Steelhead Smolt Outmigration and Survival Study: Pond A8, A7 & A5 Entrainment and Escapement.

Final Report

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Introduction

The New Almaden Mercury Mining District, established 1845 in the hills south of San Jose, California, was the first mercury mine in the state (Snell 1964). It was located at the headwaters of the Guadalupe River which flows into the Alviso Marsh at Guadalupe Slough and Alviso Slough. Over 34.5 x10^6kg quicksilver were excavated from the area. Intense cinnabar mercury mining, through the early 20th century, ultimately resulted in the contamination of the entire watershed (nps.gov). Following the closure of the facility in 1912, the abandoned mines continued to erode and deliver hundreds of kilograms of mercury per year. It was estimated that between 1845 and 1975 the New Almaden Mercury Mine District had contributed over 3.7 x 10^7 kg (a mass equivalent to 240 blue whales) to the river and marshes at their terminus (Cargill et al. 1980). In concordance with the 1972 Federal Clean Water Act, the state of California has classified the Guadalupe River as contaminated by mercury and has included them in State 303(d) listings.

In more recent years, the Alviso Marsh salt ponds, connected to the Guadalupe watershed and downstream of the New Almaden mercury mine, have been the subject of restoration activities by a consortium of state and federal agencies, as well as private cooperation *http://www.southbayrestoration.org*. In 2003, the South Bay Salt Pond Restoration Program ("SBSPRP") initiated the restoration of ~15,000 acres of former salt production ponds. Some of these areas contain highly contaminated mercury laden sediments due to previous activities at New Almaden (Mckee et al 2010, Thomas et al. 2010). Pond A8, the upstream most pond on Alviso Slough, is one of these "hotspots". Restoration of this pond raised significant concerns over legacy mercury remobilization and the potential impacts to the biota downstream of the pond. An operable tide gate system was constructed at the upstream connection to Alviso Slough. The A8 "armored notch" tide gate system allows for adaptive management of tidal flow to the adjacent slough should mercury contamination have observable effects on biota. After the completion of this structure, approximately 1,400 acres of former salt pond was opened to Alviso Slough starting in June of 2011.

The "armored notch" located in the south-east corner of pond A8 consists of eight 4-foot wide cement bays each with 10 removable aluminum doors per tide gate separating the pond from Alviso Slough (Figure 1). Currently, the eight tide gates allow for complete operational control and implementation of specific management objectives based on conditions within and surrounding this location. However, opening the pond to tidal action during the migratory period of Central California Coast (CCC) steelhead (*Oncorhynchus mykiss*) has the potential to entrain smolts in the Pond A8 and creates a potential risk of trapping. Threatened CCC steelhead are known to inhabit the watershed (Federal Register 1997, 2000).

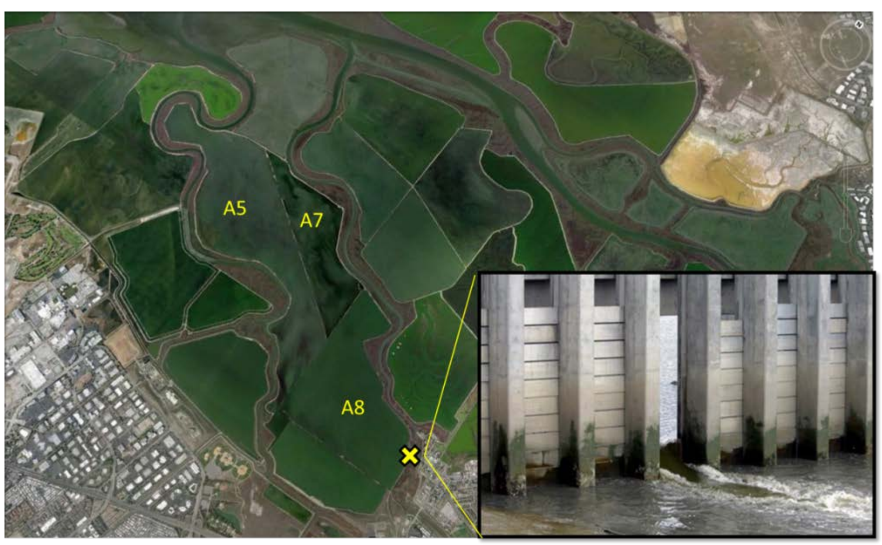

Figure 1. The "armored notch" on Pond A8 in the Alviso Marsh showing the removable aluminum doors/gates within the 8 bays. Each opening is approximately 4 feet wide by 10 feet tall.

Due to the presence of CCC steelhead, consultation pursuant to section 7 of the Endangered Species Act of 1973 (16 U.S.C. 1531 *et seq*) was conducted for the SBSPRP. The biological opinion, issued by NOAA/NMFS, covered Phase 1 actions and included future maintenance operations of the A8 notch to protect the threatened CCC steelhead (NOAA/NMFS Biological Opinion 2009). A specific management and operation schedule for pond A8, as well as two connected ponds, A7 and A5, were included to reduce the risk of steelhead smolt mortality due to fish trapping in the pond. In its implementation, the eight operable 4-ft bays at the armored notch were scheduled to function in two seasonal modes. A winter/spring operational mode, between December 1 and May 31, at which time all bays are closed, and a summer/fall operational mode, June 1 to November 30, when three of the eight bays are open. The complete management strategy of Phase 1 is outlined in Table 1.

Table 1. Phase 1 management plan. The timing of the tidal gates on Ponds A8, A7 and A5 are outlined according to the Winter/Spring and Summer/Fall operational modes

The South Bay Salt Pond Restoration Program proposed to conduct fish monitoring, water quality, mercury studies and measurement of scouring in Alviso Slough to inform the operation and ongoing configuration of the Pond A8 notch. The biological opinion issued by

NMFS requires all monitoring and applied studies proposals that involve fish sampling be submitted to NMFS for review and approval. The muted tidal action at Pond A8 was designed to function so that if unacceptable ecological impacts occur, i.e. an increase in mercury bioavailability, tidal exchange in Pond A8 will be eliminated to mitigate long-term adverse impacts. In such an event, water management of ponds A5 and A7 will revert to initial operations. Phase 1 obligates the SBSPRP to operate the complex as a managed pond with muted tidal conditions following previously stated seasonal modes.

Managing the pond according to Phase 1 ensures that CCC steelhead have the opportunity to successfully out-migrate the Guadalupe River through Alviso Slough before opening the tide gates. However, keeping the pond closed through springtime, when temperatures are rising rapidly, poses the risk of increasing the bioavailability of the inorganic mercury load present in the pond. Warmer water temperatures can result in over production of primary producers. Phytoplankton in highly productive areas is subject to massive die offs after the sun has set and photosynthesis has stopped. Dying phytoplankton then settles to the benthos stimulating microbial production. This can lead to increased methylation of inorganic mercury resulting in higher bioavailability and toxicity (Ackerman et al. 2013).

The Steelhead Smolt Outmigration and Survival study was proposed to address the impacts that operating the armored notch with three bays open year round would have on both CCC steelhead entrainment and the methylation of mercury within the A8, A7, and A5 complex. The study facilitates an earlier opening schedule for the gates, to combat increasing water temperatures within the pond via tidal flushing. Since the peak emigration period for steelhead smolts is April and May, we have focused our efforts on the spring time period. This study employed Passive Integrated Transponder (PIT) tags injected into wild *O. mykiss* collected in the Guadalupe River and Radio Frequency Identification (RFID) remote antenna interrogation systems to detect fish passage from the river and into/out of the pond A8 armored notch, A5 and A7 water control structures. This report details year one of the pilot effort and attempts to address the issues surrounding the potential trapping of outmigrating CCC steelhead smolts in Pond A8, A7 and A5.

Methods

Fish Collection & Tagging Protocol

We conducted 5 surveys at a total of 7 sites within the Guadalupe River watershed (Figure 2). Each survey consisted of sampling at 2 sites (St. Johns Street and Coleman Avenue), plus one to four additional sites.

