to the Old River route at the head of Old River based on the full sequence of tag detections (Table 5). Of these 153 tags, 81 were detected at the CVP trash racks, although one such tag was not used in the survival model for the CVP because it was subsequently detected at the radial gates and Middle River (Table 6, Table 7). Likewise, 24 of the tags assigned to the Old River route were detected at the radial gates, and only 8 of those detections were available for use in the survival model (Table 6, Table 7). A total of 6 of the Old River route tags were detected at either Jersey Point or False River (Table 6); all 6 of those tags passed through the CVP before being detected at Jersey Point or False River. Only one tag from the Old River route was detected at False River, and it was later detected at both Jersey Point and Chipps Island. Of the 153 tags assigned to the Old River route at the head of Old River, 31 were detected at Chipps Island, including predator-type detections (Table 6, Table 7).

In addition to the northern Middle River receivers (MID), tag detections were recorded at the Threemile Slough, Montezuma Slough, and Spoonbill Slough receivers but were purposely omitted from the survival model. Thirty (30) tags were detected on the Threemile Slough receivers: 21 tags came directly from the San Joaquin River receivers at Medford Island, 1 from the northern Old River site (OSJ), and 8 from Jersey Point or False River.

The predator filter used to distinguish between detections of juvenile steelhead and detections of predatory fish that had eaten the tagged steelhead classified 147 of the 1,432 tags (10%) released as being detected in a predator at some point during the study (Table 8). Of the 643 tags detected in the study area (i.e., at Mossdale or points downstream), 123 tags (19%) were classified as being in a predator in that region, although some had also been identified as a predator before entering the study area. A total of 118 tags (18% of 643) were first classified as a predator within the study area. Relatively few (43, 4%) of the 1,182 tags detected upstream of Mossdale were assigned a predator classification in that region; 14 of those 43 tags were first classified as a predator downstream of Mossdale, and then returned to the upstream region, either temporarily or permanently.

Overall, the detection site with the most first-time predator classifications was Banta Carbona (A3; 20 of 629 tags detected there, 3%). Within the study area, the detection sites with the largest number of first-time predator-type detections were the first of the predator removal study receivers (N1; 16 of 441, 4%), San Joaquin River at Lathrop (A5, 14 of 491, 3%), and the head of Old River receivers (B0; 12 of 623, 2%), and MacDonald Island (A8, 9 of 231, 4%). Nearly equal numbers of predator classifications were assigned to tags on arrival (57) as on departure (61) at the study area sites, collectively. Predator classifications on arrival were typically due to unexpected travel time or unexpected transitions between detection sites, and were most common from Mossdale (A4) through the first predator removal study site (N1) and at MacDonald Island (A8) (Table 8). Predator classifications on departure were typically due to long residence times, and were most prevalent at Banta Carbona, Lathrop, and the first predator removal study site (A3, A5, and N1) (Table 8). Only detections classified as from predators on arrival were removed from the survival model, along with any detections subsequent to the first predator-type detection for a given tag.

The predator filter performance was assessed using acoustic telemetry detections of predatory fish including Striped Bass, Largemouth Bass, White Catfish, and Channel Catfish. A total of 145 tagged predators were detected during the 2014 steelhead survival study; all the detected predators had been tagged and released in spring 2014. Of the 145 predator tags, a total of 127 tags were classified as being in a predator at some point during their detection history, based on a score of at least 2 from the predator filter. The resulting filter sensitivity measure was 87.6%. When predator tags that had fewer than 5 detections events on the visit scale were omitted, the filter sensitivity increased to 92.9%: 118 of

127 predator tags tested positive as a predator. Because some components of the predator filter used the pattern of detections over multiple detection sites and time periods, it was reasonable that the filter sensitivity was improved for tags with longer detection histories.

When the detections classified as coming from predators were removed from the detection data, there was little change in the overall number of tags detected, although the patterns of detections changed somewhat (Table 9, Table 10, and Table 11). With the predator-type detections removed, 1,073 of the 1,432 (75%) tags released were detected downstream of the release site, and 642 (45% of those released) were detected in the study area from Mossdale to Chipps Island (Table 9). A total of 241 tags were detected upstream of the release site with steelhead-type detections; 115 of these were also detected downstream of the release site. With or without the predator-type detections, the April release group had the most detections in the study area, and the May release group had the fewest (Table 5, Table 9).

The majority of steelhead detected downstream of the head of Old River were observed using the San Joaquin River route (414) rather than the Old River route (150); most of the steelhead detected taking the San Joaquin River route were from the April release group, whereas most taking the Old River route were from the March release group (Table 9). Three tags were detected in the San Joaquin River route but were recaptured and right-censored at Lathrop (A5), and so were excluded from the 414 assigned to that route. Most detection sites had fewer detections in the reduced, steelhead-only data set (Table 10 vs Table 6). However, because some tags were observed moving upriver or to an alternate route after the predator classification from the predator filter, the number of detections available for use in the survival model was actually higher in the steelhead-only data set for some detection sites (Table 11 vs Table 7). The largest change in the number of detections available for the survival analysis occurred at Lathrop (SJL), where the reduced data set had 21 more detections than the full data set that included the predator-type detection. 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, with the exception of the water export facilities, used the San Joaquin River route at the head of Old River rather than the Old River route (Table 10). The number of tags detected at Chipps Island changed from 183 when the predator-type detections were included, to 178 when such detections were excluded (Table 6 vs Table 10). Of the 414 tags that assigned to the San Joaquin River route at the head of Old River, 43 were subsequently detected in the interior Delta and 95 were detected in Turner Cut, compared to 223 tags that were detected only in the main stem San Joaquin River downstream of the head of Old River; 145 (35%) of the tags assigned to the San Joaquin River route were detected at Jersey Point, and 147 (35%) were detected at Chipps Island (Table 10). Of the 150 tags assigned to the Old River route at the head of Old River, 80 were detected at the CVP trash racks, 0 at Jersey Point, and 31 (21%) at Chipps Island. Detection counts used in the survival model follow a similar pattern (Table 11).

Tag-Survival Model and Tag-Life Adjustments

The estimated mean time to tag failure from the first (March) tag-life study, which used tags subject to the programming error and premature tag failure rate, was 16.6 days ($\widehat{SE} = 4.48$ days) (Figure 4). The complete set of detection data from the March release group, which also used tags subject to the programming error and premature tag failure rate and including any detections that may have come from predators, contained many detections that occurred after the tags began dying (Figure 5, Figure 6). Without the detections classified as coming from predators, some of the late-arriving tag detections were omitted, but there remained detections occurring well after the tags began failing in the tag-life study (e.g., Figure 7). However, the accelerated failure rate of these tags and the difference between the activation dates of the released tags and the activation date of the tags in the tag-life study made it inappropriate to adjust the estimated joint fish-tag survival and transition probability estimates by estimated tag survival for the March release group (see *Analysis of Tag Failure*). Thus, no attempt was made to adjust the estimated parameters from the March release group for premature tag failure; the reported estimates represent both fish mortality and tag failure.

For the two late-May tag-life studies, the Akaike Information Criterion (AIC) indicated that pooling data from the two types of corrections for the kill-time counter error (i.e., reset vs extended counters) was preferable to stratifying by correction time (ΔAIC = 26.0). Additionally, AIC selected pooling data from the early May and late May tag-life studies over stratifying by study (ΔAIC = 10.1). Thus, a single tag survival model was fitted for the May tag-life studies and used to adjust fish survival estimates for premature tag failure for the April and May releases. The estimated mean time to failure from the pooled data was 75.2 days ($\widehat{SE} = 15.8$ days) (Figure 8). The complete set of detection data, including any detections that may have come from predators, contained only a few detections that occurred after the tags began dying (Figure 9, Figure 10). The sites with the latest detections were the San Joaquin River sites at Medford Island, Garwood Bridge, Lathrop, Mossdale, and MacDonald Island

(Figure 9), and Old River South in the Old River route (Figure 10). Some of these late-arriving detections may have come from predators, or from residualizing steelhead. Without the predator-type detections, the late-arriving detections were mostly removed (e.g., Figure 11). Unlike for the March release group and tag-life study, the tags used in the April and May releases and May tag-life studies did not experience the tag programming error, and so it was appropriate to adjust the estimated survival estimates by estimate tag survival. Tag-life corrections were made to survival estimates to account for the premature tag failure observed in the tag-life studies. All of the estimates of reach tag survival were greater than or equal to 0.9974, and most were greater than 0.999, out of a possible range of 0 to 1; cumulative tag survival to Chipps Island was estimated at 0.9974 without predator-type detections (0.9973 with predator-type detections) for the April and May release groups, based on the May tag-life studies. Thus, there was little effect of either premature tag failure or corrections for tag failure on the estimates of steelhead reach survival for the second (April) and third (May) release groups.

Surgeon Effects

Steelhead in the release groups were evenly distributed across surgeon (Table 12). Additionally, for each surgeon, the number of steelhead tagged was well-distributed across release group. A chi-squared test found no evidence of lack of independence of surgeon across release group (χ^2 = 0.011, df = 4, P = 1.0000). The distribution of tags detected at various key detection sites was also well-distributed across surgeons and showed no evidence of a surgeon effect on survival, route selection, or detection probabilities at these sites (χ^2 = 17.551, df = 30, P = 0.9654; Table 13).

Estimates of cumulative fish-tag survival (unadjusted for tag failure) throughout the San Joaquin River route to Chipps Island showed similar patterns of survival across all surgeons. Although surgeon C had consistently lower point estimates of cumulative survival throughout the entire San Joaquin River route, there was only weak evidence of a statistical difference in cumulative survival to any site in the San Joaquin River route (P = 0.0871 for MAC/TCE/TCW, and P ≥ 0.1080 for the other sites; Figure 12). The estimate of cumulative fish-tag survival to the boundaries of the South Delta exit points in the San Joaquin River route (MacDonald Island and Turner Cut) was 0.22 ($\widehat{SE} = 0.02$) for fish tagged by surgeon C, compared to 0.28 ($\widehat{SE} = 0.02$) for both surgeons A and B (Figure 12). Despite the possibility of lower survival of fish tagged by surgeon C in the San Joaquin River route, there was no significant difference in cumulative survival to Chipps Island among surgeons for that route (P = 0.4793; Figure 12). In the Old River route, cumulative fish-tag survival to various sites was again lower for steelhead tagged by surgeon

C, but the differences were not statistically significant for any site (P ≥ 0.1293; Figure 13); in particular, there was no difference in survival to Chipps Island in the Old River route (P = 0.6343; Figure 13). Analysis of variance found no effect of tagger on reach survival in the two routes collectively (P=0.7003). Rank tests found no evidence of consistent differences in reach survival for fish from different taggers either upstream of the Head of Old River (P=0.8741), in the San Joaquin River route (P=0.4724), or in the Old River route (P=0.7939).

Survival and Route Selection Probabilities

For the March release group, likelihood ratio tests found that transitions to the exterior receivers at Clifton Court Forebay, and into the interior receivers of the Forebay, did not depend on whether the radial gates were open or closed at the time of arrival at the exterior receivers (P=0.8780). For the April release group, radial gate detections were too sparse to model transitions using the gate status. Thus, the final models for the March and April release groups used common transition probabilities to and from the external radial gate receivers, regardless of gate status. For the May release group, there were too few radial gate detections to model transitions to and from those sites, even using common transitions independent of gate status.

Only the April release group had detections at the facilities that came from the San Joaquin River route. For that release group, there was no improvement in model fit from parameterizing unique transition probabilities through the CVP to Chipps Island based on route taken at the head of Old River (i.e., route A or route B) (P=0.9099). Additionally, sparse detections at the CCFB receivers prevented modeling transition probabilities by route at that site. Thus, the final model for the April release group used common transition probabilities from the CVP trashracks to Chipps Island, and from the exterior CCFB receivers to Chipps Island, regardless of route.

Some parameters were unable to be estimated because of sparse data. For the March release group, few tags were detected in the San Joaquin River route, so no reach-specific survival or transition probabilities or route selection probabilities could be estimated in that route downstream of Lathrop (site A5). No tags from the March release group were detected at Jersey Point (Table 11), and so transitions probabilities to that site could not be estimated, because the detection probability could not be estimated. For the April release group, only one tag was detected at MRH (C1), and only two tags were detected at RGD (D2); thus, no transition parameters associated with those sites were estimated.

For the May release group, detections were sparse in both routes downstream of the head of Old River, but especially so in the Old River route (Table 11). No estimates were available for transitions involving the Middle River sites (C1, C2), CVP (E1, E2), radial gates (D1, D2), West Canal (B3), or Old River at Highway 4 (OR4), for either primary route at the head of Old River for the May release group. Additionally, the sparse detections at Rough and Ready Island and Turner Cut meant that survival and transition probabilities from those sites could not be estimated for the May release group. Finally, for all release groups combined, despite the fact that 42 tags were detected at False River (Table 6), all except 2 of those tags were either subsequently detected upriver or at Jersey Point or Chipps Island, or had gone through the holding tank at the CVP; thus no detections at False River were used in the survival model. Parameters $\phi_{x,GH}$ (for transitions from site *x*), ψ_{G1}, and ψ_{H1} were not estimable. Instead, the joint probability of arriving at the junction between the San Joaquin River and False River and then moving downriver toward Jersey Point (i.e., $\phi_{x,G1} = \phi_{x,GH}\psi_{G1}$) was estimated and reported for transitions from sites x = A8, A9, B4, C2, and F1. However, in some cases, even those parameters could not be estimated because of sparse data, as indicated above.

For both the April and May release groups, there were several tagged fish that apparently passed Jersey Point without detection, although the large majority of tags detected at that site were detected on both acoustic receiver lines there. For this reason, detections at the dual array at Jersey Point were pooled from both receiver lines, and a single detection probability for Jersey Point was estimated (P_{G1}). Likewise, detections from the lines comprising the dual arrays were pooled to form single ("redundant") arrays at DFD (A2) for all release groups, and at A8 for the April release group. Several tags passed Chipps Island without detection from each release group, as well, despite the fact that detection probabilities for the individual receiver lines at Chipps Island were sometimes estimated at 1. Thus, the detections from the dual receiver lines were pooled at Chipps Island to estimate a single detection probability at that site (P_{G2}), to avoid overestimating the detection probability and underestimating Delta survival.

Using only those detections classified as coming from juvenile steelhead by the predator filter, the estimates of total survival from Mossdale to Chipps Island, S_{Total}, ranged from 0.06 ($\widehat{SE} = 0.02$) for the May release group, to 0.43 ($\widehat{SE} = 0.03$) for the April release group; the overall population estimate for the April and May releases (i.e., all those fish with functioning tags) was 0.24 ($\widehat{SE} = 0.02$) (Table 14).

The joint probability of both the fish and tag surviving from Mossdale to Chipps Island was estimated at 0.18 ($\widehat{SE} = 0.03$) for the March release group; this estimate represents a minimum point estimate for the probably of steelhead Delta survival for that group, and is likely an underestimate of true steelhead survival (Table 14). The estimated probability of entering Old River at its head was high for the March release group (0.91, $\widehat{SE} = 0.02$), when the barrier was not installed, and considerably lower for the April and May release groups, which passed mostly after the barrier was in place (April and May population estimate = 0.08, $\widehat{SE} = 0.02$) (Table 14). There was a significant preference for the Old River route for the March release group (P<0.0001), and for the San Joaquin River route for the April and May release groups (P<0.0001 for each release group). Estimates of survival from Mossdale to Chipps Island via the San Joaquin River route (S_A) ranged from 0 for the March release group (95% upper bound = 0.21) to 0.43 ($\widehat{SE} = 0.03$) for the April release group; the population estimate, averaged over the April and May release groups, was 0.25 ($\widehat{SE} = 0.02$) overall (Table 14). The March estimate was confounded with premature tag loss. In the Old River route, estimates of survival from Mossdale to Chipps Island (S_B) ranged from 0.07 ($\widehat{SE} = 0.07$; 95% upper bound = 0.29) for the May release group to 0.31 ($\widehat{SE} = 0.09$) for the April release group (April and May population average = 0.19, $\widehat{SE} = 0.06$) (Table 14). The joint fish-tag estimate of S_B was 0.19 ($\widehat{SE} = 0.03$) for the March release group. The route-specific survival to Chipps Island was significantly different between routes only for the March release group, when survival was higher in the Old River route than in the San Joaquin River route (P<0.0001; Table 14); however, the survival estimates in that case represented the joint probability of both fish and tag survival. There was no significance difference in survival to Chipps Island between routes for the other two release groups, or for the April-May tagged population overall (P ≥ 0.2656) (Table 14).

Survival was estimated to the Jersey Point/False River junction for routes that did not pass through the holding tanks at the CVP or the CCFB. This survival measure ($S_{Total(MD)}$) was estimable only for the April release group: $\hat{S}_{Total(MD)} = 0.43$ ($\widehat{SE} = 0.03$) (Table 14). This was a minimum estimate, because it excluded the possibility of going to False River rather than to Jersey Point; however, only 2 tags were detected at False River from the April release group, compared to 137 at Jersey Point (Table 11), suggesting that the bias in the estimate of $S_{Total(MD)}$ was small. Survival to Jersey Point was different for the two routes (P < 0.0001), and was higher for fish in the San Joaquin River route (0.44, $\widehat{SE} = 0.03$) for the April release group (Table 14). However, the majority of Old River route fish from the April release group were detected at the radial gates at the entrance to the Clifton Court Forebay or at the CVP trashracks (Table 11); the survivors of these fish would not have contributed to survival to Jersey Point or False River, because those sites were not on the migration route downstream from the CVP or SWP holding tanks. Because $S_{Total(MD)}$ does not reflect survival to downstream regions via salvage, it does not necessarily indicate overall survival to Chipps Island (S_{Total}), in particular in the absence of a barrier at the head of Old River. There was a barrier installed for the April release group in 2014, and the estimates of mid-Delta survival and total Delta survival were identical for that group (Table 14).

Survival was estimated through the South Delta ($S_{A(SD)}$, $S_{B(SD)}$, and $S_{Total(SD)}$) for one or both routes for all three release groups. The "South Delta" region corresponded to the region studied for Chinook salmon survival in the 2009 VAMP study (SJRGA 2010). Survival through the Old River portion of the South Delta ($S_{B(SD)}$), i.e., from Mossdale to the CVP trashracks (CVP), radial gates exterior receivers (RGU), and Highway 4 receivers (OR4, MR4), was estimated for the March and April release groups: 0.56 ($\widehat{SE} = 0.04$) for March, and 0.83 ($\widehat{SE} = 0.09$) for April (Table 14). The March estimate was confounded by a high degree of premature tag failure, and should be considered a minimum estimate. Survival through the San Joaquin portion of the South Delta ($S_{A(SD)}$), i.e., from Mossdale to MacDonald Island (MAC) or Turner Cut (TCE/TCW), was estimated for the April and May release groups: 0.77 ($\widehat{SE} = 0.02$) for April, and 0.16 ($\widehat{SE} = 0.04$) for May (average = 0.46, $\widehat{SE} = 0.02$) (Table 14). Total estimated survival through the entire South Delta region ($S_{Total(SD)}$) was estimable only for the April release group, for which the estimate was 0.77 ($\widehat{SE} = 0.02$) (Table 14). No population-level estimate was available because no estimate was available for the Old River route for the May release group.

Including the predator-type detections in the analysis had at most a moderate effect on the survival estimates in most regions (Table 15). In South Delta region, including the predator-type detections increased the survival estimate in the San Joaquin River route from 0.77 ($\widehat{SE} = 0.02$) and 0.16 ($\widehat{SE} = 0.04$) for the April and May release groups, respectively, to 0.82 ($\widehat{SE} = 0.02$) and 0.18 ($\widehat{SE} = 0.04$)

(Table 14, Table 15). The Old River route estimate of South Delta survival was unchanged by including the predator-type detections for the March release group, but for the April release group, the estimate decreased considerably from 0.83 ($\widehat{SE} = 0.09$) without the predator-type detections to 0.56 ($\widehat{SE} = 0.11$) with those detections (Table 14, Table 15). Overall, the estimate of total survival through the South Delta increased from 0.77 ($\widehat{SE} = 0.02$) without predator-type detections, to 0.80 ($\widehat{SE} = 0.02$) with predator-type detections, for the April release group (Table 15). For total survival through the Mid-Delta region (i.e., to Jersey Point), the April estimate increased from 0.43 ($\widehat{SE} = 0.03$) to 0.45 ($\widehat{SE} =$ 0.03) when the predator-type detections were included; the increase was entirely in the San Joaquin River route (Table 15). For the May release group, the point estimate of San Joaquin River route survival to Jersey Point also increased slightly by including the predator-type detections, from 0.07 ($\widehat{SE} = 0.03$) to 0.09 ($\widehat{SE} = 0.03$) (Table 15). The change in the estimates of total Delta survival (S_{total}) from including the predator-type detections was similarly small: there was no change for either the March or May release groups, whereas the estimate of the April release group increased from 0.43 to 0.45 ($\widehat{SE} = 0.03$ for both) when the predator-type detections were included (Table 15). There was only a small change in the population-level estimate from the April and May release groups: 0.24 without the predator-type detections, compared to 0.26 with those detections; $\widehat{SE} = 0.02$ for both estimates. As in the case of the South Delta survival, the increase in estimated total Delta survival for April reflects the higher route-specific Delta survival for the San Joaquin River route with the predator-type detections (0.47 vs 0.43, $\widehat{SE} = 0.03$ for both). Including the predator-type detections had the effect of lowering the point estimate of Delta survival in the Old River route from 0.31 ($\widehat{SE} = 0.09$) to 0.23 ($\widehat{SE} = 0.07$) for the April release group (Table 15); the large standard errors reflect the small number of fish observed taking the Old River route, whether or not predator-type detections were included. Thus, including the predator-type detections had the effect of increasing estimates of total Delta survival slightly for the April release group, but the difference in point estimates (0.02) was less than the estimated standard error (0.03) (Table 14, Table 15).

Two possibilities may account for the sizeable decrease in the point estimate of South Delta survival through the Old River route, and moderate decrease in the Old River route estimate of total Delta survival, when the predator-type detections were included for the April release group. One possibility is that the tags classified as predators within the Old River route tended to exit back upstream of Old River after their first predator classification, whereupon they would not be included in the group of fish used to estimate survival in the Old River route. Another possibility is that tags in the Old River route tended to exit the South Delta region before their first predator-type detection, and then return to the South Delta region on or after their first predator-type detection. It is a combination of these two possibilities that explains the changes in April point estimates of Old River route survival when the predator-type detections were included. However, because most of the April tags were observed in the San Joaquin River route rather than the Old River route, there was little effect on estimates of total Delta or South Delta survival.

The generally small or low differences in survival estimates through the entire Delta, and in particular in the San Joaquin River route, suggests that there was little movement of the successful predators (as identified by the predator filter) from the study area to Chipps Island. Alternatively, the spatial patterns in the survival differences with and without predator-type detections may reflect a reduced ability to distinguish between behavior of steelhead and predators from the available tagging data as fish approach Chipps Island.

Survival estimates in reaches varied throughout the study, depending on the reach; for most reaches, the estimated survival was highest for the April release group. The estimates from the March group were confounded by a high degree of premature tag failure caused by a manufacturing error (e.g., Figure 5), and so the March estimates should be treated as minimum estimates of steelhead survival. Even with the negative bias caused by tag failure in the March estimates, the estimates of survival from May were often considerably lower than for either of the earlier release groups. The Chipps Island detection probability (P_{G2}) also had a lower point estimate for the May release group (0.71) compared to the earlier release groups (≥ 0.95) (Table A2). However, the estimates of survival to Chipps Island are adjusted for imperfect detection, and so the lower survival estimates from the May release group are unlikely to be related to the lower detection probabilities. Estimates of detection probability at detection sites from Mossdale to Chipps Island were generally high (≥0.92), except for the May estimates for Jersey Point (0.67) and Chipps Island (0.71, discussed above) (Table A2).

Survival from release to Mossdale, the upstream boundary of the Delta study area, varied considerably throughout the study: 0.32 ($\widehat{SE}=0.02$) for the March release group (joint fish-tag survival), 0.74 ($\widehat{SE}=0.02$) for the April release group, and 0.25 ($\widehat{SE}=0.02$) for the May release group (Table 14); estimates using the predator-type detections were similar (Table 15). Survival from Mossdale through the head of Old River, to the SJL or ORE receivers, had moderate to high estimates (0.77 to 0.97; $\widehat{SE} \leq 0.04$) for all release groups (Table A2). No reach-specific survival estimates were available for San Joaquin River route for the March release group. There was a large difference between the April and May estimates of survival in the San Joaquin River from (SJL, site A5) to Garwood Bridge (A6): 0.90 ($\widehat{SE} = 0.02$) for April, compared to 0.35 ($\widehat{SE} = 0.05$) for May (Table A2). San Joaquin survival estimates continued to be lower for the May release group than for the April group through MacDonald Island (Table A2). The estimated probability of transitioning from MacDonald Island (A8) to Medford Island (A9) was slightly higher for the May release group (0.86, $\widehat{SE} = 0.09$) than for the April release (0.81, $\widehat{SE} = 0.03$); however, overall survival from MacDonald Island to Chipps Island was considerably higher for the April release group (0.74, $\widehat{SE} = 0.03$) compared to the May release (0.42, $\widehat{SE} = 0.13$) (Table A2). Survival to Chipps Island from Turner Cut could be estimated only for the April release group: 0.17 ($\widehat{SE} = 0.04$ Table A2); the April release group had a higher probability of leaving the San Joaquin River for Turner Cut (0.31; $\widehat{SE} = 0.03$), compared to the May release group (0.13, $\widehat{SE} = 0.08$).

In the Old River route, the estimated probability of transitioning from the first detection site (ORE, site B1) to the Old River site near the head of Middle River (ORS, site B2) ($\phi_{B1,B1}$) was nearly equal for the March and April release groups (0.92 to 0.93), despite the premature tag failure reflected by the March estimate. The May release group, however, had a much lower estimate: 0.45 ($\widehat{SE} = 0.15$) (Table A2). Downstream of ORS, it was not possible to estimate reach-specific survival or transition probabilities from the May group, because the detection data were too sparse in that region. Overlooking the confounding of fish and tag survival in the March release groups, the pattern of transition probability estimates to various detection sites in the Old River route was similar between the March and April release groups, although estimates were more precise (though potentially negatively biased) for the March release group because of the higher number of tags observed in the Old River route. For both the March and April release groups, the majority of tags observed downstream of ORS were detected at the CVP trashracks, and very few were detected at the Highway 4 receivers (B4, C2). The estimated probability of getting from OR4 to Jersey Point was 0.27 for the April release group; there was high uncertainty on that estimate ($\widehat{SE} = 0.11$), and the estimate was driven entirely by fish that reached the OR4 receiver via the San Joaquin River route. None of the fish observed at the Middle River site at Highway 4 (MR4, site C2) were subsequently detected at Jersey Point, regardless of the route used to reach MR4. Of March and April tagged steelhead that reached the CVP trashracks (E1) without later being detected at the CCFB radial gates (D1, D2) or Highway 4 receivers, approximately half were estimated to have survived to the holding tank for both the March and April release groups. From the holding tank to Chipps Island, the transition probability was estimated at 1.0 for April (95% lower bound = 0.53), and 0.72 ($\widehat{SE} = 0.08$) for March; the premature tag failure reflected in the March estimates means the true survival probability was likely higher (Table A2). No estimates of survival or transition probabilities were available for the CVP for the May release group. Estimated survival in the South Delta was slightly lower when predator-type detections were included, in particular for the April release group (Table A3).

Travel Time

For tags classified as being in steelhead, average travel time through the system from release at Durham Ferry to Chipps Island was 9.77 days ($\widehat{SE} = 0.32$ days) for the April and May release groups, and 10.35 days ($\widehat{SE} = 0.43$ days) for the March release group (Table 16a). Because of the manufacturing error in the tags used for the March release group, the observed travel time for that release group may underestimate actual travel time of fish. Average travel time to Chipps Island tended to be shorter for later release groups; however, only 5 tags from the May release group were observed at Chipps Island, and the March release group had tags that turned the tags off prematurely, so no robust comparison between release groups is possible. The large majority of tags reaching Chips Island came via the San Joaquin River route and for the April release group; the average travel time observed to Chipps Island via the Old River route (7.33 days, $\widehat{SE} = 1.48$ days for April and May combined) was slightly less than the average travel time via the San Joaquin River route (9.89 days, $\widehat{SE} = 0.33$ days), but the small number of tags observed arriving via the Old River route (5) makes conclusions about route effects on travel time unreliable (Table 16a). Most tags that were observed at Chipps Island arrived within 15 days of release at Durham Ferry. However, there were 13 tags that took 20–30 days, all but one via the San Joaquin River route and via Jersey Point rather than the export facilities.

Travel time from release to the Mossdale receivers averaged approximately 4 days for the March release group (tag manufacturing error), and 2 days for the April and May release groups (Table 16a). Travel time to the Turner Cut junction (i.e., either Turner Cut receivers or MacDonald Island receivers) averaged 6.38 days (258 tags) for the April release, and 3.15 days (16 tags) for the May release; no tags from the March release were observed at the Turner Cut junction (Table 16a). Travel time from release to the CVP trash racks averaged 8.05 days ($\widehat{SE} = 1.02$) over the April and May release groups; most observations were from the April release group. Average observed travel time was lower for fish that reached the CVP via the Old River route (6.04 days) than those that used the San Joaquin River route (10.81 days; Table 16a). Fewer tags were observed at the radial gates receivers outside Clifton Court Forebay (RGU); average travel time from release was 6.55 days ($\widehat{SE} = 2.31$ days) for the April release group, and 19.27 days (1 tag) from the May release group (Table 16a).

Most (88%) of the 17 tags detected at the Old River receivers near Highway 4 (OR4) came from the San Joaquin River route and from the April release group; average travel time from release to this site averaged approximately 9 days (Table 16a). The two tags observed reaching OR4 via the Old River route had average travel time of approximately 12 days; however, these two tags came from the March release group, so their observed travel time may underestimate the true travel time distribution to that site (Table 16a). The majority (79%) of the 14 tags detected at the Middle River receivers near Highway 4 (MR4) came from the April release group and the San Joaquin River route; average observed travel time for these tags was approximately 11 days (Table 16a). One of the three tags detected at MR4 from the Old River route had travel time of nearly 29 days; the other two had observed travel times of 10–12 days, including the single tag observed there from the March group with the faulty tags (Table 16a). Travel time to Jersey Point averaged approximately 8 days, all from the San Joaquin River route; most tags detected at Jersey Point were released in April (Table 16a).

Including detections from tags classified as predators tended to lengthen average travel times slightly, but the general pattern across routes and release groups was the same as without predator-type detections (Table 16b). The largest change seen from including the predator-type detections was at the exterior receivers at the Clifton Court Forebay (RGU), where the average April-May travel time was approximately 8 days without the predator-type detections, and about 12 days without those detections; however, only 4 tags were detected at that site from the April and May release groups. The average travel time from release to Chipps Island via all routes, including the predator-type detections, was 9.93 days ($\widehat{SE} = 0.33$) (Table 16b). 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. Some sites had lower average travel times when the predator-type detections were included (e.g., West Canal); this can happen when the predator filter removes upstream-directed movement to sites that were previously visited.

Average travel time through reaches for tags classified as being in steelhead ranged from 0.01–0.02 days (17–33 minutes) from the entrance channel receivers at the Clifton Court Forebay (RGU, gates open) to the interior forebay receivers (RGD), to 4.70 days from Turner Cut to Chipps Island (Table 17a; April and May releases). 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. Travel times from the San Joaquin River receiver near Lathrop (SJL) to Garwood Bridge (SJG) averaged 1 day (~18 rkm). Average travel time from Old River South (ORS) to the CVP trashracks was also approximately 1 day (~18 rkm). Average travel time from MacDonald Island to Chipps Island (~54 rkm via the San Joaquin River) was approximately 2.6 days (Table 17a). From Jersey Point to Chipps Island was approximately 1 day (~25 rkm). Including the predator-type detections had little effect on average travel time through reaches (Table 17b).

Route Selection Analysis

Head of Old River

Old River flow (discharge) at the OH1 gaging station (near the head of Old River) at the estimated time of arrival of the tagged juvenile steelhead at the head of Old River ranged from -270 cfs to 1,534 cfs (average = 894 cfs), for study fish from the March release group that were detected at the SJL or ORE acoustic receivers before barrier closure during 2014 (8 April 2014). The flow at OH1 was negative for 3 of 116 (2%) tags upon arrival at the river junction. Water velocity ranged from -0.17 ft/s to 1.23 ft/s (average = 0.71 ft/s) at tag arrival. Flow and velocity at OH1 were highly correlated (r=0.98). Export rates averaged 3,005 cfs at CVP, and 972 cfs at SWP, at the estimated time of fish arrival at the head of Old River junction. There was little correlation between total Delta exports and flow into Old River (r=-0.02) upon fish arrival for the pre-barrier component of the March release group.

Route selection and covariate data were available for 116 tags from the March release group that were detected at the SJL or ORE receivers before barrier closure. Of these 116 tags detected, 112 were detected on the ORE receivers, and 4 were detected on the SJL receivers. Taking into account the low number of tags observed at SJL and the resulting high uncertainty in any data descriptions from those tags, a visual inspection indicated no evidence of a difference in arrival timing of the tags taking the San Joaquin River from those taking the Old River route (Figure 14). Thus, the possibility that the sets of tags observed in each route had different tag failure rates was expected to be minimal.

