2012 South Delta Chinook Salmon Survival Study

Rebecca Buchanan, University of Washington;
Pat Brandes, Mike Marshall, J. Scott Foott, Jack Ingram and David LaPlante,
U.S. Fish and Wildlife Service;
Josh Israel, U.S. Bureau of Reclamation;
Compiled and edited by Pat Brandes, U.S. Fish and Wildlife Service

Introduction

The Vernalis Adaptive Management Plan (VAMP) as part of the San Joaquin River Agreement has been measuring juvenile salmon survival through the Delta since 2000 (SJRGA 2013). Prior to 2000, similar south Delta coded-wire-tag (CWT) studies were funded by the Interagency Ecological Program and others (Brandes and McLain 2001). Since 2008, survival of juvenile Chinook Salmon through, or in, the Delta has been measured using acoustic tags. The main objective of the VAMP was to better understand the relationship between Chinook Salmon smolt survival through the Delta and San Joaquin River flows and combined CVP and SWP exports in the presence of the physical head of Old River barrier (HORB). The San Joaquin River Agreement and the VAMP study ended in 2011.

In 2012, the main objective of the Chinook Salmon survival study was to estimate survival through the Delta during the San Joaquin River Flow Modification Project (USBR 2012), during which the Merced River flows were augmented between April 15 and May 15, and compare it to survival, without the flow augmentation (after May 15), in the presence of the HORB. As part of the National Marine Fisheries Service and California Department of Water Resources Joint Stipulation Regarding South Delta Operations during April and May of 2012 (http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/ocapstip.html; accessed 8/27/15), the physical HORB was installed in 2012. The barrier had eight culverts in 2012, compared to between two and six culverts as in past years. 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).

These salmon studies also estimated route selection at some channel junctions in the south Delta along the main stem San Joaquin River and provided information on how route selection into some reaches 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 the impact of changes in hydrology with the HORB, as the primary factor relative to juvenile salmon survival however we are aware that many other factors also influence survival through the Delta.

Goals and Objectives

The goal of this study was to determine if there were differences in survival resulting from changes in hydrology (i.e. increased flow) with the HORB installed.

Objectives:

1. Determine survival of emigrating salmon smolts from Mossdale to Chipps Island during two time periods (prior to May 15 and after May 15) in the presence of the HORB to determine if there was a benefit from the flow augmentation from the Merced River in the spring of 2012.
2. Assess whether the higher flows resulted in a reduction in travel time; a potential mechanism for why survival may be higher with higher flows.
3. 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 2012.
4. Assess the influence of flow on survival between Mossdale and Jersey Point with the HOR barrier installed in 2012 and compare it to past years to further evaluate if the increased flow from the Merced River flow augmentation likely resulted in higher smolt survival through the Delta.

Background

Survival during the smolt life-stage was assumed to be the link associated with two statistically significant relationships between San Joaquin basin escapement and 1) San Joaquin River flow at Vernalis and 2) the ratio of San Joaquin River flow to Central Valley Project and State Water Project exports, 2 ½ years earlier (Figures 5-20 and 5-21 in SJRGA 2007). It is these relationships between flow and flow/exports and escapement that are the basis for the hypothesis that increasing flow and decreasing exports during the smolt outmigration would increase adult escapement and production in the San Joaquin basin.

The early, pre-VAMP studies compared survival of CWT Feather River Hatchery (FRH) smolts released into upper Old River to those released on the main stem San Joaquin River at Dos Reis. Dos Reis is located on the San Joaquin River downstream of the head of Old River. These studies were conducted between 1985 and 1990 and suggested that survival was higher for salmon smolts released on the main stem San Joaquin River at Dos Reis than for fish released into Old River (Brandes and McLain 2001). The results of these studies were the basis for recommending a rock barrier at the head of Old River (HORB) to prevent juvenile salmon from migrating down Old River where survival appeared to be less.

CWT releases made at Dos Reis were also used to assess the survival of salmon smolts on the San Joaquin River downstream of Old River. Although it is assumed that fish released at Dos Reis migrated downstream via the main stem San Joaquin River, there is the potential for fish released at Dos Reis to have moved upstream into Old River on flood tides, especially during periods of low San Joaquin River flows and high exports or into the interior Delta via Turner or Columbia Cuts or other downstream connections to the interior Delta. Data from 1989 to 1999 indicated that as San Joaquin River flows increased downstream of Old River, survival increased from Dos Reis to Jersey Point (Figure 5-14 in SJRGA 2007). These data provided the basis for the hypothesis that increased flow in the San Joaquin

River would increase salmon smolt survival. However, with the addition of more recent data (2005 and 2006) from recoveries in the trawls (as there were no or limited recovery data from the ocean fishery due to fishery closures in 2008 and 2009), the strength of this relationship appeared to lessen (Figure 5-13 in SJRGA 2007).

With the HORB in place, the majority of the fish migrating downstream would stay on the main stem San Joaquin River at the junction between the San Joaquin River and the head of Old River. With the HORB, a statistically significant relationship between CWT survival in the reach between Mossdale or Durham Ferry and Jersey Point and San Joaquin River flow at Vernalis has been observed ($r^2 = 0.73$, $p<0.01$; Figure 5-11 in SJRGA 2007), further supporting our hypothesis that increased flow in the San Joaquin River would increase juvenile salmon survival in the Delta.

In 2010, as part of the VAMP peer review, a statistical model was used to model survival through the Delta as a function of flow and exports, based on the CWT releases in the south Delta (Appendix 1). The results of this modeling also suggested survival was generally higher on the San Joaquin River than in Old River and flow tended to improve survival in the San Joaquin River route, but there was a lot of environmental noise (low signal to noise ratio). This modeling also supported our hypothesis that a HORB would improve survival, because it would reduce the number of smolts migrating through Old River.

Conceptual Model

Our hypothesis in 2012 was that survival would increase with increased flow from the Merced River flow augmentation in the presence of the HORB. Flows were an average of 3,543 cfs during the flow augmentation period and 2,327 cfs afterwards. A potential mechanism for increased survival with increased flow is that increased flow results in shorter travel times (i.e. increased migration rates) through the riverine parts of the Delta, and thus reduces the period of exposure to mortality factors such as high water temperature, predation and toxics (Figure 1). Increased flow is also expected to reduce the effect of the mortality factors by 1) decreasing water temperatures to less stressful levels for juvenile salmon, 2) decreasing the impacts of predation due to lower metabolic rates of predators at lower water temperatures and 3) reducing toxicity concentrations through dilution (Figure 1). Survival through the entire Delta (i.e. to Chipps Island) was expected to increase with the higher flows in 2012 as a consequence of higher survival through the riverine portion of the Delta because of these hypothesized relationships.

The higher flows provided by the Merced flow augmentation in 2012 may also have resulted in the tidal prism moving further downstream, because most of the increased flow would have stayed in the San Joaquin River at the head of Old River (HOR) junction with the HORB, in contrast to when there is no HORB and a large majority of the flow moves into Old River at that junction. The shift in the tidal prism's position serves to increase the portion of the Delta that is riverine and the portion of the migration pathway that potentially responds to decreases in travel time in response to increased flow (Figure 1). It is unclear how far the tidal prism would be moved downstream from the increase in flow of approximately 1200 cubic feet per second (cfs) from the Merced flow augmentation in 2012. Additionally, the shifted position of the tidal prism further downstream, which is dependent on the magnitude of the increased flow, could also potentially reduce the proportion of flow and tagged fish that enter Turner Cut (Figure 1). In summary, survival through the entire Delta was expected to increase as the riverine component of the Delta increased and the proportion of water and fish that were diverted into Turner Cut was reduced from a positional shift of the tidal prism downstream from higher flows.

Once fish enter the interior Delta or into the strongly tidally influenced San Joaquin River, residence times are hypothesized to increase and survival is hypothesized to decrease compared to the river reaches. The increased residence times are anticipated to increase the exposure time of juvenile salmonids to predation or other mortality factors. The incremental increase in flow from the Merced River flow augmentation was not anticipated to decrease water temperatures or dilute toxics in the tidally dominant areas of the Delta as much as the riverine reaches because inflow is a much lower proportion of overall flow in these tidally dominated regions. Lastly, the change to the flow patterns at the HOR from the installation and operation of the HORB was expected to result in fewer tagged fish being salvaged or entrained at the CVP and SWP in 2012 because a low proportion of the San Joaquin flow (~ 5%) and tagged fish enter Old River when the HORB is in place.

Study Design and Methods

This study was conducted in conjunction with a separate, but coordinated study assessing the HORB in 2012 (CDWR, 2015). As part of this HORB assessment, other groups of juvenile salmon were tagged with Hydroacoustic Technology Incorporated (HTI) tags prior to, during, and after the salmon tagging as part of this study (with VEMCO V5 tags). While the methods and results of the HTI study will not be discussed in this report, we have listed when the HTI fish were released with our study fish (Table 1).

Sample Size Analyses

A unique sample size analyses was not conducted for the 2012 study, instead we used information derived from the 2011 VAMP sample size analyses to guide release numbers for the 2012 study (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 effect of 100%, 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 effect 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 provide the power to estimate the relative effects between routes at either of these levels for the two groups released in 2012.

Study Fish

Study fish were obtained from the Merced River Hatchery (MRH) and transported to the Tracy Fish Collection Facility (TFCF) of the CVP on April 20 and May 7 for tagging. Fish were kept in chilled, ozonized, Delta water (14-15 ° C) until 3-4 days before tagging to minimize the progression of proliferative kidney disease (PKD). Low water temperatures inhibit the development of PKD (Ferguson 1981): PKD is progressive at temperatures greater than 15° C (Ferguson 1981). Thus 3-4 days before tagging, tanks holding the fish were slowly switched to ambient Delta water so that they could acclimate to Delta water temperatures prior to tagging and transport to the release site. Fish were sorted such that they were greater than 13 grams (~105 mm forklength [FL]) prior to tagging. Tagged study fish averaged 18.0 grams (SD = 3.7), and 112.8 mm FL (SD = 7.2). Fish were taken off feed 24 hours prior to moving them from MRH to the TFCF and 24 hours prior to surgery.

Tags

Juvenile salmon were tagged with VEMCO V5 180 kHz transmitters that weighed 0.66 grams (g) in air on average (SD = 0.012). 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 = 0.7%) for the 960 fish tagged, well below the recommended 5%. Only 3% (34 of the 960 fish) had a tag weight to body weight ratio slightly greater than 5%, with all less than 5.4%.

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 where tag signal collisions (i.e. many tags emitting signals at the same time to the same receiver) were anticipated (CVP, CCF). 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. For the first week of releases, time of activation was estimated to the nearest hour, whereas tag activation was identified to the nearest minute for the second group of releases.

Photo credit: Jake Osborne

Tagging training

Training those who conducted the tagging occurred between April 9 and April 13 at the TFCF using Chinook Salmon from MRH. Three hundred fish were used for training, and were brought to the TFCF on April 4. The training was conducted by staff from the U.S. Geological Survey (USGS)'s Columbia River Research Laboratory (CRRL). During training, the CRRL refined standard operating procedures, (SOP), and trained personnel to surgically implant acoustic tags (Liedtke 2012). Returning taggers received a refresher course on training during which they were required to tag a minimum of 35 fish. New taggers 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 feed-back. Lastly, a mock tagging session was held on April 13 to practice logistic procedures and to identify potential problems and discuss solutions.

Tagging

In 2012, two groups of 480 Chinook Salmon were tagged with VEMCO V5 tags over two weekly periods: May 1-5 and May 16-20. Each group of salmon was tagged in 3 days, over a 6 day period; Chinook Salmon were tagged every other day, to facilitate survival comparisons between Chinook Salmon and steelhead (the comparison between salmon and steelhead will not be discussed in this report). Two sessions of tagging were conducted for salmon: one in the morning and one in the afternoon. Morning and afternoon tagging sessions were further divided into shifts with each shift incorporating groups of salmon tagged with either VEMCO or HTI tags. The salmon tagged as part of this study were tagged on May 1, May 3, May 5 and May 16, May 18 and May 20 (Table 1). Tagging was conducted at the TFCF as was done since 2009. Four surgeons were used to tag the fish and each surgeon had an assistant. 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 millileters (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 20 seconds and 6 minutes 57 seconds, but most were within 2 to 3 minutes. Tagging was done using standard operating procedures (SOP) developed by the CRRL and refined during the training week. The SOP (Appendix 2) directed all aspects of the tagging operation and was based on Adams et al. (1998) and Martinelli et al (1998) and modified as needed.

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Transmitter Validation

After the surgical implantation of tags, one or two fish were placed into 19 liter (L) (5 gal) perforated buckets with high dissolved oxygen concentrations (110-130%) 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. Tags that would not verify using the VR100 were replaced with a new tag in a new fish. After validation, a pair of buckets containing either one or two fish was combined to create a bucket of 3 fish. The bucket was then moved into a holding flume of circulating water to await loading to the transport truck once the tagging session was completed.

Photo credits: Pat Brandes

Transport to Release Site

After tagging, the 19L perforated buckets, which usually contained three tagged Chinook Salmon each, were held in a flume at the TFCF until they were loaded into transport tanks at the end of each tagging session (morning or afternoon). 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 smaller groups of individually tagged fish, two specially designed transport tanks were used to move Chinook Salmon from the TFCF, 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 filled with fish. Tanks had an internal frame that held 21 or 30 buckets in individual compartments to minimize contact between containers and to prevent tipping. 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. Two trips to the release site were made each tagging day, with the morning and afternoon sessions of tagged fish being transported separately (Table 1).

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After loading buckets into the transport tank, de-chlorinated ice was usually added to the transport tanks to either 1) reduce water temperatures during transport such that they would be closer to the river temperature at the release site, or 2) to prevent water temperatures from increasing during transport. Water temperature and dissolved oxygen (DO) in the transport tanks were recorded after loading buckets and ice (if added) into transport tanks; before leaving the TFCF and at the release site after transport, prior to unloading buckets. The temperature and DO were also measured in the river at the holding/release site.

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. For all releases, perforated buckets were placed into "sleeves" in a pick-up truck and driven a short distance to the river's edge. A "sleeve" is a similar-sized, non-perforated bucket that allows more water to stay in the perforated bucket than would be the case without placing it in a "sleeve". Perforated buckets in sleeves were unloaded from the pick-up truck and carried to the river. Perforated buckets were then separated from the sleeves at the shoreline and submerged in-river to be transported to the holding containers which were anchored one to two meters from shore. Water temperature and dissolved oxygen levels 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 0.64 cm in diameter. Five buckets containing fish were emptied into each perforated garbage can. Only four of the five buckets emptied into the garbage cans contained VEMCO tagged fish while the fifth bucket of each group held 3 to 4 HTI fish. 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. Steelhead for the 6 Year Study were held at the same location and released either the day before or the day after the releases of Chinook Salmon; steelhead were released May 1-2, May 3-4, and May 5-6, and May 18-19, May 20-21, and May 22-23.

Photo credit: Pat Brandes

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 4 hours after the 24 hour holding period, at approximately 1500, 1900, 2300 hours (the day after tagging), and 0300, 0700, and 1100 hours (2 days after tagging)(Table 1). Fish releases were made at these four-hour increments through-out the 24-hour period to spread the fish out and to better represent naturally spawned fish that may migrate downstream through-out the 24 hour period. The Chinook Salmon releases were made on May 2-3, May 4-5, May 6-7 and May 17-18, May 19-20, May 21-22 (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 swam back into the container. Some exceptions to this procedure occurred as one group was released from shore due to high winds and waves, and three groups were released from shore due to a dead battery in the boat (Table 1).

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 tagging location or office for tag code identification.

Photo credit: Pat Brandes

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 2012 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, dummy tagged fish were assessed qualitatively for percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration (Table 2). In addition, two additional groups of 15 dummy-tagged fish (tagged on the same day) were held for approximately 48 hours and assessed for pathogens and other diseases (discussed below).

Fish Health Assessment

As a part of the 2012 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 dummy-tagged fish held at the release site for 48 hours. The health and physiological condition of the study fish can help explain their performance and survival during the studies. Pathogen screenings during past VAMP studies using MRH 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 4.

Tag life tests

Two tag life tests were conducted in conjunction with this study. The first tag-life study began on May 16, with 43 tags. The second tag-life study began on May 24, with 40 tags. Tags were activated and then put into mesh bags and held in holding tanks at the TFCF containing ambient Delta water. A VEMCO VR2W was installed in each tank for recording detections of each individual tag. Files of detections were reviewed to identify the tag failure of 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.

Tag retention test

On May 25, 2012, each of the 4 surgeons tagged 9 to 10 fish with dummy tags to assess tag retention and longer-term mortality of tagged fish. Thirteen of these fish were held in each of 3 separate tanks for 30 days to determine if there was any longer-term mortality of the tagged fish and whether any tags were expelled. Fish were held in tanks at the TFCF for the duration of the 30 days.

Receiver deployment, retrieval, and receiver database

The 2012 Chinook Salmon Survival Study, in conjunction with the 6-Year Steelhead Study used receivers at 26 locations in the lower San Joaquin River and South Delta to Chipps Island (i.e. Mallard Slough) for detecting juvenile salmon and steelhead as they migrated through the Delta (Figure 2). These receivers were placed at key locations throughout the south Delta and similar to those used in VAMP in 2010 and 2011 (Figure 2). Although locations of receivers are similar, the VAMP study used an HTI receiver array, whereas the 2012 study used a VEMCO receiver array. The USBR funded the USGS to deploy, maintain and remove all of the receivers in the array, including receivers at both Jersey Point and Chipps Island in 2012. The detections of tagged salmon on these receivers allowed survival of juvenile salmon to be estimated from Durham Ferry to Chipps Island.

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 (SJGRA 2011, 2013). 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 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 (SJRGA 2011, 2013). More details on all statistical methods follow.

Statistical Methods

Data Processing for Survival Analysis

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

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 pings were recorded within a 30 minute time frame on the hydrophones comprising a detection site from any of the three tag codes associated with the tag. The UW 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 was linked to 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 UW identified potentially invalid detections based on unreasonable travel times or unlikely transitions between detections, and queried the USGS processor about any discrepancies. All corrections were noted and made to the database. All subsequent analysis was based on this cleaned database.

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

Distinguishing between Detections of 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 Salmon 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 survival estimates of actively migrating juvenile Chinook Salmon through the Delta. The size and type (positive or negative) 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 2012 data was based on the predator filter designed and used in the analysis of the 2011 data (SJRGA 2013). That predator filter in turn was based on predator analyses presented by Vogel (2010, 2011), as well as conversations with fisheries biologists familiar with the San Joaquin River and Delta regions 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 2012 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). 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 study were updated to reflect river conditions and observed tag detection patterns in 2012 (Table 5a and 5b). Differences between the 2011 filter and the filter used for the 2012 study (in addition to those identified in Table 5a and 5b) were:

1. Minimum migration rates on upstream-directed transitions were set to 0.1-0.2 km/hr for most upstream transitions. Upstream transitions in Old River from the Highway 4 area to the CVP trashracks and in the Sacramento or San Joaquin River from Threemile Slough to Chipps Island were limited to migration rates no less than 0.5 km/hr.
2. Maximum regional residence times allowed for smolts were set at 60 hours for the San Joaquin River upstream of the head of Old River, and 360 hours in all other regions. In most cases, the maximum regional residence time allowed for smolts making a downstream-directed transition was set at 3 – 5 times the maximum allowable near-field residence time.
3. A maximum of 3 upstream forays and 15 upstream river kilometers was imposed.
4. Maximum allowable travel time since release at Durham Ferry was set at 15 days (360 hours).

The predator scoring and classification method used for the 2011 study was used again for the 2012 study, resulting in tags being classified as in either a predator or a 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.

The criteria used in the predator filter were spatially explicit, with different limits defined for different receivers and transitions (Table 5a and 5b). General components of the approach to various regions are described below. Only regions with observed detections are described; regions 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.

SJL = San Joaquin River near Lathrop (A5): upstream transitions from Stockton sites are not allowed.

ORE = Old River East (B1): repeat visits are not allowed.

SJG = San Joaquin River at Garwood Bridge (A6): transitions from upstream require arrival on flood tide

SJNB = San Joaquin River at Navy Bridge Drive (A7): allow longer residence time if arrive at slack tide; repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

MAC, MFE/MFW = MacDonald Island (A8), Medford Island (A9): repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

TCE/TCW = Turner Cut (F1): should not move against flow; repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

ORS = Old River South (B2): 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 against flow; no repeat visits or arrivals from downstream if not pumping.

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

Constructing Detection Histories

For each tag, the detection data summarized on the "visit" scale was converted to a detection history (i.e., capture history) that indicated the chronological sequence of detections on the fixed site receivers throughout the study area. In cases in which a tag was observed passing a particular receiver or river junction multiple times, the detection history represented the final route of the tagged fish past the receiver or river junction. Detections from the receivers comprising certain dual arrays were pooled, thereby converting the dual arrays to redundant arrays: the San Joaquin River near Mossdale Bridge (MOS, site A4), Lathrop (SJL, A5), and Garwood Bridge (SJG, A6); and Old River East near the head of Old River (ORE, B1). For some release groups, the receivers comprising the dual array just downstream of the initial release site (DFD, A2) were also pooled in order to achieve a better model fit; in other cases, very low detection probabilities at this site required omitting this site from analysis. Likewise, in some cases the dual arrays at either MacDonald Island (MAC, A8) or Old River South (B2) were pooled in order to improve model fit.

Survival Model

A two-part multi-state statistical release-recapture model was developed to estimate salmon smolt survival and migration route parameters throughout the study area. The full two-part model incorporates all receivers, with the exception of the San Joaquin River receiver just upstream of the head of Old River (HOR = B0), the northern-most receivers in Old and Middle rivers (OLD =B4 and MRE = C3) and the Threemile Slough receivers (TMS/TMN = T1) (Table 3, Figure 2). Because many acoustic receivers in the interior delta had no or few detections, a reduced model was developed by simplifying the full model and limiting it to receivers with sufficient detections for analysis. The full model is described in detail first, and then the reduced model is presented.

Full Model

The full release-recapture model is a slightly simplified version of the model used to analyze 2011 steelhead data (Buchanan 2013), and similar to the model developed by Perry et al. (2010) and the model developed for the 2009 – 2011 VAMP studies (SJRGA 2010, 2011, 2013). Figure 2 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 3, Figure 4). Individual receivers comprising dual arrays were identified separately, using “a” and “b” to represent the upstream and downstream receivers, respectively. Not all sites were used in the survival model, although all were used in the predator filter.

Fish moving through the Delta toward Chipps Island may have used any of several routes. The two primary routes modeled were the San Joaquin River route (Route A) and the Old River route (Route B). Route A followed the San Joaquin River past the distributary point with Old River near the town of Lathrop and past the city of Stockton. Downstream of Stockton, fish in the San Joaquin River route (Route A) may have remained in the San Joaquin River past its confluence with the Sacramento River and on to Chipps Island. Alternatively, fish in Route A may have exited the San Joaquin River for the interior Delta at any of several places downstream of Stockton, including Turner Cut, Columbia Cut (just upstream of Medford Island), and the confluence of the San Joaquin River with either Old River or Middle River, at Mandeville Island. Of these four exit points from the San Joaquin River between Stockton and Jersey Point, only Turner Cut was monitored and assigned a route name (F, a subroute of route A). Fish that entered the interior Delta from any of these exit points may have either moved north through the interior Delta and reached Chipps Island by returning to the San Joaquin River and passing Jersey Point and the junction with False River, or they may have moved south through the interior Delta to the state or federal water export facilities, where they may have been salvaged and trucked to release points on the San Joaquin or Sacramento rivers just upstream of Chipps Island. All of these possibilities were included in both subroute F and route A.

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

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

A = San Joaquin River: survival
B = Old River: survival
C = Middle River: survival
D = State Water Project: survival
E = Central Valley Project: survival
F = Turner Cut: survival
G = Jersey Point, Chipps Island: survival, exit point
H = False River: exit point
T = Threemile Slough: not used in survival model

The release-recapture model used parameters that denote the probability of detection (P_{hi}), route entrainment (ψ_{hl}), Chinook Salmon survival (S_{hi}), and transition probabilities equivalent to the joint probability of movement and survival ($\phi_{kj,hi}$) (Figure 3, Figure 4, Table A5-1). Unique detection probabilities were estimated for the individual receivers in a dual array: P_{hia} represented the detection probability of the upstream array at station i in route h, and P_{hib} represented the detection probability of the downstream array.

The model parameters are:

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

S_{hi} = perceived survival probability: joint probability of migration and survival from telemetry station i to station 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.

A variation on the parameter naming convention was used for parameters representing the transition probability to the junction of False River with the San Joaquin River, just upstream of Jersey Point (Figure 2). This river junction marks the distinction between routes G and H, so transition probabilities to this junction are named $\phi_{kj,GH}$ for the joint probability of surviving and moving from station j in route k to the False River junction. Fish may arrive at the junction either from the San Joaquin River or from the interior Delta. The complex tidal forces present in this region prevent distinguishing between smolts using False River as an exit from the San Joaquin and smolts using False River as an entrance to the San Joaquin from Frank's Tract. Regardless of which approach the fish used to reach this junction, the $\phi_{kj,GH}$ parameter (e.g. $\phi_{A9,GH}$) is the transition probability from station *j* in route *k* to the junction of False River with the San Joaquin River via any route; ψ_{G1} is the probability of moving downstream toward Jersey Point from the junction; and $\psi_{H1} = 1 - \psi_{G1}$ is the probability of exiting (or re-exiting) the San Joaquin River to False River from the junction (Figure 3).

Because of the complexity of routing in the vicinity of MacDonald Island (referred to as "Channel Markers" in reports from previous years, e.g., SJRGA 2013) on the San Joaquin River, Turner Cut, and Medford Island, and the possibility of reaching the interior Delta via either route A or route B, the full survival model that represented all routes was decomposed into two submodels for analysis. Submodel I modeled the overall migration from release at Durham Ferry to arrival at Chipps Island without modeling the specific routing from the lower San Joaquin River (i.e., from the Turner Cut Junction) through the interior Delta to Chipps Island, although it included detailed subroutes in route B for fish that entered Old River at its upstream junction with the San Joaquin River (Figure 3). In Submodel I, transitions from MacDonald Island (A8) and Turner Cut (F1) to Chipps Island were interpreted as survival probabilities ($S_{A8,G2}$ and $S_{F1,G2}$) because they represented all possible pathways from these sites to Chipps Island. Submodel II, on the other hand, focused entirely on Route A, and used a virtual release of tagged fish detected at the San Joaquin River receiver array near Lathrop, (SJL) to model the detailed routing from the lower San Joaquin River near MacDonald Island and Turner Cut through or around the interior Delta to Jersey Point and Chipps Island (Figure 4). Submodel II included the Medford Island detection site (A9), which was omitted from Submodel I because of complex routing in that region.

Reduced Model

Detection data of tagged Chinook Salmon in the interior Delta in 2012 were very sparse. There were very few detections at the downstream Old and Middle river sites (OR4 [model code B3] and MR4

[C2]) and Central Valley Project (model codes E1 and E2) receivers, and no detections in Middle River at its head (C1) or radial gates (D1 and D2) receivers. There were also no detections at False River (H1) used in the survival analysis because all False River detections were followed by detections either at Jersey Point (G1) or Chipps Island (G2). With so few detections in the Old River route and the interior Delta portions of the San Joaquin River route, it was not possible to fit the full release-recapture model to the 2012 Chinook Salmon data set. Instead, it was necessary to omit all detection sites in the Old River route other than the first two sites in that route: ORE (B1) and ORS (B2). The simplified submodel I (Figure 5) includes the overall probability of surviving from the Old River receivers near the head of Middle River (ORS) to Chipps Island, $S_{B2,G2}$. This parameter includes all ways of getting from ORS (site B2) to Chipps Island (site G2), and is interpreted as the sum of products of the $\phi_{kj,hi}$ parameters from the full Submodel I:

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

The reduced Submodel I does not decompose $S_{B2,G2}$ into its route-specific components because of sparse data.

The reduced Submodel II focuses on transitions in and from the lower portions of the San Joaquin River, and omits transitions from this region to the interior Delta or water export facilities (Figure 6). While the full Submodel II included transitions from MacDonald Island, Medford Island, and Turner Cut to the interior Delta and water export facilities, insufficient observations of tags making these transitions made it necessary to omit these pathways from the reduced model. Thus, the reduced Submodel II models transitions only to the Jersey Point/False River junction from the MacDonald Island/Medford Island/Turner Cut region. In fact, because no tags were observed exiting the system at False River, it was not possible to separate the probability of getting to the Jersey Point/False River junction $\left(\phi_{hi,GH}\right)$ from the probability of turning toward Jersey Point $\left(\psi_{G1}\right)$; instead, only the product was estimable: $\phi_{hi,G1} = \phi_{hi,GH}\psi_{G1}$, for transitions from site i in route h. Thus, the reduced Submodel II used parameters $\phi_{A8,G1}$, $\phi_{A9,G1}$, and $\phi_{F1,G1}$, which jointly include all routes from the lower San Joaquin River receivers to Jersey Point, including those past the interior Delta receivers in northern Old and Middle rivers (B3 and C2). Likewise, without detections at the head of Middle River receiver (MRH, code C1), it was not possible to separately estimate the probability of surviving from the head of Old River to the head of Middle River $\left(S_{B1}\right)$ from the probability of remaining in Old River at the head of Middle River $\left(\psi_{B2}\right)$. Only the product was estimate: $\phi_{B1,B2} = S_{B1}\psi_{B2}$. Finally, there were insufficient detections at the receivers upstream of the Durham Ferry release site (DFU, code A0), so the A0 site was removed from the simplified submodel I (Figure 5).

The two simplified submodels I and II were fit concurrently using unique detection and transitions probabilities at shared receivers: SJG (A6), SJNB (A7), MAC (A8), TCE/TCW (F1), and MAE/MAW (G2). Parameters at these sites were estimated separately for the two submodels to avoid “double-counting” tags used in both submodels.

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 were also estimated for the major subroutes of route A; subroutes were not distinguishable for route B. These subroutes were identified by a two-letter code, where the first letter indicates routing used at the head of Old River (i.e., A), and the second letter indicates routing used at the Turner Cut junction: A or F. Thus, the route entrainment probabilities for the route A subroutes were:

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

$\psi_{AF} = \psi_{A1}\psi_{F2}$: probability of remaining in the San Joaquin River past the head of Old River, and exiting to the interior Delta at Turner Cut, where $\psi_{F2} = 1 - \psi_{A2}$.

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:

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

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

$S_{B} = S_{A4}\phi_{B1,B2}S_{B2,G2}$: Delta survival for fish that entered Old River at its head.

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

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

The parameters $S_{A8,G2}$ and $S_{F1,G2}$ used in S_{AA} and S_{AF} represent the probability of getting to Chipps Island (i.e., Mallard Island, site MAE/MAW) from A8 and F1, respectively. Both parameters represent multiple pathways around or through the Delta to Chipps Island (Figure 2). Fish that were detected at the A8 receivers (MacDonald Island) may have remained in the San Joaquin River all the way to Chipps Island, or they may have entered the interior Delta downstream of Turner Cut. Fish that entered the interior Delta either at Turner Cut or farther downstream may have migrated through the interior Delta to Chipps Island via Frank's Tract or Fisherman's Cut, False River, and Jersey Point; returned to the San Joaquin River via its downstream confluence with either Old or Middle River at Mandeville Island; or gone through salvage and trucking from the water export facilities. All such routes are represented in the $S_{A8,G2}$ and $S_{F1,G2}$ parameters, which were estimated directly using Submodel I.

The route-specific survival probability for the Old River route, S_B, includes a transition probability, $\phi_{B1,B2}$, as a factor. As indicated above, $\phi_{B1,B2}$ is the product of a survival probability and a route entrainment probability: $\phi_{B1,B2} = S_{B1}\psi_{B2}$. No tags were detected on the Middle River receivers near the head of Middle River (site C1). However, if some tags actually had entered Middle River at its head without detection, then $\psi_{B2} < 1$ and $\phi_{B1,B2} < S_{B1}$, resulting in S_B being a minimum estimate of true Delta survival in the Old River route.

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

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

Survival was also estimated from Mossdale to Jersey Point, although this was estimable only for fish in the San Joaquin River route. Survival through this region ("Mid-Delta" or MD) was defined as follows:

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

where

$$S_{AA(MD)} = S_{A4} S_{A5} S_{A6} S_{A7} \left(\phi_{A8,G1} + \phi_{A8,A9} \phi_{A9,G1} \right), \text{ and}$$

$$S_{AF(MD)} = S_{A4} S_{A5} S_{A6} S_{A7} \phi_{F1,G1} .$$

Survival was also estimated through the southern portions of the Delta ("Southern Delta" or SD), although once again this was estimable only for fish in the San Joaquin River route:

$$S_{A(SD)} = S_{A4} S_{A5} S_{A6} S_{A7} .$$

The probability of reaching Mossdale from the release point at Durham Ferry, ϕ_{A1A4}, 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 first detection site A2 (DFD) had to be removed from analysis, the alternative model parameter $\phi_{A1,A3} = \phi_{A1,A2} S_{A2}$ was used:

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

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 A2a0 A5 A7 A8ab A9b0 G1a0 G2ab represented a tag that was released at Durham Ferry and detected at the first (but not the second) receiver just downstream of the release site (A2a0), at one or both of the receivers near Lathrop (A5), at the single receiver in the San Joaquin River near the Navy Drive Bridge (A7), both receivers at MacDonald Island (A8ab), the downstream receiver at Medford Island (A9b0), the upstream receiver at Jersey Point (G1a0), and both receivers at Chipps Island (G2ab). A tag with this detection history can be assumed to have passed by certain receivers without detection: A2b, A3, A4, A6, A9a, and G1b. In Submodel I, the detections at A9 and G1 were not modeled, yielding Submodel I parameterization:

$$\phi_{A1,A2} P_{A2a} \left(1 - P_{A2b}\right) S_{A2} \left(1 - P_{A3}\right) S_{A3} \left(1 - P_{A4}\right) S_{A4} \psi_{A1} P_{A5} S_{A5} \left(1 - P_{A6}\right) S_{A6} P_{A7} S_{A7} \psi_{A2} P_{A8a} P_{A8b} S_{A8,G2} P_{G2a} P_{G2b} .$$

In Submodel II, this detection history was parameterized starting at the virtual release at site A5 and included detections at A8, A9, and G1:

$$S_{A5} \left(1 - P_{A6}\right) S_{A6} P_{A7} S_{A7} \psi_{A2} P_{A8a} P_{A8b} \phi_{A8,A9} \left(1 - P_{A9a}\right) P_{A9b} \phi_{A9,G1} P_{G1a} \left(1 - P_{G1b}\right) \phi_{G1,G2} P_{G2a} P_{G2b} .$$

Another example is the detection history DF A2ab A4 A5 A6 A7 G2b0. A fish with this detection history was released at Durham Ferry, migrated downstream in the San Joaquin River past the head of Old River with detections at the receivers just downstream of the release site (A2ab), as well as at the Mossdale Bridge (A4), Lathrop (A5), Garwood Bridge (A6), and Navy Drive Bridge (A7) before being detected on the second Chipps Island receiver (G2b0). This fish passed the Turner Cut junction but we have no information on which route it took there, so both routes must be parameterized in both submodels. This fish presumably passed Jersey Point without being detected on either receiver there.

