APPENDIX F

Entrainment and Source Water Study

Bay Area Regional Desalination Project

Entrainment and Source Water Study Report

March 8, 2010

Prepared by:
TENERA Environmental Inc.
971 Dewing Avenue #101, Lafayette CA 94549
(925) 962-9769, Fax (925) 962-9758

EXECUTIVE SUMMARY

Four partner water agencies are working together to develop a Bay Area Regional Desalination Project (BARDP) that could provide water to Bay Area water agencies during droughts and emergencies. The four agencies are Contra Costa Water District (CCWD), East Bay Municipal Water District (EBMUD), Santa Clara Valley Water District (SCVWD), and the San Francisco Public Utilities Commission (SFPUC). The purpose of this report is to assess the potential entrainment effects of a 25 million gallons per day (mgd) BARDP feedwater intake system at a site in East Contra Costa County.

An existing permitted intake, CCWD's Mallard Slough Pump Station (MSPS), located in an unincorporated area near Pittsburg, California, was selected as the location for a pilot desalination plant. MSPS provides raw water to CCWD at a physical capacity of 40 mgd during times when the water quality is acceptable by diverting water from Mallard Slough through state-of-the-art 3/32-inch mesh wedge wire intake screens.

The following sections present entrainment and source water data collected over a 12-month period (November 5, 2008–October 9, 2009). Entrainment occurs when organisms smaller than the openings in the 3/32-inch intake screens (e.g., larval fishes) are drawn into the feedwater intake system. Entrainment sampling was conducted behind the intake screens and source water sampling was conducted in Mallard Slough. The BARDP entrainment and source water studies focused on larval fishes and fish eggs whose adult populations might be affected by operation of the BARDP feedwater intake system.

The studies were designed to specifically address the following questions:

- What are the species composition and abundance of larval fishes and fish eggs entrained by the BARDP pilot plant?
- What are the local species composition and abundance of entrainable larval fishes and fish eggs in the Mallard Slough source water?
- What are the potential impacts of entrainment losses on larval fish and fish eggs due to operation of a BARDP full-scale feedwater intake system?

Six entrainment surveys and four source water surveys were conducted during the 2008–2009 BARDP pilot plant study. Three separate runs of the pilot plant, each approximately six weeks in duration, were designed and conducted in response to actual water quality conditions encountered at the site:

- Run No. 1: Operated during the period from November 2008 to December 2008 to establish baseline system operating parameters. During this time period, entrainment and source water surveys were conducted on November 5, 2008 and December 16, 2008.

- Run No. 2: Operated during the higher salinity period from January 2009 to February 2009 to establish higher flux and mid-challenge system operating parameters. Run No. 2 occurred during the sensitive fish period. As a result, entrainment sampling could only occur when CCWD was operating its intake pumps. Only one entrainment survey was conducted during Run No. 2; it was conducted on February 20, 2009. No source water sampling was conducted during the sensitive fish period.

- Run No. 3: Operated during lower salinity period from March 2009 to April 2009 to establish highest manufacturer recommended flux and challenge system operating parameters. Run No. 3 occurred during the sensitive fish period; therefore, entrainment sampling could only occur when CCWD was operating its intake pumps. Only one entrainment survey was conducted during Run No. 3; it was conducted on March 6, 2009. No source water sampling was conducted during the sensitive fish period.

Two additional entrainment and source water surveys were conducted on July 16-17 and October 8-9, 2009 during times when the pilot plant was not operating. The purpose of these surveys was to gather information from the summer and fall time period, a time period the pilot plant did not operate.

Findings of the completed entrainment study are presented graphically in the report using the results of November 2008–October 2009 entrainment and source water field studies (Section 3.0—*Entrainment and Source Water Study*).

The results of six entrainment surveys for larval fish and fish eggs show the following:

- Three taxa of larval fishes were collected during entrainment sampling–prickly sculpin, longfin/delta smelts, and bluegill/redear sunfishes. Prickly sculpin are an abundant native species and bluegill and redear sunfishes are abundant introduced species. Both longfin smelt and delta smelt are listed species. These species were only collected during the sensitive fish period of January through June.

- For a full-scale 25 mgd desalination facility at Mallard Slough, potential losses of adult fishes, based on demographic modeling for entrained species, ranged from a low of 25 individuals per year for longfin/delta smelts to 510 per year for prickly sculpin. Sufficient life history information was obtained from the scientific literature to model impacts on two of the three taxa. Demographic modeling (*FH and AEL*) of longfin/delta smelts larval entrainment estimates showed potential losses of approximately 20 females (*FH* estimate; 2*FH* estimate = 39) and 25 adults (*AEL* estimate). *FH* modeling for prickly sculpin showed potential losses of 255 adults (2*FH* estimate = 510); *AEL* values for prickly sculpin could not be computed due to the absence of any published larval mortality information. The estimated low number of entrained bluegill/redear sunfishes (n=1,771) was less than the fecundity values of bluegill; therefore, *FH* and *AEL* values were not computed.

- Proportional entrainment estimates (*PE*) could not be calculated. The empirical transport model (*ETM*) calculates an estimate of the proportional mortality to the population due to entrainment. The underlying basis of the model is an estimate of the daily proportion of the source water entrained and therefore requires estimates of both entrainment and source water concentrations of larvae. *ETM* estimates were not calculated for any of the entrained fishes because they were not found in the collected source water samples or source water samples were not collected due to lack of permission to collect during the sensitive fish period (January through June).
- No fish eggs were collected in entrainment or source water samples during the entire study.

A summary of the estimated BARDP entrainment effects (November 2008–October 2009) for all the entrained fishes, for a 25 mgd intake, is provided in Table ES-1. These values are based on analyses using the Fecundity Hindcast (*FH*) model and the Adult Equivalent Loss (*AEL*) model. These models require species-specific estimates of age, growth, fecundity, and survivorship of various life stages. Demographic data were available to allow at least one of the two modeling approaches to be applied to two of the three fish taxa (Section 4.0—*Impact Assessment*).

Table ES-1. Potential total annual larval entrainment from a full-scale 25 mgd BARDP intake feedwater system for all entrained fishes and their adult equivalents based on Fecundity Hindcast (*FH*) and Adult Equivalent Loss (*AEL*) extrapolations from data collected during the November 2008–October 2009 entrainment surveys.

Taxa	Total Larval Entrainment	2*FH*[(a)] Estimate	*AEL* Estimate
Prickly sculpin	990,605	510	*
Longfin/Delta smelts	36,777	39	25
Bluegill/Redear sunfishes	1,771	*	*

*Unavailable information or value that could not be computed.

(a) 2*FH* (number of estimated females x 2) values are presented to provide comparison to *AEL* estimates, which include both males and females.

The species composition of larval fishes collected during the 2008–2009 BARDP entrainment and source water sampling was consistent with published life history information for species found in Suisun Bay, along with documented collections from other studies conducted in Suisun Bay (PG&E 1981, Moyle 2002, Tenera 2009, IEP/CDFG survey results). The estimated small annual loss of adult prickly sculpin and bluegill/redear sunfishes is unlikely to affect adult populations. Entrainment of longfin/delta smelts occurred during the sensitive fish period of January through June when these larvae are normally present in the vicinity of Mallard Slough.

The larvae of two species of listed fishes are susceptible to entrainment through 3/32-inch mesh intake screens in the Sacramento-San Joaquin Delta, including the MSPS in Suisun Bay. Delta smelt, under the jurisdiction of U.S. Fish and Wildlife Service (USFWS) and California Department of Fish and Game (CDFG), is listed as a threatened species under the Federal Endangered Species Act and is listed as endangered under the California Endangered Species Act. Longfin smelt is listed as a threatened species under the California Endangered Species Act. The spawning times of both species vary between years depending on water temperature and salinity. January through June has typically been designated as the sensitive period, although longfin smelt larvae may be present during December of some years. The life stages of listed Chinook salmon, steelhead, and green sturgeon normally found in the MSPS area are too large to be entrained through the 3/32-inch mesh intake screens.

Expanded operations at the MSPS to supply full-scale operation of a BARDP facility when larval delta and longfin smelts are present may require USFWS and CDFG review. To properly permit the MSPS for a full-scale desalination facility could require preparation of a Biological Assessment that would be reviewed by USFWS and CDFG. USFWS may issue a Biological Opinion and CDFG may have permit requirements. The Biological Assessment should contain the following information: a description of the project including operations, the listed species potentially affected, an analysis of impacts to species, proposed minimization and mitigation measures, and plans to monitor compliance. Listed salmonids and green sturgeon are found in Suisun Bay, and a consultation would be required with National Marine Fisheries Service (NMFS). Since entrainment impacts are highly unlikely to occur to these species it may be possible to pursue a “not likely to adversely affect” determination. However, if dredging an intake channel was included in the project description, it would need to occur within the established dredging work windows, and it would be necessary to consult with NMFS on the presence of green sturgeon and listed salmonids. Essential fish habitat for all Pacific Coast salmon, starry flounder, and northern anchovy, as designated by NMFS surrounds the MSPS. An assessment of expanded MSPS operations effects to essential fish habitat would be required by NMFS.

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

Four partner water agencies are working together to develop a Bay Area Regional Desalination Project (BARDP) that could provide water to Bay Area water agencies during droughts and emergencies. The four agencies are Contra Costa Water District (CCWD), East Bay Municipal Water District (EBMUD), Santa Clara Valley Water District (SCVWD), and the San Francisco Public Utilities Commission (SFPUC). Pre-feasibility studies were completed in 2003 and 2005 that examined potential facility sites that included 12 sites located in the San Francisco Bay-Delta and one ocean-sited facility. A feasibility study completed in 2007 narrowed the site selection to the following three locations: Mallard Slough in East Contra Costa County, the East Bay side of the Oakland Bay Bridge in Alameda County, and an ocean site in the City and County of San Francisco.

An existing permitted intake, CCWD's Mallard Slough Pump Station (MSPS), located in an unincorporated area near Pittsburg, California, was ultimately selected as the location for a pilot plant. MSPS provides raw water to CCWD at a physical capacity of 40 mgd during times when the water quality is acceptable. Under CCWD's current Biological Opinions, fish entrainment monitoring is required during times when CCWD operates its intake pumps.

The MSPS intake is located at the southern end of Mallard Slough. Mallard Slough is on the southern shore of Suisun Bay in Contra Costa County (Figure 1-1). Suisun Bay is designated critical habitat for several species of listed fishes: Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and delta smelt. Longfin smelt, listed in March 2009 as threatened under the California Endangered Species Act, also utilize Suisun Bay as does the federally listed green sturgeon. January through June has been established as the "sensitive fish period" in the Delta due to the presence of the early life stages of delta smelt, longfin smelt and other protected species.

The goals of the pilot plant test program were to collect data on technical feasibility (pretreatment options, membrane performance, design parameters) and to assess the potential environmental impacts (brine disposal, entrainment of aquatic species) of a desalination facility located in an estuarine environment. Field operations, laboratory work, and special studies were conducted while the pilot plant was operational. Approximately 50 gallons per minute (gpm) were withdrawn from a location after the water had passed through the MSPS intake screens. Performance data were collected for treatment by two types of ultra-filtration pre-treatment membranes, two types of Reverse Osmosis (RO) membranes, and one Nanofiltration (NF) membrane.

Three separate runs of the pilot plant, each approximately six weeks in duration, were designed and conducted in response to actual water quality conditions encountered at the site:

- Run No. 1: Operated during the period from November 2008 to December 2008 to establish baseline system operating parameters. During this time period, entrainment and source water surveys were conducted on November 5, 2008 and December 16, 2008.

- Run No. 2: Operated during the high salinity period from January 2009 to February 2009 to establish higher flux and mid-challenge system operating parameters. Run No. 2 occurred during the sensitive fish period. As a result, entrainment sampling could only occur when CCWD was operating its intake pumps as is required by CCWD's Biological Opinion. Only one entrainment survey was conducted during Run No. 2; it was conducted on February 20, 2009. No source water sampling was conducted during the sensitive fish period.

- Run No. 3: Operated during low salinity period from March 2009 to April 2009 to establish highest manufacturer recommended flux and challenge system operating parameters. Run No. 3 occurred during the sensitive fish period; therefore, entrainment sampling could only occur when CCWD was operating its intake pumps. Only one entrainment survey was conducted during Run No. 3; it was conducted on March 6, 2009. No source water sampling was conducted during the sensitive fish period.

Two additional entrainment and source water surveys were conducted on July 16-17 and October 8-9, 2009 during times when the pilot plant was not operating. The purpose of these surveys was to gather information from the summer and fall time period, a time period when the pilot plant did not operate.

1.1 Organization of the Report

This report is a summary and analysis of the entrainment and source water data collected from November 2008–October 2009. The report contains the following sections:

- Section 2.0—Description of the Pilot Plant and Source Water Characteristics. Descriptions of the pilot plant and the source water characteristics of Suisun Bay are provided in Section 2.0.

- Section 3.0—Entrainment and Source Water Study. The entrainment and source water study experimental design, sampling and analysis methods, and results are provided in Section 3.0. The purpose of this study was to describe the composition and abundance of larval fishes that are at risk of entrainment in the pilot plant's intake system. This section presents the results of entrainment and source water sampling.

- Section 4.0—Impact Assessment. This section evaluates the entrainment effects of a full-scale desalination facility's intake on larval fishes. The assessment utilizes two different population effects models (except when life history data were not available). These models all assume 100 percent entrainment mortality. The two analytical techniques used are Adult Equivalent Loss (*AEL*) and Fecundity Hindcasting (*FH*).

Figure 1-1. Location of Contra Costa Water District's Mallard Slough Pump Station.

2.0 DESCRIPTION OF THE SOURCE WATER AND PILOT PLANT

The San Francisco Bay-Sacramento-San Joaquin Delta (Bay-Delta) Estuary is the largest estuary on the west coast of North America. It comprises two regions, the San Francisco Bay and the Sacramento-San Joaquin Delta (Delta). The San Francisco Bay system is the largest coastal embayment on the Pacific Coast of the United States (Nichols and Pamatmat 1988). It consists of South San Francisco Bay, Central San Francisco Bay, San Pablo Bay, Carquinez Strait, and Suisun Bay. Suisun Bay is a shallow embayment between Chipps Island at the western boundary of the Delta and the Benicia-Martinez Bridge. Adjacent is Suisun Marsh, the largest brackish marsh in the United States (Monroe et al. 1992). Mallard Slough is located on the southern shore of Suisun Bay in an unincorporated area near the City of Bay Point in Contra Costa County.

2.1 Physical Characteristics of Suisun Bay

In the western Delta, the main channels of the San Joaquin and Sacramento rivers join and form a single channel that enters Suisun Bay at Chipps Island. Freshwater flowing toward the Pacific Ocean mixes with ocean water to create habitats that attract coastal fishes to spawn, and provides low salinity rearing habitat for their young. Suisun Bay, extending from Chipps Island in the east to the Benicia Bridge in the west, is the smallest of the major bays in the San Francisco Bay-Delta Estuary. Suisun Bay is extremely shallow, except for a 330 foot shipping channel along its south shore. Over 1/3 of Suisun Bay is less than 6 ft deep at mean lower low water (MLLW). The northern shore is less developed, consisting of extensive shoals and the extensively managed wetland area, Suisun Marsh.

The hydrology of Suisun Bay and the western Delta is important to the San Francisco Bay estuarine ecosystem. The aquatic environment near the MSPS fluctuates between a brackish-water environment when freshwater outflow is low and a freshwater environment in periods of high freshwater outflow. Seasonal changes in water temperature and salinity affect species composition and abundance of the aquatic community in the area. Water quality in the vicinity of the MSPS, as in the Delta in general, is influenced primarily by freshwater inflow and tidal circulation. Tidal flow entering the Delta from Suisun Bay influences both the Sacramento and San Joaquin river systems. Tides are semidiurnal, with two flood and two ebb phases per 24.8-hour tidal day. Mean tidal range at Pittsburg is about 3.3 ft. The average tidal flow in front of the adjacent Pittsburg Power Plant is approximately 170,000 cfs (4,800 m^3/s) (PG&E 1970). The effective volume of water that moves back and forth past the area depends on tidal conditions and freshwater inflow. It has been assumed to be equal to the tidal prism, i.e., the quantity of water passing the power plant between successive tidal phases minus the Delta outflow, calculated as approximately 1.3 billion ft^3 (37 million m^3) (Tetra Tech 1976).

The hydraulic characteristics of the mixing zone between freshwater flowing into the Delta from the Sacramento and San Joaquin river systems and saltwater intrusion from San Francisco Bay is characterized by a zone of particle accumulation frequently referred to as the low salinity zone or the "null zone." Data from Arthur and Ball (1978, 1979) and Kimmerer (1991) have shown that the location of the null zone can be defined by surface salinities ranging from approximately 1 to 6 ppt. Studies have shown that the location of the null zone varies in response to changes in freshwater outflow. During late winter and spring when freshwater outflow is greater (e.g., 7,500–15,000 cfs), the null zone is located downstream within Suisun Bay in the general vicinity of the MSPS.

2.2 Biological Communities of Suisun Bay

Suisun Bay provides habitat for many species of fishes. Anadromous fishes, such as Chinook salmon *Oncorhynchus tshawytscha*, striped bass *Morone saxatilis*, white sturgeon *Acipenser transmontanus*, longfin smelt *Spirinchus thaelichthys*, and Pacific lamprey *Lampetra tridentata* migrate through Suisun Bay to their spawning grounds and return through it on their way to the Pacific Ocean. Additionally, some marine species, such as Pacific staghorn sculpin *Leptocottus armatus* and starry flounder *Platichthys stellatus* spend their juvenile life stage in Suisun Bay. Many native species can be found in Suisun Bay, such as Chinook salmon, Central Valley steelhead *Oncorhynchus mykiss*, delta smelt *Hypomesus transpacificus*, longfin smelt, prickly sculpin *Cottus asper*, tule perch *Hysterocarpus traski*, green sturgeon *Acipenser medirostris*, hitch *Lavinia exilicauda*, Sacramento splittail *Pogonichthys macrolepidotus*, Sacramento sucker *Catostomus occidentalis*, Sacramento perch *Archoplites interruptus*, and hardhead *Mylopharodon conocephalus*. Suisun Bay is also utilized by many introduced fish species such as threadfin shad *Dorosoma petenense*, American shad *Alosa sapidissima*, inland silverside *Menidia beryllina*, largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, striped bass, white crappie *Pomoxis annularis*, black crappie *Pomoxis nigromaculatus*, yellowfin goby *Acanthogobius flavimanus*, Shimofuri goby *Tridentiger bifasciatus*, and Shokihaze goby *Tridentiger barbulatus*. Tides transport larvae of Pacific herring *Clupea pallasii*, which spawn in central San Francisco and San Pablo bays, to Suisun Bay. Six species of native fishes listed above are protected under the state and federal Endangered Species Acts (Table 2-1). Suisun Bay is designated critical habitat for delta smelt, Sacramento River winter run Chinook salmon, Central Valley spring-run Chinook salmon, and the southern distinct population segment (DPS) of green sturgeon.

