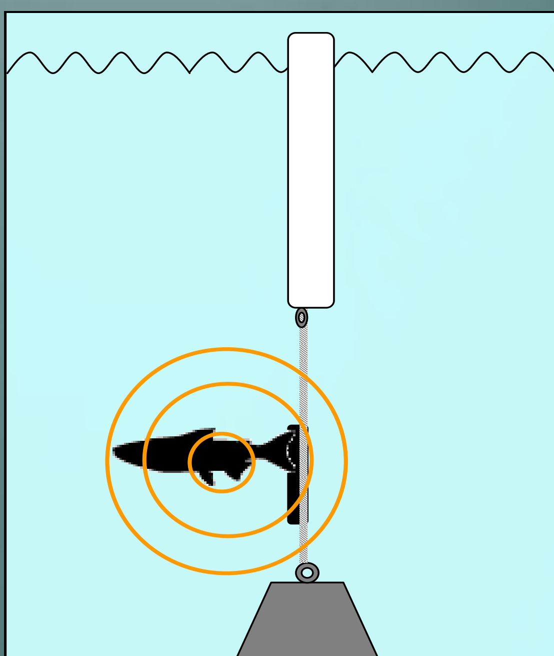
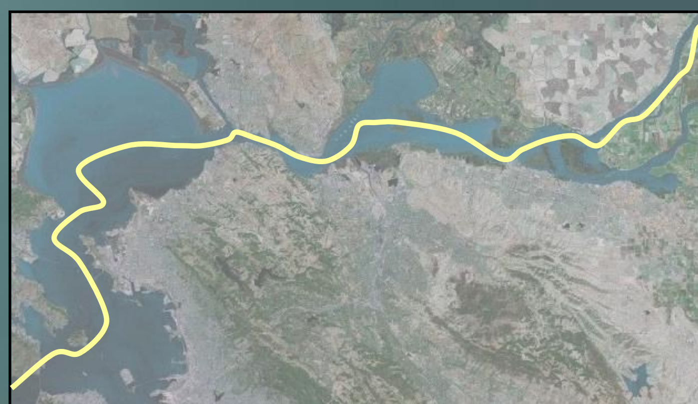
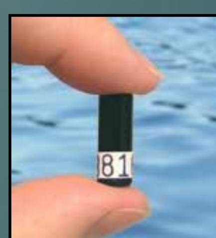
Juvenile Salmonid Outmigration and Distribution in the San Francisco Estuary: 2006-2008

Interim Draft Report







Peter Klimley, Denise Tu, Alex Hearn Department of Wildlife, Fish & Conservation Biology, University of California, Davis
William Brostoff, Peter LaCivita, Allison Bremner, San Francisco District of the United States Army Corps of Engineers
Tom Keegan, ECORP Consulting, Inc.

EXECUTIVE SUMMARY

To minimize potential impacts from dredging activities on salmonids listed under the Endangered Species Act (ESA), the Long Term Management Strategy (LTMS) established environmental work windows for the placement of dredged material in the San Francisco Bay Region. These windows were based on the assumed spatial and temporal absence of Chinook salmon and steelhead. During these established windows (June through November in most areas), any take of listed salmonids that occurs during dredging operations is authorized through a biological opinion resulting from ESA consultation between the National Marine Fisheries Service (NMFS) and the US Environmental Protection Agency and the US Army Corps of Engineers (USACE). Projects proposing to conduct dredging activities outside the LTMS work windows would need to conduct individual consultations with NMFS to address potential impacts to listed salmonids. The need to fine-tune the duration of the windows and/or the locations of restrictions was documented by the regulators and the regulated community. Issues in need of resolution or investigation were proposed in the LTMS Framework Document (LFR 2004), and provided the impetus for this quantitative investigation of juvenile salmonid (smolt) outmigration behavior.

The study's objectives were to estimate the time spent by out-migrating (migrating) salmonid smolts in areas of the bay affected by dredging and disposal of dredged material. The specific technical objectives of the study included:

1) Estimate transit times through the San Francisco Estuary
2) Measure residence times in locations of interest
3) Identify migratory pathways

The first two years of a proposed three-year study were carried out by USACE with oversight by the LTMS Science and Data Gaps Work Group (Science Group) from late summer of 2006 to summer of 2008. USACE coordinated its effort with members of the California Fish Tracking Consortium to maximize the efficiency of data collection, analysis, and interpretation. The 2006-2007 study season served as a pilot study, to determine the suitability of equipment and logistics, as well as the feasibility of addressing study questions. Improvements in field methods to more accurately record salmonid movements throughout the San Francisco Bay were reflected in subsequent years, including the 2007-2008 study year.

Juvenile late-fall run Chinook salmon and steelhead smolts were released into the lower Sacramento River, near the Rio Vista Bridge. USACE released 49 Chinook salmon and 49 steelhead in January-February 2007 and 50 of each species in March 2008. Fish released by two other studies (CALFED and USFWS) were also used in parts of the analysis. Individuals tagged with coded ultrasonic beacons were detected by an estuary-wide array of ultrasonic receivers. When a tagged fish swam with range of a receiver, its identification number and the associated date and time was recorded. Most of the receivers were placed at "choke points" and arranged in curtain arrays with overlapping ranges, making it possible to characterize both large scale movements through the estuary and migration trends related to water depth. Transit times were calculated between Rio Vista (the USACE release point) and the Richmond-San Rafael Bridge, as well as from the Richmond-San Rafael Bridge to the Golden Gate Bridge. Migratory pathway trends were analyzed using data acquired from the Richmond-San Rafael Bridge array and its associated cross sectional depth profile.

This study passively detected tagged salmonids to describe large-scale movements in and around dredge activity sites within the estuary. Based on tag-detection records for 2007-2008, the mean travel time between Rio Vista and Golden Gate bridges was 10.2 days for Chinook salmon and 8.5 days for steelhead. The median residence time at SF-10, a designated in-bay placement site for dredged material in San Pablo Bay, was 6.5 min for Chinook salmon and steelhead. Both species tended to use mid-channel waters around the Richmond-San Rafael Bridge rather than the shallow flats on either side of the channel. Each species exhibited a positive linear relationship, up to 11.3 m, between depth and frequency of detection. The analyses from both study years show a substantial proportion of both species utilized deeper channels and/or passed at least one dredged material placement site, within the range of the ultrasonic receivers. The interim analysis suggests that adjustments to this study are necessary to better obtain quantitative confirmation of the study objectives. Recommendations for the third year of study included:

1) A larger number of tagged fish
2) A release location farther upstream
3) Spacing receivers based on current range tests
4) New receiver locations to better cover dredged material placement sites.

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INTRODUCTION

Effects of Dredging on Migratory Salmonid Smolts

This report is in response to a need identified in the *Framework for Assessment of Potential Effects of Dredging on Sensitive Fish Species in San Francisco Bay* (hereafter referred to as "the Framework") (LFR 2004) for information on the distribution and migration of out-migrating (migrating) salmon and steelhead in the San Francisco Estuary. The Framework is a work plan developed to address uncertainties associated with permissible work periods, biological consultation, and permitting associated with dredging in the San Francisco Bay region. The Framework identifies issues of concern to the environmental regulatory agencies based on interviews with agency personnel.

The NOAA/NMFS Biological Opinion dated September 19, 1998 identified the following potential impacts to Chinook salmon and steelhead from dredging activities covered under the proposed Long Term Management Strategy for dredged material in the San Francisco Bay region:

> "… (1) redistribution of pollutants and/or release of contaminants during dredging and disposal, which may result in chronic or acute toxicity impacts to salmon and steelhead, particularly those that rear for prolonged periods in affected areas; (2) burial of bottom-dwelling organisms, which may reduce feeding opportunities for rearing juvenile salmon or juvenile/adult steelhead; (3) resuspension of sediment particles and resulting turbidity during dredging and dredged material disposal operations, which may interfere with visual foraging, abrade gill tissues, or interfere with migration. Increased turbidity may also interfere with primary productivity by reducing rates of photosynthesis; and (4) changes in the native sediment characteristics near disposal sites and shifts in the sediment budget and/or dynamics within embayments, which may alter available food supply for rearing salmon and steelhead juveniles."

NMFS established that dredging may have minimal affects on species like Chinook salmon and steelhead. NMFS concluded that turbidity levels produced by dredging are likely low enough in concentration and short enough in duration to avoid significant deleterious effects on fish health, foraging, or migration. NMFS also concluded that bay waters contained toxins in concentrations below chronic toxicity levels even with the pre-LTMS dredging regime. Dredging in areas with depths less than 20 feet may pose a risk of entraining smaller salmon and steelhead, thus LTMS mitigation measures were deemed necessary to minimize this risk. New dredging projects potentially reduce available shallow water rearing habitat, but beneficial re-use projects could mitigate this effect. NMFS emphasized that beneficial re-use projects which create tidal wetland habitat may provide an important food supply and rearing area for juvenile salmonids. Based on the incorporation of work windows into the LTMS program, NMFS estimated any incidental take would be minimal. California Department of Fish and Game (CDFG) concurred that dredging activities were not likely to jeopardize this species (LFR, 2004).

Through consultation with NMFS under section 7 of the ESA, the LTMS established a set of time periods, termed “work windows”, during which dredging could be carried out while avoiding a negative impact on the health and survival of listed anadromous salmonid species. Work windows were chosen based on the migration timing of smolts within the estuary. The windows within which dredging and disposal may occur are defined on a regional basis as contiguous periods within a calendar year. This study will provide information on the migration rates and residence time of salmon smolts within the estuary to better define work windows associated with the San Francisco Bay estuary.

The impetus for this study is the *Framework for Assessment of Potential Effects of Dredging on Sensitive Fish Species in San Francisco Bay*, 2004. The Framework identified work with Chinook salmon and steelhead as a high priority (see pp 65-66), which was subsequently supported by the LTMS Windows Science Group. This study will provide the foundation for more comprehensive future studies to identify migratory pathways and the species-specific timing of migrating salmonids, particularly in relation to areas and potential exposure time to dredging operations.

LTMS Tracking Goals and Objectives

The purpose of the first year of the study (2006-2007) was to determine if the proposed field methods and analyses would provide results sufficient to address the project’s technical objectives. The second year of study (2007-2008) focused on fine-tuning the methodology used to monitor salmonid movements in the estuary. Overall, this study’s purpose is to create an objective and scientific process to estimate migration rates and pathways of smolts in the San Francisco Estuary. Data collection (underwater listening devices) was focused at certain areas:

- Key dredged material placement sites (Alcatraz and SF10)
- Areas where dredging occurs or might occur (channel and marinas)
- Bridge arrays to allow detection of fish passing through particular river reaches

This information can be used in future studies to determine the potential time spent by migrating smolts in areas in which dredged materials have been removed or deposited. The technical goals include:

1) Estimate transit times through the San Francisco Estuary
2) Measure residence times in areas of interest
3) Identify trends in migratory pathways.

BACKGROUND

The LTMS collaborated with the CALFED-funded research group to decide upon tagging techniques, monitor mooring construction, placement, and conduct range testing to provide for uniformity and data comparison. The CALFED is made up of the University of California, Davis and the National Marine Fisheries Service (NMFS-NOAA). This group conducted studies on late-fall run Chinook salmon and steelhead smolts as they migrated through the Sacramento River, the Delta and the San Francisco estuary. Pertinent information from CALFED and USACE previous studies, in the Sacramento Delta and San Francisco estuary, are presented below.

Late-Fall Run Chinook Salmon and Steelhead

Chinook salmon and steelhead were formerly abundant and widely distributed throughout rivers and streams of California's Central Valley. Chinook salmon occur in four distinct subpopulations, differentiated by timing of the spawning run, timing of the spawn itself, former spawning habitat, and the emergence, freshwater residency and ocean entry of juveniles (Fisher, 1994). The names of these Chinook salmon subpopulations are drawn from the seasons when most adults return to freshwater to spawn: winter, spring, fall, and late-fall (Stone, 1874; Fry, 1961). Of the four salmon runs, the fall run is the most abundant, and heavily supplemented by hatchery production (Fisher, 1994). The late-fall and spring runs exhibit two types of juvenile life-history strategies: ocean-type and stream-type. The ocean-type juveniles spend relatively little time in streams and enter the ocean at a small size [80 mm fork length (FL)]. In contrast, the stream-type juveniles spend several months to over a year in streams and enter the ocean at a large size (120-180 mm FL). These larger stream-type smolts are also called yearlings. Only a winter run of Central Valley steelhead is currently recognized, although in the past there may have been a summer run of steelhead (Needham *et al.*, 1941). Freshwater residency and age at ocean entry also vary between steelhead populations. Some enter the ocean as smaller sub-yearlings and others as larger yearlings or older.

Coded-Wire Tagging

Survival and migration rates of Chinook salmon were estimated previously in the Sacramento Delta and San Francisco estuary using a mark-recapture method. Since 1972, coded wire tags (CWT) were placed in 40 million individual salmonids. Point-to-point migration rates can be determined from the release and recovery of fish carrying CWTs. For example, late-fall run CWT smolts released at Battle Creek travel to the Chipps Island recovery site (the eastern end of the San Francisco Estuary) in as little as five days or as long as 150 days, and averaged 22 days (n = 835, USFWS during 1998-2003, www.delta.dfg.ca.gov/usfws/maps/index.htm) over 479 km. Total average time from Battle Creek to the Golden Gate (a distance of 547.6 km) was estimated to be 62 days by combining the average transit time of 22 days from Battle Creek to the base of the estuary and a 40 day average transit time through the estuary to the Golden Gate. Another focus of these studies has been tests of juvenile release strategies aimed at determining the inland factors most responsible for out-migrant survival (Bailey, 2000). For example, a total of 854,349 CWT late-fall Chinook salmon juveniles were released from Coleman National Fish

Hatchery on Battle Creek with an estimated 19,875 of these juveniles moving past Knights Landing (based on 159 marked fish caught then divided by an estimated trap efficiency of 0.008). Over this distance (a little over 300 km), the estimated survival rate was 2.3%.

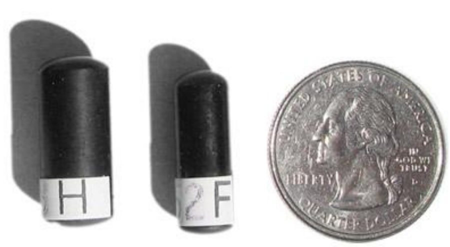
While Chinook salmon are well studied, very little is known about the reach-specific survival and migration patterns of juvenile steelhead. Yearlings were collected from the rotary screw traps at Knights Landing predominantly in January (10%), February (5%), and March (70%). Steelhead were caught with mid-water trawls at Chipps Island from 1994-1997 between October and June, with peak catch in February and March. The modal length of the individuals was 220 mm FL, with a range of 160 to 300 mm FL. Prior to 1997, it was not possible to distinguish between hatchery and wild produced steelhead, because hatchery steelhead were never marked. Since 1998, the adipose fins of most hatchery produced steelhead have been clipped to identify their source (Brandes *et al.*, 2000).

Although some data exist on migration of juvenile Chinook salmon in Northern California, only one published paper addresses migration through the San Francisco estuary. MacFarlane and Norton (2002) examined the physiological development of juvenile Chinook salmon collected at different sites during their migration through the San Francisco Estuary and early residence in the coastal waters of central California. Migration rates and residence times for Chinook salmon can be calculated using the mean ages at which they entered the estuary and at which they exited through the Golden Gate. These calculations show that juvenile Chinook salmon averaged a residence time of 40 days. This translates to an average migratory rate of 1.6 km/day through the 65 km long stretch of estuary, from the confluence of the Sacramento and San Joaquin rivers to the Golden Gate.

Ultrasonic Telemetry

The feasibility of tagging and detecting individual fish has increased with technological developments. Small, uniquely coded tags can be affixed to individual fish, and by using tag-detecting receivers at fixed locations, the movements of each fish can now be recorded (Klimley *et al.*, 1998). Small, individually coded tags (Fig. 1) can be implanted within the peritoneal (body) cavity of a juvenile salmonid without altering their swimming behavior. Also, low cost and power efficient electronic receivers (Fig. 2) are now available, which can be moored in a body of water to record the passage of juveniles (Fig. 3).

Fig. 1 Comparison of the VEMCO V9 (left) and V7 (right) transmitter tags.



An ultrasonic tag produces periodic pulse bursts at a high frequency signal of 30-100 kHz. The V7 and V9 tags developed by VEMCO Ltd. of Halifax, Canada, use piezoelectric transducers that are 7 and 9 mm in diameter, respectively. These are resonant when energized by ultrasonic signals of 69 kHz. The V7 tags were implanted in Chinook salmon and the V9 in steelhead. These pulse bursts are detected by a hydrophone and receiver. The tags are commonly being implanted into the peritoneum of juvenile salmon and used in tracking studies worldwide.

