

1 **1.D.2.3 Attachments to Comments of Natural**  
2 **Resources Defense Council and The Bay**  
3 **Institute**

This page left blank intentionally.

# 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 (SJRG 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](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 (SJRG 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 (SJRG 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 (SJRG 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 milliliters (ml) of tricaine 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.



Photo credits: Pat Brandes

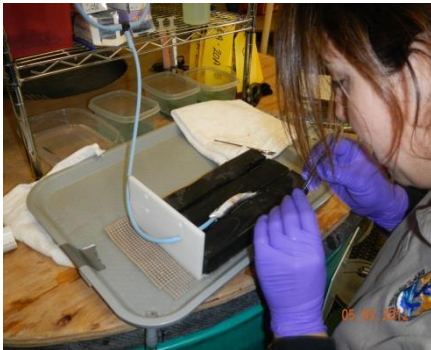


Photo credit: Pat Brandes



Photo credit: Jake Osborne



Photo credit: Pat Brandes



Photo credit: Jake Osborne

## 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).





Photo credits: Jake Osborne



Photo credits: Jake Osborne



Photo credit: Pat Brandes

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  $\text{Na}^+ - \text{K}^+$ -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 (SJGRA 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 (SJRG 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 (SJRG 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/](http://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 (SJRG 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 ( $\psi_{hi}$ ), 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  $i$ .

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

$\phi_{kj,hi}$  = transition probability: joint probability of 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;  $\psi_{G1}$  is the probability of moving downstream toward Jersey Point from the junction; and  $\psi_{H1} = 1 - \psi_{G1}$  is the probability of exiting (or re-exiting) the San Joaquin River to False River from the junction (Figure 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  $\phi_{k,j,hi}$  parameters from the full Submodel I:

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

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 MacDonal 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 MacDonal 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 ( $\phi_{hi,GH}$ ) from the probability of turning toward Jersey Point ( $\psi_{G1}$ ); 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 ( $S_{B1}$ ) from the probability of remaining in Old River at the head of Middle River ( $\psi_{B2}$ ). 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 (Mosssdale) to Chipps Island was estimated as:

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

Survival was also estimated from Mosssdale 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

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

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

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,  $\phi_{A1A4}$ , 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:

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

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

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

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

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

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

In Submodel II, this detection history is parameterized

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

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

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:

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

where  $1 - P_{A2} = (1 - P_{A2a})(1 - P_{A2b})$  and  $P_{G2} = 1 - (1 - P_{G2a})(1 - P_{G2b})$ .

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:

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

where

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

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:

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

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

## 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 ( $\alpha=0.05$ ; 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  $\theta$ , 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  $\theta_R$  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  $\alpha=0.10$  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 ( $S^{(1/\text{km})}$ ) 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 ( $t_i$ ) was estimated for tag  $i$  by a linear interpolation from the observed travel time from the SJNB or SJG acoustic receivers upstream to detection on either the MAC or TCE/TCW receivers just downstream of the junction. Linear interpolation is based on the first-order assumption of constant movement during the transition from the previous site. In a tidal area, it is likely that movement was not actually constant during the transition, but in the absence of more precise spatiotemporal tag detection data, the linear interpolation may nevertheless provide the best estimate of arrival time.



The TRN gaging station typically recorded flow, velocity, and river stage measurements every 15 minutes. 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  $t_{1(i)} \leq t_i \leq t_{2(i)}$ . 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.,  $t_{2(i)} - t_{1(i)} \leq 60$  minutes), the change in conditions between the two time points was used to represent the tidal stage (Perry 2010):

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

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

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

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

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

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

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

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

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

All continuous covariates were standardized, i.e.,

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

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

The form of the generalized linear model was

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

where  $\tilde{x}_{i1}, \tilde{x}_{i2}, \dots, \tilde{x}_{ip}$  are the observed values of standardized covariates for tag  $i$  (covariates 1, 2, ...,  $p$ , see below),  $\psi_{iA}$  is the predicted probability that the fish with tag  $i$  selected route A (San Joaquin River route), and  $\psi_{iF} = 1 - \psi_{iA}$  (F = Turner Cut route). Route choice for tag  $i$  was determined based on detection of tag  $i$  at either site A8 (route A) or site F1 (route F). Estimated detection probabilities for the 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  $\chi^2$  test (McCullagh and Nelder 1989). Covariates found to be significant alone ( $\alpha=0.05$ ) 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 ( $Q_{SJG}$ ) 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 *Aeromonas – Pseudomonas* sp. infection however there was little correlation between the two findings. As in the past, *Tetracapsuloides bryosalmonae* infection was highly prevalent ( $\geq 97\%$ ) 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 (Table 10). 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 ( $\chi^2 = 0.0279$ ,  $df=3$ ,  $P=0.9988$ ). 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 ( $\chi^2 = 16.8759$ , 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 (Figure 10). 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 ( $P \geq 0.5835$ ).

## 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 ( $\psi_A = \psi_{A1}$ ) 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 ( $S_A$ ) 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 is 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 ( $S_{A(MD)}$ ) 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 ( $S_{A(SD)}$ ) 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 ( $S_{A(SD)}$ ), 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  $\alpha=0.10$ ) 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 ( $\alpha=0.05$ ) 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 ( $S_{\text{Total}}$ ) 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 (Mosssdale, 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 Mosssdale and Mosssdale 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 (SJRG 2009) after a significant die-off of acoustic tags near this location in 2007 – a low flow year (SJRG 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 SJRG 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 byrzoan 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.

## List of References

- Adams, N.S., D.W. Rondorf, S.D. Evans, and J.E. Kelly (1998). Effects of surgically and gastrically implanted radio tags on growth and feeding behavior of juvenile Chinook Salmon: Transactions of the American Fisheries Society, v.127, p. 128-136.
- Brandes, P.L. and J.S. McLain (2001). Juvenile Chinook Salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Contributions to the Biology of the Central Valley Salmonids, Fish Bulletin 179: Volume 2.
- Buchanan, R. (2013). OCAP 2011 Steelhead Tagging Study: Statistical Methods and Results. Prepared for Bureau of Reclamation, Bay Delta Office, Sacramento CA. August 9, 2013. 110 p.
- Burnham, K. P., and D. R. Anderson (2002). Model selection and multimodel inference: A practical information-theoretic approach. 2<sup>nd</sup> edition. Springer. New York, NY. 488 pp.
- California Department of Water Resources (2015). Final: An Evaluation of Juvenile Salmonid Routing and Barrier Effectiveness, Predation, and Predatory Fishes at the Head of Old River, 2009-2012. Prepared by AECOM, ICF International and Turnpenny Horsfield Associates.  
[http://baydeltaoffice.water.ca.gov/sdb/tbp/web\\_pg/tempbar/horbereport.cfm](http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbar/horbereport.cfm)
- Cavallo, B., P. Gaskill, and J. Melgo (2013). Investigating the influence of tides, inflows, and exports on sub-daily flow in the Sacramento-San Joaquin Delta. Cramer Fish Sciences Report. 64 pp. Available online at: [http://www.fishsciences.net/reports/2013/Cavallo\\_et\\_al\\_Delta\\_Flow\\_Report.pdf](http://www.fishsciences.net/reports/2013/Cavallo_et_al_Delta_Flow_Report.pdf).
- Cormack, R.M. (1964) Estimates of survival from the sighting of marked animals. Biometrika 51, 429-438.
- Ferguson, HW. (1981). The effects of water temperature on the development of Proliferative Kidney Disease in rainbow trout, *Salmo gairdneri* Richardson. Journal of Fish Disease 4: 175-177
- Foott JS, R Stone and K Nichols (2007). Proliferative Kidney Disease (*Tetracapsuloides bryosalmonae*) in Merced River Hatchery juvenile Chinook Salmon: mortality and performance impairment in 2005 smolts. California Fish and Game 93: 57-76.
- Jolly, G.M. (1965) Explicit estimates from capture-recapture data with both death and immigration - Stochastic model. Biometrika 52: 225-247.
- Lady, J. M., and J. R. Skalski (2009). USER 4: User-Specified Estimation Routine. School of Aquatic and Fishery Sciences. University of Washington. Available from <http://www.cbr.washington.edu/paramest/user/>.
- Li, T., and J. J. Anderson (2009). The Vitality model: A Way to understand population survival and demographic heterogeneity. Theoretical Population Biology 76: 118-131.

Liedtke, T. (2012). 2012 South Delta Study Tagger Training and QA/QC Summary. Prepared by Theresa Liedtke, U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory 5501A Cook-Underwood Road, Cook, WA 98605, for J. Israel, USBR Bay-Delta Office, 801 I Street, Suite 140, Sacramento, CA 95814. 97pgs.

Martinelli, T.L., H.C. Hansel, and R.S. Shively (1998). Growth and physiological responses to surgical and gastric radio tag implantation techniques in subyearling Chinook Salmon: *Hydrobiologia*, v. 371/372, p. 79-87.

McCullagh, P., and J. Nelder (1989). *Generalized linear models*. 2<sup>nd</sup> edition. Chapman and Hall, London.

Nichols, K., A. Bolick and J.Scott Foott (2012). FY2012 Technical Report: Merced River juvenile Chinook Salmon health and physiology assessment, March-May 2012. December 2012. US Fish and Wildlife Service, California-Nevada Fish Health Center, 24411 Coleman Hatchery Road, Anderson CA 96007.

Perry, R. W. (2010). *Survival and Migration Dynamics of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin River Delta*. University of Washington, Ph.D. dissertation. 2010. 223 p.

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

San Joaquin River Group Authority (2007). 2006 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at [www.sjrg.org](http://www.sjrg.org).

San Joaquin River Group Authority (2008). 2007 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at [www.sjrg.org](http://www.sjrg.org).

San Joaquin River Group Authority (2010). 2009 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at [www.sjrg.org](http://www.sjrg.org).

San Joaquin River Group Authority (2011). 2010 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at [www.sjrg.org](http://www.sjrg.org).

San Joaquin River Group Authority (2013). 2011 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at [www.sjrg.org](http://www.sjrg.org).

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

Seber, G.A. F. (1965) A note on the multiple recapture census. *Biometrika* 52, 249-259.

Skalski, J. R., R. Townsend, J. Lady, A. E. Giorgi, J. R. Stevenson, and R. D. McDonald ( 2002). Estimating route-specific passage and survival probabilities at a hydroelectric project from smolt radiotelemetry studies. *Canadian Journal of Fisheries and Aquatic Sciences* 59: 1385 - 1393

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

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

US Bureau of Reclamation (2012). San Joaquin River Flow Modification Study. Finding of No Significant Impact. Division of Planning, Mid Pacific Region, Sacramento CA. 3 p.

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

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

## Acknowledgements:

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

## Figures

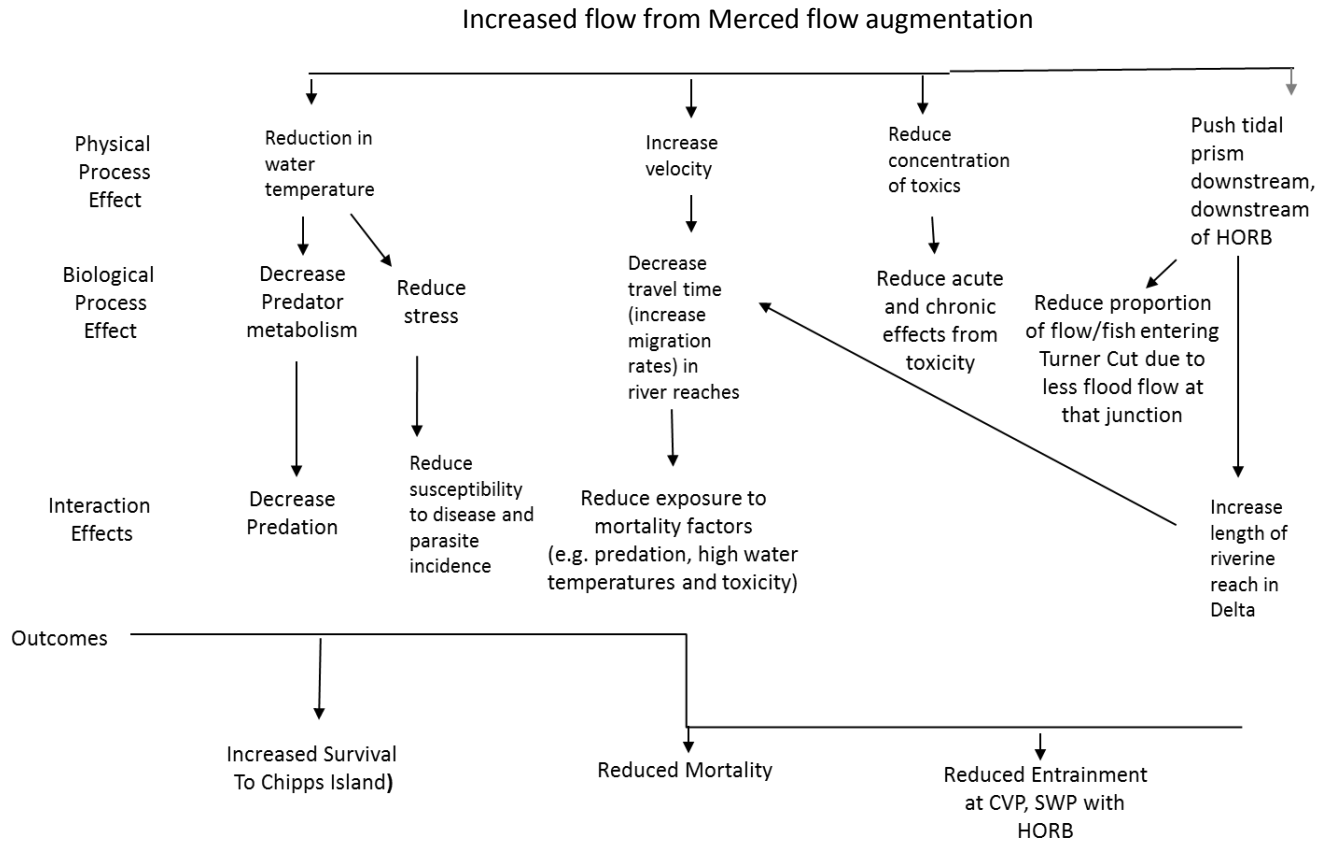


Figure 1: Conceptual model of mechanisms for increased survival from increasing Vernalis Flow with the head of Old River barrier in place.



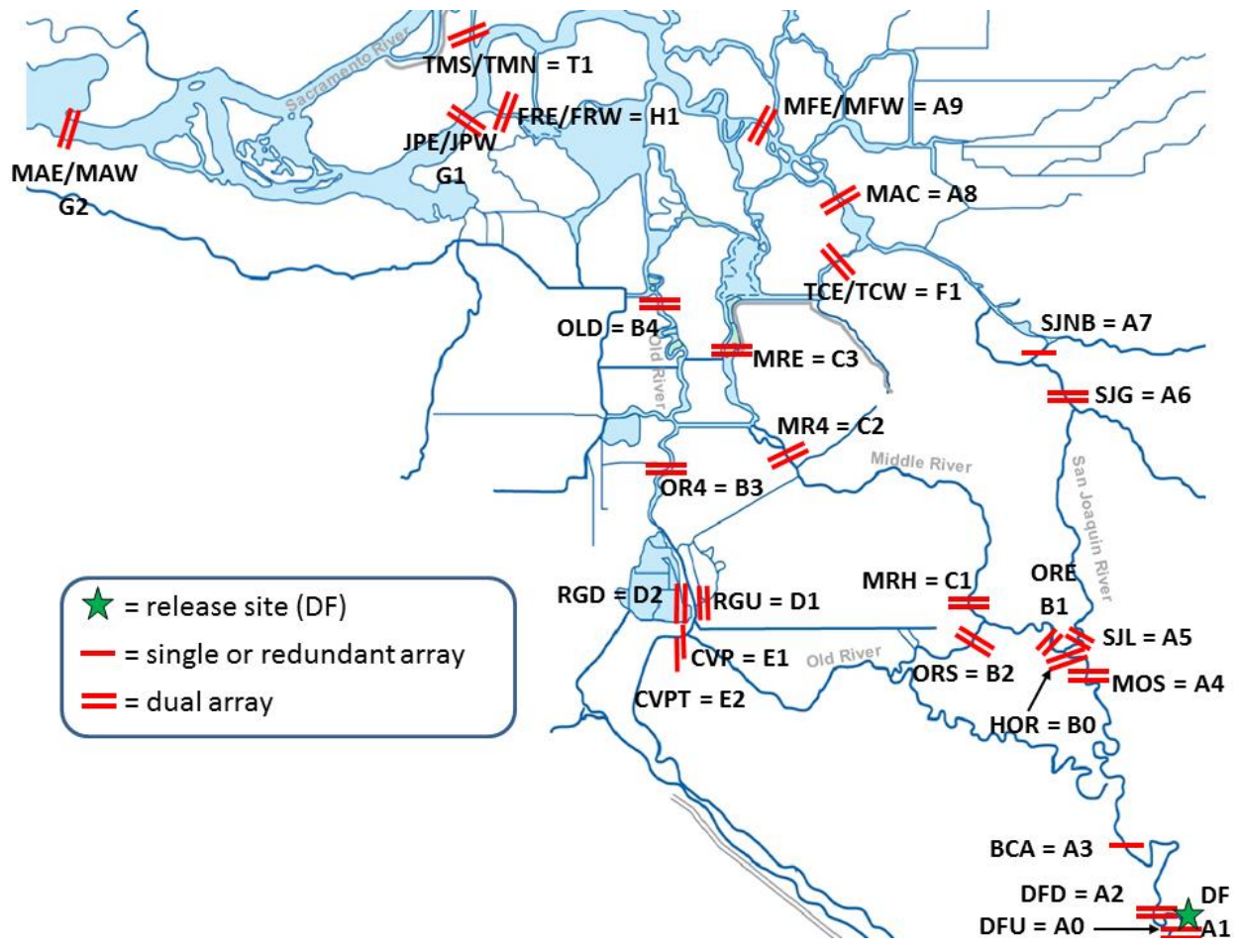


Figure 2. Locations of acoustic receivers and release site used in the 2012 Chinook Salmon study, with site code names (3- or 4-letter code) and model code (letter and number string). Site A1 is the release site at Durham Ferry. Sites B0, B4, C3, and T1 were excluded from the survival model.

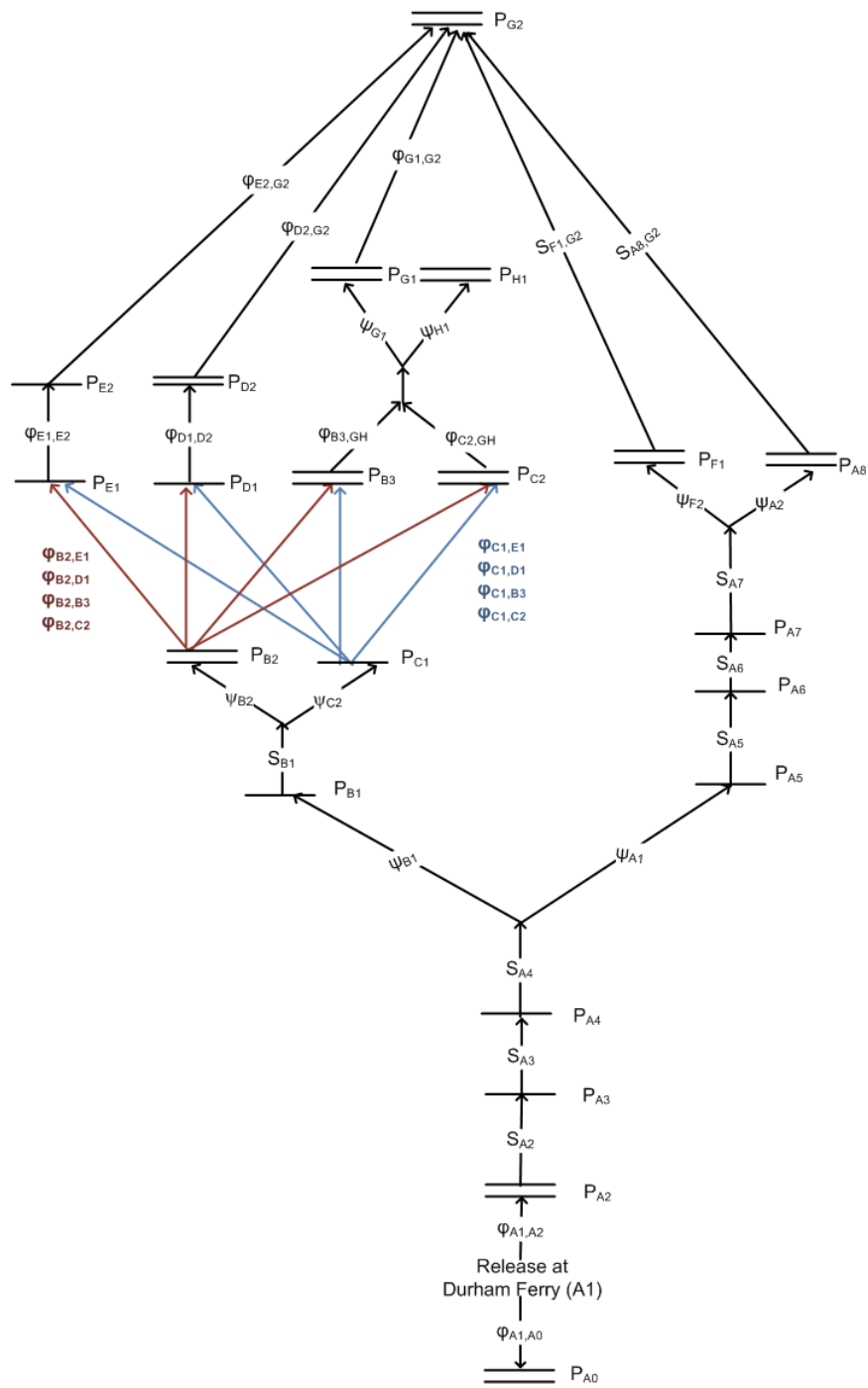


Figure 3. Schematic of 2012 mark-recapture Submodel I. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2. Migration pathways to sites B3 (OR4), C2 (MR4),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

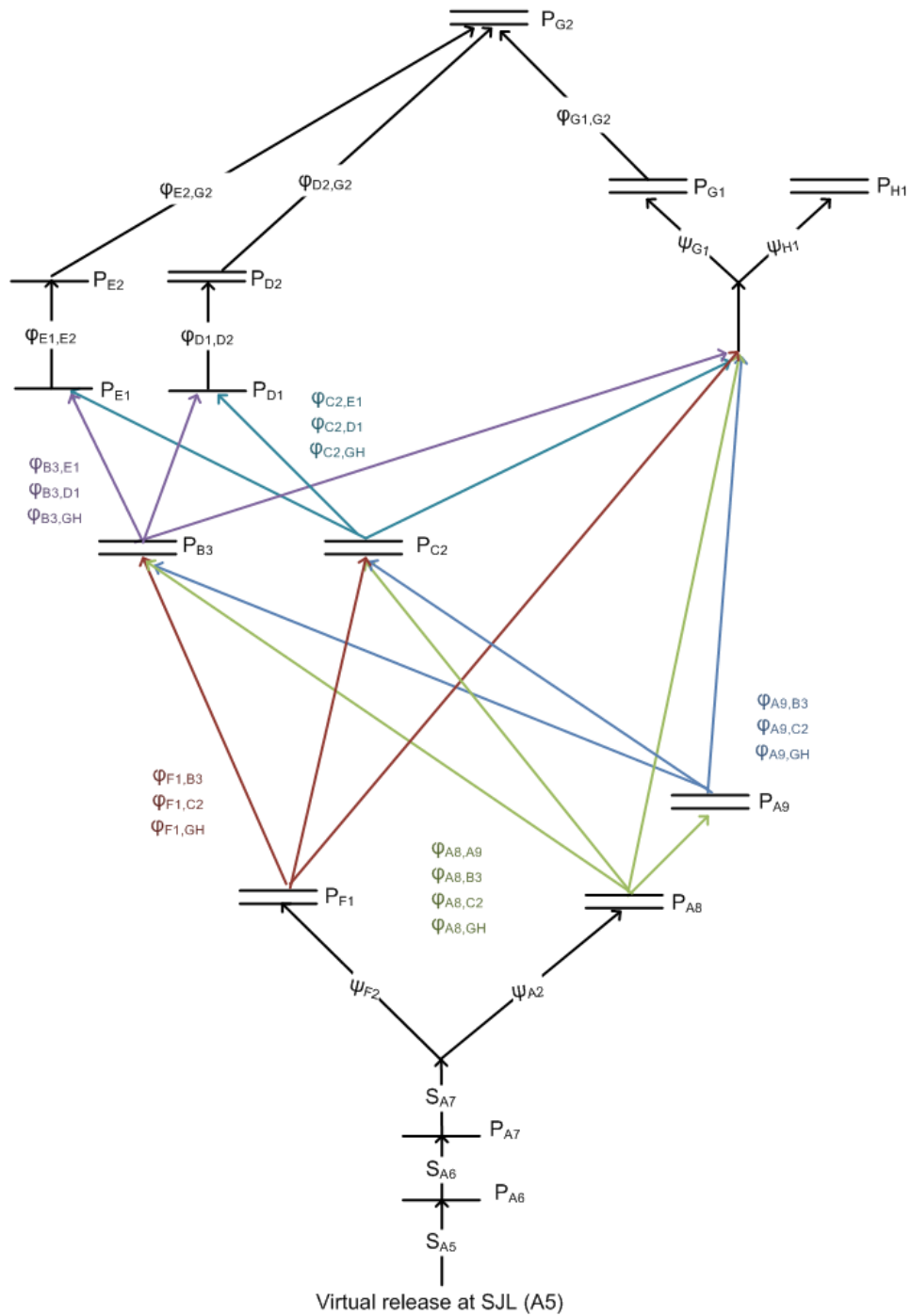


Figure 4. Schematic of 2012 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2. Migration pathways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

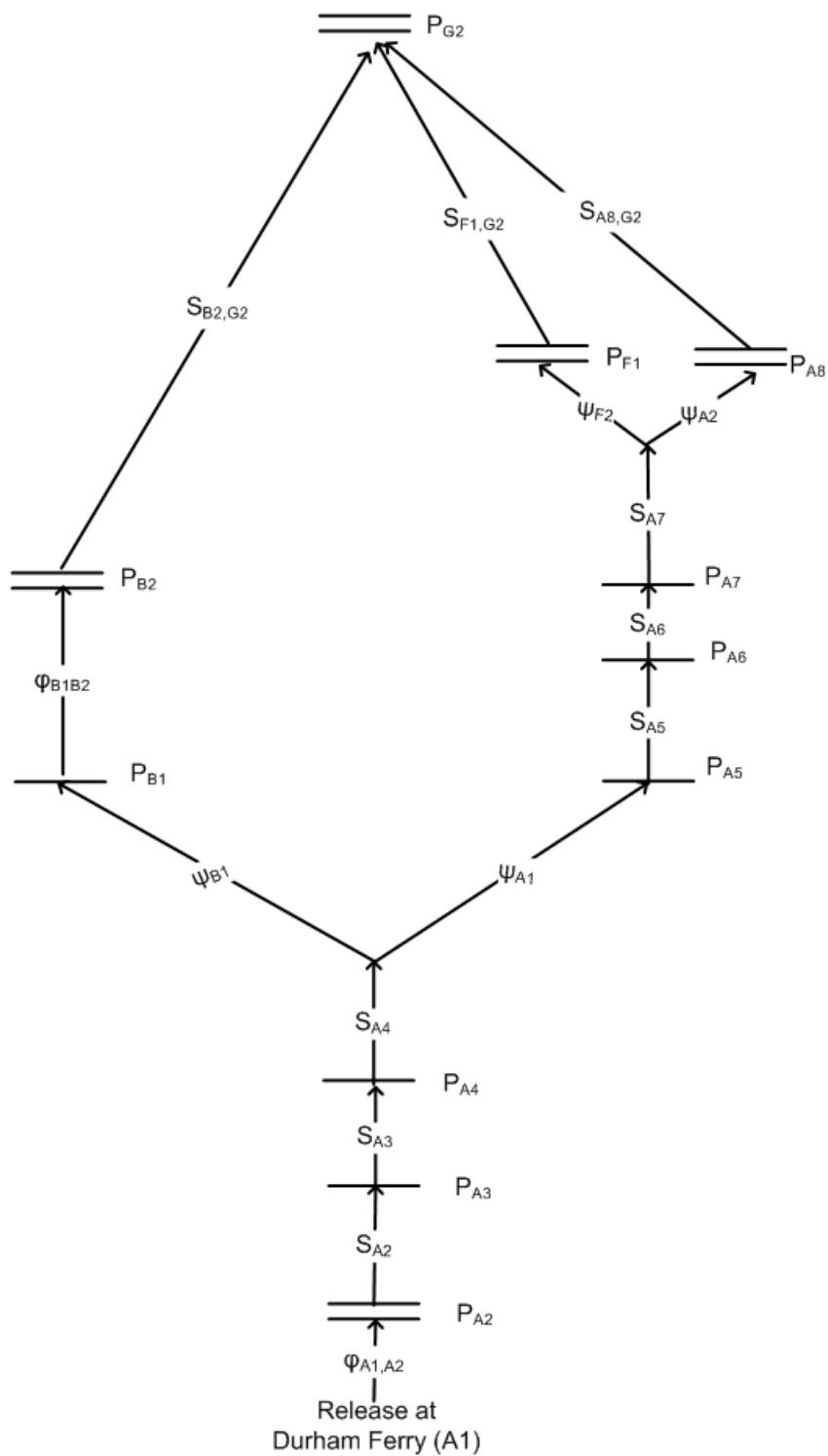


Figure 5. Schematic of reduced 2012 mark-recapture Submodel I with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2.

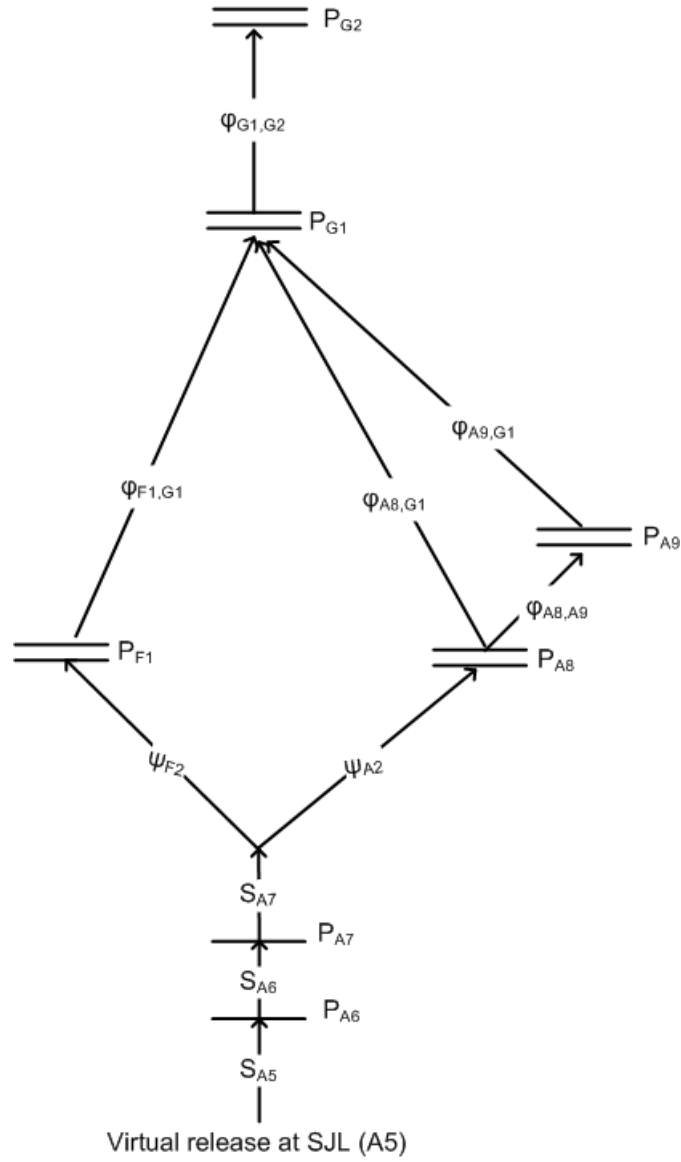


Figure 6. Schematic of reduced 2012 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2.

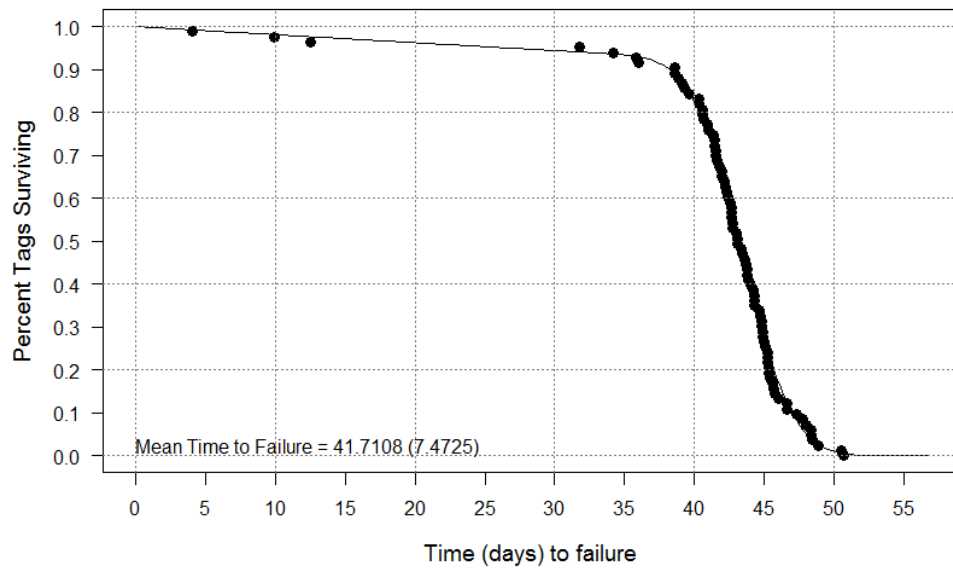


Figure 7. Observed tag failure times from the 2012 tag-life studies, pooled over the two studies, and fitted four-parameter vitality curve.

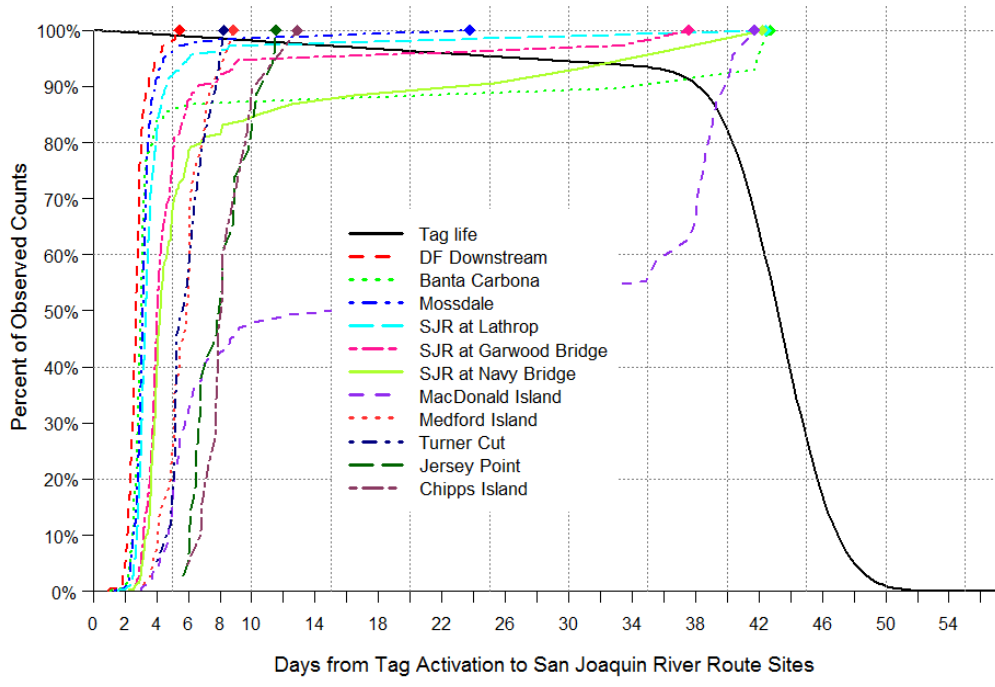


Figure 8. Four-parameter vitality survival curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the San Joaquin River route to Chipps Island in 2012, including detections that may have come from predators.

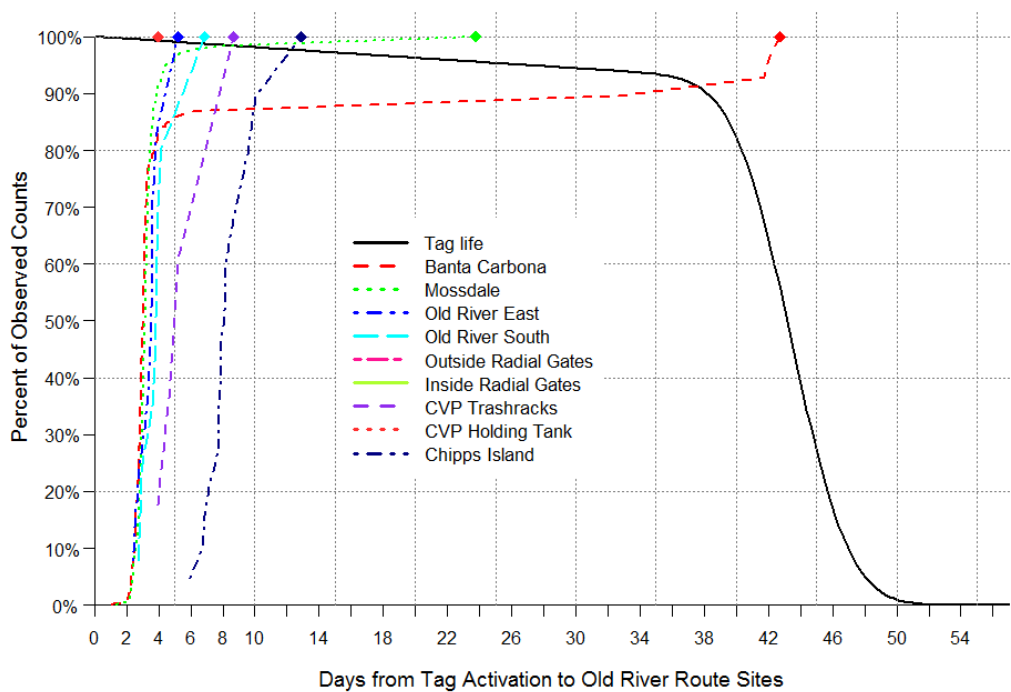


Figure 9. Four-parameter vitality survival curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the Old River route to Chipps Island in 2012, including detections that may have come from predators.



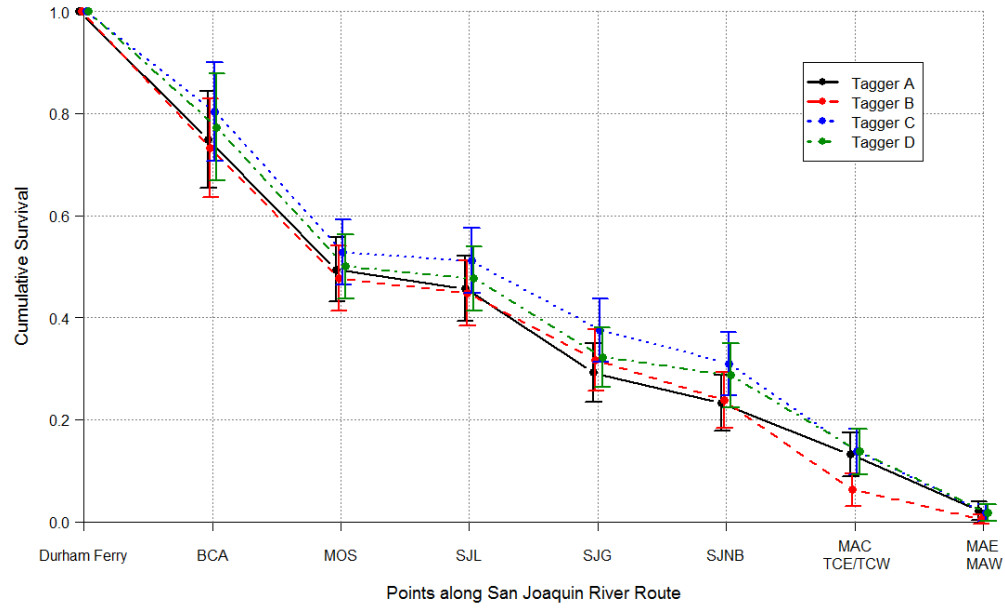


Figure 10. Cumulative survival from release at Durham Ferry to various points along the San Joaquin River route to Chipps Island, by tagger. Error bars are 95% confidence intervals.

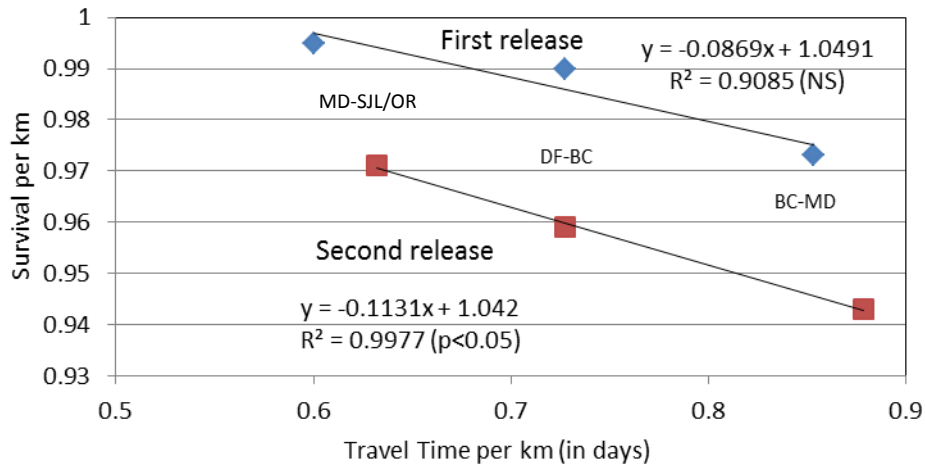


Figure 11: Travel time per km (in days) versus survival per km for river reaches, upstream of Mossdale in release group 1 and release group 2. Survival and travel time were without predator-type detections. Refer to Table 22 for data used.

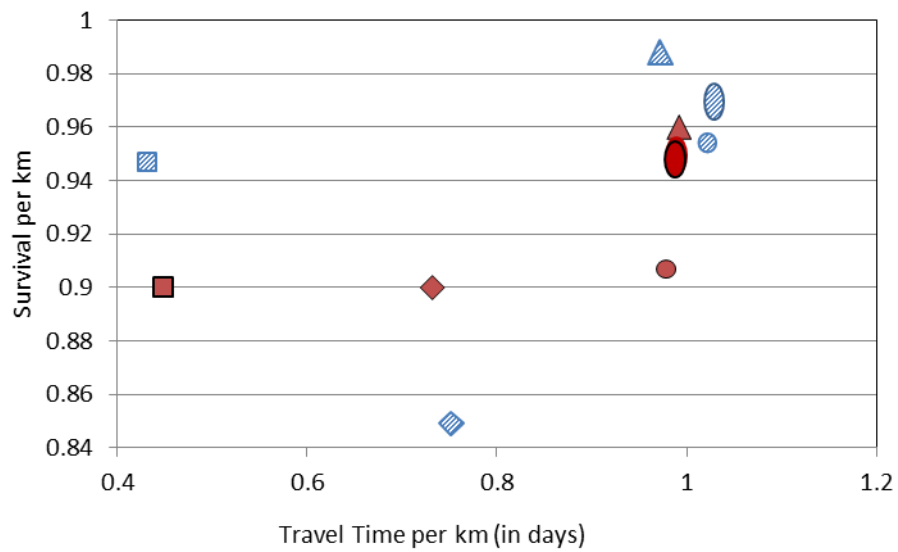


Figure 12: Travel time per km (in days) versus survival per km for reaches in the San Joaquin Delta for release group 1 (blue diagonal) and release group 2 (red solid). From Upstream to Downstream, reaches in order are: Lathrop to Garwood Bridge (triangles), Garwood Bridge to Navy Bridge Drive (squares), 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.

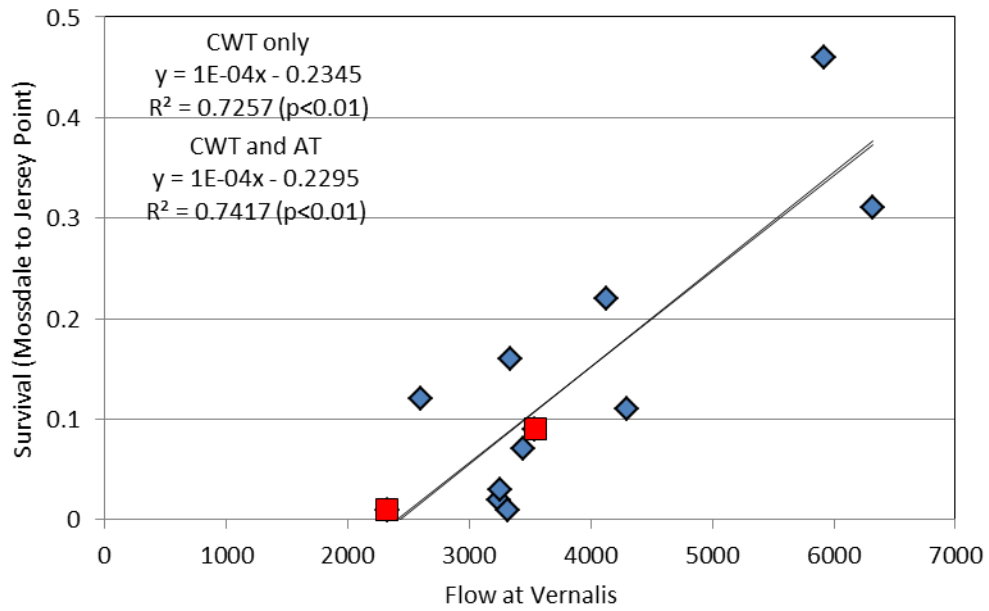


Figure 13: Estimates of survival between Mossdale and Jersey Point for CWT salmon (blue diamonds) and acoustic tag fish in 2012 (red squares) with the physical head of Old River barrier installed. Linear regression lines are plotted for both sets of data but overlap.

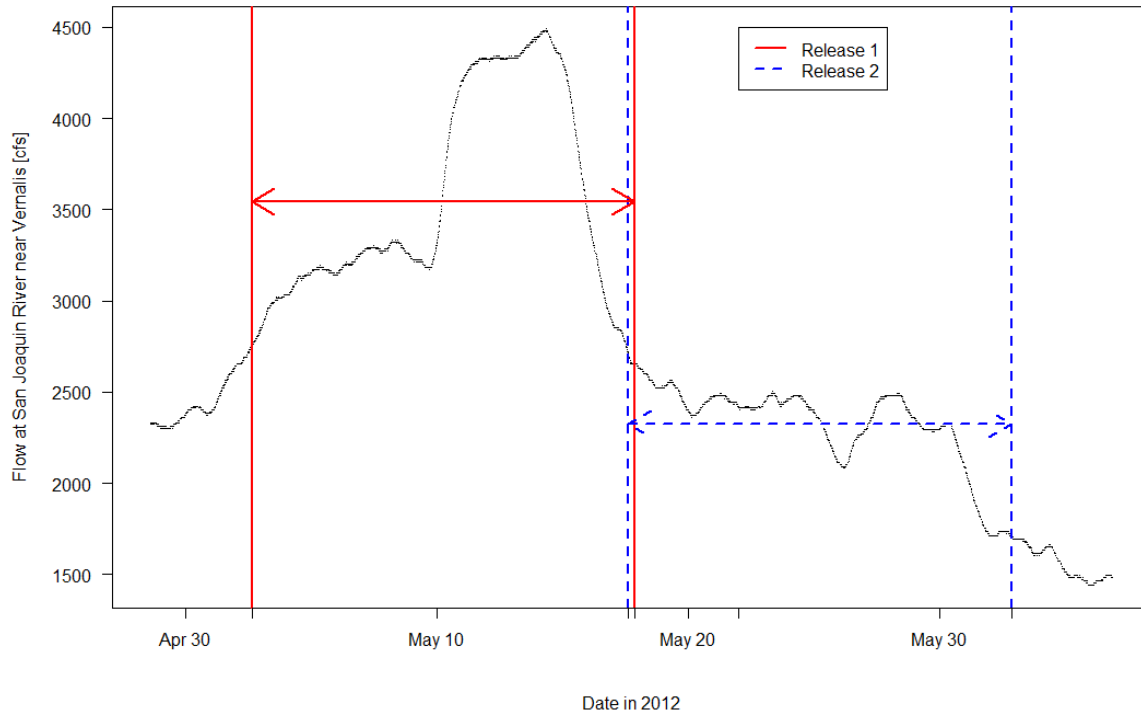


Figure 14. River discharge (flow) at Vernalis during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow heights indicates mean flow during travel period.

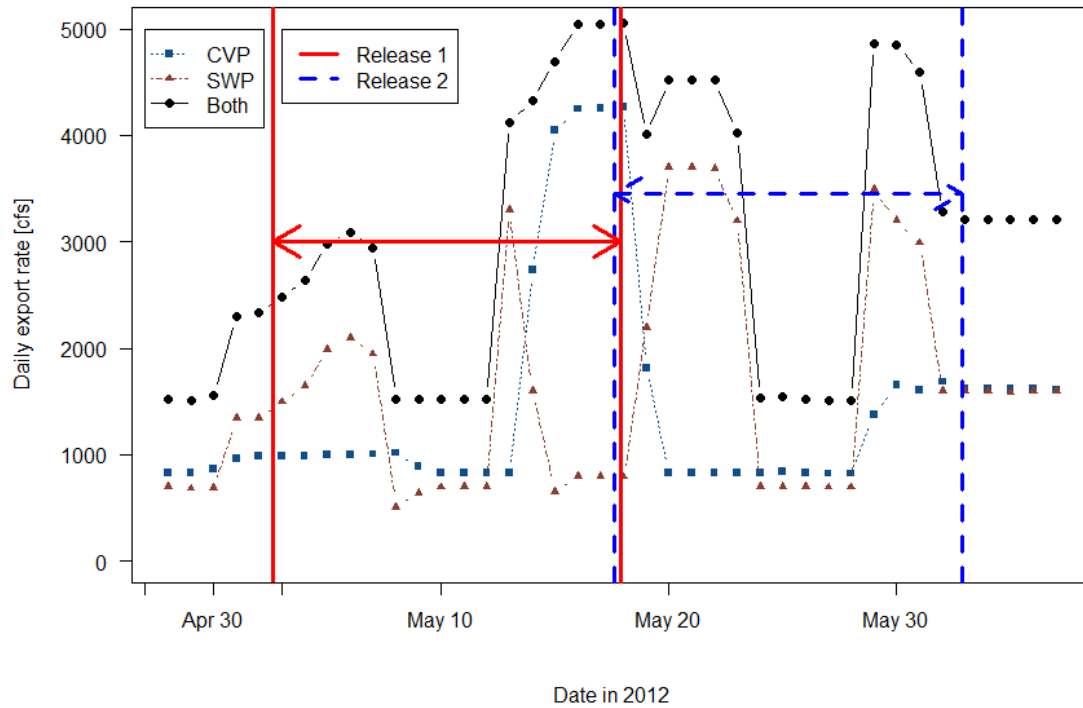


Figure 15. Daily export rate (cfs) at CVP and SWP during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow height indicates mean combined export rate during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

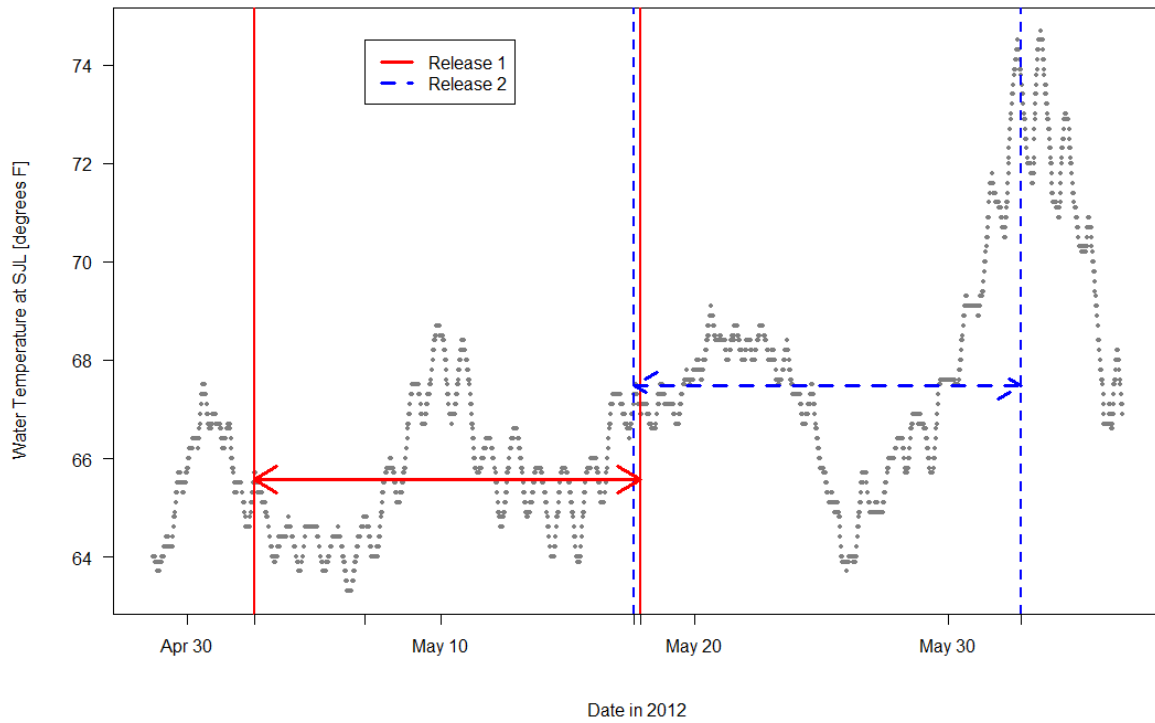


Figure 16. Temperature (°F) at the San Joaquin River gaging station near Lathrop during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow height indicates 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 transported	Transport 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 transported	Transport 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 <sup>1</sup> : 6	5/17; 1858, 1859 <sup>2</sup>	24: 6	5/17; 2302	12: 3							1	5/16; 1449	160 <sup>1</sup> : 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 <sup>2</sup>	24: 6	5/19; 0700 <sup>2</sup>	36: 10			1	5/18; 1736	
		20: 6	2									5/19; 1100 <sup>2</sup>	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			

<sup>1</sup> one tag not used in analyses; tag looked odd, <sup>2</sup> 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 <sup>a</sup>	121.322500 <sup>a</sup>	SJLU	A5a	300869/300870
San Joaquin River near Lathrop, downstream	37.810807 <sup>a</sup>	121.321269 <sup>a</sup>	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 <sup>a</sup>	121.462758 <sup>a</sup>	MACU	A8a	300899/300901
San Joaquin River at MacDonald Island, downstream	38.023877 <sup>a</sup>	121.465916 <sup>a</sup>	MACD	A8b	300900/300902
San Joaquin River near Medford Island, east	38.053134 <sup>a</sup>	121.510815 <sup>a</sup>	MFE	A9a	300903/300904
San Joaquin River near Medford Island, west	38.053773 <sup>a</sup>	121.513315 <sup>a</sup>	MFW	A9b	300905/300906
Old River East, near junction with San Joaquin, upstream	37.811653 <sup>a</sup>	121.335486 <sup>a</sup>	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 <sup>a</sup>	121.335558 <sup>a</sup>	ORED	B1b	300867/300868
Old River South, upstream	37.819583	121.378111	ORSU	B2a	300873
Old River South, downstream	37.820028	121.378889	ORSU	B2b	300874
Old River at Highway 4, upstream	37.893864 <sup>a</sup>	121.567083 <sup>a</sup>	OR4U	B3a	300882/300883
Old River at Highway 4, downstream	37.895125 <sup>a</sup>	121.566403 <sup>a</sup>	OR4D	B3b	300884/300885
Old River North of Empire Cut, upstream receiver (not used in survival model)	37.967125 <sup>a</sup>	121.574514 <sup>a</sup>	OLDU	B4a	450022
Old River North of Empire Cut, downstream receiver (not used in survival model)	37.967375 <sup>a</sup>	121.574389 <sup>a</sup>	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 <sup>a</sup>	121.533250 <sup>a</sup>	MREU	C3a	300898/450021
Middle River at Empire Cut, downstream receiver (not used in survival model)	37.942861 <sup>a</sup>	121.532370 <sup>a</sup>	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 <sup>a</sup>	121.557528 <sup>a</sup>	RGD1	D2a	300890/300892/ 460009/460011
Radial Gate at Clifton Court Forebay, downstream, array 2 in dual array	37.829822 <sup>a</sup>	121.557900 <sup>a</sup>	RGD2	D2b	300891/460010
Central Valley Project trashracks, upstream	37.816900 <sup>a</sup>	121.558459 <sup>a</sup>	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 <sup>a</sup>	121.686535 <sup>a</sup>	JPE	G1a	300915 - 300922
San Joaquin River at Jersey Point, west (downstream)	38.055167 <sup>a</sup>	121.688070 <sup>a</sup>	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 <sup>a</sup>	121.671403 <sup>a</sup>	FRW	H1a	300913/300914
False River, east (farther from San Joaquin)	38.057118 <sup>a</sup>	121.669673 <sup>a</sup>	FRE	H1b	300911/300912
Chippis Island (aka Mallard Island), east (upstream)	38.048772 <sup>a</sup>	121.931198 <sup>a</sup>	MAE	G2a	300931 - 300942
Chippis Island (aka Mallard Island), west (downstream)	38.049275 <sup>a</sup>	121.933839 <sup>a</sup>	MAW	G2b	300943, 300979 - 300983, 300985 - 300990
Threemile Slough, south (not used in survival model)	38.107771 <sup>a</sup>	121.684042 <sup>a</sup>	TMS	T1a	300909/300910
Threemile Slough, north (not used in survival model)	38.111556 <sup>a</sup>	121.682826 <sup>a</sup>	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 <sup>a</sup>
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 <sup>a</sup> (hr)		Migration Rate <sup>b,c</sup> (km/hr)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum
DFU	DF, DFD	0.5	1	0.2 (0.6 <sup>f</sup> )	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 <sup>f</sup> )	30 (12 <sup>f</sup> )	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 <sup>a</sup> (hr)		Migration Rate <sup>b,c</sup> (km/hr)		BLPS	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field	Minimum	Maximum	(Absolute value)		
		Maximum	Maximum	Maximum	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 <sup>f</sup> )	0
	HOR	3	288				2	1
	SJL	3 (4 <sup>f</sup> )	6 (8 <sup>f</sup> )	0.2 (0.1 <sup>f</sup> )	5.5 (6 <sup>f</sup> )	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 <sup>a</sup> (hr)		Migration Rate <sup>b, c</sup> (km/hr)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field Maximum	Mid-field 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.**

Detection Site	Previous Site	Flow <sup>d</sup> (cfs)		Water Velocity <sup>d</sup> (ft/sec)			Extra Conditions	Comment
		At arrival	At departure <sup>e</sup>	At arrival	At departure <sup>e</sup>	Average during transition		
DFU	DF, DFD							Alternate value if coming from DFD
	DFU						Not allowed	
DFD	DF, DFU						Not allowed	
	DFD						Not allowed	
	BCA						Not allowed	
BCA	DF, DFU						Travel time < 25	
	BCA						Not allowed	
	MOS						Travel time < 20	
MOS	DF, DFD, BCA						Travel time < 20	
	MOS							
	HOR					< 0.1		
SJL	MOS, HOR						Travel time < 20	
	SJL							
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 <sup>f</sup> )				Alternate values for change in river stage at arrival: < -0.1 or > 0.1
	SJNB	< 600 (> -250) <sup>g</sup>	> -250 (< 600) <sup>g</sup>	< 0.2 (> -0.1) <sup>g</sup>	> -0.1 (< 0.2) <sup>g</sup>	< 1.5		
MAC	SJG, SJNB							
	MAC			< 0.2 (> -0.1) <sup>g</sup>	> -0.1 (< 0.2) <sup>g</sup>			

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

e = Condition at departure from previous site

f = See comments for alternate criteria

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

Table 5b. (Continued)

Detection Site	Previous Site	Flow <sup>d</sup> (cfs)		Water Velocity <sup>d</sup> (ft/sec)			Extra Conditions	Comment
		At arrival	At departure <sup>e</sup>	At arrival	At departure <sup>e</sup>	Average during transition		
MAC	MFE/MFW			< -0.4	< 0.2	< 0.2		
MFE/MFW	MAC							
	MFE/MFW			< 0.2 (> -0.1) <sup>g</sup>	> -0.1 (< 0.2) <sup>g</sup>			
	SJG	<100 (>-300) <sup>g</sup>	>-300 (<100) <sup>g</sup>	<0.1 (>-0.5) <sup>g</sup>	>-0.5 (<0.1) <sup>g</sup>	<0.5		
HOR	DF, MOS							Alternate value if coming from MOS
	HOR						Travel time < 20	
	SJL			< 1.5	< 0.15 (0.25) <sup>f</sup>	< 1 (1.1) <sup>f</sup>		Alternate value if next transition is downstream
ORE	HOR							
	ORE						Not allowed	
ORS	ORE	> -2500		> -0.5				
	ORS	< 2500 (> -2500) <sup>g</sup>	> -2500 (< 2500) <sup>g</sup>	< 0.5 (> -0.5) <sup>g</sup>	> -0.5 (< 0.5) <sup>g</sup>			
OR4	ORS	> -700		> -0.3				
	MR4							
	OR4	< 700 (> -700) <sup>g</sup>	> -700 (< 700) <sup>g</sup>	< 0.3 (> -0.3) <sup>g</sup>	> -0.3 (< 0.3) <sup>g</sup>			
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)

Detection Site	Previous Site	Flow <sup>d</sup> (cfs)		Water Velocity <sup>d</sup> (ft/sec)		Average during transition	Extra Conditions	Comment
		At arrival	At departure <sup>e</sup>	At arrival	At departure <sup>e</sup>			
CVP	DF, ORS							
	CVP							
	OR4	< 3000	< 2000	< 1.5	< 0.8	< 0.1		CVP pumping > 1500 cfs on arrival, < 1500 cfs on departure 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) <sup>g</sup>	> 500 (< 500) <sup>g</sup>	< 0.1 (> 0.1) <sup>g</sup>	> 0.1 (< 0.1) <sup>g</sup>	-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 TMN/TMS, JPE/JPW, FRE/FRW			> -2.5				
				> -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.**

Transport		Tank #1						Tank #2						River		
Date	Loading time	Ice Added	After loading		After transport		# morts after transport	Ice Added	After loading		After transport		# morts after transport	Temp (°C)	DO (mg/L)	Mortalities just prior to release
			Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)			Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)				
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.**

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	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	ORSU	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		Total
			1	2	
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		Total
			1	2	
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	ORSU	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		Total
			1	2	
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
Chippis 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
<b>Total Tags</b>			<b>17</b>	<b>29</b>	<b>46</b>	<b>44</b>	<b>40</b>	<b>84</b>

**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
Mosssdale	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	ORSU	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		Total
			1	2	
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		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
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	ORSU	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		Total
			1	2	
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

Tagger	Release Group		Total Tags
	1	2	
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.**

Parameter	Release Occasion		Population Estimate
	1	2	
$\Psi_{AA}$	0.88 (0.03)	0.82 (0.10)	0.87 (0.03)
$\Psi_{AF}$	0.10 (0.03)	0.16 (0.10)	0.11 (0.03)
$S_{AA}$	0.05 <sup>d</sup> (0.01)	0 <sup>d</sup> (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)
$\Psi_{F2}$	0.11 (0.03)	0.16 (0.11)	0.11 (0.03)
$S_A$	0.05 <sup>cd</sup> (0.01)	0 <sup>d</sup> (0)	0.03 <sup>c</sup> (0.01)
$S_B^b$	0.16 <sup>c</sup> (0.15)	0 (0)	0.11 <sup>c</sup> (0.10)
$S_{Total}$	0.05 <sup>d</sup> (0.01)	0 <sup>d</sup> (0)	0.03 (0.01)
$S_{A(MD)}$	0.09 <sup>d</sup> (0.02)	0.01 <sup>d</sup> (0.01)	0.06 (0.01)
$S_{A(SD)}$	0.33 <sup>d</sup> (0.03)	0.07 <sup>d</sup> (0.02)	0.23 (0.02)
$\phi_{A1A4}$	0.63 <sup>d</sup> (0.02)	0.37 <sup>d</sup> (0.02)	0.50 (0.02)

a = Significant preference for route A (San Joaquin Route) ( $\alpha = 0.05$ ) 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.**

Parameter	Release Occasion		Population Estimate
	1	2	
$\Psi_{AA}$	0.86 (0.03)	0.85 (0.09)	0.86 (0.03)
$\Psi_{AF}$	0.12 (0.03)	0.13 (0.09)	0.12 (0.03)
$S_{AA}$	0.05 <sup>d</sup> (0.01)	0 <sup>d</sup> (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)
$\Psi_{F2}$	0.12 (0.03)	0.14 (0.09)	0.12 (0.03)
$S_A$	0.05 <sup>cd</sup> (0.01)	0 <sup>d</sup> (0)	0.03 <sup>c</sup> (0.01)
$S_B^b$	0.16 <sup>c</sup> (0.15)	0 (0)	0.11 <sup>c</sup> (0.10)
$S_{Total}$	0.05 <sup>d</sup> (0.01)	0 <sup>d</sup> (0)	0.03 (0.01)
$S_{A(MD)}$	0.09 <sup>d</sup> (0.02)	0.01 <sup>d</sup> (0.01)	0.06 (0.01)
$S_{A(SD)}$	0.34 <sup>d</sup> (0.03)	0.08 <sup>d</sup> (0.02)	0.24 (0.02)
$\phi_{A1A4}$	0.62 <sup>d</sup> (0.02)	0.38 <sup>d</sup> (0.02)	0.50 (0.02)

a = Significant preference for route A (San Joaquin Route) ( $\alpha = 0.05$ ) 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 19. Estimates (standard errors in parentheses) of model survival and transition parameters by release group, and of the difference ( $\Delta$ ) between release group estimates:  $\Delta$  = Release group 1 - Release group 2. P = P-value from one-sided z-test of  $\Delta > 1$ . Estimates were based on data that excluded predator-type detections. \* = significant (positive) difference between release groups for family-wise  $\alpha=0.10$ .