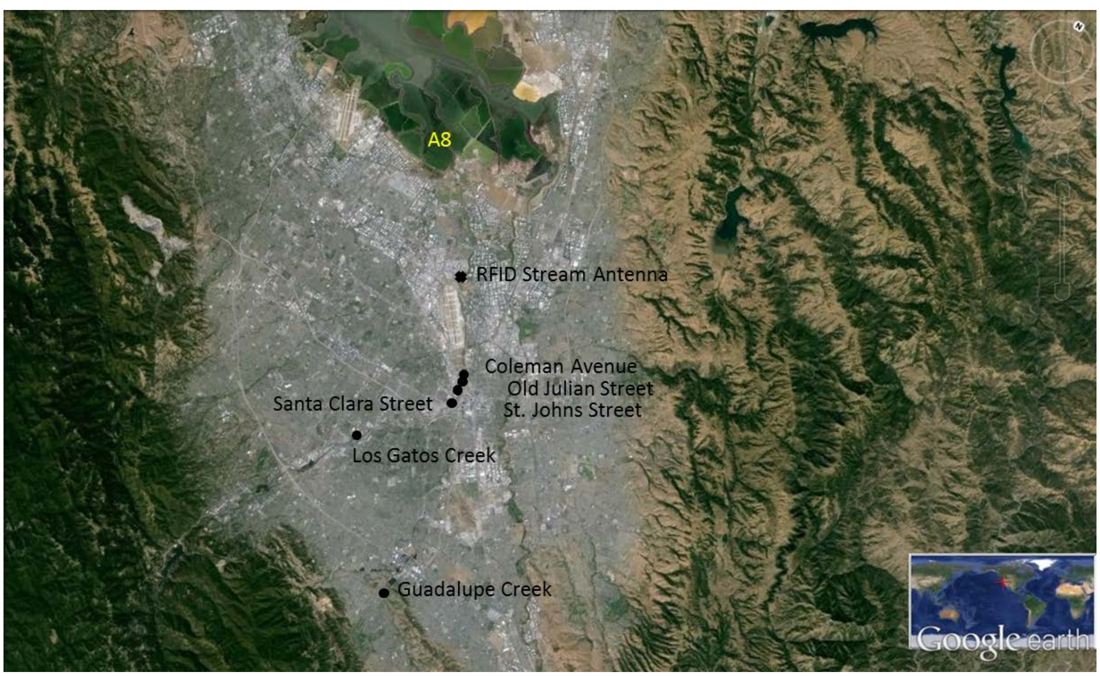

Figure 2. Google earth map of electrofishing sites and location of the stream antenna.

Survey dates were: December 16th 2013, January 17th 2014, February 12th, February 21st and March 14th (Table 2).

Survey	Date	Coleman Ave	St. John St.	Santa Clara St.	Old Julian St.	Airport Blvd.	Los Gatos Creek	Guadalupe Creek
1	12/16/2013	●	●					
2	1/17/2014	●	●	●	●			●
3	2/12/2014	●	●			●		
4	2/21/2014	●	●				●	
5	3/14/2014	●	●					

Table 2. Survey sampling dates and sites in the Guadalupe River watershed.

When possible, two passes of a riffle stretch approximately 100 linear feet was sampled. Fish were collected using a Smith Root model LR-24 backpack electrofishing unit using the standard voltage level of 25 watts average power output between the electrodes at a frequency of 30 Hz. (Figure 3)(Smith-Root.com).

Figure 3. Backpack electrofishing on the Guadalupe River. In the picture, Jason Nishijima SCVWD, Billy Tu SJSU, Jon Cook and Felipe La Luz UCD.

Multiple passes were made over the same stretch of stream with one person operating the electrofisher and 2 people netting. A fourth person followed with a flow-through live car and monitored fish recovery. At the completion of each pass, all *O. mykiss* were measured for standard length and placed in a bucket with a concentration of 40-60 ppm of Clove oil for approximately 3 minutes (Keene et al, 1998). All other species were immediately released to the stream. Once measured, a determination was made regarding which tag size was suitable for each individual fish, based on fork length. Bateman et al (2006) explored survival rates for ≤90 mm SL *O. mykiss* tagged with 23 mm HDX tags and found survival of 86%. To be conservative, we chose a threshold of 100 mm FL since survival was a priority.

Tags were implanted on the mid-ventral line posterior to the pectoral fins using an MK10 implanter from Biomark (Figure 4) (Gries and Letcher 2002). All tagging was delegated to an experienced team member to ensure maximum survival. After implantation, fish were immediately returned to an in-stream live car and allowed to recover. They were released after they became capable of remaining upright in the water column and self-oriented into the current independently. This usually occurred within the first 5 minutes of return to the live car.

Figure 4. CCC steelhead being implanted with a 23mm HDX tag. Careful consideration was taken to insert the tag posterior to pectoral fins on the mid-ventral line as to minimize potential interference with vital organs.

General RFID Technology

To detect passage of CCC steelhead, we employed Radio Frequency Identification (RFID) technology on the armored notch bays in pond A8, the water control structures in ponds A5 and A7 and in the lower Guadalupe River. RFID has been used extensively throughout the Pacific North West for determining out-migration timing in streams and estuarine residence time of salmonids (see www.ptagis.org). RFID works by emitting an alternating magnetic field in a radio frequency range from a reader (detector) through a conductive metal (e.g. copper or aluminum). The detection range of RFID tags can vary depending on the gage of wire used, the power (volts) used to create the radio frequency, the conductance of the water, and the size and orientation of the tag used.

Currently, two types of PIT RFID systems exist; half-duplex (HDX) and full duplex (FDX). The differing technology has been likened to AM and FM radios stations; where half-duplex systems send short bursts and pause (FM), and full-duplex send and receive continuously (AM). HDX RFID systems have better noise immunity and require simpler and larger antennas. FDX tags tend to have better tag detection capability since the reader is sending and receiving the signal simultaneously; however are more susceptible to noise. Two sizes of Passive Integrated Transponder (PIT) tags, 12 and 23mm, were used in this study (Figure 5), allowing fish as small as 80-mm to be tagged. The PIT tag is encoded with a unique identification number that is transmitted and received by the electromagnetic field as the tag passes by, through or over the antenna. The tags can emit their unique codes up to 30 or 14, Hz for FDX and HDX respectively, reducing the risk of a missed detection.

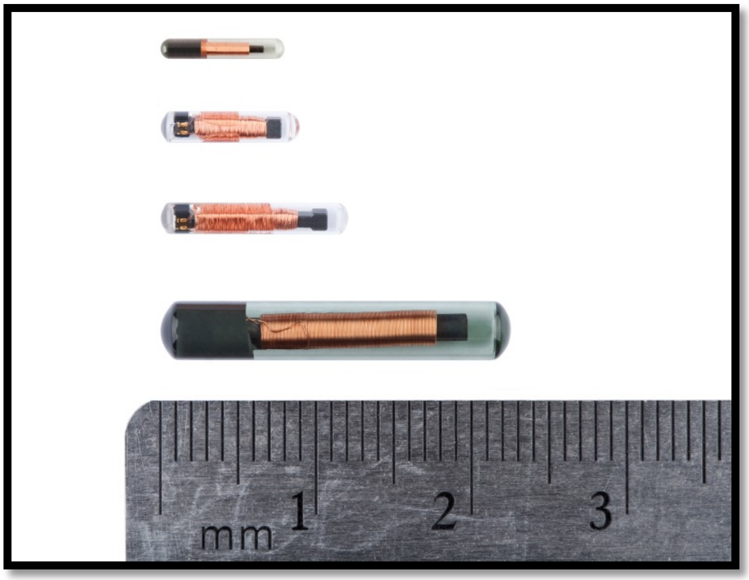

Figure 5. An array of PIT tag sizes. For this study we used both 12 mm and 23 mm tags (bottom two). Source: Biomark.com

Antenna System

Pond A8

The three antennas on Pond A8 are approximately 4 feet wide by 8 feet tall, designed to encompass the entire water column irrespective of tide height. For the physical structure, the antennas utilized a frame constructed of 2 inch plastic PVC piping. Inside of the PVC, cut corrugated plastic material (Polygal Inc.) was inserted and 2 runs of 8 AWG fine stranded copper wire was installed within the corrugations as recommended by Oregon RFID (*Warren Leach personal communication*). This configuration helped to ensure that the spacing of the internal wiring of the antenna remained consistent and led to a more effective read range. The 3 antennae are operated by 3 single HDX readers (Oregon RFID Inc.), which had been synchronized to reduce interference, and powered by six 12-V marine batteries (Figure 6).