Of the 116 tags detected at SJL or ORE and used in the route selection analysis at the head of Old River, 4 were estimated to have arrived at head of Old River junction at dawn, 67 during the day, 1 during dusk, and 44 at night. Three of the four tagged steelhead that selected the San Joaquin River route arrived during the day, and one arrived at night. Steelhead that entered Old River tended to arrive at the junction at higher levels of Old River flow measured at the OH1 gaging station (Figure 15). Flow and velocity at the OH1 gaging station in Old River were highly correlated (r=0.985) at the estimated time of tag arrival at the head of Old River junction; thus, no velocity plot is shown. Old River flow at OH1 was only moderately correlated with San Joaquin River flow at Mossdale, measured at the MSD gaging station (r=0.157); however, positive flow at OH1 typically occurred when flow was positive at MSD (Figure 16), and tagged steelhead that selected the Old River route tended to arrive at the river junction when flow was higher at MSD, as well (Figure 17).

Median river stage at OH1 was lower for fish that selected the Old River route than for the 4 tagged steelhead observed selecting the San Joaquin River route from the pre-barrier March release group, as was median river stage at SJL (Figure 15). There was less difference and more overlap in the 15-change in flow at OH1 or river stage at either OH1 or SJL between the two groups of fish. Although exports from either CVP or SWP tended to be higher for fish that took the Old River route, the range of observed export values was comparable between the fish that took both routes (Figure 15). There was little difference in fork length at tagging between the two groups of fish. The observed data are consistent with a higher propensity to take the Old River route on ebb tide, and a higher propensity for the San Joaquin River route on a moderate flood tide. In all cases, however, the low number of tagged steelhead observed taking the San Joaquin River route precluded making firm conclusions about the effects of flow or other covariates on route selection.

Turner Cut

River flow (discharge) at the Turner Cut gaging station (TRN) at the time of detection of the tagged juvenile steelhead at the Turner Cut (TCE/TCW) or MacDonald Island (MAC) receivers ranged from -4,014 cfs to 2,980 cfs (average = 366 cfs) in 2014. The flow in Turner Cut was negative (directed in to Turner Cut from the San Joaquin River) for 79 of 212 (37%) of the tags detected. Water velocity at TRN ranged from -0.74 ft/s to 0.60 ft/s (average = 0.09 ft/s) at the time of tag detection in 2014; there was high correlation between river flow and water velocity at the TRN station (r=0.999). River stage at

TRN ranged from 6.5 ft to 10.8 ft (average = 8.5 ft) at tag detection at TCE/TCW or MAC; correlation between river stage and either flow or water velocity was moderate (r=-0.79 to -0.80). The average magnitude (root mean square) of river flow at Garwood Bridge (station SJG) in the San Joaquin River during fish travel from the SJG acoustic receiver to detection at TCE/TCW or MAC ranged from 892 cfs to 2,055 cfs (average = 1,629 cfs); data were missing for one tag. Export rates at CVP averaged 1,642 cfs at the time of tag detection at TCE/TCW or MAC; SWP export rates averaged 423 cfs. There was little correlation between either CVP exports or SWP exports and flow at Turner Cut ($|r| <$ 0.02 for both).

The majority of the fish detected at either Turner Cut or MacDonald Island in 2014 were observed at MacDonald Island, and most came from the April release group (Table 11). There was little obvious pattern in variations in route selection and either flow (Figure 18), velocity (Figure 19), river stage (Figure 20), or exports (Figure 21), summarized on the weekly time scale. Of the 212 tags used in the Turner Cut route selection analysis, 163 (77%) selected the San Joaquin River route, and 49 (23%) selected the Turner Cut route. This left a maximum of 49 degrees of freedom for the regression models. Complete covariate data were unavailable for one tag, which resulted in only 211 tags for the route selection analysis.

The single-variate analyses found significant effects (family-wise α=0.05) only of flow and velocity in Turner Cut (TRN gaging station) on the probability of remaining in the San Joaquin River at Turner Cut. Several additional covariates were significant at the more lenient test-wise significance level of α=0.05: the presence of negative flow at TRN, and both river stage and the 15-minute change in stage at TRN (Table 18). Effects of the average magnitude of flow and velocity at SJG during the fish transition from Garwood Bridge to the Turner Cut junction, time of day of arrival, release group, fork length, and all measures of exports were all non-significant, as were the 15-minutes changes in both flow and velocity at TRN (P≥0.1680), whether at the family-wise α level or the test-wise α level (Table 18).

Several covariates had strong effects based on the single-variate models (Table 18). 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 single-variate measures directly produce changes in route selection at the head of Old River. Multiple regression may shed more light on which covariates are worthy of further study, but causal relationships will not be discernable.

Multiple regression found significant effects of flow, velocity, negative flow at TRN, and the 15-minute change in river stage at TRN (Table 19). Once these measures were in the models, no other covariates had significant effects (P>0.05). Each of the flow, velocity, and river stage models adequately fit the data (P>0.98). The combined stage model accounted for more variation in route selection at Turner Cut than either of the competing models (ΔAIC>10) (Table 19). The interaction effect between the 15-minute change in stage and the presence of negative flow at TRN was not significant at the 0.05 level (P=0.4494).

The stage model predicted the probability of remaining in the San Joaquin River at Turner Cut according to:

$$\hat{\psi}_A = \frac{\exp\left(1.78 - 8.58\,\Delta C_{TRN} - 1.93U\right)}{1 + \exp\left(1.78 - 8.58\,\Delta C_{TRN} - 1.93U\right)}$$

where ΔC_{TRN} and U represent the 15-minute change in river stage at TRN and the condition of negative flow at TRN, respectively, upon tag detection at the Turner Cut or MacDonald Island receivers. A negative measure of flow at TRN indicated that river flow was directed out of the San Joaquin River and into Turner Cut. Equivalently, the probability of selecting the Turner Cut route was modeled as:

$$\hat{\psi}_F = \left[1 + \exp\left(1.78 - 8.58\,\Delta C_{TRN} - 1.93U\right)\right]^{-1}.$$

This model includes effects of both river flow and river stage on the probability of selecting Turner Cut. Assuming that conditions at tag detection were similar to conditions when the fish arrived at the junction, the model predicts that fish are more likely to select the Turner Cut route if they arrive when the river flow is directed into Turner Cut from the San Joaquin River, and on a rising (incoming or flood) tide (Figure 22). Although the 15-minute change in stage tended to be higher and more variable when the flow at TRN was negative (Figure 23), the observed correlation between the two measures for the tags detected was moderate (r=-0.42). It appears that both conditions (incoming tide and negative flow), either alone or in combination with the other condition, are associated with a higher probability of taking the Turner Cut route.

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 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 (excluding predator-type detections), and also for the pooled data set from the April and May release groups (population estimate). Estimates for the March release group reflect premature tag failure from the tag manufacturing error, and so represent only minimum estimates of steelhead survival.

Estimated survival from the CVP holding tank to Chipps Island, Jersey Point, or False River ranged from 0.74 ($\widehat{SE} = 0.08$) for the March release group (joint fish-tag survival), with a 95% profile likelihood interval of (0.58, 0.88), to 1.00 ($\widehat{SE} = 0$) for the April and May release groups (based on 11 fish in April, and 1 fish in May) (Table 20). The 95% lower bound on survival from the CVP tank was 0.78 for the April and May release groups (pooled), assuming a detection probability of 0.85 (= the weighted average of Chipps Island detection probabilities for April and May). For the state facility, estimated survival from the radial gates to Chipps Island, Jersey Point, or False River ranged from 0 for the April and May release groups (sample size = 1 to 2) to 0.34 ($\widehat{SE} = 0.19$; 95% CI = (0.07, 0.73)) for the March release group (joint fish-tag survival) (Table 20). The 95% upper bound on survival from the radial gates was 0.74 for the April and May release groups (pooled). The high upper bound (0.74) on the April and May estimate of facility survival from the radial gates reflects the very low sample size available for this analysis (n=3) for these release groups, even pooled across release month, and indicates the lack of confidence in the SWP survival estimate for those releases. The sample size for the SWP analysis was slightly higher for the March release group (n=6), and considerably higher for the March estimate of CVP survival (n=34). However, the March tags had a programming error that turned them off prematurely. This means that although there was higher confidence in the estimates for that release group, the estimates are most properly interpreted as estimates of the joint survival of both steelhead and tag, and so are only minimum estimates of survival for steelhead alone.

Discussion

Surgeon Effects

The point estimates of cumulative fish-tag survival were consistently lower for steelhead tagged by surgeon C compared to the other surgeons, except for the survival to Chipps Island via the Old River Route (Figure 12, Figure 13). However, the differences were not statistically significant, and the overall pattern of survival was similar among the three surgeons. Surgeon C had the highest point estimates of survival among Chinook Salmon in the 2014 study (Buchanan et al. 2018), which suggests that the observed differences in point estimates of steelhead survival arose from statistical variability rather than negligence or inadequate skill on the part of surgeon C. However, the delicate nature of the surgeries and the intensity of the mortality risks experienced by the tagged study fish emphasize the value of providing all surgeons with thorough surgical training before tagging begins for each study year, including experienced surgeons. Such practice has been the protocol in the Six-Year Study.

Comparison between Release Groups

Survival and transition probability estimates were significantly (family-wise α=0.10) greater for the April release group compared to the May release group for all survival probabilities upstream from Mossdale, survival in the San Joaquin River from the Navy Drive Bridge to the Turner Cut junction, the Old River transition probability from Old River East (B1, located near the head of Old River) to Old River South (B2, located near the head of Middle River), and total survival from Mossdale through the Delta to Chipps Island (Table 21). There was no statistically significant difference between the April and May release groups in estimates of survival from Garwood Bridge to the Navy Drive Bridge/Burns Cutoff junction or from MacDonald Island to Chipps Island, or for estimates of survival from Old River South to Chipps Island (Table 21).

Water temperatures were considerably higher for the May release group than for the March and April releases (Figure 24); average water temperature at the SJL gaging station, during the period from the start of the release period through 11 days after the end of the release period, was 17.2°C, 17.2°C, and 23.0°C for the March, April, and May release groups, respectively. The May release group also had the lowest river flows during the migration period (average = 615 cfs), but largely comparable to the flow for the March release group (average = 734 cfs); flows were higher for the April release group (average = 2,644 cfs), which had the highest Delta survival (Figure 25). Combined exports from the CVP and SWP were highest for the March release group, and generally decreased throughout the study period; averages upon tag release were 3,666 cfs, 2,338 cfs, and 1,142 cfs for the March, April, and May release groups, respectively (Figure 26).

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Figures

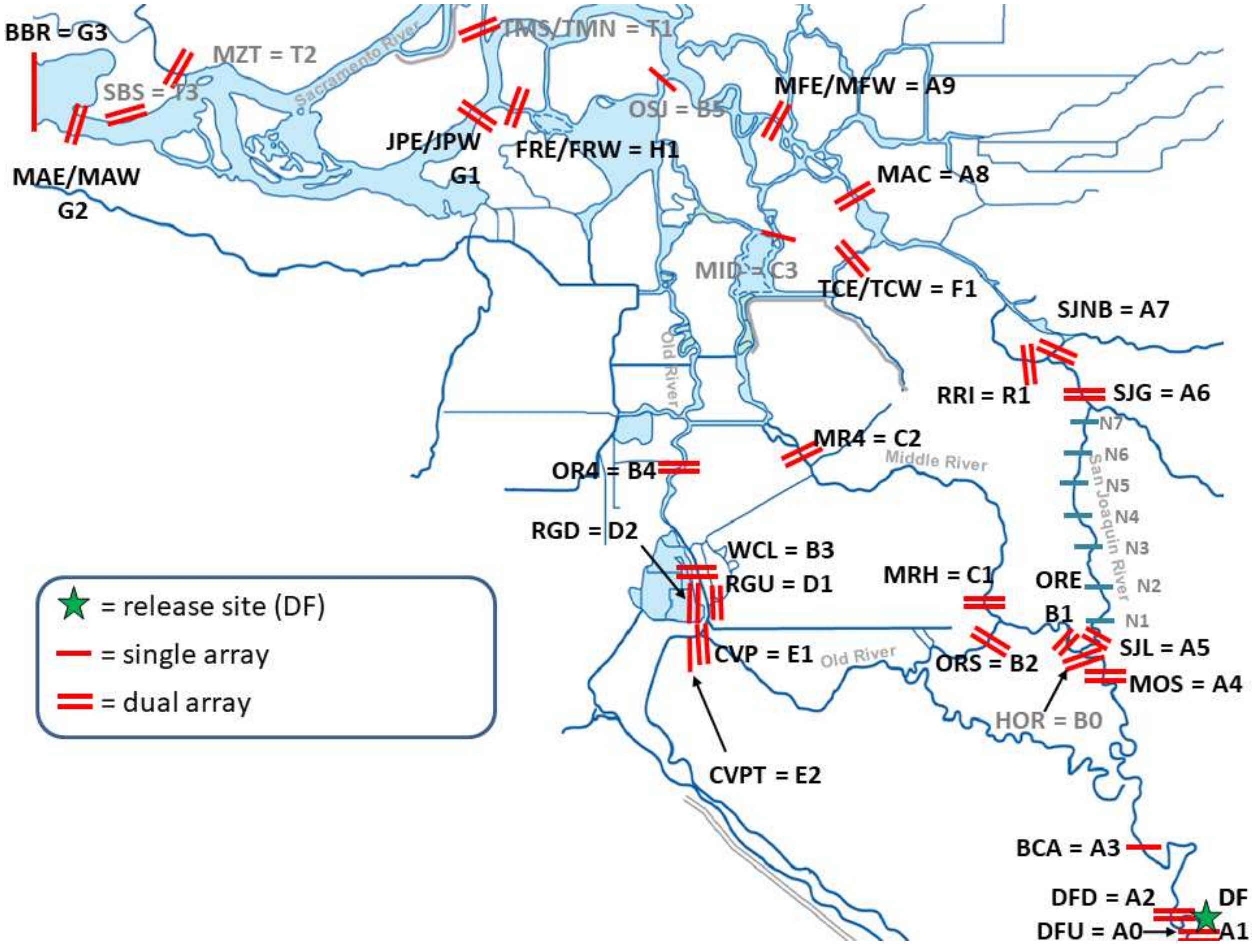

Figure 1. Locations of acoustic receivers and release site used in the 2014 steelhead tagging study, with site code names (3- or 4-letter code) and model code (letter and number string). Site A1 is the release site at Durham Ferry.

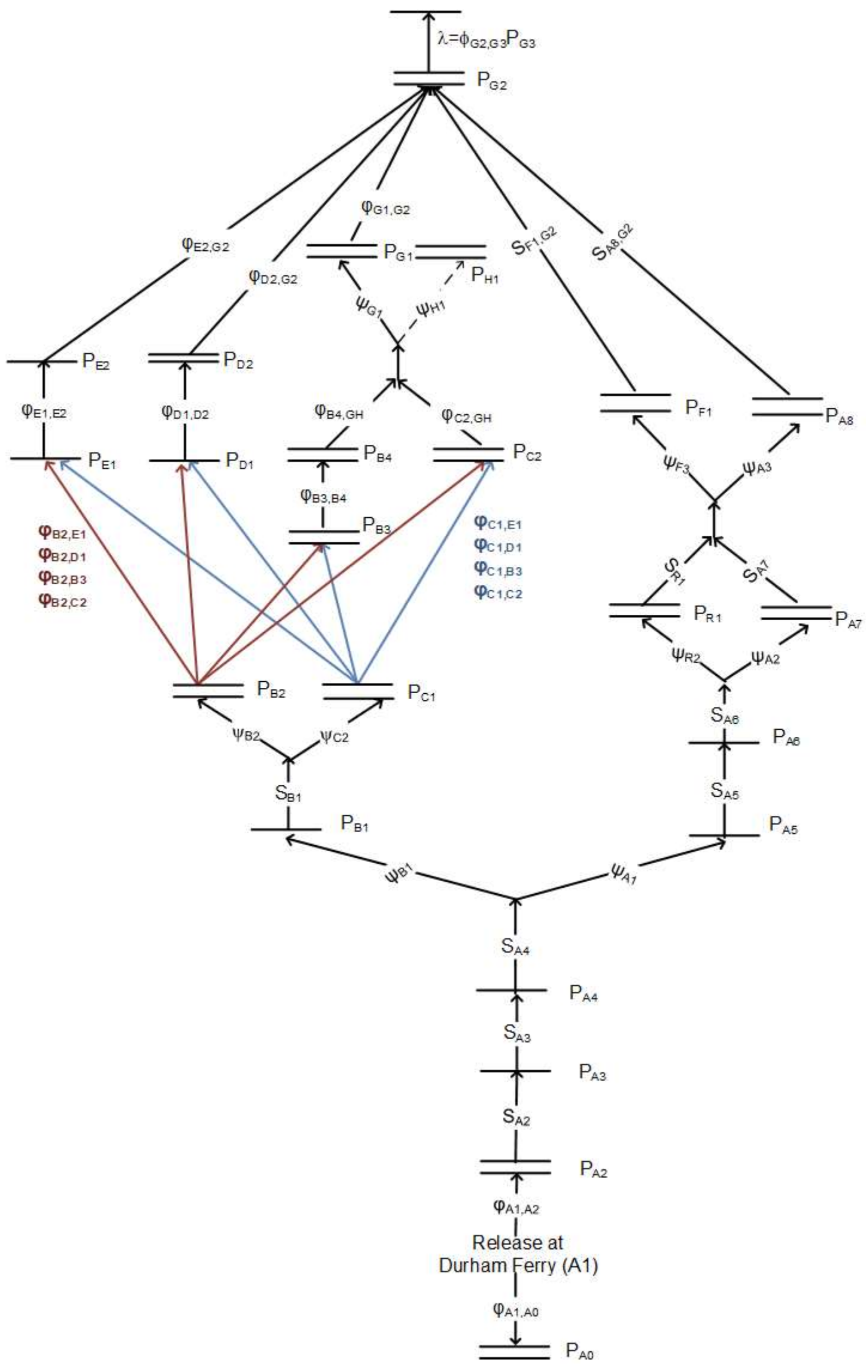

Figure 2. Schematic of 2014 mark-recapture Submodel I with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 1. Migration pathways to sites B3 (WCL), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.

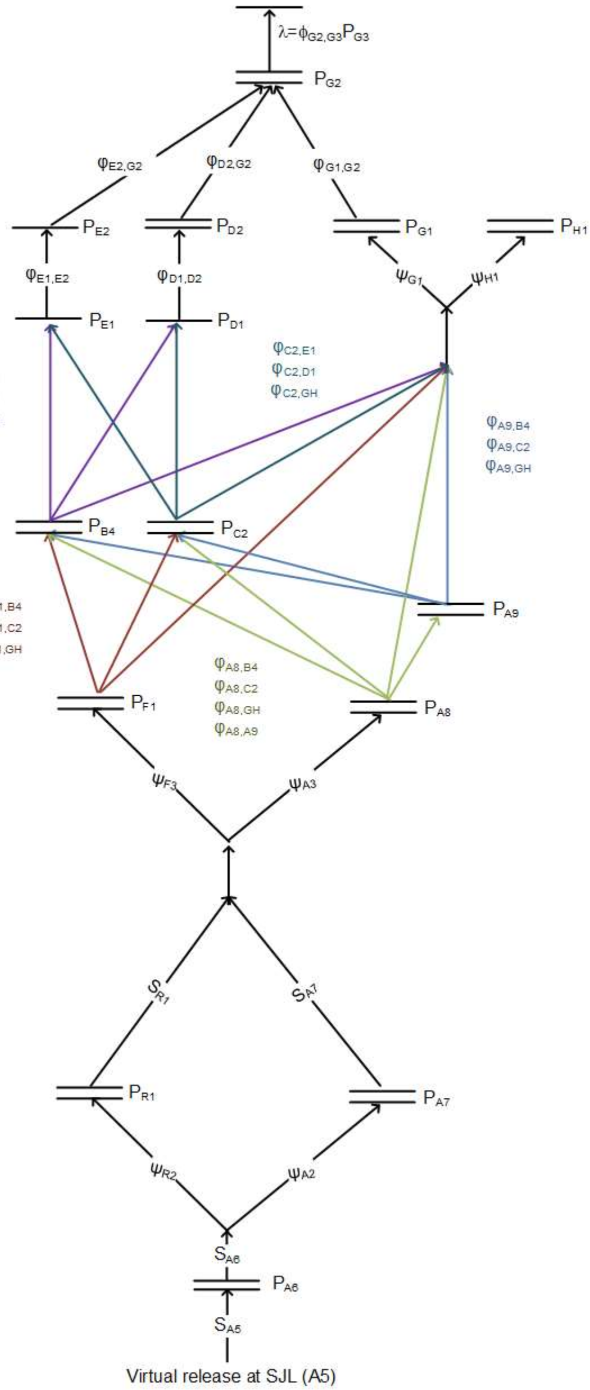

Figure 3. Schematic of 2014 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 1. Migration pathways to sites B4 (OR4), C2 (MR4), D1 (RGU), E1 (CVP), and the G1-H1 junction (JPE/JPW – FRE/FRW) are color-coded by departure site.

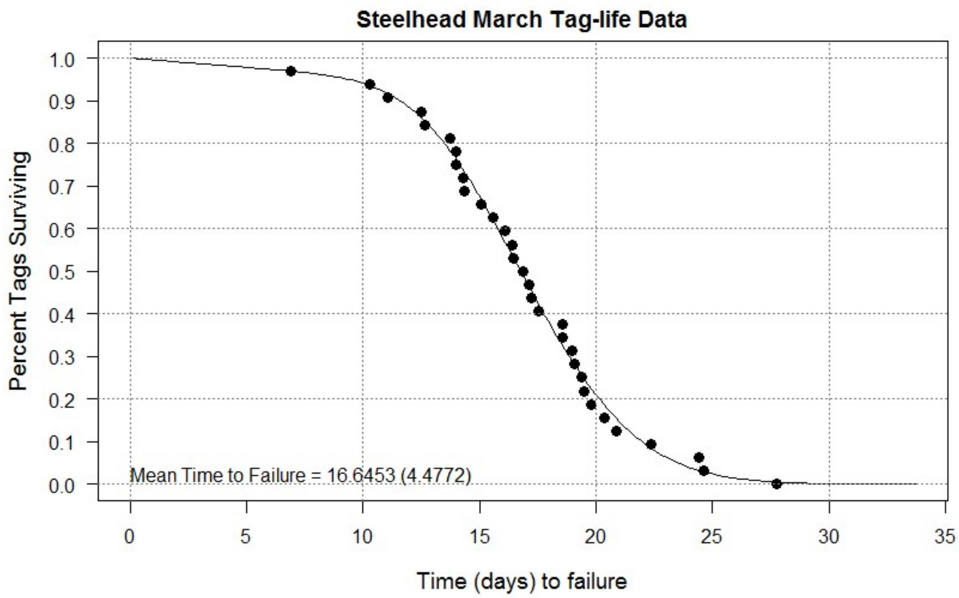

Figure 4. Observed tag failure times from the March 2014 tag-life study, and fitted four-parameter vitality curve.

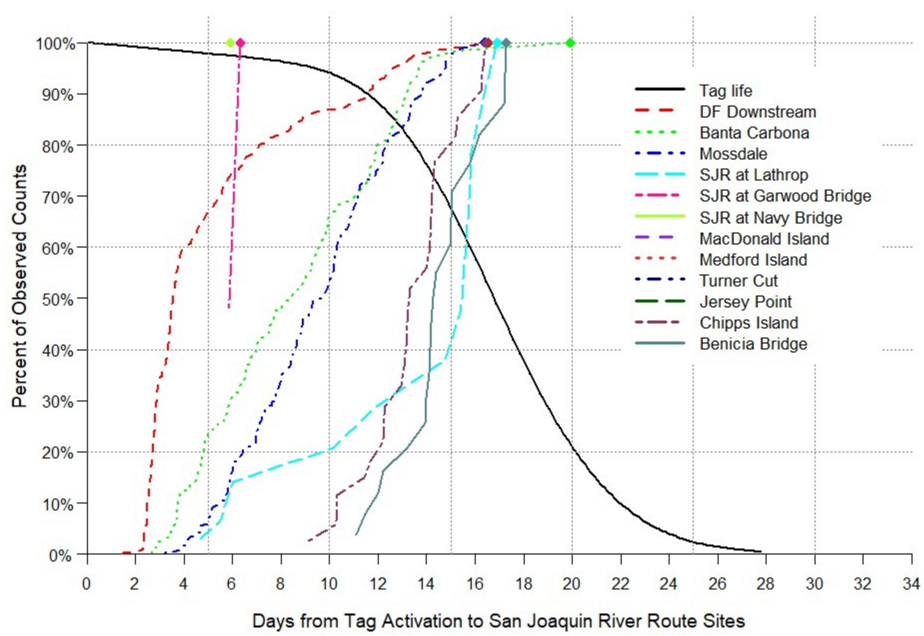

Figure 5. Four-parameter vitality survival curve for tag survival from March tag-life study (reflects tag programming error), and the cumulative arrival timing of acoustic-tagged juvenile steelhead from the March release group at receivers in the San Joaquin River route to Chipps Island in 2014, including detections that may have come from predators.

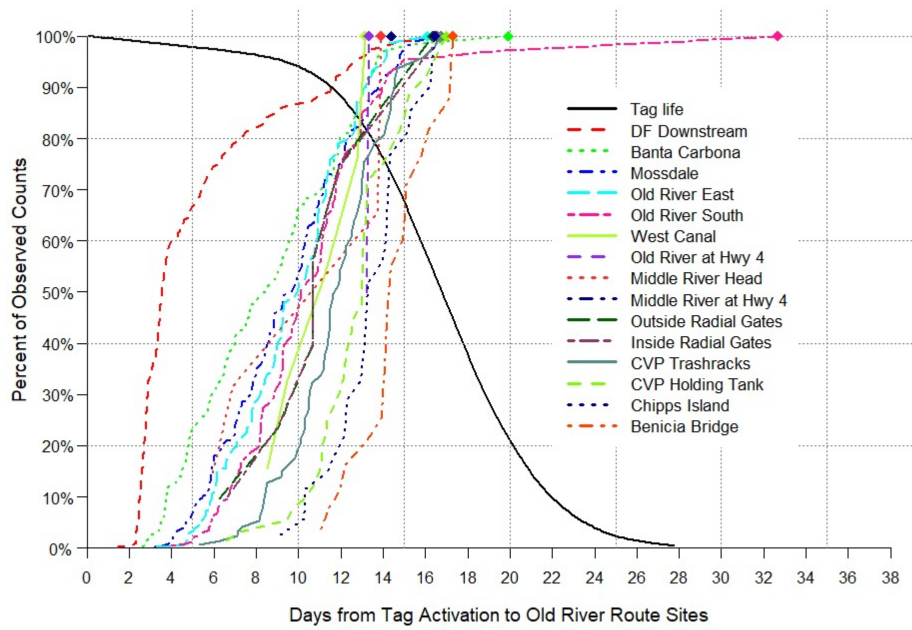

Figure 6. Four-parameter vitality survival curve for tag survival from March tag-life study (reflects tag programming error), and the cumulative arrival timing of acoustic-tagged juvenile steelhead from the March release group at receivers in the Old River route to Chipps Island in 2014, including detections that may have come from predators.

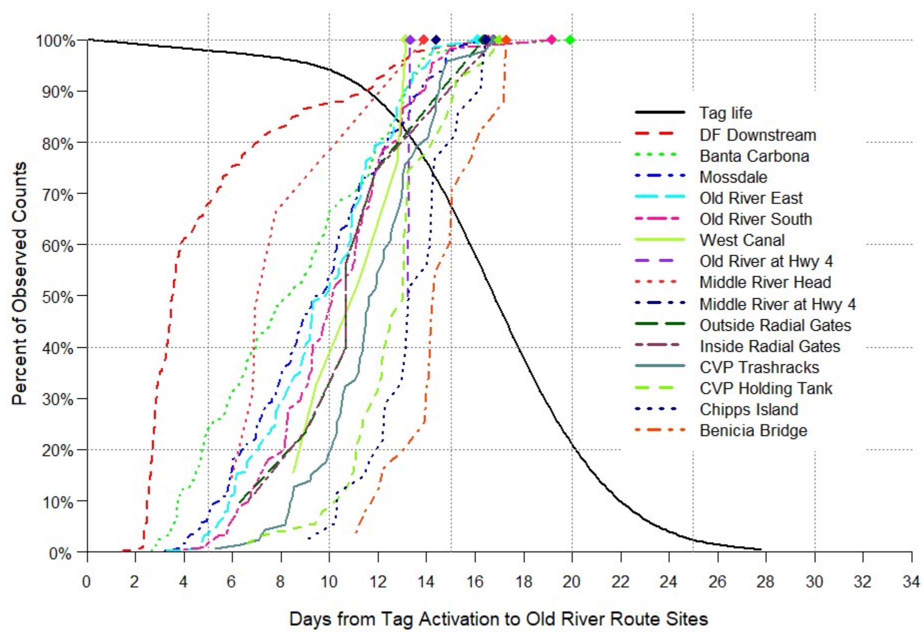

Figure 7. Four-parameter vitality survival curve for tag survival from March tag-life study (reflects tag programming error), and the cumulative arrival timing of acoustic-tagged juvenile steelhead from the March release group at receivers in the Old River route to Chipps Island in 2014, excluding detections that may have come from predators.

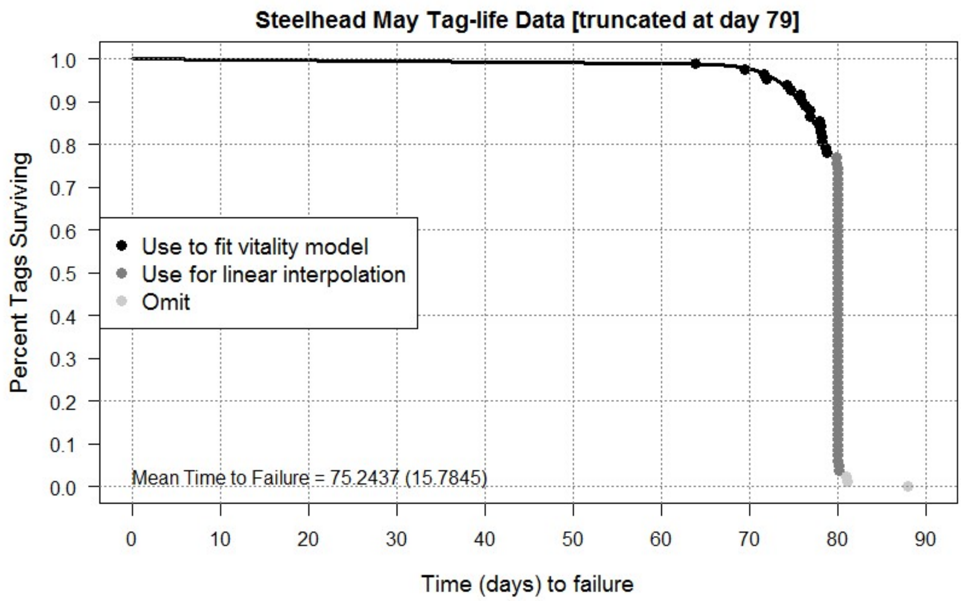

Figure 8. Observed tag failure times from the May 2014 tag-life studies, pooled over the early May and late May studies, and fitted four-parameter vitality curve. Failure times were censored at day 79 to improve fit of the model.

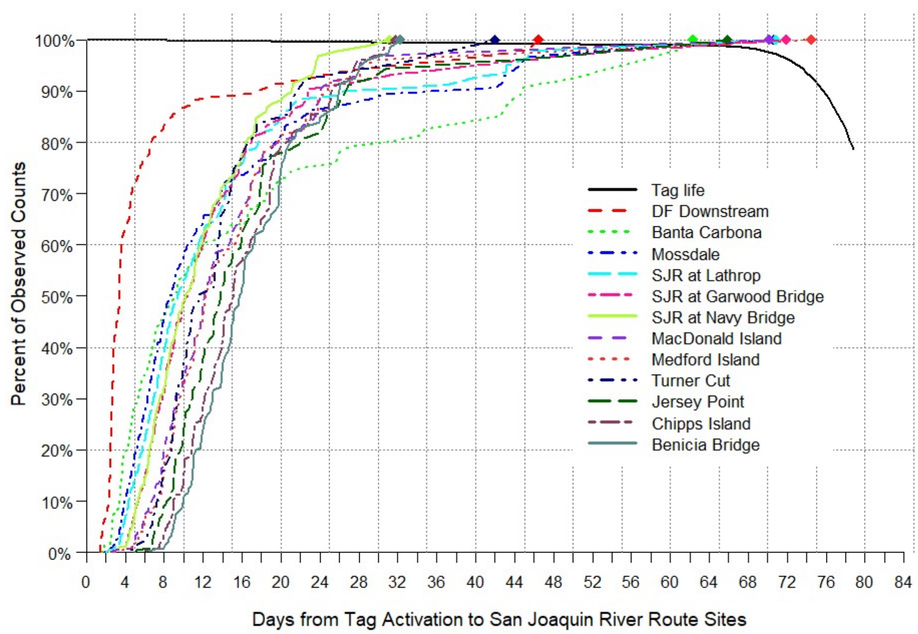

Figure 9. Four-parameter vitality survival curve for tag survival from May tag-life studies, and the cumulative arrival timing of acoustic-tagged juvenile steelhead from the April and May release groups at receivers in the San Joaquin River route to Chipps Island in 2014, including detections that may have come from predators. The tag survival curve was estimated only to day 79, to improve model fit.