This detection history is modeled partially in Submodel I and partially in Submodel II. In Submodel I, the probability of this detection history is

$$\phi_{A1,A2}P_{A2a}P_{A2b}S_{A2}\left(1-P_{A3}\right)S_{A3}P_{A4}S_{A4}\psi_{A1}P_{A5}S_{A5}P_{A6}S_{A6}P_{A7}S_{A7}\theta P_{G2a}P_{G2b},$$

where $\theta=\psi_{A2}\left(1-P_{A8}\right)S_{A8,G2}+\psi_{F2}\left(1-P_{F1}\right)S_{F1,G2}$, $1-P_{A8}=\left(1-P_{A8a}\right)\left(1-P_{A8b}\right)$, and $1-P_{F1}=\left(1-P_{F1a}\right)\left(1-P_{F1b}\right)$.

In Submodel II, this detection history is parameterized

$$S_{A5}P_{A6}S_{A6}P_{A7}S_{A7}\left[\psi_{A2}\left(1-P_{A8}\right)\left(\phi_{A8,G1}+\phi_{A8,A9}\phi_{A9,G1}\right)+\psi_{F2}\left(1-P_{F1}\right)\phi_{F1,G1}\right]\left(1-P_{G1}\right)\phi_{G1,G2}\left(1-P_{G2a}\right)P_{G2b},$$

where $1-P_{G1}=\left(1-P_{G1a}\right)\left(1-P_{G1b}\right)$.

A final example is the detection history DF A3 A4 B1 B2a0. 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 through the barrier and was detected on at least one receiver at the first Old River site (B1) and on the upstream receiver at the Old River South site (B2a0). The fish was not detected again after passing the Old River South site. It may have died between that site and Chipps Island (the next site modeled), or it may have reached Chipps Island but evaded detection there. Both possibilities must be included in the model parameterization. This detection history is parameterized only in Submodel I:

$$\phi_{A1,A2}\left(1-P_{A2}\right)S_{A2}P_{A3}S_{A3}P_{A4}S_{A4}\left(1-\psi_{A1}\right)P_{B1}\phi_{B1,B2}P_{B2a}\left(1-P_{B2b}\right)\left[1-S_{B2,G2}P_{G2}\right],$$

where $1-P_{A2}=\left(1-P_{A2a}\right)\left(1-P_{A2b}\right)$ 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.

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 UW (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. 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 San Joaquin River route using a one-sided *Z*-test with the test statistic:

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

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

Analysis of Tag Failure

The first of two tag-life studies began on May 16 with 43 tags; the last tag failure was recorded on July 6. The second tag-life study began on May 24 with 40 tags, and the last tag failure was recorded on July 12. Observed tag survival was modeled using the 4-parameter vitality curve (Li and Anderson 2009). Stratifying by tag-life study (mid-May or late May) versus pooling across studies was assessed using the Akaike Information Criterion (AIC; Burnham and Anderson 2002).

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

Analysis of 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 downstream sites were pooled for this test in order to achieve adequate cell counts, and the chi-squared test was performed via Monte Carlo simulations to accommodate remaining low cell counts.

Lack of independence may be caused by differences in survival, route entrainment, or detection probabilities. A second method visually compared estimates of cumulative survival throughout the study area among taggers. Sparse detection data in the Old River route for individual taggers prevented estimating reach survival within the Old River route by tagger, so only the overall survival to Chipps Island was estimated for route B for this analysis. 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). Tagger effects on estimates of individual parameters were also assessed using an F-test. Finally, the nonparametric Kruskal-Wallis rank sum test (Sokal and Rohlf 1995, ch. 13) was used to test for whether one or more 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 difference in survival estimates due to the tagger was tested using a two-sided Z-test on the lognormal scale. The reduced data set (without predator-type detections), pooled over release groups, was used for these analyses.

Testing Effect of Release Group on Parameter Estimates

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 $\hat{\Delta}_\theta = \theta_1 - \theta_2$. 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

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

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 0.0071 for 14 tests (Sokal and Rohlf 1995).

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.

To evaluate our hypotheses that reduced travel times increased survival, we compared average travel time and survival for the different reaches to see if they were different ($p<0.05$) for the two release groups. Given that the lengths of the reaches were different we also standardized the length of each reach and survival in the reach by the distance of each reach (in km) prior to comparing average travel time per km to survival per km (S^(1/km)) across reaches.

Route Entrainment Analysis

A physical barrier was installed at the head of Old River in 2012. The barrier was designed to keep fish from entering Old River, but included culverts that allowed limited fish passage. Only 11 of the 959 (1%) tags released in juvenile Chinook Salmon in 2012 were detected entering the Old River route in 2012, while 449 (47% of 959) were detected in the San Joaquin River route. Because of the barrier and the low number of tags detected in the Old River route, no effort was made to relate route entrainment at the head of Old River to hydrologic conditions in 2012. A route entrainment analysis was performed for the Turner Cut junction instead.

The effects of variability in hydrologic conditions on route entrainment at the junction of Turner Cut with the San Joaquin River were explored using statistical generalized linear models (GLMs) with a binomial error structure and logit link (McCullagh and Nelder 1989). The acoustic tags used in this analysis were restricted to those detected at either of the acoustic receiver dual arrays located just downstream of the Turner Cut junction: site MAC (model code A8) or site TCE/TCW (code F1). Tags were further restricted to those whose final pass of the Turner Cut junction came from either upstream sites or from the opposite leg of the junction; tags whose final pass of the junction came either from downstream sites (e.g., MFE/MFW) or from a previous visit to the same receivers (e.g., multiple visits to the MAC receivers) were excluded from this analysis. Tags were restricted in this way in order to limit the delay between initial arrival at the junction, when hydrologic covariates were measured, and the tagged fish's final route selection at the junction. No Chinook Salmon tags were observed moving from one junction leg to the other, so in fact only tags that came from upstream were used in this analysis. Predator-type detections were also excluded. Detections from a total of 89 tags were used in this analysis: 79 from release group 1, and 10 from release group 2.

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

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

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

The TRN gaging station typically recorded flow, velocity, and river stage measurements every 15 minutes. Linear interpolation was used to estimate the flow, velocity, and river stage conditions at the estimated time of tag arrival at TCJ:

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

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

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

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

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

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

for $x = Q, V, \text{ or } C$, and tag i.

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

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

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

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

where x_j = observed covariate x at time j at the SJG gaging station $\left(x = Q \text{ or } V\right)$, $T_{1(i)}$ = closest observation time of covariate x to the final detection of tag i on the SJG acoustic receivers, and $T_{2(i)}$ =

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

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

All continuous covariates were standardized, i.e.,

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

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

The form of the generalized linear model was

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

where $\tilde{x}_{i1}, \tilde{x}_{i2}, \ldots, \tilde{x}_{ip}$ are the observed values of standardized covariates for tag i (covariates 1, 2, …, p, see below), ψ_{iA} is the predicted probability that the fish with tag i selected route A (San Joaquin River route), and $\psi_{iF} = 1 - \psi_{iA}$ (F = Turner Cut route). Route choice for tag i was determined based on detection of tag i at either site A8 (route A) or site F1 (route F). Estimated detection probabilities for the two release groups were 0.97 – 1.00 for site A8 and 1.00 for site F1 (Appendix 5, Table 5A-2), so no groups were omitted because of low detection probability.

Single-variate regression was performed first, and covariates were ranked by P-values from the appropriate F-test (if the model was overdispersed) or x^2 test (McCullagh and Nelder 1989). Covariates found to be significant alone (α=0.05) were then analyzed together in a series of multivariate regression models. Because of high correlation between flow and velocity measured from the same site, and to a lesser extent, correlation between flow or velocity and river stage, the covariates flow, velocity, and river stage were analyzed in separate models. The exception was that the flow index in the reach from SJG to TCJ $\left(Q_{SJG}\right)$ was included in the river stage model. Exports at CVP and SWP had low correlation over the time period in question, so CVP and SWP exports were considered in the same models. The general forms of the three multivariate models were:

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

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

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

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

Comparison of survival between Mossdale and Jersey Point in 2012 compared to past years.

A multiple regression was run on the combined data set of survival estimates from Mossdale to Jersey Point with the HORB using CWT's in 1994, 1997, 2000-2004 (SJRGA 2013) and using acoustic tags for the two releases in 2012 to determine if tag type (acoustic tag or coded wire tag) was a significant factor in addition to flow for predicting survival. We also compared the results observed in 2012 to those predicted from the CWT relationship with flow at the same flow levels as those experienced by tagged fish in the two 2012 releases. The data were also plotted and the two regression lines were compared; CWT data only and the CWT data combined with the 2012 acoustic tag data.

Results

Transport to Release Site

No mortalities were observed after transport to the release site. Water temperatures ranged from 16.8°C to 20.3° C after loading, prior to transport. Water temperatures ranged from 16.5°C to 20.5°C after transport and before unloading at the release site. Water temperature in the river at the release site ranged from 17.5°C to 20.7°C, with the average during the first week being lower (18.3°C) than for the second week (19.7°C) (Table 6). By adding ice, water temperatures did not change substantially during transport (Table 6 and Appendix 3) and 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 (Table 6). During transport water temperatures did not rise or lower more than 0.5°C, and transport tank temperatures were similar between tanks within about 0.5 °C (Appendix 3). Dissolved oxygen levels ranged between 8.73 and 11.89 mg/l for all measurements in the transport tanks or in the river (Table 6).

Fish Releases

No mortalities occurred after holding and prior to release in the 2012 Chinook Salmon study (Table 6).

Dummy Tagged fish

None of the 60 dummy-tagged Chinook Salmon were found dead when evaluated after being held for 48 hours (Table 7). Three fish from the May 20 group had abnormal gill coloration. 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 2.3 to 5.5%. Eight of the 60 examined fish were found to have stitched organs. Mean FL of the four groups of dummy tagged fish ranged from 108.2 to 112.0 mm. These data indicate that the fish used for the Chinook Salmon study in 2012 appeared to be in generally good condition (Table 7).

Fish Health

Pathogen testing conducted on dummy-tag cohorts of acoustic tagged MRH juvenile Chinook Salmon used in studies corresponding to May 7 and May 23 releases showed no virus or *Renibacterium salmoninarum* infection detected in the fish. The May 23 group had 37% prevalence of both suture abnormalities and A*eromonas – Pseudomonas* sp. infection however there was little correlation between the two findings. As in the past, *Tetracapsuloides bryosalmonae* infection was highly prevalent (≥ 97%) and the associated Proliferative Kidney Disease became more pronounced in the May 23 sample. No mortality occurred to these fish prior to assessment after they had been held for 48 hours for either sample date. Gill Na-K-ATPase data was not reported due to a problem with a key assay reagent. The combination of kidney impairment and poor suture condition of the May 23 salmon indicates that health of the two release groups was not equivalent. See Appendix 4 for more detail on the results of the fish health evaluations.

Tag retention test

Of the 39 dummy tagged fish held for 30 days, 3 died within the first 5 days after tagging. No other mortality was observed during the 30 day period. This suggests that the tagging process alone may have caused some (less than 10%) of the mortality observed during the study. None expelled their tag.

Detections of Acoustic-Tagged Fish

There were 960 acoustic tags released in juvenile Chinook Salmon at Durham Ferry in 2012, but one was removed from the analyses due to the tag “looking odd” resulting in data from only 959 being analyzed. Of these, 713 (74%) were detected on one or more receivers either upstream or downstream of the release site (Table 8), including any predator detections. A total of 707 tags (74%) were detected at least once downstream of the release site, and 482 (50%) were detected in the study area from

Mossdale to Chipps Island (Table 8). Although more tags from the second release group were detected between the release site and the upstream boundary of the study area (Mossdale), considerably more tags from the first release group were detected in the study area than from the second release group (301 vs. 181) (Table 8).

The large majority of the tags detected in the study area were detected in the San Joaquin River route (449 of 482), while only 11 tags were detected in the Old River route (Table 8). Additionally, some tags were detected in the study area near Mossdale Bridge but not downstream of the head of Old River. In general, tag detection counts in the San Joaquin River route decreased as distance from the release point increased. Of the 449 tags observed in the San Joaquin River route, 449 were detected on the receivers near Lathrop; 310 were detected on one or both of the receivers near Stockton (SJG or SJNB); 111 were detected on the receivers in the San Joaquin River near MacDonald Island or in Turner Cut; and 47 were detected at Medford Island (Table 9).

Some of the 449 tags detected in the San Joaquin River downstream of the head of Old River were not assigned to that route for survival analysis because they were subsequently observed upstream of Old River and had no later downstream detections (Table 8). Overall, 446 of the 449 tags observed in the San Joaquin River downstream of Old River were assigned to that route for survival analysis. Of these, 13 tags were observed exiting the San Joaquin River at Turner Cut, three were observed at the Old or Middle River receivers near of Empire Cut, one was observed at the Old and Middle River receivers near Highway 4, one was observed at the CVP trashrack, and none were observed at the radial gates at the entrance to the Clifton Court Forebay (Table 9). A total of 28 San Joaquin River route tags were detected at the Jersey Point/False River receivers, including seven detections on the False River receivers (Table 9). However, all of the tags detected at False River were later detected either at Jersey Point or at Chipps Island, and so no San Joaquin River route tags were used in the survival model at False River (Table10). A total of 14 San Joaquin River route tags were eventually detected at Chipps Island, including predator-type detections (Table 9).

Only 11 tags were detected in the Old River route, and all but one, were assigned to that route for survival analysis (Table 8). Nine (9) tags were detected both at the Old River East receivers near the head of Old River (ORE) and the Old River receivers near the head of Middle River (ORS). Four tags were detected at the CVP trashracks, and none at the radial gates at the entrance to the Clifton Court Forebay (Table 9). One tag from the Old River route was detected at both the Old River sites near Highway 4 and near Empire Cut; it was last detected at Empire Cut. No tags from the Old River route were detected at any of the Middle River sites (Table 9). One of the 11 tags in the Old River route was observed at Chipps Island, and it passed through the holding tank at the Central Valley Project (Tables 9 and 10).

In addition to the Old and Middle receivers located near Empire Cut, the Threemile Slough receivers recorded detections of tags but were purposely omitted from the full survival model. Six tags were detected on the Threemile Slough receivers: four came directly from the San Joaquin River receivers at Medford Island and MacDonald Island, and two were last detected at Jersey Point before being detected at Threemile Slough (Table 9). Those that had come from Medford Island and MacDonald Island continued on to either Jersey Point or Chipps Island, while those that came upriver to Threemile Slough from Jersey Point had no subsequent detections.

The predator filter used to distinguish between detections of juvenile Chinook Salmon and detections of predatory fish that had eaten tagged smolts classified 130 of the 959 tags released (14%) as being detected in a predator at some point during the study (Table 11). Of the 482 tags detected in the study area (i.e., at Mossdale or points downstream), 95 tags (20% of 482) were classified as being in a predator, and the majority (94 of 95) were first classified as being in a predator within the study area. The remaining tag was classified as a predator at Banta Carbona (upstream of the study area) but was later detected in the San Joaquin River at the Lathrop receiver (SJL). Approximately 7% (36 of 535) of the tags detected upstream of Mossdale were classified as being in a predator in that region (Table 11). Two of the tags that were first classified as predators in the study area were subsequently detected upstream of Mossdale. Two of the nine tags detected at upstream Old River sites (ORE and ORS) were classified as in a predator (Table 11).

Within the study area, the detection sites with the largest number of first-time predator-type detections were Lathrop (14 of 449, 3%), Garwood Bridge (18 of 310, 6%), Navy Drive Bridge (23 of 241, 10%), and MacDonald Island (18 of 100, 18%) (Tables 9 and 11). The majority of predator classifications at these four sites were assigned on tag departure from the detection site in question because of long residence times and movements against the flow. Because those detections that are assigned the predator classification only on departure are not removed from analysis in the survival model, only a few detections were actually removed from these sites.

When the predator-type detections were removed, slightly fewer detections were available for the survival analysis (Tables 12-14). With the predator-type detections removed, 697 of the 959 (73%) tags released were detected downstream of the release site, and 480 (50% of those released) were detected in the study area from Mossdale to Chipps Island (Table 12). A similar percentage of the tags from each release group were detected anywhere as a smolt (73% and 72% for the two release groups). Considerably more tags from the first release group were detected in the study area than from the second release group (63% vs. 37%) (Table 12).

Removing predator-type detections did not appreciably change the spatial patterns in the detection counts. The large majority of the tags detected in the study area were detected in the San Joaquin River route (444 of 480, 93%) and assigned to that route for the survival analysis. Only 11 tags were observed in the Old River route (Table 12). Another 25 tags were detected at the Mossdale receivers, but not downstream of the head of Old River (Table 12). Most of the changes to detection counts introduced by removing predator-type detections occurred at receivers in the San Joaquin River, both upstream and downstream of the head of Old River (Tables 9 and 13). There was no change in tag counts at Jersey Point, False River, and Chipps Island. There were very few detections at receivers throughout the western and northern regions of the interior Delta (Table 13), and somewhat fewer once detections were formatted for survival analysis (Table 14). Whether predator-type detections were included or not, detections from those sites had to be omitted from the survival model (Tables 10 and 14) (See *Statistical Methods: Survival Model – Reduced Model*).

Tag-Survival Model and Tag-Life Adjustments

The Akaike Information Criterion (AIC) indicated that pooling data from both tag-life studies (AIC = 18.1) was preferable to stratifying by study month (AIC = 33.4). Thus, a single tag survival model was fitted and used to adjust fish survival estimates for premature tag failure. The estimated mean time to failure from the pooled data was 41.7 days ($SE = 7.5$ days) (Figure 7).

The complete set of detection data, including predator-type detections, contained some detections that occurred after the tags began dying (Figures 8 and 9). The sites with the latest detections were Banta Carbona and the San Joaquin River receivers near the Lathrop, Garwood Bridge, Navy Bridge and MacDonald Island. Some of these late-arriving detections may have come from predators. Tag-life corrections were made to survival estimates to account for the premature tag failure observed in the tag-life studies. All estimates of reach survival for the acoustic tags were greater than 0.99 (out of a possible range of 0 – 1). Thus, there was very little effect of either premature tag failure or corrections for tag failure on the estimates of salmon reach survival in 2012.

Tagger Effects

Fish in the release groups were evenly distributed across tagger (Table 15). For each tagger, the number tagged was distributed evenly across the two release groups. A chi-squared test found no evidence of lack of independence of tagger across the release groups (χ^2 =0.0279, df=3, P=0.9988). The distribution of tags detected at various key detection sites or regions of the study area was well-distributed across taggers, showing no evidence of a tagger effect on survival, route entrainment, or detection probabilities at these sites (χ^2 =16.8759, simulated P-value = 0.5372; Table 16).

Estimates of cumulative survival throughout the San Joaquin River route to Chipps Island showed generally small, non-significant effects of tagger through the system (Figure10). Tagger C had consistently higher point estimates of cumulative survival through the receiver at Navy Drive Bridge, after which cumulative survival from this tagger were no greater than from the other taggers. Despite the higher point estimates of survival observed for Tagger C, the differences were not statistically significant (ANOVA, P = 0.1944). Furthermore, rank tests found no evidence of consistent differences in reach survival across fish from different taggers either upstream of the head of Old River (P=0.9217) or in the San Joaquin River route (P=0.9704). Fish tagged by Tagger B had significantly lower survival estimates through the San Joaquin River reach from the Navy Bridge to the Turner Cut junction (i.e., MacDonald Island and Turner Cut) (F-test: P = 0.0078); however, fish from Tagger B showed no difference in survival estimates in other reaches or to Chipps Island overall compared to the other taggers (Figure 10).

In particular, there was no difference in overall survival to Chipps Island among taggers through the San Joaquin River route (P=0.4655). Only one fish was observed to arrive at Chipps Island via the Old River route, so no tagger effects could be explored for that route. The survival model was fit to the data pooled from all taggers without Tagger B, and estimates of four key performance measures were compared to results found with Tagger B: S_{Total} , S_A , S_B , and $\phi_{A1,A4}$. Statistical Z-tests on the log-scale found no significant difference between estimates of these parameters with and without data from fish tagged by Tagger B (P≥ 0.5835).

Survival and Route Entrainment Probabilities

As described above, detections from the receivers at the entrances to the water export facilities and in the holding tank at the Central Valley Project were removed from the survival model because of sparse data, as were detections from the Old and Middle River receivers near Highway 4. In some cases, there were too few detections at the dual array just downstream of Durham Ferry (DFD, site A2) to include this site in the model. In these cases, the model used the composite parameter $\phi_{A1,A3} = \phi_{A1,A2} S_{A2}$ in place of $\phi_{A1,A2}$ and S_{A2}. Also, in several cases analysis of model residuals showed that incorporating the full dual receiver array at some detection sites reduced the quality of the model fit to the data. In such cases when it was possible to simplify the data structure and still attain useful and valid parameter estimates, detections from the dual array in question were pooled to create a redundant array for better model fit. This occurred at the downstream Durham Ferry site (A2), MacDonald Island (A8), Old River South (near the head of Middle River, B2), and Jersey Point (G1).

No tags from the second release group (released in mid-May) were detected at Chipps Island in 2012, yielding a total Delta survival estimate of 0 ($SE = 0$) for that group whether or not predator-type detections were included. The first release group (released in early May) had positive survival ($S_{total} =$ 0.05; $SE = 0.01$), yielding a population estimate for all fish in the tagging study of 0.03 ($SE = 0.01$) (Table 17). Using only those detections classified as coming from juvenile Chinook Salmon and excluding the predator-type detections, the estimated probability of remaining in the San Joaquin River at the junction with Old River $\left(\psi_A = \psi_{A1}\right)$ was 0.98 ($SE = 0.01$) for both release groups (Table 17), and both release groups demonstrated a significant preference for the San Joaquin River route (P<0.0001 for each group). The estimated survival from Mossdale to Chipps Island via the San Joaquin River route $\left(S_A\right)$ was 0.05 ($SE = 0.01$) for the first release group, and 0 ($SE = 0$) for the second group; the overall population estimate was 0.03 ($SE = 0.01$)(Table 17). Very few fish took the Old River route (11 overall). Although the point estimate of survival to Chipps Island via this route ($S_B = 0.16$) was relatively high compared to the estimated survival via the San Joaquin River route ($S_A = 0.05$), the small number of fish observed taking the Old River route resulted in very high uncertainty in the Old River route survival estimate ($SE = 0.15$ for S_B); thus no significant difference in route-specific survival was detected for the first release group (P=0.1977). The estimated route-specific survival to Chipps Island via the Old River route was 0 for the second release group, yielding a population estimate of $S_B = 0.11$ ($SE = 0.10$); again, there was no significant difference in population survival estimates between the two routes (P=0.1999) (Table 17).

Survival in the Old River route used the parameter $\phi_{B1,B2}$ in place of S_{B1} because there were no detections at site C1 (MRH) (see *Statistical Methods*). The transition parameter $\phi_{B1,B2} = S_{B1}\psi_{B2}$, so if $\psi_{B2} < 1$, then S_B is underestimated using this formulation. For the first release group, $\phi_{B1,B2}$ = 1 ($SE =$

0), so both $S_{B1} = 1$ and $\psi_{B2} = 1$, and S_B is not underestimated (Table A5-2). For the second release group, $\phi_{B1,B2}$=0.67 ($SE = 0.27$), implying that either $S_{B1} < 1$ or $\psi_{B2} < 1$, or both (Table A5-2). However, there was only a single tag detected at site B1 (ORE) that was not later detected as a smolt at site B2 (ORS), and this tag was actually detected at B2 with a predator classification at that site. Thus, there is no evidence that $\psi_{B2} < 1$ for either release group, and so it reasonable to interpret estimates of S_B as unbiased rather than as minima. Furthermore, the lack of detections of tags from the second release group at Chipps Island would yield $S_B = 0$ for that release group in any event. Thus, there is no reason to assume that survival to Chipps Island via the Old River route is underestimated.

Survival was estimated to Jersey Point for fish that used the San Joaquin River route. This survival measure $\left(S_{A(MD)}\right)$ was estimated at 0. 09 (SE =0.02) for the first release group, 0.01 (SE =0.01) for the second release group, and 0.06 (SE =0.01) overall (Table 17). No estimates were available for the Old River route. Survival $\left(S_{A(SD)}\right)$ to the receivers just downstream of the Turner Cut junction on the San Joaquin River (i.e., MacDonald Island and Turner Cut receivers) was estimated at 0.33 ($SE = 0.03$) for the first release group, 0.07 ($SE = 0.02$) for the second release group, and 0.23 ($SE = 0.02$) overall (Table 17). Thus it is apparent that survival was low both to the Turner Cut junction and from that junction to Jersey Point, especially for fish from the second release group.

Survival was lower for the second release group than for the first group throughout the San Joaquin River. Estimated survival from the release site to Mossdale ($\phi_{A1,A4}$) was considerably lower (p<0.0001) for the second release group (0.37 for the second group vs. 0.63 for the first group), as was survival through the Southern Delta (0.07 vs. 0.33; p<0.0001), Middle Delta to Jersey Point (0.01 vs. 0.09; p<0.0001), and the entire Delta to Chipps Island (0 vs. 0.05; p<0.0001)(Table 17). Estimated survival was also lower through the modeled portions of the Old River route, i.e., from the head of Old River to the head of Middle River for the second release group. For the first release group, estimated survival through this reach was 1.0; for the second release group, it was 0.67 ($SE = 0.27$); however, the difference was not statistically significant (p= 0.1106) (Table A5-2). Although the estimate for this reach for the second release group had high uncertainty, the point estimate fits the pattern observed in the San Joaquin River of lower survival for the second release group relative to the first release group.

Including predator-type detections in the analysis produced very similar results on all spatial scales, including survival to Chipps Island, Jersey Point, and the Turner Cut junction (Table 18). The largest difference was in estimates of San Joaquin River survival through the Southern Delta to the Turner Cut junction $\left(S_{A(SD)}\right)$, which increased by 0.01 for both release groups and overall (overall estimate = 0.24, $SE = 0.02$) (Table 18). Including predator detections did not alter the comparisons between release groups; estimated survival was lower for the second release group throughout the various San Joaquin River regions (Table 18; P<0.0001).

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}, S_{A3}, S_{A4}, S_{A5}, S_{A7}, $\phi_{A8,G1}$, and $\phi_{G1,G2}$ (Table 19).

Travel Time

Average travel time through the system from release at Durham Ferry to Chipps Island was 5.75 days based on 11 detections ($SE = 0.41$ days) (Table 20a). Travel time to Chipps Island ranged from 4.1 days to 10.4 days, all from the first release group. The large majority of tags that reached Chipps Island came via the San Joaquin River route; the single tag that arrived at Chipps Island via the Old River route had a total travel time of 4.12 days, which was faster than any of the 14 tags that arrived via the San Joaquin River route. All tags observed at Jersey Point arrived via the San Joaquin River route in 3 – 9 days, with an average of approximately 6 days (Table 20a).

Travel time from release to the Mossdale Bridge receivers ranged from 0.3 to 3.9 days, and averaged 0.53 days (harmonic mean; $SE = 0.01$ days) (Table 20a). Fish with the longer travel times to Mossdale tended to come from the second release group, although both release groups included fish that arrived in under 8 hours. Travel time from release to the Turner Cut junction receivers (i.e., to Turner Cut or MacDonald Island) ranged from 1.5 days to 8.2 days, and averaged between 2 and 4 days (Table 20a). Fish with the longer travel times to Mossdale tended to come from the second release group, although both release groups included fish that arrived in under 8 hours. Travel time from release to the Turner Cut junction receivers (i.e., to Turner Cut or MacDonald Island) ranged from 1.5 days to 8.2 days, and averaged between 2 and 4 days (Table 20a).

Only 2 tags were detected at the Old River receivers near Highway 4 (OR4). One of these tags came via the Old River route and arrived 4.3 days after release, while the other tag arrived via Turner Cut from the San Joaquin River route 5.1 days after release. For the few tags that were detected at the entrance to the Central Valley Project, tags that came via the Old River route tended to have shorter travel times than tags that arrived via the San Joaquin River route (Table 20a). Sample sizes were too small to draw definitive conclusions, but these observations may have been expected because of the longer route to the interior and western receivers via the San Joaquin River route.

Including predator-type detections had only a small effect on average travel times through the system (Table 20b). Travel times to the San Joaquin River receivers at MacDonald Island and Turner Cut were generally slightly longer when predator-type detections were included. This was because travel times were measured to the beginning of the tag's final visit to each site, and many tags classified as being in predators at those sites were observed making multiple visits to those sites. The longer travel times observed for the data set that includes the predator-type detections reflect the assumption used in the predator filter that predators are more likely than smolts to exhibit long travel times.

Average travel time through reaches for tags classified as being in smolts ranged from 0.01 days (approximately 20 minutes) for the single tag observed moving from the Central Valley Project trashracks to the holding tank, to over 2 days for tags moving from MacDonald Island to Jersey Point, and over 3 days for tags moving from MacDonald Island and Medford Island to Chipps Island (Table 21a). While there were several tags that moved from MacDonald Island to Jersey Point in under 2 days, there were also several tags that took over 5 days to make the journey. Similar travel times were observed from the Medford Island receivers to the Jersey Point receivers, although the average travel time was somewhat lower from Medford Island (approximately 1.54 days over both release groups) (Table 21a). The reach from MacDonald Island to Jersey Point was one of the longer reaches in the study area (approximately 26 rkm), so it not surprising that it had some of the longer observed travel times. However, the reach from Jersey Point to Chipps Island was also approximately 26 rkm in length, and travel time through this reached tended to be shorter, ranging from 16 hours to 2.1 days and averaging 1.21 days ($SE = 0.14$ days) (Table 21a). The region between Jersey Point and Chipps Island is strongly affected by tides, which may delay migrating fish, but it is nevertheless channelized. The region between MacDonald Island and Jersey Point, on the other hand, includes Frank's Tract, and it is possible that migrating Chinook Salmon smolts are delayed there for a considerable time. In general, there were too few detections in the interior Delta to make comparisons of travel time through reaches in that region with travel time through reaches contained within the San Joaquin River route. Including predator-type detections did not greatly affect the pattern of observed travel times through the various reaches (Table 21b).

There was a significant negative relationship ($p<0.05$) between travel time per km and survival per km in river reaches upstream of the Lathrop/Old River junction for the second release group, suggesting as travel time per km increased, survival per km decreased (Figure 11, Table 22). Survival also decreased as travel time increased in reaches between Durham Ferry and Lathrop/Old River junction for the first release group, but the regression line was not significant at the $p<0.05$ level. Survival was higher for the first release group, than for the second release group in these three reaches of the river (Figure 11, Table 19). Also there appeared to be a slight increase in travel time (slower migration rate) between Mossdale and Lathrop/Old River junction and between Banta Carbona and Mossdale for the second release group relative to the first release group (Figure 11, Table 22).

In contrast, there did not appear to be a relationship between travel time per km and survival per km for reaches between the Lathrop/Old River junction and Jersey Point (tidal reaches) for either of the release groups in 2012 (Figure 12). While survival through the reach (or joint probability of moving to and surviving to the downstream location) was significantly higher (Table 19) for the first release group for three of these reaches in the San Joaquin River downstream of Lathrop (Lathrop to Garwood Bridge, S_{A5} ; Navy Drive Bridge to MacDonald Island or Turner Cut, S_{A7} ; and the reach between MacDonald Island to Jersey Point, $\phi_{A8,G1}$ [not shown on Figure 12]0, others were not significantly higher (e.g. Garwood Bridge to Navy Bridge Drive [S_{A6}], MacDonald Island to Medford Island [$\phi_{A8,A9}$], and Medford Island to Jersey Point [$\phi_{,A9,G1}$]) (Table 19). Travel times in these reaches were similar for the two release groups (Figure 12).

Route Entrainment Analysis

River flow (discharge) at the TRN gaging station in Turner Cut ranged from -4,402 cfs to 3,361 cfs (average = -1070 cfs) during the estimated arrival time of the tagged Chinook Salmon at the Turner Cut junction location (TCJ) in 2012. Water velocity in Turner Cut was highly correlated with river flow (r=0.999), and velocity values ranged from -0.8 ft/s to 0.6 ft/s (average = -0.1 ft/s). The flow in Turner

Cut was negative (i.e., directed to the interior Delta) upon arrival at TCJ of approximately 61% (54 of 89) tags in this analysis. River stage measured in Turner Cut was moderately correlated with both river flow and velocity (r=-0.70), and ranged from 6.7 ft to 10.9 ft (average = 9.1 ft). Changes in river stage in the 15-minute observation period containing the arrival of the tagged Chinook Salmon to the TCJ ranged from -0.2 ft to 0.2 ft (average = 0 ft). Changes in river stage were not correlated with stage (r=-0.13). The index of river flow in the reach from Stockton to Turner Cut was uncorrelated with flow and velocity in Turner Cut upon arrival at TCJ (r= 0.01), and only moderately correlated with river stage at Turner Cut (r= -0.29). The flow index in the Stockton-Turner Cut reach ranged from 2,324 cfs to 3,400 cfs (average = 2,785 cfs).