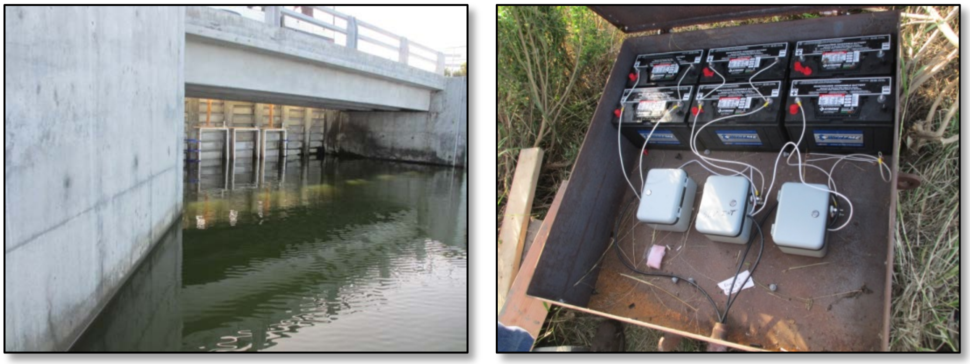

Figure 6. Left- A view of the tidal gates with antennae installed prior to opening. Right- Three synchronized reader boxes powered by six 12V marine batteries.

Pond A5 and A7 Systems

At Ponds A5 and A7 a circular antenna design, capable of encompassing their 4-ft diameter flapper gates, was utilized. Each antenna was operated by a single HDX reader (Oregon RFID Inc.) and two 12-V deep cycle marine batteries. Each antenna consisted of a 4-ft diameter octagon constructed out of 2-in PVC tubing, with 2 runs of insulated 8-AWG fine strand copper wire inside. They were then mounted on 2x4 wooden frames which were attached to the tidal control gates on the inside of Pond A7 and outside of Pond A5, using heavy duty ratchet straps (figure 7). Challenges at these locations include the high velocity of water passing through the gates at certain times in the tidal cycle as well as higher salinities than those experienced at the tidal gate on A8.

Figure 7. Left- Single HDX reader with two 12 V deep cycle marine batteries for power. Right-Antenna design mounted on the flapper gate outside of Pond A7.

Guadalupe River Antenna System

An additional system was installed on the lower Guadalupe River downstream from the San Jose International Airport (Figure 2) to provide evidence of out-migration. It consisted of a 20’ pre-fabricated antenna controlled by an IS-1001 HDX reader box (Biomark Inc.) and powered by two 12-V marine batteries (Figure 8). The antenna was secured by driving 4’ metal stakes into the stream bed and attached with the nylon straps included in the mounting kit.

Figure 8. Left- Installing the 20’ Biomark stream antenna. Right-Tuning the IS-1001 via the software’s auto-tune functions.

Results

Catch Data

We conducted 5 stream surveys between December 16th 2013 and March 14th 2014. A total of 7 sites were sampled, with two sites (St. Johns Street and Coleman Avenue) being repeatedly sampled in each survey (Table 2). Steelhead/Rainbow Trout (*Oncorynchus mykiss)* ranged from 63-215mm standard length. The catch per unit of effort (CPUE) ranged from 0-9 fish per 100-ft of stream surveyed. The CPUE was greater during the first two surveys averaging 5.2 fish per 100-ft, with the highest CPUE at the Guadalupe Creek site in the upper watershed during the first second survey. The CPUE declined during the 3rd survey and remained low through survey 5 where only a single individual was captured (Figure 9).

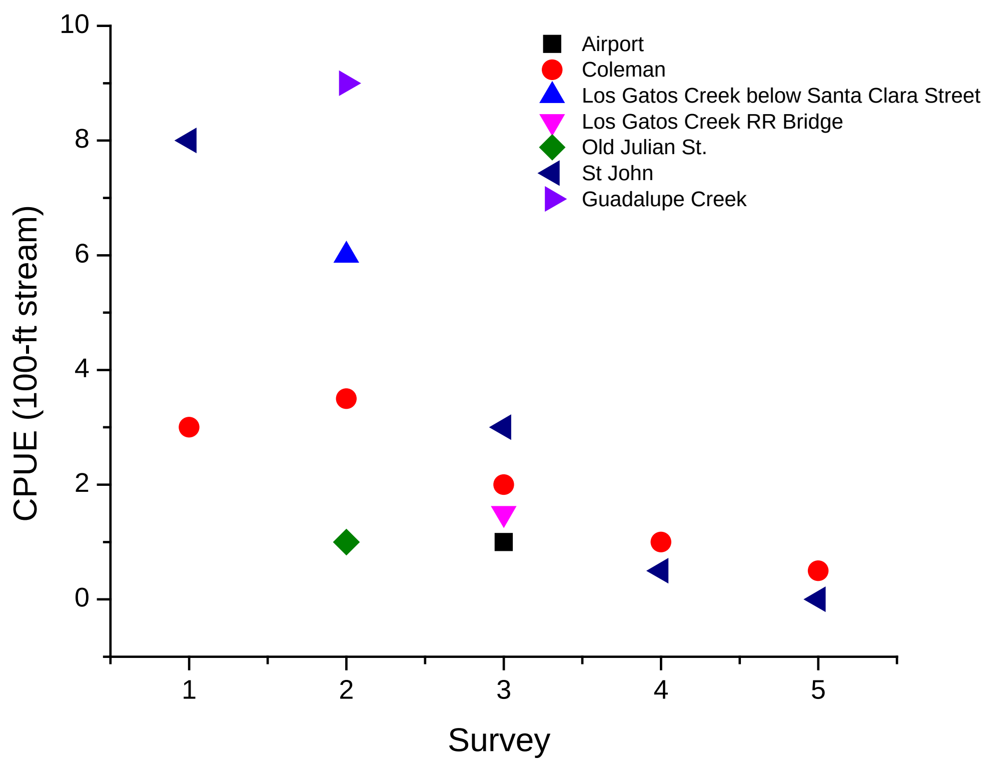

Figure 9. The catch-per-unit of effort (CPUE 100-ft of stream) of O. mykiss from 7 sites in the Guadalupe River watershed over the 5 surveys from December 2013 through March 2014.

We encountered 74 *O. mykiss* and successfully implanted 70 tags. Five individuals were recaptured and identified after their original tagging date. The only mortality associated with sampling or surgical procedures occurred on 2/21/2014 at the Los Gatos Creek site. (Appendix 1). In total, 6 fish were detected at the stream antenna located on the Guadalupe River (37°22'36.2"N 121°55'59.8"W). Most fish moved, on average, 6 kilometers to reach our stream antenna, with the longest movement being approximately 6.5 kilometers. Overall, the St. John site (37°20'5.97"N 121°53'58.75"W) contributed 4 of the 6 out-migrants. The 6 out migrating fish represents 9% of the total successfully tagged individuals, and 12% of all fish tagged in the lower Guadalupe River mainstem (w/o fish from upper Guadalupe Creek). One fish, tag # 982.0003.61656.278, was detected by the antenna at the A8 notch on March 27th, 2014. The other 5 out migrating fish presumably navigated past the notch at A8.

The average size of fish caught varied by site as evidenced by the length-frequency distributions in (figure 10). Based on length-age relationships for the Guadalupe River population of *O. mykiss,* we observed at least two year classes of fish (J. Nishijima unpublished data). Overall, the site farthest upstream on Guadalupe Creek exhibited a smaller size distribution than did the sites further downstream and no fish tagged at this site were detected by the stream antenna. Fish among sites within the lower Guadalupe River had similar length distribution ranging from 90-mm to 180-mm standard length (SL).