Data on the status of various aquatic organisms inhabiting the Estuary system show a number of changes in species composition and relative abundance of fish and macroinvertebrate populations (Moyle and Herbold 1989, Herbold et al. 1992, and CDFG 1993). During the past decade, results from these studies have demonstrated the introduction and rapid increase in abundance of non-native species such as yellowfin goby and invertebrate species such as the copepods *Pseudodiaptomus forbesi, Limnoithona tetraspina,* and *Sinocalanus doerri,* and the clam *Corbula amurensis*. Abundances of the copepods *Eurytemora affinis* and *Diaptomus* spp., mysid shrimp *Neomysis mercedis*, and shrimps (*Palaemon macrodactylu*s and *Crangon franciscorum*) have declined in recent years (Herbold et al. 1992).

Table 2-1. Fish species protected under the state or federal Endangered Species Acts that occur in Suisun Bay.

Species	Scientific Name	State Status	Federal Status
Sacramento River winter-run Chinook salmon	*Oncorhynchus tshawytscha*	Endangered	Endangered
Central Valley spring-run Chinook salmon	*Oncorhynchus tshawytscha*	Threatened	Threatened
Central Valley steelhead	*Oncorhynchus mykiss*	None	Threatened
Green sturgeon, southern DPS	*Acipenser medirostris*	None	Threatened
Longfin smelt	*Spirinchus thaelichthys*	Threatened	None
Delta smelt	*Hypomesus transpacificus*	Endangered	Threatened

In 1979, the Interagency Ecological Program (IEP) designed a program to collect biological and physical data from South San Francisco Bay to the west Delta. The IEP consists of ten member agencies, three State agencies (Department of Water Resources [DWR], California Department of Fish and Game [CDFG], and State Water Resources Control Board [SWRCB]), six Federal agencies (USFWS, Bureau of Reclamation, U.S. Geological Survey [USGS], COE, NMFS, and Environmental Protection Agency [EPA]), and one non-government organization (The San Francisco Estuarine Institute). These ten program partners work together to develop a better understanding of the Estuary's ecology and the effects of the State Water Project (SWP) and Federal Central Valley Project (CVP) operations on the physical, chemical, and biological conditions of the San Francisco Bay-Delta Estuary. The IEP is tasked with providing information on the factors that affect ecological resources in the Sacramento - San Joaquin Estuary that allows for more efficient management of the Estuary. Fish monitoring programs directed by IEP are generally conducted by CDFG.

The IEP reported a step-decline in the populations of pelagic fish species in the Estuary in 2001. The abundance indices from 2002–2004 included record lows for delta smelt and young striped bass, and near-record lows for threadfin shad and longfin smelt (DWR and CDFG 2005). IEP monitoring also continued to document declining levels of zooplankton, such as copepods. To address these declines in fish and zooplankton abundance, a new IEP working group was organized—the Pelagic Organism Decline (POD) Project Work Team. A triage model approach was recommended by POD in 2005 to better define the degree to which toxics, exotic species, and water project operations could be responsible, either individually or combined, for the declines and step-changes (IEP 2005).

2.2.1 Previous Studies Conducted in Suisun Bay

The following six surveys, conducted by CDFG, sample stations in Suisun Bay as part of their overall sampling design: 1) Summer Townet Survey, 2) Fall Midwater Trawl Survey, 3) Bay Study, 4) Spring Kodiak Trawl Survey, 5) 20-mm Survey, and 6) Smelt Larva Survey. Since 1959, the Summer Townet survey has developed indices for the abundance of young striped bass by sampling stations from San Pablo Bay through the Delta. The original purpose was to predict striped bass recruitment to the adult stock but the index has proven valuable by providing long-term indices for other fish species. The Fall Midwater Trawl survey was initiated in 1967, and historically covered the period from July or August to March. However, in 1980 the Fall Midwater Trawl survey period was shortened to cover the period of September through December. Since 1980, CDFG has been conducting the Bay Study Program which uses otter and midwater trawls to collect juvenile and adult fishes as well as mobile macroinvertebrates at sampling stations located from the South Bay to the San Joaquin River at Antioch and to the Sacramento River at Sherman Island. Since 1995, the 20-mm Survey has monitored postlarval-juvenile delta smelt (and other species) distribution and relative abundance throughout their historical spring range in the Sacramento-San Joaquin Delta and San Francisco Estuary. Beginning in 2002, the Spring Kodiak Trawl Survey was conducted every other week beginning January or February and ending typically in May. The survey targets adult delta smelt and assesses spawning condition. The Smelt Larva Survey provides near real-time distribution data for longfin smelt larvae in the Delta, Suisun Bay and Suisun Marsh and was first conducted in 2005. In 2009, the survey began in January and ended the first week of March.

Smelt Larva Survey

The 2009 Smelt Larva Survey began January 5 and ended March 3 and occurred every other week. Each 4-day survey consists of a single 10-minute oblique tow conducted at each of the 36 survey locations using an egg and larva net. The 505-micron mesh net is hung on a rigid frame shaped like an inverted-U, which in turn is attached to skis to prevent it from digging into the bottom when deployed. The net mouth area measures 0.37 m^2. The conical net tapers back from the frame 3.35 m to a 1-liter cod-end jar, which collects and concentrates the sample. Immediately after each tow, juvenile fishes are removed, identified, measured, and returned to the water, while the remaining larvae are preserved in 10% formalin for later identification in CDFG's Stockton laboratory.

A summary of the larval and juvenile fish data collected at three stations (504, 508, and 520) (Figure 2-1) in Suisun Bay is provided in Table 2-2. Nine species and one taxon (smelts) were collected at the three stations during the 2009 survey. Longfin smelt, Pacific herring, and prickly sculpin were collected during all five surveys at all three stations (Table 2-2). Yellowfin goby were first collected during the second survey at stations 504 and 508, and then were collected at all three stations during the third through fifth survey (Table 2-2).

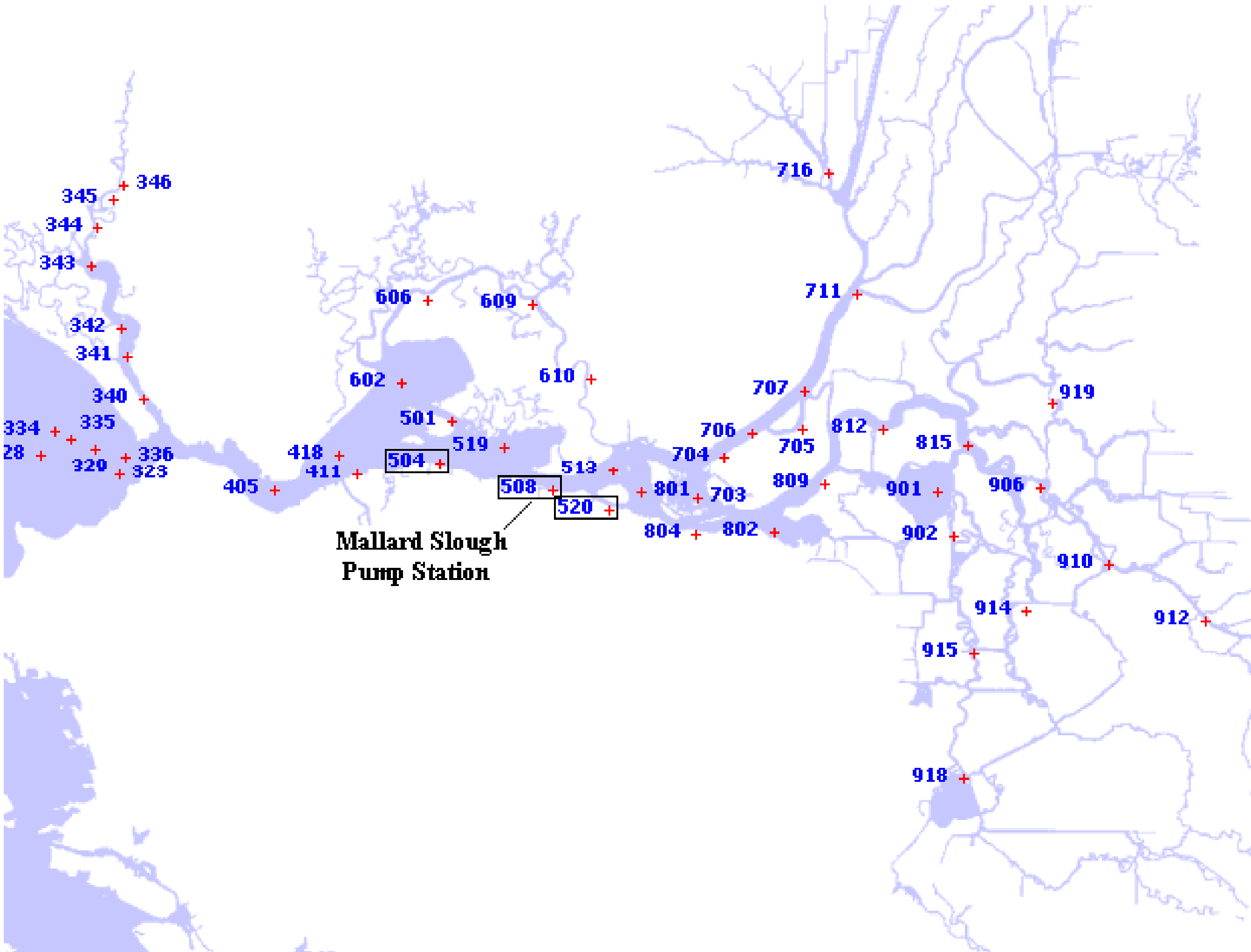

Figure 2-1. Location of CDFG sampling stations.

Note: Stations 504, 508 and 520 are located on the southern shore of Suisun Bay.

Table 2-2. Concentrations (fish/m^3) of all larval fishes collected during the 2009 Smelt Larva Survey at three stations in Suisun Bay.

Survey Date	1/5–1/8/2009			1/20–1/23/2009			2/2–2/5/2009			2/17–2/19/2009			3/2–3/3/2009		
Station	**504**	**508**	**520**	**504**	**508**	**520**	**504**	**508**	**520**	**504**	**508**	**520**	**504**	**508**	**520**
Longfin smelt <10 mm	5.24	57.95	20.59	67.16	863.8	357.87	21.58	565.67	654.83	119.64	1,100.58	512.72	347.01	1,793.55	242.99
Longfin smelt	5.24	57.95	20.59	67.16	863.8	357.87	26.97	582.98	669.71	124.42	1,109.71	512.72	347.01	1,827.15	242.99
Pacific herring	5.24	530.44	15.44	5.17	18.09	0	26.97	427.14	381.99	1,363.86	3,438.74	161.41	392.27	260.42	0
Prickly sculpin	5.24	22.29	15.44	36.16	27.14	23.27	10.79	17.32	59.53	38.28	82.2	75.96	40.23	159.61	48.6
Yellowfin goby	0	0	0	31	18.09	11.73	48.55	178.94	49.61	4.79	205.5	24.48	1,388.03	281.42	12.15
Staghorn sculpin	0	0	0	15.5	0	0	26.97	5.77	0	0	0	0	0	0	0
Arrow goby	5.24	0	0	0	0	0	5.39	0	0	0	4.57	0	10.06	0	0
Smelts (unid.)	0	0	0	0	0	0	10.79	40.4	0	0	0	0	0	0	0
Bay goby	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longjaw mudsucker	0	4.46	0	0	0	0	0	0	0	0	0	0	0	0	0
Threespine stickleback	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: CDFG Bay Delta Region. DSLS.mbdb database. Retrieved from ftp://ftp.dfg.ca.gov/Delta%20Smelt/ on November 23, 2009.

20 mm Survey

CDFG monitors delta smelt distribution throughout its historical spring range in the Sacramento-San Joaquin Estuary during the “20-mm Survey.” This survey gets its name from the size (20 mm) at which delta smelt are retained and readily identifiable at the fish facilities associated with the state and federal export pumps. Data from the surveys are used to determine the timing, distribution, and abundance of delta smelt. Data are also used to help estimate larval delta smelt losses and the magnitude of entrainment of both larval and juvenile delta smelt at the SWP and CVP intakes. The survey provides "recent time" (within 72 hours) information on the distribution and relative abundance of delta smelt throughout the Delta and the upper Estuary. Based upon the data, recommendations are made to protect delta smelt.

Surveys usually begin each year in March or April and end in July or August. Typically there are eight to ten surveys per year at a frequency of every other week; sampling frequency may increase to weekly if delta smelt numbers increase. Stations are located throughout the Delta and downstream to the eastern portion of San Pablo Bay and Napa River (see Figure 2-1). Samples are collected using a rigid opening net (net opening=1.51 m^2; total length=5.1 m) constructed of 1,600-µm mesh. Three 10-minute stepped-oblique (bottom to top) tows are made at each station. The average volume of water filtered during each tow is approximately 900 m^3.[1] Samples are preserved in neutral buffered formalin and then all fish are sorted out and identified in a laboratory. Up to 50 individuals of each species are measured (fork length) and all delta smelt are measured regardless of the number of individuals collected.

A summary of the 2009 20-mm Survey fish data collected at three stations (504, 508, and 520) (Figure 2-1) in Suisun Bay is provided in Table 2-3. A total of 4,265 fishes represented by 17 species and one taxon (unidentified *Tridentiger* spp. gobies) were collected at the three southern Suisun Bay stations during the 2009 survey. The majority of fishes collected were longfin smelt (63.5%), followed by striped bass (18.5%) and yellowfin goby (11.4%).

[1] The average volume filtered per tow was calculated from data for Stations 504, 508, 519, 520, 801, and 804 for 1995–2003.

Table 2-3. Numbers of fishes collected during the 20-mm Survey at Suisun Bay stations (504, 508, and 520) from March through July 2009.

Species	Number Collected (Stations 504, 508, 520)	Percent Composition
Longfin smelt	2,707	63.5%
Striped bass	789	18.5%
Yellowfin goby	485	11.4%
Tridentiger spp.	132	3.1%
Prickly sculpin	65	1.5%
Pacific herring	43	1.0%
Delta smelt	13	0.3%
Northern anchovy	12	0.3%
Arrow goby	5	0.1%
Threespine stickleback	4	0.1%
Starry flounder	3	0.1%
Threadfin shad	1	<0.1%
Shokihaze goby	1	<0.1%
White croaker	1	<0.1%
Cheekspot goby	1	<0.1%
Jacksmelt	1	<0.1%
Pacific staghorn sculpin	1	<0.1%
Shimofuri goby	1	<0.1%
Total	4,265	

Source: CDFG Bay Delta Region. 20-mm.mbdb database. Retrieved from ftp://ftp.dfg.ca.gov/Delta%20Smelt/ on November 23, 2009.

Pittsburg Power Plant Fishery Investigations

Pittsburg Power Plant is located just upriver of the MSPS. Studies of the effects of the Pittsburg Power Plant's cooling water system (entrainment and impingement studies) were conducted in 1978–1979 (PG&E 1981). Six species and two taxa made up nearly 86 percent of the larval and post larval fishes entrained at the power plants in 1978–1979 (Table 2-4). Another 17 taxa constituted one percent of the total amount. The remaining species were not able to be identified.

Table 2-4. Percent composition of entrained fish larvae and juveniles at the Pittsburg Power Plant under actual pump operation from March 1978 through March 1979.

Common Name	Scientific Name	Percentage Composition	Period Entrained	Peak Entrainment
Striped bass	*Morone saxatilis*	60.5	Mar –Sep	May
Smelts[1]	Osmeridae	10.7	Dec–Jun	Jan–Feb
Prickly sculpin	*Cottus asper*	6.3	Feb–May	Mar–Apr
Pacific herring	*Clupea harengus pallasii*	4.7	Nov–Feb	Dec
Yellowfin goby	*Acanthogobius flavimanus*	1.3	[2]	[2]
Northern anchovy	*Engraulis mordax*	1.1	Jun–Aug	Jul
Unidentified gobies	Gobiidae	0.9	Mar–Jul	Apr, Jun
Threadfin shad	*Dorosoma petenense*	0.2	Mar–Dec	Mar–May
Others		14.3		

Source: PG&E 1981.

(1). Delta and longfin smelts could not be distinguished from each other during the time the studies were conducted; therefore they were grouped as "smelts."

(2). All gobies (yellowfin, bay, and arrow gobies) were grouped together and concentrations were graphed for the "goby group." Reported spawning period for yellowfin goby is from January through May. Peak concentrations of the goby group occurred from May through June.

More recent Pittsburg Power Plant entrainment studies were conducted from March 7, 2008–July 8, 2008 (Tenera 2009). Entrainment sampling was conducted by towing a 1600-micron mesh net in front of the intake structure. These results provide information on the species collected during the spring-summer time period. A total of eight species and one taxon group were collected with the 1,600-micron mesh net during entrainment sampling at the PPP Units 5&6 intake structure from March 7, 2008–July 8, 2008 (Table 2-5). Almost all of these fishes (92.2%) were Pacific herring. Three other species and one taxon group comprised another 6.7% of fishes collected (Table 2-5) (Tenera 2009); *Tridentiger* spp. gobies (2.8%), prickly sculpin (2.6%), longfin smelt (0.7%) and delta smelt (0.6%).

Table 2-5. Percent composition by number of fishes collected during entrainment surveys using a 1600-micron mesh net conducted at Pittsburg Power Plant Units 5&6 intake from March 7 through July 8, 2008.

Common Name	Taxon	Percent Composition of Actual Number Collected
Pacific herring	*Clupea pallasii*	92.2%
Tridentiger spp gobies	*Tridentiger* spp.	2.8%
Prickly sculpin	*Cottus asper*	2.6%
Longfin smelt	*Spirinchus thaleichthys*	0.7%
Delta smelt	*Hypomesus transpacificus*	0.6%
Threespine stickleback	*Gasterosteus aculeatus*	0.4%
Pacific staghorn sculpin	*Leptocottus armatus*	0.4%
Northern anchovy	*Engraulis mordax*	0.2%
Rainwater killifish	*Lucania parva*	0.2%

Source: Tenera 2009.

2.2.2 Mallard Slough Fishery Investigations

The U.S. Bureau of Reclamation and the Contra Costa Water District (CCWD) are required under the Sacramento winter-run Chinook salmon and delta smelt biological opinions to minimize the incidental take of these species when diverting Delta waters through the Mallard Slough Pump Station (MSPS).