Several studies examined the effect of radio or ultrasonic tags implanted within the body on swimming performance, growth, and vulnerability to predation of juvenile salmonids. Tag mass to fish mass ratio is the best indicator of tag effects. Implanted tags weighing less than 8% of the fish's weight did not produce any significant difference in swimming performance of tagged fish from those having an operation but not carrying a tag, and those individuals that did not undergo an operation (Moore *et al*., 1990; Peake *et al*., 1997; Adams *et al*., 1998; Brown *et al*., 1999; Robertson *et al*., 2003; Anglea *et al*., 2004; Lacroix *et al*., 2004).

Fig. 2. Automated, tag-detecting receiver (VEMCO VR2).

Three studies used surgically implanted tags less than 6% of the fish's weight and found no effect on growth rates compared to controls. Another study, that surgically implanted tags, showed a reduction in the growth rates of tagged fish compared to non-tagged controls with an implanted tag weighing 8.5% of the fish's mass. Two studies provided results that indicate intraperitoneal tag implantation was superior to gastric implantation, while two additional studies that tested predator avoidance had contrasting results. Juvenile Chinook salmon carrying tags that constituted 4.6-10.4% of the fish's mass and had a 31 cm long trailing antenna were eaten in significantly greater numbers than controls. This result was most likely caused by the drag of the antenna impeding their movement. In contrast, predation on juvenile Chinook salmon carrying tags that were 4.2% of the fish's weight, and having no antenna, did not differ significantly from controls. The optimum attachment is an intraperitoneal implantation of tags that do not possess antennae with a weight less than 8% of the fish's mass (Moore *et al*., 1990; Peake *et al*., 1997; Adams *et al*., 1998; Brown *et al*., 1999; Robertson *et al*., 2003; Anglea *et al*., 2004; Lacroix *et al*., 2004). In the current study, a cut-off weight was imposed for each species based on the weight of the tag (V7 = 1.6 g, V9 = 4.7 g), so only Chinook salmon greater than 32 g, and steelhead greater than 98 g were tagged.

Automated Tag-Detecting Receivers

In the last three years, arrays of ultrasonic tag-detecting receivers were situated within many rivers along the western coast of North America. VEMCO Ltd. of Halifax, Canada produces a receiver (Fig. 2) widely used by the scientific community. The VR2 and VR2W are underwater receivers that continuously detect unique, digitally coded transmitter signals. The VR2 and VR2W receivers operate on a single-channel and possess omnidirectional hydrophones that record time, date and identity code of animals fitted with acoustic transmitters. The receiver may remain in place up to 15 months before the battery life expires (normally interrogated after 3 months). The unit can record up to 65,000 coded tags and 300,000 detections per deployment and files can be downloaded in the field. The receivers must be deployed below the water surface – this may be done by several methods depending on the conditions, but throughout the Sacramento river system several arrays are composed of lead weights, the receiver and a small buoy, which are attached to a steel cable running from a point onshore. Other systems involve suspending weighted cables from bridges and markers, or deploying receivers attached to acoustic releases where cables might interfere with shipping.

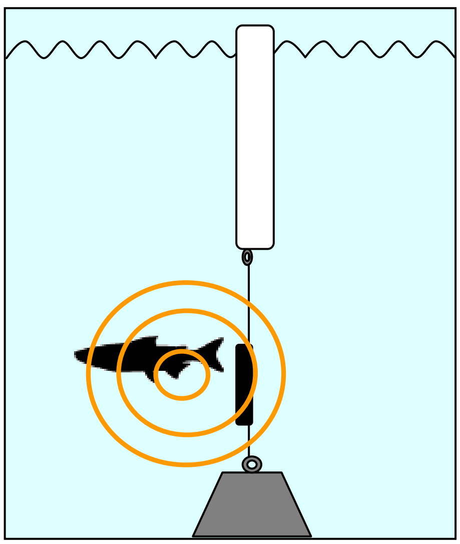


Fig. 3. Surface float mooring configuration with receiver that detects signal from fish's ultrasonic transmitter tag.

Fish swimming or resting within range of the receiver may produce multiple detections. Multiple detections can help estimate residence time within the area. Data interpretation is complex when a single hit from a particular fish at one receiver requires judgment. Following are examples which could result in a single hit:

1) a fish transiting within range of the receiver where its path is so short to only transmit one signal within range of the receiver,
2) a fish swimming or being carried by currents so fast such that it is in range for only one transmission cycle,
3) a fish transiting within range of the receiver but noise (e.g., boat traffic) obscures it,
4) reflections from solid objects (e.g., bridge traffic) changing the nature of the acoustic signature to resemble the code of another fish, and
5) false detection.

An example in which single-hit data can be confidently used include locations at the Golden Gate Bridge array of receivers where currents are often fast enough to credibly accept situations such as #2. An example in which single-hit data should be discounted is a situation in which a tag was detected at the same time by two receivers separated from each other by a great distance.

Receivers Maintained by LTMS

Receivers maintained by the LTMS were deployed at specific sites to provide information pertinent to the research objectives. The receiver sites included those between Carquinez Strait and the Golden Gate (Figure 4). The LTMS provided funds to establish a pair of linear arrays across the Golden Gate Bridge (maintained by NMFS). Refer to Appendix 1 for receiver positions and coordinates.

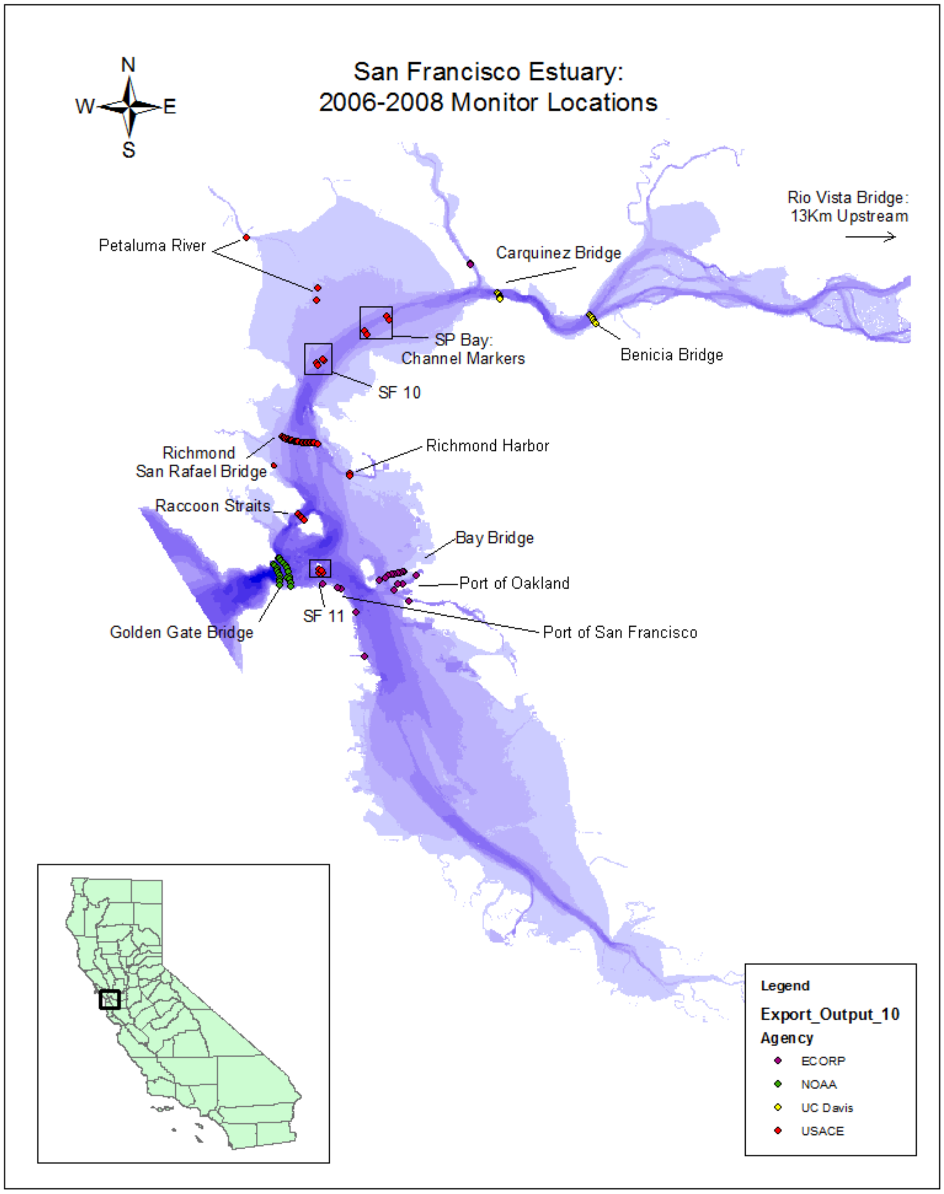


Fig. 4: Location of receivers (including USACE, ECORP, CALFED units) in the San Francisco Estuary.

Twenty one receivers (RSRB stations A-U) were placed in a linear fashion adjacent to the south side of the Richmond-San Rafael Bridge. The analysis of detection records will help determine swim preference in either shipping channels or the shallower water on either side of the shipping channels. Two receivers were placed on either side of San Pablo Bay Channel Markers, Buoys 9 and 10 in the 2006-2007, and two additional receivers were placed by Buoys 7 and 8 in 2007-2008 (Fig. 4). Buoys 9 and 10 are located approximately 5.5 miles southwest of the mouth of Carquinez Strait. The channel markers delineate the edges of the Pinole Shoal Shipping Channel and receivers will characterize fish movement in deeper dredged channels.

San Pablo Bay's major dredged material placement site, SF-10, is rectangular (approximately 914 m x 713 m) with the long axis on a roughly northeast to southwest alignment. In 2006-2007 two VR2 receivers were deployed at this placement site along the western boundary at either end of the site. One was placed 150 meters from the northwest corner; the second 300 meters southwest of the first. As the VR2s have a detection range of about 200 meters, only partial coverage of the site was achieved. In 2007-2008 four VR2 receivers were placed near the corners of the placement site. These extra receivers better characterize SF-10, but due to the receiver detection ranges this configuration also constituted only partial coverage. Detection records from these receivers were used to determine the percentage of total smolts that swam in the vicinity of SF-10.

One receiver in 2006-2007 was placed near the in-bay dredged material placement site near Alcatraz Island (SF-11). In 2007-2008, three more receivers were added to characterize a larger portion of this dredged material placement site. The records from these receivers were grouped as for SF-10.

One receiver was placed near the railroad bridge in the lower Petaluma River. The river channel is roughly 200 meters wide and only one unit was necessary to ensure the fish were detected as they passed on either side of the river. Analysis of residence time at this receiver will determine how salmonids temporarily use the Petaluma River. Four receivers were placed in a line at Raccoon Strait from Tiburon to Angel Island. Tag detections from this array would provide insight on whether tagged fish prefer to transit through Raccoon Strait or swim south past Angel Island and west to the Golden Gate while en route to the ocean. For both study years, two VR2 acoustic receivers were placed at the entrance to Richmond Harbor. One receiver was placed on the north side of the channel at Point Richmond; the other receiver was placed on the south side at the end of the training wall.

Receivers Maintained by Other Agencies

Detections from receivers installed and maintained by other research groups were also analyzed. These collaborators are part of the California Fish Tracking Consortium, who deployed receivers in their area of interest, and/or tagged their own set of fish (see Appendix 1).

ECORP Consulting, Inc. was hired by Bay Planning Coalition (BPC) to deploy 22 receivers at various sites within the San Francisco Estuary/Delta. The receiver locations included:

1) Mare Island – Pier 22 and Pier 23,
2) Paradise Cay (2006-2007 only),

3) East Span of the San Francisco-Oakland Bridge,
4) Port of Oakland,
5) Port of San Francisco, and
6) San Joaquin River.

Hanson Environmental, Inc., contracted by the sand mining industry, installed receivers in order to track salmonids in areas of sand mining activity. Two VEMCO VR2 receivers were deployed in the channel near Chipps Island, two receivers were deployed in Carquinez Strait near Dillon Point, and one receiver was placed at the downstream mouth of Montezuma Slough.

The CALFED team established an array of seventy-four tag-detecting receivers from the upper Sacramento River, within the delta, and to the Carquinez Bridge to determine whether or not juvenile salmonids migrate on a direct path through the delta or stray in other directions. Data collected at receivers maintained by the CALFED project from Rio Vista to Carquinez Bridge were used for this analysis. NMFS maintained the receivers deployed at the Golden Gate Bridge.

The San Francisco Bay Estuary is wider, deeper, and more heavily influenced by tidal flow than areas such as the Delta and Sacramento River. There is a deep channel, exceeding 20 m in depth, traversing down the center of Suisun and San Pablo bays. Five cross-channel arrays of receivers were placed within the estuary to detect tagged fish during their seaward migration. These arrays created the greatest coverage with the least amount of receivers. The first and second arrays consisted of receivers attached directly to the Benicia-Martinez and Carquinez bridges by UC Davis. The third cross-channel array was deployed by USACE at the Richmond-San Rafael Bridge. The BPC deployed a fourth array of receivers across the East Span of the San Francisco-Oakland Bay Bridge. The last linear array was located just east of the Golden Gate Bridge, formed as two semi-circular arcs of receivers, and maintained by NMFS.

Receiver Deployment

During the 2006-2007 field season, no acoustic releases were used. Due to the loss of several VR2 listening stations, twenty Teledyne Benthos 875-A acoustic releases were purchased for use in the 2007-2008 field season. Along with the 875-As, a single DS-875-AO Deck Unit was acquired. The Deck Unit and transducer are used to set up the 875-As and to activate the release mechanism when retrieving the individual units.

The VR2s are directly attached to the 875-A (fig. 5), and fitted with weights and floats for deployment. These units were deployed at stations where surface floatation was believed to present a high risk of loss or damage to the listening station. The stations were: Buoys 7, 8, 9, and 10; Richmond Bridge K, L, P, and Q; SF 10 North, East, South, and West; Alcatraz North, East, South, and West; and Raccoon Strait 1, 2, 3, and 4.

Fig. 5 Mooring configuration with acoustic release used at sites throughout the study area in 2007-8

All units were deployed during the month of March 2008. In April 2008, a unit was returned to the Corps. Examination of the unit revealed excessive corrosion of the fasteners securing the unit to the anchor, which allowed the unit to float free from the anchor. The unit was refitted with corrosion resistant fittings and redeployed. All other stations with VR2/875-A units were visited and the units that were retrieved were refitted and redeployed. It was not possible to retrieve all of the units and several were returned to us by concerned citizens. It was not always clear form the examination of the returned units whether the ground tackle or the release mechanism failed. It is also possible that units may have successfully released but were not visually detected by the crew. Several of the units suffered water damage which rendered the release mechanism in operable.

Range testing was conducted with two VEMCO VR2 ultrasonic receivers and a V9 transmitter tag at the Richmond San Rafael Bridge. Based on the results of the test, the distance between each receiver was set at 300 meters. A line of 21 VR2s was established across the bay south of the Richmond-San Rafael Bridge from Point San Quentin (Station A) to the Castro Rocks (Station U).

Tag Application

Late-fall run Chinook salmon and steelhead where chosen as the subjects of this study as:

1) late-fall Chinook salmon are candidates for listing and steelhead are listed as threatened under the ESA,

2) both species are important ecological and socioeconomic resources to California, and

3) smolts of each species are large enough to carry an ultrasonic tag at the time of out-migration. Two permits, an ESA Section 10 (a) permit from NMFS and an Animal Care Protocol from UC Davis were obtained for the USACE researchers, Allison Bremner and Susan Ma. The following summarizes procedures for handling smolts during all stages of the study.

Ninety-eight tagged smolts (49 Chinook salmon, 49 steelhead) and one hundred tagged smolts (50 Chinook salmon, 50 steelhead), were released in 2006-2007 and 2007-2008, respectively. The fish were held in outdoor cement raceways at the USFWS Coleman National Fish Hatchery in Red Bluff, CA, and then transferred to Center for Aquatic Biology and Aquaculture (CABA) facility, Davis, CA. Fish were acclimated to the warmer water temperature of this facility and held in four outdoor holding tanks for seven days prior to the first week of surgery.

Smolts were placed in a 40-liter cooler containing a 90 mg/L solution of 99.5% pure tricaine methanesulfonate (MS222). Each individual was removed from the anesthetic solution after losing equilibrium and photos, length, weight and condition were recorded. Fish were placed ventral-side up on a surgery cradle and kept in a sedative state by passing a lower concentration of MS222 (30 mg/L) over the gills. A 10-mm incision was made beside the mid-ventral line, ending 3 mm anterior to the pelvic girdle. A sterilized, individually-coded, cylindrical ultrasonic tag was inserted into the peritoneal cavity of the fish and positioned so as to lay just under the incision. The incision was then closed using two simple interrupted sutures (Supramid, 3-0 extra nylon cable). All fish were placed into a 75-gallon tank to recover from anesthesia before being moved outside to larger holding tanks. The surgeries averaged approximately four minutes. This procedure was repeated so that a total of ten late-fall run Chinook salmon smolts and ten steelhead smolts were tagged each week for five weeks. After a five-day holding period, the implanted tags were checked for proper function, before the fish were released, using a portable tracking receiver (VEMCO VR100). The vital statistics for each fish such as time and date of tagging and its body mass and fork length were provided to researchers at the Southwest Fisheries Science Center of NMFS in Santa Cruz, California.