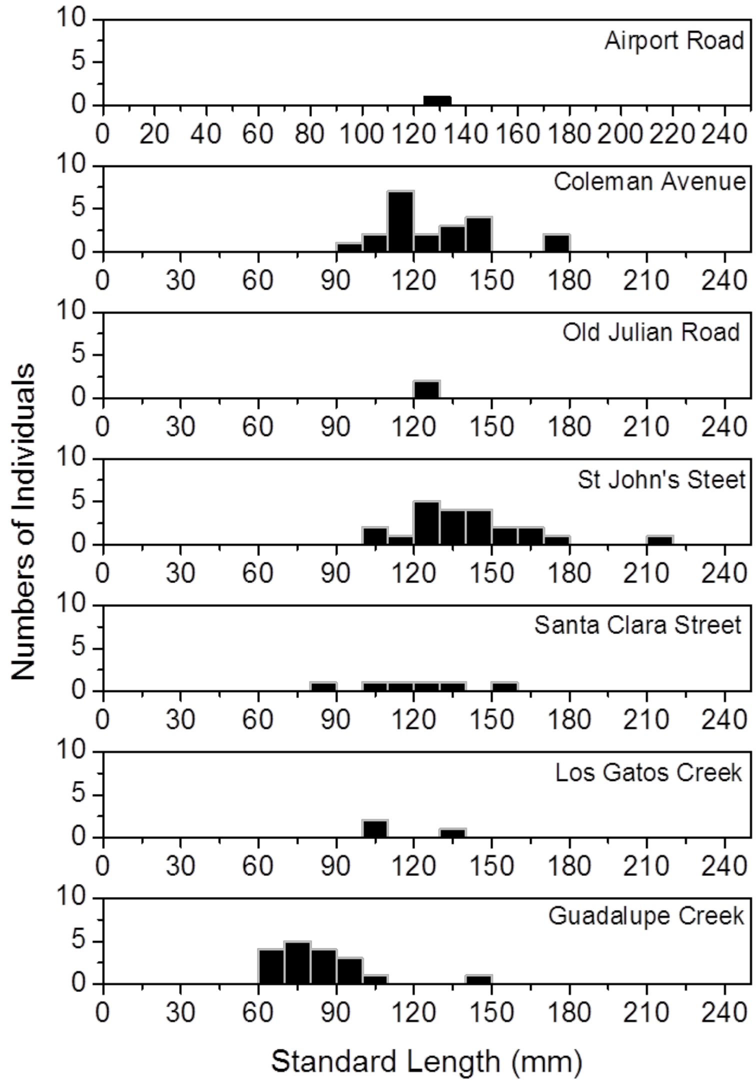

Figure 10. Length Frequency Distributions for all fish captured as part of the sampling efforts December 2013-March 2014. The farthest upstream sites are on the bottom of the figure.

The average length of fish detected at the stream antenna was 139-mm SL, with the smallest fish at 116-mm SL. The average of all fish captured was 118-mm SL (figure 11) A majority of the catch occurred during our December and January surveys with almost all of the out-migrating fish represented by those tagged during December (Appendix 1.)

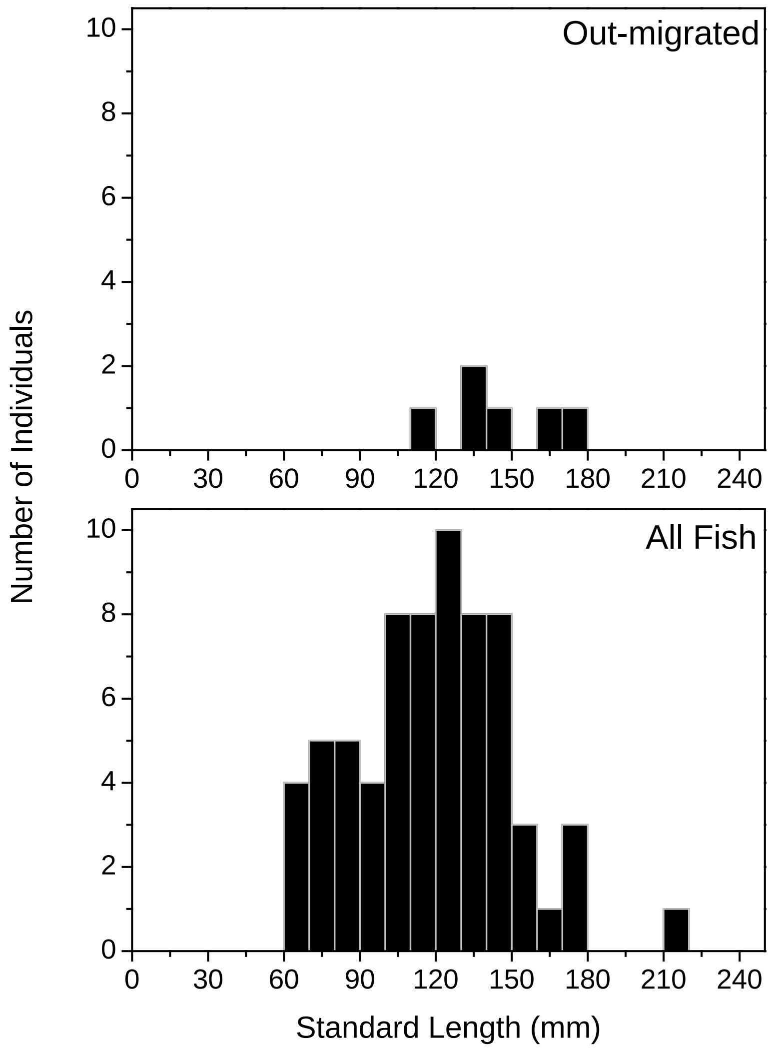

Figure 11. Length Frequency Distributions for fish that out-migrated(top) and all tagged individuals (bottom) caught during sampling.

We observed and recorded the incidence of "blackspot" disease on all *O. mykiss* collected in the mainstem of the Guadalupe River. Blackspot is the metacercaria stage of a free swimming parasite that lives as an adult in the intestines of piscivorous birds. All *O. mykiss* observed in the Guadalupe River had the presence of the parasite, with some fish having fairly severe cases (Figure 12). The fish encountered in the upper Guadalupe Creek did not exhibit symptoms associated with the parasite.

Figure 12. Left: O. mykiss with a sever incidence of "blackspot" disease. Right: *O. mykiss* from Guadalupe Creek without incidence of the parasite.

A majority of the *O. mykiss* encountered were juveniles with evidence of latent parr marks (Figure 12, right). However, during survey 2 on February 12, 2014 we encountered an individual at the Airport BLVD site that "milted" or exuded sperm during tag insertion (Figure 13).   This individual was 130-mm SL, and is most likely a resident Rainbow Trout.

Figure 13. *O. mykiss* captured February 12, 2014 at the Airport BLVD site. Fish was milting, white substance is sperm.

The presence of other species was documented, however the abundance was not consistently recorded to limit the amount of effort spent counting and measuring non-target species. We encountered 8 additional species of fish, with Riffle Sculpin (*Cottus gulosus*) found only at the upper Guadalupe Creek site. At all sites in the lower Guadalupe River we encountered native species including California Roach (*Livinia symmetricus*), Prickly Sculpin (*Cottus asper*)and Sacramento Sucker (*Catastomus occidentalis*). During the first survey we encountered Pacific Lamprey ammocetes (*Lampetra tridentata*). Adult lamprey were observed building redds during the 4th survey. We also observed non-native species including Mississippi Silverside (*Menidia audens*) at St. Johns and Coleman Avenue, and Largemouth Bass (*Micropterus salmoides*) in the pools below riffle habitats. Lastly, we observed numerous Three Spine Stickleback (*Gasterosteus aculeatus*) at our stream antenna site below the airport.

Timing of Detections

Detection of tagged *O. mykiss* at the stream antenna occurred during the tail end of rain events that caused substantial increases in the flows observed in the Guadalupe River, based on the daily mean discharge data from the USGS station 11169025. Due to the channelized conditions of the lower Guadalupe River and the limited reservoir capacity of the river, flows decreased rapidly following rain events. Three notable storms occurred; the first on February 6th, raised the river stage by approximately 1.5ft, the second period began February 27th lasting through March 1st and elevated the river stage by 4ft for approximately 24 hours and remained above the baseflow river stage (4.6ft) through March 4th and the third event began March 29th, lasting through April 2nd, raising the river by approximately 1.5 ft for over 24 hours. Fish were detected at the stream antenna on February 22nd, 26th, March, 21st,24th and 26th (Figure 14). Four of the six fish detected at the stream antenna were tagged during the first survey on December 16th 2013 (Appendix 1). The average out-migration time for fish tagged in December was 88 days ± 14 days (1sd). The other two fish were tagged during the February survey and outmigration time was 25 days ± 15 days (1sd). Fish tended to out-migrate at night and early morning hours, however; one fish was detected in the afternoon of February 26th, at the beginning of the second rain event when the river stage was approximately 1-ft higher than base flow level.