Parameter	Release 1	Release 2	$\Delta$	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*

<sup>a</sup>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.

Detection Site and Route	Without Predator-Type Detections					
	All Releases		Release 1		Release 2	
	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
Chippis Island (MAE/MAW), SJR Route	10	5.99 (0.41)	10	5.99 (0.41)	0	NA
Chippis Island (MAE/MAW), OR Route	1	4.12 (NA)	1	4.12 (NA)	0	NA
Chippis 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.**

Detection Site and Route	With Predator-Type Detections					
	All Releases		Release 1		Release 2	
	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
Chippis Island (MAE/MAW), SJR Route	10	5.99 (0.41)	10	5.99 (0.41)	0	NA
Chippis Island (MAE/MAW), OR Route	1	4.12 (NA)	1	4.12 (NA)	0	NA
Chippis 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	230	0.28 (0.01)	87	0.24 (0.01)	143	0.31 (0.01)
	MOS	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	293	0.65 (0.02)	218	0.60 (0.02)	75	0.86 (0.05)
	SJG	226	0.08 (<0.01)	176	0.08 (<0.01)	50	0.09 (0.01)
	SJNB	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	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
	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
	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
	ORS	8	0.27 (0.03)	6	0.29 (0.03)	2	0.22 (0.05)
	MRH	0	NA	0	NA	0	NA
	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 (Chippis 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 (1<sup>st</sup>) and second (2<sup>nd</sup>) 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.**

Covariate <sup>a</sup>	F-test			
	<i>F</i>	df1	df2	<i>P</i>
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

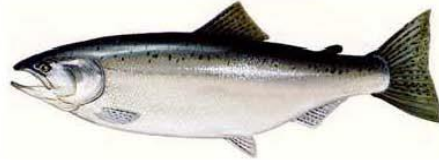


**Table 24. Summary statistics from multiple regression of flow at Vernalis and tag type to explain survival from Mossdale to Jersey Point with the physical head of Old River barrier. Tag type (CWT or Acoustic) was not significant (p value = 0.992775).**

SUMMARY OUTPUT		Mossdale data only						
<i>Regression Statistics</i>								
Multiple R	0.86119676							
R Square	0.74165986							
Adjusted R Square	0.69468892							
Standard Error	0.07221227							
Observations	14							
<i>ANOVA</i>								
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	2	0.164674977	0.082337	15.78976	0.000584865			
Residual	11	0.057360738	0.005215					
Total	13	0.222035714						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
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:**

Analyses of Salmon CWT Releases into the San Joaquin System  
Ken E. Newman, USFWS  
2 March 2010



1. Overview

- Objectives: to understand how different factors (flows, exports, barrier at head of Old River, HORE) 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

- Between 1985 and 2006, 35 Release-Recovery sets.
- Within a set, at most 3 release locations (e.g., Mossdale, Dos Reis, and Jersey Point).
- At most 3 recovery locations: Chipps Island, Ocean fisheries, and since 2000, Antioch
- ⇒ 212 observations

3. Data Analysis

- BHMs (Bayesian Hierarchical Models)
- Key idea: 2 or more levels of modeling
- Separate modeling of Observation (Sampling) noise from Survival (and capture) variation
- Level 1: Observation Models  $y^i_s \sim$  Probability Distribution( $R_i$ ,  $S_i$  and  $p_i$ )
- Level 2, Random effects:  $S_i$ ,  $p_i \sim$  Probability Distribution( $\eta$ , Covariates)
- Level 3, Hyperparameters:  $\eta \sim$  Prior Probability Distribution
- 
- Focus on Models for Survival down San Joaquin and Survival down Old River

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

- Fitting Details: WinBUGS with Reversible Jump model selection

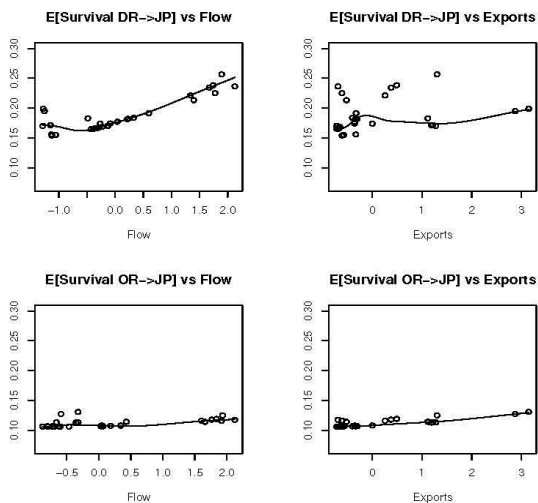
#### 4. Results

##### (a) Posterior Probabilities

Models	$S_{MD \rightarrow JP}$	$S_{OR \rightarrow JP}$
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

- Priors *do* matter, especially with Hierarchical Models
- More to wring out of CWTs? Using time of capture? Add arrival time/travel time model?
- Acoustic tags far preferable?
- 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)

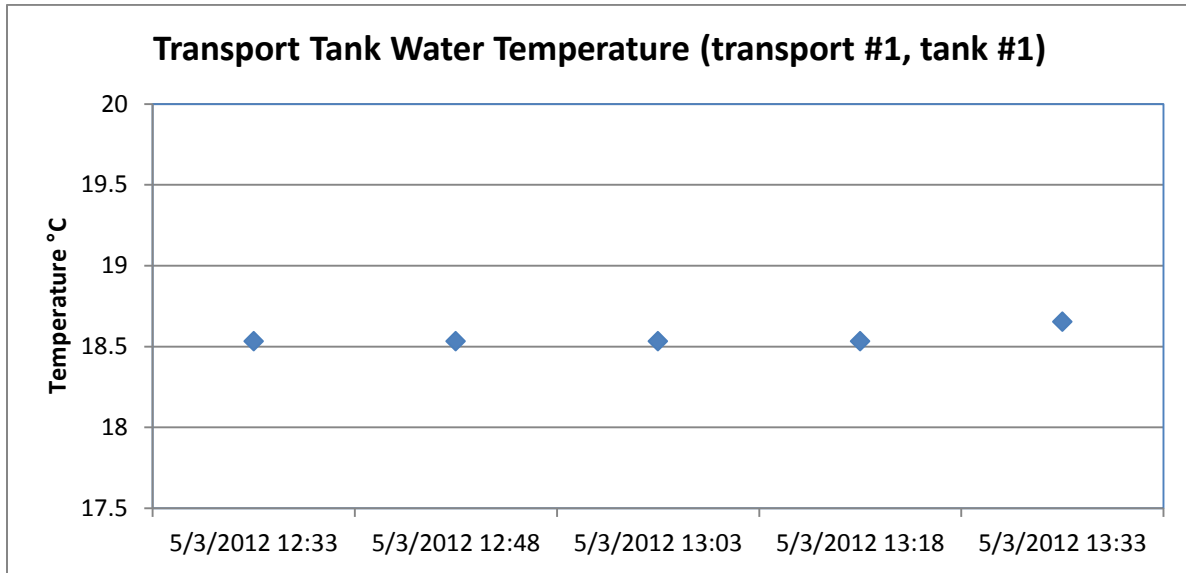


Figure A3-1. Transport tank water temperature during transport #1, tank #1 on May 3, 2012.

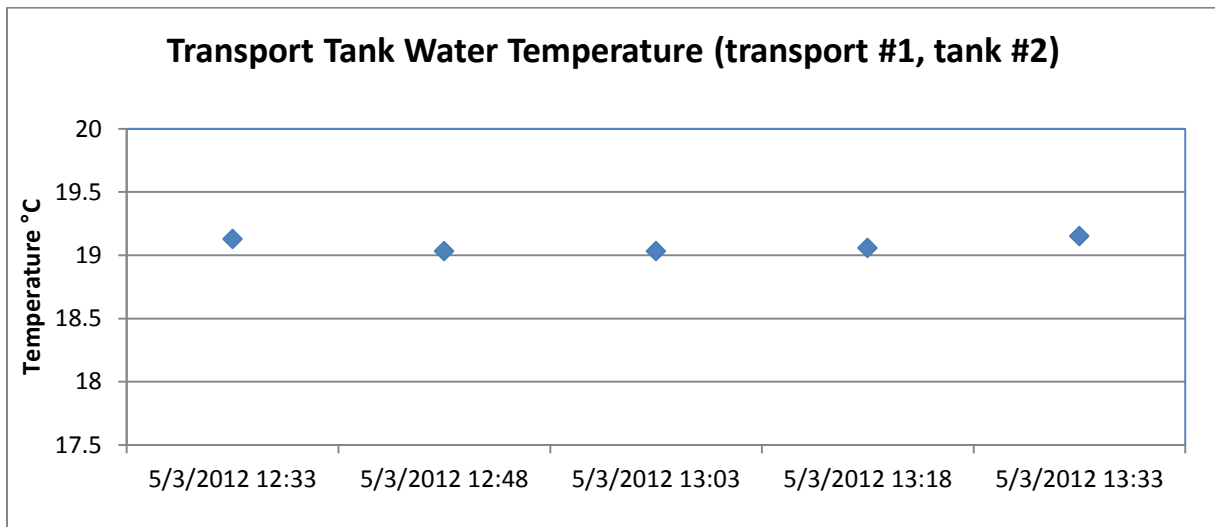


Figure A3-2. Transport tank water temperature during transport #1, tank #2 on May 3, 2012.

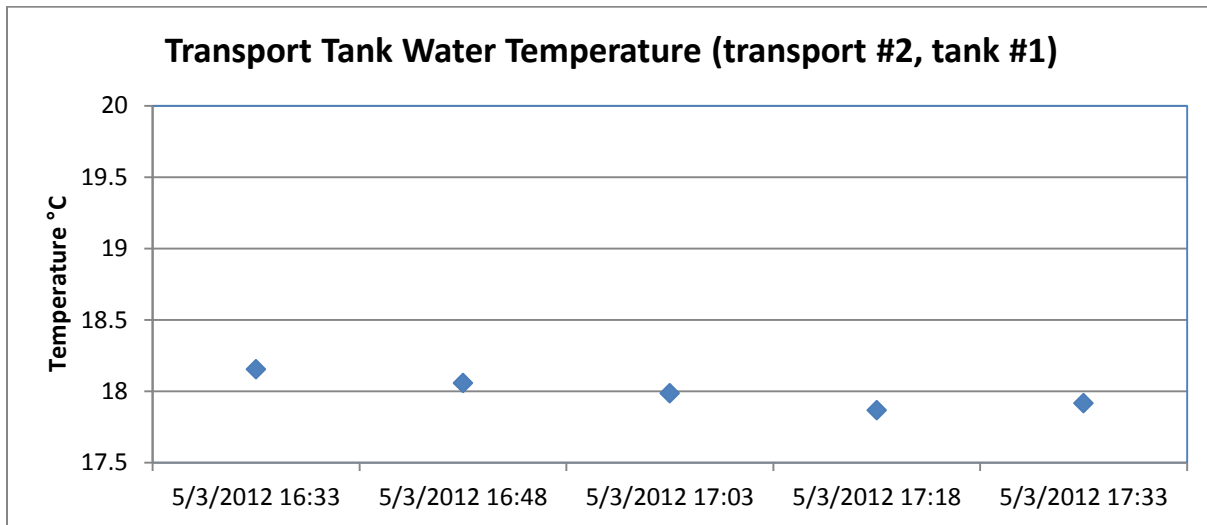


Figure A3-3. Transport tank water temperature during transport #2, tank #1 on May 3, 2012.

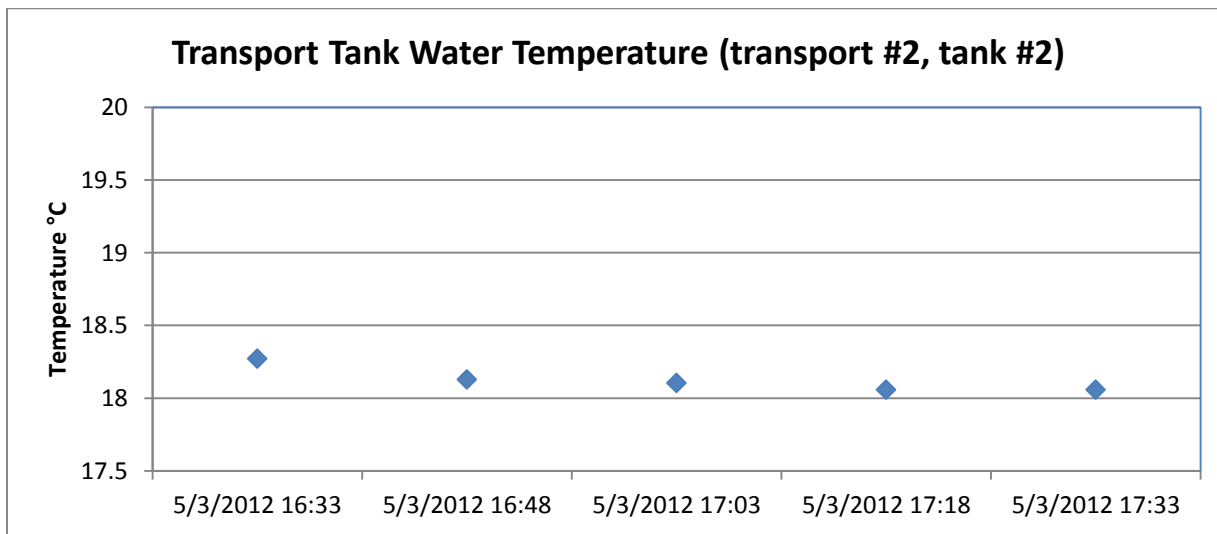


Figure A3-4. Transport tank water temperature during transport #2, tank #2 on May 3, 2012.

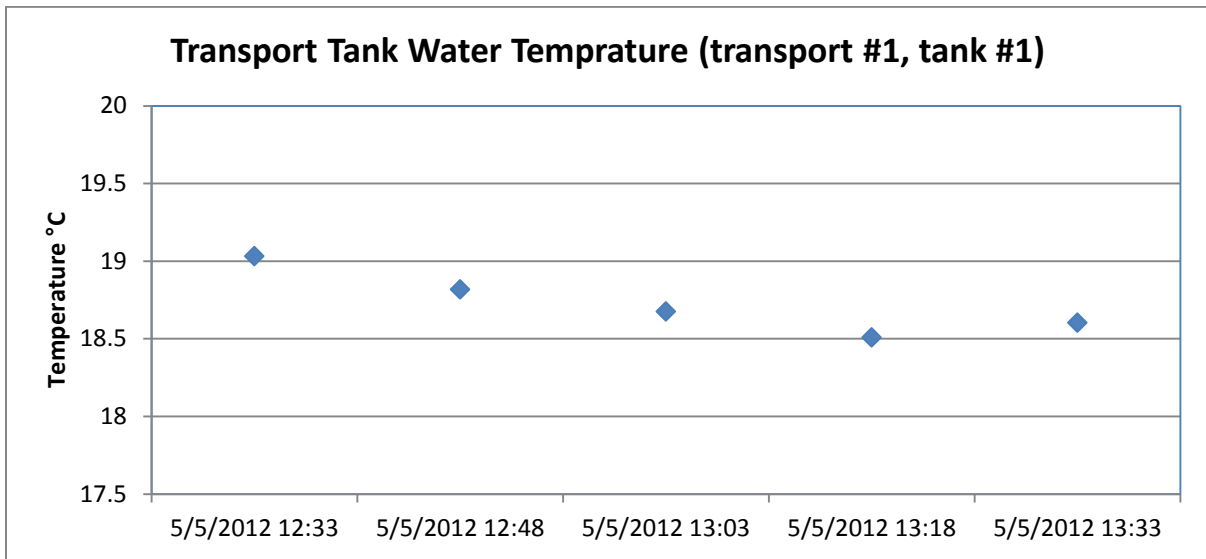


Figure A3-5. Transport tank water temperature during transport #1, tank #1 on May 5, 2012.

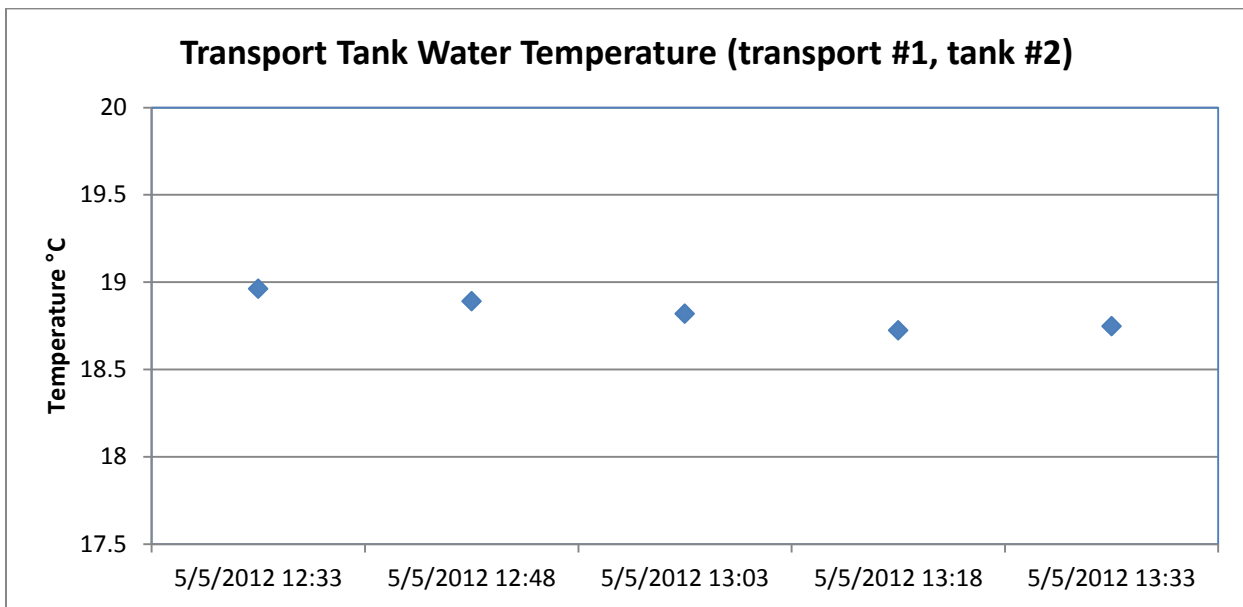


Figure A3-6. Transport tank water temperature during transport #1, tank #2 on May 5, 2012.

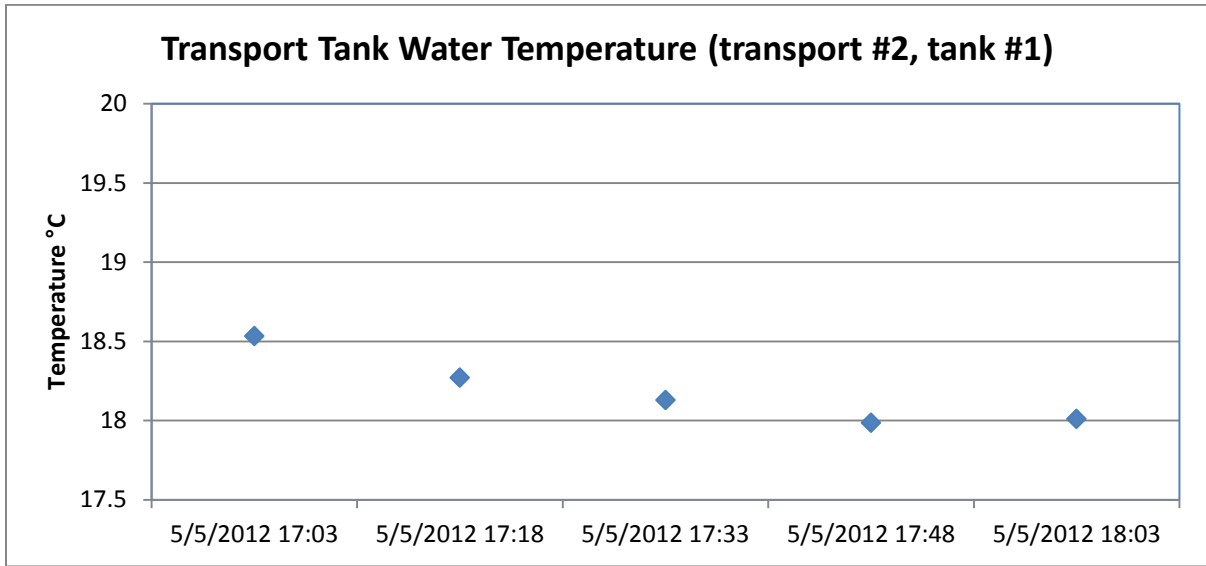


Figure A3-7. Transport tank water temperature during transport #2, tank #1 on May 5, 2012.

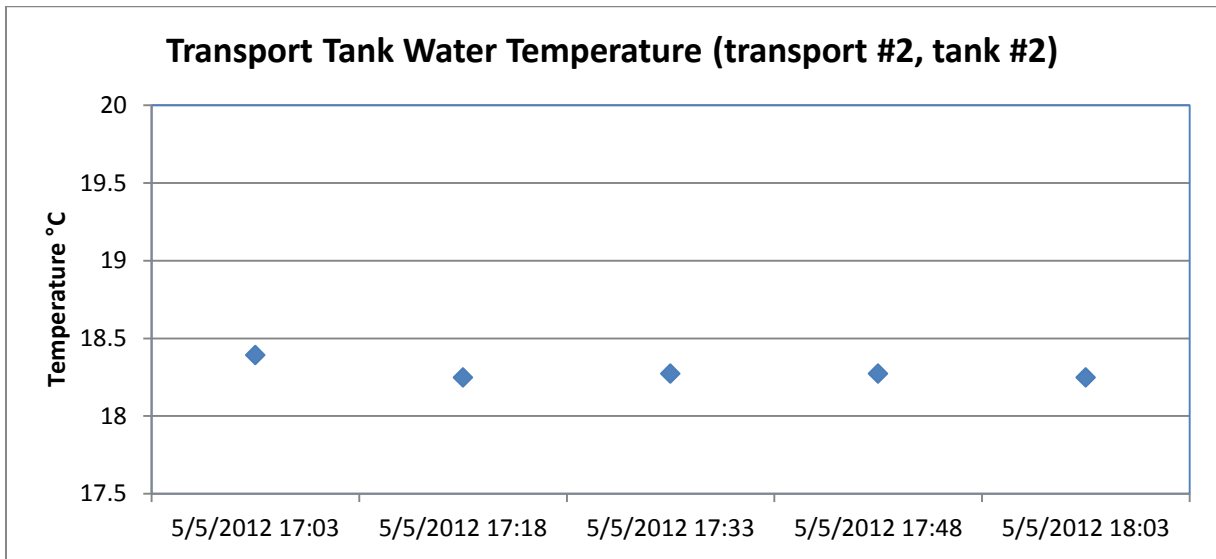


Figure A3-8. Transport tank water temperature during transport #2, tank #2 on May 5, 2012.

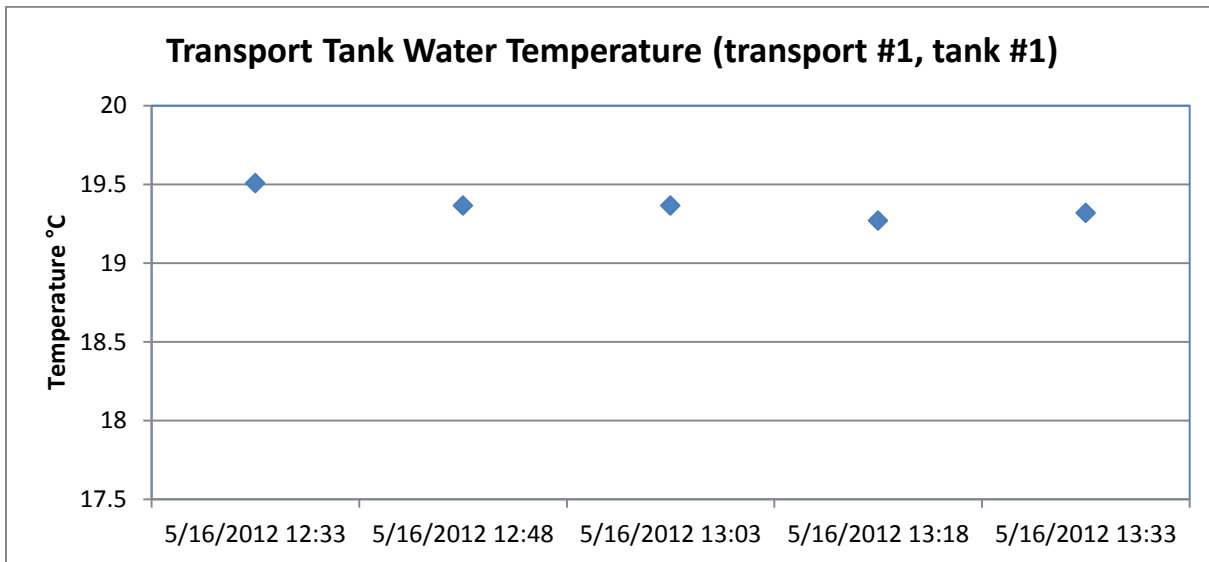


Figure A3-9. Transport tank water temperature during transport #1, tank #1 on May 16, 2012.

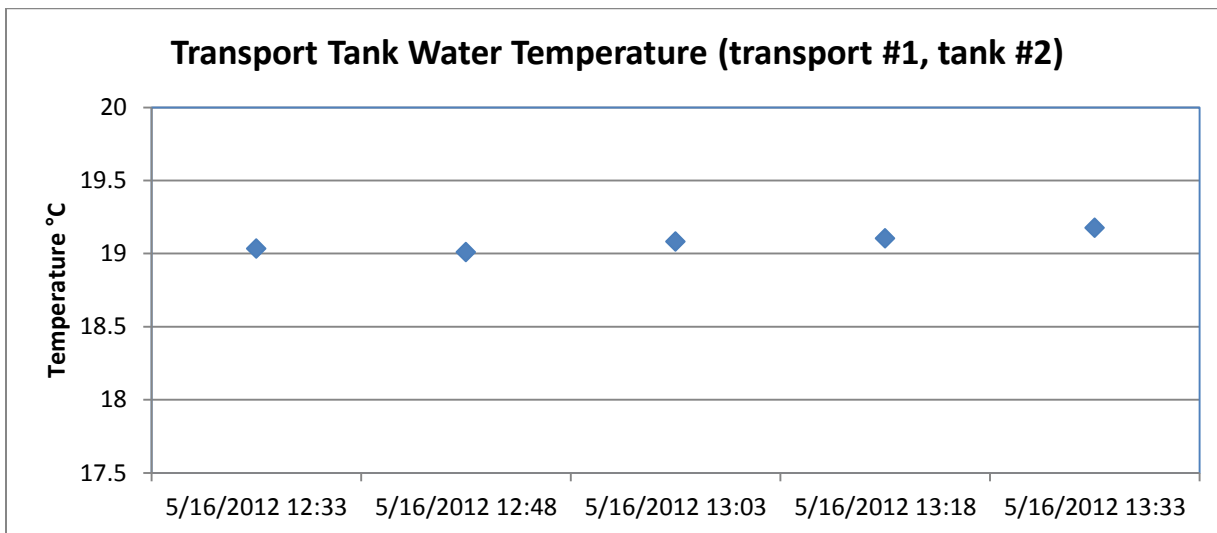


Figure A3-10. Transport tank water temperature during transport #1, tank #2 on May 16, 2012.

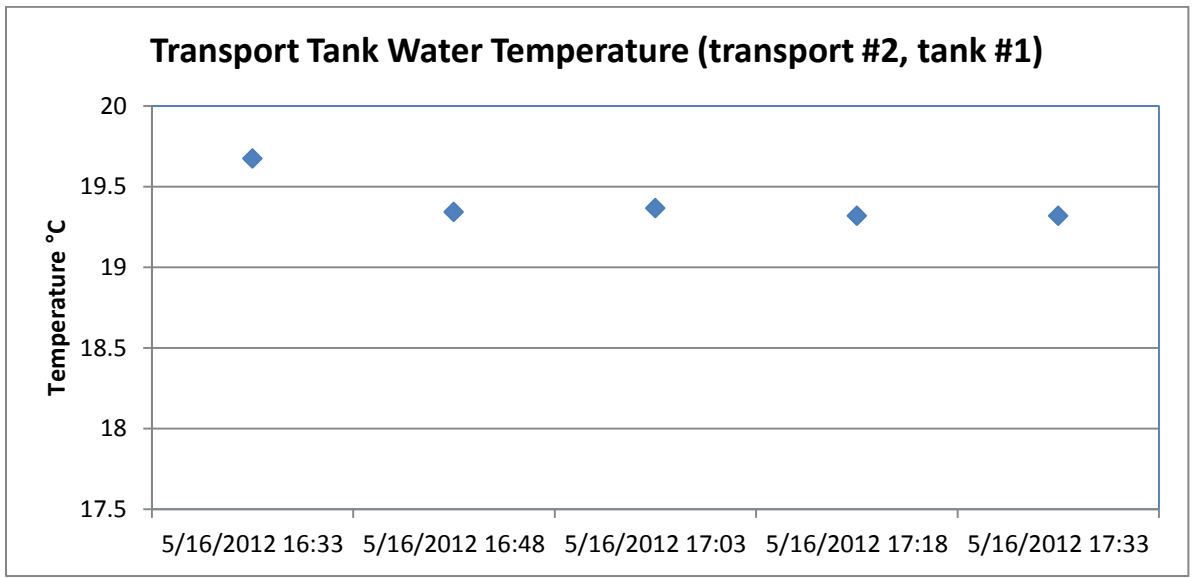


Figure A3-11. Transport tank water temperature during transport #2, tank #1 on May 16, 2012.

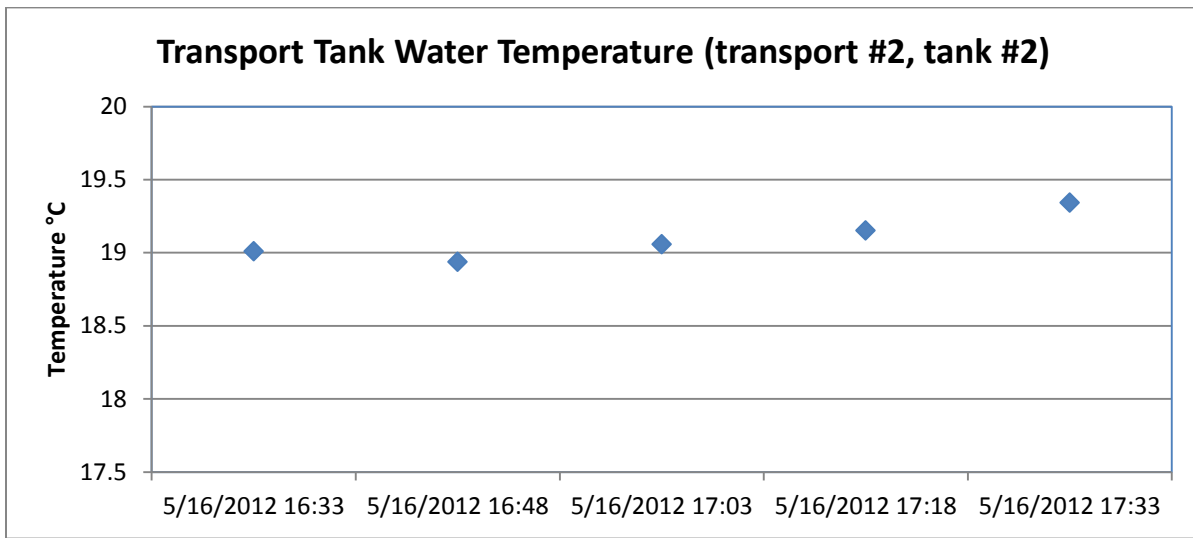


Figure A3-12. Transport tank water temperature during transport #2, tank#2 on May 16, 2012.

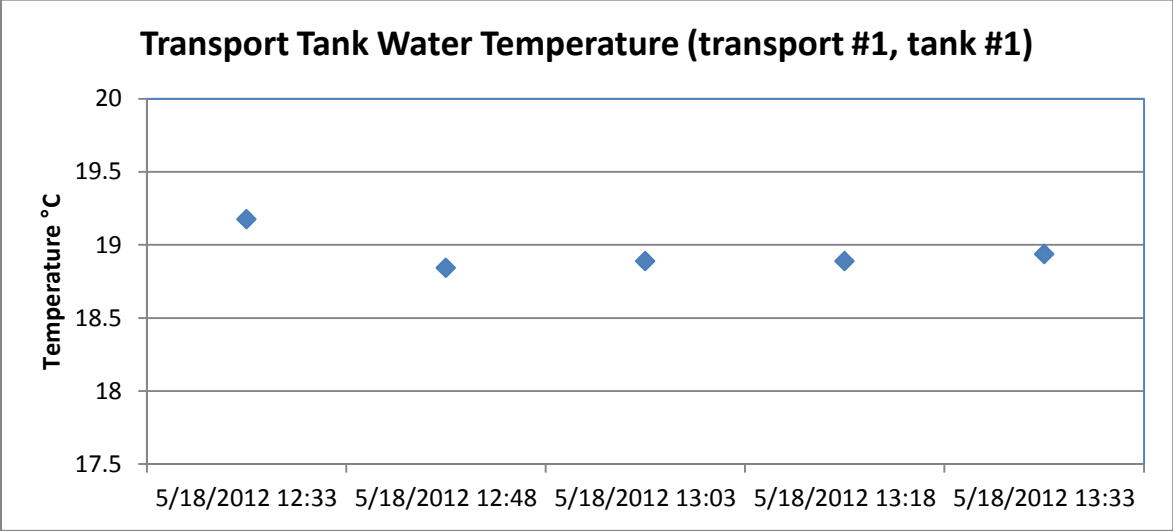


Figure A3-13. Transport tank water temperature during transport #1, tank #1 on May 18, 2012.

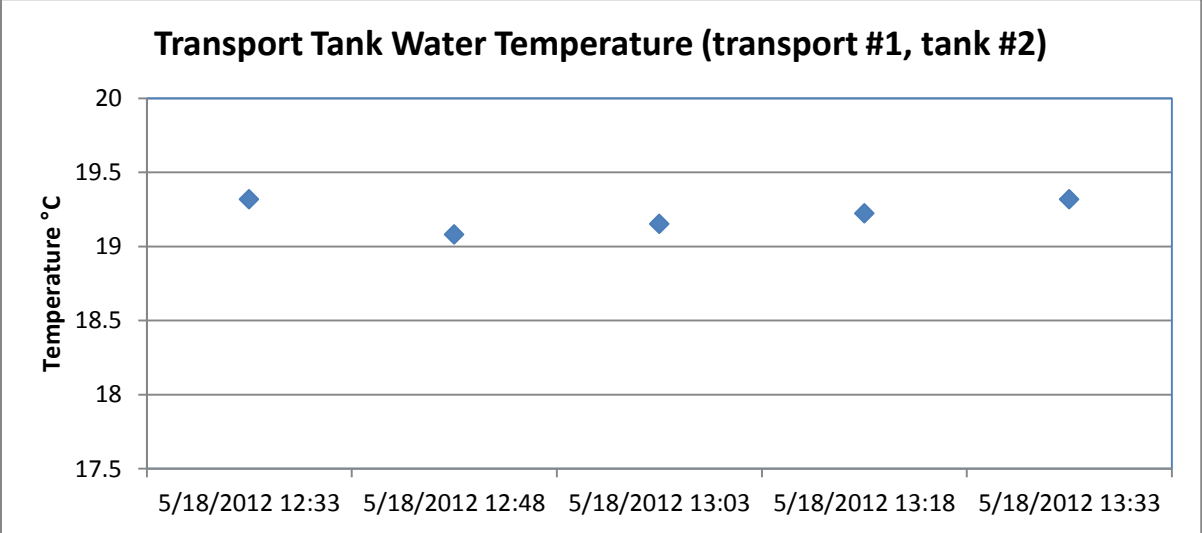


Figure A3-14. Transport tank water temperature during transport #1, tank #2 on May 18, 2012.

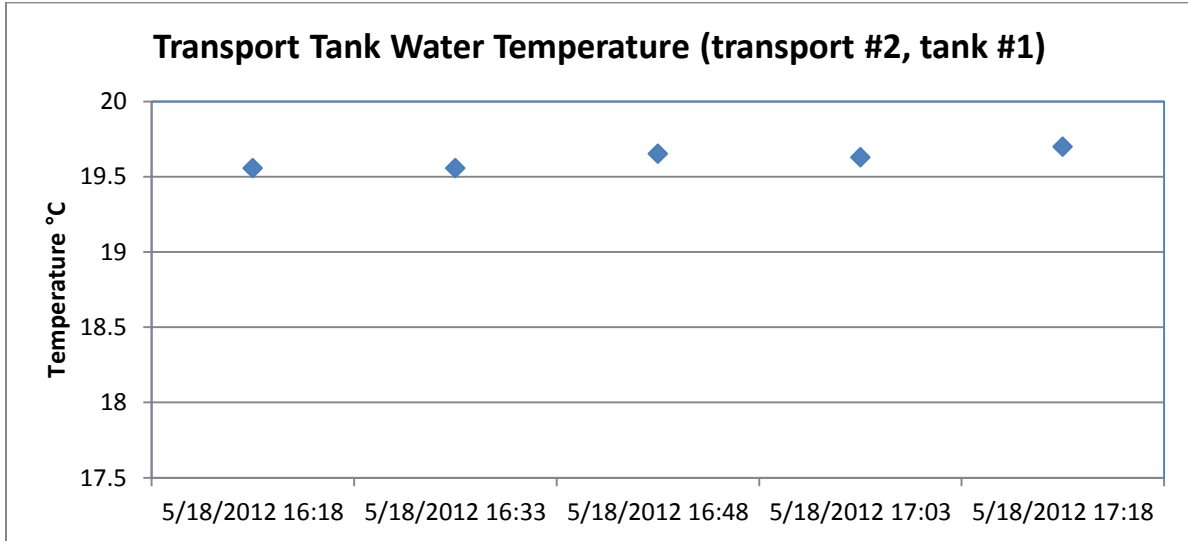


Figure A3-15. Transport tank water temperature during transport #1, tank #1 on May 18, 2012.

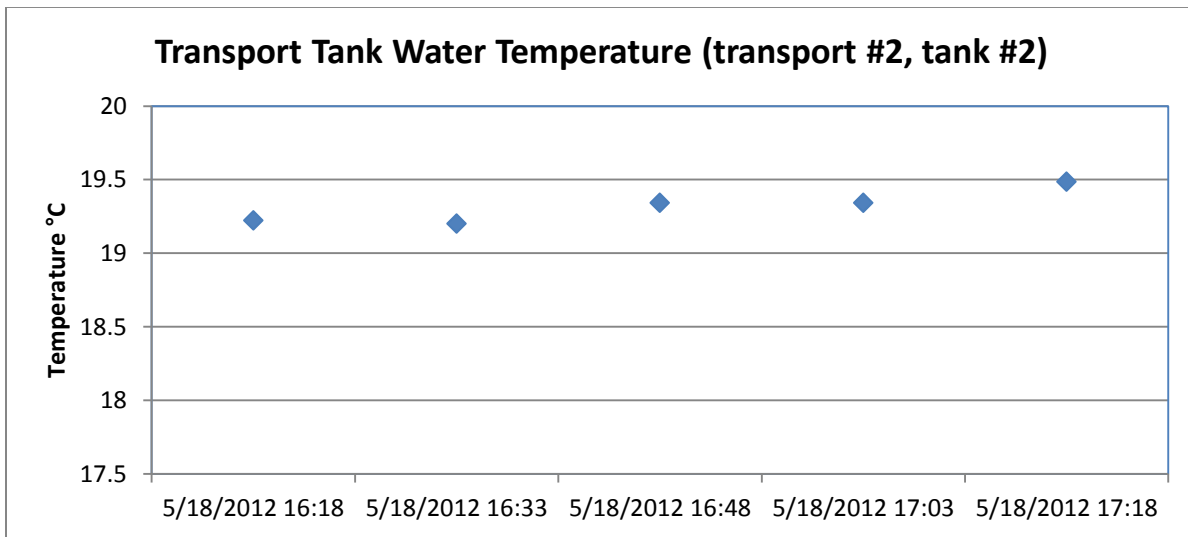


Figure A3-16. Transport tank water temperature during transport #2, tank #2 on May 18, 2012.



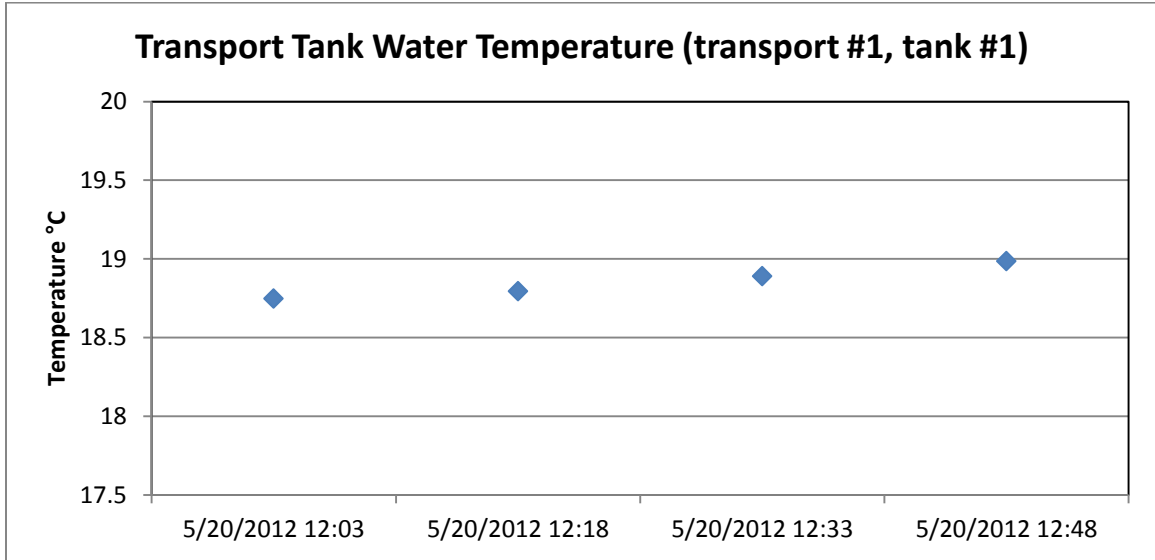


Figure A3-17. Transport tank water temperature during transport #1, tank #1 on May 20, 2012.

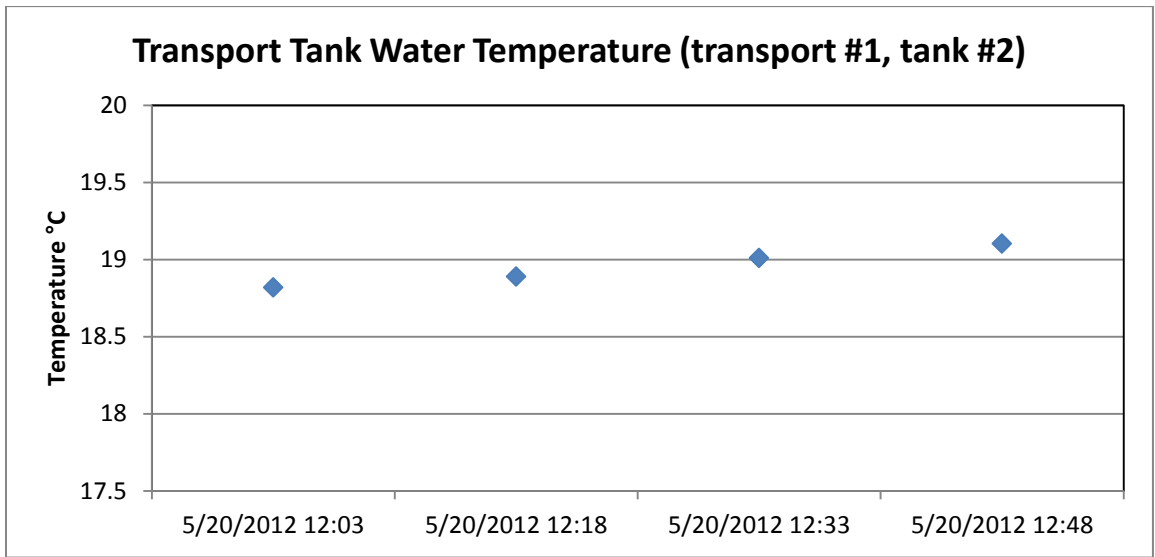


Figure A3-18. Transport tank water temperature during transport #1, tank #2 on May 20, 2012.

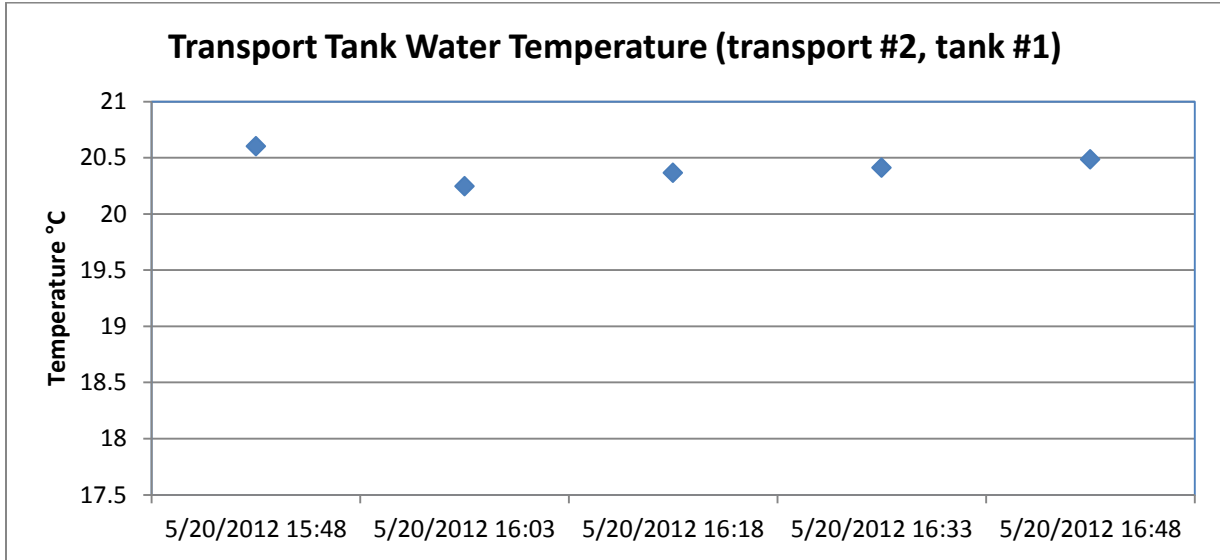


Figure A3-19. Transport tank water temperature during transport #2, tank #1 on May 20, 2012.

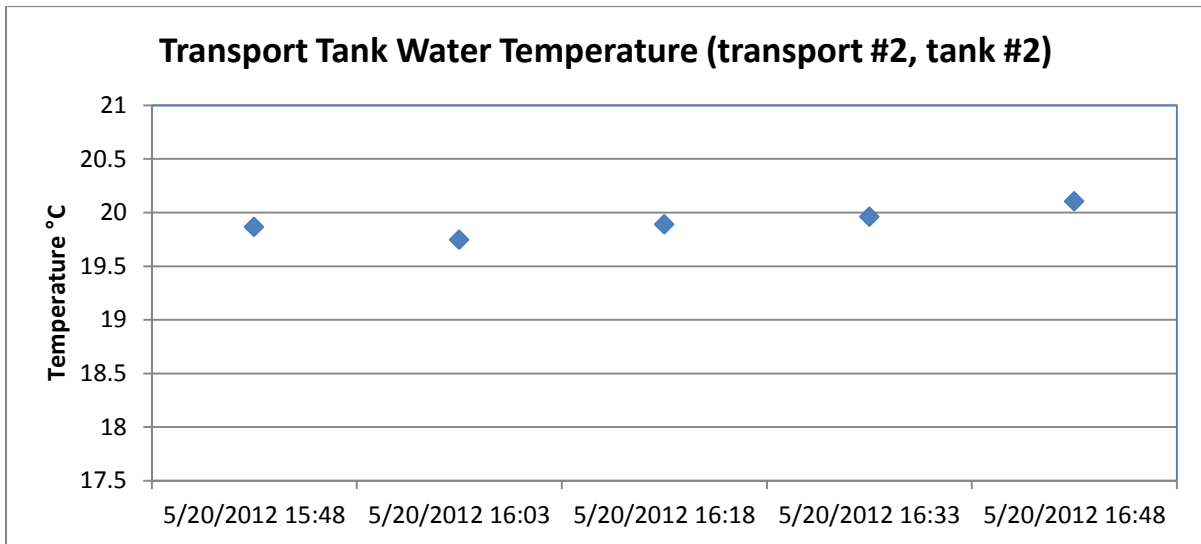


Figure A3-20. Transport tank water temperature during transport #2, tank #2 on May 20, 2012.

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 *Aeromonas* – *Pseudomonas* sp. infection however there was little correlation between the 2 findings. As in the past, *Tetracapsuloides bryosalmonae* infection was highly prevalent ( $\geq 97\%$ ) 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>.

Notice:

The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the Federal government. The findings and conclusions in this report are those of the author and do not necessarily represent the views of the US Fish and Wildlife Service.

## 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  $\text{Na}^+ - \text{K}^+$ -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  $\text{Na}^+/\text{K}^+$ -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  $\mu\text{m}$  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 (*Aeromonas* – *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.

<u>Sample date</u>	<u>Bacteria</u>	<u>Rsal - DFAT</u>	<u>Virus</u>	<u><i>T.bryosalmonae</i></u>
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.

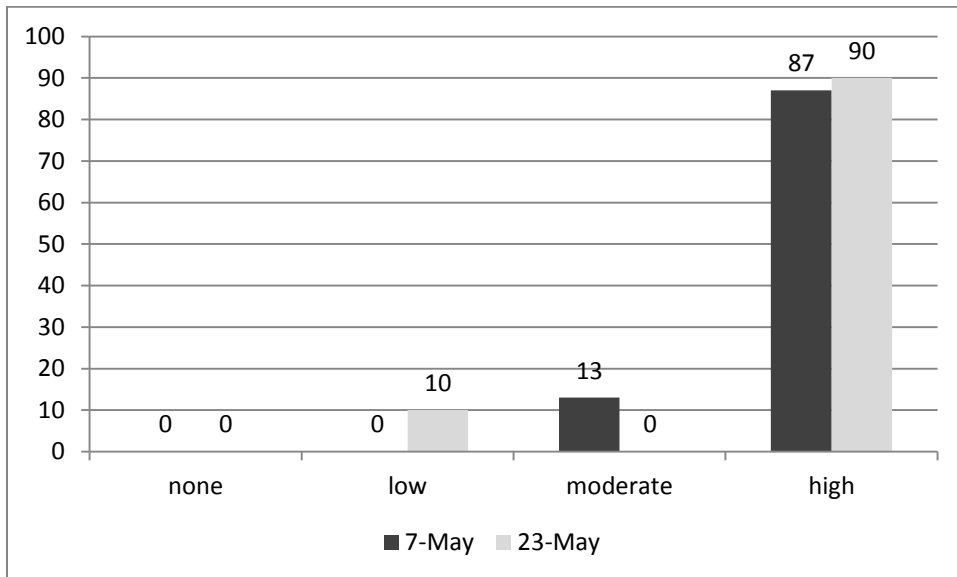


Figure A4-2. Prevalence of proliferative kidney disease ratings for Chinook salmon sampled on 7 and 23 May. Severity of kidney inflammation rated as normal, focal, multifocal, or diffuse. Numbers over ratings are prevalence data.

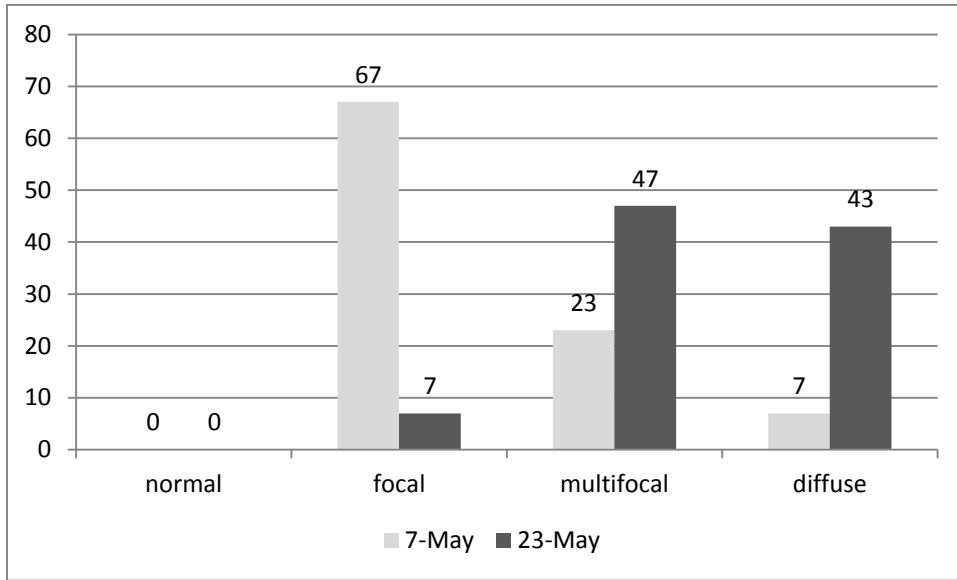


Figure A4-3. Micrograph of *T. byrosalmonae* (arrow) within gill blood vessel.

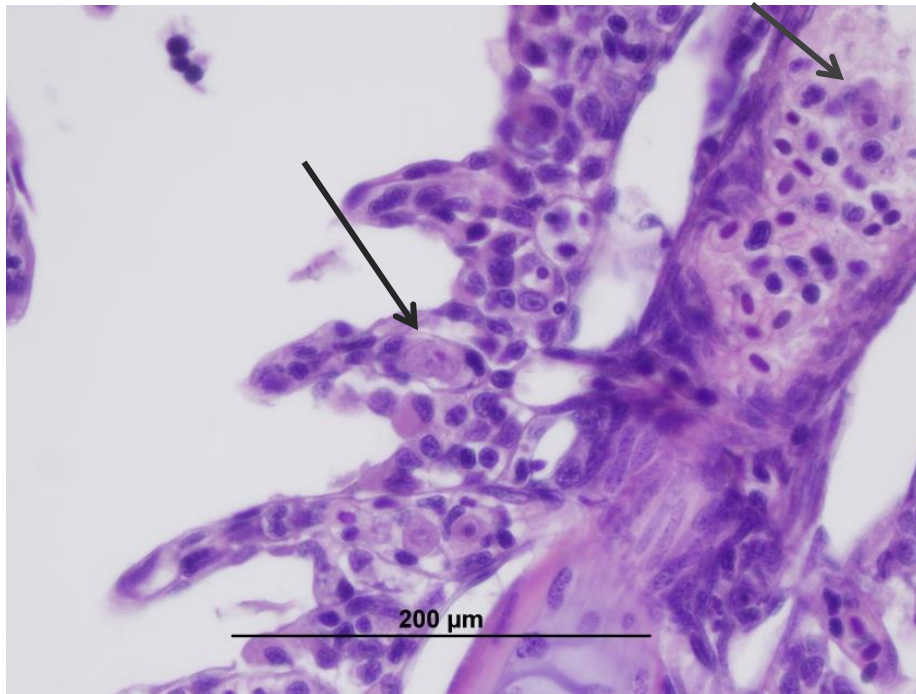




Figure A4-4. Suture condition rating 2 (exposed edge with hemorrhage) in 23 May salmon.



#### 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.

## REFERENCES

Foott JS and R Stone. 2008. FY 2008 Investigational report: Evaluation of sonic tagged Chinook juveniles used in the 2008 VAMP study for delayed mortality and saltwater survival – effects of Proliferative Kidney Disease. US Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA. Available: <http://www.fws.gov/canvfhc/reports.asp> (September 2010).

Foott JS, R Stone and K Nichols. 2007. Proliferative Kidney Disease (*Tetracapsuloides bryosalmonae*) in Merced River Hatchery juvenile Chinook salmon: mortality and performance impairment in 2005 smolts. California Fish and Game 93: 57-76.

Ferguson, HW. 1981. The effects of water temperature on the development of Proliferative Kidney Disease in rainbow trout, *Salmo gairdneri* Richardson. Journal of Fish Disease 4: 175-177.

Humason GL. 1979. Animal Tissue Techniques, 4th edition. W H Freeman and Co., San Francisco.

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

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])
$\psi_{A1}$	Both	Probability of remaining in the San Joaquin River at the head of Old River; = $1 - \psi_{B1}$
$\psi_{A2}$	Both	Probability of remaining in the San Joaquin River at the junction with Turner Cut; = $1 - \psi_{F2}$
$\psi_{B1}$	Both	Probability of entering Old River at the head of Old River; = $1 - \psi_{A1}$
$\psi_{B2}$	Full	Probability of remaining in Old River at the head of Middle River; = $1 - \psi_{C2}$
$\psi_{C2}$	Full	Probability of entering Middle River at the head of Middle River; = $1 - \psi_{B2}$
$\psi_{F2}$	Both	Probability of entering Turner Cut at the junction with the San Joaquin River; = $1 - \psi_{A2}$
$\psi_{G1(A)}$	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.