In 2006-2007, the tagged fish and approximately 90 “chaperones” (fish without tags to serve as a screen against predators) per each ten tagged fish were transported to Rio Vista and released into the Sacramento River. This site was chosen for easy boat access and tag-detecting receivers were located at the release site. The benefit of release in close proximity to a receiver site is that it serves as a means to determine the onset of downstream migration. In 2007-2008, no chaperones were used.

Analysis of Tag Detections

The downloaded files of tag detections were entered into the Microsoft Access database maintained by NMFS. Analysis of tag detection records incorporated the tagged fish released by

USACE, USFWS, EBMUD, and CALFED. For this report the analysis of late-fall Chinook salmon and steelhead smolts detection included:

1) time taken to swim through the upper and lower San Francisco Estuary (residency),
2) time spent in the vicinity of dredging sites (transit time), and
3) path taken through the cross-channel arrays located at the Richmond-San Rafael Bridge, Raccoon Strait and the eastern span of the San Francisco-Oakland Bay Bridge (channel preference).

The analyses in this report include tagged fish which were released by other researchers. The CALFED study, which investigated reach-specific survival in the river and estuary, released 300 late fall Chinook salmon and 300 steelhead in the upper river during both study years. The USFWS released 150 Chinook salmon in 2006-07 and 427 in 2007-08 close to Sacramento, as part of their study of the effects of the gates at the delta cross channel; and EBMUD released 62 steelhead in 2006-07 and 100 in 2007-08 in the Mokelumne River as part of their study of outmigration behavior of hatchery and wild fish (Table 1).

Table 1. Summary of fish used by agency in the analyses carried out in this report.

Agency	**Species**		**2006-7**	**2007-8**
USACE	Chinook salmon	# tagged	49	55
		Tag types	V7-2L	V7-2L
		Delays	30-90	15-45
		Release Site	Rio Vista	Rio Vista
		Release Date	Jan-Feb	Mar
		Size range (mm)	N/A	153-203 (Ave. 173)
	Steelhead	# tagged	49	50
		Tag types	V9-1L	V9-2L
		Delays	30-90	15-45
		Release Site	Rio Vista	Rio Vista
		Release Date	Jan-Feb	Mar
		Size range (mm)	N/A	231-285 (Ave. 258)
USFWS	Chinook salmon	# tagged	144	419
		Tag types	V7-1L	V7-2L
		Delays	30-90	20-60
		Release Site	Sacramento	Sacramento
		Release Date	Dec06-Jan07	Dec07-Jan08
		Size range (mm)	145-204 (Ave. 165)	139-195 (Ave. 155)
EBMUD	Steelhead	# tagged	128	193
		Tag types	V9-2L and V13-1L	V9-2L and V13-1L
		Delays	30-90	50-130
		Release Site	Several	Several
		Release Date	Feb & May 07	Jan-Sep 08
		Size range (mm)	163-610 (Ave. 274)	178-585 (Ave. 278)

Table 1 cont.

CALFED	Chinook salmon	# tagged	200	200
		Tag types	V7-2L	V7-2L
		Delays	30-90	15-45
		Release Site	Coleman	Red Bluff, Butte City, Hamilton City
		Release Date	Jan-Feb 07	Dec 07 -Jan 08
		Size range (mm)	141-198 (Ave. 165)	144-204 (Ave. 169)
	Steelhead	# tagged	200	300
		Tag types	V91L	V91L
		Delays	30-90	30-90
		Release Site	Red Bluff	Red Bluff, Butte City, Hamilton City
		Release Date	Jan-Feb 07	Dec 07- Jan 08
		Size range (mm)	158-264 (Ave. 217)	198-262(Ave. 224)

Transit time

Transit time was analyzed using only those fish detected at all three of the following locations: Rio Vista, Carquinez, and Golden Gate bridges. Transit time was calculated to be the time interval between the last detection between Rio Vista and the last detection at Carquinez for the upper section, and between the last detection at Carquinez and the last detection at the Golden Gate for the lower section. A further division using Richmond Bridge may be a more logical way of analyzing the data in the future, but was not possible in the current report due to the small size of the dataset.

Retrograde movements back upstream in the estuary were eliminated from the analysis and only smolts detected at all three locations were used. This was in order to reduce variation in the analysis. Retrograde movements back upstream cannot be analyzed in this way because fish make several trips to the river reach in question, some cases traveling upstream. In some cases, there were statistically significant differences between the transit time of LTMS-tagged fish and those released by others, so the transit times were analyzed separately.

Transit times were converted to rates (ms^{-1}) by dividing the distance between each bridge array by the time taken. Statistical significance was determined between two samples using a Student's t test and between multiple samples using analysis of variance when a histogram of the transit times indicated the measurements were normally distributed. When the measurements were not normally distributed, the Mann Whitney Test was used to determine whether a statistically significant difference existed between two samples. A Kruskal Wallis test was employed to assess whether a similar difference occurred between multiple samples. The standard error to mean ratios were calculated to determine the statistical power of the comparisons. A standard error to mean ratio of less than 10 indicated that the mean was a good representation of the central tendency to the distribution of measurements.

Residency analysis

To determine residence time at a site, it is necessary to distinguish whether two successive detections correspond to the same visit, or two separate visits to the site. We plotted the frequency of intervals between detection times in San Francisco Bay separately for each species, and there appeared to be a natural break after the 5 minute interval (Fig. 6). We assigned this as the cutoff point – so if the second detection of a fish was less than or equal to five minutes after the first detection, it was assumed to be part of the same visit. This allows for failed detections due to noise or interference from other tags. If the time difference between detections was greater than five minutes, the detections were considered separate visits. When summing the lengths of different visits, single detection visits were assumed to have a residence time of zero.

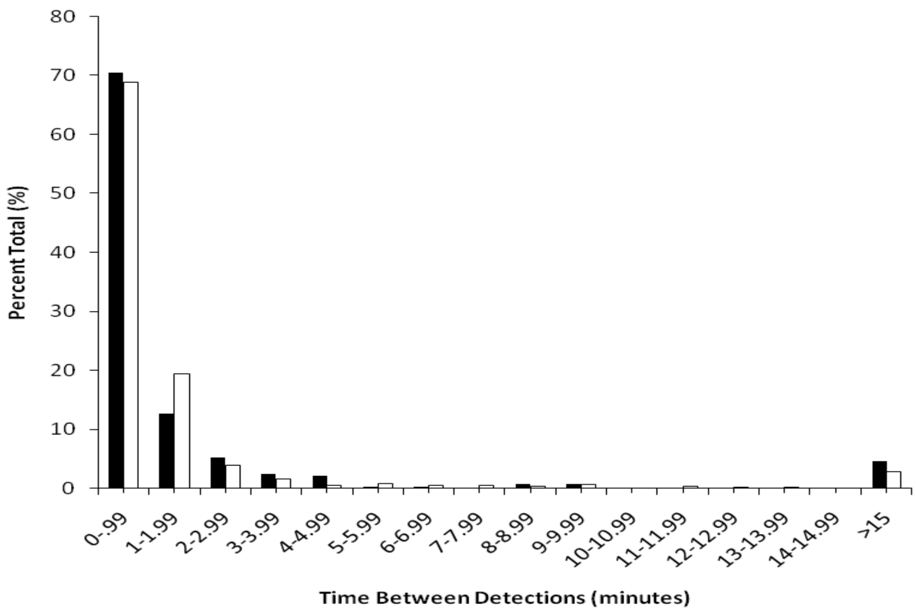


Fig. 6. Frequency histogram of 2007-2008 records of time elapsed between detections of Chinook salmon (black bars) and steelhead (white bars) at a receiver in San Francisco Bay. These data are used to determine the period of residence at a particular receiver.

It is necessary to have at least two detections of an individual, so that the time interval may be calculated. Additionally, single detections may often be false positives, due to clashes with other tags, so it is common practice to ignore these when working with large numbers of tags of similar code numbers. For this reason, single detections were omitted from this analysis – for each location, only fish with 2 or more detections were analyzed. Residency was calculated as the time interval between the first and the last detections at each site, where no intervals greater than 5 minutes occurred. Overall residency was calculated as the sum of the time spent during each visit to the site. We calculated the number of fish residing at each receiver location, along with the mean, maximum and minimum time spent at each. It is important to note that residency refers to the time spent within range of the receivers, and that this might differ from the time spent in the entire location. Assuming a circular detection range with a radius of 150 m, this corresponds to a residency within approximately 71,000 m^2.

Channel preference

For the Richmond-San Rafael and Bay Bridges, we calculated the percentage of the total fish detected at each bridge per receiver across the channel. For each species, we correlated this with water depth at each receiver location and ran a t-test to determine whether fish displayed a preference for a particular depth.

We also calculated the percentage of fish which moved through Raccoon Strait in comparison to those detected at the Golden Gate.

Transit Time

Year 1 of Study (2006-2007)

Of the 135 Chinook salmon and steelhead smolts detected at the Golden Gate in 2006-2007, a total of 46 (34%) were detected at all three locations mentioned above. Chinook salmon averaged 2.6 days to move through San Pablo and San Francisco bays, yet spent 8.3 days in the upper estuary. Steelhead averaged 1.9 days to pass through the lower estuary if released into the mainstem Sacramento River, and 2.0 days if released at the base of the Delta (Table 2), yet the mean residence time varied from 2.5 days to 9.8 days depending on whether they were released in Sacramento or at the base of the Delta.

Table 2. Chinook salmon and steelhead smolt mean transit times (in number of days) through the upper and lower estuary during 2006-2007 and standard error (SE) to mean ratio.

Transit Time (Days) Summary	Chinook salmon		Steelhead			
	USFWS + USACE +CALFED		CALFED		USACE	
	n= 26		n=9		n=11	
	Mean (μ) (days)	SE/μ	Mean (μ) (days)	SE/μ	Mean (μ) (days)	SE/μ
Upper Estuary (Rio Vista to Carquinez)	8.3	11.0	2.5	12.7	9.8	30.9
Lower Estuary (Carquinez to Golden Gate)	2.6	9.1	1.9	9.7	2.0	24.0

The standard error to mean ratios were high, indicating that one must be cautious in comparing them. The ratios for the mean transit times of Chinook salmon in the upper and lower estuary (11.0 and 9.1, respectively) are similar to those for steelhead released by CALFED in the middle-upper mainstem Sacramento River and detected in the upper and lower estuary (12.7 and 9.7, respectively). However, the ratios for mean transit times are much higher for LTMS-tagged steelhead released near Rio Vista and detected in the upper and lower estuary (30.9 and 24.9, respectively). Generally there was less variation in the duration of transit through the upper and lower estuary by Chinook salmon than by steelhead.

A straight-line passage through the upper estuary is longer than the lower estuary, the extent of the former being 56.1 km and the later 40.1 km. The mean transit rate of 0.22 m/s for Chinook salmon in the lower estuary (see white bars in Fig. 7) was faster than the mean of 0.096 m/s in the upper estuary (Mann-Whitney Test, n= 24, p<0.001).

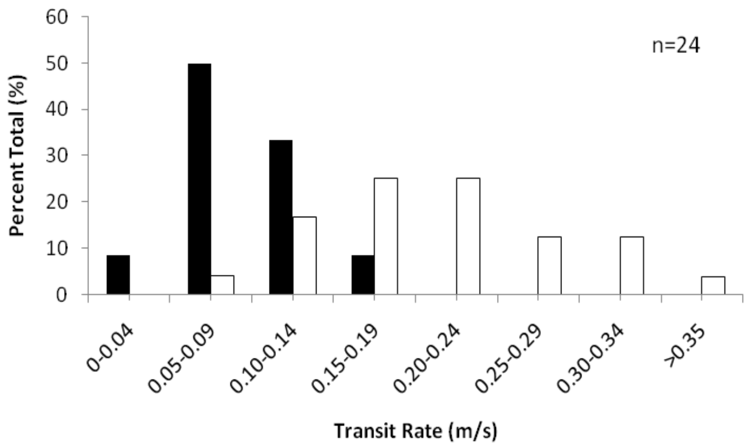


Fig. 7. Rates of movement of Chinook salmon smolts, tagged and released during 2006-2007, as they passed through the upper estuary (black bars) and lower estuary (white bars).

Transit rates of CALFED-tagged opposed to LTMS-tagged steelhead were found to differ statistically, at least in the upper estuary, and are presented separately below. LTMS-tagged steelhead, similar to Chinook salmon, transited faster in the lower estuary than in the upper estuary (Fig. 8). However, the small dataset shows a significant amount of variation, and it is difficult to draw conclusions without obtaining more data on steelhead transit times in these areas.

For CALFED-tagged steelhead, there was no statistical significance between the rates of transit in the upper and lower estuary, so the transit rates for the 9 individuals were averaged along the entire estuary. The CALFED-tagged steelhead exhibited an average transit rate of 0.28 m/s (Fig. 9), but with such a small sample size, further data are required to understand the variability displayed.

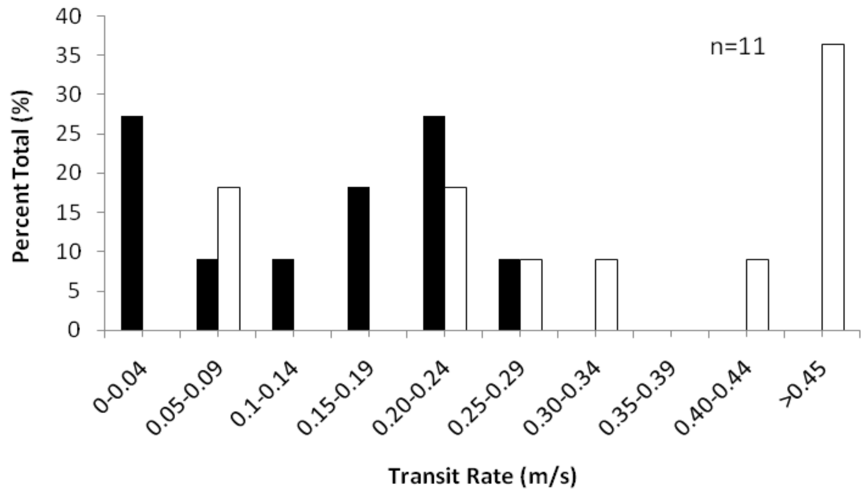


Fig. 8. Transit rates of LTMS -tagged steelhead smolts released in 2006-2007 as they passed through the upper estuary (black bars) and the lower estuary (white bars).

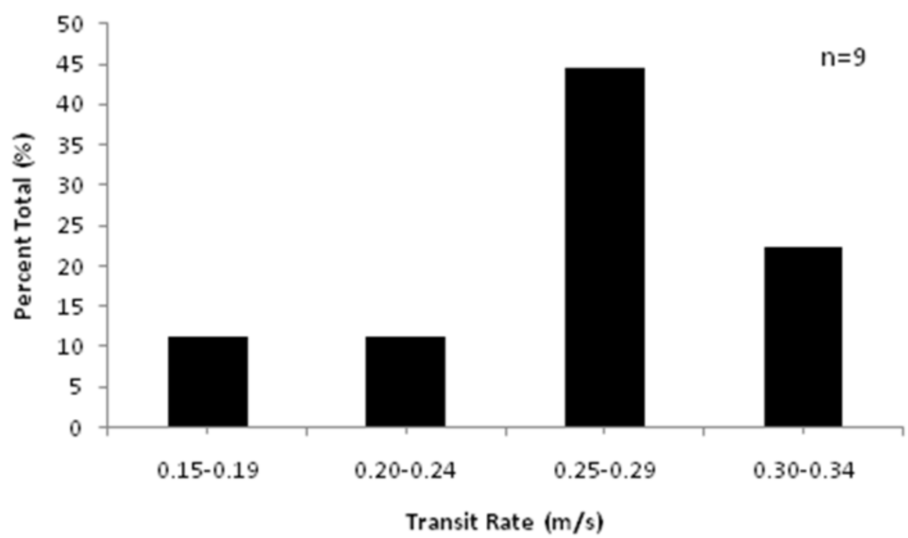


Fig. 9. Transit rates through both the upper and lower estuary for CALFED-tagged steelhead smolts released in 2006-2007.

Year 2 of Study (2007-2008)

As in 2006-2007, Chinook salmon and steelhead smolts moved more rapidly through the lower estuary than the upper estuary. Of the 194 fish detected leaving the San Francisco Estuary, a total of 58 (30 %) tagged Chinook salmon and steelhead smolts were detected by receivers at each of the three arrays deployed at the Rio Vista, Carquinez, and Golden Gate Bridges. The mean period of time that Chinook salmon smolts migrated through upper and lower sections of the estuary was 7.5 and 2.7 days, respectively (Table 3). Mean transit time for steelhead smolts in the upper and lower estuary was 6.0 and 2.5 days, respectively. The standard error to mean ratios for Chinook salmon were less than 10, indicating that the means are good representatives of central tendency in both locations. However, the standard error to mean ratios for the steelhead were 15.6 and 24.1. These ratios were considerably higher than 10, indicating less confidence in a statistical comparison between them.

