2013 South Delta Chinook Salmon Survival Study

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Introduction

Juvenile salmon mortality through the Delta is hypothesized to be related to changes in hydrology (i.e. reverse flows, San Joaquin River inflow and export volume) and other factors such as water temperature. In 2013, the main objective of the Chinook Salmon survival study was to estimate survival through the Delta and compare it to water temperature, river flow, and combined Central Valley Project (CVP) and State Water Project (SWP) exports during the time periods when the two releases of acoustic tag fish were migrating through the Delta (early and mid-May). There was no head of Old River barrier (HORB) installed in 2013 and we compared results in 2013 to those obtained in 2012 when there was a physical HORB installed (Buchanan et al 2015). Funding for this study was provided by the restoration fund of the Central Valley Project Improvement Act, the California Department of Water Resources (CDWR) and the U.S. Bureau of Reclamation (USBR).

The 2013 salmon study estimated route selection at some channel junctions in the south Delta along the mainstem San Joaquin River and provided information on how route selection influences overall survival through the Delta to Chipps Island. Recent advances in acoustic technology have allowed investigators to evaluate the influence of route selection and reach-specific survival of salmon to overall survival through the Sacramento-San Joaquin Delta (Perry et al. 2010). In this study, the hypothesis focused on how management actions, such as flow changes and the lack of a HORB, affected juvenile salmon survival in 2013: however we are aware that many other factors also influence survival through the Delta.

Background

Salmon survival studies occurred historically in the San Joaquin River and south Delta as part of the Vernalis Adaptive Management Program (VAMP) and South Delta Temporary Barriers Program. The VAMP program was developed after observing a positive relationship between spring flow and adult escapement 2.5 years later, and a similar relationship between the ratio of flow relative to exports (I/E) and adult escapement 2.5 years later. These escapement relationships resulted in a conceptual model that assumed that conditions during smolt outmigration significantly influence adult escapement. In addition, previous salmon survival studies using coded wire tags (CWT) suggested survival through the Delta was generally higher if the salmon migrated down the San Joaquin River at the head of Old River; thus a physical HORB has been used in many years to block flow and fish movement into Old River, when flow conditions allowed installation of the barrier. During the VAMP, CWT (2000-2006) and acoustic tagged fish (2006-2011) were released to try to isolate the roles of flows and combined Central Valley Project and State Water Project exports, with the HORB installed, on San Joaquin River fall run Chinook Salmon survival through the Delta (SJRGA 2013).

Transitioning into using acoustic technology to estimate survival through the Delta has been logistically difficult and expensive. For instance in 2007 and 2009, survival could not be measured to Jersey Point and Chipps Island because of the challenge of installing acoustic arrays in such large bodied river sites. In 2008, with the assistance of USGS, installation of the Jersey Point and Chipps Island downstream arrays did occur, but tags had premature battery failure and thus estimates were potentially biased (SJRGA 2009; Holbrook et al 2009, Holbrook et al 2013). Finally in 2010, we were able to estimate survival to Chipps Island, but not to Jersey Point due to funding constraints (SJRGA 2011). In both 2011 and 2012, we were successful at measuring survival through the south Delta to Jersey Point and Chipps Island (SJRGA 2013; Buchanan et al 2015). In 2013, the acoustic array was also in place throughout the Delta, including Jersey Point and Chipps Island, designed to provide unbiased estimates of survival to both Jersey Point and Chipps Island for a third consecutive year. The costs of acoustic tag studies have been significantly greater than the historical CWT studies, due to the higher tag costs and nature of detection of acoustic tags (i.e. multitude of receivers deployed through-out the Delta). However, the acoustic telemetry studies have also provided considerably more detailed information than the CWT studies, in particular spatially-detailed survival and travel time estimates; additionally, fewer fish are required for acoustic tag studies than for CWT studies.

The results of the CWT VAMP studies indicated a relationship between salmon survival and flow with the HORB in place. However, in 2003 and 2004, salmon survival decreased substantially from that in 2002, at the same flows and exports and with the HORB installed (SJRGA 2013). In addition, the VAMP peer review panel in 2010 noted that for any one level of flow (high, medium, low, very low), survival appeared to be decreasing over time (Dauble et al. 2010). The VAMP program ended in 2011.

In 2012, two acoustic tag salmon releases were made to assess a Merced River flow augmentation on survival through the Delta. The first tagged fish release was made in early May and the second was in mid-May to estimate salmon survival both during and after a Merced pulse flow which occurred between April 15 and May 15 (Buchanan et al 2015). The six-year steelhead survival study also released fish near Durham Ferry in 2011 and 2012 and is to be used to assess, in part, whether juvenile salmon are adequate surrogates for assessing steelhead survival through the Delta.

Juvenile salmon survival estimates in the Delta from 2010 to 2013 represented very different environmental conditions. In 2010 a non-physical HORB was installed during the smolt outmigration period, and flows were medium (~6000 cfs). In 2011 flows were very high and no HORB was installed. In 2012 flows were low and there was a physical HORB installed with 8 culverts. In 2013, there was no HORB installed and flows were similar to those in 2012.

With historic estimates of survival through the Delta going back to 1994, these annual survival estimates provide some context for both smolt survival goals and smolt survival responses in the future. Reduction in the abundance of salmon populations from the San Joaquin basin is considered one of the causes of reduced population resiliency in Central Valley salmon populations. Restoration of San Joaquin Basin populations may have the greatest potential for strengthening the portfolio effect and population resilience of Central Valley salmon (Carlson and Satterthwaite, 2011).

Goals and Objectives

The goal of the study in 2013 was to determine if there were differences in survival resulting from changes in hydrology (i.e. increased flow) and to compare survival estimates through the Delta without the HORB (2013) to those with the HORB (2012) to determine if there was a potential reduction in survival in 2013 due to the lack of a HORB.

Objectives:

1. Determine survival of emigrating salmon smolts through the Delta from Mossdale to Jersey Point and Chipps Island during two time periods in 2013 (prior to May 15 and after May 15).
2. Determine if juvenile salmon survival was higher for the first release relative to the second release in 2013, when flows were higher.

3. Determine if travel time was shorter for the first release with the higher flows and could be an explanation for the higher survival with the higher flows.
4. Identify route selection at HOR and Turner Cut under the two periods with varied flows to determine its effect on survival to Chipps Island in 2013.
5. Assess the influence of flows and exports on route entrainment by tagged fish.
6. Compare survival in 2013, without the HORB, to that in 2012, with the HORB, to determine if there was a reduction in survival in 2013, as anticipated in the absence of the HORB.
7. Assess the influence of flow on survival between Mossdale and Jersey Point without the HORB installed (2013) and with the HORB installed (2012).
8. Assess the role and influence of flow and exports on survival in downstream reaches (e.g. between Jersey Point and Chipps Island, or between Turner Cut and Chipps Island).

Conceptual Model

Our hypothesis in 2013 was that survival through the Delta would be lower for the second release group in 2013 because of lower flows and higher water temperatures. Why survival is higher at higher flows and lower water temperatures is uncertain but may be a result of a combination of mechanisms. Higher flows are usually associated with cooler water temperatures (K. Gleichauf, personal communication), and cooler water temperatures are also associated with higher dissolved oxygen levels , lower incidence of disease, lower predation pressure from reduced metabolic rates of predators, less suitable habitat for the production of warm water predators, and a lower production of submerged aquatic vegetation (SAV). Higher flows are also associated with higher turbidity, which would affect a visual predator's success rate, and the higher flows would serve to dilute any toxics that potentially may be harmful to salmon (e.g. ammonia from Stockton WTP). In addition, higher flows would result in higher water velocities that potentially would move fish faster through the reaches of the Delta, making them exposed to mortality factors for a shorter time period.

In addition, we hypothesized that survival through the Delta in 2013 would be less than that observed in 2012 at similar flows because there was no HORB installed at the head of Old River (HOR) in 2013. We hypothesized that without the HORB, survival would be reduced because less of the flow stays in the mainstem San Joaquin River downstream of the Old River junction and results in the tidal prism moving further upstream. The upstream shift in the tidal prism's position would decrease the portion of the Delta that is riverine and the portion of the migration pathway that potentially responds to increases in flow with decreases in travel time.   Additionally, the shifted position of the tidal prism further upstream could also potentially increase the proportion of flow and tagged fish that enter Turner Cut (TCE/TCW = F1, Figure 1) where survival has been shown to be extremely low (0.00; Buchanan et al 2015). Lastly, the reduced San Joaquin River flows downstream of the HOR, when there is no HORB, could result in poorer water quality (e.g. dissolved oxygen) near Stockton due to the reduced dilution of discharge from the Stockton Wastewater Treatment Plant (SWTP). In summary, overall survival through the Delta was expected to decrease in 2013 relative to 2012 because survival was anticipated to decrease in the mainstem San Joaquin River because the riverine component of the Delta decreased. The reduction in the riverine component of the Delta was anticipated to increase travel time through the entire Delta and result in lower through-Delta survival. Survival was also predicted to be lower in 2013 because 1) the proportion of water and fish that were diverted into Turner Cut was expected to increase because the tidal prism shifted upstream due to the lower San Joaquin River flows in 2013 downstream of the HOR, and 2) because the reduction in flows in San Joaquin River downstream of the HOR potentially reduced water quality (i.e. dissolved oxygen) from the SWTP discharge.

Study Design and Methods

Sample Size Analyses

In 2013, we used information derived from the 2011 VAMP sample size analyses to guide release numbers for the studies (SJRGA 2013). For a single release at Durham Ferry it was determined that a sample size of 475 fish would allow estimation of parameters for low route specific survival (0.05), with high detection probability (90-97%) at Chipps Island. To estimate a relative difference of 100% (effect size), between two routes (San Joaquin and Old River), 790 fish would need to be tagged with low survival and 410 for medium survival (SJRGA 2013). To estimate a relative difference between the two routes of 50%, 3,510 would need to be released in years with low survival and 1,800 would need to be released in years with medium survival (SJRGA 2013). We did not have the resources to purchase enough tags to have the power to estimate the relative effects between routes at either of these levels for the two groups released in 2013.

Study Fish

Study fish in 2013 were obtained from the Merced River (MR) Hatchery. Fish were sorted such that they were greater than 13 grams (~105 mm fork length [FL]) prior to tagging. Tagged study fish averaged 18.2 grams (SD = 2.9) and 115.3 mm FL (SD = 5.9). Fish were taken off feed 24 hours prior to surgery.

Tags

Juvenile salmon were tagged with VEMCO V5 180 kHz transmitters that weighed 0.67 grams (g) in air on average (SD = 0.008). Tags were 12.7 millimeters (mm) long, 4.3 mm in height, and 5.6 mm wide (http://vemco.com/products/v4-v5-180khz/; accessed 6/15/15). The percentage of tag weight to body weight averaged 3.8% (SD = 0.6%) for the 950 fish tagged, well below the recommended 5%.

Tags were custom programmed with two separate codes; a traditional Pulse Position Modulation (PPM) style coding along with a new hybrid PPM/High Residence (HR) coding. The HR component of the coding allows for detection at high residence receivers. High residence receivers were placed in locations where tag signal collisions (i.e. many tags emitting signals at the same time to the same receiver) were anticipated (CVP, Clifton Court Forebay). The transmission of the PPM identification code was followed by a 25-35 second delay, followed by the PPM/HR code, followed by a 25-35 second delay, and then back to the PPM code, etc. The PPM code consisted of 8 pings approximately every 1.2 to 1.5 seconds. The PPM/HR code consisted of 1 PPM code and 8 HR codes (all the same for each individual fish) with 8 pings approximately every 1.2-1.5 seconds.

Tags were soaked in saline water for at least 24 hours prior to tag activation. Tags were activated using a VEMCO tag activator approximately 24 hours prior to tag implantation. Tag activation was identified to the nearest minute. A few tags were deactivated after activation and reactivated within a day or so later. This information was contained in the database and was considered when estimating tag life (see later section).

Tag in tag activator Photo Credit: Jake Osborne

Tagging training

Training for those who conducted the tagging occurred on April 22 and April 23 at MR Hatchery. Three hundred fish were used for training. Training was conducted by staff from USFWS and was modeled after training protocols and methods developed by the US Geological Survey's (USGS) Columbia River Research Lab (CRRL) and used for steelhead in 2013 and Chinook Salmon in past years. Returning surgeons (2) received a refresher course during which they were required to tag a minimum of 35 fish. New surgeons (2) received a more thorough training on surgical techniques and were required to tag a minimum of 75 fish during training. Training included sessions on knot tying, tagging bananas, tagging dead fish and finally tagging live fish, holding them overnight and necropsying them to evaluate techniques and provide feedback. Although four surgeons participated in the training, only three were used in the actual tagging for the study. The fourth surgeon was trained as a back-up, in case one was needed. Two returning surgeons and one new surgeon were used to tag the experimental fish. The back-up tagger was not needed during the study. Lastly, a mock tagging session was held on April 29 to practice logistic procedures and to identify potential problems and discuss solutions. Seventy-five fish were held for 6 days as part of the training. Unfortunately pictures were corrupted and data was lost.

Tagging

Tagging was conducted at the MR Hatchery. In past years (2009-2012), fish were transported from MR Hatchery and held at the Tracy Fish Collection Facility (TFCF); however, space was not available during the 2013 Salmon Survival Study. As a result, fish were tagged at MR Hatchery in 2013. In 2013, two groups of 480 Chinook Salmon were tagged with VEMCO V5 tags over two weekly periods: April 30 to May 3 and May 14 to May 17. Each group of salmon was tagged over 4 consecutive days. Each surgeon had an assistant and three additional individuals (runners) helped to move fish into and out of the tagging operation.

Tags were inserted into the fish body cavity after the fish had been anesthetized with between 6.0 and 6.5 milliliters (ml) of tricane methanesulfonate (MS-222) buffered with sodium bicarbonate, until they lost equilibrium. Fish were weighed (to the nearest 0.1 g) and measured to the nearest mm (FL). Surgeries took between 1 minute 45 seconds and 5 minutes 13 seconds, but most were within 2 to 3 minutes. Tagging was done using standard operating procedures (SOP) developed by the CRRL (Liedtke et al 2012) and refined during the training week. The SOP was similar to that used in 2012 (Buchanan et al 2015) and directed all aspects of the tagging operation and were modified as needed.

Tagging set-up and tagging process Photo credits: Ron Smith

Surgeon and tag assistant Photo credit: Ron Smith

Transmitter Validation

After the surgical implantation of tags, fish were placed into 19 liter (L) (5 gal) perforated buckets with high dissolved oxygen concentrations (110-130%) at a density of 1 or 2 fish per bucket, and allowed to recover from anesthesia for 10 minutes. During this time, tag codes were verified using a 180 kHz hydrophone connected to a VR100. Two VR100s were used to facilitate verification of multiple tags concurrently and to accelerate the validation process. Tags that did not verify using the VR100 were replaced with a new tag in a new fish. After validation, pairs of buckets containing one or two fish each were combined to create buckets of three fish each. A lid was placed on the bucket and then moved into the raceway to await loading to the transport truck once the tagging session was completed.

Transmitter verification with VR100 Photo Credit: Ron Smith

Transport to Release Site

After tagging, the 19L perforated buckets, which usually contained three tagged Chinook Salmon, were held in a raceway at the MR Hatchery until they were loaded into transport tanks at the end of each tagging day. Immediately prior to loading, all fish were visually inspected for mortality or signs of poor recovery from tagging (e.g. erratic swimming behavior). Fish that died or were not recovering from surgery were replaced with a new tagged fish.

In order to minimize the stress associated with moving fish and for tracking small groups of individually tagged fish, two specially designed transport tanks were used to move Chinook Salmon from the MR Hatchery, where the tagging occurred, to the release site at Durham Ferry. The transport tanks for Chinook Salmon were designed to securely hold a series of 19 L perforated buckets. The transport tanks had an internal frame that held 21 (transport tank 1) or 30 (transport tank 2) buckets in individual compartments to minimize contact between buckets and to prevent tipping. Water levels in the transport tanks were 3 to 4 inches below the top of the buckets, to allow the fish access to air for reestablishing neutral buoyancy after the handling associated with the tagging process (Liedtke et al 2012). Buckets were covered in the transport tanks with stretched cargo nets to assure buckets did not tip over and lids did not come off. Both transport tanks were mounted on the bed of a 26 foot flatbed truck that was equipped with an oxygen tank and hosing to deliver oxygen to each of the tanks during transport. One trip to the release site was made each tagging day.

Water temperature and dissolved oxygen (DO) in the transport tanks were recorded after loading buckets into transport tanks and before leaving the MR Hatchery and at the release site after transport. Water temperature was continuously monitored during transport, and water temperature and DO were both measured prior to unloading buckets. The water temperature and DO were also measured in the river at the holding/release site.

Flatbed truck used to transport tagged fish to release/holding location
Photo Credit: Pat Brandes

Transfer to Holding Containers

Once at the release site, the perforated buckets, which typically contained three Chinook Salmon each, were removed from the transport tanks and moved to the river using a pick-up truck. Non-perforated buckets (sleeves) were filled with river water, placed into the bed of a pick-up truck and driven up the levee, and parked next to the transport truck. Perforated buckets were then lifted out of the transport tank and handed to crew in the back of the pick-up and placed into the sleeves. Once the pick-up truck was filled with buckets, the pick-up truck was driven a short distance to the river's edge. Perforated buckets in sleeves were then unloaded from the pick-up truck and carried to the river's edge. Perforated buckets were separated from the sleeves at the shoreline and submerged in-river while being moved to the holding containers which were anchored one to two meters from shore. Multiple trips were made with the pick-up truck until all perforated buckets were unloaded from the transport tanks. Water temperature and DO were measured in the river prior to placing the salmon into the holding containers in the river.

Once at the river's edge, the tagged Chinook Salmon were transferred from the perforated buckets to the holding containers: 120 L (32 gal) perforated plastic garbage cans held in the river. These holding containers were perforated with hole sizes of 0.79 cm in diameter. Holding containers were new in 2013, and had hole sizes somewhat bigger than those in past Chinook studies where hole sizes in holding containers were 0.64 cm (Buchanan et al 2015). New Five buckets containing three fish each were emptied into each holding container. Each bucket and garbage can was labeled to track the specific tag codes and assure fish were transferred to the correct holding can for later release at the correct time. Tagged salmon were held in the perforated garbage cans for approximately 24 hours prior to release.

Transfer from pick-up truck to river's edge: Photo Credits: Ron Smith

Fish Releases

The Chinook Salmon, held in perforated garbage cans, were transported downstream by boat to the release location, which was in the middle of the channel downstream of the holding location. The fish were released downstream of the holding site to potentially reduce initial predation of tagged fish immediately after release, under the assumption that predators may congregate near the holding location. Releases were made every 6 hours after the 24 hour holding period, at approximately 1900, (the day after tagging), and 0100, 0700, and 1300 hours (2 days after tagging) (Table 1). Fish releases were made at these 6-hour increments throughout the 24-hour period to spread the fish out and to better represent naturally produced fish that may migrate downstream throughout the 24 hour period. A total of 950 juvenile Chinook Salmon tagged with VEMCO V5 acoustic tags were released into the San Joaquin River at Durham Ferry in early and mid-May of 2013: 477 on May 1 – 5, and 473 on May 15 – 19 Table 1.

Immediately prior to release, each holding container was checked for any dead or impaired fish. At the release time, the lid was removed and the holding container was rotated to look for mortalities. The container was then inverted to allow the fish to be released into the river. After the holding container was inverted, the time was recorded. As the holding containers were flipped back over, they were inspected to make sure that none of the released fish had swum back into the container. A Global Positioning System (GPS) reading was taken for each release which was then converted into a latitude and longitude point estimate.

Once the release was completed, the information on any dead fish was recorded and the tags removed. The tags were bagged and labeled and returned to the office for tag code identification.

Dummy-tagged fish

In order to evaluate the effects of tagging and transport on the survival of the tagged fish, several groups of Chinook Salmon were implanted with inactive ("dummy") transmitters. Dummy tags in 2013 were systematically interspersed into the tagging order for each release group. For each day of tagging and transport, 15 fish were implanted with dummy transmitters and included in the tagging process Table 1. Procedures for tagging these fish, transporting them to the release site, and holding them at the release site were the same as for fish with active transmitters. Dummy-tagged fish were evaluated for condition and mortality after being held at the release site for approximately 48 hours. After being held and mortality assessed, dummy tagged fish were euthanized and assessed qualitatively for percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration (Table 2). Dummy tagged fish were also evaluated for condition of incision, placement of sutures and whether organs had been stitched. In addition, one additional group of 30 dummy-tagged fish were held for approximately 48 hours and assessed for pathogens and other diseases (discussed below).

Fish Health Assessment

As a part of the 2013 South Delta Chinook Salmon Survival Study, the U.S. Fish and Wildlife Service's CA-NV Fish Health Center (CNFHC) conducted a general pathogen screening and smolt physiological assessment on some of the dummy-tagged fish held at the release site for 48 hours. The health and physiological condition of the study fish can help explain their survival during the studies. Pathogen screenings during past south Delta survival studies using MR Hatchery Chinook Salmon have regularly found infection with the myxozoan parasite *Tetracapsuloides bryosalmonae*, the causative agent of Proliferative Kidney Disease (PKD). This parasite has been shown to cause mortality in Chinook Salmon with increased mortality and faster disease progression in fish at higher water temperatures (Ferguson 1981; Foott et al. 2007). The objectives of this element of the project were to evaluate the juvenile Chinook Salmon used for the studies for specific fish pathogens including *Tetracapsuloides bryosalmonae* and assess smolt development from gill Na^+ - K^+- ATPase activity to determine potential differences in health between groups. For a complete description of methods see Appendix 1.

Tag life tests

One tag life test was conducted in conjunction with this study. The tag life study began on May 17 with 25 tags from each tag delivery, for a total of 50 tags. One of the tags from the second delivery would not activate and thus the tag life study included only 49 tags. Tags were activated and then put into mesh bags and held in three holding tanks at the TFCF containing ambient Delta water. A VEMCO VR2W receiver was installed in each tank for recording detections of each individual tag. Files of detections were reviewed to identify the date and time of tag failure for each individual tag used in the tag life study. These results were then compared to observed tag travel times of the tags used in the study to estimate their tag life and make any necessary corrections to fish survival estimates.

Receiver deployment, retrieval, and receiver database

The 2013 Chinook Salmon Survival Study, in conjunction with the 6-Year Steelhead Study, used receivers at 27 locations in the lower San Joaquin River and South Delta and as far west as Chipps Island (i.e. Mallard Slough) for detecting juvenile salmon and steelhead as they migrated through the Delta (Figure 1; Table 3). These receivers were placed at key locations throughout the south Delta and similar to those used in VAMP in 2010 and 2011 and for the South Delta Chinook Salmon Study in 2012 (Figure 1). Although locations of receivers are similar, the VAMP study used an HTI receiver array, whereas the 2012 and 2013 studies used a VEMCO receiver array. The USBR funded the USGS to deploy, maintain and remove all of the receivers in the array in 2013 as they had done in 2012. The spatial distribution of receivers was designed to provide spatially detailed data to estimate survival of juvenile salmon from Durham Ferry and Mossdale to Chipps Island. Detection data were also available from 30 acoustic tags implanted into several species of predatory fish released in the Delta in March – May 2013: 25 striped bass, 4 largemouth bass, and 1 channel catfish.

Data processing and survival model

This study used the tag detection data recorded on the receiver array to populate a release-recapture model similar to that used in the 2010 and 2011 VAMP studies and for the 2012 Chinook Salmon Survival Study (SJGRA 2011, 2013; Buchanan et al 2015). The release-recapture model used the pattern of detections among all tags to estimate the probabilities of route selection, survival, and transition in various reaches and detection probability at receivers. Parameter estimates were then combined to calculate estimates of reach-specific survival, route-specific survival, and total survival through the Delta to Chipps Island. The release-recapture model (described in more detail below) is a multi-state model based on the models of Cormack (1964), Jolly (1965), and Seber (1965), in combination with the route-specific survival model of Skalski et al. (2002). Tags that appeared to be in predators were identified, and the model was fit first to the complete data set that included all detections, including those from suspected predators, and then to the reduced data set that omitted detections that appeared to come from predators. This allowed comparison of estimates of survival and route selection probabilities with and without tags that appeared to come from predators in order to assess the potential bias associated with predator detections; this approach was similar to that used in the 2010 and 2011 VAMP studies and the 2012 Chinook Salmon Survival Study (SJRGA 2011, 2013; Buchanan et al 2015). More details on all statistical methods follow.

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 surgery for each tagged Chinook Salmon released in 2013, 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 any fish mortality that was observed after transport or just prior to release. Tag serial number and three unique tag 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 Chinook Salmon and released to the river. For these tags, a "virtual activation date" was computed that accounted for the entire time the tag was actively sending a signal 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 3) were transferred to the 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 transmissions 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 Chinook Salmon tags on the fixed site receivers. The tag serial number indicated the acoustic tag ID, and was 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. HR vs. hybrid PPM/HR). The cleaned detection event data were converted to detections denoting the beginning and end of receiver "visits," with consecutive visits to a receiver separated either by a gap of 12 hours or more between detections on the receiver, or by detection on a different receiver. Detections from receivers in dual or redundant arrays were pooled for this purpose, as were detections using different tag coding schemes.

The same data structure and data processing procedure was used to summarize detections of the acoustic-tagged predator fish. Detections of the predatory fish were compared to detections of the Chinook Salmon tags to assist in distinguishing between detections of salmon and detections of predators.

Distinguishing between Detections of Chinook Salmon 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 Chinook survival model depended on the assumption that all detections of the acoustic tags represented live juvenile Chinook Salmon, rather than a mix of live salmon and predators that temporarily had a salmon 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 Chinook Salmon through the Delta. The size and direction 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 salmon. 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 2013 data was based on the predator filter designed and used in the analyses of the 2011 and 2012 data (SJRGA 2013, Buchanan et al. 2015). Those predator filters in turn were 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 and the predator decision processes used in previous years (SJRGA 2010, 2011). The filter was applied to all detections of all tags. Two data sets were then constructed: the full data set including all detections, including those classified as coming from predators (i.e., "predator-type"), and the reduced data set, restricted to those detections classified as coming from live Chinook Salmon smolts (i.e., "smolt-type"). The survival model was fit to both data sets separately. The results from the analysis of the reduced "smolt-type" data set are presented as the final results of the 2013 Chinook Salmon tagging study. Results from analysis of the full data set including "predator-type" detections were used to indicate the degree of uncertainty in survival estimates arising from the predator decision process.

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

For each tag detection, several steps were performed to determine if it should be classified as predator or salmon. Initially, all detections were assumed to be of live smolts. A tag was classified as a predator upon the first exhibition of predator-type behavior, with the acknowledged uncertainty that the salmon smolt may actually have been eaten sometime before the first obvious predator-type detection. Once a detection was classified as coming from a predator, all subsequent detections of that tag were likewise classified as predator detections. The assignment of predator status to a detection was made conservatively, with doubtful detections classified as coming from live salmon. In general, the decision process was based on the assumptions that (1) salmon smolts were unlikely to move against the flow, and (2) salmon smolts were actively migrating and thus wanted to move downriver, although they may have temporarily moved upstream with reverse flow.

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

The predator filter used various criteria on several spatial and temporal scales, as described in detail in previous reports (e.g., SJRGA 2013, Buchanan et al. 2015). Criteria fit under various categories, described in more detail in SJRGA (2013): fish speed, residence time, upstream transitions, other unexpected transitions, travel time since release, and movements against flow. The criteria used in the 2011 and 2012 studies were updated to reflect river conditions and observed tag detection patterns in 2013 (Table 5). There were two new receiver sites installed in 2013 that were added to the predator filter: RRI (R1) = Rough and Ready Island, and SJS = San Joaquin River Shipping Channel at the junction with Turner Cut (A8) (Figure 1). One of the main differences between 2012 conditions and conditions during the 2013 study was the absence of the physical barrier blocking most access to the head of Old River, which was present in 2012. The absence of the barrier made some transitions acceptable for juvenile Chinook Salmon in 2013 even though they were assumed to indicate predation in 2012. Several new criteria were developed, 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. Unless otherwise specified, the maximum total visit length at a site was limited to 360 hours (approximately 15 days); upstream of the head of Old River, the maximum total visit length was equated to the maximum regional residence time allowed upon departure from the site in question. The 2013 filter differed from the 2012 filter in that upstream-directed transitions were limited to a maximum of 20 km: whereas it was 15 km in 2011 and 2012. The other criteria are specified below and in Table 5.

The criteria used in the predator filter were spatially explicit, and different limits were defined for different receivers and transitions (Table 5). General components of the approach to various regions are described below. Only regions with observed detections are described; rule components that follow the general guidelines described in SJRGA (2013) are not highlighted here.

DFU, DFD = Durham Ferry Upstream (A0) and Durham Ferry Downstream (A2): ignore flow and velocity measures, allow long travel time to accommodate initial disorientation after release, and allow few if any repeat visits; maximum total visit length = 15 (DFU) or 54 (DFD) hours.

BCA, MOS, and HOR = Banta Carbona (A3), Mossdale (A4), and Head of Old River (B0): allow longer residence time at B0 if next transition is directed downstream; may have lower travel times to B0 if low average water velocity. Allow limited transitions to B0 from the Lathrop receiver in the San Joaquin River (A5) and the Old River East receiver (B1). Maximum total visit length = 90 (BCA), 102 (MOS), and 104 (HOR) hours.

SJL = San Joaquin River near Lathrop (A5): allow longer between repeat visits if low average water velocity during transition; upstream transitions from Stockton sites are not allowed; limited transitions from Old River East (B1) were allowed. Maximum total visit length = 82 hours.

ORE = Old River East (B1): allow limited transitions from the San Joaquin River receiver near Lathrop (A5); no previous detections in lower San Joaquin River (near Stockton or farther downstream). Maximum total visit length = 163 hours.

SJG = San Joaquin River at Garwood Bridge (A6): transitions from upstream require arrival flow/velocity to be opposite direction from flow/velocity on previous departure. Maximum total visit length = 45 hours.

SJNB, RRI = San Joaquin River at Navy Bridge Drive (A7) and Rough and Ready Island (R1): allow longer residence time if arrive at slack tide; repeated visits require arriving with opposite flow and velocity conditions to departure conditions. Maximum total visit length = 45 hours.

SJS, MAC, MFE/MFW = San Joaquin River Shipping Channel (A8), MacDonald Island (A9), and Medford Island (A10): allow more flexibility (longer residence time, transition time) if transition water velocity was low. Repeated visits require arriving with opposite flow and velocity conditions to departure conditions. Maximum total visit length = 45 hours (SJS), 60 hours (MAC), or 360 hours (MFE/MFW).

ORS, OR4, MR4 = Old River South (B2), Old River near Highway 4 (B3), and Middle River near Highway 4 (C2): repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

CVP = Central Valley Project (E1): allow multiple visits; transitions from downstream Old River should not have departed Old River site or arrived at CVP against flow or if not pumping; no repeat visits if not pumping.

JPE/JPW, FRE/FRW = Jersey Point (G1), False River (H1): mean total visit length = 80 hours.

MAE/MAW = Chipps Island (G2): should not arrive against strong negative water velocity/flow. Maximum total visit length = 50 hours.

The predator scoring and classification method used for the 2011 and 2012 studies was used again for the 2013 study, resulting in tags being classified as in either a predator or a smolt upon arrival at and departure from a given receiver site and visit; for more details, see SJRGA (2013). All detections of a tag subsequent to its first predator designation were classified as coming from a predator, as well.

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. This is a small change from previous years, in which receivers located far downstream from the junction were given precedence over receivers near the junction in determining the "final route."[1] Detections from the receivers comprising certain dual arrays were pooled, thereby converting the dual arrays to redundant arrays: the San Joaquin River just downstream of the release site at Durham Ferry (DFD, site A2) and near Mossdale Bridge (MOS, site A4). For one release group, a better model fit was found by pooling detections from the dual array at the Old River East site (ORE, site B1). There were too few detections at the radial gates at the entrance to Clifton Court Forebay to model the effect of gate status (open or closed) on arrival and transition parameters there in 2013. Detections

[1] The 2010, 2011, and 2012 Chinook Salmon data (SJRGA 2011; SJRGA 2013; Buchanan et al. 2015) were assessed using the revised route assignment protocol. There was no change in the calculated detection histories for any of these years.

on receivers at the Head of Old River site (B0) and in the San Joaquin River Shipping Channel (A8) were used in determining the detection history, but were later omitted from the survival model.

Survival Model

A multi-state statistical release-recapture model was developed and used to estimate Chinook Salmon smolt survival and migration route parameters throughout the study area. The model is based on the multi-state release-recapture models used in previous Chinook Salmon tagging studies (SJRGA 2013, Buchanan et al. 2015). All sites used in previous Chinook Salmon tagging studies were monitored in the 2013 study, with the exception of the entrance to Paradise Cut, which was monitored in 2011 (SJRGA 2013); Paradise Cut was inaccessible to salmon migrating down the San Joaquin River in 2013 because of low flows. As in previous years, the San Joaquin River receivers just upstream of the head of Old River (HOR = B0) were omitted from the survival model, as were the northern-most Middle River receivers (MRE = C3), the Threemile Slough receivers (TMN/TMS = T1), and the new receivers in the San Joaquin River just upstream of Turner Cut (SJS = A8) and in Burns Cutoff around Rough and Ready Island near Stockton (RRI = R1). All sites with detections were used in the predator filter. The lack of detections at some sites made it necessary to omit certain sites from the model for analysis of the 2013 data: Turner Cut (TCE/TCW = model code F1), Jersey Point (JPE/JPW = G1), and False River (FRE/FRW = H1). Sparse detections at some detection sites further required modification of the model to either omit those sites from the model or treat the detections as known removals (i.e., right censor the detection histories at those sites). The necessary modifications depended on the release group. The full model using all sites that had detections, other than those listed above, is presented below, followed by model modifications necessary for each release group.

The full release-recapture model is a simplified version of the model used to analyze the 2012 Chinook Salmon data (Buchanan et al. 2015). It is composed of two submodels; the primary model (Submodel I) accounts for the large-scale movements and survival through the Delta, while the secondary model (Submodel II) focuses on movement and survival in the San Joaquin River downstream of Stockton. 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 3). The survival model represents movement and perceived survival throughout the study area to the primary exit point at Chipps Island (i.e., Mallard Island) (Figure 2, Figure 3). Individual receivers comprising dual arrays were identified separately, using “a” and “b” to represent the upstream and downstream receivers, respectively. Some sites were omitted from the full survival model, as described above, although all were used in the predator filter. The following description of fish movement routes through the Delta includes all routes monitored in 2013, although some were subsequently omitted from the model because no tags were detected in those routes.

Fish moving through the Delta toward Chipps Island may have used any of several routes. The two primary routes modeled were the San Joaquin River route (Route A) and the Old River route (Route B). Route A followed the San Joaquin River past the distributary point with Old River near the town of Lathrop, and past the city of Stockton. Downstream of Stockton, fish in the San Joaquin River route (Route A) may have remained in the San Joaquin River past its confluence with the Sacramento River and on to Chipps Island. Alternatively, fish in Route A may have exited the San Joaquin River for the interior Delta at any of several places downstream of Stockton, including Turner Cut, Columbia Cut (just upstream of Medford Island), and the confluence of the San Joaquin River with either Old River or Middle River, at Mandeville Island. Of these four exit points from the San Joaquin River between Stockton and Jersey Point, only Turner Cut was monitored and was assigned a route name (F, a subroute of route A). Fish that entered the interior Delta from any of these exit points may have either moved north through the interior Delta and reached Chipps Island by returning to the San Joaquin River and passing Jersey Point and the junction with False River, or they may have moved south through the interior Delta to the state or federal water export facilities, where they may have been salvaged and trucked to release points on the San Joaquin or Sacramento rivers just upstream of Chipps Island. All of these possibilities were included in both subroute F and route A. However, because no detections were observed on the Turner Cut receivers in 2013, subroute F was omitted from the full model for the analysis of the 2013 data.

For fish that entered Old River at its distributary point on the San Joaquin River just upstream of Lathrop (route B), there were several pathways available to Chipps Island. These fish may have migrated to Chipps Island either by moving northward in either the Old or Middle rivers through the interior Delta, or they may have moved to the state or federal water export facilities to be salvaged and trucked. The Middle River route (subroute C) was monitored and contained within Route B. Passage through the State Water Project via Clifton Court Forebay was monitored at the entrance to the forebay and assigned a route (subroute D). Likewise, passage through the federal Central Valley Project was monitored at the entrance trash racks 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). Receivers located in Threemile Slough (Route T) were not used in the survival model. The routes, subroutes, and study area exit points are summarized as follows:

A = San Joaquin River: survival
B = Old River: survival
C = Middle River: survival
D = State Water Project: survival
E = Central Valley Project: survival
F = Turner Cut: survival
G = Jersey Point, Chipps Island: survival, exit point

H = False River: exit point

T = Threemile Slough: not used in survival model

There were no detections at Turner Cut in 2013, and only one tag detected at either Jersey Point or False River, and so the routes and subroutes restricted to these detection sites were omitted from the model. Additionally, one of the receivers located just upstream of the release site at Durham Ferry (DFU1, model code A0a) was stolen between 6 May 2013, the date of the first data retrieval from that site from the 2013 6-year study, and 5 September 2013, the date of the final data retrieval (Buchanan 2015). There were no detections from the DFU1 receiver after 19 April 2013, which was approximately 2 weeks before the first Chinook Salmon release group. This meant that the A0 site could not be used in the survival model for either release group, because it was not possible to estimate the detection probability at that site. However, migrating Chinook Salmon smolts were not expected to be detected upstream of the release site, and so omission of the A0 site does not alter estimation or interpretation of the model parameters.

The release-recapture model used parameters that denote the probability of detection (P_{hi}), route entrainment (ψ_{hl}), Chinook Salmon survival (S_{hi}), and transition probabilities equivalent to the joint probability of movement and survival ($\phi_{kj,hi}$) (Figure 2, Figure 3, Table A3:1). For each dual array, unique detection probabilities were estimated for the individual receivers comprising the array: P_{hia} represented the detection probability of the upstream array at station i in route h, and P_{hib} represented the detection probability of the downstream array.

The model parameters are:

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

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

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

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

Too few Chinook Salmon tags were detected at the receivers outside the entrance to the Clifton Court Forebay (RGU = D1) in 2013 to attempt to estimate unique transition and detection probabilities involving site D1 for different conditions of the radial gates (open vs. closed).

Because of the complexity of the routing in the vicinity of MacDonald Island (referred to as “Channel Markers” in VAMP reports, e.g., SJRGA 2013) on the San Joaquin River and the sparse detection data at the receivers at MacDonald Island and Medford Island, the primary model (Submodel I) makes no attempt to estimate survival directly in reaches or routes in this area, but instead models the overall survival from the San Joaquin River receivers near Garwood Bridge in Stockton, (SJG = A6) to Chipps Island using the parameter $S_{A6,G2}$ (Figure 2). This parameter represents the probability of getting from Garwood Bridge to Chipps Island, regardless of route. The secondary model (Submodel II, Figure 3) decomposes the survival probability from Garwood Bridge to Chipps Island into reach-specific survival, using detections from Garwood Bridge and the receivers at Navy Bridge (SJNB = A7), MacDonald Island (MAC = A9), and Chipps Island (MAL = G2). Unlike the 2010, 2011, and 2012 studies (SJRGA 2011, 2013; Buchanan et al. 2015) in which route-specific survival was estimated from the Turner Cut junction to Chipps Island, no attempt is made to apportion survival by subroute within the San Joaquin River route in 2013, because no tags were detected entering Turner Cut.

The two submodels I and II were fit concurrently using unique detection probabilities at shared receivers: A6 (SJG) and G2 (MAL). Unique detection probabilities were used because detections from the same fish were used in the two submodels, and it was necessary to avoid “double-counting” the detections.