CDFG conducted a study in 1996 (Mecum 1996) directed at determining relative species abundances in Mallard Slough as part of the Mallard Slough Pump Station Replacement Project (MSPSRP). The MSPSRP involved the replacement of a sixty year old, unscreened, raw water pump with a new pumping facility equipped with state of the art fish screens. Sampling was conducted from April 11 through July 10, 1996 (six sampling events total). The survey utilized tow-nets (mesh size not reported) as well as egg and larval nets (505-um micron mesh) to determine fish composition and abundance in the Mallard Slough channel and in Suisun Bay at the channel mouth.

In the Mallard Slough channel, Mecum (1996) found that the three most abundant species caught by the egg and larval net were threadfin shad, striped bass, and prickly sculpin, whereas the three most abundant species caught by the tow-net were striped bass, threadfin shad, and longfin smelt (Table 2-6). In Suisun Bay near the mouth of Mallard Slough, the three most abundant species caught by the egg and larval net were striped bass, prickly sculpin, and longfin smelt, whereas the three most abundant species caught by the tow-net were longfin smelt, striped bass, and delta smelt (Table 2-7). Chinook salmon were not taken during any of the surveys, which could have resulted from either net-avoidance or a lack of presence. Another possibility is that flow in the channel was insufficiently strong to attract downstream migrant salmon.

Table 2-6. Concentrations (#/m^3) of fishes collected in the Mallard Slough Channel by egg and larval net and tow net from April 11 through July 10, 1996.

	Egg and Larval Net (No./m^3)						
Species	**4/11/1996**	**4/25/1996**	**5/9/1996**	**5/23/1996**	**6/6/1996**	**7/10/1996**	**Mean**
Delta smelt	0	0	0.0049	0.0054	0	0	0.0017
Longfin smelt	0.0586	0	0.0046	0	0	0	0.0105
Pacific herring	0	0	0	0.0054	0	0	0.0009
Striped bass	0.0249	0	0.1385	0.1606	0.0577	0.4550	0.1395
Threadfin shad	0	0	0	0	0.0048	2.5384	0.4239
Cyprinidae	0	0	0.0092	0	0	0	0.0015
Centrarchidae	0.0053	0	0	0	0	0.0838	0.0149
Inland silverside	0	0	0	0	0	0.0120	0.0020
Bigscale logperch	0.0053	0	0.0141	0.0054	0	0	0.0041
Prickly sculpin	0.3392	0.3054	0.1085	0.0528	0.0143	0.0120	0.1387
Yellowfin goby	0	0	0	0	0	0.0120	0.0020
Shimofuri goby	0	0	0.0141	0	0	0	0.0024

	Tow-net (No./m^3)						
Species	**4/11/1996**	**4/25/1996**	**5/9/1996**	**5/23/1996**	**6/6/1996**	**7/10/1996**	**Mean**
Longfin smelt	0	0	0.0409	0	0	0	0.0068
Striped bass	0	0	0	0.0375	0.0052	0.2725	0.0525
Threadfin shad	0	0	0	0	0	0.1090	0.0182
Bigscale logperch	0	0	0	0.0054	0	0	0.0009
Yellowfin goby	0	0	0.0051	0	0	0	0.0009

Source: Mecum 1996.

Table 2-7. Concentrations (#/m^3) of fishes collected by egg and larval net and tow net in the Suisun Bay near the mouth of Mallard Slough from April 11 through July 10, 1996.

Egg and Larval Net (No./m^3)							
Species	**4/11/1996**	**4/25/1996**	**5/9/1996**	**5/23/1996**	**6/6/1996**	**7/10/1996**	**Mean**
Delta smelt	0	0.0458	0.2014	0.0639	0	0.0387	0.0582
Longfin smelt	0.5543	0.1250	0.3664	0	0	0.0097	0.1759
Striped bass	0.0762	0.0420	4.4702	0.3322	0.1910	0.1256	0.8729
Threadfin shad	0	0.0038	0	0.0314	0	0.0097	0.0075
Cyprinidae	0	0	0.0046	0	0	0	0.0008
Starry flounder	0	0.0038	0.0046	0	0	0	0.0014
Centrarchidae	0.0044	0	0.0046	0	0	0	0.0015
Prickly sculpin	0.6940	0.5245	0.3160	0.1141	0	0	0.2748
Yellowfin goby	0	0	0.0367	0	0.0152	0.0193	0.0119
Shimofuri goby	0	0	0.0046	0	0	0	0.0008

Tow-net (No./m^3)							
Species	**4/11/1996**	**4/25/1996**	**5/9/1996**	**5/23/1996**	**6/6/1996**	**7/10/1996**	**Mean**
Delta smelt	0	0	0	0	0.0149	0	0.0025
Longfin smelt	0	0	0.1256	0.0149	0.0099	0.0104	0.0268
Striped bass	0	0	0	0.0375	0.0050	0.0208	0.0043
Threadfin shad	0	0	0	0	0	0.0104	0.0017

Source: Mecum 1996.

Once the new MSPS was operating, a new sampling program was designed to better determine if fishes were being entrained by the pumps since it was not possible to determine if fish caught in the channel were in close enough proximity to the MSPS to be entrained. To correct this, the new sampling program proposed to utilize a bypass structure located 70 to 100 feet from the pumping plant. The intended use of the bypass structure was to flush debris out of the pipe prior to pumping water to CCWD customers. Due to the close proximity of the structure to the pumping plant and its ability to divert water from the main pipe, the bypass structure was determined to be an ideal site for sampling by CCWD.

A net frame was to be built to slide into iron channels located in the bypass structure. The net was to have a mouth 5.5 feet wide by 2.5 feet" high and was to be 0.5 inch Nylon Delta lined with 505 um Nytex netting. The net was composed of two sections: the first section was cylindrical in order to resist clogging and the second section was conical to guide fish into the codend (12 inches diameter, 2 feet in length). Lastly, a platform 6 feet wide by 20 feet long was constructed to support the net.

Sampling was to be conducted once per week anytime CCWD was diverting water at Mallard Slough. The sampling schedule was to cover day and night as well as flood and ebb tides during the months when species of concern were expected to be present in the river opposite the channel entrance.

The sampling procedure was initiated by setting the net into position. Next, water was diverted into the overflow structure at the turn of the tide. Samples were collected for one hour, after which time water diversion into the bypass structure was ceased. Before captured fish were removed from the net to be measured and identified, the sluice box had to be drained. Any fish too small for field identification were preserved and brought back to a lab. The above was repeated at 2 hour intervals until the sampling event was completed.

The methods used to collect the 1998–2000 MSPS entrainment samples were not described. Therefore, fish data from 1998–2009 were summarized using only presence and absence criteria (Table 2-8). As discussed previously, entrainment monitoring only occurred during times when CCWD was diverting water through the MSPS. Twelve families of fishes have been collected in entrainment samples at MSPS (Table 2-8; CCWD 1999–2009, Tenera unpubl. data 2009).

Table 2-8. Summary of fish data collected in entrainment samples at the Mallard Slough Pump Station from 1998 through 2009* during routine Contra Costa Water District monitoring.

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Number of Surveys											
		5	0	7	6	10	8	4	0	0	0	0	0
Clupeidae	Threadfin shad			X		X	X	X					
	American shad							X					
Moronidae	Striped bass			X	X	X	X	X					
Cyprinidae	Cyprinidae, unid.			X	X								
	Fathead minnow					X	X						
	Sacramento splittail			X		X							
	Golden shiner					X							
	Common carp					X	X						
Atherinopsidae	Inland silverside					X	X	X					
Centrarchidae	Centrarchidae, unid.				X	X	X						
	Pomoxis spp.				X	X							
	Lepomis spp.					X	X						
	Largemouth bass							X					
Percidae	Bigscale logperch			X	X	X	X						
Cottidae	Prickly sculpin	X		X	X	X	X						
	Staghorn sculpin				X								
Osmeridae	Osmeridae, unid.			X									
	Longfin smelt	X		X	X	X							
	Delta smelt			X	X	X							
Gobiidae	Yellowfin goby			X		X							
	Tridentiger spp. goby					X	X						
Catastomidae	Sacramento sucker			X									
Gasterosteidae	Threespine stickleback			X	X	X	X						
Clinidae	Clinidae, unid.				X								

Note: no sampling was conducted in 2001 and 2002 when the MSPS's intake screens were being replaced with new 3/32-in. mesh screens.

Sources: CCWD 1999–2009, Tenera 2009 unpublished data.

2.3 Description of the BARDP Pilot Plant

Initial studies, workshops, and technical evaluations began July 2007 and were completed between August 2007 and September 2008 to evaluate water quality, obtain a permit to discharge pilot plant wastes to the sanitary sewer, develop pilot equipment specifications and arrangements, procure equipment, erect the pilot equipment, interconnect with available utilities, and complete startup operations.

Based on this work, pilot plant systems were designed (Figure 2-2). Feed water was pumped through a 100 micron self-cleaning screen, followed by two parallel ultrafiltration (UF) units. These systems featured Norit Americas, Inc. pressurized membranes and Siemens/Memcor submerged membranes. Equipment was fabricated and leased from Layne Christensen Company and Siemens Water Technologies, Corporation.

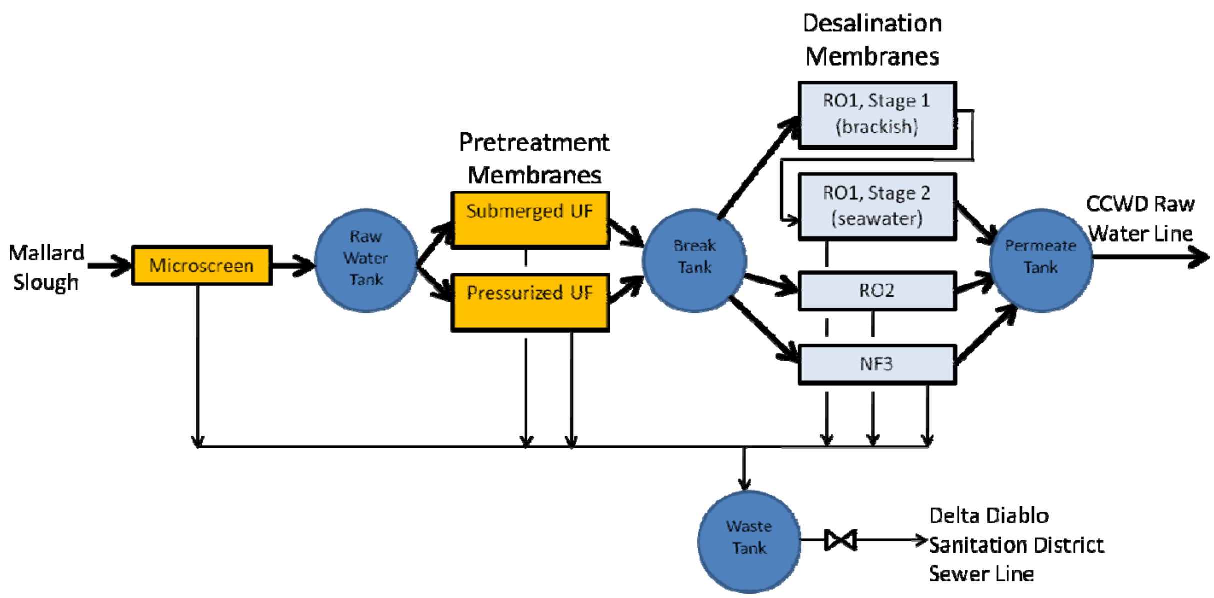

Figure 2-2. Schematic of the Bay Area Regional Desalination Project's Pilot Plant.

Source: MWH report.

Combined filtrate produced by these UF units was pumped into three parallel RO membrane desalination systems. The configurations of the RO trains are as follows:

- RO Train No. 1: Two-Stage RO desalination, brackish water membrane treatment followed by seawater membrane treatment. Concentrate from brackish water membranes is fed into the seawater membranes to increase overall permeate recovery.
- RO Train No. 2: Single stage RO desalination using seawater membranes.
- RO Train No. 3: Single stage desalination using NF membranes.

Permeate collected from these parallel desalination processes was stabilized and pumped into the CCWD untreated water supply pipeline. Concentrate and other pilot plant wastes were collected and pumped to the nearby Delta Diablo Sanitation District (DDSD) sewer pipeline.

The overall process was established to mimic a full scale treatment plant as it might be designed on behalf of the four agencies. Chemicals were utilized for disinfection, coagulation, dechlorination, filtrate conditioning, membrane cleaning, and permeate stabilization. Specific chemicals included sodium hypochlorite, aqueous ammonia, ferric chloride, sodium bisulfite, citric acid, antiscalant, and caustic soda.

All pilot test work including water intake and discharge of wastes were conducted under current permits, therefore no new permits were required.

Field operations, laboratory work, and special studies were conducted while the pilot plant was operational from October 2008 through April 2009. Three separate runs of approximately six weeks duration each were conducted and were designed in response to actual water quality conditions encountered at the site:

- Run No. 1: Operated during period from November 2008 to December 2008 to establish baseline system operating parameters.
- Run No. 2: Operated during high salinity period from January 2009 to February 2009 to establish higher flux and mid-challenge system operating parameters.
- Run No. 3: Operated during low salinity period from March 2009 to April 2009 to establish highest manufacturer recommended flux and challenge system operating parameters.

Data were collected for each pilot run by observing and recording various piloting parameters, such as pressure, temperature, pH, chemical tank levels, and flow, at regular intervals and at various points in the treatment processes. Computerized equipment was used to record and archive data, while manual entry forms were completed during daily pilot plant inspections and experiments. Routine field analyses were performed for:

- physical parameters of the test water at various points in the process,
- Silt Density Index (SDI), pressure decay tests, etc., and
- verification and calibration of various instruments and field devices.

Each desalination system had distinct operational advantages and disadvantages. Running the systems at pilot scale over the diverse feedwater conditions in the testing period provided specific performance data that can be used to project full-scale capital and operational expenditures.

2.4 Literature Cited

Arthur, J.F. and M.D. Ball. 1978. Entrapment of suspended materials in the San Francisco Bay-Delta Estuary. U.S. Bureau of Reclamation, Mid-Pacific Region, Water Quality Branch, Sacramento, CA.

Arthur, J.F. and M.D. Ball. 1979. Factors influencing the entrapment of suspended material in the San Francisco Bay-Delta Estuary. *In* T.J. Conomos, ed. San Francisco Bay: The Urbanized Estuary. Pacific Division AAAS, San Francisco, California.

California Department of Fish and Game (CDFG). 1993. Restoring Central Valley streams: A plan for action. California Department of Fish and Game, Sacramento, California.

California Department of Water Resources and California Department of Fish and Game and (DWR and CDFG). 2005. Delta Smelt Action Plan. State of California.

CDFG Bay Delta Region. 20-mm.mbdb database. Retrieved from ftp://ftp.dfg.ca.gov/Delta%20Smelt/ on November 23, 2009.

CDFG Bay Delta Region. DSLS.mbdb database. Retrieved from ftp://ftp.dfg.ca.gov/Delta%20Smelt/ on November 23, 2009.

Contra Costa Water District. 1999. Letter dated January 6, 1999, to Matt Vandenberg (USFWS) from Richard Denton (CCWD) transmitting the 1998 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2000a. Letter dated January 14, 2000, to Stephanie Brady (USFWS) from Richard Denton (CCWD) transmitting the 1999 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2000b. Letter dated December 29, 2000, to Karen Miller (USFWS) from Richard Denton (CCWD) transmitting the 2000 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2001. Letter dated December 21, 2001, to Karen Miller (USFWS) from Richard Denton (CCWD) transmitting the 2001 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2003. Letter dated March 12, 2003, to Daniel Buford (USFWS) from Richard Denton (CCWD) transmitting the 2002 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2004. Letter dated March 25, 2004, to Daniel Buford (USFWS) from Richard Denton (CCWD) transmitting the 2003 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2005. Letter dated January 26, 2005, to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2004 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2006. Letter dated February 16, 2006, to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2005 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2007. Letter dated February 17, 2007 to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2006 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2008. Letter dated February 29, 2008 to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2007 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2009. Letter dated February 27, 2009 to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2008 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Herbold, B., A. Jassby, and P.B. Moyle. 1992. Status and trends of aquatic resources of the San Francisco Bay Estuary. U.S. Environmental Protection Agency, San Francisco Estuary Project.

Interagency Ecological Program (IEP). 2005. Workplan to evaluate the decline of pelagic species in the upper San Francisco Estuary. 37 pp.

Kimmerer, W. 1991. An evaluation of existing data on the entrapment zone of the San Francisco Bay Estuary. BioSystems Analysis, Inc., Santa Cruz, California.

Mecum, W.L. 1996. Mallard Slough Intake Channel Monitoring Project Report for 1996. California Department of Fish and Game, Bay-Delta and Special Water Projects Division.

Monroe, M.W., J. Kelley, and N. Lisowski. 1992. San Francisco Bay Estuary Project: State of the Estuary. Association of Bay Area Governments. Oakland, California.

Moyle, P.B. and B. Herbold. 1989. Status of the Delta smelt, *Hypomesus transpacificus*. Report prepared for the Office of Endangered Species, U.S. Fish and Wildlife Service.

Nichols, F.H. and M.M. Pamatmat. 1988. The ecology of the soft-bottom benthos of San Francisco Bay: a community profile. U.S. Fish and Wildlife Service, Biological Report 85(7-23).

Pacific Gas and Electric Company (PG&E). 1981. Pittsburg Power Plant Cooling Water Intake Structures 316 (b) Demonstration. Prepared by Ecological Analysts, Inc. PG&E. San Francisco, California.

Pacific Gas and Electric Company. 1970. Estimates of temperature distributions resulting from the cooling water discharge modeling of Pittsburg Power Plant Units 1-7. PG&E Report 6934.14-70.

Tenera Environmental (Tenera). 2009. Entrainment and Impingement Monitoring Plan for IEP Annual Report November 2007 – October 2008 for the Contra Costa and Pittsburg Power Plants. Submitted to Mirant Delta, LLC. Pittsburg, California.

Tenera. 2009. Unpublished data collected during plankton net sampling at Mallard Slough Pump Station, March 2009. Lafayette, CA.

Tetra Tech, Inc. 1976. 316(a) demonstration Pittsburg Power Plant. Prepared for Pacific Gas and Electric Company. Tetra Tech Report TC-638. Lafayette, California.

3.0 ENTRAINMENT AND SOURCE WATER STUDY

The following sections present entrainment and source water data collected over a 12-month period (November 5, 2008–October 9, 2009). These studies focused on larval fishes and fish eggs whose adult populations might be affected by operation of the BARDP pilot plant's water intake system or a full-scale desalination facility at MSPS.