The daily export rate at CVP ranged from 821 cfs to 1,016 cfs (average = 960 cfs); exports at CVP were generally low in both early and late May, and was greatest in mid-May. The daily export rate at the State Water Project (SWP) ranged from 507 cfs to 3,698 cfs (average = 1,908 cfs). SWP exports were more variable than CVP exports but also peaked in the third week of May. Exports from CVP and SWP were uncorrelated (r= -0.01). Neither CVP nor SWP exports was correlated with either flow (r=0.09 for CVP, r=-0.03 for SWP) or river stage (r=0.00 for CVP, r=-0.14 for SWP) in Turner Cut. The majority of tags (66 of 89, 74%) arrived at the Turner Cut junction during daylight hours.

The single-variate analyses found no significant effects (α=0.05) of any of the covariates considered (P>0.40 for all covariates; Table 23). This negative result may reflect the true lack of a relationship between environmental variables and route selection at Turner Cut, or it may be an artifact of the low degrees of freedom available and the resulting low statistical power; because only 11 fish were observed entering Turner Cut (out of 89), there were only 11 degrees of freedom total. A study with a larger sample size and more fish observed using Turner Cut may provide evidence of a relationship between one or more of the covariates and route selection at this junction in future.

Comparison of Delta Survival to Past Years

In a multiple regression, tag type (acoustic or CWT) did not come out as an important variable affecting survival, whereas flow did (Table 24). Using the relationship developed from the CWT data (Figure 13), we calculated what survival from Mossdale to Jersey Point was expected to be at the two flow levels in 2012: predicted survival was 0.12 at flows of 3543 cfs and 0 at flows of 2327cfs, very close to what we observed (0.09, $SE = 0.02$, at the higher flow and 0.01, $SE = 0.01$, at the lower flow). The relationships between flow at Vernalis and survival from Mossdale to Jersey Point with the HORB, developed from the historical CWT data and from all of the data (historic CWT data and acoustic tag data added from 2012), were similar (Figure 13). The slopes of the two linear regression lines were the same (0.0001), and the intercepts were similar (-0.2345 for the CWT data only and -0.2295 for the combined data (Figure 13)) . Both relationships were statistically significant (p <0.01).

Discussion

The similarity between parameter estimates with and without predator-type detections raises questions about the predator filter. One possible explanation for the similar estimates is that the majority of the mortality was not directly caused by the predatory fish used to build the predator filter, or that many of the predatory fish feeding on the tagged salmon merely evaded detection. Chinook Salmon smolts may have been eaten by sedentary predators, birds, or mammals (e.g., otters), or by predatory fish that moved about the Delta but evaded the acoustic receivers. Alternatively, Chinook Salmon smolts may have died due to disease or habitat quality. In either case, the tags of the deceased salmon smolts may have settled on the river bottom away from the acoustic receivers; in these cases, the predator filter would correctly identify existing detections of these tags as in smolts rather than predators, and the survival model estimates would be unbiased.

Another possibility is that the filter missed detections of predators, and thus the resulting filtered data set (which supposedly has no detections from predators) is only artificially similar to the unfiltered data set (which includes detections from predators). If this is the case, then survival estimates for the (presumed) smolt-only data set would be biased because they would be based partially on predator detections. The type of bias depends on where the predator filter failed. For example, none of the tags detected at Chipps Island were classified as being in predators by the existing filter. A filter that recategorizes some of those detections as predator detections may yield survival estimates to Chipps Island that are lower than that estimated in this study (0.03). This would happen as long as the revised filter agreed with the original filter in upstream regions. On the other hand, if the predator filter was inefficient (i.e., wrong) upriver of Mossdale such that detections passed by the filter as smolts were actually detections of predators, then it is possible that true survival to Chipps Island was actually higher than estimated (0.03); this may happen if there were fewer actual smolts starting at Mossdale than appeared from the original filter. Of the 959 tags released at Durham Ferry, only 480 (50%) were detected at Mossdale, and 478 of them were classified as in smolts upon arrival at Mossdale (Tables 9 and 13). Only 15 of these tags were detected at Chipps Island. Adjusting the predator filter cannot add more detections at Chipps Island, but it may remove detections at Mossdale. A revised filter that used more stringent criteria upstream of Mossdale was constructed and implemented on the detection data. The revisions to the filter were:

- no upstream-directed transitions allowed upstream of Mossdale
- no repeat visits to sites upstream of Mossdale
- maximum residence time of 2 hours at any site upstream of Mossdale
- maximum regional residence time of 15 hours upstream of Mossdale
- minimum migration rate of 0.2 km/hr for all transitions upstream of Mossdale

This stricter filter resulted in 477 of the 480 detections at Mossdale being classified as in smolts, compared to 478 classified as in smolts using the original predator filter. The Delta survival estimate from the stricter predator filter was 0.03 for the population (i.e., both release groups pooled), unchanged from the estimate using the original filter. Thus, it is unlikely that errors in the predator filter resulted in the similar results with and without the predator-type detections.

Our first objective of the 2012 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) in the presence of the HORB to determine if there was a benefit from the flow augmentation from the Merced

River in 2012. Average river flow measured at the Vernalis gaging station when fish from the first release group were traveling through the Delta to Chipps Island (from release through approximately 10 days after the end of release period) was 3,543 cfs, while for the period of comparable length for the second release group was 2,327 cfs (Figure 14). Survival was higher ($p <0.0001$) through the Delta (S_{Total}) for the first release group (0.05) relative to the second release group (0.00) (Table 17). Thus these findings appear to support our hypothesis that the increased flow from the Merced River flow augmentation increased survival through the Delta.

Our second objective was to assess whether the higher flows from the Merced River flow augmentation resulted in a reduction in travel time and higher survival, specifically in the riverine reaches of the Delta, and resulted in higher through-Delta survival. Shorter travel times would reduce the time tagged fish were exposed to mortality factors such as predation, high water temperatures, and toxics. Travel times in reaches of the Delta between Durham Ferry and a series of downstream locations (Mossdale, Lathrop, Garwood Bridge, Navy Drive Bridge, and MacDonald Island) were all significantly less (i.e. faster migration) for the first release group than the second release group (Table 20a; $p < 0.05$). The travel times in these reaches appeared to be strongly influenced by the travel time for the reach between Lathrop (SJL) and Garwood Bridge (SJG). Travel time between SJL and SJG was significantly less ($p < 0.05$) for the first release group (0.60; $SE =$ 0.02) which experienced the higher flows, than for the second release group (0.86; $SE =$ 0.05) which experienced the lower flows (Table 21a). Survival through this reach was also higher for the first release group (0.81; $SE =$0.02) relative to the second release group (0.48; $SE =$0.04)($p < 0.0001$) (S_{A5}; Table A5-2). Thus, the data in this specific, partly riverine, reach of the Delta are consistent with our hypothesis that an increase in flow would reduce travel time and be associated with higher survival.

To further evaluate the possible relationship between travel time and survival in the remaining reaches, travel time and survival were standardized to a per-km basis. With this standardization, we found that as travel time per km increased, survival decreased for both release groups in the three riverine reaches between Durham Ferry and the Lathrop/Old River junction (Figure 11). Travel time per km was greater for the second group relative to the first group for two of the three reaches; (Banta Carbona to Mossdale and Mossdale to Lathrop/Old River, but not Durham Ferry to Banta Carbona) whereas survival was always lower for the second release group (lower flows) relative to the first group (higher flows) for these three reaches (Figure 11, Table 22). Thus the difference in travel time per km for the first group relative to the second did not always support our hypotheses that the higher survival per km resulted from a decrease in travel time per km from the higher flows in these riverine reaches.

Travel time per km was somewhat less and survival greater for the first release group relative to the second release group in two reaches: 1) between Lathrop and Garwood Bridge (discussed above) and 2) between Garwood Bridge and Navy Bridge Drive (Figure 12, Table 22); the shorter travel time from the increased flow may partially explain the higher point estimate of survival for release 1 compared to release 2 between Garwood Bridge and Navy Bridge, although the increase in survival is not statistically significant at the 5% level (Table 19); however, it is not possible to determine causation from this study.

Once fish enter the interior Delta or into the strongly tidally influenced San Joaquin River, travel times were expected to increase and survival was expected to decrease. While we did generally see longer travel times per km in the tidal reaches (reaches downstream of Navy Bridge Drive), it was not always greater (Table 22; e.g. travel time per km was shorter from MacDonald Island to Medford Island than it was from Lathrop to Garwood Bridge). Travel time per km was also less for the second release group than for the first, even though survival was generally higher for the first group relative to the second in all reaches downstream of Navy Bridge Drive, except between MacDonald Island and Medford Island, when survival per km was higher for the second group (Table 22). Since the increased flow probably was not enough to change velocities significantly in the downstream tidal reaches, the increased survival of the first group relative to the second in most of these tidal reaches suggests there are other mechanisms either associated with flow or other factors that resulted in the increases in survival in these tidal reaches of the Delta.

Once fish move into the interior Delta, they are exposed to flows moving toward the export facilities, which may increase their travel time and reduce their survival to Jersey Point or Chipps Island. While many of the tagged fish may have been diverted from the San Joaquin River into the interior Delta downstream of Turner Cut, we were only able to identify those entering the interior Delta through Turner Cut. We had hypothesized that tagged fish moving into the interior Delta (e.g. Turner Cut) would have increased travel times over those not being diverted into Turner Cut. Since none of the tagged fish that entered Turner Cut survived to Chipps Island for either the first or second release group, we could not compare travel times between release groups or for the Turner Cut route relative to the other routes. One fish that entered Turner Cut from the first release group was observed in the CVP holding tank, but did not survive to reach Chipps Island. We were also not able to assess the impact on survival of tagged fish being routed to the SWP and CVP as detections from the receivers at the entrances to the water export facilities and in the holding tank at the Central Valley Project were removed from the survival model because of sparse data due to the presence of the HORB.

The results of comparing travel time to survival suggests that the increased flow during the first release did not always result in decreased travel times, although it did coincide with an increase in survival in more of the riverine reaches. It was the higher survival in the majority of the reaches (both riverine and tidal) during the first release that resulted in a higher overall survival through the Delta for the first release group relative to the second release group.

However, there are other possible hypotheses for the lower survival in the second release group compared to the first release group, including differences in fish condition, tagging and release procedures, and other environmental conditions. The same tagging and release procedures were used for both release groups, including the same taggers, presumably with the same skill set, so that does not appear to be responsible for the differences in survival we observed. Fish from the second release group were slightly larger on average than fish from the first release group (mean FL = 109.9 mm and 115.7 mm for the first and second release groups, respectively), so it was reasonable to expect higher survival for the second release group rather than lower survival, but we did not observe this. Although the two release groups were released only two weeks apart, they experienced different environmental conditions other than flow. During the same two time periods, combined exports at CVP and SWP varied from 1,513 cfs to 5,054 (mean = 3,200 cfs), with similar means in the two periods. However, exports tended to be high toward the end of the first period, when relatively few fish from the first release were still migrating, and also high near the beginning of the second period, when the majority of fish from the second release group were migrating (Figure 15).

It is also possible that the difference in flow conditions may have resulted in the different survival rates via a mechanism other than travel time, such as temperature, increased predation or toxicity. We had hypothesized that the higher inflow from the Merced flow augmentation would potentially reduce the effects of these mortality factors by reducing temperature stress, diluting toxics or reducing predator metabolic demands from the lower water temperatures. Water temperature measured at the San Joaquin River gage near Lathrop was almost 2 degrees higher on average for the second release group (67.5 °F [19.7°C]) than for the first group (65.6 °F [18.7°C]), which may have negatively affected the survival of the second release group, and been a consequence of the lower flows experienced by the second release group (Figure 16). We were unable to assess the hypothesis that increased metabolic demands from predators due to the warmer water temperatures was the cause for the increased mortality for the second release group relative to the first release group.

To assess the hypothesis that the increased flow from the Merced River flow augmentation may have diluted toxicity in the Delta, we observed that survival was significantly higher for the first group relative to the second group in the reach between SJL and SJG (Table 19). This reach from SJL to the SJG is one of the longer reaches of the Delta at 18 km (Table 22), and it includes a variety of habitats. It is not entirely riverine, but includes the transition to tidal habitat, depending on inflow. The reach is more riverine at higher inflows, and more tidal at lower inflows. The Stockton Wastewater treatment plant releases its effluent in the lower part of this reach which may have an effect on survival, especially during periods of low flow. During periods of low flow the movement of the tidal prism upstream may result in concentration of the effluent in this reach and dilution from flow would be less. There is also the possibility that increased temperatures exacerbate the toxicity effects of the effluent on juvenile salmon survival. Further evaluation of water quality in this reach may be warranted, building on studies conducted near there in 2008 (SJRGA 2009) after a significant die-off of acoustic tags near this location in 2007 – a low flow year (SJRGA 2008).

In addition, it is possible that the higher incidence of PKD infection for the second release group reduced their survival to Chipps Island relative to the first release group. Infection does not necessarily lead to death but would reduce fitness from anemia, kidney dysfunction, and immune suppression even if the fish survived the disease (Angelidis et al 1987, Hedrick and Aronstien 1987 as cited in Nichols et al 2012). The increase in water temperature may have contributed to the higher incidence of PKD infection for the second release group relative to the first as PKD is a progressive disease at water temperatures greater than 15°C (Okamura and Wood 2002 as cited in SJRGA 2013).

Unfortunately, PKD infection is not just a problem for the experimental fish we used in 2012, but was noted as a problem in monitoring on the Merced River. Smolts caught in the Hopeton rotary screw trap on the Merced River (presumably wild stock) also had high levels of PKD infection in 2012 (Nichols et al. 2012). This is also not new, as 90-100% of naturally produced fish in a 2001 survey of Merced outmigrant salmonid health were observed to be infected with PKD (Nichols and Foott 2002 as cited in Nichols et al. 2012). Even some of salmon transferred from MRH to the lab at the Fish Health Center soon after ponding in February of 2012, developed light infections of PKD (Nichols et al 2012).

However, the worst infections identified in the 2012 study were later in the season, with gross clinical signs of PKD (anemia and swollen kidney) observed for naturally produced fish on May 9 (2 out of 24), and high numbers of parasites observed for both naturally produced (May 9 and May 15) and hatchery fish (May 15) (Nichols et al. 2012).

PKD is caused by infection by the endoparasitic myxozoan, *Tetracapsuloides bryosalmonae*. Reducing byrozoan habitat directly upstream of the hatchery and in the Merced River could be a viable disease management strategy (Foott et al. 2007). Increasing flows, if they result in decreasing water temperatures, would serve to reduce the severity of PKD for both experimental and wild fish emigrating from the San Joaquin basin. Higher water temperatures in the river and at the hatchery may have increased the severity of the PKD infection for the second group of tagged fish in 2012, relative to the first group; this may account for some of the increased mortality observed in the second group. Higher water temperatures are affected by both flow and air temperature upstream of the Delta. Cold water releases from the upstream reservoir on the Merced River may have reduced the water temperatures for the first release group over what they would have been without the water release.

Our third objective of the 2012 study was to identify route selection at HOR and at Turner Cut under the two different periods with varying flows and exports. Since the physical HORB was in place in 2012, route selection into the San Joaquin River was high for both groups (0.98; $SE = 0.02$) and did not vary between release groups (Table 17) or when predator type detections were included (Table 18). Route selection at Turner Cut was 0.11 ($SE = 0.03$) for the first release group, and 0.16 ($SE = 0.11$) for the second release group (Table 17) when predator-type detections were removed and similar when predator-type detections were included (0.12; $SE = 0.03$ for the first release group and 0.14; $SE = 0.04$ for the second release group) (Table 18). Differences in the proportion diverted into Turner Cut at the TCJ between release groups were not statistically different: with 11 to 16% of the tagged fish diverted into Turner Cut, none of which survived to Chipps Island ($S_{F1,G2}$; Tables A5-2 and A5-3). Zero probability of survival to Chipps Island for the tagged fish that entered Turner Cut negatively affected total through-Delta survival for both release groups. A study with a larger sample size and more fish observed using Turner Cut may provide evidence of a relationship between one or more covariates (e.g. flow, and tides) and route selection at this junction in future.

It is possible that the lower flows, higher water temperatures, higher toxicity, higher incident of disease (PKD) and possibly higher export rates during the time of peak migration may have combined to negatively affect salmon survival from the second release. Diversion into Turner Cut decreased survival of both groups. With only two release groups and observational data, however, it is not possible to conclude more. Combining these results with those from additional years may shed light on possible causes of mortality in the Delta. The Interagency Ecological Program has funded a multi-year analysis of the data from 2010, 2011, 2012 and 2013 and results will be forthcoming.

Based on the results of this study in 2012, naturally spawned or hatchery juvenile salmonids from the San Joaquin tributaries likely experienced variable survival within the migration period through the Delta, with greater survival during the Merced River flow augmentation period and lower survival during the later remainder period of migration. Higher flows appeared to benefit survival through multiple intertwined mechanisms including shorter travel times, lower water temperatures, and reduced disease impacts.

The comparison of estimates of survival from Mossdale to Jersey Point for the two release groups in 2012, to estimates generated using CWT's with the HORB, suggests that survival observed in 2012 was within that expected based on the past CWT relationship, and that differences in flow between the two releases in 2012 likely increased survival over what it would have been without the flow pulse. However, without direct manipulation and further replication, cause and effect cannot be determined. While this comparison supports our hypothesis that the increased flow from the flow augmentation in the Merced River during the first release group increased survival, it also shows that survival for both groups in 2012 was relatively low, compared to that measured in other years with the HORB (Figure 13). These data suggest a higher flows of approximately 6,000 cfs with the HORB, are needed to achieve survival through the Delta of approximately 0.40. Additional studies, especially during higher flow periods, with the HORB in place, are needed to confirm these results.

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Figures

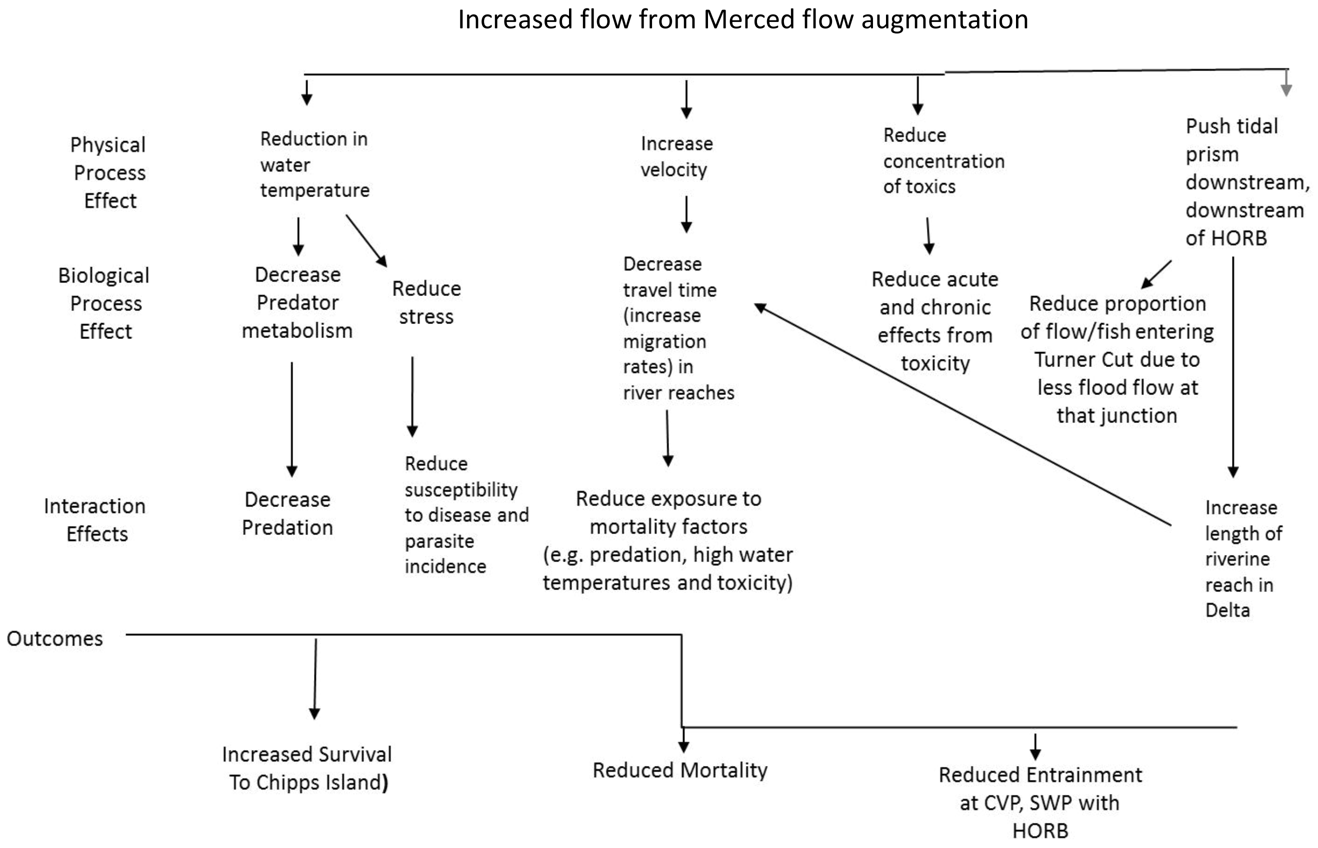


Figure 1: Conceptual model of mechanisms for increased survival from increasing Vernalis Flow with the head of Old River barrier in place.

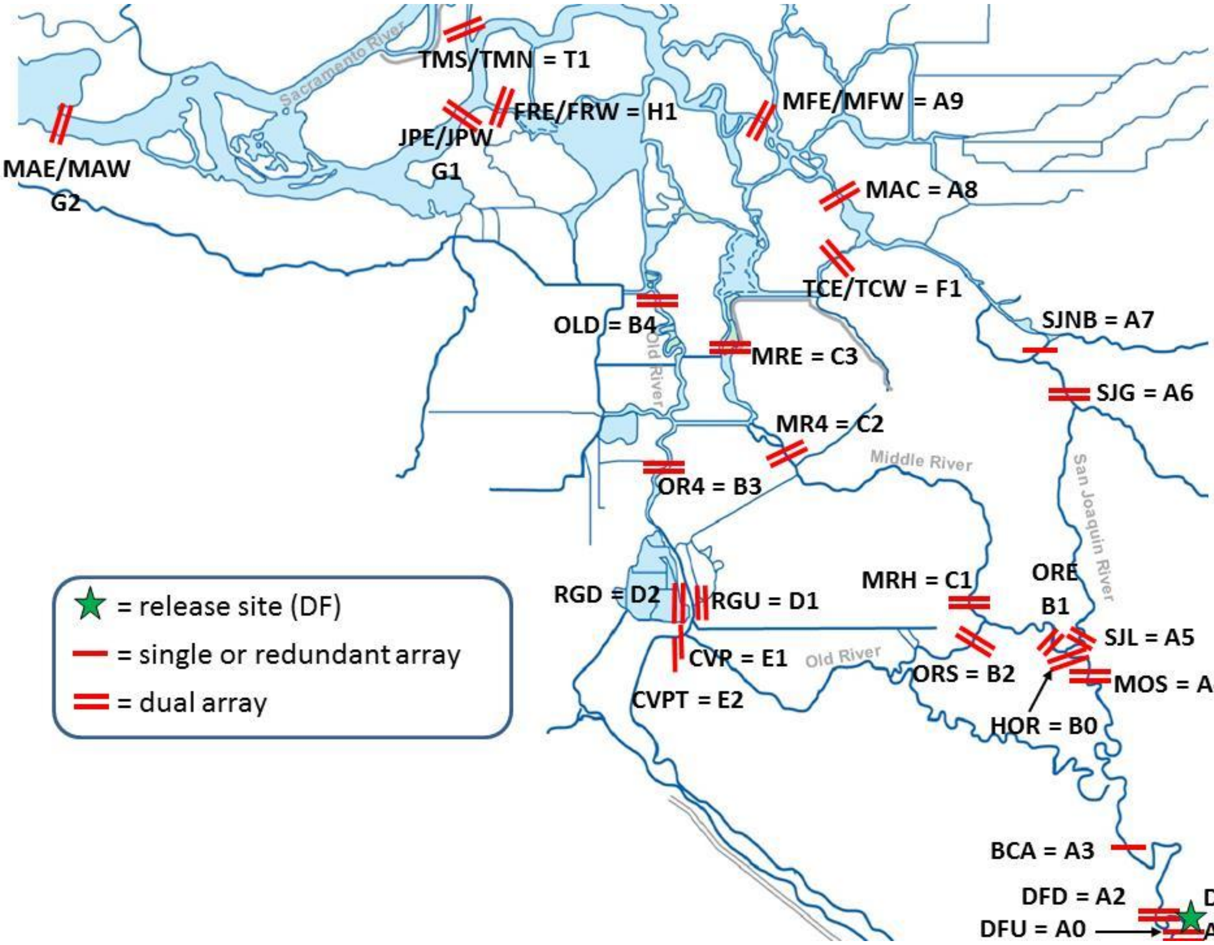


Figure 2. Locations of acoustic receivers and release site used in the 2012 Chinook Salmon study, with site code names (3- or 4-letter code) and model code (letter and number string). Site A1 is the release site at Durham Ferry. Sites B0, B4, C3, and T1 were excluded from the survival model.

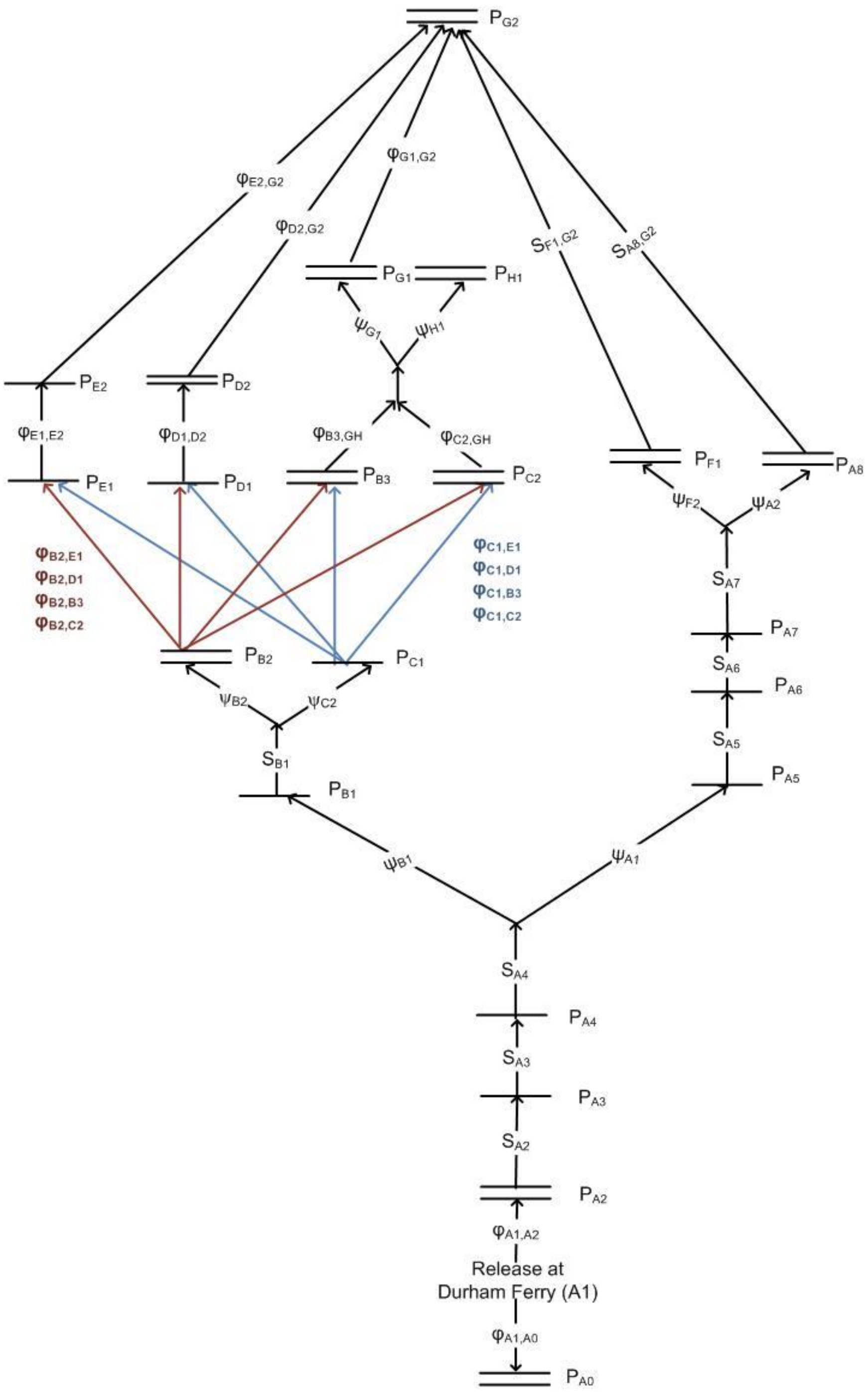


Figure 3. Schematic of 2012 mark-recapture Submodel I. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2. Migration pathways to sites B3 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.

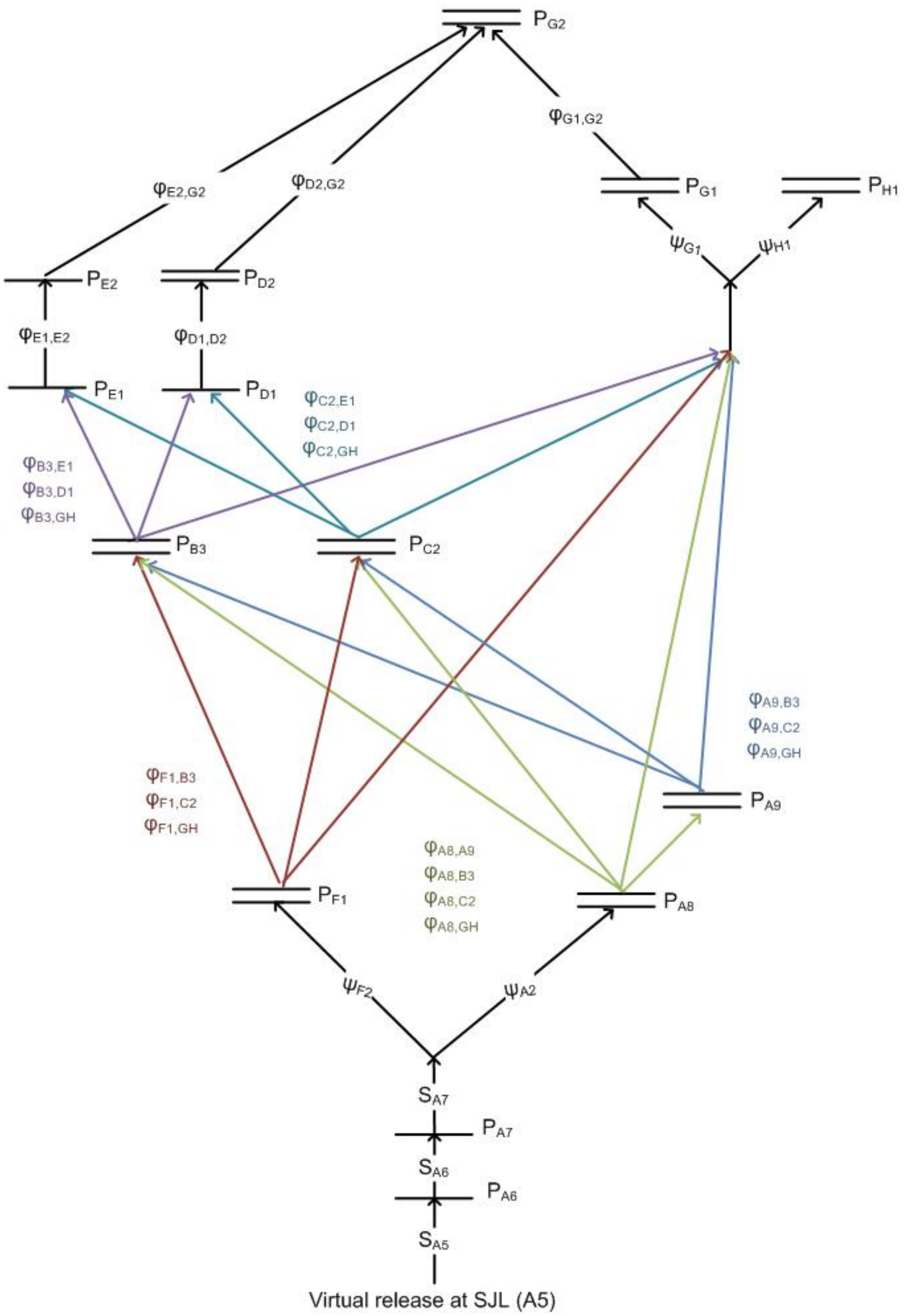


Figure 4. Schematic of 2012 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2. Migration pathways to sites B3 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.