In addition to the model parameters, derived performance metrics measuring migration route probabilities and survival were estimated as functions of the model parameters. Both route entrainment 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 entrainment and route-specific survival probabilities were available for the major subroutes of route B; subroutes were not distinguishable for route A. Subroutes were identified by a two-letter code, where the first letter indicates routing used at the head of Old River (i.e., B), and the second letter indicates routing used at the head of Middle River: B or C. Thus, the route entrainment probabilities for the route B subroutes were:

$\psi_{BB} = \psi_{B1}\psi_{B2}$: 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 $\psi_{B1} = 1 \quad \psi_{A1}$ and $\psi_{C2} = 1 \quad \psi_{B2}$. Route entrainment probabilities were estimated on the large routing scale, as well, focusing on routing only at the head of Old River. The route entrainment 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 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:

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

$S_{BB} = S_{A4} S_{B1} S_{B2,G2}$: 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 parameter $S_{A6,G2}$ represents the probability of getting to Chipps Island (i.e., Mallard Island, site MAE/MAW) from site A6 (SJG). This parameter represents multiple pathways around or through the Delta to Chipps Island (Figure 1). Fish that were detected at the A6 receivers (Garwood Bridge) may have remained in the San Joaquin River all the way to Chipps Island, or they may have entered the interior Delta at Turner Cut or 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[2]. All such routes are represented in the $S_{A6,G2}$ parameter, which was estimated directly using Submodel I.

Survival probabilities $S_{B2,G2}$ and $S_{C1,G2}$ represent survival of fish to Chipps Island 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. Because there were many unmonitored river junctions within the "reach" between sites B2 or C1 and Chipps Island, it was impossible to separate the probability of taking a specific pathway from the probability of survival along that pathway. Thus, only the joint probability of movement and survival could be estimated to the next receivers along a route (i.e., the $\phi_{kj,hi}$ parameters defined above and in Figure 2). However, the overall survival probability from B2 ($S_{B2,G2}$) or C1 ($S_{C1,G2}$) to Chipps Island was defined by summing products of the $\phi_{kj,hi}$ parameters:

$$S_{B2,G2} = \phi_{B2,B3}\phi_{B3,G2} + \phi_{B2,C2}\phi_{C2,G2} + \phi_{B2,D1}\phi_{D1,D2}\phi_{D2,G2} + \phi_{B2,E1}\phi_{E1,E2}\phi_{E2,G2},$$

$$S_{C1,G2} = \phi_{C1,B3}\phi_{B3,G2} + \phi_{C1,C2}\phi_{C2,G2} + \phi_{C1,D1}\phi_{D1,D2}\phi_{D2,G2} + \phi_{C1,E1}\phi_{E1,E2}\phi_{E2,G2}.$$

[2] No tagged Chinook Salmon were observed moving from the San Joaquin River downstream of Stockton to the Interior Delta or water export facilities in 2013.

Fish in the Old River route that successfully bypassed the water export facilities and reached the receivers in Old River or Middle River near Highway 4 (sites B3 or C2, respectively) may have used any of several subsequent routes to reach Chipps Island. In particular, they may have remained in Old or Middle rivers until they rejoined the San Joaquin downstream of Medford Island, and then migrated in the San Joaquin, or they may have passed through Frank's Tract and False River or Fisherman's Cut to rejoin the San Joaquin River. These routes were all included in the transition probabilities $\phi_{B3,G2}$ and $\phi_{C2,G2}$, representing the probability of moving (and surviving) from site B3 or C2, respectively, to Chipps Island.

The overall probability of surviving through the Delta in the Old River route was defined using the subroute-specific survival probabilities and the probabilities of taking each subroute:

$S_B = \psi_{B2}S_{BB} + \psi_{C2}S_{BC}$: Delta survival (from Mossdale to Chipps Island) for fish that entered Old River at its head.

Using the estimated migration route probabilities and route-specific survival for the two primary routes (A and B), survival of the population from Mossdale (site A4) to Chipps Island was estimated as:

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

Unlike previous tagging studies (e.g., SJRGA 2013, Buchanan et al. 2015), it was not possible to estimate survival to the Jersey Point junction in 2013 because there were too few detections at either Jersey Point or False River. Survival was estimated through the southern portions of the Delta ("Southern Delta" or SD), both within each primary route and overall:

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

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

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

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

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

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 possible residualization upstream of Old River, although the Chinook Salmon in this study were assumed to be migrating (i.e., no residualization). In cases where the second detection site (A3 = BCA) was removed from analysis, the alternative model parameter $S_{A2,A4} = S_{A2} S_{A3}$ was used:

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

Individual detection histories (i.e., capture histories) were constructed for each tag as described above. Each detection history consisted of one or more fields representing initial release (field 1) and the sites where the tag was detected, in chronological order. Detection on both receivers in a dual array was denoted by the code “ab”, detection on only the upstream receiver was denoted “a0”, and detection on only the downstream receiver was denoted “b0”. For example, the detection history DF A2 A5b0 A7 G2ab represented a tag that was released at Durham Ferry and detected at one or both of the receivers just downstream of the release site (A2), the downstream receiver in the dual array near Lathrop, CA (A5b0), the single receiver in the San Joaquin River near the Navy Drive Bridge (A7), and both receivers at Chipps Island (G2ab). A tag with this detection history can be assumed to have passed by certain receivers without detection: A3, A4, A5a, A6a, A6b, A9a, and A9b. In Submodel I, the detections at A7 and A9 were not modeled, yielding Submodel I parameterization:

$$\phi_{A1,A2} P_{A2} S_{A2} \left(1 - P_{A3}\right) S_{A3} \left(1 - P_{A4}\right) S_{A4} \psi_{A1} \left(1 - P_{A5a}\right) P_{A5b} S_{A5} \left(1 - P_{A6a}\right)\left(1 - P_{A6b}\right) S_{A6,G2} P_{G2a} P_{G2b}.$$

In Submodel II, this detection history was parameterized starting at the virtual release at site A5 and included detections at A7 and G2:

$$S_{A5} \left(1 - P_{A6a}\right)\left(1 - P_{A6b}\right) S_{A6} P_{A7} S_{A7} \left(1 - P_{A9a}\right)\left(1 - P_{A9b}\right) S_{A9,G2} P_{G2a} P_{G2b}.$$

A second example is the detection history DF A3 A4 B1ab B2a0 D1ab. A fish with this detection history was released at Durham Ferry, passed the first receivers without detection, passed the receivers at Banta Carbona (A3) and Mossdale Bridge (A4) with detection, entered Old River and was detected on both receivers at the first Old River site (B1ab), the upstream receiver at the Old River South site (B2a0), and both receivers outside the entrance to Clifton Court Forebay (D1ab). The fish was not detected again after detection at the Clifton Court Forebay exterior receiver. It may have either died before entering the Forebay or returned to the river and died before reaching another detection site (e.g., Old River at Highway 4 [B3] or the Central Valley Project [E1]), or it may have arrived at other receivers but evaded detection. The possibility of returning to the river rather than entering the Forebay is accommodated by treating the parameter $\phi_{D1,D2}$ as a transition probability that includes the probability of moving toward site D2 along with survival between D1 and D2. This detection history is parameterized only in Submodel I:

$$\phi_{A1,A2} \left(1 - P_{A2}\right) S_{A2} P_{A3} S_{A3} P_{A4} S_{A4} \psi_{B1} P_{B1a} P_{B1b} S_{B1} \psi_{B2} P_{B2a} \left(1 - P_{B2b}\right) \phi_{B2,D1} P_{D1a} P_{D1b} \chi_{D1},$$

where

$$\chi_{D1} = 1 - \phi_{D1,D2} - \phi_{D1,\overline{D}2}\left(1 - P_{\overline{D}2}\right)\left(1 - \phi_{D2,G2}P_{G2}\right),$$

$$P_{D2} = 1 - \left(1 - P_{D2a}\right)\left(1 - P_{D2b}\right),$$

and

$$P_{G2} = 1 - \left(1 - P_{G2a}\right)\left(1 - P_{G2b}\right).$$

Under the assumptions of common survival, route entrainment, and detection probabilities, and independent detections among the tagged fish in each release group, the likelihood function for the survival model for each release group is a multinomial likelihood with individual cells denoting each possible capture history.

Model Modifications: Release Group 1

The first release group had only one tag detected at the Banta Carbona receiver, so that site (BCA = model code A3) was removed from the release-recapture model. Only two tags were detected at the MacDonald Island receivers (model code A9). This was very few detections to estimate survival probabilities from MacDonald Island to Chipps Island (G2), so detection histories were right-censored at A9 in Submodel II. This approach allowed estimation of the survival probabilities from Garwood Bridge (A6) to the Navy Bridge (A7) (S_{A6}) and from A7 to A9 (S_{A7}), and the detection probability at A7 in Submodel II; the detection probability at A9 was also estimated, using the dual array detections at that site. No attempt was made to estimate survival from A9 to G2. Instead, the survival probability from Garwood Bridge (A6) to Chipps Island was estimated directly in Submodel I ($S_{A6,G2}$), and the survival probability from the Navy Bridge (A7) to Chipps Island was estimated by $S_{A7,G2} = S_{A6,G2} / S_{A6}$.

From May 2 to May 4, 2013, when fish from the first release group were migrating, there was a concurrent salvage efficiency study underway at the Central Valley Project (Cathy Karp, USBR, personal communication). During this concurrent CVP study, additional holding tanks were used at the Central Valley Project for recovery of tagged fish from that study. These additional holding tanks were unmonitored for tagged fish from our study. Fish that were recaptured during the CVP study and determined to come from our study were either re-released to the VEMCO-monitored holding tank (i.e., the tank monitored for this study), or else were recovered and their tags removed and sent to the USFWS office. It was possible for the CVP study to capture acoustic-tagged fish from both the monitored holding tank and the unmonitored holding tanks. It was necessary to right-censor the detection histories of tags that were known to be removed from the migrating population at the CVP holding tanks (E2). Unlike the censoring used at site A9, the censoring at site E2 applied only to the fish known to have been removed there rather than to all fish detected there, and was not dependent on detection at that site because some of the removed fish were captured from an unmonitored tank. Tagged fish were removed (i.e., censored) upon arrival at site E2 with probability C_{E2}.

Model Modifications: Release Group 2

It was necessary to omit site A9 (MacDonald Island) from the survival model because there were no detections there; instead, the transition probability from Navy Bridge to Chipps Island ($\phi_{A7,G2}$) was estimated directly in Submodel II. In the Old River route, it was necessary to omit site C2 (Middle River near Highway 4) because only one tag was detected there, which was too few detections to estimate the detection probability at that site. Omitting site C2 prevented estimation of the transition probability from sites B2 (Old River South) and C1 (Middle River Head) to C2, and also prevented unbiased estimation of survival through the Southern Delta region of the Old River route ($S_{B(SD)}$) because of the missing estimates of $\phi_{B2,C2}$ and $\phi_{C1,C2}$. A minimum estimate of $S_{B(SD)}$ was estimated instead, using estimates of transition probabilities to the remaining sites: B3, D1, and E1.

There was only a single tag detected in the CVP holding tank (E2) from the second release group, and another single tag detected on the interior receivers at the Clifton Court Forebay (D2). These single tags were too few to estimate detection probabilities at these sites and transition probabilities to and from these sites. Thus, both D2 and E2 were omitted from Submodel I, and transition probabilities to Chipps Island were estimated from the CVP trash racks (E1) and the exterior receivers at the Clifton Court Forebay (D1), respectively.

Parameter Estimation

The multinomial likelihood model described above was fit numerically to the observed set of detection histories according to the principle of maximum likelihood using Program USER software, developed at the University of Washington (Lady et al. 2009). Point estimates and standard errors were computed for each parameter. Standard errors of derived performance measures were estimated using the delta method (Seber 2002: 7-9). Sparse data prevented some parameters from being freely estimated for some release groups. Transition, survival, and detection probabilities were fixed to 1.0 or 0.0 in the USER model as appropriate, based on the observed detections. The model was fit separately for each release. For each release, the complete data set that included possible detections from predatory fish was analyzed separately from the reduced data set restricted to detections classified as Chinook Salmon smolt detections. Population-level estimates of parameters and performance measures, representing both release groups, were estimated by fitting the model to the pooled detection data from both release groups. To account for differences in detection probabilities between the two release groups, unique detection probabilities were estimated for the two release groups while common survival and route entrainment probabilities were estimated from the pooled data. Likelihood ratio tests were used to select the most parsimonious model that still fit the pooled data set.

For each model fit, 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 and for the pooled data set, 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

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

The parameter *V* was estimated using Program USER. Also tested was whether tagged Chinook Salmon smolts showed a preference for the Old River route using a one-sided *Z*-test with the test statistic:

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

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

The effect of release group on the values of the model survival and transition probability parameters was examined by testing for a statistically significant decrease in parameter estimates for the second release group. For each model survival and transition probability parameter θ, where $\theta = \phi_{kj,hi}$ or $\theta = S_{hi}$, the difference in parameter values between the first and second release groups was defined as

$$\Delta_\theta = \theta_1 - \theta_2,$$

for model parameter θ_R for release group R ($R = 1,2$). The difference was estimated by $\hat{\Delta}_\theta = \hat{\theta}_2 - \hat{\theta}_2$. The null hypothesis of no difference was tested against the alternative of a positive difference (i.e., higher parameter value for the first release group):

$$H_{0\theta} : \Delta_\theta = 0$$

vs

$$H_{A\theta} : \Delta_\theta > 0.$$

Only those parameters that were estimated for both release groups and were based on at least four detections at the upstream boundary of the reach were considered. Additionally, the Southern Delta survival parameter $S_{B2(SD)}$ was tested in place of the parameters $\phi_{B2,B3}$, $\phi_{B2,C2}$, $\phi_{B2,D1}$, and $\phi_{B2,E1}$ because of correlation among estimates of the $\phi_{B2,hi}$ parameters. A family-wise significance level of α=0.10 was selected, and the Bonferroni multiple comparison correction was used, resulting in a test-wise significance level of 0.0091 for 11 tests (Sokal and Rohlf 1995).

Analysis of Tag Failure

A single tag-life study of VEMCO V5 tags began on May 17, 2013, and the final detection was observed on July 25, 2013. One tag could not be activated and was excluded from the study. This left a total of 49 V5 tags used, distributed across three tanks. Tags were pooled across tanks for analysis.

Tags were monitored in the tanks using fixed-site hydrophones and receivers. There were several instances when the hydrophone came loose from its moorings and was found floating in the tank ((Table 6). Under these circumstances, it was likely that tag detectability was impaired for tags in the affected tank. A tag that emitted its final transmission during the time when the hydrophone was floating would be likely to have a last observed detection time occurring before the hydrophone came unmoored, thus giving a biased measurement of the true lifespan of the tag. As a result, failure times were right-censored for those tags whose final observed detection times occurred in the 60 minutes prior to the estimated time when a tank's hydrophone came unmoored, in order to remove the possibly corrupted data. This procedure removed failure times from 16 tags, leaving complete data on 33 tags.

Observed tag survival was modeled using the 4-parameter vitality curve (Li and Anderson 2009). The expected maximum tag-life was 80 days; however, all tags failed before day 70. The fitted tag survival model was used to adjust estimated fish survival and transition probabilities for premature tag failure using methods adapted from Townsend et al. (2006). In Townsend et al. (2006), the probability of tag survival through a reach is estimated based on the average observed travel time of tagged fish through that reach. For this study, travel time and the probability of tag survival to Chipps Island was estimated separately for the different routes (e.g., San Joaquin route and Old River route). Subroutes using truck transport were handled separately from subroutes using only in-river 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 error estimates may have been slightly low. In previous studies, however, variability in tag-survival parameters was observed to contribute little to the uncertainty in the fish survival estimates when compared with other, modeled sources of variability (Townsend et al. 2006); thus, the resulting bias in the standard errors was expected to be small.

Analysis of Tagger Effects

Tagger effects were analyzed in several ways. The simplest method used contingency tests of independence on the number of tag detections at key detection sites throughout the study area. Specifically, a lack of independence (i.e., heterogeneity) between the detections distribution and tagger was tested using a chi-squared test (α=0.05; Sokal and Rohlf, 1995). Detections from those downstream sites with sparse data across all taggers were omitted for this test in order to achieve adequate cell counts. This meant that assessment of potential tagger effects was limited to the upstream regions of the study area, in particular to Garwood Bridge, Old River near Highway 4, the CVP trash racks, and the entrance to the Clifton Court Forebay (RGU).

Lack of independence may be caused by differences in survival, route entrainment, or detection probabilities. A second method visually compared estimates of cumulative survival throughout the study area (to Garwood Bridge, Highway 4, and the export facilities) among taggers. A third method used Analysis of Variance to test for a tagger effect on individual reach survival estimates, and an F-test to test for a tagger effect on cumulative survival throughout each major route (routes A and B). Finally, the nonparametric Kruskal-Wallis rank sum test (Sokal and Rohlf 1995, ch. 13) was used to test for whether one or more taggers performed consistently poorer than others, based on individual reach survival or transition probabilities through key reaches. In the event that survival was different for a particular tagger, the model was refit to the pooled release groups without tags from the tagger in question, and the differences in survival estimates due to the tagger were examined. The reduced data set (without predator detections), pooled over release groups, was used for these analyses.

Analysis of Travel Time

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

Route Entrainment Analysis

There was no barrier at the head of Old River in 2013, so analysis of the factors affecting route selection (entrainment) at that river junction was performed. Acoustic tag detections used in this analysis were restricted to those detected at the acoustic receiver arrays located just downstream of the junction: SJL (model code A5) or ORE (B1). Tags were further restricted to those whose final pass of the junction came from either upstream sites or from the opposite leg of the junction; tags whose final pass of the junction came either from downstream sites or from a previous visit to the same receivers (e.g., multiple visits to the SJL receivers) were excluded from this analysis. Tags were restricted in this way to limit the delay between initial arrival at the junction, when hydrologic covariates were measured, and the tagged fish's final route selection at the junction. Predator-type detections were also excluded.

As in previous years (SJRGA 2013, Buchanan et al. 2015), the effects of variability in hydrologic conditions on route entrainment at the head of Old River were explored using statistical generalized linear models (GLMs) with a binomial error structure and logit link (McCullagh and Nelder, 1989). Hydrologic metrics used in the analysis are defined below. In addition to the hydrologic metrics, fork length at tagging (L_i for tag i), release group $\left(RG_i\right)$, and time of day of arrival at the head of Old River were also considered as factors potentially affecting route selection. Time of day of arrival ($time_i$ for tag i) was measured as dawn, day, dusk, or night. Dawn was assumed to end at sunrise, and dusk began at sunset. A separate measure indicated whether fish arrived at the junction during the twilight or crepuscular period (i.e., dawn or dusk; $twilight_i$).

Tags that were estimated to have arrived at the junction more than 2 hours before final route selection, indicated by detection on either SJL or ORE receivers, were excluded from the analysis, to limit the time delay between arrival at the junction and final route selection. This restriction omitted 28 of the 436 (6%) tags observed at the head of Old River junction coming from either upstream or the opposite leg of the junction, leaving 408 tags for the route entrainment analysis. Of these 408 tags, 98 took the San Joaquin River route at the head of Old River and 310 took the Old River route, giving a total of 98 degrees of freedom available for the analysis.

Hydrologic conditions were represented in several ways, primarily total river flow (discharge), water velocity, and river stage. These measures were available at 15-minute intervals from the Lathrop SJL) and Old River (OH1) gaging stations maintained by the California Department of Water Resources (Table 4). Most hydrologic data were downloaded from the California Water Data Library (www.water.ca.gov/waterdatalibrary); river stage data from OH1 were downloaded from CDEC (cdec.water.ca.gov). Conditions measured at the SJL station were labeled route A, and conditions at the OH1 station were labeled route B.

For each tag, conditions were measured at the estimated time of arrival of the tagged fish at the head of Old River junction. Arrival time for tag i (t_i) was estimated based on the first-order assumption of constant movement during the transition from the previous detection site to either SJL or OH1. The gaging stations were located 0.52 km (SJL) and 0.14 km (OH1) downstream of the junction. No effort was made to model hydrologic conditions at the junction itself (rather than at the gaging stations) at the estimated time of fish arrival.

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

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

where $x_{t_{1(i)}}$ and $x_{t_{2(i)}}$ are the two observations of metric x (x = Q [flow], V [velocity], or C [stage]) at the gaging station in route h $(h = A, B)$ nearest in time to the time t_i of tag i arrival such that $t_1 \le t_i \le t_2$. The weights w_i were defined as

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

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

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

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

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

The proportion of total flow entering each river at the time of tag arrival was measured as

$$pQ_{iA} = \begin{cases} \dfrac{Q_{iA}}{Q_{iA} + Q_{iB}}, & \text{for } Q_{iA} \geq 0 \\ 0, & \text{for } Q_{iA} < 0 \\ 1, & \text{for } Q_{iB} < 0 \end{cases}$$

into the San Joaquin River, and

$pQ_{iB} = 1 \quad Q_{iA}$ into Old River.

Flow proportion values of 0 into the San Joaquin River indicated negative flow into the San Joaquin River and positive flow into Old River, while proportion values of 1 into the San Joaquin River indicated positive flow into the San Joaquin River and negative flow into Old River.

As with measures of flow and velocity, the flow proportion into the San Joaquin River was measured at the two time points before and after tag arrival: $pQ_{t_1(i)A}$ and $pQ_{t_2(i)A}$. If $t_2 - t_1 \leq 30$ minutes, then the change in flow proportion into the San Joaquin River at the time of arrival of tag i was measured by $\Delta pQ_{iA} = pQ_{t_2(i)A} \quad pQ_{t_1(i)A}$.

Flow reversal in either river was represented by the indicator variable U_Q (Perry 2010):

$$U_{iQh} = \begin{cases} 1, & \text{for } Q_{ih} < 0 \\ 0, & \text{for } Q_{ih} \geq 0 \end{cases}.$$

Similar measures were defined for negative velocity (U_V).

Daily export rate for day of arrival of tag i at the head of Old River junction was measured at the Central Valley Project $\left(E_{iCVP}\right)$, State Water Project $\left(E_{iSWP}\right)$, and total in the Delta $\left(E_{iTotal}\right)$ (data downloaded from DayFlow on June 16, 2014).

All continuous covariates were standardized, i.e.,

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

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

The form of the generalized linear model was

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

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), and ψ_{iA} is the predicted probability that the fish with tag i selected route A (San Joaquin River route), and $\psi_{iB} = 1 \quad \psi_{iA}$ (B = Old River route). Route choice for tag i was determined based on detection of tag i at either site A5 (route A) or site B1 (route B). Estimated detection probabilities for the two release groups were 0.95 – 1.00 for both sites (Appendix 3; Table A3:2).

Single-variate regression was performed first, and covariates were ranked by P-values from the appropriate F-test (if the data were over-dispersed for the model) or χ-square test otherwise (McCullagh and Nelder 1989). Covariates that were significant alone were then analyzed together in a series of multivariate regression models. Because of high correlation between flow and velocity measured from the same site, the covariates flow and velocity were analyzed in separate models. River stage was analyzed separately from flow, velocity, and flow proportion, although using measures of negative flow.

Flow proportion into the San Joaquin River varied only when there was positive flow directed into the San Joaquin River. When flow was directed out of the San Joaquin River, flow proportion was zero. Because there were many instances with negative flow measured at the SJL gage in 2013, the flow proportion model used the flow proportion metric when flow was positive, and the SJL flow measure when flow was negative. This model allowed for a higher probability of selecting the San Joaquin River route when more of the flow entered the San Joaquin River, and lower probability of entering the San Joaquin River when flow was more negative at SJL. All flow proportion models considered included the proportion flow (pQ_A) and the product of the reverse flow indicator and the measure of flow at SJL ($U_{QA} \cdot Q_A$). Thus, four multiple regression models were compared: flow, flow proportion, velocity, and river stage. In each of these models, fork length and release group were included, as well as one measure of exports (CVP, SWP, or total; generally E) and one measure of arrival timing ($time$ or $twilight$, generally $arrival$). Which export and arrival timing measure was included depended on which accounted for the most variability in the route selection in that model. The general forms of the four multivariate models were:

Flow model: $Q_A + Q_B + \Delta Q_A + \Delta Q_B + U_{QA} + U_{QB} + arrival + E + L + RG$

Flow proportion model: $pQ_A + U_{QA} + U_{QA} \cdot Q_A + \Delta pQ_A + U_{QB} + E + arrival + L + RG$

Velocity model: $V_A + V_B + \Delta V_A + \Delta V_B + U_{VA} + U_{VB} + E + arrival + L + RG$

Stage model: $C_A + C_B + \Delta C_A + \Delta C_B + U_{QA} + U_{QB} + E + arrival + L + RG.$

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, flow proportion, velocity, or stage) was compared using an F-test to the full model (or a χ^2-test if the data were not overdispersed for the model) from that category to ensure that all significant main effects were included. AIC was used to select among the flow, flow proportion, 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 entrainment into the San Joaquin using the Pearson chi-squared test (Sokal and Rohlf 1995).

Survival through Facilities

In similar studies of acoustic-tagged steelhead (Buchanan 2013, 2015), a supplemental analysis has been 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. This analysis combined detections at Chipps Island with detections at Jersey Point and False River, and compared detection counts to counts of detections at the CVP holding tank and the interior receivers in the Clifton Court Forebay (site RGU). In 2013, there were only 8 tags detected (excluding predator-type detections) inside Clifton Court Forebay, only 6 tags detected or otherwise known to have arrived in the CVP holding tank, of which 4 were removed from the study at that site, and only 3 detected at Chipps Island. Only one tag was detected at Jersey Point or False River, and this tag came from the San Joaquin River route. Thus, the data were too sparse to complete an analysis of salvage through the facilities for Chinook Salmon in 2013.

Results

Transport to Release Site

No mortalities were observed after transport to the release site other than a dummy tagged fish on 5/15/2013 (Table 7). Water temperatures ranged from 13.7°C to 16.1° C after loading, prior to transport (Table 7). Water temperatures ranged from 14.9°C to 19.3°C after transport and before unloading at the release site (Table 7). Water temperature in the river at the release site ranged from 16.8°C to 20.3°C, with the average during the first week being lower (17.0°C) than for the second week (19.9°C) (Table 7). Water temperatures did not change substantially during transport, except for transport tank 1 on 5/2 (Table 7 and Appendix 2.). Water temperatures in the transport tanks when arriving at the release site were usually within a degree C of the water temperature in the river for the first release group, but were up to 5.3°C different for the second release group (transport tank 2 on 5/16; Table 7). Dissolved oxygen levels ranged between 8.6 and 12.0 mg/l for all measurements in the transport tanks or in the river (Table 7).

Fish Releases

No mortality occurred after holding and prior to release for the salmon used in the 2013 Chinook Salmon study (Table 7).

Dummy Tagged fish

One of the 89 dummy tagged fish died during transport (Table 7) and one was found dead when evaluated after 48 hours during the Chinook Salmon Survival Study in 2013 (Table 8). One fish was missing from the group evaluated on May 16. All remaining fish were found swimming vigorously, had normal gill coloration, normal eye quality, normal body coloration and no fin hemorrhaging. Mean scale loss for all fish assessed ranged from 5.0 to 6.7%. Eight of the examined fish were found to have stitched organs. Three of the eight fish with stitched organs were in week 1, and five of the eight were in week 2. Two others appeared to have internal infections. Mean fork length (FL) of fish in the dummy tagged groups ranged from 110.8 to 116.5mm (Table 8). A general pathogen and physiological screening was conducted on groups of 30 dummy-tagged fish from two of the eight (tagged) groups (Table 1).

Fish Health

Pathogen testing conducted on dummy-tag Chinook Salmon used in studies corresponding to May 5 and May 19 groups showed no mortality occurred with either sample group. Externally, there were no observations of pale gills, significant scale loss or external hemorrhaging. Sutures were all in good condition with minor inflammation noted in 3% (1/30) of fish on May 5 and 7% (2/30) of fish on May 19. Internally, clinical signs of PKD (swollen kidney and/or spleen) were observed in 23% (7/30) of fish on May 5 and 23% (7/30) fish on May 19. No viral or obligate bacterial pathogens were detected. No parasite infections or significant inflammation was seen in gill by histopathology from the May 5 or May 19 Chinook Salmon sample groups. In addition to the release groups, an additional 30 Chinook Salmon were sampled at MR Hatchery on May 3, 2013 (MR Hatchery group). Only kidney tissue for the histopathology assay was collected from the MR Hatchery group. The *T. bryosalmonae* parasite was detected in fish from all three Chinook Salmon release groups, with 80% to 100% of the fish infected. The intensity of the infections (based on number of parasites) was rated as high in over half of the fish from each release group (Table 4 in Appendix 1). There was no significant difference detected in the severity of the infections between release groups (Table 5 in Appendix 1; p=0.089, Fisher's exact test for count data). Gill ATPase activity levels (μmol ADP*mg protein^{-1}*hr^{-1}) in the May 5 release group was significantly higher than May 19 group (Figure 2 in Appendix 1, P<0.001, Wilcoxen rank sum test). Gill Na+/K+-ATPase activity levels declined between the May 5 and May 19 releases. Gill ATPase activity in salmonds typically increases and peaks near the time of most active migratory behavior (Duston, Saunders and Knox 1991; Ewing, Ewing and Satterthwaite 2001; Wedemeyer 1996). See Appendix 1 for more detail on the results of the fish health evaluations.

Detections of Acoustic-Tagged Fish

A total of 950 acoustic-tagged Chinook Salmon were released at Durham Ferry in 2013 and used in the survival study. Of these, 824 (87%) were detected on one or more receivers either upstream or downstream of the release site Table 9), including any predator-type detections. Equal numbers of tags were detected from the two release groups (early May and mid-May) (Table 9). A total of 811 (85%) were detected at least once downstream of the release site, and 479 (50%) were detected in the study area from Mossdale to Chipps Island (Table 9). The majority of those detected upstream of the study area came from the second release group, largely due to increased detections on the Banta Carbona receiver for the second release group (Table 9, Table 10). The majority of the tags detected within the study area (325 of 479, 68%) came from the first release group. Twenty-seven (27) tags were detected upstream of the release site; 14 of these were also detected downstream of the release site. All but one of the tags detected upstream of the release site came from the second release group (Table 10).

Overall, there were 137 tags detected on one or more receivers in the San Joaquin River route downstream of the head of Old River (Table 9). In general, tag detections decreased within each migration route as distance from the release point increased. Of these 137 tags, all 137 were detected on receivers near Lathrop; 39 were detected on one or more receivers near Stockton (SJR, SJNB, or RRI); 2 were detected on the receivers in the San Joaquin River near Turner Cut (SJS or MAC), 0 were detected in Turner Cut, and 1 was detected at Medford Island (Table 10). Although 137 tags were detected in the San Joaquin River downstream of the head of Old River, only 106 tags were assigned to the San Joaquin River route for the survival model (Table 9); the other 31 tags were subsequently observed in the Old River route or upstream of Old River. The majority of the tags assigned to the San Joaquin River route came from the first release group (Table 9). None of the tags assigned to the San Joaquin River route were detected in the Interior Delta, including the receivers in Old and Middle rivers near Highway 4 (OR4, MR4), the radial gate receivers at the entrance to Clifton Court Forebay (RGU, RGD), and the Central Valley Project (CVP, CVPtank). One tag assigned to the San Joaquin River route was subsequently detected at both Jersey Point and False River, from the first release group; that tag was also observed at Chipps Island (Table 10). No tags assigned to the San Joaquin River route from the second release group were observed downstream of the Stockton receivers near the Navy Bridge (SJNB) and Rough and Ready Island (RRI) (Table 10).

The majority (355) of the tags detected downstream of the head of Old River were detected in the Old River route (Table 99). Nearly all (351, 99%) of the tags detected in the Old River route were detected at the Old River East receivers near the head of Old River (Table 10); 233 were detected on the receivers near the head of Middle River; 89 were detected at the receivers at the water export facilities; and 27 at the Old or Middle River receivers near Highway 4 in the Interior Delta. Only one tag was detected on the Middle River receivers near Empire Cut (Table 10). All tags detected at the Old and Middle receivers in the Interior Delta (OR4, MR4, MRE) entered Old River at its head.

Three (3) of the 355 tags detected in the Old River route were assigned to the San Joaquin River route, because they were detected on the San Joaquin River receivers near Lathrop, after all Old River detections of these tags. In all, 346 tags were assigned to the Old River route at the head of Old River based on the full sequence of tag detections (Table 9). Of these 346 tags, 75 were detected at the CVP trash racks, although only 66 of these detections were used in the survival model because some tags were subsequently detected either at the radial gates or farther north in Old River (Table 10, Table 11). Likewise, 33 of the tags assigned to the Old River route were detected at the radial gates (upstream), and 17 of those detections were used in the survival model (Table 10, Table 111). None of the tags assigned to the Old River route were detected at Jersey Point or False River (Table 10). Two (2) of the tags assigned to the Old River route at the head of Old River were subsequently detected at Chipps Island, including predator-type detections (Table 10, Table 11); both of those tags passed through the Central Valley Project holding tank. Although receivers were located in Threemile Slough as in previous years (SJRGA 2013, Buchanan et al. 2015), no tags from either route were detected in Threemile Slough (Table 10).

The predator filter used to distinguish between detections of juvenile Chinook Salmon and detections of predator fish that had eaten the tagged Chinook Salmon classified 205 of the 950 tags (22%) released as being detected in a predator at some point during the study (Table 12). Of the 479 tags detected in the study area (i.e., at Mossdale or points downstream), 129 tags (27%) were classified as being in a predator, and all 129 were first classified as being in a predator in the study area, rather than farther upstream. Somewhat fewer (76, 11%) of the 674 tags detected upstream of Mossdale were classified as in a predator in that region; all 76 tags were first classified as a predator upstream of Mossdale, and none were detected downstream of Mossdale (Table 12).

A total of 81 tags from the first release group (early May) were classified as in a predator at some point during the study; the majority (72) of these 81 tags were first classified as in a predator within the study area (Mossdale or downstream) (Table 12). From the second release group (mid-May), 124 tags were classified as in a predator during the study. Of these 124 tags, slightly over half were first classified as a predator upstream of the study area (Table 12). The apparent change in location of predation classifications between the first and second release group may be due in part to the increased number of detections on the Banta Carbona receivers (BCA) for the second release group. Only 3 tags from the first release group were detected at Banta Carbona, of which 2 (67%) were classified as predators at that site, whereas 224 tags from the second release group were detected at Banta Carbona, of which 23 (10%) were first classified as predators at that site (Table 10, Table 12).

Within the study area, the detection sites with the largest number of first-time predator-type detections were the receivers at Old River East (B1, 37 of 351, 11%), Old River South (B2, 22 of 228, 10%), and the Central Valley Project trash racks (E1, 33 of 75, 44%) (Table 10, Table 12). Although there were fewer tags observed in the San Joaquin River route downstream of the head of Old River than in the Old River route, a relatively high number of tags were first classified as in a predator at the Navy Bridge receiver in Stockton (A7): 6 of 36 tags (17%) (Table 10, Table 12). Considering all detection sites together, considerably more of the 205 predator classifications were assigned upon tag departure than tag arrival at the site: 160 tags were first classified as in predators upon departure from a site, compared to only 45 tags first classified as in predators upon arrival at a site (Table 12). Predator classifications on arrival were typically due to unexpected travel time or regional residence times, and were most common upstream of the study area and, to a lesser extent, in the eastern and southern regions of Old River (sites B1 and B2) (Table 12). Predator classifications on departure were typically due to long residence times, and were most prevalent upstream of the study area, at Old River East, Old River South, and the CVP trash racks (Table 12). 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.

When the detections classified as coming from predators were removed from the detection data, slightly fewer detections were available for survival analysis (Tables 13, 14, and 15). With the predator-type detections removed, 810 of the 950 (85%) tags released were detected downstream of the release site, and 478 (50% of those released) were detected in the study area from Mossdale to Chipps Island (Table 13). A total of 12 tags were detected upstream of the release site using only smolt-type detections (Table 14); 6 of these were also detected downstream of the release site.

Many more Chinook Salmon were observed using the Old River route at the head of Old River (345) than the San Joaquin River route (106); considerably more tags were assigned to the San Joaquin

River route from the first release group compared to the second release group (Table 13). As observed from the full data set that includes the predator-type detections, all of the smolt-type tags that were detected at receivers in the western portions of the study area, including the water export facilities and the receivers near Highway 4, used the Old River route at the head of Old River rather than the San Joaquin River route. A single smolt-type tag was detected at Jersey Point, and it came from the San Joaquin River route (Table 1414). Two of the three tags detected at Chipps Island came from the Old River route (specifically, through the CVP holding tank) (Table 14). Of the 345 tags assigned to the Old River route at the head of Old River, 71 were detected at the CVP trash racks, 32 at the entrance to the Clifton Court Forebay, 24 in Old River near Highway 4, and 3 in Middle River near Highway 4 (Table 14). Detection counts used in the survival model follow a similar pattern (Table 15).

Tag-Survival Model and Tag-Life Adjustments

Using the data set resulting from right-censoring corrupted tag failure times from the tag-life study, the estimated mean time to failure was 50.6 days ($\widehat{SE}$ =8.6 days) (Figure 4). The early failure of two tags (days 5 and 13) required making tag-life corrections to all survival estimates from the fish-survival model. This was especially important for analysis using all tag detections, including those classified as coming from predators (Figure 5, Figure 6). The sites with the latest detections, including predator-type detections but restricted to those sites actually modeled, were Durham Ferry Downstream, Mossdale, and the Navy Bridge receiver (SJNB = A7) in the San Joaquin River (Figure 5), and Old River East and Old River South receivers in Old River, and the CVP trash racks and Clifton Court Forebay radial gate receivers (Figure 6). Some of these late-arriving detections may have come from predators; without the detections classified as coming from predators, all tags arrived at modeled sites before the estimated tag survival probabilities had fallen below 95%. Nevertheless, tag-life corrections were made to survival estimates for both the full data set including predator-type detections, and the reduced data set using only smolt-type detections. Using only those detections classified as coming from salmon smolts, all estimates of reach survival for the acoustic tags were greater than 0.99 (out of a possible range of 0 – 1). Using all detections, including those classified as coming from predators, the estimates of reach survival for the acoustic tags were greater than 0.95 for all reaches except from the Navy Bridge to MacDonald Island, for which the tag survival probability was estimated at 0.60, based on only 2 tags. The low tag survival for this reach was caused by the long transition time from a single tag that took 51 days from its departure from Navy Bridge to its last visit to MacDonald Island; however, its first visit to MacDonald Island was only 2.8 days after departure from Navy Bridge, and the tag was classified as in a predator at MacDonald Island on account of its long residence time at that site. Estimated cumulative tag survival to Chipps Island was estimated at 0.98 or above with or without predator-type detections. In most cases, there was little effect of premature tag failure or corrections for tag failure on the estimates of Chinook Salmon reach survival. The exception was for the reach from the Navy Bridge to MacDonald Island using predator-type detections, but as described above, it is likely that the estimated effect of tag failure in that reach is due to a predator detection or deposited tag.

Tagger Effects

Fish in the release groups were evenly distributed across tagger (Table 16). Additionally, for each tagger, the number tagged was well-distributed across release group. A chi-squared test found no evidence of lack of independence of tagger across release group (χ^2 = 0.0021, df = 2, P = 0.9989). The distribution of tags detected at various key detection sites was also well-distributed across taggers and showed no evidence of a tagger effect on survival, route entrainment, or detection probabilities at these sites (χ^2 = 11.8003, df = 16, P = 0.7576; Table 17).

Estimates of cumulative survival throughout the San Joaquin River route to Garwood Bridge showed similar patterns of survival across all taggers. Although tagger A had consistently higher point estimates of cumulative survival through the San Joaquin River route to Garwood Bridge, there was no significant difference in cumulative survival to any site in the San Joaquin River route (P ≥ 0.4772; Figure 7). In the Old River route, cumulative survival estimates differed among taggers to Highway 4 and the entrances of the water export facilities (P=0.0171). In particular, Tagger C had lower reach survival estimates than Tagger A (P=0.0072), most noticeably from Old River South to Highway 4 and the water export facilities (Figure 8). Nevertheless, rank tests found no evidence of consistent differences in reach survival estimates for fish from different taggers either upstream of the head of Old River (P=0.8752), between Old River and Garwood Bridge (P=0.3679), or between Old River and Highway 4 or the water export facilities (P=0.7939). The sensitivity of model results to data from Tagger C was explored; see “Survival and Route Entrainment Probabilities” for more details.