The studies were designed to specifically address the following questions:

- What are the species composition and abundance of larval fishes and fish eggs entrained by the BARDP pilot plant?
- What are the local species composition and abundance of entrainable larval fishes and fish eggs in the Suisun Bay source water?
- What are the potential impacts of entrainment losses on larval fish and fish eggs due to operation of the BARDP's water intake system?

The Study Plan focused on two life stages of fishes (larval fishes and fish eggs) to assess entrainment. It was agreed that several assessment approaches would be applied to each analyzed taxon, where possible, to yield more robust and comparable impact assessments.

3.1 Entrainment Sample Collection

All entrainment samples were collected from an onshore station located behind the existing 3/32 in.-mesh intake screens of CCWD's Mallard Slough Pump Station, located at the southern end of Mallard Slough (Figure 3-1). During entrainment sampling, a plankton net constructed of 505-µm mesh was used to filter the water and collect larval fishes.

A total of six entrainment surveys were conducted during the BARDP pilot plant study (Table 3-1). Five of the entrainment surveys were approximately eight hours in duration. During these 8-hour surveys, 10- to 30-minute samples were collected. The duration of pumping was chosen so that damage to entrained organisms caused by water flow or abrasion from the net was minimized. The entrainment survey conducted on February 20, 2009 consisted of a single, hour-long sample. Start and end times of the samples were recorded on field data sheets.

Figure 3-1. Location of the Mallard Slough Pump Station.

Table 3-1. Summary information regarding the collection of entrainment samples at the Bay Area Regional Desalination Project pilot plant from 2008–2009.

Survey Number	Date Survey was Conducted	Pump Used	Number of Samples Collected	Total Duration of all Samples (min)	Average Rate of Flow (m^3/min)	Total Volume of Water Filtered (m^3)
1	November 5 & 7, 2008	Pilot Plant	10	100	0.3	31*
2	December 16, 2008	Pilot Plant	7	71	0.3	20
3	February 20, 2009	CCWD Main Pump	1	67	44.6	3,010
4	March 6, 2009	CCWD Main Pump	6	180	13.6	2,446
5	July 16 & 17, 2009	Portable Pump	16	375	1.4	530
6	October 9, 2009	Portable Pump	12	291	1.5	432

*Note: the flow meter malfunctioned during one sample; therefore the volume estimated based on the average flowrate and the duration of sample.

Some aspects of the entrainment surveys varied due to the different operating scenarios of the BARDP pilot plant and to different protocols for sampling during the sensitive fish period (January through June) versus the non-sensitive fish period.

During the first and second survey (Table 3-1), water was diverted from the pumps used by the pilot plant into a collection tank so that the flow was filtered through the plankton net (Figure 3-2). A calibrated inline flow meter measured the flow of water leaving the tank and entering the net. The average rate of flow filtered by the net was 0.3 m^3/min for these surveys.

During the third and fourth surveys, the main intake pumps at CCWD MSPS were used to pump water into the bypass structure. This water was filtered by a wide net which was placed across the bypass structure (Figure 3-3). During the third survey, which consisted of a single sample, the built-in flow meter on the main pumps was used to determine volume pumped. Flow rate for this survey was 44.6 m^3/min. During the fourth survey, only a portion of the water pumped was diverted to the bypass structure so the built-in flow meter could not be used. Instead, water volume was determined using data from a CDFG report which determined "flow conditions at Mallard Slough for various pump and valve turn configurations." However as this report only had estimates for configurations with two and three pumps running, and since only one was run during our survey, further extrapolation was required to estimate volume for this survey. Flow rate for this survey was estimated to be 13.6 m^3/min.

During the fifth and sixth surveys (Table 3-1), a portable Wacker pump was used. Water was pumped from behind the MSPS intake screens to a long pipe which went down to just above the water in front of the pilot plant (Figure 3-4). The collection net was lowered on a line and placed so that the top of the net was out of the water above the opening on the long pipe, and the bottom of the net was in the water so that abrasion to fishes entering the net was minimized. A calibrated inline flow meter was installed between the intake pipe and the portable pump. The average rate of flow filtered by the net was 1.4 m^3/min for these surveys.

Figure 3-2. Entrainment sampling gear used during the Bay Area Regional Desalination Project pilot plant entrainment study for surveys conducted in November and December 2008.

Figure 3-3. Entrainment sampling gear used during the Bay Area Regional Desalination Project pilot plant entrainment study for surveys conducted in February and March 2009.

Figure 3-4. Entrainment sampling gear used during the Bay Area Regional Desalination Project pilot plant entrainment study for surveys conducted in July and October 2009.

At the end of each sample, the contents of the plankton net were rinsed down to the end (codend) of the net. The contents of the codend were rinsed into a labeled sample jar, and preserved in a 10% solution of buffered formalin. Each sample was given a sample number based on the survey number, date, and time of collection. The information was logged onto a sequentially numbered field data sheet that was used by the data manager to track the sample through laboratory processing, data analysis, and reporting.

The field sampling procedures were reviewed with all personnel prior to the start of the study. Senior staff performed quality assurance/quality control (QA/QC) checks throughout the study to ensure compliance with field sampling and data recording procedures.

3.2 Source Water Sample Collection

Four source water surveys were conducted in Mallard Slough (Table 3-2) concurrently with entrainment surveys. Daytime and nighttime samples were collected at four sampling locations during each of the four source water surveys, resulting in 32 samples of approximately 24 m^3 each.

Table 3-2. Summary information regarding the collection of source water samples for the Bay Area Regional Desalination Project from 2008–2009.

Survey Number	Date Survey was Conducted	Number of Samples Collected	Total Duration of all Samples (min)	Total Volume of Water Filtered (m^3)
1	November 5 & 7, 2008	8	35	203.2
2	December 16, 2008	8	35	188.5
3	July 16 & 17, 2008	8	45	173.5
4	October 9, 2009	8	39	193.7

Source water samples were collected at four stations within Mallard Slough. The stations were located offshore of the MSPS intake and continued to the entrance of Mallard Slough at Suisun Bay (Figure 3-5). Samples were collected using a small boat and a push-net plankton sampling apparatus consisting of a fiberglass bongo net frame, two conical plankton nets (each 0.31 m diameter) constructed of 505-µm mesh with detachable screen-walled codends, and flow meters mounted in the mouth of each net. Flow meter readings were recorded on field data sheets at the beginning and end of each push-net sampling effort. Two push-net sampling efforts were conducted at each station once during the daylight and once again during the nighttime. Due to the shallow water depth in Mallard Slough, it was necessary to sample near the surface. The water temperature, conductivity, and weather data were recorded during each sampling effort. After completion of each sampling effort, the contents of the two nets were rinsed down into the codends and combined into one sample. Samples were labeled with the survey number, station number, date, and time. Samples were preserved in a solution of 10% buffered formalin. Sample tracking methods for all source water survey samples were identical to those used for entrainment sampling.

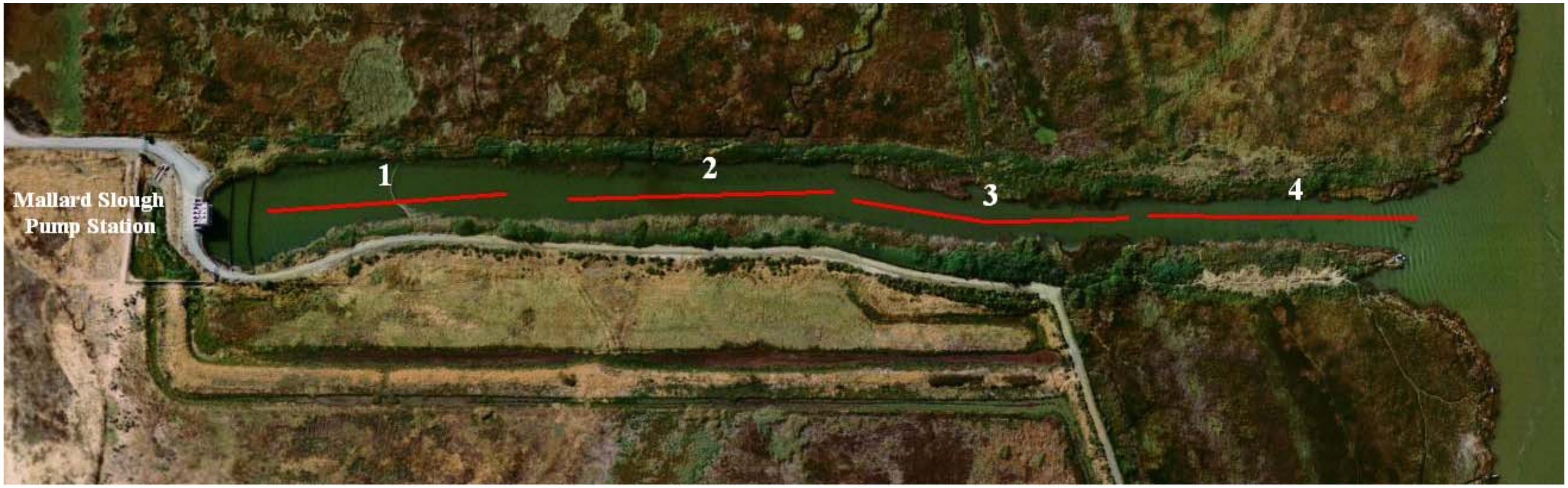

Figure 3-5. Location of the Mallard Slough source water stations sampled during the 2008–2009 Bay Area Regional Desalination Project pilot plant source water study.

3.3 Laboratory Processing

Laboratory processing consisted of sorting, removing, identifying, and enumerating all fish larvae and fish eggs from all entrainment and source water samples.

Measurements of larval fish lengths, recorded as the length of the notochord (notochord length [NL]), were taken for up to 200 of each species per entrainment survey. Fishes were measured using a either a digital imaging system or a calibrated micrometer.

Many larval fishes cannot be identified to the species level; these fishes were identified to the lowest taxonomic level possible (e.g., genus and species are the lowest levels of taxonomic classification; the next lowest taxonomic level is family, which includes genus and species). Myomere and pigmentation patterns were used to identify many species; however, this can be problematic for some species. For example, members of the sunfish genus *Lepomis* share morphologic and meristic characters during early life stages (Wang, J. pers. com) making identification to the species level difficult. It was necessary to group the *Lepomis* spp. sunfishes we were unable to identify to species into a "*Lepomis* spp." category (i.e., unidentified *Lepomis* spp.).

Due to the high volume pump used and the length of the sample, the single sample collected from the survey on February 20, 2009 contained an exceptionally large amount of debris and was therefore subsampled. Subsampling was done by placing the entire contents of the sample into a fiberglass tray (30.0 cm by 20.2 cm), and using a small section of PVC pipe (2.0 cm ID) to isolate a small portion of the total sample. This portion was then placed in a new tray and was sorted. This process was repeated until the desired proportion of sample had been sorted. The number of fishes from the subsample was divided by the proportion of the sample that was sorted to estimate the total number of fishes in the complete sample. All contents of other samples were sorted completely.

Sample sorting accuracy were verified and maintained by Tenera Environmental's quality control (QC) program described in the following section.

3.3.1 Laboratory QA/QC Program

An intensive QA/QC program was implemented for the BARDP entrainment and source water study for all sample sorting. The first ten samples sorted by an individual were re-sorted by a designated QA/QC sorter. A sorter was allowed to miss one target organism when the total number of target organisms in the sample was less than 20. For samples with 20 or more target organisms, the sorter was required to maintain a sorting accuracy of 90 percent. After a sorter completed ten consecutive samples with greater than 90 percent accuracy, one of the sorter's next ten samples was randomly selected for a QA/QC check. If the sorter failed to achieve an accuracy level of 90 percent, their next ten samples were resorted by the QA/QC sorter until they met the required level of accuracy. If the sorter maintained the required level of accuracy, one of their next ten samples was resorted by QA/QC personnel.

Taxonomic identification and measurements of all specimens were conducted by Dr. Johnson Wang, National Environmental Services, a nationally recognized expert ichthyoplankton taxonomist. Dr. Wang has written and published several papers regarding the identification of the early life stages of San Francisco Bay-Delta fishes (see Wang 1981, Wang 1986, Wang et al. 2005, Wang and Reyes 2007, Wang and Reyes 2008).

Laboratory data were recorded on preprinted data sheets formatted for entry into a computer database for analysis and archiving. Printed spreadsheets were checked for accuracy against original field and laboratory data sheets.

3.4 Data Analysis

Sample concentrations of fishes were computed by dividing the number of each taxon or species in each sample by the sample volume. Concentrations (no./1,000 m^3) of all fish taxa for each entrainment survey are provided in Table 3-3.

Two measurement procedures were used, depending on the number of individuals of a given species present in the sample. If the number of individuals per species in the sample was 30 or less, the linear measurement, life stage, and body condition codes for each individual were determined and recorded. If the number of individuals per species was greater than 30, the linear measurement and body condition code for a subsample of 30 individuals was recorded.

3.5 Entrainment Study Results

Data presented in this section are from the six entrainment surveys conducted at the MSPS intake structure from November 5, 2008 through October 9, 2009. A total of 52 samples were collected during the entrainment study. A total of 6,469 m^3 of water was filtered over the course of the six entrainment surveys.

A total of 6,443 fishes comprised of three taxa groups were collected during entrainment sampling. All except three of these fishes were collected during the high volume sampling conducted during the sensitive fish period (Table 3-3). Prickly sculpin *Cottus asper* was the most abundant fish species, followed by smelts (both longfin and delta) and sunfishes (*Lepomis* spp.). Fishes were collected in both of the surveys conducted during the sensitive fish period but only in one of the four surveys conducted during the non-sensitive fish period (Figure 3-6).
No fish eggs were collected during entrainment sampling.

Table 3-3. Information regarding the collection of fishes in entrainment samples at the Bay Area Regional Desalination Project pilot plant from 2008–2009.

	Non-sensitive fish period				Sensitive fish period				Non-sensitive fish period			
	1st Survey November 5, 2008		2nd Survey December 16, 2008		3rd Survey February 20, 2009		4th Survey March 6, 2009		5th Survey July 16-17, 2009		6th Survey October 8-9, 2009	
	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3
Longfin smelt	0	0.0	0	0.0	0	0.0	1	0.4	0	0.0	0	0.0
Smelts (longfin and delta)	0	0.0	0	0.0	118*	39.2	89	36.4	0	0.0	0	0.0
Prickly sculpin	0	0.0	0	0.0	4,126*	1,370.8	2,044	835.7	0	0.0	0	0.0
Sunfish (*Lepomis* spp.)	0	0.0	0	0.0	0	0.0	0	0.0	3	5.7	0	0.0
Total	0	0.0	0	0.0	4,244	1,410.0	2,149	878.6	3	5.7	0	0.0

Note: Due to the large volume of debris in the sample, the February 20, 2009 sample was subsampled (see Section 3.3). The number presented here are for the expanded estimate of the total number of fish in the sample.

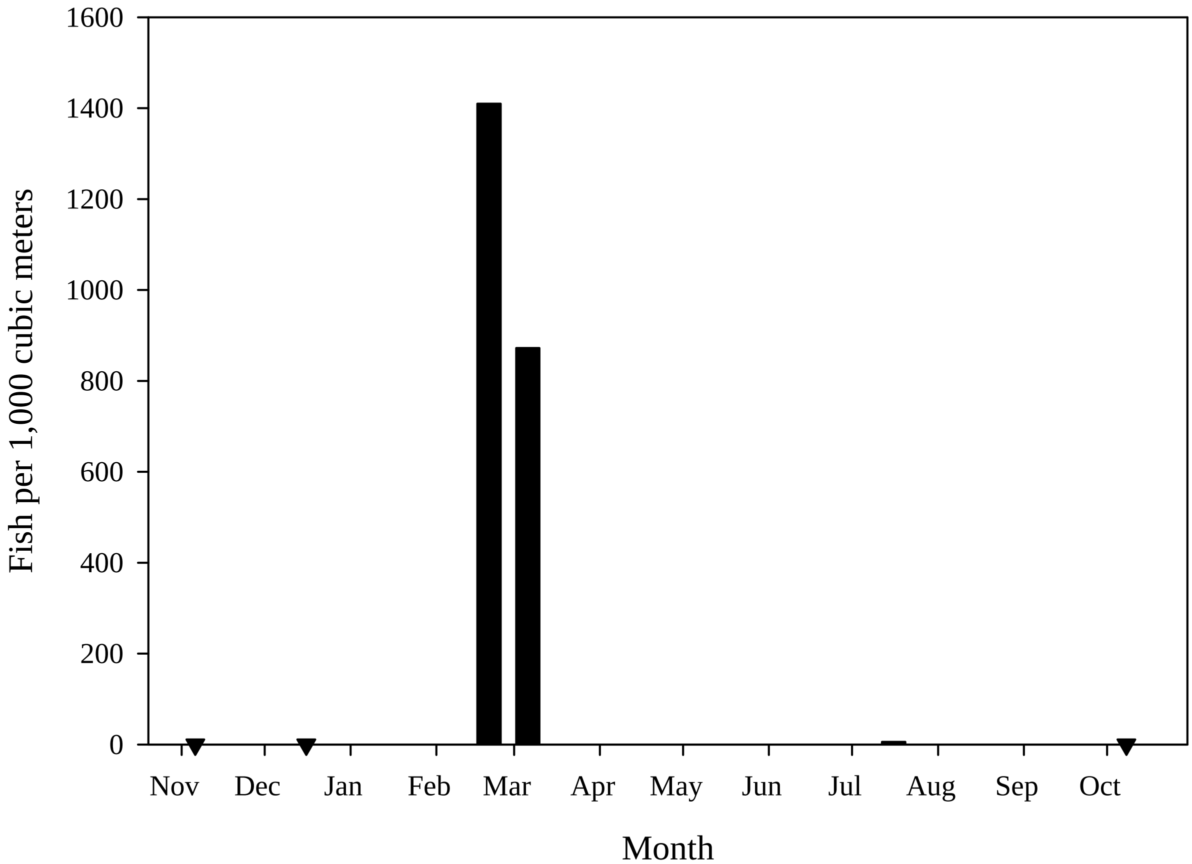

Figure 3-6. Concentrations of all fishes collected during the Bay Area Regional Desalination Project pilot plant entrainment study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no fishes were collected.

3.5.1 Prickly Sculpin *Cottus asper*

Prickly sculpin *Cottus asper* is native to California and is found in coastal streams and estuaries from the Kenai Peninsula, Alaska, down to the Ventura River, southern California (Moyle 2002). They are found in tidal and nontidal fresh waters of the Sacramento-San Joaquin system, nearby sloughs, landlocked ponds, and reservoirs (Wang 1981). Prickly sculpin are common in reservoirs and have spread via the California Aqueduct into reservoirs in southern California and to streams below them. They live in a wide range of environments including freshwater, brackish water, and seawater. Prickly sculpin spend most of their time quietly lying on the bottom and hiding under rocks and logs. They feed mostly on large benthic invertebrates, but other aquatic insects, mollusks, isopods, amphipods, small fishes, and frogs are also eaten (Moyle 2002). In the San Joaquin River, the oldest prickly sculpin collected was seven years old and measured 105 mm SL (4.1 in.).

