North Delta Hydrodynamic and Juvenile Salmon Migration Study

Introduction

The California Department of Water Resources (DWR), U.S. Geological Survey (USGS), and the California Bay-Delta Authority (CBDA) have acquired acoustic telemetry equipment that allows for detailed monitoring of juvenile salmon movements in the Sacramento-San Joaquin Delta (Delta). Multiple-hydrophone systems[1] allow 3-dimensional (3-D) positioning of salmon movements to sub-meter accuracy within limited regions, such as junctions and bends, and single-hydrophone recievers[1] permit fish tracking at larger scales, for example, within the network of channels that make up the Delta. This relatively new technology was successfully tested in the Delta under a variety of conditions in 2006 by Natural Resources Scientists, Inc (Dave Vogel) and in a pilot study conducted in the north Delta in the winter of 2006-2007. The data collected in January 2007 with this technology were successfully used to estimate juvenile salmon behavior, including route selection, transit times, and survival rates.

When combined with simultaneously collected detailed hydrodynamic data obtained with Acoustic Doppler Current Profilers (ADCP's) these acoustic tracking systems provide the data to correlate fish movements with localized flow structures and regional hydrodynamic conditions. Analyses of these data are expected to inform fish behavior algorithms that will be integrated into hydrodynamic models, through individual-based numerical particle tracking schemes, to simulate and predict how juvenile salmon move throughout the Delta under variety of conditions, including differing channel geometries (e.g., river bends), flow (discharge, cfs), and other environmental factors, such as day versus night.

Secondary currents in river channel bends, coupled with juvenile salmon behavior, likely affect route selection in the Delta. Understanding the mechanisms that control salmon out migration pathways throughout the Delta is important because survival within each reach is likely different. For example, juvenile salmon can emigrate through Sutter, Steamboat, and Georgiana Sloughs and the Sacramento River and Delta Cross Channel (DCC), each of these channels likely uniquely contributes to the overall survival through the north Delta. All of these channels are located on the outside of bends in the Sacramento River where secondary currents may play a role in route selection at these junctions.

Because of these technological developments, USGS-Sacramento (Jon Burau; jrburau@usgs.gov) and DWR (Ajay Goyal; agoyal@water.ca.gov; project manager) have planned an experiment that will track acoustically tagged juvenile salmon throughout the north, west, and central Sacramento-San Joaquin Delta. This study has two primary goals:

[1] Hydroacoustic Technology, Inc. (HTI)

1) Determine the factors (channel geometry, velocity structure, and behavior) that control entrainment in the Delta Cross Channel and Georgiana Slough (Figure 1).

2) Determine routes and survival of out migrating juvenile salmon throughout the north, west and central Delta (Figure2).

The hydrodynamics portions of this study and overall coordination and logistics are directed by USGS-Sacramento (Jon Burau, co-principal investigator). Because of their expertise in operation of the 3-D acoustic telemetry systems, the USGS Columbia River Research Laboratory (CRRL) (Noah Adams; nadams@usgs.gov) will deploy, operate and recover the 3-D systems in the Sacramento River DCC and Georgiana Slough junctions. Theresa "Marty" Liedtke (theresa_liedtke@usgs.gov) from CRRL will head the fish surgeries and recovery. And with help from USFWS, Marty will lead the acclimation and release portion of the study. Because of expertise in Delta fish telemetry and biological studies, DWR has contracted with Natural Resource Scientists, Inc. (NRS) (Dave Vogel; dvogel@resourcescientists.com), to serve as a principal investigator for telemetry, predation, and the wild fish aspects of the study. This research project is funded through a combination of sources including the DWR, USBR, and USGS.

Study Activities

The proposed field investigation at the junction of the Sacramento River with the DCC and Georgiana Slough will involve the collection of both hydrodynamic and biological data. A boat-mounted downward-looking ADCP will be used to measure the strength of the secondary currents in both junctions. This non-contact acoustic technique (a 1200 kHz transducer mounted on a boat) will be used to measure velocity profiles within both junctions. Surface current distributions within both channel junctions will be measured using another array of sideways looking ADCPs. Data on the positions of outmigrating juvenile salmon within both junctions will be measured in three dimensions using a pair of hydrophone arrays.

Two separate arrays of Hydroacoustic Technologies Inc. (HTI) 3-D acoustic tag tracking systems will be deployed in the DCC and in Georgiana Slough (Figures 3 and 4, respectively). A total of 38 transducers will be deployed using the mount shown in Figure 5. Each transducer is connected to a deck box via a ¼" diameter hydrophone communication cable deployed across the riverbed at strategic locations to allow 3-D positioning of acoustic-tagged salmon passing through the site. With the network of hydrophones shown in Figures 3 and 4 we will attempt to measure and characterize the spatial distribution of salmon outmigrants at the DCC and Georgiana Slough junctions and then to generalize these mechanisms behind the observed spatial structures to other junctions within the north Delta.