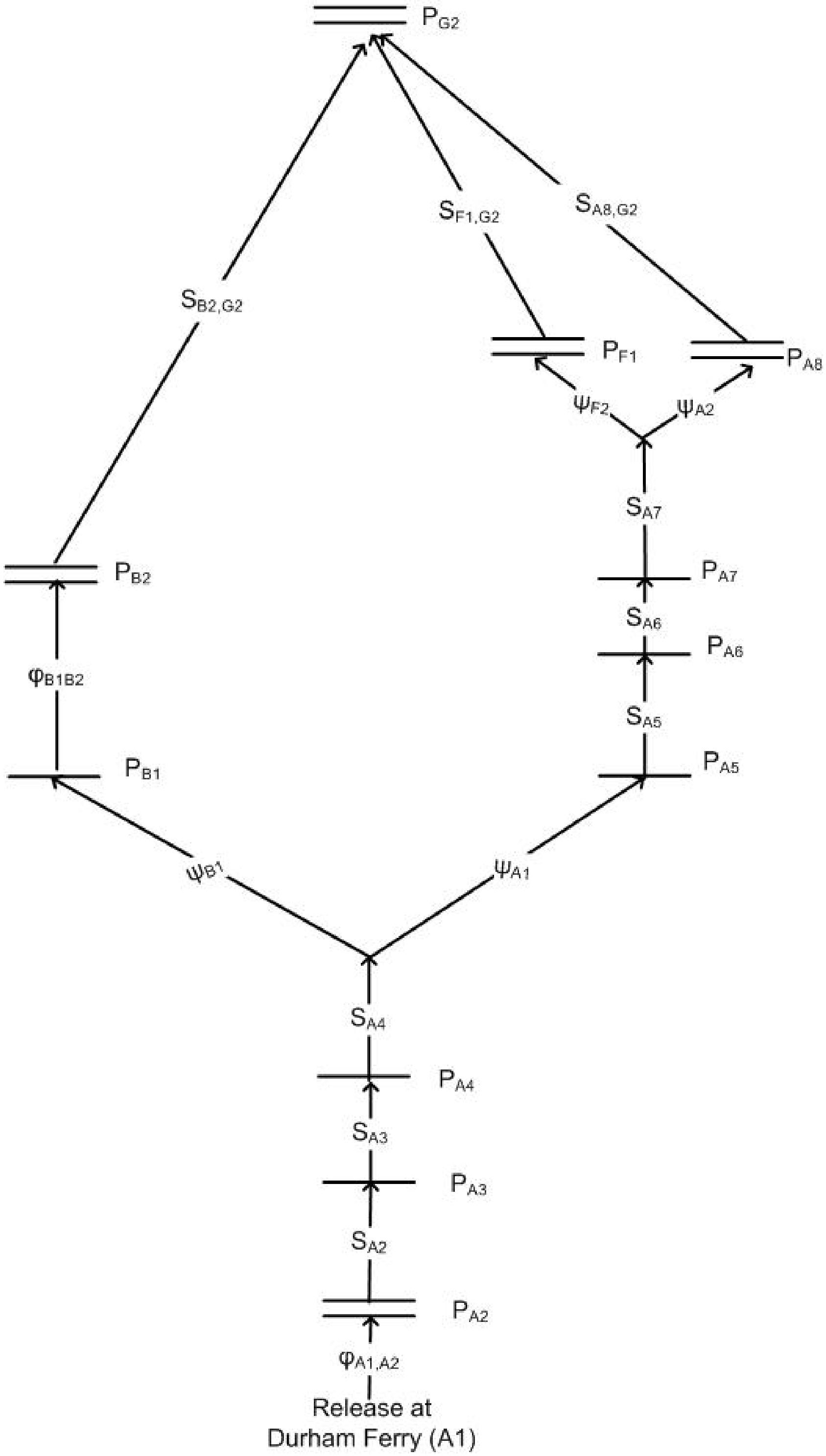


Figure 5. Schematic of reduced 2012 mark-recapture Submodel I with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2.

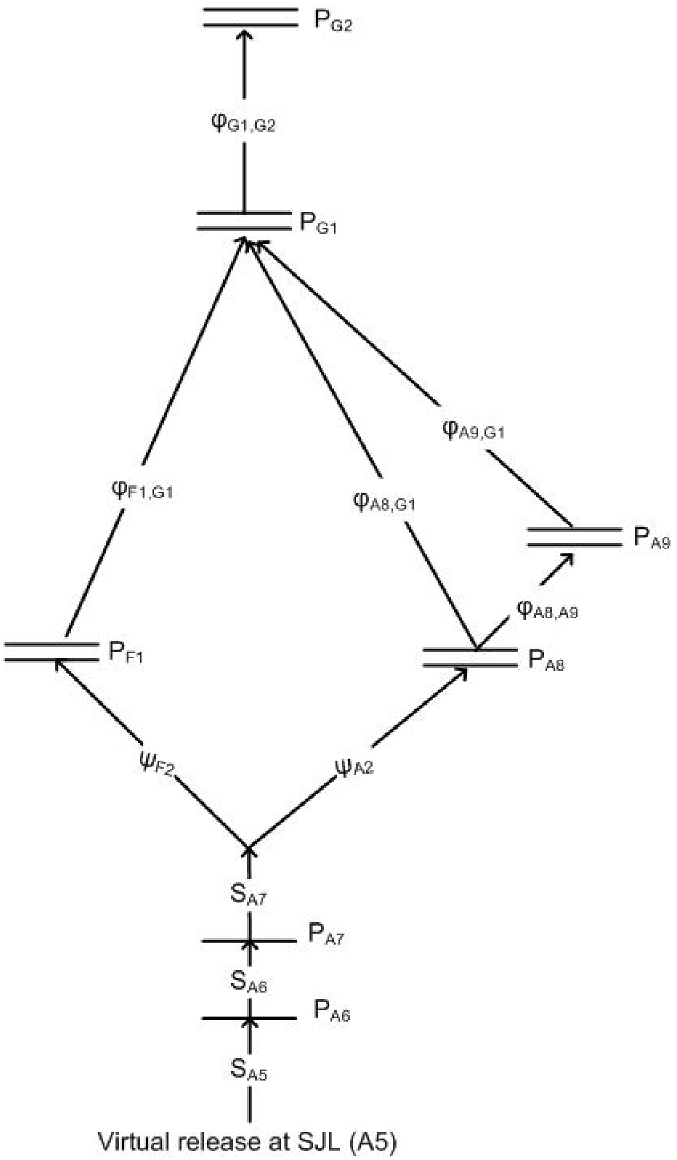


Figure 6. Schematic of reduced 2012 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2.

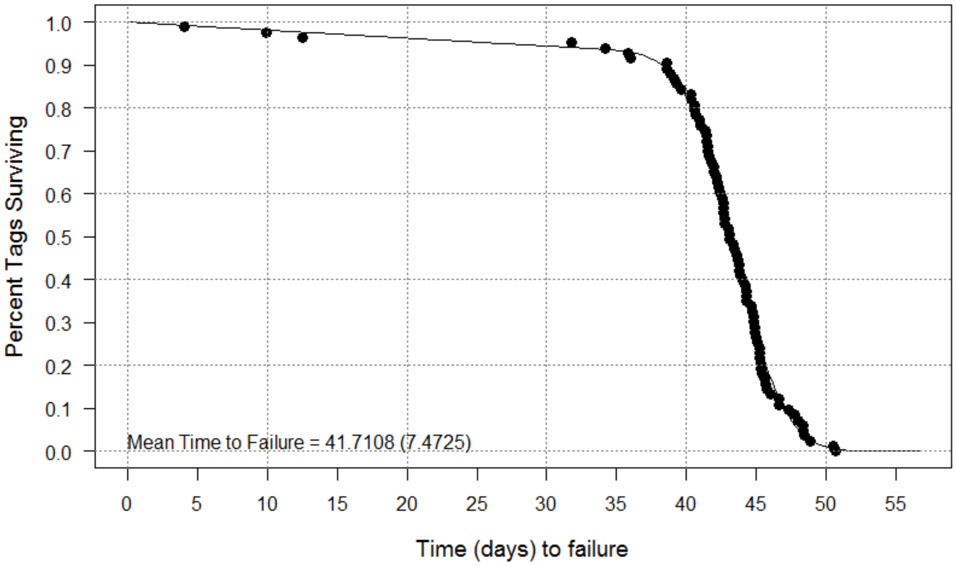


Figure 7. Observed tag failure times from the 2012 tag-life studies, pooled over the two studies, and fitted four-parameter vitality curve.

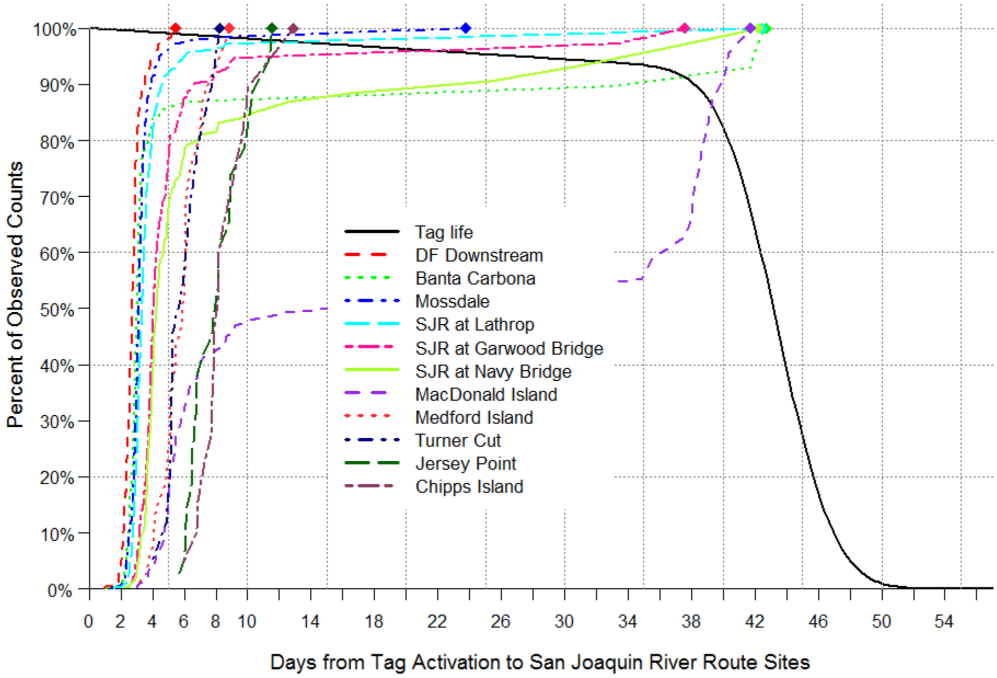


Figure 8. Four-parameter vitality survival curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the San Joaquin River route to Chipps Island in 2012, including detections that may have come from predators.

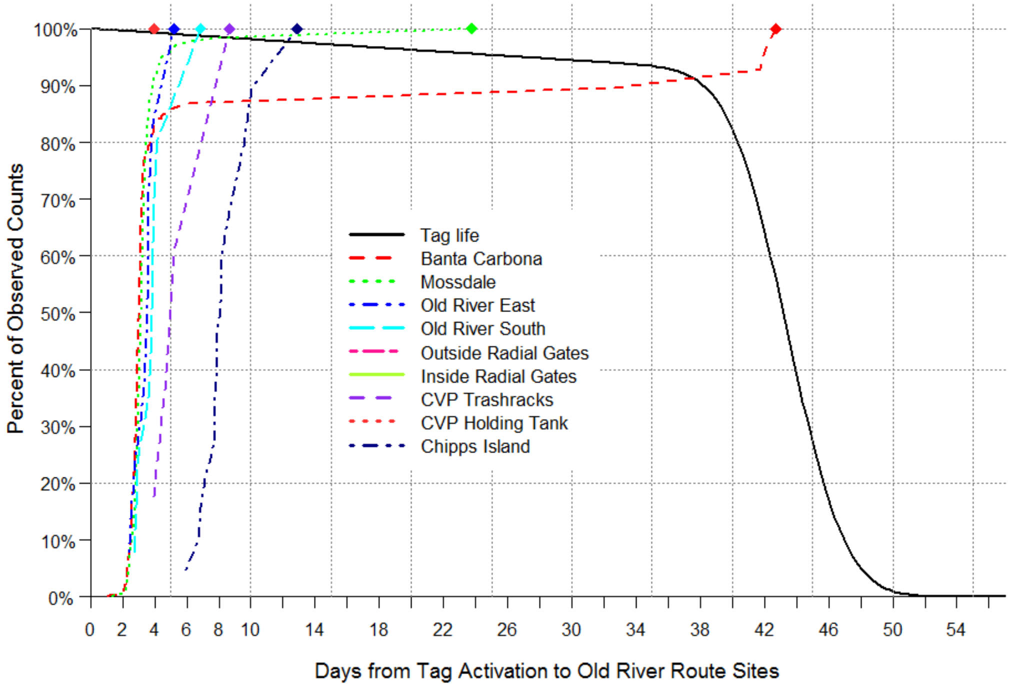


Figure 9. Four-parameter vitality survival curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the Old River route to Chipps Island in 2012, including detections that may have come from predators.

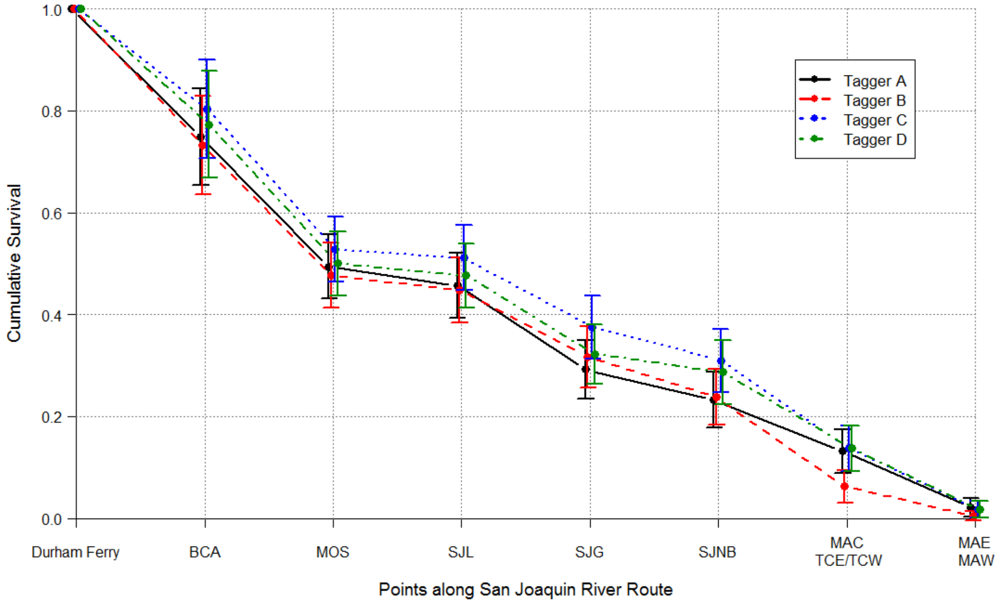


Figure 10. Cumulative survival from release at Durham Ferry to various points along the San Joaquin River route to Chipps Island, by tagger. Error bars are 95% confidence intervals.

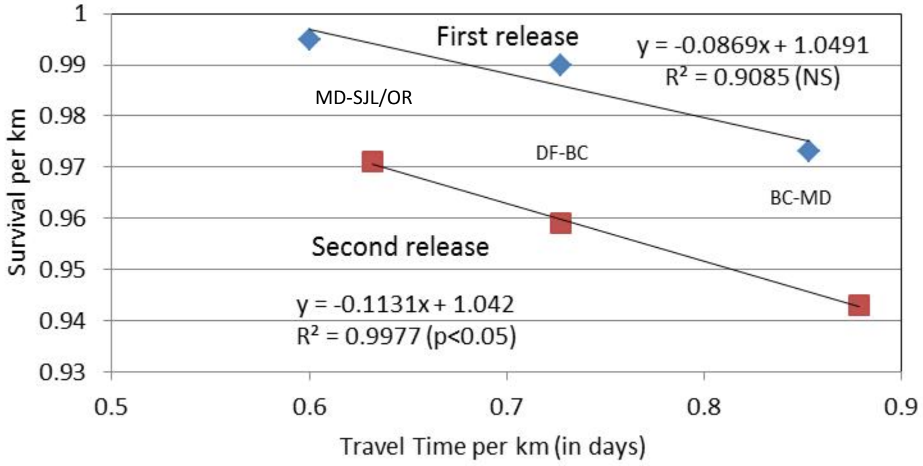


Figure 11: Travel time per km (in days) versus survival per km for river reaches, upstream of Mossdale in release group 1 and release group 2. Survival and travel time were without predator-type detections. Refer to Table 22 for data used.

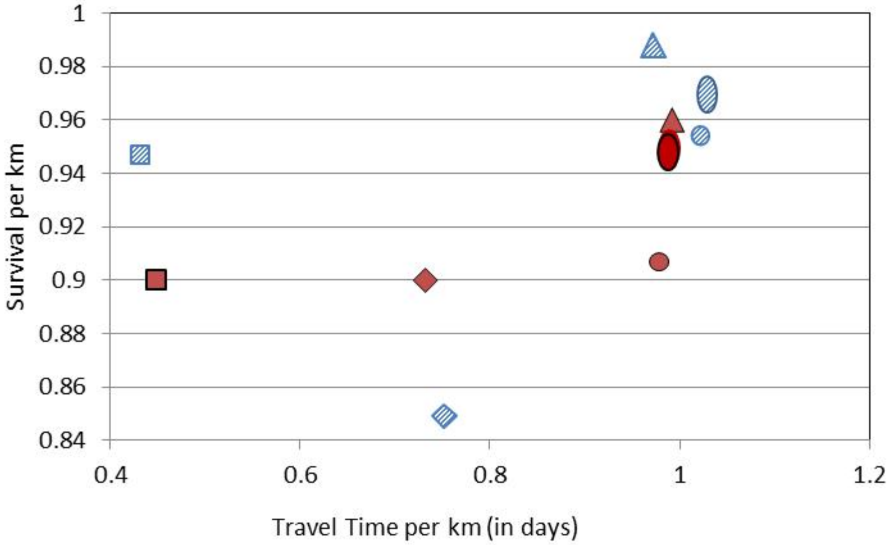


Figure 12: Travel time per km (in days) versus survival per km for reaches in the San Joaquin Delta for release group 1 (blue diagonal) and release group 2 (red solid). From Upstream to Downstream, reaches in order are: Lathrop to Garwood Bridge (triangles), Garwood Bridge to Navy Bridge Drive (squares), Navy Bridge to Turner Cut Junction (circles), MacDonald Island to Medford Island (diamonds) and Medford Island to Jersey Point (ovals). No recoveries were made at Chipps Island for the second release group to estimate travel time from Jersey Point to Chipps Island.

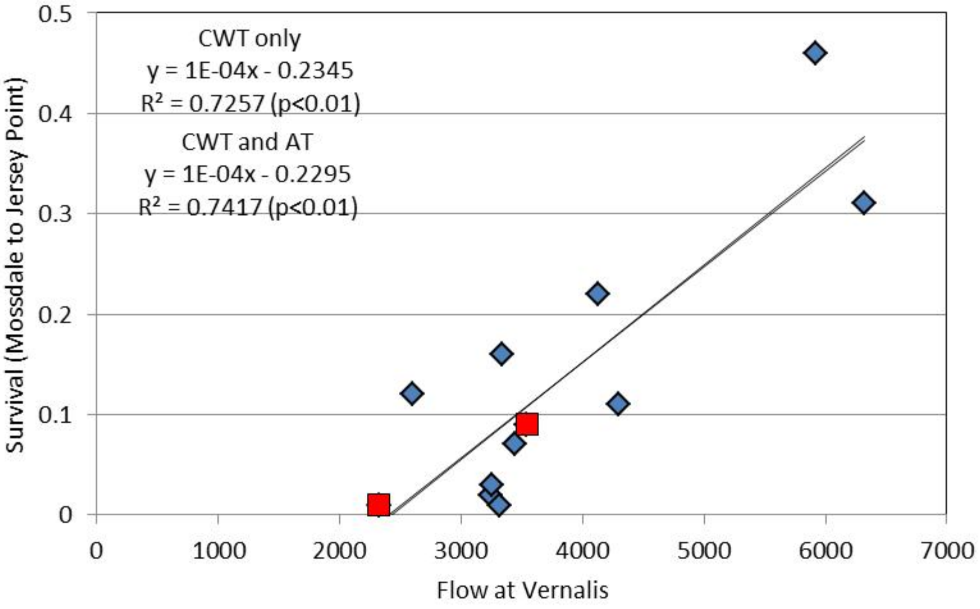


Figure 13: Estimates of survival between Mossdale and Jersey Point for CWT salmon (blue diamonds) and acoustic tag fish in 2012 (red squares) with the physical head of Old River barrier installed. Linear regression lines are plotted for both sets of data but overlap.

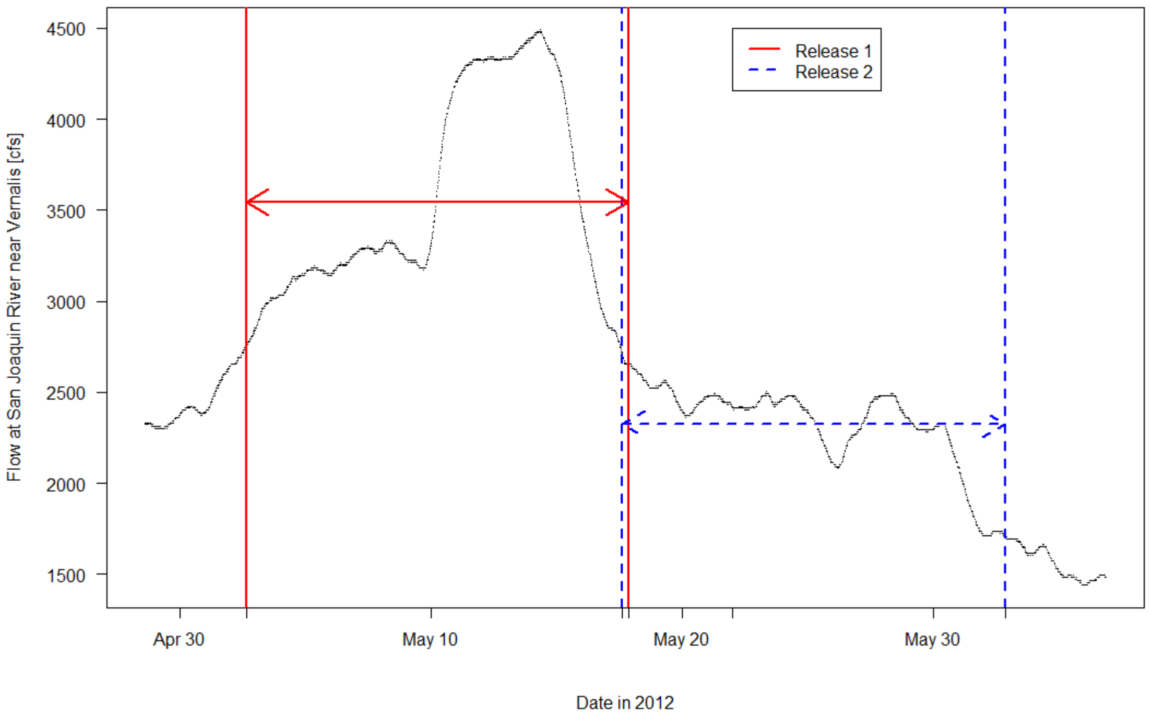


Figure 14. River discharge (flow) at Vernalis during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow heights indicates mean flow during travel period.

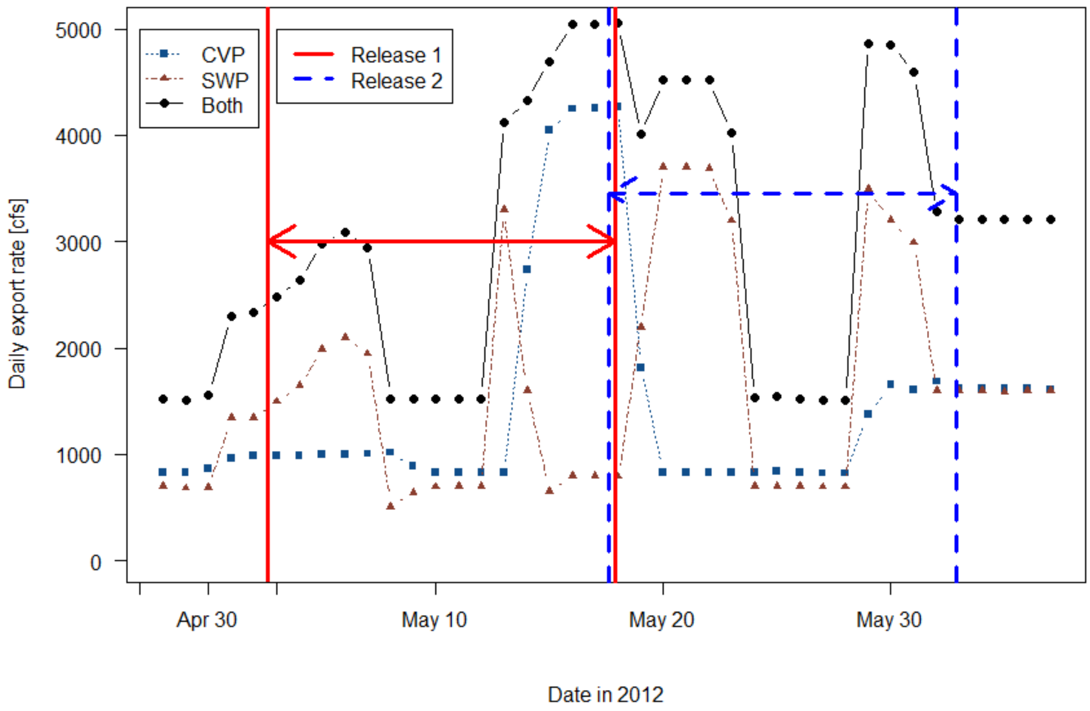


Figure 15. Daily export rate (cfs) at CVP and SWP during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow height indicates mean combined export rate during travel period.

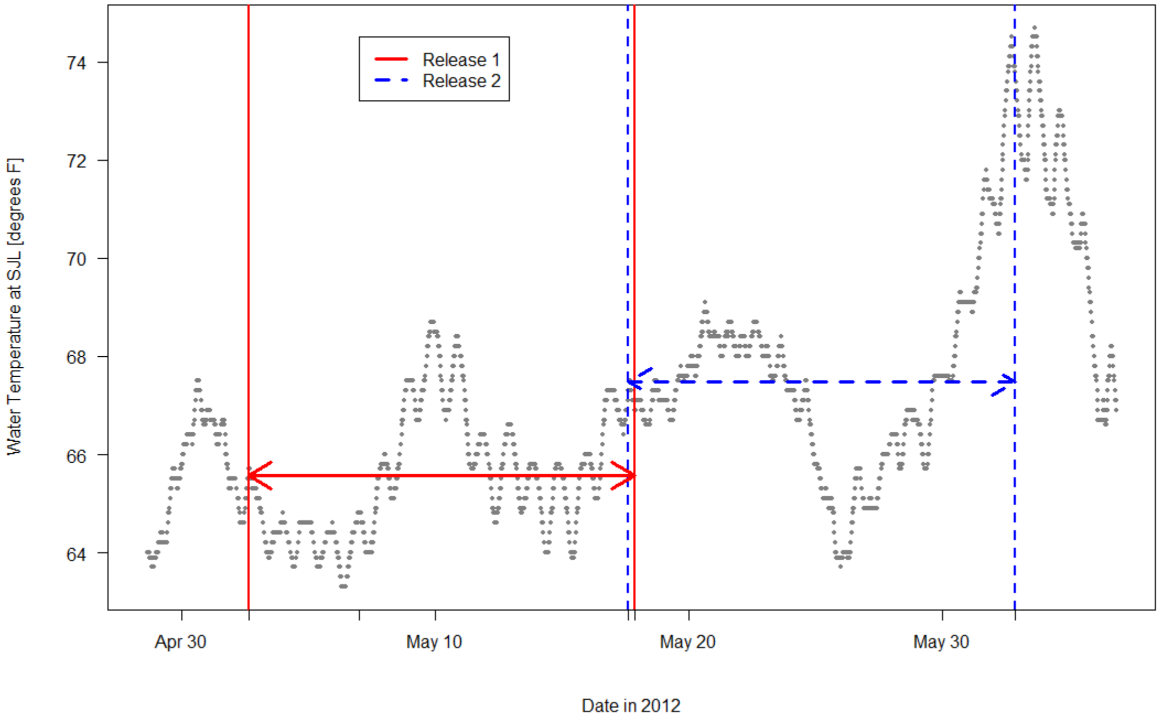


Figure 16. Temperature (°F) at the San Joaquin River gaging station near Lathrop during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow height indicates mean temperature during travel period.

Tables

Table 1. Tagging, transport and holding date and times, and the number released (N) for Chinook Salmon as part of 2012 Chinook Salmon Study. Numbers of tagged fish use the format: [Number of Vemco-tagged fish]: [Number of HTI-tagged fish].

				Release A		Release B		Release C		Release D		Release E		Release F				
Tagging Date	Transport Date/ Time	Number trans-ported	Trans-port Tank #	Date; Time	N	Date; Time	N	Date; Time	N	Date; Time	N	Date; time	N	Date; Time	N	Dummy tagged	Start Holding Date; Time	Total released (A – F)
5/1/12	5/1/12; 1352-1435	60: 15	1	5/2; 1505, 1506	24: 6	5/2; 1900, 1901	24: 6	5/2; 2256	12: 3							6	5/1; 1538	160: 42
		20: 6	2					5/2; 2257, 2306	20: 6							1		
	5/1/12; 1850-1930	60:15	1							5/3; 0300, 0301	24: 6	5/3; 0703, 0704	36: 9			0	5/1; 2020	
		20: 6	2											5/3; 1100,	20: 6	8		
5/3/12	5/3/12; 1237-1322	60: 15	1	5/4; 1500, 1503	24: 6	5/4; 1855, 1856	24: 6	5/4; 2256	12: 3							3	5/3; 1415	160: 42
		20: 6	2					5/4; 2256, 2304	20: 6							5		
	5/3/12; 1640-1725	60: 15	1							5/5; 0300	24: 6	5/5; 0702, 0703	24: 6	5/5; 1102	12: 3	3	5/3; 1808	
		20: 6	2											5/5; 1101, 1103	20: 6	4		
5/5/12	5/5/12; 1235 - 1320	60: 15	1	5/6; 1502, 1503	24: 6	5/6; 1856; 1857	24: 6	5/6; 2255	12: 3							9	5/5; 1356	160: 42
		20: 6	2					5/6; 2254, 2255	20: 6							6		
	5/5/12; 1717 - 1756	60: 15	1							5/7; 0300,	24: 6	5/7; 0700, 0701, 0702	36: 9			5	5/5; 1839	
		20: 6	2											5/7; 1100,	20: 6	9		

Table 1: (Continued)

				Release A		Release B		Release C		Release D		Release E		Release F				
Tagging Date	Transport Date/ Time	Number trans-ported	Trans-port Tank #	Date; Time	N	Date; Time	N	Date; Time	N	Date; Time	N	Date; time	N	Date; Time	N	Dummy tagged	Start Holding Date; Time	Total released (A – F)
5/16/12	5/16; 1238 - 1323	60: 15	1	5/17; 1455, 1500	24[1]: 6	5/17; 1858, 1859[2]	24: 6	5/17; 2302	12: 3							1	5/16; 1449	160[1]: 45
		20: 8	2					5/17; 2301	20: 8							6		
	5/16; 1640 - 1731	60: 16	1							5/18; 0300	24: 6	5/18; 0700, 0701	36: 10			2	5/16; 1810	
		20: 6	2											5/18; 1100	20: 6	6		
5/18/12	5/18; 1246 - 1330	60: 16	1	5/19; 1458, 1459	24: 6	5/19; 1904, 1906	24: 6	5/19; 2259	12: 4							2	5/18; 1400	160: 46
		20: 8	2					5/19; 2258, 2259	20: 8							6		
	5/18; 1619 - 1709	60:16	1							5/19; 0303, 0305[2]	24: 6	5/19; 0700[2]	36: 10			1	5/18; 1736	
		20: 6	2											5/19; 1100[2]	20: 6	6		
5/20/12	5/20; 1206 - 1249	59: 15	1	5/21; 1505, 1506	23: 6	5/21; 1902, 1903	24: 6	5/21; 2259	12: 3							6	5/20; 1324	160: 44
		21: 8	2	5/21; 1506	1: 0			5/21; 2258, 2259	20: 8							9		
	5/20; 1557 - 1638	60: 15	1							5/22; 0300	24: 6	5/22; 0701, 0702	24: 6	5/22; 1100	12: 3	6	5/20; 1712	
		20: 6	2												20: 6	9		

[1] one tag not used in analyses; tag looked odd, [2] released from shore due to high winds or dead battery in boat.

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 2012 Chinook Salmon tagging study, with receiver codes used in Figure 2, the survival model (Figures 2 – 5), and in data processing by the United States Geological Survey (USGS). The release site was located at Durham Ferry.