Table 3. Chinook salmon and steelhead smolt transit times (mean number of days) through the upper and lower estuary during 2007-2008, and standard error (SE) to mean ratio.

Transit Time (Days) Summary	Chinook salmon		Steelhead	
	USFWS + USACE +CALFED		DWR + USACE +CALFED	
	n= 22		n= 36	
	Mean μ (days)	SE/μ	Mean μ (days)	SE/μ
Upper Estuary (Rio Vista to Carquinez)	7.5	9.6	6.0	15.6
Lower Estuary (Carquinez to Golden Gate)	2.7	9.4	2.5	24.1

The upper and lower estuaries have different lengths, the upper being 56.1 km long and the lower being 40.1 km long. Therefore, transit rates provide a better comparison for movements through the upper and lower estuary. The average transit rate of 0.21 m/s for Chinook salmon in the lower estuary was significantly higher than the transit rate of 0.11 m/s in the upper estuary (Mann-Whitney Rank Sum Test, n=22, $p<0.001$). A peak of 36% in movement through the lower estuary occurred within the 0.10-0.14 m/s class (Fig. 10). In contrast, in the upper estuary a peak of 45% in movement occurred within the 0.05-0.09 m/s class (Fig. 10).

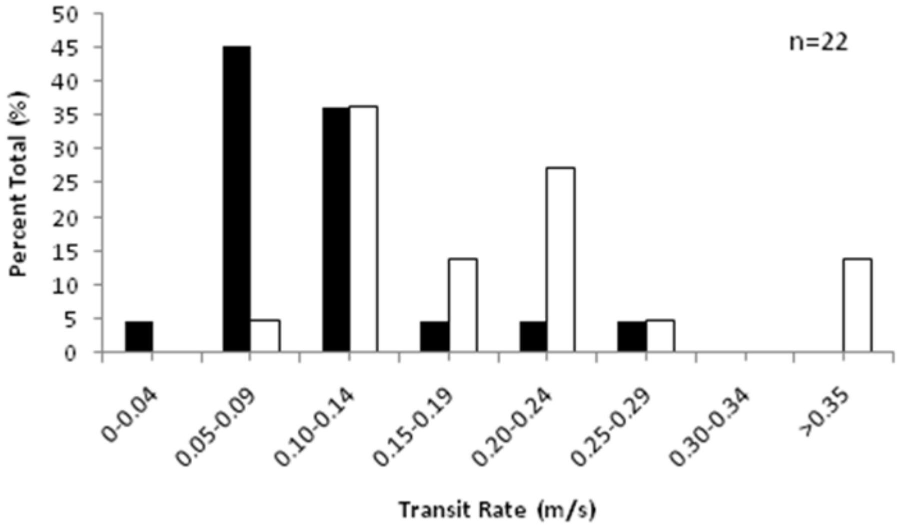


Fig.10. The rates of transit of Chinook salmon smolts released in 2007-2008 that passed through the upper estuary (black bars) and the lower estuary (white bars).

Steelhead smolts also traveled faster in the lower estuary than the upper estuary in 2007-2009 (Fig. 11). The steelhead swam at a mean rate of 0.31 m/s in the lower estuary, which was significantly greater than the mean rate of 0.17 m/s in the upper estuary (Mann-Whitney Rank Sum Test, n=36, p<0.001). The peak in frequency distribution of transit rates in the lower estuary was in the 0.25-0.29 m/s class (white bars, Fig. 11); the peak in the frequency of transit rates was in the 0.10-0.14 m/s class in the upper estuary (black bars, Fig. 11).

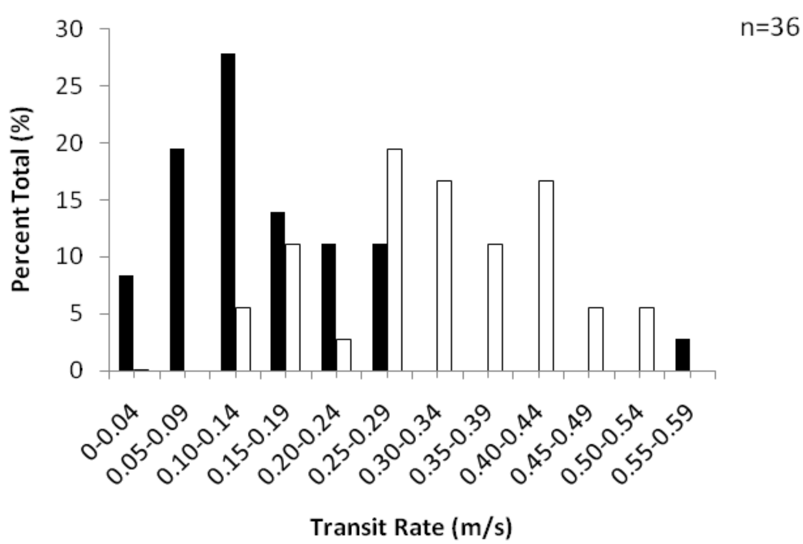


Fig. 11: Transit rates for steelhead smolts released in 2007-2008 that passed through the upper estuary (black bars) and the lower estuary (white bars).

Residence Times

The time spent by tagged fish within range of tag-detecting receivers in the estuary, is referred to as residence time. Residence time is a parameter indicating the potential period of time that the fish could be exposed to possible adverse affects of dredging activities that might be occurring during their migration through the estuary. Residence times were calculated at various locations in San Pablo and San Francisco bays, where dredging activities could possibly occur, such as dredged material disposal sites and frequently dredged channels or ports.

Year 1 of Study (2006-2007)

Residence times were recorded at particular locations where 1 to 19 Chinook salmon smolts made from 1 to 39 visits to that location during 2006-2007 (Table 4). A visit was defined as a period of time in which detections were recorded with no more than a four successive minute break, based on the log-survivorship analysis previously described. The average residence time varied from a minimum of 2.2 min at Pier 80 of the Port of San Francisco to 43.0 min near the Port of Oakland. The average recorded residence time was 19.3 min for all seven locations in the San Francisco Estuary. Chinook salmon resided within the range of receivers at Mare Island for a maximum of 206.9 min (Pier 22) and 237.0 min (Pier 23). Some fish were detected at more than one site, for example, fish # 1378 and 1955 were both detected at SF Pier 80 and 30. In the case of #1378, detections occurred over a period of several weeks – it was first detected on May 15th 2007 at both receivers, was then only detected at Pier 80 on the 9th, 14th, and 18th of June, and then again at Pier 30 on 19th June and on several occasions until the end of July. Fish #1955 on the other hand, was detected for two periods at Pier 30 and one at Pier 80 all on the same day (17th February 2007).

Table 4. Summary of the average, minimum, and maximum period of residence of Chinook salmon smolts at various sites within the San Francisco Estuary during 2006-2007.

Region	General Location	Receiver	Mean (min)	Min. (min)	Max. (min)	Number of fish
San Pablo Bay	Mare Island	Pier 22	33.4	1.3	206.9	11
		Pier 23	41.7	0.6	237.0	10
	Petaluma River	RR Bridge	4.1			1
	SF 10	N. Corner	7.1	1.5	20.8	12
		S. Corner	11.0	1.6	27.5	10
	SP Bay Channel	Buoy 9	6.5	0.7	24.8	19
SF Bay	Point Richmond	Richmond	19.8			1
	Port of Oakland	Receiver 3	43.0	5.6	116.8	2
	Port of SF	SF Pier 80	2.2	1.0	3.5	2
		SF Pier 30	21.3	0.7	63.1	5
		SF Pier 27	21.8	0.7	53.9	3
		SF Pier33	2.4			1

Residence times were recorded at particular locations where 1 to 21 steelhead smolts made from 1 to 39 visits to that location during 2006-2007 (Table 5). The average residence times varied from a minimum of 2.8 min at Paradise Cay to 230.2 min at the mouth of the Petaluma River. An average of these times was 31.6 min for all of the receivers situated at these eight sites in the San Francisco Estuary. The maximum period of time that steelhead resided within the range of receivers was not at Mare Island, as with the Chinook salmon, but at the mouth of the Petaluma River, where one of two fish was detected by the receiver over a period of 248.5 min.

Table 5. Summary of the average, minimum, and maximum period of residence of steelhead smolts at various sites within the San Francisco Estuary during 2006-2007.

Region	General Location	Receiver	Mean (min)	Min. (min)	Max. (min)	Number of fish
San Pablo Bay		Pier 22	45	21.4	66.9	5
	Mare Island	Pier 23	46.5	18	66.2	5
	Petaluma River	RR Bridge	230.2	211.9	248.5	2
		N. Corner	22.1	1	53.5	7
	SF 10	S. Corner	15.1	1.4	43.5	4
	SP Bay Channel	Buoy 9	15.9	1.3	46.3	11
SF Bay	Paradise Cay	ParadiseCay	2.8	1.3	4.8	3
	Port of Oakland	Oakland 1	12.1			1
		Oakland 3	17.1	5.2	29	2
	Bay Bridge	BayBridge 2	12			1
		BayBridge 3	14.5			1
		BayBridge 4	20.4	3.1	37.6	2
		BayBridge 5	83.8			1
		BayBridge 7	5			1
		BayBridge 8	6.1	4.8	7.4	2
		BayBridge 9	7.5	7.1	8	2
	Port of SF	SF Pier 80	28.6	7.2	55.8	6
		SF Pier 30	14.7	1.1	73.2	21
		SF Pier 27	20.8	2.2	74.2	7
		SF Pier 33	11.8	0.4	37.7	8

Year 2 of Study (2007-2008)

Residence times were recorded at particular locations where 1 to 21 Chinook salmon smolts made from 1 to 32 visits to that location during 2007-2008 (Table 6). The average residence times varied from a minimum of 2.5 min at the Port of Oakland to 38.9 min at the mouth of the Petaluma River. The maximum period of time that Chinook salmon smolts resided within the range of receivers was at the dredged material placement site in San Pablo Bay (SF 10), where one of nine fish was detected over a period of 128.5 min. An average residence time for all of the receivers situated at these 10 general locations was 11.1 min. These results are consistent with the residence times for Chinook salmon smolts recorded during the 2006-2007 study period. It must be taken into account that some fish were detected at different receivers in the same location. For example, although 7 fish are recorded at the Bay Bridge, this corresponds to only three individuals, because fish # 15208 was detected at every receiver, while fish #15268 was detected at both receiver 8 and 9.

Table 6. Summary of the average, minimum, and maximum period of residence of Chinook salmon smolts at various sites within the San Francisco Estuary during 2007-2008.

Region	General Location	Receivers	Mean (min)	Min. (min)	Max. (min)	Number of fish
San Pablo Bay	Mare Island	Pier 22	10.2	0.5	19.7	8
		Pier 23	12.9	2.2	24.1	8
	Petaluma River	RR Bridge	n/a	n/a	n/a	0
	Petaluma Channel Marker	Marker G5	38.9	0.5	103.0	6
		Maker G3	16.8	0.8	52.7	7
	SP Bay Channel	Buoy7	3.7	0.3	17.5	21
	SF 10	E. Corner	3.8	0.9	11.8	8
		S. Corner	12.3	0.9	53.4	9
		W. Corner	17.9	0.5	128.4	8
SF Bay	Point Richmond	Richmond	25.6	25.6	25.6	1
	Port of Oakland	Oakland 3	4.9	4.6	5.3	2
	Bay Bridge	BayBridge 6	12.8	12.8	12.8	1
		BayBridge 7	4.0	4.0	4.0	1
		BayBridge 8	2.5	1.1	1.4	2
		BayBridge 9	14.5	0.8	9.1	3
	Alcatraz	N. Corner	3.7	3.2	4.4	3
		S. Corner	6.5	1.2	11.9	2
	Port of SF	SF Pier 30	10.7	2.0	28.2	7
		SF Pier27	3.8	1.2	5.7	4
		SF Pier33	4.7	1.1	8.4	2

Residence times were recorded at particular locations where 1 to 25 steelhead smolts made from 1 to 117 visits to that location during 2007-2008 (Table 7). The average residence times varied from a minimum of 1.6 min at the Port of Oakland to 851.4 min at the mouth of the Petaluma River. The average residence time for all of these locations receiver was 61.3 min. The maximum period of time that steelhead smolts resided within the range of a receiver was not at the dredged material placement site in San Pablo Bay (SF 10), as was the case for Chinook salmon smolts, but rather at the mouth of the Petaluma River. At the Petaluma River, one of three fish was detected over a period of 1,458 min, although this fish was not later detected at the

Golden Gate. As in previous cases, some fish were detected at more than one receiver at any given location. Hence, the Bay Bridge sites (6-9) only detected five individuals, although several were detected at more than one receiver and on more than one date.

Table 7. Summary of the average, minimum, and maximum period of residence of steelhead smolts at various sites within the San Francisco Estuary during 2007-2008.

Region	General Location	Receivers	Mean (min)	Min. (min)	Max. (min)	Number of fish
San Pablo Bay	Mare Island	Pier 22	107.9	12.6	384.8	9
		Pier 23	107.5	11.2	432.8	9
	Petaluma River	RR Bridge	851.4	343.8	1458.1	3
	Petaluma Channel	Marker G3	16.4	4.4	41.5	5
	Marker	Marker G5	55.9	7.5	227.6	7
	Buoy 7	Buoy 7	14.6	1.1	51.4	17
	SF 10	E. Corner	6.7	0.6	28.5	20
		S. Corner	19.2	1.8	154.9	25
		W. Corner	8.3	1.0	30.5	18
SF Bay	Port of Oakland	Oakland 1	35.9			1
		Oakland 3	37.0			1
		Oakland 5	1.6			1
	Bay Bridge	BayBridge 6	4.5			1
		BayBridge 7	5.4	2.2	8.4	4
		BayBridge 8	4.1	0.7	14.2	8
		BayBridge 9	6.0	0.5	4.0	7
	Alcatraz	East Receiver	5.1	0.6	13.1	3
		N. Corner	8.2	3.6	15.1	6
		S. Corner	16.1	0.7	44.9	4
	Port of SF	SF Pier 30	10.6	3.4	19.7	8
		SF Pier 80	22.3	13.7	30.8	2
		SF Pier 27	14.9	2.8	46.6	7

Tagged salmonids were recorded at four locations in San Pablo Bay where receivers were deployed during 2007-2008 (Fig. 12): two markers (G3 and G5) on either side of the channel leading to the Petaluma River, one marker (B7) in the main channel through San Pablo Bay, and the dredged material placement site (SF10) north of the main channel. They were also recorded in waters adjacent to Mare Island and the Petaluma River.

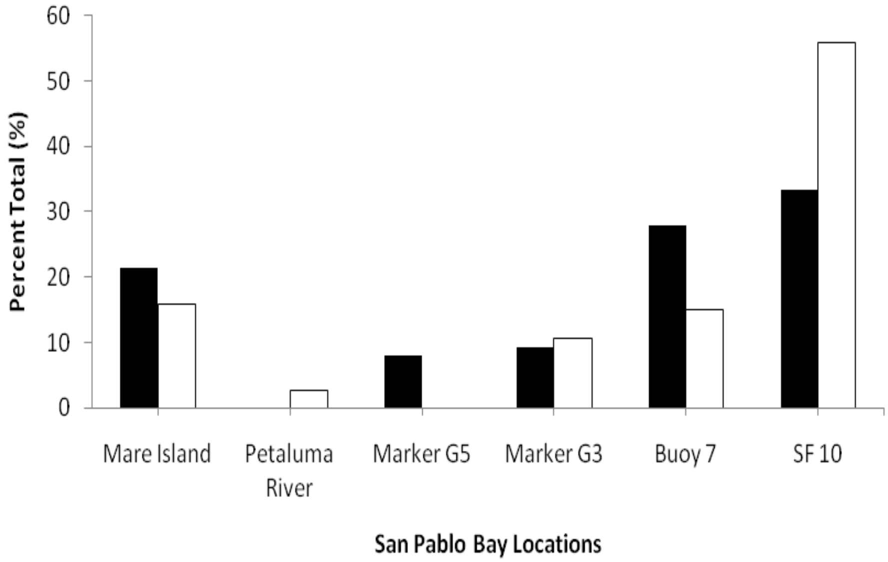


Fig. 12. Detections of salmonids at six locations in San Pablo Bay during the 2007-2008 (Chinook salmon = black bars, steelhead= white bars).

Seventy-five Chinook salmon and 113 steelhead were detected passing within range of the receivers at locations of interest in San Pablo Bay. The highest percentage of tagged Chinook salmon and steelhead smolts were recorded at receivers positioned at the dredged material placement site (SF10) in San Pablo Bay (Fig. 12).