Prickly sculpin become mature at 40–70 mm SL (1.6–2.8 in.) during their second, third, or fourth year (Moyle 2002). Before spawning, males move into intertidal or areas freshwater that contain moderate currents and large flat rocks. Males select protected nest sites, under rocks or trash, while females congregate upstream of the spawning area. The males dig the nest and clean off the "ceiling." Females are lured into the nests by the males and most spawning takes place at night (Moyle 2002). Eggs are attached to the ceiling of the nest in a cluster. The males then chase the females from the nest and guard the nest until the embryos hatch. Females produce anywhere from 280–11,000 eggs, depending on size and age. Males frequently spawn with more than one female. Larvae hatch at between 5–7 mm TL (0.2–0.3 in.) and begin swimming fairly soon after hatching (Moyle 2002). Larvae remain in the water column until they settle to the bottom at around 15–20 mm TL (0.6–0.8 in.) (Moyle 2002).

Prickly sculpin was the most abundant fish collected (n=6,171) during the November 5, 2008 through October 9, 2009 BARDP entrainment study. Prickly sculpin were only collected in the two surveys conducted during the sensitive fish period (Figure 3-7). The peak concentration of prickly sculpin (1,370.8/1,000 m^3) occurred during the February 20, 2009 survey (Figure 3-7). A total of 230 prickly sculpin were measured during the study; total length ranged from 4.0 to 9.2 mm (0.16 to 0.36 in.) and averaged 5.21 mm (0.21 in.) (Figure 3-8).

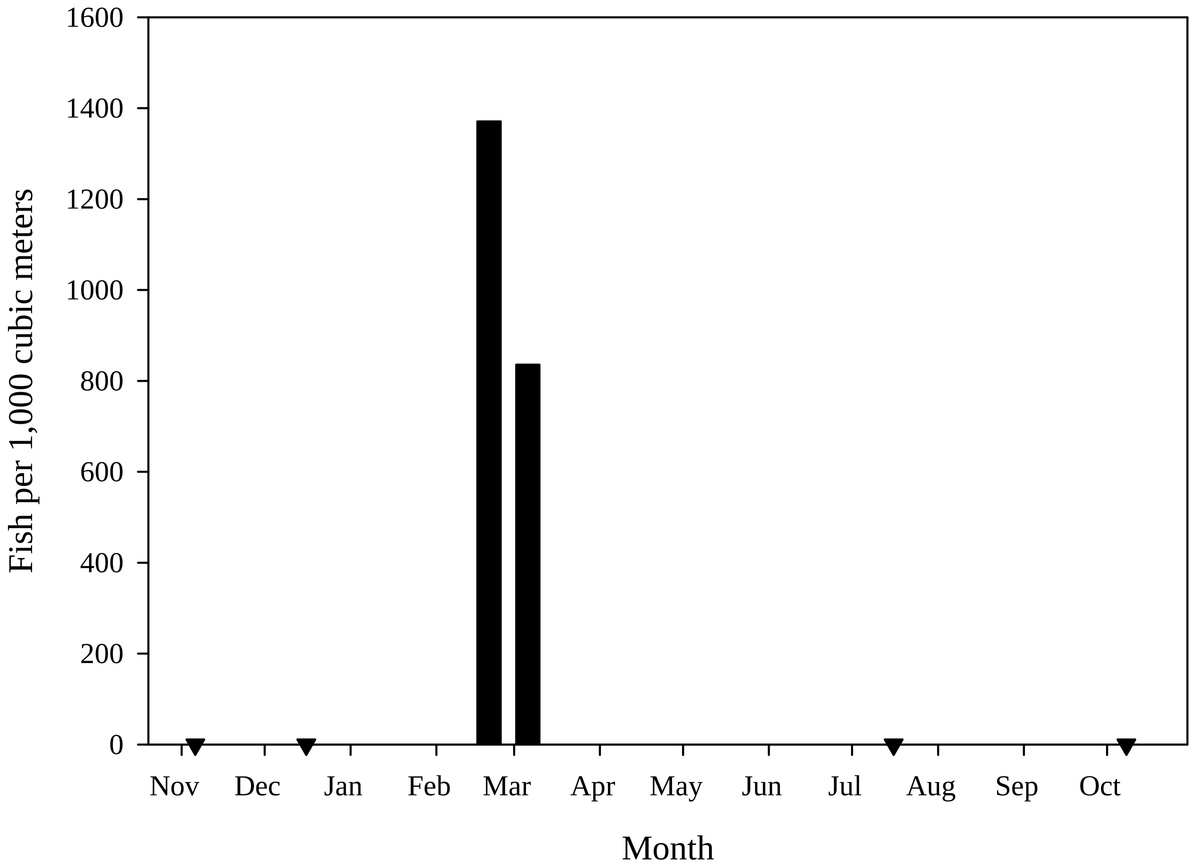

Figure 3-7. Concentrations of prickly sculpin collected during the Bay Area Regional Desalination Project pilot plant entrainment study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no prickly sculpin were collected.

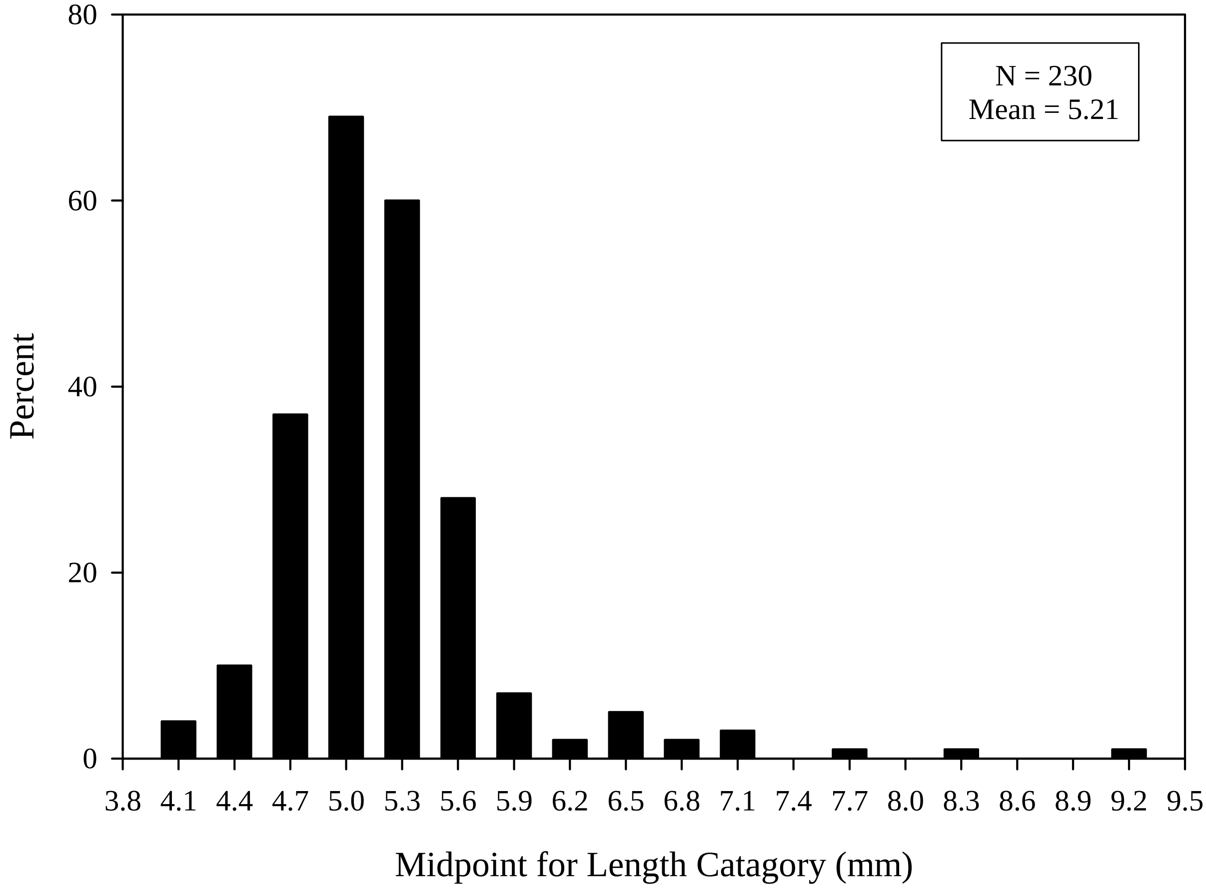

Figure 3-8. Length frequency distribution (total length in mm) for prickly sculpin collected during the Bay Area Regional Desalination Project pilot plant entrainment study from November 5, 2008 through October 9, 2009.

3.5.2 Smelts Osmeridae

There are 12 species of true smelts (Osmeridae), seven of which are found in California (Moyle 2002). Of these, three are exclusively marine and are not found in the Sacramento-San Joaquin Delta. The eulachon *Thaleichthys pacificus* is anadromous but is rarely found in the Delta. The wakasagi *Hypomesus nipponensis* is primarily freshwater but is occasionally found in the Delta. Both the delta smelt and longfin smelt are common in the Delta with the delta smelt preferring slightly fresher water than the longfin (McGinnis 2006). Delta smelt are endemic to the upper Sacramento-San Joaquin Delta (Moyle 2002). Longfin smelt are considered “weakly anadromous” and have been found in bays and estuaries from Alaska down to central California, including several in Northern California.

Delta smelt are a pelagic, midwater fish that prefers well oxygenated sections of the water column with relatively slow currents (Moyle 2002). Delta smelt feed primarily on zooplankton (mainly copepods, cladocerans, and amphipods) and occasionally on aquatic insect larvae. They are preyed upon by larger piscivorous fish, but their small size and translucent bodies enable them to effectively hide in the turbid waters they inhabit (Moyle 2002). Delta smelt spawn between February and July in the upper region of the Delta where fresh and brackish water mix (Moyle 2002). In spring most of the one-year fish spawn and die, though some fish will survive for a second year (McGinnis 2006). Maximum size is 120 mm (4.7 in.) standard length.

In 1993 delta smelt was listed as threatened under the State and Federal Endangered Species Act. In 2009, it was upgraded to endangered status under the California Endangered Species Act. Because it lives entirely in the Sacramento-San Joaquin Delta it is greatly affected by changes to this ecosystem.

Longfin smelt tolerate a large range of salinities and temperatures, which allows them to utilize a variety of habitats in and around the Bay-Delta. Its distribution patterns vary from year to year, dependent primarily on the outflow of fresh water (Moyle 2002). Longfin smelt reach sexual maturity when they are around two years old and four inches in length (Leet et al. 2001). Reproductive success is positively correlated to high outflows of fresh water (Baxter et al. 1999). Longfin smelt were once the most abundant fish in San Francisco Bay, but in recent years their population has declined dramatically (Moyle 2002).

Despite recent sharp declines in the longfin smelt population, it was denied threatened status under the federal Endangered Species Act primarily because it is not genetically distinct from stable populations in Washington (74 FR 67). Longfin smelt was listed as threatened under the California Endangered Species Act in March 2009.

A total of 208 smelts (a mix of longfin and delta) were collected during the November 5, 2008 through October 9, 2009 BARDP pilot plant entrainment study. One smelt was able to be identified to species; it was a longfin smelt measuring 10 mm total length (0.39 in.). It was collected during the March 6, 2009 entrainment survey. The remaining smelts could not be identified to the species level due to their damaged condition. However, Dr. Wang, the ichthyologist, reported that the majority were longfin smelt "with some delta smelt." He also stated that it was highly unlikely that any of the smelts were Wakasagi. During the 2009 Smelt Larva Survey, the majority of smelts collected during the March 3, 2009 survey at three stations near Mallard Slough were longfin smelt (see tables 2-2 and 2-3). At these same stations during the 20-mm Survey (which collects later-stage larvae and juveniles), six delta smelt and one Wakasagi *Hypomesus nipponensis* were collected.

Longfin/delta smelts were only collected in the two surveys conducted during the sensitive fish period (Figure 3-9). The peak concentration of longfin/delta smelts (39.2/1,000 m^3) occurred during the February 20, 2009 survey (Figure 3-9). A total of 95 longfin/delta smelts were measured during the study; total length ranged from 4.0 to 6.5 mm (0.16 to 0.26 in.) and averaged 5.15 mm (0.20 in.) (Figure 3-10).

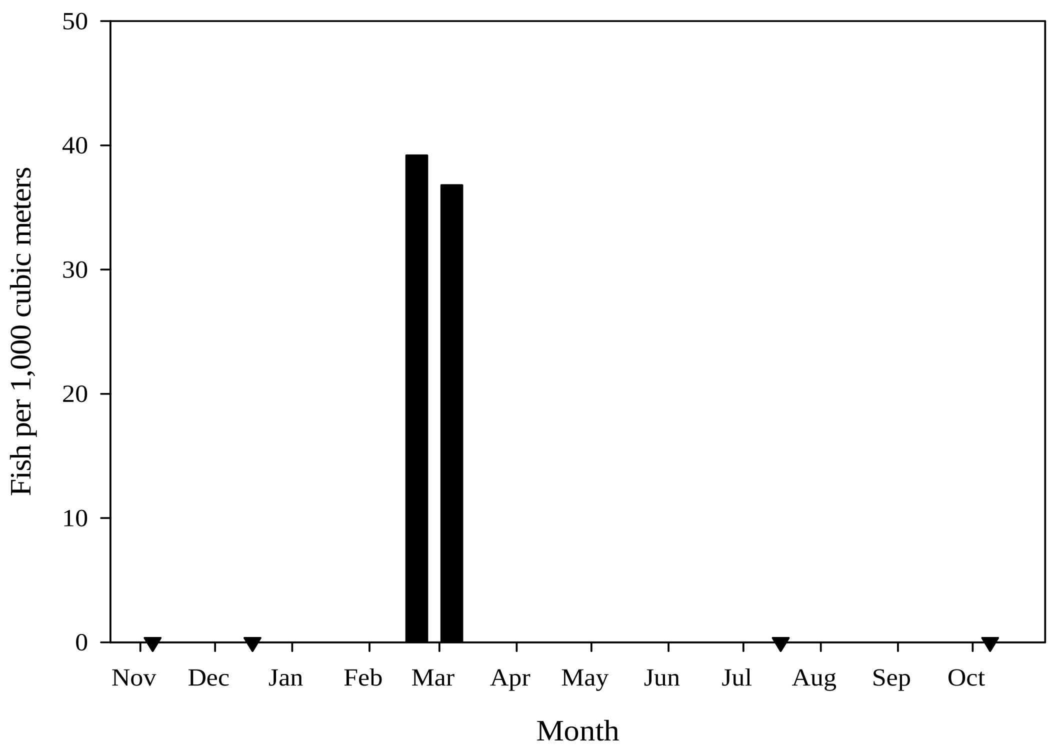

Figure 3-9. Concentrations of smelts (longfin and delta smelts) collected during the Bay Area Regional Desalination Project pilot plant entrainment study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no smelts were collected.

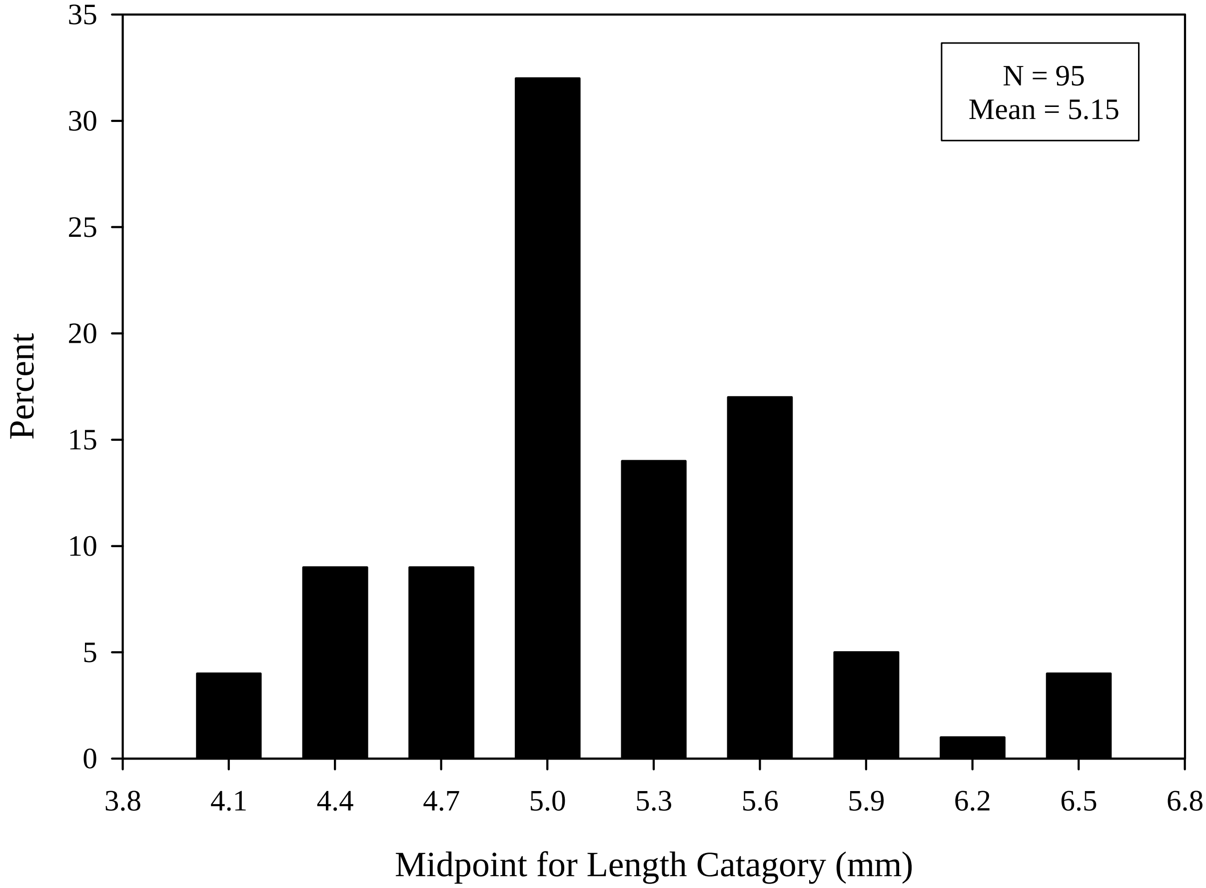

Figure 3-10. Length frequency distribution (total length in mm) for longfin/delta smelts collected during the Bay Area Regional Desalination Project pilot plant entrainment study from November 5, 2008 through October 9, 2009.