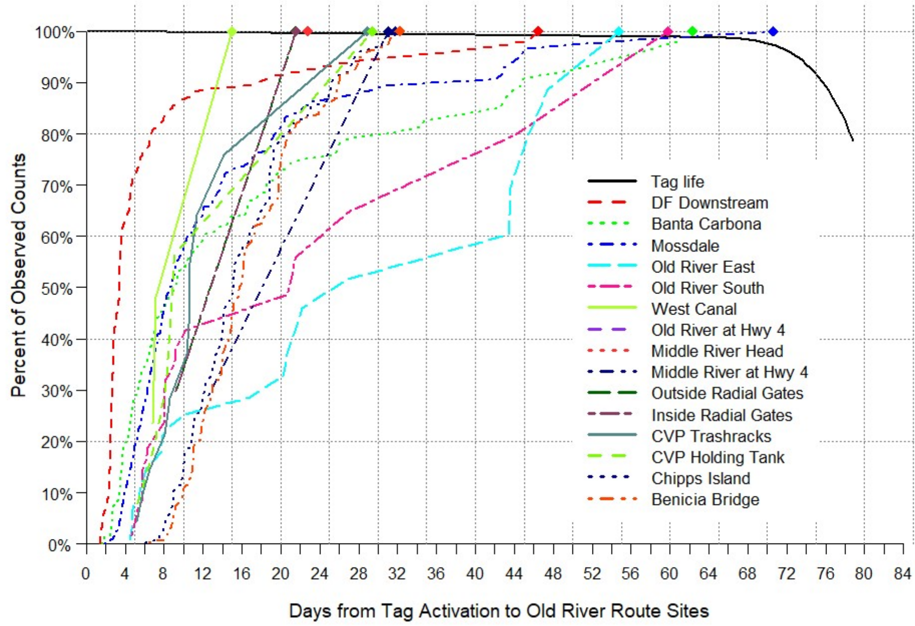

Figure 10. Four-parameter vitality survival curve for tag survival from May tag-life studies, and the cumulative arrival timing of acoustic-tagged juvenile steelhead from the April and May release groups at receivers in the Old River route to Chipps Island in 2014, including detections that may have come from predators. The tag survival curve was estimated only to day 79, to improve model fit.

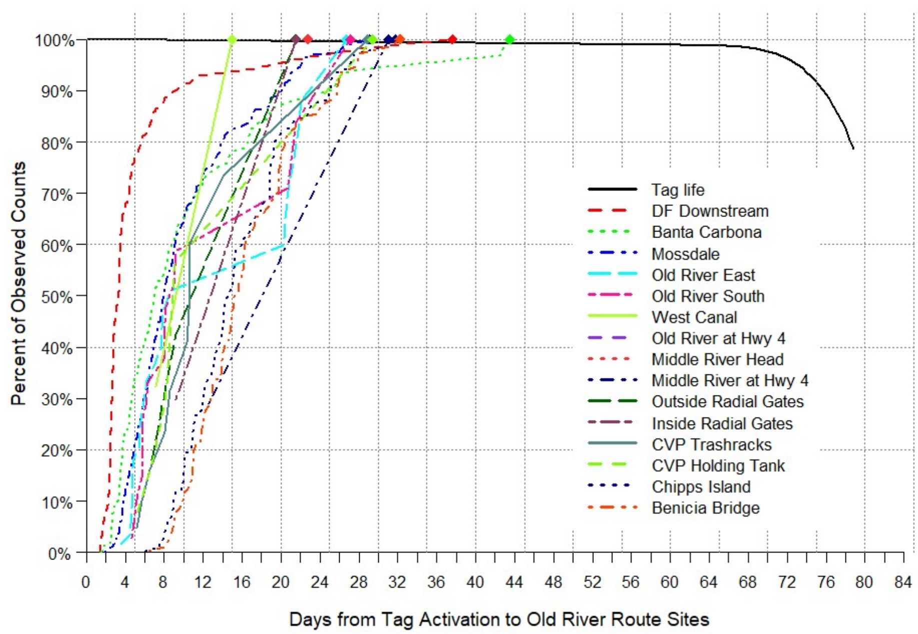

Figure 11. Four-parameter vitality survival curve for tag survival from May tag-life studies, and the cumulative arrival timing of acoustic-tagged juvenile steelhead from the April and May release groups at receivers in the Old River route to Chipps Island in 2014, excluding detections that may have come from predators. The tag survival curve was estimated only to day 79, to improve model fit.

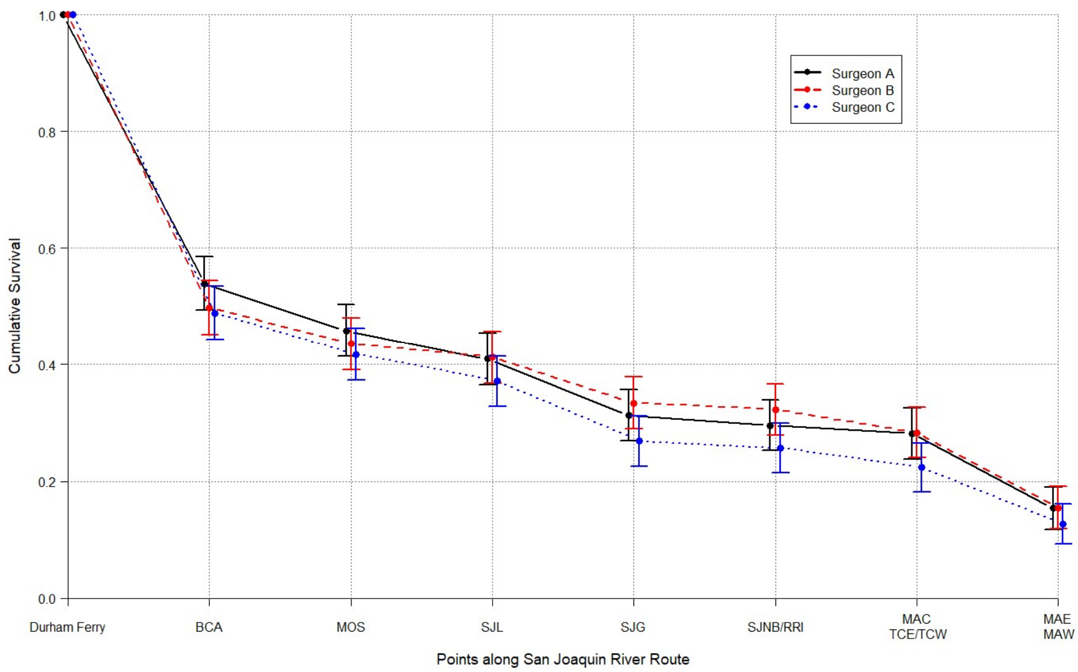

Figure 12. Cumulative survival from release at Durham Ferry to various points along the San Joaquin River route to Chipps Island, by surgeon. Error bars are 95% confidence intervals. Estimates are of joint fish-tag survival.

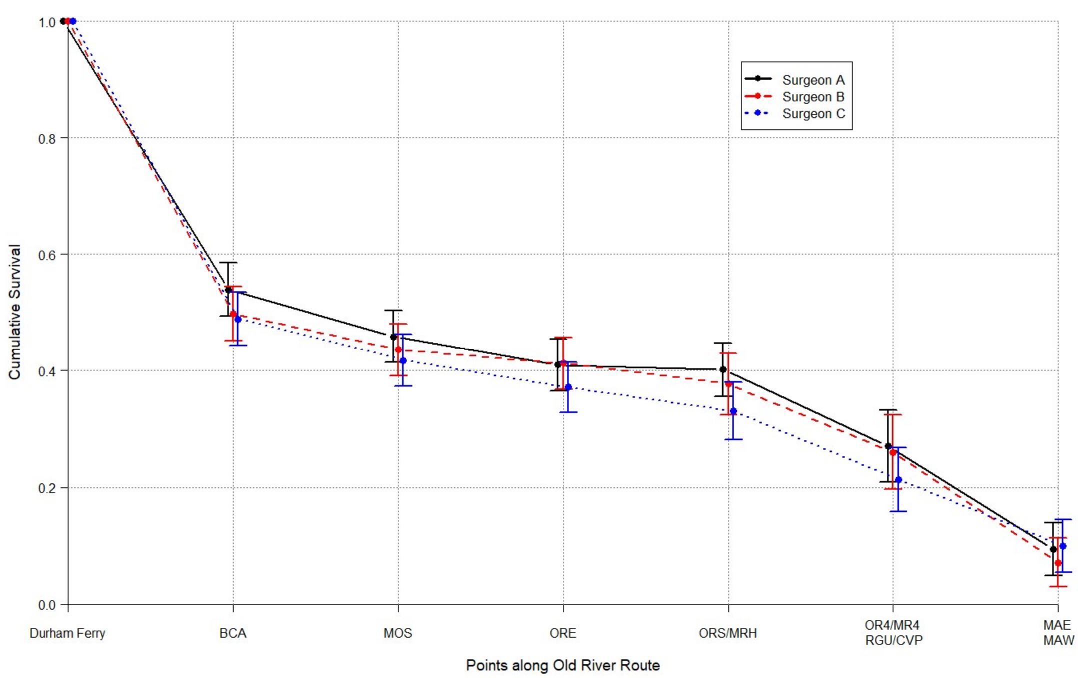

Figure 13. Cumulative survival from release at Durham Ferry to various points along the Old River route to Chipps Island, by surgeon. Error bars are 95% confidence intervals. Estimates are of joint fish-tag survival.

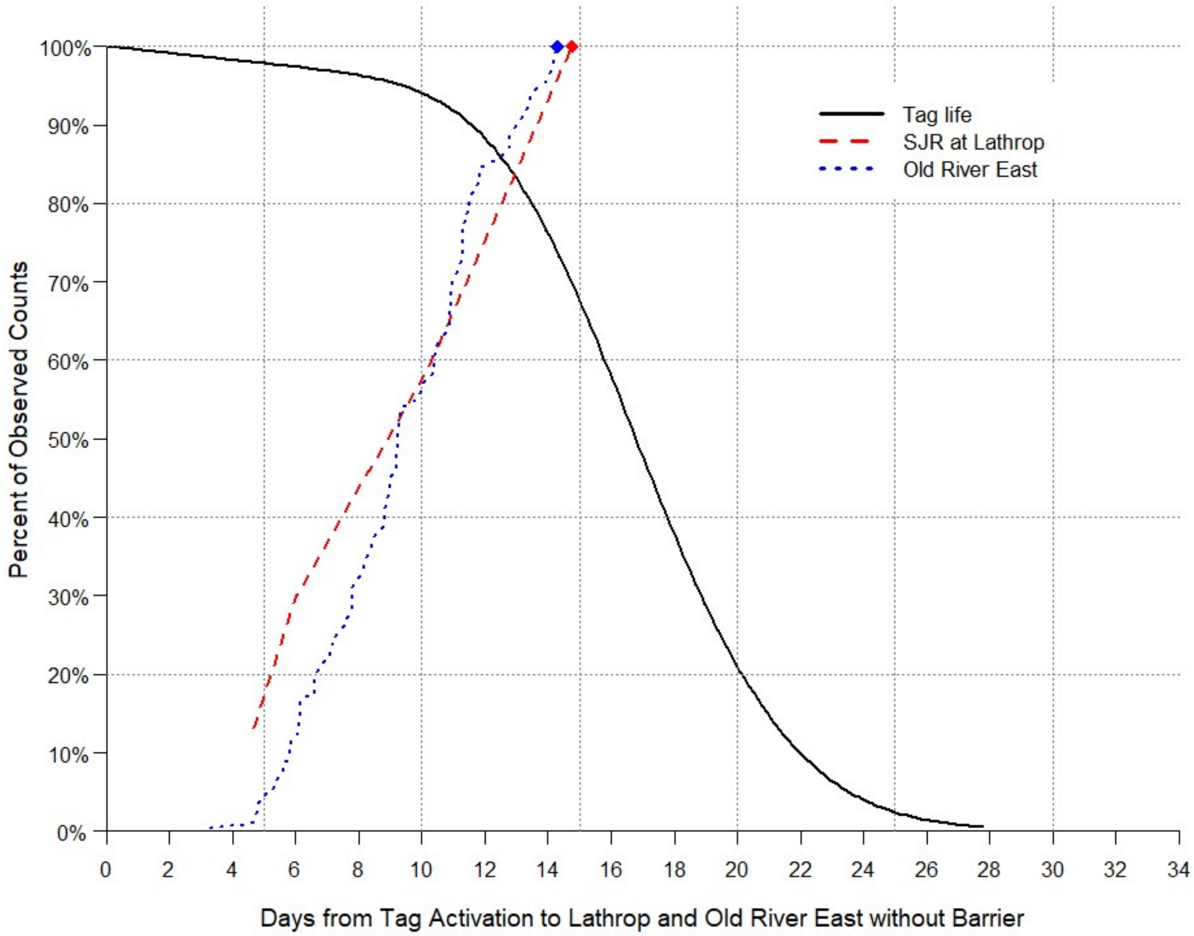

Figure 14. Cumulative arrival timing of acoustic-tagged juvenile steelhead from the March release group that were detected at either the Lathrop (SJL) or Old River East (ORE) receivers before the barrier closure date of 8 April 2014, together with the four-parameter vitality survival curve for tag survival from the March tag-life study (reflects tag programming error). Predator-type detections were excluded, as were detections that followed downstream detections or multiple successive visits to the SJL and OH1 receivers, and of tags that lingered more than 3 hours in the vicinity of the head of Old River.

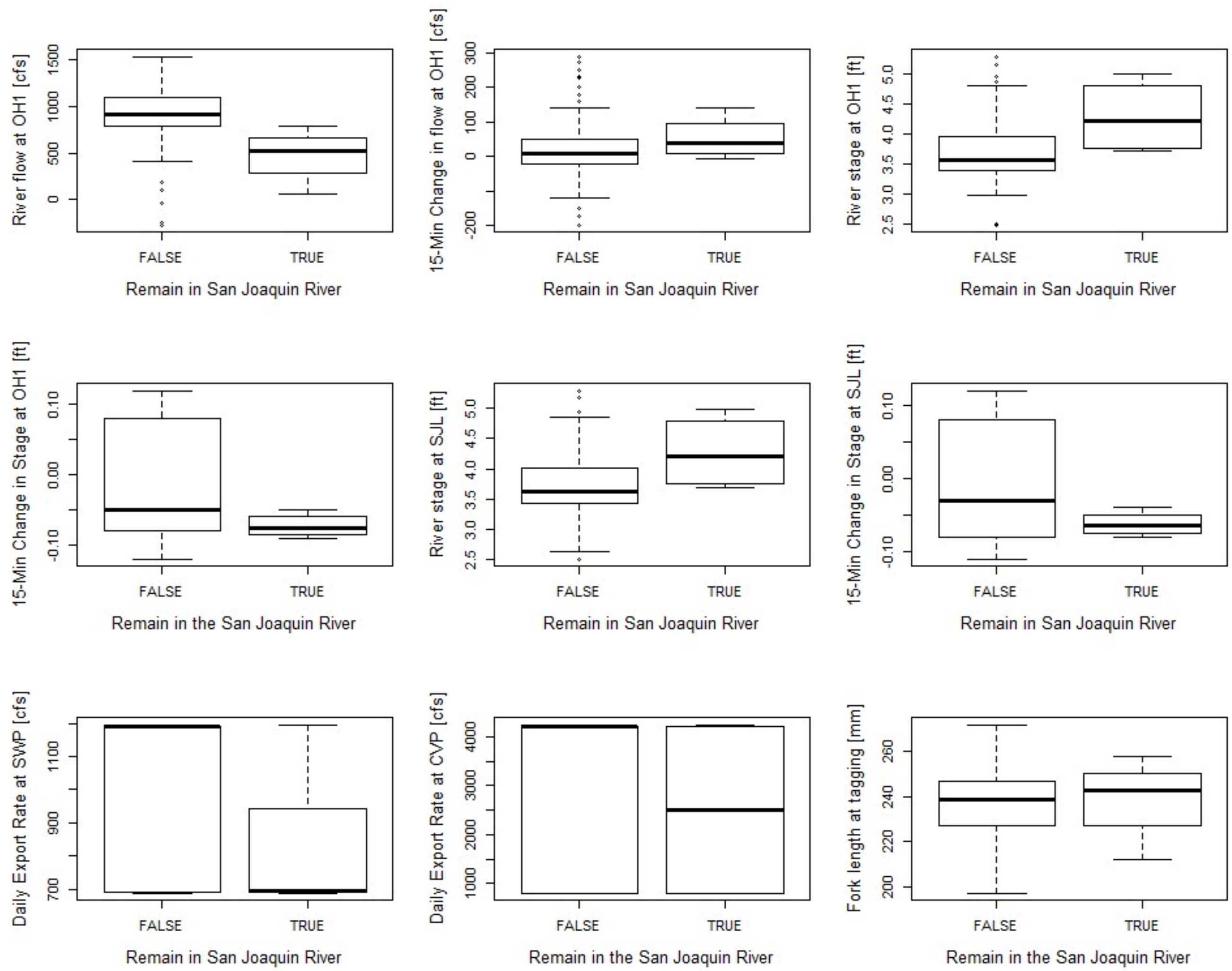

Figure 15. Conditions upon the estimated time of arrival at the head of Old River junction, daily export rates, and fork length at tagging, for steelhead from the March release group that were detected at the SJL or ORE receivers from March through 8 April 2014 (closure date for the head of Old River barrier). Data represent tags that whose most recent detections were either upstream or in the other river branch, and did not linger in the vicinity of the river junction longer than 3 hours; predator-type detections were omitted. Bolded horizontal bar is median measure, upper and lower boundaries of box are the 25th and 75th quantiles (defining the interquartile range), and whiskers are the extremes of 1.5 × the interquartile range.

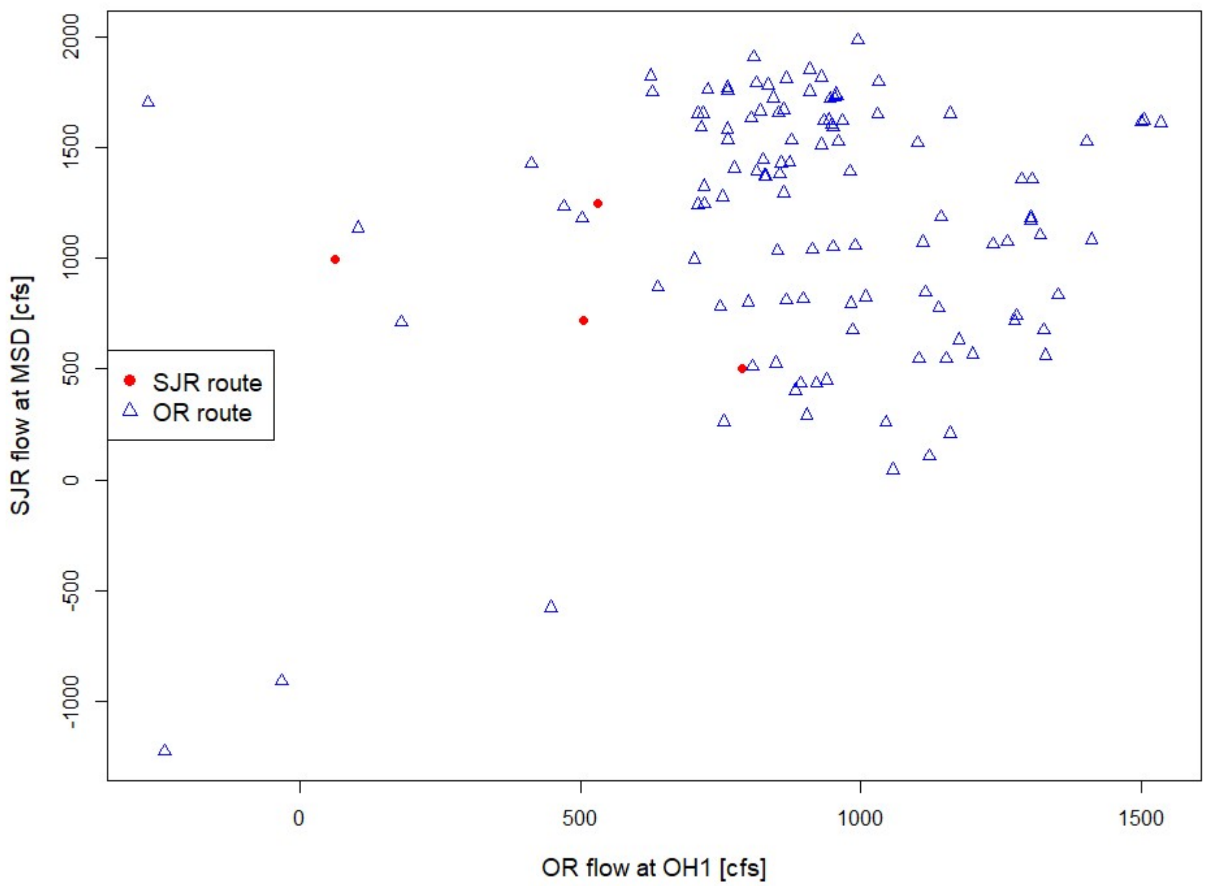

Figure 16. Discharge ("flow") of the Old River ("OR") at the OH1 gaging station, and of the San Joaquin River ("SJR") at the MSD gaging station at the estimated time of arrival at the head of Old River junction of tagged steelhead from the March release group that were detected at the SJL (filled circles) or ORE (open triangles) receivers through 8 April 2014.

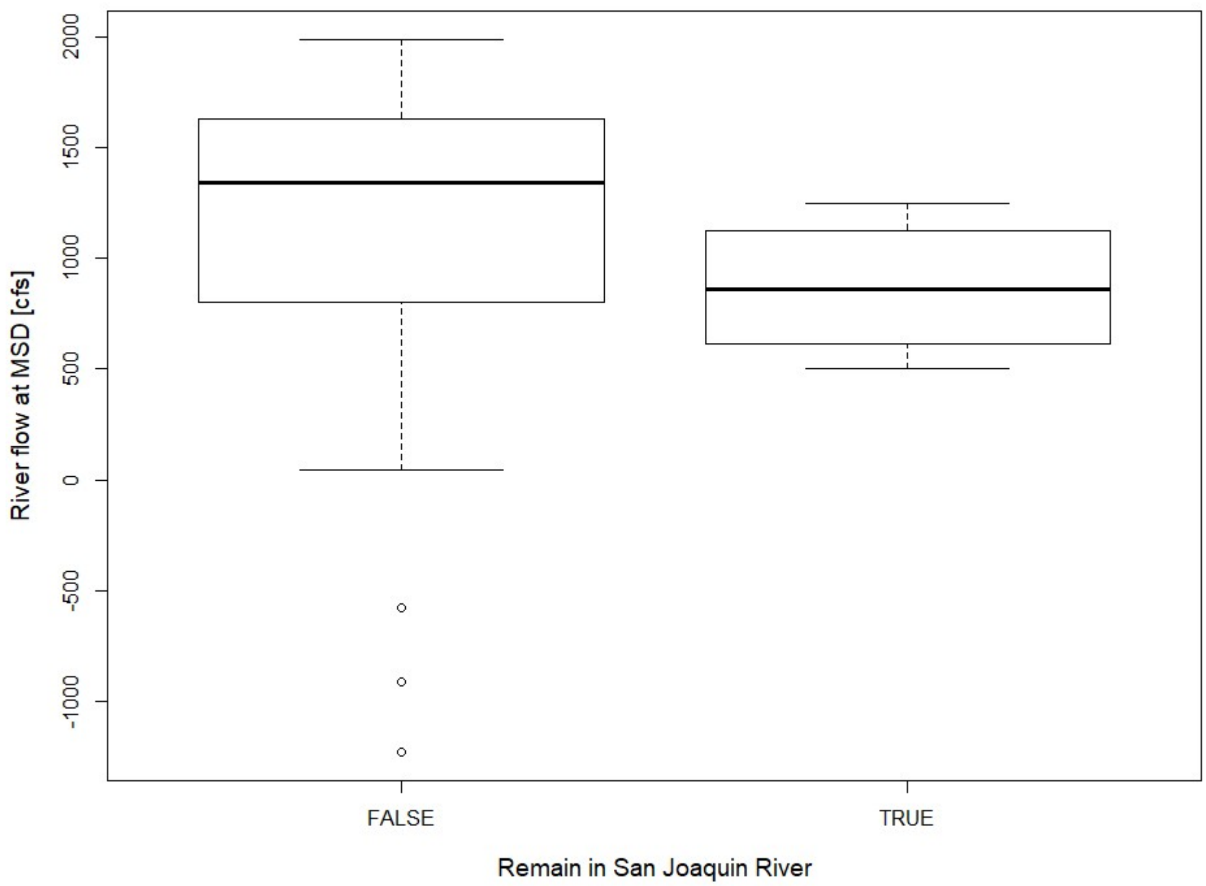

Figure 17. San Joaquin River flow conditions at the MSD gaging station upon the estimated time of arrival at the head of Old River junction, for steelhead from the March release group that were detected at the SJL or ORE receivers from March through 8 April 2014. Data represent tags that whose most recent detections were either upstream or in the other river branch, and did not linger in the vicinity of the river junction longer than 3 hours; predator-type detections were omitted. Bolded horizontal bar is median measure, upper and lower boundaries of box are the 25th and 75th quantiles (defining the interquartile range), and whiskers are the extremes of 1.5 × the interquartile range.

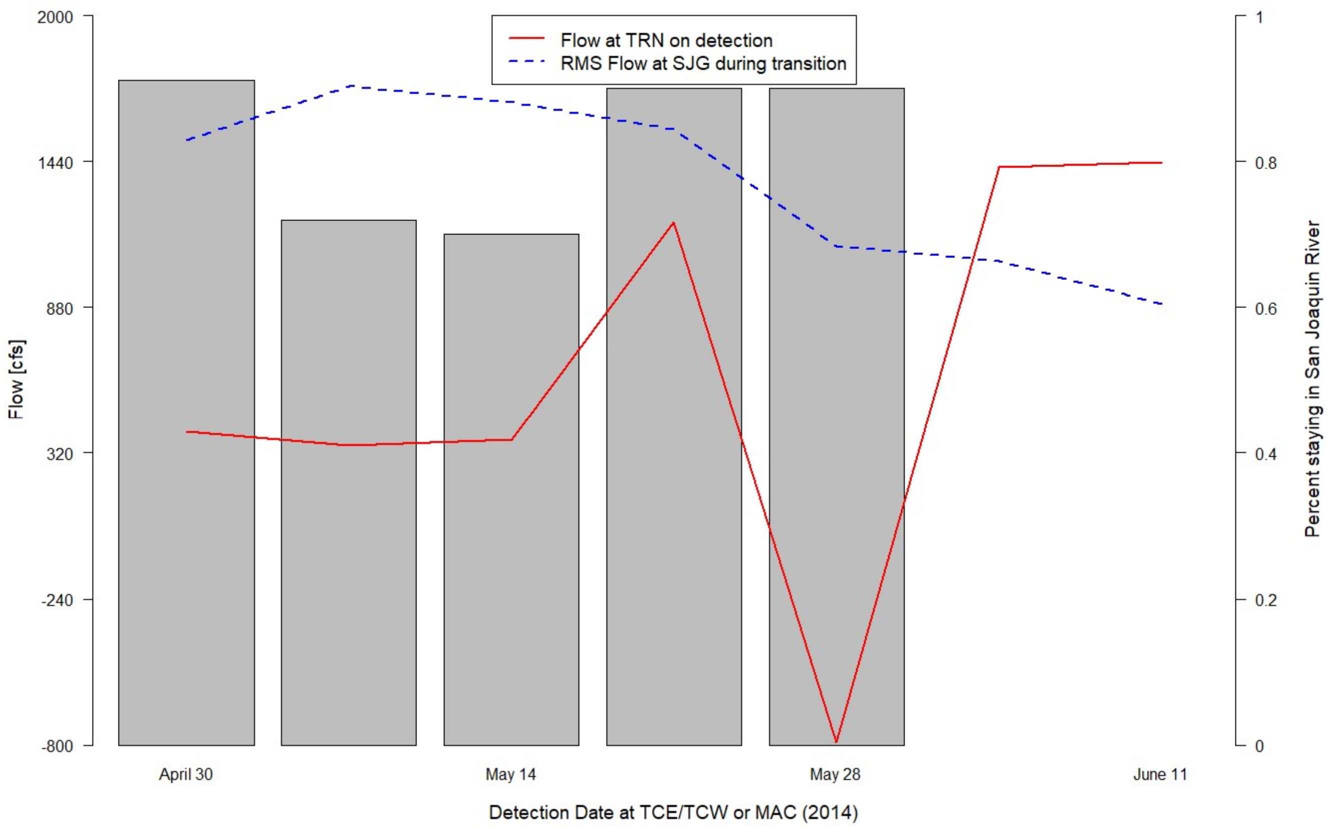

Figure 18. The observed proportion of tagged juvenile steelhead that remained in the San Joaquin River at the Turner Cut junction during the 2014 tagging study (gray bars, representing weekly periods), the measured river discharge (flow) at the TRN gaging station in Turner Cut at the time of tag detection at the Turner Cut or MacDonald Island receivers, averaged over fish (solid line), and the Root Mean Square (RMS) of river flow measured at the SJG gaging station during fish transition from the SJG acoustic receiver to the Turner Cut or MacDonald Island receivers, averaged over fish (dashed line). Proportion of fish remaining in the San Joaquin River is shown only for time periods with at least 10 fish detected.

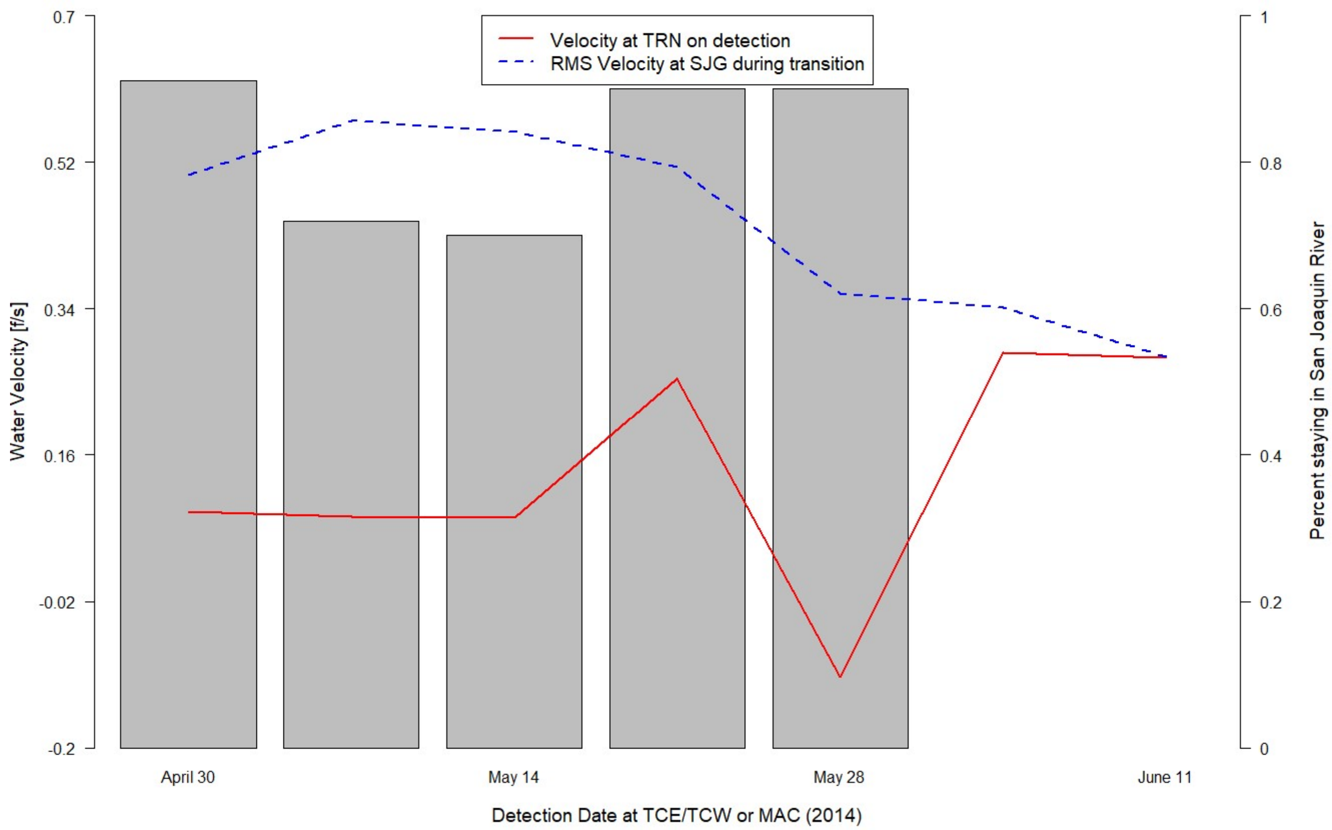

Figure 19. The observed proportion of tagged juvenile steelhead that remained in the San Joaquin River at the Turner Cut junction during the 2014 tagging study (gray bars, representing weekly periods), the measured water velocity at the TRN gaging station in Turner Cut at the time of tag detection at the Turner Cut or MacDonald Island receivers, averaged over fish (solid line), and the Root Mean Square (RMS) of water velocity measured at the SJG gaging station during fish transition from the SJG acoustic receiver to the Turner Cut or MacDonald Island receivers, averaged over fish (dashed line). Proportion of fish remaining in the San Joaquin River is shown only for time periods with at least 10 fish detected.