Survival and Route Entrainment Probabilities

Detection data of tagged Chinook Salmon in the lower San Joaquin River and in parts of the Interior Delta were sparse in 2013, and required modifications to the full model. Patterns of detections required different model modifications for the two release groups; estimation results are described for each release group and for the pooled release groups below.

Release Group 1

There were only two detections at the Middle River receivers at the head of Middle River (model code C1), and also only two detections (of different tags) at the Middle River receivers near Highway 4 (C2) (Table 15). None of the four tags detected at these sites were detected subsequently. This was very few detections for estimating detection probabilities at these sites and transitions from these sites. However, unlike right-censoring detection histories at A9, which was used for this release group, right-censoring detection histories at sites C1 and C2 prevents estimation of both the South Delta survival and total Delta survival in both the Old River route ($S_{B(SD)}$ and $S_{B(D)}$, respectively) and combined over both routes ($S_{Total(SD)}$ and S_{Total}); consequently, it was not possible to right-censor at these sites. The effect of the small number of observations at C1 and C2 on estimates of model parameters and Delta survival in the Old River route ($S_{B(D)}$) was explored by comparing the estimates with and without (i.e., omitting) those observations: the mean difference in parameter estimate caused by omitting these detections was -0.0002, and the largest effects were on parameters ψ_{B2} , whose estimate changed 0.99 from to 1.0, and $\phi_{B2,C2}$, whose estimate changed from 0.01 to 0.0. The effect of omitting the C1 and C2 observations on $S_{B(SD)}$ was to lower the estimate from 0.29 (including the C1 and C2 observations) to 0.28 (omitting the C1 and C2 observations). There was no effect on the estimate of total Delta survival either in the Old River route or in both routes combined. The following results come from the data set that includes the C1 and C2 observations.

Using only those detections classified as coming from juvenile Chinook Salmon, the estimated probability of surviving from Mossdale to the Chipps Island receivers, $\hat{S}_{total}$, was 0.02 ($\widehat{SE}$ =0.01) (Table 18). The estimated probability of entering Old River at its head was 0.71 ($\widehat{SE}$ =0.02), and there was a significant preference for the Old River route (route B) (P<0.0001) (Table 18). With only three tags detected at Chipps Island, survival was very low in both the San Joaquin River route (route A) and the Old River route (route B): $\hat{S}_A$ =0.01 ($\widehat{SE}$ =0.01) and $\hat{S}_B$ =0.03 ($\widehat{SE}$ =0.01), and there was no significant difference in survival between the two routes (P=0.4088) (Table 18).

Survival estimates varied in different regions of the study area, and between the release site and the entrance to the study area at Mossdale. The estimated probability of surviving from release at Durham Ferry to Mossdale was 0.68 ($\widehat{SE}$ =0.02) (Table 18). The probability of surviving from Mossdale past the head of Old River to either the San Joaquin River receivers near Lathrop (A5) or the first Old River receivers (B1) was high, 0.99 ($\widehat{SE}$ =0.01; Appendix 3; Table A3:2). For fish that survived past the head of Old River and remained in the San Joaquin River, survival from Lathrop to Garwood Bridge (A5; 18 km) was considerably lower (0.36, $\widehat{SE}$ =0.05); survival from Garwood Bridge to Navy Bridge (2.5 km) was high (0.91, $\widehat{SE}$ =0.05), whereas estimated survival from Navy Bridge to the MacDonald Island receivers (15 km) was considerably lower at 0.07 ($\widehat{SE}$ =0.05) (Table A3:2). When scaled by reach length, the same patterns were observed: survival rate per km was lowest between Navy Bridge and MacDonald Island and between Lathrop and Garwood Bridge.

In the Old River route, survival from the head of Old River to the head of Middle River($\phi_{B1,B2}$) was estimated at 0.72 ($\widehat{SE}$ =0.03) for the first release group (Appendix 3: Table A3:2). The large majority of fish arriving at the head of Middle River remained in Old River ($\hat{\psi}_{B2}$ =0.99, $\widehat{SE}$ =0.01) (Appendix 3: Table A3:2). Of the tagged fish that arrived at the Old River South receivers near the head of Middle River (site B2), the probability of surviving from B2 to either the entrances to the export facilities (CVP or CCFB) or the Highway 4 receivers (OR4 or MR4) was 0.41 ($\widehat{SE}$ =0.04); however, the large majority of the tagged fish detected at one of those sites were observed at the CVP trash racks (67%) rather than the CCFB (19%), Old River near Highway 4 (10%), or Middle River near Highway 4 (3%). The only tags from the Old River route that were detected at Chipps Island came via the CVP holding tank. However, the probability of moving from the CVP trash rack to the holding tank was estimated at only 0.13 ($\widehat{SE}$ =0.05), demonstrating considerable risk at passing the CVP trash racks in the subroute to Chipps Island.

The primary effect of including detections that were classified as coming from predators by the predator filter was to slightly increase survival through the South Delta region: $\hat{S}_{A(SD)}$ =0.02 and $\hat{S}_{B(SD)}$ =0.29 when predator-type detections were omitted included, compared to $\hat{S}_{A(SD)}$ =0.04 and $\hat{S}_{B(SD)}$ =0.31 when predator-type detections were included (Table 18, Table 19). Among the survival and transition probability parameters, the largest effect of including the predator-type detections was in estimates of $\phi_{D1,D2}$, the transition probability from the exterior to interior receivers at the radial gates at the entrance to the Clifton Court Forebay: $\hat{\phi}_{D1,D2}$=0.54 without the predator-type detections, and $\hat{\phi}_{D1,D2}$=0.85 including the predator-type detections (Appendix 3: Table A3:2). This difference reflects the fact that 20% of the tags detected at site D1 (RGU) were classified as predators upon departure from that site (Table 12).

Release Group 2

There were few (13) tagged Chinook Salmon from the second release group (released May 15-19, 2013) that were detected taking the San Joaquin River route downstream of the head of Old River; the majority (117) were detected taking the Old River route (Table 13). Estimated route entrainment probabilities at the head of Old River were $\hat{\psi}_A$=0.10 and $\hat{\psi}_B$=0.90 ($\widehat{SE}$ =0.02) for the San Joaquin River route (route A) and Old River route (route B), respectively; there was a significant (α=0.05) preference for the Old River route (P<0.0001) (Table 18). No tagged Chinook Salmon from this release group were detected at Chipps Island, so route-specific survival was estimated at 0 for both routes and overall: $\hat{S}_{Total} = \hat{S}_A$ $\hat{S}_B$=0 (Table 18). These estimates are based on the assumption that the acoustic receivers at Chipps Island were functioning well during the time when tagged fish might have been passing. There were no detections at Chipps Island from this release group with which to estimate detection probability or to test that assumption. However, the estimated Chipps Island detection probability from acoustic-tagged steelhead from the May release group in the 6-year study was 0.99 based on 61 fish (Buchanan 2015), indicating that the receivers at Chipps Island were functioning reasonably well in mid- to late May when acoustic-tagged Chinook Salmon from this study may have been passing Chipps Island.

Within the San Joaquin River route, only five tags were detected downstream of Lathrop from the second release group, and survival from Lathrop to Garwood Bridge was estimated at $\hat{S}_{A5}$=0.39 ($\widehat{SE}$ =0.14) (Table A3:2). All five tags were detected at both Garwood Bridge (A6) and Navy Bridge (A7), but no tags were detected downstream of Navy Bridge. This meant that it was not possible to estimate the detection probability at Navy Bridge, which had only a single receiver. However, all of the five tags detected downstream of Lathrop (model code A5) were detected at both Garwood Bridge and Navy Bridge, and all were detected on both receivers at Garwood Bridge; this pattern of detections suggests 100% survival from Garwood Bridge to Navy Bridge. Nevertheless, because the estimate is based on only five tags, it is possible that there were mortality factors operating within this short reach that were not represented by this small number of tags. None of the tags detected in the San Joaquin River route were detected at Chipps Island, yielding $\hat{\phi}_{A7,G2}$=0. The small number of tags detected within the San Joaquin River route makes it difficult to apportion survival to the different reaches in the route with confidence.

Within the Old River route, survival from the first Old River receiver (B1) to the receivers just downstream of the head of Middle River (B2 and C1) was estimated $\hat{S}_{B1}$=0.54 ($\widehat{SE}$ =0.05) (Appendix 3,Table A2). The large majority of the tags remained in Old River at Middle River, yielding $\hat{\psi}_{B2}$=0.94 and $\hat{\psi}_{C2}$=0.06 ($\widehat{SE}$ =0.03) (Appendix 3: Table A3:2). None of the four tags detected on the first Middle River site (C1) were detected again. Transition probabilities from Old River South site (B2) were $\hat{\phi}_{B2,B3}$=0.15

($\widehat{SE}$ =0.05) to Old River near Highway 4, $\hat{\phi}_{B2,D1}$ =0.07 ($\widehat{SE}$ =0.03) to the exterior receivers at the radial gates at the entrance to Clifton Court Forebay, and $\hat{\phi}_{B2,E1}$ =0.28 ($\widehat{SE}$ =0.06) at the CVP trash racks (Appendix 3. Table A3:2). There was only one tag detected at the Middle River receivers near Highway 4 (C2), which was too few detections to estimate the detection probability at that site. Thus, it was not possible to estimate the transition probability from site B2 to site C2, or from site C1 to site C2; omitting these transition probabilities lowered the estimate of survival through the Southern Delta region in the Old River route ($S_{B(SD)}$) by an unknown amount. However, the existing survival and route entrainment probability estimates in the Old River route provide estimates of the minimum (i.e., the observed estimate) and maximum (i.e., if $\phi_{B2,B3} + \phi_{B2,C2} + \phi_{B2,D1} + \phi_{B2,E1}$ =1 and $\phi_{C1,C2} = 1$) bounds on $S_{B(SD)}$ of approximately 0.22 – 0.46 for this release group.

Because sites E2 (CVP holding tank) and D2 (interior receivers at Clifton Court Forebay) were omitted from the model due to sparse data, the transition probabilities $\phi_{D1,G2}$ and $\phi_{E1,G2}$ were estimated directly in Submodel I. No tags were detected at Chipps Island, so both $\phi_{D1,G2}$ and $\phi_{E1,G2}$ were estimated at 0 (Appendix 3: Table A3:2).

There was little effect of including the predator-type detections on estimates of route selection and route-specific survival (absolute difference ≤ 0.01, Table 18,Table 19). Among the model survival and transition probability parameters, the largest effect of including predator-type detections was to make it possible to estimate the transition probability between the exterior and interior receivers at the radial gates at the entrance to Clifton Court Forebay: $\hat{\phi}_{D1,D2}$ =1 including predator-type detections, and was not estimable when predator-type detections were omitted (Appendix 3. Tables A3:2, A3:3). As with the first release group, this difference reflects the high proportion of tags detected at site D1 (RGU) that were classified as being in predators upon departure from that site (Table 12).

Pooled Release Groups

Model selection using likelihood ratio tests found resulted in a model that equated all parameters across release groups except for detection probabilities P_{A2}, P_{A3}, P_{D2a}, and P_{E1b} (P<0.0001). In addition, fish from the first release group were allowed to be removed (censored) at the CVP holding tank as part of the concurrent salvage efficiency study ($C_{E2} > 0$), whereas fish from the second release group were not allowed to be removed ($C_{E2} = 0$).

Survival estimates from the pooled release group were intermediate between the relatively high estimates from the first release group and the relatively low estimates from the second release group (Table 18, Appendix 3: Table A3:2). Survival from the release site to the study area at Mossdale was estimated at 0.50 ($\widehat{SE}$ =0.02) for the pooled release group, and total survival through the Delta was estimated at 0.01 ($\widehat{SE}$ =0.01) (Table 18). The probability of entering Old River at its head was estimated at 0.77 ($\widehat{SE}$ =0.02) for the pooled release group; route-specific survival from Mossdale to Chipps Island was estimated at 0.01 ($\widehat{SE}$ =0.01) for both the Old River route and the San Joaquin River route (Table 18).

Fitting the model without data from Tagger C resulted in changes in parameter estimates ranging from essentially no change for $\phi_{B2,B3}$ to a decrease of 0.50 for $\phi_{A9,G2}$; the large change in $\hat{\phi}_{A9,G2}$ is a result of the very sparse data at site A9, and the fact that the sole tag detected at Chipps Island via the San Joaquin River route came from Tagger C. The estimated probability of survival through the South Delta region changed from 0.21 ($\widehat{SE}$ =0.02) with Tagger C to 0.24 ($\widehat{SE}$ =0.02) without Tagger C, while there was no change in the estimated probability of survival through the entire Delta when data from Tagger C was removed.

The effect of including predator-type detections on estimates from the pooled release groups was similar to the effects on the individual release groups: $\hat{\phi}_{D1,D2}$ increased from 0.47 to 0.88 on account of the relatively large number of first-type predator classifications at the exterior receivers at the Clifton Court Forebay radial gates (site D1) (Appendix 3: Tables A3:2, A3:3). Estimates of South Delta survival increased slightly from $\hat{S}_{SD}$=0.21 ($\widehat{SE}$ =0.02) without predator-type detections, to $\hat{S}_{SD}$=0.23 ($\widehat{SE}$ =0.02) with predator-type detections (P=0.24); there was no difference in total Delta survival resulting from including predator-type detections (Table 18, Table 19).

Comparison between Release Groups

Parameter estimates were significantly (family-wise α=0.10) higher for the first release group compared to the second release group for parameters $S_{A2,A4}$, S_{A4}, S_{B1}, and $\phi_{A1,A2}$ (Table 20). There was no significant difference between release groups in estimates of survival from Navy Bridge to Chipps Island ($\phi_{A7,G2}$) or from the CVP trash racks to Chipps Island ($\phi_{E1,G2}$), despite the positive estimates of these parameters for the first release group compared to estimates of 0 for the second group (Table 20, Appendix 3: Table A3:2). The estimated total Delta survival from Mossdale to Chipps Island was significantly higher for the first release group (0.02, $\widehat{SE}$ =0.01) compared to the second group (0) (P=0.0037), despite the very low survival estimate for the first group (Table 18).

Travel Time

Of the three tags detected at Chipps Island, the single tag that arrived there via the San Joaquin River route took 8.08 days from release at Durham Ferry, while the two tags that passed through the CVP holding tank and on to Chipps Island took 3.8 and 4.0 days, respectively, from Durham Ferry.

Travel time from release to the Mossdale receivers averaged approximately 0.5 ($\widehat{SE}$ =0.01) days for the early May release group (excluding predator-type detections), and 0.7 ($\widehat{SE}$ =0.02) days for the mid-May release group (Table 21a). Average travel time to Garwood Bridge in the San Joaquin River was approximately 1.9 ($\widehat{SE}$ =0.09) days for the first release, and 2.3 ($\widehat{SE}$ =0.38) days for the second release, while average travel time to the Old River South receivers, near the head of Middle River, was approximately 0.9 ($\widehat{SE}$ =0.02) days for the first release group, and 1.3 ($\widehat{SE}$ =0.05) days for the second release group (Table 21a). Average travel times from release were slightly longer to most receivers for the second release group than for the first release group, but the smaller number of detections from the second release group at most sites makes direct comparisons difficult. For both release groups, the average travel time was between 2 and 3 days to both the CVP trash racks and the exterior receivers at the Clifton Court Forebay (RGU) (Table 21a). The four tags that were observed in the (monitored) CVP holding tank arrived there before the bulk of the tags arrived at the CVP trash racks (average = 1.9 days). When predator-type detections were included, average travel times tended to be slightly longer to receivers in the San Joaquin River downstream of Garwood Bridge and to the CVP trash rack, but there was little or no difference in travel time to most sites (Table 21b).

Average travel time through reaches for tags classified as being in juvenile Chinook Salmon ranged from 0.02 days (approximately 30 minutes) from the entrance channel receivers at the Clifton Court Forebay (RGU) to the interior forebay receivers (RGD), to 4.58 days for the single fish observed moving from the MacDonald Island receivers (MAC) to Chipps Island (MAE/MAW) (Table 22a). 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 1.2 – 1.5 days (~18 rkm). Average travel time per release group from Old River South (ORS) to the Old River receivers near Highway 4 (OR4) (~27 rkm) ranged from 1.0 day for the early May release group, to 1.8 days for the mid-May release group (Table 22a). From Old River South to the CVP trash racks, average travel time was approximately 1.2 days for the first release group, and 0.8 days for the second release group (Table 22a). For most reaches, average travel time was slightly longer for the second release group; the exceptions were the reaches from Old River South (ORS) to the CVP trash racks and the entrance channel to the Clifton Court Forebay (RGU), and to the Middle River receivers (MRH, MR4) (Table 22a). Including the predator-type detections had little effect on average travel time through reaches (Table 22b).

Route Entrainment Analysis at the Head of Old River

River flow (discharge) at the San Joaquin River gaging station near Lathrop, (station SJL) at the time of arrival of the tagged juvenile Chinook Salmon at the head of Old River ranged from -860 cfs to 1,849 cfs (average =1,057 cfs) in 2013. The flow in the San Joaquin River was negative for 51 of 408 (12%) tags upon their arrival to the head of Old River in 2013. River flow at the Old River gaging station near the head of Old River (station OH1) ranged from 267 cfs to 3,213 cfs (average = 2,109 cfs) during the same time; river flow at OH1 was positive for arrival of all 408 tags. Correlation was low between flow in the San Joaquin River and flow in Old River at the time of tag arrival at the river junction ($r<0.01$) (Figure 9). Flow proportion into the San Joaquin River ranged from 0 (for 51 tags) to 0.77 in 2013, and averaged 0.33 (Figure 10); flow proportion was correlated with flow into the San Joaquin River ($r=0.85$), but less so with flow into Old River ($r=-0.46$). Water velocities ranged from -0.70 ft/s to 1.46 ft/s (average = 0.78 ft/s) at SJL, and from 0.17 ft/s to 2.08 ft/s (average = 1.40 ft/s) at OH1 (Figure 11). Flow and velocity at the same gaging station were highly correlated in 2013: $r=0.96$ at SJL, and $r=0.93$ at OH1. River stage at tag arrival was highly correlated between the SJL and OH1 gaging stations ($r=1.00$), and tended to be higher for the first release group compared to the second group (Figure 12). Export rates were variable throughout the study, but were generally higher for the first release group (early May) (Figure 13). Export rates at CVP averaged 2,082 cfs for the first release group, and 814 cfs for the second release group (mid-May). Export rates at SWP averaged 981 cfs for the first release group, and 714 cfs for the second release group. There was little correlation between total Delta exports and either flow into the San Joaquin River ($r=0.32$) or flow proportion into the San Joaquin River ($r=-0.07$); there was moderate correlation between total Delta exports and flow into Old River ($r=0.66$).

The majority of the fish that arrived at the head of Old River junction in 2013 selected the Old River route, regardless of release group (Table 18), flow (Figure 9), flow proportion (Figure 10), water velocity (Figure 11), river stage (Figure 12), or exports (Figure 13). Of the 408 tags used in the head of Old River route entrainment analysis, 310 (76%) selected Old River. This left 98 degrees of freedom for the regression models.

The single-variate analyses found significant effects (α=0.05) of several covariates on the probability of entering Old River at its distributary point on the San Joaquin River (or conversely, of remaining in the San Joaquin River): flow and velocity at SJL, 15-minute change in river stage at both SJL and OH1, flow proportion into the San Joaquin River, negative flow and velocity at SJL, total daily export rate, and release group (Table 23). Effects of flow and velocity at OH1, the 15-minute change in flow or velocity at both SJL and OH1, measures of exports at either CVP alone or SWP alone, all measures of time of day of arrival at the junction, and fork length were all non-significant (P≥0.1246). The 15-minute change in flow proportion into the San Joaquin River was significant at the 10% level, but not the 5% level (P=0.0607; Table 23).

Several covariates had highly significant effects based on the single-variate models (Table 23). However, while the single-variate models may suggest possible relationships, confounding among the independent covariates and the possibility of a causal relationship with an unobserved factor both make it impossible to conclude that changes in any of the significant single-variate measures directly produce changes in the route entrainment 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, and the 15-minute change in river stage at OH1 (Table 24). Once measures of flow or velocity at SJL were in the model, the additional effects of negative flow or velocity and exports were not significant. Similarly, if the 15-minute change in river stage was in the model, then the added effect of the 15-minute change in river stage at SJL was not significant. All four models adequately fit the data (P≥0.3690). Model selection using AIC found the flow model to account for the most variation in route selection at the head of Old River (ΔAIC>4) (Table 24).

The flow model predicted the probability of remaining in the San Joaquin River at the head of Old River according to:

$$\widehat{\psi_A} = \frac{e^{-3.96+0.0022Q_{SJL}}}{1+e^{-3.96+0.0022Q_{SJL}}},$$

where Q_{SJL} represents the river discharge (flow) at SJL upon tag arrival at the head of Old River junction. Equivalently, the probability of entering Old River was modeled as

$$\widehat{\psi_B} = \frac{1}{1+e^{-3.96+0.0022Q_{SJL}}}.$$

The model predicts that fish that arrived at the head of Old River during times of higher flow in the San Joaquin River at station SJL were less likely to enter Old River (Figure 14).

Discussion

Objective 1: Estimating survival in 2013 and the effect of sparse data.

Our first objective of the 2013 Chinook Salmon Study was to determine survival of emigrating salmon smolts from Mossdale to Chipps Island during two time periods (prior to May 15 and after May 15) without a HORB. But detections of tagged fish from the 2013 Chinook Salmon tagging study were sparse in the downstream regions of the San Joaquin River and Chipps Island for both release groups, and at the export facilities for the second release group. The lack of detections complicated analysis, in particular at sites where only few tags were detected. Detection probability estimates can often be calculated for dual arrays from only a few detections, but the estimates may be highly inaccurate.

For the first release group, the detection probability at Chipps Island was estimated at 0.67 at the first receiver line at that site, and 1.0 at the second receiver line, for an overall detection probability of 1.0 (Appendix 3:Table A3:2). However, these estimates were based on only three tags detected at Chipps Island for the early May release group (Table 15). Considerably more tags were detected at Chipps Island from the late April (27 tags) and early May (61 tags) releases of acoustic-tagged yearling steelhead as part of the concurrent 6-year study; for these two releases of steelhead, the estimated detection probability at the Chipps Island dual array was estimated at 0.99 ($\widehat{SE} \leq 0.01$) (Table A2 in Buchanan 2015). Thus, there is evidence that the receivers were functioning at Chipps Island during several weeks around the time when tagged Chinook Salmon were likely to have been passing. Having detection probability estimates < 1.0 at Chipps Island would have the effect of increasing the estimate of surviving through the total Delta from the observed estimate of 0.02. For example, the adjusted estimate of total Delta survival would be 0.03 or 0.04 if the Chipps Island detection probability were 0.7 or 0.5, respectively. These values are similar to the observed estimate of 0.02, and thus it seems reasonable to conclude that total Delta survival from Mossdale to Chipps Island was approximately 0.02 for the first release group in 2013.

For the second release group, there were no Chinook Salmon tags detected at Chipps Island (Table 10), and it was not possible to estimate the detection probability at that site. However, acoustic-tagged steelhead from the 6-year study were detected on the Chipps Island receivers during the time when the Chinook Salmon from the second release group were expected to have been passing the receivers, i.e., May 18 – 27, approximately 3 – 8 days after release. The estimated detection probability from the steelhead detections during this time period was 1.0 based on 32 fish, which provides evidence that the receivers at Chipps Island were functioning well during the expected time of Chinook Salmon passage from the second release group. Under the assumption of 100% detection at Chipps Island for the second release group of Chinook Salmon, the estimated Delta survival to Chipps Island was 0. However, the 95% upper bound is 0.0196, using the “Rule of Threes” (Van Belle, 2008, p. 49). This upper bound is nearly as high as the point estimate from the first release group.

There were sparse data at other sites in 2013, in addition to Chipps Island. Only two tags were detected at MacDonald Island (site A9), both from the first release group. Two detections provide limited information with which to estimate the detection probability at a site, and the only reasonable detection probability estimate from a dual array in such a case is 1.0; however, the small sample size means that it is possible that the true detection probability was actually < 1.0. If this was the case, then the estimated survival probability from the Navy Bridge to MacDonald Island was underestimated. For the first release group in 2013, there were 30 tags detected at the Navy Bridge (site A7), and only 2 of these were detected at MacDonald Island (site A9). Using the estimated detection probability of 1.0 at MacDonald Island, this yielded a survival estimate from Navy Bridge to MacDonald Island of 0.07 (Appendix 3. Table A3:2). If the detection probability at MacDonald Island was actually lower, then the survival probability from Navy Bridge to MacDonald Island would have been higher: for example, 0.13 if the detection probability was 0.5, and 0.33 if the detection probability were 0.2. Steelhead detections at MacDonald Island from the late April and early May releases of the 2013 6-year study also provided a detection probability estimate of 1.0 at site A9 (MAC); however, this estimate was based on few steelhead detections (5 – 12, depending on the release group; Buchanan 2015). Thus, there is little information available to estimate the detection probability at MacDonald Island and apportion survival to the reaches upstream and downstream of MacDonald Island for Chinook Salmon in 2013. Despite this, because only one of the 106 Chinook Salmon tags detected in the San Joaquin River route (and of the 30 tags detected at Navy Bridge) was detected at Chipps Island in 2013, there is little doubt that survival was low between Navy Bridge and Chipps Island and throughout the San Joaquin route.

Four of the tags from the first release group were known to be recovered from the holding tanks at the Central Valley Project during the concurrent salvage efficiency study in early May: one was detected in the VEMCO-monitored holding tank, and three were undetected after leaving the CVP trash racks (presumably recovered from an unmonitored holding tank). The records of all four tags were right-censored at the CVP holding tank (site E2) because the fish were removed from the migrating population. This left only two tags detected at site E2 with which to estimate the transition probability to Chipps Island via this route. Although both of these tags were subsequently detected at Chipps Island, the survival estimate must be interpreted with caution because of the very low sample size at the CVP holding tank. The estimated survival probability to Chipps Island from the CVP holding tank (i.e., 1.0) may be too high by an unknown amount. The sensitivity of the estimate of total Delta survival from Mossdale to Chipps Island, via any route, to this parameter is high on a relative scale because two-thirds of the fish that successfully reached Chipps Island passed through the CVP holding tank. On an absolute scale, however, there is little room for change in the estimate of total Delta survival on account of changes in $\phi_{E2,G2}$, because of high mortality before reaching the CVP holding tank. For example, if the transition probability from the holding tank (E2) to Chipps Island were only 0.5 instead of the estimated 1.0, then total Delta survival would have been estimated at 0.01 instead of 0.02. This is a large relative change but a small absolute change.

Very few tags from the second release group were detected either in the CVP holding tank or at the receivers at the entrance to Clifton Court Forebay (sites D1 and D2). Of the 17 tags detected at the CVP trash racks (site E1), only 1 was detected in the CVP holding tank. If the detection probability in the holding tank was 100%, then the transition probability from the trash racks to the holding tank would have been estimated at 0.06. At the entrance to Clifton Court Forebay, there were only four tags detected on the exterior receiver (site D1); all four of these tags were detected on the interior receivers, but three of them were classified as being in predators at the interior receivers. Detection probability estimates at both site D1 and site D2 were 1.0 using predator-type detections, based on the four tags. Thus, the transition probability from the exterior to the interior receivers was estimated at $\hat{\phi}_{D1,D2} = 1$ using all detections, but would have been estimated at only 0.25 when restricted to smolt-type detections. However, if the detection probability at the exterior receivers was actually < 1.0, then the estimated transition probability into the Forebay was overestimated by an unknown amount. Detection probability estimates from acoustic-tagged steelhead in the CVP holding tank and at the exterior and interior Clifton Court Forebay receivers were 100% for the May release of steelhead in 2013 study (Buchanan 2015). This is not conclusive evidence that detection probabilities were also 100% for tagged Chinook Salmon, but it does indicate that the receivers were operating at these three sites during the time period when the tagged Chinook Salmon may have been passing the receivers. If detection probabilities at these sites were 100% for tagged Chinook Salmon, then transition probabilities from the exterior to interior sites at both the CVP and Clifton Court Forebay were low (≤0.25), and transition probabilities from the interior sites to Chipps Island were both 0. However, such speculation cannot be verified from the available data.

Objective 2: Comparison Between Release Groups

Our second objective was to determine if survival was higher during the first release, when flows were higher, than for the second release with lower flows. Overall, total survival through the Delta from Mossdale to Chipps Island was higher for the first release group than for the second group (P = 0.0037). Survival for the first group was higher than the second group for the reaches between Durham Ferry and Mossdale ($S_{A2,A4}$), and between Mossdale and Lathrop (SJL) or Old River East (ORE)(S_{A4}). The first release group also had higher survival than the second release group between Old River East (ORE) and Old River South (ORS); (S_{B1}) (Table 20). Possible explanations include changes in fish condition or changes in environmental conditions. Fish from the second release group tended to be slightly larger than fish from the first release group, with a mean fork length of 113.5 mm ($\widehat{SE}$ =0.24 mm) in the first group compared to 117.1 mm ($\widehat{SE} = 0.28$ mm) for the second group (P<0.0001), so it was reasonable to expect higher survival for the second release group rather than lower survival. The first group had higher ATPase levels than the second group, although it is difficult to say whether this influenced their resulting survival. Although the two release groups were released only two weeks apart, they experienced different environmental conditions. Average river flow measured at the Vernalis gaging station was considerably higher during the period (through approximately 8 days from end of release) when fish from the first release group were traveling through the Delta to Chipps Island (mean flow = 3,717 cfs) than during a period of the same length for the second release group (1,243 cfs) (Figure 15).

During the same two periods, combined exports at CVP and SWP varied from 1,499 cfs to 4,008 cfs (mean = 2,049 cfs); the mean combined export rate was higher for the first period (2,440 cfs) than for the second period (1,568 cfs) (Figure 16). Exports tended to be highest at the beginning of the first period, when the majority of the pumping was at the CVP (Figure 16). Of the two tags observed moving from the CVP holding tank to Chipps Island, one arrived at the holding tank on May 3, when CVP export rate was 3,088 cfs, and the other arrived at the holding tank on May 5, when the CVP export rate was 938 cfs. Water temperature measured at the San Joaquin River gage near Lathrop was higher on average for the second release group (67.6 °F [19.8 °C]) than for the first group (63.2 °F [17.3 °C]), as expected from the lower flows experienced by the second release group (Figure 17). A combination of lower flows and higher temperatures may have combined to negatively affect salmon survival during the period following the second release. Continued linkages between flow and exports (higher exports at higher flows and lower exports at lower flows) makes identification of the role of exports independent of flow, problematic. Decoupling of these two factors in future years, in addition to combining these results with those from additional years may shed further light on possible drivers of mortality in the Delta.

Objective 3: Determine if travel time could be an explanation for the higher survival with the higher flows.

Our third objective was to determine if travel time was shorter with the higher flows and could be an explanation for the higher survival with the higher flows. Average travel times were generally shorter for the first group relative to the second (excluding predator-type detections) for travel time from release to the Mossdale receivers, Garwood Bridge in the San Joaquin River and to the Old River South receivers, near the head of Middle River (Table 21a). While the average travel times from release were slightly longer to most receivers for the second release group than for the first release group, the smaller number of detections from the second release group at most sites makes direct comparisons difficult.

Objective 4: Identify route selection at HOR and Turner Cut and its effect on survival in 2013.

Our fourth objective was to identify route selection at HOR and at Turner Cut under the two periods of varied flows to determine the effect of route selection on survival to Chipps Island. The majority of the fish that arrived at the head of Old River junction in 2013 selected the Old River route (0.71; $\widehat{SE}$ =0.02 and 0.90; $\widehat{SE}$ =0.02 for the first and second groups, respectively; (Table 18). However, in 2013, there was no significant difference in survival between the two routes for either the first or second release group (Table 18), so survival to Chipps Island was insensitive to route choice at the HOR. As stated initially, our sample sizes were not adequate to detect differences between routes unless the effect size was greater than 100%. No tags were detected in Turner Cut in 2013, as mortality upstream of Turner Cut was significant and reduced the number of tags available to enter Turner Cut, so route entrainment at Turner Cut could not be examined for the two periods under the different flows.

Objective 5: Assess the influence of flows and exports on route entrainment

Our fifth objective was to assess the influence of flows and exports on route entrainment of tagged fish. While single-variate analyses found significant effects (α = 0.05) of flow, velocity, the 15-minute change in river stage at OH1 and SJL, flow proportion, exports, and release group on route entrainment at the HOR (Table 23), multi-variable model selection using AIC found the flow model to account for the most variation in route selection at the head of Old River (ΔAIC>4) (Table 23). This analysis suggests that increasing flow at Vernalis (and hence at Lathrop) would decrease the proportion of fish diverted into Old River. As we saw, a lower proportion of fish was diverted into Old River for the first release group with the higher flows (0.71; $\widehat{SE}$ =0.02) than for the second release group with the lower flows (0.90; $\widehat{SE} = 0.02$).

Objective 6: Determine if there was a reduction in survival without the HORB, and the potential reasons for the reduction, if found.

Our sixth objective was to compare survival in 2013 (without the HORB) to that in 2012 (with the HORB) to determine if there was a reduction in survival coincident with not having the HORB installed in 2013. Because survival to Chipps Island was estimated as zero (0) for the second release groups in both 2012 and 2013, we compared only the first release groups across years for this assessment. Total through-Delta survival was lower (P=0.0267) for the first group in 2013 without the HORB (0.02; $\widehat{SE} = 0.01$) than it was for the first release group in 2012 with the HORB (0.05; $\widehat{SE} = 0.01$). Survival from Mossdale to Chipps Island for fish using the San Joaquin River at the HOR was also lower (P=0.0176) in 2013: (0.01; $\widehat{SE} = 0.01$) without the HORB than in 2012 with the HORB (0.05; $\widehat{SE} = 0.01$). Survival from Mossdale to Chipps Island using the Old River route was also lower (P<0.0001) for the first group in 2013 (0.03; $\widehat{SE}$ =0.01) relative to the first group in 2012 (0.16; $\widehat{SE}$ =0.15), but there was high uncertainty associated with the estimate in 2012, as not many fish went down Old River due to the HORB installation that year.

To determine if the decrease in through-Delta and San Joaquin River route survival in 2013 was due to environmental conditions, differences in fish size, or other conditions such as the absence of a HORB, we compared flow, water temperature and exports and fish size between years. We also compared reach specific survival downstream of the HOR between the two years.

Environmental conditions between years were similar: average flows for the first release groups at Vernalis were 3717 cfs in 2013 and 3543 cfs in 2012 (Figure 15 and Figure 18); average water temperatures were 63.2°F in 2013 and 65.6°F in 2012 (Figure 17 and Figure 19); and average exports were 2440 cfs in 2013 and 2999 cfs in 2012 (Figure 16 and Figure 20). Fish size was also similar between years: the fish tagged in 2013 had an average size of 18.2 grams (SD = 2.9) and 115.3 mm FL (SD = 5.9), while in 2012, average fish size was 18.0 grams (SD = 3.7) and 112.8 mm FL (SD = 7.2). In both 2012 and 2013, VEMCO V5 tags were used for the study, which were on average 0.65 grams. The number of dummy-tagged fish that died was similar between years with no mortality in 2012, and only one, mortality during transport and one after being held for 48 hours in 2013. Four of 60 fish examined had stitched organs in 2012 (Errata, this report) while 8 of 89 fish had stitched organs in 2013.

When comparing reach specific survival for reaches downstream of the HOR, we found survival estimates for some reaches were significantly lower for 2013 than for 2012. Survival estimates were 0.36 ($\widehat{SE}$ =0.05) in 2013 and 0.81 ($\widehat{SE}$ =0.02) in 2012 between Lathrop and Stockton (Garwood Bridge) and 0.07 ($\widehat{SE}$ =0.05) in 2013 and 0.49 ($\widehat{SE}$ =0.04) in 2012 between Navy Bridge and the Turner Cut Junction (Appendix 3. and Buchanan et al 2015). Because environmental conditions and fish size were similar between years, but survival was considerably lower in these reaches of the San Joaquin route in 2013 compared to 2012, these data suggest the differences in survival between years may have been because there was no HORB installed in 2013.

One potential mechanism for the decrease in survival in 2013 (without the HORB) relative to 2012 (with the HORB) for the two reaches discussed above may be the lower amount of San Joaquin River flow that stayed in the San Joaquin River downstream of HOR in 2013 when the HORB was absent. And because there is a relationship between flow at Brandt Bridge and survival for the reach between Mossdale and Turner Cut for those fish staying on the San Joaquin River (Figure 21), it seems reasonable to conclude that survival was decreased in 2013 due to the lack of a HORB which reduced flows in this reach. Our conceptual model hypothesized that a decrease in survival at lower flows is from lower flows resulting in slower velocities, which exposes the fish to mortality factors for a longer period of time. The data supported this hypothesized mechanism as the average 15 minute velocities were lower in the San Joaquin River at Brandt Bridge (downstream of upper Old River) for the first half of May in 2013 (0.75 ft/sec) relative to the first half of May in 2012 (1.55 ft/sec) (http://cdec.water.ca.gov/cgi-progs/queryCSV?station_id=BDT&dur_code=E&sensor_num=21&start_date=5/1/12&end_date=5/31/13, accessed 12/19/16).

Another potential hypothesis for reduced survival at lower flows is increased water temperature. Consistent with our conceptual model, water temperature was higher in 2013 than in 2012 on the San Joaquin River downstream of upper Old River, with average daily water temperatures a half of a degree C higher in 2013 than in 2012 (average of 19.8^{o} in 2012 and 20.3^{o} in 2013) for the first 15 days in May at Rough and Ready Island; http://cdec.water.ca.gov/cgi-progs/queryCSV?station_id=RRI&dur_code=D&sensor_num=25&start_date=5/1/2012&end_date=5/31/2013, accessed 12/13/16), which may have contributed to the lower survival in these two reaches.

Our conceptual model also suggested another potential mechanism for lower survival with lower flows and higher water temperatures, and that is a reduction in dissolved oxygen levels (Figure 22. However, this water quality hypothesis was not consistent with our findings from dissolved oxygen measurements in 2012 and 2013. There was no differences in average dissolved oxygen levels between the two years near Stockton at Rough and Ready Island (average for the first 15 days of May was 7.7 mg/l in 2012 and 7.8 mg/l in 2013; E. Siegfried, DWR-DES Environmental Monitoring Program, personal communication, 12/7/16).

Lastly, decreased flows in these reaches in 2013 could have reduced the dilution of any toxics that potentially could have been harmful to salmon (e.g. ammonia from Stockton WTP) and while we did see an increase in mean total ammonia and soluble ammonia ($N0_{3+}N0_2$-N) between Mossdale and Brandt Bridge and between Brandt Bridge and Stockton in 2012 (RM39 Near Louis Park)(Spier et al 2013), we didn't have comparable information for 2013. The possibility of other unknown differences in environmental or fish conditions between the two years prevents a firm conclusion that the survival differences were due primarily to the absence of the HORB in 2013; however, the data are consistent with our expectations of lower survival without the HORB.

Objective 7: Assess the influence of flow and HORB on survival between Mossdale and Jersey Point.