There were 14 Chinook salmon and six steelhead smolts that were detected by the two receivers located at SF10 during 2006-2007. There was no statistically significant difference between the distributions of residence times for the Chinook salmon and steelhead at this site. Hence, the data set was pooled in a single histogram (Fig. 13). The median residence time spent at the site was 8.7 min. Four individuals spent greater than 30 minutes at this site.

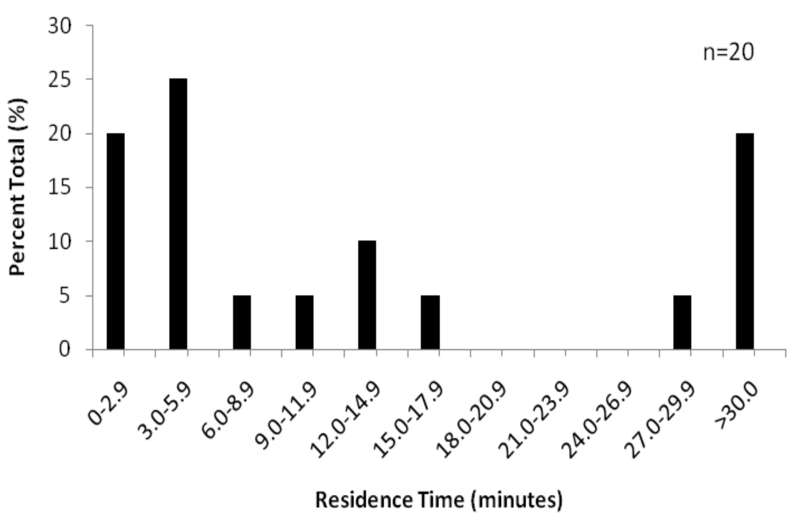


Fig.13. Frequency distribution of residence times for salmonid smolts detected at the dredged material disposal site SF10 during 2006-2007. Note that the last time interval is grouped and must therefore not be considered as a “second peak”.

There was no significant difference between the residence times of the 16 Chinook salmon and 36 steelhead smolts detected at the SF10 dredged material disposal site during 2007-2008, and therefore the data sets were pooled in a single histogram (Fig. 14). The distribution of these times is skewed, with a peak percent total of residence times in the 0-4.99 min interval. The median period of time spent within the detection range of the receivers was 6.5 min.

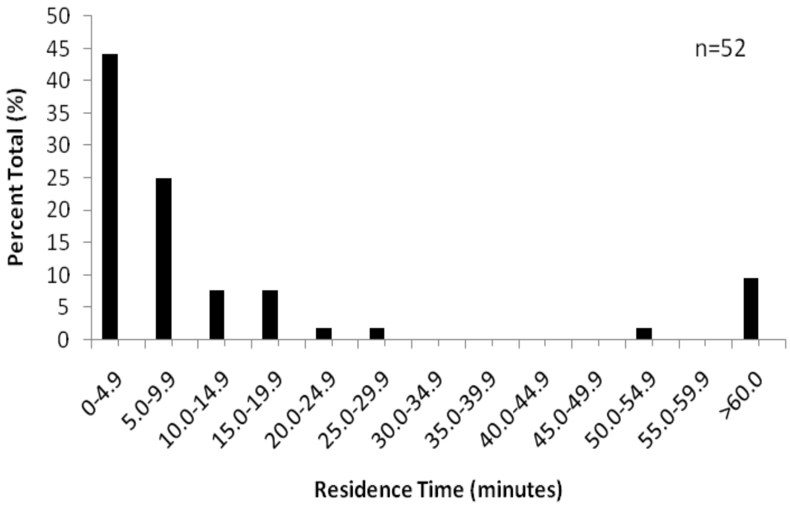


Fig.14. Frequency distribution of residence times for salmonid smolts detected at the dredged material placement site SF10 during 2007-2008

The receivers near buoys on either side of the main shipping channel in San Pablo Bay detected the migrating smolts. Chinook salmon and steelhead smolts were detected only as they passed Buoy 7 because the receivers installed at Buoys 8, 9, and 10 were lost and not replaced after the initial download of files of tag detections in March, 2008. The periods of detection by the receivers on either side of the channel leading to the Petaluma River varied greatly during 2007-2008. The durations of the intervals over which Chinook salmon smolts were detected ranged from 0.5 min to 1.7 h; steelhead residence times ranged from 4.4 min to 3.8 h.

Twenty-one Chinook salmon and 33 steelhead smolts were detected by receivers deployed at locations in San Francisco Bay during the 2007-2008 study period. Both Chinook salmon and steelhead smolts were detected moving past the dredged material placement site near Alcatraz Island (SF11), as well as near two of the piers, 27 and 30, in the Port of San Francisco (Fig. 15). However, there were fewer fish detected passing through San Francisco Bay than San Pablo Bay.

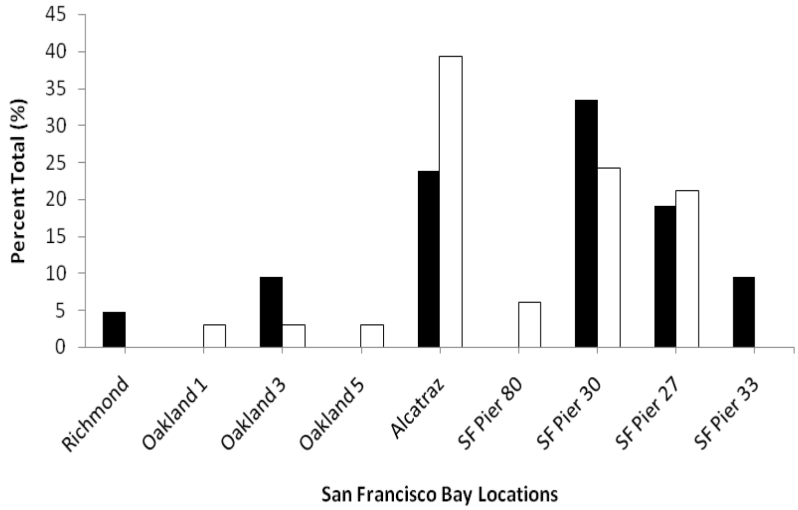


Fig. 15. Relative percentage of Chinook salmon (black bars) and steelhead smolts (white bars) that were detected by receivers deployed at nine locations in San Francisco Bay in the 2007-2008 study period. SF=San Francisco.

There was no statistically significant difference between residence times of the two study species in and around the Alcatraz dredged material placement site (SF-11). These two data sets were pooled in the histogram below (Fig. 16). At the Alcatraz dredged material placement site, the greatest percentage of residence times for five Chinook salmon and eight steelhead smolts were within the 3.0-4.9 and 5.0-6.9 time intervals. The scarcity of detections at this site is likely due to the loss of three out of the four receivers deployed.

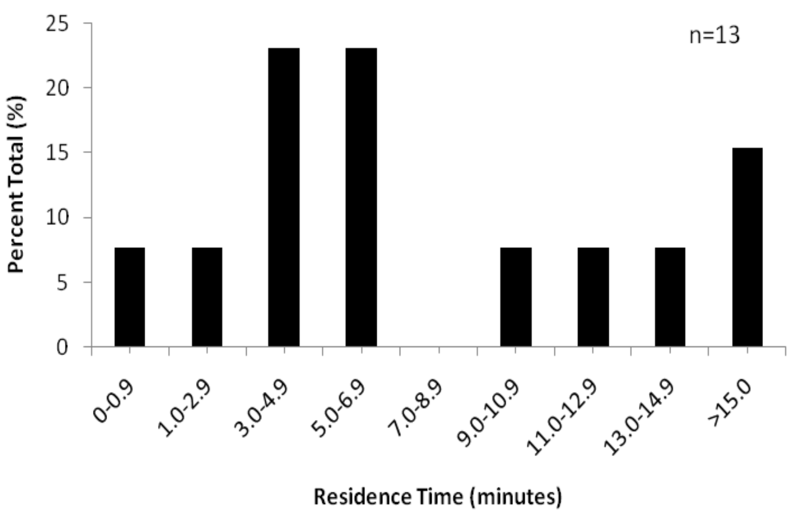


Fig. 16. Frequency histogram of residence times at the dredged material disposal site near Alcatraz Island during 2007-2008.

Migratory Pathways

Receivers were deployed near the concrete buttresses of the Richmond–San Rafael Bridge to form a linear array across San Pablo Bay. The depth of the bay increased from the shoreline on either side of the bay to 17 m within the channels at the center of the bay. This depth variation provided an opportunity to relate the movement of fish to the depth of the bay, and provided an opportunity to determine whether salmonid smolts swam mainly within the channel during their out-migration (Fig. 17).

Both Chinook salmon and steelhead smolts were detected more frequently swimming within the deep channels in the middle of the bay (Fig. 17). The receivers detected 139 Chinook salmon and 219 steelhead smolts in 2007-2008. Note that those locations, at which detections were missing (H, I, K and M), were due to the inability to retrieve receivers. However, receivers A and T reflect the absence of tagged fish.

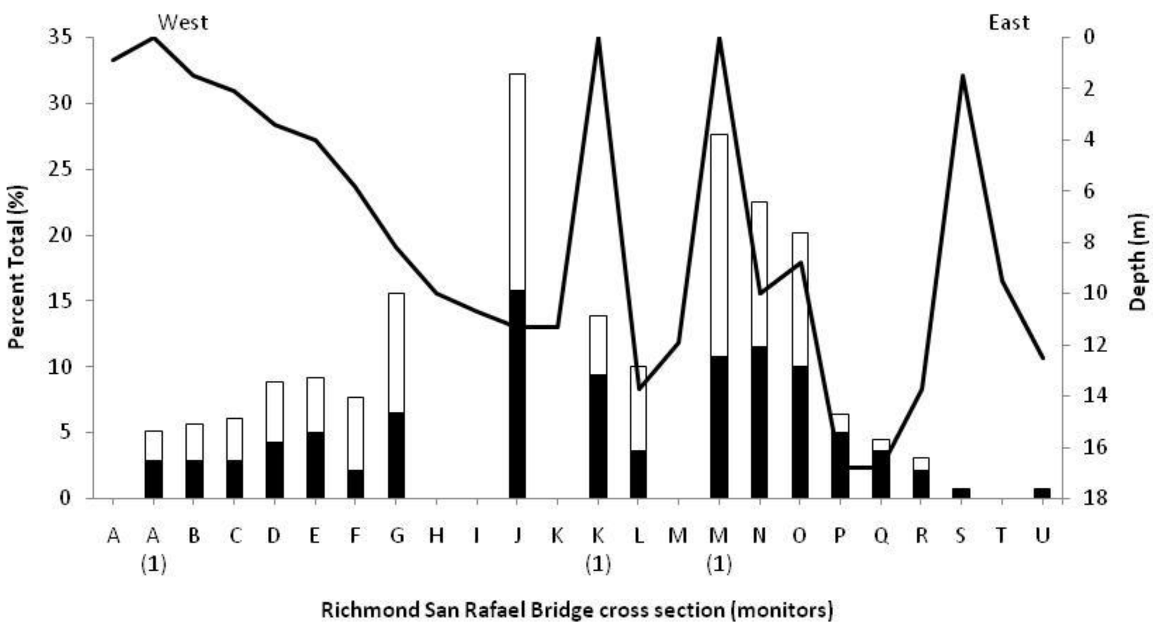


Fig. 17. Relative percentages of Chinook salmon (black bars) and steelhead smolts (white bars) detected by receivers along the length of the Richmond-San Rafael Bridge compared to distribution of depths across the bay (black line) given from west to east.

A low linear dependence existed between the frequency of detection of migrating salmonids and the full range of water depths (r^2=0.08 for Chinook salmon and r^2=0.03 for steelhead). However, a positive linear correlation between the detection frequencies of both species existed with depths up to 11.3 m (see solid diamonds and regression line in Figs. 18 and 19). The coefficient of regression (r^2) for Chinook salmon smolts was 0.5, and a positive slope of 0.89 differed significantly from a slope of zero (t-test, n=13, p<0.001). In both cases, if the outlier (receiver #20, 9.5m depth, had zero detections of tagged fish), then the coefficient of regression is much greater – 0.83 and 0.93 for Chinook salmon and steelhead, respectively.

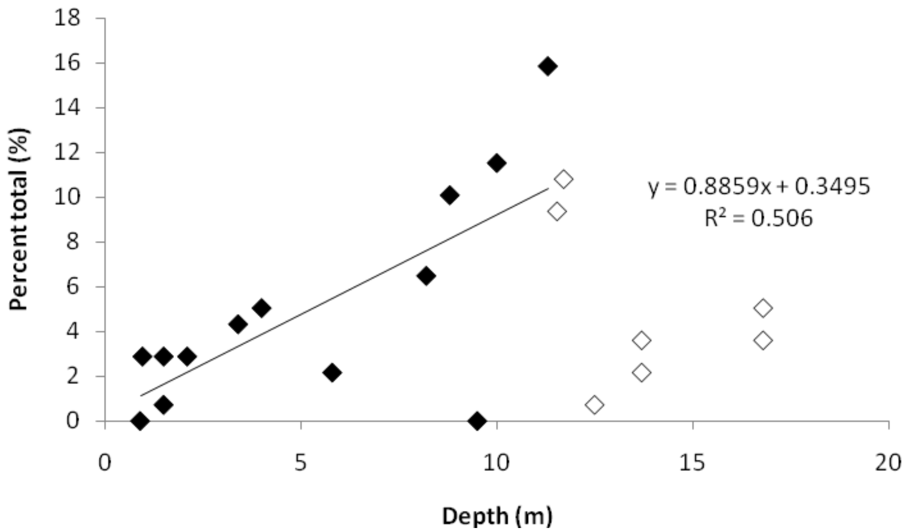


Fig. 18. Percentage of Chinook salmon smolts detected by receivers deployed at varying depths near the Richmond-San Rafael Bridge during 2007-2008. Filled data points were used for regression.

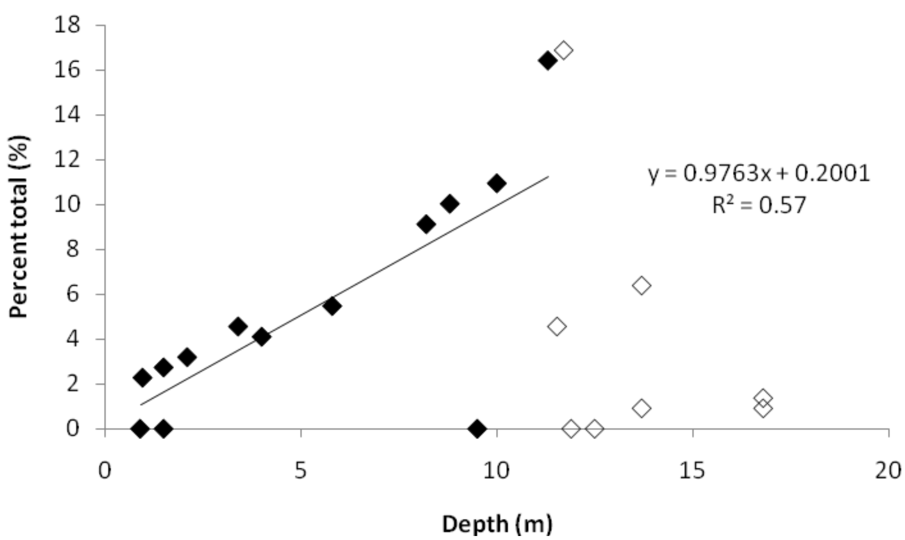


Fig. 19. Percentage of steelhead smolts detected by receivers deployed at varying depths near the Richmond-San Rafael Bridge during 2007-2008. Filled data points were used for regression.

A positive correlation also occurred between depths up to 11.3m and steelhead smolt detections. The coefficient of regression for steelhead smolts was 0.57, and a positive slope of 0.98 was also significantly different from a slope of zero (t-test, n=13, p<0.001). However, for both species there was no linear correlation between frequency of detection and depths >11.3 m [see open diamonds in Figs. 17 and 18, (t-test, n=7,8 p>0.05)].

During 2007-2008, four Chinook salmon smolts (5%) and 15 steelhead (13%) passed through Raccoon Strait and were later detected at the Golden Gate array (Table 8). The majority of fish, which were not detected by the receivers in Raccoon Straits, but were later detected at the Golden Gate likely passed south of Angel Island and swam westward toward the Golden Gate. However, the low percentages of detections in Raccoon Straits may also have been due to loss of the receivers during the study period. In 2007-2008, three out of the four receivers were not retrieved. A total of 59 Chinook salmon (42%) and 105 steelhead smolts (48%) detected at the Richmond-San Rafael Bridge were not detected at the Golden Gate Bridge.

Table 8. The numbers of Chinook salmon and steelhead smolts detected by the arrays of receivers at the Richmond-San Rafael Bridge, Raccoon Straits, and Golden Gate Bridge during 2007-2008.