Note: the one identified longfin smelt (10 mm TL) is not included in this histogram.

3.5.3 Sunfishes *Lepomis* spp.

Sunfishes (*Lepomis* spp.), along with "black" basses (*Micropterus* spp.) and crappies (*Pomoxis* spp.), belong to the Centrarchidae family. They evolved in North America but now have a worldwide distribution due to stocking of various species (Moyle 2002). The predatory habits and high reproductive rates of sunfishes have contributed to the decline of many native fishes, especially native minnows in lowland habitats and pupfishes in desert springs. Sunfishes of the genus *Lepomis* spp. are one of the most abundant fishes in warmwater ponds, lakes, and streams in North America. In California, they are often the most abundant fishes in reservoirs, sloughs, and low elevation streams (Moyle 2002). Both bluegill *Lepomis macrochirus* and redear sunfish *Lepomis microlophus* are found near Mallard Slough (Tenera 2009).

Redear sunfish *Lepomis microlophus* are native to the southeastern U. S., and were introduced into the lower Colorado River in 1948 or 1949 by the Arizona Department of Fish and Game. They were first collected in California in 1951. The preferred habitat of this species is deeper waters of warm ponds, lakes, and river backwaters and sloughs. Redear sunfish feed mostly by picking hard-shelled invertebrates from the bottom and from aquatic plants (Moyle 2002).

Bluegill *Lepomis macrochirus* was originally distributed throughout much of eastern and southern North America. They were introduced into California in 1908 and became widely distributed in the next 10–20 years. They are now found in most reservoirs throughout the state and are probably the most widely distributed warm water fish. Bluegill can be found in warm shallow lakes, reservoirs, ponds, streams, and sloughs at low elevations (Moyle 2002). They hide and feed in rooted aquatic plants and are found over silt, sand, or gravel substrates. They feed on whatever animal food is most abundant, whether on the bottom, in midwater, in aquatic vegetation, or on the surface.

A total of three sunfishes (genus *Lepomis*) were collected during the November 5, 2008 through October 9, 2009 BARDP entrainment study. These specimens could not be identified to the species level. *Lepomis* spp. was only collected during the July 16-17, 2009 survey. The concentration of *Lepomis* spp. during this survey was 5.7/1,000 m^3 (Figure 3-11). All three *Lepomis* spp. were measured during the study; total length ranged from 4.5 to 5.2 mm (0.18 to 0.2 in.) and averaged 4.9 mm (0.19 in.) (Figure 3-12).

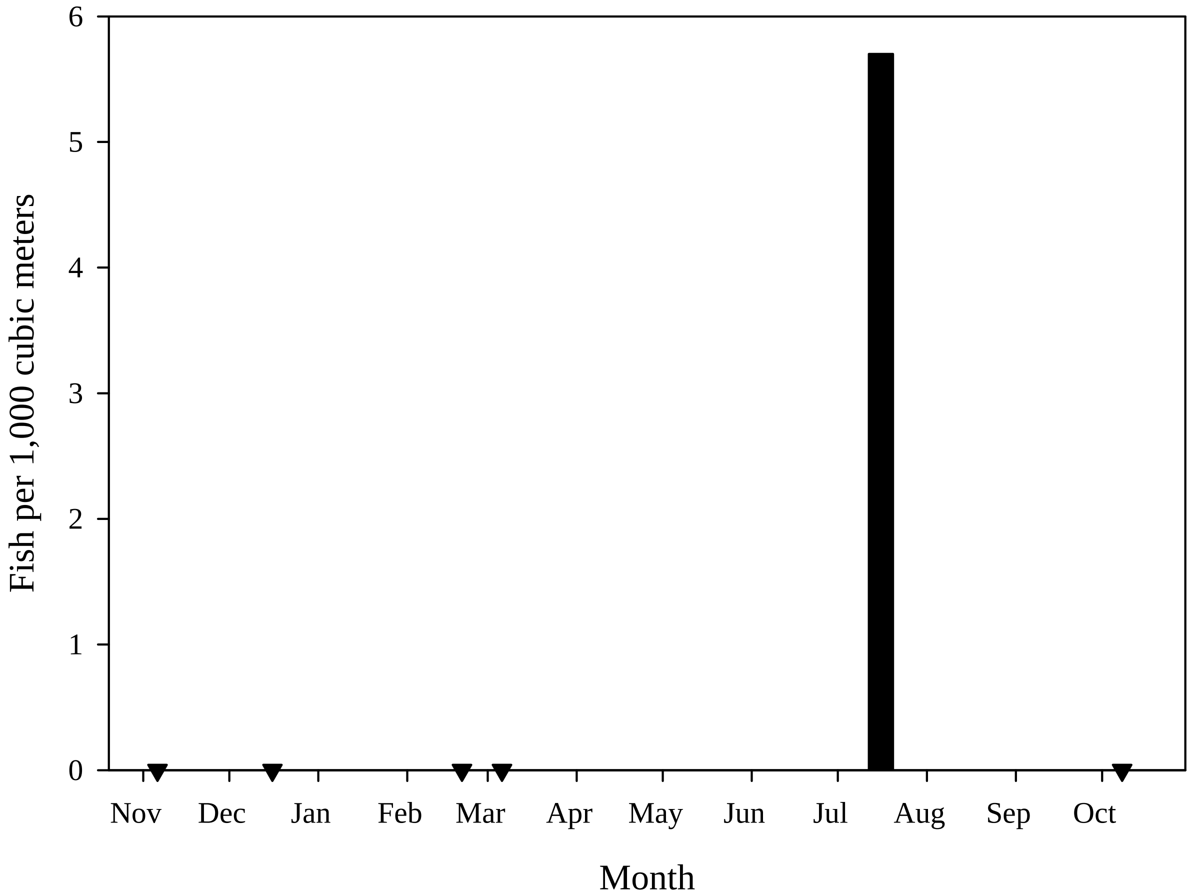

Figure 3-11. Concentrations of *Lepomis* spp. collected during the Bay Area Regional Desalination Project pilot plant entrainment study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no *Lepomis* spp. were collected.

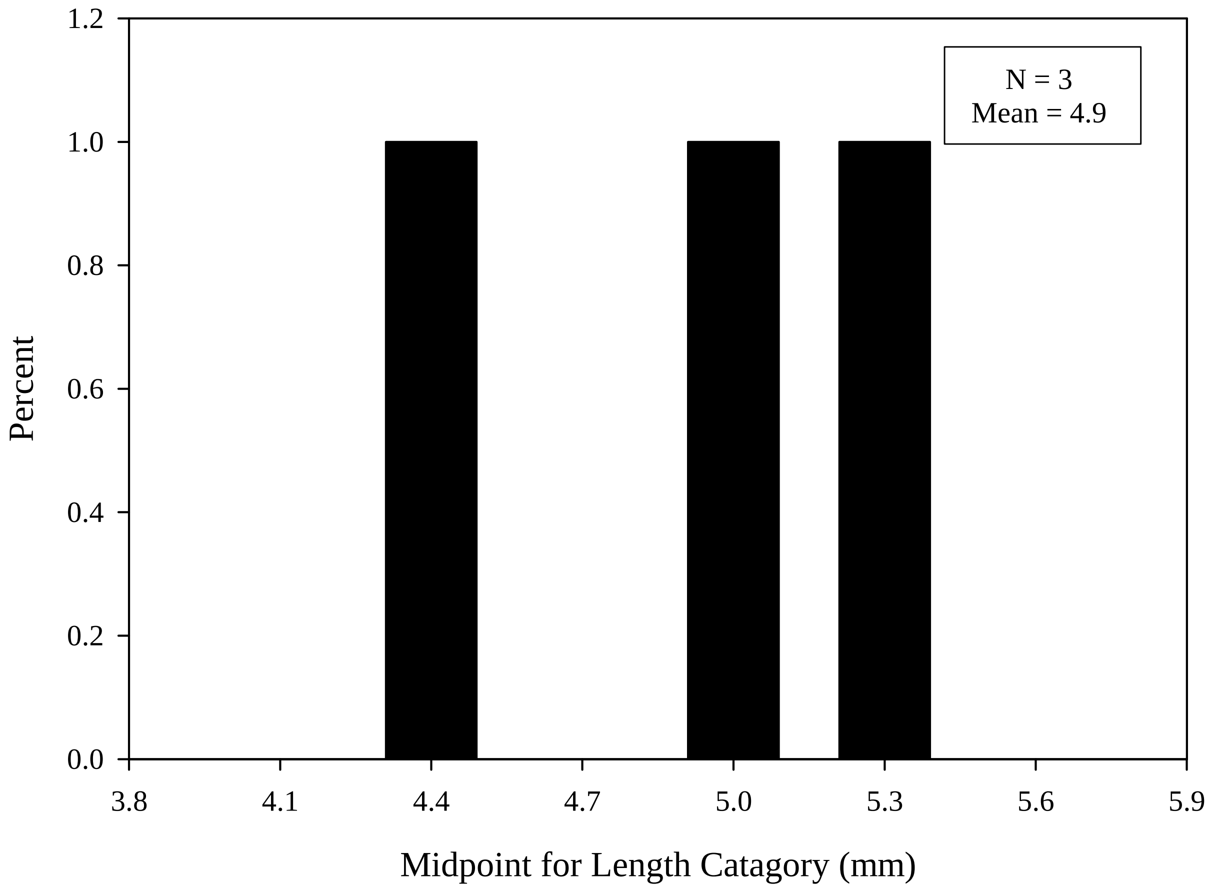

Figure 3-12. Length frequency distribution (total length in mm) for *Lepomis* spp. collected during the Bay Area Regional Desalination Project pilot plant entrainment study from November 5, 2008 through October 9, 2009.

3.6 Source Water Study Results

Data presented in this section are from the four source water surveys conducted in Mallard Slough from November 5, 2008 through October 9, 2009. Source water surveys were conducted on November 5 and 7, December 16, July 16 and 17, 2008 and October 9, 2009. A total of 32 samples were collected during course of the source water study. No source water sampling was conducted during the sensitive fish period of January through June. A total of 759 m^3 of water was filtered over the course of the four source water surveys.

A total of 21 fishes comprised of four species were collected during source water sampling. Fishes were collected in three of the four surveys (Table 3-4). Northern anchovy *Engraulis mordax* was the most abundant fish species, followed by Pacific herring *Clupea pallasii*, inland silverside *Menidia beryllina* and prickly sculpin. With the exception of the one prickly sculpin collected during the December 16, 2008 survey, none of the same species or taxa of fishes collected in the entrainment samples were collected in the source water samples. (Source water sampling did not occur during the sensitive fish period of January through June.) No fish eggs were collected during the 2008–2009 BARDP source water study.

Table 3-4. Information regarding the collection of fishes in source water samples during the Bay Area Regional Desalination Project pilot plant entrainment study from 2008–2009.

	November 5 2008		December 16, 2008		July 16-17, 2009		October 8-9, 2009	
	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3	Number collected	Fish per 1,000 m^3
Prickly sculpin	0	0.0	1	5.3	0	0.0	0	0.0
Pacific herring	0	0.0	6	31.7	0	0.0	0	0.0
Inland silverside	0	0.0	0	0.0	2	11.6	0	0.0
Northern anchovy	0	0.0	0	0.0	0	0.0	12	61.9
Total	0	0.0	7	37.0	2	11.6	12	61.9

3.6.1 Northern Anchovy *Engraulis mordax*

A total of 12 northern anchovy were collected during the November 5, 2008 through October 9, 2009 BARDP source water study. Northern anchovy was only collected during the October 8-9, 2009 survey. The concentration of northern anchovy during this survey was 61.9/1,000 m^3 (Figure 3-13). All twelve northern anchovy were measured during the study; total length ranged from 3.5 to 9.0 mm (0.14 to 0.35 in.) and averaged 5.7 mm (0.23 in.) (Figure 3-14).

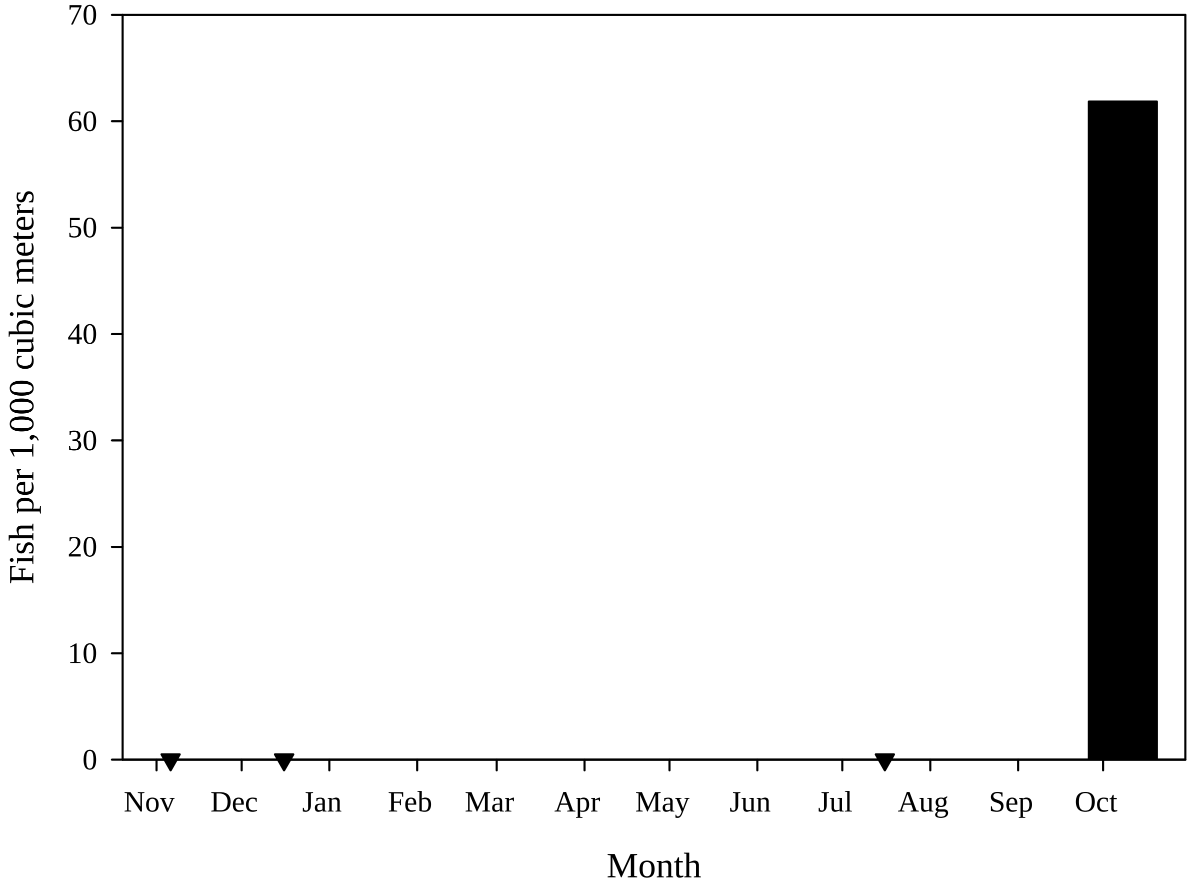

Figure 3-13. Concentrations of northern anchovy collected during the Bay Area Regional Desalination Project pilot plant source water study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no northern anchovy were collected.

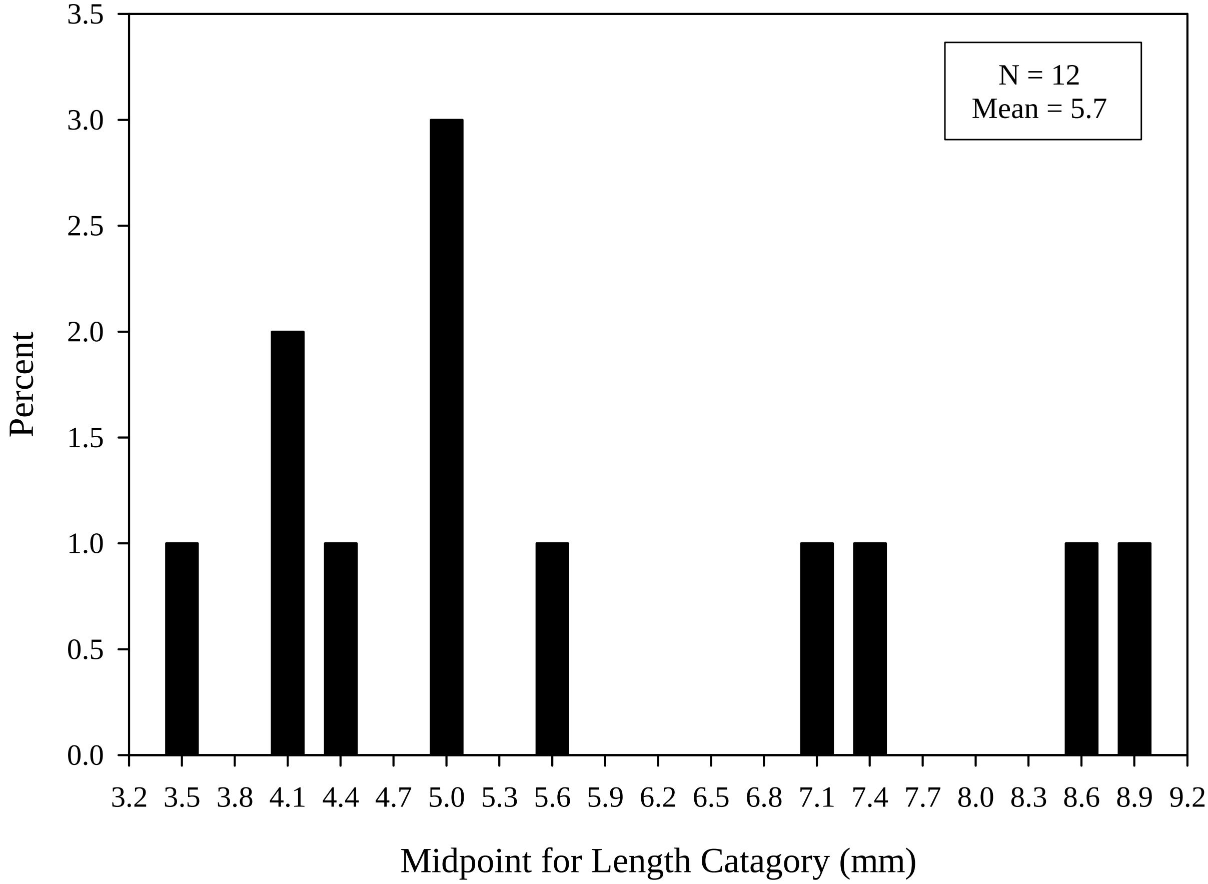

Figure 3-14. Length frequency distribution (total length in mm) for northern anchovy collected during the Bay Area Regional Desalination Project pilot plant source water study from November 5, 2008 through October 9, 2009.