The hardware will be placed in the river bottom in both the DCC and Georgiana Slough study sites prior to the first fish release in early November (refer to the timeline below). The 3-D equipment will be installed by USGS-CRRL personnel.

Additionally, 41 HTI single-hydrophone acoustic receivers (red circles in Figure 2) that can detect presence or absence of acoustic-tagged salmon will be installed by USGS staff with assistance from NRS in downstream areas. The single-hydrophone HTI recievers will be deployed off the banks of Delta levees as depicted in Figure 6 or from existing structures such as USGS flow station installations, pump stands, or docks. In order to achieve complete acoustic coverage in the wider channels of the western Delta five (5) four-hydrophone receivers will be deployed in (blue circles in Figure 2): (1) the Sacramento River at Mallard Island (two independent units will be deployed at this location so detection probabilities can be calculated) (Figure 7), (2) the Sacramento River at Threemile Slough (Figure 8), (3) The San Joaquin River at Jersey Point (Figure 9), and (4) the San Joaquin River at San Andreas Point (Figure 10). The exact deployment location and the specific placement of the hydrophones at these locations will be determined through detailed field reconnaissance and testing conducted this summer/fall.

A total of 5200 late-fall Chinook salmon smolts from Coleman National Fish Hatchery will be surgically implanted with individually-identifiable, small (~ 0.9-g weight in air) acoustic transmitters (307.2 kHz) by a combination of USFWS and USGS-CRRL. During the main study release periods, November 2008 through January 2009, acoustic-tagged salmon will be transported to the Delta by DWR and placed in live pens in the Sacramento River at Old Sacramento and at Dagmars Landing in Walnut Grove adjacent to a dock for overnight acclimation prior to release (Figure 11).

A pilot level study will be performed the last week of October 2008 to capture the behavior of 200 acoustic-tagged salmon at the DCC with the gate half-way closed. These tagged fish will be transported from the hatchery to the Sacramento River below Steamboat Slough. The fish will be release in two groups, distributing each group release over 24 hours, with differing gate operation half-way closed and open. Then USFWS and USGS personnel will release twelve groups of 400 tagged salmon in the Sacramento River and in Georgiana Slough near the holding/acclimation site during four different river conditions. DCC gates are anticipated to be open during the lower-flow conditions in December and early January and closed during high-flow conditions in mid- to late-January. During each DCC gate operation condition, four fish groups, a total of 1600 acoustic-tagged hatchery salmon along with some wild salmon, will be released separately over a 24-hour period for each group. The exact number of wild salmon will depend on how many we are permitted to take and how many we can actually capture for tagging. Within each 24-hour period, 400 salmon will be released at daytime, nighttime, and morning and evening crepuscular periods to encompass a range of potential diel changes in fish behavior.

As the acoustic-tagged salmon migrate through the junction of the Sacramento River with the DCC and Georgiana Sloughs, detailed hydrodynamic data will be simultaneously collected using high frequency radar and boat-mounted ADCPs. As acoustic-tagged salmon pass the single- and four- hydrophone HTI receivers, their presence will be electronically recorded. Additionally, during each of the four 10 day periods of the

study, mobile acoustic telemetry reconnaissance will be conducted in Delta channels by boat using an HTI single-hydrophone receiver.

Before the salmon study begins, Dave Vogel will capture up to 120 predator fish in the North Delta. The predators will be tagged and monitored with the HTI equipment during the full study period. The predation data collection will be used to distinguish the monitored movements of live tagged salmon from movements of consumed tagged salmon within predators.

