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Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration

Spring-Run Chinook Salmon in Mill Creek, California (Photo by Dave Vogel)

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Prepared for:

**Northern California Water Association
and
Sacramento Valley Water Users**

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Exhibit 29

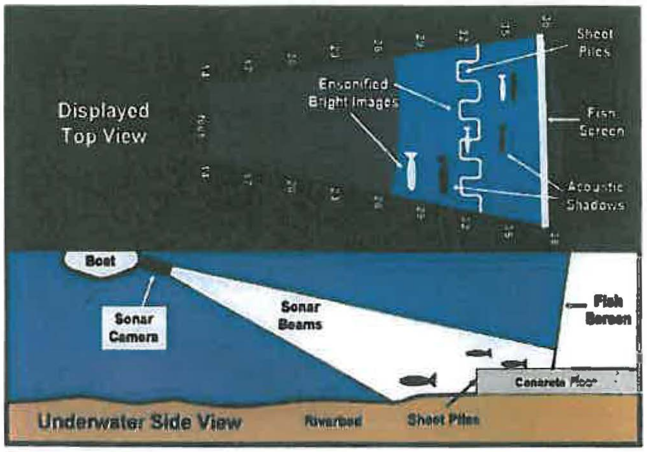

Figure 60. Schematics of DIDSON™ imaging at the base of a flat-plate fish screen. Bottom diagram shows orientation of sonar beams from the acoustic camera off the side of a boat and submerged objects at the fish screens. Top diagram shows the resultant corresponding sonar imaging of objects ensonified with acoustic shadows from the objects. (from Vogel 2008b)

From 1996 through 2010, Natural Resource Scientists, Inc. conducted 22 separate research projects on juvenile salmon (including four studies of predatory fish) in the Delta using acoustic or radio telemetry as a means to gain an improved understanding of fish movements and mortality (Vogel 2010a). The reason juvenile salmon telemetry studies were initiated in the Delta was to acquire detailed data on fish behavior, fish route selection through complex channels, and estimate fish survival in discrete reaches. Past efforts using traditional coded-wire tagging could not answer those critically important questions. Research findings from the telemetry investigations indicate that smolt survival assumptions and models must incorporate these new conclusions to avoid misinterpretation of data and improve quantitative estimates of fish survival and movements (Vogel 2010a).

The first successful use of telemetry on juvenile salmon in the Central Valley was conducted by Natural Resource Scientists, Inc. on behalf of EBMUD in 1996 and 1997. At that time, the specific behavior of juvenile salmon in the Delta was largely unknown. The initial studies quickly determined that the fish did not move as a school, but instead, dispersed, exhibiting a wide range in migratory behaviors in the complex Delta environment. Salmon moved many miles back and forth each day with the ebb and flood tides and the side channels (where flow was minimal) were largely unused. Site-specific hydrodynamic conditions present at flow splits when the fish arrived had a major affect in initial route selection. Importantly, some of the salmon were believed to have been preyed upon based on very unusual behavior patterns (Vogel 2010a).

Subsequent, additional juvenile salmon telemetry studies were conducted by Natural Resource Scientists Inc. on behalf of the USFWS and CALFED in the north Delta (Vogel 2001, Vogel 2004). Triangulating radio-tagged fish locations in real time (Figure 61) clearly demonstrated

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how juvenile salmon move long distances with the tides and were advected into regions with very large tidal prisms, such as upstream into Cache Slough and into the flooded Prospect and Liberty Islands (Figure 62). During the studies, it was determined that some radio-tagged salmon were eaten by predatory fish in northern Cache Slough, near the levee breaches into flooded islands (discussed below). Also, monitoring telemetered fish revealed that higher predation occurred in Georgiana Slough as compared to the lower Sacramento River (Figure 63). As discussed previously, past coded-wire tagging studies found that salmon released into northern Georgiana Slough were found to have a higher mortality rate than fish released downstream of the slough in the Sacramento River (Brandes and McLain 2001).

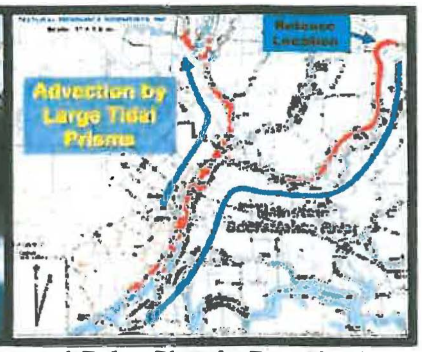


Figure 61. Left picture, mobile telemetry conducted in the north Delta. Photo by Dave Vogel.
Figure 62. Right picture, telemetered locations of approximately 100 radio-tagged salmon smolts released in the lower Sacramento River near Ryde (data from Vogel 2001 and Vogel 2004).