Our seventh objective was to assess the influence of flow on survival between Durham Ferry or Mossdale and Jersey Point without the HOR barrier installed in 2013 and compare it to 2012 and other years when the HORB was present at various Vernalis flows. Because only one tag from the first group was detected at Jersey Point, the estimate of survival from Mossdale to Jersey Point is very uncertain in 2013, and no attempt was made to estimate survival to Jersey Point. If we assume that the single tag detection was a true representation of survival to Jersey Point in 2013 (i.e., detection probability at Jersey Point = 100%), and compare this result to past CWT and AT estimates of survival from Durham Ferry and Mossdale to Jersey Point with the HORB, we see that survival between Mossdale and Jersey

Point in 2013, without the HORB, is less than survival with the HORB at similar flows at Vernalis (in 2012 and other years; Figure 23). Based on this relationship between flow at Vernalis and survival between Durham Ferry or Mossdale and Jersey Point with the HORB, we estimate survival would have been 0.11 between Mossdale and Jersey Point with the HORB installed for the first release group in 2013 (at flows of 3717 at Vernalis), but we only got an estimate of survival to Jersey Point at most of 0.02, which is between 0.01 ($S_{A;}$ survival between Mossdale and Chipps Island for fish in route A) and 0.02 ($S_{A(SD)}$; survival between Mossdale and Turner Cut) (Table 18). Based on the historical regression, we predicted survival from Mossdale to Jersey Point to be 0.09 for the first release group in 2012 at a flow level of 3543 at Vernalis with the HORB installed, and that prediction agrees with the estimate from the tagging data (Buchanan et al. 2015). These data suggest that survival would have been slightly higher to Jersey Point for the first release group in 2013 if the HORB had been installed that year.

Although survival for the first release group in 2013 was lower potentially due to the lack of a HORB, the through-Delta survival of the first release group in 2012 with the HORB was still low (only 0.05), and the second release groups in both 2012 and 2013 resulted in survival estimates to Chipps Island of zero (0), regardless of the HORB status. In addition, the relationship we have observed using many years of data (Figure 23) predicts that survival to Jersey Point would be zero at flows less than 2500 cfs, even with a HORB, and that is what we observed for the second release in 2012 (with the HORB at Vernalis flows of 2327). Survival to Jersey Point was not estimable for the second release in 2013 although it would still be predicted to be 0.0 at Vernalis flows of 1243. Thus, survival is predicted to be low during low flows, even with a HORB.

High mortality from low flows in the San Joaquin River between Durham Ferry and the HOR makes it is difficult to estimate the benefits of the HORB at lower Vernalis flows because of reduced effective sample sizes downstream of the HORB combined with low survival in downstream reaches. On a population level, high mortality upstream of the head of Old River with lower flows limits the potential of the HORB to increase overall survival from the San Joaquin River and its tributaries through the Delta because relatively few fish survive to the HORB.

To obtain high survival (0.50 or above) through the reach between Mossdale and Turner Cut for fish staying on the San Joaquin River, it appears that flows would need to be greater than 3000 cfs at Brandt Bridge (Figure 21). Installing the HORB is one mechanism to increase flows at Brandt Bridge up to flows of approximately 7000 cfs. The HORB cannot be installed at San Joaquin River flows at Vernalis greater than 5000 cfs or operated at flows greater than 7000 cfs at Vernalis. To obtain high levels of survival (0.40) between Durham Ferry or Mossdale and Jersey Point (Figure 23), it appears that flows of 6500 cfs at Vernalis, with the HORB installed are needed.

Objective 8: Assess the role and influence of flow and exports on survival in downstream reaches of the Delta.

Our last objective (8) was to assess the role and influence of flow and exports on survival in downstream reaches (e.g. between Jersey Point and Chipps Island, or between Turner Cut and Chipps Island). To improve survival all the way to Chipps Island, we need also understand the factors influencing survival between Jersey Point and Chipps Island. One benefit of using acoustic tags is that survival can be estimated directly between Jersey Point and Chipps Island. With CWT fish only survival to Jersey

Point could be estimated because the survival estimates were based on recovery rates at Chipps Island and in the ocean fishery for upstream releases at Durham Ferry or Mossdale relative to downstream releases at Jersey Point. However, we have only two years of AT data encompassing 6 data points (2011 [4] and 2012 [2]) for assessing survival between Jersey Point and Chipps Island and the potential factors influencing it. The study design in 2013 was developed to provide an estimate of survival to Jersey Point, and from Jersey Point to Chipps Island; however, high mortality upstream of Old River and high rates of selecting the Old River route resulted in sparse data in the lower San Joaquin River route, including at Jersey Point, and it was not possible to estimate survival either to or from Jersey Point in 2013. The six data points available to study a relationship between flow and exports and survival to Jersey Point are inadequate for drawing reliable conclusions.

In an effort to look at survival in the downstream reaches of the Delta we used survival estimates from Turner Cut to Chipps Island between 2010 and 2012. In 2013, we were not able to estimate survival from Turner Cut to Chipps Island for either of the two releases, resulting in thirteen data points (13). A preliminary scatter plot for data from 2010 to 2012 of survival from Turner Cut to Chipps Island suggests survival in this reach is negatively associated with combined exports at the CVP and SWP (Figure 24). More data and modeling of multiple factors are needed before firm conclusions can be made from this data. While salmon survival studies were conducted in 2014 and 2015 and analyses is forthcoming, it is not likely that all the results from those years will further inform this relationship. Both 2014 and 2015 were drought years, thus it is likely survival was so poor in upstream areas that measuring survival in downstream reaches of the Delta was not possible. However, in 2015, some releases were made near Medford Island and they may help us to better estimate survival in these lower reaches even during the drought. A similar study design, with both an upstream and downstream release, was used in 2016, providing yet more potential information. A multi-year analysis (2010-2013) of the AT salmon studies are ongoing and may shed further light on these topics.

Conclusions

In summary, the goals of our study were met such that we were able to determine there were differences in survival between release groups in 2013 and it was associated with changes in flow and water temperature. The results in 2013 supported our hypotheses that survival through the Delta is lower during conditions of lower flows and higher water temperatures. We also observed somewhat lower survival in 2013 than in 2012 (first release groups from each year), at similar flows at Vernalis, water temperatures and exports, supporting our hypothesis that survival is higher with the HORB (2012) than without the HORB (2013).

We had predicted that survival would be reduced in 2013 without a HORB, because less flow would stay in the mainstem San Joaquin River (downstream of the Old River junction) without a HORB, and result in the tidal prism moving further upstream. We observed less flow remaining in the San Joaquin River downstream of the HOR junction and more negative flows associated with tidal variation near Stockton in 2013 (no HORB) than in 2012 (HORB), which agrees with our expectations of the effect of the HORB on hydrodynamics (Figure 25). We were not able to assess if the change in the tidal prism (which was further upstream in 2013) affected the proportion of fish entering Turner Cut between years, as there were not enough fish that arrived at Turner Cut in 2013 to make an estimate. However, in 2012 a higher proportion of fish entered Turner Cut during the second release (0.16; $\widehat{SE}$ =0.11), with lower flows than during the first release in 2012 (0.11; $\widehat{SE}$ =0.03) with higher flows (Buchanan et al., 2015). Both releases in 2012 had the HORB installed. These data in 2012 support our hypothesis that when flows are lower (and the tidal prism is further upstream), a larger proportion of fish enter Turner Cut. This was also the case at the HOR in 2013 without the barrier; at lower flows (second release group) a higher proportion of tagged fish entered Old River (0.90 $\widehat{SE}$ =0.02) than at higher flows (first release group: 0.71 $\widehat{SE}$ =0.02)(Table 18).

Lastly, data also support the hypothesis that with lower flows at Stockton, water temperatures were increased and water velocities were decreased. It is possible that water quality in 2013 was reduced from an increase in ammonia concentrations from discharges from the SWTP, but we didn't have the data to evaluate it. Further study is needed on the role of poor water quality on salmon survival through the Delta.

Survival to Chipps Island for the early (first) release groups was low for both 2012 and 2013, and was zero for the late (second) release groups in both 2012 and 2013, regardless of the status of the HORB. It appears that having the HORB at low flows (of less than 2500 cfs) does not result in markedly better survival to Chipps Island. Without higher flows or increases in flow to more than 3000 cfs at Brandt Bridge, either with or without a HORB, survival will likely continue to be low from Durham Ferry or Mossdale to the Turner Cut junction. Furthermore survival in downstream reaches, from Turner Cut to Chipps Island, also needs to be improved, in addition to needed improvements in the these upstream reaches. Gathering more data in the lower reaches of the Delta, may further determine if reducing exports will increase survival in the downstream reaches as suggested by data obtained between 2010 and 2012.

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Figures

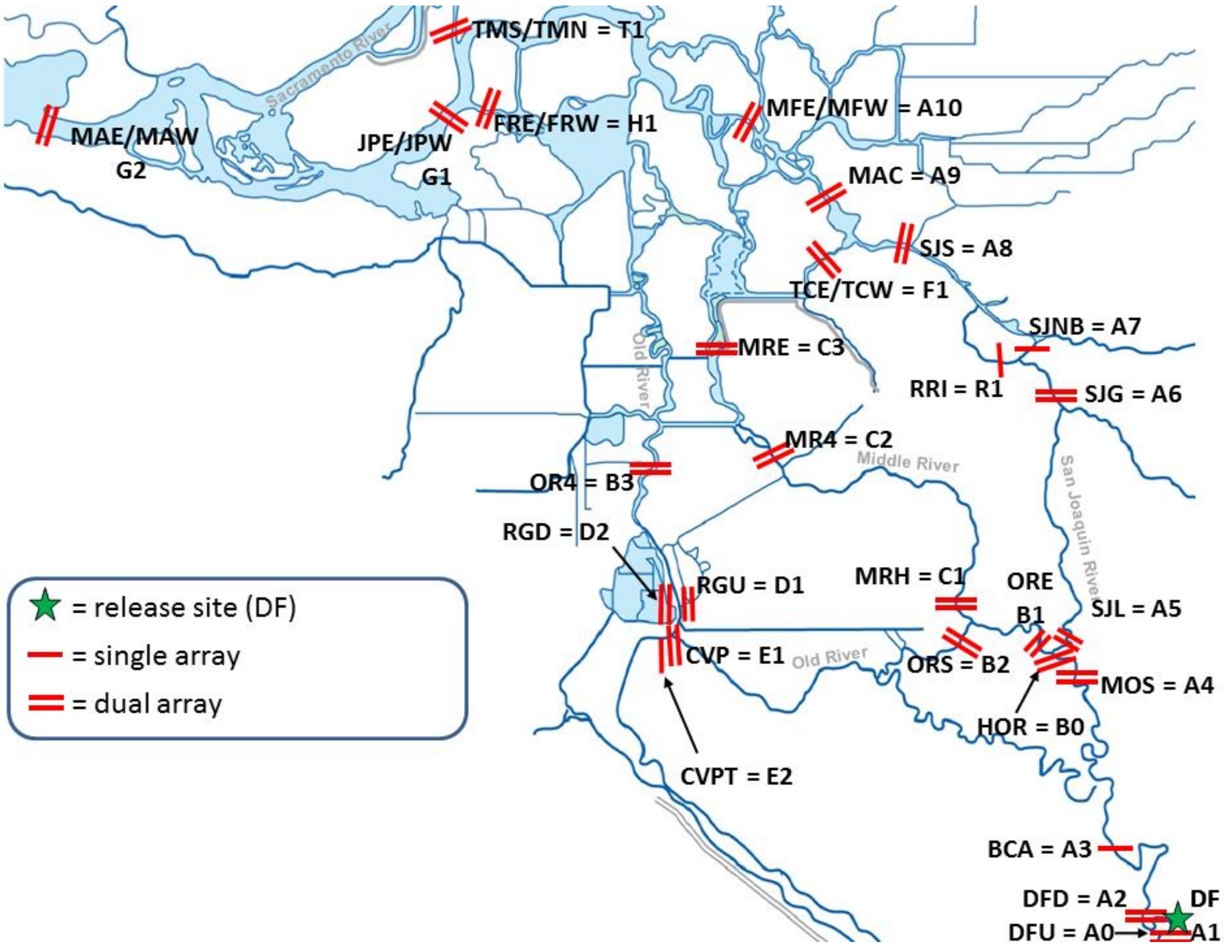


Figure 1. Locations of acoustic receivers and release site used in the 2013 Chinook tagging study, with site code names (3- or 4-letter code) and model code (letter and number string). Site A1 is the release site at Durham Ferry.

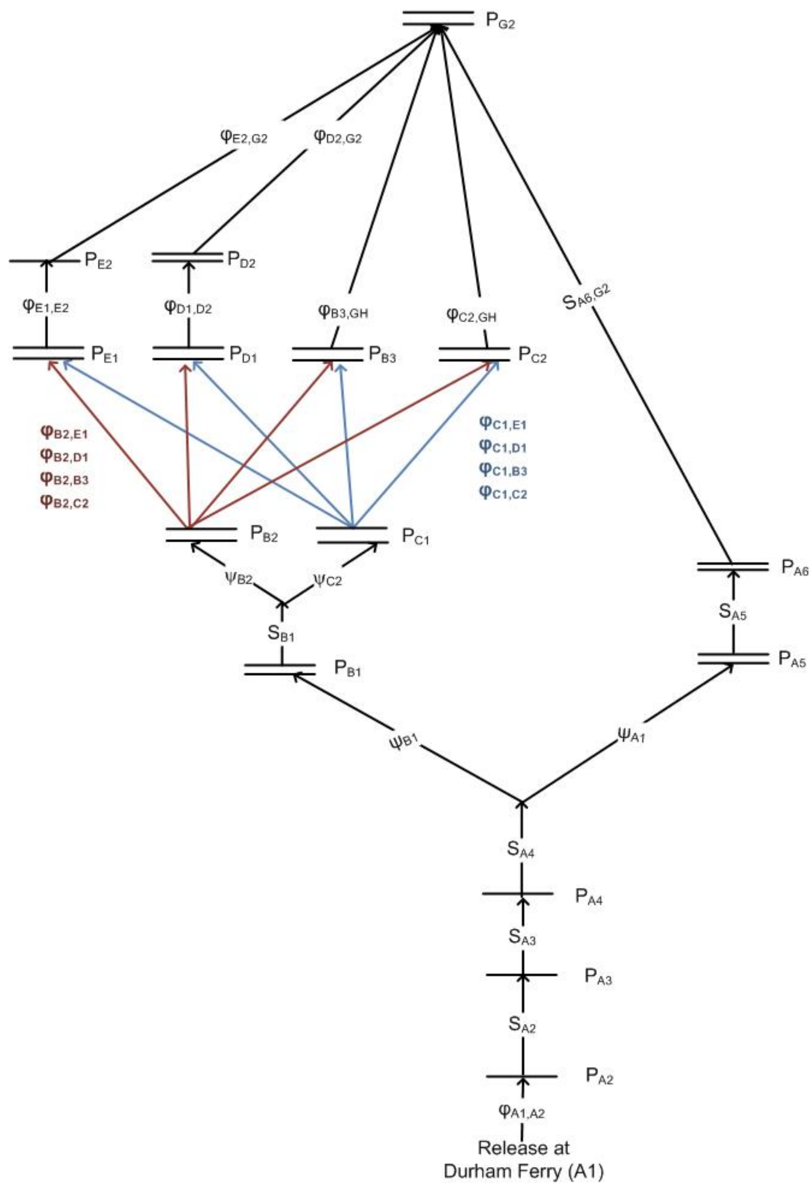


Figure 2. Schematic of 2013 mark-recapture Submodel I with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 1. Migration pathways to sites B3 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.

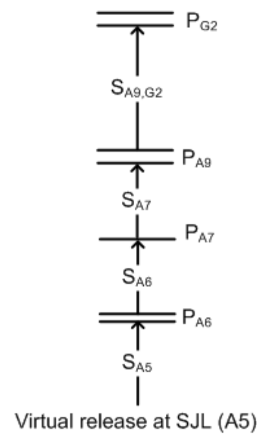


Figure 3. Schematic of 2013 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 1.

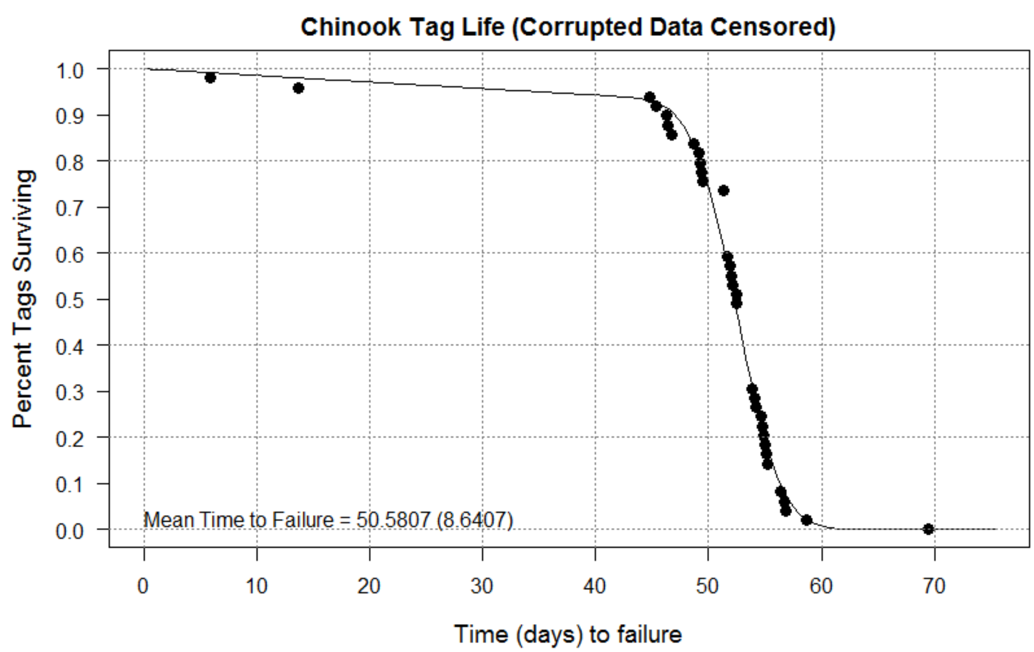


Figure 4. Observed tag failure times from the 2013 tag-life study of VEMCO V5 tags, and fitted four-parameter vitality curve. Failure times were right-censored for tags with final detections observed within 60 minutes of the unmooring of the hydrophone.

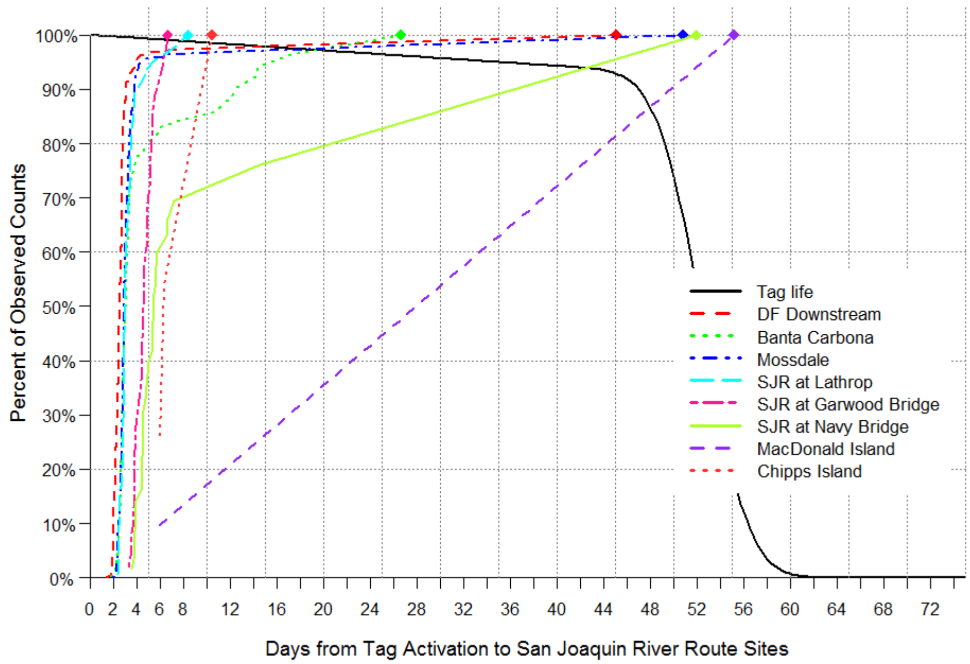


Figure 5. Four-parameter vitality survivorship curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the San Joaquin River route to Chipps Island in 2013, including detections that may have come from predators.

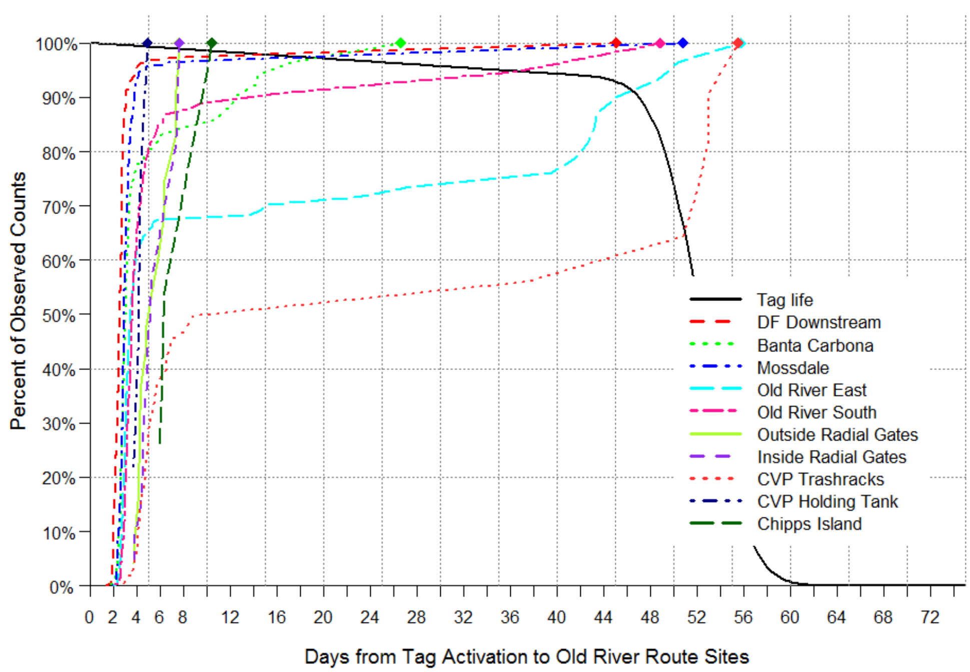


Figure 6. Four-parameter vitality survivorship curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the Old River route to Chipps Island in 2013, including detections that may have come from predators.

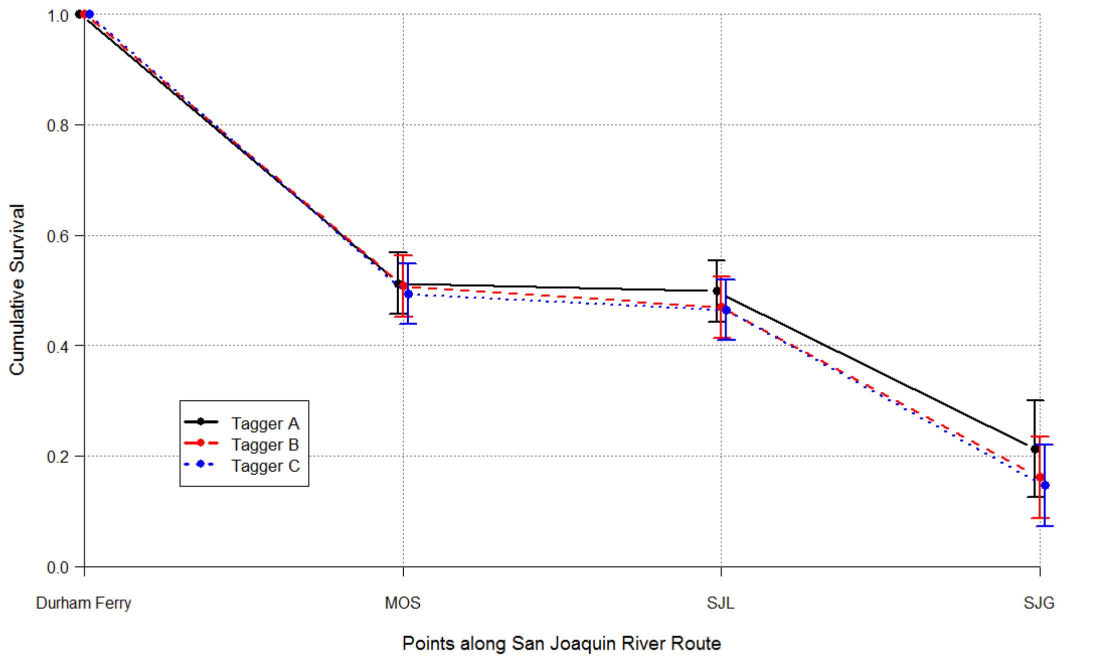


Figure 7. Cumulative survival from release at Durham Ferry to various points along the San Joaquin River route, by tagger. Error bars are 95% confidence intervals.

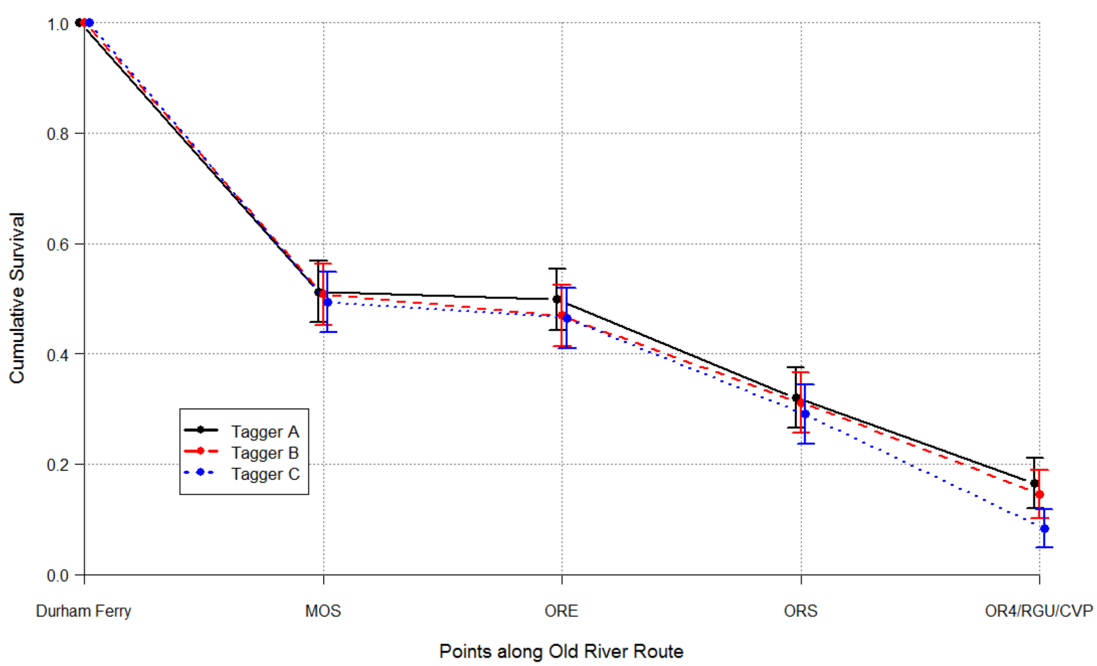


Figure 8. Cumulative survival from release at Durham Ferry to various points along the Old River route, by tagger. Error bars are 95% confidence intervals.

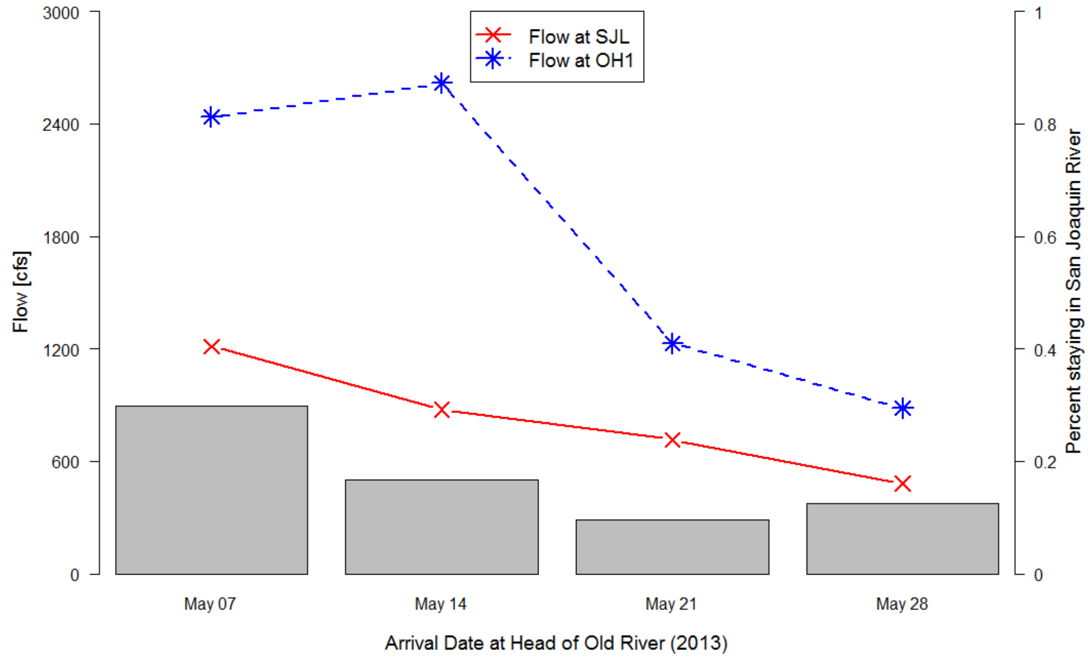


Figure 9. The observed proportion of acoustic-tagged juvenile Chinook Salmon that remained in the San Joaquin River at the head of Old River during the 2013 tagging study (bars, representing weekly periods), and the measured flow at the SJL and OH1 gaging stations at the estimated time of fish arrival at the junction, averaged over fish.

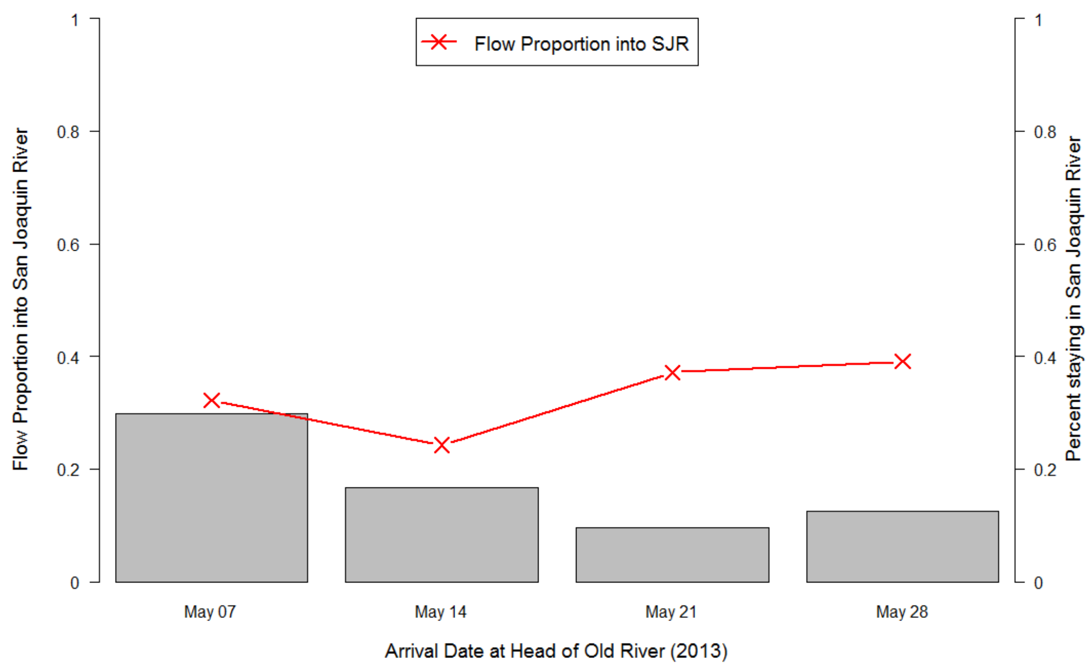


Figure 10. The observed proportion of acoustic-tagged juvenile Chinook Salmon that remained in the San Joaquin River at the head of Old River during the 2013 tagging study (bars, representing weekly periods), and the measured flow proportion entering the San Joaquin River at the estimated time of fish arrival at the junction, averaged over fish.

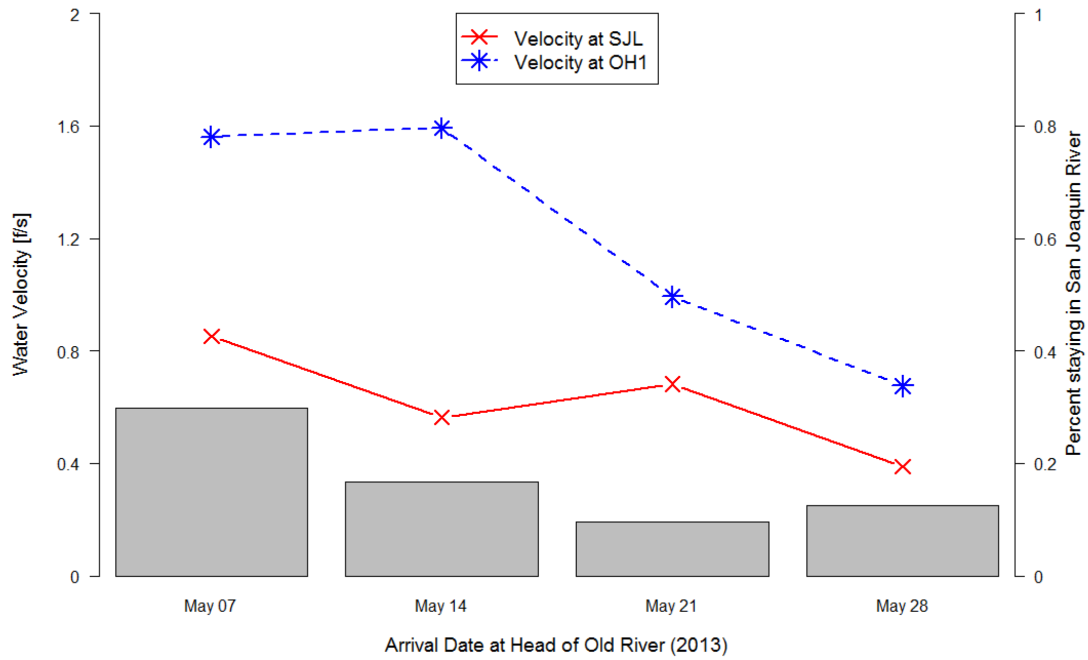


Figure 11. The observed proportion of acoustic-tagged juvenile Chinook Salmon that remained in the San Joaquin River at the head of Old River during the 2013 tagging study (bars, representing weekly periods), and the measured water velocity at the SJL and OH1 gaging stations at the estimated time of fish arrival at the junction, averaged over fish.

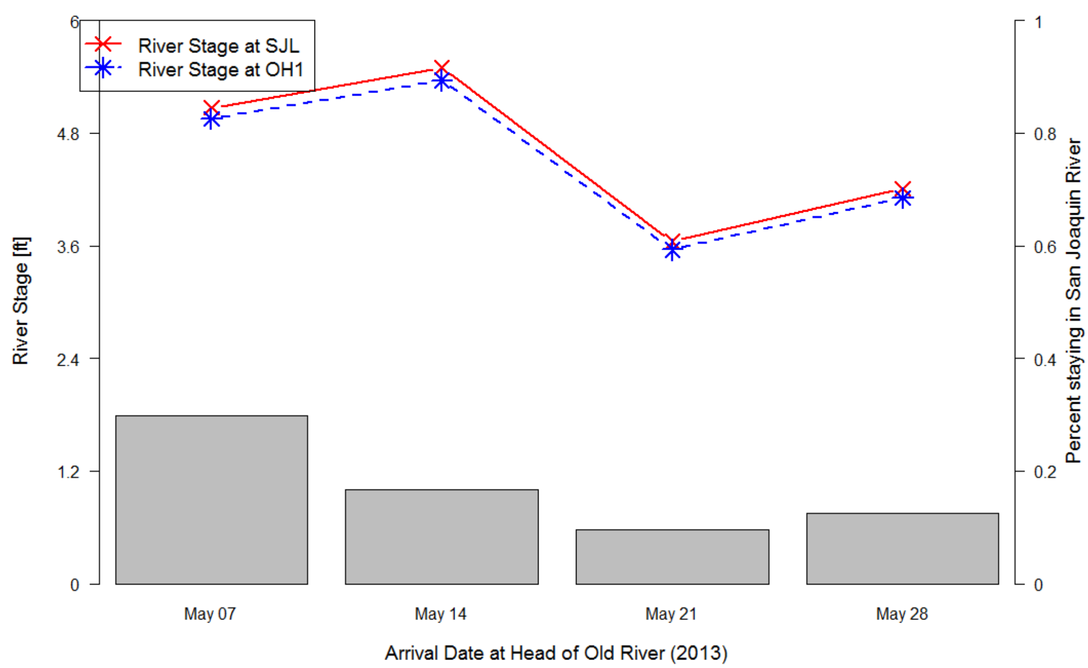


Figure 12. The observed proportion of acoustic-tagged juvenile Chinook Salmon that remained in the San Joaquin River at the head of Old River during the 2013 tagging study (bars, representing weekly periods), and the measured river stage at the SJL and OH1 gaging stations at the estimated time of fish arrival at the junction, averaged over fish.

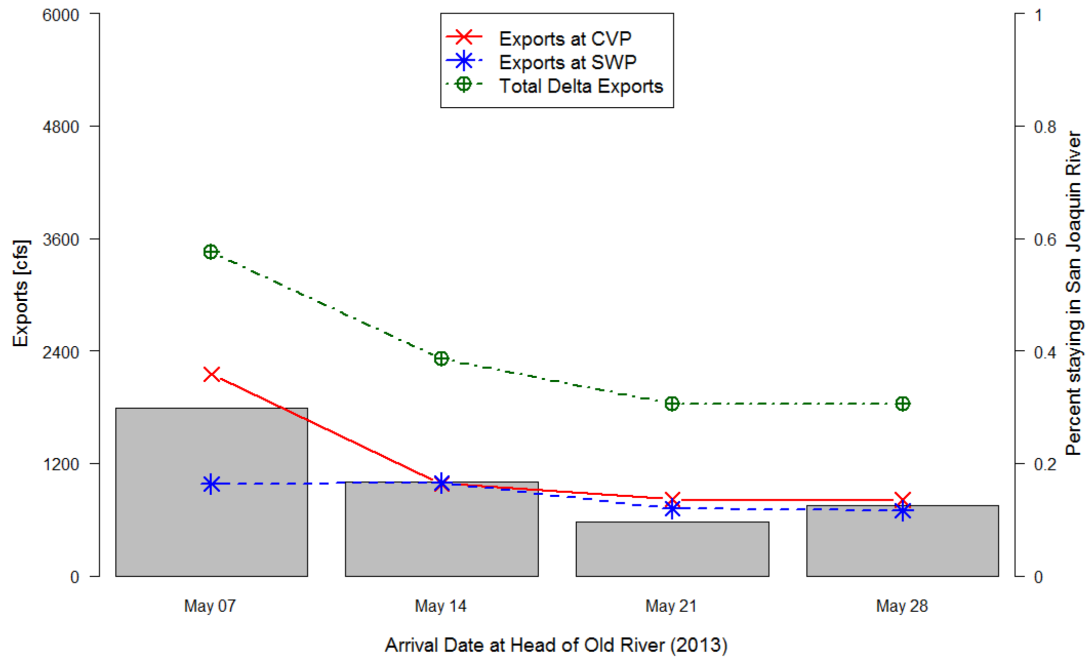


Figure 13. The observed proportion of acoustic-tagged juvenile Chinook Salmon that remained in the San Joaquin River at the head of Old River during the 2013 tagging study (bars, representing weekly periods), and the measured daily export rate at CVP, SWP, and total in the Delta on the estimated day of fish arrival at the junction, averaged over fish.