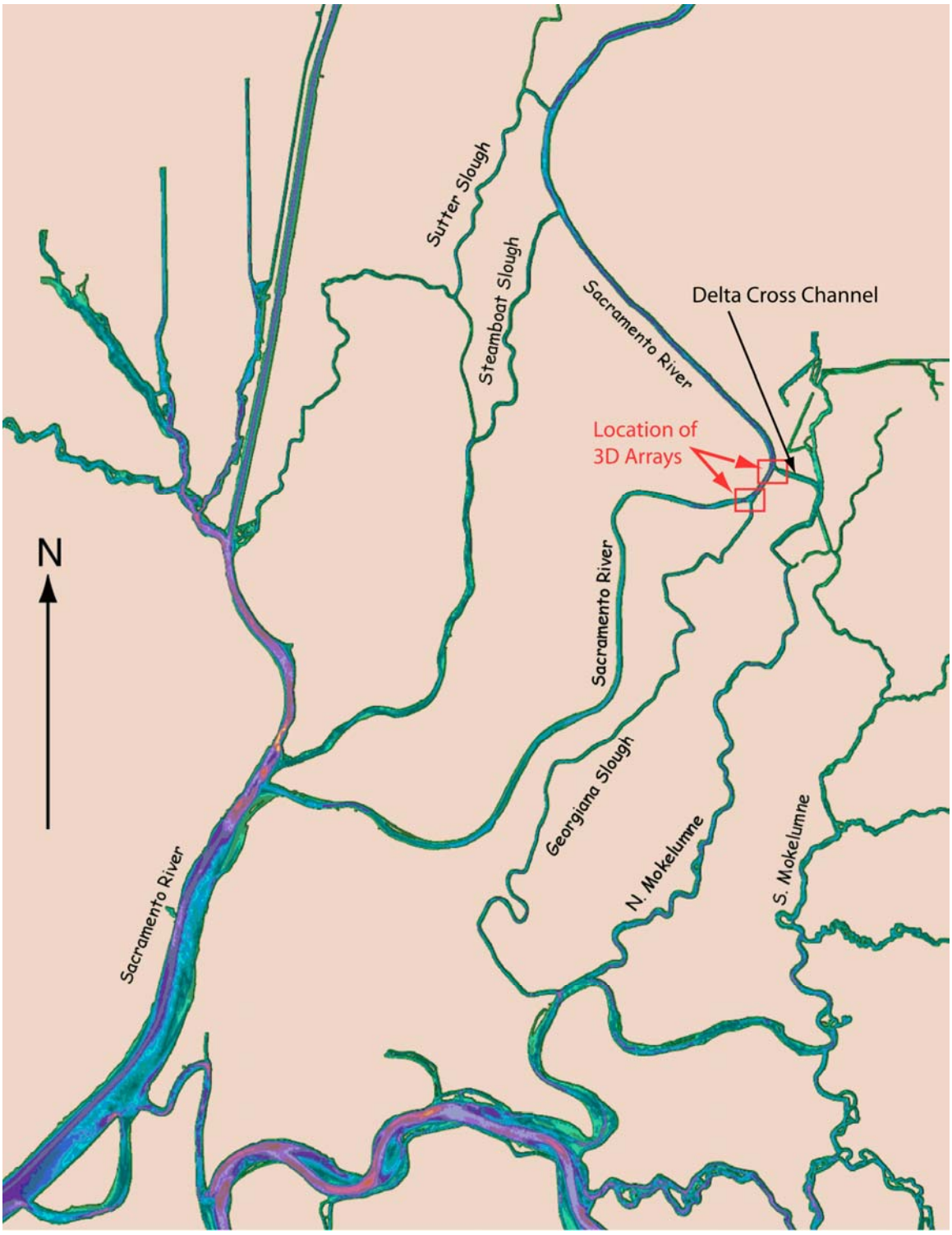