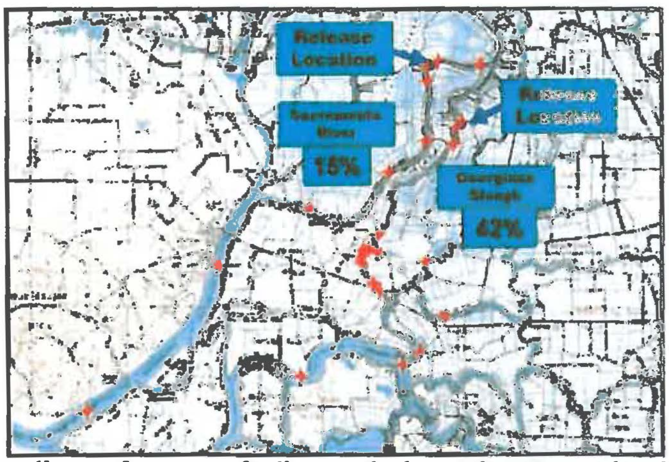
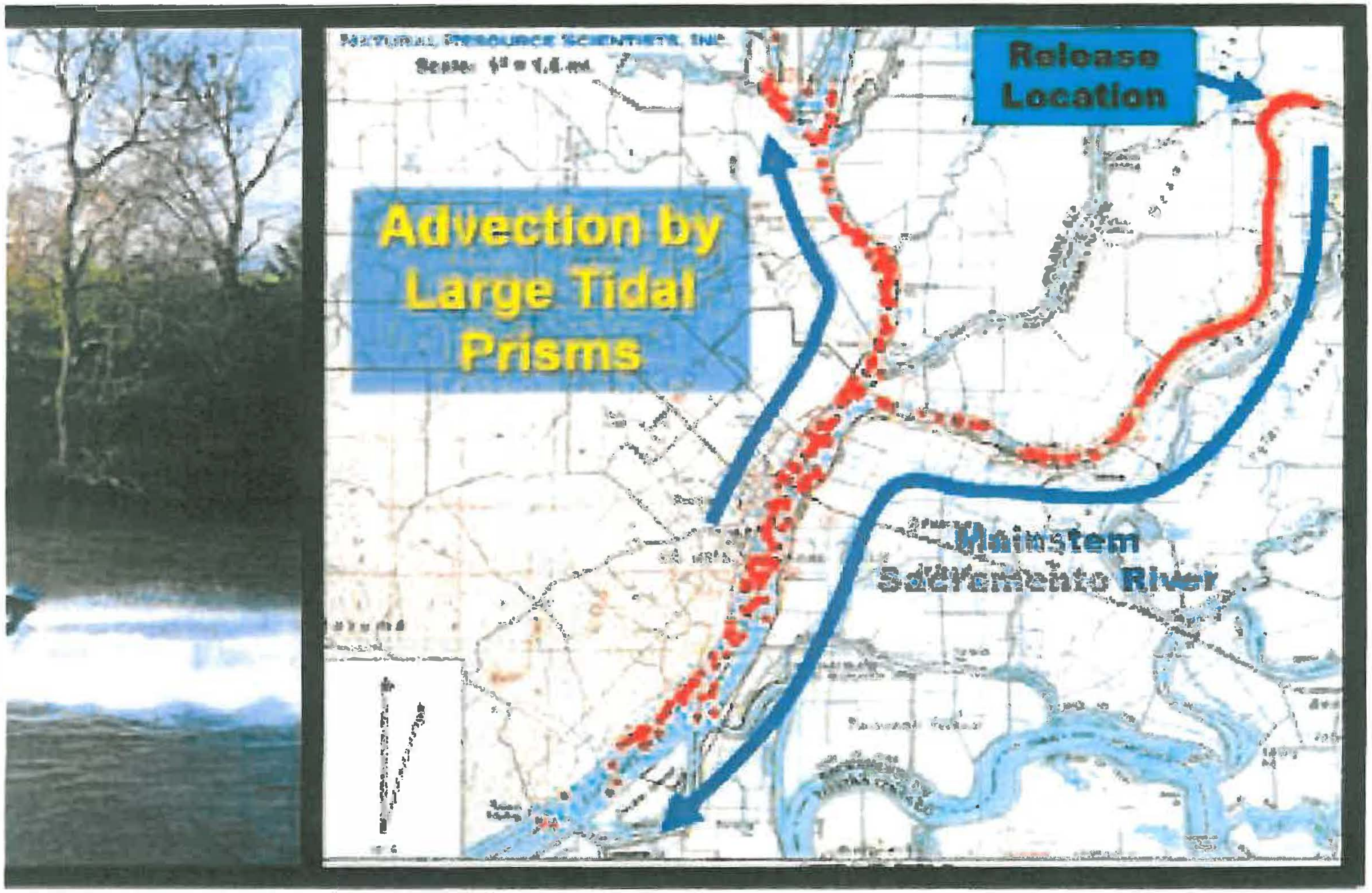