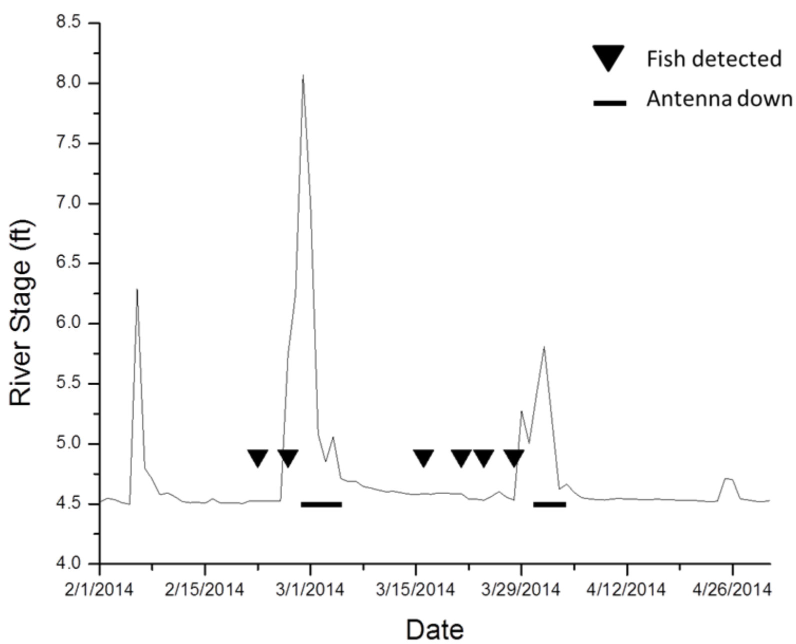

Figure 14. River stage (ft) USGS 11169025 Guadalupe River above highway 101, San Jose Ca. Inverted black arrows denote the date a PIT tagged steelhead was detected at the stream antenna located adjacent to the station gauge. Black bars depict the dates the stream antenna was not operating. http://waterdata.usgs.gov/ca/nwis/uv.

Pond A8 Detection

One fish; PIT tag ID 982.0003.61656.278, 131-mm SL and caught on December 16th at the St. John site (37°20'5.97"N 121°53'58.75"W), was recorded making a one way transit past the A8 pond antenna on March 27th at 7:51 pm. Previous to this event, this fish passed our stream antenna 11 days earlier on March 16th. It was detected simultaneously on two antennas on the A8 notch for a period of approximately 3 seconds. Since we were unable to implement a bi-directional antenna detection system at the A8 notch, we cannot definitively determine whether the fish was entering the pond or exiting the pond. We infer direction the fish was passing using the predicted tide stage at the Gold Street Bridge-Alviso Slough, CA, Station ID 9414551, at the time of detection and our observations on tide delays in reference to tide predictions and water levels at the base of the armored notch. The tide prediction for the time of fish detection was approximately +2.0-ft MLLW on an incoming tide at 7:51pm (Figure 15).

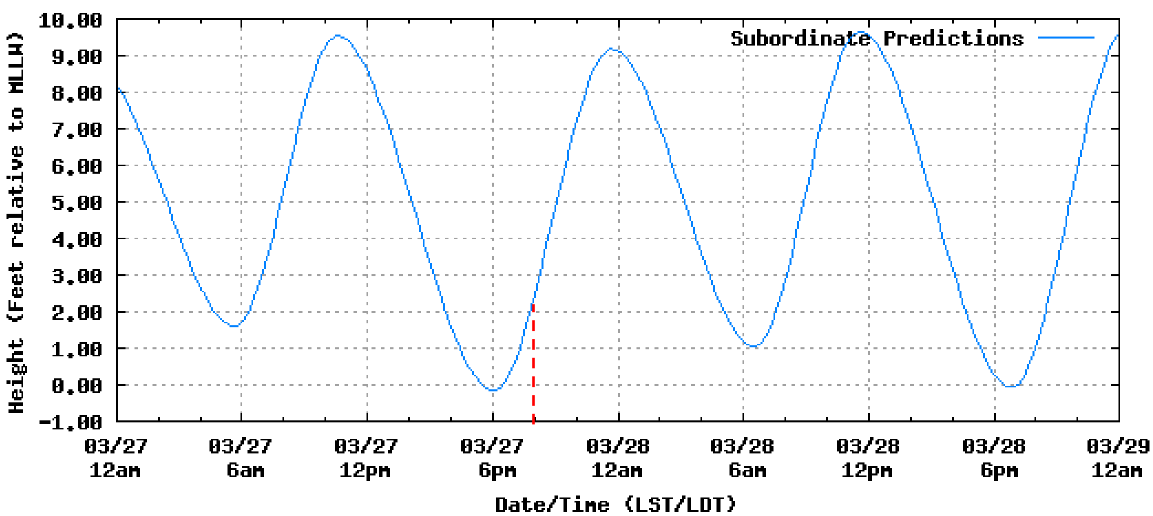

Figure 15. Water level prediction from subordinate station Gold Street Bridge, Alviso Slough ID 9414551 for March 27th – 29th, 2014.

However, the actually water level change at the A8 notch is delayed from predictions by approximately 1.5 hours resulting in an actual tide height of +0.5-ft MLLW.   The base of the A8 notch was constructed at +4.0-ft above MLLW (PWA 2009), and to alleviate flow stress on the base of the A8 notch antenna, the bottom weir boards were left in place, resulting in an additional 18 inches of elevation. This design results in a greater than +5-ft difference between pond water level and slough level and a significant delay in response of pond discharge flows in reference to tide directions changes (Figure 16). Given the tide level prediction, the height of notch construction and our observations of water levels and flow from the pond, the data suggest the fish was likely exiting the pond when detected as the pond would have been spilling into the starter channel at the time of detection.

Figure 16. Left: Pond A8 armored notch side view at +1.0-ft MLLW. Right: Starter channel outside pond A8 at +1.0-ft MLLW.

Antenna Down Times

During this pilot study we did encounter periods of time when antennas were not in place or recording data (Appendix 2). The stream antenna was initially installed and operational on February 12th, two days after the first storm even of 2014 and was subsequently out of commission during the two subsequent storm events. During the second storm event between February 27th and March 1st our antenna was dislodged from its location and sent downstream on the morning of the 27th. This occurred because the flow event resulted in scouring of the gravel bed where the antenna was anchored. The antenna was recovered and reinstalled approximately 100 yards downstream from the previous location and began operating the afternoon of March 5th, resulting in a six day period where no data was recorded for fish out-migrating from the river. On March 29th the stream antenna was intentionally removed during the third rain event to prevent the antenna from being washed out. It was reinstalled on March 31st after 3 days of non-operation. The A8 system was initially installed on March 6th but was dislodged and severely damaged on March 21st. It was reinstalled and operational on March 24th, thus no data was recorded for a period of 12 days at the A8 notch. The A5 and A7 systems were both installed on March 15th. The A5 antenna was non-operational from March 15th to April 1st, due to a faulty secure digital (SD) data card. All antenna were fully operational from April 2nd through July 15th (Appendix 2)

Discussion

Overview

This pilot study, led by UC Davis researchers, was intended to inform adaptive management efforts to alleviate methyl mercury production and restoration of a 1400 acre former solar evaporation pond located at the terminus of Alviso Slough in Santa Clara California. The primary goal was to determine if CCC steelhead smolts, out-migrating from the Guadalupe

River, would be entrained into, and subsequently trapped in, pond A8 through the 40-ft wide armored notch that connects the pond with Alviso Slough.

Antennae

The study employed an HDX RFID antenna, located in the Guadalupe River, upstream of tidal influence, as well a system monitoring the open bays on the A8 notch and two systems monitoring 4-ft circular culverts at the north end of the A5-A7-A8 pond complex. The design posed considerable technical difficulties with regard to antenna design, construction and installation. First, the tide and salinity variability experienced in Alviso Slough was greater than published studies employing RFID technology (Warren Leach, chief engineer with Oregon RFID, personal communication). High salinity environments have been shown to limit electromagnetic fields generated by the antenna through dissipation caused by high conductivity (Bass et al. 2012). Changing water levels due to tidal movement also posed a challenge as the changes in depth would create variable pressures experience by the antennas. This can affect the electromagnetic field generated by the antenna. Using a high-grade, double-stranded 8-gauge wire and corrugated polycarbonate sheeting, to minimize movement and vibration of the antenna, we were able to successfully design a system that consistently operated in the extreme environment at the A8 notch and completely covered the three open bays. Previous studies had not been able to successfully operate RFID antennas in environments with salinities greater than 15-ppt. Salinity at the A8 notch typically ranged from 18-23-ppt during this study.