Parameter	Release Occasion		Population Estimate
	1	2	
$S_{A2}$	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)
$\psi_{A1}$	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
$\psi_{A2}$	0.89 (0.03)	0.84 (0.11)	0.89 (0.03)
$\psi_{B1}$	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
$\psi_{F2}$	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		Population Estimate
	1	2	
P <sub>B2a</sub>	1	[pooled]	1
P <sub>B2b</sub>	0.83 (0.15)	[pooled]	1.00 (< 0.01)
P <sub>B2</sub>	1	1	1
P <sub>F1a</sub>	0.88 (0.12)	1	0.90 (0.09)
P <sub>F1b</sub>	0.78 (0.14)	1	0.82 (0.12)
P <sub>F1</sub>	0.97 (0.03)	1	0.98 (0.02)
P <sub>G1a</sub>	[pooled]	1	0.96 (0.04)
P <sub>G1b</sub>	[pooled]	1	0.92 (0.05)
P <sub>G1</sub>	0.93 (0.07)	1	1.00 (< 0.01)
P <sub>G2a</sub>	1		1
P <sub>G2b</sub>	1		1
P <sub>G2</sub>	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.

Parameter	Release Occasion		Population Estimate
	1	2	
$S_{A2}$	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)
$\psi_{A1}$	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
$\psi_{A2}$	0.88 (0.03)	0.86 (0.09)	0.88 (0.03)
$\psi_{B1}$	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
$\psi_{F2}$	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 <sub>B2a</sub>	1	[pooled]	1
P <sub>B2b</sub>	0.83 (0.15)	[pooled]	0.56 (0.17)
P <sub>B2</sub>	1	1	1
P <sub>F1a</sub>	0.86 (0.13)	1	0.89 (0.10)
P <sub>F1b</sub>	0.60 (0.15)	1	0.67 (0.14)
P <sub>F1</sub>	0.94 (0.06)	1	0.96 (0.04)
P <sub>G1a</sub>	[pooled]	1	0.96 (0.04)
P <sub>G1b</sub>	[pooled]	1	0.92 (0.05)
P <sub>G1</sub>	0.93 (0.07)	1	1.00 (< 0.01)
P <sub>G2a</sub>	1		1
P <sub>G2b</sub>	1		1
P <sub>G2</sub>	1		1

## Appendix B. Errata from 2011 VAMP Report

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

**Recovery of Coded-Wire Tags from  
Chinook Salmon in California's Central Valley  
Escapement and Ocean Harvest in 2010**

**Brett Kormos<sup>1</sup>, Melodie Palmer-Zwahlen<sup>1</sup> and Alice Low<sup>2</sup>**

**California Department of Fish and Game**

**Fisheries Branch Administrative Report 2012-02**

**March 2012**

<sup>1</sup> Marine Region, Ocean Salmon Project, 5355 Skylane Blvd Suite B, Santa Rosa, CA 95403

<sup>2</sup> Fisheries Branch, Anadromous Fisheries, 830 S Street, Sacramento, CA 95811

## NOTE TO READERS

*Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2010* presents important data for the improvement of Central Valley salmon management. Until 2007, only experimental releases of fall-run Chinook salmon from Central Valley hatcheries were marked and coded-wire tagged (low, inconsistent numbers), resulting in a lack of data for harvest management, evaluation of hatchery rearing and release practices, hatchery impacts to natural-origin fish, and the success of habitat improvement programs.

The Central Valley Constant Fractional Marking Program (CFM) was initiated in 2007 to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed in the Central Valley. Beginning with Brood Year 2006 fall-run Chinook, the program has marked and coded-wire tagged a minimum of 25 percent of releases from the Central Valley hatcheries each year (Buttars 2007, 2008, 2009, 2010). The program is a cooperative effort of the California Department of Fish and Game (DFG), the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service (FWS), the East Bay Municipal Utilities District (EBMUD), and the Pacific States Marine Fisheries Commission (PSMFC).

In 2010, almost 27,000 Code Wire Tags were recovered from ad-clipped Chinook sampled in Central Valley natural area spawning surveys, at Central Valley hatcheries, Central Valley river creel surveys, and California commercial and recreational ocean fisheries. Almost all of the fall run Chinook Code Wire Tags recovered in the Central Valley were tagged as part of the CFM program, since most Central Valley fish return at ages two, three, or four, and age five Chinook made up a very small fraction (0.01%) of the total Central Valley fall escapement in 2010.

This report evaluates the 2010 Central Valley fall, spring, and late fall runs Chinook Code Wire Tags recovery data in accordance with program objectives. In particular, this report attempts to answer the following questions with this first full year of recovery data from the CFM program:

- What are the proportions of hatchery and natural-origin fish in spawning returns to Central Valley hatcheries and natural areas, and in ocean harvest?
- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Straits?
- What are the relative recovery rates for fish acclimated in net pens and released in the bay compared to salmon released directly into the waters of the Carquinez Straits?
- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

As with all of its products, Fisheries Branch is interested in comments on the utility of this document, particularly regarding its application to monitoring and management decision

processes. Therefore, we encourage you to provide us with your comments. Comments should be directed to Ms. Alice Low, Fisheries Branch, 830 S Street, Sacramento, CA 95814, (916) 323-9583, [alow@dfg.ca.gov](mailto:alow@dfg.ca.gov).



Stafford Lehr  
Chief, Fisheries Branch

## Introduction

Each year, approximately 32 million fall-run Chinook salmon are produced at five hatcheries in California's Central Valley (CV): Coleman National Fish Hatchery (CNFH), Feather River Hatchery (FRH), Nimbus Fish Hatchery (NFH), Mokelumne River Hatchery (MOK), and Merced River Fish Facility (MER). Production from these hatcheries contributes to major sport and commercial fisheries in ocean and inland areas. Prior to 2007, only small experimental releases (generally <100,000 fish) of CV fall-run Chinook were consistently released with microscopic ( $\leq 1$  mm) coded-wire tags (CWT) inserted in their snouts. Each CWT contains a binary or alpha-numeric code that identifies a specific release group of salmon (e.g., agency, species, run, brood year, hatchery or wild stock, release size, release date(s), release location(s), number tagged and untagged). Any CV salmon containing a CWT is also externally marked with a clipped adipose fin (ad-clipped) to allow for visual identification. Although FRH did mark and tag a portion of their fall-run Chinook during 2000 through 2006, tagging rates were not consistent or representative of the 6-8 million fish produced annually by FRH. Almost all of the fall-run Chinook production releases at the other CV hatcheries were untagged during this time.

In 2004, the CALFED Ecosystem Restoration Program (ERP) funded a study to design a constant fractional marking and coded-wire tagging program for CV fall-run Chinook production at all CV hatcheries. The primary goal of this program was to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed throughout the CV. The study recommended the implementation of a system-wide marking and tagging program for production releases. Planning studies indicated an optimum marking and tagging rate of 25% for all CV fall-run Chinook production releases (Hicks et al. 2005).

Beginning with brood year 2006, at least 25% of fall-run Chinook production releases at CNFH (12-13 million), FRH (9-10 million), NFH (5-6 million), and MOK (4-5 million) have been marked and tagged each spring-run (Buttars 2007, 2008, 2009, 2010). This Constant Fractional Marking (CFM) program is a cooperative effort of the California Department of Fish and Game (DFG), the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service (FWS), the East Bay Municipal Utilities District (EBMUD), and the Pacific States Marine Fisheries Commission (PSMFC).

In addition, 100% of the fall-run Chinook produced at the MER (approximately 50,000-300,000 annually) are marked and coded-wire tagged. Almost 100% of the spring-run Chinook reared at FRH and the late fall-run Chinook reared at CNFH have also been marked and coded-wire tagged. It should be noted that due to their extremely low production numbers, MOK marked and tagged 100% of their fall-run Chinook releases for brood years 2008 and 2009.

During 2010, almost 27,000 CWTs were recovered from ad-clipped Chinook sampled in CV natural area spawning surveys, at CV hatcheries, in CV river creel surveys, and in California ocean commercial and recreational fisheries. Almost all of the fall-run Chinook CWTs recovered in the CV were tagged as part of the CFM program since most CV fish return at ages two, three, or four. Age five Chinook made up a very small fraction (0.01%) of the total CV fall-run escapement in 2010. This report evaluates the 2010 CV fall, spring, and late fall runs Chinook CWT recovery data in



accordance with program objectives. In particular, this report attempts to answer the following questions with this first essentially complete year of recovery data:

- What are the proportions of hatchery and natural-origin fish in spawning returns to CV hatcheries and natural areas, and in ocean harvest? Of the hatchery proportions, what proportions originated from in-basin versus out-of-basin CWT recoveries?
- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Straits? The latter includes salmon acclimated in net pens that are pulled for several hours into San Pablo Bay before fish are released.
- What are the relative recovery rates for fish acclimated in net pens and released in the bay versus salmon released directly into the waters of the Carquinez Straits?
- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

## **Data and Methods**

### **Inland Escapement Monitoring**

During 2010, monitoring of Chinook escapement occurred at all five salmon hatcheries and on major rivers and tributaries throughout the CV. In addition, creel surveys were conducted on river fisheries in the Feather, American, and Sacramento River basins. Returning salmon were counted and 100% sampled at CV hatcheries while sample rates and methods (e.g., carcass surveys, weir counts, redd counts) varied among natural spawner surveys (Table 1).

Approximately 26,500 ad-clipped salmon were observed and 25,700 heads collected by various CV projects. Monitoring agencies include DFG, DWR, EBMUD, FWS, and PSMFC. Most heads were processed by DFG at the Santa Rosa CWT lab (15,839 heads) and by FWS staff at CNFH (9,531 heads). Remaining heads were processed by individual projects and their data submitted to the Santa Rosa CWT Lab. Almost 97% (24,838) of these heads contained valid CWTs, 2% of heads had shed their CWTs prior to processing, and 1% contained CWTs that either were lost during processing or too damaged to read.

Total escapement estimates and the number of salmon sampled for ad-clips in this report were provided by individual CV projects or hatcheries. These data, along with their respective CWT recovery data, were uploaded to the Regional Mark Processing Center (RMPC) and are readily accessible at [www.rmhc.org](http://www.rmhc.org).

### **Ocean Harvest Monitoring**

Since 1962, the DFG's Ocean Salmon Project (OSP) has monitored California's ocean salmon fisheries at approximately 20 ports between Point Conception and the California-Oregon border. The goal of OSP is to sample at least 20% of all Chinook landed and to collect the heads from all ad-clipped salmon observed during monitoring. In 2010, the seasons for California sport and commercial ocean salmon fisheries were relatively constrained (Table 2) to protect both

Sacramento River fall-run Chinook and Klamath River fall-run Chinook. Field staff sampled 13,344 salmon and collected 2,211 heads that were processed by the Santa Rosa CWT lab. About 90% (1,987) of these heads contained valid CWTs, 10% were missing CWTs and <1% contained CWTs that were too damaged to read. Although it is generally agreed that CWTs missing from inland head recoveries is the result of salmon “shedding” these tags prior to release, this can not be assumed for heads recovered from mixed-stock ocean fisheries. Oregon and Washington hatcheries have recently begun to “mass-mark” (i.e., ad-clipped salmon that do not contain a CWT) Chinook to support small mark-selective fisheries in the northwest. During the last several years, OSP has noticed a gradual increase in the number of ocean heads collected that do not contain CWTs, especially in California’s northern ports, and assume that this is due to the increased production of mass-marked salmon in Oregon and Washington.

### **CWT Data Analysis**

A “Master” release database of CWT codes was created to determine species, brood year, run, stock origin (hatchery or natural), release site, release date(s), number of salmon CWT tagged, total number of salmon released and any other pertinent release information (e.g., trucked, net pen acclimation, disease) for all 2010 CWT recoveries. All west coast CWT release data for broods 2006 through 2009 were downloaded from the RMPC. Approximately 105 million CV Chinook were released for these five brood years, of which, 37 million fish were marked and tagged utilizing 500 unique CWT codes. Although a few natural origin salmon are trapped, marked, and tagged each year, salmon produced by hatcheries make up more than 95% of all releases. In 2010, there were 319 individual CWT codes recovered in the CV, primarily from age two-, three-, and four-year old Chinook. The CWT master file was updated with any additional information obtained for these CV Chinook releases (e.g., number of untagged salmon associated with 2008 fall-run CNFH production CWT releases) and the production factor calculated for each CWT code. The production factor,  $F_{\text{prod}}$ , is the total number of fish released (tagged and untagged) represented by each CWT recovery.  $F_{\text{prod}}$  was calculated for each CWT code and is defined as,

$$F_{\text{prod}} = (\text{Ad.CWT} + \text{Ad.noCWT} + \text{noAd.CWT} + \text{noAd.noCWT}) / \text{Ad.CWT} ,$$

where Ad.CWT is the number of fish released with ad-clips and CWTs, Ad.noCWT is the number of fish released with ad-clips but without CWTs (i.e., shed tags), noAd.CWT is the number of fish released without ad-clips but with CWTs, and noAd.noCWT is the number of fish released without ad-clips and without CWTs.  $F_{\text{prod}}$  allows expansion to total hatchery production from observed recoveries of CV CWTs.

For this analysis, each CV CWT release was further classified into “release types” based on the following criteria: run, stock, hatchery or natural, production or experimental, release location, and holding strategy. All CV CWT codes were assigned by brood year into one of 16 fall-run Chinook release types, 4 spring-run Chinook release types, or 2 late fall-run Chinook release types:

### Sacramento River Basin Fall-run Chinook Release Types

- CFHFe Coleman National Fish Hatchery fall-run experimental releases
- CFHFh Coleman National Fish Hatchery fall-run in-basin (at hatchery) releases
- CFHFn Coleman National Fish Hatchery fall-run net pen releases

FRHFe Feather River Hatchery fall-run experimental releases  
 FRHF<sub>n</sub> Feather River Hatchery fall-run net pen releases  
 FRHF<sub>t</sub> Feather River Hatchery fall-run trucked releases (no net pen acclimation)  
 FRHF<sub>tn</sub> Feather River Hatchery fall-run Tiburon net pen releases (held 3-4 months; released in fall)  
 FeaFw Feather River fall-run wild  
 YubFw Yuba River fall-run wild  
 NIMF In-basin releases  
 NIMF<sub>n</sub> Nimbus Fish Hatchery fall-run net pen releases  
 NIMF<sub>tib</sub> Nimbus Fish Hatchery fall-run Tiburon net pen releases (held 3-4 months; released in fall)

---

San Joaquin River Basin Fall-run Chinook Release Types

MOKF Mokelumne River Hatchery fall-run in-basin releases  
 MOKF<sub>n</sub> Mokelumne River Hatchery fall-run net pen releases  
 MOKF<sub>t</sub> Mokelumne River Hatchery fall-run trucked releases (no net pen acclimation)  
 MokFw Mokelumne River fall-run wild  
 MERF Merced River Fish Facility fall-run releases (primarily in-basin)

---

Central Valley Spring-run Chinook Release Types

FRHS Feather River Hatchery spring-run in-basin releases  
 FRHS<sub>n</sub> Feather River Hatchery spring-run net pen releases  
 FRHS<sub>t</sub> Feather River Hatchery spring-run trucked releases (no net pen acclimation)  
 YubSw Yuba River spring-run wild

---

Central Valley Late fall-run Chinook Release Types

CFHLe Coleman National Fish Hatchery late fall-run experimental releases  
 CFHLh Coleman National Fish Hatchery late fall-run in-basin (at hatchery) releases

It should be noted that not all release types occurred every brood year and release sites sometimes varied within a given release type (Table 3). There were also several problem CWT releases where stock origin did not match hatchery origin (e.g., American River fall-run Chinook salmon raised at MOK), stocks or runs were mixed prior to CWT tagging and released utilizing various strategies (e.g., American and Mokelumne fall-run Chinook accidentally mixed and tagged together at MOK, FRH fall-run and spring-run Chinook spawned together and released as experimental “hybrid” salmon for Delta studies), or a percentage of the salmon trucked for net pen acclimation were actually released directly into the waters of the Carquinez Strait.

To estimate the total escapement (or harvest) associated with each CWT recovery, each tag recovery was expanded by its respective  $F_{\text{prod}}$  and sample expansion factor,  $F_{\text{samp}}$ , which is defined as,

$$F_{\text{samp}} = 1 / (f_e \times f_a \times f_d),$$

where  $f_e$  is the fraction of the total salmon escapement sampled and examined for ad-clipped fish,  $f_a$  is the fraction of heads from ad-clipped salmon collected and processed, and  $f_d$  is the fraction of observed CWTs that were successfully decoded (Tables 4 and 5). A few heads were collected opportunistically during redd counts and snorkel surveys but are not included in this analysis since they are not representative of the escapement.

To help delineate between raw CWT recoveries, CWT recoveries expanded for production, CWTs expanded for sampling, and CWTs expanded for production and sampling, the following nomenclature will be used:

- CWT = Raw count CWT recoveries
- CWT<sub>prod</sub> = CWT recoveries expanded only by their respective production factor, F<sub>prod</sub>
- CWT<sub>samp</sub> = CWT recoveries expanded only by their respective sample expansion factor, F<sub>samp</sub>
- CWT<sub>total</sub> = CWT recoveries expanded by both F<sub>prod</sub> and F<sub>samp</sub>

**Determining hatchery and natural-origin proportions in CV escapement**

To determine the contribution of hatchery and natural-origin Chinook for each natural-area escapement survey or hatchery, all hatchery CWT<sub>total</sub> were summed to produce the total number of hatchery fish. The contribution of natural-origin fish was then determined by subtracting the total number of hatchery fish from the total escapement estimate, as follows:

$$\text{Estimate of natural-origin Chinook} = \text{Total Escapement Estimate} - \sum_{i=1}^m \text{CWT}_{total,i}$$

where m = total number of CWT release groups identified in an escapement survey or hatchery.

**Determining recovery rates of various release types in CV escapement and ocean harvest**

To determine the relative CV recovery rate, R<sub>cwt</sub>, of each unique CWT release group (i.e., code), all recoveries were expanded by their location-specific F<sub>samp</sub>, summed over all recovery locations, and then divided by the total number of fish tagged and released with this CWT. Since expanded recoveries for several individual CWT groups were less than 0.001% of the numbers released, recovery rates are reported in recoveries per 100,000 CWT salmon released, as follows:

$$R_{cwt} = \sum_{j=1}^l \text{CWT}_{samp,j} \text{ recoveries} / (\text{CWT release group size} / 100,000),$$

where j (=1,2,3,,l) denotes recovery location.

Data from all CWT release groups belonging to the same brood year and release type were combined and an overall release type-specific CV recovery rate, R<sub>type</sub>, was calculated as:

$$R_{type} = \sum_{j=1}^l \sum_{k=1}^n \text{CWT}_{samp,j,k} / \left( \sum_{k=1}^n \text{release group size of CWT } k / 100,000 \right),$$

where: k (= 1,2,3,,n) denotes release group and j (=1,2,3,,l) denotes recovery location.

**Determining stray proportions of various release groups in CV escapement**

Basin of origin is defined here as the drainage of any major river as it pertains to the geographic region of the CV where a hatchery is located. For this report the CV was segregated into five primary hatchery basins: Battle Creek (including the mainstem of the upper Sacramento River), Feather River (including the Yuba River), American River, Mokelumne River, and the Merced River. Hatchery-origin Chinook returning to streams not included in these five primary basins were considered to be strays. Through discussion with regional biologists it was determined that CNFH stocks are often considered to be analogous to Chinook that originate from the mainstem of the upper Sacramento River and thus are not considered to be strays. Alternatively, FRH stocks are often considered to be strays when they return to the Yuba River, a major tributary in

the basin. As a result of differing opinions of what constitutes a stray throughout the CV any CWTs recovered outside of these defined basins of origin based on their reported stock or hatchery were considered strays. Further evaluation of these definitions is warranted as future CFM recovery data become available.

To determine the CV stray proportion,  $S_{cwt}$ , for each CWT code, the sum of all  $CWT_{samp}$  recoveries collected out of the basin of origin was divided by total CV  $CWT_{samp}$  recoveries for that release group, as follows:

$$S_{cwt} = \sum_{p=1}^o CWT_{samp,p} (\text{out-of-basin locations}) / \sum_{p=1}^q CWT_{samp,p} (\text{all CV locations}),$$

where  $p$  denotes recovery location,  $o$  denotes the number of out-of-basin recovery locations, and  $q$  denotes the total number of recovery locations.

Data from all CWT releases belonging to the same brood year and release group were then combined and release type-specific CV stray proportion,  $S_{type}$ , was calculated as:

$$S_{type} = \sum_{p=1}^o \sum_{k=1}^n CWT_{samp,p,k} (\text{out-of-basin}) / \sum_{p=1}^o \sum_{k=1}^n CWT_{samp,p,k} (\text{all CV locations})$$

## Results

### General Overview of 2010 CV inland recoveries and California ocean harvest

All but two of the 24,838 valid CWTs recovered in the CV during 2010 were CV Chinook releases; most CWTs originated from brood year 2006 through 2008 releases (Table 6). More than 84% of all expanded CWT recoveries were fall-run Chinook, followed by spring-run (10%) and late fall-run (6%) releases. No Sacramento River winter-run Chinook CWTs were recovered. The majority of fall-run CWTs were age-3 (67%) and age-2 (31%) fish. It should be noted that a few age-1 fall-run CWTs were also sampled which is relatively rare in the CV. Age-3 (92%) fish dominated the spring-run return while age-4 (59%), age-3 (20%), and age-5 (16%) made up most of the late fall-run return. A few age-6 late fall-run fish were also recovered.

All but 141 of the 1,987 valid CWT recoveries from the California ocean harvest in 2010 were CV Chinook releases; most CWTs were brood year 2006 through 2008 releases (Table 7). Approximately 62% of all expanded CWTs in the ocean harvest were fall-run Chinook, followed by late fall-run (30%), spring-run (3%), and winter-run (<1%). The majority of fall-run Chinook CWTs were age-3 (86%) and age-2 (12%) fish. Age-3 (93%) fish dominated the spring-run Chinook harvest while age-4 (62%), age-3 (21%), and age-5 (17%) made up most of the late-fall Chinook catch. A few age-6 late fall-run Chinook were also caught. The remaining 5% of ocean CWT recoveries originated from non-CV rivers, including the Klamath, Trinity, Smith, Chetco and Columbia rivers; most were age-3 (51%) and age-4 (49%) fish.

### 1. Proportion of hatchery- and natural-origin fish in CV escapement

The proportion of hatchery-origin fish on the natural area spawning grounds varied throughout the CV and by run. The lowest hatchery proportion (1%) was observed in the Butte Creek spring-run

Chinook mark-recapture survey while the highest proportion (78%) was observed in the Feather River fall/spring-run Chinook mark-recapture survey (Figure 1).

The hatchery proportion of fall-run Chinook returning to CV hatcheries ranged from 79% to 95% (Figure 2). The spring-run Chinook return to FRH was 82% hatchery-origin fish whereas the late fall-run return to CNFH was almost 100% hatchery-origin fish.

Overall, there were 23 individual CWT release types contributing to CV escapement in 2010. To facilitate the breakout of the hatchery proportion by stock and release strategy, all release types from the same hatchery/basin were given the same color scheme (Figure 3) in Figures 4 through 9. All net pen releases contain black dots while most trucked, experimental, or Tiburon net pen releases are designated by black stripes when possible (i.e., release types did not overlap for a particular basin).

### **Upper Sacramento River Basin**

Ten escapement surveys were conducted in the Upper Sacramento River Basin: fall and late fall runs Chinook counts at CNFH, fall and late fall runs Chinook mark-recapture surveys in the mainstem Sacramento River, a fall-run Chinook mark-recapture survey in Clear Creek, and spring-run and fall-run Chinook mark-recapture surveys in Butte Creek. Spring and fall runs Chinook redd count surveys were conducted in Mill Creek and a spring-run Chinook snorkel survey (maximum count) was conducted in Deer Creek. Representative sampling for ad-clipped salmon did not occur in Mill and Deer Creek. Returns to CNFH were predominantly hatchery-origin fish released from this facility while escapement into natural areas was primarily natural-origin fish (Figures 4 and 5):

- Fall-run returns at CNFH were 89% hatchery-origin fish (96% CFHFh)
- Fall-run spawners in the mainstem Sacramento River were 20% hatchery-origin fish (48% FRHF<sub>n</sub>, 19% CFHF<sub>h</sub>, 17% FRHS<sub>n</sub>)
- Fall-run spawners in Clear Creek were 4% hatchery-origin fish (45% FRHF<sub>n</sub>, 32% CFHF<sub>h</sub>)
- Late fall-run returns at CNFH were almost 100% hatchery-origin fish (99% CFHL<sub>h</sub>)
- Late fall-run spawners in the mainstem Sacramento River were 6% hatchery-origin fish (73% CFHL<sub>h</sub>)
- Spring-run spawners in Butte Creek were 1% hatchery-origin fish (63% FRHS<sub>n</sub>)
- Fall-run spawners in Butte Creek were 11% hatchery-origin fish (89% FRHF<sub>n</sub>)

### **Feather River Basin**

Four escapement surveys were conducted in the Feather River Basin: spring and fall runs Chinook counts at FRH, a combined fall/spring run Chinook mark-recapture survey in the Feather River, and a combined fall/spring run Chinook mark-recapture survey in the Yuba River. Spring and fall runs Chinook returns to FRH and in the natural areas were predominantly of hatchery-origin (Figure 6):

- Spring-run returns at FRH were 82% hatchery-origin (50% FRHS, 39% FRHS<sub>n</sub>)
- Fall-run returns at FRH were 95% hatchery-origin (87% FRHF<sub>n</sub>)
- Fall/spring-run spawners in the Feather River were 78% hatchery-origin (88% FRHF<sub>n</sub>)
- Fall/spring-run spawners in the Yuba River were 71% hatchery-origin (48% FRHF<sub>n</sub>, 22% FRHS, 21% FRHS<sub>n</sub>)

### **American River Basin**

Three escapement surveys were conducted in the American River Basin: fall-run Chinook counts at NFH, a fall-run Chinook mark-recapture survey on the American River and a single late fall-run Chinook carcass count on the American River. In addition, dead salmon were recovered from the NFH weir, which is located just upstream from the hatchery and was installed on September 15<sup>th</sup> to force returning salmon into NFH. Salmon that migrated upstream beyond the hatchery prior to installation of the weir were trapped in the upstream area. Many of those salmon washed back onto the weir upon death. There is minimal spawning habitat above the weir. Spawner returns to natural areas and those from the NFH weir fish were predominantly of natural-origin while returns to NFH were predominantly of hatchery-origin (Figure 7):

- Fall-run returns to NFH were 79% hatchery-origin (81% NIMFn)
- Fall-run spawners in the American River were 32% hatchery-origin (48% NIMFn, 24% FRHF<sub>n</sub>, 19% CFHF<sub>n</sub>)
- Late fall-run spawners in the American River were 24% hatchery-origin (97% CFHLe)
- Salmon recovered on the NFH Weir were 38% hatchery-origin (40% NIMFn, 36% FRHF<sub>n</sub>)

### **Mokelumne River Basin**

Three escapement surveys were conducted in the Mokelumne River Basin: fall-run Chinook counts at MOK, a video weir count at Woodbridge Dam of all fall-run Chinook escapement into Mokelumne River, and a daily collection of salmon carcasses from the MOK weir, which is installed to prevent salmon from bypassing the MOK fish ladder. This barrier was originally installed on October 8<sup>th</sup> but removed on October 15<sup>th</sup> to allow for increased water releases from Camanche Reservoir designed to produce attraction flows for upstream migrating Chinook. The weir was then reinstalled on October 19<sup>th</sup> when flows returned to a rate that would not damage the weir. Any salmon above the weir when it was installed were trapped and many washed back onto the weir after their death.

All adult Chinook salmon migrating upstream into the Mokelumne River to spawn were counted by the video fish counting device operated by EBMUD at Woodbridge Dam. These counts also included the number of ad-clipped salmon entering the system. By subtracting the 5,520 Chinook that returned to MOK and that were collected on the MOK weir from the total video count of 7,196 Chinook, it was assumed that the remaining 1,676 Chinook remained in the Mokelumne River. Utilizing the same logic, it was also assumed that there were 820 ad-clipped Chinook remaining in the river since only 2,866 of the 3,686 ad-clipped Chinook counted in the video monitoring were recovered at MOK and on the weir. After reviewing the CWT codes recovered from 59 heads collected during sporadic surveys on the Mokelumne River, we found that the proportions of the 12 individual CWT codes collected were very similar to the proportion of these codes recovered at MOK and on the weir; however there were 45 additional CWT codes recovered at the hatchery and weir. Because 100% of Chinook salmon observed at MOK and the weir were sampled, we felt that the MOK recoveries best represented the entire run and thus expanded the estimated 820 ad-clips in the Mokelumne River based on their proportions, including heads that lacked a CWT (approx 1.5%). This approach is based on the methodology used by the Klamath River Technical Team (KRTT) to determine the hatchery composition of fall-run Chinook above Willow Creek Weir on the Trinity River (e.g., KRTT 2011).

Spawner returns to the Mokelumne River Basin were dominated by hatchery-origin fish (Figure 8):

- Fall-run returns at MOK were 90% hatchery-origin (34% MOKFt, 18% MOKFn, 32% NIMFn)
- Salmon carcasses recovered on the MOK weir were 74% hatchery-origin (50% MOKFt, 18% MOKFn, 27% NIMFn)
- Fall-run spawners in the Mokelumne River were 73% hatchery-origin (50% MOKFt, 18% MOKFn, 31% NIMFn)

### **San Joaquin River Basin Tributaries**

Four additional escapement surveys were conducted in tributaries of the San Joaquin River: fall-run Chinook counts at MER, as well as fall-run Chinook mark-recapture surveys conducted on the Stanislaus, Tuolumne, and Merced rivers. Fall-run Chinook returns to the Merced River were dominated by hatchery-origin fish while the Stanislaus and Tuolumne rivers were almost equally split between hatchery- and natural-origin spawners (Figure 9):

- Fall-run returns at MER were 79% hatchery-origin (37% MOKFt, 18% NIMFn, 12% NIMFtib, 11% CFHFn, 10% MERF)
- Fall-run spawners in the Merced River were 78% hatchery-origin (31% NIMFn, 20% FRHFn, 16% MOKFn, 14% MOKFt)
- Fall-run spawners in the Stanislaus River were 50% hatchery-origin (31% NIMFn, 26% MOKFn, 23% MOKFt)
- Fall-run spawners in the Tuolumne River were 49% hatchery-origin (29% CFHFn, 23% MERF, 19% FRHFn)

## **2. Relative recovery and stray proportions for hatchery-origin Chinook released in-basin versus hatchery-origin Chinook trucked and released into the waters of the Carquinez Strait (includes Chinook salmon acclimated in net pens and released into San Pablo Bay).**

Release strategies vary widely among hatcheries from year to year. This variability has often been in response to fluctuating abundances of certain stocks or differing policies among mitigating agencies with respect to “best” release practices. Lack of consistency and “problem releases” among CV hatcheries has limited the number of release groups available for direct comparison of differing release strategies. For these reasons, there are only six release groups recovered in 2010 that allows in-basin releases to be compared directly to trucked/net pen releases.

Table 8 summarizes the recovery rates  $R_{type}$  (in-basin, stray, and ocean) for all release groups with representative recoveries from the CV in 2010. Figures 10 and 11 provide a graphical representation of  $R_{type}$  for the Sacramento River fall-run Chinook and other CV stocks, respectively. In general, Chinook that were trucked and released directly into the waters of Carquinez Strait or acclimated in bay area net pens had higher relative recovery rates than their respective in-basin releases. These releases also had higher stray proportions than their paired in-basin counterparts.

### **Coleman National Fish Hatchery Releases - Fall-run Chinook Broods 2007 and 2008**

For brood 2008 CNFH fall-run Chinook releases, the CV age-2 recovery rate for net pen CNFHn releases (161.5) was 2.3 times greater than in-basin CFHFh releases (70.9). However, while



CNFHh releases were only recovered in-basin, the proportion of CFHFh recoveries out-of-basin was very high at 89%.

There were three different CNFH release types for brood 2007 fall-run Chinook. The CV age-3 recovery rate for experimental CFHFe releases (164.0) was more than 3.0 times greater than in-basin CFHFh (54.6) and net pen CFHFh (41.2) releases. Less than 1% of CFHFh were recovered out-of-basin compared to straying proportions of 98% and 25% for CFHFh and CFHFe, respectively.

#### **Feather River Hatchery Releases – Spring-run Chinook Broods 2006, 2007, and 2008**

For brood 2008 FRH spring-run releases, the CV age-2 recovery rate for net pen FRHSn releases (32.2) was slightly higher than in-basin FRHS (28.0) releases. Approximately 10% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2007 FRH spring-run releases, the CV age-3 recovery rate for net pen FRHSn releases (440.4) was 1.3 times higher than in-basin FRHS (348.4) releases. Approximately 15% of age-3 FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2006 FRH spring-run releases, the CV age-4 recovery rate for net pen FRHSt releases (19.4) was 3.0 times higher than in-basin FRHS (6.4) releases. Approximately 18% of both FRHSt and FRHS CWTs were recovered out-of-basin.

#### **Nimbus Fish Hatchery Release – Fall-run Chinook Brood 2008**

For brood 2008 NFH fall-run releases, the CV age-2 recovery rate for net pen NIMFn releases (86.9) was 2.6 times greater than in-basin NIMF releases (33.5). However, while NIMF releases were only recovered in-basin, the proportion of NIMFn recoveries out-of-basin was very low at 6%.

#### **Feather River Hatchery Releases – Fall-run Chinook Brood 2008**

Although FRH did not have any in-basin releases for broods 2006, 2007 or 2008, they did have experimental FRHFe, net pen FRHFh and trucked FRHFt releases that can be compared.

For brood 2008 FRH fall-run releases, the CV age-2 recovery rate for experimental FRHFe releases (135.6) was slightly higher than net pen FRHFh (117.6) releases. The FRHFe releases were actually “hybrid” fish (FRH fall-run x FRH spring-run Chinook). Approximately 5% of both FRHFe and FRHFh were recovered out-of-basin.

For brood 2006 FRH fall-run releases, the CV age-4 recovery rate for net pen FRHFh releases (17.2) was 3.1 times higher than experimental FRHFe (5.6) releases. Recoveries of trucked FRHFt (0.7) releases were too low for comparison purposes. Approximately 10% of FRHFh and 9% of FRHFe releases were recovered out-of-basin. It should be noted that many of the FRHFh releases had some fish released directly into the bay so it is impossible to separate true net pen releases from trucked/direct bay ones.

### **3. Relative CV recovery and stray rates of bay releases acclimated in net pens and released directly without acclimatization**

The same issues related to release practices that limited the available recovery comparisons in the previous section also limited the comparison of net pen releases and direct releases in the Carquinez Strait area. As a result there is only one release type comparison possible.

#### **Feather River Hatchery Release – Fall-run Chinook Brood 2007**

For brood 2007 FRH fall-run releases, the CV age-3 recovery rate for net pen FRHF<sub>n</sub> releases (478.4) was 3.9 times higher than trucked/direct bay FRHF<sub>t</sub> (122.9) releases. Approximately 19% of FRHF<sub>t</sub> fish were recovered out-of-basin compared to 8% of FRHF<sub>n</sub> releases.

### **4. Relative recovery rate and contribution of CV release groups to ocean harvest**

The relative recovery rate of CV hatchery releases in the 2010 ocean salmon fisheries (sport and commercial combined) varied by age and release group (Figure 12). Of the 4,755 CV CWT<sub>sample</sub> collected in the fisheries, most were age-3 (84%), followed by age-2 (12%), age-4 (4%) and age-5 (<1%) fish.

The majority of age-2 CV Chinook harvested were in the sport fishery due to its lower size limit (20"-24" total length) compared to the commercial fishery (27" total length). For all age-2 CV releases, trucked MOKF<sub>t</sub> (42.7) had the highest recovery rate per 100,000 fish released, followed by net pen CFHF<sub>n</sub> (23.6), San Joaquin basin MERF (11.3), and net pen FRHF<sub>n</sub> (7.9) releases (Table 8).

Net pen releases had the highest recovery rates for age-3 CV fall and spring runs Chinook. The recovery rate for net pen FRHF<sub>n</sub> (81.2) was more than twice that of NIMF<sub>n</sub> (37.7) CFHF<sub>n</sub>, (32.1), FRHS<sub>n</sub> (29.4) and MOKF<sub>n</sub> (22.8). There were only in-basin releases of CV late fall-run CFHL<sub>h</sub> (24.4) for age-3 fish.

Relatively few age-4 or age-5 CWT recoveries were made compared to age-2 and age-3 CV fish. In-basin CV late fall-run Chinook CFHL<sub>h</sub> had the highest recovery rate for age-4 (16.0) and age-5 (0.6) CV releases.

#### **Contribution of CV release groups to sport ocean harvest**

In 2010, anglers harvested an estimated 14,697 Chinook in the California sport ocean salmon fishery. Based on the expanded CWT<sub>total</sub> collected in the fishery, including non-CV Chinook release types, hatchery-origin fish contributed 31%-63% of the total harvest, depending on major port area (Figure 13). Of the hatchery-origin fish, fall-run net pen FRHF<sub>n</sub> releases dominated the sport catch in all port areas: Monterey (43%), San Francisco (38%), Fort Bragg (22%), and Eureka/Crescent City (27%). Other CV releases contributing to all sport fisheries were net pen NIMF<sub>n</sub> (4-8%), in-basin CFHF<sub>h</sub> (5-10%) and net pen CFHF<sub>n</sub> (3-5%); however there were no recoveries of CFHF<sub>h</sub> and CFHF<sub>n</sub> in the Eureka/Crescent City port area. Non-CV stocks also made up a higher proportion (3%) in this northern area.

#### **Contribution of CV release groups to commercial ocean harvest**

Commercial trollers landed an estimated 15,098 Chinook in the California commercial ocean salmon fishery; most salmon (83%) were caught in the Fort Bragg port area. Based on the

expanded CWT<sub>total</sub> collected in the fishery, hatchery-origin fish contributed 22%-74% of the total harvest, depending on major port area (Figure 14). Of the hatchery release types, fall-run net pen FRHF<sub>n</sub> dominated the commercial catch in all port areas: Monterey (50%), San Francisco (14%), and Fort Bragg (22%). The Eureka / Crescent City port area was completely closed to commercial fishing in 2010. Other CV releases contributing to the California commercial fishery were net pen NIMF<sub>n</sub> (3%-10%) and in-basin CFHF<sub>h</sub> (3%-8%). In addition, non-CV stocks contributed at a higher overall proportion in the commercial fishery (6%) than in the sport fishery (1%), especially in Fort Bragg (7%) where most of the commercial season occurred in 2010.

## Discussion

Estimates of hatchery contributions that are presented in this report should be viewed simply as a “single year (2010) snapshot” of CV Chinook escapement and the California ocean harvest. This was the first year that the majority of all CWT recoveries from CV releases were representatively marked and tagged at a minimum 25% level. Although there were definite differences observed in recovery rates and straying proportions among runs, brood years, and CV release groups, this is just the first step in many needed to statistically analyze the contribution of hatchery and natural-origin salmon to natural areas throughout the CV, evaluate hatchery release strategies, improve California ocean and river salmon fisheries management, and determine if other goals of the CFM program are being met. It is also important to note that most of the CV CWT release groups in this study were produced, released and/or recovered during a time when Sacramento River fall-run Chinook were at historically low levels. Thus these salmon were not susceptible to “normal” ocean or river salmon fisheries since these fisheries were either completely closed or very constrained during the last three years.

The effect of interannual variation in survival and year-class strength of both hatchery-origin and natural-origin stocks should be considered when evaluating the status of CV Chinook stocks. At this time neither year class strength or age structure of CV natural-origin Chinook are known. Scale-aging work done on 2006, 2007, and 2008 CV Chinook escapement by OSP has indicated that there may be different maturation rates for hatchery and natural-origin fish by stock and basin. It is premature to compare hatchery and natural-origin proportions without having complete brood- and/or stock-specific population estimates. While it may appear that total escapement by hatchery fish in the CV may exceed that of natural-origin fish in any given year, comparing age-specific total escapement (hatchery and natural) once broods complete their life cycle may indicate differences in hatchery and natural ratios for specific age groups and stocks. Such analyses may provide the basis for changing hatchery practices to better mimic wild population parameters. They may also further clarify the effects of specific environmental stressors unique to natural-origin fish and/or specific hatchery CWT release groups.

Strategies for CV fall-run production releases in any given year are often a result of two conflicting objectives. Increasing survival rates to allow for greater harvest and escapement often favors release strategies that bypass the Sacramento-San Joaquin Delta. Alternatively, in-basin release practices are aimed at maximizing homing rates back to the hatchery of origin to reduce impacts on natural stocks. It is impossible to make a thorough comparison of hatchery

release practices at this time due to the large variability that existed among CWT release types within the same CV hatchery broods examined in this study. Most release types included individual CWT codes that were released at numerous locations at different times and under various conditions (e.g., river water flows and temperatures, bay tidal flows for trucked and net pen releases). While some individual CWT codes were recovered at a relatively high rate, others within the same release type were not recovered at all. The recovery rate  $R_{cwt}$  for individual CWT codes should be examined on a release type basis and the release strategies (in-basin, trucked, net-pen acclimation) that produce the greatest resource value (i.e., highest recovery rate, lowest straying proportion) adopted for future release strategy evaluation. Coordinated and paired hatchery release types will allow for direct comparisons to be made between them and will enrich the available data set used for subsequent evaluation of the hatchery program in the future. The CDFG Fisheries Branch has performed some very preliminary statistical testing to evaluate the significance of differences noted between the performance of individual pairs of release types (Ferreira 2011).

Prior to the CFM program, the primary purpose of CV Chinook escapement monitoring was to provide basic status information (e.g., grilse and adult escapement counts) by individual stocks and basins for California hatchery and ocean harvest management needs. The marking, tagging, or collection of CV CWT fish was not a high priority. CV escapement monitoring has expanded to provide data for a broad range of management applications related to recovery planning for listed stocks. These applications include assessing recovery efforts, including habitat restoration work, improving ocean and river fisheries management, and evaluating CV salmon hatchery programs to ensure both mitigation and conservation goals are being met. To meet the needs of these various assessment efforts, a review of current methodologies being employed among CV inland escapement monitoring programs was undertaken by DFG in 2008. The goal of this review was to identify needed changes and/or additions to survey protocols that will ensure both statistically valid estimates of escapement and the collection of biological data, including CWTs and scales, needed for assessment efforts. In 2012, DFG completed the Central Valley Chinook Salmon Escapement Monitoring Plan that recommends methods for estimating escapement and collecting biological data necessary for improved stock assessment in the CV (Bergman et al. 2012). Survey modifications included changes in the current mark-recapture models being utilized, changes in sampling protocols to ensure representative sampling and proper accounting, and the use of counting devices in place of some mark-recapture programs. This monitoring plan is now being implemented among CV surveys to provide the basis for sound CV Chinook assessment and subsequent management. The OSP and DFG Fisheries Branch CWT laboratories in Santa Rosa and Sacramento respectively, have both been expanded and additional staff hired to process the 40,000-60,000 tagged Chinook expected to be recovered annually during CV escapement and California ocean salmon fisheries monitoring. The OSP lab has also expanded its scale-aging capability utilizing state-of-the-art digital imaging. If these data are going to be used in a timely manner to manage CV salmon production and ocean/river fisheries, all CWT data and stock-specific age composition of CV escapement will be needed by February each year.

The CV CFM program has been successful in marking and tagging the target numbers of salmon each year at each of the CV hatcheries, and has just begun recovering CWTs in a statistically valid manner throughout the CV. The results from this program, in conjunction with future

aging work will provide the best opportunity to manage CV Chinook salmon based on scientifically defensible data. The CFM program should be continued with the current design for several years to provide comparable, consistent data needed for harvest and hatchery management. Current funding for both CFM CWT recovery/processing and scale-aging programs expires in July 2013. Identifying future funding for these programs is essential for the continued enhancement of Chinook management in California's Central Valley.

### **Literature Cited**

- Bergman, J., Nielson, R., and Low, A. 2012. Central Valley Chinook Salmon In-River Escapement Monitoring Plan. California Department of Fish and Game. Fisheries Branch Administrative Report Number: 2012-1. January 2012
- Buttars, B. 2007. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2007 Marking Season. Pacific States Marine Fisheries Commission.
- Buttars, B. 2008. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2008 Marking Season. Pacific States Marine Fisheries Commission.
- Buttars, B. 2009. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2009 Marking Season. Pacific States Marine Fisheries Commission.
- Buttars, B. 2010. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2010 Marking Season. Pacific States Marine Fisheries Commission.
- Ferreira, J. 2011. Coded Wire Tag Recovery Analysis for Central Valley Chinook. California Department of Fish and Game, Fisheries Branch.
- Hicks, A.C., Newman, K.B., and Hankin D.G. 2005. A second analysis of a marking, tagging, and recovery program for Central valley hatchery Chinook salmon. Unpublished report to Central Valley Salmon Team.
- Klamath River Technical Team 2011. Klamath River Fall Chinook Salmon Age-Specific Escapement, River Harvest, and Run Size Estimates, 2010 Run. 24 February 2011

### **Acknowledgements**

Thanks to the following individuals for their assistance in compiling, reviewing and editing data for this report: Jennifer Simon, Barry Miller, and Julie Coombes. Thanks to Rob Titus and Russ Bellmer of DFG Fisheries Branch and David Hankin of Humboldt State University for providing text review and edits for this report. Special kudos are extended to Roxanne Jordan and Barry Dreher of the OSP Santa Rosa CWT lab for processing and reading the thousands of CWTs used in this analysis. We thank the following agencies for providing 2010 CV escapement estimates and their salmon heads/CWT recoveries: DWR Feather River Program, FWS, PSFMC, EBMUD,

and YARMT. Additional thanks are extended to staff at the following hatcheries for their cooperation in this monitoring effort: Coleman National Fish Hatchery, Feather River Hatchery, Nimbus Fish Hatchery, Mokelumne River Fish Hatchery, and the Merced River Fish Facility. Last but not least, we want to acknowledge Stan Allen (PSMFC) for his efforts in facilitating the funding, staffing, tagging, and coordination needs of the CFM program. Funding was provided by DFG, DWR, EBMUD, BOR, and the CALFED Ecosystem Restoration Program.

### **List of Acronyms and Abbreviations**

Ad-clipped	clipped adipose fin
BOR	U.S. Bureau of Reclamation
CFM	Constant Fractional Marking
CNFH	Coleman National Fish Hatchery
CV	California Central Valley
CWT	coded-wire tag
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utilities District
ERP	Ecosystem Restoration Program
FRH	Feather River Hatchery
FWS	U.S. Fish and Wildlife Service
MER	Merced River Hatchery
MOK	Mokelumne River Hatchery
NFH	Nimbus Fish Hatchery
OSP	Ocean Salmon Project
PSMFC	Pacific States Marine Fisheries Commission
RMPC	Regional Mark Processing Center
YARMT	Yuba Accord River Management Team

Table 1. Estimation and sampling methods used for the 2010 Central valley Chinook run assessment. (page 1 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
<b>Hatchery Spawners</b>		
Coleman National Fish Hatchery (CNFH) Fall and Late Fall	Direct count. All fish examined for fin-clips, tags, marks. Hatchery takes a one month break in between the fall and late fall run spawning periods. Fish that arrive during this 'break' are counted and excised. Those fish that contain a fall cwt code or have their adipose fin present are later counted as a part of the fall run. Fish containing a late fall CWT code are later counted as late fall. Systematic random bio-sample <sup>a/</sup> of all fish with adipose fin absent. Grilse cutoff: 760 mm.	FWS
Feather River Hatchery (FRH) Spring and Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish arriving at the hatchery April-June tagged with two uniquely-numbered floytags. All fish marked with floytags returning to FRH during August and September are spawned as spring run. All other fish are spawned as fall run. All spring Chinook are bio-sampled. Systematic random bio-sample ~10% of aggregate fall run fish with adipose fin present and absent. All fall run fish with adipose fin absent are bio-sampled. All spawned fall run fish are bio-sampled. Grilse cutoff: 650 mm.	CDFG
Nimbus Fish Hatchery (NFH) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG
Nimbus Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Mokelumne River Hatchery (MOK) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 males.	CDFG
Mokelumne Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Merced River Fish Facility (MER) Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG

Table 1. Estimation and sampling methods used for the 2010 Central valley Chinook run assessment. (page 2 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
<b>Natural Spawners</b>		
Upper Sacramento River Mainstem Fall and Late Fall	Superpopulation modification of the Jolly-Seber mark-recapture estimate applied using large females with adipose fin present within survey area (Keswick Dam to Balls Ferry). Chinook removed during the survey for CWT recovery are added to the J-S estimate. Total escapement estimate (Keswick Dam to Princeton) is derived using expansions for: Fish spawning outside of the survey area (Balls Ferry to Princeton) through aerial redd surveys, large male Chinook based on the sex ratio at CNFH, and grilse based on the rate encountered during the mark recapture survey. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG, FWS
Clear Creek Fall	Modified Schaefer mark-recapture estimate. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG, FWS
Butte Creek Spring and Fall	Modified Schaefer mark-recapture estimate for spring run. Peterson mark-recapture estimate for fall run. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG
Feather River Fall	Modified Schaefer mark recapture-estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring run Chinook are included. Grilse cutoff: 650 mm.	DWR
Yuba River Fall	Modified Schaefer mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring Chinook are included in estimate. Grilse cutoff: 650	CDFG, YARMT
American River Fall	Modified Schaefer mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm.	CDFG
Mokelumne River Fall	Video count at Woodbridge Irrigation District Dam. Additionally, in river survey conducted to collect bio-samples from all fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 males.	EBMUD
Stanislaus River Fall	Pooled-Petersen mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Tuolumne River Fall	Pooled-Petersen mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Merced River Fall	Pooled-Petersen mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG



Table 1. Estimation and sampling methods used for the 2010 Central valley Chinook run assessment. (page 3 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
<b>Recreational Harvest</b>		
Upper Sacramento River Fall	Open October 9th to October 31st from Highway 113 Bridge to Deschutes Road Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
Feather River Fall	Open July 31st to August 29th below the Thermolito Afterbay Outlet. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
American River Fall	Open October 30th to November 28th from the mouth to the SMUD power line crossing at Ancil Hoffman Park. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
Lower Sacramento River Fall	Open September 4th to October 3rd from the Carquinez Bridge to the Highway 113 Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
Upper Sacramento River Late Fall	Open November 1st to December 12th from Highway 113 Bridge to Deschutes Road Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG

a/ Biological samples ("bio-samples" or "bio-data") of live fish or carcasses generally include: sex, fork length, scales, tags or marks, and CWT recovery from ad-clipped fish.

Table 2. 2010 California ocean sport and commercial salmon fishery seasons by major port area.

Major Port Area	Sport		Commercial		
	Season	Size Limit <sup>a/</sup>	Season	Size Limit <sup>a/</sup>	Quota
Crescent City/Eureka	May 29-Sep 6	24" TL	closed	--	--
Fort Bragg	Apr 3-30	20" TL	July 1-4, 8-11	27" TL	none
	May 1-Sep 6	24" TL	July 15-29	27" TL	18,000
			Aug 1-31	27" TL	9,375
San Francisco	Apr 3-30	20" TL	July 1-4, 8-11	27" TL	none
	May 1-Sep 6	24" TL			
	(closed Tue/Wed)				
Monterey/Morro Bay	Apr 3-30	20" TL	July 1-4, 8-11	27" TL	none
	May 1-Sep 6	24" TL			
	(closed Tue/Wed)				

a/ Size limit in total length (TL).

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release type, brood years 2006-2009. (page 1 of 2)

**Age 2 CWT releases**

Release type*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
FRHS	2008	FRH	Fea R	Spr	5	1,016,835	1,015,717	100%	Basin	Boyds Pump Ramp
FRHSn	2008	FRH	Fea R	Spr	5	1,007,177	1,005,727	100%	Bay pens	San Pablo Bay net pens
CFHFh	2008	CNFH	Sac R	Fall	27	12,529,146	3,128,111	25%	Basin	CNFH
CFHFfn	2008	CNFH	Sac R	Fall	3	1,427,439	371,685	26%	Bay pens	Mare Island net pens, San Pablo Bay net pens
FRHFfn	2008	FRH	Fea R	Fall	11	7,760,969	2,061,211	27%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFfe	2008	FRH	Fea R	Hybrid	30	498,341	481,853	97%	CV exper	Fall x Spr hybrid releases: Benicia, Discovery Pk, Elkhorn Boat Launch, Miller Park, Sac River at Garcia Bend and Pittsburg
FRHFtib	2008	FRH	Fea R	Fall	2	91,631	89,859	98%	Tiberon pens	Held 3-4 mos Tiberon net pens, released as yearlings
FeaFw	2008	wild	Fea R	Fall	37	292,423	289,830	99%	Basin	Feather River Hatchery, Thermalito Bypass
NIMF	2008	NIM	Ame R	Fall	1	267,003	264,006	99%	Basin	American River
NIMFn	2008	NIM	Ame R	Fall	4	3,924,440	976,955	25%	Bay pens	Mare Island net pens
MOKFt	2008	MOK	Mok R	Fall	4	250,969	250,300	100%	Trucked	Sherman Island
MokFw	2008	wild	Mok R	Fall	5	24,911	20,680	83%	Basin	Woodbridge, Mok R Vino farms
MERF	2008	MER	Mer R	Fall	2	34,532	32,978	95%	Basin	Jersey Pt (San Joaquin River)
CFHLh	2009	CNFH	Sac R	Late	16	1,134,119	1,115,378	98%	Basin	CNFH (includes spring surrogate releases)
Total age 2 releases:					152	30,259,935	11,104,290	37%	1% wild releases	

**Age 3 CWT releases**

Release type*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
ButSw	2007	wild	Butte Ck	Spr	30	317,706	311,061	98%	Basin	Baldwin Construction Yard
FRHS	2007	FRH	Fea R	Spr	8	1,414,343	1,378,941	97%	Basin	Boyds Pump Ramp (on Feather River)
FRHSn	2007	FRH	Fea R	Spr	2	1,271,761	1,242,480	98%	Bay pens	San Pablo Bay net pens, Wickland Oil net pens
CFHFfe	2007	CNFH	Sac R	Fall	8	200,619	196,993	98%	CV exper	Clarksburg, Red Bluff Diversion Dam
CFHFh	2007	CNFH	Sac R	Fall	14	11,232,241	2,801,459	25%	Basin	CNFH
CFHFfn	2007	CNFH	Sac R	Fall	3	1,266,949	314,681	25%	Bay pens	San Pablo Bay net pens (Conoco Phillips, Mare Island); 75% truck mortality noted for one release
FRHFfe	2007	FRH	Fea R	Fall	19	623,567	619,085	99%	CV exper	Elkhorn Boat Ramp, Isleton, Lighthouse Marina, West Sacramento
FRHFfn	2007	FRH	Fea R	Fall	9	9,422,521	2,347,396	25%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFt	2007	FRH	Fea R	Fall	4	102,225	101,712	99%	Trucked	Benicia
FeaFw	2007	wild	Fea R	Fall	19	208,717	206,683	99%	Basin	Thermalito Bypass
NIMFn	2007	NIM/MOK	Ame R	Fall	7	6,879,664	1,714,858	25%	Bay pens	Raised at both NIM and MOK; San Pablo Bay net pens
NIMFtib	2007	MOK	Ame R	Fall	1	51,600	51,600	100%	Tiberon pens	Raised at MOK; held 3-4 mos Tiberon net pens, released as yearlings
MOKF	2007	MOK	Mok R	Fall	1	406,593	101,458	25%	Basin	New Hope Landing
MOKFn	2007	MOK	Mok R	Fall	2	2,203,488	550,668	25%	Bay pens	San Pablo Bay net pens
MokFw	2007	wild	Mok R	Fall	1	315	315	100%	Basin	Mokelumne River
CFHLh	2008	CNFH	Sac R	Late	14	1,106,673	1,072,854	97%	Basin	CNFH (includes spring surrogate releases)
Total age 3 releases:					142	36,708,982	13,012,244	35%	1% wild releases	

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release type, brood years 2006-2009. (page 2 of 2)

**Age 4 CWT releases**

Release type*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
ButSw	2006	wild		Spr	27	283,749	279,936	99%	Basin	Baldwin Construction Yard
FRHS	2006	FRH	Fea R	Spr	1	1,043,284	1,004,683	96%	Basin	Fea R Hatchery
FRHSt	2006	FRH	Fea R	Spr	9	1,036,931	1,026,561	99%	Trucked	Wickland Oil Terminal (no pens)
YubSw	2006	wild	Yub R	Spr	16	182,730	179,853	98%	Basin	Yuba River
CFHFe	2006	CNFH	Sac R	Fall	8	201,812	196,108	97%	CV exper	Clarksburg, Red Bluff Diversion Dam
CFHFh	2006	CNFH	Sac R	Fall	8	12,113,781	3,032,082	25%	Basin	CNFH
FRHFe	2006	FRH	Fea R	Fall	34	573,386	564,904	99%	CV exper	Elkhorn Boat Ramp, Isleton, Lighthouse Marina, West Sacramento, Yolo Bypass
FRHFn	2006	FRH	Fea R	Fall	8	8,154,003	1,995,912	24%	Bay pens, Trucked	Wickland Oil net pens - proportion of trucked fish placed in pens, varies from 35%-100%; remainder dumped directly into bay
FRHFt	2006	FRH	Fea R	Fall	9	1,018,073	305,755	30%	Trucked	Benicia, Wickland Oil Terminal (no pens)
FeaFw	2006	wild	Fea R	Fall	17	188,293	186,478	99%	Basin	Thermalito Bypass
YubFw	2006	wild	Yub R	Fall	14	62,426	61,295	98%	Basin	Yuba River
NIMFn	2006	NIM	Ame-Mok	Fall	5	6,128,032	1,527,846	25%	Coastal & Bay pens, Trucked	Amer-Moke fish accidentally mixed, released into multiple net pens: 18% coastal (Avila, Santa Cruz), 82% Bay net pens. American stock trucked to Wickland Oil net pens (approx 87% placed into pens)
MOKF	2006	MOK	Mok R	Fall	7	3,706,436	925,826	25%	Basin	New Hope Landing
MOKFn	2006	MOK	Mok R	Fall	2	227,412	55,427	24%	Coastal & Bay pens	Coastal and ocean net pens (Port San Luis, Santa Cruz, Moss Landing & Selby/Wickland net pens)
MOKFt	2006	MOK	Mok R	Fall	1	1,127,138	281,582	25%	Trucked	Wickland Oil Terminal (no pens)
MokFw	2006	wild	Mok R	Fall	2	13,903	10,968	79%	Basin	Mok R
MERF	2006	MER	Mer R	Fall	12	312,294	304,121	97%	Basin	Hatfield State Area, MER
CFHLe	2007	CNFH	Sac R	Late	17	309,829	299,292	97%	CV exper	Sac R (Colusa to RBDD), Georgianna Slough, Port Chicago, Ryde-Koket
CFHLh	2007	CNFH	Sac R	Late	9	738,638	723,091	98%	Basin	CNFH (includes spring surrogate releases)
Total age 4 releases:					206	37,422,150	12,961,720	35%	2% wild releases	

**\*CV CWT release types:**

**Sacramento River Basin Fall Chinook CWT release groups**

CFHFe	Coleman National Fish Hatchery (CNFH) fall experimental releases
CFHFh	Coleman National Fish Hatchery fall hatchery releases
CFHFn	Coleman National Fish Hatchery fall net pen releases
FRHFe	Feather River Hatchery fall experimental (2008 brdry includes spring x fall hybrids)
FRHFn	Feather River Hatchery fall net pen releases
FRHFt	Feather River Hatchery fall trucked releases (no net pens)
FRHFtn	Feather River Hatchery fall Tiburon net pen releases (released as yearlings following fall)
FeaFw	Feather River fall wild
YubFw	Yuba River fall wild
NIMFn	Nimbus Fish Hatchery fall net pens
NIMFtib	Nimbus Fish Hatchery fall Tiburon net pens (released as yearlings following fall)

**Sacramento River Basin Late Fall Chinook CWT release groups**

CFHLe	Coleman National Fish Hatchery late fall experimental releases
CFHLh	Coleman National Fish Hatchery late fall hatchery releases

**San Joaquin Basin Fall Chinook CWT release groups**

MOKF	Mokelumne Hatchery fall basin releases
MOKFn	Mokelumne Hatchery fall net pen releases
MOKFt	Mokelumne Hatchery fall trucked releases
MokFw	Mokelumne River fall wild
MerF	Merced Hatchery fall releases

**Central Valley Spring Chinook CWT release groups**

FRHS	Feather River Hatchery spring basin releases
FRHSn	Feather River Hatchery spring net pen releases
FRHSt	Feather River Hatchery spring trucked releases
ButSw	Butte Creek spring wild
YubSw	Yuba River spring wild

Table 4. Escapement estimates and sample data for 2010 CV escapement.