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

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

Table 3. (Continued)

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

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

Table 3. (Continued)

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

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

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

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

a = California Water Library was used for river stage

Table 5a. Cutoff values used in predator filter in 2012. Observed values past cutoff or unmet conditions indicate a predator. Only transitions observed in 2012 are represented here. No detections were observed at MRH, RGU, or RGD in 2012. 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)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field					
		Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum
DFU	DF, DFD	0.5	1	0.2 (0.6[f])	4		1	1
	DFU	0.5	1				2	0
DFD	DF, DFU	4	8	0.05	4		1	0
	DFD	2	49				2	0
	BCA	2	4	0.1	4		0	0
BCA	DF, DFU	5	10	0.1	4		1	0
	BCA	0.1	168				2	0
	MOS	0.1	0.2	0.1	4		0	0
MOS	DF, DFD, BCA	10	20	0.2	5.5	8	1	0
	MOS	2	261				2	1
	HOR	1	2	0.2	5.5	8	2	1
SJL	MOS, HOR	5	15	0.2	5.5	8	2	0
	SJL	1	293				3	1
SJG	HOR, SJL	12	24	0.2	5.5	8	1	0
	SJG	6	360				1	1
	SJNB	3	6	0.2	4	8	2	2
SJNB	SJG	15 (6[f])	30 (12[f])	0.2	5.5	8	2	0
	SJNB	4	360				2	3
MAC	SJG, SJNB	30	60	0.2	5.5	8	1	0
	MAC	30	360				2	3
	MFE/MFW	15	30	0.2	4	8	2	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

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 5a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr)		Migration Rate[b, c] (km/hr)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field					
		Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum
MFE/MFW	MAC	30	60	0.2	5.5	8	2	0
	MFE/MFW	15	360				3	3
HOR	DF, MOS	10	20	0.2	5.5	8	1 (2[f])	0
	HOR	3	288				2	1
	SJL	3 (4[f])	6 (8[f])	0.2 (0.1[f])	5.5 (6[f])	8	2	1
ORE	HOR	5	15	0.2	5.5	8	1	0
	ORE	1	287				1	0
ORS	ORE	12	24	0.2	5.5	8	1	0
	ORS	4	360				2	1
OR4	ORS	40	80	0.2	5.5	8	1	0
	MR4	40	80	0.1	5.5		2	3
	OR4	25	129				2	2
OLD	OR4	40	80	0.2	5.5	8	2	0
	MRE	40	80	0.1	5.5		1	0
MR4	MRE	10	20	0.2	5.5	8	1	2
MRE	SJNB, MAC	20	40	0.1	5.5		1	0
	TCE/TCW	20	40	0.1	5.5		1	0
CVP	DF, ORS	10	20	0.2	5.5	8	1	1
	CVP	10	390				3	3
	OR4	10	20	0.5	5.5	8	2	3
CVPtank	CVP	20	360				2	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

b = Approximate migration rate calculated on most direct pathway

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

f = See comments for alternate criteria

Table 5a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr)		Migration Rate[b, c] (km/hr)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field					
		Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum
TCE/TCW	SJG, SJNB	12	24	0.2	5.5	8	1	0
	MAC	12	24	0.2	5.5	8	2	3
	TCE/TCW	3	360				1	3
JPE/JPW	MAC, MFE/MFW, TMN/TMS	40	80	0.1	5.5	8	1	0
	FRE/FRW	30	360	0.1	5.5		3	3
	JPE/JPW	30	360				3	0
MAE/MAW	MFE/MFW, CVPtank	40	80	0.1	5.5	8	1	0
	TMN/TMS, JPE/JPW, FRE/FRW	40	80	0.1	5.5	8	2	0
FRE/FRW	MAC, MFE/MFW, OLD	40	80	0.1	5.5	8	1	0
	JPE/JPW	30	360	0.1			3	3
TMN/TMS	MAC, MFE/MFW	10	20	0.2	3	8	1	0
	JPE/JPW	10	20	0.5	3	8	1	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

b = Approximate migration rate calculated on most direct pathway

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

Table 5b. Cutoff values used in predator filter in 2012. Observed values past cutoff or unmet conditions indicate a predator. Only transitions observed in 2012 are represented here. No detections were observed at MRH, RGU, or RGD in 2012. 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 < 25	
	MOS						Not allowed	
MOS	DF, DFD, BCA							
	MOS						Travel time < 20	
	HOR					< 0.1		
SJL	MOS, HOR							
	SJL						Travel time < 20	
SJG	HOR, SJL							
	SJG							
	SJNB	< 1700	< 4000	< 0.5	< 1	< 0.5	Change in river stage at arrival: -0.1 to 0.1	
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		
MAC	SJG, SJNB							
	MAC			< 0.2 (> -0.1)[g]	> -0.1 (< 0.2)[g]			

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)

		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
MAC	MFE/MFW			< -0.4	< 0.2	< 0.2		
MFE/MFW	MAC							
	MFE/MFW			< 0.2 (> -0.1)[g]	> -0.1 (< 0.2)[g]			
	SJG	<100 (>-300)[g]	>-300 (<100)[g]	<0.1 (>-0.5)[g]	>-0.5 (<0.1)[g]	<0.5		
HOR	DF, MOS							Alternate value if coming from MOS
	HOR						Travel time < 20	
	SJL			< 1.5	< 0.15 (0.25[f])	< 1 (1.1[f])		Alternate value if next transition is downstream
ORE	HOR							
	ORE						Not allowed	
ORS	ORE	> -2500		> -0.5				
	ORS	< 2500 (> -2500)[g]	> -2500 (< 2500)[g]	< 0.5 (> -0.5)[g]	> -0.5 (< 0.5)[g]			
OR4	ORS	> -700		> -0.3				
	MR4							
	OR4	< 700 (> -700)[g]	> -700 (< 700)[g]	< 0.3 (> -0.3)[g]	> -0.3 (< 0.3)[g]			
OLD	OR4	> -2000	> -1000	> -0.1	> -0.05			
	MRE							
MR4	MRE	< 2500	< 1000	< 0.25	< 0.1	< 0.1		
MRE	SJNB, MAC	< 1000		< 0.1				
	TCE/TCW	< 1000	< 200	< 0.1	< 0.05			

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)

		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
CVP	DF, ORS							
	CVP						CVP pumping > 1500 cfs on arrival, < 1500 cfs on departure	
	OR4	< 3000	< 2000	< 1.5	< 0.8	< 0.1	CVP pumping > 1500 cfs on arrival	
CVPtank	CVP						Travel time < 100	
TCE/TCW	SJG, SJNB	< 1200		< 0.2				
	MAC	< 1200		< 0.2	< 0.2	< 0.2		
	TCE/TCW	< 500 (> 500)[g]	> 500 (< 500)[g]	< 0.1 (> 0.1)[g]	> 0.1 (< 0.1)[g]	-0.2 to 0.2	Travel time < 13	
JPE/JPW	MAC, MFE/MFW, TMN/TMS FRE/FRW							
	JPE/JPW						Travel time < 50	
MAE/MAW	MFE/MFW, CVPtank			> -2.5				
	TMN/TMS, JPE/JPW, FRE/FRW			> -2.5				
FRE/FRW	MAC, MFE/MFW, OLD							
FRE/FRW	MAC, MFE/MFW, OLD JPE/JPW							
TMN/TMS	MAC, MFE/MFW JPE/JPW				> -0.4			

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 6: Water temperature and dissolved oxygen in the transport tank after loading prior to transport, after transport, and in the river at Durham Ferry release site, just prior to placing fish in holding containers; the number of mortalities after transport and prior to release.

		Tank #1						Tank #2								
Transport			After loading		After transport				After loading		After transport			River		
Date	Loading time	Ice Added	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	# morts after transport	Ice Added	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	# morts after transport	Temp (˚C)	DO (mg/L)	Mortalities just prior to release
5/1/2012	1331	Yes	18.4	8.73	18.5	11.7	0	Yes	18.6	8.22	18.5	9.94	0	19.3	10.54	0
5/1/2012	1810	No	16.8	9.68	16.5	9.83	0	No	17.1	8.57	16.7	9.12	0	18.8	10.91	0
5/3/2012	1219	No	18.8	9.64	19.1	9.76	0	No	18.5	9.07	18.7	9.41	0	18.0	9.22	0
5/3/2012	1616	Yes	18.2	10.04	18.1	10.67	0	Yes	18.1	10.01	17.8	10.22	0	18.4	9.55	0
5/5/2012	1208	Yes	18.9	10.44	19.1	11.76	0	Yes	18.9	10.23	18.8	10.57	0	17.5	9.66	0
5/5/2012	1652	Yes	18.4	10.36	18.5	11.89	0	Yes	18.3	10.47	18.1	10.63	0	18.0	10.14	0
													Average	18.3		
5/16/2012	1222	Yes	19.3	9.37	19.7	9.38	0	Yes	19.4	9.46	19.7	9.42	0	19.1	11.45	0
5/16/2012	1617	Yes	19.4	9.35	19.7	10.25	0	Yes	19.5	9.38	19.5	9.51	0	19.9	9.59	0
5/18/2012	1228	Yes	19.0	9.71	19.8	10.86	0	Yes	18.9	9.64	19.3	9.74	0	19.0	8.4	0
5/18/2012	1556	Yes	19.5	9.66	19.6	10.74	0	Yes	19.6	9.67	19.8	9.73	0	19.8	8.56	0
5/20/2012	1143	Yes	19.4	10.05	19.6	10.97	0	Yes	19.0	9.67	19.3	9.81	0	19.6	9.40	0
5/20/2012	1537	Yes	20.0	10.16	20.3	11.38	0	Yes	20.3	9.61	20.5	9.84	0	20.7	10.38	0
													Average	19.7		

Table 7. Results of dummy tagged Chinook Salmon evaluated after being held for 48 hours at the release sites as part of the 2012 Chinook Salmon Study.

Holding Site	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
Durham Ferry	5/3/12, 1100	108.2 (5.6)	0/15	5.5 (2.9)	15/15	15/15	15/15	15/15
Durham Ferry	5/5/12, 1100	108.3 (3.7)	0/15	3.3 (1.0)	15/15	15/15	15/15	15/15
Durham Ferry	5/18/12, 1100	111.3 (5.4)	0/15	2.3 (1.0)	15/15	15/15	15/15	15/15
Durham Ferry	5/20/12, 1100	112.0 (4.8)	0/15	2.7 (1.5)	15/15	15/15	15/15	12/15

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

Release Group	1	2	Total
Number Released	480	479	959
Number Detected	355	358	713
Number Detected Downstream	354	353	707
Number Detected Upstream of Study Area	196	339	535
Number Detected in Study Area	301	181	482
Number Detected in San Joaquin River Route	288	161	449
Number Detected in Old River Route	8	3	11
Number Assigned to San Joaquin River Route	286	160	446
Number Assigned to Old River Route	7	3	10

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

			Release Group		
Detection Site	Site Code	Survival Model Code	1	2	Total
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream	DFU	A0	1	10	11
Durham Ferry Downstream	DFD	A2	101	168	269
Banta Carbona	BCA	A3	120	244	364
Mossdale	MOS	A4	299	181	480
Head of Old River	HOR	B0	297	172	469
Lathrop	SJL	A5	288	161	449
Garwood Bridge	SJG	A6	232	78	310
Navy Drive Bridge	SJNB	A7	187	54	241
MacDonald Island Upstream	MACU	A8a	88	12	100
MacDonald Island Downstream	MACD	A8b	84	9	93
MacDonald Island (Pooled)	MAC	A8	88	12	100
Medford Island East	MFE	A9a	41	6	47
Medford Island West	MFW	A9b	41	6	47
Medford Island (Pooled)	MFE/MFW	A9	41	6	47
Turner Cut East	TCE	F1a	10	2	12
Turner Cut West	TCW	F1b	8	2	10
Turner Cut (Pooled)	TCE/TCW	F1	11	2	13
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	3	9
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	3	9
Old River at Highway 4, Upstream	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route	OR4	B3	1	0	1
Old River at Highway 4, OR Route	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)	OR4	B3	2	0	2
Old River near Empire Cut, Upstream	OLDU	B4a	2	0	2
Old River near Empire Cut, Downstream	OLDD	B4b	0	0	0
Old River near Empire Cut, SJR Route	OLD	B4	1	0	1
Old River near Empire Cut, OR Route	OLD	B4	1	0	1
Old River near Empire Cut (Pooled)	OLD	B4	2	0	2
Middle River Head	MRH	C1	0	0	0
Middle River at Highway 4, Upstream	MR4U	C2a	1	0	1
Middle River at Highway 4, Downstream	MR4D	C2b	1	0	1
Middle River at Highway 4, SJR Route	MR4	C2	1	0	1
Middle River at Highway 4, OR Route	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)	MR4	C2	1	0	1

Table 9. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Middle River near Empire Cut, Upstream	MREU	C3a	3	0	3
Middle River near Empire Cut, Downstream	MRED	C3b	3	0	3
Middle River near Empire Cut, SJR Route	MRE	C3	3	0	3
Middle River near Empire Cut, OR Route	MRE	C3	0	0	0
Middle River near Empire Cut (Pooled)	MRE	C3	3	0	3
Radial Gates Upstream (Pooled)	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)	RGD	D2	0	0	0
Central Valley Project Trashrack	CVP	E1	4	1	5
CVP Trashrack: SJR Route	CVP	E1	1	0	1
CVP Trashrack: OR Route	CVP	E1	3	1	4
Central Valley Project Holding Tank	CVPtank	E2	1	0	1
CVP tank: SJR Route	CVPtank	E2	0	0	0
CVP tank: OR Route	CVPtank	E2	1	0	1
Threemile Slough South	TMS	T1a	6	0	6
Threemile Slough North	TMN	T1b	4	0	4
Threemile Slough (Pooled)	TMS/TMN	T1	6	0	6
Jersey Point East	JPE	G1a	26	2	28
Jersey Point West	JPW	G1b	25	2	27
Jersey Point: SJR Route	JPE/JPW	G1	26	2	28
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	26	2	28
False River West	FRW	H1a	7	0	7
False River East	FRE	H1b	6	0	6
False River: SJR Route	FRE/FRW	H1	7	0	7
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	7	0	7
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

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

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream*	DFU	A0	1	7	8
Durham Ferry Downstream	DFD	A2	101	166	267
Banta Carbona	BCA	A3	120	243	363
Mossdale	MOS	A4	297	181	478
Lathrop	SJL	A5	286	160	446
Garwood Bridge	SJG	A6	232	78	310
Navy Drive Bridge	SJNB	A7	186	53	239
MacDonald Island Upstream	MACU	A8a	80	11	91
MacDonald Island Downstream	MACD	A8b	74	8	82
MacDonald Island (Pooled)	MAC	A8	86	12	98
Medford Island East	MFE	A9a	38	6	44
Medford Island West	MFW	A9b	38	6	44
Medford Island (Pooled)	MFE/MFW	A9	38	6	44
Turner Cut East	TCE	F1a	10	2	12
Turner Cut West	TCW	F1b	7	2	9
Turner Cut (Pooled)	TCE/TCW	F1	11	2	13
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	3	9
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	3	9
Old River at Highway 4, Upstream*	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream*	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route*	OR4	B3	1	0	1
Old River at Highway 4, OR Route*	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)*	OR4	B3	2	0	2
Middle River Head*	MRH	C1	0	0	0
Middle River at Highway 4, Upstream*	MR4U	C2a	0	0	0
Middle River at Highway 4, Downstream*	MR4D	C2b	0	0	0
Middle River at Highway 4, SJR Route*	MR4	C2	0	0	0
Middle River at Highway 4, OR Route*	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)*	MR4	C2	0	0	0
Radial Gates Upstream (Pooled)*	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)*	RGD	D2	0	0	0
Central Valley Project Trashrack*	CVP	E1	4	1	5
CVP Trashrack: SJR Route*	CVP	E1	1	0	1
CVP Trashrack: OR Route*	CVP	E1	3	1	4

Table 10. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Central Valley Project Holding Tank*	CVPtank	E2	1	0	1
CVP tank: SJR Route*	CVPtank	E2	0	0	0
CVP tank: OR Route*	CVPtank	E2	1	0	1
Jersey Point East	JPE	G1a	24	2	26
Jersey Point West	JPW	G1b	23	2	25
Jersey Point: SJR Route	JPE/JPW	G1	24	2	26
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	24	2	26
False River West	FRW	H1a	0	0	0
False River East	FRE	H1b	0	0	0
False River: SJR Route	FRE/FRW	H1	0	0	0
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	0	0	0
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

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

Detection Site and Code			Durham Ferry Release Groups					
			Classified as Predator on Arrival at Site			Classified as Predator on Departure from Site		
Detection Site	Site Code	Survival Model Code	1	2	Total	1	2	Total
Durham Ferry Upstream	DFU	A0	0	8	8	0	0	0
Durham Ferry Downstream	DFD	A2	4	7	11	0	10	10
Banta Carbona	BCA	A3	0	2	2	1	4	5
Mossdale	MOS	A4	1	2	3	0	3	3
Head of Old River	HOR	B0	1	4	5	0	1	1
Lathrop	SJL	A5	1	1	2	6	6	12
Garwood Bridge	SJG	A6	3	1	4	9	5	14
Navy Drive Bridge	SJNB	A7	1	2	3	11	9	20
MacDonald Island	MAC	A8	2	1	3	15	0	15
Medford Island	MFE/MFW	A9	0	0	0	0	0	0
Old River East	ORE	B1	0	1	1	0	0	0
Old River South	ORS	B2	0	0	0	0	1	1
Old River at Highway 4	OR4	B3	0	0	0	0	0	0
Old River near Empire Cut	OLD	B4	1	0	1	0	0	0
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	0	0	0
Radial Gates Downstream	RGD	D2	0	0	0	0	0	0
Central Valley Project Trashrack	CVP	E1	0	0	0	0	1	1
Central Valley Project Holding Tank	CVPtank	E2	0	0	0	0	0	0
Turner Cut	TCE/TCW	F1	3	0	3	2	0	2
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			17	29	46	44	40	84

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

Release Group	1	2	Total
Number Released	480	479	959
Total Number Detected	351	346	697
Total Number Detected Downstream	350	345	695
Total Number Detected Upstream of Study Area	191	327	518
Total Number Detected in Study Area	301	179	480
Number Detected in San Joaquin River Route	287	157	444
Number Detected in Old River Route	8	3	11
Number Assigned to San Joaquin River Route	287	157	444
Number Assigned to Old River Route	7	3	10

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

Detection Site	Site Code	Survival Model Code	Release Group		Total
			1	2	
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream	DFU	A0	1	1	2
Durham Ferry Downstream	DFD	A2	97	159	256
Banta Carbona	BCA	A3	119	242	361
Mossdale	MOS	A4	299	179	478
Head of Old River	HOR	B0	297	169	466
Lathrop	SJL	A5	287	157	444
Garwood Bridge	SJG	A6	231	75	306
Navy Drive Bridge	SJNB	A7	186	51	237
MacDonald Island Upstream	MACU	A8a	88	10	98
MacDonald Island Downstream	MACD	A8b	84	8	92
MacDonald Island (Pooled)	MAC	A8	88	10	98
Medford Island East	MFE	A9a	41	6	47
Medford Island West	MFW	A9b	41	6	47
Medford Island (Pooled)	MFE/MFW	A9	41	6	47
Turner Cut East	TCE	F1a	9	2	11
Turner Cut West	TCW	F1b	8	2	10
Turner Cut (Pooled)	TCE/TCW	F1	10	2	12
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	2	8
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	2	8
Old River at Highway 4, Upstream	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route	OR4	B3	1	0	1
Old River at Highway 4, OR Route	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)	OR4	B3	2	0	2
Old River near Empire Cut, Upstream	OLDU	B4a	1	0	1
Old River near Empire Cut, Downstream	OLDD	B4b	0	0	0
Old River near Empire Cut, SJR Route	OLD	B4	1	0	1
Old River near Empire Cut, OR Route	OLD	B4	0	0	0
Old River near Empire Cut (Pooled)	OLD	B4	1	0	1
Middle River Head	MRH	C1	0	0	0
Middle River at Highway 4, Upstream	MR4U	C2a	1	0	1
Middle River at Highway 4, Downstream	MR4D	C2b	1	0	1
Middle River at Highway 4, SJR Route	MR4	C2	1	0	1
Middle River at Highway 4, OR Route	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)	MR4	C2	1	0	1

Table 13. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Middle River near Empire Cut, Upstream	MREU	C3a	3	0	3
Middle River near Empire Cut, Downstream	MRED	C3b	3	0	3
Middle River near Empire Cut, SJR Route	MRE	C3	3	0	3
Middle River near Empire Cut, OR Route	MRE	C3	0	0	0
Middle River near Empire Cut (Pooled)	MRE	C3	3	0	3
Radial Gates Upstream (Pooled)	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)	RGD	D2	0	0	0
Central Valley Project Trashrack	CVP	E1	4	1	5
CVP Trashrack: SJR Route	CVP	E1	1	0	1
CVP Trashrack: OR Route	CVP	E1	3	1	4
Central Valley Project Holding Tank	CVPtank	E2	1	0	1
CVP tank: SJR Route	CVPtank	E2	0	0	0
CVP tank: OR Route	CVPtank	E2	1	0	1
Threemile Slough South	TMS	T1a	6	0	6
Threemile Slough North	TMN	T1b	4	0	4
Threemile Slough (Pooled)	TMS/TMN	T1	6	0	6
Jersey Point East	JPE	G1a	26	2	28
Jersey Point West	JPW	G1b	25	2	27
Jersey Point: SJR Route	JPE/JPW	G1	26	2	28
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	26	2	28
False River West	FRW	H1a	7	0	7
False River East	FRE	H1b	6	0	6
False River: SJR Route	FRE/FRW	H1	7	0	7
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	7	0	7
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

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

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream*	DFU	A0	1	1	2
Durham Ferry Downstream	DFD	A2	97	159	256
Banta Carbona	BCA	A3	119	242	361
Mossdale	MOS	A4	299	179	478
Lathrop	SJL	A5	287	157	444
Garwood Bridge	SJG	A6	231	75	306
Navy Drive Bridge	SJNB	A7	185	50	235
MacDonald Island Upstream	MACU	A8a	83	9	92
MacDonald Island Downstream	MACD	A8b	80	8	88
MacDonald Island (Pooled)	MAC	A8	87	10	97
Medford Island East	MFE	A9a	38	6	44
Medford Island West	MFW	A9b	38	6	44
Medford Island (Pooled)	MFE/MFW	A9	38	6	44
Turner Cut East	TCE	F1a	9	2	11
Turner Cut West	TCW	F1b	8	2	10
Turner Cut (Pooled)	TCE/TCW	F1	10	2	12
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	2	8
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	2	8
Old River at Highway 4, Upstream*	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream*	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route*	OR4	B3	1	0	1
Old River at Highway 4, OR Route*	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)*	OR4	B3	2	0	2
Middle River Head*	MRH	C1	0	0	0
Middle River at Highway 4, Upstream*	MR4U	C2a	0	0	0
Middle River at Highway 4, Downstream*	MR4D	C2b	0	0	0
Middle River at Highway 4, SJR Route*	MR4	C2	0	0	0
Middle River at Highway 4, OR Route*	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)*	MR4	C2	0	0	0
Radial Gates Upstream (Pooled)*	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)*	RGD	D2	0	0	0
Central Valley Project Trashrack*	CVP	E1	4	1	5
CVP Trashrack: SJR Route*	CVP	E1	1	0	1
CVP Trashrack: OR Route*	CVP	E1	3	1	4

Table 14. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Central Valley Project Holding Tank*	CVPtank	E2	1	0	1
CVP tank: SJR Route*	CVPtank	E2	0	0	0
CVP tank: OR Route*	CVPtank	E2	1	0	1
Jersey Point East	JPE	G1a	24	2	26
Jersey Point West	JPW	G1b	23	2	25
Jersey Point: SJR Route	JPE/JPW	G1	24	2	26
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	24	2	26
False River West	FRW	H1a	0	0	0
False River East	FRE	H1b	0	0	0
False River: SJR Route	FRE/FRW	H1	0	0	0
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	0	0	0
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

Table 15. Number of juvenile Chinook Salmon tagged by each tagger in each release group during the 2012 tagging study. OK with updated numbers

	Release Group		
Tagger	1	2	Total Tags
A	119	120	239
B	118	119	237
C	120	119	239
D	123	121	244
Total Tags	480	479	959

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

Detection Site	Tagger			
	A	B	C	D
Release at Durham Ferry*	239	237	239	244
Mossdale (MOS)*	118	112	126	122
Lathrop (SJL)*	108	102	120	114
MacDonald Island (MAC)	27	13	29	28
Turner Cut (TCE/TCW)	4	1	3	4
Medford Island (MFE/MFW)	13	8	9	14
MacDonald Island, Medford Island, or Turner Cut (pooled)*	31	14	32	32
Old River East (ORE)*	1	4	2	2
Old River South (ORS)	1	3	2	2
Old River at Highway 4 (OR4)	1	0	0	1
Middle River at Highway 4 (MR4)	0	0	0	0
Clifton Court Forebay Interior (RGD)	0	0	0	0
Central Valley Project Holding Tank (CVPtank)	0	0	0	1
Jersey Point (JPE/JPW)*	10	3	6	7
Chipps Island (MAE/MAW)*	5	1	4	5

Table 17. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2012 tagging study, excluding predator-type detections. South Delta ("SD") survival extended to MacDonald Island and Turner Cut in Route A. Population-level estimates were from pooled release groups.

	Release Occasion		
Parameter	1	2	Population Estimate
ψ_{AA}	0.88 (0.03)	0.82 (0.10)	0.87 (0.03)
ψ_{AF}	0.10 (0.03)	0.16 (0.10)	0.11 (0.03)
S_{AA}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
S_{AF}	0 (0)	0 (0)	0 (0)
$\psi_{A}{}^{a}$	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
$\psi_{B}{}^{a}$	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.11 (0.03)	0.16 (0.11)	0.11 (0.03)
S_{A}	0.05^{cd} (0.01)	0^{d} (0)	0.03^{c} (0.01)
$S_{B}{}^{b}$	0.16^{c} (0.15)	0 (0)	0.11^{c} (0.10)
S_{Total}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
$S_{A(MD)}$	0.09^{d} (0.02)	0.01^{d} (0.01)	0.06 (0.01)
$S_{A(SD)}$	0.33^{d} (0.03)	0.07^{d} (0.02)	0.23 (0.02)
ϕ_{A1A4}	0.63^{d} (0.02)	0.37^{d} (0.02)	0.50 (0.02)

a = Significant preference for route A (San Joaquin Route) (α = 0.05) for all release occasions and for population estimate.

b = No tags were detected in subroute C; survival estimate used $\phi_{B1,B2} = S_{B1}*\psi_{B2}$ under assumption $\psi_{B2} = 1$.

c = No significant difference between route A and route B estimate ($P \geq 0.19$).

d = Release group 1 had significantly higher survival than release group 2 ($P < 0.0001$).

Table 18. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2012 tagging study, including predator-type detections. South Delta ("SD") survival extended to MacDonald Island and Turner Cut in Route A. Population-level estimates were from pooled release groups.

	Release Occasion		
Parameter	1	2	Population Estimate
ψ_{AA}	0.86 (0.03)	0.85 (0.09)	0.86 (0.03)
ψ_{AF}	0.12 (0.03)	0.13 (0.09)	0.12 (0.03)
S_{AA}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
S_{AF}	0 (0)	0 (0)	0 (0)
ψ_{A}^{a}	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
ψ_{B}^{a}	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.12 (0.03)	0.14 (0.09)	0.12 (0.03)
S_{A}	0.05^{cd} (0.01)	0^{d} (0)	0.03^{c} (0.01)
S_{B}^{b}	0.16^{c} (0.15)	0 (0)	0.11^{c} (0.10)
S_{Total}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
$S_{A(MD)}$	0.09^{d} (0.02)	0.01^{d} (0.01)	0.06 (0.01)
$S_{A(SD)}$	0.34^{d} (0.03)	0.08^{d} (0.02)	0.24 (0.02)
ϕ_{A1A4}	0.62^{d} (0.02)	0.38^{d} (0.02)	0.50 (0.02)

a = Significant preference for route A (San Joaquin Route) (α = 0.05) for all release occasions and for population estimate.

b = No tags were detected in subroute C; survival estimate used $\phi_{B1,B2} = S_{B1} * \psi_{B2}$ under assumption ψ_{B2} = 1.

c = No significant difference between route A and route B estimate ($P \geq 0.19$).

d = Release group 1 had significantly higher survival than release group 2 ($P < 0.0001$).

Table 19. 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 $\Delta>1$. 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}	0.90 (0.06)	0.63 (0.04)	0.27 (0.07)	0.0001*
S_{A3}	0.78 (0.04)	0.59 (0.03)	0.19 (0.05)	0.0001*
S_{A4}	0.98 (0.01)	0.89 (0.02)	0.08 (0.02)	0.0004*
S_{A5}	0.81 (0.02)	0.48 (0.04)	0.33 (0.05)	<0.0001*
S_{A6}	0.85 (0.03)	0.73 (0.08)	0.13 (0.08)	0.0594
S_{A7}	0.49 (0.04)	0.23 (0.06)	0.27 (0.07)	0.0001*
$S_{B2,G2}$[a]	0.17 (0.15)	0	0.17 (0.15)	0.1367
$\phi_{A1,A2}$	0.89 (0.05)	1.00 (0.06)	-0.11 (0.07)	0.9407
$\phi_{A8,A9}$	0.44 (0.05)	0.59 (0.16)	-0.16 (0.16)	0.8309
$\phi_{A8,G1}$	0.08 (0.03)	0	0.08 (0.03)	0.0030*
$\phi_{A9,G1}$	0.49 (0.09)	0.33 (0.19)	0.16 (0.21)	0.2265
$\phi_{B1,B2}$[a]	1	0.67 (0.27)	0.33 (0.27)	0.1106
$\phi_{F1,G1}$	0	0	0	NA
$\phi_{G1,G2(A)}$	0.54 (0.10)	0	0.54 (0.10)	<0.0001*

[a] These reaches are in the Old River route

Table 20a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2012 tagging study, without predator-type detections (see Table 20b for travel time from release with predator-type detections). Standard errors are in parentheses. There were no detections at the MRH, RGU, or RGD sites; all tags detected at FRE/FRW or MR4 were later detected at competing receivers, so those sites are omitted here.

	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 Upstream (DFU)	2	0.06 (0.02)	1	0.10 (NA)	1	0.04 (NA)
Durham Ferry Downstream (DFD)	251	0.03 (<0.01)	92	0.03 (<0.01)	159	0.03 (<0.01)
Banta Carbona (BCA)	353	0.27 (0.01)	111	0.25 (0.01)	242	0.29 (0.01)
Mossdale (MOS)	464	0.53 (0.01)	285	0.48 (0.01)	179	0.61 (0.02)
Lathrop (SJL)	430	0.71 (0.01)	273	0.65 (0.01)	157	0.85 (0.03)
Garwood Bridge (SJG)	293	1.41 (0.03)	218	1.31 (0.02)	75	1.85 (0.08)
Navy Drive Bridge (SJNB)	226	1.48 (0.03)	176	1.39 (0.02)	50	1.96 (0.10)
MacDonald Island (MAC)	89	2.83 (0.10)	79	2.74 (0.10)	10	3.88 (0.44)
Turner Cut (TCE/TCW)	12	2.84 (0.16)	10	2.91 (0.19)	2	2.57 (0.19)
Medford Island (MFE/MFW)	44	3.39 (0.25)	38	3.32 (0.27)	6	3.88 (0.55)
Old River East (ORE)	9	0.70 (0.06)	6	0.66 (0.04)	3	0.80 (0.19)
Old River South (ORS)	8	1.01 (0.07)	6	0.97 (0.04)	2	1.16 (0.43)
Old River at Highway 4 (OR4), SJR Route	1	5.08 (NA)	1	5.08 (NA)	0	NA
Old River at Highway 4 (OR4), OR Route	1	4.29 (NA)	1	4.29 (NA)	0	NA
Central Valley Project Trashrack (CVP), SJR Route	1	5.62 (NA)	1	5.62 (NA)	0	NA
Central Valley Project Trashrack (CVP), OR Route	4	2.52 (0.57)	3	2.41 (0.72)	1	2.92 (NA)
Central Valley Project Holding Tank (CVPtank), SJR Route	0	NA	0	NA	0	NA
Central Valley Project Holding Tank (CVPtank), OR Route	1	2.15 (NA)	1	2.15 (NA)	0	NA
Jersey Point (JPE/JPW), SJR Route	26	5.98 (0.63)	24	6.91 (0.69)	2	4.26 (1.26)
Jersey Point (JPE/JPW), OR Route	0	NA	0	NA	0	NA
Chipps Island (MAE/MAW), SJR Route	10	5.99 (0.41)	10	5.99 (0.41)	0	NA
Chipps Island (MAE/MAW), OR Route	1	4.12 (NA)	1	4.12 (NA)	0	NA
Chipps Island (MAE/MAW)	11	5.75 (0.41)	11	5.75 (0.41)	0	NA

Table 20b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2012 tagging study, with predator-type detections (see Table 20a for travel time from release without predator-type detections). Standard errors are in parentheses. There were no detections at the MRH, RGU, or RGD sites; all tags detected at FRE/FRW or MR4 were later detected at competing receivers, so those sites are omitted here.

	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 Upstream (DFU)	8	0.20 (0.11)	1	0.10 (NA)	7	0.23 (0.16)
Durham Ferry Downstream (DFD)	262	0.03 (<0.01)	96	0.03 (<0.01)	166	0.04 (<0.01)
Banta Carbona (BCA)	355	0.28 (0.01)	112	0.25 (0.01)	243	0.29 (0.01)
Mossdale (MOS)	464	0.53 (0.01)	283	0.48 (0.01)	181	0.63 (0.02)
Lathrop (SJL)	432	0.72 (0.01)	272	0.65 (0.01)	160	0.89 (0.03)
Garwood Bridge (SJG)	297	1.44 (0.03)	219	1.33 (0.02)	78	1.93 (0.09)
Navy Drive Bridge (SJNB)	230	1.56 (0.04)	177	1.44 (0.03)	53	2.19 (0.13)
MacDonald Island (MAC)	90	3.21 (0.17)	78	3.07 (0.17)	12	4.55 (0.72)
Turner Cut (TCE/TCW)	13	3.11 (0.26)	11	3.23 (0.31)	2	2.57 (0.19)
Medford Island (MFE/MFW)	44	3.39 (0.25)	38	3.32 (0.27)	6	3.88 (0.55)
Old River East (ORE)	9	0.77 (0.09)	6	0.66 (0.04)	3	1.18 (0.46)
Old River South (ORS)	9	1.11 (0.13)	6	0.97 (0.04)	3	1.52 (0.64)
Old River at Highway 4 (OR4), SJR Route	1	5.08 (NA)	1	5.08 (NA)	0	NA
Old River at Highway 4 (OR4), OR Route	1	4.29 (NA)	1	4.29 (NA)	0	NA
Central Valley Project Trashrack (CVP), SJR Route	1	5.62 (NA)	1	5.62 (NA)	0	NA
Central Valley Project Trashrack (CVP), OR Route	4	2.52 (0.57)	3	2.41 (0.72)	1	2.92 (NA)
Central Valley Project Holding Tank (CVPtank), SJR Route	0	NA	0	NA	0	NA
Central Valley Project Holding Tank (CVPtank), OR Route	1	2.15 (NA)	1	2.15 (NA)	0	NA
Jersey Point (JPE/JPW), SJR Route	26	5.98 (0.63)	24	6.19 (0.69)	2	4.26 (1.26)
Jersey Point (JPE/JPW), OR Route	0	NA	0	NA	0	NA
Chipps Island (MAE/MAW), SJR Route	10	5.99 (0.41)	10	5.99 (0.41)	0	NA
Chipps Island (MAE/MAW), OR Route	1	4.12 (NA)	1	4.12 (NA)	0	NA
Chipps Island (MAE/MAW)	11	5.75 (0.41)	11	5.75 (0.41)	0	NA

Table 21a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta river reaches during the 2012 tagging study, without predator-type detections (see Table 21b for travel time through reaches with predator-type detections). Standard errors are in parentheses. Reaches beginning at sites with no detections are not shown (i.e., reaches that start at MRH, MR4, RGU, RGD, and FRE/FRW).