Collection, Tagging and Comparable Watersheds

We successfully captured and tagged 70 Central Coast California Steelhead Trout, a federally threatened species, in the Guadalupe River watershed. Very little is known about CCC Steelhead in the study area, including the status and relative health of the population. The Guadalupe River watershed is one of the largest drainages in the San Francisco Bay Area and is one of the watersheds identified in CCC steelhead restoration efforts (Becker et al. 2008). Densities of *O. mykiss* ranged from 0.1 to 0.9 fish per linear foot of riffle habitat, and at least 1 fish was encountered in 65% (13 of out 20 distinct) of the sites in our sampling events during this study. *O. mykiss* abundance in Stevens Creek (adjacent watershed) ranged from 0.1 to 0.5 per linear foot among 12 sites in 2010 (Abel 2010). Frequency of occurrence estimates from Steelhead in the Guadalupe River, over a 10 year period, ranged from 11% to 78% and average 38% of sampled habitats obtaining at least one *O. mykiss* in dry years (Jason Nishijima SCVWD unpublished data). Densities of *O. mykiss* in our study were similar to recent surveys, indicating population status may be stable in recent years. These studies were conducted in the fall, after fish would have survived peak summer temperatures, while our study was conducted in the winter when temperatures were cooler.

Size distributions were also similar to previous studies conducted by biologist with the Santa Clara Valley Water District, with fish in the upper tributaries averaging 60-90-mm SL, while fish in the lower river on the valley floor ranged 120-150-mm SL with few individuals >250-mm SL. Age-length distributions from Stevens Creek identified 120-mm as the approximate break between YOY and 1+ aged fish, and 185-mm SL between 1+ and 2+ fish. (J. Abel SCVWD unpublished data) If this age-length relationship can be applied to our winter collected fish, a majority of fish tagged in the Guadalupe River mainstem where 1+ fish, while fish in the upper tributaries were likely YOY. All but one fish had distinguished parr marks and very few fish had any silver coloration at the time of capture. We did observe a single individual in Survey five that had clearly undergone smoltification, thus it appeared that smolting occurred later than the peak of out-migration. We cannot be certain fish underwent smolting in between survey two and survey three downstream of our sampling locations.

Steelhead Trout have a phenotypically plastic life history where out-migrating fish can range 80-240-mm SL and corresponding ages from YOY to 3+ and a majority of *O. mykiss* out-migrate from freshwater streams to the estuary and ocean between April-May (Shapolov and Taft 1954). Densities of *O. mykiss* declined over the survey period, primarily between the second and third surveys. Given the length of these fish, it was likely that the decline in fish density corresponded to out-migration. Survey 3 (2/12/14) occurred several days after the first significant rain event in 2014, and thus a majority of the *O. mykiss* rearing in the lower Guadalupe River likely out-migrated with the first rainstorm. Unfortunately the stream antenna was not installed until Survey 3, and thus we missed the peak of steelhead out migration by only a few days. Fortunately, a majority of our fish detected at the stream antenna were tagged during the first two surveys prior to the first rain storm, thus not all fish had out-migrated prior to antenna installation. Moreover, many of these fish remained in the river for up to a month after the first rain event. Regardless, pond A8 was not opened to Alviso Slough until March 5th, more than a month after the first rain event. Antennas were operational during the opening and thus it is unlikely any tagged fish that migrated out during the first rain event entered Pond A8 without detection.

Black Spot Disease and Habitat Quality

All *O. mykiss* collected in the mainstem of the Guadalupe River showed signs of "blackspot" disease. Blackspot disease is an encysted larval (metacercaria) trematode fluke parasite (Bangham and Adams 1954). This parasite has been observed in other salmonid populations and was recorded as early as the 1930's in Steelhead found Waddell Creek, Santa Cruz Co. (Cairns et al. 2011, Shapolov and Taft 1954). The prevalence of the disease in the mainstem of the Guadalupe River may be partially due to stress associated with lack of high quality habitat and relatively warm water temperatures. Infestation rates in Coho salmon juveniles in an Oregon stream was associated with warm summer stream temperatures causing an interaction of thermal stress on the fish and the elevated metabolic rate of the parasite resulting in high infestation rates(Cairns et al. 2011). Much of the mainstem flows through downtown San Jose and is heavily channelized and stream temperatures in summer can be near the upper range of thermal tolerance for O*. mykiss*. We did not observe the disease in fish collected in upstream tributaries (Guadalupe Creek and Los Gatos Creek). We cannot discern whether the infection status is a function of habitat quality in the mainstem Guadalupe River or the residence time of larger, older fish in the mainstem. Regardless, the effect of blackspot disease on *O. mykiss* health in the Guadalupe River is unknown.

Predation

The effect of non-native predatory species in the mainstem Guadalupe River is another uncertainty and may have adverse effects on the Steelhead population. A large number of relatively deep, slow moving pools occur throughout the lower Guadalupe River in which

Largemouth Bass (*Salmoides micropterus*) were frequently observed. Largemouth bass are highly piscivorous and likely to feed on out-migrating O. mykiss. Mortality from predation in the river is currently unknown.

Striped Bass (*Morone saxatilis*), another introduced piscivore, was regularly encountered in Pond A8 near the armored notch and were present during the period when a single steelhead was detected at the armored notch on March 27th. March 15th we conducted a hook and line survey along the rip rap levee between Pond A8 and A8S approximately 500-m from the armored notch, and PIT tagged six striped bass ranging from 440-530-mm SL. April 10th, we collected and PIT tagged twelve adult striped bass, ranging from 305-965 mm SL, using three 50-ft gill nets deployed just inside of the A8 notch (100-m) for one hour. Striped bass (140-330-mm SL) were also found in Alviso Slough near the Alviso boat launch during otter trawl surveys from March – May. One tagged striped bass, (tag # 982.000362654.514), was detected moving out of the pond, via the A8 on March 15th (approximately 4 hours after being tagged), notch then detected again on the stream antenna ten days later on March 25th. Predation mortality in pond A8 was not directly examined, but the presence of striped bass in Pond A8 near the armored notch, in Alviso Slough and the Guadalupe River during the out-migration season is a concern.

Life History Phenotype

Partial anadromy is a behavioral phenomenon where individuals of the same population adopt different life history phenotypes (Hendry 2004). Steelhead and Rainbow Trout are migratory and non-migratory phenotypes of *O.* mykiss capable of co-occurring within the same population (Moyle 2000). The relative proportion of the two can depend on a multitude of environmental factors, such as stream temperature, habitat quality, distance from the ocean and genetic factors (Jonsson and Jonsson 1993). Moreover, one phenotype can produce offspring of the other phenotype in a phenomenon known as “life-history cross-over” (Courter et al. 2013). The proportion of Steelhead and Rainbow Trout phenotypes in the Guadalupe River population is currently unknown. We encountered a single individual that exuded “milt” or sperm during PIT tag insertion. Steelhead are not known to become reproductive in freshwater prior to out migration, therefore this individual was likely a resident Rainbow Trout . No other *O. mykiss* encountered exhibited external features suggesting sexual maturation. Successful management and understanding of the population dynamics of the threatened CCC Steelhead requires a better understanding of “life-history cross over” occurring in the population as well as better information regarding the proportion of resident Rainbow Trout to Steelhead.

Summary

The pilot study conducted in Winter 2013/Spring 2014 was a success. We were able to design and construct an RFID antenna that functions with high precision in a very dynamic and extreme environment. We successfully tagged 70 *O. mykiss* over a four month period, and measured densities and size classes that were comparable to previous studies in the area. We detected six tagged O. mykiss at the stream antenna location, providing the first evidence of anadromy for the Guadalupe River Steelhead population.