3.6.2 Pacific Herring *Clupea pallasii*

A total of six Pacific herring were collected during the November 5, 2008 through October 9, 2009 BARDP source water study. Pacific herring were only collected during the December 16, 2008 survey. The concentration of Pacific herring during this survey was 31.7/1,000 m^3 (Figure 3-15). All six Pacific herring were measured during the study; total length ranged from 10.3 to 28.3 mm (0.41 to 1.11 in.) and averaged 13.8 mm (0.54 in.) (Figure 3-16).

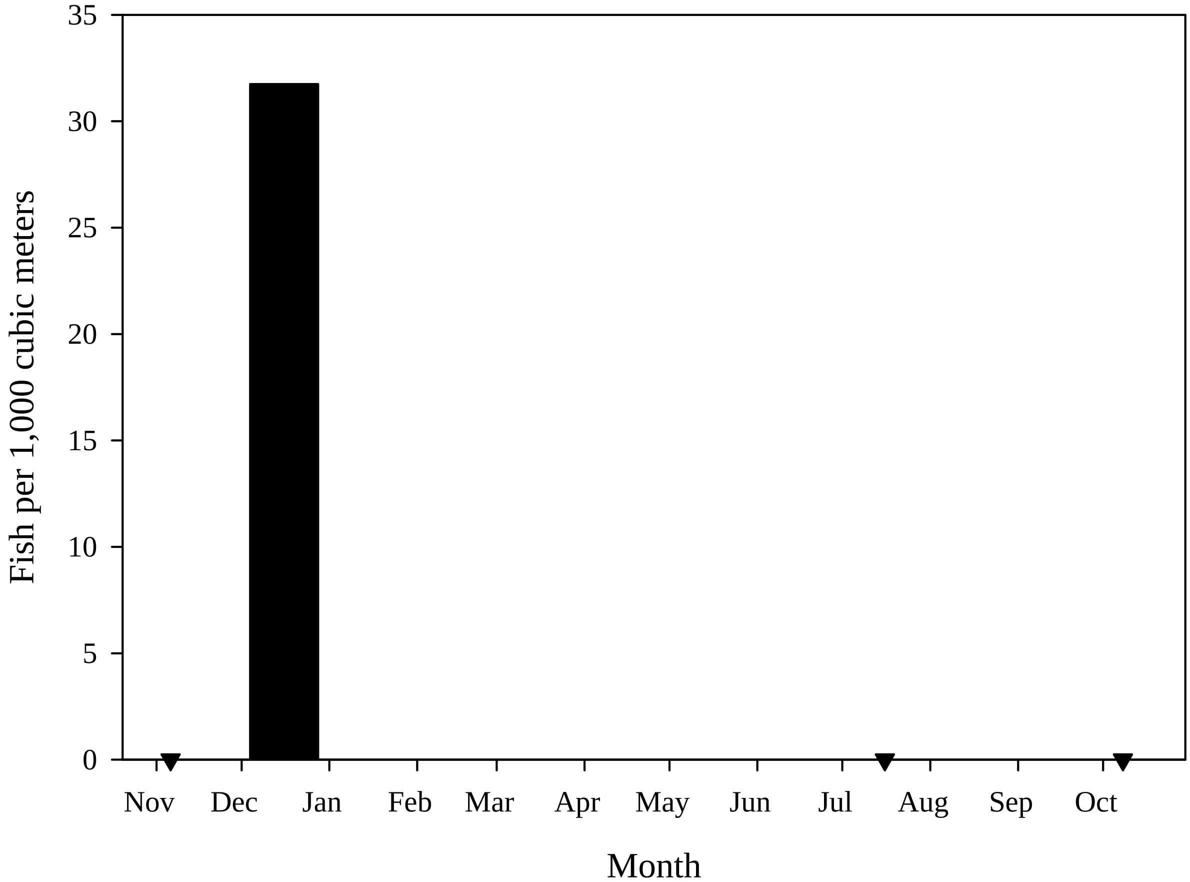

Figure 3-15. Concentrations of Pacific herring collected during the Bay Area Regional Desalination Project pilot plant source water study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no Pacific herring were collected.

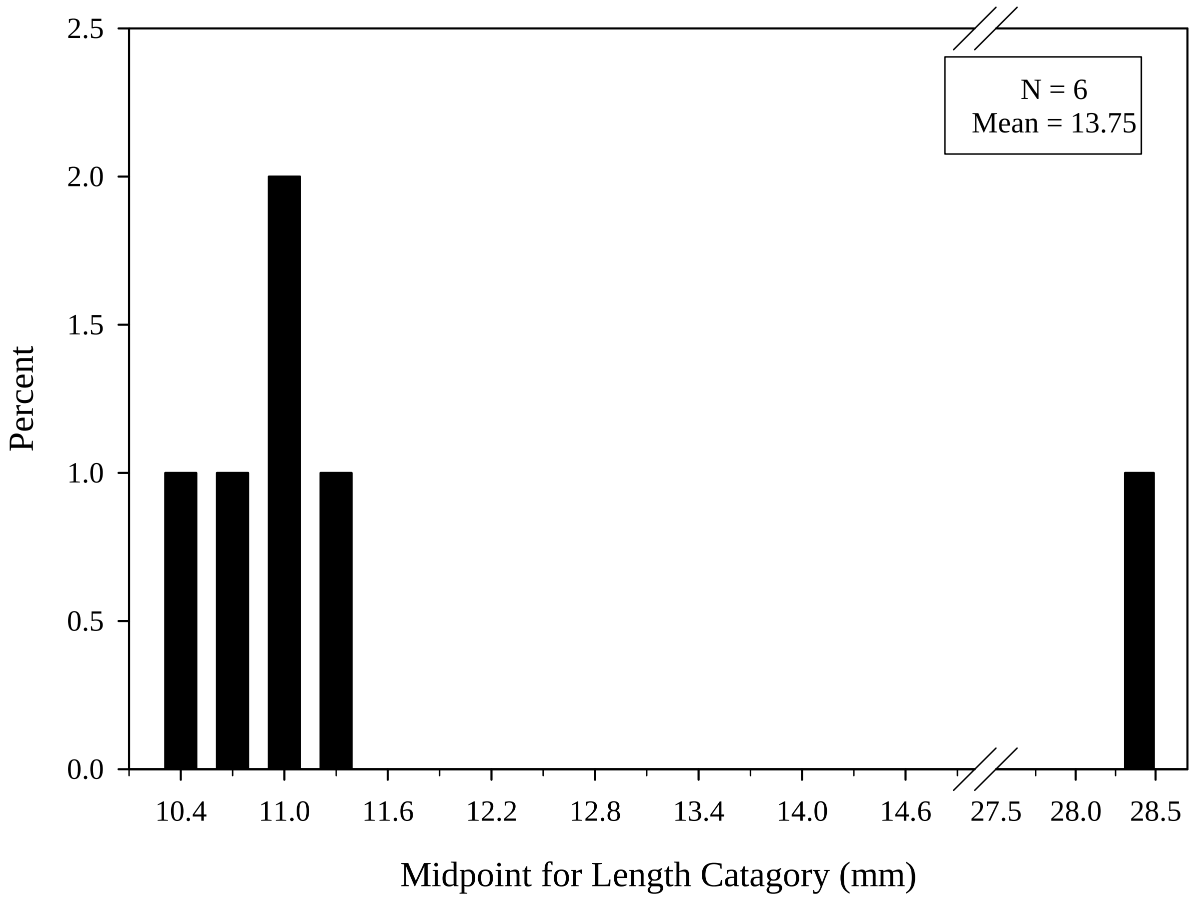

Figure 3-16. Length frequency distribution (total length in mm) for Pacific herring collected during the Bay Area Regional Desalination Project pilot plant source water study from November 5, 2008 through October 9, 2009.

3.6.3 Inland Silverside *Menidia beryllina*

A total of two inland silverside were collected during the November 5, 2008 through October 9, 2009 BARDP source water study. Inland silverside were only collected during the July 16-17, 2009 survey. The concentration of inland silverside during this survey was 11.6/1,000 m^3 (Figure 3-17). Both inland silverside were measured during the study; total length ranged from 4.0 to 4.5 mm (0.16 to 0.18 in.).

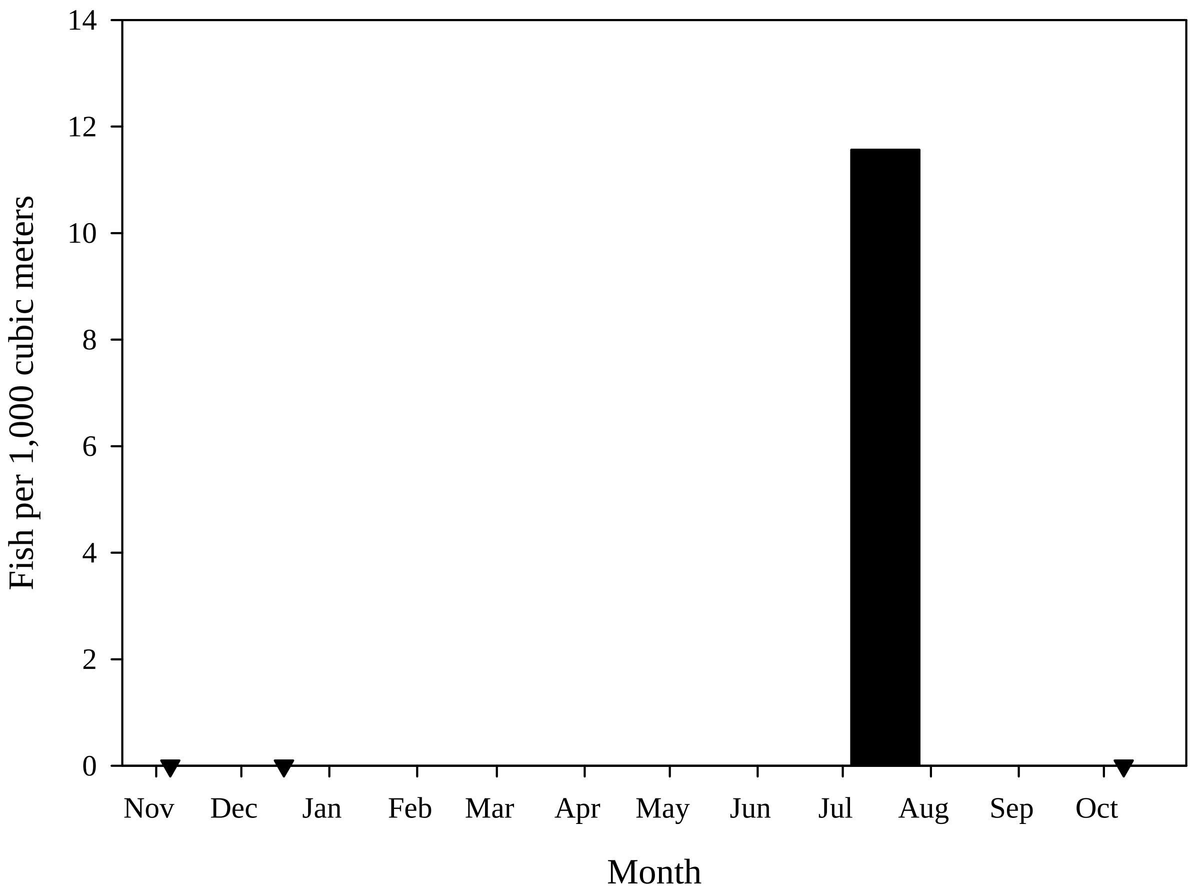

Figure 3-17. Concentrations of inland silverside collected during the Bay Area Regional Desalination Project pilot plant source water study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no inland silverside were collected.

3.6.4 Prickly Sculpin *Cottus asper*

A total of one prickly sculpin was collected during the November 5, 2008 through October 9, 2009 BARDP source water study. Prickly sculpin was only collected during the December 16, 2008 survey. The concentration of prickly sculpin during this survey was 5.3/1,000 m^3 (Figure 3-18). The total length of the prickly sculpin was 5.7 mm (0.22 in.).

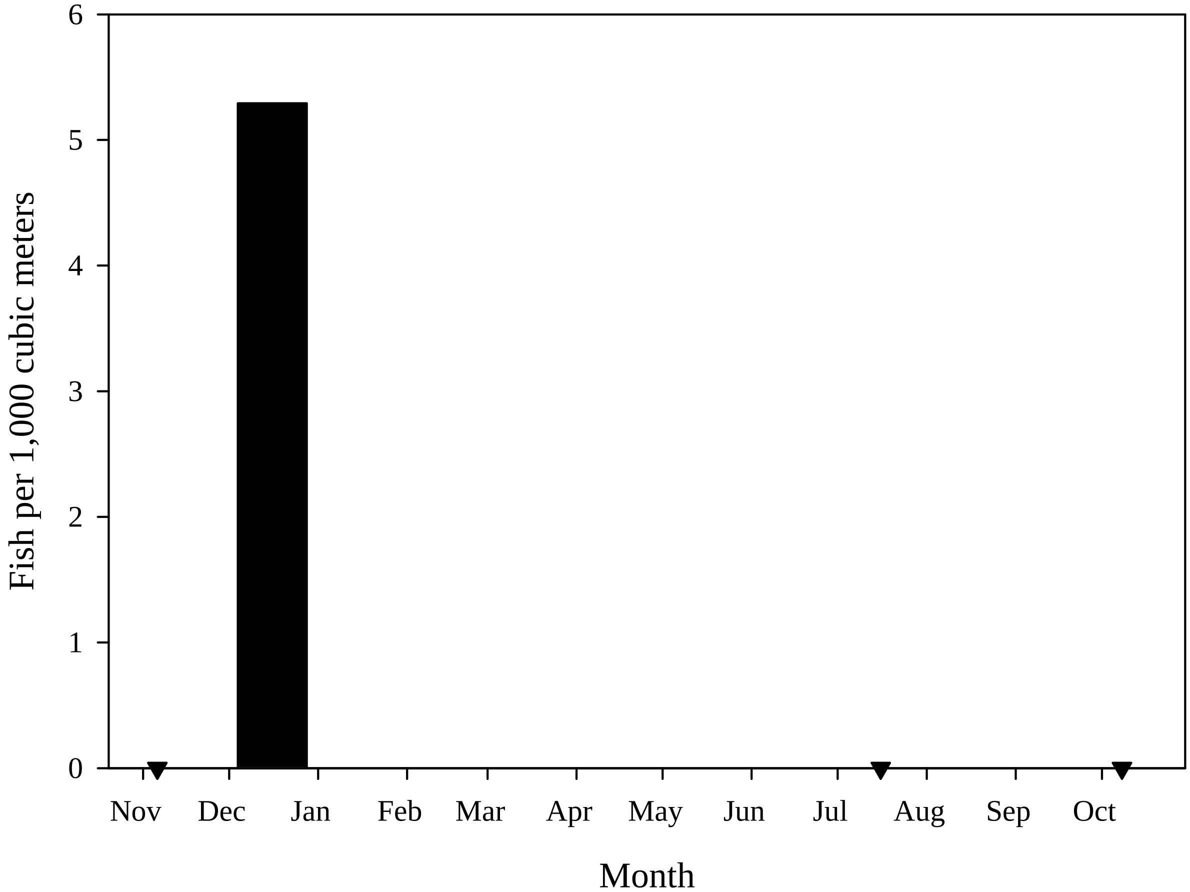

Figure 3-18. Concentration of prickly sculpin collected during the Bay Area Regional Desalination Project pilot plant source water study standardized in units of individuals per thousand m^3 sampled (#/1,000 m^3) from November 5, 2008 through October 9, 2009.

Note: inverted triangle indicates that no prickly sculpin were collected.

3.7 Discussion

The Sacramento-San Joaquin Delta is the mixing point of the Central Valley's freshwater rivers and the Pacific Ocean. Water conditions at individual locations in the Delta are primarily influenced by the annual and seasonal variation in freshwater outflow and the ebb and flow of the tide. The fishes that inhabit the Delta vary in the hydrological conditions they tolerate and will inhabit different parts of the Delta at different times of year in response to this annual variation. Mallard Slough is one such location in the Delta, and is subject to this variation in conditions and the associated variation in utilization by different fish species.

3.7.1 Prickly Sculpin

Prickly sculpin live in a wide range of environments from clear, fresh, well-oxygenated mountain streams, to the brackish, turbid waters of the Delta and are abundant throughout much of the state. In the Delta, spawning is related to increased outflow and cool temperatures and occurs from February to May (Moyle 2002). Prickly sculpin are most susceptible to entrainment during the three to five weeks after hatching in which they are planktonic.

Both historic and recent data confirm that larval prickly sculpin occur in the vicinity of Mallard Slough during the winter/spring months. Concentrations of prickly sculpin collected during the January 5–March 3, 2009 Smelt Larva Survey at the three samples stations near Mallard Slough (see Figure 2-1) increased as the season progressed, peaking in March (see Table 2-2). During the 1978-1979 entrainment study at the nearby Pittsburg Power Plant, prickly sculpin were only entrained during the February to May spawning season; peak entrainment concentrations occurred in March and April (see Table 2-4).

During the BARDP pilot plant entrainment study, prickly sculpin were only found in the surveys conducted during their spawning season (February and March surveys); they were not found in the surveys that did not occur during their spawning season. The length of the specimens collected (4.0 to 9.2 mm TL [0.2 to 0.4 in.]) is consistent with the length of larvae in the first few weeks after hatching when the prickly sculpin are still planktonic and before they assume their benthic existence (McLarney 1968).

3.7.2 Longfin Smelt

Longfin smelt are considered "weakly anadromous" and are found in bays and estuaries from Alaska down to central California. They can tolerate a large range of salinities and temperatures, which allows them to utilize a variety of habitats in and around the Bay. Their distribution patterns vary from year to year and depend primarily on the outflow of fresh water (Moyle 2002). During April and June they tend to be concentrated in San Pablo Bay, then move downstream into the Central San Francisco Bay and the Pacific Ocean during late summer and fall (Leet et al. 2001). From December to April, fish move upstream to areas with low salinities to spawn. It is after the eggs hatch that they are susceptible to entrainment. As mentioned previously, larval longfin smelt are difficult to distinguish from larval delta smelt, especially so when specimens are damaged.