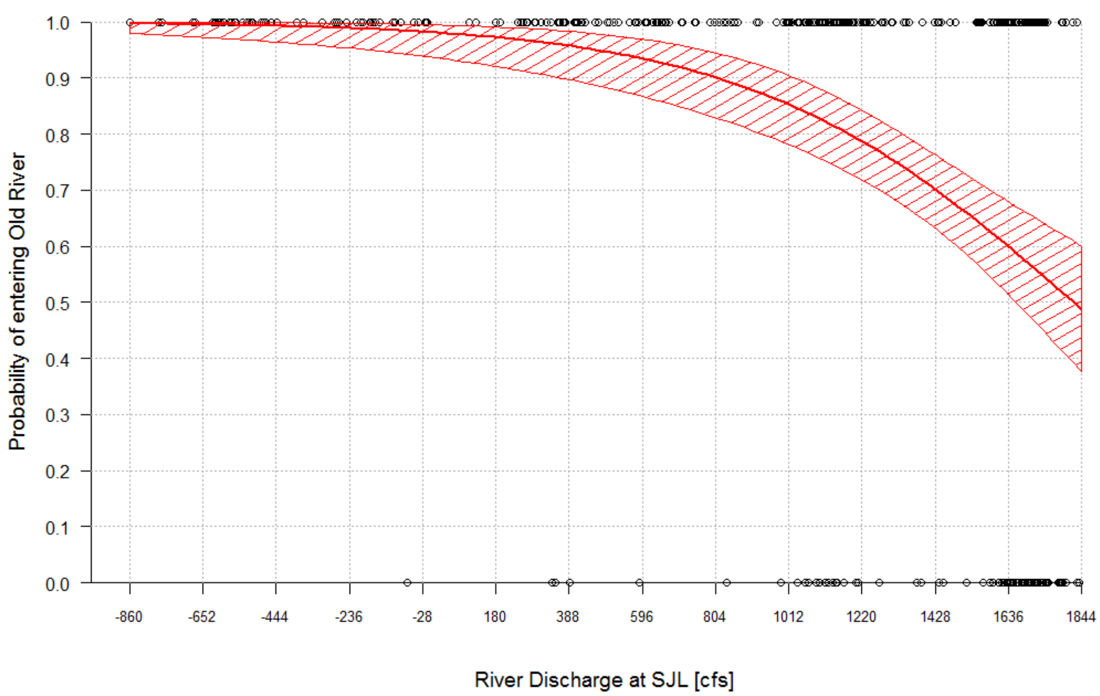


Figure 14. Predicted probability of entering Old River at its head versus river discharge (flow) measured at the SJL gaging station in the San Joaquin River, with 95% confidence bands, in 2013.

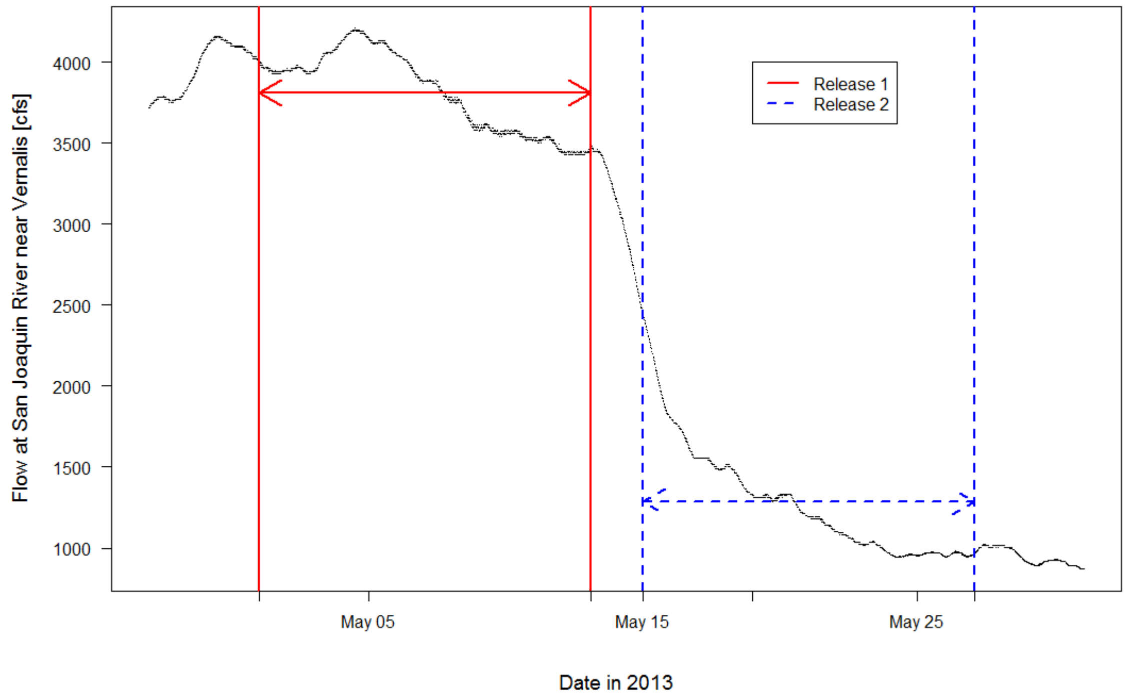


Figure 15. River discharge (flow) at Vernalis during 2013 study. Vertical lines represent period from first day of release to 8 days after last day of release. Arrow heights indicates mean flow during travel period.

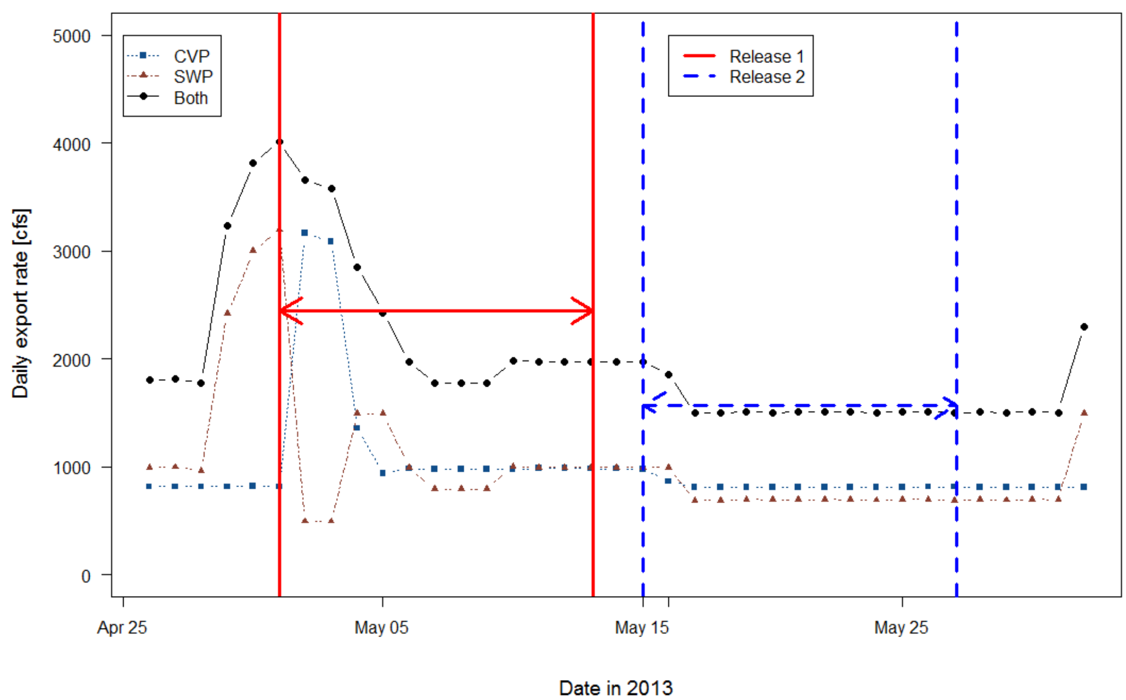


Figure 16. Daily export rate (cfs) at CVP and SWP during 2013 study. Vertical lines represent period from first day of release to 8 days after last day of release. Arrow height indicates mean combined export rate during travel period.

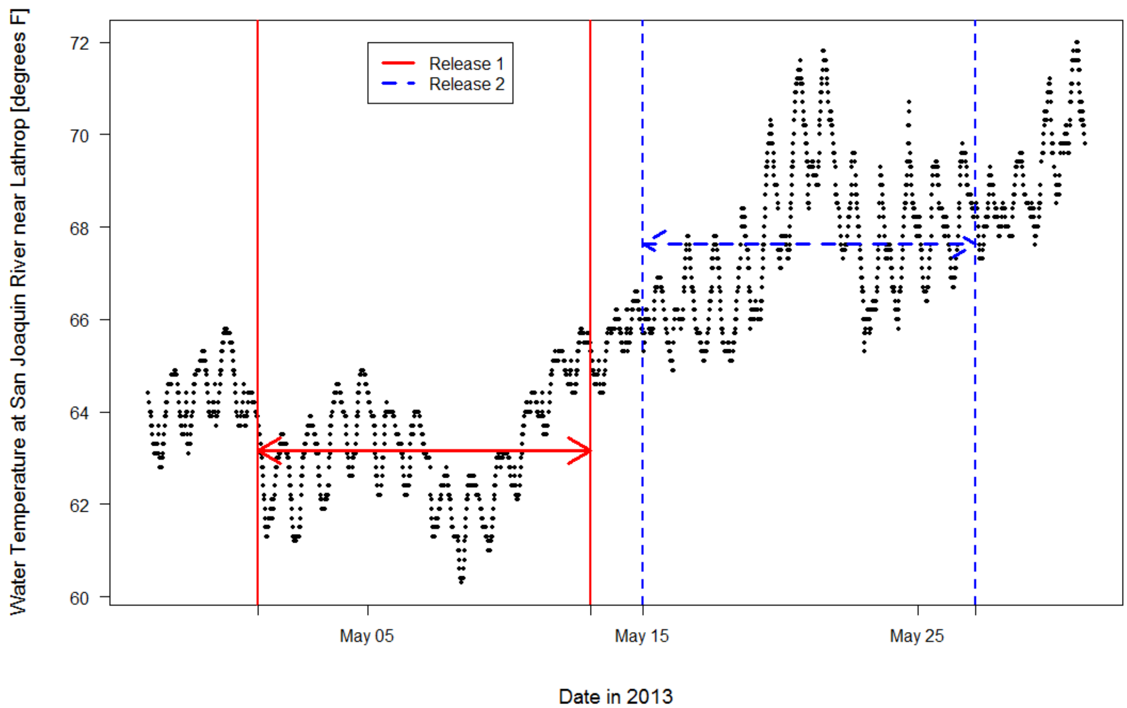


Figure 17. Temperature (°F) at the San Joaquin River gaging station near Lathrop during 2013 study. Vertical lines represent period from first day of release to 8 days after last day of release. Arrow height indicates mean temperature during travel period.

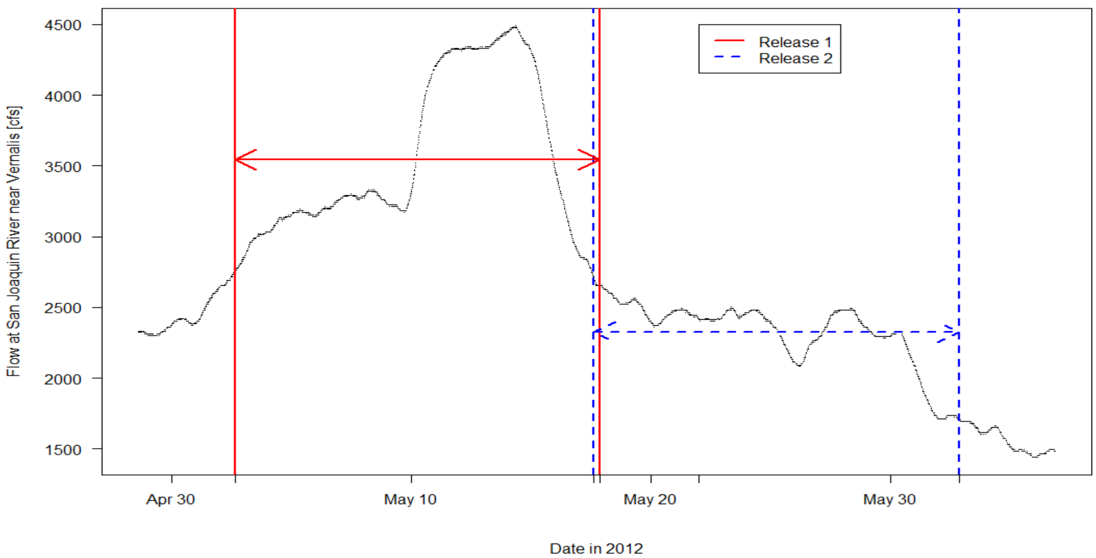


Figure 18. River discharge (flow) at Vernalis during 2012 study. Vertical lines represent period from first day of release to 8 days after last day of release. Arrow heights indicates mean flow during travel period.

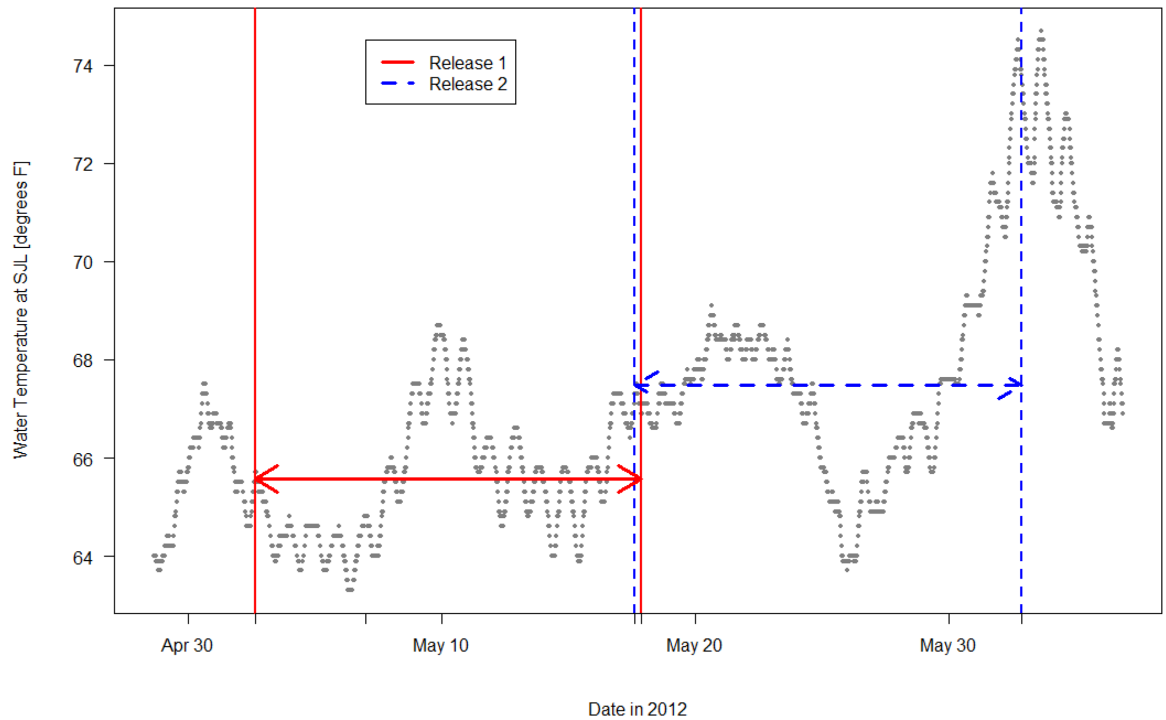


Figure 19. Temperature (°F) at the San Joaquin River gaging station near Lathrop during 2012 study. Vertical lines represent period from first day of release to 8 days after last day of release. Arrow height indicates mean temperature during travel period

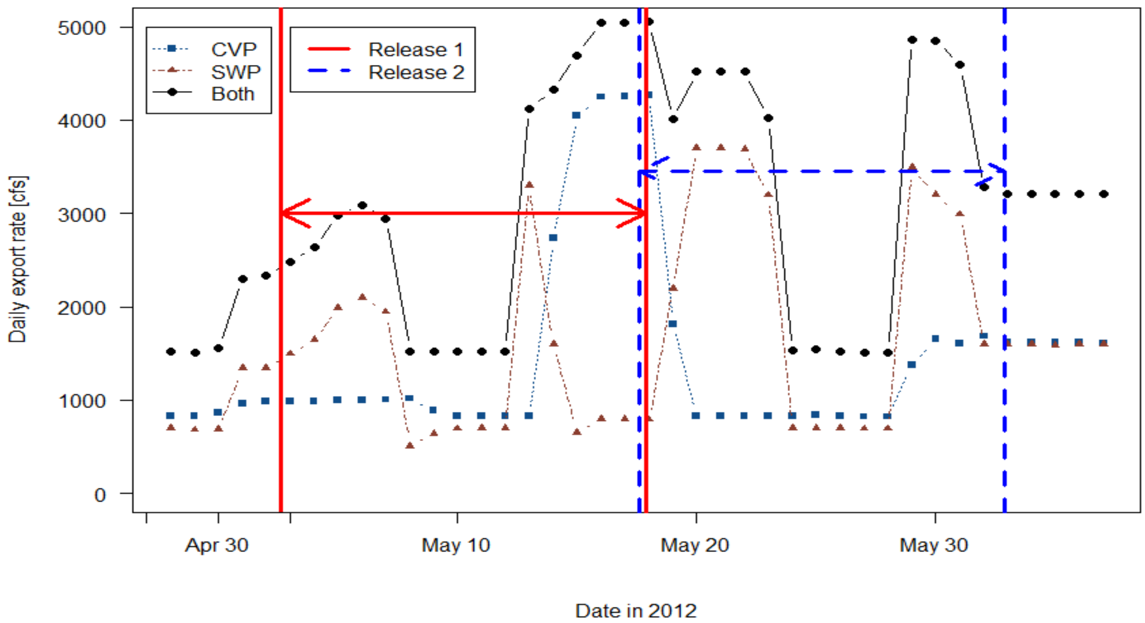


Figure 20. Daily export rate (cfs) at CVP and SWP during 2012 study. Vertical lines represent period from first day of release to 8 days after last day of release. Arrow height indicates mean combined export rate during travel period.

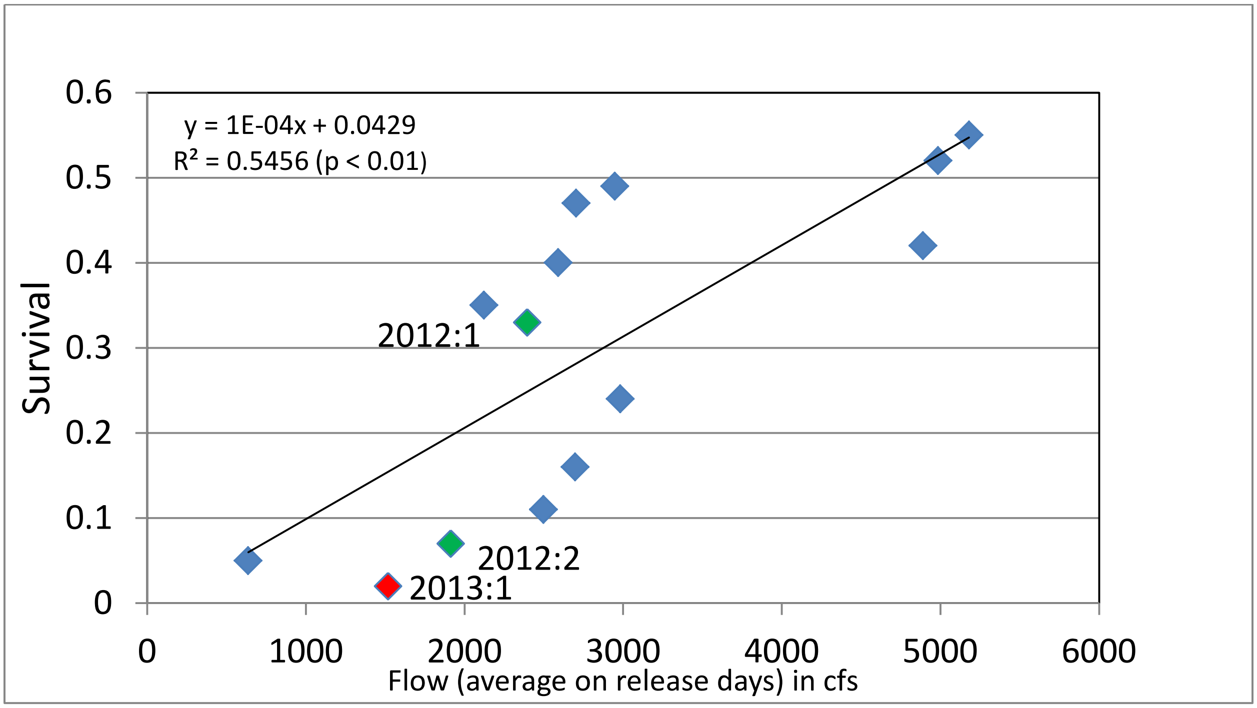


Figure 21. Relationship between flow on the San Joaquin River at Brandt Bridge and survival (SA(SD)) on the San Joaquin River between Mossdale and Turner Cut junction between 2009 and 2013. The first release in 2012 is denoted as 2012:1 (green diamond) and the first release in 2013 is denoted as 2013:1 (red diamond). Survival was not estimable for the second release group in 2013 (Table 18). Data for other years obtained from SJRGA 2010, SJRGA 2011, SJRGA 2013, Buchanan et al 2015).

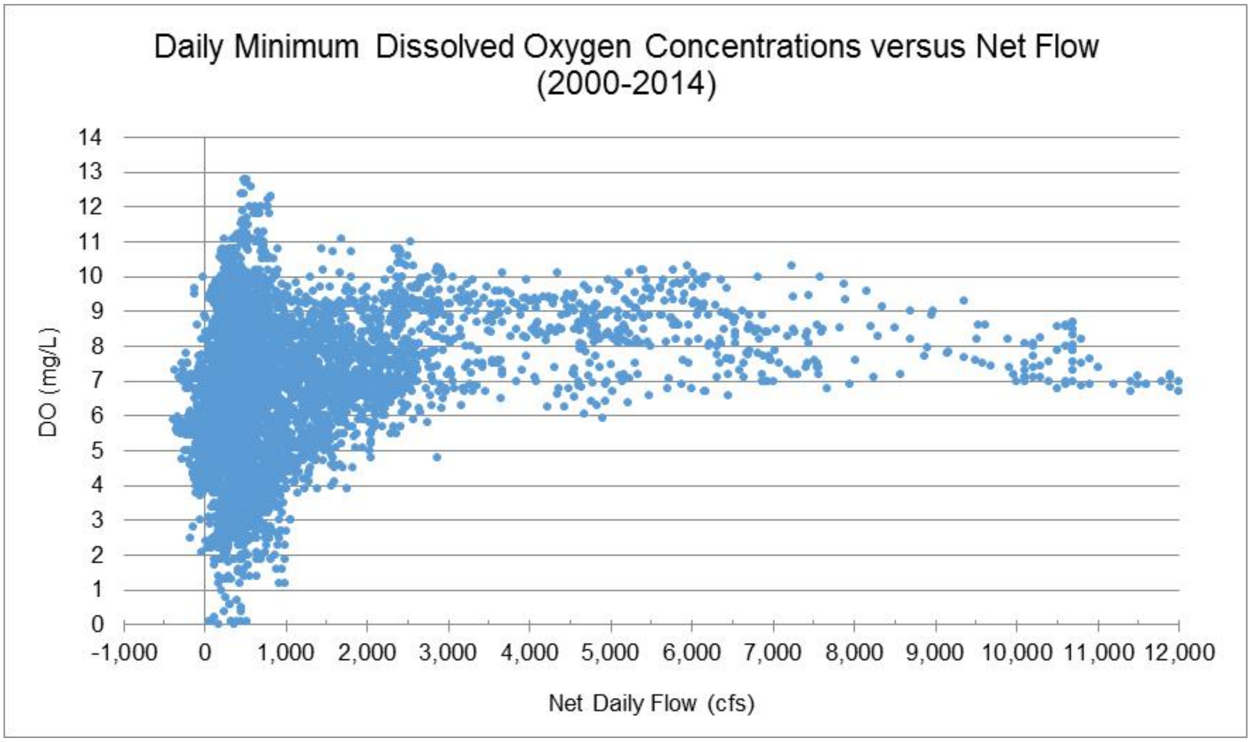


Figure 22. This chart displays the relationship between daily minimum dissolved oxygen concentrations (mg/L) measured at the Rough and Ready Island monitoring station versus net daily flow (cfs) measured at the U.S. Geological Survey Garwood Flow Station located upstream of the Stockton DWSC. Source: https://www.epa.gov/sites/production/files/2015-07/documents/5-stockton-do-tmdl-implementation-report-2015-06-15.pdf (accessed 6/13/16).

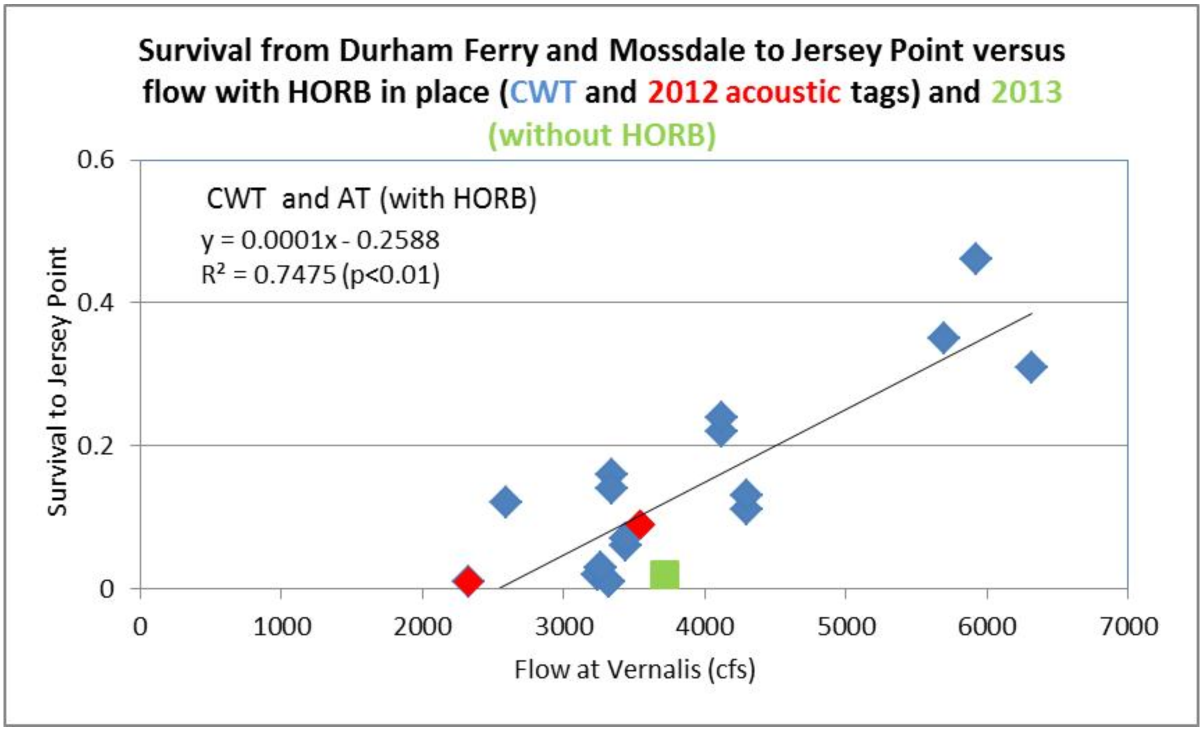


Figure 23. Relationship between survival from Durham Ferry and Mossdale to Jersey Point between 1994 and 2013 and flow at Vernalis with the HORB in place (with the exception of 2013 data [green square]. Data from 1994, 1997, 2000 – 2004 used CWT's, whereas 2012 and 2013 used AT's.

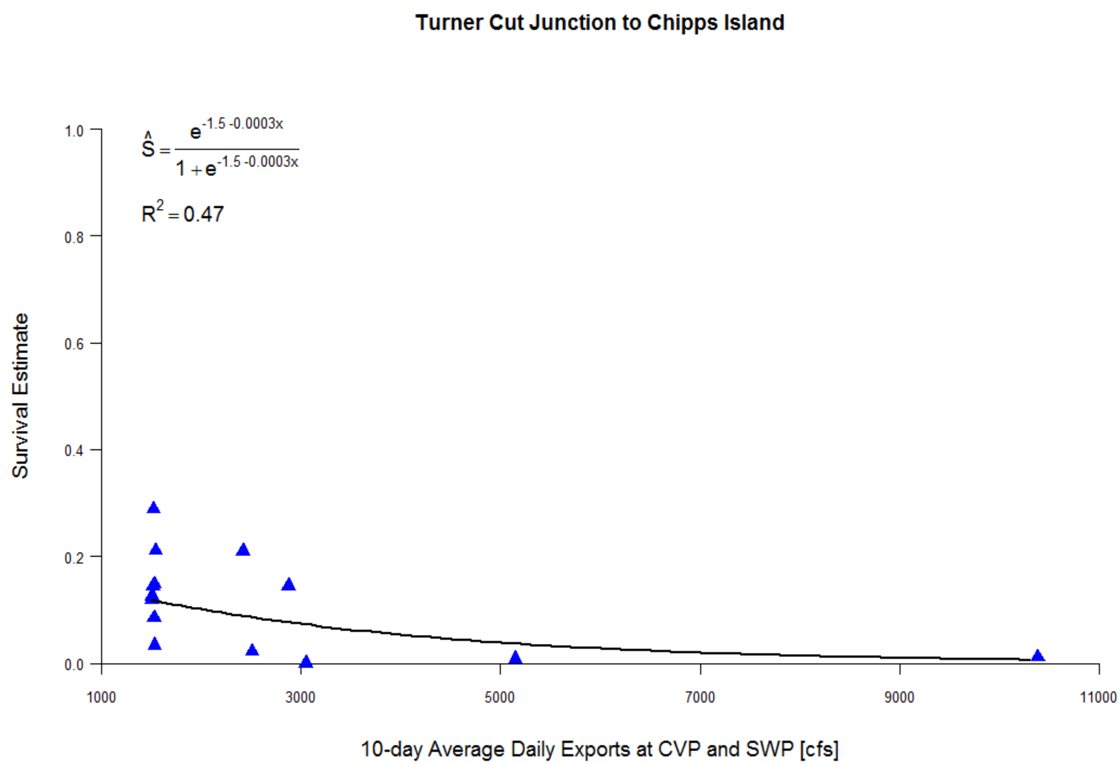
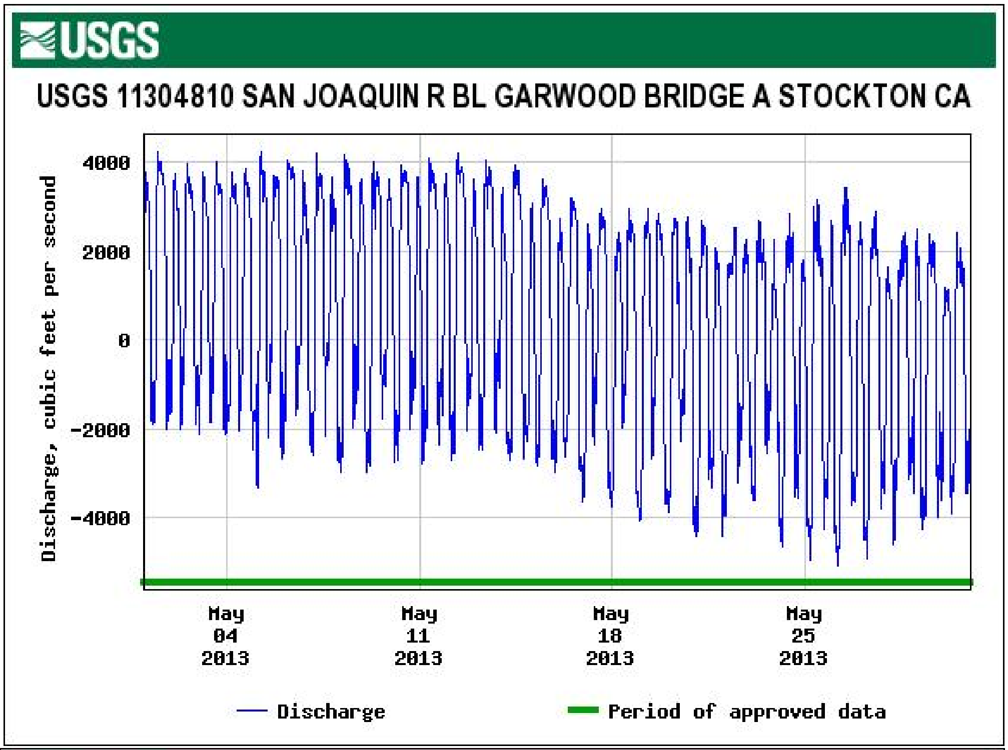


Figure 24. Relationship between survival (Turner Cut to Chipps Island) and combined exports at the CVP and SWP. Data obtained in 2010 (7), 2011 (4) and 2012 (1). (SJRGA 2011, SJRGA 2013 and Buchanan et al 2015).



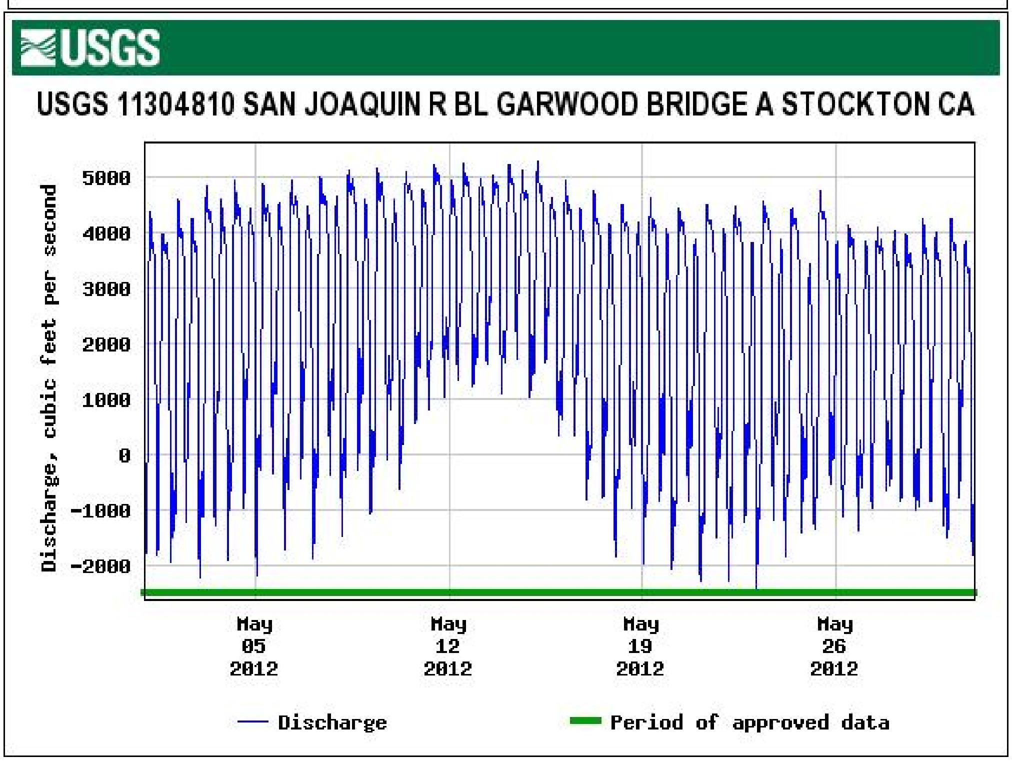


Figure 25. Daily discharge every 15 minutes at Garwood Bridge in Stockton during May 2013 (no HORB; top graph) and 2012 (HORB; bottom graph). Note scales are not equal on the y axis between years. Source: http://nwis.waterdata.usgs.gov/nwis/uv?cb_00060=on&format=gif_default&site_no=11304810&period=&begin_date=2012-05-01&end_date=2012-05-30 (accessed 6/14/16).

Tables

Table 1. Tagging, transport and holding date and times and the number released for Chinook Salmon as part of Salmon Survival Study. Fish released over a 24 hour period after being held for a minimum of 24 hours.

Tagging Date/Time	Transport Date/ Time	Transport Tank	Start Holding Time	Total released (A+B+C+D)	A Date/Time	A Number released	B Date/Time	B Number released	C Date/Time	C Number released	D Date/time	D Number released	Dummy tagged
4/30/2013	4/30/13; 1400-1526	1	4/30/13; 1642	120					5/2; 0658	3	5/2; 1257	30	15
		2			5/1; 1903	30	5/2; 0058	30	5/2; 0658	27			
5/1/2013	5/1/13; 1333-1500	1	5/1/13; 1605	120					5/3; 0703	3	5/3; 1301	30	15
		2			5/2; 1659	30	5/3/13; 0058	30	5/3; 0703	27			
5/2/2013	5/2/13; 1318 - 1503	1	5/2/12; 1540	120					5/4; 0700	3	5/4; 1301	30	15
		2			5/3; 1859	30	5/4; 0100	30	5/4; 0700	27			
5/3/2013	5/3/13; 1324 - 1451	1	5/3/13; 1550	117					5/5; 0658	3	5/5; 1303	27	30
		2			5/4; 1859	30	5/5; 0057,0058	30	5/5; 0658	27			
5/14/2013	5/14/13; 1351 - 1510	1	5/14/13; 1600	120					5/16; 0650	3	5/16; 1300	30	15
		2			5/15; 1901	30	5/16; 0101	30	5/16; 0650	27			
5/15/2013	5/15/13; 1350 - 1515	1	5/15/13; 1607	120					5/17; 0651	3	5/17; 1300	30	15
		2			5/16; 1902	30	5/17; 0058	30	5/17; 0651	27			
5/16/2013	5/16/13; 1447 - 1610	1	5/16/13; 1655	120					5/18; 0700	3	5/18; 1304	30	15
		2			5/17; 1859	30	5/18; 0059	30	5/18; 0700	27			
5/17/2013	5/17/13; 1355 - 1515	1	5/15/13; 1604	113					5/19; 0701	3	5/19; 1302	23	30
		2			5/18; 1859	30	5/19; 0058	30	5/19; 0701	27			

Table 2. Characteristics assessed for Chinook Salmon smolt condition and short-term survival

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

Table 3. Names and descriptions of receivers and hydrophones used in the 2013 Chinook Salmon tagging study, with receiver codes used in Figure 1, the survival model (Figures 2, 3), and in data processing by the United States Geological Survey (USGS). The release site was located at Durham Ferry.