Figure 63. Estimated mortality rate for groups of radio-tagged salmon released at two locations in the north Delta and locations where radio-tagged salmon smolts were detected to have been preyed upon (Vogel 2001, Vogel 2004).

More recently, a 2007 study conducted by releasing acoustic-tagged juvenile salmon in the San Joaquin River found 116 motionless juvenile salmon transmitters in the lower San Joaquin River near the Stockton Waste Water Treatment Plant and a nearby bridge (Figure 64) (Vogel 2007b). This was an all-time record for the largest number of dead radio- or acoustic-telemetered juvenile



ducted in the north Delta. Photo by Dave Vogel.
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vegetation at some sites in the Delta and water clarity. Increased water clarity for sight predators such as black bass and striped bass would presumably favor predatory fish over prey (*e.g.*, juvenile salmon). Fewer native fish species are found in *Egeria* stands compared to introduced fish species (Grimaldo and Hymanson 1999). Additionally, it has been hypothesized that high densities of *Egeria* in portions of the Delta may restrict juvenile salmon access to preferred habitats, forcing salmon to inhabit deep water or channel areas where predation risks may be higher (Grimaldo *et al.* 2000).

During recent years, there has been an emphasis to reclaim or create shallow, tidal wetlands to assist in re-recreating the form and function of ecosystem processes in the Delta with the intent of benefitting native fish species (Simenstad *et al.* 1999). Among a variety of measures to create such wetlands, Delta island levees either have been breached purposefully or have remained unrepaired so the islands became flooded. A recent example is the flooding of Prospect Island which was implemented under the auspices of creating shallow water habitat to benefit native fish species such as anadromous fish (Christophel *et al.* 1999). Initial fish sampling of the habitat created in Prospect Island suggested the expected benefits may not have been realized due to an apparent dominance of non-native fish (Christophel *et al.* 1999). Importantly, a marked reduction of sediment load to the Delta in the past century (Shvidchenko *et al.* 2004) has implications in the long-term viability of natural conversion of deep water habitats on flooded Delta islands into shallow, tidal wetlands. The very low rates of sediment accretion on flooded Delta islands indicate it would take many years to convert the present-day habitats to intertidal elevations which has potentially serious implications for fish restoration (Nobriga and Chotkowski (2000) due to likely favorable conditions for non-salmonid fish species that can prey on juvenile salmon. Studies of the shallow water habitats at flooded Delta islands showed that striped bass and largemouth bass represented 88 percent of the individuals among 20 fish species sampled (Nobriga *et al.* 2003).

There have likely been significant adverse, unintended consequences of breaching levees in the Delta. There is a high probability that site-specific conditions at the breaches have resulted in hazards for juvenile anadromous fish through the creation of favorable predator habitats. The breaches have changed the tidal prisms in the Delta and can change the degree in which juvenile fish are advected back and forth with the tides (Figure 61; previously discussed). Additionally, many of the breaches were narrow which have created deep scour holes favoring predatory fish. Sport anglers are often seen fishing at these sites during flood or ebb tides. Breaching the levees at Liberty Island is an example (Figure 72 and 73). Recent acoustic-tagging of striped bass in this vicinity confirmed a high presence of striped bass (Figure 74, D. Vogel, unpub. data).

Figure 72. Liberty Island in the north Delta before and after flooding.

Figure 73. Liberty Island in the north Delta before and after flooding showing locations of narrow breaches in the levee.

Figure 74. Locations (squares) where predatory striped bass were acoustic-tagged with transmitters during the winter of 2008 – 2009 in the north Delta near Liberty Island (D. Vogel, unpublished data).