Escapement Survey	Run	Total Escapement	Chinook Sampled <sup>a/</sup>	Observed Ad-Clips	Valid CWTs	Sample Fractions <sup>b/</sup>			Sample Expansion
						fe	fa	fd	
<b>Hatcheries</b>									
Feather River Hatchery	Spring	1,661	1,661	1,279	1,234	1.000	1.000	0.998	1.00
Coleman National Fish Hatchery	Fall	17,238	17,238	4,140	4,040	1.000	1.000	0.990	1.01
Feather River Hatchery	Fall	19,972	19,972	6,373	6,049	1.000	1.000	0.969	1.03
Nimbus Fish Hatchery	Fall	9,095	9,095	2,060	2,025	1.000	1.000	0.997	1.00
Nimbus Weir	Fall	7,115	7,115	999	948	1.000	1.000	0.999	1.00
Mokelumne River Hatchery	Fall	5,276	5,276	2,747	2,707	1.000	1.000	1.000	1.00
Mokelumne Weir	Fall	244	244	119	115	1.000	1.000	1.000	1.00
Merced River Fish Facility	Fall	146	146	83	81	1.000	1.000	0.988	1.01
Coleman National Fish Hatchery	Late Fall	5,505	5,505	5,391	5,258	1.000	1.000	0.995	1.00
<b>Natural Areas</b>									
Mill Creek	Spring	482	482	1	1	1.000	1.000	1.000	1.00
Butte Creek	Spring	1,979	1,113	21	16	0.562	1.000	1.000	1.78
Sacramento River-Above Red Bluff	Fall	16,372	1,415	130	117	0.086	0.992	1.000	11.66
Mill Creek	Fall	144	144	1	1	1.000	1.000	1.000	1.00
Deer Creek	Fall	166	166	2	2	1.000	1.000	1.000	1.00
Clear Creek	Fall	7,192	1,496	19	19	0.208	1.000	1.000	4.81
Butte Creek	Fall	370	83	3	3	0.224	1.000	1.000	4.46
Feather River	Fall	44,914	5,077	1,388	1,276	0.113	0.964	0.998	9.20
Yuba River	Fall	13,097	789	341	330	0.060	1.000	1.000	16.60
American River	Fall	7,573	1,435	142	134	0.189	1.000	0.985	5.36
Mokelumne River	Fall	1,920	1,920	820	808 <sup>c/</sup>	1.000	1.000	0.999	1.00
Stanislaus River	Fall	1,086	155	38	36	0.143	1.000	1.000	7.01
Tuolumne River	Fall	540	85	27	24	0.157	1.000	1.000	6.35
Merced River	Fall	651	132	49	46	0.203	1.000	1.000	4.93
American River	Late Fall	162	162	37	37	1.000	1.000	1.000	1.00
Sacramento River-Above Red Bluff	Late Fall	4,282	811	47	43	0.189	0.979	0.977	5.52
<b>Inland Sport Harvest</b>									
Sacramento River-Above Feather Confluence	Fall	2,080	187	23	21	0.090	1.000	1.000	11.12
Feather River	Fall	1,194	111	26	26	0.093	1.000	1.000	10.76
Sacramento River-Below Feather Confluence	Fall	2,008	126	45	44	0.063	1.000	1.000	15.94
American River	Fall	248	14	7	6	0.056	1.000	1.000	17.71
Sacramento River-Above Feather Confluence	Late Fall	<u>1,117</u>	<u>144</u>	<u>87</u>	<u>86</u>	0.129	1.000	0.989	7.85
	<b>Total</b>	<b>173,829</b>	<b>82,299</b>	<b>26,445</b>	<b>24,838</b>				

a/ Number of salmon visually checked for an ad-clip.

b/ Sample Fractions:

fe = fraction of total salmon escapement sampled and examined for ad-clipped fish.

fa = fraction of heads from ad-clipped salmon collected and processed.

fd = fraction of observed CWTs that were successfully decoded.

c/ Mokelumne River natural area includes expanded CWTs based on ad-clip count at Woodbridge dam weir.

Table 5. Catch estimates and sample data for 2010 ocean salmon sport and commercial fisheries by major port area.

Major Port Area	Total Harvest Estimate	Chinook Sampled <sup>a/</sup>	Observed Ad-Clips	Valid CWTs	Sample Fractions <sup>b/</sup>			Sample Expansion
					fe	fa	fd	
<b><u>Commercial</u></b>								
Fort Bragg	12,577	7,563	1,018	858	0.601	0.993	1.000	1.67
San Francisco	1,086	856	81	69	0.788	1.000	1.000	1.27
Monterey	1,435	677	158	152	0.472	0.987	1.000	2.15
<b><u>Sport</u></b>								
Eureka/Crescent	720	168	36	25	0.233	1.000	1.000	4.29
Fort Bragg	1,702	499	95	89	0.293	0.989	1.000	3.45
San Francisco	5,927	2,149	478	454	0.363	0.985	0.998	2.81
Monterey	6,348	1,432	358	340	0.226	0.992	0.997	4.48
<b>Total</b>	<b>29,795</b>	<b>13,344</b>	<b>2,224</b>	<b>1,987</b>				

a/ Number of salmon visually checked for ad-clip

b/ Sample fractions:

fe = fraction of the total salmon sampled and examined for ad-clipped fish.

fa = fraction of heads from ad-clipped salmon collected and processed.

fd = fraction of observed CWTs that were successfully decoded.

Table 6. Raw and expanded CV coded-wire-tag (CWT) recoveries by stock and age, brood years 2004-2010.

<b>Fall</b>		2009	2008	2007	2006	2005	2004	Total CV	
Age		1	2	3	4	5	6	CWTs	Total CV %
Raw CWT Recoveries		36 ( $< 1\%$ )	7,087 (46%)	8,022 (52%)	272 (2%)	2 ( $< 1\%$ )		15,419	62%
Expanded CWT <sub>total</sub>		<b>137</b> ( $< 1\%$ )	<b>29,451</b> (31%)	<b>63,868</b> (67%)	<b>2,197</b> (2%)	<b>2</b> ( $< 1\%$ )		95,655	84%
<b>Spring</b>		2009	2008	2007	2006	2005	2004	Total CV	
Age		1	2	3	4	5	6	CWTs	Total CV %
Raw CWT Recoveries			306 (8%)	3,340 (89%)	91 (2%)	1 ( $< 1\%$ )		3,738	15%
Expanded CWT <sub>total</sub>			<b>608</b> (5%)	<b>10,582</b> (92%)	<b>308</b> (3%)	<b>1</b> ( $< 1\%$ )		11,499	10%
<b>Late Fall</b>		2010	2009	2008	2007	2006	2005	Total CV	
Age		1	2	3	4	5	6	CWTs	Total CV %
Raw CWT Recoveries			153 (3%)	781 (14%)	3,824 (67%)	918 (16%)	5 ( $< 1\%$ )	5,681	23%
Expanded CWT <sub>total</sub>			<b>334</b> (5%)	<b>1,358</b> (20%)	<b>4,093</b> (59%)	<b>1,122</b> (16%)	<b>5</b> ( $< 1\%$ )	6,912	6%
<b>All Runs</b>		2010	2009	2008	2007	2006	2005	Total CV	
Age		1	2	3	4	5	6	CWTs	Total CV %
Raw CWT Recoveries		36 ( $< 1\%$ )	7,546 (30%)	12,143 (49%)	4,187 (17%)	921 (4%)	5 ( $< 1\%$ )	24,838	100%
Expanded CWT <sub>total</sub>		<b>137</b> ( $< 1\%$ )	<b>30,392</b> (27%)	<b>75,809</b> (66%)	<b>6,597</b> (6%)	<b>1,125</b> (1%)	<b>5</b> ( $< 1\%$ )	114,066	100%

Table 7. Raw and expanded ocean coded-wire-tag (CWT) recoveries by stock and age, brood years 2004-2009.

<b>Fall</b>		2008	2007	2006	2005	2004	Total CV	
Age	2	3	4	5	6	CWTs	Total CV %	
Raw CWT Recoveries	183 (12%)	1,282 (86%)	34 (2%)				1,499	75%
Expanded CWT <sub>total</sub>	<b>1,603</b> (12%)	<b>11,704</b> (86%)	<b>250</b> (2%)				13,557	62%
<b>Spring</b>		2008	2007	2006	2005	2004	Total CV	
Age	2	3	4	5	6	CWTs	Total CV %	
Raw CWT Recoveries	10 (6%)	162 (93%)	3 (1%)				175	9%
Expanded CWT <sub>total</sub>	<b>35</b> (6%)	<b>575</b> (93%)	<b>9</b> (1%)				619	3%
<b>Late Fall</b>		2009	2008	2007	2006	2005	Total CV	
Age	2	3	4	5	6	CWTs	Total CV %	
Raw CWT Recoveries		111 (65%)	56 (33%)	1 (< 1%)	2 (1%)		170	9%
Expanded CWT <sub>total</sub>		<b>1,358</b> (21%)	<b>4,093</b> (62%)	<b>1,122</b> (17%)	<b>5</b> (< 1%)		6,578	30%
<b>Winter</b>		2008	2007	2006	2005	2004	Total CV	
Age	2	3	4	5	6	CWTs	Total CV %	
Raw CWT Recoveries	1 (50%)	1 (50%)					2	< 1%
Expanded CWT <sub>total</sub>	<b>4</b> (67%)	<b>2</b> (33%)					6	< 1%
<b>Non CV Rivers</b>		2008	2007	2006	2005	2004	Total CV	
Age	2	3	4	5	6	CWTs	Total CV %	
Raw CWT Recoveries		84 (60%)	56 (40%)		1 (< 1%)		141	7%
Expanded CWT <sub>total</sub>		<b>523</b> (51%)	<b>509</b> (49%)		<b>2</b> (< 1%)		1,034	5%
<b>All Runs</b>		2008	2007	2006	2005	2004	Total CV	
Age	2	3	4	5	6	CWTs	Total CV %	
Raw CWT Recoveries	194 (10%)	1,640 (83%)	149 (7%)	1 (< 1%)	3 (< 1%)		1,987	100%
Expanded CWT <sub>total</sub>	<b>1,642</b> (8%)	<b>14,162</b> (65%)	<b>4,861</b> (22%)	<b>1,122</b> (5%)	<b>7</b> (< 1%)		21,794	100%



Table 8. 2010 CWT recovery rate (recoveries per 100,000 CWTs released) by release type, brood year, and recovery location. (page 1 of 2)

**Age 2 CV recoveries**

Release type	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location								CV CWT <sub>samp</sub> totals			Ocean CWT <sub>samp</sub>	Recovery Rate per 100,000 released				CV Stray Proportion	
				Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray		Basin	Stray	CV total	Ocean		
FRHS	2008	Spr	1,015,717				284						284	284		12	28.0		28.0	1.2	0.00
FRHSn	2008	Spr	1,005,727		23		291	8	1				323	291	33	23	28.9	3.2	32.2	2.3	0.10
CFHFh	2008	Fall	3,128,111	2,196	23								2,219	2,219		102	70.9		70.9	3.3	0.00
CFHFn	2008	Fall	371,685	44	23	14	213	221	44	7	33		600	68	533	88	18.2	143.3	161.5	23.6	0.89
FRHFn	2008	Fall	2,061,211	17	12		2,297	70	13	1	13		2,423	2,297	126	163	111.4	6.1	117.6	7.9	0.05
FRHFe	2008	Fall	481,853				623	30					653	623	30	27	129.3	6.3	135.6	5.6	0.05
FRHFtib	2008	Fall	89,859	7			48	11					67	48	18	5	53.6	20.5	74.1	5.1	0.28
FeaFw	2008	Fall	289,830				12						12	12			4.2		4.2		0.00
NIMF	2008	Fall	264,006					88					88	88			33.5		33.5		0.00
NIMFn	2008	Fall	976,955		12		3	800	33	1			849	800	49	34	81.9	5.0	86.9	3.5	0.06
MOKFt	2008	Fall	250,300	2		4	3	151	2,176	111	158		2,606	2,176	430	107	869.4	171.8	1041.2	42.7	0.17
MokFw	2008	Fall	20,680						4				4	4		2	18.7		18.7	7.4	0.00
MERF	2008	Fall	32,978	4		6	36	23	100	31	78		278	31	247	4	93.5	749.6	843.0	11.3	0.89
CFHLh	2009	Late	1,115,378	130				1			2		133	130	3		11.7	0.3	12.0		0.02

**Age 3 CV recoveries**

Release type	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location								CV CWT <sub>samp</sub> totals			Ocean CWTs	Recovery Rate per 100,000 released				CV Stray Proportion	
				Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray		Basin	Stray	CV total	Ocean		
ButSw	2007	Spr	311,061			5							5	5			1.7		1.7		0.00
FRHS	2007	Spr	1,378,941				4,804						4,804	4,804		195	348.4		348.4	14.1	0.00
FRHSn	2007	Spr	1,242,480	11	501	24	4,650	245	22		19		5,471	4,650	822	365	374.2	66.1	440.4	29.4	0.15
CFHFe	2007	Fall	196,993	68	175	5	55	20	1				323	243	81	30	123.1	40.9	164.0	15.2	0.25
CFHFh	2007	Fall	2,801,459	1,392	117	20							1,529	1,508	20	311	53.8	0.7	54.6	11.1	0.01
CFHFn	2007	Fall	314,681	2			33	73	15	6			130	2	128	101	0.6	40.5	41.2	32.1	0.98
FRHFe	2007	Fall	619,085		12		203	8					223	203	20	22	32.8	3.2	36.0	3.6	0.09
FRHFn	2007	Fall	2,347,396	18	373	39	10,339	390	39	25	6		11,230	10,339	891	1905	440.4	38.0	478.4	81.2	0.08
FRHFt	2007	Fall	101,712		12		101	10	3				125	101	24	15	99.1	23.8	122.9	14.7	0.19
FeaFw	2007	Fall	206,683				29						29	29			14.0		14.0		0.00
NIMFn	2007	Fall	1,714,858	2	12		6	1,159	457	43	48		1,727	1,159	568	646	67.6	33.1	100.7	37.7	0.33
NIMFtib	2007	Fall	51,600				3	140	386	59	7		594	140	454		270.8	880.7	1151.5		0.76
MOKF	2007	Fall	101,458					1	21				22	21	1	3	20.3	1.0	21.3	2.6	0.05
MOKFn	2007	Fall	550,668	2			29	148	278	22	35		514	278	236	126	50.4	42.9	93.3	22.8	0.46
MokFw	2007	Fall	315																		
CFHLh	2008	Late	1,072,854	711	6				1				718	717	1	261	66.8	0.1	66.9	24.4	0.00

Table 8. 2010 CWT recovery rate (recoveries per 100,000 CWTs released) by release type, brood year, and recovery location. (page 2 of 2)

**Age 4 CV recoveries**

Release type	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location									CV CWT <sub>samp</sub> totals			Ocean CWTs	Recovery Rate per 100,000 released				CV Stray Proportion
				Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray	Basin		Stray	CV total	Ocean		
ButSw	2006	Spr	279,936			5							5	5		2	1.9	1.9	0.6	0.00	
FRHS	2006	Spr	1,004,683		12		53						65	53	12	6	5.3	1.2	6.4	0.18	
FRHSt	2006	Spr	1,026,561		12		164	23					199	164	35		16.0	3.4	19.4	0.18	
YubSw	2006	Spr	179,853				33						33	33		3	18.5		18.5	1.6	0.00
CFHFe	2006	Fall	196,108	1			9						10	1	9	2	0.5	4.7	5.2	0.8	0.90
CFHFh	2006	Fall	3,032,082	82	12	5							98	93	5	8	3.1	0.2	3.2	0.3	0.05
FRHFe	2006	Fall	564,904				29	3					32	29	3		5.1	0.5	5.6		0.09
FRHFn	2006	Fall	1,995,912	1	12	5	308	17	1				343	308	35	45	15.4	1.8	17.2	2.2	0.10
FRHFt	2006	Fall	305,755				2						2	2		5	0.7		0.7	1.5	0.00
FeaFw	2006	Fall	186,478																		
YubFw	2006	Fall	61,295																		
NIMFn	2006	Fall	1,527,846					36	8				44	36	8	4	2.4	0.5	2.9	0.3	0.18
MOKF	2006	Fall	925,826																		
MOKFn	2006	Fall	55,427					1					1		1	2		1.8	1.8	2.9	1.00
MOKFt	2006	Fall	281,582				1		1				2	1	1	2	0.5	0.4	0.8	0.6	0.44
MokFw	2006	Fall	10,968																		
MERF	2006	Fall	304,121																		
CFHLe	2007	Late	299,292	7	6			16	4				32	13	20	12	4.2	6.6	10.8	3.8	0.61
CFHLh	2007	Late	723,091	3,770	72			1					3843	3842	1	115	531.3	0.1	531.4	16.0	0.00

**Age 5 CV recoveries**

Release type	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location									CV CWT <sub>samp</sub> totals			Ocean CWT <sub>samp</sub>	Recovery Rate per 100,000 released				CV Stray Proportion
				Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray	Basin		Stray	Ocean			
FRHS	2005	Spr	762,021				1						1	1			0.1				
FRHFt	2005	Fall	1,000,606				1	1					2	1	1		0.1	0.1			0.49
CFHLe	2006	Late	264,277	8	61			24					93	69	24		26.0	9.1			0.26
CFHLh	2006	Late	854,496	858	94								952	952		5	111.4			0.6	

\* - Natural creeks include Clear Creek, Butte Creek, and Deer Creek.

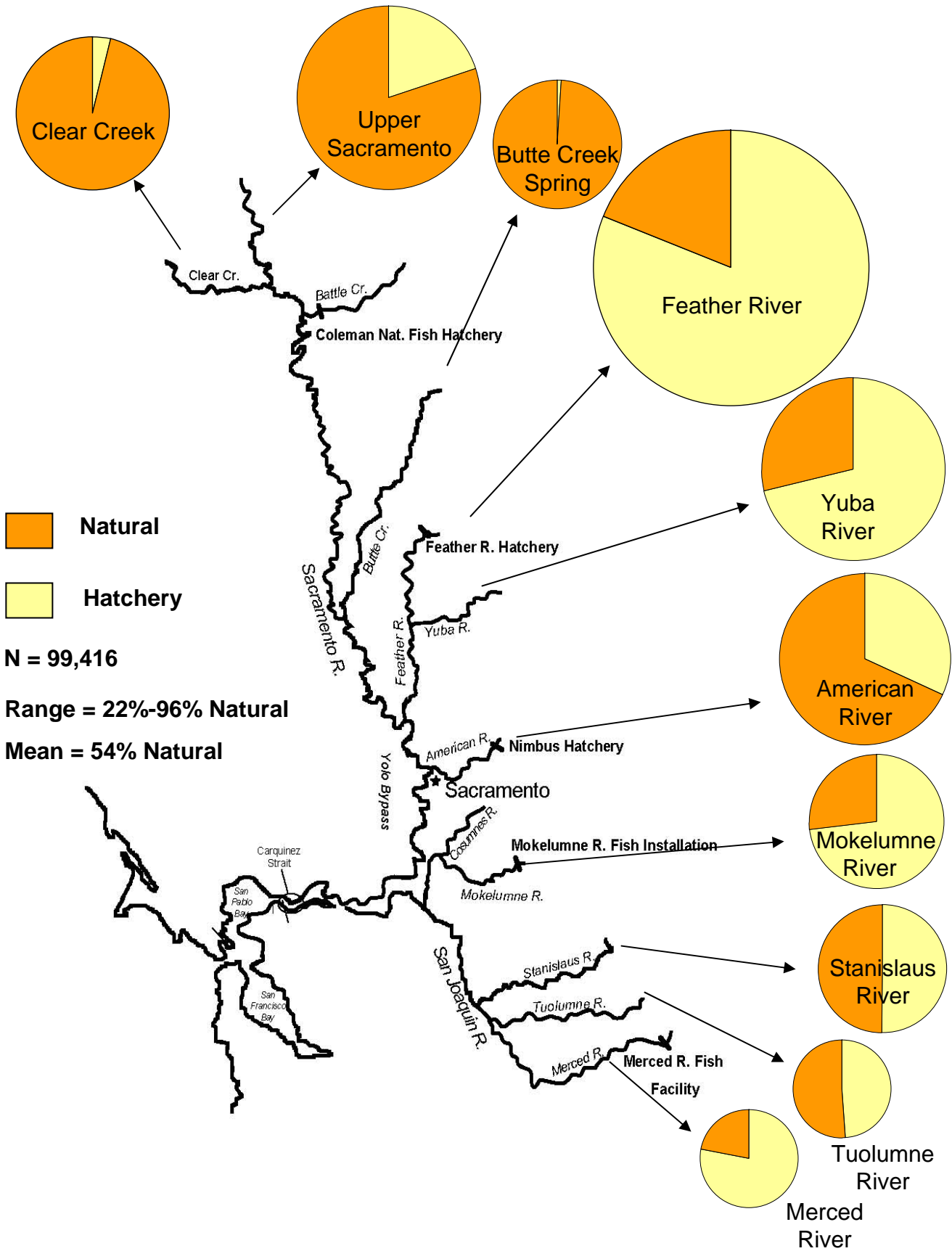


Figure 1. 2010 Fall Chinook Natural Area Escapement, Hatchery and Natural Proportions

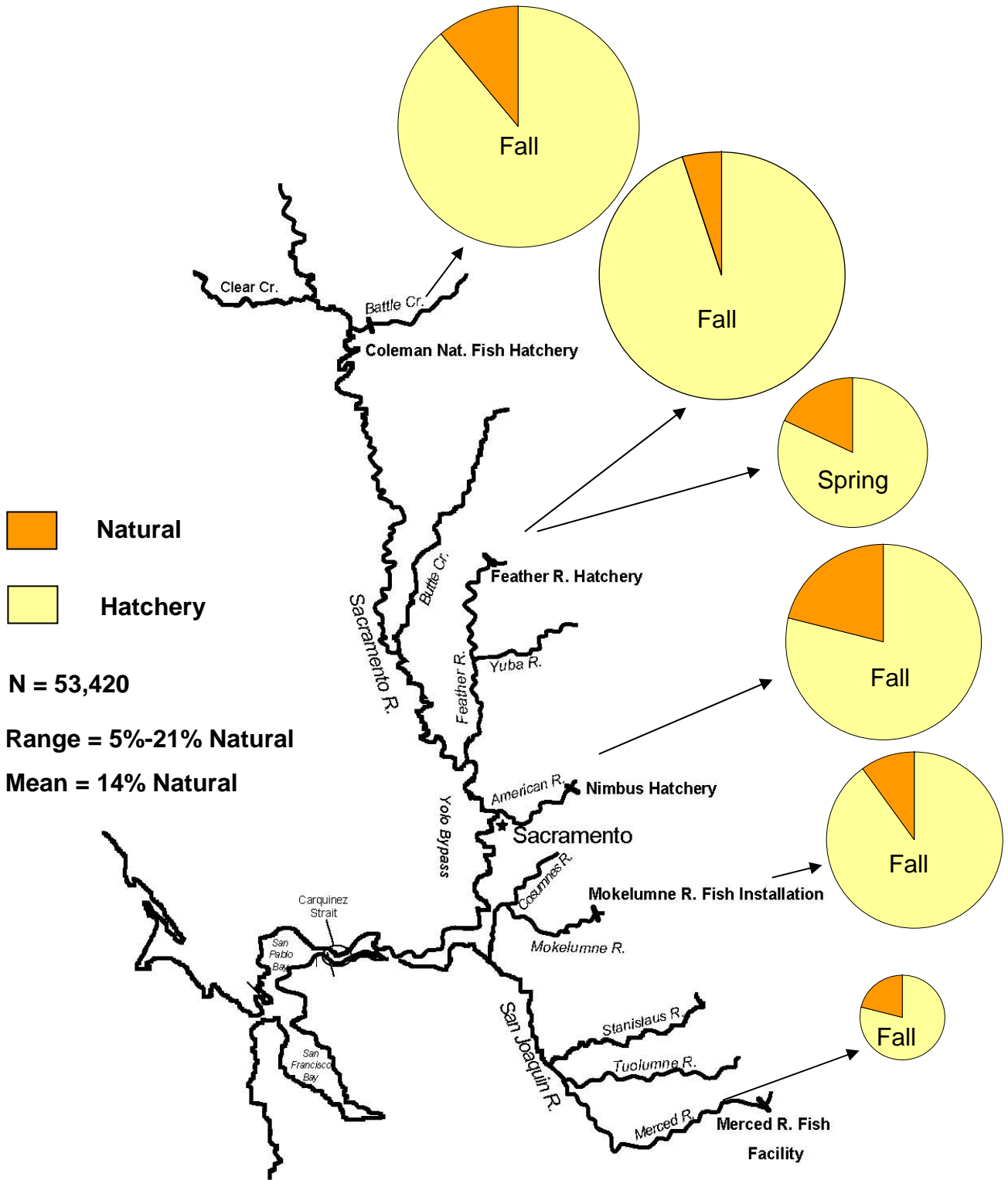


Figure 2. 2010 Fall Chinook Hatchery Escapement, Hatchery and Natural Proportions

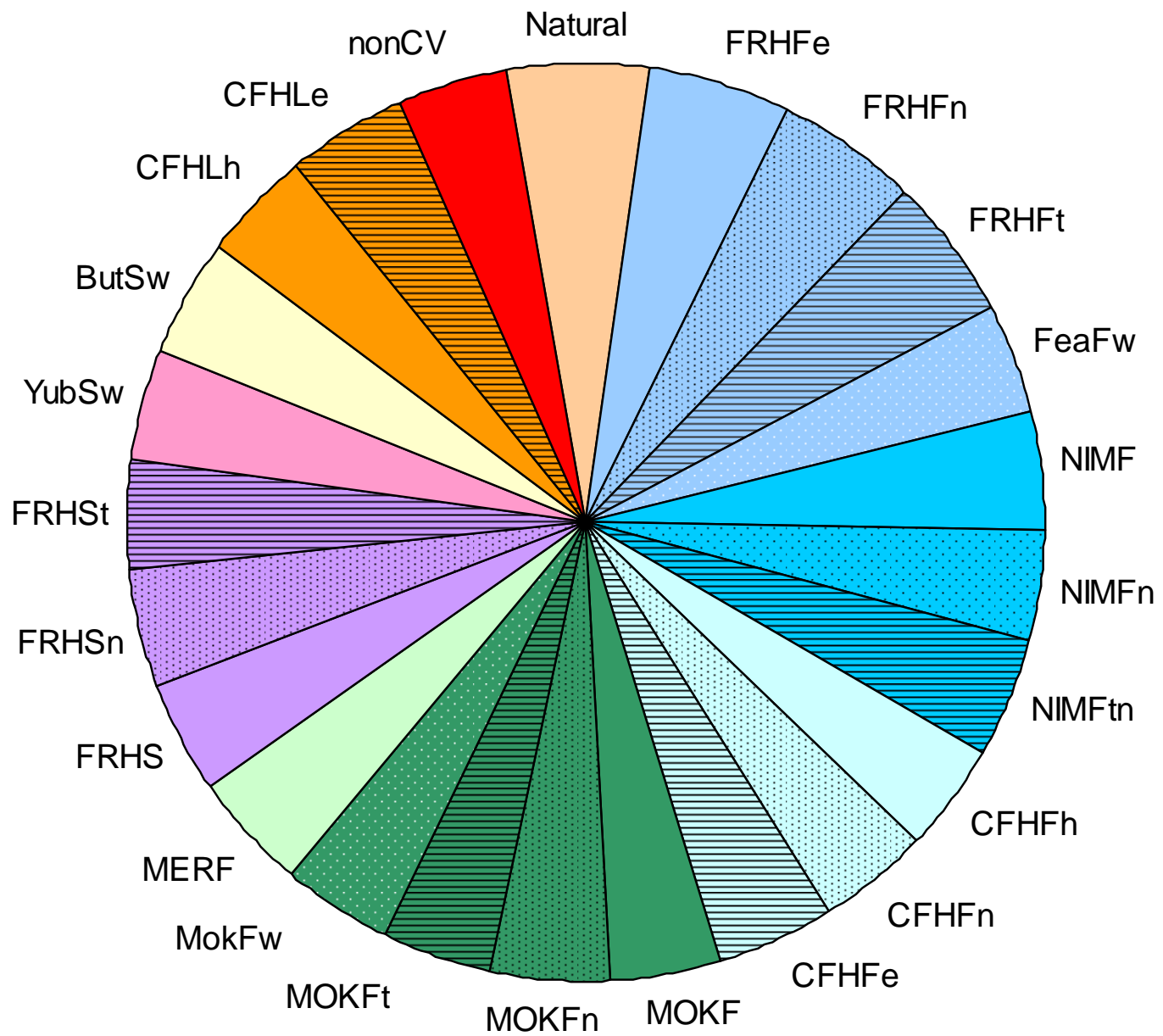


Figure 3. 2010 Central Valley hatchery release types color scheme.

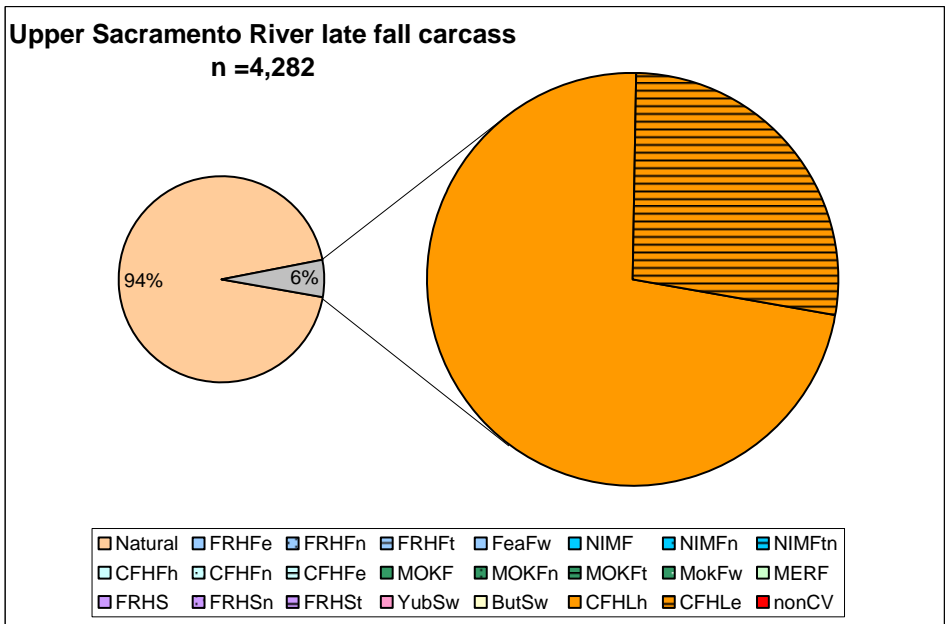
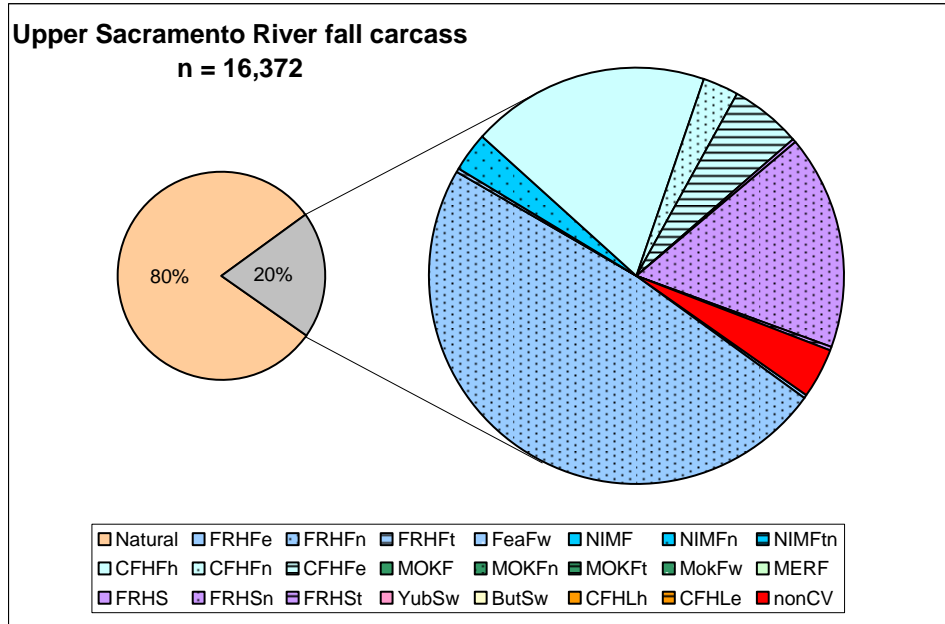
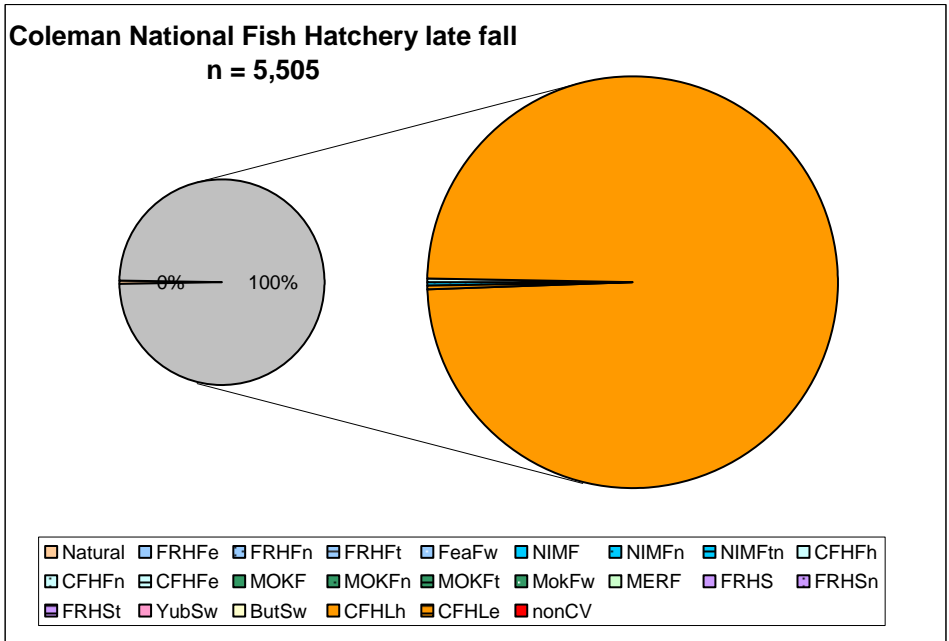
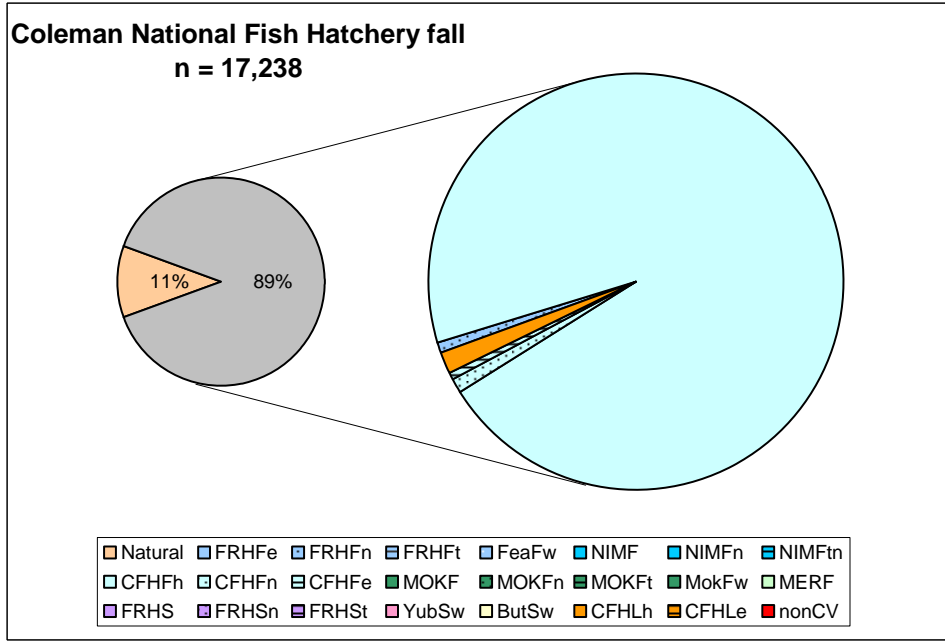


Figure 4. Proportion of hatchery and natural-origin fish in the Upper Sacramento River Basin.

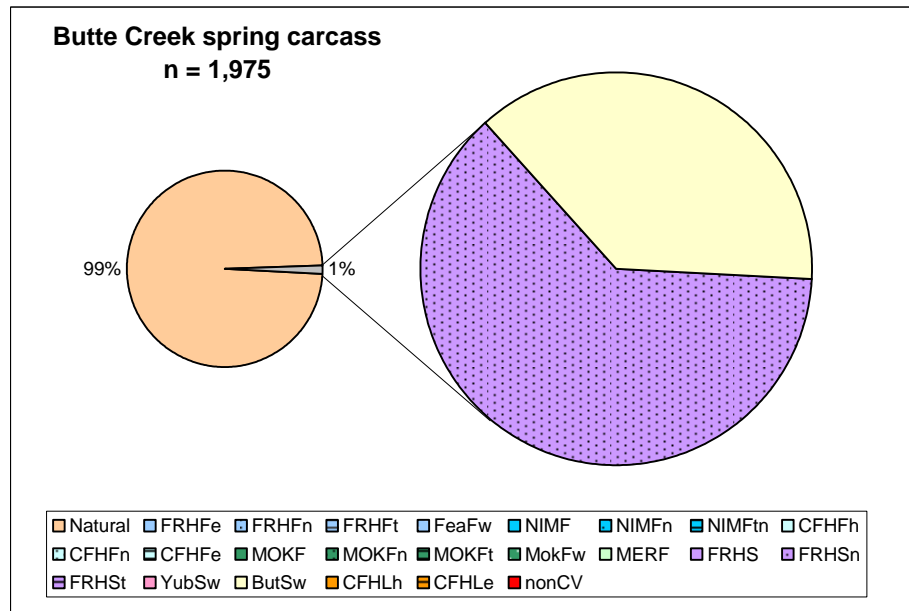
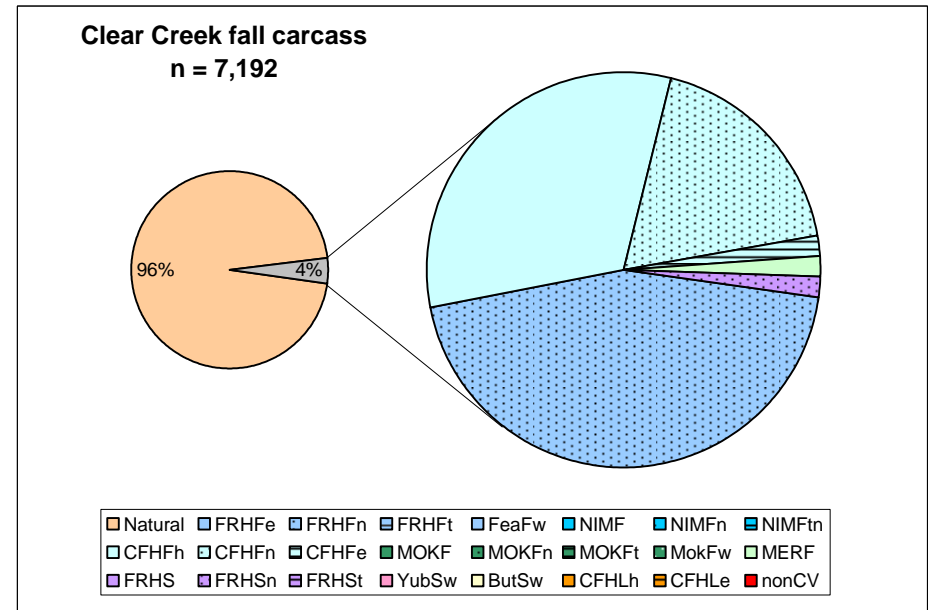
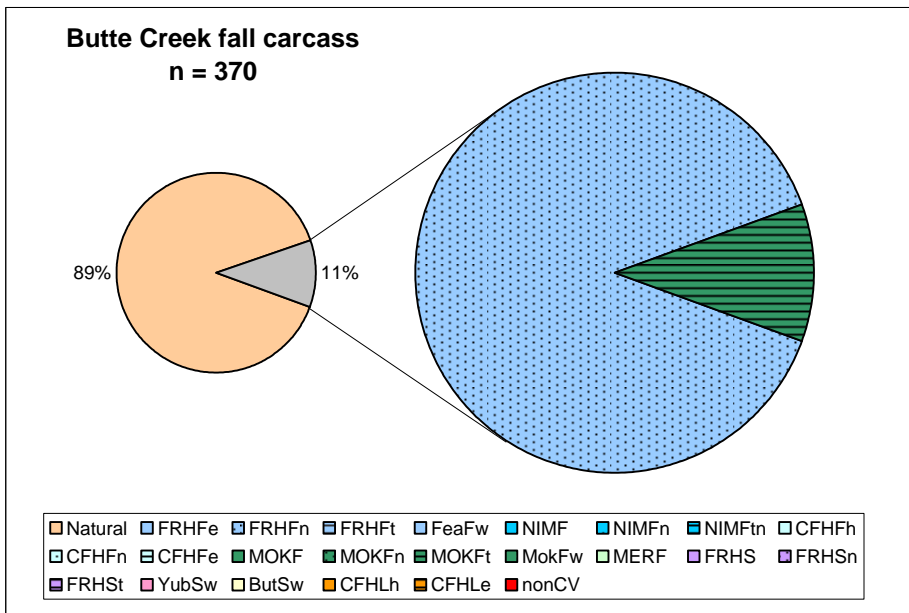


Figure 5. Proportion of hatchery and natural-origin fish in the Upper Sacramento River Basin.

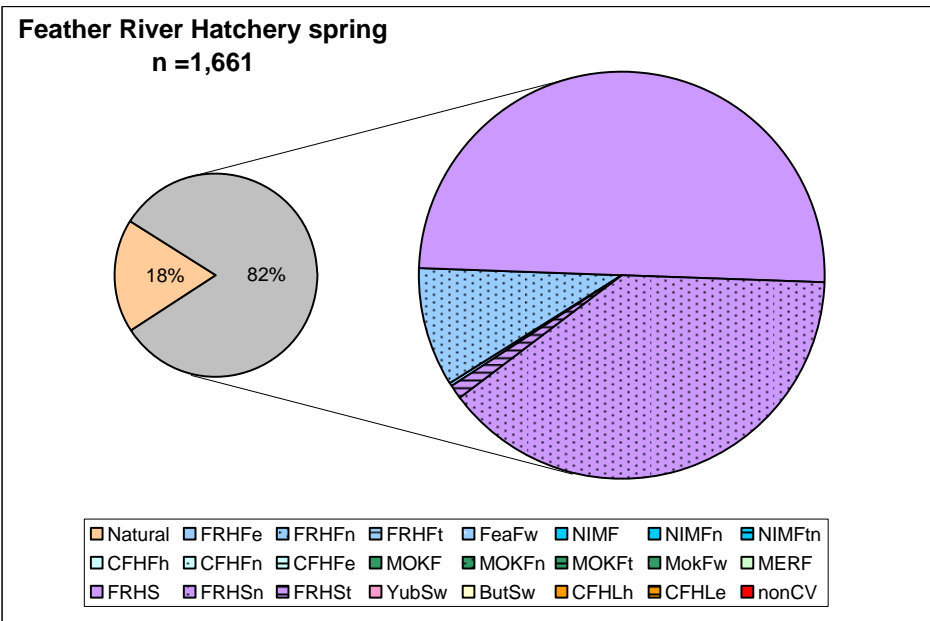
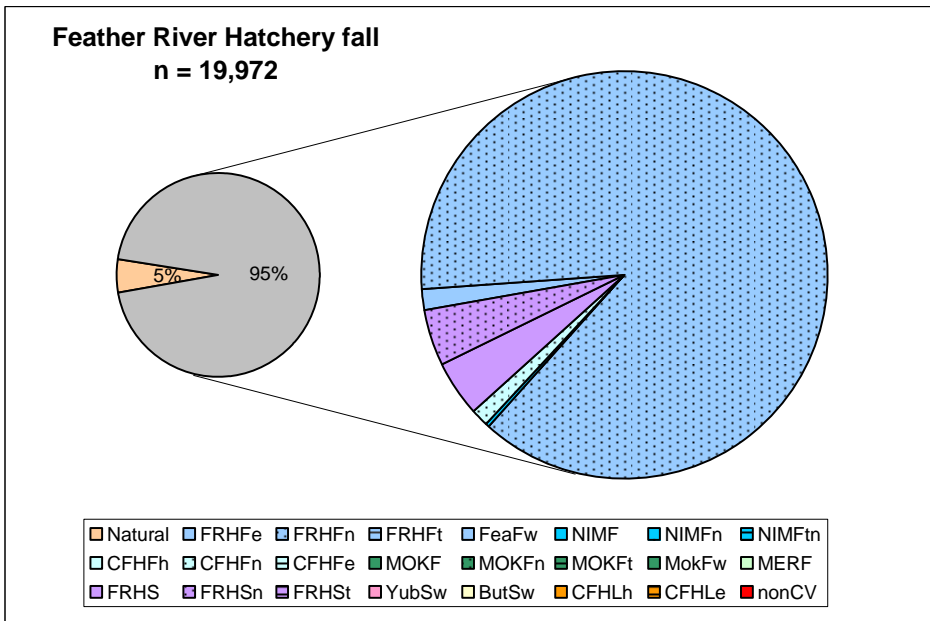
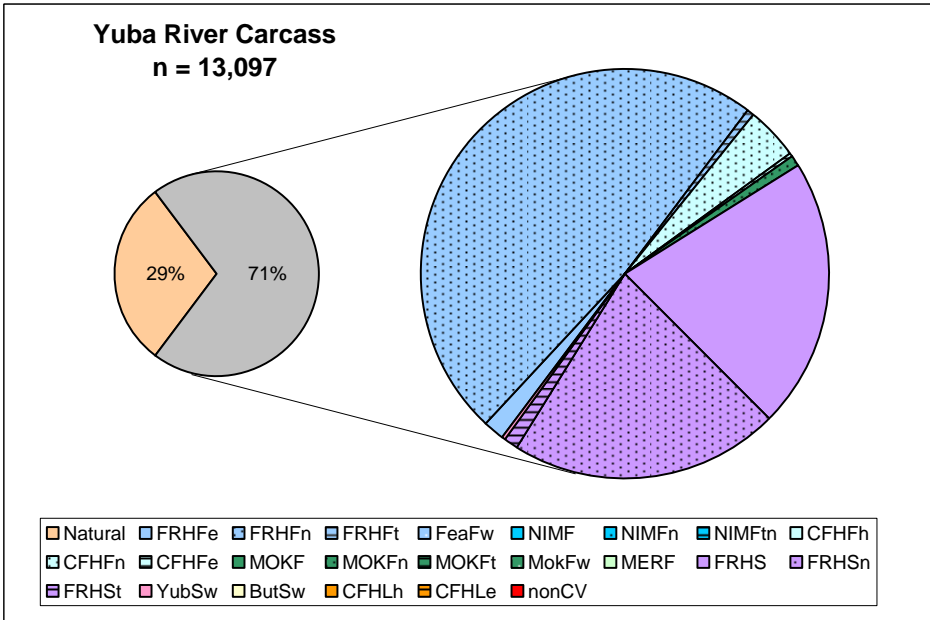
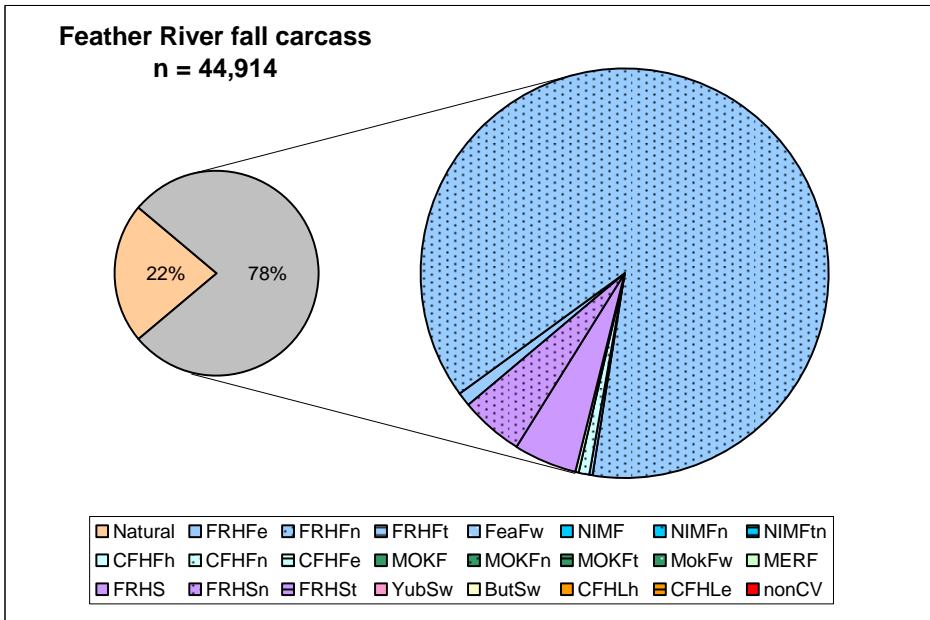


Figure 6. Proportion of hatchery and natural-origin fish in the Feather River Basin.



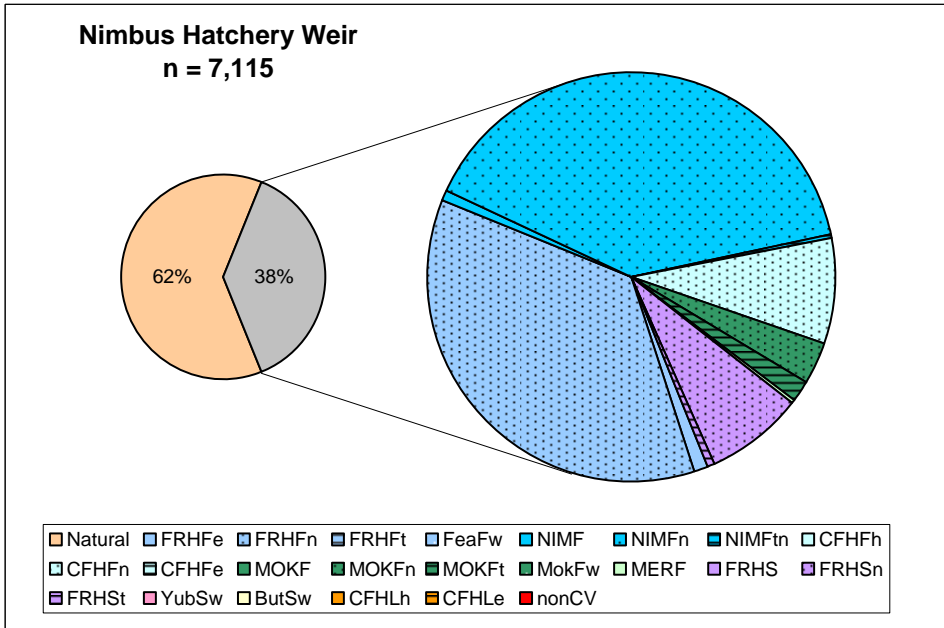
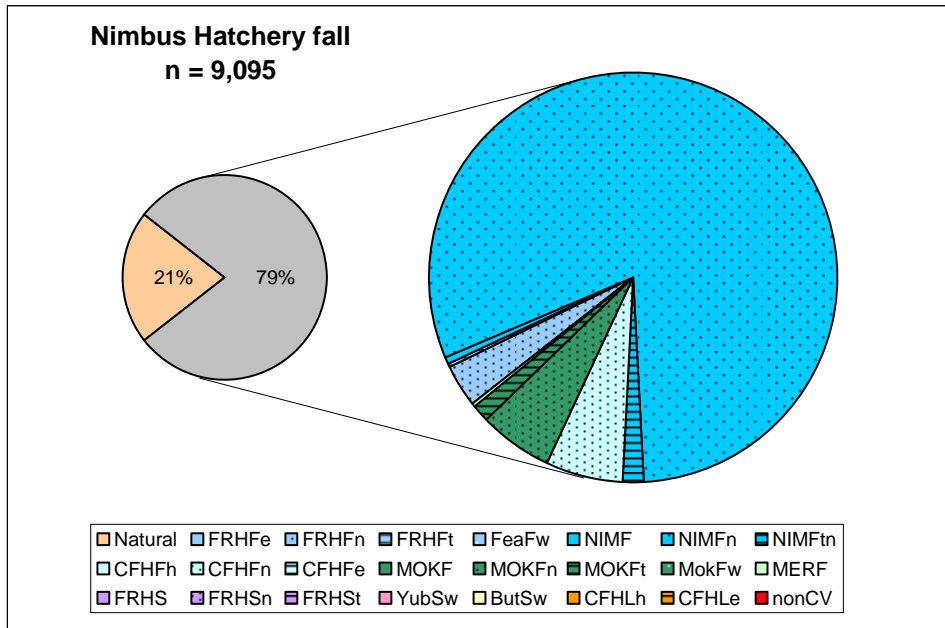
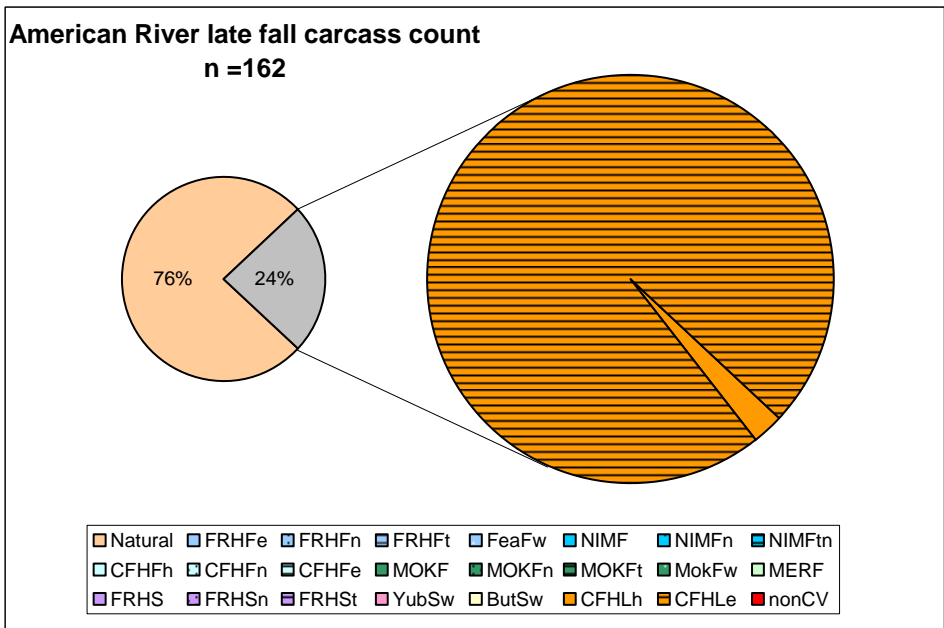
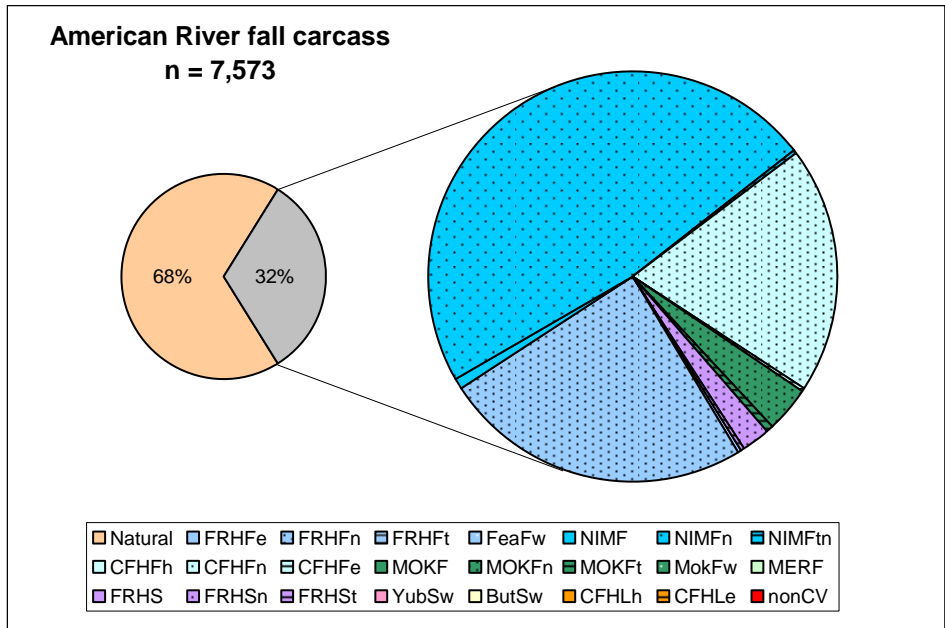


Figure 7. Proportion of hatchery and natural-origin fish in the American River Basin.

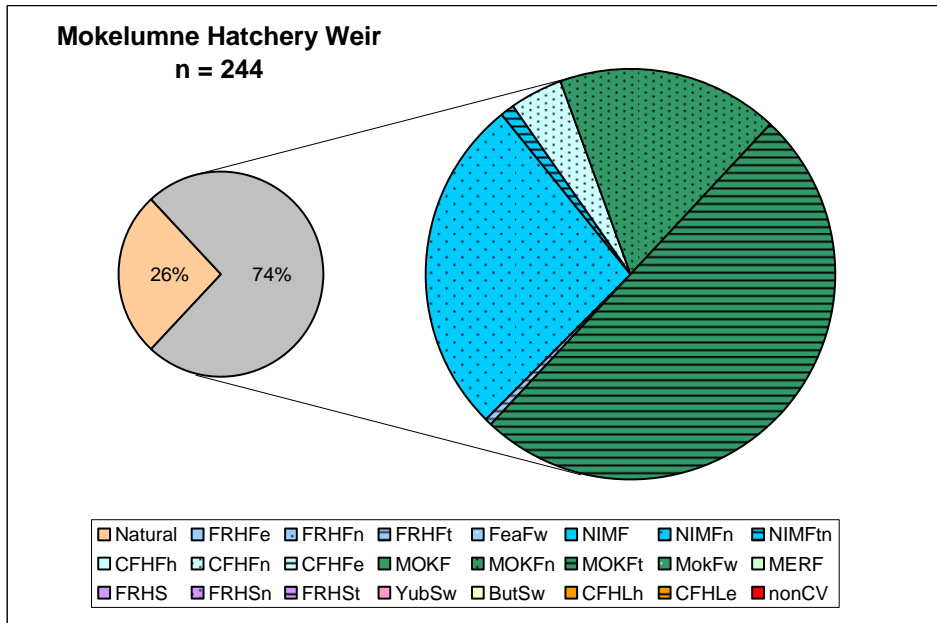
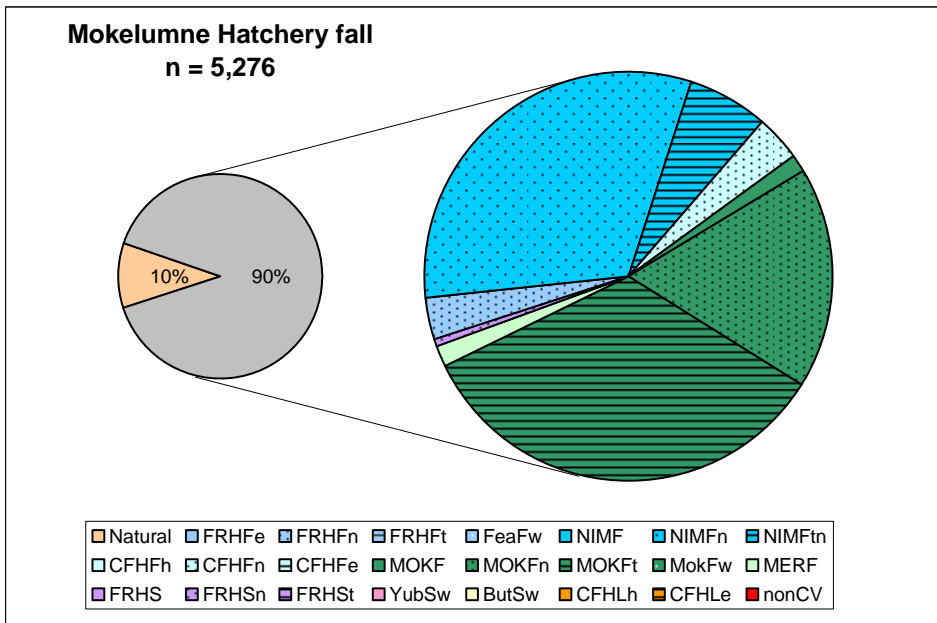
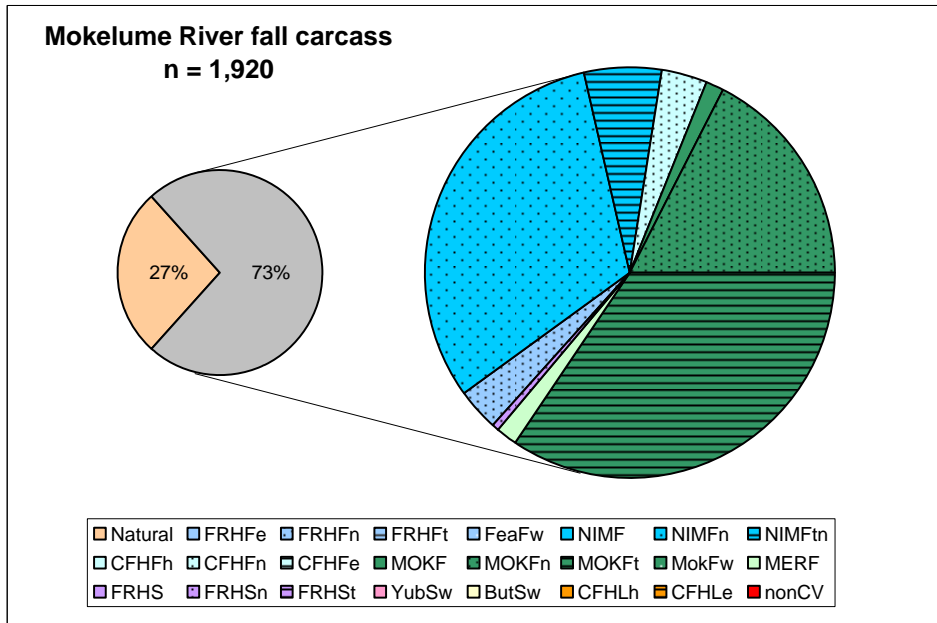


Figure 8. Proportion of hatchery and natural-origin fish in the Mokelumne River Basin.