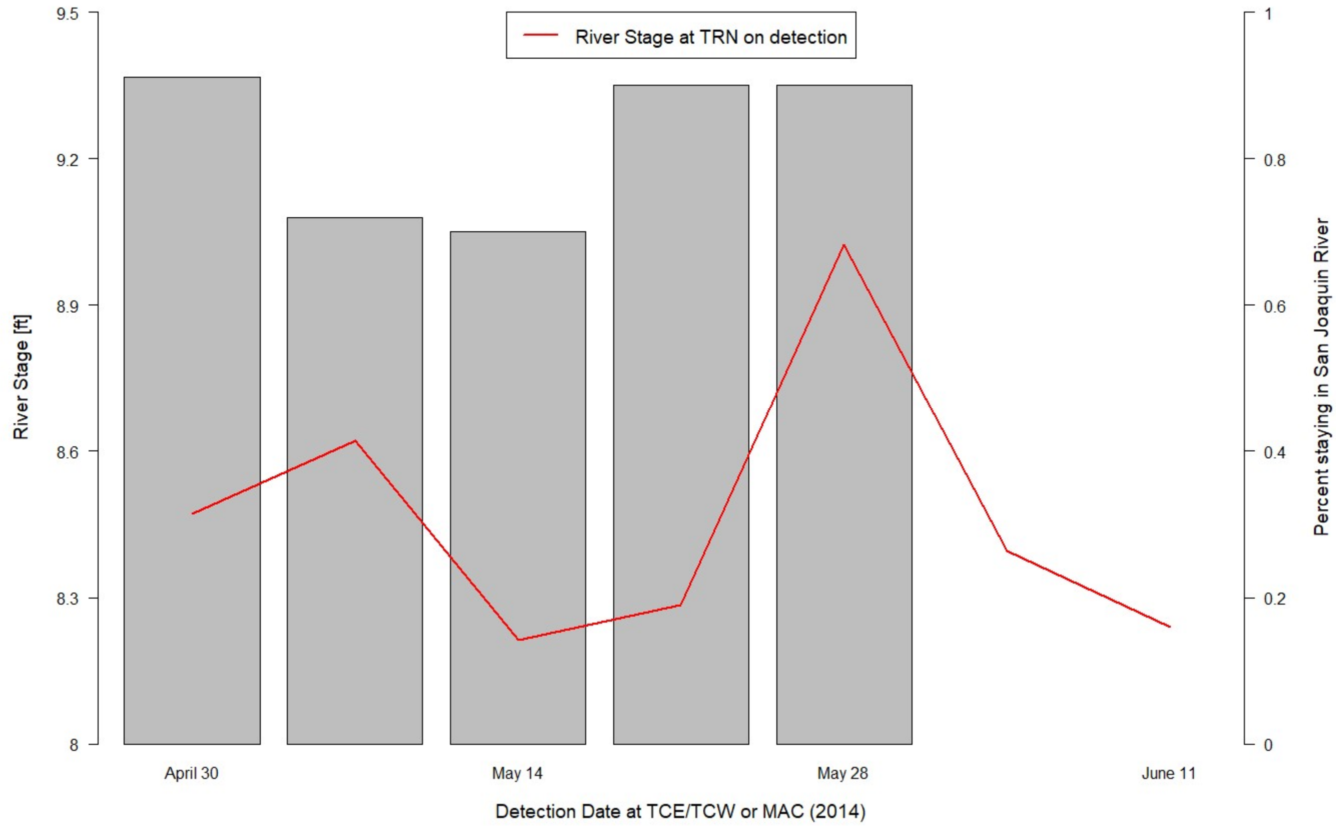

Figure 20. The observed proportion of tagged juvenile steelhead that remained in the San Joaquin River at the Turner Cut junction during the 2014 tagging study (gray bars, representing weekly periods), and the measured river stage at the TRN gaging station in Turner Cut at the time of tag detection at the Turner Cut or MacDonald Island receivers, averaged over fish. Proportion of fish remaining in the San Joaquin River is shown only for time periods with at least 10 fish detected.

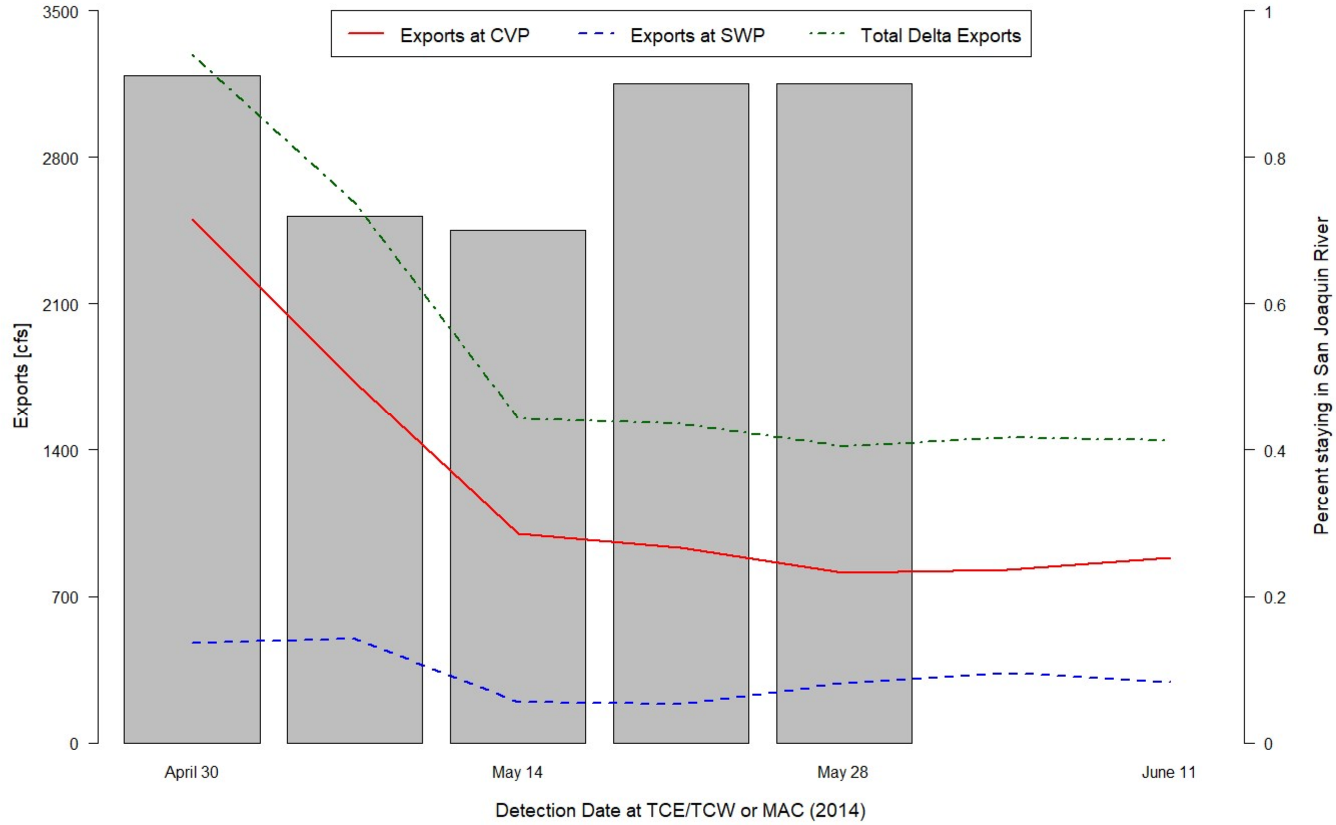

Figure 21. The observed proportion of tagged juvenile steelhead that remained in the San Joaquin River at the Turner Cut junction during the 2014 tagging study (gray bars, representing weekly periods), and the measured daily export rate at CVP, SWP, and total in the Delta at the time of tag detection at the Turner Cut or MacDonald Island receivers, averaged over fish. Proportion of fish remaining in the San Joaquin River is shown only for time periods with at least 10 fish detected.

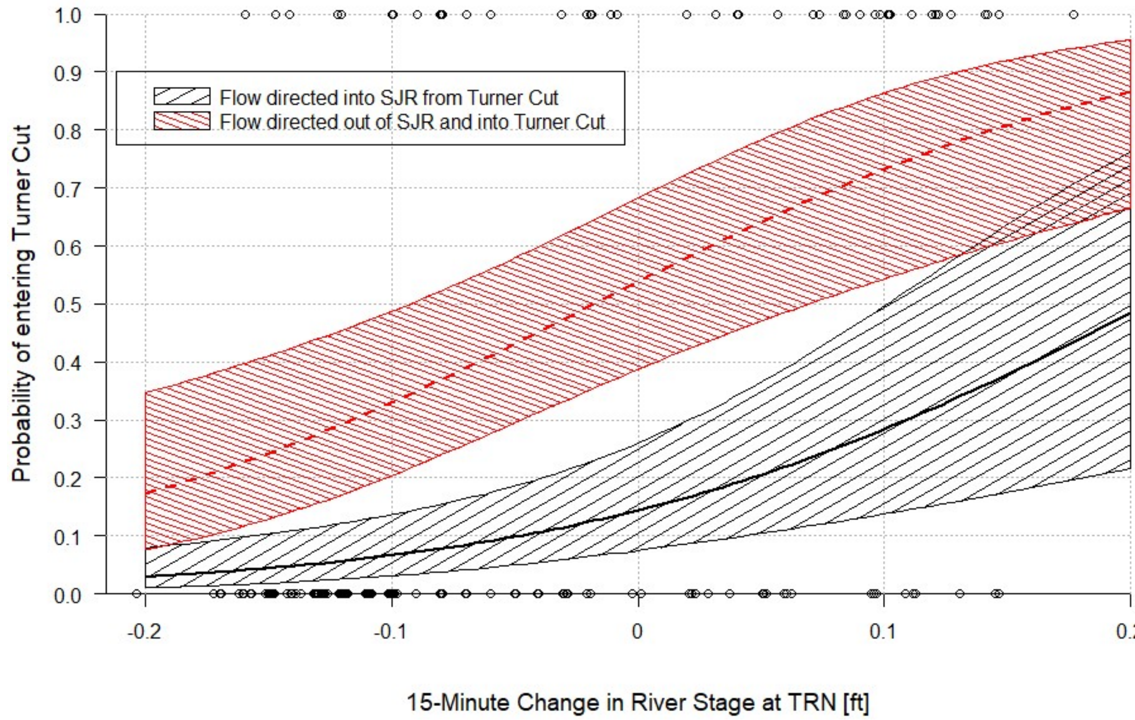

Figure 22. Fitted probability of entering Turner Cut from the San Joaquin River as a function of the 15-minute change of river stage and river flow direction measured at the TRN gaging station in Turner Cut at the time of tag detection at the Turner Cut or MacDonald Island acoustic receivers, with 95% confidence bands, in 2014. Points indicate the observed route selection (0 = San Joaquin River, 1 = Turner Cut) for each observed value of 15-minute change in river stage; observed 15-minute change in river stage values have been offset slightly to avoid overlap in plotting.

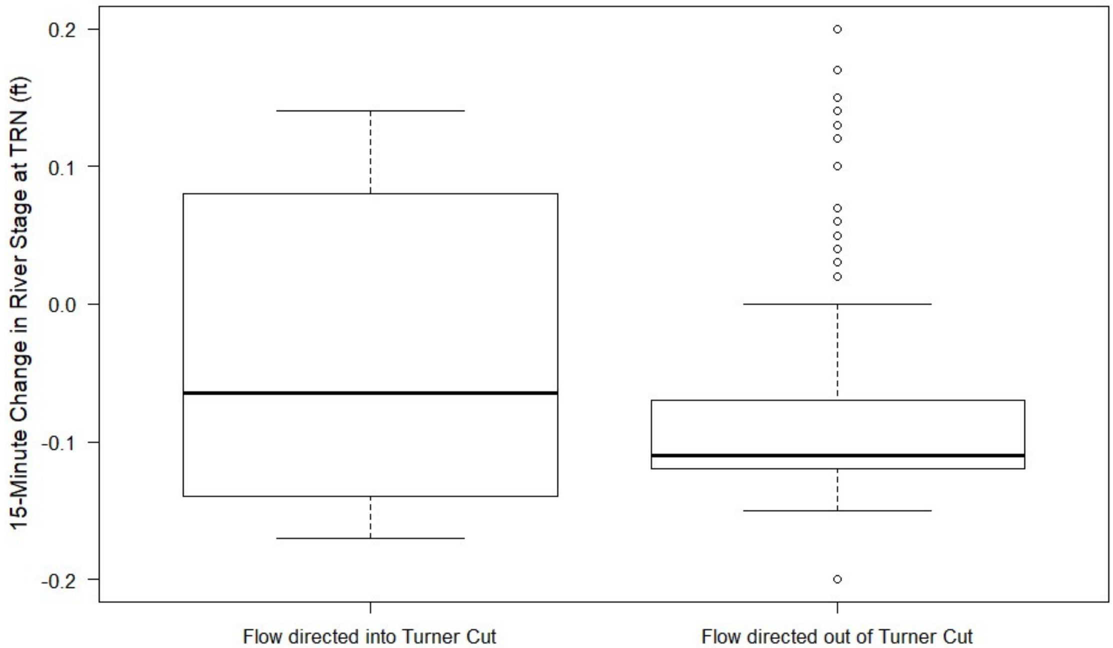

Figure 23. Fifteen-minute change in river stage measured at TRN gaging station in Turner Cut at the time of tag detection at the acoustic receivers in Turner Cut or at MacDonald Island. Bolded horizontal bar is median measure, upper and lower boundaries of box are the 25th and 75th quantiles (defining the interquartile range), and whiskers are the extremes of 1.5 × the interquartile range.

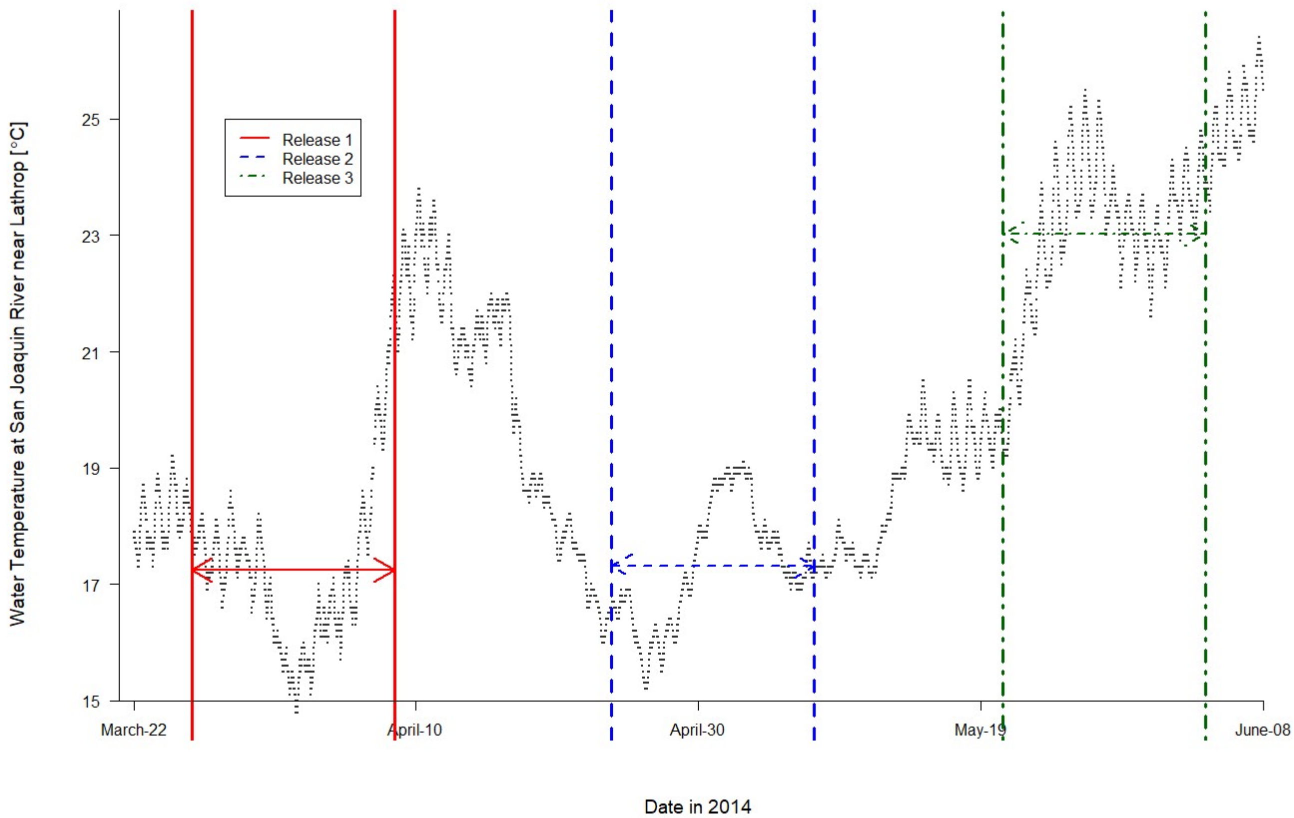

Figure 24. Water temperature at the San Joaquin River gaging station near Lathrop (SJL) during the 2014 study. Vertical lines represent the time period from the first day of release to 11 d after the final day of release. Arrow height indicates mean temperature: 17.2°C, 17.2°C, and 23.0°C, respectively.

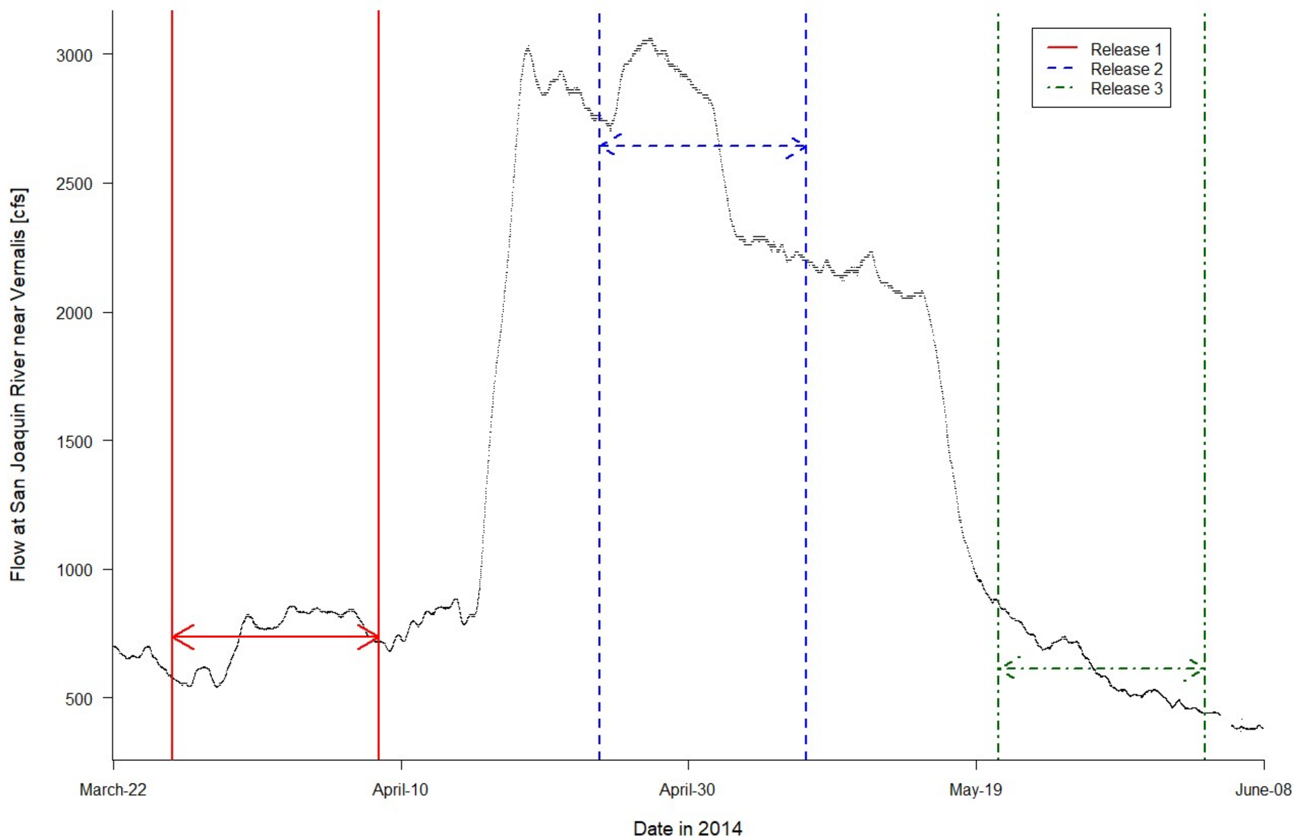

Figure 25. River discharge (flow) measured at the San Joaquin River gaging station near Vernalis (VNS) during the 2014 study. Vertical lines represent the time period from the first day of release to 11 d after the final day of release. Arrow height indicates mean discharge: 734 cfs, 2,644 cfs, and 615 cfs, respectively.

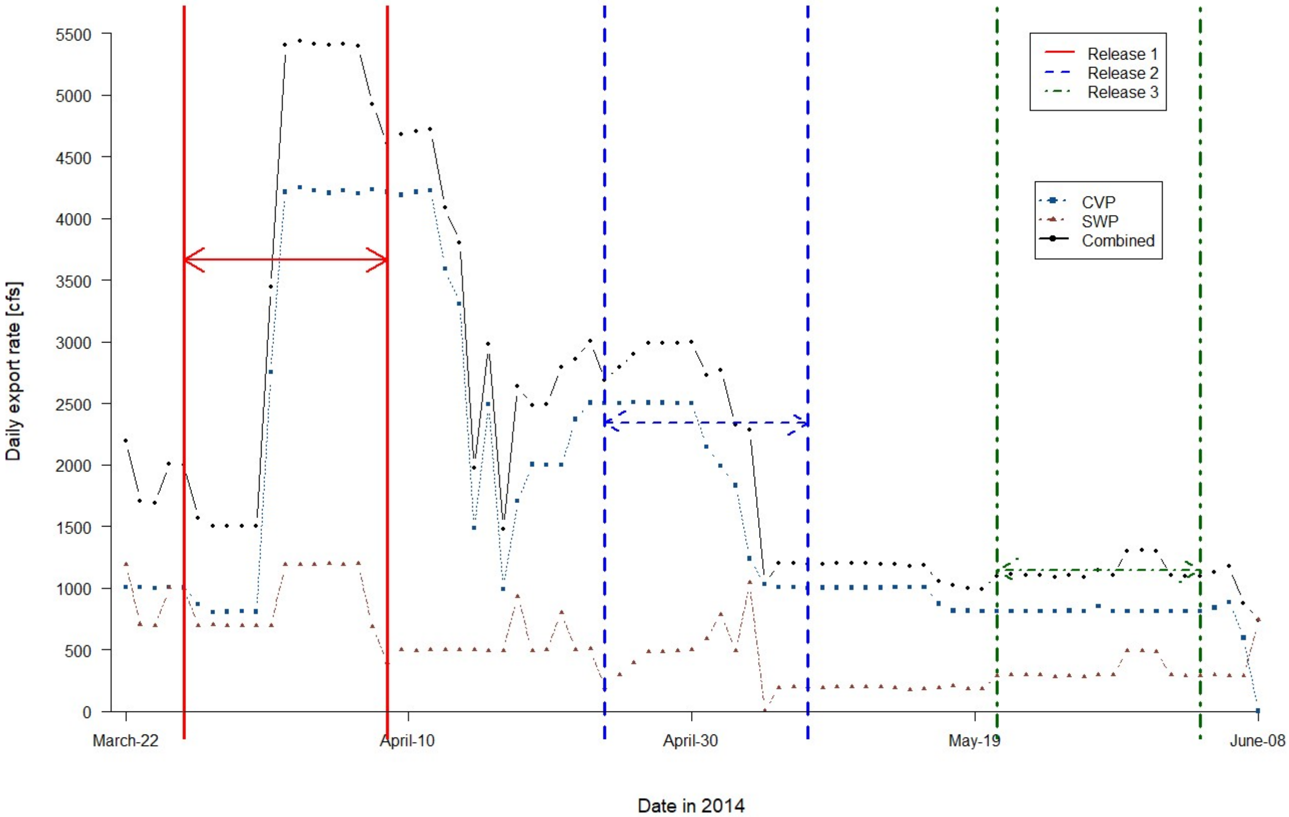

Figure 26. Daily export rate at CVP and SWP during the 2014 study. Vertical lines represent the time period from the first day of release to 11 d after the final day of release. Arrow height indicates mean combined export rate: 3,666 cfs, 2,338 cfs, and 1,142 cfs, respectively.

Tables

Table 1. Names and descriptions of receivers and hydrophones used in the 2014 steelhead survival study, with receiver codes used in Figure 1, the survival model (Figure 2 and Figure 3), and in data processing by the United States Geological Survey (USGS). The release site was located at Durham Ferry. Average latitude and longitude are given for sites with multiple hydrophones.

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	37° 41.139'N	121° 15.384'W	DFU1	A0a	300895
San Joaquin River near Durham Ferry upstream of the release site, downstream	37° 41.182'N	121° 15.399'W	DFU2	A0b	300896
San Joaquin River near Durham Ferry; release site (no acoustic hydrophone located here)	37° 41.225'N	121° 15.783'W	DF	A1	
San Joaquin River near Durham Ferry downstream of the release site, upstream	37° 41.316'N	121° 16.562'W	DFD1	A2a	300894/460084
San Joaquin River near Durham Ferry downstream of the release site, downstream	37° 41.338'N	121° 16.554'W	DFD2	A2b	460085
San Joaquin River near Banta Carbona, upstream	37° 43.658'N	121° 17.924'W	BCAU	A3a	300897
San Joaquin River near Banta Carbona, downstream	37° 43.700'N	121° 17.912'W	BCAD	A3b	460021
San Joaquin River near Mossdale Bridge, upstream	37° 47.505'N	121° 18.419'W	MOSU	A4a	300870
San Joaquin River near Mossdale Bridge, downstream	37° 47.552'N	121° 18.408'W	MOSD	A4b	300873
San Joaquin River upstream of Head of Old River, upstream (not used in survival model)	37° 48.347'N	121° 19.122'W	HORU	B0a	300872/455000
San Joaquin River upstream of Head of Old River, downstream (not used in survival model)	37° 48.336'N	121° 19.192'W	HORD	B0b	300871/450020
San Joaquin River near Lathrop, upstream	37° 48.666'N	121° 19.176'W	SJLU	A5a	450043/450044
San Joaquin River near Lathrop, downstream	37° 48.697'N	121° 19.124'W	SJLD	A5b	300880/300881
Predator Removal Study Site 4	37° 49.116'N	121° 19.050'W	RS4	N1	301501/301502
Predator Removal Study Site 5	37° 49.912'N	121° 18.734'W	RS5	N2	301503/301504
Predator Removal Study Site 6	37° 51.082'N	121° 19.331'W	RS6	N3	301505/301506
Predator Removal Study Site 7	37° 51.871'N	121° 19.418'W	RS7	N4	301507/301508
Predator Removal Study Site 8	37° 53.266'N	121° 19.813'W	RS8	N5	301509/301510
Predator Removal Study Site 9	37° 54.347'N	121° 19.408'W	RS9	N6	301511/301512
Predator Removal Study Site 10	37° 55.087'N	121° 19.235'W	RS10	N7	300991
San Joaquin River near Garwood Bridge, upstream	37° 56.108'N	121° 19.809'W	SJGU	A6a	300879/450023
San Joaquin River near Garwood Bridge, downstream	37° 56.119'N	121° 19.828'W	SJGD	A6b	300882/450045
San Joaquin River at Stockton Navy Drive Bridge, upstream	37° 56.798'N	121° 20.393'W	SJNBU	A7a	300884

Table 1. (Continued)

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
San Joaquin River at Stockton Navy Drive Bridge, downstream	37° 56.806'N	121° 20.365'W	SJNBD	A7b	300906
Burns Cutoff at Rough and Ready Island, upstream	37° 56.412'N	121° 21.064'W	RRIU	R1a	300910
Burns Cutoff at Rough and Ready Island, downstream	37° 56.407'N	121° 21.076'W	RRID	R1b	300911
San Joaquin River at MacDonald Island, upstream	38° 01.012'N	121° 27.692'W	MACU	A8a	455008/455009
San Joaquin River at MacDonald Island, downstream	38°01.373'N	121° 27.934'W	MACD	A8b	455006/455007
San Joaquin River near Medford Island, east	38° 03.184'N	121° 30.682'W	MFE	A9a	300938/300940
San Joaquin River near Medford Island, west	38° 03.222'N	121° 30.790'W	MFW	A9b	300923/300930
Old River East, near junction with San Joaquin, upstream	37° 48.709'N	121° 20.134'W	OREU	B1a	300885/300886
Old River East, near junction with San Joaquin, downstream	37° 48.738'N	121° 20.136'W	ORED	B1b	450021/450022
Old River South, upstream	37° 49.232'N	121° 22.657'W	ORSU	B2a	300887
Old River South, downstream	37° 49.201'N	121° 22.667'W	ORSD	B2b	300889
West Canal, upstream (not used in survival model)	37° 50.784'N	121° 33.573'W	WCLU	B3a	300860
West Canal, downstream (not used in survival model)	37° 50.857'N	121° 33.601'W	WCJLD	B3b	300861
Old River at Highway 4, upstream	37° 53.632'N	121° 34.026'W	OR4U	B4a	300864/300865
Old River at Highway 4, downstream	37° 53.704'N	121° 33.991'W	OR4D	B4b	300875/300876
Old River at the San Joaquin River mouth (not used in survival model)	38° 4.272'N	121° 34.538'W	OSJ	B5	300903/300905
Middle River Head, upstream	37° 49.470'N	121° 22.766'W	MRHU	C1a	300890
Middle River Head, downstream	37° 49.484'N	121° 22.807'W	MRHD	C1b	300892
Middle River at Highway 4, upstream	37° 53.768'N	121° 29.583'W	MR4U	C2a	300893/300899
Middle River at Highway 4, downstream	37° 53.807'N	121 °29.594'W	MR4D	C2b	300900/300901
Middle River near Mildred Island (not used in survival model)	38° 00.134'N	121° 30.706'W	MID	C3	300942/300983
Radial Gate at Clifton Court Forebay, upstream (in entrance channel to forebay), array 1	37° 49.802'N	121° 33.397'W	RGU1	D1a	301162
Radial Gate at Clifton Court Forebay, upstream, array 2	37° 49.784'N	121° 33.481'W	RGU2	D1b	301163
Radial Gate at Clifton Court Forebay, downstream (inside forebay), array 1 in dual array	37° 49.812'N	121° 33.454'W	RGD1	D2a	301161/460010
Radial Gate at Clifton Court Forebay, downstream, array 2 in dual array	37° 49.812'N	121° 33.454'W	RGD2	D2b	301160/460009
Central Valley Project trashracks, upstream	37° 49.012'N	121° 33.507'W	CVPU	E1a	460012/460023/ 301164

Table 1. (Continued)

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
Central Valley Project trashracks, downstream	37° 48.999'N	121° 33.537'W	CVPD	E1b	301157
Central Valley Project holding tank	37° 48.951'N	121° 33.548'W	CVPtank	E2	301159
Turner Cut, east (closer to San Joaquin)	37° 59.496'N	121° 27.298'W	TCE	F1a	000003/300915
Turner Cut, west (farther from San Joaquin)	37° 59.472'N	121° 27.336'W	TCW	F1b	300913/450024
San Joaquin River at Jersey Point, east (upstream)	38° 03.366'N	121° 41.200'W	JPE	G1a	300917,300918,300920 -300922,300924, 300928,300929
San Joaquin River at Jersey Point, west (downstream)	38° 03.322'N	121° 41.294'W	JPW	G1b	300931- 300933,300936, 300937,300939, 300941,300943
False River, west (closer to San Joaquin)	38° 03.444'N	121° 40.230'W	FRW	H1a	300914/300916
False River, east (farther from San Joaquin)	38° 03.422'N	121° 40.164'W	FRE	H1b	300907/300912
Chipps Island (aka Mallard Island), east (upstream)	38° 02.922'N	121° 55.834'W	MAE	G2a	250456, 300908,300909, 300934, 300935,300979- 300982,300985,300986
Chipps Island (aka Mallard Island), west (downstream)	38° 02.975'N	121° 56.018'W	MAW	G2b	300883,300888, 300891,300898, 300902,300904, 300989,300990, 301153,301154
Benicia Bridge	38° 02.440'N	122° 07.409'W	BBR	G3	301486-30193
Threemile Slough, south (not used in survival model)	38° 06.454'N	121° 41.041'W	TMS	T1a	301165/301166
Threemile Slough, north (not used in survival model)	38° 06.681'N	121° 40.992'W	TMN	T1b	301155/301156
Montezuma Slough, upstream (not used in survival model)	38° 4.288'N	121° 52.111'W	MZTU	T2a	300877
Montezuma Slough, downstream (not used in survival model)	38° 4.288'N	121° 52.181'W	MZTD	T2b	300878
Spoonbill Slough, upstream (not used in survival model)	38° 3.315'N	121° 53.718'W	SBSU	T3a	300984
Spoonbill Slough, downstream (not used in survival model)	38° 3.328'N	121° 53.733'W	SBSD	T3b	301158

Table 2. Environmental monitoring sites used in predator decision rule and route selection analysis for 2014 steelhead study. 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	
BDT	37.8650	121.3231	RS6, RS7, RS8	Yes	Yes	Yes	No	No	Water Library
CLC	37.8298	121.5574	RGU, RGD	No	No	No	No	Yes	CDEC
CSE	38.0740	121.8501	MTZ	No	No	Yes	No	No	CDEC
FAL	38.0554	121.6672	FRE/FRW	Yes	Yes	Yes	No	No	CDEC
GLC	37.8201	121.4497	ORS	No	No	Yes	No	No	Water Library
HLT	38.0030	121.5108	MID	Yes	Yes	Yes	No	No	CDEC
MAL	38.0428	121.9201	MTZ, SBS, MAE/MAW	No	Yes	Yes[b]	No	No	CDEC
MDB	37.8908	121.4883	MR4	No	No	Yes	No	No	Water Library
MDM	37.9425	121.5340	MR4	Yes	Yes	No	No	No	CDEC
MRU	37.8339	121.3860	MRH	Yes	Yes	No	No	No	Water Library
MRZ	38.0276	122.1405	BBR	No	No	Yes	No	No	CDEC
MSD	37.7860	121.3060	HOR, MOS	Yes	Yes	Yes	No	No	Water Library
OBI	37.9694	121.5722	OR4	No	No	Yes	No	No	Water Library
ODM	37.8101	121.5419	CVP/CVPtank	Yes	Yes	Yes	No	No	CDEC[a]
OH1	37.8080	121.3290	ORE	Yes	Yes	Yes	No	No	Water Library
OH4	37.8900	121.5697	OR4	Yes	Yes	No	No	No	CDEC
ORX	37.8110	121.3866	ORS	Yes	Yes	No	No	No	Water Library
OSJ	38.0711	121.5789	OSJ	Yes	Yes	Yes	No	No	CDEC
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, WCL	No	No	Yes	No	No	Water Library
SJG	37.9351	121.3295	RS9, RS10, SJG, SJNB, RRI	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, RS4, RS5	No	No	Yes	No	No	Water Library

[a] = California Water Library was used for river stage.