Locations	Chinook salmon	Steelhead
Richmond San Rafael Bridge	139	219
Raccoon Straits	4	15
Golden Gate	80	114

Eight receivers were deployed on the eastern span of the San Francisco-Oakland Bay Bridge during 2006-2007. They were deployed from west to east at varying depths and distances. There was one Chinook salmon and 12 steelhead smolts that were detected passing through the eastern passage, into the southern region of San Francisco Estuary (Fig. 20). The single Chinook salmon was detected by a receiver deployed at a depth of 15 m (see black bar in Fig. 21). In contrast, the 12 steelhead were detected by receivers ranging in depth from 4 to 15 m (see white bars in Fig. 20).

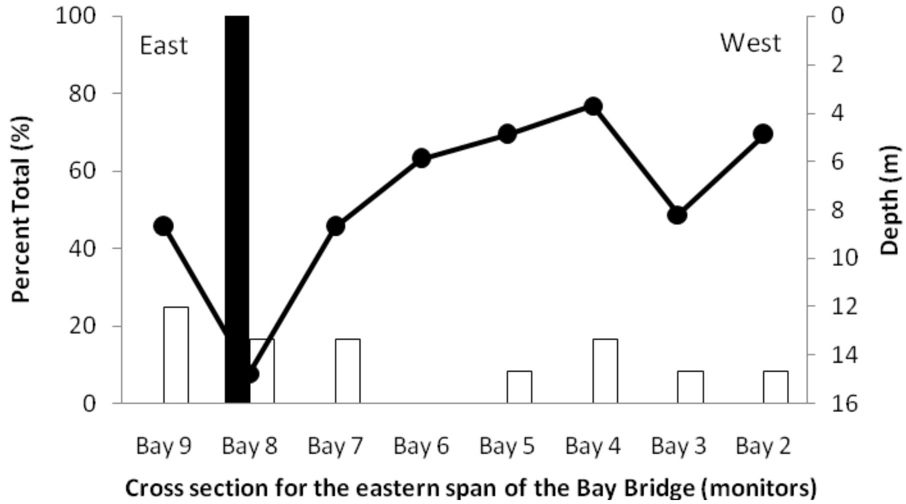


Fig. 20. Percentages of Chinook salmon (black bar) and steelhead (white bars) detected at receivers deployed at different distances from shore along with the depths of the receiver locations during 2006-2007.

Receivers were also deployed at the same locations along the San Francisco-Oakland Bay Bridge during 2007-2008. There were 17 detections of Chinook salmon smolts (corresponding to 8 individuals, some of which were detected more than once) and 14 detections of steelhead smolts (corresponding to 6 individuals, some of which were detected more than once) by the receivers. Again, the Chinook salmon were only detected by the receiver deployed in the deep channel where the depth is 14 m (see black bar in Fig. 21), whereas steelhead were detected by all but one of the receivers in depths ranging from 4-15 m (see white bars in Fig. 21).

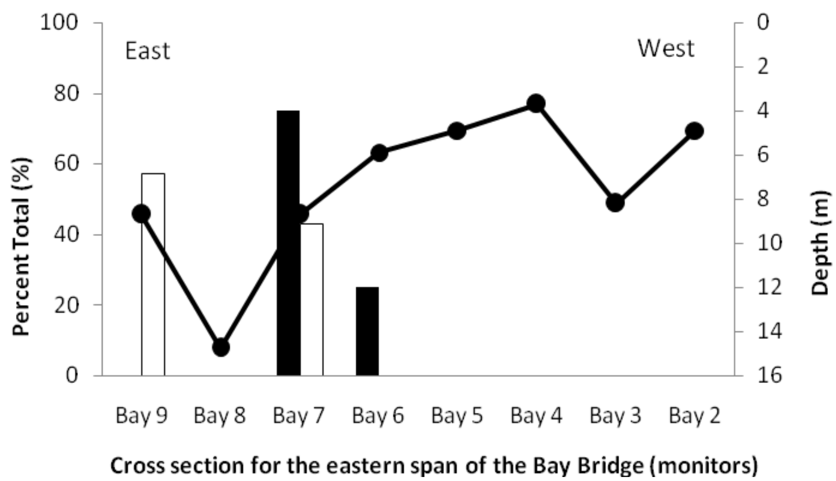


Fig. 21. Percentages of Chinook salmon (black bars) and steelhead (white bars) detections at receivers deployed at different distances from shore along with the depths of the receiver locations during 2007-2008. Some individuals had multiple detections.

DISCUSSION

A fundamental assumption is that the tagging process does not affect the behavior of the individual being studied, and that by observing the tagged individuals, we can extrapolate to the general population. Although this may not hold true, recent experimental work by Ammann (2006) found no difference in growth or swimming speed between three groups of hatchery-reared juvenile steelhead – those with tags, those which had surgery, and those which were not manipulated.

A second assumption is that hatchery-reared fish behave in the same way as wild fish. There is evidence that suggests that this is not the case – studies of steelhead smolts on the Russian River indicate that hatchery spawned fish may go through the system quite rapidly, perhaps because they are already released at a critical size, whereas naturally spawned fish may spend more time utilizing the river and delta-estuarine habitats (Josh Fuller, NMFS pers. comm.). However, on the other hand, wild Chinook salmon in San Francisco Bay demonstrated little estuarine dependency in a study by MacFarlane and Norton (2002) – migrating through the estuary in 40 days, during which growth was insignificant and condition declined. This indicates that the estuary might be conceived as an obstacle to be traversed as quickly as possible.

Transit and Residence Times

The difference in the rates of movement and residence times between LTMS and CALFED tagged steelhead in the upper estuary in 2007 might be attributed to the different release times. The CALFED fish were released earlier in the year, when flow rates are higher, so a more rapid transit time through the upper estuary might be expected. Another factor which may affect movement rates is the acclimation period upon release which can vary between groups of fish and between hatcheries (Phillip Sandstrom, UC Davis, pers. comm.).

Transit time is an important indicator of large scale movement through the San Francisco estuary. Individuals of both species released during 2007-2008 passed through San Pablo and San Francisco bays in periods averaging 2.7 days for Chinook salmon and 2.5 days for steelhead smolts, similar rates to those shown in 2006-2007, and faster than transit times of 5-38 days found in earlier studies (MacFarlane & Norton 2002). A substantial proportion of the migrating salmonids were detected near the dredged material placement site in San Pablo Bay (SF-10). Smolts migrating through the system have to pass close to this site, in contrast with peripheral sites such as Petaluma River. In 2007-2008, the three receivers at this site recorded the highest number of fish moving through San Pablo Bay with 60% of detected fish spending less than ten minutes within the dredged material placement site. The longer residence times exhibited at Mare Island and Petaluma River indicate that these locations provide habitat favorable to the migrating smolts. At Mare Island, Chinook salmon exhibited an average residence time of 11.6 min with maximum residence period of 24.1 min. Steelhead, on the other hand, spent a considerably longer time in this area with an average residence of 1.8 h with a minimum of 11.2 min and a maximum of over 7 hours. Only three steelhead smolts were detected near the mouth of the Petaluma River, but their average residence was 14.1 h with a minimum of 5.7 h. If migrating salmonid smolts are passing through or using dredge disposal sites, then further work is required to determine the actual level of threat. This includes an analysis of the potential harmful effects of chemicals released into the water column during the disposal, the persistence of the plume of potentially harmful water in the area after disposal, and the dispersal rate of potentially harmful substances. This must then be placed in context with the timing of the presence of smolts at the sites and the exposure times at these sites, and whether they re-visit sites more than once. However, the results from this report all suggest that exposure to these sites is in the order of minutes rather than hours or days.

Migratory Pathways

The observation that the majority of both Chinook salmon and steelhead moved within channels at the center of the bay is consistent with trawl catches in deeper waters (Jahn, 2004). The predominance of detections by receivers in the deeper waters at the Richmond-San Rafael Bridge indicates that fish may migrate mainly within the ship channel as opposed to the bordering shallow waters. Also, there was a positive correlation between the frequency of smolt detections and depths ranging from 1-11.3 m. However, this relationship was not evident in waters deeper than 11.3 m. In a similar fashion, fish detected at the San Francisco-Oakland Bay Bridge were also found in mid-range water depths. During 2007-2008, Chinook salmon and steelhead smolts were detected in water ranging from 6-8 m in depth along the eastern span of the San Francisco-Oakland Bay Bridge. Both species were detected most by receivers closer to Treasure Island than to Oakland.

Many migratory fish, such as the ones studied here, vary their migration pattern based on a range of environmental conditions. The most important may be the rate of tidal current through the estuary. High water velocity can affect fish migratory patterns in terms of swimming speed, net speed (*i.e.*, swimming speed plus current), and habitat preference. Another critical factor in migration patterns is that of the halocline; migrating salmonids are traveling toward areas of successively increasing salinity. Thus, this factor could also affect the rate of passage through the system. A rigorous examination of these factors was not conducted during this analysis.

Concerns for Future Studies

There was no mortality during transport of fish from the Coleman National Fish Hatchery in Red Bluff to the CABA Putah Creek Facility in Davis, California. Thus, this phase needs no adjustment. There were concerns with regard to the health of salmonid smolts during the holding period following transport, the surgery, and post surgery. Few individuals died during the seven-day pre-surgery holding period during 2006-2007. One fish was killed during surgery due to error in tag implantation. No loss of life occurred during the transport, holding or surgeries stages during 2007-2008. During both study years, all fish survived the five-day holding period following surgery, as well as during the transport from CABA to the release site at Rio Vista, California. Of the 98 tagged fish released in 2006-2007, 15 USACE-tagged fish were detected at the Golden Gate, which constitutes 15% of the total released. In 2007-2008, a total of 31 out of 100 USACE-tagged fish were detected at the Golden Gate – double the survival rate. Fish tagged and released by the other agencies, varied from 5-10%. Although there are differing survival rates, it would be more ecologically accurate to release the smolts tagged for the LTMS farther upstream at Elk Landing near the Feather River.

The acoustic release design used during 2007-8 was inadequate to withstand the depths in San Pablo and San Francisco bays. The floats were made of Styrofoam which compressed when submerged in deep water which compromised their flotation capabilities. This made retrieval of the receivers impossible at times. Hard plastic buoys should be used in 2008-2009 with acoustic releases. In future study years receivers added to the cross array on the Bay Bridge should be implemented to more accurately record migratory pathways trends in the San Francisco Bay. For a better assessment of movement at San Pablo Bay, additional control and cross arrays should be utilized during the third year of the study, 2008-2009.

The study design for the third year should be improved based on the methods used in the two previous years as well as with constructive advice from the study collaborators. Recommendations were provided by Bruce MacFarlane and Steven Lindley, fisheries biologists at NMFS with a detailed research plan for 2008-2009. The results in this report are intended, in part, to serve as the basis for estimating sample size of fish for subsequent years. Tag detections recorded by the receivers at the SF 10 site for the placement of dredging material can be used and applied as a "rule of thumb" to determine sample size rather than standard calculations. The rule of thumb suggests that about 60 fish should be counted for an estimate to be reliable. A minimum of about 500 tagged smolts of both late-fall run Chinook salmon and steelhead smolts must survive the out-migration through the California Delta and be detected by the receivers in the San Francisco Estuary to properly address the research objectives.

During the first two years, the fish tagged for USACE were released at Rio Vista. A release further upstream is recommended for USACE-tagged smolts. This alteration in the study plan is in response to the potential for smolts to exhibit anomalous behavior during the acclimation period, which might be one-two days (Phillip Sandstrom, UC Davis, pers. comm.). A release in the upper reaches of the estuary likely produces more natural downstream migratory movements. Fish should be released at Elk Landing near the Feather River during 2008-2009. This point of release is considerably higher than previous points of release at Rio Vista, but will result in less mortality during outmigration than releases at other sites on the Sacramento River. A total of 1000 late-fall run Chinook salmon and steelhead smolts should be released at Elk Landing in 2009.

Further modifications to receiver moorings should be introduced in 2008-2009. The mechanical acoustic releases used during the second year of the study were unreliable. Corrosive acoustic releases should be used to increase the success rate of receiver retrieval. This type of release functions in salt water due to salt water's ability to conduct electricity. These corrosive acoustic releases have been observed by the researchers at NMFS to release more reliably than acoustically triggered mechanical releases. No surface floats should be used on the receiver moorings during 2008-2009. The use of acoustic releases is also desirable because they eliminate the need for a surface buoy, which may be caught in the propellers of a passing boat or removed by vandals. Iron lifting plates should be used to anchor the moorings instead of cement moorings. This will reduce the amount of artificial materials left on the bottom of San Francisco Bay. The design of the bridge and pier attachments will remain the same as prior years. The use of additional receivers in both experimental and control configurations at the SF-10 and SF-11 sites should create a more scientific basis for determining the time spent in this area, as an input for studying the potential effect of these dredged material placement sites on salmon migrations. More site-specific range testing should be completed near the dredged material placement sites such as SF-10 and SF-11.

CONCLUSIONS

The LTMS has made significant progress in scientifically addressing questions relating to the distribution and migratory patterns of juvenile salmonids. Continuous discussion with scientists at NMFS and UC Davis by the LMTS Science Group during the first and second year of the study resulted in a comprehensive and improved study plan for the third year of the study. With continuing work there will be sufficient data on which to reexamine aspects of the current dredging windows, facilitate consultations with NMFS, and result in scientific publications that can be used in biological opinions relating to dredging activities in the San Francisco Bay region.

Two additional years of study with 500 tagged smolts of each species would provide a larger data set and permit more statistically robust analyses.

ACKNOWLEDGMENTS

This project was carried out by personnel from the San Francisco District, U.S. Army Corps of Engineers together with personnel from UC Davis and NMFS in Santa Cruz. The smolts were tagged by Allison Bremner and Susan Ma of the San Francisco District Office of USACE. The receivers were deployed and interrogated by Allison Bremner, Bill Brostoff, and Peter LaCivita of the San Francisco District Office of USACE. Guidance on salmonid tagging and field deployments were provided by Eric Chapman, Mike Thomas, and Phil Sandstrom, of the University of California, Davis.

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Appendix 1. VR2 Receiver locations and agencies

		2006-2007		2007-2008	
Station	**Agency**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
Petaluma River	USACE	38.1133	-122.5	38.1133	-122.5
S P Bay Buoy 7	USACE	n/a	n/a	38.0311	-122.37
S P Bay Buoy 8	USACE	n/a	n/a	38.0282	-122.37
Buoy 9	USACE	38.0343	-122.35	38.0439	-122.35
Buoy 9 West	USACE	38.0471	-122.35	n/a	n/a
Buoy 10	USACE	38.04	-122.35	38.041	-122.35
Buoy 10 East	USACE	38.0392	-122.34	n/a	n/a
Petaluma River G5	USACE	38.0689	-122.42	38.0689	-122.42
Petaluma River G3	USACE	38.0583	-122.43	38.0583	-122.43
SF-10 SE	USACE	n/a	n/a	38.0064	-122.42
SF-10 NE	USACE	n/a	n/a	38.0074	-122.42
SF-10 NW	USACE	n/a	n/a	38.0035	-122.43
SF-10 SW	USACE	n/a	n/a	38.0017	-122.42
SF-10 North	USACE	38.011	-122.42	n/a	n/a
SF-10 South	USACE	38.0083	-122.42	n/a	n/a
RSRB A	USACE	37.9414	-122.48	37.9414	-122.48
RSRB B	USACE	37.9389	-122.48	37.9389	-122.48
RSRB C	USACE	37.9384	-122.47	37.9384	-122.47
RSRB D	USACE	37.9375	-122.47	37.9375	-122.47
RSRB E	USACE	37.937	-122.47	37.937	-122.47
RSRB F	USACE	37.936	-122.46	37.936	-122.46
RSRB G	USACE	37.9352	-122.41	37.9352	-122.46
RSRB H	USACE	37.9338	-122.46	37.9338	-122.46
RSRB I	USACE	37.9339	-122.45	37.9339	-122.45
RSRB J	USACE	37.9338	-122.45	37.9338	-122.45
RSRB K	USACE	37.936	-122.45	37.936	-122.45
RSRB L	USACE	37.9338	-122.44	37.9338	-122.44
RSRB M	USACE	37.9338	-122.43	37.9338	-122.43
RSRB N	USACE	37.9334	-122.44	37.9334	-122.44
RSRB O	USACE	37.9325	-122.43	37.9325	-122.43
RSRB P	USACE	37.9324	-122.43	37.9324	-122.43
RSRB Q	USACE	37.8994	-122.42	37.9328	-122.42
RSRB R	USACE	37.9322	-122.42	37.9322	-122.42
RSRB S	USACE	37.9306	-122.42	37.9306	-122.42
RSRB T	USACE	37.9306	-122.42	37.9306	-122.42
RSRB U	USACE	37.931	-122.41	37.931	-122.41
Point Richmond	USACE	37.9075	-122.39	37.9075	-122.39
Richmond Wall	USACE	37.9053	-122.39	37.9053	-122.39