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)	BCA	251	0.03 (<0.01)	92	0.03 (<0.01)	159	0.03 (<0.01)
BCA	MOS	230	0.28 (0.01)	87	0.24 (0.01)	143	0.31 (0.01)
MOS	SJL	429	0.14 (<0.01)	272	0.13 (<0.01)	157	0.16 (0.01)
	ORE	9	0.25 (0.04)	6	0.23 (0.04)	3	0.32 (0.09)
SJL	SJG	293	0.65 (0.02)	218	0.60 (0.02)	75	0.86 (0.05)
SJG	SJNB	226	0.08 (<0.01)	176	0.08 (<0.01)	50	0.09 (0.01)
SJNB	MAC	84	1.25 (0.07)	75	1.21 (0.07)	9	1.72 (0.37)
	TCE/TCW	12	1.19 (0.18)	10	1.37 (0.15)	2	0.72 (0.31)
MAC	MFE/MFW	39	0.23 (0.03)	33	0.24 (0.03)	6	0.21 (0.07)
	JPE/JPW/FRE/FRW	22	2.20 (0.26)	20	2.47 (0.27)	2	1.05 (0.13)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
MFE/MFW	JPE/JPW/FRE/FRW	17	1.54 (0.21)	15	1.80 (0.19)	2	0.74 (0.20)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
TCE/TCW	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	OR4	1	2.25 (NA)	1	2.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
ORE	ORS	8	0.27 (0.03)	6	0.29 (0.03)	2	0.22 (0.05)
	MRH	0	NA	0	NA	0	NA
ORS	OR4	1	3.25 (NA)	1	3.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	3	0.95 (0.12)	2	0.90 (0.16)	1	1.09 (NA)

Table 21a. (Continued)

Reach		Without Predator-Type Detections					
		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
OR4 via OR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
OR4 via SJR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	1	0.55 (NA)	1	0.55 (NA)	0	NA
CVP via OR	CVPtank	1	0.01 (NA)	1	0.01 (NA)	0	NA
CVP via SJR	CVPtank	0	NA	0	NA	0	NA
JPE/JPW	MAE/MAW (Chipps Island)	9	1.21 (0.14)	9	1.21 (0.14)	0	NA
MAC		10	3.54 (0.34)	10	3.54 (0.34)	0	NA
MFE/MFW		8	3.04 (0.25)	8	3.04 (0.259)	0	NA
TCE/TCW		0	NA	0	NA	0	NA
OR4		0	NA	0	NA	0	NA
CVPtank		1	1.97 (NA)	1	1.97 (NA)	0	NA

Table 21b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta river reaches during the 2012 tagging study, with predator-type detections (see Table 21a for travel time through reaches without predator-type detections). Standard errors are in parentheses. Reaches beginning at sites with no detections are not shown (i.e., reaches that start at MRH, MR4, RGU, RGD, and FRE/FRW).

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)	BCA	262	0.03 (<0.01)	96	0.03 (<0.01)	166	0.04 (<0.01)
BCA	MOS	231	0.28 (0.01)	86	0.24 (0.01)	145	0.31 (0.01)
MOS	SJL	431	0.14 (<0.01)	271	0.13 (<0.01)	160	0.17 (0.01)
	ORE	9	0.28 (0.06)	6	0.23 (0.04)	3	0.52 (0.27)
SJL	SJG	297	0.67 (0.02)	219	0.62 (0.02)	78	0.90 (0.05)
SJG	SJNB	230	0.08 (<0.01)	177	0.08 (<0.01)	53	0.09 (0.01)
SJNB	MAC	85	1.38 (0.10)	74	1.32 (0.10)	11	2.04 (0.49)
	TCE/TCW	13	1.33 (0.23)	11	1.57 (0.24)	2	0.72 (0.31)
MAC	MFE/MFW	39	0.23 (0.03)	33	0.24 (0.03)	6	0.21 (0.07)
	JPE/JPW/FRE/FRW	22	2.20 (0.26)	20	2.47 (0.27)	2	1.05 (0.13)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
MFE/MFW	JPE/JPW/FRE/FRW	17	1.54 (0.21)	15	1.80 (0.19)	2	0.74 (0.20)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
TCE/TCW	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	OR4	1	2.25 (NA)	1	2.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
ORE	ORS	9	0.29 (0.04)	6	0.29 (0.03)	3	0.31 (0.14)
	MRH	0	NA	0	NA	0	NA
ORS	OR4	1	3.25 (NA)	1	3.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	3	0.95 (0.12)	2	0.90 (0.16)	1	1.09 (NA)

Table 21b. (Continued)

Reach		With Predator-Type Detections					
		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
OR4 via OR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
OR4 via SJR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	1	0.55 (NA)	1	0.55 (NA)	0	NA
CVP via OR	CVPtank	1	0.01 (NA)	1	0.01 (NA)	0	NA
CVP via SJR	CVPtank	0	NA	0	NA	0	NA
JPE/JPW	MAE/MAW (Chipps Island)	9	1.21 (0.14)	9	1.21 (0.14)	0	NA
MAC		10	3.54 (0.34)	10	3.54 (0.34)	0	NA
MFE/MFW		8	3.04 (0.225)	8	3.04 (0.25)	0	NA
TCE/TCW		0	NA	0	NA	0	NA
OR4		0	NA	0	NA	0	NA
CVPtank		1	1.97 (NA)	1	1.97 (NA)	0	NA

Table 22: Distance in km, estimated survival and survival rate per km (S^(1/km)), travel time in days, and travel time in days per km (TT^(1/km)), for the first (1st) and second (2nd) release groups of Chinook Salmon in 2012. Survival and travel time data were obtained from tables Table A5-2, and Table 21a. Distance was estimated using the shortest distance between the two points calculated from Google Earth. Data were used to generate Figure 12.

Reach	Distance in km	Survival		Survival per km		Travel time		Travel time per km	
		1st	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
Durham Ferry (Release) to Banta Carbona	11	0.90	0.63	0.990	0.959	0.03	0.03	0.727	0.727
Banta Carbona to Mossdale	9	0.78	0.59	0.973	0.943	0.24	0.31	0.853	0.878
Mossdale to Lathrop/Old River	4	0.98	0.89	0.995	0.971	0.13	0.16	0.600	0.632
Lathrop to Stockton South (Garwood Bridge)	18	0.81	0.48	0.988	0.960	0.60	0.86	0.972	0.992
Stockton South to Stockton Navy Bridge	3	0.85	0.73	0.947	0.900	0.08	0.09	0.431	0.448
Navy Bridge to Turner Cut Junction	15	0.49	0.23	0.954	0.907	1.37	0.72	1.021	0.978
MacDonald Island to Medford Island	5	0.44	0.59	0.849	0.900	0.24	0.21	0.752	0.732
Medford Island to Jersey Point	21	0.49	0.33	0.967	0.949	1.80	0.74	1.028	0.986
Jersey Point to Chipps Island	22	0.54	0.00	0.972	0.000	1.21		1.009	

Table 23. Results of single-variate analyses of route entrainment at the Turner Cut Junction (all release groups). The values df1, df2 are degrees of freedom for the F-test.

	F-test			
Covariate[a]	*F*	df1	df2	*P*
Change in flow at TRN	0.6896	1	8	0.4304
Change in velocity at TRN	0.6470	1	8	0.4444
Exports at CVP	0.3355	1	9	0.5766
Change in stage at TRN	0.2824	1	8	0.6095
Flow during transition from SJG	0.1864	1	9	0.6761
Stage at TRN	0.1696	1	9	0.6901
Velocity during transition from SJG	0.1311	1	9	0.7256
Release Group	0.0730	1	9	0.7931
Arrive during day at junction	0.0558	1	9	0.8185
Fork Length	0.0331	1	9	0.8597
Exports at SWP	0.0286	1	9	0.8694
Negative flow at TRN	0.0063	1	9	0.9385
Flow at TRN	0.0031	1	9	0.9568
Velocity at TRN	0.0024	1	9	0.9623

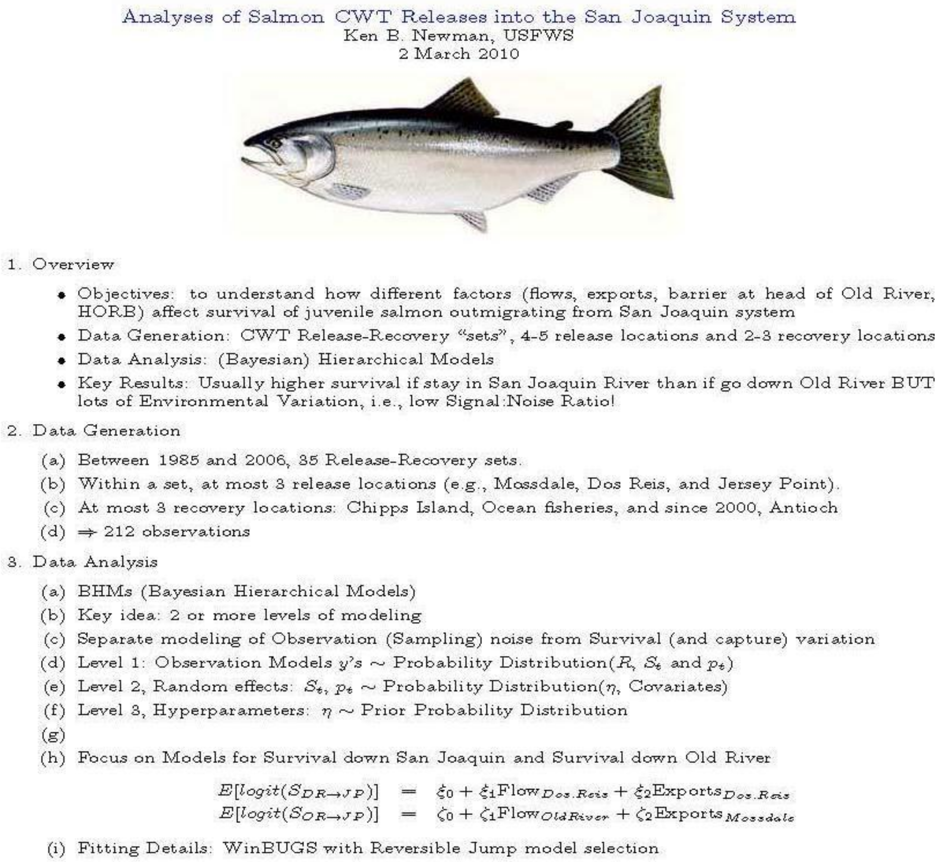
a = No covariate was significant at 5% level

Table 24. Summary statistics from multiple regression of flow at Vernalis and tag type to explain survival from Mossdale to Jersey Point with the physical head of Old River barrier. Tag type (CWT or Acoustic) was not significant (p value = 0.992775).

SUMMARY OUTPUT			Mossdale data only					
Regression Statistics								
Multiple R	0.86119676							
R Square	0.74165986							
Adjusted R Square	0.69468892							
Standard Error	0.07221227							
Observations	14							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	2	0.164674977	0.082337	15.78976	0.000584865			
Residual	11	0.057360738	0.005215					
Total	13	0.222035714						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.2287319	0.10572806	-2.1634	0.053388	-0.461437753	0.00397403	-0.46143775	0.003974031
X Variable 1 (tag)	-0.0005306	0.057279985	-0.00926	0.992775	-0.126603014	0.12554178	-0.12660301	0.125541781
X Variable 2 (flow)	9.533E-05	1.76263E-05	5.408389	0.000214	5.65346E-05	0.00013413	5.6535E-05	0.000134125

Appendices 1-5:

Appendix 1. Analyses of CWT salmon released in the south Delta by Ken Newman as part of the VAMP peer review in 2010.



Analyses of Salmon CWT Releases into the San Joaquin System

Ken B. Newman, USFWS
2 March 2010

1. Overview
   - Objectives: to understand how different factors (flows, exports, barrier at head of Old River, HORB) affect survival of juvenile salmon outmigrating from San Joaquin system
   - Data Generation: CWT Release-Recovery "sets", 4-5 release locations and 2-3 recovery locations
   - Data Analysis: (Bayesian) Hierarchical Models
   - Key Results: Usually higher survival if stay in San Joaquin River than if go down Old River BUT lots of Environmental Variation, i.e., low Signal:Noise Ratio!
2. Data Generation
   - (a) Between 1985 and 2006, 35 Release-Recovery sets.
   - (b) Within a set, at most 3 release locations (e.g., Mossdale, Dos Reis, and Jersey Point).
   - (c) At most 3 recovery locations: Chipps Island, Ocean fisheries, and since 2000, Antioch
   - (d) $\Rightarrow$ 212 observations
3. Data Analysis
   - (a) BHMs (Bayesian Hierarchical Models)
   - (b) Key idea: 2 or more levels of modeling
   - (c) Separate modeling of Observation (Sampling) noise from Survival (and capture) variation
   - (d) Level 1: Observation Models y's $\sim$ Probability Distribution(R, S_t and p_t)
   - (e) Level 2, Random effects: S_t, p_t $\sim$ Probability Distribution(η, Covariates)
   - (f) Level 3, Hyperparameters: $\eta \sim$ Prior Probability Distribution
   - (g)
   - (h) Focus on Models for Survival down San Joaquin and Survival down Old River

$$\begin{aligned} E[logit(S_{DR \rightarrow JP})] &= \xi_0 + \xi_1 \text{Flow}_{Dos.Reis} + \xi_2 \text{Exports}_{Dos.Reis} \\ E[logit(S_{OR \rightarrow JP})] &= \zeta_0 + \zeta_1 \text{Flow}_{OldRiver} + \zeta_2 \text{Exports}_{Mossdale} \end{aligned}$$

   - (i) Fitting Details: WinBUGS with Reversible Jump model selection

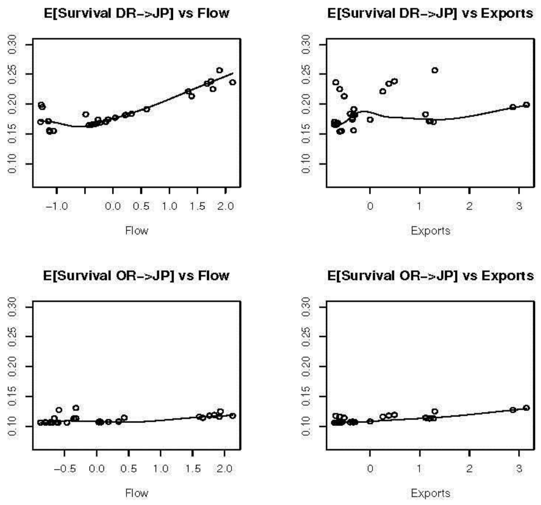
4. Results

   (a) Posterior Probabilities

Models	$S_{MD\to JP}$	$S_{OR\to JP}$
Constant	0.38	0.45
Flow	0.29	0.23
Exports	0.17	0.21
Both	0.16	0.11

   (b) Coefficients

Covariate	Average	SD	2.5%	median	97.5%
SJ-flow	0.16	0.25	-0.09	0.0	0.77
SJ-exports	0.07	0.19	-0.17	0.0	0.61
OR-flow	0.04	0.22	-0.42	0.0	0.62
OR-exports	0.04	0.20	-0.32	0.0	0.60



5. Caveats and Comments

   (a) Priors *do* matter, especially with Hierarchical Models

   (b) More to wring out of CWTs? Using time of capture? Add arrival time/travel time model?

   (c) Acoustic tags far preferable?

   (d) Value in probing extreme values for flows and exports

Some references:

- Clark, J.S. 2005. "Why environmental scientists are becoming Bayesians." *Ecology Letters*, **8**: 2–14.
- Clark, J.S., and Gelfand, A.E. 2006. "A future for models and data in environmental science." *Trends in Ecology and Evolution*, **21**: 375–380.
- Newman, K.B., and Brandes, P.L. 2010. Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports. *North American Journal of Fisheries Management*, **30**: 157–169.

Appendix 2: Standard Operating Procedure

Acoustic Tagging for Salmon 2012 South Delta Studies 4/10/12 (file dated 4/23/12)

Equipment Set Up:

- Fill surgical instrument disinfection trays with chlorhexidine (brand name Nolvasan)
    - Autoclave instruments such that each tagging event begins with sterile instruments
- Activate transmitters and confirm operational status
    - Position the transmitter in an isolated compartment to enable tracking of the transmitter ID through the implantation process
- Disinfect transmitters in chlorhexidine
    - Ensure at least 20 minutes of contact time with chlorhexidine
    - Following disinfection, thoroughly rinse transmitters in distilled or de-ionized water prior to implantation
    - Following disinfection, transmitters should only be handled by gloved hands or clean surgical instruments such as forceps
- Fill rinse tray with de-ionized or distilled water
- Set up scale, measuring board, and surgical platform or foam
    - Apply stress coat to weigh boat, measuring board, and platform to reduce damage to fish skin or mucus layer
- Fill gravity feed carboys. Add 2 ml of the MS-222 stock solution and 2 ml of the sodium bicarbonate stock solution to the 10 L of water in the MS-222 carboy. Concentration may be increased upon group consensus and in consultation with coordinator.
- Fill anesthesia container to indicated volume line. Set the initial concentration in collaboration with the tagging coordinator. Suggested starting concentration is 70 mg/ L. Concentration may be adjusted upon group consensus and in consultation with coordinator. Concentration changes should be executed for all taggers simultaneously and recorded on the tagging datasheet.
- Prepare recovery containers by filling with water, adding stress coat, and supersaturating with oxygen
    - Immediately following surgery fish will be held in recovery containers that provide 130% to 150% DO for a minimum of 10 minutes
    - Holding time in recovery containers begins when the last fish is added to the container and will be monitored using a timer
- Prepare a reject container for fish that cannot be tagged by filling with water and equipping with a bubbler . These fish will be returned to a separate holding tank.
- Start tagging data sheets. Note the time the tagging session was started and complete all appropriate data fields. Start a Daily Fish Reject Tally datasheet to account for fish that are handled but not tagged.
- The tagger should wear medical-grade exam gloves during all fish handling and tagging procedures
- Prepare the transport truck to accept containers of tagged fish.
- Prepare transport containers and lids to receive tagged fish

Surgery

- Food should be withheld from fish for ~24 h prior to surgical implantation of the transmitter.
- Anesthetize fish
    - Net one fish from source tank/raceway and place directly into an anesthesia container. Immediately start a timer to monitor anesthesia exposure time and place a lid on the container.
    - Remove the lid after about 1 minute to observe the fish for loss of equilibrium. Keep the fish in the water for an additional 30-60 seconds after it has lost equilibrium. Time to sedation should normally be 2-4 minutes, with an average of about 3 minutes. If loss of equilibrium takes less than 1 minute or if a fish is exposed to anesthesia for more than 5 minutes, reject that fish. If after anesthetizing a few fish they are consistently losing equilibrium in more or less time than typical, the anesthesia concentration may need to

    be adjusted. Anesthesia concentration should only be adjusted in coordination with all study taggers and the tagging coordinator.
        - Changes to anesthesia concentration should be done at 5 mg/L increments. For example, if the initial dosage was 70 mg/L, an adjusted dose should be 65 mg/L or 75 mg/L.
        - When an anesthesia change is agreed upon, all taggers should drain their anesthesia containers, refill with 10 L of water, and re-mix to the new anesthesia concentration
    - If a fish is unacceptable for tagging due to issues with anesthesia, place the fish in the "Reject" container and log it on the reject tally datasheet.
    - The anesthesia container should be emptied and remixed at regular intervals throughout the tagging operation to ensure the appropriate concentration and to avoid warming
    - The gravity feed containers should be monitored for volume and temperature and changed as needed to avoid inadequate volume to complete a surgery and significant warming

- Recording fish length, weight, and condition
    - Start a timer when a fish is removed from the anesthesia container to record the time the fish is out of water (recorded as "air time").
    - Transfer the fish to the scale and record the weigh to the nearest 0.1g
        - Scales should be calibrated regularly to ensure accuracy
        - Fish must weigh at least 13 g to be selected for tagging so that tag burden does not exceed 5% of the weight of the fish. Transmitters used for this study are Vemco brand V5 models, weighing 0.65 g in air.
    - Transfer the fish to the measuring board and determine forklength to the nearest mm.
    - Check for any abnormalities and descaling. If the fish is abnormal or grossly descaled, note this on the datasheet and place the fish in the reject container.
        - Scale condition is noted as Normal (N), Partial (P), or Descaled (D) and is assessed on the most compromised side of each fish. The normal scale condition is defined as loss of less than 5% of scales on one side of the fish. Partial descaling is defined as loss of 6-19% of scales on one side of the fish. Fish are classified as descaled if they have lost 20% or more of the scales on one side of the fish, and should not be tagged due to compromised osmoregulatory ability.
    - Data must be vocally relayed to the recorder, and the recorder should repeat the information back to the tagger to avoid miscommunication.
    - Any fish dropped on the floor should be rejected.

- Transmitter Implantation
    - Anesthesia should be administered through the gravity feed irrigation system as soon as the fish is on the surgical platform. Use the flow control valves to adjust the flow rate as needed so that the opercular rate of the fish is steady.
        - Note that low-flow or inconsistent irrigation can mimic shallow anesthesia
    - Using a scalpel, make an incision approximately 3-5 mm in length beginning a few mm in front of the pelvic girdle. The incision should be about 3 mm away from and parallel to the mid-ventral line, and just deep enough to penetrate the peritoneum, avoiding the internal organs. The spleen is generally near the incision point so the depth and placement of the incision are critical.
        - There is no exact specification for the selection of a micro scalpel for steelhead. A general recommendation is to use a 5 mm blade for fish larger than about 50 g.
        - The incision should only be long enough to allow entry of the tag.
    - Forceps may be used to open the incision to check for potential organ damage. If you observe damage or note excessive bleeding, reject the fish.
    - Scalpel blades can be used on several fish, but if the scalpel is pulling roughly or making jagged incisions, it should be changed prior to tagging the next fish.

    - Gently insert the tag into the body cavity and position it so that it lies directly beneath the incision and the ceramic head is facing forward. This positioning will provide a barrier between the suture needle and internal organs.
    - Close the incision with two simple interrupted stitches.
        - Vicryl Plus sutures are recommended
        - 5-0 suture size is appropriate for juvenile Chinook Salmon or similar fish with weights less than~ 50 g
        - If the incision cannot effectively be closed with two stitches, a third stitch may be added. The presence of a third suture should be noted on the datasheet.
    - Ideally the gravity feed irrigation system should be switched to fresh water or a combination of sedation and freshwater during the final stages of surgery to begin recovery from anesthesia. Typically a good time to switch to freshwater is when the second suture is initiated.
    - Transfer the fish from the surgical platform to a recovery container and stop the timer recording air time
        - Avoid excessive handling of fish during transfer. Ideally the fish will be moved to the recovery container on the surgical platform to reduce handling.
    - Once a recovery container has been fully stocked, start a timer to monitor the 10 min of exposure to high DO concentrations for recovery.
    - Between surgeries the tagger should place surgical instruments and any partially consumed suture material into the chlorhexidine bath. Multiple sets of surgical instruments should be rotated to ensure 10 min of contact time with chlorhexidine. Once disinfected, instruments should be rinsed in distilled or de-ionized water. Organic debris in the disinfectant bath reduces effectiveness, so be sure to change the bath regularly.

Tag Validation

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

Cleanup

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

Important things to remember:

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

Appendix 3: Water temperature (every 15 minutes) in transport tanks during transport of tagged fish from the Tracy Fish Collection Facility to the release site (Durham Ferry)

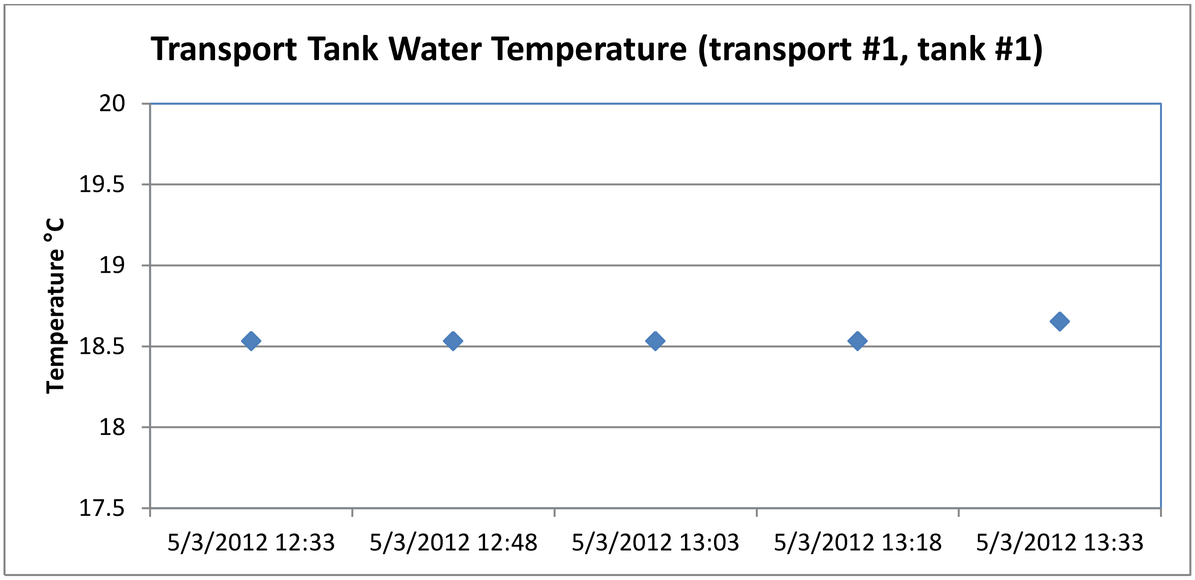


Figure A3-1. Transport tank water temperature during transport #1, tank #1 on May 3, 2012.

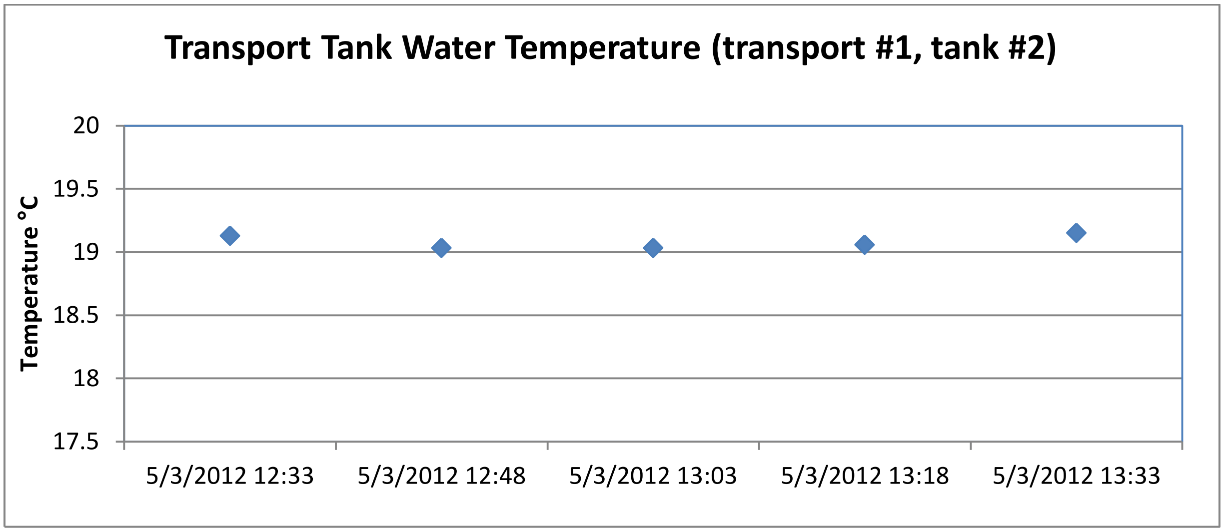


Figure A3-2. Transport tank water temperature during transport #1, tank #2 on May 3, 2012.

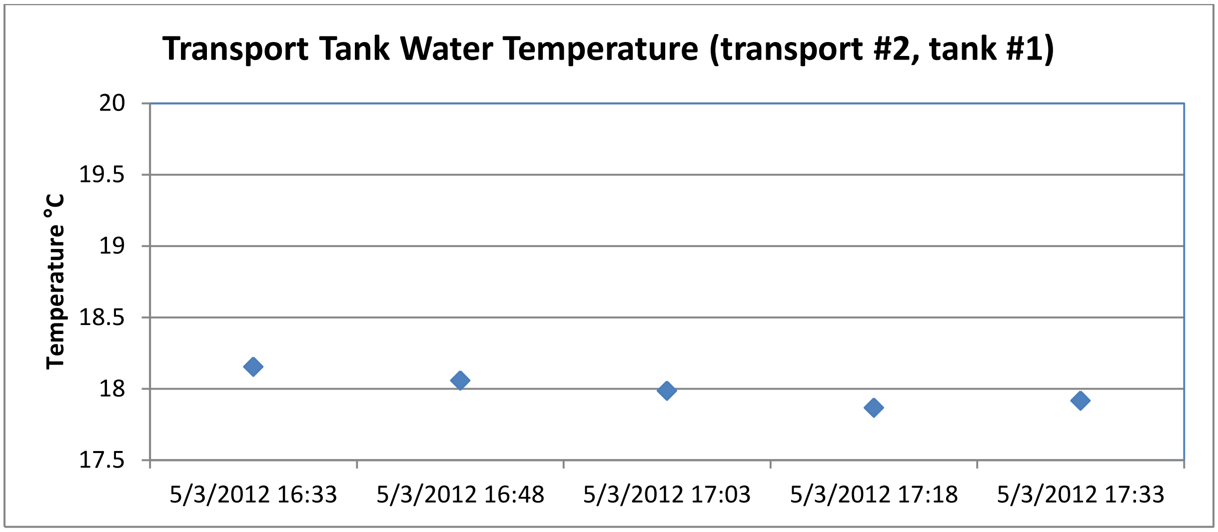


Figure A3-3. Transport tank water temperature during transport #2, tank #1 on May 3, 2012.

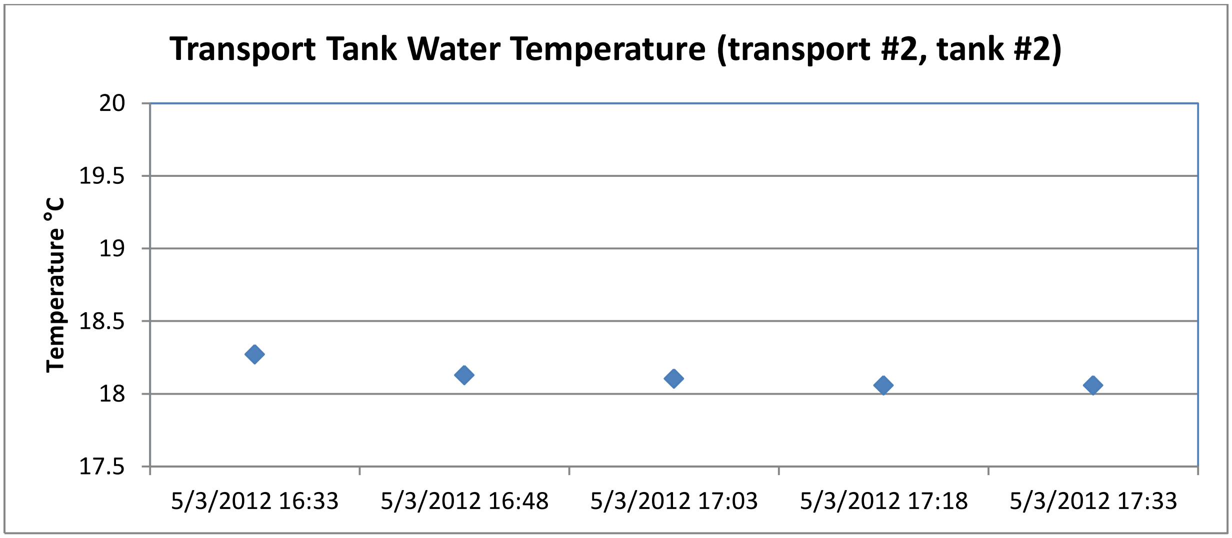


Figure A3-4. Transport tank water temperature during transport #2, tank #2 on May 3, 2012.

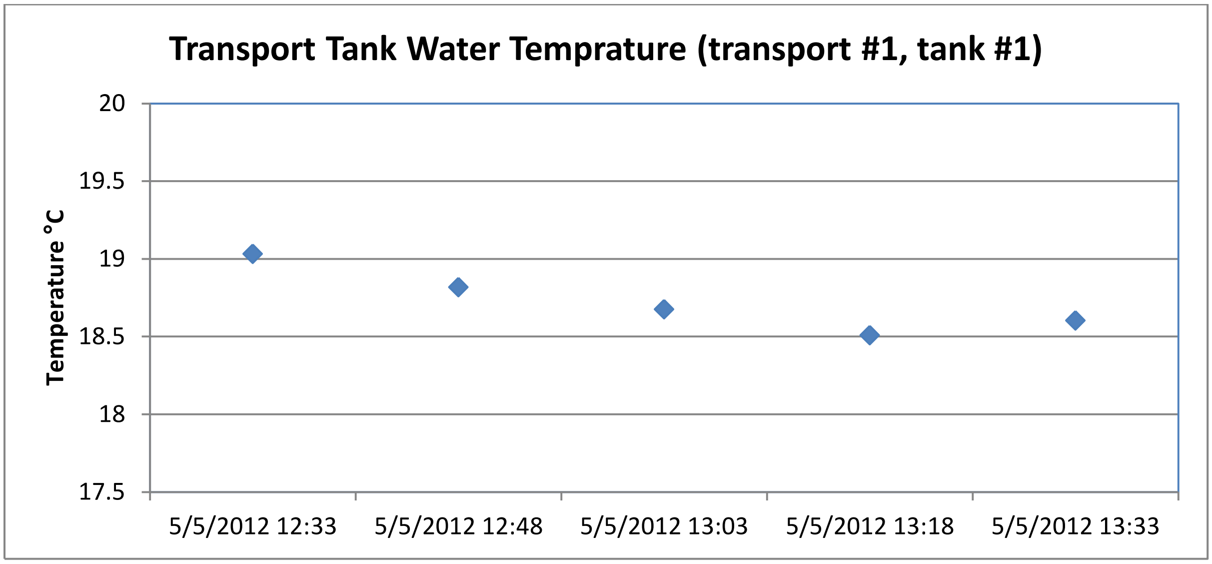


Figure A3-5. Transport tank water temperature during transport #1, tank #1 on May 5, 2012.