[b] = Used for river stage for SBS and MAE/MAW.

Table 2. (Continued)

Environmental Monitoring Site			Detection Site	Data Available					Database
Site Name	Latitude (°N)	Longitude (°W)		River Flow	Water Velocity	River Stage	Pumping	Reservoir Inflow	
TRN	37.9927	121.4541	TCE/TCW	Yes	Yes	Yes	No	No	CDEC
TRP	37.8165	121.5596	CVP/CVPtank	No	No	No	Yes	No	CDEC
TSJ	38.0900	121.6869	TMS/TMN	No	No	Yes	No	No	Water Library
TSL	38.1004	121.6866	TMS/TMN	Yes	Yes	No	No	No	CDEC
VNS	37.6670	121.2670	DFU, DFD, BCA	Yes	No	Yes	No	No	CDEC
WCI	37.8316	121.5541	RGU, RGD, WCL	Yes	Yes	No	No	No	Water Library

[a] = California Water Library was used for river stage.

[b] = Used for river stage for SBS and MAE/MAW.

Table 3a. Cutoff values used in predator filter in 2014. Observed values past cutoff or unmet conditions indicate a predator. Time durations are in hours unless otherwise specified. See Table 3b for Flow, Water Velocity, Extra Conditions, and Comment. Footnotes refer to both this table and Table 3b.

Detection Site	Previous Site	Residence Time[a] (hr) Near Field	Residence Time[a] (hr) Mid-field	Residence Time[a] (hr) Far-field	Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Magnitude)	No. of Visits	No. of Cumulative Upstream Forays
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
DFU	DF	200	400	800	0	4			1	0
	DFU, DFD	200	400	1,000	0	4			2	2
DFD	DF	300	600	1,000	0	4.5			1	0
	DFU, DFD	300	600 (1,000[f])	1,000	0	4.5 (NA[f])			10	0 (2[f])
	BCA, MOS	300 (0[f])	600 (50[f])	1,000 (100[f])	0.2 (100[f])	4 (NA[f])			3	2
BCA	DF	30 (1000[f])	60 (1000[f])	1,000	0	4.5			1	0
	DFD	30 (1000[f])	60 (1000[f])	1,000	0	4.5			3	0
	BCA	60 (1000[f])	340 (1000[f])	1,000					5	1
	MOS, HOR	1	2	1,000	0.1	4			2	2
MOS	DF, DFD	50 (100[f])	100 (200[f])	1,000	0.1	6		4.5	1	0
	BCA	50 (100[f])	100 (200[f])	1,000	0	6		4.5	3	0
	MOS	30	500	1,000					4	4
	HOR	30	60	1,000	0	6		4.5	4	8
SJL	MOS, HOR	24	48	96	0.1 (0.2[f])	6	30	4.5	8 (6[f])	0
	SJL	24	164	385					5	3
	ORE	5 (1[f])	10 (2[f])	20 (4[f])	0.5	6	15 (10[f])	4.5	2 (1[f])	0
	RS4, RS5	10	20	481 (500[f])	0.1 (0.3[f])	4		4.5	8	5
RS4	SJL	24	48	449	0.1	6	25	4.5	8	0
	RS4	5	89	500					5	3
	RS5, RS6	15	30	500	0.2 (0.4[f])	4	72	4.5	8	7
RS5	RS4	24	48	500	0.1	6	25	4.5	6	0
	RS5	5	69	500					6	3

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; far-field ("regional") residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 3a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr) Near Field Maximum	Mid-field Maximum	Far-field Maximum	Migration Rate[b, c] (km/hr) Minimum	Maximum	Time since last visit (hr) Maximum	BLPS (Magnitude) Maximum	No. of Visits Maximum	No. of Cumulative Upstream Forays Maximum
RS5	RS6	15	30	500	0.2	4	72	4.5	7	7
RS6	RS5	24	48	500	0.1	6	25	4.5	5	0
	RS6	5	69 (63[f])	500					3	3
	RS7	15	30	500	0.2	4	72	4.5	5	7
RS7	RS6	24	48	500	0.1	6	40	4.5	4	0
	RS7	5	69 (63[f])	500					3	2
	RS8	15	30	500	0.3	4	72	4.5	5	7
RS8	RS6, RS7	24	48	500	0.1	6	40	4.5	4	0
	RS8	5	69 (63[f])	500					3	2
	RS9	15	30	500	0.2	4	72	4.5	5	7
RS9	RS8	24	48	500	0.1	6	40	4.5	5	0
	RS9	5	69 (63[f])	500					3	2
	RS10, SJG	15	30	500	0.1 (0.3[f])	4	72	4.5	5	7
RS10	RS8, RS9	10	20	500	0.1	6	40	4.5	5	0
	RS10	5	55 (49[f])	500					3	2
	SJG	15	30	500	0.2	4	40	4.5	5	7
SJG	RS8, RS9, RS10	30	60	500	0.1	6	60	4.5	5	0
	SJG	24	98	500					3	2
	SJNB, RRI	15	30	500	0.2	4	60	4.5	4	7
SJNB	RS7, RS10, SJG	30	60	500		6 (2[f])	35	4.5	5	0
	SJNB	24	98	500					3	4
	RRI	15	30	500	0.1	6	35		3	2
	MAC, TCE/TCW	10	20	128		4	35	4.5	4	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; far-field ("regional") residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 3a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr) Near Field	Mid-field	Far-field	Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Magnitude)	No. of Visits	No. of Cumulative Upstream Forays
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
RRI	RS10, SJG	20	40	500		6 (2[f])	25	4.5	1	0
	RRI	10	70	500					2	4
	SJNB	10	20	500	0.1	6	25		2	2
MAC	SJG, SJNB, RRI	24	48	96	0.1 (0.3[f])	6	60	4.5	2	0
	MAC	15	95 (83[f])	227 (203[f])					2	4
	MFE/MFW	15	30	414	0.4	4	36	4.5	2	4
	TCE/TCW	15	30	316	0.2	6	24		2	1
	MID	15	30	60	0.1	4	24		2	4
MFE/MFW	MAC	24	48	372 (331[f])	0.1 (0.3[f])	6	36	4.5	2	0
	MFE/MFW	10	104	500					2	4
	MID	24	48	96	0.1	4.5	36		2	4
	OSJ	10	20	40		4	36	4.5	1	4
HOR	BCA	50 (100[f])	100 (200[f])	1,000		6		4.5	8	0
	MOS	50 (100[f])	100 (200[f])	1,000		6		4.5	2	0
	HOR	50	500	1,000					6	4
	SJL	20	40	1,000	0.1	6	72	4.5	12	10
	ORE	20 (1[f])	40 (2[f])	1,000	0.1 (0.6[f])	6	72 (5[f])	4.5	4 (0[f])	4 (3[f])
ORE	HOR	15	30	60	0.1	6	25	5	2 (1[f])	0
	ORE	5 (2[f])	70 (67[f])	170 (167[f])					2	1
	SJL	5 (2[f])	10 (4[f])	20 (8[f])	0.5	6	15 (10[f])	5	2 (1[f])	0
	ORS	1	2	280	0.6	4	25	5	2 (1[f])	2 (1[f])
	MRH	1	2	252	0.6	4	25	5	2 (1[f])	2 (1[f])
ORS	ORE	24	48	268	0.1	6	40	4.5	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; far-field ("regional") residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 3a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr) Near Field			Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Magnitude)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field	Far-field						
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
ORS	ORS	12	146	500					4	2
	MRH	12	24	339	0.2	6	40	4.5	2	2
WCL	RGU/RGD	15	30	800	0.2	4	100	5	3	0
	CVP	15	30	800	0.1	4	100	4.5	3	0
	ORS	15	30	800	0.1	4	100	4.5	1	0
	WCL	2	104	800					3	3
	MR4	15	30	30	0.1	4	100	4.5	1	0
	OR4	15	30	800	0.1	4	100	4.5	3	3
OR4	WCL	20	40	800	0.1	4	100	4.5	4	0
	OR4	10	140	800					4	4
	MR4	10	20	40	0.1	4	100	4.5	2	0
	MID, TCE/TCW	10	20	40	0.2	4	100	4.5	2 (1[f])	0
OSJ	MAC, MFE/MFW	15	30	60	0.1	6	36	4.5	1 (2[f])	0
	MID	15	30	60	0.1	6	36	4.5	1	0
	OR4	15	30	60	0.1	6	36	4.5	1	0
	TCE/TCW	15	30	60	0.1	6	36	4.5	1	0
	OSJ	5	54	138					2	4
	FRE/FRW	1	2	4		4	36	4.5	2	4
MRH	ORE	10	20	240	0.1	6	40	4.5	1	0
	ORS	2	4	500	0.2	6	40	4.5	1	2
	MRH	2	46	310					0	2
MR4	ORS, MRH	10	20	40	0.1	4.5		4.5	1	0
	MR4	10	60	130					2	2

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; far-field ("regional") residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 3a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr)			Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Magnitude)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field	Far-field						
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
MR4	MID	10	20	217	0.1	4	100	4.5	2	2
	OR4, WCL	10	20	40	0.1	4	100		1	0
	RGU/RGD	10	20	40	0.1	4	100		1	0
	TCE/TCW	10	20	40	0.1	4	100		1	0
MID	OR4	12	24	48	0.1	4	100		1	2
	MAC, MFE/MFW, OSJ	12	24	48	0.1	4	100	4.5	1	0 (3[f])
	MID	12	134	282					3	2
	TCE/TCW	12	24	48	0.1	4	100	4.5	1	0
RGU/RGD	ORS	80 (336[h]; 800[i])	80 (336[h]; 800[i])	800	0.1	4.5	150	4.5	1	0
	CVP	80 (336[h]; 800[i])	80 (336[h]; 800[i])	800	0.1	4.5	150	4.5	3	0
	WCL	80 (336[h]; 800[i])	80 (336[h]; 800[i])	800	0.1	5	150	4.5	4	3
CVP	ORS	100	200	1,000	0.1	4.5	200	4	1	0
	CVP	50	260	1,000					4	3
	RGU/RGD	60	120	1,000	0.1	4	200	4	3 (1[f])	3
	WCL	60	120	1,000	0.1	4	200	4	3 (1[f])	3
CVPtank	CVP	30	100	1,000					2	4
TCE/TCW	SJNB, RRI	24	48	96	0.1	6	24	4.5	1	0
	TCE/TCW	12	106	262					2	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; far-field ("regional") residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

h = If returned to Forebay entrance channel from Clifton Court Forebay and most detections were at RGU (not RGD)

i = 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

Table 3a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr) Near Field	Mid-field	Far-field	Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Magnitude)	No. of Visits	No. of Cumulative Upstream Forays
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
TCE/TCW	MAC	12	24	275	0.2	6	24		2	4
	MID	12	24	48	0.1	4	24		1	4
JPE/JPW	MAC, MFE/MFW, TCE/TCW, MID	40	80	160	0.2	4.5	30	4.5	1	0
	TMN/TMS	40	80	224	0.2	4.5	30	4.5	2	0
	OSJ	40	80	160	0.2	4.5	30	4.5	1	0
	CVPtank	40	80	160			30	4.5	1	3
	JPE/JPW	20	140	414					3	3
	FRE/FRW	20	140	414	0.2	7	30		3	3
	SBS, BBR	2	4	500	1	4	30	4.5	2	3
MAE/MAW	MFE/MFW	40	200	500	0.2	4.5	50	4.5	1	0
	CVP, CVPtank	40	200	500		4	50	4.5	1	0
	RGU/RGD	40	200	500		5	50	4.5	1	0
	JPE/JPW, TMN/TMS, MTZ, SBS	40	200	500	0.2	4.5	50	4.5	1 (2[f])	0
	MAE/MAW	20	100	500					3	3
	BBR	10	50	500	0.2	4.5	50	4.5	3	4
BBR	MAE/MAW	40	200	500	0.2	6		4.5	2	0
	MTZ	40	200	500	0.2	6		4.5	1	0
	CVPtank	40	200	500	0.2	7		4.5	1	0
	JPE/JPW	40	200	500	0.2	6		4.5	1	0
	BBR	10	50	500					3	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; far-field ("regional") residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 3a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr)			Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Magnitude)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field	Far-field						
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
FRE/FRW	MFE/MFW, OR4, MID, TCE/TCW	10	20	40	0.2	4.5	15	4.5	1	0
	OSJ	10	20	40	0.2	4.5	15	4.5	2	0
	JPE/JPW	10	73	143	0.2	7	15		3	3
	FRE/FRW	3	73	143					3	3
TMN/TMS	MFE/MFW	10	20	40	0.2	4.5	15	4.5	1	0
	OSJ	10	20	40	0.2	4.5	15	4.5	1	0
	TMN/TMS	3	47	111					2	3
	JPE/JPW, FRE/FRW	10	20	277 (94[f])	0.2	4.5	15	4.5	2	4
	BBR	10	20	500	0.2	4.5	15	4.5	1	4
MTZ	CVPtank	5	10	20	0.2	4.5	15	4.5	1	0
	JPE/JPW, TMN/TMS	5	10	500	0.2	4.5	15	4.5	1	0
	MTZ	1	40	500					2	3
	SBS, MAE/MAW	1	2	500	0.2	4.5	15	4.5	2 (1[f])	4
SBS	JPE/JPW, MAE/MAW	2 (1[f])	4 (2[f])	500	0.2	4.5	15	4.5	1	0 (4[f])

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; far-field ("regional") residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 3b. Cutoff values used in predator filter in 2014. 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 3a.

		Flow[d] (cfs)		Water Velocity[d] (ft/sec)			Extra Conditions	Comment
Detection Site	Previous Site	At arrival	At departure[e]	At arrival	At departure[e]	Average during transition		
DFU	DF						Travel time ≤ 300	
	DFU, DFD						Travel time ≤ 300 (600[f])	Alternate value if coming from DFU
DFD	DF						Travel time ≤ 200	
	DFU, DFD						Travel time ≤ 200	Alternate value if coming from DFD
	BCA, MOS							Alternate value if coming from MOS
BCA	DF						Travel time ≤ 500	Alternate value if next transition is downstream
	DFD						Travel time ≤ 500	Alternate value if next transition is downstream
	BCA						Maximum of 3 visits if arrival flow > 12000 cfs; travel time ≤ 200 (500[f])	Alternate value if next transition is downstream; otherwise, known presence in detection range < 30 hours.
	MOS, HOR		<5000					
MOS	DF, DFD						Allow 3 visits, travel time ≤ 500 if arrival flow ≤ 11,000 cfs	Alternate value if next transition is downstream
	BCA						Travel time ≤ 500; allow 1 visit, travel time ≤ 200 if arrival flow > 11,000 cfs	Alternate value if next transition is downstream
	MOS	<14000				<2.7	Travel time ≤ 35	
	HOR	<14000				<3	Travel time ≤ 60	
SJL	MOS, HOR							Alternate value if coming from MOS
	SJL						Travel time ≤ 125	

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

f = See comments for alternate criteria

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
SJL	ORE						Regional residence time ≤ 25 (15[f]) on departure from ORE	Alternate value if HOR barrier
	RS4, RS5							Alternate value if coming from RS5
RS4	SJL							
	RS4						Travel time ≤ 50	
	RS5, RS6						Regional residence time ≤ 100 on departure from previous site	Alternate value if coming from RS6
RS5	RS4							
	RS5						Travel time ≤ 30	
	RS6						Regional residence time ≤ 100 on departure from RS6	
RS6	RS5	>-500						
	RS6					<1	Travel time ≤ 30 (24[f])	Alternate value if water velocity condition is not met
	RS7	<800					Regional residence time ≤ 120 on departure from RS7	
RS7	RS6							
	RS7					<1	Travel time ≤ 30 (24[f])	Alternate value if water velocity condition is not met
	RS8						Regional residence time ≤ 120 on departure from RS8	
RS8	RS6, RS7	>-1000						
	RS8					<1	Travel time ≤ 30 (24[f])	Alternate value if water velocity condition is not met

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

f = See comments for alternate criteria

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
RS8	RS9	<1500					Regional residence time ≤ 100 on departure from RS9	
RS9	RS8							
	RS9					< 1	Travel time ≤ 30 (24[f])	Alternate value if water velocity condition is not met
	RS10, SJG						Regional residence time ≤ 120 on departure from previous site	Alternate value if coming from SJG
RS10	RS8, RS9							
	RS10					<1	Travel time ≤ 30 (24[f])	Alternate value if water velocity condition is not met
	SJG						Regional residence time ≤ 150 on departure from SJG	
SJG	RS8, RS9, RS10							
	SJG	<1800 (>-1800)[g]	>-1800 (<1800)[g]	<0.5 (>-0.5)[g]	>-0.5 (<0.5)[g]	<0.8	Travel time ≤ 24	
	SJNB, RRI	<3500	<3500	<1.1	<1.1	<1.1		
SJNB	RS7, RS10, SJG					>-0.15	Travel time ≤ 24	Alternate value if water velocity condition is not met
	SJNB						Travel time ≤ 24	
	RRI							
	MAC, TCE/TCW						Travel time ≤ 12	
RRI	RS10, SJG					>-0.15	Travel time ≤ 24	Alternate value if water velocity condition is not met

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

f = See comments for alternate criteria

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

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
RRI	RRI						Travel time ≤ 20	
	SJNB							
MAC	SJG, SJNB, RRI					-0.1 to 0.4		Alternate value if water velocity condition is not met
	MAC	<40000 (>-40000)[g]	>-40000 (<40000)[g]	<0.75 (>-0.75)[g]	>-0.75 (<0.75)[g]	-0.1 to 0.4	Travel time ≤ 36 (24[f])	Alternate value if water velocity condition is not met
	MFE/MFW			<0.5				
	TCE/TCW							
	MID							
MFE/MFW	MAC					-0.1 to 0.4		Alternate value if water velocity condition is not met
	MFE/MFW	<40000 (>-40000)[g]	>-40000 (<40000)[g]	<0.75 (>-0.75)[g]	>-0.75 (<0.75)[g]		Travel time ≤ 60	
	MID		> -2500		> -0.1			
	OSJ			<0.5		<0.1	Travel time ≤ 12	
HOR	BCA						Travel time ≤ 500; 2 visits allowed and travel time ≤ 200 if arrival flow > 11,000 cfs	Alternate value if next transition is downstream
	MOS						Travel time ≤ 500; 1 visit allowed and travel time ≤ 200 if arrival flow > 11,000 cfs	Alternate value if next transition is downstream
	HOR	<14000				<2.7	Travel time ≤ 35	
	SJL	<14000 (5000[f])				<3	Regional residence time ≤ 120 at departure from SJL	Alternate value if HOR barrier

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

f = See comments for alternate criteria

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

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
HOR	ORE	<14000 (5000[f])				<3	Regional residence time ≤ 25 (15[f]) at departure from ORE	Alternate value if HOR barrier
ORE	HOR							Alternate value if HOR barrier
	ORE						Travel time ≤ 40	Alternate value if HOR barrier
	SJL	>-200 (>200[f])		>-0.1 (>0.2[f])			Regional residence time ≤ 40 (20[f]) on departure from previous site	Alternate value if HOR barrier
	ORS	<3000						Alternate value if HOR barrier
	MRH	<3000						Alternate value if HOR barrier
ORS	ORE							
	ORS						Travel time ≤ 100	
	MRH							
WCL	RGU/RGD	>-6000		>-1			CCFB inflow ≤ 3000 cfs on departure[e]	
	CVP	>-6000	>-1500	>-1	>-0.8		CVP pumping ≤ 4000 cfs on departure[e]	
	ORS	>-6000		>-1				
	WCL						Travel time ≤ 72	
	MR4							
	OR4	<700	<1200	<0.1	<0.3			
OR4	WCL	>-3000		>-0.8				
	OR4						Travel time ≤ 100	
	MR4							

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

f = See comments for alternate criteria

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
OR4	MID, TCE/TCW	<3000		<0.8	<0.1 (0.2[f])		Known presence in detection range ≤ 5	Alternate value if coming from TCE/TCW
OSJ	MAC, MFE/MFW			<0.4				Alternate value if coming from MAC
	MID							
	OR4			>-0.4				
	TCE/TCW							
	OSJ	<8000 (>-8000)[g]	>-8000 (<8000)[g]	<0.4 (>-0.4)[g]	>-0.4 (<0.4)[g]		Travel time ≤ 24	
	FRE/FRW						Travel time ≤ 12	
MRH	ORE							
	ORS							
	MRH						Travel time ≤ 24	Not allowed
MR4	ORS, MRH							
	MR4	<6500 (>-6500)[g]	>-6500 (<6500)[g]	<0.5 (>-0.5)[g]	>-0.5 (<0.5)[g]		Travel time ≤ 30	
	MID			<0.5	<0.1	<0.1		
	OR4, WCL							
	RGU/RGD						CCFB inflow ≤ 3000 cfs on departure[e]	
	TCE/TCW			<0.5	<0.2			
MID	OR4	>-2500	>-3000	>-0.1	>-0.8			
	MAC, MFE/MFW, OSJ	<2500		<0.1				Alternate value if coming from OSJ
	MID	<2500 (>-2500)[g]	>-2500 (<2500)[g]	<0.1 (>-0.1)[g]	>-0.1 (<0.1)[g]		Travel time ≤ 100	

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

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

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
MID	TCE/TCW	>-2500		>-0.1	<0.2			
RGU/RGD	ORS							
	CVP		>-1500		>-0.8		CVP pumping ≤ 4000 cfs at departure[e]	
	WCL		<3500		<0.6			
CVP	ORS							
	CVP						Travel time ≤ 100; CVP pumping ≥ 800 cfs on arrival, and ≤ 1200 on departure from previous visit	
	RGU/RGD	<1500		<0.8			CVP pumping ≥ 800 cfs on arrival	Alternate value if came from lower SJR via Interior Delta
	WCL	<1500	<3500	<0.8	<0.6		CVP pumping ≥ 800 cfs on arrival	Alternate value if came from lower SJR via Interior Delta
CVPtank	CVP						Travel time ≤ 30	
TCE/TCW	SJNB, RRI			<0.1				
	TCE/TCW	<1500 (>-1500)[g]	>-1500 (<1500)[g]	<0.3 (>-0.3)[g]	>-0.3 (<0.3)[g]		Travel time ≤ 60	
	MAC			<0.1		<0.1		
	MID	>-500	<2500	>-0.1	<0.1	>-0.2		
JPE/JPW	MAC, MFE/MFW, TCE/TCW, MID							Alternate value if coming from MID
	TMN/TMS							
	OSJ							
JPE/JPW	CVPtank						Travel time from 2 to 48	Trucking release sites are downstream of JPW

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

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

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
JPE/JPW	JPE/JPW						Travel time ≤ 50	
	FRE/FRW						No minimum travel time	
	SBS, BBR							
MAE/MAW	MFE/MFW			>-1				
	CVP, CVPtank			>-1			Travel time ≤ 60	
	RGU/RGD			>-1			Travel time ≤ 500	
	JPE/JPW, TMN/TMS, MTZ, SBS			>-1				Alternate value if coming from MTZ or SBS
	MAE/MAW						Travel time ≤ 24	
	BBR			<1				
BBR	MAE/MAW							
	MTZ							
	CVPtank						Travel time ≤ 150	
	JPE/JPW							
	BBR						Travel time ≤ 24	
FRE/FRW	MFE/MFW, OR4, MID, TCE/TCW							Alternate value if coming from OR4 or MID
	OSJ							
	JPE/JPW						No minimum travel time	
	FRE/FRW						Travel time ≤ 30	
TMN/TMS	MFE/MFW		>-27000		>-0.5			
	OSJ							
	TMN/TMS	<0 (>0)[g]	>0 (<0)[g]	<0 (>0)[g]	>0 (<0)[g]		Travel time ≤ 24	

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

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

Table 3b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs) At arrival	Flow[d] (cfs) At departure[e]	Water Velocity[d] (ft/sec) At arrival	Water Velocity[d] (ft/sec) At departure[e]	Water Velocity[d] (ft/sec) Average during transition	Extra Conditions	Comment
TMN/TMS	JPE/JPW, FRE/FRW							Alternate value if coming from FRE/FRW
	BBR							
MTZ	CVPtank							
	JPE/JPW, TMN/TMS							
	MTZ						Travel time ≤ 24	
	SBS, MAE/MAW							Alternate value if coming from MAE/MAW
SBS	JPE/JPW, MAE/MAW							Alternate value if coming from MAE/MAW

d = Flow or velocity condition referred to in "Comment" is used to select criteria that prompts Comment. Otherwise, classified as predator if flow or velocity condition is violated

e = Condition at departure from previous site

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

Table 4. Regions used in the far-field residence time components of the predator filter in 2014.

Region	Detection Sites
I	DFU, DFD, BCA, MOS, HOR
IIA	SJL, RS4–RS10, SJG, SJNB, RRI
IIB	ORE, ORS, MRH
IIIA	MAC, MFE/MFW, TCE/TCW
IIIB	WCL, OR4, RGU, RGD, CVP, CVPtank
IIIC	MR4, MID
IV	JPE/JPW, MAE/MAW, FRE/FRW, TMN/TMS, MTZ, SBS, BBR
IVB	OSJ

Table 5. Number of tags from each release group that were detected after release in 2014, including predator-type detections and detections omitted from the survival analysis.

Release Group	1	2	3	Total
Number Released	474	480	478	1,432
Number Detected	361	441	398	1,200
Number Detected Downstream	322	433	319	1,074
Number Detected Upstream of Study Area	361	423	398	1,182
Number Detected in Study Area	156	357	130	643
Number Detected in San Joaquin River Route	43	333	115	491
Number Detected in Old River Route	127	19	14	160
Number Assigned to San Joaquin River Route	13	310	71	394
Number Assigned to Old River Route	122	19	12	153

Table 6. Number of tags observed from each release group at each detection site in 2014, 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			474	480	478	1,432
Durham Ferry Upstream	DFU	A0	75	33	139	247
Durham Ferry Downstream	DFD	A2	322	379	318	1,019
Banta Carbona (Pooled)	BCA	A3	171	283	175	629
Mossdale (Pooled)	MOS	A4	156	357[a]	129	642
Head of Old River (Pooled)	HOR	B0	146	352[b]	125[c]	623
Lathrop, Upstream	SJLU	A5a	43	332	115	490
Lathrop, Downstream	SJLD	A5b	43	333	115	491
Lathrop (Pooled)	SJL	A5	43	333	115[d]	491
Predator Removal Study 4	RS4	N1	18	326	97	441
Predator Removal Study 5	RS5	N2	8	318	79	405
Predator Removal Study 6	RS6	N3	6	314[e]	61	381
Predator Removal Study 7	RS7	N4	5	308	52	365
Predator Removal Study 8	RS8	N5	5	307	46	358
Predator Removal Study 9	RS9	N6	5	304	44	353
Predator Removal Study 10	RS10	N7	4	304	37	345
Garwood Bridge, Upstream	SJGU	A6a	2	295	30	327
Garwood Bridge, Downstream	SJGD	A6b	2	295	30	327
Garwood Bridge (Pooled)	SJG	A6	2	295	30	327
Navy Drive Bridge, Upstream	SJNBU	A7a	2	274	27	303
Navy Drive Bridge, Downstream	SJNBD	A7b	2	273	27	302
Navy Drive Bridge (Pooled)	SJNB	A7	2	275	27	304
Rough and Ready Island, Upstream	RRIU	R1a	0	58	5	63
Rough and Ready Island, Downstream	RRID	R1b	0	58	5	63
Rough and Ready Island (Pooled)	RRI	R1	0	58	5	63
MacDonald Island Upstream	MACU	A8a	0	215	16	231
MacDonald Island Downstream	MACD	A8b	0	205	16	221
MacDonald Island (Pooled)	MAC	A8	0	215	16	231
Medford Island East	MFE	A9a	0	150	13	163
Medford Island West	MFW	A9b	0	150	12	162
Medford Island (Pooled)	MFE/MFW	A9	0	150	13	163
Turner Cut, Upstream	TCE	F1a	0	94	3	97
Turner Cut, Downstream	TCW	F1b	0	92	3	95
Turner Cut (Pooled)	TCE/TCW	F1	0	94	3	97

a = One tagged steelhead was recaptured between detections at MOS and HOR, and returned to the river

b = One tagged steelhead was recaptured between detections at HOR and SJL, and returned to the river

c = Two tagged steelhead were recaptured between detections at HOR and SJL, and returned to the river

d = One tagged steelhead was recaptured between detections at SJL and HOR, and returned to the river.

e = One tagged steelhead was recaptured between detections at RS6 and RS7, and then returned to the river.