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
San Joaquin River near Durham Ferry upstream of the release site, upstream node	37°41'10.80"N	121°15'24.12"W	DFU1	A0a	300856 (unit stolen)
San Joaquin River near Durham Ferry upstream of the release site, downstream node	37°41'13.56"N	121°15'26.04"W	DFU2	A0b	300857
San Joaquin River near Durham Ferry; release site (no acoustic hydrophone located here)	37°41'13.24"N	121°15'48.41"W	DF	A1	
San Joaquin River near Durham Ferry downstream of the release site, upstream node	37°41'32.16"N	121°16'15.24"W	DFD1	A2a	300858
San Joaquin River near Durham Ferry downstream of the release site, downstream node	37°41'37.41"N[a]	121°16'13.47"W[a]	DFD2	A2b	460010/460021
San Joaquin River near Banta Carbona	37°43'39.42"N	121°17'55.02"W	BCA	A3	300859
San Joaquin River near Mossdale Bridge, upstream node	37°47'33.06"N	121°18'25.62"W	MOSU	A4a	300860
San Joaquin River near Mossdale Bridge, downstream node	37°47'36.18"N	121°18'24.48"W	MOSD	A4b	300861
San Joaquin River upstream of Head of Old River, upstream node (not used in survival model)	37°48'20.19"N[a]	121°19'10.38"W[a]	HORU	B0a	300862/450048
San Joaquin River upstream of Head of Old River, downstream node (not used in survival model)	37°48'19.11"N[a]	121°19'14.37"W[a]	HORD	B0b	300863/455000
San Joaquin River near Lathrop, upstream	37°48'38.70"N[a]	121°19'16.56"W[a]	SJLU	A5a	300864/300865
San Joaquin River near Lathrop, downstream	37°48'38.85"N[a]	121°19'14.49"W[a]	SJLD	A5b	450020/450023
San Joaquin River near Garwood Bridge, upstream	37°56'06.54"N[a]	121°19'48.21"W[a]	SJGU	A6a	450045/300930
San Joaquin River near Garwood Bridge, downstream	37°56'07.32"N[a]	121°19'49.56"W[a]	SJGD	A6b	450046/300931
San Joaquin River at Stockton Navy Drive Bridge	37°56'48.30"N	121°20'22.02"W	SJNB	A7	300875
Burns Cutoff at Rough and Ready Island (not used in survival model)	37°56'24.72"N	121°21'3.66"W	RRI	R1	300876
San Joaquin River Shipping Channel, upstream (not used in survival model)	37°59'41.70"N	121°26'17.52"W	SJSU	A8a	300881
San Joaquin River Shipping Channel, downstream (not used in survival model)	37°59'43.86"N	121°26'20.64"W	SJSD	A8b	300882
San Joaquin River at MacDonald Island, upstream	38°01'04.86"N[a]	121°27'45.93"W[a]	MACU	A9a	300878/300879
San Joaquin River at MacDonald Island, downstream	38°01'26.34"N[a]	121°27'58.29"W[a]	MACD	A9b	300883/300884
San Joaquin River near Medford Island, east	38°03'11.07"N[a]	121°30'41.07"W[a]	MFE	A10a	300885/300886
San Joaquin River near Medford Island, west	38°03'13.44"N[a]	121°30'47.43"W[a]	MFW	A10b	300887/300888

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

Table 3. (Continued)

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
Old River East, near junction with San Joaquin, upstream	37°48'41.85"N[a]	121°20'14.52"W[a]	OREU	B1a	300866/300867
Old River East, near junction with San Joaquin, downstream	37°48'43.65"N[a]	121°20'08.10"W[a]	ORED	B1b	450021/450022
Old River South, upstream	37°49'13.92"N	121°22'39.42"W	ORSU	B2a	300868
Old River South, downstream	37°49'12.00"N	121°22'40.14"W	ORSD	B2b	300869
Old River at Highway 4, upstream	37°53'37.89"N[a]	121°34'01.53"W[a]	OR4U	B3a	300900/300901
Old River at Highway 4, downstream	37°53'42.15"N[a]	121°33'59.64"W[a]	OR4D	B3b	300902/300903
Middle River Head, upstream	37°49'29.28"N	121°22'48.60"W	MRHU	C1a	300870
Middle River Head, downstream	37°49'29.94"N	121°22'50.76"W	MRHD	C1b	300871
Middle River at Highway 4, upstream	37°53'45.48"N	121°29'36.24"W	MR4U	C2a	300898
Middle River at Highway 4, downstream	37°53'45.96"N	121°29'33.72"W	MR4D	C2b	300899
Middle River at Empire Cut, upstream receiver (not used in survival model)	37°56'28.38"N	121°31'57.36"W	MREU	C3a	300873
Middle River at Empire Cut, downstream receiver (not used in survival model)	37°56'34.26"N	121°31'54.48"W	MRED	C3b	300872
Radial Gate at Clifton Court Forebay, upstream (in entrance channel to forebay), array 1	37°49'48.09"N	121°33'23.80"W	RGU1	D1a	300894
Radial Gate at Clifton Court Forebay, upstream, array 2	37°49'46.57"N	121°33'25.10"W	RGU2	D1b	300895
Radial Gate at Clifton Court Forebay, downstream (inside forebay), array 1 in dual array	37°49'50.40"N	121°33'25.32"W	RGD1	D2a	300896/460011
Radial Gate at Clifton Court Forebay, downstream, array 2 in dual array	37°49'47.34"N	121°33'28.74"W	RGD2	D2b	300897/460009
Central Valley Project trash racks, upstream	37°49'0.79"N	121°33'30.40"W	CVPU	E1a	300889/460012/ 460023
Central Valley Project trash racks, downstream	37°48'59.93"N	121°33'32.20"W	CVPD	E1b	300890
Central Valley Project holding tank (all holding tanks pooled)	37°48'57.04"N	121°33'32.86"W	CVPtank	E2	300891
Turner Cut, east (closer to San Joaquin)	37°59'30.03"N[a]	121°27'17.52"W[a]	TCE	F1a	300880/450043
Turner Cut, west (farther from San Joaquin)	37°59'28.53"N[a]	121°27'19.83"W[a]	TCW	F1b	300877/450044
San Joaquin River at Jersey Point, east (upstream)	38°03'22.84"N[a]	121°41'11.41"W[a]	JPE	G1a	300912 - 300920
San Joaquin River at Jersey Point, west (downstream)	38°03'18.58"N[a]	121°41'17.21"W[a]	JPW	G1b	300921 - 300929
False River, west (closer to San Joaquin)	38°03'26.61"N[a]	121°40'14.13"W[a]	FRW	H1a	300906/300907
False River, east (farther from San Joaquin)	38°03'24.99"N[a]	121°40'09.69"W[a]	FRE	H1b	300904/300905

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

Table 3. (Continued)

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
Chipps Island (aka Mallard Island), east (upstream)	38°02'53.85"N[a]	121°55'51.35"W[a]	MAE	G2a	300933 - 300943, 300979
Chipps Island (aka Mallard Island), west (downstream)	38°02'57.25"N[a]	121°56'0.90"W[a]	MAW	G2b	300980 - 300983, 300985 - 300990, 301153/301154
Threemile Slough, south (not used in survival model)	38°06'27.72"N[a]	121°41'01.98"W[a]	TMS	T1a	300910-300911
Threemile Slough, north (not used in survival model)	38°06'41.22"N[a]	121°40'59.19"W[a]	TMN	T1b	300908/300909

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

Table 4. Environmental monitoring sites used in predator decision rule and route entrainment analysis for 2013 Chinook Salmon 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	
CLC	37.8298	121.5574	RGU, RGD	No	No	No	No	Yes	CDEC
FAL	38.0554	121.6672	FRE/FRW	Yes	Yes	Yes	No	No	CDEC
GLC	37.8201	121.4497	ORS	Yes	Yes	Yes	No	No	CDEC
MAL	38.0428	121.9201	MAE/MAW	No	Yes	Yes	No	No	CDEC
MDM	37.9425	121.5340	MR4, MRE	Yes	Yes	Yes	No	No	CDEC[a]
MRU	37.8339	121.3860	MRU	Yes	Yes	No	No	No	CDEC
MSD	37.7860	121.3060	HOR, MOS	Yes	Yes	Yes	No	No	Water Library
ODM	37.8101	121.5419	CVP	Yes	Yes	Yes	No	No	CDEC
OH1	37.8080	121.3290	ORE	Yes	Yes	Yes	No	No	Water Library[b]
OH4	37.8900	121.5697	OR4	Yes	Yes	Yes	No	No	CDEC
PRI	38.0593	121.5575	SJS, MAC, MFE/MFW	Yes	Yes	Yes	No	No	CDEC
RMID040	37.8350	121.3838	MRH	No	No	Yes	No	No	Water Library
ROLD040	37.8286	121.5531	RGU, RGD	No	No	Yes	No	No	Water Library
SJG	37.9351	121.3295	SJG, SJNB, 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	Yes	Yes	Yes	No	No	Water Library
TRN	37.9927	121.4541	TCE/TCW	Yes	Yes	Yes	No	No	CDEC
TRP	37.8165	121.5596	CVP/CVPtank	No	No	No	Yes	No	CDEC
TSL	38.1004	121.6866	TMS/TMN	Yes	Yes	Yes	No	No	CDEC
VNS	37.6670	121.2670	DFU, DFD, BCA	Yes	No	Yes	No	No	CDEC
WCI	37.8316	121.5541	RGU, RGD	Yes	Yes	No	No	No	Water Library

a = California Water Library was used for river stage.

b = CDEC was used for river stage.

Table 5a. Cutoff values used in predator filter in 2013. Observed values past cutoff or unmet conditions indicate a predator. Time durations are in hours unless otherwise specified. See Table 5b for Flow, Water Velocity, Extra Conditions, and Comment. Footnotes refer to both this table and Table 5b.

Detection Site	Previous Site	Residence Time[a] (hr)			Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field	Far-field						
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
DFU	DF, DFD	0.5	1	15	0.2 (0.8[f])	4			1	1
	DFU	0.5	2	15					2	0
DFD	DF, DFU	4	8	15	0.05	4			1	0
	DFD	2	27	54					2	0
	BCA	2	4	15	0.1	4			0	0
BCA	DF, DFU	10	20	40	0.1	4			1	0
	BCA	0.1	45	90					2	0
MOS	DF, DFD, BCA	12	24	60	0.1	5.5		8	1	0
	MOS	2	51	102					2	1
	HOR	1	2	60	0.1	5.5		8	2	1
SJL	HOR	5	15	30	0.1	5.5	15	8	2	0
	SJL	1	41	82					2	1
	SJG	0.1	10	20	1.5	4		8	2	0
	ORE	1	10	20	0.4	5.5	12		1	0
SJG	SJL	12	24	360	0.1	5.5		8	1	0
	SJNB	3	6	360	0.1	4	15	8	2	2
SJNB	SJG	15 (6[f])	30 (12[f])	360	0.1	5.5	15	8	2	0
	SJNB	4	63	360					2	3
	RRI	4	8	360	0.1	5.5	15		2	0
RRI	SJG	15	30	360	0.1	5.5	15	8	1	0
	SJNB	4	8	360	0.1	5.5	15		2	0
SJS	SJNB	30 (15[f])	60 (30[f])	360	0.1 (0.3[f])	5.5	24	8	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 residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was 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 alternative criteria.

Table 5a. (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 (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
MAC	SJS	30 (20[f])	60 (40[f])	360	0.1 (0.3[f])	5.5	24	8	1	0
	MAC	30	119	238					2	3
MFE/MFW	MAC	30 (20[f])	60 (40[f])	360	0.1 (0.3[f])	5.5	36	8	2	0
HOR	DF, DFD, MOS	12	24	60	0.1	5.5		8	1 (2[f])	0
	HOR	3	52	104					2	1
	SJL, ORE	3 (4[f])	6 (8[f])	60	0.1	5.5 (6[f])	15	8	2	1
ORE	HOR, MOS	5	10	20	0.1	5.5	15	8	1	0
	ORE	1	36	72					2	1
	ORS	1	2	163	0.6	4	24	8	2	1
	SJL	5	10	20	0.4	5.5	15		2	0
ORS	BCA, HOR, ORE	15	30	60 (360[f])	0.1	5.5	36	8	1	0
	ORS	5	64	128					2	1
OR4	ORS	40	80	360	0.1	5.5	36	8	1	0
	RGU/RGD	40	80	360	0.1	5.5	36	8	3	3
	CVP	40	80	360	0.1	5.5	36	8	3	3
	OR4	25	134	360					2	2
MRH	ORE	6	12	360	0.1	5.5	36	8	1	0
	ORS	2	4	128	0.1	5.5	36		1	0
MR4	ORS, OR4	10	20	360	0.1	5.5	NA (36[f])	8 (NA[f])	1	0
	MR4	10	59	360					2	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 residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was 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 alternative criteria.

Table 5a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr)			Migration Rate[b, c] (km/hr)		Time since last visit (hr)	BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field	Far-field						
		Maximum	Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum
RGU/RGD	ORS	24 (40[h]; 80[i])		360	0.1	5.5		8	1	0
	CVP	24 (40[h]; 80[i])		360	0.1	5.5		8	2	0
	OR4	24 (40[h]; 80[i])		360	0.1	5.5		8	2	3
CVP	BCA, ORS	20	40	360	0.1	5.5	36	8	1	0
	CVP	10	79	360					3	3
	OR4	10	20	360	0.2	5.5	36		2	3
	RGU/RGD	10	20	360	0.2	5.5	36		2	3
CVPtank	CVP	20	150	360					2	3
JPE/JPW	MFE/MFW	40	80	160	0.1	5.5	36	8	1	0
MAE/MAW	CVPtank	40	200	360	0.1	5.5		8	1	0
	FRE/FRW	40	200	360	0.1	5.5		8	2	0
FRE/FRW	JPE/JPW	30	80	360	0.1	7	15		3	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 residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was 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."

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 < 24 hours, or if present at RGU < 80% of total residence time before returning to Forebay entrance channel.

Table 5b. Cutoff values used in predator filter in 2013. Observed values past cutoff or unmet conditions indicate a predator. Time durations are in hours unless otherwise specified. Footnotes, Extra Conditions and Comment refer to both this table and Table 5a.

		Flow[d] (cfs)		Water Velocity[d] (ft/sec)				
Detection Site	Previous Site	At arrival	At departure[e]	At arrival	At departure[e]	Average during transition	Extra Conditions	Comment
DFU	DF, DFD							Alternate value if coming from DFD
	DFU						Not allowed	
DFD	DF, DFU							
	DFD						Not allowed	
	BCA						Not allowed	
BCA	DF, DFU							
	BCA						Travel time < 20	
MOS	DF, DFD, BCA							
	MOS	<14000				<2.7	Travel time < 20	
	HOR	<14000				<0.1		
SJL	HOR							
	SJL						Travel time < 20	
	SJG					<1.0	Travel time < 12	
	ORE						Far-field residence time < 10 on departure from previous site	
SJG	SJL							
	SJNB	<3500	<3500	<1.1	<1.1	<0.5		
SJNB	SJG			<2 (>2[f])				Alternate values for change in river stage at arrival: < -0.1 or > 0.1
	SJNB	<600 (>-250)[g]	>-250 (<600)[g]	<0.2 (>-0.1)[g]	>-0.1 (<0.2)[g]	<1.5		
	RRI							

d = Classified as predator if flow or velocity condition, if any, 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 5b. (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	SJG							
	SJNB							
SJS	SJNB					-0.2 to 0.5		Alternate values if velocity condition not met
MAC	SJS					-0.1 to 0.4		Alternate values if velocity condition not met
	MAC			<0.2 (>-0.1)[g]	>-0.1 (<0.2)[g]			
MFE/MFW	MAC					-0.1 to 0.4		Alternate values if velocity condition not met
HOR	DF, DFD, MOS							Alternate value if coming from MOS
	HOR	<14000					Travel time < 20	
	SJL, ORE	<14000		<2	<2	<1.0 (1.3[f])	Far-field residence time < 10 at departure from previous site	Alternate value if next transition is downstream
ORE	HOR, MOS							
	ORE						Travel time < 20	
	ORS	<3000						
	SJL	>200					Far-field residence time < 10 on departure from previous site; no previous transition via HOR from SJR downstream of HOR	

d = Classified as predator if flow or velocity condition, if any, 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 5b. (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
ORS	BCA, HOR, ORE	>-2500		>-0.5				Alternate value if coming from ORE
	ORS	<2500 (>-2500)[g]	>-2500 (<2500)[g]	<0.5 (>-0.5)[g]	>-0.5 (<0.5)[g]			
OR4	ORS	>-1500		>-0.5				
	RGU/RGD	>-1500		>-0.5			CCFB inflow < 3000 cfs on departure[e]	
	CVP	>-1500	>-1500	>-0.5	>-1.0		CVP pumping < 1500 cfs on departure[e]	
	OR4	<1500 (>-1500)[g]	>-1500 (<1500)[g]	<0.5 (>-0.5)[g]	>-0.5 (<0.5)[g]			
MRH	ORE							
	ORS							
MR4	ORS,OR4							Alternate value if coming from OR4
	MR4	<-5500	>-6000					
		(>-6000)[g]	(<-5500)[g]	<-0.5 (>-0.5)[g]	>-0.5 (<-0.5)[g]			
MRE	MR4	>-1500		>-0.1				
RGU/RGD	ORS							
	CVP		>-1500		>-0.1		CVP pumping < 1500 cfs on departure[e]	
	OR4		<2000		<0.8			

d = Classified as predator if flow or velocity condition, if any, is violated.

e = Condition at departure from previous site.

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

Table 5b. (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
CVP	BCA, ORS						Transition from BCA not allowed	
	CVP						CVP pumping > 800 cfs on arrival, < 850 cfs on departure[e]	
	OR4	<3000	<2000	<1.5	<0.8		CVP pumping > 800 cfs on arrival	
	RGU/RGD	<3000		<1.5				
CVPtank	CVP						Travel time < 100	
JPE/JPW	MFE/MFW							
MAE/MAW	CVPtank			>-0.2				
	FRE/FRW			>-0.2				
FRE/FRW	JPE/JPW							

d = Classified as predator if flow or velocity condition, if any, is violated.

e = Condition at departure from previous site.

Table 6. Time periods when hydrophones were floating in tanks (estimated start and end times). Tags affected were those with last detections occurring within 60 minutes of the start of the floating period.

		Floating Hydrophone		
Tank	Hydrophone	Start	End	Tags Affected
C	300951	7/3/2013 15:48	7/7/2013 22:51	1161011, 1161031, 1161191, 1161331
B	300959	7/5/2013 16:00	7/7/2013 22:00	1157546, 1157606
B	300959	7/8/2013 16:35	7/9/2013 17:15	1161451, 1161491
C	300951	7/8/2013 16:46	7/9/2013 17:19	1161051, 1161211, 1161231, 1161251, 1161271, 1161311
C	300951	7/10/2013 22:41	7/11/2013 16:25	1161131, 1161171

Table 7. Water temperature and dissolved oxygen in the transport tanks after loading prior to transport , after transport, and in-river at the Durham Ferry release site, just prior to placing fish in holding containers and the number of mortalities after transport for Chinook Salmon released as part of the 2013 Salmon Survival study.

Transport	Tank 1 after loading		Tank 2 after loading		Tank 1 after transport		Tank 2 after transport		River			
Date	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Mortalities after transport	Temp (˚C)	DO (mg/L)	Mortalities just prior to release
4/30/2013	14.8	8.6	14.7	8.7	17.2	10.8	16.6	10.1	0	17.3	9.8	0
5/1/2013	15.3	9.2	14.8	8.7	16.9	10.7	16.8	10.2	0	16.8	9.8	0
5/2/2013	16.1	9.0	14.8	8.8	19.3	9.8	17.5	10.6	0	16.9	9.9	0
5/3/2013	15.2	9.0	15.3	8.8	16.8	10.2	16.7	10.4	0	17.1	10.0	0
Average	**15.4**	**9.0**	**14.9**	**8.7**	**17.6**	**10.4**	**16.9**	**10.3**		**17.0**	**9.9**	
5/14/2013	14.5	10.1	14.9	9.8	17.2	10.5	16.7	10.9	1*	19.1	11.8	0
5/15/2013	14.8	10.3	15.2	10.2	16.8	10.4	16.5	10.7	0	20.3	12.0	0
5/16/2013	13.7	11.0	13.9	10.8	15.3	11.1	14.9	10.9	0	20.2	11.2	0
5/17/2013	14.3	11.2	14.1	11.0	16.1	11.3	15.8	11.3	0	20.1	11.5	0
Average	**14.3**	**10.6**	**14.5**	**10.4**	**16.4**	**10.8**	**16.0**	**11.0**		**19.9**	**11.6**	

* Mortality during transport was a dummy tagged fish

Table 8. Results of dummy tagged Chinook evaluated after being held for 48 hours at the release site as part of the 2013 Chinook Salmon Survival Study. One fish died during transport on 5/14 which resulted in only 14 left to assess on 5/16.

Examination Date, Time	Mean (SD) Fork Length (mm)	Mortality	Mean (SD) Scale Loss %	Normal Body Color	No Fin Hemorrhaging	Normal Eye Quality	Normal Gill Color
5/2/13, 1115	110.8 (4.9)	0/15	5.3 (1.3)	15/15	15/15	15/15	15/15
5/3/13, 1115	114.3 (5.3)	0/15	6.7 (2.4)	15/15	15/15	15/15	15/15
5/4/13, 1115	111.4 (6.1)	0/15	5.7 (3.2)	15/15	15/15	15/15	15/15
5/16/13, 1115	116.4 (6.7)	0/14	5.0 (2.0)	14/14	14/14	14/14	14/14
5/17/13, 1115	113.9 (5.8)	1/15	5.7 (7.8)	14/14	14/14	14/14	14/14
5/18/13, 1115	116.5 (3.8)	0/15	5.3 (2.3)	15/15	15/15	15/15	15/15

Table 9. Number of tags from each release group that were detected after release in 2013, including predator-type detections and detections omitted from the survival analysis.

Release Group	1	2	Total
Number Released	477	473	950
Number Detected	412	412	824
Number Detected Downstream	411	400	811
Number Detected Upstream of Study Area	263	411	674
Number Detected in Study Area	325	154	479
Number Detected in San Joaquin River Route	100	37	137
Number Detected in Old River Route	230	125	355
Number Assigned to San Joaquin River Route	93	13	106
Number Assigned to Old River Route	228	118	346

Table 10. Number of tags observed from each release group at each detection site in 2013, 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	Total
Release site at Durham Ferry			477	473	950
Durham Ferry Upstream	DFU	A0	1	26	27
Durham Ferry Downstream	DFD	A2	261	399	660
Banta Carbona	BCA	A3	3	224	227
Mossdale	MOS	A4	314	152	466
Head of Old River	HOR	B0	324	143	467
Lathrop Upstream	SJLU	A5a	100	36	136
Lathrop Downstream	SJLD	A5b	100	36	136
Lathrop (Pooled)	SJL	A5	100	37	137
Garwood Bridge Upstream	SJGU	A6a	33	6	39
Garwood Bridge Downstream	SJGD	A6b	32	6	38
Garwood Bridge (Pooled)	SJG	A6	33	6	39
Navy Drive Bridge	SJNB	A7	30	6	36
Rough and Ready Island	RRI	R1	1	1	2
San Joaquin Shipping Channel Upstream	SJSU	A8a	2	0	2
San Joaquin Shipping Channel Downstream	SJSD	A8b	2	0	2
San Joaquin Shipping Channel (Pooled)	SJS	A8	2	0	2
MacDonald Island Upstream	MACU	A9a	2	0	2
MacDonald Island Downstream	MACD	A9b	1	0	1
MacDonald Island (Pooled)	MAC	A9	2	0	2
Medford Island East	MFE	A10a	1	0	1
Medford Island West	MFW	A10b	1	0	1
Medford Island (Pooled)	MFE/MFW	A10	1	0	1
Turner Cut (Pooled)	TCE/TCW	F1	0	0	0
Old River East Upstream	OREU	B1a	213	119	332
Old River East Downstream	ORED	B1b	228	121	349
Old River East (Pooled)	ORE	B1	229	122	351
Old River South Upstream	ORSU	B2a	163	61	224
Old River South Downstream	ORSD	B2b	165	62	227
Old River South (Pooled)	ORS	B2	165	63	228
Old River at Highway 4 Upstream	OR4U	B3a	14	11	25
Old River at Highway 4 Downstream	OR4D	B3b	14	11	25
Old River at Highway 4 (Pooled)	OR4	B3	14	11	25
Middle River Head Upstream	MRHU	C1a	2	4	6
Middle River Head Downstream	MRHD	C1b	2	4	6
Middle River Head (Pooled)	MRH	C1	2	4	6
Middle River at Highway 4 Upstream	MR4U	C2a	2	1	3
Middle River at Highway 4 Downstream	MR4D	C2b	2	1	3
Middle River at Highway 4 (Pooled)	MR4	C2	2	1	3

Table 10. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Middle River near Empire Cut (Pooled)	MRE	C3	0	1	1
Radial Gates Upstream #1	RGU1	D1a	24	9	33
Radial Gates Upstream #2	RGU2	D1b	19	9	28
Radial Gates Upstream (Pooled)	RGU	D1	24	9	33
Radial Gates Downstream #1	RGD1	D2a	10	4	14
Radial Gates Downstream #2	RGD2	D2b	11	4	15
Radial Gates Downstream (Pooled)	RGD	D2	11	4	15
Central Valley Project Trash rack Upstream	CVPU	E1a	52	23	75
Central Valley Project Trash rack Downstream	CVPD	E1b	48	12	60
Central Valley Project Trash rack (Pooled)	CVP	E1	52	23	75
Central Valley Project Holding Tank[a]	CVPtank	E2	3	1	4
Threemile Slough (Pooled)	TMS/TMN	T1	0	0	0
Jersey Point East	JPE	G1a	1	0	1
Jersey Point West	JPW	G1b	0	0	0
Jersey Point: SJR Route	JPE/JPW	G1	1	0	1
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	1	0	1
False River West	FRW	H1a	1	0	1
False River East	FRE	H1b	1	0	1
False River: SJR Route	FRE/FRW	H1	1	0	1
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	1	0	1
Chipps Island East	MAE	G2a	2	0	2
Chipps Island West	MAW	G2b	3	0	3
Chipps Island: SJR Route	MAE/MAW	G2	1	0	1
Chipps Island: OR Route	MAE/MAW	G2	2	0	2
Chipps Island (Pooled)	MAE/MAW	G2	3	0	3

a = There were 4 tagged Chinook Salmon recovered from the holding tank from the first release group, as part of a concurrent salvage efficiency study: 1 tagged was recovered from the monitored holding tank, and 3 were recovered from an unmonitored holding tank.

Table 11. Number of tags observed from each release group at each detection site in 2013 and used in the survival analysis, including predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags.

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			477	473	950
Durham Ferry Downstream	DFD	A2	261	392	653
Banta Carbona	BCA	A3	3	217	220
Mossdale	MOS	A4	314	152	466
Lathrop Upstream	SJLU	A5a	93	13	106
Lathrop Downstream	SJLD	A5b	93	12	105
Lathrop (Pooled)	SJL	A5	93	13	106
Garwood Bridge Upstream	SJGU	A6a	33	5	38
Garwood Bridge Downstream	SJGD	A6b	32	5	37
Garwood Bridge (Pooled)	SJG	A6	33	5	38
Navy Drive Bridge	SJNB	A7	28	5	33
MacDonald Island Upstream	MACU	A9a	2	0	2
MacDonald Island Downstream	MACD	A9b	1	0	1
MacDonald Island (Pooled)	MAC	A9	2	0	2
Old River East Upstream	OREU	B1a	206	107	313
Old River East Downstream	ORED	B1b	225	110	335
Old River East (Pooled)	ORE	B1	227	114	341
Old River South Upstream	ORSU	B2a	152	57	209
Old River South Downstream	ORSD	B2b	165	60	225
Old River South (Pooled)	ORS	B2	165	61	226
Old River at Highway 4 Upstream	OR4U	B3a	7	10	17
Old River at Highway 4 Downstream	OR4D	B3b	7	10	17
Old River at Highway 4 (Pooled)	OR4	B3	7	10	17
Middle River Head Upstream	MRHU	C1a	2	4	6
Middle River Head Downstream	MRHD	C1b	2	4	6
Middle River Head (Pooled)	MRH	C1	2	4	6
Middle River at Highway 4 Upstream	MR4U	C2a	2	1	3
Middle River at Highway 4 Downstream	MR4D	C2b	2	1	3
Middle River at Highway 4 (Pooled)	MR4	C2	2	1	3
Radial Gates Upstream #1	RGU1	D1a	13	4	17
Radial Gates Upstream #2	RGU2	D1b	12	4	16
Radial Gates Upstream (Pooled)	RGU	D1	13	4	17
Radial Gates Downstream #1	RGD1	D2a	10	4	14
Radial Gates Downstream #2	RGD2	D2b	11	4	15
Radial Gates Downstream (Pooled)	RGD	D2	11	4	15
Central Valley Project Trash rack Upstream	CVPU	E1a	45	19	64
Central Valley Project Trash rack Downstream	CVPD	E1b	42	7	49
Central Valley Project Trash rack (Pooled)	CVP	E1	47	19	66

Table 11. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Central Valley Project Holding Tank[a]	CVPtank	E2	3	1	4
Chipps Island East	MAE	G2a	2	0	2
Chipps Island West	MAW	G2b	3	0	3
Chipps Island: SJR Route	MAE/MAW	G2	1	0	1
Chipps Island: OR Route	MAE/MAW	G2	2	0	2
Chipps Island (Pooled)	MAE/MAW	G2	3	0	3

a = There were 4 tagged Chinook Salmon recovered from the holding tank from the first release group, as part of a concurrent salvage efficiency study: 1 tagged was recovered from the monitored holding tank, and 3 were recovered from an unmonitored holding tank.

Table 12. Number of tags from each release group in 2013 first classified as in a predator at each detection site, based on the predator filter.

Detection Site and Code			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	Total	1	2	Total
Durham Ferry Upstream	DFU	A0	1	9	10	0	1	1
Durham Ferry Downstream	DFD	A2	3	9	12	3	25	28
Banta Carbona	BCA	A3	2	3	5	0	20	20
Mossdale	MOS	A4	0	0	0	0	1	1
Head of Old River	HOR	B0	1	0	1	2	7	9
Lathrop	SJL	A5	1	0	1	0	6	6
Garwood Bridge	SJG	A6	2	0	2	0	0	0
Navy Drive Bridge	SJNB	A7	1	0	1	3	2	5
Rough and Ready Island	RRI	R1	0	0	0	0	0	0
San Joaquin River Shipping Channel	SJS	A8	0	0	0	0	0	0
MacDonald Island	MAC	A9	1	0	1	0	0	0
Medford Island	MFE/MFW	A10	0	0	0	0	0	0
Old River East	ORE	B1	1	4	5	11	21	32
Old River South	ORS	B2	5	0	5	11	6	17
Old River at Highway 4	OR4	B3	0	0	0	2	0	2
Middle River Head	MRH	C1	0	0	0	0	0	0
Middle River at Highway 4	MR4	C2	0	0	0	0	0	0
Middle River near Empire Cut	MRE	C3	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	0	0	0	5	3	8
Radial Gates Downstream	RGD	D2	0	0	0	0	0	0
Central Valley Project Trash rack	CVP	E1	1	1	2	25	6	31
Central Valley Project Holding Tank	CVPtank	E2	0	0	0	0	0	0
Turner Cut	TCE/TCW	F1	0	0	0	0	0	0
Jersey Point	JPE/JPW	G1	0	0	0	0	0	0
Chipps Island	MAE/MAW	G2	0	0	0	0	0	0
False River	FRE/FRW	H1	0	0	0	0	0	0
Threemile Slough	TMS/TMN	T1	0	0	0	0	0	0
Total Tags			19	26	45	62	98	160

Table 13. Number of tags from each release group that were detected after release in 2013, excluding predator-type detections, and including detections omitted from the survival analysis.

Release Group	1	2	Total
Number Released	477	473	950
Number Detected	410	406	816
Number Detected Downstream	410	400	810
Number Detected Upstream of Study Area	261	405	666
Number Detected in Study Area	325	153	478
Number Detected in San Joaquin River Route	99	36	135
Number Detected in Old River Route	229	124	353
Number Assigned to San Joaquin River Route	93	13	106
Number Assigned to Old River Route	228	117	345

Table 14. Number of tags observed from each release group at each detection site in 2013, 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	Total
Release site at Durham Ferry			477	473	950
Durham Ferry Upstream	DFU	A0	0	12	12
Durham Ferry Downstream	DFD	A2	261	398	659
Banta Carbona	BCA	A3	1	223	224
Mossdale	MOS	A4	314	152	466
Head of Old River	HOR	B0	324	143	467
Lathrop Upstream	SJLU	A5a	99	35	134
Lathrop Downstream	SJLD	A5b	99	35	134
Lathrop (Pooled)	SJL	A5	99	36	135
Garwood Bridge Upstream	SJGU	A6a	33	6	39
Garwood Bridge Downstream	SJGD	A6b	32	6	38
Garwood Bridge (Pooled)	SJG	A6	33	6	39
Navy Drive Bridge	SJNB	A7	30	6	36
Rough and Ready Island	RRI	R1	1	0	1
San Joaquin Shipping Channel Upstream	SJSU	A8a	2	0	2
San Joaquin Shipping Channel Downstream	SJSD	A8b	2	0	2
San Joaquin Shipping Channel (Pooled)	SJS	A8	2	0	2
MacDonald Island Upstream	MACU	A9a	2	0	2
MacDonald Island Downstream	MACD	A9b	1	0	1
MacDonald Island (Pooled)	MAC	A9	2	0	2
Medford Island East	MFE	A10a	1	0	1
Medford Island West	MFW	A10b	1	0	1
Medford Island (Pooled)	MFE/MFW	A10	1	0	1
Turner Cut (Pooled)	TCE/TCW	F1	0	0	0
Old River East Upstream	OREU	B1a	212	118	330
Old River East Downstream	ORED	B1b	227	120	347
Old River East (Pooled)	ORE	B1	228	121	349
Old River South Upstream	ORSU	B2a	161	59	220
Old River South Downstream	ORSD	B2b	163	60	223
Old River South (Pooled)	ORS	B2	163	61	224
Old River at Highway 4 Upstream	OR4U	B3a	14	10	24
Old River at Highway 4 Downstream	OR4D	B3b	14	10	24
Old River at Highway 4 (Pooled)	OR4	B3	14	10	24
Middle River Head Upstream	C1a	2	2	4	6
Middle River Head Downstream	C1b	2	2	4	6
Middle River Head (Pooled)	C1	2	2	4	6
Middle River at Highway 4 Upstream	MR4U	C2a	2	1	3
Middle River at Highway 4 Downstream	MR4D	C2b	2	1	3
Middle River at Highway 4 (Pooled)	MR4	C2	2	1	3

Table 14. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group		Total
			1	2	
Middle River near Empire Cut (Pooled)	MRE	C3	0	1	1
Radial Gates Upstream #1	RGU1	D1a	24	8	32
Radial Gates Upstream #2	RGU2	D1b	19	8	27
Radial Gates Upstream (Pooled)	RGU	D1	24	8	32
Radial Gates Downstream #1	RGD1	D2a	6	1	7
Radial Gates Downstream #2	RGD2	D2b	7	1	8
Radial Gates Downstream (Pooled)	RGD	D2	7	1	8
Central Valley Project Trash rack Upstream	CVPU	E1a	50	21	71
Central Valley Project Trash rack Downstream	CVPD	E1b	48	12	60
Central Valley Project Trash rack (Pooled)	CVP	E1	50	21	71
Central Valley Project Holding Tank[a]	CVPtank	E2	3	1	4
Threemile Slough (Pooled)	TMS/TMN	T1	0	0	0
Jersey Point East	JPE	G1a	1	0	1
Jersey Point West	JPW	G1b	0	0	0
Jersey Point: SJR Route	JPE/JPW	G1	1	0	1
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	1	0	1
False River West	FRW	H1a	1	0	1
False River East	FRE	H1b	1	0	1
False River: SJR Route	FRE/FRW	H1	1	0	1
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	1	0	1
Chipps Island East	MAE	G2a	2	0	2
Chipps Island West	MAW	G2b	3	0	3
Chipps Island: SJR Route	MAE/MAW	G2	1	0	1
Chipps Island: OR Route	MAE/MAW	G2	2	0	2
Chipps Island (Pooled)	MAE/MAW	G2	3	0	3

a = There were 4 tagged Chinook Salmon recovered from the holding tank from the first release group, as part of a concurrent salvage efficiency study: 1 tagged was recovered from the monitored holding tank, and 3 were recovered from an unmonitored holding tank.

Table 15. Number of tags observed from each release group at each detection site in 2013 and used in the survival analysis, excluding predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags.

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			477	473	950
Durham Ferry Downstream	DFD	A2	261	395	656
Banta Carbona	BCA	A3	1	223	224
Mossdale	MOS	A4	314	152	466
Lathrop Upstream	SJLU	A5a	93	13	106
Lathrop Downstream	SJLD	A5b	93	13	106
Lathrop (Pooled)	SJL	A5	93	13	106
Garwood Bridge Upstream	SJGU	A6a	33	5	38
Garwood Bridge Downstream	SJGD	A6b	32	5	37
Garwood Bridge (Pooled)	SJG	A6	33	5	38
Navy Drive Bridge	SJNB	A7	30	5	35
MacDonald Island Upstream	MACU	A9a	2	0	2
MacDonald Island Downstream	MACD	A9b	1	0	1
MacDonald Island (Pooled)	MAC	A9	2	0	2
Old River East Upstream	OREU	B1a	211	111	322
Old River East Downstream	ORED	B1b	226	113	339
Old River East (Pooled)	ORE	B1	227	114	341
Old River South Upstream	ORSU	B2a	153	57	210
Old River South Downstream	ORSD	B2b	163	59	222
Old River South (Pooled)	ORS	B2	163	60	223
Old River at Highway 4 Upstream	OR4U	B3a	7	9	16
Old River at Highway 4 Downstream	OR4D	B3b	7	9	16
Old River at Highway 4 (Pooled)	OR4	B3	7	9	16
Middle River Head Upstream	MRHU	C1a	2	4	6
Middle River Head Downstream	MRHD	C1b	2	4	6
Middle River Head (Pooled)	MRH	C1	2	4	6
Middle River at Highway 4 Upstream	MR4U	C2a	2	1	3
Middle River at Highway 4 Downstream	MR4D	C2b	2	1	3
Middle River at Highway 4 (Pooled)	MR4	C2	2	1	3
Radial Gates Upstream #1	RGU1	D1a	13	4	17
Radial Gates Upstream #2	RGU2	D1b	12	4	16
Radial Gates Upstream (Pooled)	RGU	D1	13	4	17
Radial Gates Downstream #1	RGD1	D2a	6	1	7
Radial Gates Downstream #2	RGD2	D2b	7	1	8
Radial Gates Downstream (Pooled)	RGD	D2	7	1	8
Central Valley Project Trash rack Upstream	CVPU	E1a	44	17	61
Central Valley Project Trash rack Downstream	CVPD	E1b	44	8	52
Central Valley Project Trash rack (Pooled)	CVP	E1	45	17	62

Table 15. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Central Valley Project Holding Tank[a]	CVPtank	E2	3	1	4
Chipps Island East	MAE	G2a	2	0	2
Chipps Island West	MAW	G2b	3	0	3
Chipps Island: SJR Route	MAE/MAW	G2	1	0	1
Chipps Island: OR Route	MAE/MAW	G2	2	0	2
Chipps Island (Pooled)	MAE/MAW	G2	3	0	3

a = There were 4 tagged Chinook Salmon recovered from the holding tank from the first release group, as part of a concurrent salvage efficiency study: 1 tagged was recovered from the monitored holding tank, and 3 were recovered from an unmonitored holding tank.

Table 16. Number of juvenile Chinook Salmon tagged by each tagger in each release group during the 2013 tagging study.

	Release Group		
Tagger	1	2	Total Tags
A	159	158	317
B	159	157	316
C	159	158	317
Total Tags	477	473	950

Table 17. Release size and counts of tag detections at key detection sites by tagger in 2013, excluding predator-type detections. * = used in chi-square test of independence.

Detection Site	Tagger		
	A	B	C
Release at Durham Ferry*	317	316	317
Mossdale (MOS)*	156	158	152
Lathrop (SJL)*	33	38	35
Navy Bridge (SJNB)*	14	12	9
MacDonald Island (MAC)	0	1	1
Old River East (ORE)*	120	109	112
Old River South (ORS)*	80	73	70
Old River at Highway 4 (OR4)*	5	6	5
Middle River at Head of Middle River (MRH)	4	1	1
Middle River at Highway 4 (MR4)	0	2	1
Clifton Court Forebay Exterior (RGU)*	10	5	2
Clifton Court Forebay Interior (RGD)	6	1	1
Central Valley Project Trash Rack (CVP)*	26	23	13
Central Valley Project Holding Tank (CVPtank)	3	1	0
Chipps Island (MAE/MAW)	1	1	1

Table 18. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2013 tagging study, excluding predator-type detections. Population-level estimates were from pooled release groups.