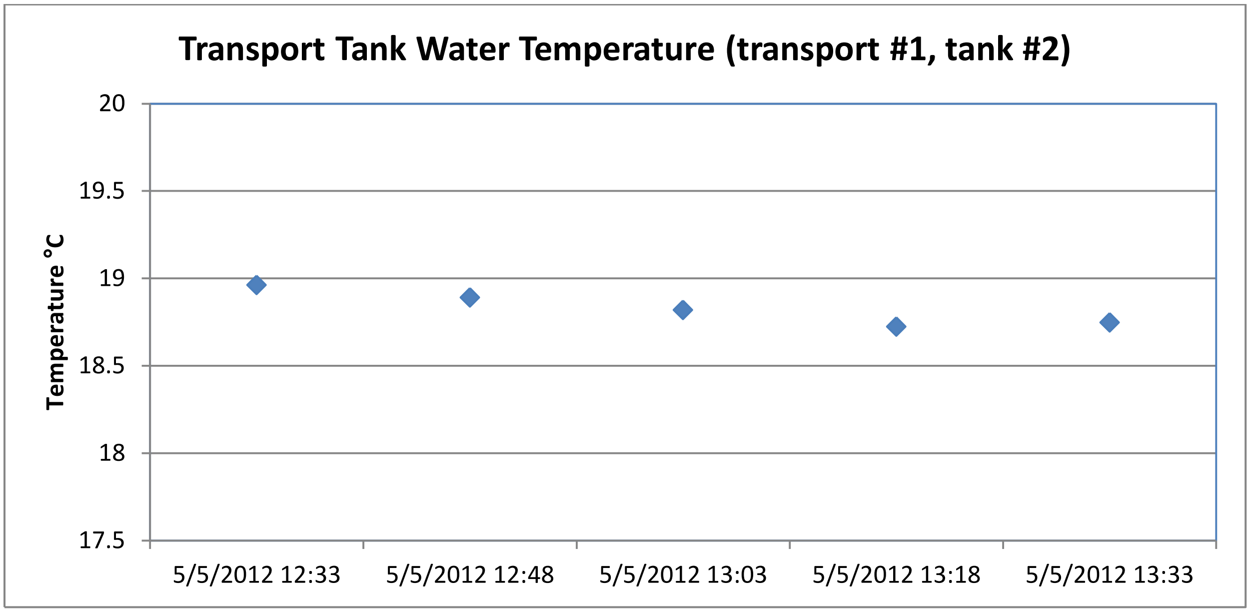


Figure A3-6. Transport tank water temperature during transport #1, tank #2 on May 5, 2012.

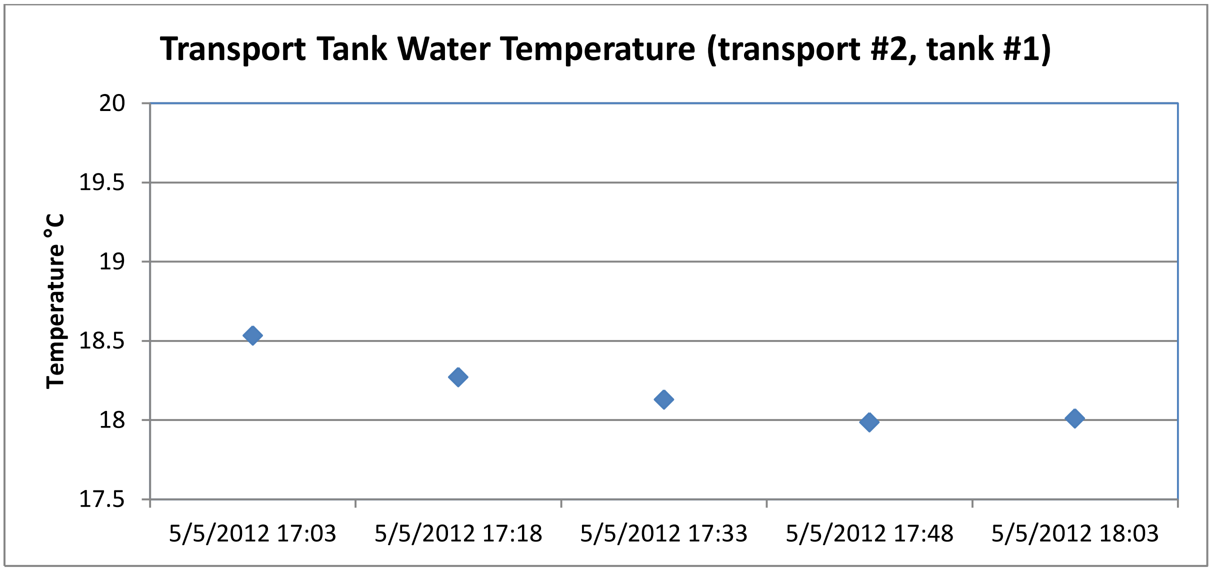


Figure A3-7. Transport tank water temperature during transport #2, tank #1 on May 5, 2012.

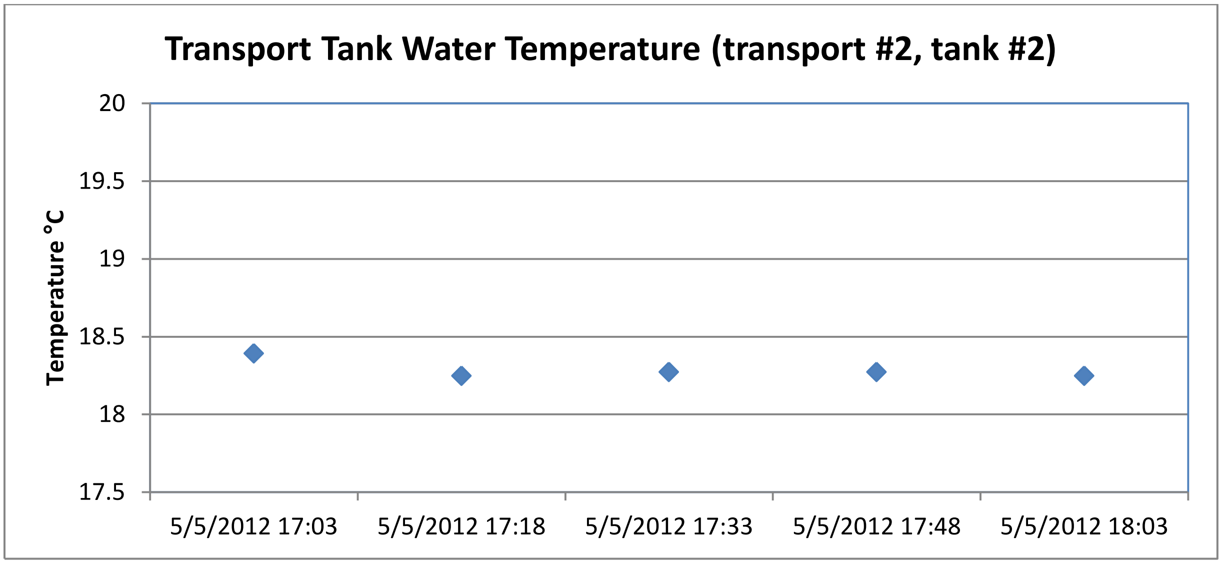


Figure A3-8. Transport tank water temperature during transport #2, tank #2 on May 5, 2012.

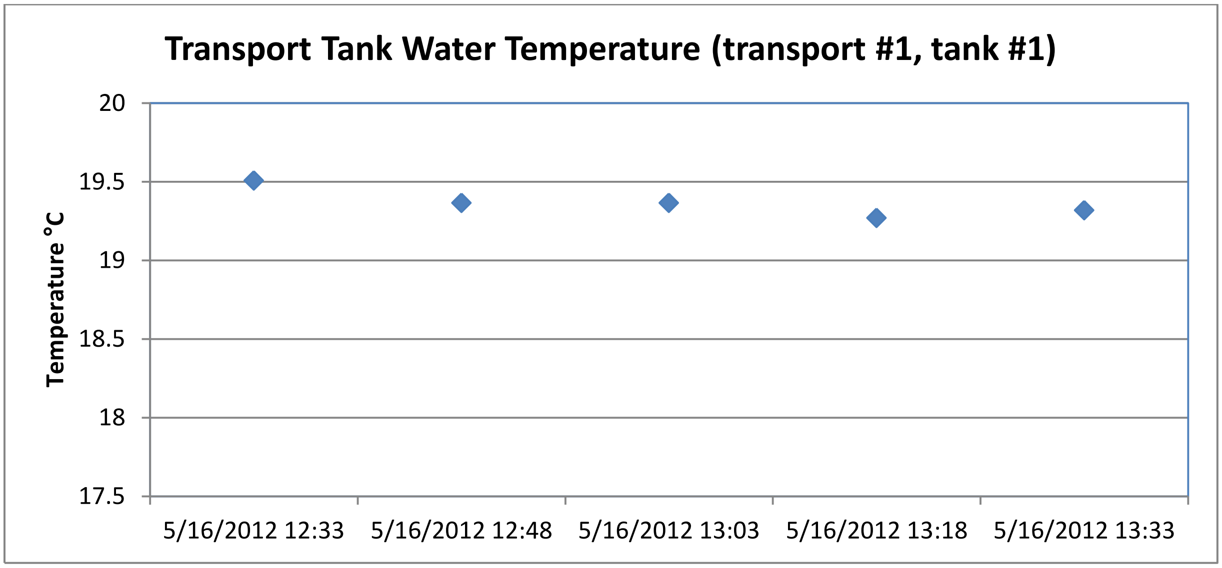


Figure A3-9. Transport tank water temperature during transport #1, tank #1 on May 16, 2012.

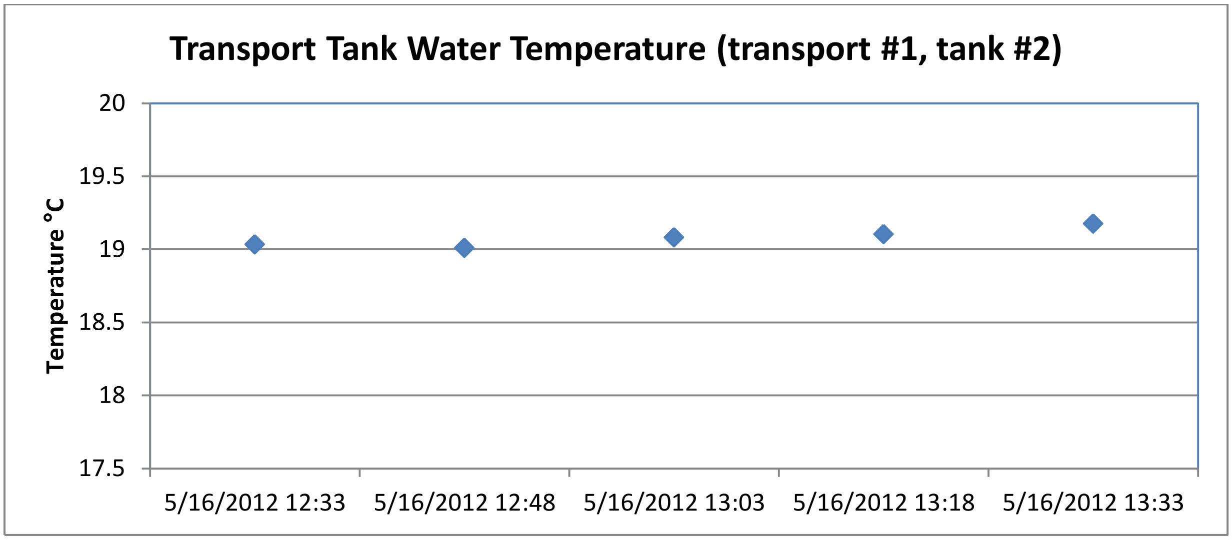


Figure A3-10. Transport tank water temperature during transport #1, tank #2 on May 16, 2012.

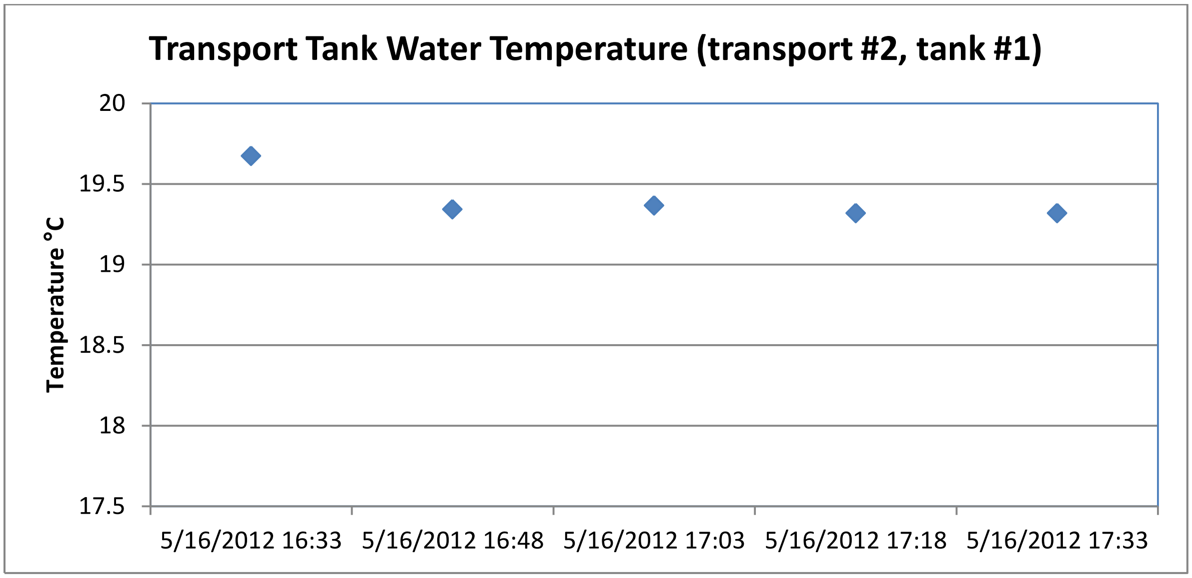


Figure A3-11. Transport tank water temperature during transport #2, tank #1 on May 16, 2012.

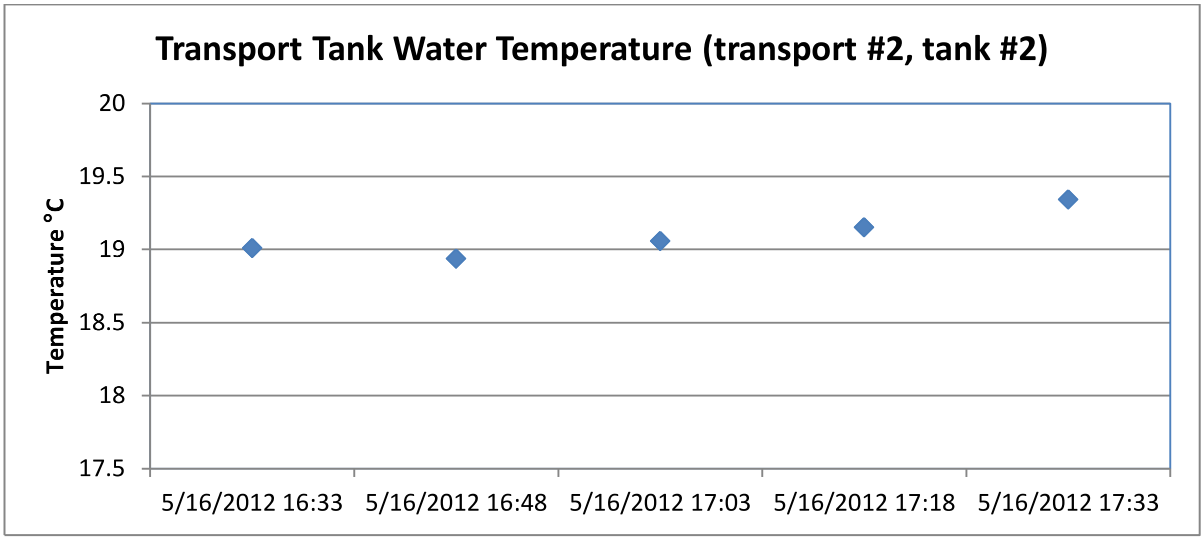


Figure A3-12. Transport tank water temperature during transport #2, tank#2 on May 16, 2012.

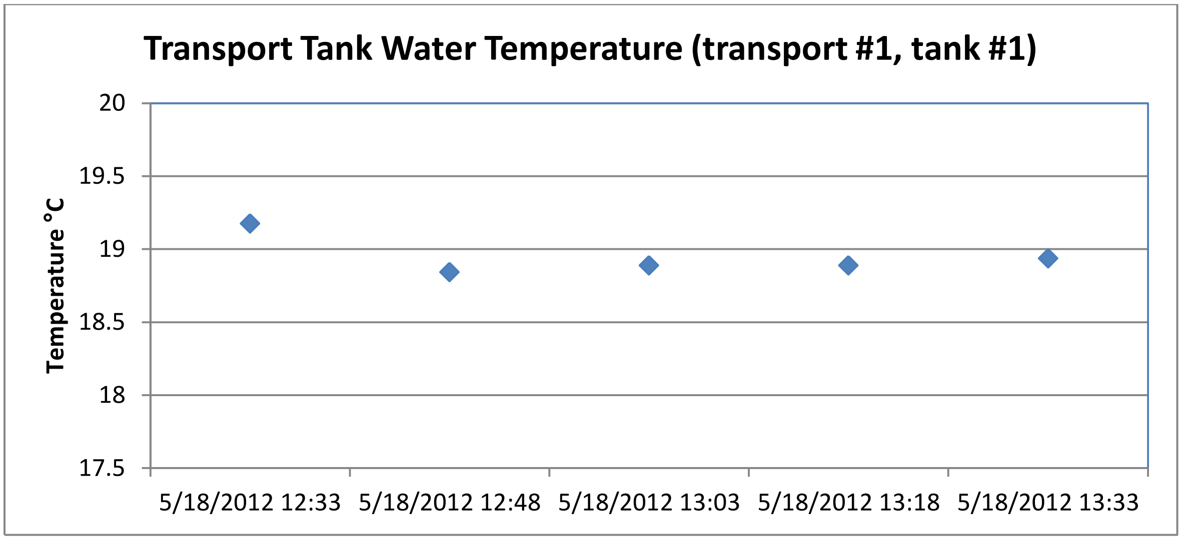


Figure A3-13. Transport tank water temperature during transport #1, tank #1 on May 18, 2012.

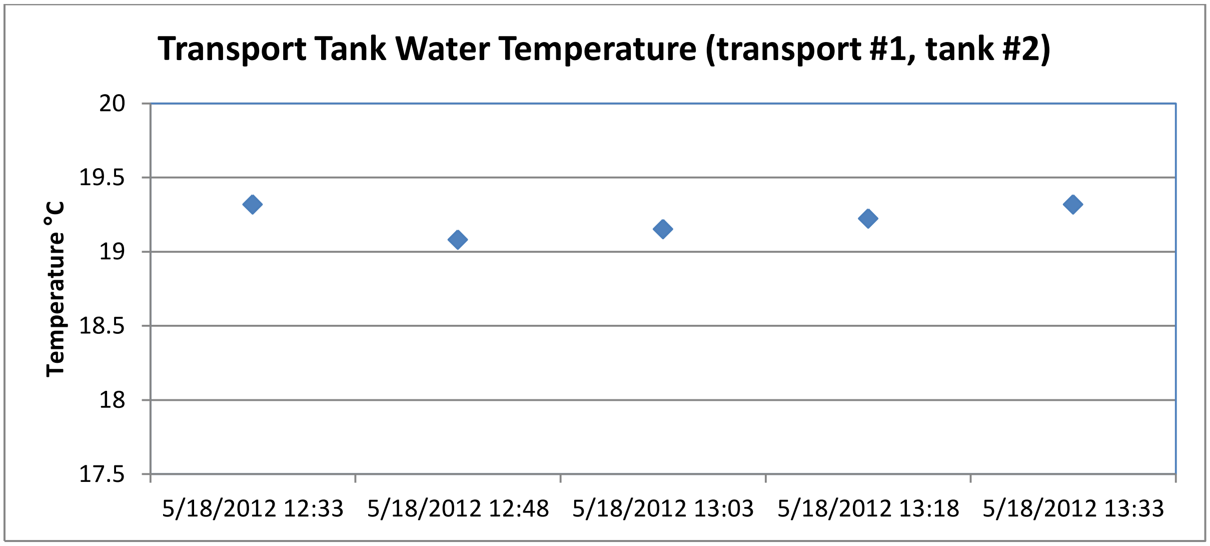


Figure A3-14. Transport tank water temperature during transport #1, tank #2 on May 18, 2012.

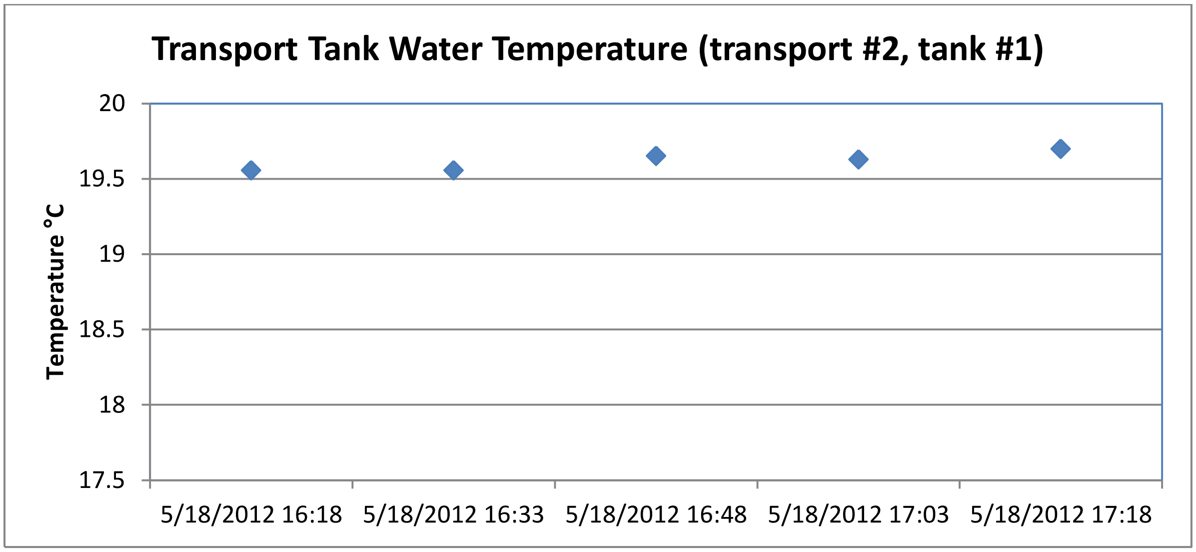


Figure A3-15. Transport tank water temperature during transport #1, tank #1 on May 18, 2012.

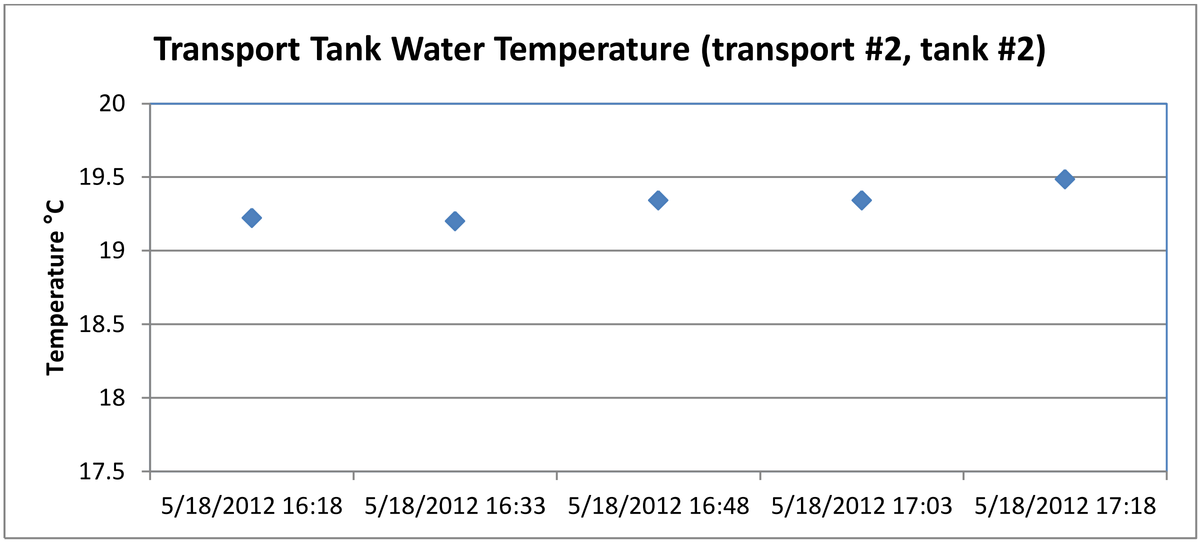


Figure A3-16. Transport tank water temperature during transport #2, tank #2 on May 18, 2012.

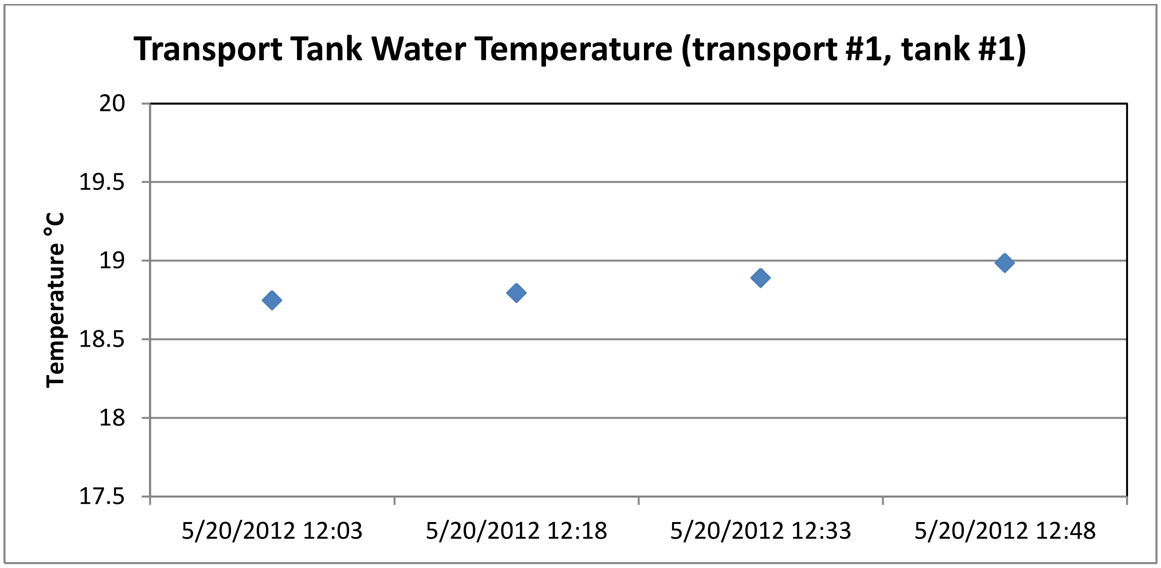


Figure A3-17. Transport tank water temperature during transport #1, tank #1 on May 20, 2012.

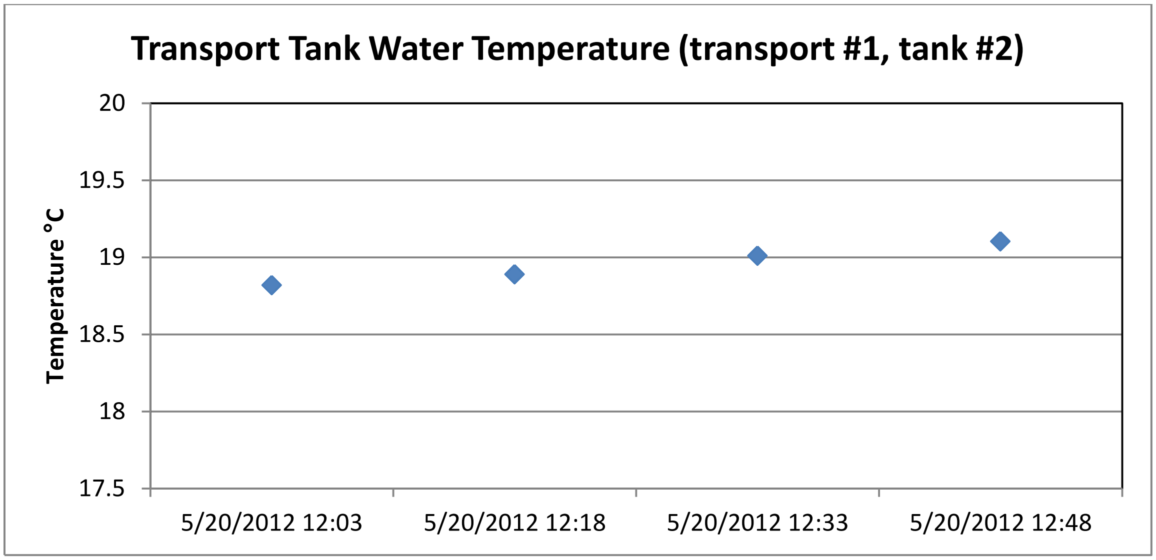


Figure A3-18. Transport tank water temperature during transport #1, tank #2 on May 20, 2012.

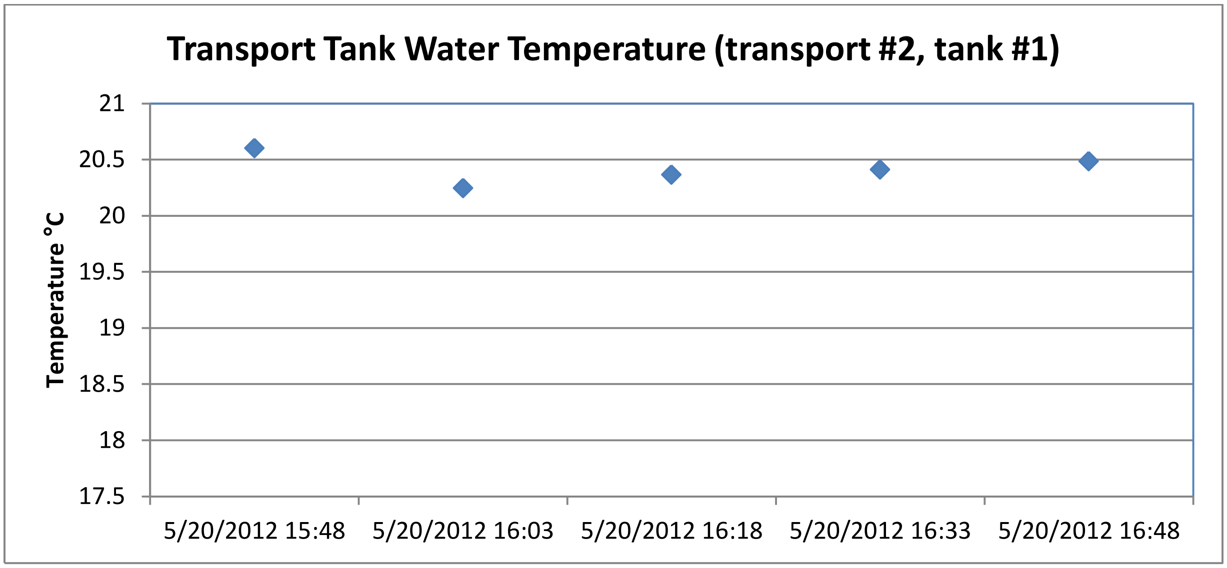


Figure A3-19. Transport tank water temperature during transport #2, tank #1 on May 20, 2012.

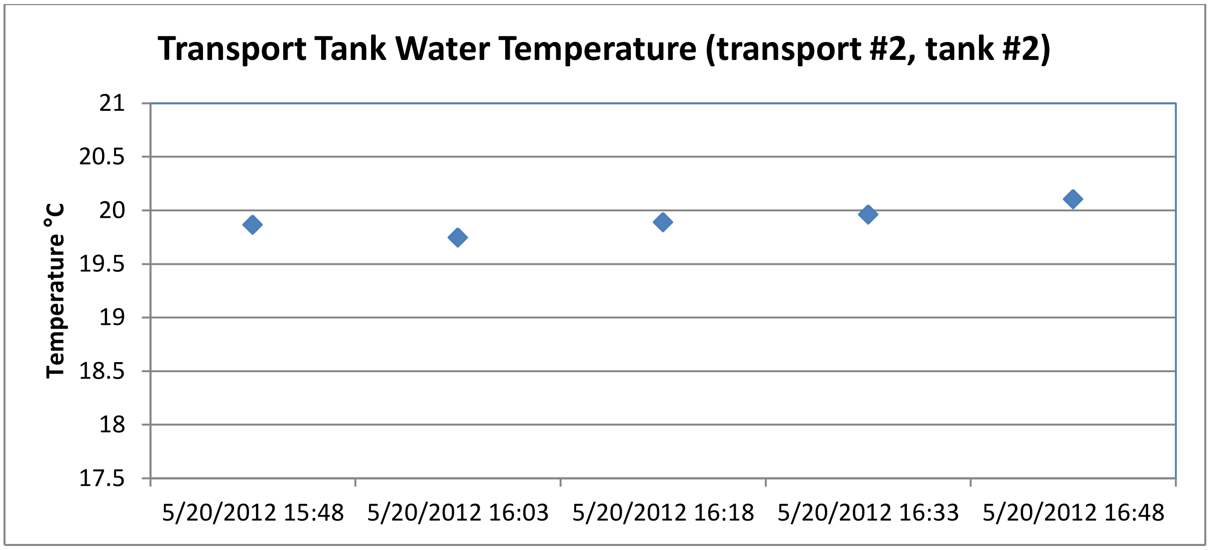


Figure A3-20. Transport tank water temperature during transport #2, tank #2 on May 20, 2012.

Appendix 4:

U.S. Fish & Wildlife Service

FY2012 Technical Report:
Pathogen screening and gill Na-K-ATPase assessment of juvenile Chinook salmon used in south delta acoustic tag studies.