Table 6. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
Old River East, Upstream	OREU	B1a	127	19	14	160
Old River East, Downstream	ORED	B1b	127	19	14	160
Old River East (Pooled)	ORE	B1	127	19	14	160
Old River South, Upstream	ORSU	B2a	120	16	10	146
Old River South, Downstream	ORSD	B2b	120	16	10	146
Old River South (Pooled)	ORS	B2	120	16	10	146
West Canal, Upstream	WCLU	B3a	20	24	2	46
West Canal, Downstream	WCLD	B3b	20	24	2	46
West Canal, SJR Route	WCL	B3	0	21	0	21
West Canal, OR Route	WCL	B3	20	3	2	25
West Canal (Pooled)	WCL	B3	20	24	2	46
Old River at Highway 4, Upstream	OR4U	B4a	4	16	0	20
Old River at Highway 4, Downstream	OR4D	B4b	4	16	0	20
Old River at Highway 4, SJR Route	OR4	B4	0	16	0	16
Old River at Highway 4, OR Route	OR4	B4	4	0	0	4
Old River at Highway 4 (Pooled)	OR4	B4	4	16	0	20
Old River at the San Joaquin, SJR Route	OSJ	B5	0	17	0	17
Old River at the San Joaquin, OR Route	OSJ	B5	0	0	0	0
Old River at the San Joaquin	OSJ	B5	0	17	0	17
Middle River Head, Upstream	MRHU	C1a	5	1	0	6
Middle River Head, Downstream	MRHD	C1b	5	1	0	6
Middle River Head (Pooled)	MRH	C1	5	1	0	6
Middle River at Highway 4, Upstream	MR4U	C2a	1	17	1	19
Middle River at Highway 4, Downstream	MR4D	C2b	1	17	1	19
Middle River at Highway 4, SJR Route	MR4	C2	0	16	0	16
Middle River at Highway 4, OR Route	MR4	C2	1	1	1	3
Middle River at Highway 4 (Pooled)	MR4	C2	1	17	1	19
Middle River near Mildred Island , SJR Route	MID	C3	0	25	0	25
Middle River near Mildred Island , OR Route	MID	C3	0	0	0	0
Middle River near Mildred Island	MID	C3	0	25	0	25
Radial Gates Upstream #1	RGU1	D1a	15	14	3	32
Radial Gates Upstream #2	RGU2	D1b	13	12	3	28
Radial Gates Upstream: SJR Route	RGU	D1	0	10	0	10
Radial Gates Upstream: OR Route	RGU	D1	17	4	3	24
Radial Gates Upstream (Pooled)	RGU	D1	17	14	3	34
Radial Gates Downstream #1	RGD1	D2a	6	2	1	9
Radial Gates Downstream #2	RGD2	D2b	6	2	1	9

Table 6. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
Radial Gates Downstream: SJR Route	RGD	D2	0	1	0	1
Radial Gates Downstream: OR Route	RGD	D2	6	1	1	8
Radial Gates Downstream (Pooled)	RGD	D2	6	2	1	9
Central Valley Project Trashrack, Upstream	CVPU	E1a	69	25	3	97
Central Valley Project Trashrack, Downstream	CVPD	E1b	67	24	2	93
CVP Trashrack: SJR Route	CVP	E1	0	16	0	16
CVP Trashrack: OR Route	CVP	E1	69	9	3	81
Central Valley Project Trashrack (Pooled)	CVP	E1	69	25	3	97
CVP tank: SJR Route	CVPtank	E2	0	6	0	6
CVP tank: OR Route	CVPtank	E2	35	5	1	41
Central Valley Project Holding Tank	CVPtank	E2	35	11	1	47
Threemile Slough, Upstream	TMS	T1a	0	27	3	30
Threemile Slough, Downstream	TMN	T1b	0	22	3	25
Threemile Slough (Pooled)	TMS/TMN	T1	0	27	3	30
Jersey Point East	JPE	G1a	5	145	6	156
Jersey Point West	JPW	G1b	5	142	6	153
Jersey Point: SJR Route	JPE/JPW	G1	0	144	6	150
Jersey Point: OR Route	JPE/JPW	G1	5	1	0	6
Jersey Point (Pooled)	JPE/JPW	G1	5	145	6	156
False River West	FRW	H1a	1	40	2	43
False River East	FRE	H1b	1	38	2	41
False River: SJR Route	FRE/FRW	H1	0	40	2	42
False River: OR Route	FRE/FRW	H1	1	0	0	1
False River (Pooled)	FRE/FRW	H1	1	40	2	43
Montezuma Slouth, Upstream	MTZU	T2a	0	1	0	1
Montezuma Slouth, Downstream	MTZD	T2b	0	1	0	1
Montezuma Slough (Pooled)	MTZ	T2	0	1	0	1
Spoonbill Slough, Upstream	SBSU	T3a	0	1	0	1
Spoonbill Slough, Downstream	SBSD	T3b	0	1	0	1
Spoonbill Slough (Pooled)	SBS	T3	0	1	0	1
Chipps Island East	MAE	G2a	26	146	5	177
Chipps Island West	MAW	G2b	26	149	4	179
Chipps Island: SJR Route	MAE/MAW	G2	0	148	4	152
Chipps Island: OR Route	MAE/MAW	G2	26	4	1	31
Chipps Island (Pooled)	MAE/MAW	G2	26	152	5	183
Benicia Bridge: SJR Route	BBR	G3	0	147	6	153
Benicia Bridge: OR Route	BBR	G3	20	5	1	26
Benicia Bridge	BBR	G3	20	152	7	179

Table 7. Number of tags observed from each release group at each detection site in 2014 and used in the survival analysis, including predator-type detections. Numbers in parentheses are numbers of tags whose detection histories were right-censored. 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			474	480	478	1,432
Durham Ferry Upstream	DFU	A0	50	22	112	184
Durham Ferry Downstream	DFD	A2	311	365	285	961
Banta Carbona (Pooled)	BCA	A3	168	272	165	605
Mossdale (Pooled)	MOS	A4	153	345 (2)	119 (2)	617 (4)
Lathrop, Upstream	SJLU	A5a	13	305	72	390
Lathrop, Downstream	SJLD	A5b	12	311	72	395
Lathrop	SJL	A5	13	311 (1)	72 (1)	396 (2)
Garwood Bridge, Upstream	SJGU	A6a	2[a]	290	29	321
Garwood Bridge, Downstream	SJGD	A6b	2[a]	288	29	319
Garwood Bridge (Pooled)	SJG	A6	2[a]	290	29	321
Navy Drive Bridge, Upstream	SJNBU	A7a	1[a]	259	26	286
Navy Drive Bridge, Downstream	SJNBD	A7b	1[a]	259	25	285
Navy Drive Bridge (Pooled)	SJNB	A7	1[a]	261	26	288
Rough and Ready Island, Upstream	RRIU	R1a	0[a]	21	2	23
Rough and Ready Island, Downstream	RRID	R1b	0[a]	21	2	23
Rough and Ready Island (Pooled)	RRI	R1	0[a]	21	2	23
MacDonald Island Upstream	MACU	A8a	0[a]	179	15	194
MacDonald Island Downstream	MACD	A8b	0[a]	177	15	192
MacDonald Island (Pooled)	MAC	A8	0[a]	182	15	197
Medford Island East	MFE	A9a	0[a]	147	13	160
Medford Island West	MFW	A9b	0[a]	148	12	160
Medford Island (Pooled)	MFE/MFW	A9	0[a]	148	13	161
Turner Cut, Upstream	TCE	F1a	0[a]	81	3	84
Turner Cut, Downstream	TCW	F1b	0[a]	80	3	83
Turner Cut (Pooled)	TCE/TCW	F1	0[a]	82	3	85
Old River East, Upstream	OREU	B1a	122	19	12	153
Old River East, Downstream	ORED	B1b	122	19	12	153
Old River East (Pooled)	ORE	B1	122	19	12	153
Old River South Upstream	ORSU	B2a	114	15	8	137
Old River South Downstream	ORSD	B2b	115	15	8	138
Old River South (Pooled)	ORS	B2	115	15	8	138
West Canal, Upstream	WCLU	B3a	5	2a	1[a]	8
West Canal, Downstream	WCLD	B3b	5	2a	1[a]	8
West Canal, OR Route	WCL	B3	5	2a	1[a]	8
Old River at Highway 4, Upstream	OR4U	B4a	2	15	0[a]	17
Old River at Highway 4, Downstream	OR4D	B4b	2	15	0[a]	17

[a] = detections were not used in the survival model

Table 7. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
Old River at Highway 4, SJR Route	OR4	B4	0[a]	15	0[a]	15
Old River at Highway 4, OR Route	OR4	B4	2	0	0[a]	2
Old River at Highway 4 (Pooled)	OR4	B4	2	15	0[a]	17
Middle River Head, Upstream	MRHU	C1a	4	1	0[a]	5
Middle River Head, Downstream	MRHD	C1b	4	1	0[a]	5
Middle River Head (Pooled)	MRH	C1	4	1	0[a]	5
Middle River at Highway 4, Upstream	MR4U	C2a	1	13	1[a]	15
Middle River at Highway 4, Downstream	MR4D	C2b	1	13	1[a]	15
Middle River at Highway 4, SJR Route	MR4	C2	0[a]	12	0[a]	12
Middle River at Highway 4, OR Route	MR4	C2	1	1	1[a]	3
Middle River at Highway 4 (Pooled)	MR4	C2	1	13	1[a]	15
Radial Gates Upstream #1	RGU1	D1a	6	2	1[a]	9
Radial Gates Upstream #2	RGU2	D1b	6	2	1[a]	9
Radial Gates Upstream: SJR Route	RGU	D1	0[a]	1	0[a]	1
Radial Gates Upstream: OR Route	RGU	D1	6	1	1[a]	8
Radial Gates Upstream (Pooled)	RGU	D1	6	2	1[a]	9
Radial Gates Downstream #1	RGD1	D2a	6	2[a]	1[a]	9
Radial Gates Downstream #2	RGD2	D2b	6	2[a]	1[a]	9
Radial Gates Downstream: SJR Route	RGD	D2	0[a]	1[a]	0[a]	1
Radial Gates Downstream: OR Route	RGD	D2	6	1[a]	1[a]	8
Radial Gates Downstream (Pooled)	RGD	D2	6	2[a]	1[a]	9
Central Valley Project Trashrack, Upstream	CVPU	E1a	69	21	2[a]	92
Central Valley Project Trashrack, Downstream	CVPD	E1b	67	20	2[a]	89
CVP Trashrack: SJR Route	CVP	E1	0[a]	13	0[a]	13
CVP Trashrack: OR Route	CVP	E1	69	9	2[a]	80
Central Valley Project Trashrack (Pooled)	CVP	E1	69	22	2[a]	93
CVP tank: SJR Route	CVPtank	E2	0[a]	6	0[a]	6
CVP tank: OR Route	CVPtank	E2	35	5	1[a]	41
Central Valley Project Holding Tank	CVPtank	E2	35	11	1[a]	47
Jersey Point East	JPE	G1a	0[a]	140	6	146
Jersey Point West	JPW	G1b	0[a]	139	6	145
Jersey Point: SJR Route	JPE/JPW	G1	0[a]	141	6	147
Jersey Point: OR Route	JPE/JPW	G1	0[a]	0	0[a]	0
Jersey Point (Pooled)	JPE/JPW	G1	0[a]	141	6	147
False River West	FRW	H1a	0[a]	2[a]	0[a]	2

[a] = detections were not used in the survival model

Table 7. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
False River East	FRE	H1b	0[a]	1[a]	0[a]	1
False River: SJR Route	FRE/FRW	H1	0[a]	2[a]	0[a]	2
False River: OR Route	FRE/FRW	H1	0[a]	0[a]	0[a]	0
False River (Pooled)	FRE/FRW	H1	0[a]	2[a]	0[a]	2
Chipps Island East	MAE	G2a	24	146	5	175
Chipps Island West	MAW	G2b	26	148	4	178
Chipps Island: SJR Route	MAE/MAW	G2	0	148	4	152
Chipps Island: OR Route	MAE/MAW	G2	26	4	1	31
Chipps Island (Pooled)	MAE/MAW	G2	26	152	5	183
Benicia Bridge: SJR Route	BBR	G3	0	147	6	153
Benicia Bridge: OR Route	BBR	G3	20	5	1	26
Benicia Bridge	BBR	G3	20	152	7	179

[a] = detections were not used in the survival model

Table 8. Number of tags from each release group in 2014 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	0	3	0	3	0	1	4	5
Durham Ferry Downstream	DFD	A2	0	1	0	1	0	0	0	0
Banta Carbona	BCA	A3	0	4	2	6	2	2	10	14
Mossdale	MOS	A4	0	2	5	7	0	0	0	0
Head of Old River	HOR	B0	0	3	3	6	0	5	1	6
Lathrop	SJL	A5	1	3	1	5	1	4	4	9
Predator Removal Study 4	RS4	N1	0	3	5	8	0	5	3	8
Predator Removal Study 5	RS5	N2	0	0	1	1	0	0	1	1
Predator Removal Study 6	RS6	N3	0	0	1	1	0	3	3	6
Predator Removal Study 7	RS7	N4	0	0	1	1	0	1	1	2
Predator Removal Study 8	RS8	N5	0	1	3	4	0	1	0	1
Predator Removal Study 9	RS9	N6	0	0	0	0	0	0	1	1
Predator Removal Study 10	RS10	N7	0	2	0	2	0	3	1	4
Garwood Bridge	SJG	A6	0	2	2	4	0	2	0	2
Navy Drive Bridge	SJNB	A7	0	1	1	2	0	0	0	0
Rough and Ready Island	RRI	R1	0	2	0	2	0	0	0	0
MacDonald Island	MAC	A8	0	6	0	6	0	3	0	3
Medford Island	MFE/MFW	A9	0	0	0	0	0	1	0	1
Old River East	ORE	B1	0	0	1	1	3	0	2	5
Old River South	ORS	B2	0	0	0	0	1	0	0	1
West Canal	WCL	B3	0	1	0	1	1	1	0	2
Old River at Highway 4	OR4	B4	0	0	0	0	0	0	0	0
Old River at the San Joaquin	OSJ	B5	0	0	0	0	0	0	0	0
Middle River Head	MRH	C1	2	0	0	2	1	0	0	1
Middle River at Highway 4	MR4	C2	0	0	0	0	0	1	1	2
Middle River near Mildred Island	MID	C3	0	0	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	0	0	0	0	0	0	0	0
Radial Gates Downstream	RGD	D2	0	0	0	0	0	0	0	0
Central Valley Project Trashrack	CVP	E1	1	0	0	1	0	5	0	5
Central Valley Project Holding Tank	CVPtank	E2	0	0	0	0	0	0	0	0
Turner Cut	TCE/TCW	F1	0	3	0	3	0	0	0	0
Jersey Point	JPE/JPW	G1	0	0	0	0	0	1	0	1
Chipps Island	MAE/MAW	G2	0	0	0	0	0	0	0	0
Benicia Bridge	BBR	G3	0	0	0	0	0	0	0	0
False River	FRE/FRW	H1	0	0	0	0	0	0	0	0
Threemile Slough	TMS/TMN	T1	0	0	0	0	0	0	0	0

Table 8. (Continued)

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
Montezuma Slough	MTZ	T2	0	0	0	0	0	0	0	0
Spoonbill Slough	SBS	T3	0	0	0	0	0	0	0	0
Total Tags			4	37	26	67	9	39	31	80

Table 9. Number of tags from each release group that were detected after release in 2014, excluding predator-type detections and detections omitted from the survival analysis.

Release Group	1	2	3	Total
Number Released	474	480	478	1,432
Number Detected	361	440	398	1,199
Number Detected Downstream	322	432	319	1,073
Number Detected Upstream of Study Area	361	422	398	1,181
Number Detected in Study Area	156	356	130	642
Number Detected in San Joaquin River Route	43	329	113	485
Number Detected in Old River Route	127	14	11	152
Number Assigned to San Joaquin River Route	12	324	78	414
Number Assigned to Old River Route	125	14	11	150

Table 10. Number of tags observed from each release group at each detection site in 2014, 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			474	480	478	1,432
Durham Ferry Upstream	DFU	A0	75	27	139	241
Durham Ferry Downstream	DFD	A2	322	377	318	1,017
Banta Carbona (Pooled)	BCA	A3	171	282	175	628
Mossdale (Pooled)	MOS	A4	156	356[a]	129	641
Head of Old River (Pooled)	HOR	B0	146	350[b]	125[c]	621
Lathrop, Upstream	SJLU	A5a	43	328	113	484
Lathrop, Downstream	SJLD	A5b	43	329	113	485
Lathrop (Pooled)	SJL	A5	43	329	113[d]	485
Predator Removal Study 4	RS4	N1	18	320	93	431
Predator Removal Study 5	RS5	N2	8	311	75	394
Predator Removal Study 6	RS6	N3	6	308[e]	57	371
Predator Removal Study 7	RS7	N4	5	300	47	352
Predator Removal Study 8	RS8	N5	5	301	40	346
Predator Removal Study 9	RS9	N6	4	299	39	342
Predator Removal Study 10	RS10	N7	3	298	34	335
Garwood Bridge, Upstream	SJGU	A6a	1	291	28	320
Garwood Bridge, Downstream	SJGD	A6b	1	291	28	320
Garwood Bridge (Pooled)	SJG	A6	1	291	28	320
Navy Drive Bridge, Upstream	SJNBU	A7a	1	270	24	295
Navy Drive Bridge, Downstream	SJNBD	A7b	1	269	24	294
Navy Drive Bridge (Pooled)	SJNB	A7	1	271	24	296
Rough and Ready Island, Upstream	RRIU	R1a	0	56	5	61
Rough and Ready Island, Downstream	RRID	R1b	0	56	5	61
Rough and Ready Island (Pooled)	RRI	R1	0	56	5	61
MacDonald Island Upstream	MACU	A8a	0	210	15	225
MacDonald Island Downstream	MACD	A8b	0	200	15	215
MacDonald Island (Pooled)	MAC	A8	0	210	15	225
Medford Island East	MFE	A9a	0	146	12	158
Medford Island West	MFW	A9b	0	146	11	157
Medford Island (Pooled)	MFE/MFW	A9	0	146	12	158
Turner Cut, Upstream	TCE	F1a	0	93	2	95
Turner Cut, Downstream	TCW	F1b	0	91	2	93
Turner Cut (Pooled)	TCE/TCW	F1	0	93	2	95

a = One tagged steelhead was recaptured between detections at MOS and HOR, and returned to the river

b = One tagged steelhead was recaptured between detections at HOR and SJL, and returned to the river

c = Two tagged steelhead were recaptured between detections at HOR and SJL, and returned to the river

d = One tagged steelhead was recaptured between detections at SJL and HOR, and returned to the river.

e = One tagged steelhead was recaptured between detections at RS6 and RS7, and then returned to the river.

Table 10. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
Old River East, Upstream	OREU	B1a	127	14	11	152
Old River East, Downstream	ORED	B1b	127	14	11	152
Old River East (Pooled)	ORE	B1	127	14	11	152
Old River South, Upstream	ORSU	B2a	120	14	5	139
Old River South, Downstream	ORSD	B2b	120	14	5	139
Old River South (Pooled)	ORS	B2	120	14	5	139
West Canal, Upstream	WCLU	B3a	20	23	2	45
West Canal, Downstream	WCLD	B3b	20	23	2	45
West Canal, SJR Route	WCL	B3	0	21	0	21
West Canal, OR Route	WCL	B3	20	2	2	24
West Canal (Pooled)	WCL	B3	20	23	2	45
Old River at Highway 4, Upstream	OR4U	B4a	4	15	0	19
Old River at Highway 4, Downstream	OR4D	B4b	4	15	0	19
Old River at Highway 4, SJR Route	OR4	B4	0	15	0	15
Old River at Highway 4, OR Route	OR4	B4	4	0	0	4
Old River at Highway 4 (Pooled)	OR4	B4	4	15	0	19
Old River at the San Joaquin, SJR Route	OSJ	B5	0	17	0	17
Old River at the San Joaquin, OR Route	OSJ	B5	0	0	0	0
Old River at the San Joaquin	OSJ	B5	0	17	0	17
Middle River Head, Upstream	MRHU	C1a	5	1	0	6
Middle River Head, Downstream	MRHD	C1b	5	1	0	6
Middle River Head (Pooled)	MRH	C1	5	1	0	6
Middle River at Highway 4, Upstream	MR4U	C2a	1	16	1	18
Middle River at Highway 4, Downstream	MR4D	C2b	1	16	1	18
Middle River at Highway 4, SJR Route	MR4	C2	0	15	0	15
Middle River at Highway 4, OR Route	MR4	C2	1	1	1	3
Middle River at Highway 4 (Pooled)	MR4	C2	1	16	1	18
Middle River near Mildred Island , SJR Route	MID	C3	0	25	0	25
Middle River near Mildred Island , OR Route	MID	C3	0	0	0	0
Middle River near Mildred Island	MID	C3	0	25	0	25
Radial Gates Upstream #1	RGU1	D1a	15	14	3	32
Radial Gates Upstream #2	RGU2	D1b	13	12	3	28
Radial Gates Upstream: SJR Route	RGU	D1	0	10	0	10
Radial Gates Upstream: OR Route	RGU	D1	17	4	3	24
Radial Gates Upstream (Pooled)	RGU	D1	17	14	3	34
Radial Gates Downstream #1	RGD1	D2a	6	2	1	9
Radial Gates Downstream #2	RGD2	D2b	6	2	1	9

Table 10. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
Radial Gates Downstream: SJR Route	RGD	D2	0	1	0	1
Radial Gates Downstream: OR Route	RGD	D2	6	1	1	8
Radial Gates Downstream (Pooled)	RGD	D2	6	2	1	9
Central Valley Project Trashrack, Upstream	CVPU	E1a	69	25	2	96
Central Valley Project Trashrack, Downstream	CVPD	E1b	67	24	1	92
CVP Trashrack: SJR Route	CVP	E1	0	16	0	16
CVP Trashrack: OR Route	CVP	E1	69	9	2	80
Central Valley Project Trashrack (Pooled)	CVP	E1	69	25	2	96
CVP tank: SJR Route	CVPtank	E2	0	6	0	6
CVP tank: OR Route	CVPtank	E2	34	5	1	40
Central Valley Project Holding Tank	CVPtank	E2	34	11	1	46
Threemile Slough, Upstream	TMS	T1a	0	25	2	27
Threemile Slough, Downstream	TMN	T1b	0	20	2	22
Threemile Slough (Pooled)	TMS/TMN	T1	0	25	2	27
Jersey Point East	JPE	G1a	5	141	5	151
Jersey Point West	JPW	G1b	5	138	5	148
Jersey Point: SJR Route	JPE/JPW	G1	0	140	5	145
Jersey Point: OR Route	JPE/JPW	G1	5	1	0	6
Jersey Point (Pooled)	JPE/JPW	G1	5	141	5	151
False River West	FRW	H1a	1	40	1	42
False River East	FRE	H1b	1	38	1	40
False River: SJR Route	FRE/FRW	H1	0	40	1	41
False River: OR Route	FRE/FRW	H1	1	0	0	1
False River (Pooled)	FRE/FRW	H1	1	40	1	42
Montezuma Slouth, Upstream	MTZU	T2a	0	1	0	1
Montezuma Slouth, Downstream	MTZD	T2b	0	1	0	1
Montezuma Slough (Pooled)	MTZ	T2	0	1	0	1
Spoonbill Slough, Upstream	SBSU	T3a	0	1	0	1
Spoonbill Slough, Downstream	SBSD	T3b	0	1	0	1
Spoonbill Slough (Pooled)	SBS	T3	0	1	0	1
Chipps Island East	MAE	G2a	26	141	5	172
Chipps Island West	MAW	G2b	26	144	4	174
Chipps Island: SJR Route	MAE/MAW	G2	0	143	4	147
Chipps Island: OR Route	MAE/MAW	G2	26	4	1	31
Chipps Island (Pooled)	MAE/MAW	G2	26	147	5	178
Benicia Bridge: SJR Route	BBR	G3	0	142	6	148
Benicia Bridge: OR Route	BBR	G3	20	5	1	26
Benicia Bridge	BBR	G3	20	147	7	174

Table 11. Number of tags observed from each release group at each detection site in 2014 and used in the survival analysis, excluding predator-type detections. Numbers in parentheses are numbers of tags whose detection histories were right-censored. 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			474	480	478	1,432
Durham Ferry Upstream	DFU	A0	50	18	112	180
Durham Ferry Downstream	DFD	A2	311	367	285	963
Banta Carbona (Pooled)	BCA	A3	170	276	165	611
Mossdale (Pooled)	MOS	A4	154	353 (2)	118 (1)	625 (3)
Lathrop, Upstream	SJLU	A5a	12	319	80	411
Lathrop, Downstream	SJLD	A5b	12	325	79	416
Lathrop	SJL	A5	12	325 (1)	80 (2)	417 (3)
Garwood Bridge, Upstream	SJGU	A6a	1[a]	289	27	317
Garwood Bridge, Downstream	SJGD	A6b	1[a]	288	27	316
Garwood Bridge (Pooled)	SJG	A6	1[a]	289	27	317
Navy Drive Bridge, Upstream	SJNBU	A7a	1[a]	254	22	277
Navy Drive Bridge, Downstream	SJNBD	A7b	1[a]	253	22	276
Navy Drive Bridge (Pooled)	SJNB	A7	1[a]	255	22	278
Rough and Ready Island, Upstream	RRIU	R1a	0[a]	22	2	24
Rough and Ready Island, Downstream	RRID	R1b	0[a]	23	2	25
Rough and Ready Island (Pooled)	RRI	R1	0[a]	23	2	25
MacDonald Island Upstream	MACU	A8a	0[a]	175	14	189
MacDonald Island Downstream	MACD	A8b	0[a]	172	14	186
MacDonald Island (Pooled)	MAC	A8	0[a]	177	14	191
Medford Island East	MFE	A9a	0[a]	143	12	155
Medford Island West	MFW	A9b	0[a]	143	11	154
Medford Island (Pooled)	MFE/MFW	A9	0[a]	143	12	155
Turner Cut, Upstream	TCE	F1a	0[a]	81	2	83
Turner Cut, Downstream	TCW	F1b	0[a]	79	2	81
Turner Cut (Pooled)	TCE/TCW	F1	0[a]	81	2	83
Old River East, Upstream	OREU	B1a	125	14	11	150
Old River East, Downstream	ORED	B1b	125	14	11	150
Old River East (Pooled)	ORE	B1	125	14	11	150
Old River South Upstream	ORSU	B2a	115	13	5	133
Old River South Downstream	ORSD	B2b	115	13	5	133
Old River South (Pooled)	ORS	B2	115	13	5	133
West Canal, Upstream	WCLU	B3a	5	1[a]	1[a]	7
West Canal, Downstream	WCLD	B3b	5	1[a]	1[a]	7
West Canal, OR Route	WCL	B3	5	1[a]	1[a]	7
Old River at Highway 4, Upstream	OR4U	B4a	2	15	0[a]	17
Old River at Highway 4, Downstream	OR4D	B4b	2	15	0[a]	17

[a] = detections were not used in the survival model

Table 11. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
Old River at Highway 4, SJR Route	OR4	B4	0[a]	15	0[a]	15
Old River at Highway 4, OR Route	OR4	B4	2	0	0[a]	2
Old River at Highway 4 (Pooled)	OR4	B4	2	15	0[a]	17
Middle River Head, Upstream	MRHU	C1a	5	1	0[a]	6
Middle River Head, Downstream	MRHD	C1b	5	1	0[a]	6
Middle River Head (Pooled)	MRH	C1	5	1	0[a]	6
Middle River at Highway 4, Upstream	MR4U	C2a	1	12	1[a]	14
Middle River at Highway 4, Downstream	MR4D	C2b	1	12	1[a]	14
Middle River at Highway 4, SJR Route	MR4	C2	0[a]	11	0[a]	11
Middle River at Highway 4, OR Route	MR4	C2	1	1	1[a]	3
Middle River at Highway 4 (Pooled)	MR4	C2	1	12	1[a]	14
Radial Gates Upstream #1	RGU1	D1a	6	3	1[a]	9
Radial Gates Upstream #2	RGU2	D1b	6	3	1[a]	9
Radial Gates Upstream: SJR Route	RGU	D1	0[a]	1	0[a]	1
Radial Gates Upstream: OR Route	RGU	D1	6	2	1[a]	9
Radial Gates Upstream (Pooled)	RGU	D1	6	3	1[a]	10
Radial Gates Downstream #1	RGD1	D2a	6	2[a]	1[a]	9
Radial Gates Downstream #2	RGD2	D2b	6	2[a]	1[a]	9
Radial Gates Downstream: SJR Route	RGD	D2	0[a]	1[a]	0[a]	1
Radial Gates Downstream: OR Route	RGD	D2	6	1[a]	1[a]	8
Radial Gates Downstream (Pooled)	RGD	D2	6	2[a]	1[a]	9
Central Valley Project Trashrack, Upstream	CVPU	E1a	69	21	0[a]	91
Central Valley Project Trashrack, Downstream	CVPD	E1b	66	20	1[a]	87
CVP Trashrack: SJR Route	CVP	E1	0[a]	13	0[a]	13
CVP Trashrack: OR Route	CVP	E1	69	9	1[a]	79
Central Valley Project Trashrack (Pooled)	CVP	E1	69	22	1[a]	92
CVP tank: SJR Route	CVPtank	E2	0[a]	6	0[a]	6
CVP tank: OR Route	CVPtank	E2	34	5	1[a]	40
Central Valley Project Holding Tank	CVPtank	E2	34	11	1[a]	46
Jersey Point East	JPE	G1a	0[a]	137	5	142
Jersey Point West	JPW	G1b	0[a]	135	5	140
Jersey Point: SJR Route	JPE/JPW	G1	0[a]	137	5	142
Jersey Point: OR Route	JPE/JPW	G1	0[a]	0	0[a]	0
Jersey Point (Pooled)	JPE/JPW	G1	0[a]	137	5	142
False River West	FRW	H1a	0[a]	2[a]	0a	2

[a] = detections were not used in the survival model

Table 11. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Release Group 3	Total
False River East	FRE	H1b	0[a]	1[a]	0[a]	1
False River: SJR Route	FRE/FRW	H1	0[a]	2[a]	0[a]	2
False River: OR Route	FRE/FRW	H1	0[a]	0[a]	0[a]	0
False River (Pooled)	FRE/FRW	H1	0[a]	2[a]	0[a]	2
Chipps Island East	MAE	G2a	24	141	5	170
Chipps Island West	MAW	G2b	26	143	4	173
Chipps Island: SJR Route	MAE/MAW	G2	0	143	4	147
Chipps Island: OR Route	MAE/MAW	G2	26	4	1	31
Chipps Island (Pooled)	MAE/MAW	G2	26	147	5	178
Benicia Bridge: SJR Route	BBR	G3	0	142	6	148
Benicia Bridge: OR Route	BBR	G3	20	5	1	26
Benicia Bridge	BBR	G3	20	147	7	174

[a] = detections were not used in the survival model

Table 12. Number of juvenile Steelhead tagged by each surgeon in each release group during the 2014 tagging study.

Surgeon	Release Group 1	Release Group 2	Release Group 3	Total Tags
A	158	160	160	478
B	157	160	158	475
C	159	160	160	479
Total Tags	474	480	478	1,432

Table 13. Release size and counts of juvenile Steelhead tag detections at key detection sites by surgeon in 2014, excluding predator-type detections. * = omitted from chi-square test of independence because of low counts.

Detection Site	Surgeon		
	A	B	C
Release at Durham Ferry	478	475	479
Banta Carbona (BCA)	219	200	192
Mossdale (MOS)	218	207	200
Lathrop (SJL)	144	149	124
Garwood Bridge (SJG)	110	118	89
Navy Bridge (SJNB)	93	104	81
MacDonald Island (MAC)	65	68	58
Turner Cut (TCE/TCW)	34	33	16
Medford Island (MFE/MFW)	54	55	46
Old River East (ORE)	50	46	54
Old River South (ORS)	48	40	45
West Canal (WCL)*	2	2	3
Middle River Head (MRH)*	1	2	3
Middle River at Highway 4 (MR4)*	5	7	2
Clifton Court Forebay Exterior (RGU)*	4	3	3
Clifton Court Forebay Interior (RGD)*	4	2	3
Central Valley Project Trash Rack (CVP)	33	31	28
Central Valley Project Holding Tank (CVPtank)	14	15	17
Jersey Point (JPE/JPW)	50	48	44
Chipps Island (MAE/MAW)	64	60	54
Benicia Bridge (BBR)	59	60	55

Table 14. Performance metric estimates (standard error in parentheses) for tagged juvenile Steelhead released in the 2014 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.

Parameter	Release Group			Population Estimate[b]
	1[a]	2	3	
ψ_{AA}	NA[c]	0.66 (0.03)	0.77 (0.08)	0.71 (0.04)
ψ_{AF}	NA	0.30 (0.03)	0.11 (0.07)	0.21 (0.04)
ψ_{BB}	0.87 (0.03)	0.04 (0.01)	NA	NA
ψ_{BC}	0.04 (0.02)	0.00 (<0.01)	NA	NA
S_{AA}	NA	0.57 (0.03)	0.07 (0.03)	0.32 (0.02)
S_{AF}	NA	0.13 (0.03)	NA	NA
S_{BB}	0.20 (0.04)	0.33 (0.09)	NA	NA
S_{BC}	0	NA	NA	NA
ψ_{A}[d]	0.09 (0.02)	0.96 (0.01)	0.88 (0.03)	0.92 (0.02)
ψ_{B}[d]	0.91 (0.02)	0.04 (0.01)	0.12 (0.03)	0.08 (0.02)
S_{A}	0[e]	0.43 (0.03)	0.06 (0.02)	0.25 (0.02)
S_{B}	0.19[e] (0.03)	0.31 (0.09)	0.07 (0.07)	0.19 (0.06)
S_{Total}	0.18 (0.03)	0.43 (0.03)	0.06 (0.02)	0.24 (0.02)
$S_{A(MD)}$[f]	NA	0.44[g] (0.03)	0.07 (0.03)	0.26 (0.02)
$S_{B(MD)}$[f]	NA[h]	0[g]	NA	NA
$S_{Total(MD)}$[f]	NA	0.43 (0.03)	NA	NA
$S_{A(SD)}$	NA	0.77 (0.02)	0.16 (0.04)	0.46 (0.02)
$S_{B(SD)}$	0.56 (0.04)	0.83 (0.09)	NA	NA
$S_{Total(SD)}$	NA	0.77 (0.02)	NA	NA
ϕ_{A1A4}	0.32 (0.02)	0.74 (0.02)	0.25 (0.02)	0.49 (0.01)

a = Parameter estimates for group 1 represent joint fish-tag survival

b = Population estimate is weighted average of estimates from releases 2 and 3, using weights proportional to release size

c = NA estimates resulted when there were too few tags detected in the route to estimate route selection or/and survival

d = significant preference for route B (Old River Route) for release 1, and for route A (San Joaquin River route) for releases 2 and 3 and the population estimate (α=0.05)

e = estimated survival is significantly higher in route B (Old River Route) than in route A (San Joaquin River Route) (tested only for Delta and Mid-Delta survival; α=0.05)

f = estimates are the joint probability of surviving to the Jersey Point/False River junction, and moving downstream from that junction toward Jersey Point

g = estimated survival is significantly higher in route A (San Joaquin River Route) than in route B (Old River Route) (tested only for Delta and Mid-Delta survival; α=0.05)

h = all of the tags from fish that entered Old River at its head and were subsequently detected at Jersey Point or False River came via the CVP

Table 15. Performance metric estimates (standard error in parentheses) for tagged juvenile Steelhead released in the 2014 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.