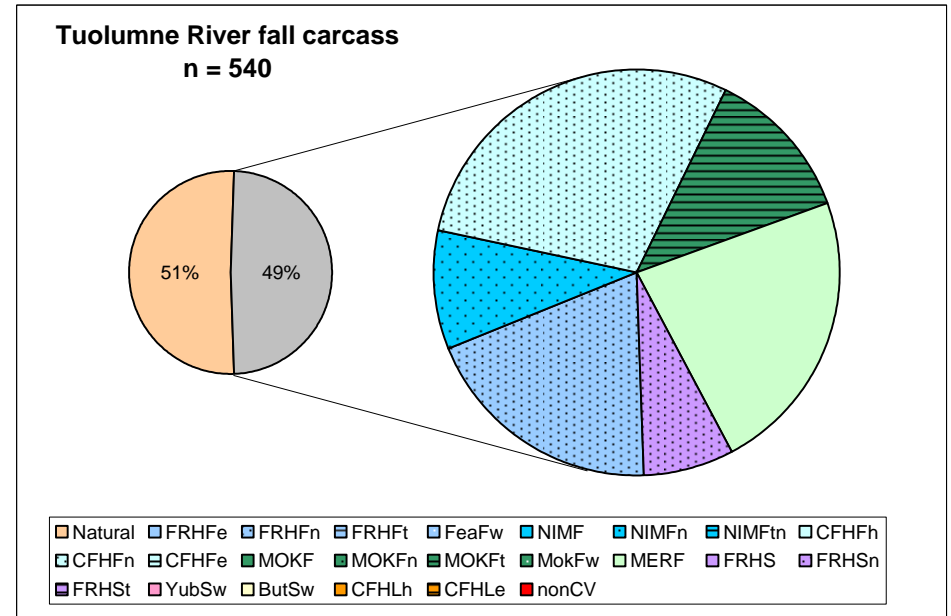
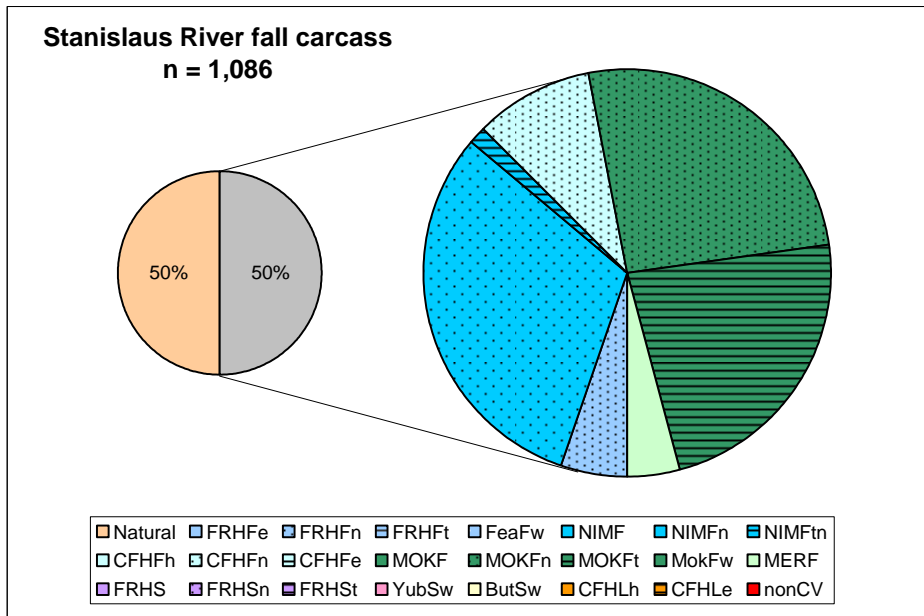
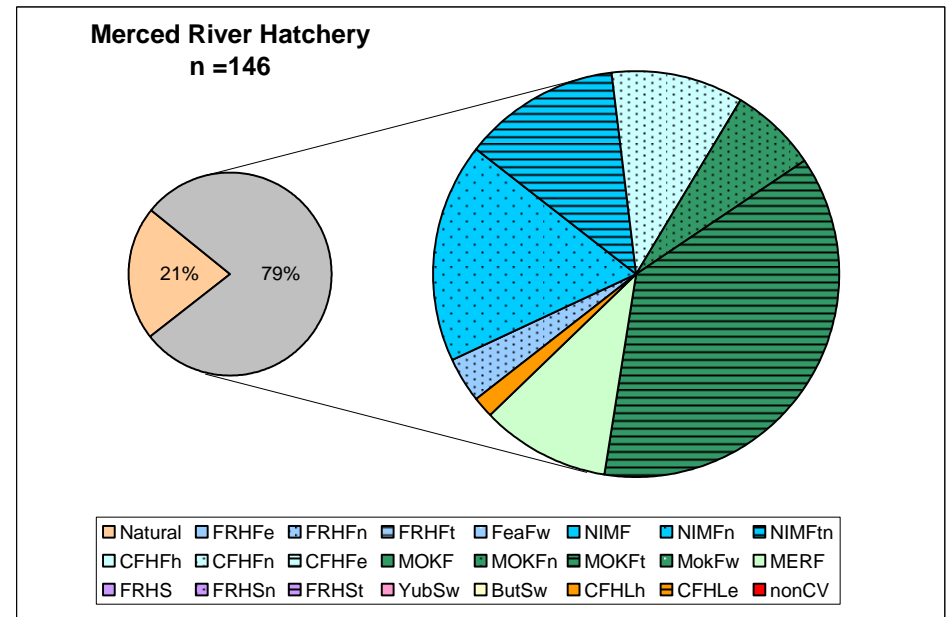
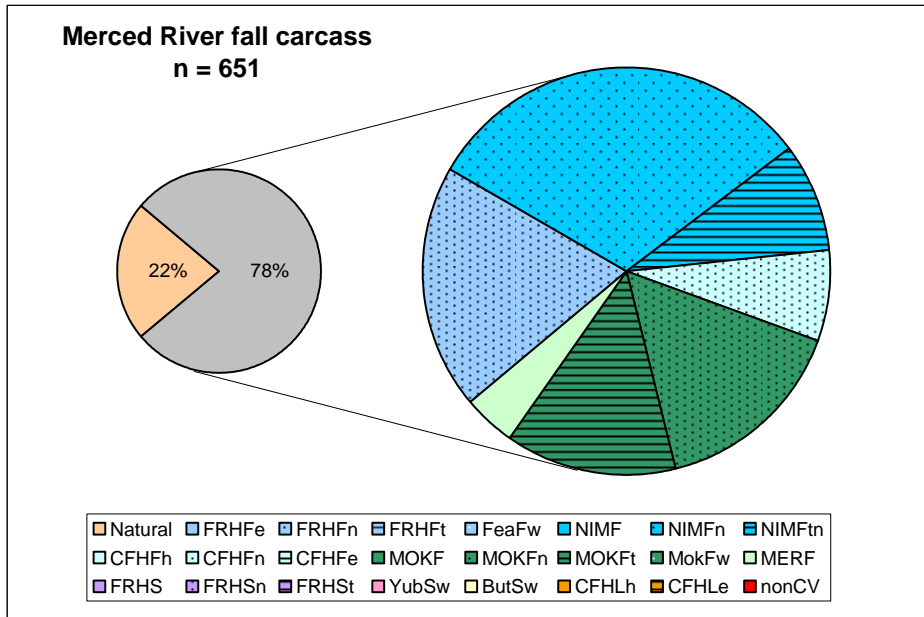


Figure 9. Proportion of hatchery and natural-origin fish in other San Joaquin River tributaries.

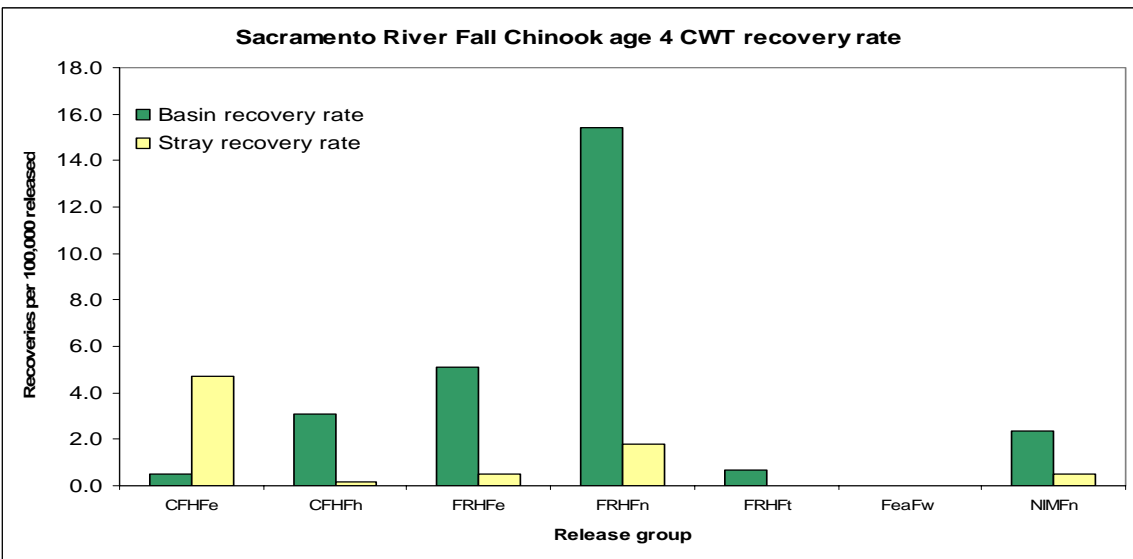
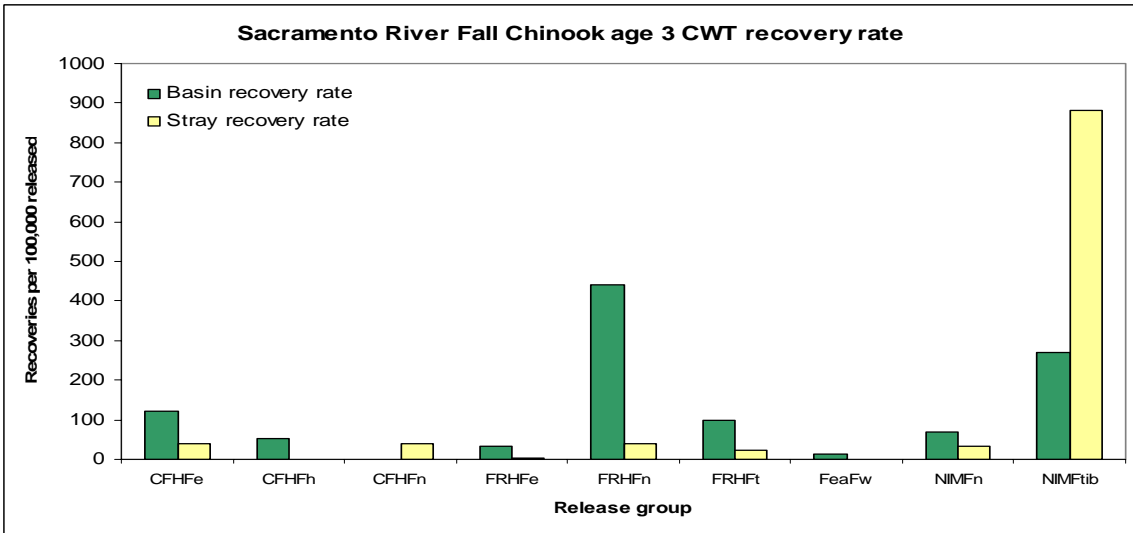
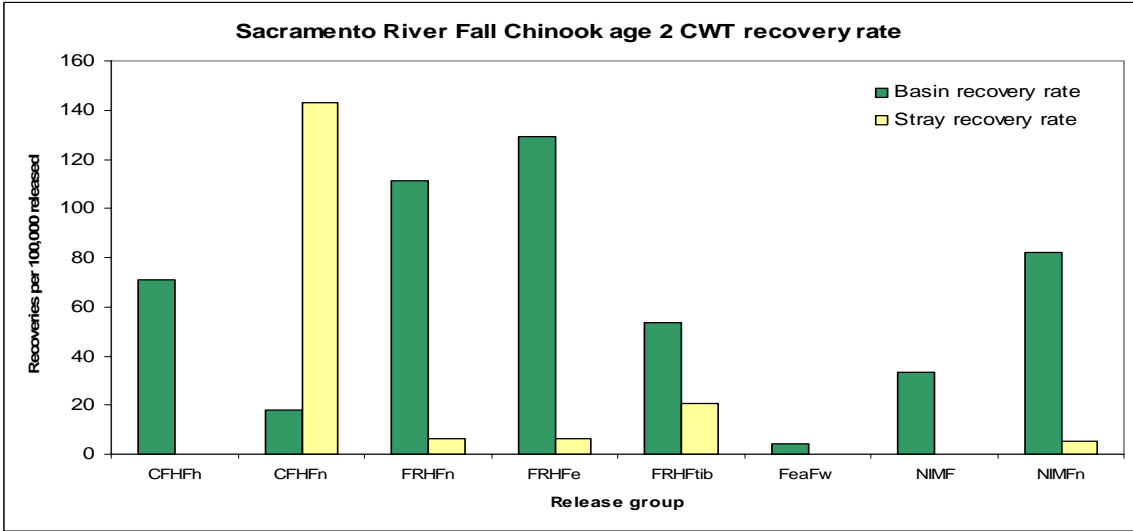


Figure 10. 2010 fall run Chinook recovery and stray rates in the Central Valley.

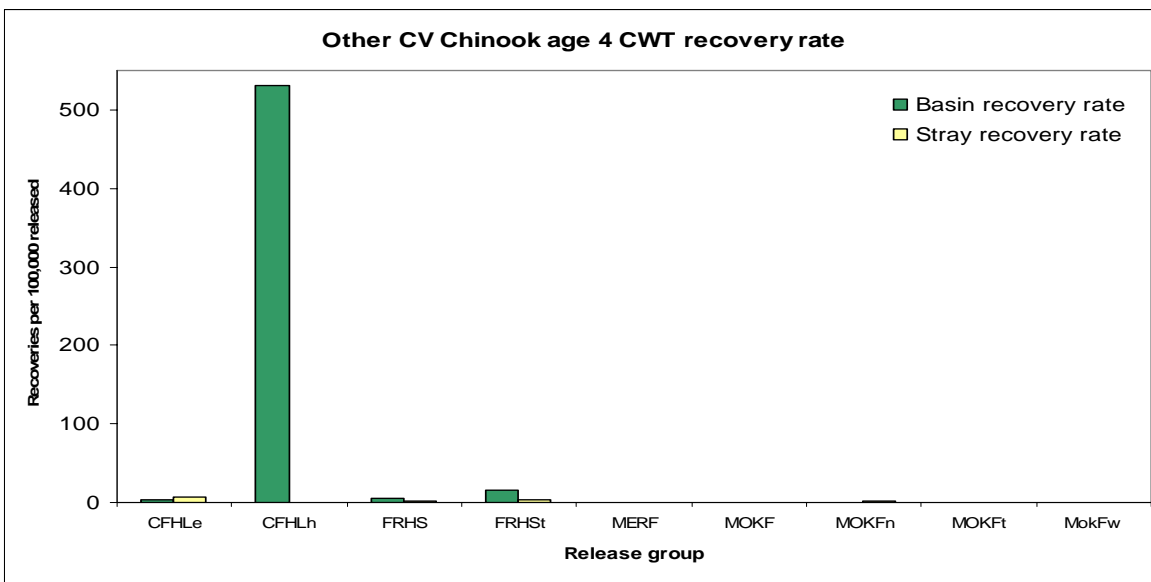
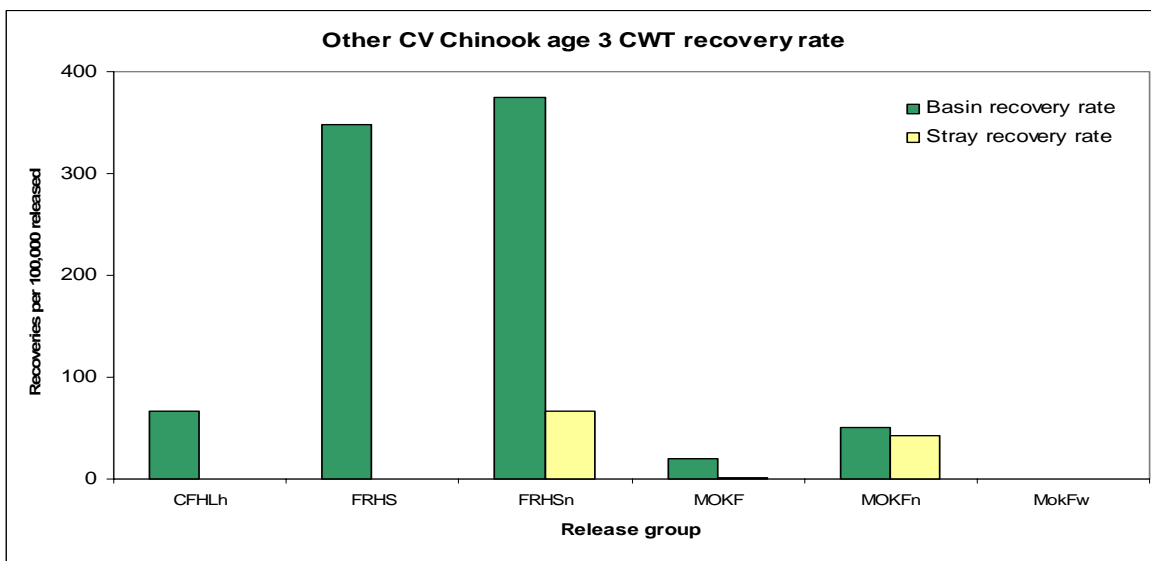
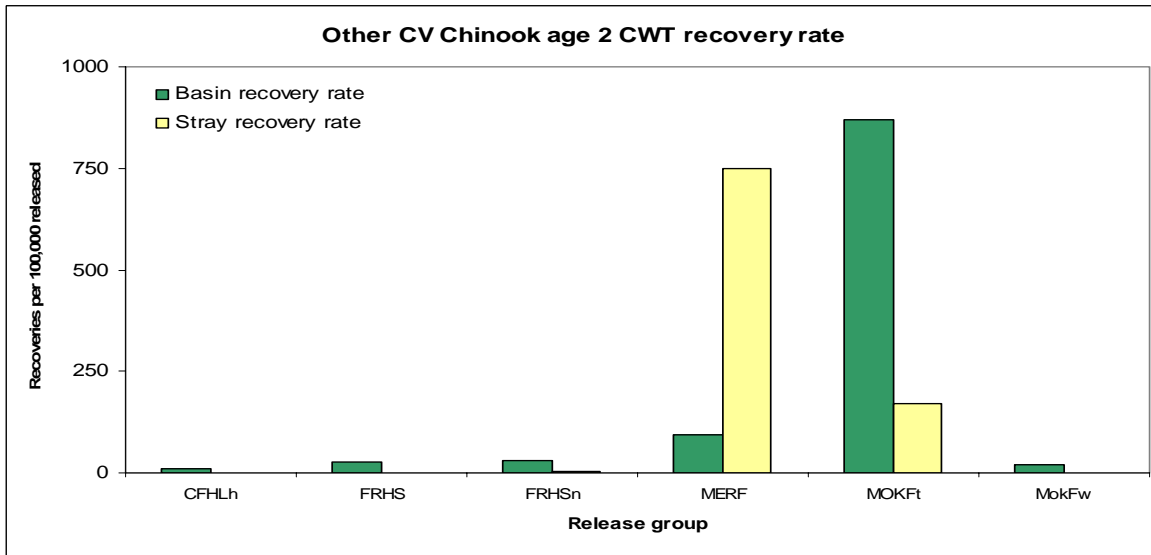


Figure 11. 2010 recovery and stray rates for other CV Chinook

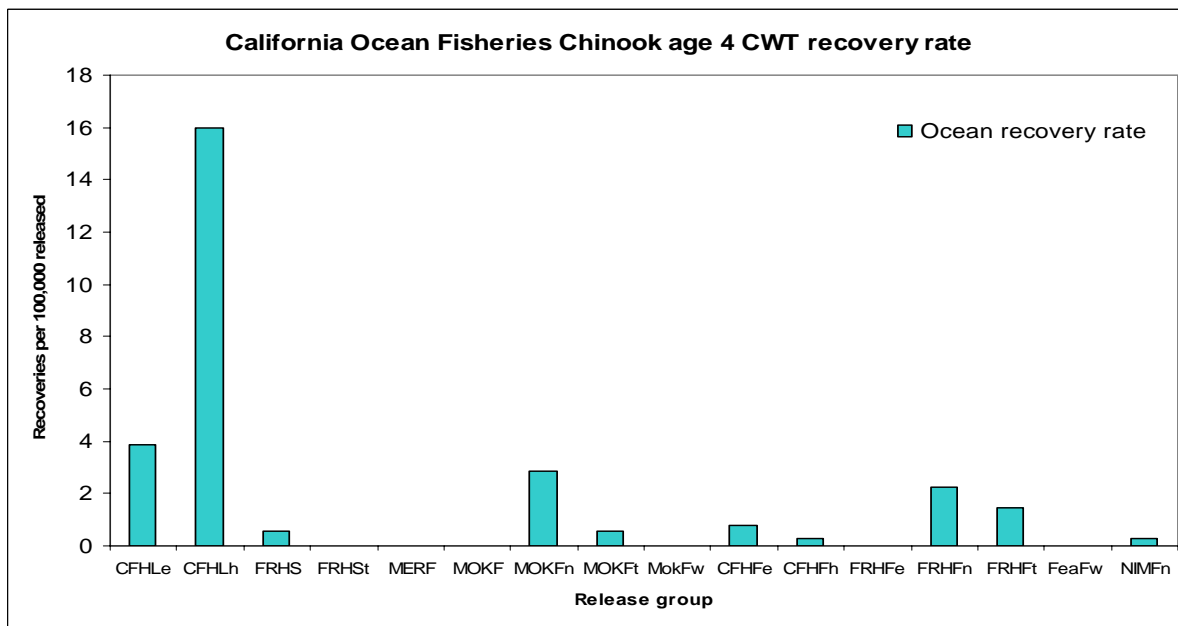
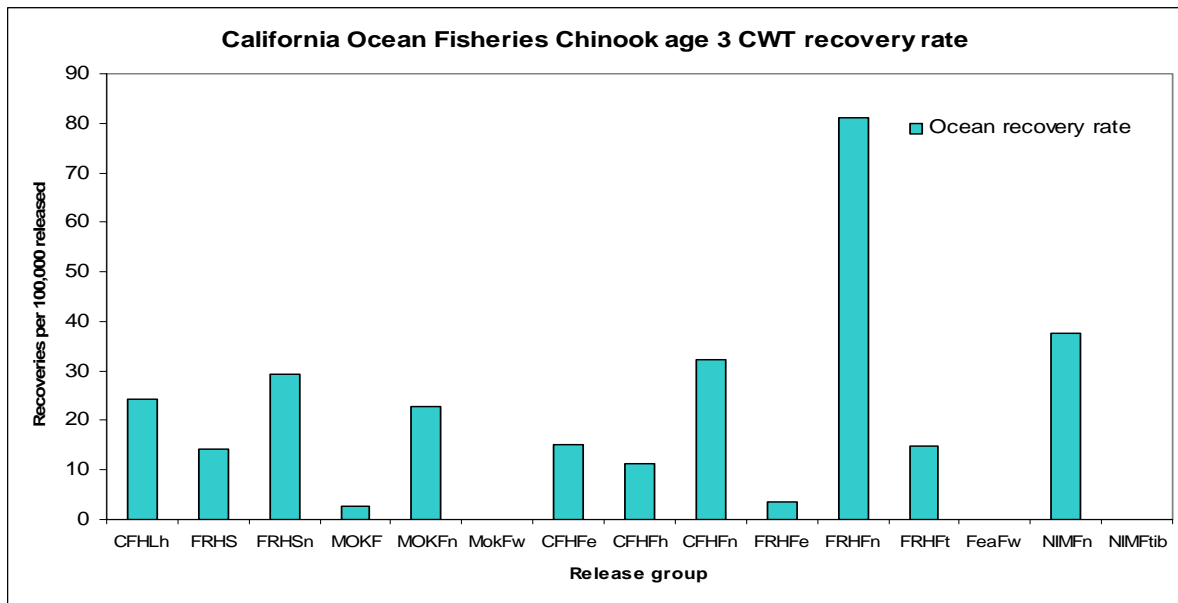
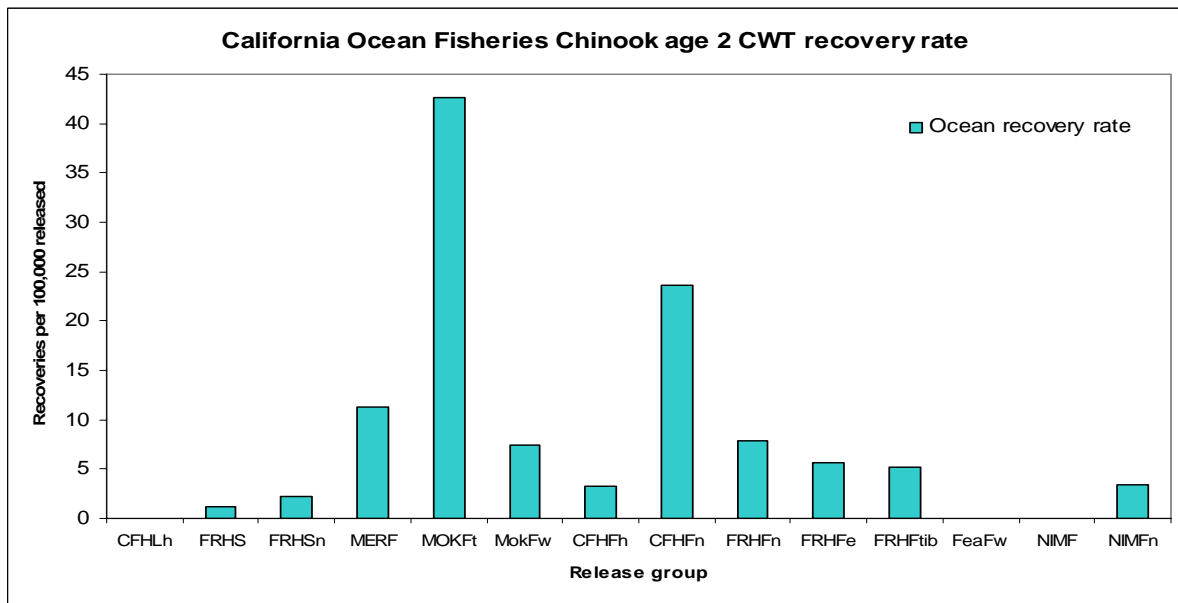
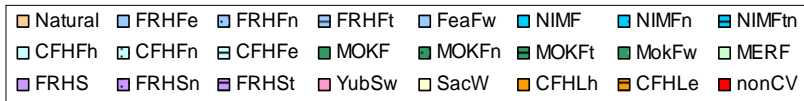
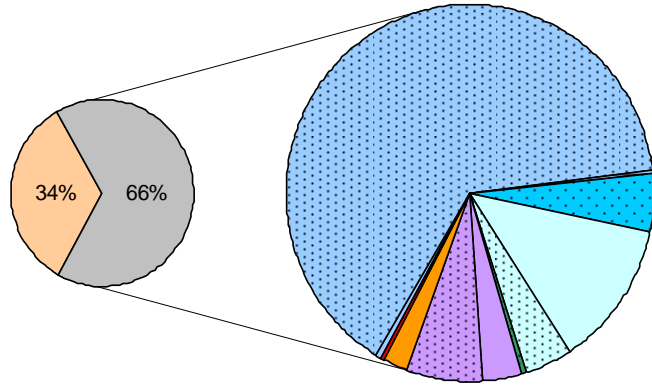
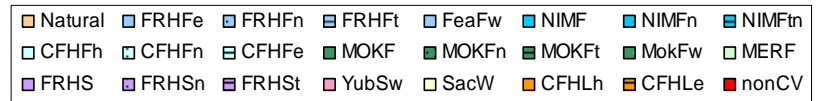
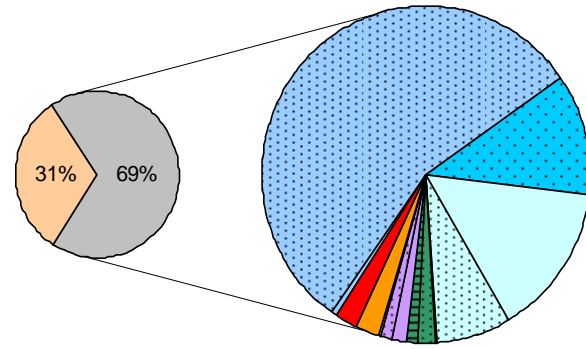


Figure 12. 2010 CV Chinook recovery rates in the ocean fishery.

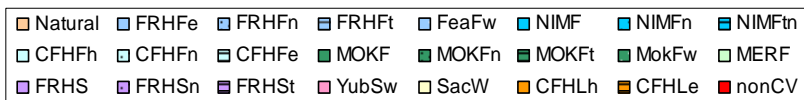
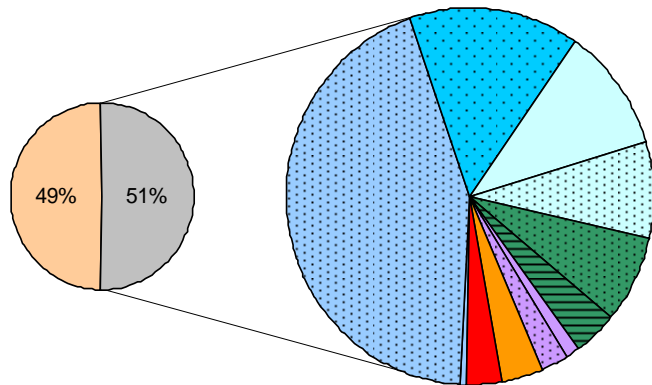
**Monterey Sport**  
n = 6,348



**San Francisco Sport**  
n = 5,927



**Fort Bragg Sport**  
n = 1,702



**Eureka / Crescent City Sport**  
n = 720

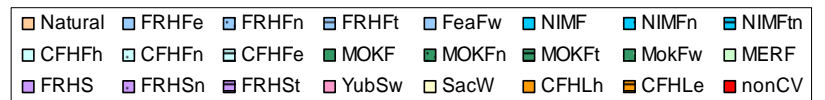
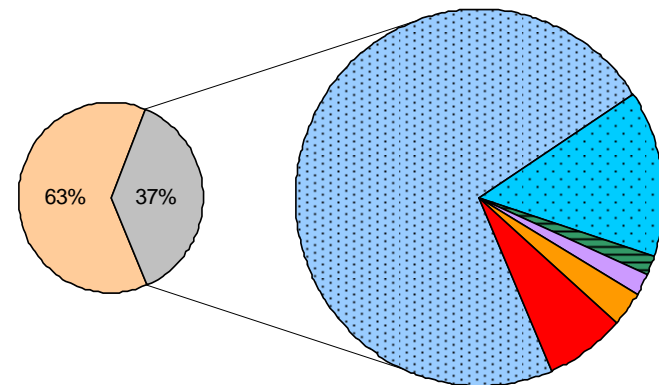


Figure 13. Proportion of hatchery and natural-origin fish in the 2010 ocean sport fishery.

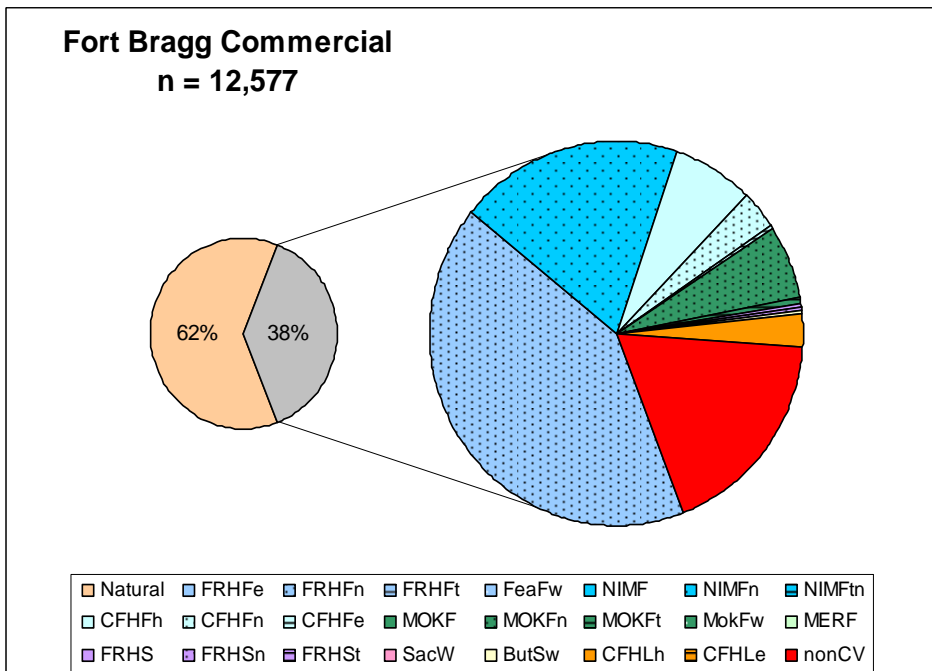
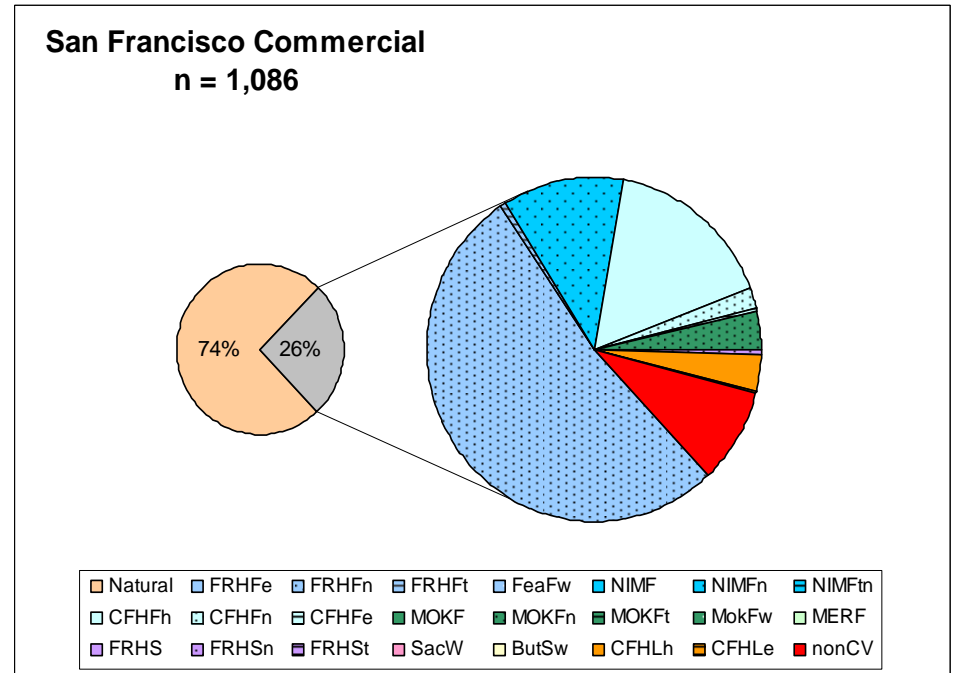
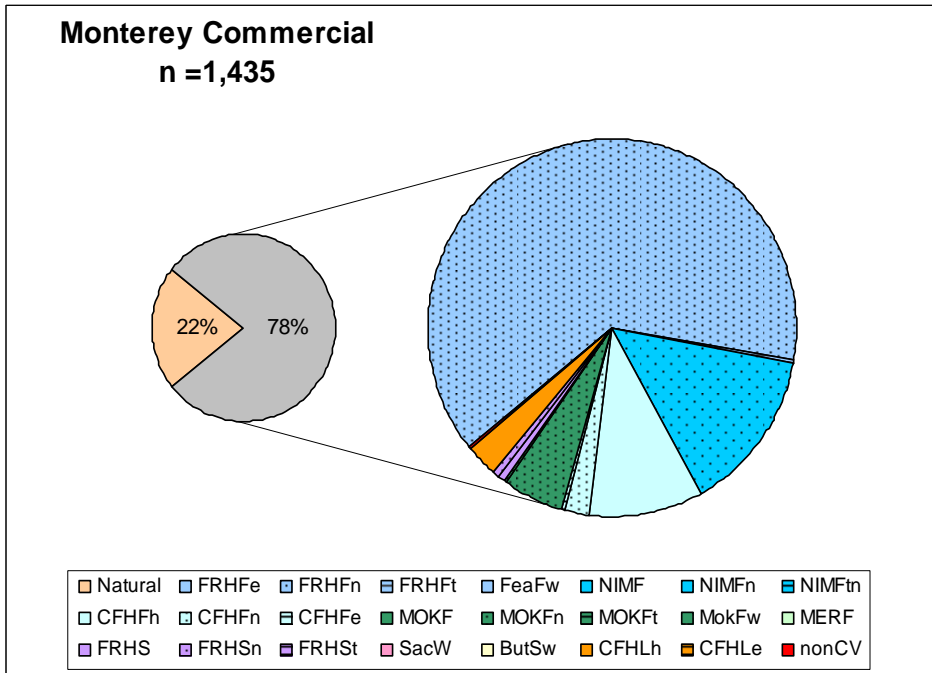


Figure 14. Proportion of hatchery and natural-origin fish in the 2010 ocean commercial fishery.



# **Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011**

Melodie Palmer-Zwahlen<sup>1</sup> and Brett Kormos<sup>1</sup>  
California Department of Fish and Wildlife

Fisheries Branch Administrative Report 2013-02

December 2013



<sup>1</sup> Marine Region, Ocean Salmon Project, 5355 Skylane Blvd Suite B, Santa Rosa, CA 95403

## NOTE TO READERS

*Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011* presents important data for the improvement of Central Valley salmon management. Until 2007, only experimental releases of fall-run Chinook salmon from Central Valley hatcheries were marked and coded-wire tagged (low, inconsistent numbers), resulting in a lack of data for harvest management, evaluation of hatchery rearing and release practices, hatchery impacts to natural-origin fish, and the success of habitat improvement programs.

The Central Valley Constant Fractional Marking Program (CFM) was initiated in 2007 to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed in the Central Valley. Beginning with Brood Year 2006 fall-run Chinook, the program has marked and coded-wire tagged a minimum of 25 percent of releases from the Central Valley hatcheries each year (Buttars 2007, 2008, 2009, and 2010). The program is a cooperative effort of the California Department of Fish and Game (DFG), the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service (FWS), the East Bay Municipal Utilities District (EBMUD), and the Pacific States Marine Fisheries Commission (PSMFC).

In 2011, more than 55,300 Code Wire Tags were recovered from ad-clipped Chinook sampled in Central Valley natural area spawning surveys, at Central Valley hatcheries, Central Valley river creel surveys, and California commercial and recreational ocean fisheries. All of the fall run Chinook Code Wire Tags recovered in the Central Valley were tagged as part of the CFM program.

This report evaluates the 2011 Central Valley fall, spring, and late fall runs Chinook Code Wire Tags recovery data in accordance with program objectives. In particular, this report attempts to answer the following questions with this second complete year of recovery data:

- What are the proportions of hatchery- and natural-origin fish in spawning returns to CV hatcheries and natural areas, in inland harvest, and in ocean harvest? Of the hatchery proportions, what proportions originated from in-basin versus out-of-basin CWT recoveries?
- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Strait? The latter includes salmon acclimated in net pens that are pulled for several hours into San Pablo Bay before fish are released. In addition, salmon trucked to and held for several days in coastal net pens before release are also evaluated.
- What are the relative recovery rates for fish acclimated in net pens and released in the bay versus salmon released directly into the waters of the Carquinez Strait?

- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

As with all of its products, Fisheries Branch is interested in comments on the utility of this document, particularly regarding its application to monitoring and management decision processes. Therefore, we encourage you to provide us with your comments. Comments should be directed to Dr. Russell J. Bellmer, Fisheries Branch, 830 S Street, Sacramento, CA 95814, (916) 327-8840, [Russ.Bellmer@wildlife.ca.gov](mailto:Russ.Bellmer@wildlife.ca.gov).

A handwritten signature in black ink, appearing to read 'Stafford Lehr', written over a horizontal line.

Stafford Lehr  
Chief, Fisheries Branch

## INTRODUCTION

Each year, approximately 32 million fall-run Chinook salmon (salmon) are produced at five hatcheries in California's Central Valley (CV): Coleman National Fish Hatchery (CNFH), Feather River Hatchery (FRH), Nimbus Fish Hatchery (NFH), Mokelumne River Hatchery (MOK), and Merced River Hatchery (MER). Production from these hatcheries contributes to major sport and commercial fisheries in ocean and inland areas. Prior to 2007, only small experimental releases (generally <100,000 fish) of CV fall-run salmon were consistently released with microscopic ( $\leq 1$  mm) coded-wire tags (CWT) inserted in their snouts. Each CWT contains a binary or alpha-numeric code that identifies a specific release group of salmon (e.g., agency, species, run, brood year, hatchery or wild stock, release size, release date(s), release location(s), number tagged and untagged). Any CV salmon containing a CWT is also externally marked with a clipped adipose fin (ad-clipped) to allow for visual identification. Almost all of the fall-run salmon production releases from CV hatcheries were either untagged or tagged at inconsistent and relatively low rates prior to the Constant Fractional Marking (CFM) program.

In 2004, the CALFED Ecosystem Restoration Program (ERP), under the direction of the Central Valley Salmon Project Work Team (CVSPWT), funded a study to design a constant fractional marking and coded-wire tagging program for CV fall-run salmon production at all CV hatcheries. The primary goal of this program was to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed throughout the CV. The study recommended the implementation of a system-wide marking and tagging program for production releases. Planning studies indicated an optimum marking and tagging rate of 33% for all CV fall-run salmon production releases (Hicks et al. 2005). Following subsequent review of the planning study recommendations, and communication with managers in the Northwest, the CVSPWT recommended a marking and tagging rate of 25% of fall-run production releases. The CVSPWT is an interagency group tasked with coordinating salmon and steelhead monitoring activities in the CV and they helped develop the CFM program. CVSPWT members included staff from the California Department of Fish and Wildlife (CDFW), California Department of Water Resources (DWR), East Bay Municipal Utility District (EBMUD), Metropolitan Water District, Central Valley Project Water Association, National Marine Fisheries Service (NMFS), Pacific States Marine Fisheries Commission (PSMFC), U.S. Bureau of Reclamation (BOR), and the U.S. Fish and Wildlife Service (FWS).

Beginning with brood year 2006, at least 25% of fall-run salmon production releases at CNFH (12-13 million), FRH (9-10 million), NFH (5-6 million), and MOK (4-5 million) have been marked and tagged each spring (Buttars 2007, 2008, 2009, 2010, 2011). This CFM program is a cooperative effort of the CDFW, DWR, BOR, FWS, EBMUD, and PSMFC. It should be noted that due to extremely low production numbers, MOK marked and tagged 100% of their fall-run salmon releases for brood years 2008 and 2009. In addition, almost all of the fall-run salmon production at MER (50,000-300,000 fish), spring-run salmon production at FRH (2 million fish), late-fall-run salmon production at CNFH (1 million fish), and winter-run salmon production reared at Livingston Stone National Fish Hatchery (100,000-200,000 fish) have been marked and coded-wire tagged each year.

During 2011, more than 55,300 CWTs were recovered from ad-clipped salmon sampled in CV fall-, spring-, and late-fall-run natural area spawning surveys, at CV hatcheries, in CV river creel surveys, and in California ocean commercial and recreational fisheries. All of the fall-run salmon CWTs recovered in 2011 were tagged as part of the CFM program. This report evaluates the 2011 CV fall-, spring-, and late-fall-run salmon CWT recovery data in accordance with program objectives. In particular, this report attempts to answer the following questions with this second complete year of recovery data:

- What are the proportions of hatchery- and natural-origin fish in spawning returns to CV hatcheries and natural areas, in inland harvest, and in ocean harvest? Of the hatchery proportions, what proportions originated from in-basin versus out-of-basin CWT recoveries?
- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Strait? The latter includes salmon acclimated in net pens that are pulled for several hours into San Pablo Bay before fish are released. In addition, salmon trucked to and held for several days in coastal net pens before release are also evaluated.
- What are the relative recovery rates for fish acclimated in net pens and released in the bay versus salmon released directly into the waters of the Carquinez Strait?
- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

## **DATA AND METHODS**

### **Inland Escapement Monitoring**

During 2011, monitoring of salmon escapement occurred at all five salmon hatcheries and on major rivers and tributaries throughout the CV. In addition, creel surveys were conducted on sport fisheries in the Feather, American, and Sacramento River basins. Returning salmon were counted and 100% of the ad-clipped salmon sampled at all CV hatcheries except CNFH, which sampled every other ad-clipped salmon (i.e., 50% sample rate) for fall-run escapement and 100% of ad-clipped salmon for the late-fall-run escapement. Similar to 2010, sample rates and methods (e.g., carcass surveys, weir counts, redd counts) varied among natural spawner surveys throughout the CV (Table 1).

Approximately 52,900 ad-clipped salmon were observed and 48,138 heads collected by various CV projects. Monitoring agencies include CDFW, DWR, EBMUD, FWS, and PSMFC. Most heads were processed by CDFW at their Santa Rosa and Sacramento CWT labs with the exception of approximately 9,500 heads collected from Clear Creek and CNFH that were processed by FWS staff at the Red Bluff FWS office. Additionally a few hundred heads were processed by individual projects, most notably at the Red Bluff and La Grange CDFW offices. Their respective data were submitted to the Santa Rosa CWT Lab for inclusion in the 2011 CV CWT recovery database. Almost 97% (46,596) of these heads contained valid CWTs, 2% of heads had shed their CWTs prior to processing, and less than 1% contained CWTs that were either too damaged to read or lost during processing.

Total escapement estimates and the number of salmon sampled for ad-clips in this report were provided by individual CV projects or hatcheries. These data, along with their respective CWT recovery data, were uploaded to the Regional Mark Processing Center (RMPC) and are readily accessible at [www.rmhc.org](http://www.rmhc.org).

### **Ocean Harvest Monitoring**

Since 1962, the CDFW's Ocean Salmon Project (OSP) has monitored California's ocean salmon fisheries at approximately 20 ports between Point Conception and the California-Oregon border. The goal of OSP is to sample at least 20% of all salmon landed and to collect the heads from all ad-clipped salmon observed during monitoring. In 2011, the seasons for California sport and commercial ocean salmon fisheries were less constrained (Table 2) than in recent years due to an increase in the ocean abundance of both Sacramento River and Klamath River fall-run salmon. Field staff sampled more than 47,600 salmon and collected 9,768 heads that were processed by the Santa Rosa CWT lab. About 90% (8,717) of these heads contained valid CWTs, 10% were missing CWTs and <1% contained CWTs that were too damaged to read or lost during processing. Although it is generally agreed that CWTs missing from inland head recoveries is the result of salmon "shedding" these tags prior to release, this cannot be assumed for heads recovered from mixed-stock ocean fisheries. Oregon and Washington hatcheries have been "mass-marking" salmon (i.e., ad-clip only without a CWT) to support small mark-selective fisheries in the northwest. During the last several years, OSP has noticed a gradual increase in the number of ocean heads collected that do not contain CWTs, especially in California's northern ports, and assume that this is due to the increased production of mass-marked salmon in Oregon and Washington.

### **CWT Data Analysis**

A "master" release database of CWT codes was created to determine species, brood year, run, stock origin (hatchery or natural), release site, release date(s), number of salmon CWT tagged, total number of salmon released and any other pertinent release information (e.g., trucked, net pen acclimation, disease) for all 2011 CWT recoveries. All west coast CWT release data for broods 2007 through 2010 were downloaded from the RMPC. Approximately 100.6 million CV salmon were released for these four brood years (BY), of which, 38.5 million fish were marked and tagged utilizing 444 unique CWT codes. Although a few natural-origin salmon are trapped, marked, and tagged each year, salmon produced by hatcheries make up more than 98% of all CWT releases. In 2011, there were 310 individual CWT codes recovered in the CV, primarily from age-2, age-3 and age-4 salmon. The CWT master file was updated with any additional information obtained for these CV salmon releases (e.g., number of untagged salmon associated with BY 2008 fall-run CNFH production CWT releases) and the production factor calculated for each CWT code. The production factor,  $F_{\text{prod}}$ , is the total number of fish released (tagged and untagged) represented by each CWT recovery.  $F_{\text{prod}}$  was calculated for each CWT code and is defined as,

$$F_{\text{prod}} = (\text{Ad.CWT} + \text{Ad.noCWT} + \text{noAd.CWT} + \text{noAd.noCWT}) / \text{Ad.CWT} ,$$

where Ad.CWT is the number of fish released with ad-clips and CWTs, Ad.noCWT is the number of fish released with ad-clips but without CWTs (i.e., shed tags prior to release or CWT

not correctly inserted), noAd.CWT is the number of fish released without ad-clips but with CWTs, and noAd.noCWT is the number of fish released without ad-clips and without CWTs.  $F_{prod}$  allows expansion to total hatchery production from observed recoveries of CV CWTs.

For this analysis, each CV CWT release was further classified into “release types” based on the following criteria: run, stock, hatchery or natural, production or experimental, release location, and holding strategy. All CV CWT codes were assigned by brood year into one of 17 fall-run release types, 3 spring-run release types, or 2 late-fall-run release types:

#### Sacramento River Basin fall-run Chinook salmon release types

- CFHFe Coleman National Fish Hatchery fall-run experimental releases
- CFHFh Coleman National Fish Hatchery fall-run in-basin (at hatchery) releases
- CFHFh Coleman National Fish Hatchery fall-run net pen releases
- FRHFe Feather River Hatchery fall-run experimental releases (includes fall x spring hybrid salmon)
- FRHFh Feather River Hatchery fall-run net pen releases
- FRHFnc Feather River Hatchery fall-run net pen coastal releases (Santa Cruz)
- FRHFt Feather River Hatchery fall-run trucked releases (no net pen acclimation)
- FRHFtib Feather River Hatchery fall-run Tiburon net pen releases (held 2-6 months)
- FeaFw Feather River fall-run wild
- NIMF Nimbus Fish Hatchery fall-run in-basin releases
- NIMFn Nimbus Fish Hatchery fall-run net pen releases
- NIMFtib Nimbus Fish Hatchery fall-run Tiburon net pen releases (held 3-4 months)

#### San Joaquin River Basin fall-run Chinook salmon release types

- MOKF Mokelumne River Hatchery fall-run in-basin releases
- MOKFn Mokelumne River Hatchery fall-run net pen releases
- MOKFt Mokelumne River Hatchery fall-run trucked releases (no net pen acclimation)
- MokFw Mokelumne River fall-run wild
- MERF Merced River Fish Facility fall-run releases (primarily in-basin)

#### Central Valley spring-run Chinook salmon release types

- FRHS Feather River Hatchery spring-run in-basin releases
- FRHSn Feather River Hatchery spring-run net pen releases
- ButSw Butte Creek spring-run wild

#### Central Valley Late-Fall-run Chinook salmon release types

- CFHLe Coleman National Fish Hatchery late-fall-run experimental releases
- CFHLh Coleman National Fish Hatchery late-fall-run in-basin (at hatchery) releases

It should be noted that not all release types occurred every brood year and release sites sometimes varied within a given release type (Table 3). There were also several problem CWT releases where stock origin did not match hatchery origin (e.g., BY 2007 American River fall-run salmon raised at MOK), stocks or runs were mixed prior to CWT tagging and released utilizing various strategies (e.g., known pairs of FRH fall- and spring-run salmon spawned and identified by CWT subsequently released as experimental “hybrid” salmon for Delta studies), or a high percentage of the salmon trucked for net pen acclimation actually died prior to release

(e.g., 75% mortality reported in truckload of CNFH fall-run salmon being transported to San Pablo Bay net pens).

To estimate the total escapement (or harvest) associated with each CWT recovery, each tag recovery was expanded by its respective  $F_{\text{prod}}$  and sample expansion factor,  $F_{\text{samp}}$ , which is defined as,

$$F_{\text{samp}} = 1 / (f_e \times f_a \times f_d),$$

where  $f_e$  is the fraction of the total salmon escapement sampled and examined for ad-clipped fish,  $f_a$  is the fraction of heads from ad-clipped salmon collected and processed, and  $f_d$  is the fraction of observed CWTs that were successfully decoded (Tables 4 and 5). A few heads were collected opportunistically during redd counts or snorkel surveys; these CWTs were given an  $F_{\text{samp}}$  of 1.00 (i.e., no expansion) since they were not representative of the total escapement.

After the release of the 2010 report (Kormos et al. 2012), Mohr and Satterthwaite (in press) demonstrated how the potential misidentification of ad-clipped salmon in carcass surveys can significantly bias estimations of the total hatchery contribution since they frequently encounter both fresh and non-fresh (decayed) carcasses.

Salmon sampled in some CV carcass surveys are generally recorded as ‘fresh’ or ‘decayed’ based on criteria such as condition of the eyes (clear vs. opaque) or gills (pink vs. grey). Often the ad-clipped (marked) status of a decayed salmon can be uncertain due to the deteriorating condition of the carcass. Mohr and Satterthwaite (in press) identified four possible outcomes: 1) certain (all ad-clipped and non-marked salmon are correctly identified), 2) false negatives (ad-clipped salmon identified as not marked), 3) false positives (non-marked salmon identified as ad-clipped) or 4) false negatives/positives (ad-clipped salmon identified as non-marked and non-marked salmon identified as ad-clipped).

While condition criteria are somewhat ambiguous and classification may be inconsistent among surveys, differences in the ad-clip rate between fresh and decayed fish have been observed. During the 2010 upper Sacramento River fall-run salmon carcass survey, 21% of the fresh fish sampled were classified as ad-clipped compared to only 6% of decayed fish (i.e., false negative). The fresh carcass heads also contained a CWT more frequently than the heads collected from decayed carcasses (i.e., false positive). Furthermore, the sample sizes for these categories were also significantly different, with the number of decayed fish sampled ( $n=1,124$ ) nearly four times greater than the fresh fish ( $n=291$ ). The latter appears to be fairly common among CV carcass surveys currently collecting fish condition data.

Mohr and Satterthwaite (in press) demonstrated how the differences noted above negatively biased the hatchery contribution estimations for the 2010 upper Sacramento River fall-run salmon carcass survey as reported in Kormos et al. (2012). This was also shown to be true for the 2010 upper Sacramento late-fall-run survey. Furthermore, they cautioned that using only fresh CWT data may eliminate the occurrence of rare CWT codes in analyses due to the small sample sizes common with fresh carcasses in these surveys. Since both of these surveys contained false negatives and false positives, and sample sizes for decayed carcasses were much



larger than those of fresh carcasses, we have adopted the following equation developed by Mohr and Satterthwaite (in press) to calculate  $F_{\text{samp}}$  for carcass surveys collecting fish condition data, thus reducing the potential bias associated with these surveys:

$$F_{\text{samp}} = (N \times p_{\text{adc|fresh}} \times p_{\text{cwt|fresh,adc}}) / n_{\text{valid cwt}},$$

where  $N$  = estimated total escapement,  $p_{\text{adc|fresh}}$  = proportion of fresh fish sampled that were ad-clipped,  $p_{\text{cwt|fresh,adc}}$  = proportion of ad-clipped fresh fish that contained a CWT, and  $n_{\text{valid cwt}}$  = total number of valid CWTs collected from both fresh and decayed fish.

Table 6 shows the original and revised  $F_{\text{samp}}$  for the 2010 upper Sacramento River fall-run and late-fall-run carcass surveys. This new equation was also used to determine  $F_{\text{samp}}$  for the five CV salmon carcass surveys that collected fish condition sample data in 2011: upper Sacramento River fall-run, upper Sacramento late-fall-run, Clear Creek fall-run, Cottonwood Creek fall-run, and American River fall-run. We are hopeful that other CV carcass surveys will begin to collect fish condition information to reduce the known bias in CWT sample rate calculations and hatchery contribution estimations as demonstrated by Mohr and Satterthwaite (in press). We realize that the calculated hatchery contribution rates of the other carcass surveys in this report are most likely negatively biased.

To help delineate between raw CWT recoveries, CWT recoveries expanded for production, CWTs expanded for sampling, and CWTs expanded for production and sampling, the following nomenclature will be used:

- CWT = Raw count CWT recoveries
- $CWT_{\text{prod}}$  = CWT recoveries expanded only by their respective production factor,  $F_{\text{prod}}$
- $CWT_{\text{samp}}$  = CWT recoveries expanded only by their respective sample expansion factor,  $F_{\text{samp}}$
- $CWT_{\text{total}}$  = CWT recoveries expanded by both  $F_{\text{prod}}$  and  $F_{\text{samp}}$

### **Determining hatchery- and natural-origin proportions in CV escapement and harvest**

To determine the contribution of hatchery- and natural-origin salmon, all  $CWT_{\text{total}}$  were summed to estimate the total number of hatchery fish in each survey. The contribution of natural-origin fish for each survey was then determined by subtracting the total number of hatchery fish from the total escapement estimate, as follows:

$$\text{Estimate of natural-origin salmon} = \text{Total escapement estimate} - \sum_{i=1}^m CWT_{\text{total},i},$$

where  $m$  = total number of hatchery-origin CWT release groups identified in an escapement survey or hatchery.

### **Determining recovery rates of various release types in CV escapement and ocean harvest**

To determine the relative CV recovery rate,  $R_{\text{cwt}}$ , of each unique CWT release group (i.e., code), all recoveries were expanded by their location-specific  $F_{\text{samp}}$ , summed over all recovery locations, and then divided by the total number of fish tagged and released with this CWT. Since expanded recoveries for several individual CWT groups were less than 0.001% of the total

number released, recovery rates are reported in recoveries per 100,000 CWT salmon released, as follows:

$$R_{\text{cwt}} = \sum_{j=1}^l \text{CWT}_{\text{samp},j} \text{ recoveries} / \text{CWT release group size} / 100,000,$$

where  $j$  ( $=1,2,3,,l$ ) denotes recovery location.

Data from all CWT release groups belonging to the same brood year and release type were combined and an overall release type-specific CV recovery rate,  $R_{\text{type}}$ , was calculated as:

$$R_{\text{type}} = \sum_{j=1}^l \sum_{k=1}^n \text{CWT}_{\text{samp},k} / \sum_{k=1}^n \text{release group size of CWT}_k / 100,000,$$

where  $k$  ( $=1,2,3,,n$ ) denotes release group.

### **Determining stray proportions of various release groups in CV escapement**

To be consistent with Kormos et al. (2012), basin of origin is defined here as the drainage of any major river as it pertains to the geographic region of the CV where a hatchery is located. The CV was again segregated into five primary hatchery basins: upper Sacramento River (including Battle Creek), Feather River (including the Yuba River), American River, Mokelumne River, and the Merced River. Hatchery-origin salmon returning to streams not included in these five primary basins were considered to be strays. Any CWTs recovered outside of these defined basins of origin based on their reported stock or hatchery were considered strays.

Further evaluation of these definitions is warranted as future CFM recovery data become available and the definition of straying as it pertains to sub-basins of the CV is determined through hatchery program evaluation. To help facilitate this discussion, Appendix 1 presents alternative recovery and stray rates for CNFH and FRH CWT releases based on the assumption that recoveries in the upper Sacramento River and Yuba River, respectively, are strays.

To determine the CV stray proportion,  $S_{\text{cwt}}$ , for each CWT code, the sum of all  $\text{CWT}_{\text{samp}}$  recoveries collected out of the basin of origin was divided by total CV  $\text{CWT}_{\text{samp}}$  recoveries for that release group, as follows:

$$S_{\text{cwt}} = \sum_{p=1}^o \text{CWT}_{\text{samp},p} (\text{out-of-basin locations}) / \sum_{p=1}^q \text{CWT}_{\text{samp},p} (\text{all CV locations}),$$

where  $p$  denotes recovery location,  $o$  denotes the number of out-of-basin recovery locations, and  $q$  denotes the total number of recovery locations.

Data from all CWT releases belonging to the same brood year and release type were then combined and release type-specific CV stray proportion,  $S_{\text{type}}$ , was calculated as:

$$S_{\text{type}} = \sum_p^o \sum_k^n \text{CWT}_{\text{samp},p,k} (\text{out-of-basin}) / \sum_p^o \sum_k^n \text{CWT}_{\text{samp},p,k} (\text{all CV locations})$$

## RESULTS

### **General Overview of 2011 CV inland recoveries and California ocean harvest**

All but three of the 46,596 valid CWTs recovered in the CV during 2011 were CV salmon releases; most CWTs originated from brood year 2007 through 2009 releases (Table 7). More than 93% of all expanded salmon CWT recoveries were fall-run, followed by spring-run (3%) and late-fall-run (3%) releases. Data from the 2011 escapement survey of Sacramento River winter-run (SacW) salmon is not included in this report (USFWS report); however there were two SacW CWTs recovered at CNFH during fall-run spawning operations.

The majority of fall-run CWTs were age-2 (57%) and age-3 (36%) fish. Three age-1 fall-run CWTs were also sampled. The spring-run CWTs consisted primarily of age-3 (56%), age-2 (24%), and age-4 (20%) fish. Age-4 (51%), age-3 (30%), and age-5 (14%) made up most of the late-fall-run return. Only four age-6 fish were recovered in the CV; all were BY 2006 late-fall-run. It should be noted that there were also eight coho CWTs recovered from BY 2009 Lake Oroville releases; six were recovered during fall-run spawning at FRH while the other two were recovered in the Yuba River carcass survey above the Daguerre Point Dam (DPD) dam. Non-Chinook salmon CWTs were not included in any analyses.

Almost 90% of the 8,717 valid CWT recoveries from the California ocean harvest in 2011 were CV salmon releases; most CWTs were brood year 2007 through 2009 releases (Table 8). Approximately 86% of all expanded CWTs in the ocean harvest were fall-run, followed by late-fall-run (2%), spring-run (1%), and winter-run (<0.4%) salmon. The majority of fall-run salmon CWTs were age-3 (60%) and age-2 (35%) fish. Age-3 (85%) and age-4 (14%) made up most of the late-fall-run salmon catch while age-3 (72%) and age-2 (25%) fish dominated the spring-run salmon harvest. Almost all (99%) of the winter-run salmon were age-3. A few age-6 late-fall-run salmon were also caught. The remaining 10% of ocean CWT recoveries originated from non-CV hatcheries or waters, including the Klamath, Trinity, and Smith rivers in northern California as well as the Rogue, Chetco, Umpqua, Columbia, Snake and other Pacific Northwest rivers; most were age-3 (64%) and age-4 (34%) fish.

### **1. Proportion of hatchery- and natural-origin fish in CV escapement**

In 2011, there were 22 individual CWT release types contributing to CV escapement and ocean fisheries. To facilitate the breakout of the hatchery proportion by stock and release strategy, all release types from the same hatchery/basin were given the same color scheme (Figure 1) in all pie chart figures. All net pen releases, except salmon released from net pens in Santa Cruz and Tiburon, contain black dots. Coastal and Tiburon net pen releases are designated with a crisscross pattern. Trucked and experimental releases are designated by black stripes. The revised hatchery and natural components of the 2010 upper Sacramento River fall-run and late-fall-run carcass surveys from Kormos et al. (2012) are shown in Figure 2.

The proportion of hatchery-origin fish on the natural area spawning grounds in 2011 varied throughout the CV and by run. The lowest hatchery proportion occurred in the Butte Creek spring-run salmon mark-recapture survey where no ad-clipped salmon were encountered (0%)

while the highest proportion (90%) was observed in the Feather River fall/spring-run salmon carcass mark-recapture survey (Figure 3).