J. Scott Foott

September 2012

US Fish and Wildlife Service

California-Nevada Fish Health Center

24411 Coleman Fish Hatchery Rd

Anderson, CA 96007

SUMMARY:

Pathogen testing was conducted on dummy-tag cohorts of acoustic tagged Merced River Hatchery juvenile Chinook salmon used in studies corresponding to 7 May and 23 May releases. No virus or *Renibacterium salmoninarum* infection was detected in the fish. The 23 May group had 37% prevalence of both suture abnormalities and A*eromonas – Pseudomonas* sp. infection however there was little correlation between the 2 findings. As in the past, *Tetracapsuloides bryosalmonae* infection was highly prevalent (≥ 97%) and the associated Proliferative Kidney Disease became more pronounced in the 23 May sample. No mortality occurred in the live cage populations at either sample date. Gill Na-K-ATPase data is not reported due to a problem with a key assay reagent. The combination of kidney impairment and poor suture condition of the 23 May salmon indicates that health of the two release groups was not equivalent.

Recommended citation for this report is:
Foott JS. 2012. FY2012 Technical Report: Pathogen screening and gill Na-K-ATPase assessment of juvenile Chinook salmon used in south delta acoustic tag studies. U.S. Fish & Wildlife Service California-Nevada Fish Health Center, Anderson, CA. Available: http://www.fws.gov/canvfhc/reports.asp.

INTRODUCTION

As a component of the 2012 Chinook salmon survival studies on reach-specific survival and distribution of migrating Chinook salmon in the San Joaquin River and delta, the CA-NV Fish Health Center conducted a general pathogen screening and smolt physiological assessment. The health and physiological condition of the study fish can help explain their performance and survival during the studies. Pathogen screenings during past VAMP studies using Merced River Hatchery (MRH) Chinook 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 project were to survey 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.

METHODS

Prior to the 7 May and 23 May sample, 30 juvenile salmon were held within live cages for approximately 48h in the San Joaquin River at Durham Ferry. These fish were surgically-implanted with a dummy tag similar in size to the acoustic tag of release cohorts. Fish were evaluated for gill and skin condition (including suture) and tissues collected for assays. A grading scale ranging 0-3 was used to score inflammation or ulceration of tissue at the suture location and openness of the surgical incision (based on training session by Cramer Fish Sciences attended by J. Day).

> 0: Clean, completely closed and healed incision with taut suture. No external indication of pulling of tissue or inflammation.
>
> 1: Mostly closed, but not healed incision. Minor petechial hemorrhage.
>
> 2: Incision more than half open, and not healed. Inflammation present over more than half the suture area.
>
> 3: Incision completely open. Severely inflamed tissue surrounding and/or pushing out from incision site. Severe hemorrhaging extending equal to or greater than the length of the incision site. Suture may be lost entirely or embedded within inflamed tissue. Necrotic tissue visible.

Gill lamellae were collected first into SEI buffer and frozen on dry ice. Gill Na^+/K^+-Adenosine Triphosphatase (ATPase) activity was assayed by the method of McCormick (1993). Kidney 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). *Renibacterium salmoninarum* (bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test (FAT) of kidney imprints. Three fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 cell lines held at 15°C for 21 d (USFWS and AFS-FHS 2010). The gill, liver, intestine and posterior kidney were rapidly removed from the fish and immediately fixed in Davidson's fixative, processed for 5 µm paraffin sections and stained with hematoxylin and eosin (Humason 1979). Infections of the myxozoan parasite, *T. bryosalmonae,* were rated for intensity of parasite infection and associated tissue inflammation (Proliferative Kidney Disease). 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 (PKD) was rated as normal, focal, multifocal or diffuse.

RESULTS AND DISCUSSION

All salmon were alive at the time of sample collection for both dates. Suture condition of 23 May fish was judged to be poor (11 of 30 fish with #2 or 3 ratings). Several sutures were observed on the pelvic girdle. All sutures in the 7 May group were intact and showed no hemorrhage.

The prevalence of systemic bacterial infection (A*eromonas – Pseudomonas* sp. (aquatic bacteria clade) was also 37% in the 23 May group however there was little association with suture hemorrhage (only 4 of 11 fish with hemorrhaged sutures had bacterial infections). No virus or *Renibacterium salmoninarum* infection was detected in the fish (Table 1). *Tetracapsuloides bryosalmonae* was seen in $\geq$ 97% of the kidney sections from both sample groups (Table 1).

Table A4-1. Prevalence of infection (number positive / total sample) for systemic bacteria (AP= *Aeromonas* or *Pseudomonas sp.)*, *R. salmoninarum* by direct fluorescent antibody test (Rsal-DFAT), virus, and *T. bryosalmonae* observed in kidney sections.

Sample date	Bacteria	Rsal - DFAT	Virus	*T.byrosalmonae*
7 May	1 / 30 (3) AP	0 / 29	0 / 10 (3p)	29 / 30 (97)
23 May	11 / 30 (37) AP	0 / 30	0 / 10 (3p)	30 / 30 (100)

The *T. bryosalmonae* infection was judged to be at an early state in the 7 May sample fish. High numbers of the parasites were seen in both groups however kidney inflammation was markedly worse in the 23 May fish (Fig. 1 and 2). Swollen kidneys and spleens were also observed in the 23 May group. Overt anemia (pale gills) was not seen in any salmon on either collection date. The systemic nature of the infection was reflected in the occurrence of the parasite in multiple tissues (spleen, visceral adipose capillaries, liver sinuses, and kidney) including blood vessels within the gill (Fig. 3). One 7 May gill section contained two *Ichthyophthirius multifilii* trophozoites however there was little tissue response. Liver hepatocytes showed little glycogen or fat content in both sample groups possibly reflective of low feed rate. No gill Na-K-ATPase data is reported due to abnormal kinetic profiles. The ADP standard curve was normal which indicates that the majority of enzymes and co-factors were functional. The pH and magnesium conditions were also normal for the assay. We suspect that the recently purchased Sigma Chemical Adenosine TriPhosphate was faulty as this nucleotide is the substrate for the ouabain-sensitive gill Na-K-ATPase enzyme.

The advanced proliferative kidney disease, increased prevalence of systemic bacteria, and hemorrhaged sutures observed in the 23 May salmon suggests that the two release groups were not equivalent in health condition. The impact on immediate (1-3 days) post-release survival of these impairments on 23 May salmon is likely to be limited however longer term survival and swimming performance could be reduced. Past work on PKD effects on smolt performance have shown that severe kidney inflammation and anemia are associated with impaired swimming and saltwater adaptation (Foott et al. 2007 and 2008).

Figure A4-1. Prevalence of *T. byrosalmonae* intensity ratings for Chinook salmon sampled on 7 and 23 May. Intensity of *T. byrosalmonae* infection observed in kidney section rated as none (0), low (<10), moderate (11-30), and high (>30). Numbers over ratings are prevalence data. Majority of parasites observed in the 7 May kidneys were found in the sinuses indicating an early stage of infection.

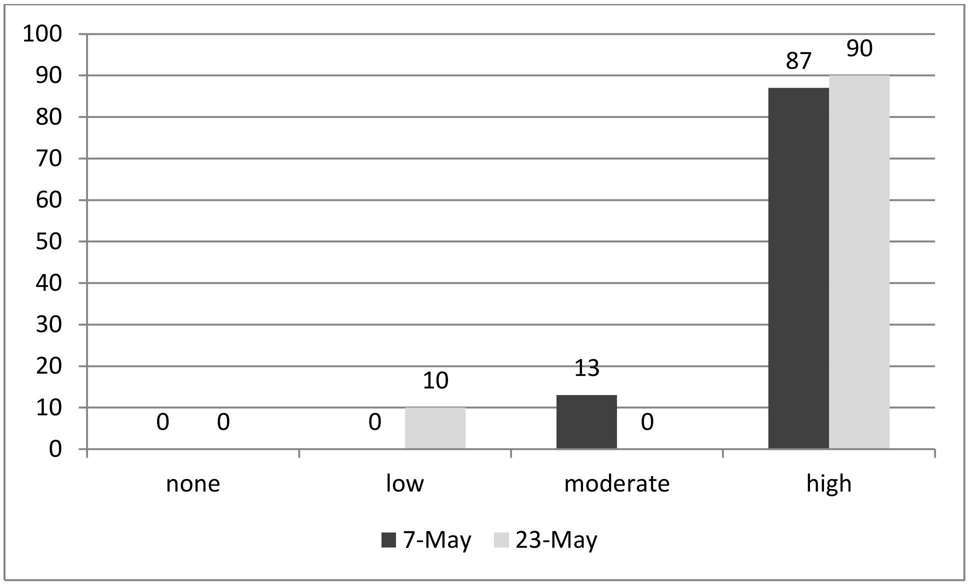


Figure A4-2. Prevalence of proliferative kidney disease ratings for Chinook salmon sampled on 7 and 23 May. Severity of kidney inflammation rated as normal, focal, multifocal, or diffuse. Numbers over ratings are prevalence data.

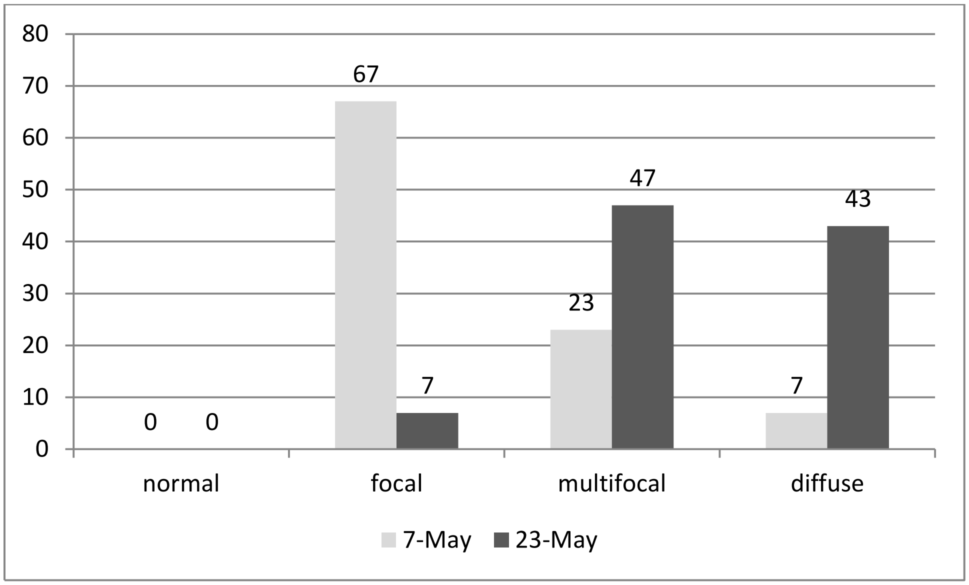


Figure A4-3. Micrograph of *T. byrosalmonae* (arrow) within gill blood vessel.

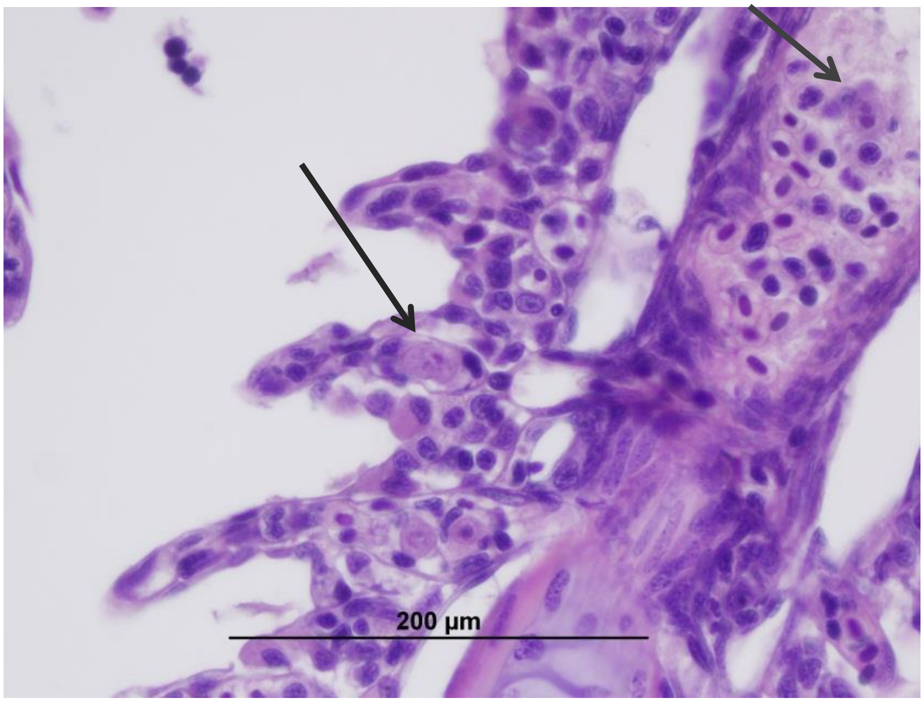
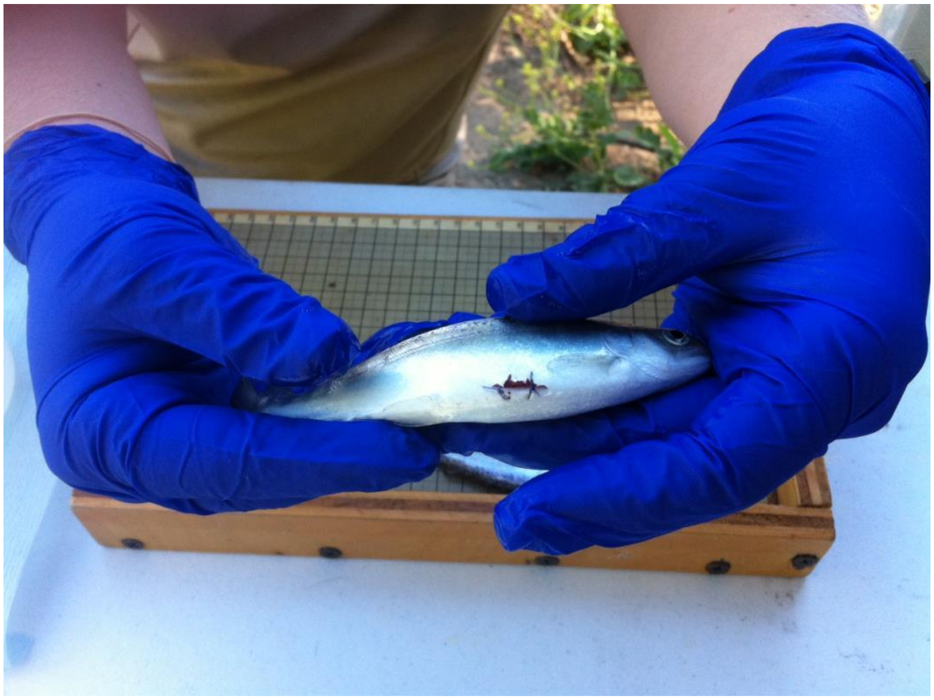


Figure A4-4. Suture condition rating 2 (exposed edge with hemorrhage) in 23 May salmon.



ACKNOWLEDGEMENTS

Ken Nichols, Anne Bolick, Kim True, and Julie Day with the FHC performed both field and laboratory work on this project and biologists with the USFWS Stockton FWO provided access to the live cages at Durham Ferry.

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USFWS and AFS-FHS (U.S. Fish and Wildlife Service and American Fisheries Society-Fish Health Section). 2010. Standard procedures for aquatic animal health inspections. *In* AFS-FHS. FHS blue book: suggested procedures for the detection and identification of certain finfish and shellfish pathogens, 2010 edition. AFS-FHS, Bethesda, Maryland.

Appendix 5. Survival Model Parameters

Table A5-1. Definitions of parameters used in the release-recapture survival model; full or reduced model, or both, is specified. Parameters used only in particular submodels are noted.

Parameter	Model	Definition
S_{A2}	Both	Probability of survival from Durham Ferry Downstream (DFD) to Banta Carbona (BCA)
S_{A3}	Both	Probability of survival from Banta Carbona (BCA) to Mossdale (MOS)
S_{A4}	Both	Probability of survival from Mossdale (MOS) to Lathrop (SJL) or Old River East (ORE)
S_{A5}	Both	Probability of survival from Lathrop (SJL) to Garwood Bridge (SJG)
S_{A6}	Both	Probability of survival from Garwood Bridge (SJG) to Navy Drive Bridge (SJNB)
S_{A7}	Both	Probability of survival from Navy Drive Bridge (SJNB) to MacDonald Island (MAC) or Turner Cut (TCE/TCW)
$S_{A7,G2}$	Both	Overall survival from Navy Drive Bridge (SJNB) to Chipps Island (MAE/MAW) (derived from Submodel I)
$S_{A8,G2}$	Both	Overall survival from MacDonald Island (MAC) to Chipps Island (MAE/MAW) (Submodel I)
S_{B1}	Full	Probability of survival from Old River East (ORE) to Old River South (ORS)
$S_{B2,G2}$	Reduced	Overall survival from Old River South (ORS) to Chipps Island (MAE/MAW) (derived from Submodel I)
$S_{F1,G2}$	Both	Overall survival from Turner Cut (TCE/TCW) to Chipps Island (MAE/MAW) (Submodel I)
$\phi_{A1,A0}$	Full	Joint probability of moving from Durham Ferry release site upstream toward DFU, and surviving to DFU
$\phi_{A1,A2}$	Both	Joint probability of moving from Durham Ferry release site downstream toward DFD, and surviving to DFD
$\phi_{A1,A3}$	Both	Joint probability of moving from Durham Ferry release site downstream toward BCA, and surviving to BCA; = $\phi_{A1,A2}\, S_{A2}$
$\phi_{A8,A9}$	Both	Joint probability of moving from MAC toward MFE/MFW, and surviving from MAC to MFE/MFW (Submodel II)
$\phi_{A8,B3}$	Full	Joint probability of moving from MAC toward OR4, and surviving from MAC to OR4 (Submodel II)
$\phi_{A8,C2}$	Full	Joint probability of moving from MAC toward MR4, and surviving from MAC to MR4 (Submodel II)
$\phi_{A8,GH}$	Full	Joint probability of moving from MAC directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW) without passing Highway 4 sites, and surviving JPE/JPW or FRE/FRW (Submodel II)
$\phi_{A8,G1}$	Reduced	Joint probability of moving from MAC toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{A8,GH}\psi_{G1(A)}$
$\phi_{A9,B3}$	Full	Joint probability of moving from MFE/MFW toward OR4, and surviving from MFE/MFW to OR4 (Submodel II)
$\phi_{A9,C2}$	Full	Joint probability of moving from MFE/MFW toward MR4, and surviving from MFE/MFW to MR4 (Submodel II)
$\phi_{A9,GH}$	Full	Joint probability of moving from MFE/MFW directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW) without passing Highway 4 sites, and surviving to JPE/JPW or FRE/FRW (Submodel II)
$\phi_{A9,G1}$	Reduced	Joint probability of moving from MFE/MFW toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{A9,GH}\psi_{G1(A)}$
$\phi_{B1,B2}$	Reduced	Joint probability of moving from ORE toward ORS, and surviving from ORE to ORS; = $S_{B1}\psi_{B2}$
$\phi_{B2,B3}$	Full	Joint probability of moving from ORS toward OR4, and surviving from ORS to OR4
$\phi_{B2,C2}$	Full	Joint probability of moving from ORS toward MR4, and surviving from ORS to MR4
$\phi_{B2,D1}$	Full	Joint probability of moving from ORS toward RGU, and surviving from ORS to RGU
$\phi_{B2,E1}$	Full	Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP
$\phi_{B3,D1}$	Full	Joint probability of moving from OR4 toward RGU and surviving from OR4 to RGU conditional on coming from lower San Joaquin River (Submodel II)

Table A5-1. (Continued)

Parameter	Model	Definition
$\phi_{B3,E1}$	Full	Joint probability of moving from OR4 toward CVP, and surviving from OR4 to CVP, conditional on coming from lower San Joaquin River (Submodel II)
$\phi_{B3,GH(A)}$	Full	Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from OR4 to JPE/JPW or FRE/FRW (Submodel II [route A])
$\phi_{B3,GH(B)}$	Full	Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from OR4 to JPE/JPW or FRE/FRW (Submodel I [route B])
$\phi_{C1,B3}$	Full	Joint probability of moving from MRH toward OR4, and surviving from MRH to OR4
$\phi_{C1,C2}$	Full	Joint probability of moving from MRH toward MR4, and surviving from MRH to MR4
$\phi_{C1,D1}$	Full	Joint probability of moving from MRH toward RGU, and surviving from MRH to RGU
$\phi_{C1,E1}$	Full	Joint probability of moving from MRH toward CVP, and surviving from MRH to CVP
$\phi_{C2,D1}$	Full	Joint probability of moving from MR4 toward RGU and surviving from MR4 to RGU conditional on coming from lower San Joaquin River (Submodel II)
$\phi_{C2,E1}$	Full	Joint probability of moving from MR4 toward CVP, and surviving from MR4 to CVP, conditional on coming from lower San Joaquin River (Submodel II)
$\phi_{C2,GH(A)}$	Full	Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from MR4 to JPE/JPW or FRE/FRW (Submodel II [route A])
$\phi_{C2,GH(B)}$	Full	Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from MR4 to JPE/JPW or FRE/FRW (Submodel I [route B])
$\phi_{D1,D2}$	Full	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD (equated between submodels I and II)
$\phi_{D2,G2}$	Full	Joint probability of moving from RGD toward Chipps Island (MAE/MAW) and surviving from RGU to MAE/MAW (equated between submodels I and II)
$\phi_{E1,E2}$	Full	Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank (equated between submodels I and II)
$\phi_{E2,G2}$	Full	Joint probability of moving from CVPtank toward Chipps Island (MAE/MAW) and surviving from CVPtank to MAE/MAW (equated between submodels I and II)
$\phi_{F1,B3}$	Full	Joint probability of moving from TCE/TCW toward OR4, and surviving from TCE/TCW to OR4 (Submodel II)
$\phi_{F1,C2}$	Full	Joint probability of moving from TCE/TCW toward MR4, and surviving from TCE/TCW to MR4 (Submodel II)
$\phi_{F1,GH}$	Full	Joint probability of moving from TCE/TCW directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW) without passing Highway 4 sites, and surviving to JPE/JPW or FRE/FRW (Submodel II)
$\phi_{F1,G1}$	Reduced	Joint probability of moving from TCE/TCW toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{F1,GH}\psi_{G1(A)}$
$\phi_{G1,G2(A)}$	Both	Joint probability of moving from JPE/JPW toward Chipps Island (MAE/MAW), and surviving to MAE/MAW (Submodel II [route A])
$\phi_{G1,G2(B)}$	Full	Joint probability of moving from JPE/JPW toward Chipps Island (MAE/MAW), and surviving to MAE/MAW (Submodel I [route B])
ψ_{A1}	Both	Probability of remaining in the San Joaquin River at the head of Old River; = 1 - ψ_{B1}
ψ_{A2}	Both	Probability of remaining in the San Joaquin River at the junction with Turner Cut; = 1 - ψ_{F2}
ψ_{B1}	Both	Probability of entering Old River at the head of Old River; = 1 - ψ_{A1}
ψ_{B2}	Full	Probability of remaining in Old River at the head of Middle River; = 1 - ψ_{C2}
ψ_{C2}	Full	Probability of entering Middle River at the head of Middle River; = 1 - ψ_{B2}
ψ_{F2}	Both	Probability of entering Turner Cut at the junction with the San Joaquin River; = 1 - ψ_{A2}
$\psi_{G1(A)}$	Full	Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction (Submodel II [route A]); = 1 - $\psi_{H1(A)}$
$\psi_{G1(B)}$	Full	Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction (Submodel I [route B]); = 1 - $\psi_{H1(B)}$

Table A5-1. (Continued)

Parameter	Model	Definition
$\psi_{H1(A)}$	Full	Probability of entering False River at the Jersey Point/False River junction (Submodel II [route A]); = 1 - $\psi_{G1(A)}$
$\psi_{H1(B)}$	Full	Probability of entering False River at the Jersey Point/False River junction (Submodel I [route B]); = 1 - $\psi_{G1(B)}$
P_{A0a}	Full	Conditional probability of detection at DFU1
P_{A0b}	Full	Conditional probability of detection at DFU2
P_{A2a}	Both	Conditional probability of detection at DFD1
P_{A2b}	Both	Conditional probability of detection at DFD2
P_{A2}	Both	Conditional probability of detection at DFD (either DFD1 or DFD2)
P_{A3}	Both	Conditional probability of detection at BCA
P_{A4}	Both	Conditional probability of detection at MOS
P_{A5}	Both	Conditional probability of detection at SJL
P_{A6}	Both	Conditional probability of detection at SJG
P_{A7}	Both	Conditional probability of detection at SJNB
P_{A8a}	Both	Conditional probability of detection at MACU
P_{A8b}	Both	Conditional probability of detection at MACD
P_{A8}	Both	Conditional probability of detection at MAC (either MACU or MACD)
P_{A9a}	Both	Conditional probability of detection at MFE
P_{A9b}	Both	Conditional probability of detection at MFW
P_{A9}	Both	Conditional probability of detection at MFE or MFW
P_{B1}	Both	Conditional probability of detection at ORE
P_{B2a}	Both	Conditional probability of detection at ORSU
P_{B2b}	Both	Conditional probability of detection at ORSD
P_{B2}	Both	Conditional probability of detection at ORS (either ORSU or ORSD)
P_{B3a}	Full	Conditional probability of detection at OR4U
P_{B3b}	Full	Conditional probability of detection at OR4D
P_{C1}	Full	Conditional probability of detection at MRH
P_{C2a}	Full	Conditional probability of detection at MR4U
P_{C2b}	Full	Conditional probability of detection at MR4D
P_{D1}	Full	Conditional probability of detection at RGU (either RGU1 or RGU2)
P_{D2a}	Full	Conditional probability of detection at RGD1
P_{D2b}	Full	Conditional probability of detection at RGD2
P_{E1}	Full	Conditional probability of detection at CVP
P_{E2}	Full	Conditional probability of detection at CVPtank
P_{F1a}	Both	Conditional probability of detection at TCE
P_{F1b}	Both	Conditional probability of detection at TCW
P_{F1}	Both	Conditional probability of detection at TCE/TCW
P_{G1a}	Both	Conditional probability of detection at JPE
P_{G1b}	Both	Conditional probability of detection at JPW

Table A5-1. (Continued)

Parameter	Model	Definition
P_{G1}	Both	Conditional probability of detection at JPE/JPW
P_{G2a}	Both	Conditional probability of detection at MAE
P_{G2b}	Both	Conditional probability of detection at MAW
P_{G2}	Both	Conditional probability of detection at MAE/MAW
P_{H1a}	Full	Conditional probability of detection at FRW
P_{H1b}	Full	Conditional probability of detection at FRE

Table A5-2. Parameter estimates (standard errors in parentheses) from reduced survival model for tagged juvenile Chinook Salmon released in 2012, 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.

	Release Occasion		
Parameter	1	2	Population Estimate
S_{A2}	0.90 (0.06)	0.63 (0.04)	0.79 (0.04)
S_{A3}	0.78 (0.04)	0.59 (0.03)	0.65 (0.03)
S_{A4}	0.98 (0.01)	0.89 (0.02)	0.95 (0.01)
S_{A5}	0.81 (0.02)	0.48 (0.04)	0.69 (0.02)
S_{A6}	0.85 (0.03)	0.73 (0.08)	0.82 (0.03)
S_{A7}	0.49 (0.04)	0.23 (0.06)	0.44 (0.03)
$S_{A7,G2}$	0.07 (0.02)	0	0.06 (0.01)
$S_{A8,G2}$	0.16 (0.04)	0	0.14 (0.04)
$S_{B2,G2}$	0.17 (0.15)	0	0.13 (0.12)
$S_{F1,G2}$	0	0	0
$\phi_{A1,A2}$	0.89 (0.05)	1.00 (0.06)	0.97 (0.04)
$\phi_{A1,A3}$	0.80 (0.04)	0.63 (0.03)	0.76 (0.02)
$\phi_{A8,A9}$	0.44 (0.05)	0.59 (0.16)	0.45 (0.05)
$\phi_{A8,G1}$	0.08 (0.03)	0	0.07 (0.03)
$\phi_{A9,G1}$	0.49 (0.09)	0.33 (0.19)	0.46 (0.08)
$\phi_{B1,B2}$	1	0.67 (0.27)	0.89 (0.10)
$\phi_{F1,G1}$	0	0	0
$\phi_{G1,G2(A)}$	0.54 (0.10)	0	0.52 (0.01)
ψ_{A1}	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
ψ_{A2}	0.89 (0.03)	0.84 (0.11)	0.89 (0.03)
ψ_{B1}	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.11 (0.03)	0.16 (0.11)	0.11 (0.03)
P_{A2a}	[pooled]	[pooled]	[pooled]
P_{A2b}	[pooled]	[pooled]	[pooled]
P_{A2}	0.23 (0.02)	0.33 (0.03)	0.27 (0.02)
P_{A3}	0.31 (0.03)	0.80 (0.03)	0.49 (0.02)
P_{A4}	1.00 (< 0.01)	1	1.00 (< 0.01)
P_{A5}	1	1	1
P_{A6}	1	1	1
P_{A7}	0.94 (0.02)	0.92 (0.08)	0.94 (0.02)
P_{A8a}	[pooled]	0.88 (0.12)	0.94 (0.02)
P_{A8b}	[pooled]	0.78 (0.14)	0.90 (0.03)
P_{A8}	1	0.97 (0.03)	0.99 (< 0.01)
P_{A9a}	1	1	1
P_{A9b}	1	1	1
P_{A9}	1	1	1
P_{B1}	1	1	1

Table A5-2. (Continued)

Parameter	Release Occasion 1	 2	Population Estimate
P_{B2a}	1	[pooled]	1
P_{B2b}	0.83 (0.15)	[pooled]	1.00 (< 0.01)
P_{B2}	1	1	1
P_{F1a}	0.88 (0.12)	1	0.90 (0.09)
P_{F1b}	0.78 (0.14)	1	0.82 (0.12)
P_{F1}	0.97 (0.03)	1	0.98 (0.02)
P_{G1a}	[pooled]	1	0.96 (0.04)
P_{G1b}	[pooled]	1	0.92 (0.05)
P_{G1}	0.93 (0.07)	1	1.00 (< 0.01)
P_{G2a}	1		1
P_{G2b}	1		1
P_{G2}	1		1

Table A5-3. Parameter estimates (standard errors in parentheses) from reduced 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.

	Release Occasion		
Parameter	1	2	Population Estimate
S_{A2}	0.87 (0.06)	0.62 (0.04)	0.77 (0.04)
S_{A3}	0.77 (0.04)	0.59 (0.03)	0.65 (0.02)
S_{A4}	0.98 (0.01)	0.90 (0.02)	0.95 (0.01)
S_{A5}	0.81 (0.02)	0.49 (0.04)	0.70 (0.02)
S_{A6}	0.86 (0.03)	0.73 (0.07)	0.82 (0.03)
S_{A7}	0.50 (0.04)	0.26 (0.06)	0.44 (0.03)
$S_{A7,G2}$	0.07 (0.02)	0	0.06 (0.01)
$S_{A8,G2}$	0.16 (0.04)	0	0.14 (0.03)
$S_{B2,G2}$	0.17 (0.15)	0	0.11 (0.11)
$S_{F1,G2}$	0	0	0
$\phi_{A1,A2}$	0.93 (0.05)	1.03 (0.06)	1.00 (0.04)
$\phi_{A1,A3}$	0.81 (0.04)	0.64 (0.03)	0.77 (0.03)
$\phi_{A8,A9}$	0.43 (0.05)	0.49 (0.14)	0.44 (0.05)
$\phi_{A8,G1}$	0.08 (0.03)	0	0.07 (0.03)
$\phi_{A9,G1}$	0.49 (0.09)	0.33 (0.19)	0.46 (0.08)
$\phi_{B1,B2}$	1	1	1
$\phi_{F1,G1}$	0	0	0
$\phi_{G1,G2(A)}$	0.54 (0.10)	0	0.52 (0.10)
ψ_{A1}	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
ψ_{A2}	0.88 (0.03)	0.86 (0.09)	0.88 (0.03)
ψ_{B1}	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.12 (0.03)	0.14 (0.09)	0.12 (0.03)
P_{A2a}	[pooled]	[pooled]	[pooled]
P_{A2b}	[pooled]	[pooled]	[pooled]
P_{A2}	0.23 (0.02)	0.34 (0.03)	0.28 (0.02)
P_{A3}	0.31 (0.03)	0.80 (0.03)	0.49 (0.02)
P_{A4}	1.00 (< 0.01)	1	1.00 (< 0.01)
P_{A5}	1	1	1
P_{A6}	1	1	1
P_{A7}	0.94 (0.02)	0.93 (0.07)	0.94 (0.02)
P_{A8a}	[pooled]	0.87 (0.12)	[pooled]
P_{A8b}	[pooled]	0.64 (0.15)	[pooled]
P_{A8}	1	0.95 (0.05)	1
P_{A9a}	1	1	1
P_{A9b}	1	1	1
P_{A9}	1	1	1
P_{B1}	1	1	1

Table A5-3. (Continued)

Parameter	Release Occasion		Population Estimate
	1	2	
P_{B2a}	1	[pooled]	1
P_{B2b}	0.83 (0.15)	[pooled]	0.56 (0.17)
P_{B2}	1	1	1
P_{F1a}	0.86 (0.13)	1	0.89 (0.10)
P_{F1b}	0.60 (0.15)	1	0.67 (0.14)
P_{F1}	0.94 (0.06)	1	0.96 (0.04)
P_{G1a}	[pooled]	1	0.96 (0.04)
P_{G1b}	[pooled]	1	0.92 (0.05)
P_{G1}	0.93 (0.07)	1	1.00 (< 0.01)
P_{G2a}	1		1
P_{G2b}	1		1
P_{G2}	1		1

Appendix B. Errata from 2011 VAMP Report

In Table H-2 (page 283) of the 2011 VAMP report (SJRGA 2013), the definition for parameter $\phi_{A8,G2}$ should read “Overall survival from STN to Chipps Island (CHPE/CHPW).”