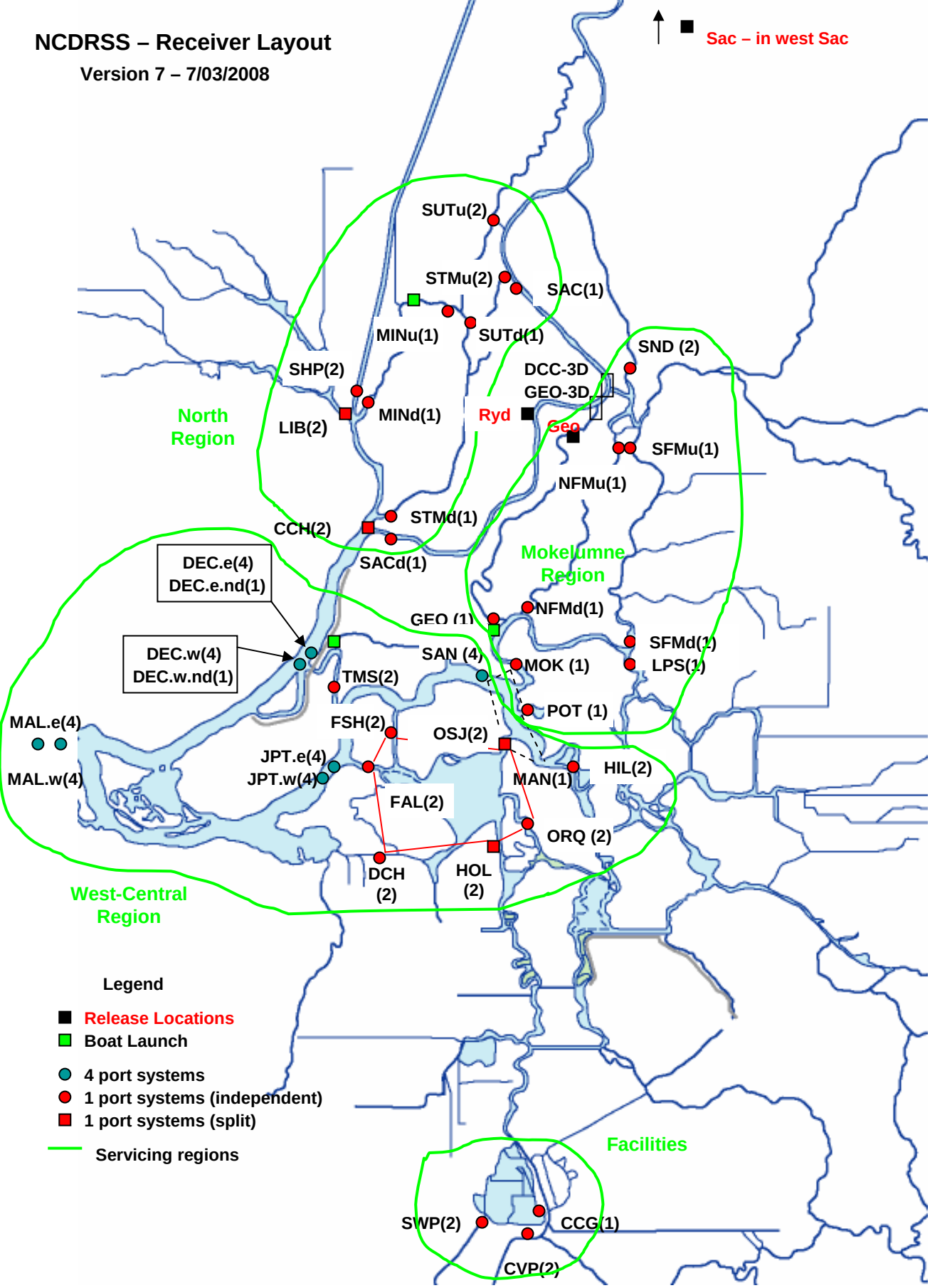