Parameter	Release Group			Population Estimate[b]
	1[a]	2	3	
ψ_{AA}	NA[c]	0.65 (0.03)	0.71 (0.08)	0.68 (0.04)
ψ_{AF}	NA	0.29 (0.03)	0.14 (0.08)	0.22 (0.04)
ψ_{BB}	0.87 (0.03)	0.05 (0.01)	NA	NA
ψ_{BC}	0.03 (0.01)	0.00 (<0.01)	NA	NA
S_{AA}	NA	0.61 (0.03)	0.07 (0.03)	0.34 (0.02)
S_{AF}	NA	0.14 (0.03)	NA (NA)	NA
S_{BB}	0.20 (0.04)	0.24 (0.08)	NA	NA
S_{BC}	0	NA	NA	NA
ψ_A[d]	0.10 (0.03)	0.94 (0.01)	0.86 (0.04)	0.90 (0.02)
ψ_B[d]	0.90 (0.03)	0.06 (0.01)	0.14 (0.04)	0.10 (0.02)
S_A	0[e]	0.47[f] (0.03)	0.06 (0.02)	0.26 (0.02)
S_B	0.20[e] (0.03)	0.23[f] (0.07)	0.06 (0.06)	0.14 (0.05)
S_{Total}	0.18 (0.03)	0.45 (0.03)	0.06 (0.02)	0.26 (0.02)
$S_{A(MD)}$[g]	NA	0.48[f] (0.03)	0.09 (0.03)	0.28 (0.02)
$S_{B(MD)}$[g]	NA[h]	0[f]	NA	NA
$S_{Total(MD)}$[g]	NA	0.45 (0.03)	NA	NA
$S_{A(SD)}$	NA	0.82 (0.02)	0.18 (0.04)	0.50 (0.02)
$S_{B(SD)}$	0.56 (0.04)	0.56 (0.11)	NA	NA
$S_{Total(SD)}$	NA	0.80 (0.02)	NA	NA
ϕ_{A1A4}	0.32 (0.02)	0.72 (0.02)	0.25 (0.02)	0.49 (0.01)

a = Parameter estimates for group 1 represent joint fish-tag survival

b = Population estimate is weighted average of estimates from releases 2 and 3, using weights proportional to release size

c = NA estimates resulted when there were too few tags detected in the route to estimate route selection or/and survival

d = significant preference for route B (Old River Route) for release 1, and for route A (San Joaquin River route) for releases 2 and 3 and the population estimate (α=0.05)

e = estimated survival is significantly higher in route B (Old River Route) than in route A (San Joaquin River Route) (tested only for Delta and Mid-Delta survival; α=0.05)

f = estimated survival is significantly higher in route A (San Joaquin River Route) than in route B (Old River Route) (tested only for Delta and Mid-Delta survival; α=0.05)

g = estimates are the joint probability of surviving to the Jersey Point/False River junction, and moving downstream from that junction toward Jersey Point

h = all of the tags from fish that entered Old River at its head and were subsequently detected at Jersey Point or False River came via the CVP

Table 16a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Steelhead from release at Durham Ferry during the 2014 tagging study, without predator-type detections. Standard errors are in parentheses. See Table 16b for travel time from release with predator-type detections.

	Without Predator-Type Detections							
	Release 1		Release 2		Release 3		Releases 2, 3	
Detection Site and Route	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry Upstream (DFU)	50	0.40 (0.15)	18	0.60 (0.47)	112	0.45 (0.07)	130	0.47 (0.08)
Durham Ferry Downstream (DFD)	311	0.16 (0.01)	367	0.05 (<0.01)	285	0.15 (0.01)	652	0.07 (<0.01)
Banta Carbona (BCA)	170	1.91 (0.16)	276	0.76 (0.06)	165	1.32 (0.10)	441	0.90 (0.05)
Mossdale (MOS)	154	4.07 (0.25)	353	2.10 (0.11)	118	2.35 (0.20)	471	2.16 (0.10)
Lathrop (SJL)	12	6.56 (1.74)	325	2.89 (0.14)	80	2.97 (0.32)	405	2.90 (0.13)
Garwood Bridge (SJG)	1	3.61 (NA)	289	4.39 (0.17)	27	2.79 (0.43)	316	4.18 (0.17)
Navy Drive Bridge (SJNB)	1	3.65 (NA)	255	4.50 (0.19)	22	2.53 (0.38)	277	4.24 (0.18)
Rough and Ready Island (RRI)	0	NA	23	6.96 (0.80)	2	7.34 (3.56)	25	6.99 (0.77)
MacDonald Island (MAC)	0	NA	177	6.23 (0.29)	14	2.88 (0.56)	191	5.74 (0.30)
Turner Cut (TCE/TCW)	0	NA	81	6.74 (0.36)	2	8.77 (0.52)	83	6.78 (0.36)
Turner Cut Junction (MAC or TCE/TCW)	0	NA	258	6.38 (0.23)	16	3.15 (0.62)	274	6.02 (0.25)
Medford Island (MFE/MFW)	0	NA	143	6.57 (0.33)	12	3.74 (0.78)	155	6.20 (0.33)
Old River East (ORE)	125	4.88 (0.30)	14	4.20 (0.58)	11	3.13 (0.59)	25	3.65 (0.43)
Old River South (ORS)	115	5.73 (0.29)	13	4.63 (0.54)	5	3.98 (1.29)	18	4.43 (0.54)
West Canal (WCL)	5	8.36 (1.04)	1	13.71 (NA)	1	4.08 (NA)	2	6.29 (3.40)
Old River at Highway 4 (OR4), SJR Route	0	NA	15	9.12 (0.79)	0	NA	15	9.12 (0.79)
Old River at Highway 4 (OR4), OR Route	2	11.58 (0.49)	0	NA	0	NA	0	NA
Middle River Head (MRH)	5	4.73 (0.78)	1	20.39 (NA)	0	NA	1	20.39 (NA)
Middle River at Highway 4 (MR4), SJR Route	0	NA	11	10.96 (0.76)	0	NA	11	10.96 (0.76)
Middle River at Highway 4 (MR4), OR Route	1	11.32 (NA)	1	28.69 (NA)	1	10.07 (NA)	2	14.91 (7.16)
Radial Gates Upstream (DFU), SJR Route	0	NA	1	14.07 (NA)	0	NA	1	14.07 (NA)
Radial Gates Upstream (DFU), OR Route	6	7.57 (1.04)	2	5.17 (1.62)	1	19.27 (NA)	3	6.84 (2.75)
Radial Gates Upstream (DFU)	6	7.57 (1.04)	3	6.55 (2.31)	1	19.27 (NA)	4	7.85 (2.81)
Radial Gates Downstream (DFD), SJR Route	0	NA	1	14.47 (NA)	0	NA	1	14.47 (NA)
Radial Gates Downstream (DFD), OR Route	6	7.74 (1.00)	1	7.55 (NA)	1	19.29 (NA)	2	10.86 (4.75)
Radial Gates Downstream (DFD)	6	7.74 (1.00)	2	9.92 (3.12)	1	19.29 (NA)	3	11.84 (3.43)

Table 16a. (Continued)

Detection Site and Route	Without Predator-Type Detections							
	Release 1		Release 2		Release 3		Releases 2, 3	
	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
Central Valley Project Trashrack (CVP), SJR Route	0	NA	13	10.81 (1.09)	0	NA	13	10.81 (1.09)
Central Valley Project Trashrack (CVP), OR Route	69	7.86 (0.39)	9	6.60 (1.30)	1	3.43 (NA)	10	6.04 (1.10)
Central Valley Project Trashrack (CVP)	69	7.86 (0.39)	22	8.57 (1.06)	1	3.43 (NA)	23	8.05 (1.02)
Central Valley Project Holding Tank (CVPtank), SJR Route	0	NA	6	9.79 (1.80)	0	NA	6	9.79 (1.80)
Central Valley Project Holding Tank (CVPtank), OR Route	34	9.22 (0.48)	5	6.04 (1.81)	1	4.61 (NA)	6	5.74 (1.36)
Central Valley Project Holding Tank (CVPtank)	34	9.22 (0.48)	11	7.63 (1.48)	1	4.61 (NA)	12	7.24 (1.27)
Jersey Point (JPE/JPW), SJR Route	0	NA	137	8.27 (0.31)	5	7.11 (0.93)	142	8.23 (0.30)
Jersey Point (JPE/JPW), OR Route	0	NA	0	NA	0	NA	0	NA
False River (FRE/FRW), SJR Route	0	NA	2	7.95 (3.83)	0	NA	2	7.95 (3.83)
False River (FRE/FRW), OR Route	0	NA	0	NA	0	NA	0	NA
Chipps Island (MAE/MAW), SJR Route	0	NA	143	9.88 (0.33)	4	10.12 (1.82)	147	9.89 (0.33)
Chipps Island (MAE/MAW), OR Route	26	10.35 (0.43)	4	8.14 (2.05)	1	5.24 (NA)	5	7.33 (1.48)
Chipps Island (MAE/MAW)	26	10.35 (0.43)	147	9.82 (0.33)	5	8.53 (1.67)	152	9.77 (0.32)
Benicia Bridge (BBR)	20	11.65 (0.46)	147	10.73 (0.34)	7	9.06 (1.39)	154	10.64 (0.33)

Table 16b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Steelhead from release at Durham Ferry during the 2014 tagging study, with predator-type detections. Standard errors are in parentheses. See Table 16a for travel time from release without predator-type detections.

	Without Predator-Type Detections							
	Release 1		Release 2		Release 3		Releases 2, 3	
Detection Site and Route	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry Upstream (DFU)	50	0.40 (0.15)	22	0.73 (0.58)	112	0.45 (0.07)	134	0.48 (0.08)
Durham Ferry Downstream (DFD)	311	0.17 (0.01)	365	0.05 (<0.01)	285	0.15 (0.01)	650	0.07 (<0.01)
Banta Carbona (BCA)	168	1.91 (0.16)	272	0.76 (0.06)	165	1.35 (0.10)	437	0.91 (0.05)
Mossdale (MOS)	153	4.11 (0.25)	345	2.10 (0.12)	119	2.42 (0.21)	464	2.18 (0.10)
Lathrop (SJL)	13	5.88 (1.38)	311	2.85 (0.15)	72	2.95 (0.35)	383	2.87 (0.14)
Garwood Bridge (SJG)	2	3.52 (0.08)	290	4.46 (0.18)	29	2.99 (0.48)	319	4.27 (0.18)
Navy Drive Bridge (SJNB)	1	3.65 (NA)	261	4.56 (0.19)	26	3.05 (0.53)	287	4.36 (0.19)
Rough and Ready Island (RRI)	0	NA	21	6.82 (0.84)	2	7.34 (3.56)	23	6.86 (0.80)
MacDonald Island (MAC)	0	NA	182	6.36 (0.30)	15	3.05 (0.61)	197	5.87 (0.31)
Turner Cut (TCE/TCW)	0	NA	82	6.84 (0.38)	3	10.70 (2.39)	85	6.93 (0.38)
Turner Cut Junction (MAC or TCE/TCW)	0	NA	264	6.50 (0.24)	18	3.46 (0.70)	282	6.16 (0.26)
Medford Island (MFE/MFW)	0	NA	148	6.72 (0.34)	13	3.97 (0.85)	161	6.36 (0.34)
Old River East (ORE)	122	4.94 (0.30)	19	5.51 (1.00)	12	3.70 (0.80)	31	4.63 (0.66)
Old River South (ORS)	115	5.74 (0.29)	15	5.26 (0.77)	8	4.42 (1.00)	23	4.93 (0.61)
West Canal (WCL)	5	8.36 (1.04)	2	6.20 (3.40)	1	4.08 (NA)	3	5.29 (1.62)
Old River at Highway 4 (OR4), SJR Route	0	NA	15	9.12 (0.79)	0	NA	15	9.12 (0.79)
Old River at Highway 4 (OR4), OR Route	2	11.58 (0.49)	0	NA	0	NA	0	NA
Middle River Head (MRH)	4	5.60 (1.67)	1	20.39 (NA)	0	NA	1	20.39 (NA)
Middle River at Highway 4 (MR4), SJR Route	0	NA	12	11.34 (0.85)	0	NA	12	11.34 (0.85)
Middle River at Highway 4 (MR4), OR Route	1	11.32 (NA)	1	28.69 (NA)	1	10.07 (NA)	2	14.91 (7.16)
Radial Gates Upstream (DFU), SJR Route	0	NA	1	14.07 (NA)	0	NA	1	14.07 (NA)
Radial Gates Upstream (DFU), OR Route	6	7.57 (1.04)	1	7.54 (NA)	1	19.27 (NA)	2	10.84 (4.74)
Radial Gates Upstream (DFU)	6	7.57 (1.04)	2	9.82 (2.97)	1	19.27 (NA)	3	11.74 (3.36)
Radial Gates Downstream (DFD), SJR Route	0	NA	1	14.47 (NA)	0	NA	1	14.47 (NA)
Radial Gates Downstream (DFD), OR Route	6	7.74 (1.00)	1	7.55 (NA)	1	19.29 (NA)	2	10.86 (4.75)
Radial Gates Downstream (DFD)	6	7.74 (1.00)	2	9.92 (3.12)	1	19.29 (NA)	3	11.84 (3.43)

Table 16b. (Continued)

Detection Site and Route	Without Predator-Type Detections							
	Release 1		Release 2		Release 3		Releases 2, 3	
	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
Central Valley Project Trashrack (CVP), SJR Route	0	NA	13	10.89 (1.11)	0	NA	13	10.89 (1.11)
Central Valley Project Trashrack (CVP), OR Route	69	7.87 (0.39)	9	6.60 (1.30)	2	4.98 (2.26)	11	6.23 (1.08)
Central Valley Project Trashrack (CVP)	69	7.87 (0.39)	22	8.60 (1.07)	2	4.98 (2.26)	24	8.11 (1.00)
Central Valley Project Holding Tank (CVPtank), SJR Route	0	NA	6	9.79 (1.80)	0	NA	6	9.79 (1.80)
Central Valley Project Holding Tank (CVPtank), OR Route	35	9.30 (0.49)	5	6.04 (1.81)	1	4.61 (NA)	6	5.74 (1.36)
Central Valley Project Holding Tank (CVPtank)	35	9.30 (0.49)	11	7.63 (1.48)	1	4.61 (NA)	12	7.24 (1.27)
Jersey Point (JPE/JPW), SJR Route	0	NA	141	8.44 (0.33)	6	8.27 (1.70)	147	8.43 (0.32)
Jersey Point (JPE/JPW), OR Route	0	NA	0	NA	0	NA	0	NA
False River (FRE/FRW), SJR Route	0	NA	2	7.95 (3.83)	0	NA	2	7.95 (3.83)
False River (FRE/FRW), OR Route	0	NA	0	NA	0	NA	0	NA
Chipps Island (MAE/MAW), SJR Route	0	NA	148	10.05 (0.34)	4	10.12 (1.82)	152	10.05 (0.34)
Chipps Island (MAE/MAW), OR Route	26	10.35 (0.43)	4	8.14 (2.05)	1	5.24 (NA)	5	7.33 (1.48)
Chipps Island (MAE/MAW)	26	10.35 (0.43)	152	9.98 (0.34)	5	8.53 (1.67)	157	9.93 (0.33)
Benicia Bridge (BBR)	20	11.65 (0.46)	152	10.90 (0.35)	7	9.06 (1.39)	159	10.80 (0.34)

Table 17a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Steelhead through the San Joaquin River Delta river reaches during the 2014 tagging study, without predator-type detections. Standard errors are in parentheses. See Table 17b for travel time through reaches with predator-type detections. * = all routes combined between upstream and downstream boundaries.

Reach		Without Predator-Type Detections							
		Release 1		Release 2		Release 3		Releases 2, 3	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry (Release)	DFU	50	0.40 (0.15)	18	0.60 (0.47)	112	0.45 (0.07)	130	0.47 (0.08)
	DFD	311	0.16 (0.01)	367	0.05 (<0.01)	285	0.15 (0.01)	652	0.07 (<0.01)
DFD	BCA	170	1.31 (0.11)	239	0.53 (0.04)	164	0.67 (0.07)	403	0.58 (0.03)
BCA	MOS	154	0.94 (0.07)	252	0.60 (0.03)	118	0.67 (0.07)	370	0.62 (0.03)
MOS	SJL	12	0.85 (0.25)	325	0.33 (0.01)	79	0.33 (0.05)	404	0.33 (0.02)
	ORE	125	0.41 (0.04)	14	0.41 (0.12)	11	0.68 (0.16)	25	0.50 (0.11)
SJL	SJG	1	0.37 (NA)	289	1.04 (0.03)	27	0.66 (0.12)	316	0.99 (0.04)
SJG	SJNB	1	0.04 (NA)	254	0.10 (0.01)	22	0.06 (0.01)	276	0.10 (<0.01)
	RRI	0	NA	23	0.26 (0.04)	2	0.72 (0.07)	25	0.27 (0.04)
SJNB	MAC	0	NA	163	0.98 (0.04)	12	0.41 (0.06)	175	0.89 (0.04)
	TCE/TCW	0	NA	74	1.19 (0.10)	2	1.81 (0.10)	76	1.20 (0.10)
RRI	MAC	0	NA	13	0.90 (0.15)	2	1.36 (0.33)	15	0.94 (0.15)
	TCE/TCW	0	NA	7	0.96 (0.39)	0	NA	7	0.96 (0.39)
MAC	MFE/MFW	0	NA	143	0.18 (0.01)	12	0.15 (0.03)	155	0.18 (0.01)
	JPE/JPW*	0	NA	126	1.55 (0.05)	5	1.33 (0.30)	131	1.54 (0.05)
	OR4*	0	NA	3	2.23 (0.82)	0	NA	3	2.23 (0.82)
	MR4*	0	NA	3	1.86 (0.27)	0	NA	3	1.86 (0.27)
	RGU*	0	NA	0	NA	0	NA	0	NA
	CVP*	0	NA	4	4.43 (0.38)	0	NA	4	4.43 (0.38)
MFE/MFW	JPE/JPW*	0	NA	114	1.11 (0.05)	5	0.93 (0.25)	119	1.10 (0.05)
	OR4	0	NA	3	1.94 (0.61)	0	NA	3	1.94 (0.61)
	MR4	0	NA	0	NA	0	NA	0	NA
	RGU*	0	NA	0	NA	0	NA	0	NA
	CVP*	0	NA	2	3.43 (0.14)	0	NA	2	3.43 (0.14)
TCE/TCW	JPE/JPW*	0	NA	11	3.37 (0.46)	0	NA	11	3.37 (0.46)

Table 17a. (Continued)

Reach		Without Predator-Type Detections							
		Release 1		Release 2		Release 3		Releases 2, 3	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
TCE/TCW	OR4	0	NA	12	2.43 (0.34)	0	NA	12	2.43 (0.34)
	MR4	0	NA	8	1.52 (0.24)	0	NA	8	1.52 (0.24)
	RGU*	0	NA	1	1.57 (NA)	0	NA	1	1.57 (NA)
	CVP*	0	NA	9	3.45 (0.64)	0	NA	9	3.45 (0.64)
ORE	ORS	115	0.36 (0.02)	13	0.37 (0.06)	5	0.21 (0.06)	18	0.31 (0.05)
	MRH	5	0.61 (0.11)	1	0.63 (NA)	0	NA	1	0.63 (NA)
ORS	WCL	5	1.78 (0.43)	1	9.23 (NA)	1	1.34 (NA)	2	2.34 (1.75)
	OR4	2	1.57 (0.49)	0	NA	0	NA	0	NA
	MR4	1	2.60 (NA)	0	NA	1	7.33 (NA)	1	7.33 (NA)
	RGU	6	1.74 (0.34)	2	0.69 (0.24)	1	0.79 (NA)	3	0.72 (0.15)
	CVP	69	1.32 (0.12)	9	1.13 (0.40)	1	1.04 (NA)	10	1.12 (0.35)
WCL	OR4	2	0.19 (0.13)	0	NA	0	NA	0	NA
OR4 via OR	JPE/JPW	0	NA	0	NA	0	NA	0	NA
OR4 via SJR	JPE/JPW	0	NA	4	1.55 (0.23)	0	NA	4	1.55 (0.23)
OR4 via SJR	RGU	0	NA	0	NA	0	NA	0	NA
OR4 via SJR	CVP	0	NA	8	1.02 (0.25)	0	NA	8	1.02 (0.25)
MRH	WCL	0	NA	0	NA	0	NA	0	NA
	OR4	0	NA	0	NA	0	NA	0	NA
	MR4	0	NA	1	8.30 (NA)	0	NA	1	8.30 (NA)
	RGU	0	NA	0	NA	0	NA	0	NA
	CVP	0	NA	0	NA	0	NA	0	NA
MR4 via OR	JPE/JPW	0	NA	0	NA	0	NA	0	NA
MR4 via SJR	JPE/JPW	0	NA	0	NA	0	NA	0	NA
MR4 via SJR	RGU	0	NA	1	0.42 (NA)	0	NA	1	0.42 (NA)
MR4 via SJR	CVP	0	NA	5	1.57 (0.59)	0	NA	5	1.57 (0.59)
RGU via OR	RGD	6	0.01 (0.01)	1	0.01 (NA)	1	0.02 (NA)	2	0.02 (<0.01)
RGU via SJR	RGD	0	NA	1	0.39 (NA)	0	NA	1	0.39 (NA)

Table 17a. (Continued)

Reach		Without Predator-Type Detections							
		Release 1		Release 2		Release 3		Releases 2, 3	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
CVP via OR	CVPtank	34	0.19 (0.08)	5	0.11 (0.04)	1	1.18 (NA)	6	0.13 (0.05)
CVP via SJR	CVPtank	0	NA	6	0.05 (0.02)	0	NA	6	0.05 (0.02)
JPE/JPW	MAE/MAW* (Chipps Island)	0	NA	126	0.94 (0.03)	2	0.95 (0.07)	128	0.94 (0.03)
MAC		0	NA	129	2.61 (0.07)	4	2.87 (0.48)	133	2.61 (0.07)
MFE/MFW		0	NA	117	2.19 (0.07)	4	2.43 (0.39)	121	2.19 (0.07)
TCE/TCW		0	NA	14	4.70 (0.41)	0	NA	14	4.70 (0.41)
OR4		0	NA	4	2.54 (0.17)	0	NA	4	2.54 (0.17)
MR4		0	NA	0	NA	0	NA	0	NA
RGD		2	3.64 (1.29)	0	NA	0	NA	0	NA
CVPtank		23	1.23 (0.12)	10	1.15 (0.19)	1	0.63 (NA)	11	1.07 (0.16)
MAE/MAW	BBR	19	0.71 (0.17)	144	0.59 (0.04)	5	0.91 (0.18)	149	0.59 (0.04)

Table 17b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Steelhead through the San Joaquin River Delta river reaches during the 2014 tagging study, with predator-type detections. Standard errors are in parentheses. See Table 17a for travel time through reaches without predator-type detections. * = all routes combined between upstream and downstream boundaries.

Reach		Without Predator-Type Detections							
		Release 1		Release 2		Release 3		Releases 2, 3	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry (Release)	DFU	50	0.40 (0.15)	22	0.73 (0.58)	112	0.45 (0.07)	134	0.48 (0.08)
	DFD	311	0.17 (0.01)	365	0.05 (<0.01)	285	0.15 (0.01)	650	0.07 (<0.01)
DFD	BCA	168	1.31 (0.11)	236	0.52 (0.04)	164	0.68 (0.07)	400	0.58 (0.03)
BCA	MOS	153	0.96 (0.06)	246	0.61 (0.03)	119	0.67 (0.07)	365	0.63 (0.03)
MOS	SJL	13	0.51 (0.23)	311	0.33 (0.02)	71	0.31 (0.05)	382	0.33 (0.02)
	ORE	122	0.41 (0.04)	19	0.51 (0.14)	12	0.78 (0.20)	31	0.59 (0.13)
SJL	SJG	2	0.45 (0.10)	290	1.05 (0.04)	29	0.70 (0.13)	319	1.01 (0.04)
SJG	SJNB	1	0.04 (NA)	259	0.10 (0.01)	26	0.07 (0.01)	285	0.10 (<0.01)
	RRI	0	NA	21	0.24 (0.03)	2	0.72 (0.07)	23	0.25 (0.03)
SJNB	MAC	0	NA	168	0.97 (0.04)	13	0.43 (0.06)	181	0.89 (0.04)
	TCE/TCW	0	NA	75	1.21 (0.11)	3	0.68 (0.43)	78	1.17 (0.11)
RRI	MAC	0	NA	13	0.92 (0.17)	2	1.36 (0.33)	15	0.96 (0.16)
	TCE/TCW	0	NA	7	0.97 (0.40)	0	NA	7	0.97 (0.40)
MAC	MFE/MFW	0	NA	148	0.18 (0.01)	13	0.16 (0.03)	161	0.18 (0.01)
	JPE/JPW*	0	NA	130	1.55 (0.05)	6	1.58 (0.46)	136	1.55 (0.05)
	OR4*	0	NA	3	2.23 (0.82)	0	NA	3	2.23 (0.82)
	MR4*	0	NA	3	1.86 (0.27)	0	NA	3	1.86 (0.27)
	RGU*	0	NA	0	NA	0	NA	0	NA
	CVP*	0	NA	4	4.43 (0.38)	0	NA	4	4.43 (0.38)
MFE/MFW	JPE/JPW*	0	NA	117	1.11 (0.05)	6	1.10 (0.36)	123	1.11 (0.05)
	OR4	0	NA	3	1.94 (0.61)	0	NA	3	1.94 (0.61)
	MR4	0	NA	0	NA	0	NA	0	NA
	RGU*	0	NA	0	NA	0	NA	0	NA
	CVP*	0	NA	2	3.43 (0.14)	0	NA	2	3.43 (0.14)
TCE/TCW	JPE/JPW*	0	NA	11	3.37 (0.46)	0	NA	11	3.37 (0.46)

Table 17b. (Continued)

Reach		Without Predator-Type Detections							
		Release 1		Release 2		Release 3		Releases 2, 3	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
TCE/TCW	OR4	0	NA	12	2.43 (0.34)	0	NA	12	2.43 (0.34)
	MR4	0	NA	9	1.67 (0.30)	0	NA	9	1.67 (0.30)
	RGU*	0	NA	1	1.57 (NA)	0	NA	1	1.57 (NA)
	CVP*	0	NA	9	3.49 (0.67)	0	NA	9	3.49 (0.67)
ORE	ORS	115	0.36 (0.02)	15	0.41 (0.07)	8	0.29 (0.09)	23	0.36 (0.06)
	MRH	4	0.79 (0.33)	1	0.63 (NA)	0	NA	1	0.63 (NA)
ORS	WCL	5	1.78 (0.43)	2	1.11 (0.97)	1	1.34 (NA)	3	1.18 (0.64)
	OR4	2	1.57 (0.49)	0	NA	0	NA	0	NA
	MR4	1	2.60 (NA)	0	NA	1	7.33 (NA)	1	7.33 (NA)
	RGU	6	1.74 (0.34)	1	1.06 (NA)	1	0.79 (NA)	2	0.90 (0.13)
	CVP	69	1.32 (0.12)	9	1.13 (0.40)	2	1.09 (0.06)	11	1.12 (0.32)
WCL	OR4	2	0.19 (0.13)	0	NA	0	NA	0	NA
OR4 via OR	JPE/JPW	0	NA	0	NA	0	NA	0	NA
OR4 via SJR	JPE/JPW	0	NA	4	1.55 (0.23)	0	NA	4	1.55 (0.23)
OR4 via SJR	RGU	0	NA	0	NA	0	NA	0	NA
OR4 via SJR	CVP	0	NA	8	1.03 (0.26)	0	NA	8	1.03 (0.26)
MRH	WCL	0	NA	0	NA	0	NA	0	NA
	OR4	0	NA	0	NA	0	NA	0	NA
	MR4	0	NA	1	8.30 (NA)	0	NA	1	8.30 (NA)
	RGU	0	NA	0	NA	0	NA	0	NA
	CVP	0	NA	0	NA	0	NA	0	NA
MR4 via OR	JPE/JPW	0	NA	0	NA	0	NA	0	NA
MR4 via SJR	JPE/JPW	0	NA	0	NA	0	NA	0	NA
MR4 via SJR	RGU	0	NA	1	0.42 (NA)	0	NA	1	0.42 (NA)
MR4 via SJR	CVP	0	NA	5	1.57 (0.59)	0	NA	5	1.57 (0.59)
RGU via OR	RGD	6	0.01 (0.01)	1	0.01 (NA)	1	0.02 (NA)	2	0.02 (<0.01)
RGU via SJR	RGD	0	NA	1	0.39 (NA)	0	NA	1	0.39 (NA)

Table 17b. (Continued)

Reach		Without Predator-Type Detections							
		Release 1		Release 2		Release 3		Releases 2, 3	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time	N	Travel Time
CVP via OR	CVPtank	35	0.18 (0.08)	5	0.11 (0.04)	1	1.18 (NA)	6	0.13 (0.05)
CVP via SJR	CVPtank	0	NA	6	0.05 (0.02)	0	NA	6	0.05 (0.02)
JPE/JPW	MAE/MAW* (Chipps Island)	0	NA	130	0.94 (0.03)	2	0.95 (0.07)	132	0.94 (0.03)
MAC		0	NA	134	2.61 (0.07)	4	2.87 (0.48)	138	2.62 (0.07)
MFE/MFW		0	NA	121	2.19 (0.07)	4	2.43 (0.39)	125	2.19 (0.07)
TCE/TCW		0	NA	14	4.70 (0.41)	0	NA	14	4.70 (0.41)
OR4		0	NA	4	2.54 (0.17)	0	NA	4	2.54 (0.17)
MR4		0	NA	0	NA	0	NA	0	NA
RGD		2	3.64 (1.29)	0	NA	0	NA	0	NA
CVPtank		23	1.23 (0.12)	10	1.15 (0.19)	1	0.63 (NA)	11	1.07 (0.16)
MAE/MAW	BBR	19	0.71 (0.17)	149	0.58 (0.04)	5	0.91 (0.18)	154	0.59 (0.04)

Table 18. Results of single-variate analyses of 2014 route selection at the Turner Cut junction. All F-tests had 1 and 47 degrees of freedom. Covariates are ordered by P-value and F statistic.

Covariate	F-test	
	F	*P*
Flow at TRN[a]	11.8763	0.0012
Velocity at TRN[a]	11.6586	0.0013
Negative flow at TRN	8.7483	0.0048
Change in stage at TRN	7.7899	0.0076
Stage at TRN	4.2285	0.0453
Velocity during transition from SJG	1.9605	0.1680
Flow during transition from SJG	1.4584	0.2332
Arrive at TCJ during day	1.2186	0.2753
Release Group	0.6555	0.4222
Change in flow at TRN	0.4846	0.4898
Change in velocity at TRN	0.4767	0.4933
Exports at SWP	0.3311	0.5678
Exports at CVP	0.0577	0.8112
Total Exports in Delta	0.0019	0.9657
Fork Length	0.0009	0.9756

a = Significant at family-wise 5% level (test-wise $\alpha = 0.0033$)

Table 19. Results of multivariate analyses of route selection at the Turner Cut junction in 2014. Modeled response is the probability of selecting the San Joaquin River route.

Model Type	Covariate[a]	Estimate	S.E.	*t*-test *t*	*t*-test df	*t*-test *P*
Flow	Intercept	1.5331	0.2122	7.224	47	< 0.0001
	Q_{TRN}	1.1809	0.1945	6.072	47	< 0.0001
	Goodness-of-fit: χ^2= 4.1766, df=13, P=0.9892; AIC = 186.57					
Velocity	Intercept	1.5366	0.2130	7.2154	47	< 0.0001
	V_{TRN}	1.1840	0.1973	5.9998	47	< 0.0001
	Goodness-of-fit: χ^2=2.2033, df=13, P=0.9996; AIC = 187.25					
Stage	Intercept	2.3191	0.3145	7.3734	46	< 0.0001
	ΔC_{TRN}	-0.8008	0.1716	-4.6654	46	< 0.0001
	U	-1.9348	0.3963	-4.8825	46	< 0.0001
	Goodness-of-fit: χ^2=3.9805, df=13, P=0.9914; AIC = 175.82					

a = Continuous covariates (Q_{TRN}, V_{TRN}, ΔC_{TRN}) are standardized. Intercept and slope estimates for the unstandardized covariates are 1.7819 ($\widehat{SE} =$ 0.3105) for the intercept, -8.5803 ($\widehat{SE} =$ 1.8391) for ΔC_{TRN}, and -1.9348 ($\widehat{SE} =$ 0.3963) for U for the stage model.

Table 20. 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 in 2014, excluding predator-type detections (95% profile likelihood interval or sample size in parentheses). Population estimate is based on data pooled from the April and May release groups. * = Parameter estimates for group 1 represent joint fish-tag survival.

Facility	Upstream Model Site Code	Release Group			Population Estimate
		1*	2	3	
CVP	E2	0.74 (0.58, 0.88)	1 (n=11)	1 (n=1)	1 (n=12)
SWP	D2	0.34 (0.07, 0.73)	0 (n=2)	0 (n=1)	0 (n=3)

Table 21. Estimates (standard errors in parentheses) of model survival and transition parameters by release group, and of the difference (Δ) between release group estimates: Δ = Release group 2 - Release group 3. P = P-value from one-sized z-test of Δ>0. Estimates were based on data that excluded predator-type detections. * = significant (positive) difference between release groups for family-wise α=0.10.

Parameter	Release 2	Release 3	Δ	P
S_{A2}	0.90 (0.02)	0.58 (0.03)	0.32 (0.03)	<0.0001*
S_{A3}	0.91 (0.02)	0.72 (0.04)	0.19 (0.04)	<0.0001*
S_{A4}	0.97 (0.01)	0.77 (0.04)	0.20 (0.04)	<0.0001*
S_{A5}	0.90 (0.02)	0.35 (0.05)	0.55 (0.06)	<0.0001*
S_{A6}	0.96 (0.01)	0.89 (0.06)	0.07 (0.06)	0.1171
S_{A7}	0.93 (0.02)	0.64 (0.10)	0.29 (0.10)	0.0024*
$S_{A8,G2}$	0.74 (0.03)	0.43 (0.13)	0.31 (0.14)	0.0112
$S_{B2,G2}$	0.35 (0.10)	0.20 (0.18)	0.15 (0.20)	0.2361
$\phi_{A1,A2}$	0.90 (0.02)	0.60 (0.02)	0.30 (0.03)	<0.0001*
$\phi_{A1,A4}$	0.74 (0.02)	0.25 (0.02)	0.49 (0.03)	<0.0001*
$\phi_{B1,B2}$	0.93 (0.07)	0.45 (0.15)	0.47 (0.17)	0.0021*
S_{Total}	0.43 (0.03)	0.06 (0.02)	0.37 (0.03)	<0.0001*

a = significant negative difference between release groups for family-wise α=0.10

Appendix A. Survival Model Parameters

Table A1. Definitions of parameters used in the release-recapture survival model in the 2014 tagging study. Parameters used only in particular submodels are noted. * = estimated directly or derived from model.