It should be noted that since there has not been a carcass survey or CWT recovery program in Battle Creek since 2005, it is not possible to directly determine the hatchery contribution, recovery rate, or stray rate into the natural escapement of this tributary. Total natural escapement is estimated by subtracting the number of salmon returning to CNFH from the total video weir count into Battle Creek. The hatchery contribution to the natural area escapement in Battle Creek is considered equivalent to the hatchery return at CNFH (Robert Null, FWS, pers comm).

The hatchery proportion of fall-run salmon returning to CV hatcheries ranged from 77% to 98% (Figure 4). The spring-run salmon return to FRH was 94% hatchery-origin fish whereas the late-fall-run return to CNFH was almost 100% hatchery-origin fish. The percentage of hatchery and natural-origin contribution to the total escapement for all surveys by release type is shown in Table 9.

### **Upper Sacramento River Basin**

Eight escapement surveys were conducted in the Upper Sacramento River Basin that allow for expansion of CWTs: fall-run and late-fall-run salmon counts at CNFH, fall-run and late-fall-run salmon mark-recapture carcass surveys in the mainstem Sacramento River, a fall-run salmon mark-recapture survey in Clear Creek, a video count and associated carcass survey in Cottonwood Creek, and spring- and fall-run salmon mark-recapture carcass surveys in Butte Creek. Four additional escapement surveys were conducted: video counts of fall-run salmon escapement with associated carcass surveys to opportunistically collect CWTs and other bio-data were conducted in Mill and Deer Creeks while redd surveys were conducted in Mill and Deer Creeks to estimate spring-run salmon escapement. Since representative sampling for ad-clipped salmon did not occur in any of these surveys, any CWT recovery in these creeks represents only itself (i.e.,  $F_{\text{samp}} = 1.00$ ) and the reported hatchery percentages represent their minimal hatchery contribution. Returns to CNFH were predominantly hatchery-origin fish released from this facility while escapement into natural areas was primarily natural-origin fish (Table 9, Figures 5 and 6):

- Fall-run returns at CNFH were 89% hatchery-origin fish
- Late-fall-run returns at CNFH were 100% hatchery-origin fish
- Fall-run spawners in the upper Sacramento River were 27% hatchery-origin fish
- Late-fall-run spawners in the upper Sacramento River were 44% hatchery-origin fish
- Fall-run spawners in Clear Creek were 8% hatchery-origin fish
- Fall-run spawners in Cottonwood Creek were 58% hatchery-origin fish
- Fall-run spawners in Butte Creek were 7% hatchery-origin fish
- Spring-run spawners in Butte Creek were 0% hatchery-origin fish

### **Feather River Basin**

Five escapement surveys were conducted in the Feather River Basin: spring-run and fall-run salmon counts at FRH, a combined fall/spring-run salmon mark-recapture survey in the Feather River, a combined fall/spring-run salmon mark-recapture survey in the Yuba River below DPD, and a combined fall/spring-run salmon Vaki Riverwatcher count above DPD (with associated

bio-sample). The Vaki Riverwatcher count also included the number of ad-clipped salmon entering the system. The 107 heads recovered in the bio-survey above DPD were expanded to the total 1,733 ad-clipped salmon counted at DPD. Hatchery contribution by release type was based on the proportion of valid CWT codes recovered. Spring-run and fall-run salmon returns to FRH and in the natural areas were predominantly of hatchery-origin (Table 9, Figures 7 and 8):

- Spring-run returns at FRH were 94% hatchery-origin
- Fall-run returns at FRH were 96% hatchery-origin
- Fall/spring-run spawners in the Feather River were 90% hatchery-origin
- Fall/spring-run spawners in the Yuba River below DPD were 34% hatchery-origin
- Fall/spring-run spawners in the Yuba River above DPD were 65% hatchery-origin

### **American River Basin**

Two escapement surveys were conducted in the American River Basin: fall-run salmon counts at NFH and a fall-run salmon mark-recapture survey on the American River. In addition, dead salmon were recovered from the NFH weir, which is located just upstream from the hatchery and was installed on September 10<sup>th</sup> to force returning salmon into NFH. Salmon that migrated upstream beyond the hatchery prior to installation of the weir were trapped in the upstream area. Many of those salmon washed back onto the weir upon death. There is minimal spawning habitat above the weir. Spawner returns to natural areas and those from the NFH were predominantly of hatchery-origin while returns above the NFH weir were predominantly of natural-origin (Table 9, Figure 6):

- Fall-run returns to NFH were 77% hatchery-origin
- Fall-run spawners in the American River were 66% hatchery-origin
- Salmon recovered on the NFH Weir were 26% hatchery-origin

### **Mokelumne River Basin**

Two escapement surveys were conducted in the Mokelumne River Basin: fall-run salmon counts at MOK and a video weir count at Woodbridge Dam of all fall-run salmon escapement into the Mokelumne River.

All adult salmon migrating upstream into the Mokelumne River to spawn were counted by the video fish counting device operated by EBMUD at Woodbridge Dam. These counts also included the total number of ad-clipped salmon above the Dam. By subtracting the 15,922 salmon that returned to MOK from the total video count of 18,589 Chinook, it was assumed that the remaining 2,667 salmon remained in the Mokelumne River. Utilizing the same logic, it was also assumed that there were 2,227 ad-clipped salmon remaining in the river since only 14,724 of the 16,951 ad-clipped salmon counted in the video monitoring were recovered at MOK. After reviewing the CWTs recovered from heads collected during sporadic surveys on the Mokelumne River, it was found that the proportions of the CWT codes collected were very similar to the proportion of the same codes recovered at MOK. Because 100% of Chinook salmon observed at MOK were sampled, including seven ad-clipped salmon recovered from the hatchery weir, we felt that the MOK CWT recoveries best represented the entire run and thus expanded the estimated 2,227 ad-clips in the Mokelumne River based on the proportion of valid CWTs recovered. This approach is based on the methodology used by the Klamath River Technical

Team (KRTT) to determine the hatchery composition of fall-run salmon above Willow Creek Weir on the Trinity River (KRTT 2012).

Spawner returns to the Mokelumne River Basin were dominated by hatchery-origin fish (Table 9, Figure 10):

- Fall-run returns at MOK were 98% hatchery-origin
- Fall-run spawners in the Mokelumne River were 88% hatchery-origin

### **San Joaquin River Basin Tributaries**

Four escapement surveys were conducted in tributaries of the San Joaquin River that allow for expansion of CWTs: fall-run salmon counts at MER, as well as fall-run salmon mark-recapture surveys conducted on the Stanislaus, Tuolumne, and Merced rivers. One additional redd survey was conducted on the Calaveras River with an associated carcass survey to opportunistically collect CWTs and other bio-data. Fall-run salmon returns to the Merced, Stanislaus, and Tuolumne Rivers were dominated by hatchery-origin spawners (Table 9, Figure 11):

- Fall-run returns at MER were 88% hatchery-origin
- Fall-run spawners in the Merced River were 89% hatchery-origin
- Fall-run spawners in the Stanislaus River were 83% hatchery-origin
- Fall-run spawners in the Tuolumne River were 73% hatchery-origin

### **Inland Creel Survey**

Five separate creel surveys were conducted in the Sacramento River and its tributaries: upper and lower Sacramento River fall, American River fall, Feather River fall, and a late-fall-run survey on the Sacramento River. The results of these surveys were not shown in 2010 due to extremely high sample expansions that caused hatchery contribution estimates to exceed estimated harvest totals in some cases. Although this over-estimation did not occur in 2011, sample expansions remained high for some of these surveys and thus estimates of hatchery contribution may also be biased high. All inland harvest was dominated by hatchery-origin salmon (Table 9, Figures 12 and 13):

- Upper Sacramento River fall-run harvest was 75% hatchery-origin
- Lower Sacramento River fall-run harvest was 81% hatchery-origin
- Feather River fall-run harvest was 83% hatchery-origin
- American River fall-run harvest was 95% hatchery-origin
- Sacramento River late-fall-run harvest was 68% hatchery-origin

## **2. Relative recovery and stray rates for hatchery-origin salmon released in-basin versus hatchery-origin salmon trucked and released into the waters of the Carquinez Strait (includes salmon acclimated in net pens and released in San Pablo Bay or Santa Cruz Harbor).**

Release strategies vary among hatcheries from year to year. This variability has often been in response to fluctuating abundances of certain stocks or differing policies among mitigating agencies with respect to “best” release practices. Lack of consistency and “problem releases” among CV hatcheries has limited the number of release groups available for direct comparison of differing release strategies. In 2011, there were 11 release groups consisting of 22 individual brood specific release types recovered that allow in-basin releases to be compared directly to trucked/net pen releases.

Table 10 summarizes the recovery rates  $R_{type}$  (in-basin, stray, and ocean) for all release groups with representative recoveries from the CV and ocean in 2011. Recovery rates displayed there, in the following figures, and discussed below are scaled for comparison at total recoveries per 100,000 salmon released. Figures 14 and 15 provide a graphical representation of  $R_{type}$  for the Sacramento River fall-run salmon and other CV stocks, respectively, and include the total number of salmon released with CWTs for each release type. In general, salmon that were trucked and released directly into the waters of Carquinez Strait or acclimated in net pens had higher relative recovery rates than their respective in-basin releases. These releases also had higher stray proportions than their paired in-basin counterparts.

### **Coleman National Fish Hatchery releases - Fall-run salmon broods 2007, 2008, and 2009**

For brood 2009 CNFH fall-run salmon releases, the overall age-2 inland and ocean recovery rate for net pen CNFHn releases (729) was 1.9 times greater than in-basin CFHFh releases (385). While the total CV recovery rate was equivalent (216) between these two release types, the CNFHn ocean recovery rate (513) was 3.0 times higher than that of CNFHh (170). However, the proportion of CNFHh out-of-basin recoveries was only 1%, while the proportion of CFHFn out-of-basin recoveries was very high at 95%.

For brood 2008 CNFH fall-run salmon releases, the overall age-3 inland and ocean recovery rate for net pen CNFHn releases (1,387) was 3.5 times greater than in-basin CFHFh releases (399). The total CV recovery rate for CNFHn releases (296) was also more than double that of CNFHh (120) and the CNFHn ocean recovery rate (1,091) was 3.9 times higher than that of CNFHh (279). However, again the proportion of CNFHh out-of-basin recoveries was only 1%, while the proportion of CFHFn out-of-basin recoveries was very high at 95%.

For brood 2007 CNFH fall-run salmon releases, the overall age-4 inland and ocean recovery rate for net pen CNFHn releases (97) was 3.7 times greater than in-basin CFHFh releases (26). The total CV recovery rate for CNFHn releases (27) was also double that of CNFHh (13) and the CNFHn ocean recovery rate (70) was 5.4 times higher than that of CNFHh (13). However, zero CNFHh recoveries came from out-of-basin, while the proportion of CFHFn out-of-basin recoveries was very high at 98%.

### **Feather River Hatchery releases – Spring-run salmon broods 2007, 2008, and 2009**

For brood 2009 FRH spring-run releases, the overall age-2 inland and ocean recovery rate for net pen FRHSn releases (121) was 1.8 times higher than in-basin FRHS releases (66). The total CV recovery rate for FRHSn releases (110) was also higher than that of FRHS (58) by 1.9 times, and the FRHSn ocean recovery rate (11) was fairly equivalent to that of FRHS (8). Approximately 2% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2008 FRH spring-run salmon releases, the overall age-3 inland and ocean recovery rate for net pen FRHSn releases (238) was slightly lower than that of FRHS releases (249). The total CV recovery rate for FRHSn releases (207) was also slightly lower than that of FRHS (233), and the FRHSn ocean recovery rate (31) was fairly equivalent to that of FRHS (26). Approximately 2% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2007 FRH spring-run salmon releases, the overall age-4 inland and ocean recovery rate for net pen FRHSn releases (67) was slightly higher than that of FRHS releases (50). The total CV recovery rate for FRHSn releases (66) was also slightly higher than that of FRHS (49), and the FRHSn ocean recovery rate (1) was identical to that of FRHS (1). Again, approximately 2% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

### **Feather River Hatchery releases – Fall-run salmon broods 2007, 2008, and 2009**

Although FRH did not have any in-basin releases for broods 2007, 2008 or 2009, they did have experimental FRHFe, bay net pen FRHF<sub>n</sub>, coastal net pen FRHF<sub>nc</sub>, central bay net pen FRHF<sub>tib</sub>, and trucked direct bay FRHF<sub>t</sub> releases that can be evaluated.

For brood 2009 FRH fall-run salmon releases, the overall age-2 inland and ocean recovery rate for net pen FRHF<sub>n</sub> releases (578) was higher than that of central bay net pen FRHF<sub>tib</sub> releases (301), but lower than that of coastal net pen FRHF<sub>nc</sub> releases (644). The differences however, in recovery rates for CV and ocean areas are more revealing. The CV recovery rate for net pen FRHF<sub>n</sub> releases (349) was higher than that of central bay net pen FRHF<sub>tib</sub> releases (227), and much higher than that of the relatively few coastal net pen FRHF<sub>nc</sub> releases (60). The ocean recovery rate for net pen FRHF<sub>n</sub> releases (229) was much higher than that of central bay net pen FRHF<sub>tib</sub> releases (75), but much lower than that of coastal net pen FRHF<sub>nc</sub> releases (584). Approximately 4% and 5% of FRHF<sub>n</sub> and FRHF<sub>tib</sub> were recovered out-of-basin respectively, while 18% of FRHF<sub>nc</sub> CWTs were recovered out-of-basin.

For brood 2008 FRH fall-run salmon releases, the overall age-3 inland and ocean recovery rate for net pen FRHF<sub>n</sub> releases (754) was much higher than that of central bay net pen FRHF<sub>tib</sub> releases (433) and experimental FRHFe releases (401). The FRHFe releases were actually “hybrid” fish (FRH fall-run x FRH spring-run). The CV recovery rates for net pen FRHF<sub>n</sub> releases (358), central bay net pen FRHF<sub>tib</sub> releases (299), and experimental FRHFe releases (332) were fairly equivalent. The ocean recovery rate for net pen FRHF<sub>n</sub> releases (396) was much higher than that of central bay net pen FRHF<sub>tib</sub> releases (133) and experimental FRHFe releases (69). Approximately 4% of FRHF<sub>n</sub> and FRHFe were recovered out-of-basin, while 14% of FRHF<sub>tib</sub> CWTs were recovered out-of-basin.



For brood 2007 FRH fall-run salmon releases, the overall age-4 inland and ocean recovery rate for net pen FRHF<sub>n</sub> releases (165) was much higher than experimental FRHF<sub>e</sub> releases (8). Approximately 2% of FRHF<sub>e</sub> were recovered out-of-basin. A more in-depth comparison of the net pen FRHF<sub>n</sub> and trucked direct bay FRHF<sub>t</sub> releases from this brood are discussed in Section 3 below.

#### **Nimbus Fish Hatchery releases – Fall-run salmon broods 2008 and 2009**

For brood 2009 NFH fall-run salmon releases, the CV overall age-2 inland and ocean recovery rate for net pen NIMF<sub>n</sub> releases (315) was 1.8 times lower than that of NIMF releases (584). The total CV recovery rate for NIMF<sub>n</sub> releases (129) was 1.5 times lower than that of NIMF (196), and the NIMF<sub>n</sub> ocean recovery rate (185) was over 2 times lower than that of NIMF (388). Approximately 11% of NIMF<sub>n</sub> were recovered out-of-basin while only 2% of NIMF CWTs were recovered out-of-basin.

For brood 2008 NFH fall-run salmon releases, the CV overall age-3 inland and ocean recovery rate for net pen NIMF<sub>n</sub> releases (1,372) was 18.5 times higher than that of NIMF releases (74). The total CV recovery rate for NIMF<sub>n</sub> releases (247) was 7 times higher than that of NIMF (35), and the NIMF<sub>n</sub> ocean recovery rate (1,124) was nearly 29 times higher than that of NIMF (39). Approximately 4% of NIMF<sub>n</sub> were recovered out-of-basin while all NIMF CWTs were recovered in-basin.

#### **Mokelumne Fish Hatchery releases – Fall-run salmon broods 2007 and 2009**

For brood 2009 MOK fall-run salmon releases, the CV overall age-2 inland and ocean recovery rate for net pen MOKF<sub>n</sub> releases (947) was 4.2 times higher than that of MOKF releases (224). The total CV recovery rate for MOKF<sub>n</sub> releases (811) was 3.6 times higher than that of MOKF (224). The MOKF<sub>n</sub> ocean recovery rate was 135 while the MOKF ocean recovery rate was zero. Approximately 14% of MOKF<sub>n</sub> were recovered out-of-basin while only 1% of MOKF CWTs were recovered out-of-basin.

For brood 2007 MOK fall-run salmon releases, the CV overall age-4 inland and ocean recovery rate for net pen MOKF<sub>n</sub> releases (35) was much higher than that of MOKF releases (1). The total CV recovery rate for MOKF<sub>n</sub> releases (11) was also much higher than that of MOKF (1). The ocean recovery rate for MOKF<sub>n</sub> releases was 24 while there were no ocean recoveries for MOKF. Approximately 65% of MOKF<sub>n</sub> were recovered out-of-basin while the lone MOKF recovery was in-basin.

### **3. Relative CV recovery and stray rates of bay releases acclimated in net pens and released directly without acclimatization**

The same issues related to release practices that limited the available recovery comparisons in the previous section also limited the comparison of net pen releases and direct releases in the Carquinez Strait area. As a result there is only one release type comparison possible.

### **Feather River Hatchery releases – Fall-run salmon brood 2007**

For brood 2007 FRH fall-run salmon releases, the overall age-4 recovery rate inland and ocean for net pen FRHF<sub>n</sub> releases (165) was 3.5 times higher than that of trucked direct bay FRHF<sub>t</sub> releases (47). The CV recovery rate was 2.7 times higher for net pen FRHF<sub>n</sub> releases (97) compared to that of trucked direct bay FRHF<sub>t</sub> releases (36) and the ocean recovery rate for net pen FRHF<sub>n</sub> releases (68) was 6.8 times higher than that of trucked direct bay FRHF<sub>t</sub> releases (10). Approximately 11% of FRHF<sub>n</sub> were recovered out-of-basin while 66% of FRHF<sub>t</sub> CWTs were recovered out-of-basin.

### **4. Relative recovery rate and contribution of CV release groups to ocean harvest**

The relative recovery rate of CV hatchery releases in the 2011 ocean salmon fisheries (sport and commercial combined) varied by age and release type (Figure 16). Of the 58,843 CV CWT<sub>sample</sub> recovered in the fisheries, most were age-3 (60%), followed by age-2 (34%), age-4 (1%) and age-5 (<.01%) fish (Table 10). The majority of age-2 CV salmon were harvested in the sport fishery (Figure 16) due to its lower size limit (24" total length) compared to the commercial fishery (27" total length).

For all age-2 CV releases, coastal net pen FRHF<sub>nc</sub> (584) had the highest recovery rate, followed by net pen CFHF<sub>n</sub> (513), in-basin NIMF (388), and San Joaquin basin MERF (372) releases.

Net pen releases also had the highest recovery rates for age-3 CV salmon releases. The recovery rates for net pen NIMF<sub>n</sub> (1,124) and CFHF<sub>n</sub> (1,091) releases were similarly high, almost double that of trucked MOKF<sub>t</sub> releases (573), and nearly three times that of net pen FRHF<sub>n</sub> releases (396).

Relatively few age-4 or age-5 CWT recoveries were made compared to age-2 and age-3 CV fish. The central bay NIMF<sub>tib</sub> releases had the highest recovery rate for age-4 (144) and late-fall-run in-basin CFHL<sub>h</sub> had the highest recovery rate for age-5 (0.6).

### **Contribution of CV release groups to sport ocean harvest**

In 2011, anglers harvested an estimated 49,822 salmon in the California sport ocean salmon fishery. The majority (65%) of the harvest occurred in San Francisco and Monterey port areas (Table 11). Based on the expanded CWT<sub>total</sub> collected in the fishery, including non-CV salmon release types, hatchery-origin fish contributed 57%-77% of the total harvest, depending on major port area (Figure 17). Of all hatchery release types, fall-run net pen FRHF<sub>n</sub> contributed the most (18.2%) to the total sport harvest, followed by fall-run in-basin CFHF<sub>h</sub> (14.4%), net pen NIMF<sub>n</sub> (8.5%) and in-basin NIMF (7.2%). Non-CV releases contributed 3.2% to the total harvest.

Fall-run net pen FRHF<sub>n</sub> releases contributed the greatest to the sport harvest in Monterey (23%), San Francisco (20%), and Fort Bragg (16%). In Eureka-Crescent City, the fall-run in-basin CFHF<sub>h</sub> releases contributed the most (12%) to the hatchery sport catch. Other CV releases contributing to California sport fisheries were net pen NIMF<sub>n</sub> (6-14%), in-basin CFHF<sub>h</sub> (12-16%), in-basin NIMF (2-12%), and net pen CFHF<sub>n</sub> (4-9%). The contribution of non-CV stocks was highest (11%) in the Eureka-Crescent City port area, most likely due to its proximity to rivers and salmon hatcheries in northern California, Oregon and Washington.

### **Contribution of CV release groups to commercial ocean harvest**

Commercial trollers landed an estimated 70,028 salmon in the California commercial ocean salmon fishery; most salmon (56%) were landed in the Fort Bragg port area (Table 11). Based on the expanded CWT<sub>total</sub> collected in the fishery, hatchery-origin fish contributed 26%-57% of the total harvest, depending on major port area (Figure 18). Of all hatchery-origin release types, fall-run net pen NIMFn contributed the most (11.2%) to the total commercial harvest, followed by fall-run in-basin CFHFh (8.9%), net pen FRHFh (8.8%) and non-CV releases (7.4%).

The Monterey port area catch was dominated by fall-run net pen FRHFh releases (20%), while San Francisco and Fort Bragg port areas were dominated by fall-run net pen NIMFn releases (16% and 10%, respectively). The Eureka-Crescent City port area was dominated by non-CV releases (10%). The other CV release type contributing a relatively high percentage to the California commercial fishery was in-basin CFHFh (4%-13%). The contribution of non-CV stocks was highest (11.1%) in the Fort Bragg area, followed by Eureka-Crescent City (10.3%). Again this is most likely due to the proximity of these port areas to rivers and salmon hatcheries in northern California, Oregon and Washington.

## **DISCUSSION**

Estimates of 2011 hatchery contributions and recovery rates by release type that are presented in this report should be viewed as the second “single year snapshot” of salmon escapement and harvest in the CV and California ocean fisheries. All CWT recoveries in 2011 were from CV releases that were representatively marked and tagged at the CFM minimum 25% level. Although there were definite differences observed in recovery rates and straying proportions among runs, brood years, and CV release groups, this effort continues the initial phase of the work needed to statistically analyze the contribution of hatchery- and natural-origin salmon to hatchery and natural areas throughout the CV, evaluate hatchery release strategies, improve California ocean and river salmon fisheries management, and determine if other goals of the CFM program are being met. Most of the CV CWT release groups in this study were produced, released and recovered during a time when Sacramento River fall-run salmon were at historically low levels or still in the stages of recovery. Although the 2011 ocean and river salmon fisheries were much less constrained than those in 2009-2010, salmon were still not susceptible to the historical levels of effort observed in ocean or river salmon fisheries prior to 2008.

Another critical factor to consider is that 2011 had the highest age-2 escapement of CV fall-run salmon on record. Thus the age-2 recoveries presented in this report are part of a very strong brood, compared to the weaker broods that preceded it. This apparent disparity in year class strength is important to note when comparing the relative recovery rates and hatchery contribution of various release types to harvest and escapement.

Again, the effects of interannual variation on survival and year-class strength for both hatchery- and natural-origin stocks should be considered when evaluating the status of CV salmon stocks. At this time, neither year class strength or age structure of CV natural-original salmon is known.

As noted in Kormos et al. (2012), scale-aging work done on 2006, 2007, and 2008 CV salmon escapement has indicated there may be different maturation rates between hatchery- and natural-origin fish by stock and basin. It remains premature to compare hatchery and natural-origin proportions without having complete brood- and/or stock-specific population estimates. While it may appear that total escapement of hatchery fish in the CV may exceed that of natural-origin fish in any given year, comparing age-specific total escapement (hatchery and natural) after broods complete their life cycle may identify differences in hatchery and natural ratios on a basin- and stock-specific basis. Such analyses may provide the basis for changing hatchery practices to better mimic wild population parameters. They may also further clarify the effects of specific environmental stressors unique to natural-origin fish or specific hatchery CWT release groups.

Strategies for CV fall-run production releases in any given year are often a result of two conflicting objectives. Increasing survival rates to allow for improved escapement and harvest often favors release strategies that bypass the Sacramento-San Joaquin Delta and acclimate salmon prior to release to reduce mortality from predators or other environmental factors. Alternatively, in-basin release practices are aimed at maximizing homing rates back to the hatchery of origin to reduce impacts on natural stocks. It is impossible to make a thorough comparison of hatchery release practices at this time due to the large variability that existed among CWT release types within the same CV hatchery broods examined in this study. Many release types included individual CWT codes that were released at numerous locations at different times and under various conditions (e.g., river water flows and temperatures, different net pen locations, incoming vs. outgoing bay tidal flows). While some individual CWT codes were recovered at a relatively high rate, others within the same release type were recovered at minimal levels if at all. The recovery rate  $R_{cwt}$  for individual CWT codes should be examined on a release type basis and the release strategies (e.g., in-basin, net pen acclimation) that produce the greatest resource value (i.e., high recovery rate with low straying) adopted for future release strategy evaluation. Coordinated and paired hatchery release types will allow for direct comparisons to be made between them and will enrich the available data set used for subsequent evaluation of the hatchery program in the future. Only FRH spring-run salmon in-basin and net pen releases have consistently allowed a true comparison during the last several broods.

There has been much debate among salmon biologists and managers on the definition of straying. Although it seems straight-forward to simply define any salmon not returning to the river of its hatchery location as a stray, decades of sharing broodstock and juvenile production among hatcheries, including different run-types, and releasing juvenile salmon at various sites and times throughout the CV have complicated this issue.

Years of sharing broodstock or progeny can confound the straying definitions in any system, especially when salmon return en masse to rivers where the shared broodstock or progeny originated. In addition, juvenile salmon production raised at other rearing facilities or released near the confluences of other rivers or within the delta system appear to exacerbate the problem of salmon straying to other systems. Although many of these practices have been recently terminated, it may take years before the long-term effects of these actions diminish and stray rates can be accurately determined and compared. In addition, preliminary analysis of individual

CWT codes within the same release type indicate that the timing of water releases within the CV during juvenile outmigration and adult escapement may also affect recovery and stray rates.

Another critical issue is the definition of straying when a mitigation hatchery is not located on the river being impacted. In 1942, CNFH was built specifically to mitigate for the loss of salmon spawning habitat in the upper Sacramento River basin caused by the construction of Shasta Dam. Because CNFH was built on Battle Creek, approximately 6 miles upstream of its confluence with the Sacramento River, the Keswick Fish Trap was constructed concurrently in the upper Sacramento River specifically to collect salmon broodstock for the hatchery (Black 1999). Historically, salmon taken at the Keswick Fish Trap contributed as much as 50 to 75 percent of the annual fall-run broodstock used at CNFH from the 1940s through the late 1970s (USFWS 2011) and this facility was utilized for fall-run broodstock collection until the late 1980s. Although the collection of fall-run broodstock at Keswick Fish Trap ceased completely in 1987, the introgression of CNFH hatchery- and natural-origin fall-run salmon continues naturally in the upper Sacramento River. Late-fall-run salmon are still collected at the trap for CNFH propagation purposes so that a genetically integrated hatchery stock can be maintained and the effects of domestication can be reduced (USFWS 2011). It is for these reasons that some salmon biologists continue to consider CNFH stocks to be analogous to salmon that originate from the mainstem of the upper Sacramento River.

Hatchery objectives for CNFH fall-run salmon unambiguously state that CNFH stocks are intended to escape to Battle Creek alone, and all other recoveries outside of that stream are strays. Tributaries of a larger river basin with an existing mitigation hatchery are also not intended to receive hatchery escapement, as is the case with the Yuba River. Hatchery objectives for FRH state that hatchery salmon originating there are intended to escape to only the Feather River. This is true despite many factors beyond the control of managers that affect salmon migration patterns such as dam operations, water temperatures and water diversions. Hatchery release location alone is the tool available to managers to mitigate the straying of hatchery stocks, and it often comes at a cost to the survival of hatchery production. In both the upper Sacramento River and Feather River basins, the rate of historical and present introgression of natural-origin stocks among their respective tributaries is unknown.

Given the issues identified above and to be consistent with Kormos et al. (2012), the same primary CV basins were used to define stray rates in this report; however to allow further evaluation and discussion of these issues, all CNFH and FRH CWT releases that were recovered in the upper Sacramento River and Yuba River, respectively, during 2011 are treated as strays in Appendix 1. It should be noted that differences in stray rates for FRH and CNFH under this alternative stray definition are relatively small as compared to the previous definition. A primary goal of this report is to provide information that will be useful in California salmon management, including the upcoming hatchery review process.

The advent of Santa Cruz coastal bay net pen release recoveries in the CV and ocean fisheries during 2011 also warrants some attention. These “enhancement” releases are intended to provide additional harvest to local ocean fisheries in the Monterey Bay area but they may also pose a potential risk to coastal salmon and steelhead stocks that may suffer from introgression or competition with hatchery stocks. As noted above, this release type should be evaluated after

several broods have completed their respective life cycle so that their relative age-specific contribution to ocean fisheries and inland escapement can be determined. However, work is currently underway to monitor central California coastal streams to determine if this release type is straying into these areas. All coastal net pen releases are ad-clipped and contain a unique CWT code so identifying these fish should be relatively simple. If it appears that coastal net pen releases are competing or hybridizing via introgression with ESA-listed coastal salmon or steelhead stocks, then these programs should be seriously evaluated in the near term.

Prior to the creation of the CFM program, the primary purpose of CV salmon escapement monitoring was to provide basic status information (e.g., grilse and adult escapement counts) by individual stocks and major tributaries for California hatchery and ocean harvest management needs. The marking, tagging, or collection of CV CWT fish was not a high priority. CV escapement monitoring has since expanded to provide data for a broad range of management applications, including the recovery planning for ESA-listed salmonid stocks. These applications include assessing recovery efforts, including habitat restoration work, improving ocean and river fisheries management, and evaluating CV salmon hatchery programs to ensure both mitigation and conservation goals are being met. To meet the needs of these various assessment efforts, a review of current methodologies being employed among CV inland escapement monitoring programs was undertaken by CDFW in 2008. The goal of this review was to identify needed changes and/or additions to survey protocols that will ensure both statistically valid estimates of escapement and the collection of biological data, including CWTs and scales, needed for assessment efforts. In 2012, CDFW completed the “Central Valley Chinook Salmon Escapement In-River Monitoring Plan” that recommends methods for estimating escapement and collecting biological data necessary for improved stock assessment in the CV (Bergman et al. 2012). Survey modifications included changes in the current mark-recapture models being utilized, changes in sampling protocols to ensure representative sampling and proper accounting, and the use of counting devices in place of some mark-recapture programs. This monitoring plan is now being implemented among CV surveys to provide the basis for sound CV salmon assessment and subsequent management.

One critical item that was omitted from the recommended CV sampling protocol modifications was the need to account for the fresh versus decayed condition of fish sampled in CV carcass surveys. As identified by Mohr and Satterthwaite (in press) and discussed in this report, this information is needed to minimize the bias in determining the hatchery contribution by release type in natural areas. We know it is incorrect to assume that all sampled carcasses have the same ad-clip detection probability when a large disparity between fresh and decayed fish has been shown. Sample sizes related to these two conditions are also a factor when attempting to recover relatively small CWT releases (e.g., less than 200,000 ESA-listed Sacramento River winter-run salmon CWTs are released annually) or release types with typically low rates of contribution.

Overall, the CV CFM program has been successful in marking and tagging its targeted numbers of salmon each year at the five CV hatcheries. In addition, CWTs are now being recovered throughout the CV in a statistically valid manner. The CDFW CWT laboratories in Santa Rosa and Sacramento have both been expanded and are able to process the 50,000-70,000 heads recovered annually from ad-clipped salmon observed during CV escapement and California ocean and river fisheries monitoring.

The CFM program should be continued with the current design for several years to provide comparable, consistent data needed for harvest and hatchery management. Efforts continue to secure future funding for this program. The results from this program, in conjunction with the creation and funding of a permanent scale-aging program, should provide the best opportunity to manage CV salmon based on scientifically defensible data. Secure adequate funding will allow both CWT and scale-aging data to be available by February each year in order to manage CV salmon stocks, hatchery production, and California ocean and river fisheries in a real-time manner, similar to Klamath River fall-run salmon management. This work is essential for the continued enhancement of salmon management in California's Central Valley.

## **ACKNOWLEDGEMENTS**

Thanks to the following individuals for their assistance in compiling, reviewing and editing data for this report: Vanessa Gusman, Jennifer Simon, Alex Letvin and Barry Miller. Thanks to Michael Lacy, Alive Low, Rob Titus, Kevin Shaffer and Doug Killam of CDFW for providing internal text review and edits for this report. Our sincere appreciation is extended to Michael Mohr and Will Satterthwaite of the NMFS Southwest Fisheries Science Center in Santa Cruz for reviewing this document and developing a new methodology to reduce bias associated with expansions of carcass survey recovery data. Additional thanks go to FWS Red Bluff and CNFH staff Scott Hamelberg, Kevin Niemela, and Robert Null for their thoughtful review and comments.

Credit and admiration must be offered to the myriad of staff among the many agencies that work tirelessly in the field to gather the necessary data and CWT recoveries that provide the basis for this report. They are too numerous to name, however without them, this valuable analysis would not be available for evaluation. We thank the following agencies for providing 2011 CV escapement estimates and their salmon heads/CWT recoveries: Department of Water Resources, United States Fish and Wildlife Service, Pacific States Marine Fisheries Commission, East Bay Municipal Utilities District, and the Yuba Accord River Management Team. Additional thanks are extended to staff at the following hatcheries for their cooperation in this monitoring effort: Coleman National Fish Hatchery, Feather River Hatchery, Nimbus Fish Hatchery, Mokelumne River Fish Hatchery, and the Merced River Hatchery.

Special kudos are extended to both the OSP Santa Rosa and Fisheries Branch Sacramento CWT labs for processing, reading, and validating the thousands of CWTs used in this analysis. Further thanks must be given to the CDFW staff in the Red Bluff and La Grange offices, as well as FWS staff in Red Bluff for their efforts in processing, reading, and validating CWTs collected from their regional surveys and hatcheries.

Last but not least, we want to acknowledge Stan Allen (PSMFC) and Alice Low for their efforts in facilitating the funding, staffing, tagging, and coordination needs of the CFM program. Funding was provided by CDFW, DWR, EBMUD, BOR, and the CALFED Ecosystem Restoration Program.

## LITERATURE CITED

- Bergman, J., Nielson, R., and Low, A. 2012. Central Valley Chinook Salmon In-River Escapement Monitoring Plan. California Department of Fish and Game. Fisheries Branch Administrative Report Number: 2012-1. January 2012
- Black, M. 1999. Shasta salmon salvage efforts: Coleman National Fish Hatchery on Battle Creek, 1895-1992. Prepared for the Battle Creek Technical Advisory Committee and the Battle Creek Work Group by Kier Associates Sausalito, California: 1-39.
- Buttars, B. 2007. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2007 Marking Season. Pacific States Marine Fisheries Commission.
- Buttars, B. 2008. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2008 Marking Season. Pacific States Marine Fisheries Commission.
- Buttars, B. 2009. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2009 Marking Season. Pacific States Marine Fisheries Commission.
- Buttars, B. 2010. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2010 Marking Season. Pacific States Marine Fisheries Commission.
- Buttars, B. 2011. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2011 Marking Season. Pacific States Marine Fisheries Commission.
- Hicks, A.C., Newman, K.B., and Hankin D.G. 2005. A second analysis of a marking, tagging, and recovery program for Central Valley hatchery Chinook salmon. Unpublished report to Central Valley Salmon Team.
- Klamath River Technical Team 2011. Klamath River Fall Chinook Salmon Age-Specific Escapement, River Harvest, and Run Size Estimates, 2010 Run. 24 February 2011
- Kormos, B., Palmer-Zwahlen, M., and Low, A. 2012. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2010. Fisheries Branch Administrative Report 2012-02.
- Mohr, M. S. and W. H. Satterthwaite. In press. Coded wire tag expansion factors for Chinook salmon carcass surveys in California: estimating the numbers and proportions of hatchery-origin fish. San Francisco Estuary and Watershed Science.
- U.S. Fish and Wildlife Service (USFWS). 2011. Biological Assessment of Artificial Propagation at Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery: program description and incidental take of Chinook salmon and steelhead. July 2011.



## LIST OF ACRONYMS AND ABBREVIATIONS

Ad-clipped	clipped adipose fin
BOR	U.S. Bureau of Reclamation
CFM	Constant Fractional Marking
CNFH	Coleman National Fish Hatchery
CV	California Central Valley
CWT	coded-wire tag
CDFW	California Department of Fish and Wildlife
DPD	Daguerre Point Dam
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utilities District
ERP	Ecosystem Restoration Program
FRH	Feather River Hatchery
FWS	U.S. Fish and Wildlife Service
MER	Merced River Hatchery
MOK	Mokelumne River Hatchery
NMFS	National Marine Fisheries Service
NFH	Nimbus Fish Hatchery
OSP	Ocean Salmon Project
PSMFC	Pacific States Marine Fisheries Commission
RMPC	Regional Mark Processing Center
YARMT	Yuba Accord River Management Team

Table 1. Estimation and sampling methods used for the 2011 CV Chinook run assessment. (page 1 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
<b><u>Hatchery Spawners</u></b>		
Coleman National Fish Hatchery (CNFH) Fall and Late-Fall	Direct count. All fish examined for fin-clips, tags, marks. Hatchery takes a one month break in between the fall and late-fall run spawning periods. Fish that arrive during this 'break' are counted and excised. Those fish that contain a fall CWT code or have their adipose fin present are later counted as a part of the fall run. Fish containing a late-fall CWT code are later counted as late-fall. Systematic random bio-sample <sup>al</sup> of all fish with adipose fin absent. Grilse cutoff: 700 mm.	FWS
Feather River Hatchery (FRH) Spring and Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish arriving at the hatchery April-June tagged with two uniquely-numbered floytags. All fish marked with floytags returning to FRH during August and September are spawned as spring run. All other fish are spawned as fall run. All spring Chinook are bio-sampled. Systematic random bio-sample ~10% of aggregate fall run fish with adipose fin present and absent. All fall run fish with adipose fin absent are bio-sampled. All spawned fall run fish are bio-sampled. Grilse cutoff: 650 mm.	CDFW
Nimbus Fish Hatchery (NFH) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 685 mm.	CDFW
Nimbus Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 685 mm.	CDFW
Mokelumne River Hatchery (MOK) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 mm males.	CDFW
Mokelumne Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 mm males.	CDFW
Merced River Fish Facility (MER) Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 635 mm.	CDFW
<b><u>Natural Spawners</u></b>		
Upper Sacramento River Mainstem Fall and Late-Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate applied using all females within survey area (Keswick Dam to Balls Ferry). Total female escapement estimate (Keswick Dam to Princeton) is derived using expansions for females spawning outside of the survey area (Balls Ferry to Princeton) through aerial redd surveys. Male Chinook expanded based on the sex ratio at CNFH. Total estimate from Keswick to Princeton is then males and females. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 675 mm females, 755 mm males.	CDFW, FWS

Table 1. Estimation and sampling methods used for the 2011 CV Chinook run assessment. (page 2 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
Clear Creek Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 675 mm females, 755 mm males.	CDFW, FWS
Cottonwood Creek Fall	Video weir count at mouth of creek to determine total escapement. Systematic carcass survey conducted to collect bio-samples from all fish with adipose fin present and absent. Grilse cutoff: 750 mm.	FWS, CDFW
Butte Creek Spring and Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate for spring run. Peterson mark-recapture estimate for fall run. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFW
Feather River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark recapture-estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring run Chinook are included. Grilse cutoff: 650 mm.	DWR
Yuba River Fall	Above Daguerre Point Dam: Vaki Riverwatcher direct count. Additionally, systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Below Daguerre Point Dam: Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring Chinook are included in estimate. Grilse cutoff: 650 mm.	CDFW, YARMT
American River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm.	CDFW
Mokelumne River Fall	Video count at Woodbridge Irrigation District Dam. Additionally, in river survey conducted to collect bio-samples from all fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 mm males.	EBMUD
Stanislaus River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 760 mm males.	CDFW
Tuolumne River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 760 mm males.	CDFW
Merced River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 760 mm males.	CDFW

Table 1. Estimation and sampling methods used for the 2011 CV Chinook run assessment. (page 3 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
<b>Recreational Harvest</b>		
Upper Sacramento River Fall	Open July 16th to December 18th from Highway 113 Bridge to the Lower Red Bluff Boat Ramp. An additional river reach from the Red Bluff Diversion Dam to the Deschutes Road Bridge was open August 1st through December 18th. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
Feather River Fall	Open July 16th to December 11th from the mouth to 1,000 ft below the Thermolito Afterbay Outfall. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
American River Fall	Open July 16th to December 31st from the Jiboom Street Bridge to the base of Nimbus Dam with the following reach specific exceptions. The reach from the mouth to the Jiboom Street Bridge was open from July 16th to December 11th. The reach from the SMUD power line crossing to the USGS cable crossing was open from July 16th to October 31st, and the reach from the USGS cable crossing to the Hazel Avenue Bridge was open from July 16th to September 14th. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
Lower Sacramento River Fall	Open July 16th to December 11th from the Carquinez Bridge to the Highway 113 Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
Upper Sacramento River Late Fall	Open November 1st to December 18th from Highway 113 Bridge to Deschutes Road Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW

a/ Biological samples ("bio-samples" or "bio-data") of live fish or carcasses generally include: sex, fork length, scales, tags or marks, and CWT recovery from ad-clipped fish.

Table 2. 2011 California ocean sport and commercial salmon fishery seasons by major port area.

Major Port Area	Sport		Commercial		
	Season	size limit <sup>a</sup>	Season	size limit <sup>a</sup>	quota
Eureka/Crescent City	May 14 - Sep 5	24" TL	Jul 2-6, 9-13, 16-20	27" TL	1,400
			Aug 1 - 15	27" TL	1,000
Fort Bragg	Apr 2 - Oct 30	24" TL	Jul 23 - 27	27" TL	
			Jul 29 - Aug 29	27" TL	
			Sep 1 - 30	27" TL	
San Francisco	Apr 2 - Oct 30	24" TL	May 1 - 31	27" TL	
			Jun 25 - Jul 5	27" TL	
			Jul 9-13, 16-20, 23-27	27" TL	
			Jul 29 - Aug 29	27" TL	
			Sep 1 - 30	27" TL	
			Oct 3-7, 10-14 <sup>b</sup>	27" TL	
Monterey <sup>c</sup>	Apr 2 - Sep 18	24" TL	May 1 - 31	27" TL	
			Jun 25 - Jul 5	27" TL	
			Jul 9-13, 16-20, 23-27	27" TL	
			Jul 29 - Aug 29	27" TL	
			Sep 1 - 30	27" TL	
South of Pt Sur <sup>d</sup>			May 1 - 31	27" TL	
			Jun 1 - 24	27" TL	
			Jun 25 - Jul 5	27" TL	
			July 9-13, 16-20, 23-27	27" TL	
			Jul 29 - Aug 29	27" TL	

a/ Size limit in inches total length (TL).

b/ Open only between Pt Reyes and San Pedro Pt.

c/ Recreational regulations apply from the Monterey area to the U.S./Mexico border

d/ Separate commercial regulations apply from Pt. Sur to the U.S./Mexico border

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release group, brood years 2007-2010. (page 1 of 2)

**Age 2 CWT releases**

Release group*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
FRHS	2009	FRH	Fea R	Spr	1	1,040,645	1,026,954	99%	Basin	Feather River (Boyds Pump Ramp)
FRHSn	2009	FRH	Fea R	Spr	6	1,085,409	1,058,635	98%	Bay pens	San Pablo Bay net pens
CFHFh	2009	CNFH	Sac R	Fall	25	10,209,934	2,543,157	25%	Basin	CNFH
CFHFfn	2009	CNFH	Sac R	Fall	3	1,359,232	339,179	25%	Bay pens	Mare Island net pens
FRHFfn	2009	FRH	Fea R	Fall	11	9,536,050	2,367,209	25%	Bay pens	San Pablo Bay net pens; Wickland Oil net pens
FRHFnc	2009	FRH	Fea R	Fall	1	122,334	118,879	97%	Coastal pens	Santa Cruz net pens; MBSTE project; held approx 1 week
FRHFtib	2009	FRH	Fea R	Fall	2	60,739	60,104	99%	Tibur. pens	Tiburon net pens, released as fingerlings (May) & yearlings (Oct)
FeaFw	2009	wild	Fea R	Fall	18	178,063	177,657	100%	Basin	Thermalito Bypass
NIMF	2009	NIM	Ame R	Fall	3	3,221,137	1,000,559	31%	Basin	American River (at Sunrise Launch Ramp & Discovery Park)
NIMFn	2009	NIM	Ame R	Fall	2	1,391,632	347,527	25%	Bay pens	Mare Island net pens
MOKF	2009	MOK	Mok R	Fall	1	99,157	99,048	100%	Basin	Mokelumne Hatchery
MOKFn	2009	MOK	Mok R	Fall	13	2,023,958	2,015,730	100%	Delta pens	Sherman Island net pens
MokFw	2009	wild	Mok R	Fall	2	1,529	1,113	73%	Basin	Mokelumne River (Woodbridge, Mok R Vino farms)
MERF	2009	MER	Mer R	Fall	6	165,213	154,685	94%	Basin	San Joaquin River (Jersey Pt)
CFHLh	2010	CNFH	Sac R	Late	26	2,036,844	1,984,094	97%	Basin	CNFH (includes spring surrogate releases)
Total age 2 releases:					120	32,531,876	13,294,530	41%	<1% wild releases	

**Age 3 CWT releases**

Release group*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
FRHS	2008	FRH	Fea R	Spr	5	1,016,835	1,015,717	100%	Basin	Feather River (Boyds Pump Ramp)
FRHSn	2008	FRH	Fea R	Spr	5	1,007,177	1,005,727	100%	Bay pens	San Pablo Bay net pens
CFHFh	2008	CNFH	Sac R	Fall	27	12,530,336	3,128,111	25%	Basin	CNFH
CFHFfn	2008	CNFH	Sac R	Fall	3	1,427,792	371,685	26%	Bay pens	Mare Island net pens, San Pablo Bay net pens
FRHFfn	2008	FRH	Fea R	Fall	11	7,761,167	2,061,211	27%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFe	2008	FRH	Fea R	Hybrid	30	498,341	481,853	97%	CV exper	Fall x Spr hybrid releases: Benicia, Discovery Pk, Elkhorn Boat Launch, Miller Park, Sac River at Garcia Bend and Pittsburg
FRHFtib	2008	FRH	Fea R	Fall	2	91,801	89,859	98%	Tibur. pens	Held 3-4 mos Tiburon net pens, released as yearlings
FeaFw	2008	wild	Fea R	Fall	37	292,423	289,830	99%	Basin	Thermalito Bypass, Feather River
NIMF	2008	NIM	Ame R	Fall	1	270,000	264,006	98%	Basin	American River (Sunrise Launch Ramp)
NIMFn	2008	NIM	Ame R	Fall	4	3,924,887	976,955	25%	Bay pens	Mare Island net pens
MOKFt	2008	MOK	Mok R	Fall	4	250,969	250,300	100%	Trucked	Sherman Island
MokFw	2008	wild	Mok R	Fall	5	21,860	20,680	95%	Basin	Mokelumne River (Woodbridge, Mok R Vino farms)
MERF	2008	MER	Mer R	Fall	2	34,532	32,978	95%	Basin	San Joaquin River (Jersey Pt)
CFHLh	2009	CNFH	Sac R	Late	16	1,154,761	1,115,378	97%	Basin	CNFH (includes spring surrogate releases)
Total age 3 releases:					152	30,282,881	11,104,290	37%	1% wild releases	

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release group, brood years 2007-2010. (page 2 of 2)

**Age 4 CWT releases**

Release group*	Brood year	Hatchery	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
ButSw	2007	wild	Butte Ck	Spr	33	330,672	323,916	98%	Basin	Butte Creek (Baldwin Construction Yard)
FRHS	2007	FRH	Fea R	Spr	8	1,414,343	1,378,941	97%	Basin	Boyds Pump Ramp (on Feather River)
FRHSn	2007	FRH	Fea R	Spr	2	1,271,761	1,242,480	98%	Bay pens	San Pablo Bay net pens, Wickland Oil net pens
CFHFe	2007	CNFH	Sac R	Fall	8	201,125	196,993	98%	CV exper	Clarksburg, Red Bluff Diversion Dam
CFHFh	2007	CNFH	Sac R	Fall	14	11,232,501	2,801,459	25%	Basin	CNFH
CFHFn	2007	CNFH	Sac R	Fall	3	1,266,949	314,681	25%	Bay pens	San Pablo Bay net pens (Conoco Phillips, Mare Island); 75% truck mortality noted for one release
FRHFe	2007	FRH	Fea R	Fall	19	623,567	619,085	99%	CV exper	Elkhorn Boat Ramp, Isleton, Lighthouse Marina, West Sacramento
FRHFn	2007	FRH	Fea R	Fall	9	9,422,521	2,347,396	25%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFt	2007	FRH	Fea R	Fall	4	102,225	101,712	99%	Trucked	Benicia
FeaFw	2007	wild	Fea R	Fall	19	208,717	206,683	99%	Basin	Thermalito Bypass
NIMFn	2007	NIM/MOK	Ame R	Fall	7	6,879,664	1,714,858	25%	Bay pens	Raised at both NIM and MOK; San Pablo Bay net pens
NIMFtib	2007	MOK	Ame R	Fall	1	51,600	51,600	100%	Tiburon pens	Raised at MOK; held 3-4 mos Tiburon net pens, released as yearlings
MOKF	2007	MOK	Mok R	Fall	1	406,593	101,458	25%	Basin	Lower Mokelumne River (New Hope Landing)
MOKFn	2007	MOK	Mok R	Fall	2	2,203,488	550,668	25%	Bay pens	San Pablo Bay net pens
MokFw	2007	wild	Mok R	Fall	1	315	315	100%	Basin	Mokelumne River
CFHLh	2008	CNFH	Sac R	Late	14	1,108,540	1,072,854	97%	Basin	CNFH (includes spring surrogate releases)

Total age 4 releases: 145 36,724,581 13,025,099 35% 1% wild releases

**Age 5 CWT releases**

Release group*	Brood year	Hatchery	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
CFHLe	2007	CNFH	Sac R	Late	17	310,099	299,292	97%	CV exper	Sac R (Colusa to RBDD), Georgianna Slough, Port Chicago, Ryde-Koket
CFHLh	2007	CNFH	Sac R	Late	10	751,208	732,952	98%		CNFH (includes spring surrogate releases)

Total age 5 releases: 27 1,061,307 1,032,244 97%

**\*CV CWT release groups:**

**Sacramento River Basin Fall Chinook CWT release groups**

CFHFe	Coleman National Fish Hatchery fall experimental releases
CFHFh	Coleman National Fish Hatchery fall hatchery releases
CFHFn	Coleman National Fish Hatchery fall net pen releases
FRHFe	Feather River Hatchery fall experimental (2008 brdyr includes spring x fall hybrids)
FRHFn	Feather River Hatchery fall bay net pen releases
FRHFnc	Feather River Hatchery fall coastal net pen releases
FRHFt	Feather River Hatchery fall trucked releases (no net pens)
FRHFtib	Feather River Hatchery fall Tiburon net pen releases
FeaFw	Feather River fall wild
NIMF	Nimbus Fish Hatchery fall basin releases
NIMFn	Nimbus Fish Hatchery fall net pens
NIMFtib	Nimbus Fish Hatchery fall Tiburon net pens releases

**San Joaquin Basin Fall Chinook CWT release groups**

MOKF	Mokelumne Hatchery fall basin releases
MOKFn	Mokelumne Hatchery fall net pen releases
MOKFt	Mokelumne Hatchery fall trucked releases
MokFw	Mokelumne River fall wild
MERF	Merced Hatchery fall releases

**Central Valley Spring Chinook CWT release groups**

FRHS	Feather River Hatchery spring basin releases
FRHSn	Feather River Hatchery spring net pen releases
ButSw	Butte Creek spring wild

**Sacramento River Basin Late Fall Chinook CWT release groups**

CFHLe	Coleman National Fish Hatchery late fall experimental releases
CFHLh	Coleman National Fish Hatchery late fall hatchery releases

**Table 4. Escapement estimates and sample data for 2011 CV escapement.**

Escapement Survey	Run	Total Escapement	Chinook Sampled <sup>a</sup>	Observed Ad-Clips	Heads Processed	Valid CWTs	Sample rate (fe)	Ad-clips processed (fa)	Valid CWTs (fd)	CWT Sample Expansion
<b>Hatchery Escapement</b>										
Coleman National Fish Hatchery	Late-fall <sup>b</sup>	4,534	4,534	4,445	4,445	4,356	100%	100%	100%	1.00
Feather River Hatchery	Spring	1,969	1,969	1,424	1,424	1,329	100%	100%	99%	1.01
Coleman National Fish Hatchery	Fall	42,380	42,380	9,735	4,999	4,895	100%	51%	99%	1.96
Feather River Hatchery	Fall	32,616	32,616	10,302	10,302	9,983	100%	100%	99%	1.01
Nimbus Fish Hatchery	Fall	12,680	12,680	3,490	3,489	3,377	100%	100%	99%	1.01
Nimbus Fish Hatchery Weir	Fall	3,917	3,917	367	367	335	100%	100%	99%	1.01
Mokelumne River Hatchery	Fall	15,922	15,922	14,724	14,712	14,341	100%	100%	99%	1.01
Merced River Hatchery	Fall	437	437	349	349	337	100%	100%	99%	1.01
<b>Total Hatchery Escapement</b>		<b>114,455</b>	<b>114,455</b>	<b>44,836</b>	<b>40,087</b>	<b>38,953</b>				
fall		107,952	107,952	38,967	34,218	33,268				
<b>Natural Area Escapement</b>										
Upper Sacramento River (above RBDD)	Late-fall <sup>b</sup>	3,725	114	83	81	76	3%	98%	100%	20.21 <sup>c</sup>
Butte Creek	Spring	4,497	2,313	0	0	0	100%	100%	100%	-
Clear Creek	Fall	4,841	647	42	40	36	13%	95%	97%	3.50 <sup>c</sup>
Battle Creek	Fall	12,867	video							<sup>d</sup>
Cottonwood Creek	Fall	2,144	127	62	61	54	19%	98%	98%	5.94 <sup>c</sup>
Upper Sacramento River (above RBDD)	Fall	10,583	378	75	74	67	4%	99%	97%	12.12 <sup>c</sup>
Mill Creek	Fall	1,485	video	29	29	28				1.00 <sup>e</sup>
Deer Creek	Fall	662	video	1	1	1				1.00 <sup>e</sup>
Butte Creek	Fall	419	179	4	4	4	43%	100%	100%	2.34
Feather River	Fall	47,289	5,094	1,632	1,631	1,518	11%	100%	98%	9.48
Yuba River (above Daguerre Point dam)	Fall	7,723	video	1,733	1,733	1,620				1.00 <sup>f</sup>
Yuba River (below Daguerre Point dam)	Fall	1,398	216	27	27	25	15%	100%	96%	6.73
American River	Fall	21,320	921	480	473	440	4%	99%	98%	9.19 <sup>c</sup>
Mokelumne River	Fall	2,667	video	2,234	2,234	2,175				1.00 <sup>f</sup>
Calaveras River	Fall	465	redd	54	54	50				1.00 <sup>e</sup>
Stanislaus River	Fall	1,063	494	305	305	294	46%	100%	99%	2.18
Tuolumne River	Fall	878	444	249	249	241	51%	100%	100%	1.99
Merced River	Fall	1,615	401	284	284	270	25%	100%	98%	4.10
<b>Total Natural Area Escapement</b>		<b>125,641</b>	<b>11,328</b>	<b>7,294</b>	<b>7,280</b>	<b>6,899</b>				
fall		117,419	8,901	7,211	7,199	6,823				
<b>CV Sport Harvest</b>										
Sacramento River (above Feather River)	Fall	19,971	1,389	270	268	257	7%	99%	97%	14.94
Sacramento River (below Feather River)	Fall	14,900	600	170	168	163	4%	99%	99%	25.28
Feather River	Fall	4,218	231	54	52	49	5%	96%	98%	19.35
American River	Fall	21,411	585	165	163	158	3%	99%	99%	37.52
Sacramento River (above Feather River)	Late-fall <sup>b</sup>	1,730	186	123	120	117	11%	98%	99%	9.62
<b>Total Sport Harvest</b>		<b>62,230</b>	<b>2,991</b>	<b>782</b>	<b>771</b>	<b>744</b>				
<b>Total</b>		<b>302,326</b>	<b>128,774</b>	<b>52,912</b>	<b>48,138</b>	<b>46,596</b>				

a/ Number of salmon sampled and visually checked for an ad-clip.

b/ Late-fall hatchery and natural escapement occurred in late fall 2010; late-fall sport harvest occurred in late fall 2011.

c/ Sample expansion factor calculated based on the ad-clip rate and proportion of ad-clipped fish containing CWTs of fresh fish only and expanded to all CWTs (Mohr and Satterthwaite, in press).

d/ Battle creek fall Chinook natural escapement not sampled; escapement estimate based on total Battle Creek adult and jack video weir counts minus returns to Coleman National Fish Hatchery.

e/ Escapement estimates based on redd surveys or video counts; CWTs collected opportunistically and are not representative of total escapement.



**Table 5. Catch estimates and sample data for 2011 Ocean Salmon Sport and Commercial Fisheries by major port area.**

Port	Total Harvest Estimate	Chinook Sampled <sup>a</sup>	Observed Ad-Clips	Heads Processed	Valid CWTs	Sample Rate (fe)	Ad-clips Processed (fa)	Valid CWTs (fd)	CWT Sample Expansion
<b>Commercial</b>									
Eureka/Crescent	2,391	1,441	164	164	98	60%	100%	99%	1.68
Fort Bragg	39,311	17,087	2,536	2,530	1,943	43%	100%	100%	2.33
San Francisco	21,912	9,207	1,703	1,701	1,598	42%	100%	100%	2.38
Monterey	6,414	2,759	568	568	532	43%	100%	99%	2.35
<b>Commercial total</b>	<b>70,028</b>	<b>30,494</b>	<b>4,971</b>	<b>4,963</b>	<b>4,171</b>				
<b>Sport</b>									
Eureka/Crescent	9,987	2,510	558	555	472	25%	99%	100%	4.04
Fort Bragg	7,398	2,026	430	429	398	27%	100%	100%	3.70
San Francisco	19,734	9,171	2,716	2,694	2,637	46%	99%	100%	2.20
Monterey	12,703	3,400	1,093	1,072	1,039	27%	98%	100%	3.78
<b>Sport total</b>	<b>49,822</b>	<b>17,107</b>	<b>4,797</b>	<b>4,750</b>	<b>4,546</b>				
<b>Ocean total</b>	<b>119,850</b>	<b>47,601</b>	<b>9,768</b>	<b>9,713</b>	<b>8,717</b>				

a/ Number of salmon visually checked for an ad-clip

Table 6. Revised CWT sample expansion rate  $F_{\text{samp}}$  and hatchery proportion of 2010 Upper Sacramento River fall and late-fall carcass surveys.

<b>2010 Upper Sacramento River fall Chinook carcass survey</b>													
<b>Original CWT sample expansion rate <math>F_{\text{samp}}</math> and hatchery proportion</b>													
Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	$p_{\text{adc}}$	$p_{\text{adc-cwt}}$	$F_{\text{samp}}$	Total CWT Production	$\sum_{i=1}^m CWT_{\text{total},i}$	Hatchery proportion
Combined	16,372	1415	130	129	117	<b>117</b>	8.6%	<b>9.2%</b>	<b>91%</b>	<b>11.66</b>	276.71	3,226	<b>20%</b>
<b>Revised CWT sample expansion rate <math>F_{\text{samp}}</math> and hatchery proportion to reduce bias from false negatives and false positives (Mohr and Satterthwaite, in press)</b>													
Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	$p_{\text{adc}}$	$p_{\text{adc-cwt}}$	$F_{\text{samp}}$	Total CWT Production	$\sum_{i=1}^m CWT_{\text{total},i}$	Hatchery proportion
Fresh		291	60	59	56	56	2%	<b>21%</b>	<b>95%</b>	57.21			
<u>Decayed</u>		<u>1,124</u>	<u>70</u>	<u>70</u>	<u>61</u>	<u>61</u>	<u>7%</u>	<u>6%</u>	<u>87%</u>				
Combined	16,372	1,415	130	129	117	<b>117</b>	9%			<b>27.38</b>	276.71	7,578	<b>46%</b>
<b>2010 Upper Sacramento River late-fall Chinook carcass survey</b>													
<b>Original CWT sample expansion rate <math>F_{\text{samp}}</math> and hatchery proportion</b>													
Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	$p_{\text{adc}}$	$p_{\text{adc-cwt}}$	$F_{\text{samp}}$	Total CWT Production	$\sum_{i=1}^m CWT_{\text{total},i}$	Hatchery proportion
Combined	4,282	811	47	46	44	<b>43</b>	19%	<b>6%</b>	<b>96%</b>	<b>5.52</b>	45.2	250	<b>6%</b>
<b>Revised CWT sample expansion rate <math>F_{\text{samp}}</math> and hatchery proportion to reduce bias from false negatives and false positives (Mohr and Satterthwaite, in press)</b>													
Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	$p_{\text{adc}}$	$p_{\text{adc-cwt}}$	$F_{\text{samp}}$	Total CWT Production	$\sum_{i=1}^m CWT_{\text{total},i}$	Hatchery proportion
Fresh		187	28	27	27	27	4%	<b>15%</b>	<b>100%</b>	23.75			
<u>Decayed</u>		<u>624</u>	<u>19</u>	<u>19</u>	<u>17</u>	<u>16</u>	<u>15%</u>	<u>3%</u>	<u>89%</u>				
Combined	4,282	811	47	46	44	<b>43</b>	19%			<b>14.91</b>	45.2	674	<b>16%</b>

$$\text{Original } F_{\text{samp}} = (N \times p_{\text{adc}} \times p_{\text{cwt|adc}}) / n_{\text{valid cwt}}$$

where N = estimated total escapement,  $p_{\text{adc}}$  = proportion of fish sampled that were ad-clipped,  $p_{\text{cwt|adc}}$  = proportion of ad-clipped fish that contained a CWT, and  $n_{\text{valid cwt}}$  = total number of valid CWTs collected from both fresh and decayed fish. (Kormos et al. 2012)

$$\text{New } F_{\text{samp}} = (N \times p_{\text{adc|fresh}} \times p_{\text{cwt|fresh,adc}}) / n_{\text{valid cwt}}$$

where N = estimated total escapement,  $p_{\text{adc|fresh}}$  = proportion of fresh fish sampled that were ad-clipped,  $p_{\text{cwt|fresh,adc}}$  = proportion of ad-clipped fresh fish that contained a CWT, and  $n_{\text{valid cwt}}$  = total number of valid CWTs collected from both fresh and decayed fish. (Mohr and Satterthwaite, in press)

Table 7. Raw and expanded CV Chinook CWT recoveries by stock and age, brood years 2006-2011.