Figure 1. Site location map. Location of the 3-D acoustic telemetry arrays. Deployments are proposed in the Sacramento River at the junctions of the DCC and Georgiana Slough.



Note: Number in parenthesis represents the number of hydrophones
Stations with "(2)" represent two independent systems
Stations with "(4)" represent model 291 four port receivers - -shore power required

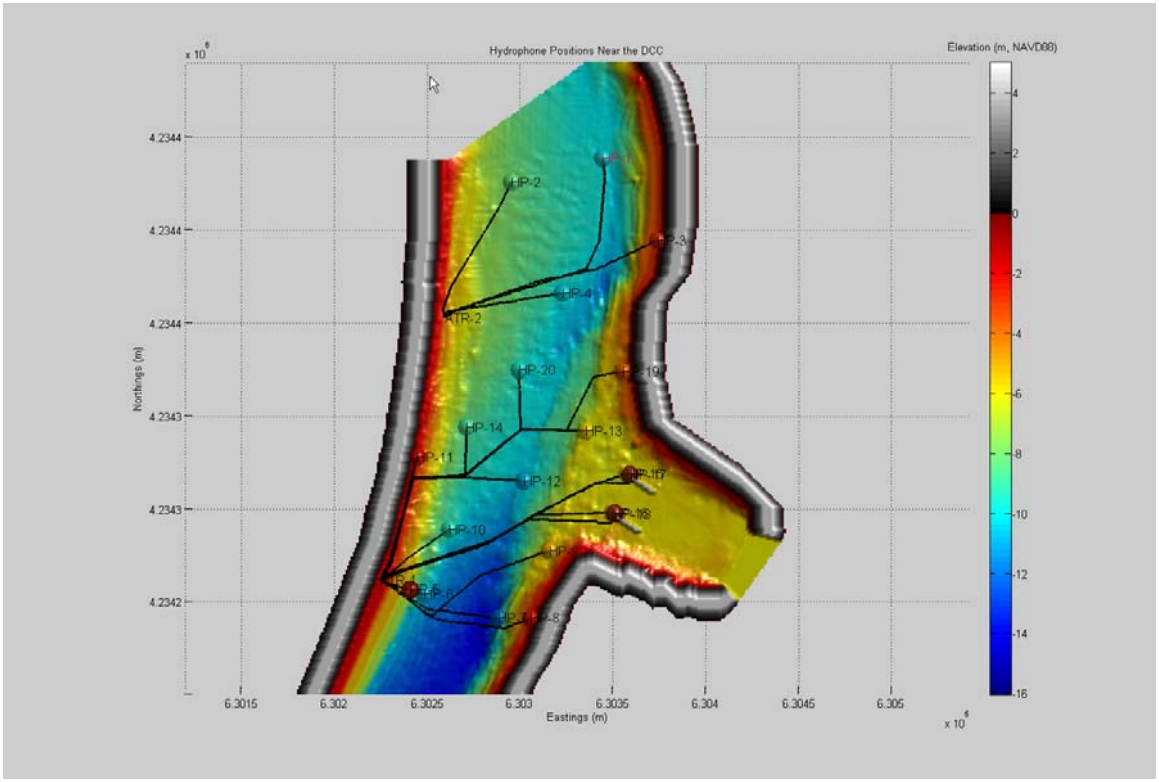


Figure 3. Hydrophone and communication cable locations for arrays deployed in the Sacramento River/DCC. Exact hydrophone and cable locations will be determined through detailed field reconnaissance and testing conducted in the summer/fall of 2008.

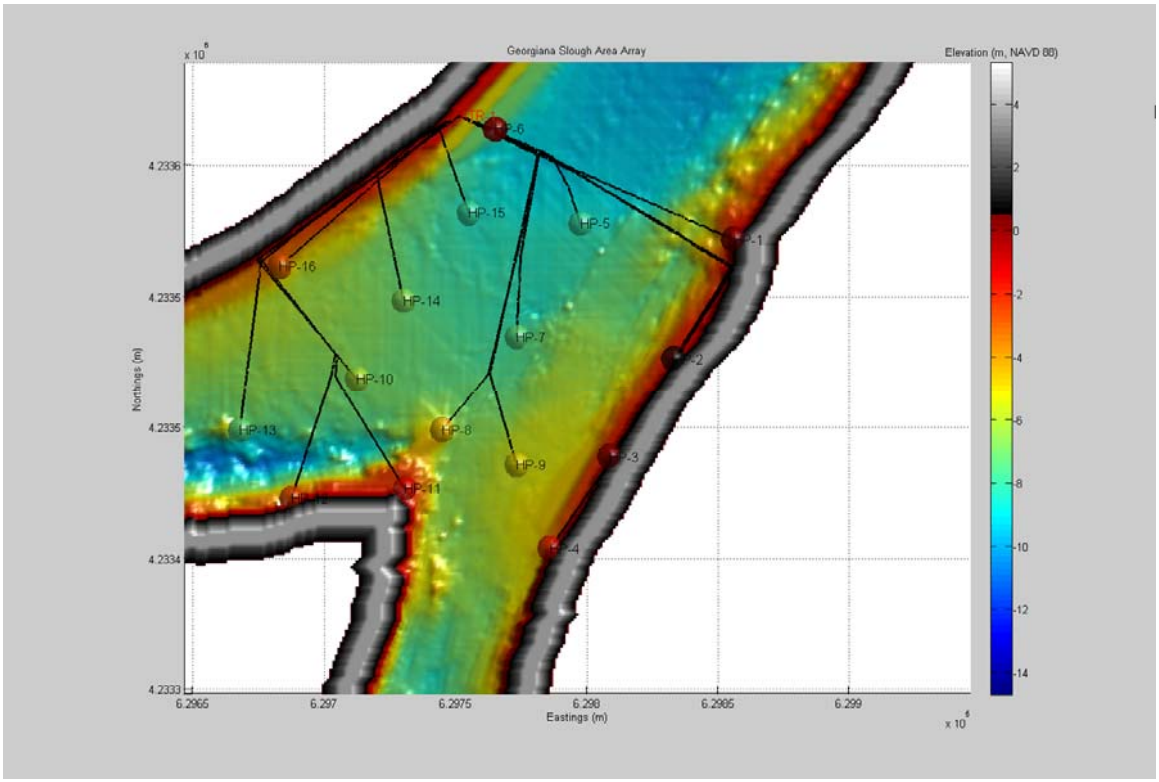


Figure 4. Hydrophone and communication cable locations for arrays deployed in the Sacramento River/Georgiana Slough junction. Exact hydrophone and cable locations will be determined through detailed field reconnaissance and testing conducted in the summer/fall of 2008.