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)
$S_{A5,G2}$	Overall survival from Lathrop (SJL) to Chipps Island (MAE/MAW) (Submodel I*)
S_{A6}	Probability of survival from Garwood Bridge (SJG) to Navy Drive Bridge (SJNB) or Rough and Ready Island (RRI)
$S_{A6,G2}$	Overall survival from Garwood Bridge (SJG) to Chipps Island (MAE/MAW) (Submodel I*)
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)
$S_{A9,G2}$	Overall survival from Medford Island (MFE/MFW) to Chipps Island (MAE/MAW) (derived from Submodel II)
S_{B1}	Probability of survival from Old River East (ORE) to Old River South (ORS) or Middle River Head (MRH) (Submodel I)
$S_{B1,G2}$	Overall survival from Old River East (ORE) to Chipps Island (MAE/MAW) (Submodel I*)
$S_{B2,G2}$	Overall survival from Old River South (ORS) to Chipps Island (MAE/MAW) (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) (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)
S_{R1}	Probability of survival from Rough and Ready Island (RRI) to MacDonald Island (MAC) or Turner Cut (TCE/TCW)
$\phi_{A1,A0}$	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; $= \phi_{A1,A2} S_{A2}$
$\phi_{A1,A4}$	Joint probability of moving from Durham Ferry release site downstream toward MOS, and surviving to MOS; $= \phi_{A1,A2} S_{A2} S_{A3}$
$\phi_{A8,A9}$	Joint probability of moving from MAC toward MFE/MFW, and surviving from MAC to MFE/MFW (Submodel II)
$\phi_{A8,B4}$	Joint probability of moving from MAC directly toward OR4, and surviving from MAC to OR4 (Submodel II)
$\phi_{A8,C2}$	Joint probability of moving from MAC directly toward MR4, and surviving from MAC to MR4 (Submodel II)
$\phi_{A8,D1O}$	Joint probability of moving from MAC directly toward RGU, surviving to RGU, and arriving when the radial gates are open (Submodel II*)
$\phi_{A8,D1C}$	Joint probability of moving from MAC directly toward RGU, surviving to RGU, and arriving when the radial gates are closed (Submodel II*)
$\phi_{A8,D1}$	Joint probability of moving from MAC directly toward RGU and surviving to RGU (Submodel II*)
$\phi_{A8,E1}$	Joint probability of moving from MAC directly toward CVP and surviving to CVP (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); $= \phi_{A9,GH}\psi_{G1(A)}$
$\phi_{A9,B4}$	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)

Table A1. (Continued)

Parameter	Definition
$\phi_{A9,D1O}$	Joint probability of moving from MFE/MFW toward RGU, surviving to RGU, and arriving when the radial gates are open (Submodel II*)
$\phi_{A9,D1C}$	Joint probability of moving from MFE/MFW toward RGU, surviving to RGU, and arriving when the radial gates are closed (Submodel II*)
$\phi_{A9,D1}$	Joint probability of moving from MFE/MFW toward RGU and surviving to RGU (Submodel II*)
$\phi_{A9,E1}$	Joint probability of moving from MFE/MFW toward CVP and surviving to CVP (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); = $\phi_{A10,GH}\psi_{G1(A)}$
$\phi_{B1,B2}$	Joint probability of moving from ORE toward ORS, and surviving from ORE to ORS (Submodel I)
$\phi_{B2,B3}$	Joint probability of moving from ORS toward WCL, and surviving from ORS to WCL (Submodel I)
$\phi_{B2,B4}$	Joint probability of moving from ORS toward OR4, and surviving from ORS to OR4 (Submodel I*); = $\phi_{B2,B3}\ \phi_{B3,B4}$
$\phi_{B2,C2}$	Joint probability of moving from ORS toward MR4, and surviving from ORS to MR4 (Submodel I)
$\phi_{B2,D1O}$	Joint probability of moving from ORS toward RGU, surviving to RGU, and arriving when the radial gates are open (Submodel I)
$\phi_{B2,D1C}$	Joint probability of moving from ORS toward RGU, surviving to RGU, and arriving when the radial gates are closed (Submodel I)
$\phi_{B2,D1}$	Joint probability of moving from ORS toward RGU, and surviving from ORS to RGU (Submodel I)
$\phi_{B2,E1}$	Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP (Submodel I)
$\phi_{B3,B4}$	Joint probability of moving from WCL toward OR4, and surviving from WCL to OR4 (Submodel I)
$\phi_{B4,D1O}$	Joint probability of moving from OR4 toward RGU, surviving from OR4 to RGU, and arriving when the radial gate are open (Submodel II)
$\phi_{B4,D1C}$	Joint probability of moving from OR4 toward RGU, surviving from OR4 to RGU, and arriving when the radial gate are closed (Submodel II)
$\phi_{B4,D1}$	Joint probability of moving from OR4 toward RGU, and surviving from OR4 to RGU (Submodel II)
$\phi_{B4,E1}$	Joint probability of moving from OR4 toward CVP, and surviving from OR4 to CVP (Submodel II)
$\phi_{B4,GH}$	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 (equated between submodels)
$\phi_{B4,G1}$	Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) and surviving from OR4 to JPE/JPW (equated between submodels); = $\phi_{B4,GH}\psi_{G1}$
$\phi_{C1,B3}$	Joint probability of moving from MRH toward WCL, and surviving from MRH to WCL (Submodel I)
$\phi_{C1,B4}$	Joint probability of moving from MRH toward OR4, and surviving from MRH to OR4 (Submodel I*); = $\phi_{C1,B3}\ \phi_{B3,B4}$
$\phi_{C1,C2}$	Joint probability of moving from MRH toward MR4, and surviving from MRH to MR4 (Submodel I)
$\phi_{C1,D1O}$	Joint probability of moving from MRH toward RGU, surviving to RGU, and arriving when the radial gates are open (Submodel I)
$\phi_{C1,D1C}$	Joint probability of moving from MRH toward RGU, surviving to RGU, and arriving when the radial gates are closed (Submodel I)
$\phi_{C1,D1}$	Joint probability of moving from MRH toward RGU, and surviving from MRH to RGU (Submodel I)
$\phi_{C1,E1}$	Joint probability of moving from MRH toward CVP, and surviving from MRH to CVP (Submodel I)
$\phi_{C2,D1O}$	Joint probability of moving from MRH toward RGU, surviving from MRH to RGU, and arriving when the radial gate are open (Submodel II)
$\phi_{C2,D1C}$	Joint probability of moving from MRH toward RGU, surviving from MRH to RGU, and arriving when the radial gate are closed (Submodel II)
$\phi_{C2,D1}$	Joint probability of moving from MRH toward RGU, and surviving from MRH to RGU (Submodel II)
$\phi_{C2,E1}$	Joint probability of moving from MRH toward CVP, and surviving from MRH to CVP (Submodel II)
$\phi_{C2,GH}$	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 (equated between submodels)

Table A1. (Continued)

Parameter	Definition
$\phi_{C2,G1}$	Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) and surviving from MR4 to JPE/JPW (equated between submodels); = $\phi_{C2,GH}\psi_{G1}$
$\phi_{D1O,D2}$	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD, conditional on arrival at RGU when radial gates are open (equated between submodels)
$\phi_{D1C,D2}$	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD, conditional on arrival at RGU when radial gates are closed (equated between submodels)
$\phi_{D1,D2}$	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD (equated between submodels)
$\phi_{D1O,G2}$	Joint probability of moving from RGU toward Chipps Island (MAE/MAW) via CCFB and surviving to MAE/MAW, conditional on arrival at RGU when radial gates are open (equated between submodels); = $\phi_{D1O,D2}\phi_{D2,G2}$
$\phi_{D1C,G2}$	Joint probability of moving from RGU toward Chipps Island (MAE/MAW) via CCFB and surviving to MAE/MAW, conditional on arrival at RGU when radial gates are closed (equated between submodels); = $\phi_{D1C,D2}\phi_{D2,G2}$
$\phi_{D1,G2}$	Joint probability of moving from RGU toward Chipps Island (MAE/MAW) via CCFB and surviving to MAE/MAW (equated between submodels); = $\phi_{D1,D2}\phi_{D2,G2}$
$\phi_{D2,G2}$	Joint probability of moving from RGD toward Chipps Island (MAE/MAW) and surviving from RGD to MAE/MAW (equated between submodels)
$\phi_{E1,E2}$	Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank (equated between submodels)
$\phi_{E2,G2}$	Joint probability of moving from CVPtank toward Chipps Island (MAE/MAW) and surviving from CVPtank to MAE/MAW (equated between submodels)
$\phi_{F1,B4}$	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)
$\phi_{F1,D1O}$	Joint probability of moving from TCE/TCW toward RGU, surviving to RGU, and arriving when the radial gates are open (Submodel II*)
$\phi_{F1,D1C}$	Joint probability of moving from TCE/TCW toward RGU, surviving to RGU, and arriving when the radial gates are closed (Submodel II*)
$\phi_{F1,D1}$	Joint probability of moving from TCE/TCW toward RGU and surviving to RGU (Submodel II*)
$\phi_{F1,E1}$	Joint probability of moving from TCE/TCW toward CVP and surviving to CVP (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); = $\phi_{F1,GH}\psi_{G1(A)}$
$\phi_{G1,G2}$	Joint probability of moving from JPE/JPW toward Chipps Island (MAE/MAW), and surviving to MAE/MAW (equated between submodels)
λ	Joint probability of moving from Chipps Island (MAE/MAW) toward Benicia Bridge (BBR), surviving from MAE/MAW to BBR, and detection at BBR; = $\phi_{G2,G3}P_{G3}$
ψ_{A1}	Probability of remaining in the San Joaquin River at the head of Old River; = $1 - \psi_{B1}$
ψ_{A2}	Probability of remaining in the San Joaquin River at the junction with Burns Cutoff; = $1 - \psi_{R2}$
ψ_{A3}	Probability of remaining in the San Joaquin River at the junction with Turner Cut; = $1 - \psi_{F3}$
ψ_{B1}	Probability of entering Old River at the head of Old River; = $1 - \psi_{A1}$
ψ_{B2}	Probability of remaining in Old River at the head of Middle River; = $1 - \psi_{C2}$
ψ_{C2}	Probability of entering Middle River at the head of Middle River; = $1 - \psi_{B2}$
ψ_{R2}	Probability of entering Burns Cutoff at the junction with the San Joaquin River; = $1 - \psi_{A2}$
ψ_{F3}	Probability of entering Turner Cut at the junction with the San Joaquin River; = $1 - \psi_{A3}$
ψ_{G1}	Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction (equated between submodels); = $1 - \psi_{H1}$
ψ_{H1}	Probability of entering False River at the Jersey Point/False River junction (equated between submodels); = $1 - \psi_{G1}$
P_{A0a}	Conditional probability of detection at DFU1

Table A1. (Continued)

Parameter	Definition
P_{A0b}	Conditional probability of detection at DFU2
P_{A0}	Conditional probability of detection at DFU (either DFU1 or 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_{A7a}	Conditional probability of detection at SJNBU
P_{A7b}	Conditional probability of detection at SJNBD
P_{A7}	Conditional probability of detection at SJNB (either SJNBU or SJNBD)
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_{A9}	Conditional probability of detection at MFE/MFW (either MFE or MFW)
P_{B1a}	Conditional probability of detection at OREU
P_{B1b}	Conditional probability of detection at ORED
P_{B1}	Conditional probability of detection at ORE (either OREU or ORED)
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 WCLU
P_{B3b}	Conditional probability of detection at WCLD
P_{B3}	Conditional probability of detection are WCL (either WCLU or WCLD)
P_{B4a}	Conditional probability of detection at OR4U
P_{B4b}	Conditional probability of detection at OR4D
P_{B4}	Conditional probability of detection are OR4 (either OR4U or 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 (either MRHU or MRHD)
P_{C2a}	Conditional probability of detection at MR4U
P_{C2b}	Conditional probability of detection at MR4D
P_{C2}	Conditional probability of detection at MR4 (either MR4U or 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

Table A1. (Continued)

Parameter	Definition
P_{E2}	Conditional probability of detection at CVPtank
P_{F1a}	Conditional probability of detection at TCE
P_{F1b}	Conditional probability of detection at TCW
P_{F1}	Conditional probability of detection at TCE/TCW (either TCE or 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 (either JPE or 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 (either MAE or 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 (either FRE or FRW)
P_{R1a}	Conditional probability of detection at RRIU
P_{R1b}	Conditional probability of detection at RRID
P_{R1}	Conditional probability of detection at RRI (either RRIU or RRID)

Table A2. Parameter estimates (standard errors or 95% bound [UB = upper bound, LB = lower bound] in parentheses) for tagged juvenile Steelhead released in 2014, 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 from releases 2 and 3. Some parameters were not estimable because of sparse data. * = Parameter estimates for group 1 represent joint fish-tag survival.

	Release Group			
Parameter	1*	2	3	Population Estimate (2, 3)
S_{A2}	0.55 (0.03)	0.90 (0.02)	0.58 (0.03)	0.74 (0.02)
S_{A3}	0.91 (0.02)	0.91 (0.02)	0.72 (0.04)	0.82 (0.02)
S_{A4}	0.89 (0.03)	0.97 (0.01)	0.77 (0.04)	0.87 (0.02)
S_{A5}		0.90 (0.02)	0.35 (0.05)	0.62 (0.03)
$S_{A5,G2}$	0 (95% UB: 0.21)	0.45 (0.03)	0.08 (0.03)	0.26 (0.02)
S_{A6}		0.96 (0.01)	0.89 (0.06)	0.93 (0.03)
$S_{A6,G2}$		0.50 (0.03)	0.22 (0.08)	0.36 (0.04)
S_{A7}		0.93 (0.02)	0.64 (0.10)	0.78 (0.05)
$S_{A7,G2}$		0.52 (0.03)	0.24 (0.09)	0.38 (0.05)
$S_{A8,G2}$		0.74 (0.03)	0.43 (0.13)	0.59 (0.07)
$S_{A9,G2}$		0.83 (0.03)	0.50 (0.14)	0.67 (0.07)
S_{B1}	0.96 (0.02)	1 (95% LB: 0.81)		
$S_{B1,G2}$	0.22 (0.04)	0.32 (0.09)	0.09 (0.09)	0.21 (0.06)
$S_{B2,G2}$	0.24 (0.04)	0.35 (0.10)	0.20 (0.18)	0.27 (0.10)
$S_{B2(SD)}$	0.68 (0.04)	0.85 (0.10)		
$S_{C1,G2}$	0			
$S_{C1(SD)}$	0			
$S_{F1,G2}$		0.17 (0.04)		
S_{R1}		0.87 (0.07)		
$\phi_{A1,A0}$	0.11 (0.01)	0.04 (0.01)	0.23 (0.02)	0.14 (0.01)
$\phi_{A1,A2}$	0.66 (0.02)	0.90 (0.02)	0.60 (0.02)	0.75 (0.01)
$\phi_{A1,A3}$	0.36 (0.02)	0.81 (0.02)	0.35 (0.02)	0.58 (0.01)
$\phi_{A1,A4}$	0.32 (0.02)	0.74 (0.02)	0.25 (0.02)	0.49 (0.01)
$\phi_{A8,A9}$		0.81 (0.03)	0.86 (0.09)	0.83 (0.05)
$\phi_{A8,B4}$		0		
$\phi_{A8,C2}$		0.02 (0.01)		
$\phi_{A8,D1O}$		0.00 (<0.01)		
$\phi_{A8,D1C}$		0.00 (<0.01)		
$\phi_{A8,D1}$		0.00 (<0.01)		
$\phi_{A8,E1}$		0.01 (0.01)		
$\phi_{A8,GH}$				
$\phi_{A8,G1}$		0.07 (0.02)	0	0.03 (0.01)
$\phi_{A9,B4}$		0.02 (0.01)		
$\phi_{A9,C2}$		0		
$\phi_{A9,D1O}$		0		
$\phi_{A9,D1C}$		0		
$\phi_{A9,D1}$		0		

Table A2. (Continued)

Parameter	Release Group 1*	2	3	Population Estimate (2, 3)
$\phi_{A9,E1}$		0.01 (0.01)		
$\phi_{A9,GH}$				
$\phi_{A9,G1}$		0.88 (0.03)	0.63 (0.16)	0.75 (0.08)
$\phi_{B1,B2}$	0.92 (0.02)	0.93 (0.07)	0.45 (0.15)	0.69 (0.08)
$\phi_{B2,B3}$	0.04 (0.02)			
$\phi_{B2,B4}$	0.02 (0.01)	0		
$\phi_{B2,C2}$	0.01 (0.01)	0		
$\phi_{B2,D1O}$	0.03 (0.01)	0.08 (0.05)		
$\phi_{B2,D1C}$	0.03 (0.01)	0.08 (0.05)		
$\phi_{B2,D1}$	0.05 (0.02)	0.15 (0.10)		
$\phi_{B2,E1}$	0.60 (0.05)	0.69 (0.13)		
$\phi_{B3,B4}$	0.40 (0.22)			
$\phi_{B4,D1O}$		0		
$\phi_{B4,D1C}$		0		
$\phi_{B4,D1}$		0		
$\phi_{B4,E1}$		0.53 (0.13)		
$\phi_{B4,GH}$				
$\phi_{B4,G1}$		0.27 (0.11)		
$\phi_{C1,B3}$	0			
$\phi_{C1,B4}$	0			
$\phi_{C1,C2}$	0			
$\phi_{C1,D1O}$	0			
$\phi_{C1,D1C}$	0			
$\phi_{C1,D1}$	0			
$\phi_{C1,E1}$	0			
$\phi_{C2,D1O}$		0.05 (0.04)		
$\phi_{C2,D1C}$		0.05 (0.04)		
$\phi_{C2,D1}$		0.09 (0.09)		
$\phi_{C2,E1}$		0.45 (0.15)		
$\phi_{C2,GH}$				
$\phi_{C2,G1}$		0		
$\phi_{D1O,D2}$	1			
$\phi_{D1C,D2}$	1			
$\phi_{D1,D2}$	1 (95% LB: 0.61)			
$\phi_{D1O,G2}$	0.34 (0.20)	0		
$\phi_{D1C,G2}$	0.34 (0.20)	0		
$\phi_{D1,G2}$	0.34 (0.20)	0 (95% UB: 0.79)		
$\phi_{D2,G2}$	0.34 (0.20)			
$\phi_{E1,E2}$	0.51 (0.06)	0.50 (0.11)		
$\phi_{E2,G2}$	0.72 (0.08)	1 (95% LB: 0.53)		
$\phi_{F1,B4}$		0.15 (0.04)		

Table A2. (Continued)

Parameter	Release Group 1*	2	3	Population Estimate (2, 3)
$\phi_{F1,C2}$		0.10 (0.03)		
$\phi_{F1,D1O}$		0.00 (<0.01)		
$\phi_{F1,D1C}$		0.00 (<0.01)		
$\phi_{F1,D1}$		0.01 (0.01)		
$\phi_{F1,E1}$		0.12 (0.03)		
$\phi_{F1,GH}$				
$\phi_{F1,G1}$		0.09 (0.03)		
$\phi_{G1,G2}$		0.93 (0.02)		
λ	0.73 (0.09)	0.98 (0.01)	1	0.99 (0.01)
ψ_{A1}	0.09 (0.02)	0.96 (0.01)	0.88 (0.03)	0.92 (0.02)
ψ_{A2}		0.92 (0.02)	0.92 (0.06)	0.92 (0.03)
ψ_{A3}		0.69 (0.03)	0.87 (0.08)	0.78 (0.04)
ψ_{B1}	0.91 (0.02)	0.04 (0.01)	0.12 (0.03)	0.08 (0.02)
ψ_{B2}	0.96 (0.02)	0.93 (0.07)		
ψ_{C2}	0.04 (0.02)	0.07 (0.07)		
ψ_{R2}		0.08 (0.02)	0.08 (0.06)	0.08 (0.03)
ψ_{F3}		0.31 (0.03)	0.13 (0.08)	0.22 (0.04)
ψ_{G1}				
ψ_{H1}				
P_{A0a}	0.94 (0.03)	0.85 (0.10)	0.99 (0.01)	0.92 (0.05)
P_{A0b}	0.98 (0.02)	0.69 (0.12)	0.95 (0.02)	0.82 (0.06)
P_{A0}	1.00 (<0.01)	0.95 (0.04)	1.00 (<0.01)	0.98 (0.02)
P_{A2a}				
P_{A2b}				
P_{A2}	1	0.85 (0.02)	0.99 (0.01)	0.92 (0.01)
P_{A3}	1	0.71 (0.02)	1	0.86 (0.01)
P_{A4}	1	1	0.99 (0.01)	0.99 (0.01)
P_{A5}	1	1	1	1
P_{A6}		1.00 (<0.01)	1	1.00 (<0.01)
P_{A7a}		0.99 (0.01)	1	1.00 (<0.01)
P_{A7a}		0.99 (0.01)	1	0.99 (<0.01)
P_{A7}		1.00 (<0.01)	1	1.00 (<0.01)
P_{A8a}			1	
P_{A8b}			1	
P_{A8}		1	1	1
P_{A9a}		1	1	1
P_{A9b}		1	0.92 (0.08)	0.96 (0.04)
P_{A9}		1	1	1
P_{B1a}	1	1	1	1
P_{B1b}	1	1	1	1
P_{B1}	1	1	1	1

Table A2. (Continued)

Parameter	Release Group 1*	2	3	Population Estimate (2, 3)
P_{B2a}	1	1	1	1
P_{B2b}	1	1	1	1
P_{B2}	1	1	1	1
P_{B3a}	1			
P_{B3b}	1			
P_{B3}	1			
P_{B4a}	1	1		
P_{B4b}	1	1		
P_{B4}	1	1		
P_{C1a}	1			
P_{C1b}	1			
P_{C1}	1	1		
P_{C2a}	1	1		
P_{C2b}	1	1		
P_{C2}	1	1		
P_{D1}	1	1		
P_{D2a}	1			
P_{D2b}	1			
P_{D2}	1			
P_{E1}	1	1		
P_{E2}	0.96 (0.04)	1		
P_{F1a}		1	1	1
P_{F1b}		0.98 (0.02)	1	0.99 (0.01)
P_{F1}		1	1	1
P_{G1a}				
P_{G1b}				
P_{G2a}				
P_{G2b}				
P_{G2}	0.95 (0.05)	0.98 (0.01)	0.71 (0.17)	0.85 (0.09)
P_{H1a}				
P_{H1b}				
P_{H1}				
P_{R1a}		0.96 (0.04)	1	0.98 (0.02)
P_{R1b}		1	1	1
P_{R1}		1	1	1

Table A3. Parameter estimates (standard errors or 95% bound [UB = upper bound, LB = lower bound] in parentheses) for tagged juvenile Steelhead released in 2014, 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 from releases 2 and 3. Some parameters were not estimable because of sparse data. * = Parameter estimates for group 1 represent joint fish-tag survival.

	Release Group			
Parameter	1*	2	3	Population Estimate (2, 3)
S_{A2}	0.54 (0.03)	0.89 (0.02)	0.58 (0.03)	0.74 (0.02)
S_{A3}	0.91 (0.02)	0.90 (0.02)	0.73 (0.03)	0.82 (0.02)
S_{A4}	0.88 (0.03)	0.96 (0.01)	0.71 (0.04)	0.84 (0.02)
S_{A5}		0.94 (0.01)	0.41 (0.06)	0.68 (0.03)
$S_{A5,G2}$	0 (95% UB: 0.19)	0.48 (0.03)	0.08 (0.03)	0.29 (0.02)
S_{A6}		0.97 (0.01)	0.97 (0.03)	0.97 (0.02)
$S_{A6,G2}$		0.51 (0.03)	0.21 (0.08)	0.36 (0.04)
S_{A7}		0.93 (0.02)	0.62 (0.10)	0.77 (0.05)
$S_{A7,G2}$		0.53 (0.03)	0.21 (0.08)	0.37 (0.04)
$S_{A8,G2}$		0.75 (0.03)	0.40 (0.13)	0.57 (0.07)
$S_{A9,G2}$		0.83 (0.03)	0.46 (0.14)	0.65 (0.07)
S_{B1}	0.98 (0.01)	0.84 (0.08)		
$S_{B1,G2}$	0.22 (0.04)	0.24 (0.08)	0.08 (0.08)	0.16 (0.06)
$S_{B2,G2}$	0.24 (0.04)	0.30 (0.09)	0.12 (0.12)	0.21 (0.07)
$S_{B2(SD)}$	0.68 (0.04)	0.67 (0.12)		
$S_{C1,G2}$	0			
$S_{C1(SD)}$	0			
$S_{F1,G2}$		0.17 (0.04)		
S_{R1}		0.95 (0.05)		
$\phi_{A1,A0}$	0.11 (0.01)	0.05 (0.01)	0.23 (0.02)	0.14 (0.01)
$\phi_{A1,A2}$	0.66 (0.02)	0.89 (0.02)	0.60 (0.02)	0.75 (0.01)
$\phi_{A1,A3}$	0.35 (0.02)	0.80 (0.02)	0.35 (0.02)	0.57 (0.01)
$\phi_{A1,A4}$	0.32 (0.02)	0.72 (0.02)	0.25 (0.02)	0.49 (0.01)
$\phi_{A8,A9}$		0.81 (0.03)	0.87 (0.09)	0.84 (0.05)
$\phi_{A8,B4}$		0		
$\phi_{A8,C2}$		0.02 (0.01)		
$\phi_{A8,D1O}$		0.00 (<0.01)		
$\phi_{A8,D1C}$		0.00 (<0.01)		
$\phi_{A8,D1}$		0.00 (<0.01)		
$\phi_{A8,E1}$		0.01 (<0.01)		
$\phi_{A8,GH}$				
$\phi_{A8,G1}$		0.07 (0.02)	0	0.04 (0.01)
$\phi_{A9,B4}$		0.02 (0.01)		
$\phi_{A9,C2}$		0		
$\phi_{A9,D1O}$		0		
$\phi_{A9,D1C}$		0		
$\phi_{A9,D1}$		0		

Table A3. (Continued)

Parameter	Release Group 1*	2	3	Population Estimate (2, 3)
$\phi_{A9,E1}$		0.01 (0.01)		
$\phi_{A9,GH}$				
$\phi_{A9,G1}$		0.88 (0.03)	0.69 (0.17)	0.78 (0.09)
$\phi_{B1,B2}$	0.94 (0.02)	0.79 (0.09)	0.67 (0.14)	0.73 (0.08)
$\phi_{B2,B3}$	0.04 (0.02)			
$\phi_{B2,B4}$	0.02 (0.01)	0		
$\phi_{B2,C2}$	0.01 (0.01)	0		
$\phi_{B2,D1O}$	0.03 (0.01)	0.03 (0.03)		
$\phi_{B2,D1C}$	0.03 (0.01)	0.03 (0.03)		
$\phi_{B2,D1}$	0.05 (0.02)	0.07 (0.06)		
$\phi_{B2,E1}$	0.60 (0.05)	0.60 (0.13)		
$\phi_{B3,B4}$	0.40 (0.22)			
$\phi_{B4,D1O}$		0		
$\phi_{B4,D1C}$		0		
$\phi_{B4,D1}$		0		
$\phi_{B4,E1}$		0.53 (0.13)		
$\phi_{B4,GH}$				
$\phi_{B4,G1}$		0.27 (0.11)		
$\phi_{C1,B3}$	0			
$\phi_{C1,B4}$	0			
$\phi_{C1,C2}$	0			
$\phi_{C1,D1O}$	0			
$\phi_{C1,D1C}$	0			
$\phi_{C1,D1}$	0			
$\phi_{C1,E1}$	0			
$\phi_{C2,D1O}$		0.04 (0.04)		
$\phi_{C2,D1C}$		0.04 (0.04)		
$\phi_{C2,D1}$		0.08 (0.08)		
$\phi_{C2,E1}$		0.42 (0.14)		
$\phi_{C2,GH}$				
$\phi_{C2,G1}$		0		
$\phi_{D1O,D2}$	1			
$\phi_{D1C,D2}$	1			
$\phi_{D1,D2}$	1 (95% LB: 0.61)			
$\phi_{D1O,G2}$	0.34 (0.20)	0		
$\phi_{D1C,G2}$	0.34 (0.20)	0		
$\phi_{D1,G2}$	0.34 (0.20)	0 (95% UB: 0.97)		
$\phi_{D2,G2}$	0.34 (0.20)			
$\phi_{E1,E2}$	0.53 (0.06)	0.50 (0.11)		
$\phi_{E2,G2}$	0.70 (0.08)	1 (95% LB: 0.53)		
$\phi_{F1,B4}$		0.15 (0.04)		

Table A3. (Continued)

Parameter	Release Group 1*	2	3	Population Estimate (2, 3)
$\phi_{F1,C2}$		0.11 (0.03)		
$\phi_{F1,D1O}$		0.00 (<0.01)		
$\phi_{F1,D1C}$		0.00 (<0.01)		
$\phi_{F1,D1}$		0.01 (0.01)		
$\phi_{F1,E1}$		0.12 (0.03)		
$\phi_{F1,GH}$				
$\phi_{F1,G1}$		0.09 (0.03)		
$\phi_{G1,G2}$		0.94 (0.02)		
λ	0.73 (0.09)	0.98 (0.01)	1	0.99 (0.01)
ψ_{A1}	0.10 (0.03)	0.94 (0.01)	0.86 (0.04)	0.90 (0.02)
ψ_{A2}		0.93 (0.02)	0.93 (0.05)	0.93 (0.03)
ψ_{A3}		0.69 (0.03)	0.83 (0.09)	0.76 (0.05)
ψ_{B1}	0.90 (0.03)	0.06 (0.01)	0.14 (0.04)	0.10 (0.02)
ψ_{B2}	0.97 (0.02)	0.94 (0.06)		
ψ_{C2}	0.03 (0.02)	0.06 (0.06)		
ψ_{R2}		0.07 (0.02)	0.07 (0.05)	0.07 (0.03)
ψ_{F3}		0.31 (0.03)	0.17 (0.09)	0.24 (0.05)
ψ_{G1}				
ψ_{H1}				
P_{A0a}	0.94 (0.03)	0.88 (0.08)	0.99 (0.01)	0.94 (0.04)
P_{A0b}	0.98 (0.02)	0.75 (0.10)	0.95 (0.02)	0.85 (0.05)
P_{A0}	1.00 (<0.01)	0.97 (0.02)	1.00 (<0.01)	0.99 (0.01)
P_{A2a}				
P_{A2b}				
P_{A2}	1	0.85 (0.02)	0.99 (0.01)	0.92 (0.01)
P_{A3}	1	0.71 (0.02)	1	0.86 (0.01)
P_{A4}	1	1	0.99 (0.01)	0.99 (0.01)
P_{A5}	1	1	1	1
P_{A6}		0.99 (0.00)	1	1.00 (<0.01)
P_{A7a}		0.99 (0.01)	1	0.99 (<0.01)
P_{A7a}		0.99 (0.01)	0.96 (0.04)	0.98 (0.02)
P_{A7}		1.00 (<0.01)	1	1.00 (<0.01)
P_{A8a}			1	
P_{A8b}			1	
P_{A8}		1	1	1
P_{A9a}		0.99 (0.01)	1	1.00 (<0.01)
P_{A9b}		1	0.92 (0.07)	0.96 (0.04)
P_{A9}		1	1	1
P_{B1a}	1	1	1	1
P_{B1b}	1	1	1	1
P_{B1}	1	1	1	1

Table A3. (Continued)

Parameter	Release Group 1*	2	3	Population Estimate (2, 3)
P_{B2a}	0.99 (0.01)	1	1	1
P_{B2b}	1	1	1	1
P_{B2}	1	1	1	1
P_{B3a}	1			
P_{B3b}	1			
P_{B3}	1			
P_{B4a}	1	1		
P_{B4b}	1	1		
P_{B4}	1	1		
P_{C1a}	1			
P_{C1b}	1			
P_{C1}	1	1		
P_{C2a}	1	1		
P_{C2b}	1	1		
P_{C2}	1	1		
P_{D1}	1	1		
P_{D2a}	1			
P_{D2b}	1			
P_{D2}	1			
P_{E1}	1	1		
P_{E2}	0.96 (0.04)	1		
P_{F1a}		0.99 (0.01)	1	0.99 (0.01)
P_{F1b}		0.98 (0.02)	1	0.99 (0.01)
P_{F1}		1.00 (<0.01)	1	1.00 (<0.01)
P_{G1a}				
P_{G1b}				
P_{G2a}		0.92 (0.02)	0.67 (0.19)	0.79 (0.10)
P_{G2b}				
P_{G2}				
P_{H1a}	0.95 (0.05)	0.98 (0.01)	0.71 (0.17)	0.85 (0.09)
P_{H1b}				
P_{H1}				
P_{R1a}				
P_{R1b}		1	1	1
P_{R1}		1	1	1