<b>Fall</b>		2010	2009	2008	2007	2006	Total CV CWTs	Total CV %	
Age	1	2	3	4	5				
Raw CWT Recoveries	3 ( $< 1\%$ )	27,506 (72%)	9,053 (24%)	1,381 (4%)	1 ( $< 1\%$ )		37,944	81%	
Expanded CWT total	<b>47</b> ( $< 1\%$ )	<b>121,939</b> (57%)	<b>76,753</b> (36%)	<b>13,412</b> (6%)	<b>4</b> ( $< 1\%$ )		212,155	93%	
<b>Spring</b>		2010	2009	2008	2007	2006	Total CV CWTs	Total CV %	
Age	1	2	3	4	5				
Raw CWT Recoveries		1,317 (33%)	2,125 (54%)	540 (14%)			3,982	9%	
Expanded CWT total		<b>1,880</b> (24%)	<b>4,421</b> (56%)	<b>1,541</b> (20%)			7,843	3%	
<b>Late-Fall</b>		2011	2010	2009	2008	2007	2006	Total CV CWTs	Total CV %
Age	1	2	3	4	5	6			
Raw CWT Recoveries		102 (2%)	1,077 (23%)	2,974 (64%)	511 (11%)	4 ( $< 1\%$ )		4,668	10%
Expanded CWT total		<b>375</b> (5%)	<b>2,273</b> (30%)	<b>3,941</b> (51%)	<b>1,104</b> (14%)	<b>4</b> ( $< 1\%$ )		7,698	3%
<b>Winter</b>		2011	2010	2009	2008	2007	2006	Total CV CWTs	Total CV %
Age	1	2	3	4	5	6			
Raw CWT Recoveries			1 (50%)	1 (50%)				2	0%
Expanded CWT total			<b>2</b> (50%)	<b>2</b> (50%)				4	0%
<b>All Runs</b>		2011	2010	2009	2008	2007	2006	Total CV CWTs	Total CV %
Age	1	2	3	4	5	6			
Raw CWT Recoveries	3 ( $< 1\%$ )	28,926 (62%)	12,256 (26%)	4,895 (11%)	512 (1%)	4 ( $< 1\%$ )		46,596	100%
Expanded CWT total	<b>47</b> ( $< 1\%$ )	<b>124,196</b> (54%)	<b>83,450</b> (37%)	<b>18,895</b> (8%)	<b>1,108</b> ( $< 1\%$ )	<b>4</b> ( $< 1\%$ )		227,700	100%

Table 8. Raw and expanded Ocean CWT recoveries by stock and age, brood years 2006-2010

<u>Fall</u>		2009	2008	2007	2006	Total Ocean CWTs	Total Ocean%
Age		2	3	4	5		
Raw CWT Recoveries		3,171 (43%)	3,815 (52%)	304 (4%)	1 (< 1%)	7,291	84%
Expanded CWT total		<b>20,055</b> (35%)	<b>33,975</b> (60%)	<b>2,825</b> (5%)	<b>5</b> (< 1%)	56,860	86%
<u>Spring</u>		2009	2008	2007	2006	Total Ocean CWTs	Total Ocean%
Age		2	3	4	5		
Raw CWT Recoveries		69 (25%)	194 (72%)	8 (3%)	0	271	3%
Expanded CWT total		<b>200</b> (25%)	<b>573</b> (72%)	<b>19</b> (3%)	<b>0</b>	793	1%
<u>Late-Fall</u>		2010	2009	2008	2007	Total Ocean CWTs	Total Ocean%
Age		2	3	4	5		
Raw CWT Recoveries		0	383 (85%)	66 (15%)	3 (< 1%)	452	5%
Expanded CWT total		<b>0</b>	<b>1,015</b> (85%)	<b>168</b> (14%)	<b>7</b> (< 1%)	1,191	2%
<u>Winter</u>		2010	2009	2008	2007	Total Ocean CWTs	Total Ocean%
Age		2	3	4	5		
Raw CWT Recoveries		0	71 (99%)	1 (< 1%)	0	72	1%
Expanded CWT total		<b>0</b>	<b>243</b> (99%)	<b>3</b> (< 1%)	<b>0</b>	246	0%
<u>Non CV Rivers</u>		2009	2008	2007	2006	Total Ocean CWTs	Total Ocean%
Age		2	3	4	5		
Raw CWT Recoveries		2 (< 1%)	358 (57%)	244 (39%)	27 (4%)	631	7%
Expanded CWT total		<b>28</b> (< 1%)	<b>4,329</b> (64%)	<b>2,299</b> (34%)	<b>103</b> (2%)	6,758	10%
<u>All Runs</u>		2009	2008	2007	2006	Total Ocean CWTs	Total Ocean%
Age		2	3	4	5		
Raw CWT Recoveries		3,242 (37%)	4,821 (55%)	623 (7%)	31 (< 1%)	8,717	100%
Expanded CWT total		<b>20,283</b> (31%)	<b>40,136</b> (61%)	<b>5,314</b> (8%)	<b>114</b> (< 1%)	65,848	100%

Table 9. Percentage of inland CWT<sub>total</sub> recoveries by location, run, and release type<sup>a</sup> in hatchery returns, natural escapement and sport harvest during 2011.

Location	Run	Coleman National Fish Hatchery					Feather River Hatchery <sup>b</sup>							Nimbus Hatchery			Mokelumne/Merced hatcheries <sup>b</sup>					Total %		Total Run		
		CFHLh	CFHLe	CFHFh	CFHFf	CFHFe	FRHS	FRHSn	FRHFe	FRHFf	FRHFnc	FRHft	FRHFt	FEAFw	NIMF	NIMFn	NIMFtb	MOKF	MOKFn	MOKFt	MokFw	MERF	nonCV		Hatchery	Natural
<b>Hatchery Spawners</b>																										
Coleman Hatchery	Late	98.4%	-	2.0%	0.1%																			100%	0%	4,534
Feather River Hatchery	Spring					24.2%	29.5%	6.4%	33.1%									0.2%						94%	6%	1,969
Coleman Hatchery	Fall	0.6%		86.8%	0.5%	-			0.6%															89%	11%	42,380
Feather River Hatchery	Fall				2.6%	-	3.3%	4.0%	1.6%	83.6%	0.1%	-	0.4%	0.1%	0.1%			0.1%	-					96%	4%	32,616
Nimbus Hatchery	Fall				2.0%					2.1%	-	-		25.9%	37.4%	0.1%		6.3%	0.6%		2.5%			77%	23%	12,680
Nimbus Weir	Fall				3.3%			0.2%	0.1%	3.4%			0.3%	11.3%	5.0%			1.4%	0.1%		0.7%			26%	74%	3,917
Mokelumne Hatchery	Fall				2.5%			0.1%	-	2.0%	-		0.1%	0.1%	3.5%	0.2%		1.2%	77.3%	7.1%	-	3.6%		98%	2%	15,922
Merced Hatchery	Fall	0.2%			3.7%					6.4%			0.2%		0.9%			39.6%	3.9%		33.0%			88%	12%	437
<b>Total Hatchery Fall Run</b>		<b>0.3%</b>		<b>34.1%</b>	<b>1.7%</b>	<b>-</b>	<b>1.0%</b>	<b>1.2%</b>	<b>0.5%</b>	<b>26.2%</b>	<b>-</b>	<b>-</b>	<b>0.1%</b>	<b>-</b>	<b>3.5%</b>	<b>5.1%</b>	<b>-</b>	<b>0.2%</b>	<b>12.4%</b>	<b>1.1%</b>	<b>-</b>	<b>1.0%</b>		<b>89%</b>	<b>11%</b>	<b>107,952</b>
<b>Natural Spawners</b>																										
Upper Sacramento River	Late	37.2%	4.0%											2.2%	1.1%									44%	56%	3,725
Butte Creek	Spring																							0%	100%	4,497
Clear Creek	Fall			2.3%		0.1%		0.5%	0.1%	5.0%			0.2%											8%	92%	4,841
Cottonwood Creek <sup>c</sup>	Fall			42.2%	6.7%					8.1%	0.3%		0.3%											58%	42%	2,144
Mill Creek <sup>c</sup>	Fall			6.2%	0.8%					0.3%			0.1%											7%	93%	1,485
Battle Creek <sup>d</sup>	Fall	0.6%		86.8%	0.5%	-				0.6%														89%	11%	12,867
Butte Creek	Fall				4.1%					2.1%								0.5%						7%	93%	419
Upper Sac River	Fall			12.4%	1.2%	0.2%		0.3%	0.4%	11.7%						0.1%		0.5%			0.1%			27%	73%	10,583
Feather River	Fall				3.1%		4.2%	4.3%	1.8%	75.8%	-	-	0.3%		0.1%	-								90%	10%	47,289
Yuba River - Above DPD	Fall				8.9%		0.4%	1.7%	1.3%	48.3%			1.5%	0.8%				1.3%			0.2%			65%	35%	7,723
Yuba River - Below DPD	Fall				5.8%		0.5%	1.0%	0.5%	17.4%			0.5%	3.9%	1.9%			1.9%	0.5%					34%	66%	1,398
American River	Fall				11.5%					4.6%		0.1%		17.0%	30.6%	0.1%		1.6%	0.4%		0.5%	0.1%		66%	34%	21,320
Mokelumne River	Fall				2.5%			0.1%	-	2.0%			0.1%	0.1%	3.1%	0.1%		1.1%	69.0%	6.4%	3.2%			88%	12%	2,667
Calaveras River <sup>e</sup>	Fall				0.9%										1.7%	0.2%		6.2%	1.9%		2.6%			14%	86%	465
Stanislaus River	Fall				21.4%					3.4%					3.3%	0.2%		0.2%	25.7%	15.6%	12.9%			83%	17%	1,063
Tuolumne River	Fall				8.7%			0.2%	0.5%	13.9%					0.9%	0.2%		21.1%	5.2%		21.9%			73%	27%	878
Merced River	Fall				15.7%					2.0%	0.5%				5.1%	0.2%		25.4%	15.5%		24.6%			89%	11%	1,615
<b>Total Natural Area Fall Run<sup>e</sup></b>		<b>0.1%</b>		<b>11.2%</b>	<b>4.9%</b>	<b>-</b>	<b>1.8%</b>	<b>2.0%</b>	<b>0.9%</b>	<b>37.8%</b>	<b>-</b>	<b>-</b>	<b>0.2%</b>	<b>3.3%</b>	<b>6.0%</b>	<b>-</b>	<b>-</b>	<b>2.9%</b>	<b>0.6%</b>	<b>0.9%</b>	<b>-</b>	<b>-</b>		<b>73%</b>	<b>27%</b>	<b>112,663</b>
<b>Sport Harvest</b>																										
Inland Creel - Late Fall	Late	65.1%		2.2%				0.6%										0.6%						68%	32%	1,730
Inland Creel - Upper Sac	Fall	0.3%		69.6%	1.5%			0.2%	0.2%	2.8%												0.1%		75%	25%	19,971
Inland Creel - Lower Sac	Fall	1.6%		4.1%	9.0%			0.3%	0.5%	36.4%				15.9%	6.1%	0.2%		4.4%	0.8%		1.4%	0.2%		81%	19%	14,900
Inland Creel - Feather	Fall				7.1%		0.5%		0.9%	73.9%														83%	17%	4,218
Inland Creel - American	Fall				10.5%			0.2%		7.8%				42.4%	29.5%			3.5%	0.2%		0.4%			95%	5%	21,411
<b>Total Sport Fall Harvest</b>		<b>0.5%</b>		<b>24.0%</b>	<b>6.9%</b>	<b>-</b>	<b>-</b>	<b>0.2%</b>	<b>0.2%</b>	<b>17.8%</b>	<b>-</b>	<b>-</b>	<b>0.2%</b>	<b>18.9%</b>	<b>12.0%</b>	<b>-</b>	<b>-</b>	<b>2.3%</b>	<b>0.3%</b>	<b>0.5%</b>	<b>0.1%</b>	<b>-</b>		<b>84%</b>	<b>16%</b>	<b>60,500</b>

a/ Any values resulting in less than 0.05% are displayed here as "-". Note: These values represent a small number of recoveries and are not actual zeros.

b/ Natural-origin Feather River (FeaW) and Mokelumne River (Mokw) CWT releases are not included in this table due to minimal recoveries occurring only at the Feather River and Mokelumne hatcheries (contributed 0.02% and 0.01%, respectively).

c/ Surveys without representative sampling of CWTs; proportions shown are based only on CWTs collected opportunistically.

d/ No CWT recovery survey or ad-clip count available for Battle Creek natural escapement. CWT release group and total hatchery proportions assumed to be equivalent to Coleman National Fish Hatchery (FWS staff, per. comm).

e/ Total natural area fall run total only includes surveys with representative sampling of CWTs.

**Table 10. 2011 CWT recovery rate (recoveries per 100,000 CWTs released) by release group, brood year, and recovery location (page 1 of 2).**

**Age 2 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location									CV CWT <sub>samp</sub> totals			Ocean	Recovery rate per 100,000 released				CV Stray	
				Bat Cr	Up Sac	Nat crks <sup>al</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT <sub>samp</sub>	Basin	Stray	CV total	Ocean	Proportion	
FRHS	2009	Spr	1,026,954				578	16						594		594	87	58	58	8	0.00	
FRHSn	2009	Spr	1,058,635			18	1,033	104	6	4				1,136	28	1,164	113	107	3	110	11	0.02
CFHFh	2009	Fall	2,543,157	5,390	36	212	1			1				5,426	214	5,640	4,321	213	8	222	170	0.04
CFHFn	2009	Fall	339,179	35		35	243	85	215	92	25	28		35	722	757	1,741	10	213	223	513	0.95
FRHFn	2009	Fall	2,367,209	43	97	67	7,492	403	76	73	14	20		7,896	391	8,286	5,421	334	17	350	229	0.05
FRHFnc	2009	Fall	118,879			6	58		1	2	8			58	18	76	694	49	15	64	584	0.23
FRHFtib	2009	Fall	60,104				130		1	5	1			130	7	136	45	216	11	227	75	0.05
FeaFw	2009	Fall	177,657				4							4		4	2	2		2	1	0.00
NIMF	2009	Fall	1,000,559				6	30	1,916	6				1,916	42	1,958	3,881	191	4	196	388	0.02
NIMFn	2009	Fall	347,527			1	1		401	38	8			401	49	450	644	115	14	129	185	0.11
MokF	2009	Fall	99,048							220		2		220	2	222		222	2	224		0.01
MokFn	2009	Fall	2,015,730	10		27	33	124	1,145	14,034	534	449		14,034	2,321	16,354	2,730	696	115	811	135	0.14
MokFw	2009	Fall	1,113																			-
MerF	2009	Fall	154,685	2	12	11	28	16	386	605	487	293		487	1,353	1,840	576	315	875	1190	372	0.74
CFHLh	2010	Late	992,047	157						1	1			157	2	159		16	0.2	16		0.01
Total				5,637	145	376	9,607	778	4,146	15,081	1,078	793		32,494	5,147	37,641	20,255	2,545	1,277	3,822	2,672	

**Age 3 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location									CV CWT <sub>samp</sub> totals			Ocean	Recovery rate per 100,000 released				CV Stray	
				Bat Cr	Up Sac	Nat crks <sup>al</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT <sub>samp</sub>	Basin	Stray	CV total	Ocean	Proportion	
FRHS	2008	Spr	1,015,717				2,237	23		1				2,260	1	2,261	265	223	0.1	223	26	0.00
FRHSn	2008	Spr	1,005,727		24	4	2,006	39	1	10		2		2,045	41	2,086	308	203	4	207	31	0.02
CFHFh	2008	Fall	3,128,111	3,461	267	60								3,727	60	3,788	8,716	119	2	121	279	0.02
CFHFn	2008	Fall	371,685	21	36	8	351	97	472	23	45	51		57	1,048	1,105	4,056	15	282	297	1,091	0.95
FRHFe	2008	Fall	481,853	2	36	4	1,429	104	12	8		4		1,533	66	1,598	334	318	14	332	69	0.04
FRHFn	2008	Fall	2,061,211	20	109	34	6,626	435	135	17	1	24		7,061	340	7,401	8,161	343	17	359	396	0.05
FRHFtib	2008	Fall	89,859	4		17	111	120	11	11				231	43	274	120	257	48	305	133	0.16
FeaFw	2008	Fall	289,830				3							3		3	11	1		1	4	0.00
NIMF	2008	Fall	264,006						92					92		92	104	35		35	39	0.00
NIMFn	2008	Fall	976,955				15	7	2,330	55	9	2		2,330	87	2,417	10,983	238	9	247	1,124	0.04
MokFt	2008	Fall	250,300	2		9	1	7	159	1,305	267	211		1,305	657	1,962	1,433	521	262	784	573	0.33
MokFw	2008	Fall	20,680							2				2		2	4	11		11	21	0.00
MerF	2008	Fall	32,978				1		35	19	27	16		27	70	97	52	81	214	294	157	0.73
CFHLh	2009	Late	1,115,378	1,023	81									1,104		1,104	1,015	99		99	91	0.00
Total				4,532	554	136	12,779	831	3,249	1,451	349	311		21,777	2,414	24,191	35,563	2,465	851	3,316	4,035	

**Table 10. 2011 CWT recovery rate (recoveries per 100,000 CWTs released) by release group, brood year, and recovery location (page 2 of 2).**

**Age 4 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location								CV CWT <sub>samp</sub> totals			Ocean	Recovery rate per 100,000 released				CV Stray		
				Bat Cr	Up Sac	Nat crks <sup>a/</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT <sub>samp</sub>	Basin	Stray	CV total	Ocean	Proportion	
ButSw	2007	Spr	323,916																			-
FRHS	2007	Spr	1,378,941				672							672		672	12	49		49	1	0.00
FRHSn	2007	Spr	1,242,480		12		811				1			811	13	824	7	65	1	66	1	0.02
CFHFfe	2007	Fall	196,993	12	24	4	1							36	5	41	2	18	2	21	1	0.11
CFHFh	2007	Fall	2,801,459	343	24	6								367	6	373	359	13	0.2	13	13	0.02
CFHFf	2007	Fall	314,681	2		1	9	16	53	3				2	83	85	219	1	26	27	70	0.98
FRHFfe	2007	Fall	619,085				43			1				43	1	44	6	7	0.2	7	1	0.02
FRHFf	2007	Fall	2,347,396	2	109	9	1,858	162	138	4		2		2,020	264	2,284	1,595	86	11	97	68	0.12
FRHFt	2007	Fall	101,712				13		24					13	24	37	10	12	24	36	10	0.66
FeaFw	2007	Fall	206,683				1							1		1		0.5		0.5		0.00
NIMFf	2007	Fall	1,714,858		20	1				127	66	4	9	193	34	227	430	11	2	13	25	0.15 <sup>b/</sup>
NIMFtib	2007	Fall	51,600	1	53	1	9			34	30	4	4	64	72	136	74	123	140	264	144	0.53 <sup>b/</sup>
MokF	2007	Fall	101,458								1			1		1		1		1		0.00
MokFf	2007	Fall	550,668		12	1	2			11	22	12	2	22	41	63	129	4	7	11	23	0.65
MokFw	2007	Fall	315																			-
CFHLh	2008	Late	1,072,854	2,932	808									3,740		3,740	168	349		349	16	0.00
Total				3,292	1,063	23	3,419	178	388	128	21	17		7,984	543	8,527	3,013	740	215	955	372	

**Age 5 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location								CV CWT <sub>samp</sub> totals			Ocean	Recovery rate per 100,000 released				CV Stray		
				Bat Cr	Up Sac	Nat crks <sup>a/</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT <sub>samp</sub>	Basin	Stray	CV total	Ocean	Proportion	
CFHLe	2007	Late	299,292	1	141									142		142		48		48		0.00
CFHLh	2007	Late	732,952	481	445									926		926	5	126		126	0.6	0.00

a/ Natural creeks include Clear Creek, Cottonwood Creek, Butte Creek and Mill Creek.

b/ Nimbus Hatchery fall Chinook net pen releases (NIMFf and NIMFtib) brood year 2007 contained salmon from the American River raised at Mokelumne River Fish Hatchery.

**Sacramento River fall Chinook releases (SFC)**

- CFHFfe Coleman Hatchery fall experimental releases
- CFHFh Coleman Hatchery fall hatchery releases
- CFHFf Coleman Hatchery fall net pen releases
- FRHFfe Feather River Hatchery fall experimental (2008 brdry includes spring x fall hybrids)
- FRHFf Feather River Hatchery fall bay net pen releases
- FRHFfc Feather River Hatchery fall coastal net pen releases
- FRHFft Feather River Hatchery fall trucked releases (no net pens)
- FRHFftib Feather River Hatchery fall Tiburon net pen releases (released as yearlings following fall)
- FeaFw Feather River fall wild
- NIMF Nimbus Hatchery fall basin releases
- NIMFf Nimbus Hatchery fall net pens
- NIMFtib Nimbus Hatchery fall Tiburon net pens (released as yearlings following fall)

**Other CV releases (OCV)**

- CFHLe Coleman Hatchery late fall experimental releases
- CFHLh Coleman Hatchery late fall hatchery releases
- FRHS Feather River Hatchery spring basin releases
- FRHSn Feather River Hatchery spring net pen releases
- FRHSst Feather River Hatchery spring trucked releases
- MerF Merced River fall releases
- MokF Mokelumne Hatchery fall basin releases
- MokFf Mokelumne Hatchery fall net pen releases
- MokFst Mokelumne Hatchery fall trucked releases
- MokFw Mokelumne River fall wild

**Wild releases**

- ButSw Butte Creek spring wild

Table 11. Percentage of ocean CWT<sub>total</sub> recoveries by majorport, month and release type<sup>a</sup> in 2011 California sport and commercial fisheries (page 1 of 2).

<u>Livingston/Coleman Hatcheries</u>						<u>Feather River Hatchery</u>							<u>Nimbus Hatchery</u>			<u>Mokelumne/Merced Hatcheries<sup>b</sup></u>					nonCV	Total		Total %		Total Harvest
SacW	CFHLh	CFHLe	CFHFh	CFHFf	CFHFe	FRHS	FRHSn	FRHFe	FRHFf	FRHFnc	FRHft	FRHftib	FeaW	NIMF	NIMFn	NIMFtib	MOKF	MOKFn	MOKFt	MokFw		MERF	CV	Hatchery	Natural	
<b>Sport Harvest</b>																										
<b>Eureka/Crescent City</b>																										
May	0.5%		15.4%	5.8%			0.5%	1.0%	20.0%					0.5%	13.5%			1.9%	0.5%	0.5%	4.0%	60.1%	64%	36%	666	
Jun			12.8%				0.5%	0.5%	8.0%						8.1%				2.0%		8.3%	31.9%	40%	60%	946	
Jul	0.1%		12.7%	6.2%		0.1%	0.1%		11.2%					1.0%	9.8%			0.7%	2.2%	0.1%	9.8%	44.2%	54%	46%	4,384	
Aug	0.7%		10.0%	2.2%		0.9%	0.6%		7.8%	0.4%				4.8%	12.4%	0.1%		4.5%	0.6%	0.8%	14.4%	45.8%	60%	40%	3,690	
Sep			9.1%	9.2%		1.2%			18.4%	1.2%				4.6%	9.1%			18.3%		6.3%	4.6%	77.4%	82%	18%	301	
<b>Total</b>	<b>0.3%</b>		<b>11.8%</b>	<b>4.2%</b>		<b>0.4%</b>	<b>0.3%</b>	<b>0.1%</b>	<b>10.4%</b>	<b>0.2%</b>				<b>2.4%</b>	<b>10.8%</b>	<b>-</b>		<b>2.7%</b>	<b>1.4%</b>	<b>0.6%</b>	<b>10.8%</b>	<b>45.7%</b>	<b>57%</b>	<b>43%</b>	<b>9,987</b>	
<b>Fort Bragg</b>																										
Apr	0.4%		17.4%	13.2%		1.3%	0.5%	0.4%	23.4%			0.4%			24.4%					3.6%	0.9%	85.0%	86%	14%	880	
May			13.2%	1.6%		1.0%	1.9%		17.1%						29.7%					0.9%	2.1%	65.4%	67%	33%	705	
Jun	0.9%		6.4%	5.6%		0.3%	0.3%	0.3%	29.2%			0.3%		3.4%	8.1%	0.3%			1.8%		23.1%	57.0%	80%	20%	938	
Jul	1.6%		14.1%	3.1%			0.1%	0.1%	12.3%	0.1%		0.1%		0.4%	10.7%	0.1%		1.0%	1.7%	0.3%	1.7%	45.7%	47%	53%	4,043	
Aug	1.0%		17.2%	13.5%		0.5%	0.5%		17.2%	1.0%				9.7%	7.6%			4.8%	0.9%		73.8%	74%	26%	510		
Sep	1.8%		11.0%						7.2%			0.9%		19.2%	14.6%			7.3%		1.9%	64.0%	64%	36%	204		
Oct	4.1%		16.1%				8.2%		4.1%					16.0%				4.0%			52.6%	53%	47%	118		
<b>Total</b>	<b>1.2%</b>		<b>13.6%</b>	<b>5.1%</b>		<b>0.3%</b>	<b>0.5%</b>	<b>0.2%</b>	<b>16.2%</b>	<b>0.2%</b>		<b>0.2%</b>		<b>2.1%</b>	<b>13.5%</b>	<b>0.1%</b>		<b>1.1%</b>	<b>1.7%</b>	<b>0.2%</b>	<b>4.2%</b>	<b>56.3%</b>	<b>60%</b>	<b>40%</b>	<b>7,398</b>	
<b>San Francisco</b>																										
Apr	0.9%		13.9%	8.3%		0.9%	1.3%	0.9%	18.2%			1.4%			22.6%				2.6%		70.7%	71%	29%	432		
May	2.7%		15.4%	4.2%		1.2%	0.4%	0.6%	11.5%			0.6%			14.6%				2.5%		53.6%	54%	46%	934		
Jun	0.7%	2.2%	7.9%	13.1%		2.1%	2.8%	2.8%	33.5%			2.0%		0.8%	8.3%				2.8%		3.0%	79.0%	82%	18%	326	
Jul	0.2%	1.1%	18.4%	10.6%		0.2%	0.2%	0.2%	22.8%	1.6%		0.3%	0.1%	6.6%	3.7%			5.8%	0.2%	0.7%	0.1%	72.7%	73%	27%	4,457	
Aug	0.2%	0.3%	25.1%	10.5%		-	0.1%		25.1%	1.0%		0.1%		7.2%	2.4%			5.0%	0.2%	1.3%	78.6%	79%	21%	6,531		
Sep	0.1%	0.2%	7.4%	2.7%		0.3%	0.2%		16.0%	0.2%		-		23.1%	11.9%	0.1%		14.3%	0.7%	-	3.3%	80.6%	81%	19%	5,914	
Oct	0.2%	3.7%	3.0%	2.3%			0.6%		3.8%	0.2%	0.2%	-		13.4%	12.2%	0.4%		15.9%	0.2%	3.6%	59.4%	59%	41%	1,140		
<b>Total</b>	<b>0.2%</b>	<b>0.8%</b>	<b>16.0%</b>	<b>7.4%</b>		<b>0.2%</b>	<b>0.3%</b>	<b>0.1%</b>	<b>20.0%</b>	<b>0.8%</b>	<b>-</b>	<b>0.2%</b>	<b>-</b>	<b>11.6%</b>	<b>7.2%</b>	<b>-</b>		<b>8.2%</b>	<b>0.6%</b>	<b>-</b>	<b>1.8%</b>	<b>0.1%</b>	<b>75.4%</b>	<b>75%</b>	<b>25%</b>	<b>19,734</b>
<b>Monterey</b>																										
Apr	0.3%	0.9%	17.2%	12.7%		2.1%	1.7%	2.5%	24.2%			0.3%		0.1%	9.7%	0.1%			1.1%		4.8%	72.8%	78%	22%	4,210	
May			8.5%	8.6%			4.3%	2.2%	17.2%						17.0%						57.8%	58%	42%	280		
Jun	3.8%	3.4%	11.8%	7.0%				0.5%	21.8%	0.8%		0.4%		1.5%	5.5%	0.4%		0.7%	0.7%	0.4%	58.7%	59%	41%	1,170		
Jul	1.1%	0.7%	14.4%	10.4%		0.3%	0.4%		25.5%	3.6%		0.1%		11.0%	3.7%			8.3%	0.1%	2.0%	81.6%	82%	18%	3,998		
Aug	3.3%	0.7%	14.2%	2.5%		0.5%	0.9%		19.5%	5.0%		0.3%		14.6%	2.6%			10.5%		2.0%	76.5%	77%	23%	2,369		
Sep			6.5%						8.7%	31.7%		1.1%		17.4%				11.3%	1.1%	1.7%	79.5%	79%	21%	676		
<b>Total</b>	<b>1.4%</b>	<b>1.0%</b>	<b>14.5%</b>	<b>8.8%</b>		<b>0.9%</b>	<b>1.0%</b>	<b>0.9%</b>	<b>22.5%</b>	<b>3.8%</b>		<b>0.3%</b>		<b>7.3%</b>	<b>5.7%</b>	<b>0.1%</b>		<b>5.2%</b>	<b>0.5%</b>	<b>1.1%</b>	<b>1.6%</b>	<b>75.0%</b>	<b>77%</b>	<b>23%</b>	<b>12,703</b>	
<b>Total CA Harvest</b>																										
	<b>0.4%</b>	<b>0.8%</b>	<b>14.4%</b>	<b>6.8%</b>		<b>0.5%</b>	<b>0.5%</b>	<b>0.3%</b>	<b>18.2%</b>	<b>1.3%</b>	<b>-</b>	<b>0.2%</b>	<b>-</b>	<b>7.2%</b>	<b>8.5%</b>	<b>0.1%</b>		<b>5.3%</b>	<b>0.9%</b>	<b>-</b>	<b>1.2%</b>	<b>3.2%</b>	<b>66.5%</b>	<b>70%</b>	<b>30%</b>	<b>49,822</b>

a/ Any values resulting in less than 0.05% are displayed here as "-". Note: These values represent some small number of recoveries and are not actual zeros.

b/ Mokelumne River natural-origin tagged Chinook recoveries are not included in this table due to very small recovery totals in SF commercial (month 7) and SF sport (month 9), contributing only 0.03% and 0.04% respectively



Table 11. Percentage of ocean CWT<sub>total</sub> recoveries by majorport, month and release type<sup>a</sup> in 2011 California sport and commercial fisheries (page 2 of 2).

<u>Livingston/Coleman Hatcheries</u>						<u>Feather River Hatchery</u>							<u>Nimbus Hatchery</u>			<u>Mokelumne/Merced Hatcheries<sup>b</sup></u>					nonCV	Total CV	Total %		Total Harvest		
SacW	CFHLh	CFHLe	CFHFh	CFHFf	CFHFe	FRHS	FRHSn	FRHFe	FRHFf	FRHFnc	FRHFt	FRHFtib	FeaW	NIMF	NIMFn	NIMFtib	MOKF	MOKFn	MOKFt	MokFw			MERF	Hatchery		Natural	
<b>Commercial Harvest</b>																											
<b>Eureka/Crescent City</b>																											
Jul	0.1%		4.0%	1.9%					6.1%					4.0%					1.0%	0.1%		10.3%	17%	28%	72%	1,584	
Aug	0.2%		4.6%					1.9%						3.5%	0.5%				0.5%			10.2%	11%	21%	79%	807	
<b>Total</b>	<b>0.1%</b>		<b>4.2%</b>	<b>1.2%</b>				<b>4.7%</b>						<b>3.9%</b>	<b>0.2%</b>				<b>0.8%</b>	<b>0.1%</b>		<b>10.3%</b>	<b>15%</b>	<b>26%</b>	<b>74%</b>	<b>2,391</b>	
<b>Fort Bragg</b>																											
Jul	0.7%		5.8%	1.7%		0.1%	0.1%	-	5.1%	-	-	-	-	0.1%	7.1%	0.1%		0.1%	0.9%	0.1%		12.7%	22%	34%	66%	21,085	
Aug	-	1.5%	-	8.1%	1.8%	0.1%	0.1%	-	5.0%	0.1%	-	-	-	0.5%	12.4%	-		0.4%	1.6%	0.1%		9.4%	32%	41%	59%	17,766	
Sep		4.5%		7.4%	2.5%			0.6%	0.7%	7.5%					32.4%			2.5%	3.7%			3.1%	62%	65%	35%	460	
<b>Total</b>	<b>-</b>	<b>1.1%</b>	<b>-</b>	<b>6.9%</b>	<b>1.7%</b>	<b>0.1%</b>	<b>0.1%</b>	<b>-</b>	<b>5.1%</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>0.3%</b>	<b>9.8%</b>	<b>0.1%</b>		<b>0.2%</b>	<b>1.3%</b>	<b>0.1%</b>		<b>11.1%</b>	<b>27%</b>	<b>38%</b>	<b>62%</b>	<b>39,311</b>	
<b>San Francisco</b>																											
May		0.3%		10.1%	6.0%	-	0.5%	0.7%	0.8%	14.8%			0.4%	0.2%	7.9%	-			1.0%	-		2.2%	43%	45%	55%	7,753	
Jun		1.2%		15.5%	6.6%				11.9%				0.2%		17.5%				2.9%			0.2%	56%	56%	44%	2,830	
Jul		2.1%		10.6%	5.9%		0.1%	0.1%	0.2%	11.3%		-	0.2%	0.2%	19.3%	0.1%		0.1%	2.8%	-	0.1%	3.3%	53%	56%	44%	8,305	
Aug	0.2%	0.9%		26.4%	13.8%					15.1%			0.2%	2.8%	17.3%			0.2%	1.2%				78%	78%	22%	1,395	
Sep		0.5%		10.0%	2.0%		0.2%			7.4%				9.4%	34.7%	0.3%		6.0%	2.1%	1.4%			74%	74%	26%	1,312	
Oct		3.7%						0.8%						2.9%	23.2%	0.7%		4.3%	0.7%				36%	36%	64%	317	
<b>Total</b>	<b>-</b>	<b>1.2%</b>		<b>11.9%</b>	<b>6.2%</b>	<b>-</b>	<b>0.2%</b>	<b>0.3%</b>	<b>0.4%</b>	<b>12.5%</b>	<b>-</b>	<b>0.3%</b>		<b>0.9%</b>	<b>15.9%</b>	<b>0.1%</b>		<b>0.5%</b>	<b>2.0%</b>	<b>-</b>	<b>0.1%</b>	<b>2.0%</b>	<b>52%</b>	<b>54%</b>	<b>46%</b>	<b>21,912</b>	
<b>Monterey</b>																											
May	0.2%	0.3%		10.8%	9.3%		1.4%	2.2%	1.7%	25.1%			0.1%	0.1%	2.2%			0.5%	0.4%			2.4%	54%	57%	43%	3,979	
Jun	0.6%	2.5%		17.4%	11.2%				0.6%	14.3%		0.1%	0.1%	0.3%	12.4%				0.7%	0.1%		0.2%	60%	61%	39%	1,359	
Jul		1.6%		12.4%	3.6%		0.5%			6.3%				2.1%	10.4%			2.0%	1.6%				41%	41%	59%	695	
Aug	2.2%	5.5%		17.3%	8.6%					17.4%	1.1%			14.1%	21.7%			1.1%	1.1%				90%	90%	10%	333	
Sep										7.7%													8%	8%	92%	48	
<b>Total</b>	<b>0.4%</b>	<b>1.2%</b>		<b>12.6%</b>	<b>9.0%</b>		<b>0.9%</b>	<b>1.4%</b>	<b>1.2%</b>	<b>20.2%</b>	<b>0.1%</b>	<b>-</b>	<b>-</b>	<b>1.1%</b>	<b>6.2%</b>			<b>0.6%</b>	<b>0.6%</b>	<b>-</b>		<b>1.6%</b>	<b>56%</b>	<b>57%</b>	<b>43%</b>	<b>6,414</b>	
<b>Total CA Harvest</b>																											
	-	1.1%	-	8.9%	3.8%	-	0.2%	0.3%	0.2%	8.8%	-	-	0.1%	-	0.5%	11.2%	0.1%		0.3%	1.4%	-	0.1%	7.4%	37%	44%	56%	70,028

a/ Any values resulting in less than 0.05% are displayed here as "-". Note: These values represent some small number of recoveries and are not actual zeros.

b/ Mokelumne River natural-origin tagged Chinook recoveries are not included in this table due to very small recovery totals in SF commercial (month 7) and SF sport (month 9), contributing only 0.03% and 0.04% respectively

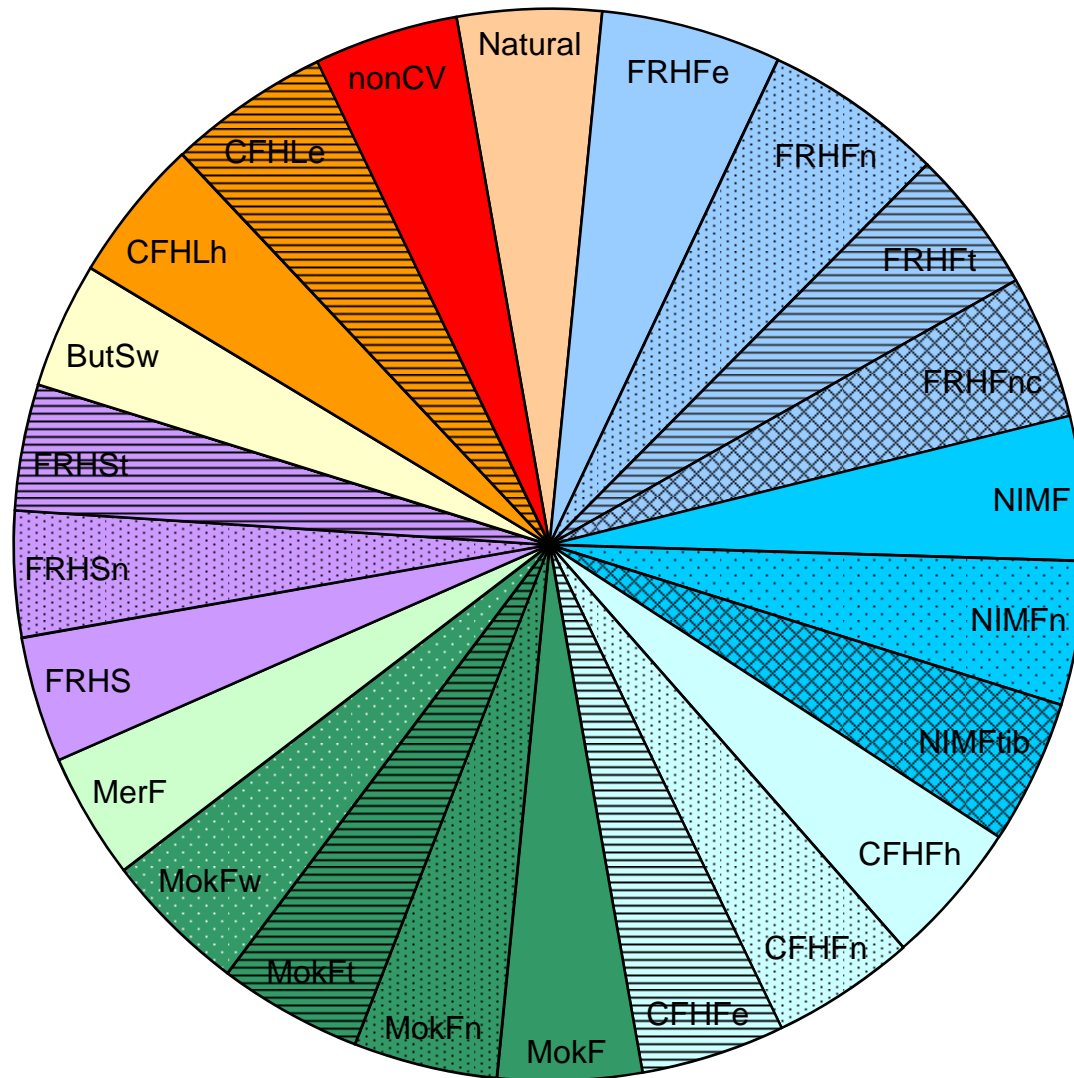
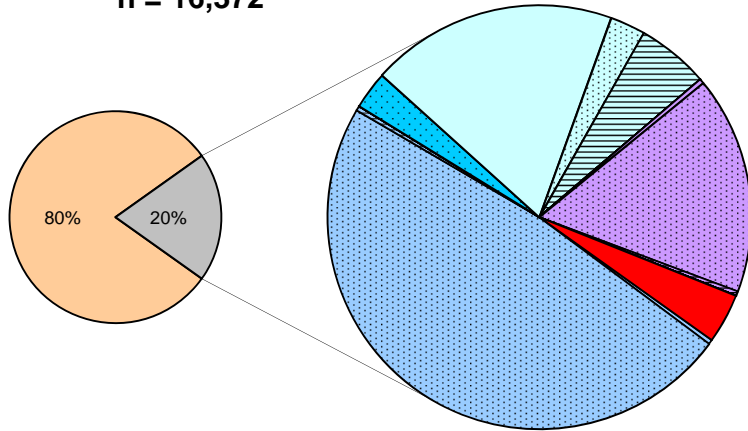
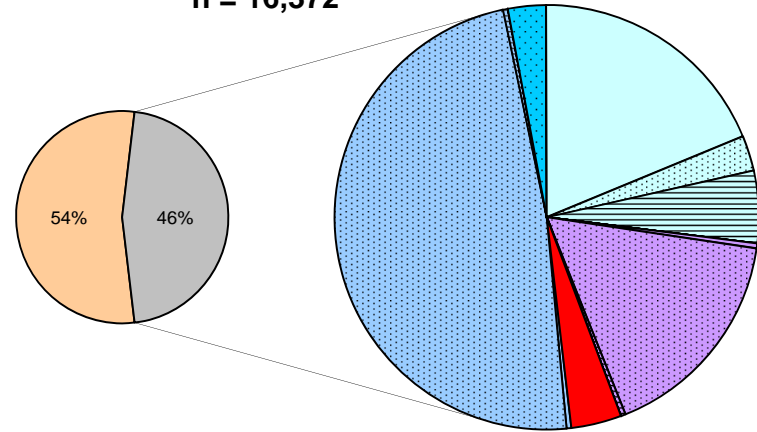


Figure 1. Central Valley hatchery release types color scheme (note: FRHFnc includes FRH fall Tiburon net pen releases).

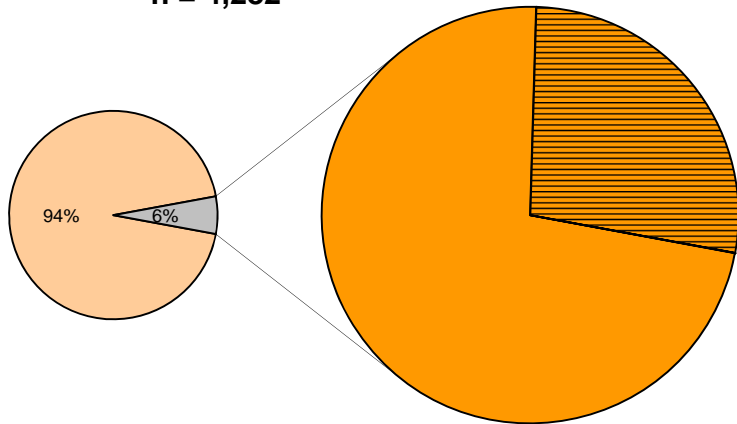
**2010 Upper Sac River fall carcass**  
n = 16,372



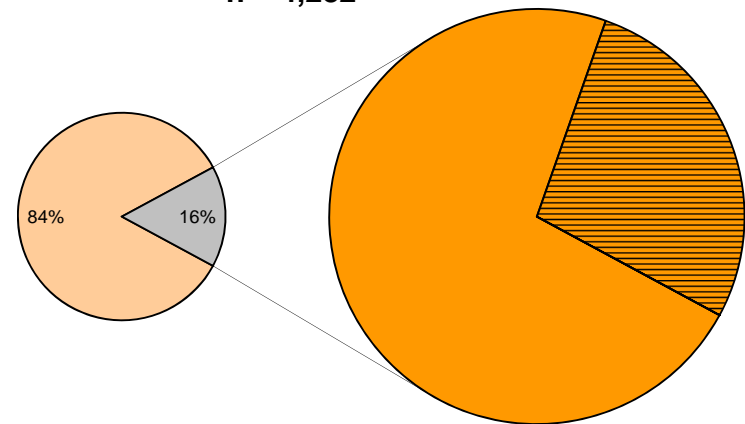
**2010 Upper Sac River fall carcass (revised)**  
n = 16,372



**2010 Upper Sac River late-fall carcass**  
n = 4,282



**2010 Upper Sac River late-fall carcass (revised)**  
n = 4,282



- Natural
  FRHFe
  FRHFn
  FRHFt
  FRHFnc
  NIMF
  NIMFn
  NIMFtn
  CFHFh
  CFHFfn
  CFHFfe
  MokF
  MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 2. Revised proportion of hatchery and natural-origin fish in 2010 carcass surveys in the Upper Sacramento River Basin.

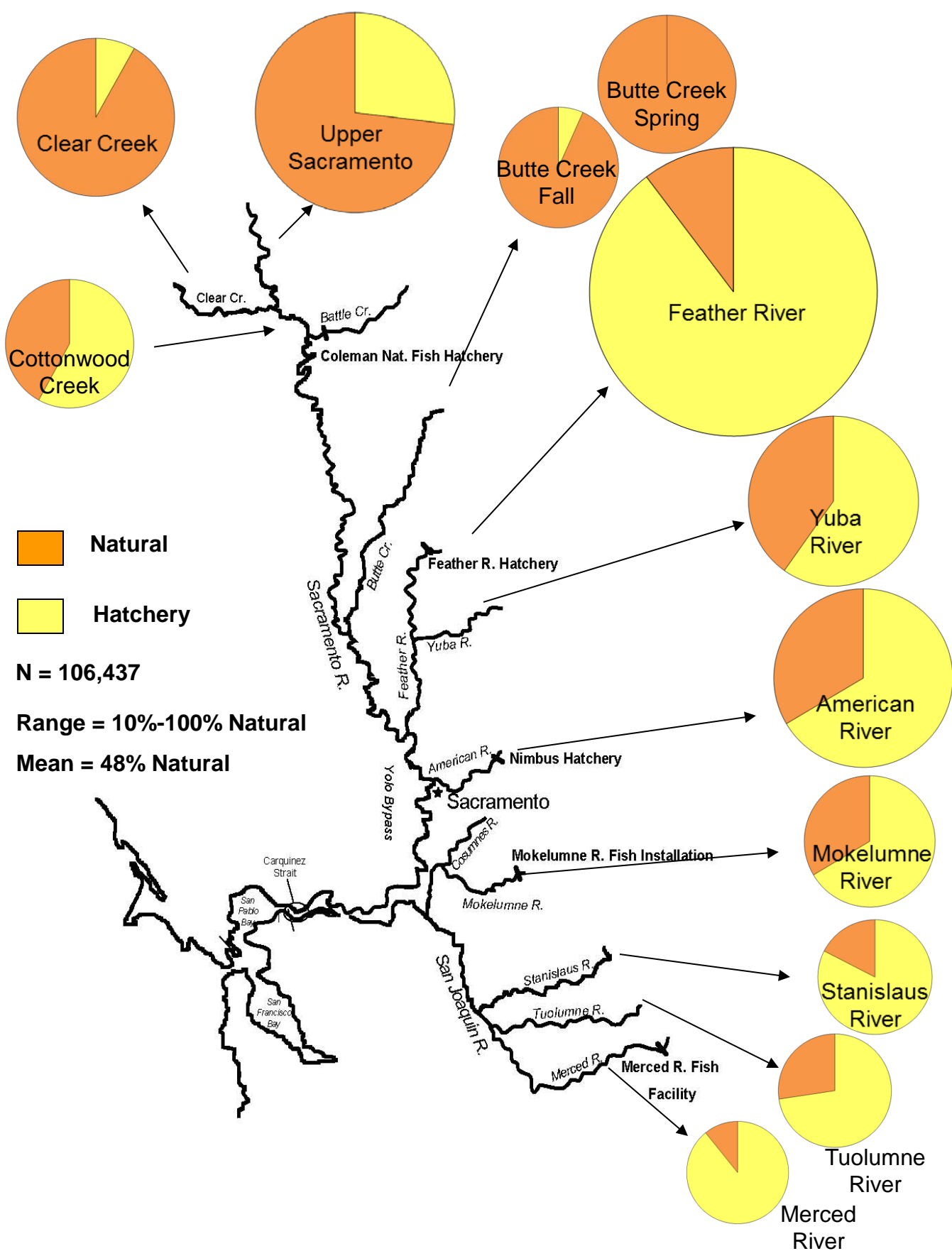


Figure 3. 2011 Chinook Salmon Natural Area Escapement, Hatchery and Natural Proportions.

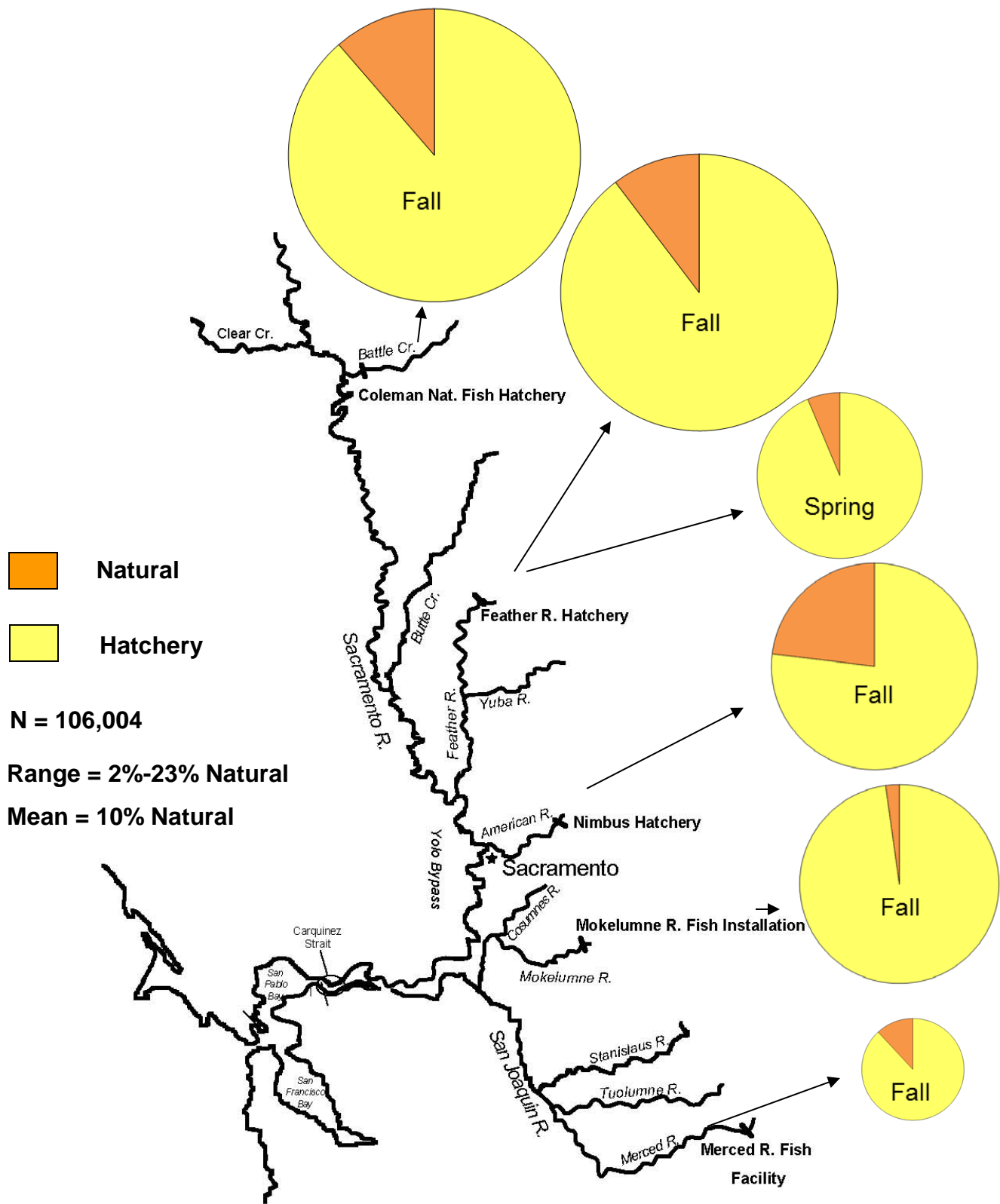
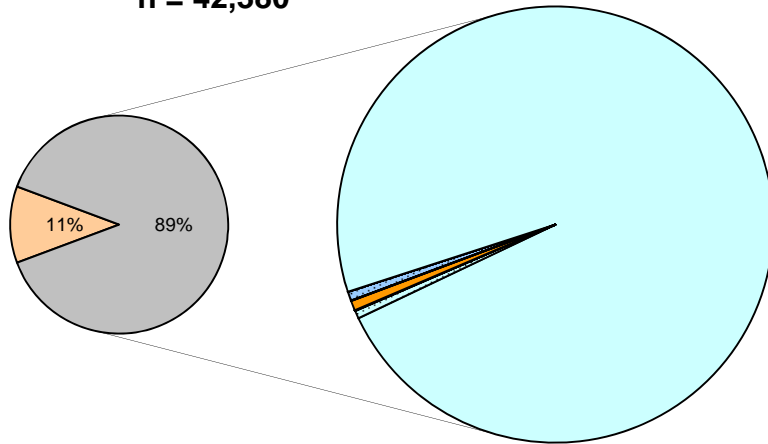
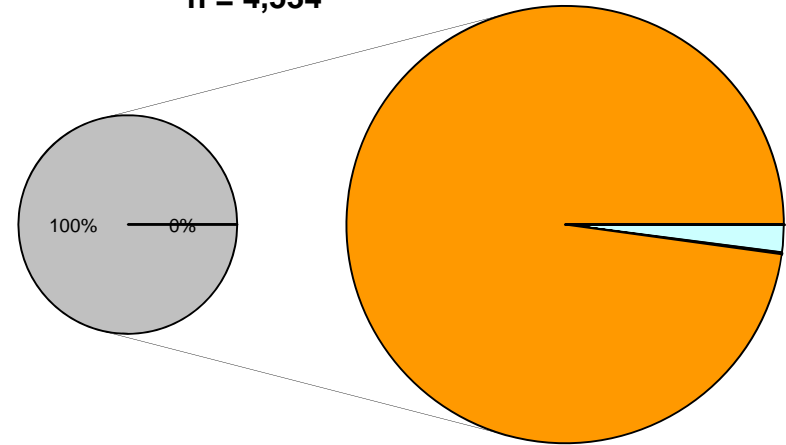


Figure 4. 2011 Chinook Salmon Hatchery Escapement, Hatchery and Natural Proportions.

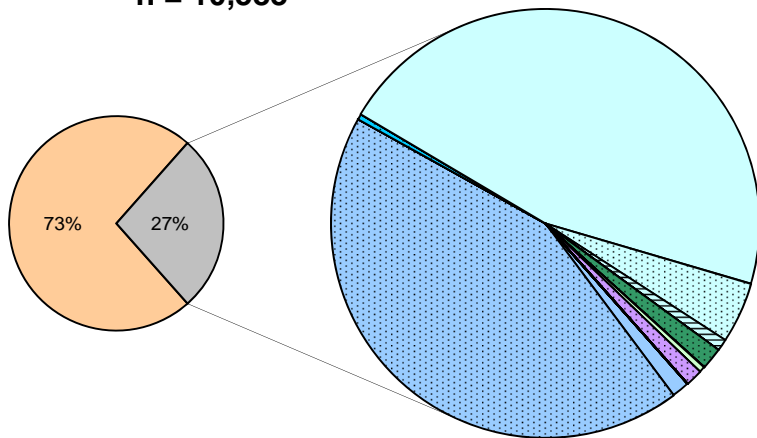
**Coleman National Fish Hatchery fall**  
n = 42,380



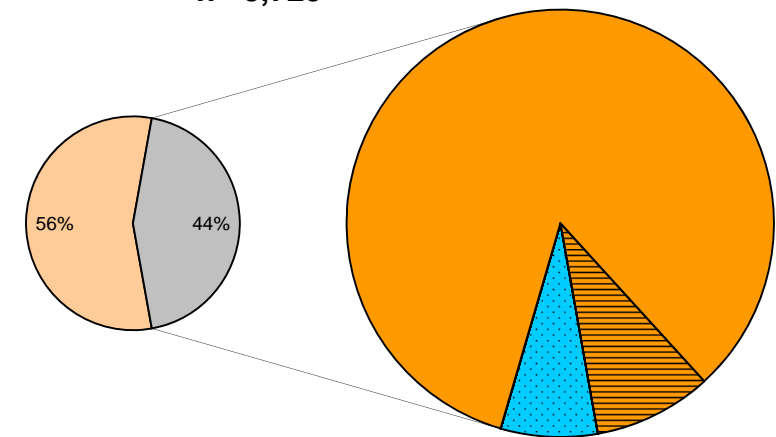
**Coleman National Fish Hatchery late-fall**  
n = 4,534



**Upper Sacramento River fall carcass**  
n = 10,583



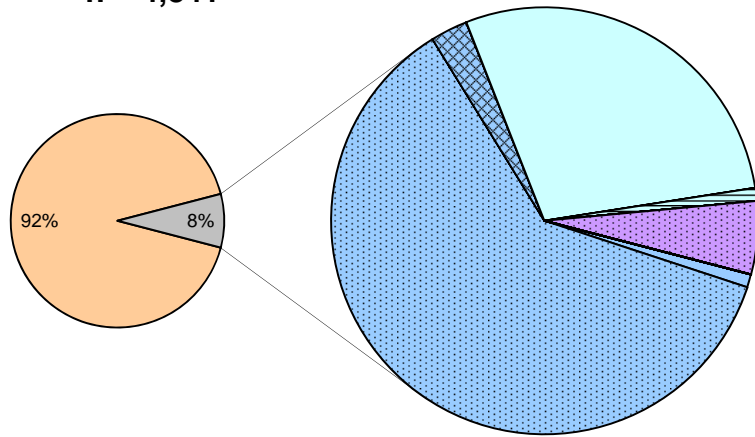
**Upper Sacramento River late-fall carcass**  
n = 3,725



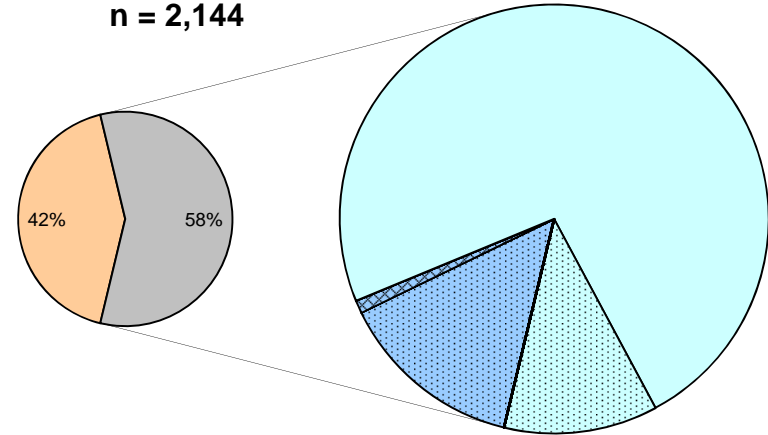
- Natural
  FRHFe
  FRHFn
  FRHFt
  FRHFnc
  NIMF
  NIMFn
  NIMFtn
  CFHFh
  CFHFfn
  CFHFfe
  MokF
  MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 5. Proportion of hatchery- and natural-origin fish in the Upper Sacramento River Basin.