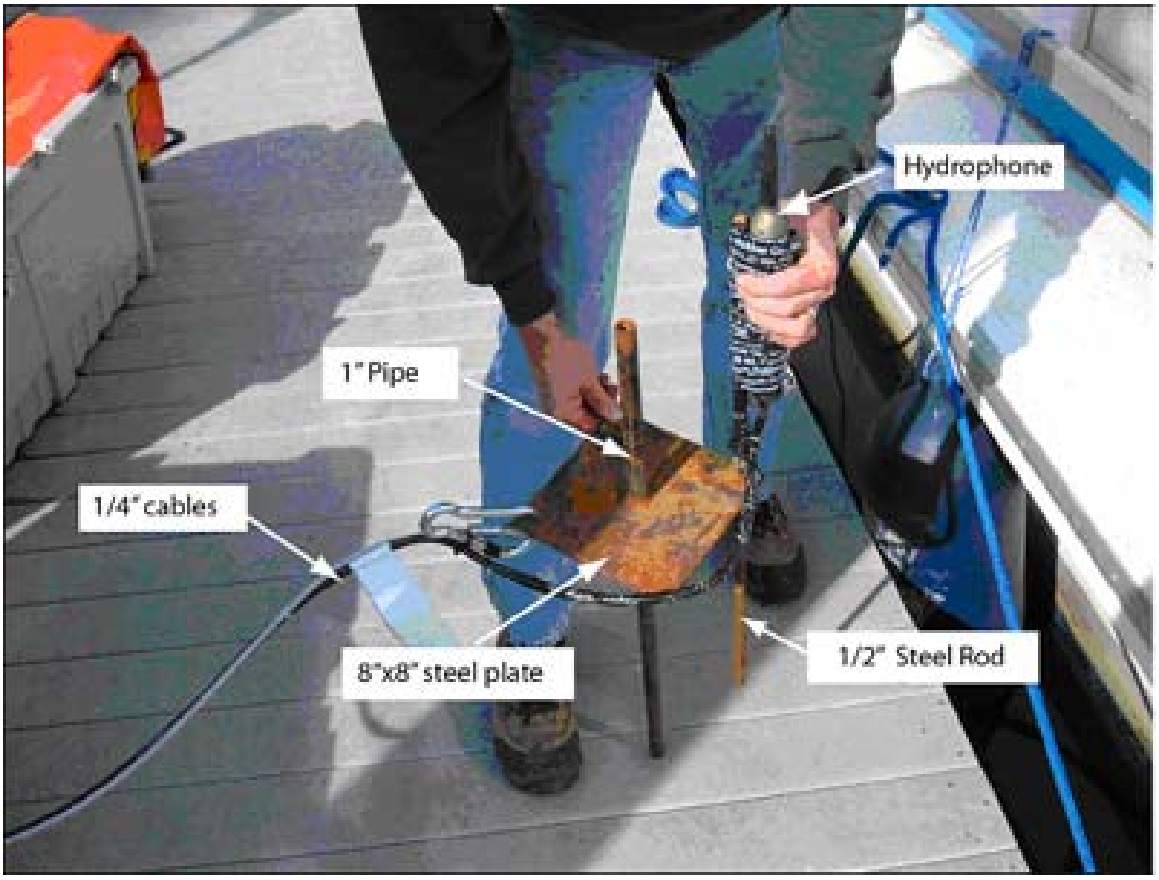


Figure 5. Hydrophone mount. The hydrophone is approximately 6” in length and 1.5” in diameter as is indicated in the photo. Physically, these mounts consist of an 8” square plate which has a ½” steel rod, on which the hydrophone is mounted, welded to the corner of the plate and a 1” pipe welded in the center. This entire configuration is pushed into the river bed with the hydrophone directed upward. Two ~1/4” inch diameter cables connect each hydrophone to an electronic deck box that computes the 3-D positions of acoustic-tagged fish.