Parameter	Release Occasion 1	Release Occasion 2	Population Estimate
ψ_{BB}	0.70 (0.02)	0.84 (0.04)	0.75 (0.02)
ψ_{BC}	0.01 (0.01)	0.06 (0.03)	0.02 (0.01)
S_{BB}	0.03 (0.01)	0 (0)	0.01 (0.01)
S_{BC}	0 (0)	0 (0)	0 (0)
ψ_A[a]	0.29 (0.02)	0.10 (0.02)	0.23 (0.02)
ψ_B[a]	0.71 (0.02)	0.90 (0.02)	0.77 (0.02)
S_A	0.01[b] (0.01)	0 (0)	0.01[b] (0.01)
S_B	0.03[b] (0.01)	0 (0)	0.01[b] (0.01)
S_{Total}	0.02 (0.01)	0 (0)	0.01 (0.01)
$S_{A(SD)}$	0.02 (0.01)	NA[c]	0.02 (0.01)
$S_{B(SD)}$	0.29 (0.03)	0.22[d] (0.04)	0.27 (0.02)
$S_{Total(SD)}$	0.21 (0.02)	NA[c]	0.21 (0.02)
ϕ_{A1A4}	0.68 (0.02)	0.32 (0.02)	0.50 (0.02)

a = Significant preference for route B (Old River Route) (a=0.05) for all release occasions and for population estimate.

b = No significant difference between route A and route B estimates ($P \geq 0.41$) (tested only for Delta survival).

c = There were too few tags detected in route A (San Joaquin River Route) to estimate survival through the South Delta region.

d = Minimum estimate; omits route detections at Middle River receiver near Highway 4 (model code C2).

Table 19. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2013 tagging study, including predator-type detections. Population-level estimates were from pooled release groups.

Parameter	Release Occasion 1	Release Occasion 2	Population Estimate
ψ_{BB}	0.70 (0.03)	0.85 (0.04)	0.75 (0.02)
ψ_{BC}	0.01 (0.01)	0.05 (0.03)	0.02 (0.01)
S_{BB}	0.03 (0.01)	0 (0)	0.01 (0.01)
S_{BC}	0 (0)	0 (0)	0 (0)
ψ_A[a]	0.29 (0.03)	0.10 (0.03)	0.23 (0.02)
ψ_B[a]	0.71 (0.03)	0.90 (0.03)	0.77 (0.02)
S_A	0.01[b] (0.01)	0 (0)	0.01[b] (0.01)
S_B	0.03[b] (0.01)	0 (0)	0.01[b] (0.01)
S_{Total}	0.02 (0.01)	0 (0)	0.01 (0.01)
$S_{A(SD)}$	0.04 (0.03)	NA[c]	0.03 (0.02)
$S_{B(SD)}$	0.31 (0.03)	0.24[d] (0.04)	0.29 (0.02)
$S_{Total(SD)}$	0.23 (0.02)	NA[c]	0.23 (0.02)
ϕ_{A1A4}	0.68 (0.02)	0.33 (0.02)	0.51 (0.02)

a = Significant preference for route B (Old River Route) (a=0.05) for all release occasions and for population estimate.

b = No significant difference between route A and route B estimates ($P \geq 0.41$) (tested only for Delta survival).

c = There were too few tags detected in route A (San Joaquin River Route) to estimate survival through the South Delta region.

d = Minimum estimate; omits route detections at Middle River receiver near Highway 4 (model code C2).

Table 20. 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 1 - Release group 2. P = P-value from one-sized z-test of Δ>1. Estimates were based on data that excluded predator-type detections. * = significant (positive) difference between release groups for family-wise α=0.10.

Parameter	Release 1	Release 2	Δ	P
$S_{A2,A4}$	0.68 (0.03)	0.38 (0.02)	0.29 (0.04)	< 0.0001*
S_{A4}	0.99 (0.01)	0.87 (0.03)	0.12 (0.03)	< 0.0001*
S_{A5}	0.36 (0.05)	0.38 (0.14)	-0.03 (0.14)	0.5817
S_{A6}	0.91 (0.05)	1 (0)	-0.09 (0.05)	0.9648
S_{B1}	0.72 (0.03)	0.54 (0.05)	0.19 (0.06)	0.0003*
$S_{B2(SD)}$	0.41 (0.04)	0.50 (0.06)	-0.09 (0.08)	0.8803
$\phi_{A1,A2}$	1.01 (0.03)	0.84 (0.02)	0.17 (0.03)	< 0.0001*
$\phi_{A7,G2}$	0.03 (0.03)	0 (0)	0.03 (0.03)	0.1553
$\phi_{B3,G2}$	0 (0)	0 (0)	0 (0)	NA
$\phi_{D1,G2}$	0 (0)	0 (0)	0 (0)	NA
$\phi_{E1,G2}$	0.13 (0.05)	0 (0)	0.13 (0.05)	0.4257

Table 21a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2013 tagging study, excluding predator-type detections. Standard errors are in parentheses. There were no detections at the TCE/TCW receivers, and too few detections at the MRE/MRW, FRE/FRW, and JPE/JPW receivers to estimate travel times to those sites. See Table 21b for travel time from release with predator-type detections.

	Without Predator-Type Detections					
	All Releases		Release 1		Release 2	
Detection Site and Route	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry Downstream (DFD)	656	0.05 (0.00)	261	0.04 (0.00)	395	0.06 (0.00)
Banta Carbona (BCA)	224	0.35 (0.01)	1	0.25 (NA)	223	0.35 (0.01)
Mossdale (MOS)	466	0.51 (0.01)	314	0.46 (0.01)	152	0.69 (0.02)
Lathrop (SJL)	106	0.63 (0.02)	93	0.60 (0.02)	13	0.92 (0.13)
Garwood Bridge (SJG)	38	1.94 (0.09)	33	1.90 (0.09)	5	2.29 (0.38)
Navy Drive Bridge (SJNB)	35	2.17 (0.11)	30	2.13 (0.11)	5	2.43 (0.44)
MacDonald Island (MAC)	2	4.06 (0.65)	2	4.06 (0.65)	0	NA
Old River East (ORE)	341	0.70 (0.01)	227	0.62 (0.01)	114	0.94 (0.03)
Old River South (ORS)	223	1.01 (0.02)	163	0.93 (0.02)	60	1.32 (0.05)
Old River at Highway 4 (OR4)	16	2.73 (0.33)	7	2.17 (0.42)	9	3.40 (0.24)
Middle River Head (MRH)	6	1.34 (0.12)	2	1.41 (0.39)	4	1.31 (0.10)
Middle River at Highway 4 (MR4)	3	2.11 (0.68)	2	2.93 (1.16)	1	1.36 (NA)
Radial Gates Upstream (DFU)	17	2.51 (0.22)	13	2.48 (0.25)	4	2.62 (0.61)
Radial Gates Downstream (DFD)	8	2.86 (0.43)	7	2.70 (0.40)	1	5.10 (NA)
Central Valley Project Trash rack (CVP)	62	2.21 (0.10)	45	2.24 (0.13)	17	2.12 (0.15)
Central Valley Project Holding Tank (CVPtank)	4	1.87 (0.13)	3	1.94 (0.17)	1	1.70 (NA)
Chipps Island (MAE/MAW), SJR Route	1	8.08 (NA)	1	8.08 (NA)	0	NA
Chipps Island (MAE/MAW), OR Route	2	3.89 (0.10)	2	3.89 (0.10)	0	NA
Chipps Island (MAE/MAW)	3	4.71 (0.99)	3	4.71 (0.99)	0	NA

Table 21b.

Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2013 tagging study, including predator-type detections. Standard errors are in parentheses. There were no detections at the TCE/TCW receivers, and too few detections at the MRE/MRW, FRE/FRW, and JPE/JPW receivers to estimate travel times to those sites. See Table 21a for travel time from release without predator-type detections.

	With Predator-Type Detections					
	All Releases		Release 1		Release 2	
Detection Site and Route	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry Downstream (DFD)	653	0.05 (0.00)	261	0.04 (0.00)	392	0.06 (0.00)
Banta Carbona (BCA)	220	0.36 (0.01)	3	0.71 (0.67)	217	0.36 (0.01)
Mossdale (MOS)	466	0.52 (0.01)	314	0.46 (0.01)	152	0.69 (0.02)
Lathrop (SJL)	106	0.63 (0.02)	93	0.60 (0.02)	13	0.99 (0.17)
Garwood Bridge (SJG)	38	1.99 (0.09)	33	1.95 (0.09)	5	2.29 (0.38)
Navy Drive Bridge (SJNB)	33	2.36 (0.16)	28	2.20 (0.12)	5	4.02 (1.37)
MacDonald Island (MAC)	2	6.57 (5.76)	2	6.57 (5.76)	0	NA
Old River East (ORE)	341	0.73 (0.02)	227	0.64 (0.01)	114	1.02 (0.05)
Old River South (ORS)	226	1.04 (0.03)	165	0.95 (0.03)	61	1.40 (0.06)
Old River at Highway 4 (OR4)	17	2.85 (0.38)	7	2.36 (0.60)	10	3.34 (0.21)
Middle River Head (MRH)	6	1.34 (0.12)	2	1.41 (0.39)	4	1.31 (0.10)
Middle River at Highway 4 (MR4)	3	2.11 (0.68)	2	2.93 (1.16)	1	1.36 (NA)
Radial Gates Upstream (DFU)	17	2.51 (0.22)	13	2.48 (0.25)	4	2.62 (0.61)
Radial Gates Downstream (DFD)	15	2.67 (0.26)	11	2.51 (0.28)	4	3.24 (0.62)
Central Valley Project Trash rack (CVP)	66	2.45 (0.15)	47	2.44 (0.18)	19	2.47 (0.28)
Central Valley Project Holding Tank (CVPtank)	4	1.87 (0.13)	3	1.94 (0.17)	1	1.70 (NA)
Chipps Island (MAE/MAW), SJR Route	1	8.08 (NA)	1	8.08 (NA)	0	NA
Chipps Island (MAE/MAW), OR Route	2	3.89 (0.10)	2	3.89 (0.10)	0	NA
Chipps Island (MAE/MAW)	3	4.71 (0.99)	3	4.71 (0.99)	0	NA

Table 22a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta river reaches during the 2013 tagging study, without predator-type detections. Standard errors are in parentheses. See Table 18b for travel time through reaches with predator-type detections.

Reach		Without Predator-Type Detections					
		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry (Release)	DFD	656	0.05 (0.00)	261	0.04 (0.00)	395	0.06 (0.00)
DFD	BCA	223	0.26 (0.01)	1	0.16 (NA)	222	0.26 (0.01)
	MOS	323	0.49 (0.01)	172	0.41 (0.01)	151	0.60 (0.02)
BCA	MOS	115	0.34 (0.01)	1	0.18 (NA)	114	0.34 (0.02)
MOS	SJL	105	0.13 (0.01)	92	0.13 (0.00)	13	0.17 (0.04)
	ORE	331	0.14 (0.00)	217	0.13 (0.00)	114	0.16 (0.01)
SJL	SJG	38	1.28 (0.08)	33	1.25 (0.08)	5	1.47 (0.28)
SJG	SJNB	35	0.09 (0.01)	30	0.09 (0.01)	5	0.08 (0.02)
SJNB	MAC	2	1.90 (0.61)	2	1.90 (0.61)	0	NA
ORE	ORS	219	0.23 (0.01)	162	0.23 (0.01)	57	0.26 (0.02)
	MRH	6	0.33 (0.10)	2	0.62 (0.02)	4	0.27 (0.09)
ORS	OR4	16	1.31 (0.34)	7	0.96 (0.40)	9	1.84 (0.23)
	MR4	3	1.14 (0.45)	2	1.65 (1.00)	1	0.70 (NA)
	RGU	17	1.19 (0.20)	13	1.32 (0.24)	4	0.90 (0.33)
	CVP	62	1.09 (0.08)	45	1.24 (0.11)	17	0.83 (0.09)
MRH	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	0	NA	0	NA	0	NA
RGU	RGD	8	0.02 (0.01)	7	0.02 (0.01)	1	0.02 (NA)
CVP	CVPtank	4	0.03 (0.01)	3	0.04 (0.03)	1	0.02 (NA)
MAC	MAE/MAW	1	4.58 (NA)	1	4.58 (NA)	0	NA
OR4		0	NA	0	NA	0	NA
MR4		0	NA	0	NA	0	NA
RGD		0	NA	0	NA	0	NA
CVPtank		2	1.77 (0.38)	2	1.77 (0.38)	0	NA

Table 22b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta river reaches during the 2013 tagging study, with predator-type detections. Standard errors are in parentheses. See Table 18a for travel time through reaches without predator-type detections.

Reach		With Predator-Type Detections					
		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry (Release)	DFD	653	0.05 (0.00)	261	0.04 (0.00)	392	0.06 (0.00)
DFD	BCA	219	0.27 (0.01)	2	0.31 (0.30)	217	0.27 (0.01)
	MOS	323	0.49 (0.01)	172	0.41 (0.01)	151	0.60 (0.02)
BCA	MOS	115	0.34 (0.02)	1	0.18 (NA)	114	0.34 (0.02)
MOS	SJL	105	0.13 (0.01)	92	0.13 (0.01)	13	0.17 (0.04)
	ORE	331	0.15 (0.00)	217	0.14 (0.00)	114	0.18 (0.01)
SJL	SJG	38	1.32 (0.08)	33	1.30 (0.08)	5	1.47 (0.28)
SJG	SJNB	33	0.10 (0.01)	28	0.10 (0.01)	5	0.10 (0.05)
SJNB	MAC	2	2.80 (2.65)	2	2.80 (2.65)	0	NA
ORE	ORS	222	0.24 (0.01)	164	0.23 (0.01)	58	0.28 (0.02)
	MRH	6	0.33 (0.10)	2	0.62 (0.02)	4	0.27 (0.09)
ORS	OR4	17	1.31 (0.33)	7	1.00 (0.45)	10	1.68 (0.23)
	MR4	3	1.14 (0.45)	2	1.65 (1.00)	1	0.70 (NA)
	RGU	17	1.19 (0.20)	13	1.32 (0.24)	4	0.90 (0.33)
	CVP	65	1.18 (0.10)	47	1.34 (0.13)	18	0.91 (0.12)
MRH	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	0	NA	0	NA	0	NA
RGU	RGD	15	0.03 (0.01)	11	0.03 (0.01)	4	0.06 (0.05)
CVP	CVPtank	4	0.03 (0.01)	3	0.04 (0.03)	1	0.02 (NA)
MAC	MAE/MAW	1	4.58 (NA)	1	4.58 (NA)	0	NA
OR4		0	NA	0	NA	0	NA
MR4		0	NA	0	NA	0	NA
RGD		0	NA	0	NA	0	NA
CVPtank		2	1.77 (0.38)	2	1.77 (0.38)	0	NA

Table 23. Results of single-variate analyses of 2013 route entrainment at the head of Old River. The values df1, df2 are degrees of freedom for the F-test. Covariates are ordered by P-value and F statistic.

Covariate	F-test			
	F	df1	df2	*P*
Flow at SJL[a]	18.9184	1	96	<0.0001
Velocity at SJL[a]	13.9704	1	96	0.0003
Change in stage at OH1[a]	9.2245	1	96	0.0031
Change in stage at SJL[a]	8.1432	1	96	0.0053
Flow proportion into San Joaquin River[a]	6.9133	1	96	0.0100
Negative flow at SJL[a]	5.0227	1	96	0.0273
Negative velocity at SJL[a]	5.0227	1	96	0.0273
Total Exports in Delta[a]	4.0006	1	96	0.0483
Release Group[a]	3.9907	1	96	0.0486
Change in flow proportion into San Joaquin River	3.6012	1	96	0.0607
Exports at CVP	2.4005	1	96	0.1246
Change in velocity at OH1	1.3668	1	96	0.2453
Stage at OH1	1.3159	1	96	0.2542
Change in flow at OH1	1.1059	1	96	0.2956
Fork Length	1.0720	1	96	0.3031
Stage at SJL	0.9940	1	96	0.3213
Change in velocity at SJL	0.4307	1	96	0.5132
Flow at OH1	0.3293	1	96	0.5674
Change in flow at SJL	0.2209	1	96	0.6394
Time of day of arrival	0.5450	3	94	0.6527
Arrive at junction during twilight	0.1728	1	96	0.6786
Velocity at OH1	0.1179	1	96	0.7321
Exports at SWP	0.0004	1	96	0.9838

a = Significant at 5% level

Table 24. Results of multivariate analyses of route entrainment at the head of Old River in 2013.

				t-test		
Model Type	Covariate[a]	Estimate	S.E.	*t*	df	*P*
Flow	Intercept	-1.6616	0.1845	-9.0057	96	<0.0001
	Q_{SJL}	1.5373	0.2396	6.4150	96	<0.0001
	Goodness-of-fit: χ^2=12.8915, df=13, P=0.4562; AIC = 379.81					
Flow Proportion	Intercept	-1.5198	0.1822	-8.3407	95	< 0.0001
	pQ_{SJL}	-0.2451	0.2785	-0.8801	95	0.3811
	u_{QSJL}*Q_{SJL}	1.4970	0.2777	5.3899	95	<0.0001
	Goodness-of-fit: χ^2=14.0686, df=13, P=0.3690; AIC = 384.56					
Velocity	Intercept	-1.2842	0.1746	-7.3549	95	<0.0001
	Release Group 2	-1.2321	0.3543	-3.4780	95	0.0008
	V_{SJL}	1.3058	0.2255	5.7920	95	<0.0001
	Goodness-of-fit: χ^2=8.4308, df=13, P=0.8144; AIC = 384.20					
Stage	Intercept	-0.9778	0.1717	-5.6960	94	<0.0001
	Release Group 2	-2.1631	0.4853	-4.4569	94	<0.0001
	C_{OH1}	-0.1953	0.1880	-1.0386	94	0.2990
	□C_{OH1}	-1.1715	0.1954	-5.9942	94	<0.0001
	Goodness-of-fit: χ^2=11.6130, df=13, P=0.5596; AIC = 384.87					

a = Continuous covariates (Q_{SJL}, pQ_{SJL}, u_{QSJL}, V_{SJL}, C_{OH1}, □C_{OH1}) are standardized. Intercept and slope estimates for the unstandardized covariates are -3.9576 ($\hat{SE}$ = 0.5084) and 0.0022 ($\hat{SE}$ = 0.0003) for the flow model.

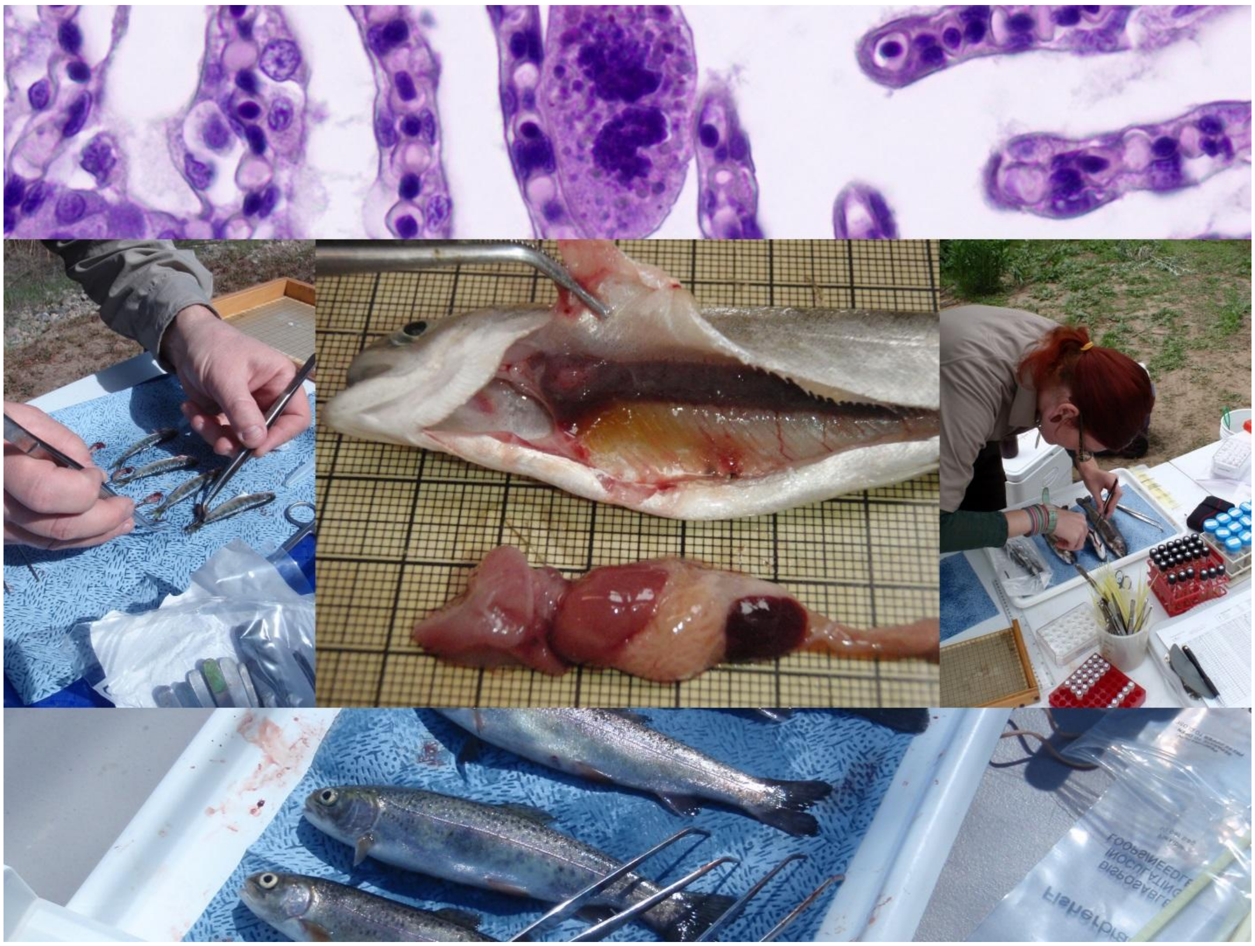
Appendices

Appendix 1

U.S. Fish & Wildlife Service

FY2013 Technical Report: Pathogen Screening and Gill Na^+/K^+- ATPase Assessment of South Delta Chinook and Steelhead 2013 Release Groups

Ken Nichols



August 2013

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http://www.fws.gov/canvfhc/

Summary

As a component of studies examining the reach-specific survival and distribution of migrating juvenile Chinook Salmon and steelhead in the San Joaquin River and Delta, the CA-NV Fish Health Center conducted a general pathogen screening and smolt physiological assessment. Juvenile Chinook Salmon and steelhead trout were surveyed for specific fish pathogens and smolt development using gill Na^+/K^+-ATPase (gill ATPase) activity levels. The health and physiological condition of the study fish can help explain their performance and survival during the studies. In both steelhead and Chinook release groups, survival over the 24 holding period was high. The myxozoan parasite *Tetracapsuloides bryosalmonae* was detected at moderate to high levels in a majority of the Chinook sampled. Anemia associated with late stage PKD was not observed. The infection was progressive and impacts on survival could occur within the study period (30 days). No other significant pathogen infections were detected in either the Chinook or steelhead. Gill ATPase activity levels were lower in later release groups of both Chinook and Steelhead suggesting these later groups were beyond the peak of smoltification.

Recommended citation for this report is:

Nichols, K. 2013. FY2013 Technical Report: Pathogen Screening and Gill Na+/K+- ATPase Assessment of South Delta Chinook and Steelhead 2013 Release Groups. U.S. Fish & Wildlife Service, California-Nevada Fish Health Center, Anderson, CA. Available: http://www.fws.gov/canvfhc/reports.asp.

Background

As a component of studies examining the reach-specific survival and distribution of migrating juvenile Chinook Salmon and steelhead in the San Joaquin River and Delta, the CA-NV Fish Health Center conducted a general pathogen screening and smolt physiological assessment. Steelhead trout were examined in support of the 6-year Study required by the 2009 Biological Opinion on Central Valley Project and State Water Project operations (RPA IV.2.2). The health and physiological condition of the study fish can help explain their performance and survival during the studies. Similar pathogen screening and physiological assessments have been conducted on south delta study fish since 1996. These past examinations have identified the myxozoan parasite *Tetracapsuloides bryosalmonae*, the causative agent of Proliferative Kidney Disease (PKD), in juvenile Merced River Hatchery Chinook. This parasite has been shown to cause mortality in Chinook Salmon with increased mortality and faster disease progression in fish at higher water temperatures (Ferguson 1981; Foott et al. 2007). In 2013, juvenile Chinook Salmon and steelhead trout were surveyed for specific fish pathogens and smolt development using gill Na^+/K^+-ATPase activity levels.

Methods

Fish Sampling

All study fish were cohorts of acoustic tagged release groups and shadowed each release group through handling, tagging (dummy tagged), transport, and in-river holding. Study fish were held for 48 hours at the Durham Ferry release site on the San Joaquin River before sampling. Groups of 30 juvenile Merced River Hatchery Chinook Salmon were sampled on 5 May and 19 May, 2013. Groups of 24 Mokelumne River Hatchery yearling steelhead trout were sampled on 9 March, 6 April and 11 May, 2013. Fish were euthanized; fork length (FL), weight (Wt) and any abnormalities were noted; and tissue samples for lab assays were collected. In addition to the release groups, an additional 30 Chinook were sampled at Merced River Hatchery on 3 May, 2013 (MRH group). Only kidney tissue for the histopathology assay was collected from the MRH group.

Lab Assays

Bacteriology – A sample of kidney tissue was collected aseptically and inoculated onto brain-heart infusion agar. Bacterial isolates were screened by standard microscopic and biochemical tests (USFWS and AFS-FHS 2010). These screening methods would not detect *Flavobacterium columnare*. *Renibacterium salmoninarum* (the bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test of kidney imprints.

Virology – Three fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 at 15°C as described in the AFS Bluebook (USFWS and AFS-FHS 2010) with the exception that no blind pass was performed.

Histopathology – The gill and/or posterior kidney were removed from the fish and immediately fixed in Davidson's fixative. In the lab, the tissues were processed for 5 µm paraffin sections and stained with hematoxylin and eosin (Humason 1979). All tissues for a given fish were placed on one slide and identified by a unique code number. Each slide was examined under a light microscope and observations of abnormalities were noted. Gill was sampled from both Chinook and steelhead release groups and examined for signs of external parasite infection. Kidney was sampled from Chinook release groups and screened for the *T. bryosalmonae* parasite. Infections of the myxozoan parasite *T. bryosalmonae* were rated for intensity of parasite infection and associated tissue inflammation. Intensity of infection was rated as none (zero), low (<10), moderate (11-30) or high (>30) based on number of *T. bryosalmonae* trophozoites observed in the kidney section. Severity of kidney inflammation was rated as normal, focal, multifocal or diffuse.

Gill ATPase – Gill Na^+/K^+-Adenosine Triphosphatase (gill ATPase) activity was assayed by the method of McCormick (1993). Gill ATPase activity is correlated with osmoregulatory ability in saltwater, and high concentrations are found in the chloride cells of the lamellae.

Results

Fish condition

Chinook – The size and condition of the release groups are summarized in Table 1. No mortality occurred with either sample group. Externally, there were no observations of pale gills, significant scale loss or external hemorrhaging. Sutures were all in good condition with minor inflammation noted in 3% (1/30) of fish on 5 May and 7% (2/30) of fish on 19 May. Internally, clinical signs of PKD (swollen kidney and/or spleen) were observed in 23% (7/30) of fish on 5 May and 23% (7/30) fish on 19 May.

Table 1. Mean (± standard deviation) fork length (FL), weight (Wt), Fulton condition factor (KFL) and sample size (N) for Chinook Salmon release groups.

Group	FL (mm)	Wt (g)	KFL	N
5 May	113.9 ±5.0	17.0 ±2.4	1.15 ±0.06	30
19 May	117.2 ±5.9	18.6 ±2.9	1.15 ±0.04	30

Steelhead – The size and condition of the release groups are summarized in Table 2. No mortalities prior to sampling occurred in the March group, one moribund (dying) fish was observed in the April group, and there was one mortality and one moribund fish in the May group. All fish were euthanized at once on the March sample, so some fish were dead up to 2 hours before sampling. In the April and May samples, fish were euthanized in three fish groups immediately before sampling. No pale gills, excessive scale loss or external hemorrhaging were observed; however one fish with a missing eye and another with a healed wound on the belly were noted in the March fish group. No problems with sutures were noted in the fish sampled in March (0/23); minor inflammation at the suture site was noted in 17% (4/24) of the April fish; and 8% (2/24) of the May fish had poorly healed partly open sutures. Internally, an unidentified kidney cyst was observed in one (1/23) fish from the March group, and no other gross internal abnormalities were observed in the steelhead examined in March, April or May.

Table 2. Mean (± standard deviation) fork length (FL), weight (Wt), Fulton condition factor (KFL) and sample size (N) for steelhead sample groups.

Group	FL (mm)	Wt (g)	KFL	N
March	201 ±21	79 ±27	0.94 ±0.08	23
April	209 ±19	84 ±23	0.89 ±0.06	24
May	221 ±14	102 ±18	0.93 ±0.10	24

Bacteriology and virology

In both Chinook and steelhead sample groups, no virus or other cytopathic effects were observed by cell culture over the 21 day incubation period. No obligate fish pathogens were detected, and other isolates were isolated in 5-23% of sample groups (Table 3). These other isolates were common fauna in the environment and fishes GI tract (Aoki 1999) and were likely contaminates due to field sampling conditions.

Table 3. Summary of bacteria isolated from the kidneys of dummy tagged fish. These isolates were likely contaminates from which are commonly found in surface water, soil or the fish's GI tract.

Species	*Aeromonas* /*Pseudomonas*	various Gram positive bacteria
Chinook	5% (3/60)	23% (14/60)
Steelhead	6% (4/71)	10% (7/71)

Gill histology

Chinook – No parasite infections or significant inflammation was seen in gill sections from the 5 May or 19 May Chinook sample groups.

Steelhead – The majority of the fish sampled in March demonstrated epithelial edema which was most likely a post mortem change due to premature euthanization of this group. Minor gill edema was observed in 33% (8/24) of steelhead in the April sample and 4% (1/24) in May, but no significant inflammation or gill lesions were observed in any of the sample groups. An unidentified protozoan parasite (Figure 1A) was observed in 39% (9/23) of fish sampled in March, 63% (15/24) of fish in April and 8% (2/24) of fish sampled in May. Cyst-like zenomas of an unidentified Microsporidia (Figure 1B) were noted in 8% (2/24) of fish from the April and May samples groups, but were not observed in fish from the March group. As noted above, there was no significant gill inflammation or other signs of gill damage associated with these infections.

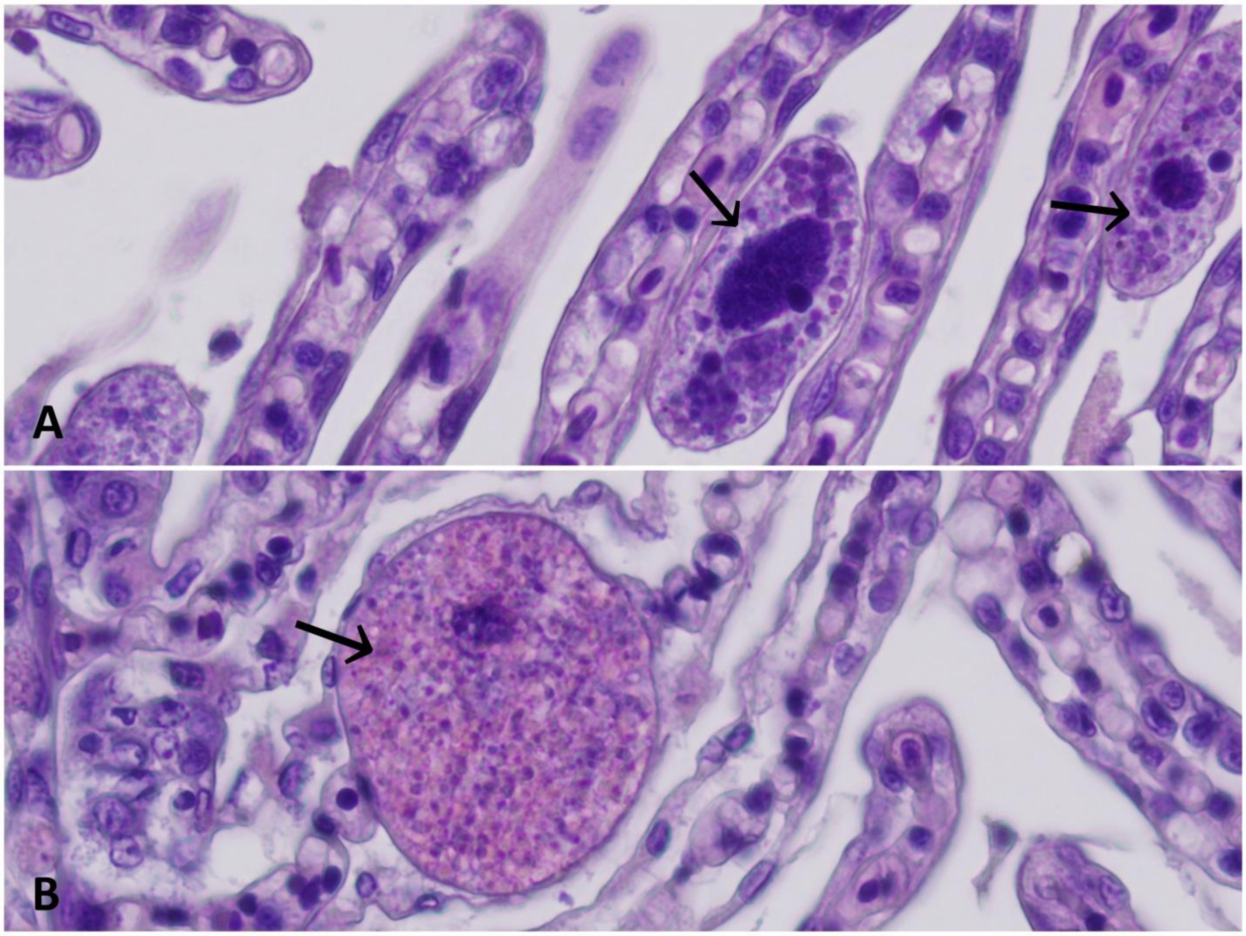

Figure 261. Parasite infections observed in histopathological examination of steelhead gills. No inflammation or other tissue damage was associated with these infections. (A) Unidentified external protozoan observed on steelhead gills from March, April and May release groups. (B) Zenoma of an unidentified Microsporidea observed in April and May release groups.

Kidney histology

Chinook – The *T. bryosalmonae* parasite was detected in fish from all three Chinook release groups, with 80% to 100% of the fish infected. The intensity of the infections (based on number of parasites) was rated as high in over half of the fish from each release group (Table 4). There was no significant difference detected in the severity of the infections between release groups (Table 5, p=0.089, Fisher's exact test for count data).

Table 4. Prevalence and intensity of *T. bryosalmonae* infection in kidney tissue of juvenile Chinook Salmon. Data presented as number of fish with zero (None), few than 10 (Low), 11-30 (Moderate) or greater than 30 (High) parasites observed in kidney tissue by histopathology. No significant difference was detected between release groups (p=0.101, Fisher's Exact Test for Count Data).

Group	None	Low	Moderate	High
MRH (3 May)	1	10	2	16
5 May	5	5	1	14
19 May	0	9	5	16

Table 5. Severity of kidney inflammation associated with *T. bryosalmonae* infection in juvenile Chinook. Data presented as the number of fish with kidney inflammation rated as normal, focal, multifocal or diffuse by histopathology. No significant difference was detected between release groups (p=0.089, Fisher's Exact Test for Count Data).

Group	Normal	Focal	Multifocal	Diffuse
MRH (3 May)	4	11	11	3
5 May	5	9	7	4
19 May	0	12	8	10

Gill ATPase activity

Chinook – Gill ATPase activity levels (μmol ADP*mg protein^{-1}*hr^{-1}) ranged from 2.8 to 19.3. The activity levels in the 5 May release group was significantly higher than 19 May (Figure 2, P<0.001, Wilcoxen rank sum test).

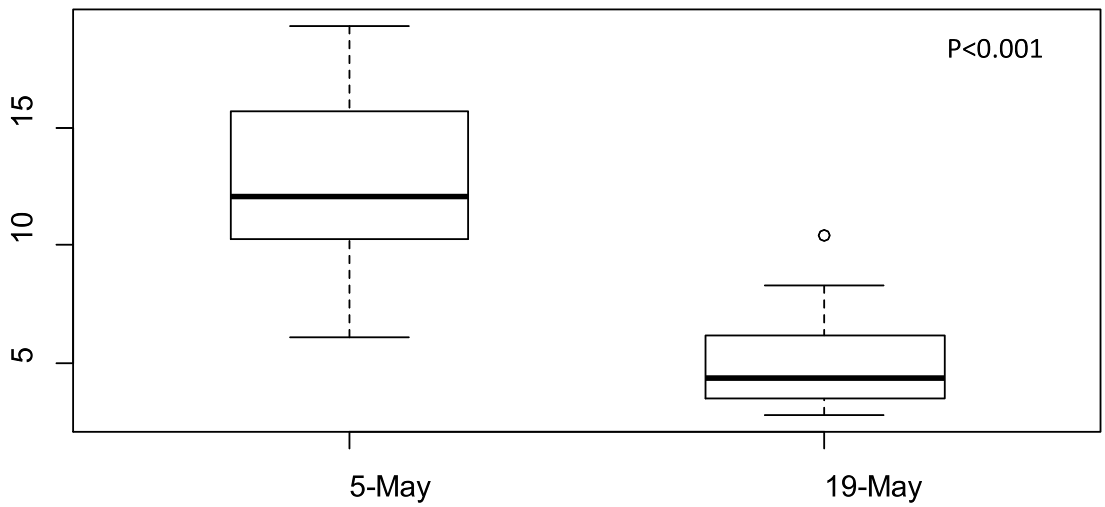

Figure 2. Boxplot of median gill ATPase activity (µmol ADP·mg protein^{-1}·hr^{-1}) in juvenile Chinook Salmon sampled from the 5 May and 19 May release groups. A significant difference was detected between the release groups (P<0.001, Wilcoxon rank sum test).

Steelhead – Gill ATPase activity levels (µmol ADP*mg protein^{-1}*hr^{-1}) ranged from 0.78 to 10.34. Activity levels were greatest in the March release group and decreased in the April and May groups (Figure 3, P<0.001, ANOVA)

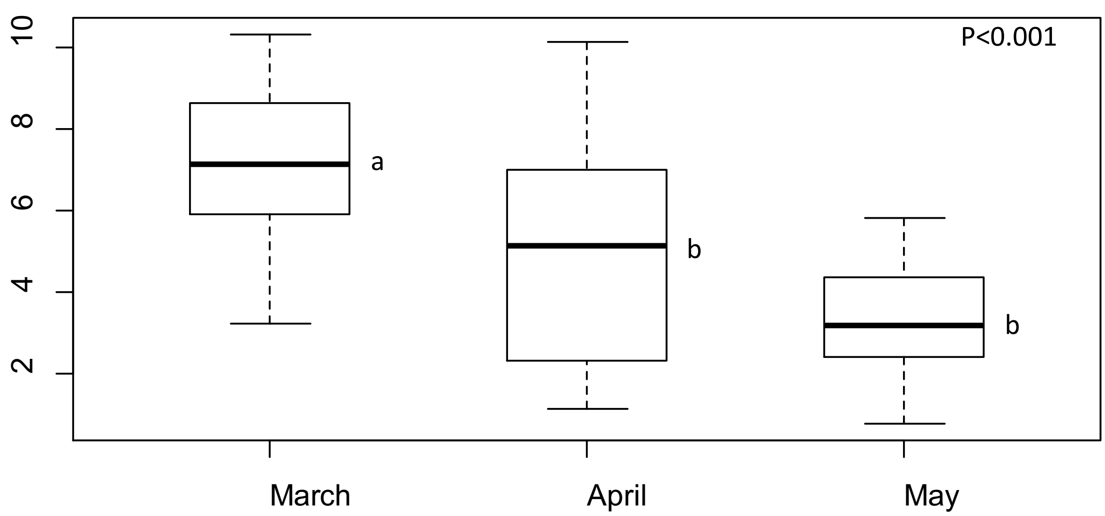

Figure 273. Boxplot of median gill ATPase activity (µmol ADP·mg protein^{-1}·hr^{-1}) in juvenile steelhead from the March, April or May release groups. Groups with letter subscripts in common were not significantly different (P<0.001, ANOVA).