We did encounter several problems and limitations that must be addressed prior to the 2014-15 study. The stream antenna was dislodged by a high flow event and was removed intentionally a second time to avoid dislodgement during a subsequent storm event. The antenna unit on the A8 notch was also destroyed after the initial installation. Determining whether individuals were entering or exiting Pond A8 was not possible due to the configuration of our antenna array. Lastly, we likely missed the first pulse of out migrating fish. Problems encountered will be addressed in 2015-16 with the assistance of the Santa Clara Valley Water District (SCVWD). The SCVWD will provide heavy equipment for a permanent installation of the stream antenna in the general area below the airport. We will construct additional antennae on the A8 notch such that direction can be determined. Our second installation, where we anchored the antenna into the cement with Tapcon® anchors was much more robust and did not fail. Design in year two would use the cement anchors and use strut materials rather than wood for framing. This would provide a more durable and longer lasting antenna frame. Installation of all antennas would occur in late fall before the first rains to eliminate the potential for missing the first out migration pulse. Lastly the number of fish tagged would be increased considerably to provide a better estimate of out migration and potential entrainment.

2015 Study Plan

We are currently applying for additional funding to support efforts in 2015. In June, we applied for funding through the National Fish and Wildlife Foundation (NFWF) to conduct 3 field surveys in 2015/16 to tag an additional 200 *O. mykiss* and construct additional antennas on the A8 notch for bi-directional detection and operation through spring 2015. We are also currently discussing implementation of RFID/PIT tag studies for the Three-Creeks Habitat Conservation Plan for the Santa Clara Valley Water District. A total of 13 antenna stations would be installed by the SCVWD to track the movement of PIT tagged fish. These antennas will be installed at the locations listed below. These sites have been strategically selected because they provide three key parameters – a migration passage chokepoint; isolate a specific tributary, channel reach or other instream feature; and accessibility by SCVWD staff to install and maintain the antenna. The SCVWD is equipped with staff and ample heavy equipment for constructed RFID antennas for long-term deployment as well as the construction of permanent fixed stations connected to DC power and remote uploading of detections via the internet.

<u>Guadalupe River Watershed</u>

- Guadalupe River downstream Highway 101
- Los Gatos Creek at Lincoln Ave
- Guadalupe River downstream of Alamitos Dam Fish Ladder
- Guadalupe Creek near of Almaden Expressway
- Alamitos Creek upstream of Almaden Lake
- Calero Creek upstream confluence with Alamitos Creek

<u>Stevens Creek Watershed</u>

- Steven Creek upstream Moffett Blvd. Fish Ladder
- Steven Creek upstream annual dry back area (need geographic locator/maybe at new gauge station)

<u>Coyote Creek Watershed</u>

- Coyote Creek upstream 237
- Upper Penitencia Creek
- Coyote Creek downstream Coyote Percolation Dam or Edenvale Gauge Coyote Creek between Coyote and Oiger Ponds
- Coyote Creek upstream Oiger Ponds

PIT tagging would occur during juvenile rearing monitoring conducted by the SCVWD with assistance from UCD Researches. Up to 100 fish would be tagged in each of the creeks and river, within the HCP area , as listed below

- Guadalupe River: 100
- Guadalupe Creek: 100
- Alamitos Creek: 100
- Calero Creek: 100
- Los Gatos Creek: 100
- Stevens Creek: 100
- Coyote Creek: 100
- Upper Permanente Creek: 100

If the target number of fish to be fitted with PIT tags is not achieved during the juvenile rearing monitoring, other areas will be sought where the likelihood of reaching the target number can be achieved. Fitting the fish with PIT tags may include use of single-use or multiple-use injectors, or incision method. The size of PIT tag used will follow the manufacturer's guidelines. Following the first year of PIT tagging we will have a better understanding of population and may readjust the number of fish to be tagged in consultation with the regulatory agencies.

Acoustic Tagging

PIT tagging has limitations in high flow conditions in which tagged fish may not pass closely enough to an antenna to register a detection. Therefore, acoustic tags may be installed on a limited basis with acoustic sensors installed at strategic locations. The use of acoustic tags would only be used after assessing the results of the first year of PIT tagging and tracking. Implementation of acoustics would be on a pilot scale basis in 2015-16.

Acknowledgements

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Appendix 1. PIT tag codes for O. mykiss collected in December 2013-March 2014 at stream locations in the Guadalupe River watershed and tributaries. Information regarding the detection of fish was recorded as date and time.

Tag ID	Date	Site Name	Site Coordinates (Start of transect)		Fish Size (SL)	Tag Size (mm)	Outmigration Information			
			Latitude	Longitude			Guadalupe	A8	A7	A5
982.0003.61656.277	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	110	23				
982.0003.62992.269	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	110	12				
982.0003.62992.296	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	98	12				
982.0003.61656.260	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	148	23				
982.0003.61656.243	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	116	23	3/21/14 07:08			
982.0003.61656.235	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	123	23				
982.0003.61656.226	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	113	23				
982.0003.61656.222	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	131	23				
982.0003.61656.230	12/16/2013	Coleman	37°20'40.16"N	121°54'10.81"W	115	23				
982.0003.61656.249	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	159	23				
982.0003.61656.269	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	166	23	3/24/14 22:50			
982.0003.61656.267	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	215	23				
982.0003.61656.263	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	120	23				
982.0003.61656.237	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	150	23				
982.0003.61656.258	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	141	23	2/22/14 01:49			
982.0003.61656.218	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	142	23				
982.0003.62992.258	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	100	12				
982.0003.62992.279	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	104	12				
982.0003.62992.356	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	113	23				
982.0003.61656.274	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	132	23				
982.0003.61656.278	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	131	23	3/16/14 06:54	3/27/14 19:54		
982.0003.61656.280	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	137	23				
982.0003.61656.215	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	126	23				
982.0003.61656.209	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	125	23				
982.0003.61656.294	12/16/2013	St John	37°20'5.97"N	121°53'58.75"W	125	23				
982.0003.62992.272	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	95	12				
982.0003.62992.306	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	80	12				
982.0003.62992.263	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	72	12				
982.0003.62992.333	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	100	12				
982.0003.62992.327	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	91	12				
982.0003.62992.289	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	82	12				
982.0003.62992.303	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	99	12				
982.0003.62992.312	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	88	12				
982.0003.62992.325	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	64	12				
982.0003.62992.278	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	77	12				
982.0003.62992.330	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	73	12				
982.0003.62992.340	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	63	12				
982.0003.62992.290	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	72	12				
982.0003.62992.328	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	70	12				

Tag ID	Date	Site Name	Site Coordinates (Start of transect)		Fish Size (SL)	Tag Size (mm)	Outmigration Information			
			Latitude	Longitude			Guadalupe	A8	A7	A5
982.0003.62992.315	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	84	12				
982.0003.61656.305	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	142	23				
982.0003.62992.302	1/17/2014	Guadalupe Creek	37°13'18.2"N	121°54'29.7"W	68	12				
982.0003.61656.288	1/17/2014	Santa Clara St.	37°19'56.8"N	121°53'56.9"W	130	23				
982.0003.61656.298	1/17/2014	Santa Clara St.	37°19'56.8"N	121°53'56.9"W	117	23				
982.0003.61656.229	1/17/2014	Santa Clara St.	37°19'56.8"N	121°53'56.9"W	150	23				
982.0003.61656.299	1/17/2014	Santa Clara St.	37°19'56.8"N	121°53'56.9"W	128	23				
982.0003.61656.217	1/17/2014	Santa Clara St.	37°19'56.8"N	121°53'56.9"W	107	23				
982.0003.62992.298	1/17/2014	Santa Clara St.	37°19'56.8"N	121°53'56.9"W	80	12				
982.0003.61656.247	1/17/2014	Old Julian	37°20'09.3"N	121°53'59.7"W	125	23				
982.0003.61656.521	1/17/2014	Old Julian	37°20'09.3"N	121°53'59.7"W	124	23				
982.0003.61656.250	1/17/2014	Coleman	37°20'40.16"N	121°54'10.81"W	108	23				
982.0003.61656.265	1/17/2014	Coleman	37°20'40.16"N	121°54'10.81"W	140	23				
982.0003.61656.252	1/17/2014	Coleman	37°20'40.16"N	121°54'10.81"W	105	23				
982.0003.61656.290	1/17/2014	Coleman	37°20'40.16"N	121°54'10.81"W	110	23				
982.0003.61656.216	1/17/2014	Coleman	37°20'40.16"N	121°54'10.81"W	125	23				
982.0003.61656.264	1/17/2014	Coleman	37°20'40.16"N	121°54'10.81"W	175	23				
982.0003.61656.238	1/17/2014	Coleman	37°20'40.16"N	121°54'10.81"W	145	23				
982.0003.61656.219	2/12/2014	Airport	37°22'28.5"N	121°55'59.3"W	130	23				
982.0003.61656.225	2/12/2014	Coleman	37°20'40.16"N	121°54'10.81"W	177	23				
982.0003.61656.244	2/12/2014	Coleman	37°20'40.16"N	121°54'10.81"W	144	23				
982.0003.61656.242	2/12/2014	St John	37°20'5.97"N	121°53'58.75"W	138	23				
982.0003.61656.294	2/12/2014	St John	37°20'5.97"N	121°53'58.75"W	140	23				
982.0003.61656.231	2/12/2014	St John	37°20'5.97"N	121°53'58.75"W	169	23	2/26/14 13:58			
982.0003.61656.227	2/12/2014	St John	37°20'5.97"N	121°53'58.75"W	140	23				
982.0003.61656.272	2/12/2014	St John	37°20'5.97"N	121°53'58.75"W	121	23				
982.0003.61656.250	2/21/2014	Coleman	37°20'40.16"N	121°54'10.81"W	118	23				
982.0003.61656.311	2/21/2014	Coleman	37°20'40.16"N	121°54'10.81"W	134	23				
982.0003.61656.213	2/21/2014	Los Gatos Creek	37°20'18.8"N	121°54'09.1"W	104	23				
982.0003.61656.270	2/21/2014	Los Gatos Creek	37°20'18.8"N	121°54'09.1"W	134	23	3/28/14 0:52			
982.0003.61656.454	2/21/2014	Los Gatos Creek	37°20'18.8"N	121°54'09.1"W	104	23	Mortality			
982.0003.61654.515	3/14/2014	Coleman	37°20'40.16"N	121°54'10.81"W	134	23				