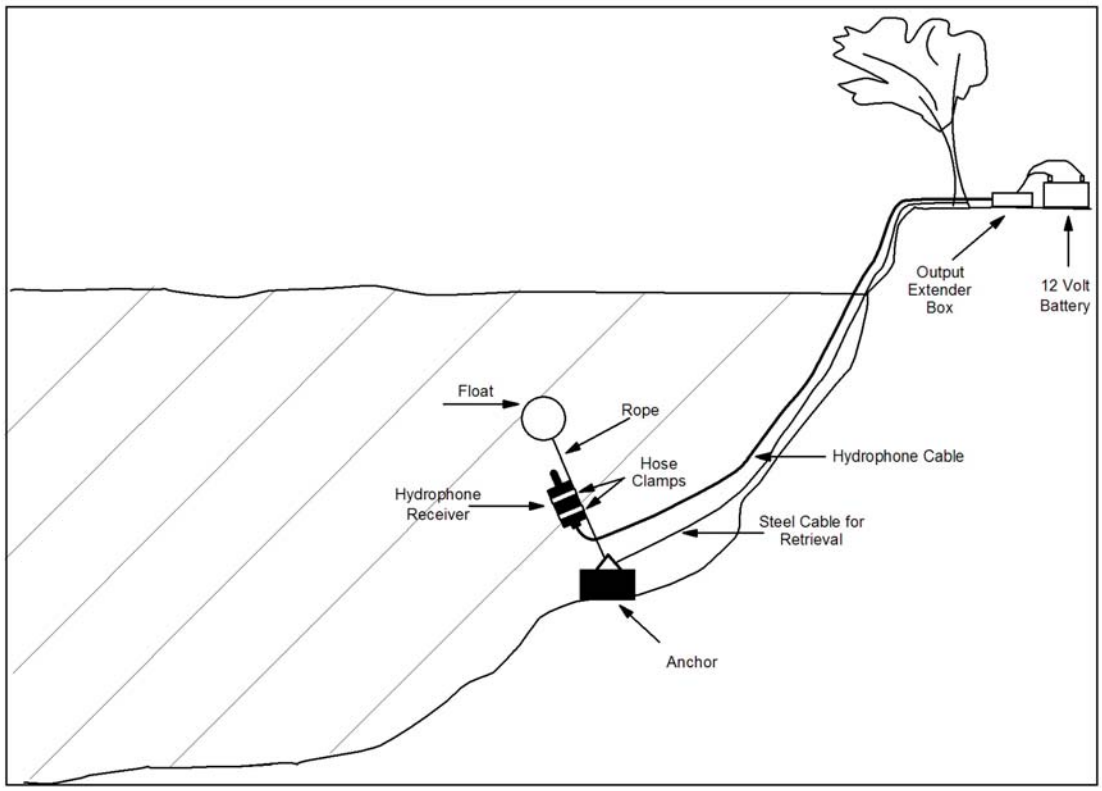


Figure 6. Schematic showing deployment of a HTI single-hydrophone reciever off the bank of a Delta levee.