Raccoon 1	USACE	37.8722	-122.45	37.8722	-122.45
Raccoon 2	USACE	37.8705	-122.45	37.8705	-122.45
Raccoon 3	USACE	37.8687	-122.44	37.8687	-122.44
Raccoon 4	USACE	37.867	-122.44	37.867	-122.44
SF-11	USACE	37.8252	-122.43	n/a	n/a
SF-11 N	USACE	n/a	n/a	37.8209	-122.42
SF-11 E	USACE	n/a	n/a	37.8208	-122.42
SF-11 S	USACE	n/a	n/a	37.824	-122.42
SF-11 W	USACE	n/a	n/a	37.8239	-122.42
BayBridge1	ECORP	37.821967	-122.331567	n/a	n/a
BayBridge2	ECORP	37.82145	-122.33305	n/a	n/a
BayBridge3	ECORP	37.82115	-122.33595	n/a	n/a
BayBridge4	ECORP	37.820583	-122.33925	n/a	n/a
BayBridge5	ECORP	37.820233	-122.34235	n/a	n/a
BayBridge6	ECORP	37.81965	-122.346133	37.81965	-122.346133
BayBridge7	ECORP	37.818933	-122.3499	37.818933	-122.3499
BayBridge8	ECORP	37.81645	-122.352567	37.81645	-122.352567
BayBridge9	ECORP	37.814517	-122.3586	37.814517	-122.3586
PortOakland1	ECORP	37.810917	-122.333083	37.810917	-122.333083
PortOakland2	ECORP	37.79885	-122.325317	37.79885	-122.325317
PortOakland3	ECORP	37.805533	-122.342533	37.805533	-122.342533
PortOakland4	ECORP	37.818783	-122.318733	37.818783	-122.318733
PortSFPier80	ECORP	37.748611	-122.375556	37.748611	-122.375556
PortSFPier45	ECORP	37.811111	-122.420556	37.811111	-122.420556
PortSFPier33/35	ECORP	37.808611	-122.404444	37.808611	-122.404444
PortSFPier30/32	ECORP	37.787222	-122.384444	37.787222	-122.384444
PortSFPier27	ECORP	37.80727	-122.40037	37.80727	-122.40037
Mare Island Pier23	ECORP	38.088017	-122.256583	38.088017	-122.256583
Mare Island Pier22	ECORP	38.088733	-122.257317	38.088733	-122.257317
Paradise Cay	ECORP	37.915233	-122.4754	n/a	n/a
Carquinez_Bridge_North	UC Davis	38.06383333	-122.2269667	38.06383333	-122.2269667
Carquinez_Bridge_Center_North	UC Davis	38.06233333	-122.22525	38.06233333	-122.22525
Carquinez_Bridge_South	UC Davis	38.05866667	-122.2251	38.05866667	-122.2251
Carquinez_Bridge_South_East	UC Davis	38.05795	-122.22455	38.05795	-122.22455
Carquinez_Bridge_Center_South2	UC Davis	n/a	n/a	38.06068	-122.22513
Benicia_Bridge_South1	UC Davis	38.03645	-122.1201	38.03645	-122.1201
Benicia_Bridge_South2	UC Davis	38.03761667	-122.1210833	38.03761667	-122.1210833
Benicia_Bridge_South3	UC Davis	38.03896	-122.12192	38.03896	-122.12192
Benicia_Bridge_North1	UC Davis	38.04376667	-122.12595	38.04376667	-122.12595
Benicia_Bridge_North2	UC Davis	38.04243333	-122.1250167	38.04243333	-122.1250167

Benicia_Bridge_North3	UC Davis	38.04123333	-122.1238167	38.04123333	-122.1238167
Benicia_Bridge_Center	UC Davis	n/a	n/a	38.03994	-122.12301
Rio_Vista_Bridge_West	UC Davis	38.15906	-121.68491	38.15906	-121.68491
Rio_Vista_Bridge_East	UC Davis	38.15869	-121.68384	38.15869	-121.68384
Rio_Vista_Bridge_East_Bank	UC Davis	38.15673333	-121.67955	38.15673333	-121.67955
Golden Gate Bridge 1	USACE/NMFS/CALFED	37.82898	-122.4741	37.82898	-122.4741
Golden Gate Bridge 1.5	USACE/NMFS/CALFED	37.82737	-122.47266	37.82737	-122.47266
Golden Gate Bridge 2	USACE/NMFS/CALFED	37.82561	-122.47125	37.82561	-122.47125
Golden Gate Bridge 2.5	USACE/NMFS/CALFED	37.82344	-122.47022	37.82344	-122.47022
Golden Gate Bridge 3	USACE/NMFS/CALFED	37.82126	-122.46918	37.82126	-122.46918
Golden Gate Bridge 3.5	USACE/NMFS/CALFED	37.81877	-122.46816	n/a	n/a
Golden Gate Bridge 3.6	USACE/NMFS/CALFED	n/a	n/a	37.81958	-122.46544
Golden Gate Bridge 4	USACE/NMFS/CALFED	37.81615	-122.46799	n/a	n/a
Golden Gate Bridge 4.1	USACE/NMFS/CALFED	n/a	n/a	37.81681	-122.46422
Golden Gate Bridge 4.5	USACE/NMFS/CALFED	37.81375	-122.46766	37.81375	-122.46766
Golden Gate Bridge 5	USACE/NMFS/CALFED	37.8112	-122.46778	37.8112	-122.46778
Golden Gate Bridge 5.5	USACE/NMFS/CALFED	37.83478	-122.46967	37.83478	-122.46967
Golden Gate Bridge 6	USACE/NMFS/CALFED	37.83393	-122.46794	37.83393	-122.46794
Golden Gate Bridge 6.5	USACE/NMFS/CALFED	37.83218	-122.4659	37.83218	-122.4659
Golden Gate Bridge 7	USACE/NMFS/CALFED	37.83025	-122.46376	37.83025	-122.46376
Golden Gate Bridge 7.2	USACE/NMFS/CALFED	n/a	n/a	37.82794	-122.46168
Golden Gate Bridge 7.5	USACE/NMFS/CALFED	37.82542	-122.45993	37.82542	-122.45993
Golden Gate Bridge 7.7	USACE/NMFS/CALFED	37.8221	-122.45841	37.8221	-122.45841
Golden Gate Bridge 8	USACE/NMFS/CALFED	37.81856	-122.45764	n/a	n/a
Golden Gate Bridge 8.4	USACE/NMFS/CALFED	n/a	n/a	37.81696	-122.45953
Golden Gate Bridge 8.5	USACE/NMFS/CALFED	37.8159	-122.45675	n/a	n/a
Golden Gate Bridge 9	USACE/NMFS/CALFED	37.81305	-122.45598	37.81305	-122.45598
Golden Gate Bridge 9.5	USACE/NMFS/CALFED	37.8094	-122.45549	37.8094	-122.45549
Chipps Island 1	Sand Miners	38.0465	-121.93805	n/a	n/a
Chipps Island 4	Sand Miners	38.04273	-121.89783	n/a	n/a

Chipps Island 15	Sand Miners	n/a	n/a	38.05111	-121.92694
Chipps Island 16	Sand Miners	n/a	n/a	38.04398	-121.93089
Chipps Island 17	Sand Miners	n/a	n/a	38.05007	-121.8982
Chipps Island 18	Sand Miners	n/a	n/a	38.04084	-121.9086
Chipps Island 6	UC Davis	38.05025	-121.92018	n/a	n/a
Chipps Island 8	UC Davis	38.04636667	-121.92035	n/a	n/a
Chipps Island 11	UC Davis	38.04613	-121.89687	n/a	n/a
Chipps Island 12	UC Davis	n/a	n/a	38.04628	-121.92974
Chipps Island 13	UC Davis	n/a	n/a	38.04832	-121.93108
Chipps Island 14	UC Davis	n/a	n/a	38.04977	-121.93125
Montezuma Slough	Sand Miners	38.07188	-121.87516	38.07188	-121.87516

Appendix 2. Letter from NMFS Regarding Project

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
777 Sonoma Ave., Room 325
Santa Rosa, CA 95404-6528

October 27, 2006

In response refer to:
SWR/F/SWR3:DPW

Al Panicia, LTMS Program Manager
U.S. Army Corps of Engineers
333 Market Street
San Francisco, California 94105

Dear Mr. Panicia:

I am writing you at the request of Ellen Johnck of the Bay Planning Coalition (BPC). Ms. Johnck has requested that NOAA's National Marine Fisheries Service (NMFS) provide comments on the U.S. Army Corps of Engineers' (Corps) draft document titled "Juvenile Salmonid Outmigration and Distribution Study Design for the San Francisco Estuary." Specifically, NMFS has been asked to provide: 1) a statement regarding our level of support for the study, 2) our role in the study, and 3) how we will use the information collected during the study in our Endangered Species Act (ESA) consultations.

As you know, the Corps and NMFS have been meeting with other Federal and state agencies on a regular basis during the last several years to address the concern of the dredging community regarding the work windows established under the Long-Term Management Strategy (LTMS) for the placement of dredged material in the San Francisco Bay region. One of the outcomes of these meetings was a written report titled "Framework for Assessment of Potential Effects of Dredging on Sensitive Fish Species in San Francisco Bay," which addresses information gaps identified by the resource agencies in regard to potential adverse effects on species from dredging activities. One of the studies identified in the assessment as a high priority by NMFS was the spatial and temporal distribution of salmonids as they migrate through the estuary en route to the Pacific Ocean as juveniles or to natal streams to spawn as adults. Currently, little is known about the life history of juvenile anadromous salmonids in the San Francisco estuary, and even less regarding how these fish are affected by dredging-related activities.

Last year, Bruce MacFarlane from NMFS' Southwest Fisheries Science Center and Peter Klimley from University of California (UC), Davis were awarded funds through California Bay-Delta Authority (CALFED) to conduct research on juvenile salmonid emigration from the Central Valley. Specifically, they will be placing miniature acoustic-transmitting devices into the abdominal cavities of 1200 juvenile late fall-run Chinook salmon and Central Valley steelhead over a three year period starting in January, 2007. The goal of their research is to track these fish from their release point far upstream in the Sacramento River to determine their transit times and potential issues with how the Sacramento River and delta is currently being operated *(i.e.,* effected by water exports).

The LTMS environmental windows working group agreed to allocate substantial funds in the support of monitoring the **1200** salmonids that will be tagged by **MacFarlane** and **Klimley** from 2007-2009. Subsequently, monitors and tags were purchased and a meeting was held with the researchers in order to coordinate efforts between the two groups. Another coordination meeting of these researchers is schedule for November 16, 2006. In addition to the financial contribution from the LTMS group, members of the BPC also contributed funds in order to participate in the study. The Corps drafted the study design document in order to facilitate collaboration between these research efforts.

In answer to the first two questions, NMFS supports this research and is very interested in the potential data that may be collected. One need look no further than the partnership of **NMFS'** Santa Cruz Laboratory scientists who co-authored the original proposal to **CALFED,** and who have been conducting field tests with the monitors as well as fine tuning their surgical technique. As discussed above, NMFS has placed a high priority regarding the need to understand how these fish utilize the estuary en route to the ocean. It is my understanding that David **Woodbury** of my staff has been consistently advocating the **LTMS'** participation in this effort for the past two years. It is likely that if not for the funding that NMFS and UC Davis received from CALFED, as well as their expertise in this emerging field of acoustic technology, the LTMS environmental windows working group would not have been able to undertake **such** a large effort, either financially or with the logistic aspects of the study.

The simple answer to the third question of how NMFS will use the data collected from this study is that we are mandated by law to use the "best scientific and commercial data available" in our ESA consultations. Thus, the results of this study may be used in our biological opinions and concurrence letters concluding either formal or informal ESA section 7 consultations relating to activities conducted in the San Francisco Bay region.

However, please bear in mind that the **MacFarlane/Klimley** study was not designed to answer questions regarding potential impacts to listed salmonids from dredging or to determine if the dredging work windows are set properly. **Thus,** given that the Corps and BPC are primarily interested in tracking tagged fish to assess the effects of various activities in San Francisco Bay, there will likely be a need for additional future studies to address specific questions related to dredging and environmental windows. For example, the **1,200** tagged salmonids will all be released in January. Typically, the progeny of naturally-spawned fish emigrate over a several month period. Therefore, the data that will be collected is not likely to provide substantial insight on whether or not the environmental windows are set properly. Also, there will likely be no dredging activities occurring when the fish migrate through the estuary, so determining how the fish react to dredging or the disposal of dredged material will not be possible. Additionally, only juveniles are being tagged, so the utilization of the bay by adult salmonids will not be answered.

On the other hand, if enough monitors are placed along the migration route in the estuary, then we should be able to determine the rate at which these fish pass through the estuary and how they are spatially distributed. That information would substantially increase our understanding of the life history of juvenile anadromous salmonids in San Francisco Bay, and some inferences can be made regarding the potential effects of dredging related activities. For example, duration of exposure is a critical metric in terms of contaminant uptake as the fish migrate through the estuary. If it is shown that the fish migrate rapidly through the estuary, then their duration of exposure to contaminants resuspended during dredging operations would be minimal and not likely result in any adverse effects. As for spatial distribution, if the fish remain in the deep-water channels, then dredging projects located in the shallow margins of the estuary may have less restrictive conditions placed in the dredging permits.

The draft study design document indicates that the lowest priority monitoring sites include the dredged material disposal sites. In order to determine if salmonids are present at the disposal sites, it is imperative that monitors are positioned there, but not at the cost of removing monitors from other locations such as the Golden Gate Bridge, Richmond-San Rafael Bridge, or across Raccoon Strait.

As the 400 juvenile salmonids per year are being released far upstream in the Sacramento River, there remains the question of how many will survive to be picked up by monitors situated within the estuary. It is my understanding that an additional 100 juvenile salmonids may be tagged and released near Rio Vista in order to boost the number of tagged fish in the San Francisco estuary. As with any study, an adequate sample size is important, especially given the spatial scale of the lower estuary. After the first year, an analysis should be conducted to determine if the number of fish tagged should be increased, as well as any change in the placement of monitors. Another concern is the interannual variation that may exist regarding the temporal and spatial distribution of juvenile salmonids as they migrate through the estuary. For example, outflow has been shown to strongly influence juvenile salmonid migration. Hopefully, there will be a "dry" and "wet" year in 2007-2009, so we can correlate this variable with results obtained from the monitors.

In summary, there is currently a lack of scientific data regarding the spatial and temporal distribution of juvenile listed salmonids in San Francisco Bay. The results obtained from this study are expected to expand our knowledge regarding the life history of juvenile salmonids in San Francisco Bay and assist in our assessment of potential efforts during ESA section 7 consultations. Thus, by obtaining information on how these fish utilize the estuary, NMFS will have additional scientific data to make informed decisions regarding the potential impacts of dredging activities on juvenile listed salmonids.

If you have any questions regarding NMFS comments, please feel free to contact me at 707-575-6058 or Mr. David Woodbury of my staff at 707-575-6088.

Sincerely,

Dick Butler
Santa Rosa Area Office Supervisor
Protected Resources Division

cc: Russ Strach, NMFS, Sacramento, California
LTC Craig Kiley, Corps, San Francisco, California
Bill Brostoff, Corps, San Francisco, California
Peter LaCivita, Corps, San Francisco, California
Ellen Johnck, Bay Planning Coalition, San Francisco, California
Brian Ross, EPA, San Francisco, California
Steve Goldbeck, BCDC, San Francisco, California
Ryan Olah, USFWS, Sacramento, California
George Isaac, CDFG, Monterey, California

Appendix 2. Sample Logbooks

Date:	Study name:	Species:	Run:	Raceway:	Holding tank temp/DO:
Surgeon:	Data Recorder:	Drug conc. KO/Surgery:	Suture type/size:	Tag type:	Surgery tank temp/DO:

Fish ID	Time	(hh:mm:ss)	Fork Length	Weight	Scales	Fins	Eyes	Photo?	Tag weight	Tag ID/SN	Holding tank#	DNA sample?
			(mm)	(g)	(Good, Fair, Poor)			(Y/N)	(g)			(Y/N)
	In drugs:	: :										
	out drugs:	: :										
	out surgery:	: :										
	recovery:	: :										
	Notes:											
	In drugs:	: :										
	out drugs:	: :										
	out surgery:	: :										
	recovery:	: :										
	Notes:											
	In drugs:	: :										
	out drugs:	: :										
	out surgery:	: :										
	recovery:	: :										
	Notes:											

The surgery data sheet was designed by a staff biologist for the NMFS Southwest Fisheries Science Center. Data recorded on this form will provide information on the individual fishes' physical parameters and condition before, during and after the surgery, and specific details of the surgical procedure.