Appendix 2. Conditions of Guadalupe River (river stage, flow) at USGS station ID 11169025. Alviso Slough water temperature USGS 11169750. Antenna operations- check mark denotes antennas in operating mode, back denotes when antennas were down.

Date	Stage (ft)	Flow (CFS)	Slough (°C)	Pond (°C)	Steam Antenna	A8	A7	A5
12/15/2013	4.7	31.6	9.1					
12/16/2013	**4.6**	26.0	9.3					
12/17/2013	4.6	25.3	9.8					
12/18/2013	4.6	22.3	10.1					
12/19/2013	4.6	22.0	10.3					
12/20/2013	4.6	20.7	10.1					
12/21/2013	4.6	20.5	9.8					
12/22/2013	4.6	22.6	10.0					
12/23/2013	4.6	22.6	10.2					
12/24/2013	4.6	21.3	10.5					
12/25/2013	4.6	21.5	10.8					
12/26/2013	4.6	21.6	10.9					
12/27/2013	4.6	21.0	11.0					
12/28/2013	4.6	21.3	10.8					
12/29/2013	4.6	20.6	10.7					
12/30/2013	4.6	20.5	10.6					
12/31/2013	4.6	20.8	10.4					
1/1/2014	4.6	21.1	10.4					
1/2/2014	4.6	20.9	10.3					
1/3/2014	4.6	21.4	10.4					
1/4/2014	4.6	20.6	10.6					
1/5/2014	4.6	21.1	10.7					
1/6/2014	4.6	20.6	10.6					

1/7/2014	4.6	21.0	10.8		[redacted]
1/8/2014	4.6	20.5	11.5		
1/9/2014	4.6	20.8	12.2		
1/10/2014	4.6	21.2	12.6		
1/11/2014	4.6	21.1	12.5		
1/12/2014	4.6	21.1	12.2		
1/13/2014	4.6	21.2	12.0		
1/14/2014	4.6	22.0	11.8		
1/15/2014	4.7	26.8	11.8		
1/16/2014	4.6	24.4	11.7		
1/17/2014	**4.6**	21.6	11.9		
1/18/2014	4.6	20.9	11.9		
1/19/2014	4.6	20.5	11.8		
1/20/2014	4.6	20.7	11.7		
1/21/2014	4.6	20.9	11.7		
1/22/2014	4.6	20.0	11.8		
1/23/2014	4.6	19.5	12.1		
1/24/2014	4.5	18.6	12.3		
1/25/2014	4.5	19.3	12.7		
1/26/2014	4.5	19.0	13.0		
1/27/2014	4.5	18.6	13.2		
1/28/2014	4.5	18.6			
1/29/2014	4.5	18.7	14.4		
1/30/2014	4.6	26.4	14.8		
1/31/2014	4.6	19.4	14.2		
2/1/2014	4.5	17.1	13.2		
2/2/2014	4.5	19.4	12.2		
2/3/2014	4.5	18.5	11.8		
2/4/2014	4.5	16.7	11.7		
2/5/2014	4.5	15.9	11.6		
2/6/2014	6.3	251.2	11.5		
2/7/2014	4.8	38.9	11.1		
2/8/2014	4.7	30.6	11.8		

2/9/2014	4.6	20.5	12.7					
2/10/2014	4.6	22.0	13.7					
2/11/2014	4.6	19.5	14.3					
2/12/2014	**4.5**	16.6	**14.6**		✓			
2/13/2014	4.5	16.1	14.8		✓			
2/14/2014	4.5	16.3	15.3		✓			
2/15/2014	4.5	15.8	15.1		✓			
2/16/2014	4.5	18.4	15.0		✓			
2/17/2014	4.5	15.9	14.7		✓			
2/18/2014	4.5	15.7	14.4		✓			
2/19/2014	4.5	16.1	14.6		✓			
2/20/2014	4.5	15.7	14.7		✓			
2/21/2014	**4.5**	17.2	**14.9**		✓			
2/22/2014	4.5	17.1	15.4		✓			
2/23/2014	4.5	17.0	15.8		✓			
2/24/2014	4.5	17.4	16.1		✓			
2/25/2014	4.5	16.9	16.1		✓			
2/26/2014	5.7	209.9	15.5		✓			
2/27/2014	6.2	293.1	15.0					
2/28/2014	8.1	805.9	14.5					
3/1/2014	7.0	387.2	14.2					
3/2/2014	5.1	58.0	14.3					
3/3/2014	4.8	35.6	14.4					
3/4/2014	5.1	57.7						
3/5/2014	4.7	23.9	15.6		✓			
3/6/2014	4.7	21.9	16.5		✓	✓		
3/7/2014	4.7	22.3	17.0		✓	✓		
3/8/2014	4.6	19.1	17.2		✓	✓		
3/9/2014	4.6	18.2	18.0		✓	✓		
3/10/2014	4.6	17.1	18.3		✓	✓		
3/11/2014	4.6	16.2	17.3		✓	✓		
3/12/2014	4.6	16.5	16.1		✓	✓		
3/13/2014	4.6	15.6	16.2		✓			

3/14/2014	**4.6**	14.9	**16.7**		✓			
3/15/2014	4.6	14.7	17.4		✓		✓	✓
3/16/2014	4.6	14.9	18.1		✓		✓	✓
3/17/2014	4.6	14.8	17.7		✓		✓	✓
3/18/2014	4.6	15.6	17.1		✓		✓	✓
3/19/2014	4.6	15.5	17.2		✓		✓	✓
3/20/2014	4.6	15.0	17.8		✓		✓	✓
3/21/2014	4.6	15.4	17.8		✓		✓	✓
3/22/2014	4.6	15.6	17.8		✓		✓	✓
3/23/2014	4.6	15.4	18.1		✓		✓	✓
3/24/2014	4.6	15.4	18.5		✓		✓	
3/25/2014	4.6	15.3	18.0		✓	✓	✓	
3/26/2014	4.6	15.4	17.1		✓	✓	✓	
3/27/2014	4.6	15.4	16.6		✓	✓	✓	
3/28/2014	4.6	15.4	16.8		✓	✓	✓	
3/29/2014	4.6	15.4	16.6			✓	✓	
3/30/2014	4.6	15.4	15.9			✓	✓	
3/31/2014	4.6	15.4	15.3			✓	✓	
4/1/2014	4.6	15.4	13.8		✓	✓	✓	
4/2/2014	4.6	15.4	13.9		✓	✓	✓	✓
4/3/2014	4.6	15.4	15.0		✓	✓	✓	✓
					☐	☐	☐	☐
7/12/2014	4.6	15.4	24.4		✓	✓	✓	✓

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