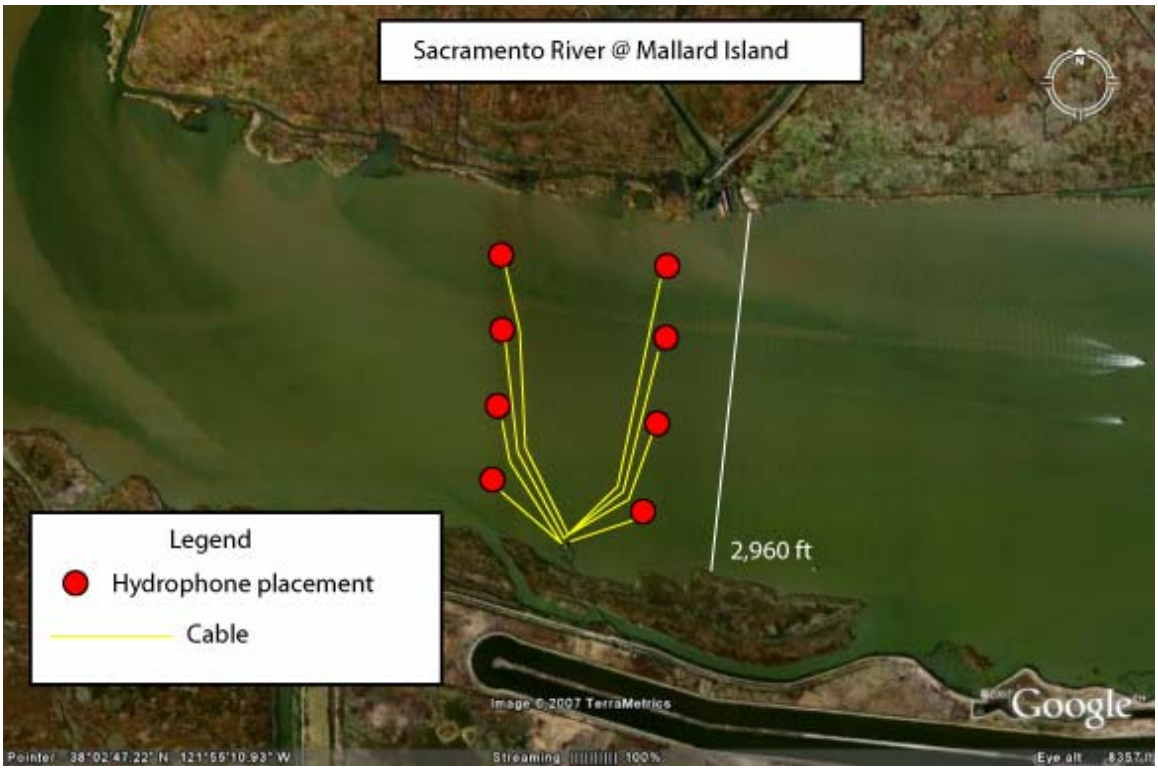


Figure 7. Proposed 4-port system: hydrophone and communication cable locations in the Sacramento River at Mallard Island. Exact hydrophone and cable locations will be determined through detailed field reconnaissance and testing conducted in the summer/fall of 2008.

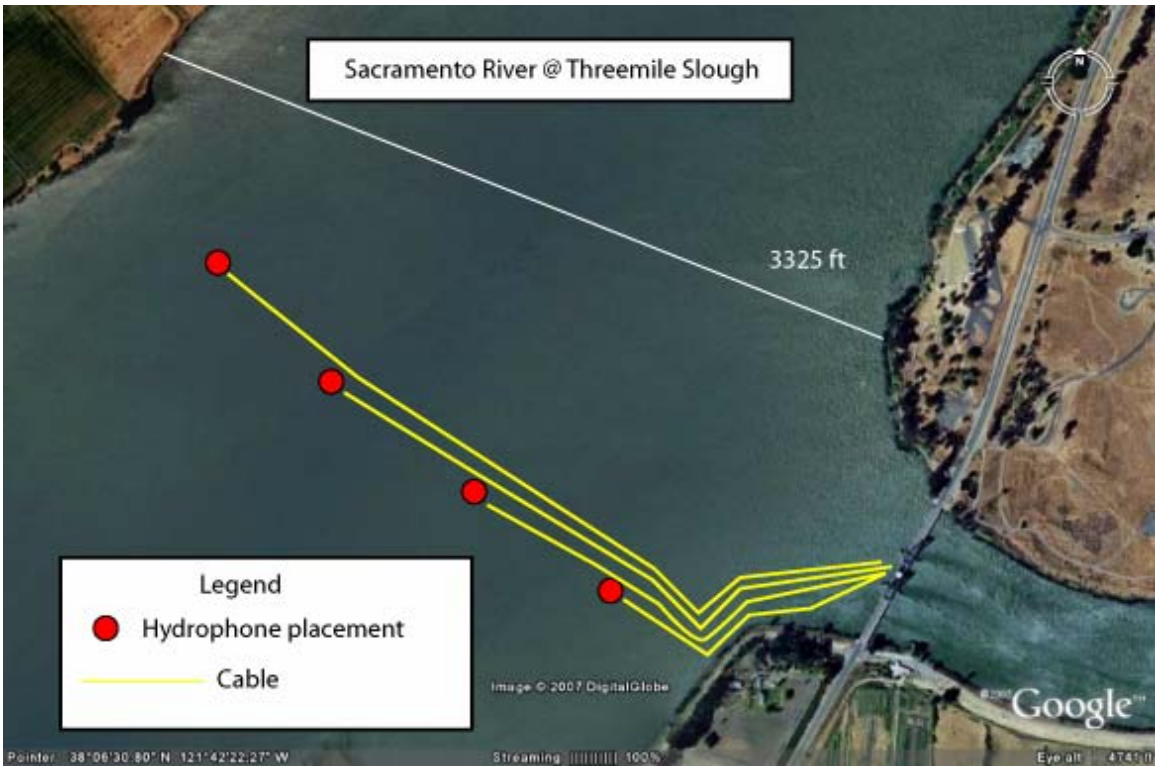


Figure 8. Proposed 4-port system: hydrophone and communication cable locations in the Sacramento River at Three-Mile Slough. Exact hydrophone and cable locations will be determined through detailed field reconnaissance and testing conducted in the summer/fall of 2008.

Figure 9. Proposed 4-port system: hydrophone and communication cable locations in the San Joaquin River, at Jersey Point. Exact hydrophone and cable locations will be determined through detailed field reconnaissance and testing conducted in the summer/fall of 2008.

Figure 10. Proposed 4-port system: hydrophone and communication cable locations in the San Joaquin River, at San Andreas Point. Exact hydrophone and cable locations will be determined through detailed field reconnaissance and testing conducted in the summer/fall of 2008.

Figure 11. Acclimation and holding pen used for the Delta acoustic-telemetry.