Discussion

The most significant health problem observed was the *T. bryosalmonae* infection in the Chinook release groups. Anemia associated with late stage PKD was not observed. The infection is progressive and may have impacted survival of the Chinook release groups within the typical (30 day) battery life of the acoustic tags (Ferguson 1981; Foott, Stone and Nichols 2007). In past VAMP studies where fish were held in the laboratory for monitoring, total mortality due to the disease was low at 20%-27% (Foott, Stone and Nichols 2007; Foott and Stone 2008). Direct and indirect mortality rates due to PKD in study fish which must actively traverse the Delta are not known.

Gill ATPase activity levels in both the Steelhead and Chinook release groups were lower in the later release(s) which suggests activities were beyond peak levels and declining in those groups. Gill ATPase activity in salmonds typically increases and peaks near the time of most active migratory behavior (Duston, Saunders and Knox 1991; Ewing, Ewing and Satterthwaite 2001; Wedemeyer 1996). Decreases in gill ATPase activity can also occur due to increases in water temperature (Duston et al. 1991). More active migratory behavior in the 5 May Chinook and March steelhead release groups would be consistent with the gill ATPase levels.

Acknowledgments

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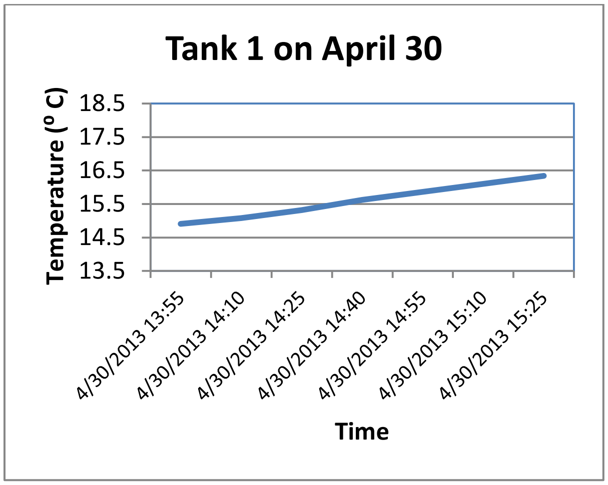
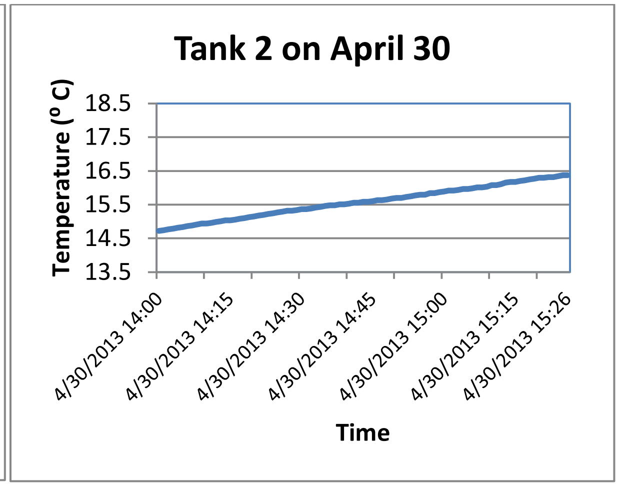
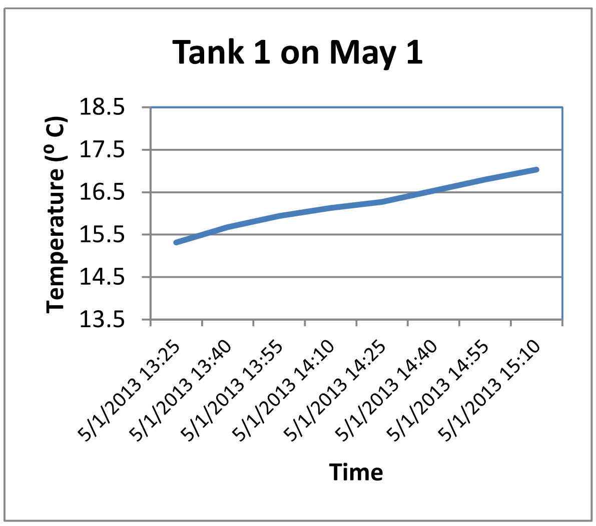
Appendix 2.

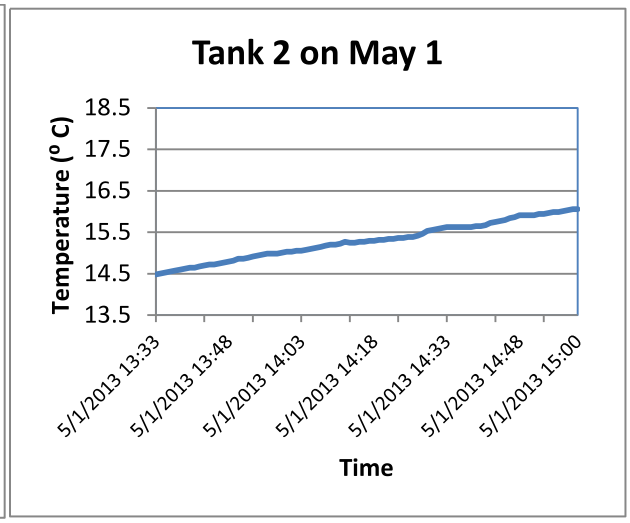
Water temperature in degrees C. during transport

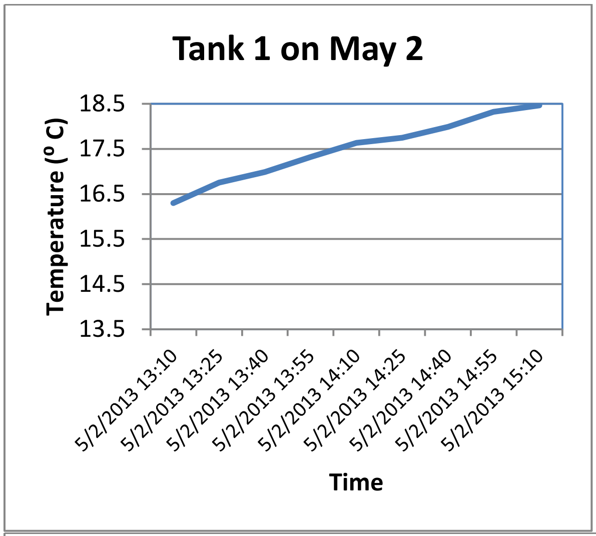
Water temperature in transport tanks of tagged fish in 2013 during transport from Merced River Hatchery to Durham Ferry.

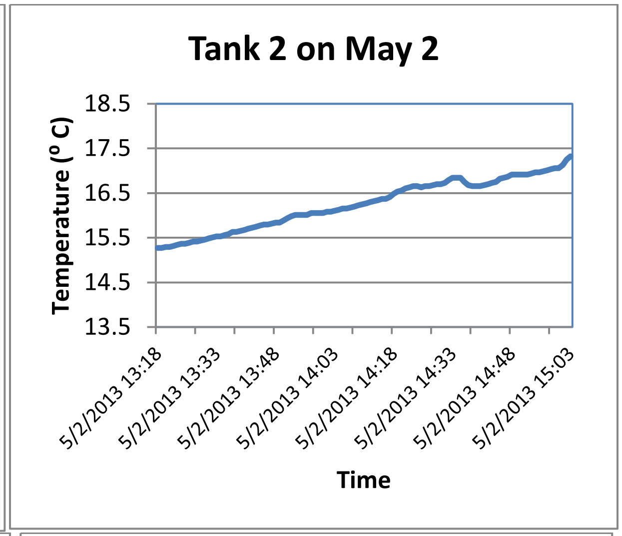


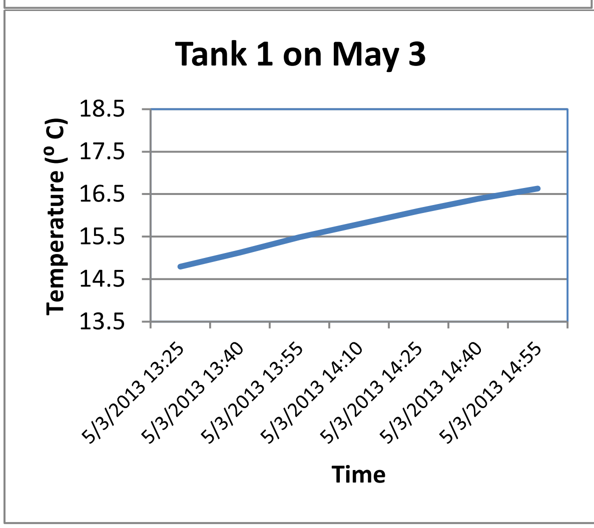


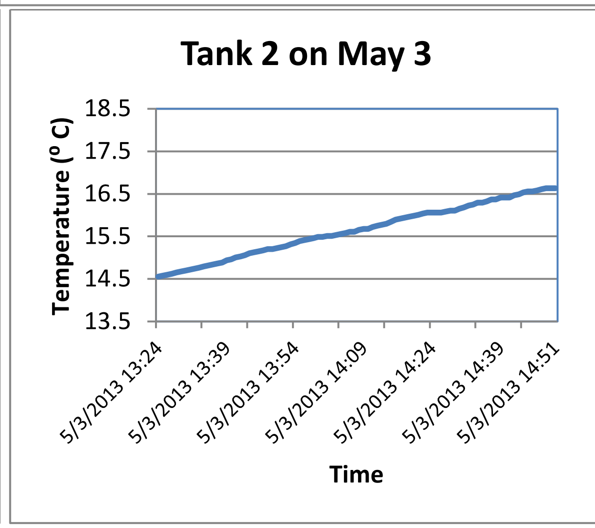


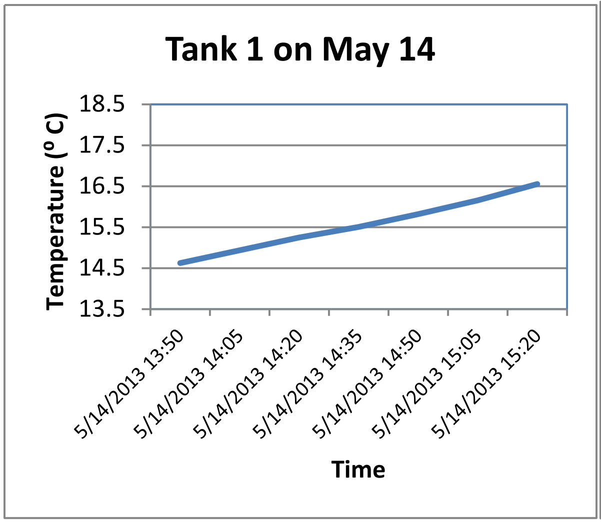


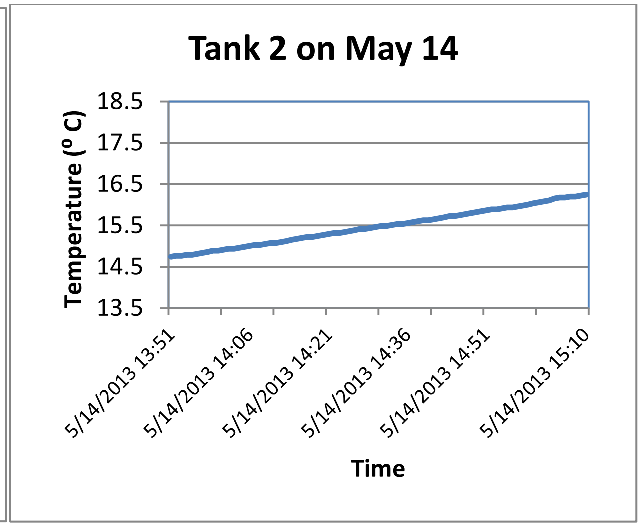

Tank 1 on May 2
Temperature (° C)
18.5
17.5
16.5
15.5
14.5
13.5
5/2/2013 13:10
5/2/2013 13:25
5/2/2013 13:40
5/2/2013 13:55
5/2/2013 14:10
5/2/2013 14:25
5/2/2013 14:40
5/2/2013 14:55
5/2/2013 15:10
Time


Tank 2 on May 2
Temperature (° C)
18.5
17.5
16.5
15.5
14.5
13.5
5/2/2013 13:18
5/2/2013 13:33
5/2/2013 13:48
5/2/2013 14:03
5/2/2013 14:18
5/2/2013 14:33
5/2/2013 14:48
5/2/2013 15:03
Time


Tank 1 on May 3
Temperature (° C)
18.5
17.5
16.5
15.5
14.5
13.5
5/3/2013 13:25
5/3/2013 13:40
5/3/2013 13:55
5/3/2013 14:10
5/3/2013 14:25
5/3/2013 14:40
5/3/2013 14:55
Time


Tank 2 on May 3
Temperature (° C)
18.5
17.5
16.5
15.5
14.5
13.5
5/3/2013 13:24
5/3/2013 13:39
5/3/2013 13:54
5/3/2013 14:09
5/3/2013 14:24
5/3/2013 14:39
5/3/2013 14:51
Time


Tank 1 on May 14
Temperature (º C)
18.5
17.5
16.5
15.5
14.5
13.5
5/14/2013 13:50
5/14/2013 14:05
5/14/2013 14:20
5/14/2013 14:35
5/14/2013 14:50
5/14/2013 15:05
5/14/2013 15:20
Time


Tank 2 on May 14
Temperature (º C)
18.5
17.5
16.5
15.5
14.5
13.5
5/14/2013 13:51
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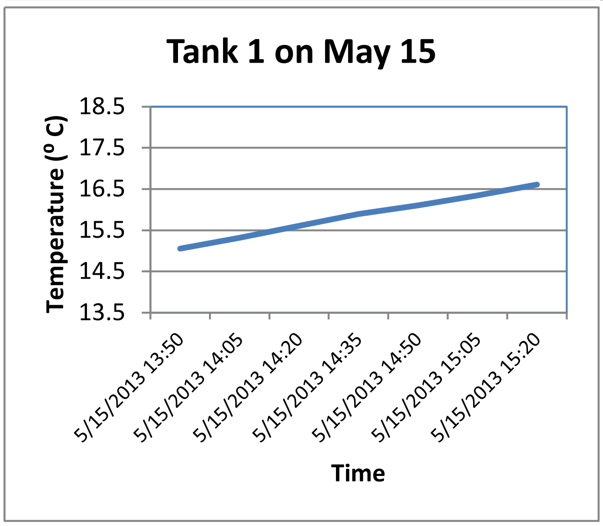
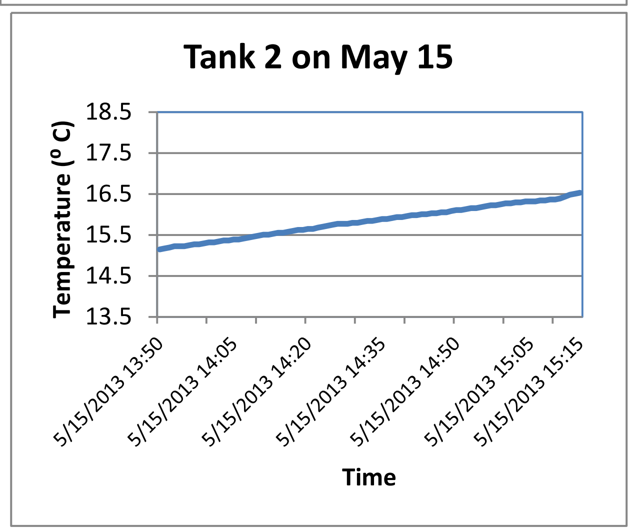
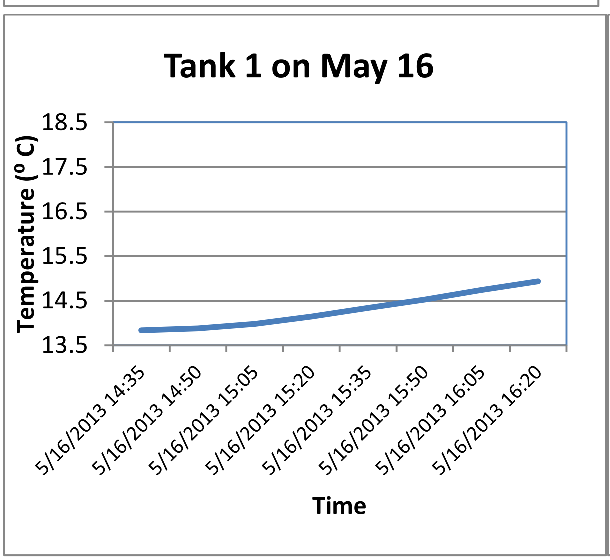
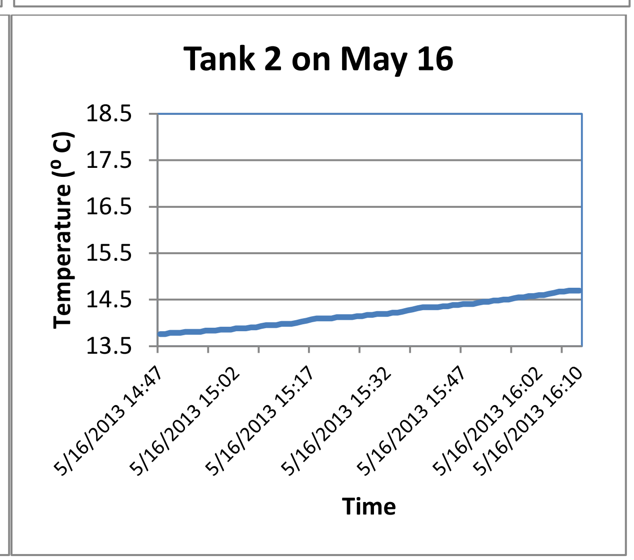
5/14/2013 14:51
5/14/2013 15:10
Time


Tank 1 on May 15
Temperature (º C)
18.5
17.5
16.5
15.5
14.5
13.5
5/15/2013 13:50
5/15/2013 14:05
5/15/2013 14:20
5/15/2013 14:35
5/15/2013 14:50
5/15/2013 15:05
5/15/2013 15:20
Time


Tank 2 on May 15
Temperature (º C)
18.5
17.5
16.5
15.5
14.5
13.5
5/15/2013 13:50
5/15/2013 14:05
5/15/2013 14:20
5/15/2013 14:35
5/15/2013 14:50
5/15/2013 15:05
5/15/2013 15:15
Time


Tank 1 on May 16
Temperature (º C)
18.5
17.5
16.5
15.5
14.5
13.5
5/16/2013 14:35
5/16/2013 14:50
5/16/2013 15:05
5/16/2013 15:20
5/16/2013 15:35
5/16/2013 15:50
5/16/2013 16:05
5/16/2013 16:20
Time


Tank 2 on May 16
Temperature (º C)
18.5
17.5
16.5
15.5
14.5
13.5
5/16/2013 14:47
5/16/2013 15:02
5/16/2013 15:17
5/16/2013 15:32
5/16/2013 15:47
5/16/2013 16:02
5/16/2013 16:10
Time

Appendix 3.

Survival Model Parameters

Table A3:1. Definitions of parameters used in the release-recapture survival model in the 2013 tagging study. Parameters used only in particular submodels are noted.

Parameter	Definition
S_{A2}	Probability of survival from Durham Ferry Downstream (DFD) to Banta Carbona (BCA)
S_{A3}	Probability of survival from Banta Carbona (BCA) to Mossdale (MOS)
$S_{A2,A4}$	Probability of survival from Durham Ferry Downstream (DFD) to Mossdale (MOS)
S_{A4}	Probability of survival from Mossdale (MOS) to Lathrop (SJL) or Old River East (ORE)
S_{A5}	Probability of survival from Lathrop (SJL) to Garwood Bridge (SJG)
S_{A6}	Probability of survival from Garwood Bridge (SJG) to Navy Drive Bridge (SJNB) (Submodel II)
$S_{A6,G2}$	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) (Submodel II)
$S_{A7,G2}$	Overall survival from Navy Drive Bridge (SJNB) to Chipps Island (MAE/MAW) (derived from Submodel II)
$S_{A9,G2}$	Overall survival from MacDonald Island (MAC) to Chipps Island (MAE/MAW) (Submodel II)
S_{B1}	Probability of survival from Old River East (ORE) to Old River South (ORS)
$S_{B2,G2}$	Overall survival from Old River South (ORS) to Chipps Island (MAE/MAW) (derived from Submodel I)
$\phi_{A1,A2}$	Joint probability of moving from Durham Ferry release site downstream toward DFD, and surviving to DFD
$\phi_{B1,B2}$	Joint probability of moving from ORE toward ORS, and surviving from ORE to ORS; = $S_{B1}\psi_{B2}$
$\phi_{B2,B3}$	Joint probability of moving from ORS toward OR4, and surviving from ORS to OR4
$\phi_{B2,C2}$	Joint probability of moving from ORS toward MR4, and surviving from ORS to MR4
$\phi_{B2,D1}$	Joint probability of moving from ORS toward RGU, and surviving from ORS to RGU
$\phi_{B2,E1}$	Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP
$\phi_{B3,G2}$	Joint probability of moving from OR4 toward Chipps Island (MAE/MAW), and surviving from OR4 to MAE/MAW
$\phi_{C1,B3}$	Joint probability of moving from MRH toward OR4, and surviving from MRH to OR4
$\phi_{C1,C2}$	Joint probability of moving from MRH toward MR4, and surviving from MRH to MR4
$\phi_{C1,D1}$	Joint probability of moving from MRH toward RGU, and surviving from MRH to RGU
$\phi_{C1,E1}$	Joint probability of moving from MRH toward CVP, and surviving from MRH to CVP
$\phi_{C2,G2}$	Joint probability of moving from MR4 toward Chipps Island (MAE/MAW), and surviving from MR4 to MAE/MAW
$\phi_{D1,D2}$	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD
$\phi_{D1,G2}$	Joint probability of moving from RGU toward Chipps Island (MAE/MAW), and surviving from RGU to MAE/MAW
$\phi_{D2,G2}$	Joint probability of moving from RGD toward Chipps Island (MAE/MAW) and surviving from RGU to MAE/MAW
$\phi_{E1,E2}$	Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank
$\phi_{E1,G2}$	Joint probability of moving from CVP toward Chipps Island (MAE/MAW), and surviving from CVP to MAE/MAW
$\phi_{E2,G2}$	Joint probability of moving from CVPtank toward Chipps Island (MAE/MAW) and surviving from CVPtank to MAE/MAW
ψ_{A1}	Probability of remaining in the San Joaquin River at the head of Old River; = 1 - ψ_{B1}
ψ_{B1}	Probability of entering Old River at the head of Old River; = 1 - ψ_{A1}
ψ_{B2}	Probability of remaining in Old River at the head of Middle River; = 1 - ψ_{C2}
ψ_{C2}	Probability of entering Middle River at the head of Middle River; = 1 - ψ_{B2}
P_{A2}	Conditional probability of detection at DFD
P_{A3}	Conditional probability of detection at BCA
P_{A4}	Conditional probability of detection at MOS

Table A3:1. (Continued)

Parameter	Definition
P_{A5a}	Conditional probability of detection at SJLU
P_{A5b}	Conditional probability of detection at SJLD
P_{A5}	Conditional probability of detection at SJL (either SJLU or SJLD)
P_{A6a}	Conditional probability of detection at SJGU
P_{A6b}	Conditional probability of detection at SJGD
P_{A6}	Conditional probability of detection at SJG (either SJGU or SJGD)
P_{A7}	Conditional probability of detection at SJNB
P_{A9a}	Conditional probability of detection at MACU
P_{A9b}	Conditional probability of detection at MACD
P_{A9}	Conditional probability of detection at MAC (either MACU or MACD)
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 OR4U
P_{B3b}	Conditional probability of detection at OR4D
P_{B3}	Conditional probability of detection at 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_{D1a}	Conditional probability of detection at RGU1
P_{D1b}	Conditional probability of detection at RGU2
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_{E1a}	Conditional probability of detection at CVPU
P_{E1b}	Conditional probability of detection at CVPD
P_{E1}	Conditional probability of detection at CVP (either CVPU or CVPD)
P_{E2}	Conditional probability of detection at CVPtank
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
C_{E2}	Probability of known removal at E2, conditional on arriving at E2

Table A3:2. Parameter estimates (standard errors in parentheses) from survival model for tagged juvenile Chinook Salmon released in 2013, excluding predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are from pooled release groups. Some parameters were not estimable because of sparse data.

Parameter	Release 1	Release 2	Population Estimate
S_{A2}		0.75 (0.03)	0.82 (0.02)
S_{A3}		0.52 (0.03)	0.69 (0.02)
$S_{A2,A4}$	0.68 (0.03)	0.39 (0.02)	0.56 (0.02)
S_{A4}	0.99 (0.01)	0.87 (0.03)	0.94 (0.01)
S_{A5}	0.36 (0.05)	0.39 (0.14)	0.36 (0.05)
S_{A6}	0.91 (0.05)	1 (0)	0.92 (0.04)
$S_{A6,G2}$	0.03 (0.03)	0 (0)	0.03 (0.03)
S_{A7}	0.07 (0.05)		0.06 (0.04)
$S_{A7,G2}$	0.03 (0.03)	0 (0)	0.03 (0.03)
$S_{A9,G2}$			0.50 (0.36)
S_{B1}	0.72 (0.03)	0.54 (0.05)	0.66 (0.03)
$S_{B2,G2}$	0.04 (0.01)	0 (0)	0.02 (0.01)
$\phi_{A1,A2}$	1.01 (0.03)	0.84 (0.02)	0.89 (0.01)
$\phi_{B1,B2}$	0.72 (0.03)	0.50 (0.05)	0.65 (0.03)
$\phi_{B2,B3}$	0.04 (0.02)	0.15 (0.05)	0.07 (0.02)
$\phi_{B2,C2}$	0.01 (0.01)		0.01 (0.01)
$\phi_{B2,D1}$	0.08 (0.02)	0.07 (0.03)	0.08 (0.02)
$\phi_{B2,E1}$	0.28 (0.04)	0.28 (0.06)	0.28 (0.03)
$\phi_{B3,G2}$	0 (0)	0 (0)	0 (0)
$\phi_{C1,B3}$	0 (0)	0 (0)	0 (0)
$\phi_{C1,C2}$	0 (0)		0 (0)
$\phi_{C1,D1}$	0 (0)	0 (0)	0 (0)
$\phi_{C1,E1}$	0 (0)	0 (0)	0 (0)
$\phi_{C2,G2}$	0 (0)		0 (0)
$\phi_{D1,D2}$	0.54 (0.14)		0.47 (0.12)
$\phi_{D1,G2}$	0 (0)	0 (0)	0 (0)
$\phi_{D2,G2}$	0 (0)		0 (0)
$\phi_{E1,E2}$	0.13 (0.05)		0.12 (0.04)
$\phi_{E1,G2}$	0.13 (0.05)	0 (0)	0.07 (0.04)
$\phi_{E2,G2}$	1 (0)		0.58 (0.30)
ψ_{A1}	0.29 (0.03)	0.10 (0.03)	0.23 (0.02)
ψ_{B1}	0.71 (0.01)	0.90 (0.03)	0.77 (0.02)
ψ_{B2}	0.99 (0.01)	0.94 (0.03)	0.97 (0.01)
ψ_{C2}	0.01 (0.01)	0.06 (0.03)	0.03 (0.01)
P_{A2}	0.54 (0.03)	0.99 (0.01)	NA[a]
P_{A3}		0.75 (0.03)	NA[a]
P_{A4}	0.97 (0.01)	0.99 (0.01)	0.97 (0.01)

a = unique parameters were estimated for different release groups; no pooled estimate is available.

Parameter	Release 1	Release 2	Population Estimate
S_{A2}		0.75 (0.03)	0.82 (0.02)
S_{A3}		0.52 (0.03)	0.69 (0.02)
$S_{A2,A4}$	0.68 (0.03)	0.39 (0.02)	0.56 (0.02)
S_{A4}	0.99 (0.01)	0.87 (0.03)	0.94 (0.01)
S_{A5}	0.36 (0.05)	0.39 (0.14)	0.36 (0.05)
S_{A6}	0.91 (0.05)	1 (0)	0.92 (0.04)
$S_{A6,G2}$	0.03 (0.03)	0 (0)	0.03 (0.03)
S_{A7}	0.07 (0.05)		0.06 (0.04)
$S_{A7,G2}$	0.03 (0.03)	0 (0)	0.03 (0.03)
$S_{A9,G2}$			0.50 (0.36)
S_{B1}	0.72 (0.03)	0.54 (0.05)	0.66 (0.03)
$S_{B2,G2}$	0.04 (0.01)	0 (0)	0.02 (0.01)
$\square_{A1,A2}$	1.01 (0.03)	0.84 (0.02)	0.89 (0.01)
$\square_{B1,B2}$	0.72 (0.03)	0.50 (0.05)	0.65 (0.03)
$\square_{B2,B3}$	0.04 (0.02)	0.15 (0.05)	0.07 (0.02)
$\square_{B2,C2}$	0.01 (0.01)		0.01 (0.01)
$\square_{B2,D1}$	0.08 (0.02)	0.07 (0.03)	0.08 (0.02)
$\square_{B2,E1}$	0.28 (0.04)	0.28 (0.06)	0.28 (0.03)
$\square_{B3,G2}$	0 (0)	0 (0)	0 (0)
$\square_{C1,B3}$	0 (0)	0 (0)	0 (0)
$\square_{C1,C2}$	0 (0)		0 (0)
$\square_{C1,D1}$	0 (0)	0 (0)	0 (0)
$\square_{C1,E1}$	0 (0)	0 (0)	0 (0)
$\square_{C2,G2}$	0 (0)		0 (0)
$\square_{D1,D2}$	0.54 (0.14)		0.47 (0.12)
$\square_{D1,G2}$	0 (0)	0 (0)	0 (0)
$\square_{D2,G2}$	0 (0)		0 (0)
$\square_{E1,E2}$	0.13 (0.05)		0.12 (0.04)
$\square_{E1,G2}$	0.13 (0.05)	0 (0)	0.07 (0.04)
$\square_{E2,G2}$	1 (0)		0.58 (0.30)
$\square_{A1}$	0.29 (0.03)	0.10 (0.03)	0.23 (0.02)
$\square_{B1}$	0.71 (0.01)	0.90 (0.03)	0.77 (0.02)
$\square_{B2}$	0.99 (0.01)	0.94 (0.03)	0.97 (0.01)
$\square_{C2}$	0.01 (0.01)	0.06 (0.03)	0.03 (0.01)
P_{A2}	0.54 (0.03)	0.99 (0.01)	NA[a]
P_{A3}		0.75 (0.03)	NA[a]
P_{A4}	0.97 (0.01)	0.99 (0.01)	0.97 (0.01)

a = unique parameters were estimated for different release groups; no pooled estimate is available.

Table A3:2. (Continued)

Parameter	Release 1	Release 2	Population Estimate
P_{A5a}	1 (0)	1 (0)	1 (0)
P_{A5b}	1 (0)	1 (0)	1 (0)
P_{A5}	1 (0)	1 (0)	1 (0)
P_{A6a}	1 (0)	1 (0)	1 (0)
P_{A6b}	0.97 (0.03)	1 (0)	0.97 (0.03)
P_{A6}	1 (0)	1 (0)	1 (0)
P_{A7}	1 (0)		1 (0)
P_{A9a}	1 (0)		1 (0)
P_{A9b}	0.50 (0.35)		0.50 (0.35)
P_{A9}	1 (0)		1 (0)
P_{B1a}	0.93 (0.02)		0.93 (0.01)
P_{B1b}	0.99 (0.01)		0.98 (0.01)
P_{B1}	1 (0)	0.95 (0.03)	1 (0)
P_{B2a}	0.94 (0.02)	0.95 (0.03)	0.94 (0.02)
P_{B2b}	1 (0)	0.98 (0.02)	1 (0)
P_{B2}	1 (0)	1 (0)	1 (0)
P_{B3a}	1 (0)	1 (0)	1 (0)
P_{B3b}	1 (0)	1 (0)	1 (0)
P_{B3}	1 (0)	1 (0)	1 (0)
P_{C1a}	1 (0)	1 (0)	1 (0)
P_{C1b}	1 (0)	1 (0)	1 (0)
P_{C1}	1 (0)	1 (0)	1 (0)
P_{C2a}	1 (0)		1 (0)
P_{C2b}	1 (0)		1 (0)
P_{C2}	1 (0)		1 (0)
P_{D1a}	1 (0)	1 (0)	1 (0)
P_{D1b}	0.92 (0.07)	1 (0)	0.94 (0.06)
P_{D1}	1 (0)	1 (0)	1 (0)
P_{D2a}	0.86 (0.13)		NA[a]
P_{D2b}	1 (0)		1 (0)
P_{D2}	1 (0)		1 (0)
P_{E1a}	0.98 (0.02)	1 (0)	0.98 (0.02)
P_{E1b}	0.98 (0.02)	0.47 (0.12)	NA[a]
P_{E1}	1 (0)	1 (0)	NA[a]
P_{E2}	0.50 (0.20)		NA[a]
P_{G2a}	0.67 (0.27)		0.67 (0.27)
P_{G2b}	1 (0)		1 (0)
P_{G2}	1 (0)		1 (0)
C_{E2}	0.67 (0.19)		NA[a]

a = unique parameters were estimated for different release groups; no pooled estimate is available.

Table A3:3. Parameter estimates (standard errors in parentheses) from survival model for tagged juvenile Chinook Salmon released in 2012, including predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are from pooled release groups. Some parameters were not estimable because of sparse data.

Parameter	Release 1	Release 2	Population Estimate
S_{A2}		0.73 (0.03)	0.81 (0.02)
S_{A3}		0.54 (0.03)	0.70 (0.02)
$S_{A2,A4}$	0.68 (0.03)	0.39 (0.02)	0.57 (0.02)
S_{A4}	0.99 (0.01)	0.87 (0.03)	0.95 (0.01)
S_{A5}	0.36 (0.05)	0.39 (0.14)	0.36 (0.05)
S_{A6}	0.85 (0.06)	1 (0)	0.88 (0.06)
$S_{A6,G2}$	0.03 (0.03)	0 (0)	0.03 (0.03)
S_{A7}	0.12 (0.08)		0.10 (0.07)
$S_{A7,G2}$	0.04 (0.04)	0 (0)	0.03 (0.03)
$S_{A9,G2}$			0.30 (0.21)
S_{B1}	0.73 (0.03)	0.54 (0.05)	0.67 (0.03)
$S_{B2,G2}$	0.04 (0.01)	0 (0)	0.02 (0.01)
$\phi_{A1,A2}$	1.01 (0.03)	0.83 (0.02)	0.89 (0.01)
$\phi_{B1,B2}$	0.72 (0.03)	0.51 (0.05)	0.65 (0.03)
$\phi_{B2,B3}$	0.05 (0.02)	0.16 (0.05)	0.08 (0.02)
$\phi_{B2,C2}$	0.01 (0.01)		0.01 (0.01)
$\phi_{B2,D1}$	0.08 (0.02)	0.06 (0.03)	0.07 (0.02)
$\phi_{B2,E1}$	0.30 (0.04)	0.31 (0.06)	0.31 (0.03)
$\phi_{B3,G2}$	0 (0)	0 (0)	0 (0)
$\phi_{C1,B3}$	0 (0)	0 (0)	0 (0)
$\phi_{C1,C2}$	0 (0)		0 (0)
$\phi_{C1,D1}$	0 (0)	0 (0)	0 (0)
$\phi_{C1,E1}$	0 (0)	0 (0)	0 (0)
$\phi_{C2,G2}$	0 (0)		0 (0)
$\phi_{D1,D2}$	0.85 (0.10)	1 (0)	0.88 (0.08)
$\phi_{D1,G2}$	0 (0)	0 (0)	0 (0)
$\phi_{D2,G2}$	0 (0)	0 (0)	0 (0)
$\phi_{E1,E2}$	0.12 (0.05)		0.11 (0.04)
$\phi_{E1,G2}$	0.12 (0.05)	0 (0)	0.06 (0.04)
$\phi_{E2,G2}$	1 (0)		0.58 (0.30)
ψ_{A1}	0.29 (0.03)	0.10 (0.03)	0.23 (0.02)
ψ_{B1}	0.71 (0.03)	0.90 (0.03)	0.77 (0.02)
ψ_{B2}	0.99 (0.01)	0.94 (0.03)	0.97 (0.01)
ψ_{C2}	0.01 (0.01)	0.06 (0.03)	0.03 (0.01)
P_{A2}	0.54 (0.03)	1 (0)	NA[a]
P_{A3}		0.75 (0.03)	NA[a]
P_{A4}	0.97 (0.01)	0.98 (0.01)	0.97 (0.01)
P_{A5a}	1 (0)	1 (0)	1 (0)

a = unique parameters were estimated for different release groups; no pooled estimate is available.

Table A3:3. (Continued)

Parameter	Release 1	Release 2	Population Estimate
P_{A5b}	1 (0)	0.92 (0.07)	0.99 (0.01)
P_{A5}	1 (0)	1 (0)	1 (0)
P_{A6a}	1 (0)	1 (0)	1 (0)
P_{A6b}	0.97 (0.03)	1 (0)	0.97 (0.03)
P_{A6}	1 (0)	1 (0)	1 (0)
P_{A7}	1 (0)		1 (0)
P_{A9a}	1 (0)		1 (0)
P_{A9b}	0.50 (0.35)		0.50 (0.35)
P_{A9}	1 (0)		1 (0)
P_{B1a}	0.90 (0.02)		NA[a]
P_{B1b}	0.99 (0.01)		NA[a]
P_{B1}	1 (0)	0.94 (0.03)	NA[a]
P_{B2a}	0.92 (0.02)	0.92 (0.04)	0.92 (0.02)
P_{B2b}	1 (0)	0.97 (0.02)	0.99 (0.01)
P_{B2}	1 (0)	1 (0)	1 (0)
P_{B3a}	1 (0)	1 (0)	1 (0)
P_{B3b}	1 (0)	1 (0)	1 (0)
P_{B3}	1 (0)	1 (0)	1 (0)
P_{C1a}	1 (0)	1 (0)	1 (0)
P_{C1b}	1 (0)	1 (0)	1 (0)
P_{C1}	1 (0)	1 (0)	1 (0)
P_{C2a}	1 (0)		1 (0)
P_{C2b}	1 (0)		1 (0)
P_{C2}	1 (0)		1 (0)
P_{D1a}	1 (0)	1 (0)	1 (0)
P_{D1b}	0.92 (0.07)	1 (0)	0.94 (0.06)
P_{D1}	1 (0)	1 (0)	1 (0)
P_{D2a}	0.91 (0.09)	1 (0)	0.93 (0.06)
P_{D2b}	1 (0)	1 (0)	1 (0)
P_{D2}	1 (0)	1 (0)	1 (0)
P_{E1a}	0.95 (0.03)	1 (0)	0.96 (0.03)
P_{E1b}	0.89 (0.05)	0.37 (0.11)	NA[a]
P_{E1}	1 (0)	1 (0)	NA[a]
P_{E2}	0.50 (0.20)		NA[a]
P_{G2a}	0.67 (0.27)		0.67 (0.27)
P_{G2b}	1 (0)		1 (0)
P_{G2}	1 (0)		1 (0)
C_{E2}	0.67 (0.19)		NA[a]

a = unique parameters were estimated for different release groups; no pooled estimate is available.

Errata

Errata for the 2012 Chinook Salmon survival report:

Page 34: Dummy Tagged fish, 5th sentence: Should read “Four of the 60 examined fish were found to have stitched organs”.