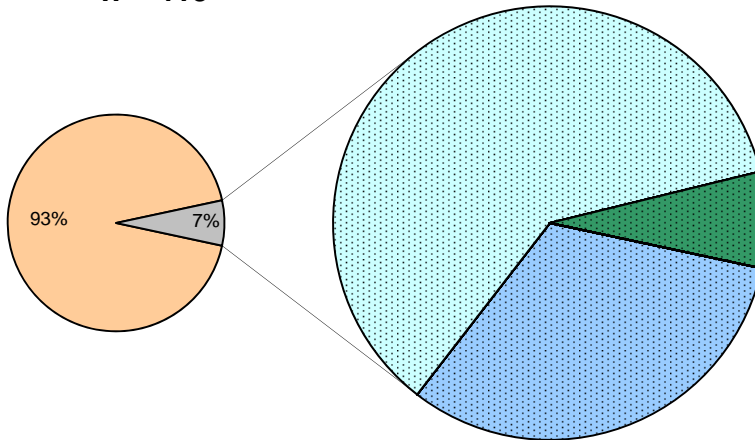
**Clear Creek fall carcass**  
n = 4,841



**Cottonwood Creek fall carcass**  
n = 2,144



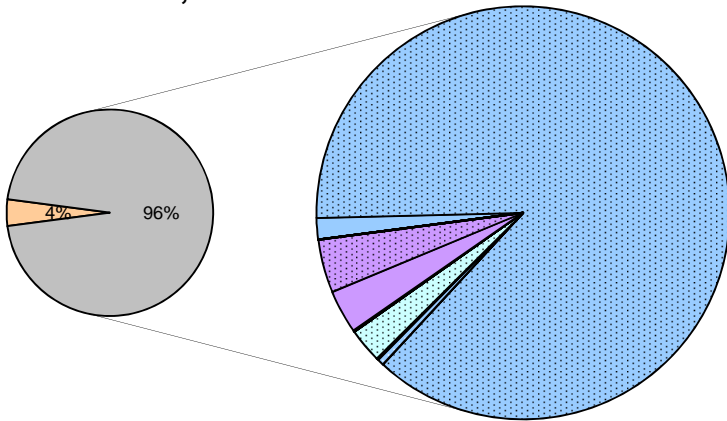
**Butte Creek fall carcass**  
n = 419



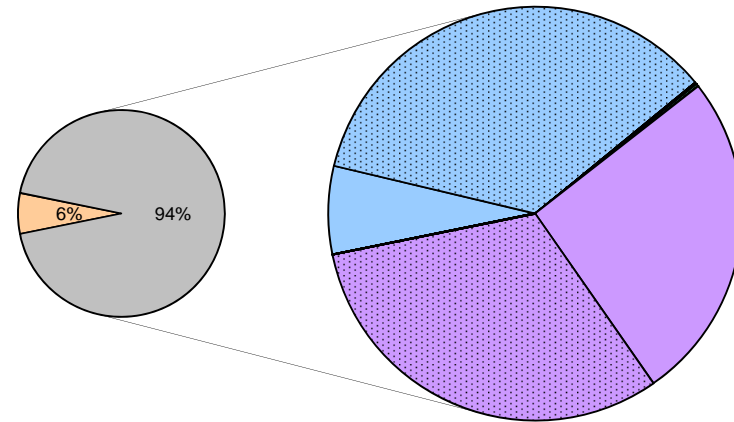
- Natural
  FRHFe
  FRHFn
  FRHFt
  FRHFnc
  NIMF
  NIMFn
  NIMFtn
  CFHFh
  CFHFfn
  CFHFe
  MokF
- MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 6. Proportion of hatchery- and natural-origin fish in Clear, Cottonwood, and Butte creeks.

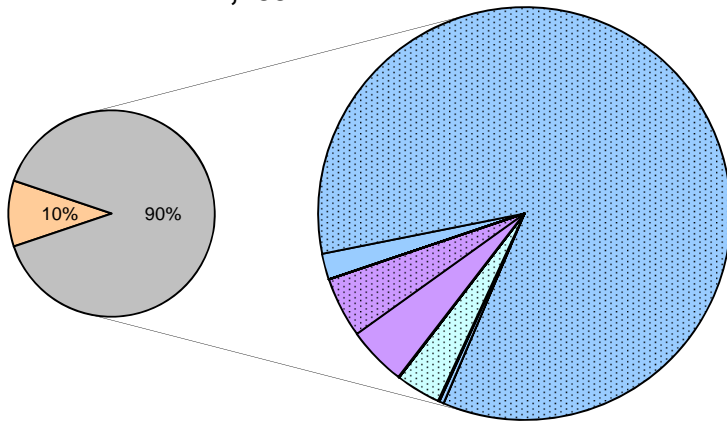
**Feather River Hatchery fall**  
n = 32,616



**Feather River Hatchery spring**  
n = 1,969



**Feather River spring-fall carcass**  
n = 47,289

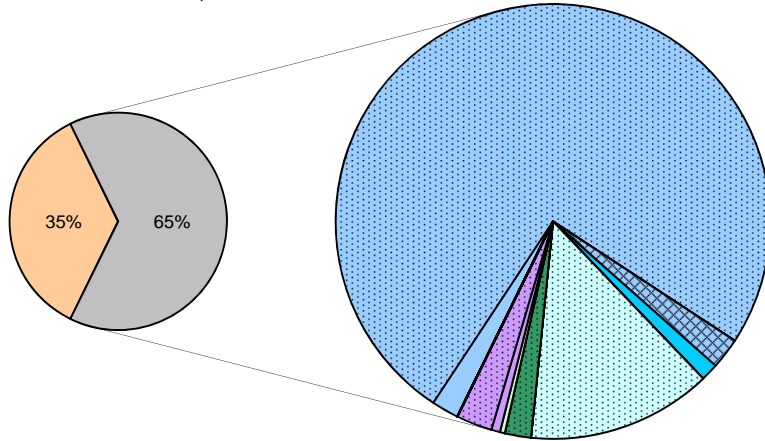


- Natural
  FRHFe
  FRHFfn
  FRHft
  FRHFnc
  NIMF
  NIMfn
  NIMftn
  CFHFh
  CFHFfn
  CFHFfe
  MokF
- MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

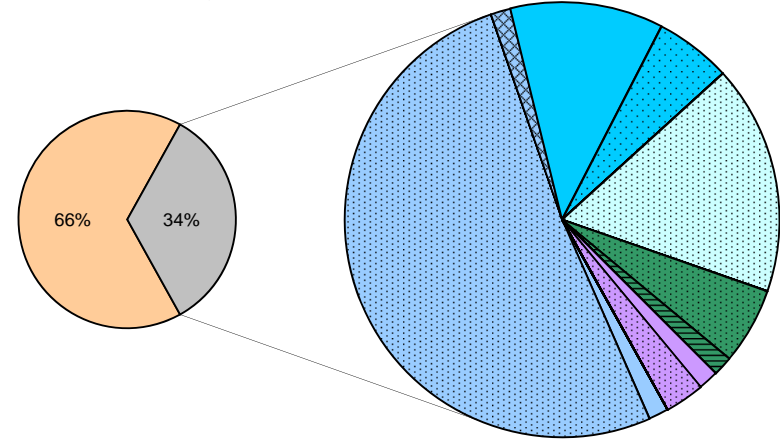
Figure 7. Proportion of hatchery- and natural-origin fish in the Feather River Basin.



**Yuba River carcass (above DPD)**  
n = 7,723



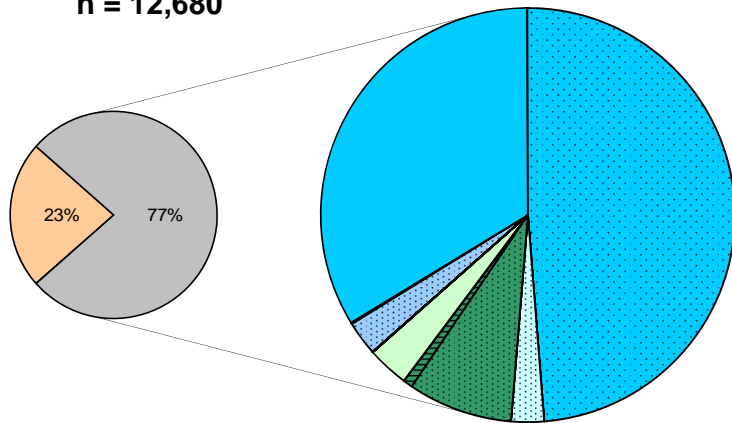
**Yuba River carcass (below DPD)**  
n = 1,398



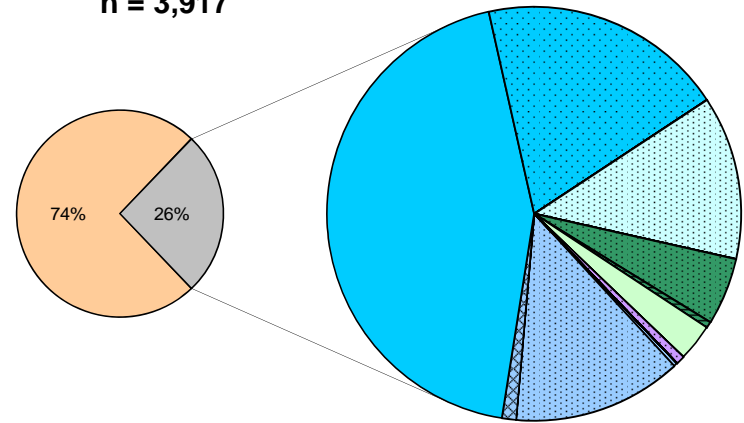
- Natural
  FRHFe
  FRHFn
  FRHFt
  FRHFnc
  NIMF
  NIMFn
  NIMFtn
  CFHFh
  CFHFfn
  CFHFfe
  MokF
- MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 8. Proportion of hatchery- and natural-origin fish in the Yuba River.

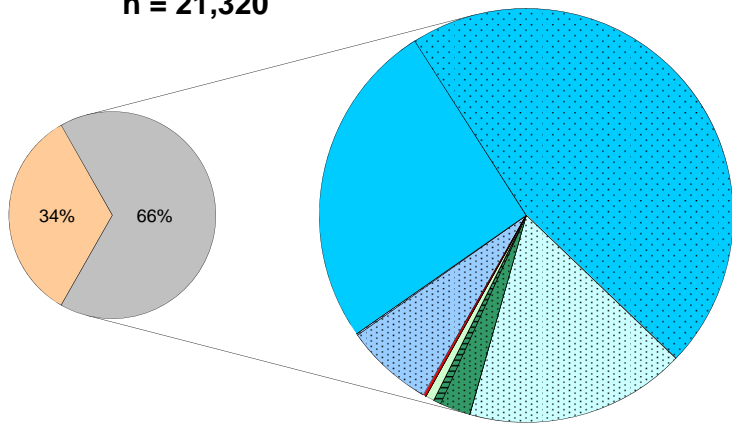
**Nimbus Hatchery fall**  
n = 12,680



**Nimbus Hatchery weir**  
n = 3,917



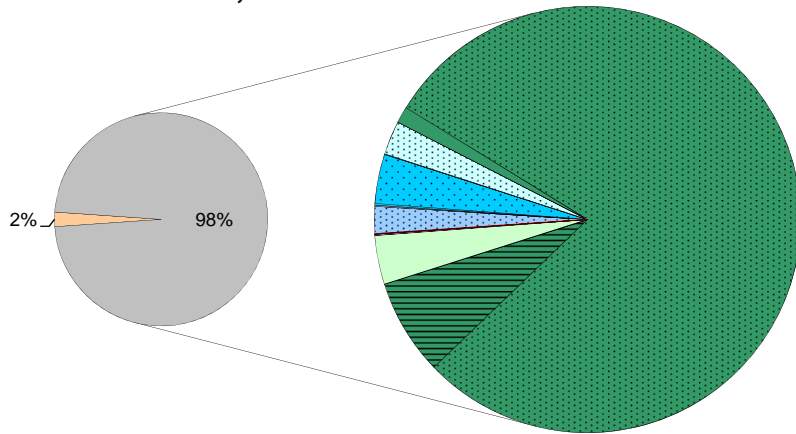
**American River fall carcass**  
n = 21,320



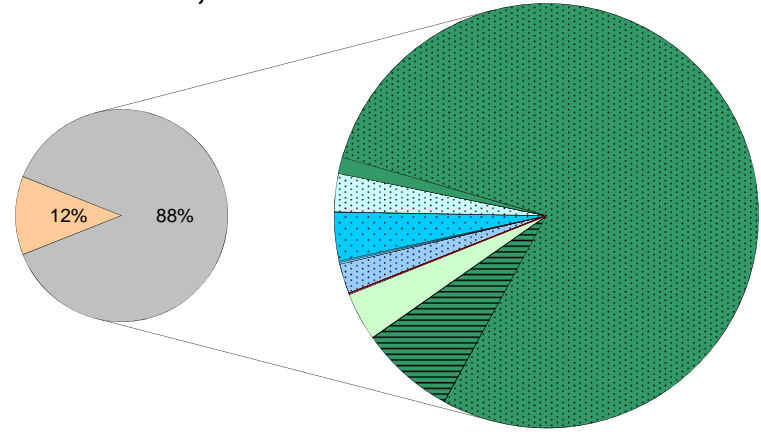
- Natural
  FRHFe
  FRHFn
  FRHFt
  FRHFnc
  NIMF
  NIMFn
  NIMFtn
  CFHFh
  CFHFfn
  CFHFfe
  MokF
  MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 9. Proportion of hatchery- and natural-origin fish in the American River Basin.

**Mokelumne Hatchery fall**  
n = 15,922



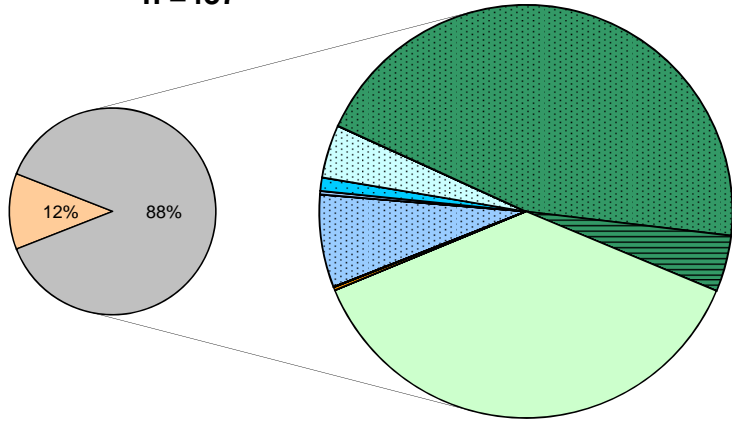
**Mokelumne River fall carcass**  
n = 2,667



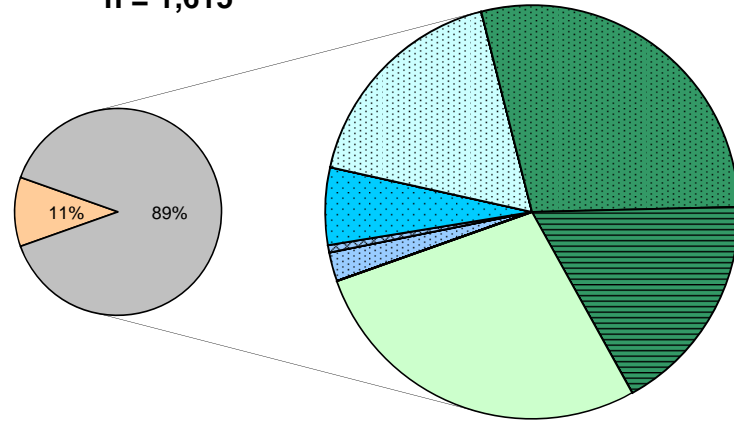
- Natural
  FRHFe
  FRHFn
  FRHFt
  FRHFnc
  NIMF
  NIMFn
  NIMFtn
  CFHFh
  CFHFfn
  CFHFfe
  MokF
  MokFn
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 10. Proportion of hatchery- and natural-origin fish in the Mokelumne River Basin.

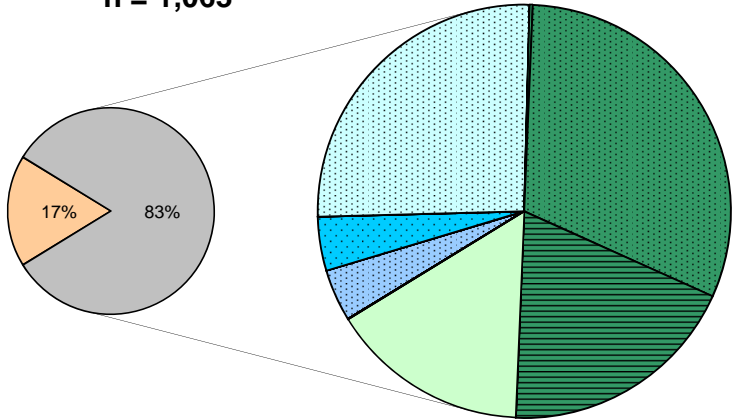
**Merced River Hatchery fall**  
n = 437



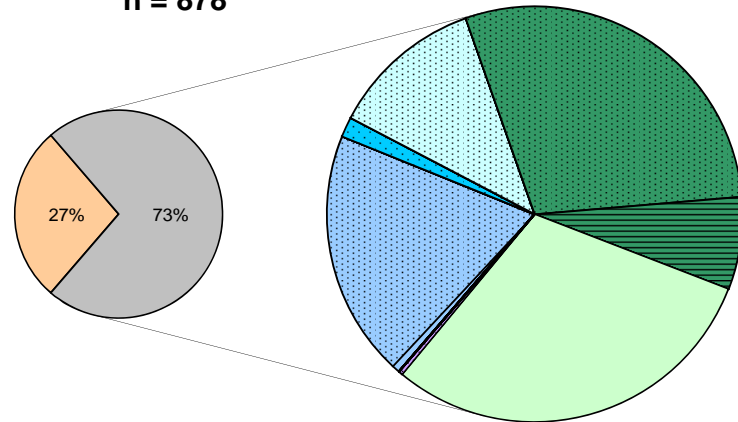
**Merced River fall carcass**  
n = 1,615



**Stanislaus River fall carcass**  
n = 1,063



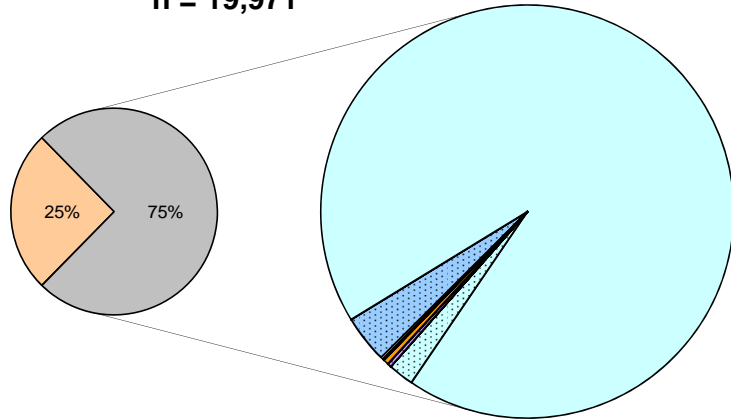
**Tuolumne River fall carcass**  
n = 878



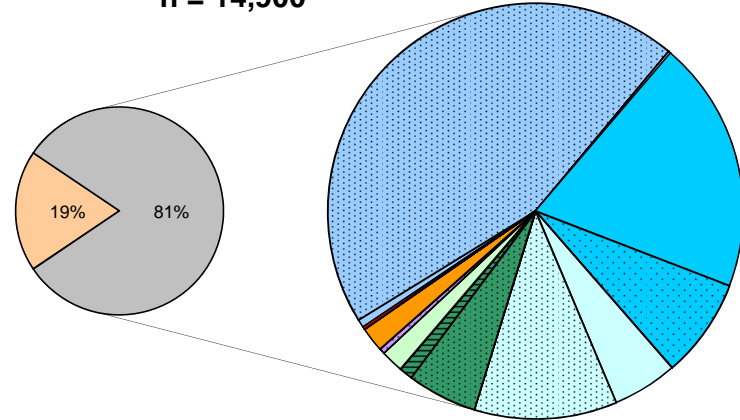
- Natural
  FRHFe
  FRHFn
  FRHFt
  FRHFnc
  NIMF
  NIMFn
  NIMFtn
  CFHFh
  CFHFn
  CFHFe
  MokF
  MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 11. Proportion of hatchery- and natural-origin fish in other San Joaquin River tributaries.

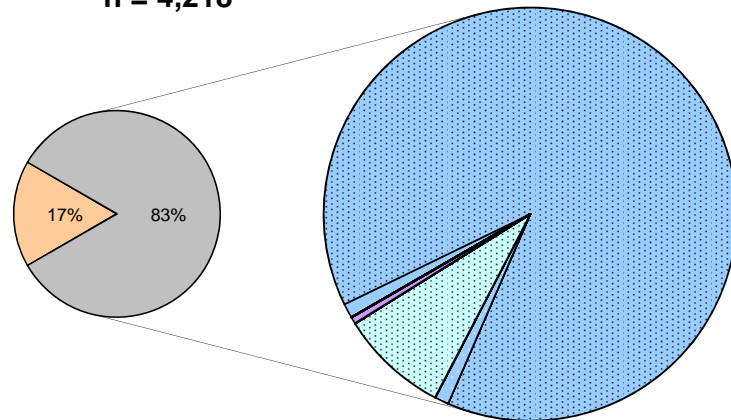
**Upper Sacramento River fall creel**  
n = 19,971



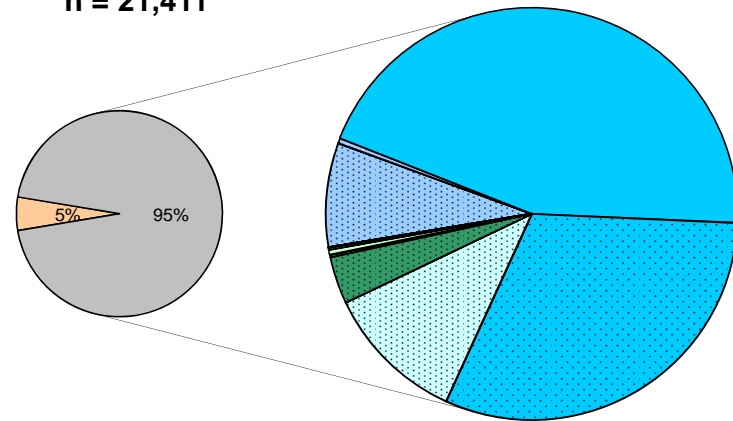
**Lower Sacramento River fall creel**  
n = 14,900



**Feather River fall creel**  
n = 4,218



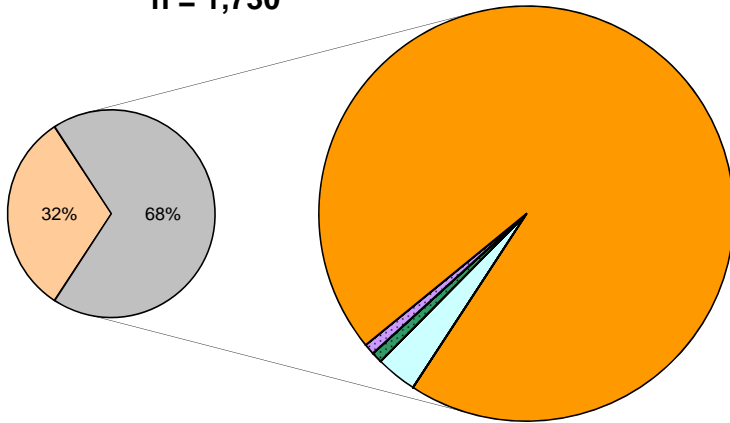
**American River fall creel**  
n = 21,411



- Natural
  FRHFe
  FRHFfn
  FRHFft
  FRHFfnc
  NIMF
  NIMFfn
  NIMFfn
  CFHFh
  CFHFfn
  CFHFfe
  MokF
- MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  YubSw
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 12. Proportion of hatchery- and natural-origin fish in fall creel surveys on Sacramento, American & Feather rivers.

Upper Sacramento River late-fall creel  
n = 1,730



- Natural
- FRHFe
- FRHFfn
- FRHFft
- FRHFnc
- NIMF
- NIMFfn
- NIMFtn
- CFHFh
- CFHFfn
- CFHFfe
- MokF
- MokFn
- MokFt
- MokFw
- MerF
- FRHS
- FRHSn
- FRHSt
- YubSw
- ButSw
- CFHLh
- CFHLe
- nonCV

Figure 13. Proportion of hatchery- and natural-origin fish in late-fall creel survey on Upper Sacramento River.

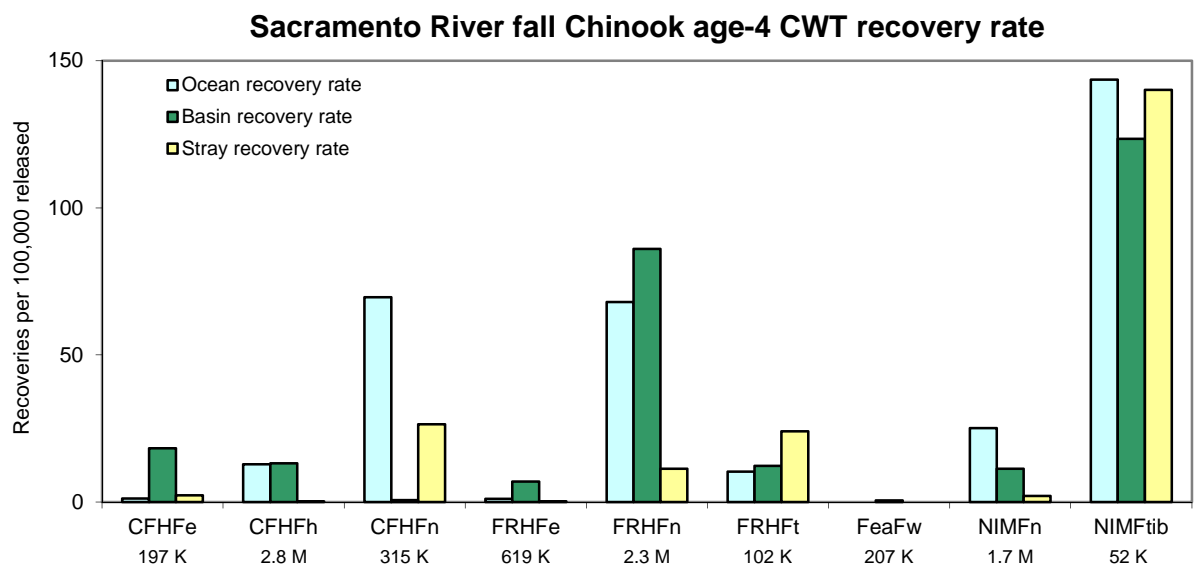
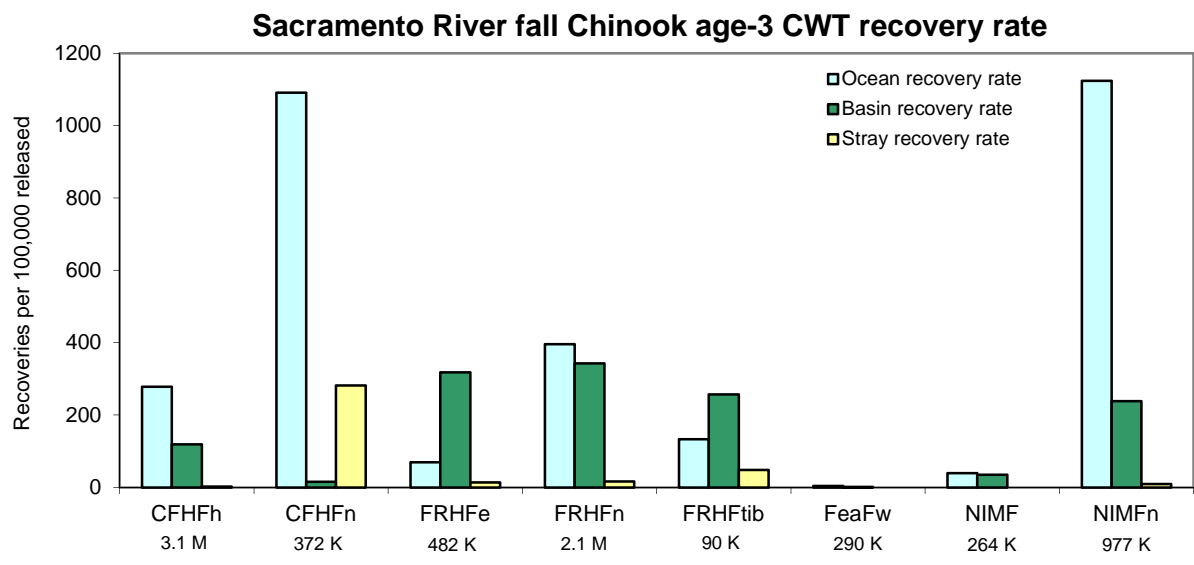
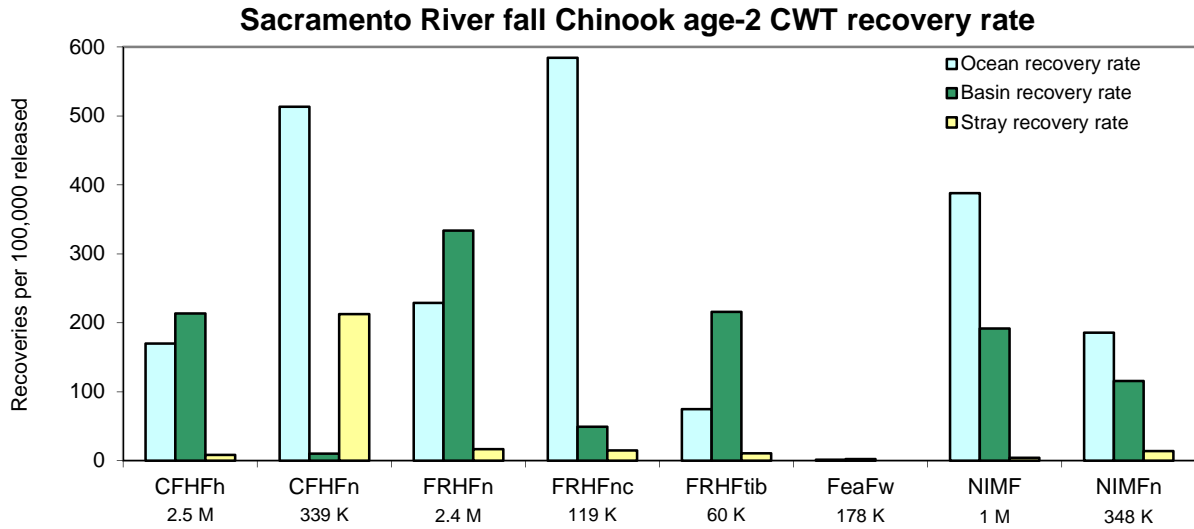


Figure 14. 2011 recovery rates for Sacramento fall Chinook CWT releases by age.

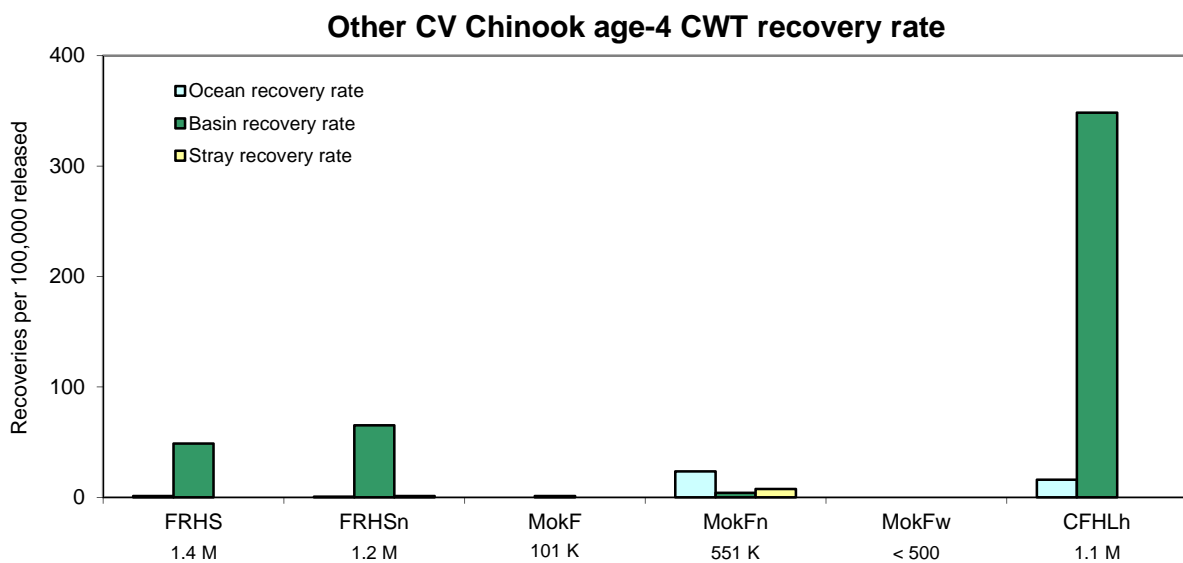
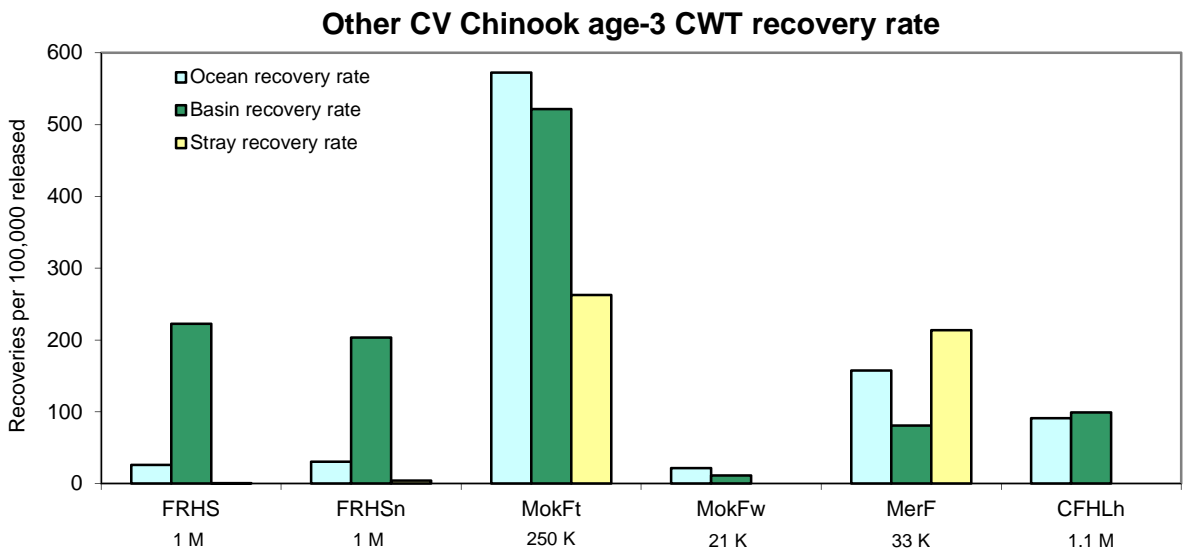
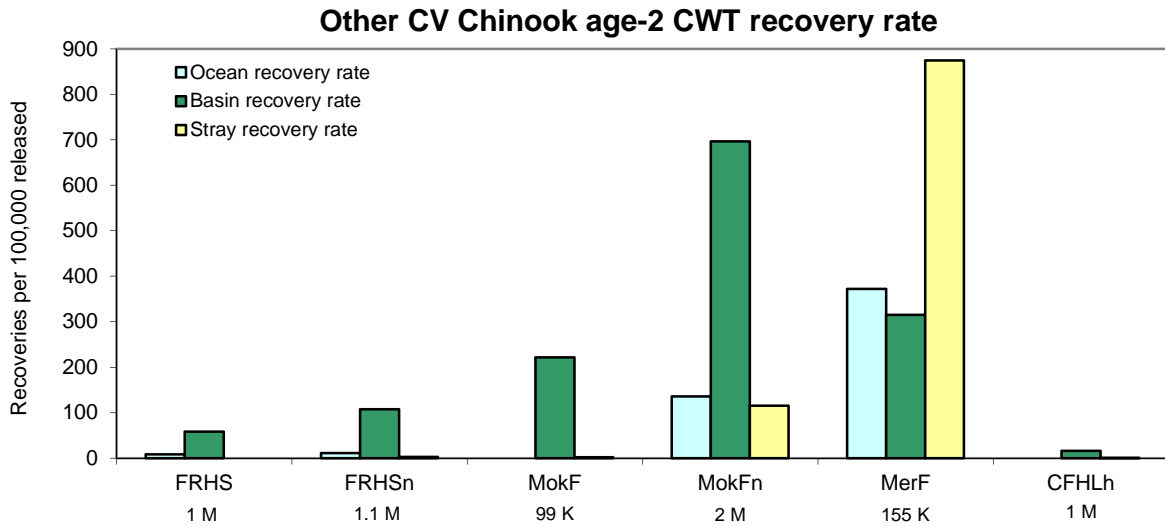
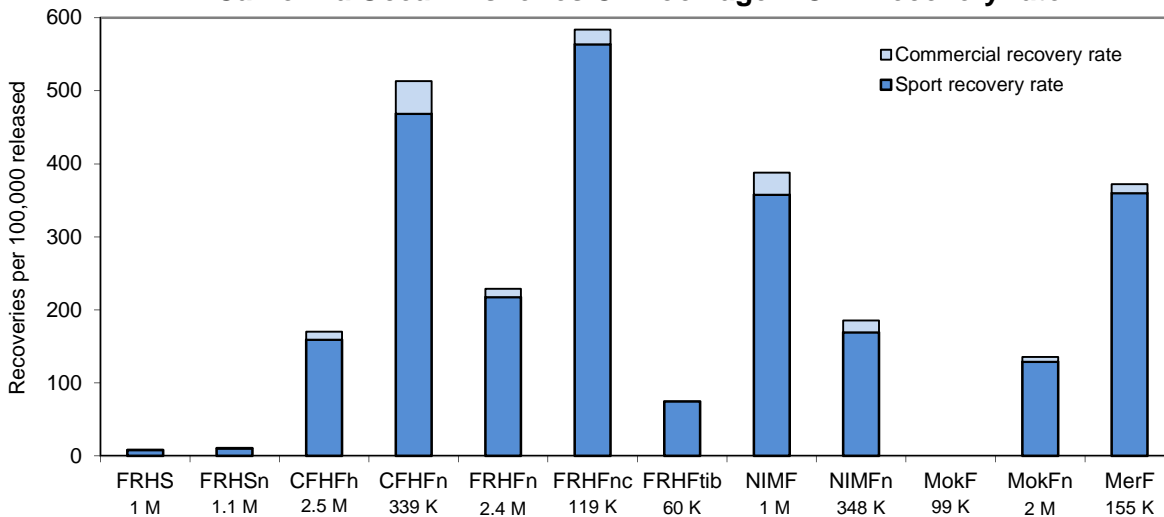


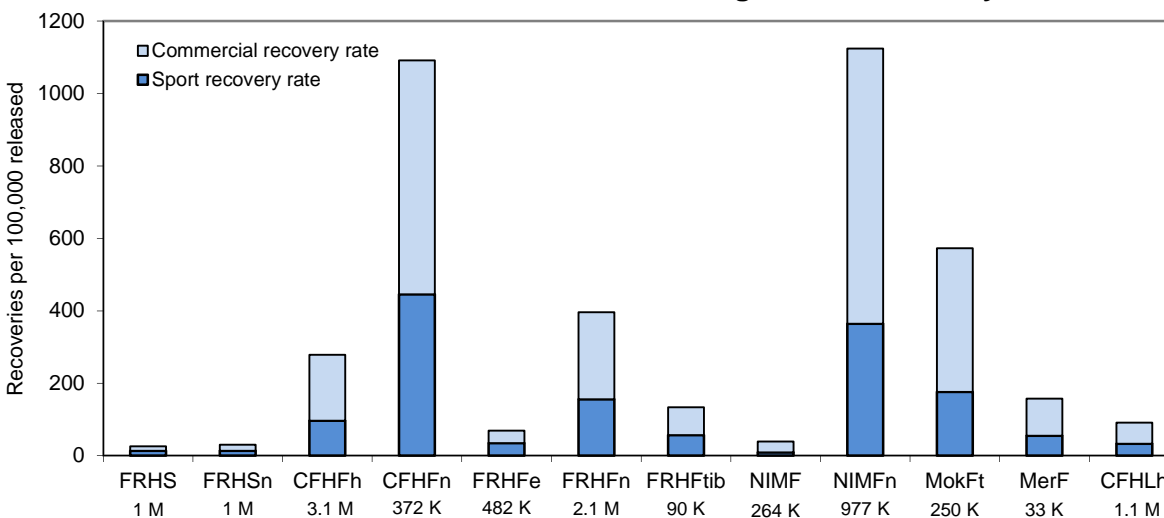
Figure 15. 2011 recovery rates for other CV Chinook CWT releases by age.



### California Ocean Fisheries Chinook age-2 CWT recovery rate



### California Ocean Fisheries Chinook age-3 CWT recovery rate



### California Ocean Fisheries Chinook age-4 CWT recovery rate

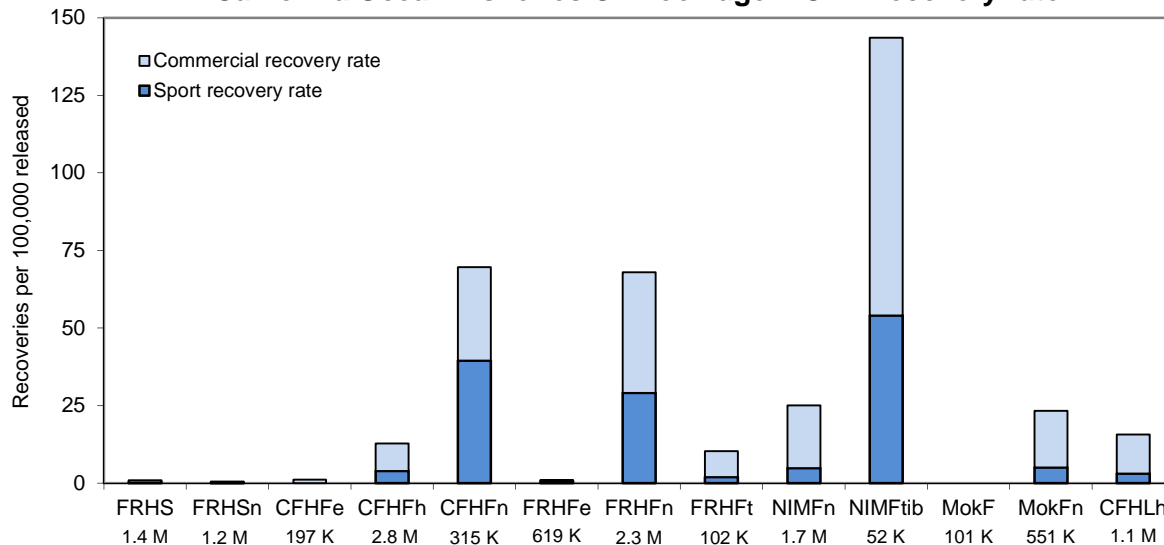
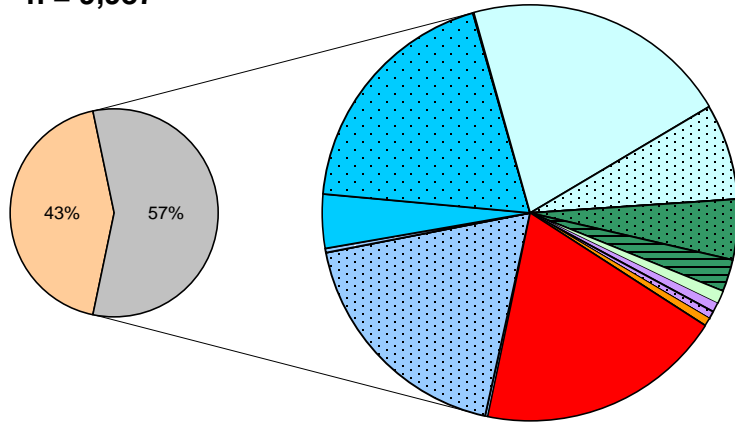
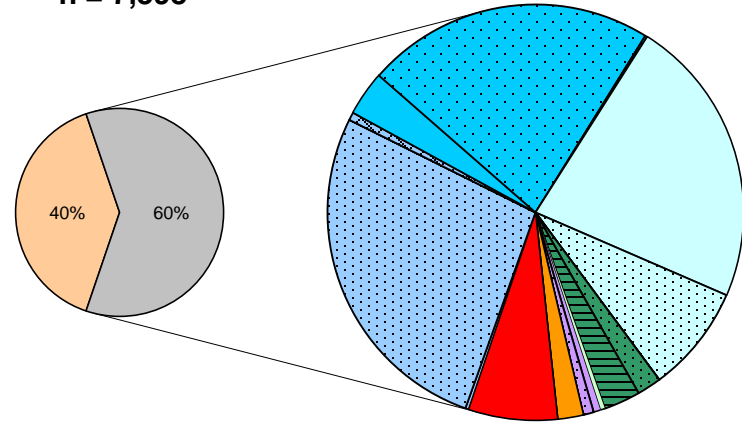


Figure 16. 2011 CV Chinook recovery rates in ocean sport and commercial fisheries.

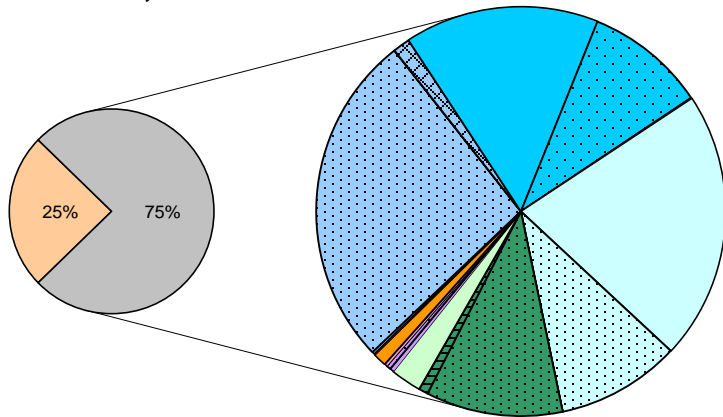
**Eureka Sport**  
n = 9,987



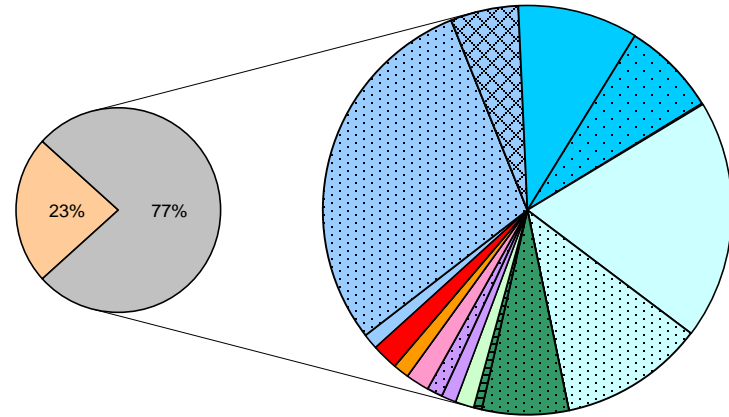
**Fort Bragg Sport**  
n = 7,398



**San Francisco Sport**  
n = 19,734



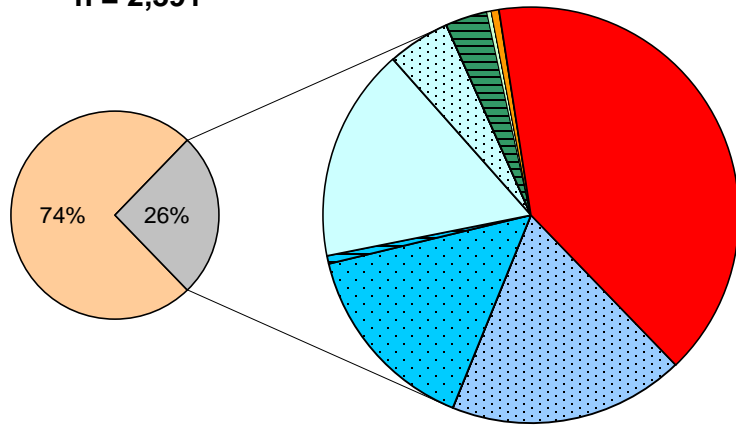
**Monterey Sport**  
n = 12,703



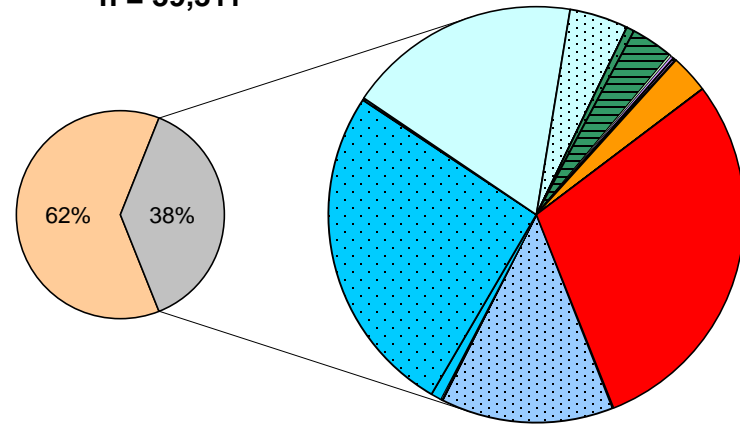
- Natural
  FRHFe
  FRHFn
  FRHft
  FRHFnc
  NIMF
  NIMFn
  NIMFtib
  CFHFh
  CFHFfn
  CFHFfe
  MokF
  MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  SacW
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 17. Proportion of hatchery- and natural-origin salmon in the 2011 California ocean sport fishery.

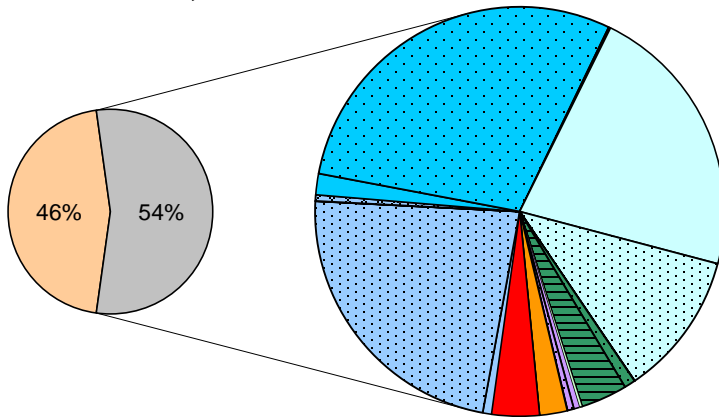
**Eureka Commercial**  
n = 2,391



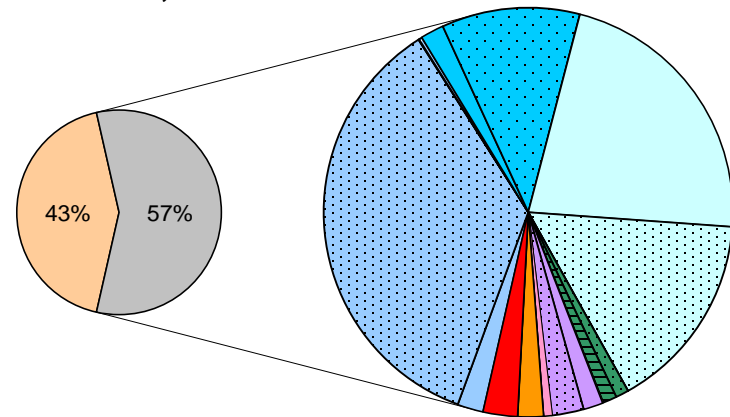
**Fort Bragg Commercial**  
n = 39,311



**San Francisco Commercial**  
n = 21,912



**Monterey Commercial**  
n = 6,414



- Natural
  FRHFe
  FRHFn
  FRH Ft
  FRHFnc
  NIMF
  NIMFn
  NIMFtib
  CFHFh
  CFHFfn
  CFHFe
  MokF
  MokFn
  MokFt
  MokFw
  MerF
  FRHS
  FRHSn
  FRHSt
  SacW
  ButSw
  CFHLh
  CFHLe
  nonCV

Figure 18. Proportion of hatchery- and natural-origin salmon in the 2011 California ocean commercial fishery.

**Appendix 1a. Alternative 2011 CWT recovery and stray rates (recoveries per 100,000 CWTs released) of CNFH and FRH releases.<sup>a/</sup>**

**Age 2 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location										CV CWT <sub>samp</sub> totals			Ocean CWT <sub>samp</sub>	Recovery rate per 100,000 released				CV Stray Proportion
				Bat Cr	Up Sac	Nat crks <sup>b/</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	Basin		Stray	CV total	Ocean		
CFHFh	2009	Fall	2,543,157	5,390	36	212	1				1			5,390	250	5,640	4,321	212	10	222	170	0.04
CFHFh	2009	Fall	339,179	35		35	243	85	215	92	25	28		35	722	757	1,741	10	213	223	513	0.95
CFHLh	2010	Late	992,047	157							1	1		157	2	159		16	0.2	16		0.01
FRHFh	2009	Fall	2,367,209	43	97	67	7,492	403	76	73	14	20		7,492	794	8,286	5,421	317	34	350	229	0.10
FRHFnc	2009	Fall	118,879			6	58		1	2	8			58	18	76	694	49	15	64	584	0.23
FRHFtib	2009	Fall	60,104				130		1	5	1			130	7	136	45	216	11	227	75	0.05
FRHS	2009	Spr	1,026,954				578	16						578	16	594	87	56	2	58	8	0.03
FRHSn	2009	Spr	1,058,635			18	1,033	104	6	4				1,033	132	1,164	113	98	12	110	11	0.11

**Age 3 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location										CV CWT <sub>samp</sub> totals			Ocean CWT <sub>samp</sub>	Recovery rate per 100,000 released				CV Stray Proportion
				Bat Cr	Up Sac	Nat crks <sup>b/</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	Basin		Stray	CV total	Ocean		
CFHFh	2008	Fall	3,128,111	3,461	267	60								3,461	327	3,788	8,716	111	10	121	279	0.09
CFHFh	2008	Fall	371,685	21	36	8	351	97	472	23	45	51		21	1,084	1,105	4,056	6	292	297	1,091	0.98
CFHLh	2009	Late	1,115,378	1,023	81									1,023	81	1,104	1,015	92	7	99	91	0.07
FRHFe	2008	Fall	481,853	2	36	4	1,429	104	12	8		4		1,429	170	1,598	334	296	35	332	69	0.11
FRHFh	2008	Fall	2,061,211	20	109	34	6,626	435	135	17	1	24		6,626	775	7,401	8,161	321	38	359	396	0.10
FRHFtib	2008	Fall	89,859	4		17	111	120	11	11				111	163	274	120	123	182	305	133	0.60
FRHS	2008	Spr	1,015,717				2,237	23			1			2,237	24	2,261	265	220	2.4	223	26	0.01
FRHSn	2008	Spr	1,005,727		24	4	2,006	39	1	10		2		2,006	80	2,086	308	199	8	207	31	0.04

**Age 4 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location										CV CWT <sub>samp</sub> totals			Ocean CWT <sub>samp</sub>	Recovery rate per 100,000 released				CV Stray Proportion
				Bat Cr	Up Sac	Nat crks <sup>b/</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	Basin		Stray	CV total	Ocean		
CFHFe	2007	Fall	196,993	12	24	4	1							12	29	41	2	6	15	21	1	0.71
CFHFh	2007	Fall	2,801,459	343	24	6								343	30	373	359	12	1.1	13	13	0.08
CFHFh	2007	Fall	314,681	2		1	9	16	53	3				2	83	85	219	1	26	27	70	0.98
CFHLh	2008	Late	1,072,854	2,932	808									2,932	808	3,740	168	273	75	349	16	0.22
FRHFe	2007	Fall	619,085				43		1					43	1	44	6	7	0.2	7	1	0.02
FRHFh	2007	Fall	2,347,396	2	109	9	1,858	162	138	4		2		1,858	426	2,284	1,595	79	18	97	68	0.19
FRHFt	2007	Fall	101,712				13		24					13	24	37	10	12	24	36	10	0.66
FRHS	2007	Spr	1,378,941				672							672		672	12	49		49	1	0.00
FRHSn	2007	Spr	1,242,480		12		811				1			811	13	824	7	65	1	66	1	0.02

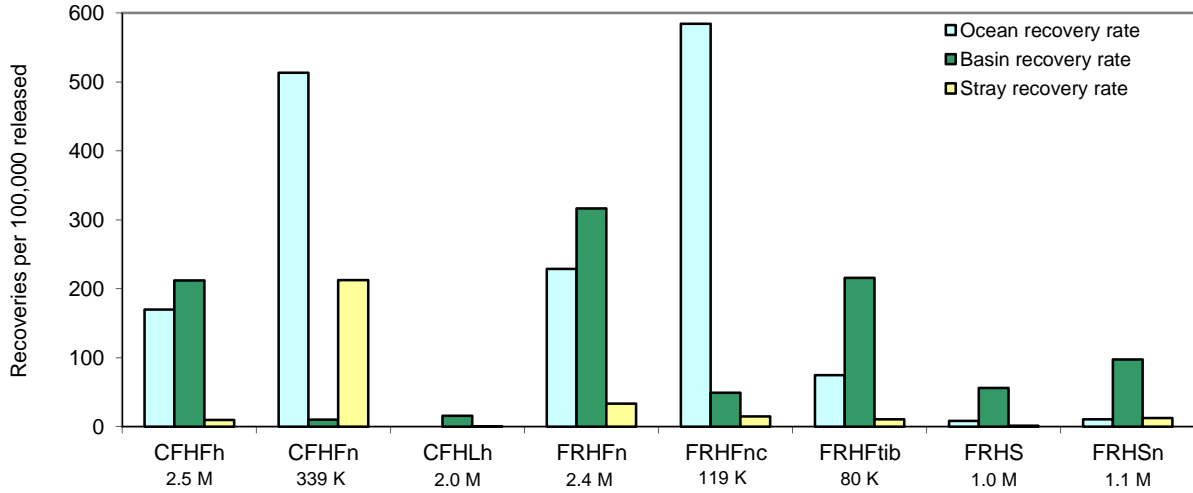
**Age 5 CV recoveries**

Release group	Brood year	Run type	# CWT tagged	Central Valley CWT <sub>samp</sub> recoveries by location										CV CWT <sub>samp</sub> totals			Ocean CWT <sub>samp</sub>	Recovery rate per 100,000 released				CV Stray Proportion
				Bat Cr	Up Sac	Nat crks <sup>b/</sup>	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	Basin		Stray	CV total	Ocean		
CFHLe	2007	Late	299,292	1	141									1	141	142		0	47	48		0.99
CFHLh	2007	Late	732,952	481	445									481	445	926	5	66	61	126	0.6	0.48

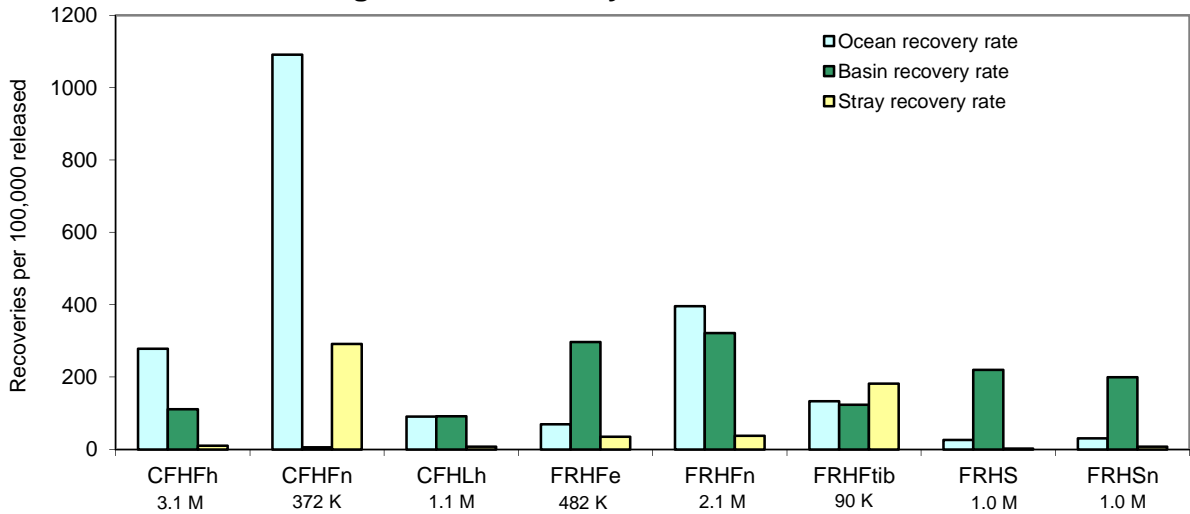
a/ CNFH and FRH releases recovered in upper Sacramento River and Yuba River, respectively, considered as stray recoveries.

b/ Natural creeks include Clear Creek, Cottonwood Creek, Butte Creek and Mill Creek.

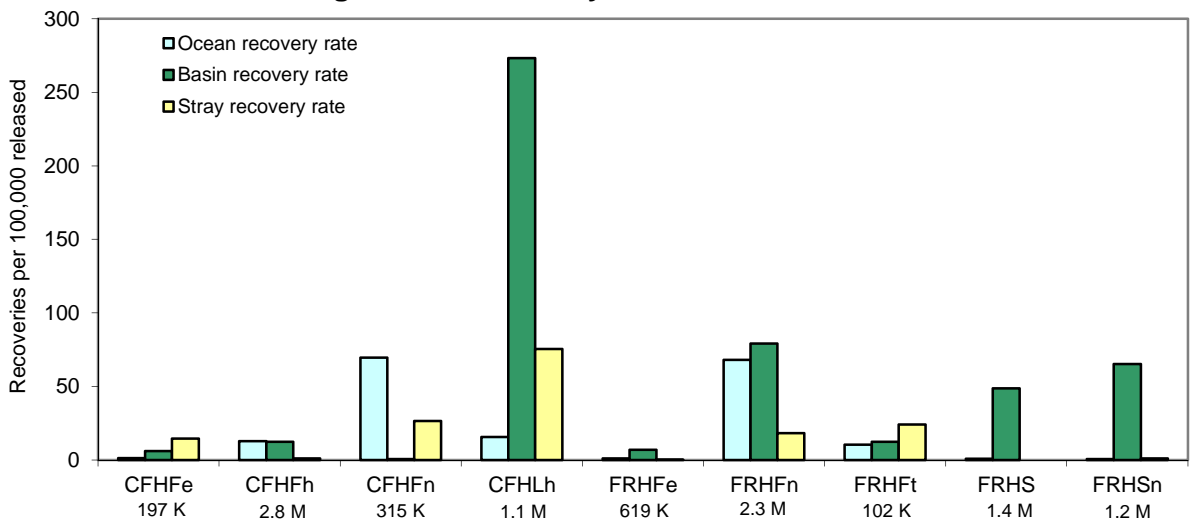
### Alternative age-2 CWT recovery rate for CNFH and FRH releases



### Alternative age-3 CWT recovery rate for CNFH and FRH releases



### Alternative age-4 CWT recovery rate for CNFH and FRH releases



Appendix 1b. Graphs of alternative 2011 recovery rates for CNFH and FRH releases.