Release Log		
Date:	**Time:**	**Study name:**
Species:	**Total # released:**	**Released by:**
Location:		
Lat:	**Lon:**	**Location Photo?**
Transport method:		
Time in transport:	**Flow conditions:**	**Weather notes:**
Tags tested before release?	**# of Ushers?**	
List Tag Codes:		
Notes:		

This form, created by a staff biologist for the NMFS Southwest Fisheries Science Center, is designed so the data recorder provides a detailed account of each fish release. Information on the environmental conditions the fish were released in can be used when analyzing the fishes' initial swimming behavior.

Monitor deployment data entry form

IMPORTANT: The computer you use to initialize and download the monitors must be in Pacific Standard Time (UTC-8hrs), DO NOT USE DAYLIGHT SAVINGS TIME!!! It must also have the exact time! Check and correct the computers time before downloading data.

This form has only the critically important deployment data. It does not have all of the fields in the Monitor_Download_Record. Please fill out this excel form using the correct data formats and email to both: cyril.michel@noaa.gov and arnold.ammann@noaa.gov

				Deployment Times				**Depths**				
Location Name	VR2 SN	Latitude	Longitude	Start	End	New Study Initialized?	Correct Pacific Standard Time?	Water Depth	VR2 meters above bottom	VR2 meters below surface	VR2 orientation	Notes
				(put in water)	**(taken out of water)**							
		(degrees decimal)	(degrees decimal)	(MM/DD/YYYY 00:00)	(MM/DD/YYYY 00:00)	(Y or N)	(Y or N)	(meters)	(meters)	(meters)	(up or down)	
EXAMPLE	3007	37.828978	-122.474102	8/10/2006 12:02	11/16/2006 12:38	Y	Y	48	4	45	up	

The monitor deployment data forms are designed to ensure that all collaborators in the study use the same protocol and collect the same data when deploying monitors and downloading data from the monitors.

California Salmon Tracking Project

If found with data, please return to Pete LaCivita

1455 Market St. 15th Floor San Francisco, CA 94103

415-503-6864

Monitor Download Record

Deployment Location:

Location Name:

VR2 serial number:

Lat:

Lon:

(preferred format is Decimal degrees e.g. 37.8945)

Water depth (m):

Visual cues:

Previous download or initialization:

Date:

New study initialized? **YES NO**

(circle one.)

Name of laptop used:

Did it have correct time (PST)? **YES NO**

Current Download:

Date and time:

Operator's Name:

Operator's Phone:

Operator's email:

Name of laptop used:

Set to correct time before use (PST)? **YES NO**

(no daylight savings, get time from GPS or atomic clock)

Time removed from water:

Time returned to water:

From downloaded data file:

New file name:

Time (yyyy-mm-dd hh:mm:ss)

VR2 start time:

VR2 stop time:

PC time at download:

Last battery replacement:

Total deployments:

Percent memory full:

Total Syncs:

Checksum invalid:

Total pulses received:

Total detections:

Gear Inspection? **YES NO**

Hardware condition:

(rusted, pitted, bent, etc.?)

Rope/cable condition:

(chaffing, fraying, etc.?)

VR2 condition:

Fouling organisms:

Overall level of fouling:

(light, medium or heavy?)

Acoustic Release? **YES NO**

Make and model:

Serial Number:

Release code:

Last battery replacement:

Approx time for surfacing:

Hobo temp logger? **YES NO**

Serial number:

Frequency of recordings:

Date hobo first used:

Depth of hobo:

Deployment Method:

Depth of VR2 from bottom:

Depth of VR2 from surface:

Mooring method:

(e.g. attached to solid object above or below water-line, hanging from buoy, attached to a bouy-to-weight line)

Additional Notes:
(e.g. exceptional water or climate conditions, lost/stolen/vandalized/broken gear, dead batteries)

This form is designed so the data recorder provides all details of the monitor download event.

California Salmon Tracking Project - Monitor Location Record

Location Name:		map of monitor location:
Lattitude (dec.deg) :		
Longitude (dec.deg):		
Monitor Information		
Owner's name:		
Owner's phone:		
VR2 serial number:		
Installed Code Map:		
Date Map upgraded:		
Monitor Deployment Method		
Describe mooring:		diagram mooring:
Detail construction materials:		
Estimated VR2 depth(m):		
hydrophone oriented up or down?:		
Attached to fixed structure?:		
Date of first installation:		insert photo of monitor location:
Date of removal:		
Dates of gaps in coverage : (e.g. lost, batteries died, malfunction):		
Tips for finding and retreiving monitor:		

This form summarizes the information associated with each individual monitor site.

Appendix 4. Statistical Analyses

Transit Time 2007 Statistical Analysis

<u>Statistical Analysis between Agency Tagged Fish: Chinook 2007</u>

Summary: There is no statistical difference between agency tagged fish between the upper or lower estuary. Regionally, there is a statistical difference.

1. Agency Tagged Fish: CALFED, USACE, USFWS: Upper Estuary Comparison

One Way Analysis of Variance Friday, November 14, 2008, 10:32:53 AM

Data source: Upper Estuary Days Chinook 2007 in Notebook 1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, November 14, 2008, 10:32:53 AM

Data source: Upper Estuary Days Chinook 2007 in Notebook 1

Group	N	Missing	Median	25%	75%
Col 1	5	1	9.556	6.411	18.532
Col 2	22	1	6.726	5.556	9.209
Col 3	2	1	3.979	3.979	3.979

H = 3.520 with 2 degrees of freedom. (P = 0.172)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.172)

2. Agency Tagged Fish: CALFED, USACE, USFWS: Lower Estuary Comparison

One Way Analysis of Variance Friday, November 14, 2008, 10:36:58 AM

Data source: Lower Estuary Days Chinook 2007 in Notebook 1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, November 14, 2008, 10:36:58 AM

Data source: Lower Estuary Days Chinook 2007 in Notebook 1

Group	N	Missing	Median	25%	75%
Col 1	2	1	0.921	0.921	0.921
Col 2	5	1	3.352	1.890	60.442
Col 3	22	1	2.452	1.947	3.365

H = 3.190 with 2 degrees of freedom. (P = 0.203)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference   (P = 0.203).

3. Upper and Lower Estuary Comparison

t-test Tuesday, January 06, 2009, 9:02:38 AM

Data source: Data 3 in Interest Sites

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Tuesday, January 06, 2009, 9:02:38 AM

Data source: Data 3 in Interest Sites

Group	N	Missing	Median	25%	75%
Col 1	262	0.0953	0.0681	0.112	
Col 2	262	0.215	0.155	0.273	

Mann-Whitney U Statistic= 519.000

T = 357.000 n(small)= 24 n(big)= 24 (P = <0.001)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

Statistical Analysis Between Agency Tagged Fish: Steelhead 2007

Summary: There is no statistical difference between agency tagged fish in the upper or lower estuary. Transit between the two regions are statistically different.

1. Agency tagged fish CALFED, USACE Upper Estuary Comparison

t-test Friday, November 14, 2008, 11:29:07 AM

Data source: Steelhead 2007 Upper in Transit 2007_Final.SNB

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Friday, November 14, 2008, 11:29:07 AM

Data source: Steelhead 2007 Upper in Transit 2007_Final.SNB

Group	N	Missing	Median	25%	75%

Col 1	9	0	2.017	1.949	2.825
Col 2	11	0	3.973	2.915	18.345

Mann-Whitney U Statistic= 86.000

T = 58.000 n(small)= 9 n(big)= 11 (P = 0.006)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = 0.006)

2. CALFED region comparison: Upper and lower estuaries

t-test Friday, November 14, 2008, 11:34:31 AM

Data source: Region Comparison Steelhead CALFED 2007 in Transit 2007_Final.SNB

Normality Test: Passed (P = 0.061)

Equal Variance Test: Passed (P = 0.585)

Group Name	N	Missing	Mean	Std Dev	SEM
Col 1	9	0	2.474	0.940	0.313
Col 2	9	0	1.881	0.546	0.182

Difference 0.592

t = 1.635 with 16 degrees of freedom. (P = 0.122)

95 percent confidence interval for difference of means: -0.176 to 1.361

The difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. There is not a statistically significant difference between the input groups (P = 0.122).

Power of performed test with alpha = 0.050: 0.217

3. USACE region comparison: Upper and Lower estuaries

t-test Friday, November 14, 2008, 11:35:49 AM

Data source: Region Comparison STH USACE 2007 in Transit 2007_Final.SNB

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Friday, November 14, 2008, 11:35:49 AM

Data source: Region Comparison STH USACE 2007 in Transit 2007_Final.SNB

Group	N	Missing	Median	25%	75%

Col 1	11	0	3.973	2.915	18.345
Col 2	11	0	1.542	0.983	1.924

Mann-Whitney U Statistic= 12.000

T = 175.000 n(small)= 11 n(big)= 11 (P = 0.002)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = 0.002)

Transit Time 2008 Statistical Analysis

Statistical Analysis between Agency Tagged Fish: Chinook 2008

1. Upper Estuary: Agency tagged fish Comparison- CALFED, USFWS, USACE

One Way Analysis of Variance Friday, November 14, 2008, 2:06:00 PM

Data source: Agency CLF 2008 Upper Comparison in Notebook 1

Normality Test: Passed (P = 0.224)

Equal Variance Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, November 14, 2008, 2:06:00 PM

Data source: Agency CLF 2008 Upper Comparison in Notebook 1

Group	N	Missing	Median	25%	75%
Col 1	11	1	5.983	5.630	6.754
Col 2	2	1	10.729	10.729	10.729
Col 3	12	1	9.423	5.109	11.552

H = 3.028 with 2 degrees of freedom. (P = 0.220)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.220)

2. Lower Estuary: Agency Tagged Fish Comparison- CALFED, USFWS, USACE

One Way Analysis of Variance Friday, November 14, 2008, 2:08:35 PM

Data source: Agency CLF 2008 Lower Comparison in Transit 2008_ Final.SNB

Normality Test: Passed (P = 0.347)

Equal Variance Test: Passed (P = 0.739)

Group Name	N	Missing	Mean	Std Dev	SEM
Col 1	10	0	2.734	1.048	0.331
Col 2	1	0	1.019	0.000	0.000
Col 3	11	0	2.768	1.271	0.383

Source of Variation	DF	SS	MS	F	P
Between Groups	1	0.00619	0.00619	0.00452	0.947
Residual	19	26.051	1.371		
Total	20	26.057			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.947).

Power of performed test with alpha = 0.050: 0.048

The power of the performed test (0.048) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists.
Negative results should be interpreted cautiously.

3. Region Comparison: Upper vs. Lower Estuary – Chinook 2008

t-test Friday, November 14, 2008, 2:10:12 PM

Data source: Region Comparison CLF in Transit 2008_ Final.SNB

Normality Test: Passed (P = 0.215)

Equal Variance Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Friday, November 14, 2008, 2:10:12 PM

Data source: Region Comparison CLF in Transit 2008_ Final.SNB

Group	N	Missing	Median	25%	75%
Col 1	22	0	6.501	5.334	9.595
Col 2	22	0	2.395	1.938	3.446

Mann-Whitney U Statistic= 29.000

T = 708.000 n(small)= 22 n(big)= 22 (P = <0.001)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

Statistical Analysis between Agency Tagged Fish: Steelhead 2008

1. Upper Estuary: Agency Tagged Fish Comparison- DWR, USACE, CALFED

One Way Analysis of Variance Friday, November 14, 2008, 2:27:37 PM

Data source: Agency STH 2008 Upper in Transit 2008_ Final.SNB

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, November 14, 2008, 2:27:37 PM

Data source: Agency STH 2008 Upper in Transit 2008_ Final.SNB

Group	N	Missing	Median	25%	75%
Col 1	2	1	1.127	1.127	1.127
Col 2	6	1	5.675	3.636	6.752
Col 3	31	1	4.666	3.018	7.107

H = 2.941 with 2 degrees of freedom. (P = 0.230)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.230)

2. Lower Estuary: Agency Tagged Fish Comparison- DWR, CALFED, USACE

One Way Analysis of Variance Friday, November 14, 2008, 2:29:27 PM

Data source: Agency STH 2008 Lower in Transit 2008_ Final.SNB

Normality Test: Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Friday, November 14, 2008, 2:29:27 PM

Data source: Agency STH 2008 Lower in Transit 2008_ Final.SNB

Group	N	Missing	Median	25%	75%
Col 1	1	0	1.550	1.550	1.550
Col 2	5	0	1.924	1.314	5.832
Col 3	30	0	1.385	1.077	1.821

H = 1.808 with 2 degrees of freedom. (P = 0.405)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.405)

3. Region Comparison: Steelhead 2008

t-test Friday, November 14, 2008, 2:30:26 PM

Data source: Region Comparison STH 2008 in Transit 2008_ Final.SNB

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Friday, November 14, 2008, 2:30:26 PM

Data source: Region Comparison STH 2008 in Transit 2008_ Final.SNB

Group	N	Missing	Median	25%	75%

Col 1	36	0	4.666	2.866	7.014
Col 2	36	0	1.425	1.103	1.887

Mann-Whitney U Statistic= 148.000

T = 1814.000 n(small)= 36 n(big)= 36 (P = <0.001)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

2007 SF 10 Statistical Analysis

Data source: SF 10 2007 in Notebook 1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Monday, November 24, 2008, 2:59:34 PM

Data source: SF 10 2007 in Notebook 1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 1	14	0	5.275	3.533	12.100
Col 2	6	0	20.683	7.983	45.467

Mann-Whitney U Statistic= 25.000

T = 80.000 n(small)= 6 n(big)= 14 (P = 0.174)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.174)

SF 10 and Alcatraz 2008 Statistical Analysis

SF 10 Chinook Agency Tagged Fish 2008

t-test Sunday, November 16, 2008, 6:07:26 PM

Data source: SF 10 Agency Fish Chinook 2008 in Notebook 1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Sunday, November 16, 2008, 6:07:26 PM

Data source: SF 10 Agency Fish Chinook 2008 in Notebook 1

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Col 1	19	0	4.150	1.513	9.475
Col 2	6	0	2.083	0.883	4.033

Mann-Whitney U Statistic= 75.000

T = 60.000 n(small)= 6 n(big)= 19 (P = 0.265)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.265)

SF 10 Steelhead Agency Fish 2008

t-test Sunday, November 16, 2008, 6:11:56 PM

Data source: SF 10 Agency Fish Steelhead 2008 in Notebook 1

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Sunday, November 16, 2008, 6:11:56 PM

Data source: SF 10 Agency Fish Steelhead 2008 in Notebook 1

Group	N	Missing	Median	25%	75%
Col 1	20	0	5.108	3.117	15.208
Col 2	43	0	4.033	2.404	7.604

Mann-Whitney U Statistic= 344.000

T = 726.000 n(small)= 20 n(big)= 43 (P = 0.207)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.207)

SF 10 Species Comparison 2008

t-test Monday, November 24, 2008, 3:37:11 PM

Data source: Species Comparison SF 10 2008 in Residence SF10 and Alcatraz 2008

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Monday, November 24, 2008, 3:37:11 PM

Data source: Species Comparison SF 10 2008 in Residence SF10 and Alcatraz 2008

Group	N	Missing	Median	25%	75%
Col 1	16	0	3.067	1.225	12.675
Col 2	36	0	7.108	3.583	12.892

Mann-Whitney U Statistic= 370.000

T = 342.000 n(small)= 16 n(big)= 36 (P = 0.106)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.106)

Alcatraz Steelhead Agency Tagged Fish 2008

t-test Sunday, November 16, 2008, 6:41:17 PM

Data source: Data 5 in Residence SF10 and Alcatraz 2008.SNB

Normality Test: Failed (P < 0.050)

Test execution ended by user request, Rank Sum Test begun

Mann-Whitney Rank Sum Test Sunday, November 16, 2008, 6:41:17 PM

Data source: Data 5 in Residence SF10 and Alcatraz 2008.SNB

Group	N	Missing	Median	25%	75%
Col 1	8	0	4.158	1.125	14.100
Col 2	5	0	8.817	5.996	11.725

Mann-Whitney U Statistic= 15.000

T = 40.000 n(small)= 5 n(big)= 8 P(est.)= 0.510 P(exact)= 0.524

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.524)

Alcatraz Species Comparison 2008

t-test Monday, November 24, 2008, 3:38:48 PM

Data source: Alcatraz Species Comparison 2008 in Residence SF10 and Alcatraz 2008

Normality Test: Passed (P = 0.055)

Equal Variance Test: Passed (P = 0.391)

Group Name	N	Missing	Mean	Std Dev	SEM
Col 1	5	0	4.840	4.087	1.828
Col 2	8	0	13.390	13.693	4.841

Difference -8.550

t = -1.339 with 11 degrees of freedom. (P = 0.207)

95 percent confidence interval for difference of means: -22.600 to 5.501

The difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. There is not a statistically significant difference between the input groups (P = 0.207).

Power of performed test with alpha = 0.050: 0.122

The power of the performed test (0.122) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists.
Negative results should be interpreted cautiously.

The difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. There is not a statistically significant difference between the input groups (P = 0.360).

Power of performed test with alpha = 0.050: 0.050

The power of the performed test (0.050) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists.
Negative results should be interpreted cautiously.