Both historic and recent data confirm that larval longfin smelt occur in the vicinity of Mallard Slough during the winter/spring months. Longfin smelt were collected in high abundance during the 2009 Smelt Larva Survey at the three stations near Mallard Slough (see Figure 2-1). At Station 520, the furthest station upstream of Mallard Slough, concentrations increased throughout the survey period (January 5–March 3), peaked on February 2-5, and then decreased until the end of the survey on March 3(see Table 2-2). At Station 508, which is downstream from 520 and closest to Mallard Slough, concentration peaked during the January 20-23 survey, then decreased reaching a low during the February 2–5 survey, and then increased once again until the end of the survey on March 3 (see Table 2-2).

A total of 2,707 longfin smelt, representing 63.5% of all fishes collected, were collected during the 2009 20-mm Survey at stations near Mallard Slough (see Table 2-3). During the 1978–1979 Pittsburg Power Plant entrainment study, smelts (delta and longfin smelts were grouped together as “smelts”) were entrained from January to June with most entrainment occurring during January and February (see Table 2-4).

In the BARDP pilot plant entrainment study, smelts were found in surveys conducted during their spawning season (February and March) but were not found in the surveys that did not take place during their spawning season. The size of fish collected (4.0 to 6.5 mm TL [0.2 to 0.3 in.]) is consistent with the length of recently hatched specimens (Wang 1986).

3.7.3 Delta Smelt

Delta smelt are endemic to the Delta and spend their entire life there. They are primarily found in the mixing zone where freshwater and saltwater meet and salinities are between 2 and 7 ppt (Moyle 2002). The adults move throughout the Delta in response to the location of this mixing zone, which, depending on outflow conditions, can be located near Mallard Slough during late winter and spring. Spawning occurs from February through July (McGinnis 2006). Delta smelt eggs are adhesive and not susceptible to entrainment. However, once the eggs hatch, the larvae are planktonic and susceptible to entrainment. Delta smelt can be difficult to distinguish from longfin smelt during early life stages, especially if the specimens are damaged.

No delta smelt were identified from samples collected during the 2009 Smelt Larva Survey, although a percentage (roughly 10%) of unidentified smelts were collected during the February 5–7 survey (see Table 2-2) at the three stations near Mallard Slough (see Figure 2-1). A total of 13 delta smelt, representing 0.3% of all fishes collected, were collected during the 2009 20-mm survey at the three stations near Mallard Slough (see Table 2-3). During the 1978-1979 Pittsburg Power Plant entrainment study, smelts (delta and longfin smelts were grouped together as "smelts") were entrained from January to June with most entrainment occurring during January and February (see Table 2-4).

In the BARDP pilot plant entrainment study, smelts were found in large numbers during the surveys conducted during their spawning season, but were not found in the surveys that did not take place during their spawning season. The size of specimens collected (4.0 to 6.5 mm TL [0.2 to 0.3 in.) is consistent with the size of delta smelt in the first few weeks after hatching (Wang 1986).

3.7.4 *Lepomis* spp. (Bluegill and Redear Sunfishes)

Bluegill and redear sunfishes are both introduced species that are well established in the Sacramento-San Joaquin Delta (Moyle 2002). Though mainly found in freshwater they can tolerate moderate salinities and are found in the upper reaches of the San Francisco Estuary (Moyle 2002). Bluegill and redear sunfishes have protracted spawning seasons starting in the spring and continuing through the summer and into the fall (Moyle 2002).

No bluegill or redear sunfish larvae were collected during 2009 Smelt Larva Survey, the 2009 20-mm Survey, or the 1978–1979 Pittsburg Power Plant entrainment study. The lack of *Lepomis* spp. larvae in these studies could be due to the nesting and guarding habits of sunfishes, the deeper depth sampled by CDFG, and/or the lack of suitable nesting habitat near the power plant. The area near the MSPS intake may provide nesting habitat for these sunfishes. In the BARDP pilot plant entrainment study, three sunfishes were collected during the July 16-17 survey (see Figure 3-11). The length of the specimens (4.5 to 5.2 mm TL [0.18 to 0.2 in.]) is consistent with the reported length of newly hatched larvae.

3.8 Literature Cited

Baxter, R. K. Hieb, S. DeLeon, K. Flemming, J. Orsi. 1999. Report on the 1980-1995 Fish, Shrimp and Crab Sampling in the San Francisco Estuary, California. California Department of Fish and Game, Technical Report 63. November 1999.

Federal Register, Volume 74. No. 67. 2009. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt (*Spirinchus thaleichthys*) as Endangered. Vol. 74, No. 67, April 9, 2009, Page 16169. frwebgate3.access.gpo.gov Accesed on 12/4/09.

Leet, W.S., C.M. Dewees, R. Klingbeil, E.J. Larson. 2001. California's Living Marine Resources: A Status Report. California Department of Fish and Game. December 2001.

McLarney, W.O. 1968. Spawning habitats and morphological variation in the coast range sculpin, *Cottus aleuticus* and the prickly sculpin *Cottus asper*. Transactions American Fisheries Society. 97:46-48.

McGinnis, S. 2006. Field Guide to Freshwater Fishes of California, University of California Press, Berkeley CA, 2006.

Moyle, P. 2002. Inland Fishes of California, University of California Press, Berkeley CA, 2002.

Tenera Environmental (Tenera). 2009. Entrainment and Impingement Monitoring Plan for IEP Annual Report November 2007 – October 2008 for the Contra Costa and Pittsburg Power Plants. Submitted to Mirant Delta, LLC. Pittsburg, California.

Wang, J.C.S. 2009. National Environmental Services. Personal communication with Carol Raifsnider, Tenera Environmental. NES, Clayton, CA.

Wang, J.C.S. and R. Reyes. 2008. Early Life Stages and Life Histories of Centrarchids in the Sacramento-San Joaquin River Delta System, California. Volume 42. Tracy Fish Facility Studies, California. December 2008. Published by the U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Denver Technical Service Center.

Wang, J.C.S. and R. Reyes. 2007. Early Life Stages and Life Histories of Cyprinid Fish in the Sacramento-San Joaquin Delta, California: with Emphasis on Spawning by Splittail, *Pogonichthys macrolepidotus*. Volume 32. Tracy Fish Facility Studies, California. April 2007. Published by the U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Denver Technical Service Center.

Wang, J.C.S., L. Lynch, B. Bridges, and L. Grimaldo. 2005. Using Morphometric Characteristics to Identify the Early Life Stages of Two Sympatric Osmerids (Delta Smelt and Wakasagi, *Hypomesus transpacificus* and *Hypomesus nipponensis* in the Sacramento-San Joaquin Delta, California. Volume 30. Tracy Fish Facility Studies, California. April 2005. Published by the U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Denver Technical Service Center.

Wang, J.C.S. 1986. Fishes of the Sacramento San Joaquin Estuary and Adjacent Waters, California: A guide to the Early Life History Stages. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. January 1986.

Wang, J.C.S. 1981. Taxonomy of the Early Life Stages of Fishes. Ecological Analysts, Inc. 1981.

4.0 IMPACT ASSESSMENT

This assessment on the effects of entrainment by a 25 mgd full-scale BARDP feedwater intake system is based on data collected during six entrainment surveys from November 2008 through October 2009. Entrainment occurs when organisms smaller than the openings in the 3/32-inch intake screens (e.g., larval fishes) are drawn into the feedwater system. For the purposes of this study we assume that mortality of entrained organisms is 100%, and that the BARDP feedwater intake pumps will operate at maximum flow (25 mgd) 24 hours per day, seven days per week, with no scheduled or unscheduled maintenance outages.

Three methods for assessing effects on larval fishes were described in the BARDP study plan, which was submitted to the four partner water agencies in September 2008. They were empirical transport modeling (*ETM*), and the demographic modeling approaches of fecundity hindcasting (*FH*), and adult equivalent loss (*AEL*). This report contains estimates of *FH* and *AEL* (where applicable) for BARDP from data collected from the six entrainment surveys. The empirical transport model (*ETM*) calculates an estimate of the proportional mortality to the population due to entrainment. The underlying basis of the model is an estimate of the daily proportion of the source water entrained and therefore requires estimates of both entrainment and source water concentrations of larvae. *ETM* estimates were not calculated for any of the entrained fishes because they were not collected in the source water samples.

4.1 Entrainment Effects Assessment

For this report, we have focused our assessment of BARDP entrainment effects on the three species/taxa collected during the six entrainment surveys conducted from November 2008 through October 2009.

Results from the sampling showed that one species and two taxa of larval fishes were collected in entrainment samples. Numerically, the most abundant species collected was prickly sculpin (n=6,171), followed by delta/longfin smelts (n=208), and *Lepomis* spp. (n=3). Prickly sculpin, longfin smelt and delta smelt are native species, and *Lepomis* spp. (bluegill and redear sunfish) are introduced species. None of these taxa are commercially or recreationally important species. Delta smelt are listed as a threatened species under the federal Endangered Species Act and as endangered under the California Endangered Species Act. Longfin smelt is listed as threatened under the California Endangered Species Act. Concentrations (no./1,000 m^3) for all fish taxa collected during intake and source water sampling are presented by survey in Section 3.0.

Estimated entrainment from November 5, 2008–October 9, 2009 shows that the three taxa in rank order were prickly sculpin *Cottus asper* (96.25%), longfin/delta smelts (3.57%), and *Lepomis* spp. sunfishes (0.17%) (Table 4-1).

Table 4-1. Estimates of total annual larval fish entrainment based on BARDP maximum feedwater volume (25 mgd) based on six entrainment surveys conducted from November 2008 through October 2009.

Common Name	Taxon	Estimated Annual # of Entrained Larvae	Percent of Total Entrainment (%)
Prickly sculpin	*Cottus asper*	990,605	96.25
Longfin/Delta smelts	*Spirinchus thaleichthys/Hypomesus transpacificus*	36,777	3.57
Bluegill/Redear	*Lepomis microlophus/Lepomis macrochirus*	1,771	0.17
Total Fishes		1,029,153	*

*Does not total 100% due to rounding.

4.1.1 Demographic Approaches for Estimating Entrainment Effects

Entrainment losses were assessed from total larval entrainment at BARDP using Fecundity Hindcast (*FH*) and Adult Equivalent Loss (*AEL*) models. These models require species-specific estimates of age, growth, fecundity, and survivorship of various life stages. Demographic data were available to allow at least one of the two modeling approaches to be applied to two of the three fish taxa. Estimates of the model parameters were collected from several sources, but estimates of the sampling error or uncertainty associated with the reported values were not presented in any of the sources. Therefore, a standard error to mean ratio (coefficient of variation) of 30% was used to estimate the sample variance for all of the life history parameters.

4.2 Individual Taxa Results

4.2.1 Prickly Sculpin Cottus asper

Prickly sculpin was the most abundant larval fish entrained at the BARDP pilot plant during the course of this study and comprised 96% of the estimated total entrainment of all fish larvae (Table 4-1). For a 25 mgd facility, the annual estimate of BARDP entrainment for November 5, 2008–October 9, 2009 was 990,605. This estimate of entrainment was used to calculate losses of equivalent adults using the *FH* model. While life history information on fecundity was available there were no estimates of larval survival available that are necessary for computing *AEL* estimates.

Fecundity Hindcast Model (*FH*)

While information on fecundity was available for prickly sculpin, there were no references found that provided information on larval growth or mortality. Normally, some estimate of larval mortality, in addition to fecundity, are necessary for calculating *FH*, but the average length of the larvae collected during the study (5.2 mm [0.21 in.]) was at the low end of the range for the reported hatch length of 5-7 mm TL (0.2–0.3 in.) (Wang 1986, Moyle 2002). Therefore, we assumed that the larvae entrained were age zero allowing calculation of *FH* using only the fecundity estimates. It is expected that egg mortality in prickly sculpin is minor since the eggs are demersal, laid in protected nest sites, and guarded by the male (Moyle 2002). For the purposes of the modeling we assumed that egg mortality was 10%. The range of annual fecundity estimates provided in Wang (1986) was used to estimate annual fecundity at 4,317 eggs. This estimate was used with an average age of maturity of three years and longevity of seven years to calculate an estimate of total lifetime fecundity as follows:

$$TLF = 8{,}634 = 4{,}317 eggs/year \bullet \left(\frac{7years - 3years}{2} \right).$$

The estimate of *FH* of 255 adult female prickly sculpin was calculated as follows:

$$FH = 255 = \left(\frac{990{,}605}{4{,}317 * 0.9} \right).$$

Estimated adult equivalent losses due to entrainment assuming a 50:50 sex ratio is 2*FH*, or 510 prickly sculpin per year.

Adult Equivalent Loss (*AEL*)

No estimate of *AEL* was calculated for prickly sculpin due to the absence of any estimates of larval mortality in the literature.

4.2.2 Osmeridae Smelts

Longfin/delta smelts were the second most abundant larval fish entrained at the BARDP pilot plant during the course of this study and comprised 3.57% of the estimated total entrainment of all fish larvae (Table 4-1). For a 25 mgd facility, the annual estimate of BARDP entrainment for November 5, 2008–October 9, 2009 was 36,777 larvae. This estimate of entrainment was used to calculate losses of equivalent adults using both *FH* and *AEL* models as life history information for both models were available from the scientific literature.

Fecundity Hindcast Model (*FH*)

Demographic rates from studies of delta smelt were used for estimating adult equivalent losses using the *FH* model. Smelt lifetime fecundity was estimated as 1,900 eggs, the average of the range from 1,200–2,600 eggs per female reported in Moyle (2002). The average size of entrained smelt larvae was 5.2 mm, similar to hatch lengths given by Wang (1986) and Wang and Brown (1991) that ranged from 4.5 to 6 mm averaging 5.25 mm. The estimated total entrainment is hindcast through an egg stage with an estimated incubation period of 12.1 days (Baskerville-Bridges data in Bennett 2005 Figure 10). Delta smelt eggs are likely not entrained because they are demersal and adhesive, sticking by means of a stalk to hard substrates (Moyle 2002) but they may be subject to other sources of mortality. Egg instantaneous mortality was estimated using the 1995-2003 average mortality for the egg to post-larva stage in Bennett (2005 Figure 26) as 0.01789 per day (80.5% survival over 12.1 days). The estimated number of females that are equivalent to the entrained number of smelts, *FH*, using the following relation is 24 females.

$$FH = \text{Entrainment}/(\text{Survival} \times \text{Lifetime Fecundity})$$

$$FH = 24 = \left(\frac{36{,}777}{0.805 \times 1{,}900}\right)$$

Estimated adult equivalent losses due to entrainment assuming a 50:50 sex ratio is 2 *FH*, or 48 smelt per year. Assuming no egg mortality, 2*FH* would be 39 fish.

Adult Equivalent Loss (*AEL*)

The *AEL* method uses larval, juvenile and early adult mortality to estimate adult equivalents from the number of entrained larvae. Because the average size of entrained larvae was similar to hatch lengths, survival rates were applied to the year life cycle of smelt, that is, 365 days minus 12 days of egg incubation. The 1995–2003 average mortality for the egg to post-larva and juvenile to adult stages in Bennett (2005) were used to estimate survivals. Average instantaneous daily mortalities for the two periods were 0.01789 and 0.02389 per day corresponding to survivals of 98.227% and 97.64% per day respectively. The mortalities presented by Bennett (2005 Figure 26) were separated into two average time periods of 192.6 and 160.4 days for computing a 353 day survival of 0.0681%. Adult equivalents were estimated at 25 fish per year.

$$AEL = \text{Entrainment} \times \text{Survival},$$

$$AEL = 25 = 36{,}777 \times 0.000681$$

4.2.3 Lepomis spp.

Bluegill/redear sunfishes (*Lepomis* spp.) were the third most abundant larval fish entrained at the BARDP pilot plant during the course of this study and comprised 0.17% of the estimated total entrainment of all fish larvae (Table 4-1). For a 25 mgd facility, the annual estimate of BARDP entrainment for November 5, 2008–October 9, 2009 was 1,771 larvae. The low estimated number of entrained bluegill/redear sunfishes (n=1,771) was less than the fecundity values of bluegill (2,000–50,000 eggs/female/year [Emig 1966]) and redear (9,000–80,000 eggs/female/year [Wang 1986]), therefore *FH* and *AEL* values were not computed.

4.3 Summary

Three taxa of larval fishes were collected during entrainment sampling: prickly sculpin, longfin/delta smelts, and bluegill/redear sunfishes. No fish eggs were collected in entrainment samples. Prickly sculpin are an abundant native species in Suisun Bay, and bluegill and redear sunfishes are abundant introduced species. Both longfin and delta smelt are listed species. These species were only collected during the sensitive fish period of January through June when CCWD was diverting water for entrainment sampling.

Based on results of the six entrainment surveys, estimates of annual entrainment were calculated assuming that mortality of entrained organisms is 100%, and that the BARDP feedwater intake pumps will operate at maximum flow (25 mgd) 24 hours per day, seven days per week, with no scheduled or unscheduled maintenance outages. Annual entrainment estimates for a 25 mgd intake ranged from a low of 1,771 for larval bluegill/redear sunfishes to a high of 990,605 larval prickly sculpin (Table 4-2) Annual estimated entrainment for longfin/delta smelt was 36,777 larvae (Table 4-2).

Table 4-2. BARDP intake feedwater system (25 mgd) estimated total annual larval entrainment for all entrained fishes and their adult equivalents based on Fecundity Hindcast (*FH*) and Adult Equivalent Loss (*AEL*) extrapolations (based on six entrainment surveys conducted from November 2008–October 2009).

Taxa	Estimated Total Annual Larval Entrainment	2*FH*[(a)] Estimate	*AEL* Estimate
Prickly sculpin	990,605	510	*
Longfin/Delta smelts	36,777	39	25
Bluegill/Redear sunfishes	1,771	*	*

*Unavailable information or value that could not be computed.

(a) 2*FH* (number of estimated females x 2) values are presented to provide comparison to AEL estimates, which include both males and females.

Proportional entrainment estimates (*PE*) could not be calculated. The empirical transport model (*ETM*) calculates an estimate of the proportional mortality to the population due to entrainment. The underlying basis of the model is an estimate of the daily proportion of the source water entrained and therefore requires estimates of both entrainment and source water concentrations of larvae. *ETM* estimates were not calculated for any of the entrained fishes because they were not found in the collected source water samples or source water samples were not collected due to lack of permission to collect during the sensitive fish period.

Potential losses of adult fishes, based on demographic modeling for entrained species, ranged from a low of 25 individuals per year for longfin/delta smelts to 510 per year for prickly sculpin (Table 4-2). Sufficient life history information was obtained from the scientific literature to model impacts on two of the three taxa. Demographic modeling (*FH* and *AEL*) of longfin/delta smelts larval entrainment estimates showed potential losses of approximately 20 females (*FH* estimate; *2FH* estimate=39) and 25 adults (*AEL* estimate) (Table 4-2). *FH* modeling for prickly sculpin showed potential losses of 255 adults (*2FH* estimate=510); *AEL* values for prickly sculpin could not be computed due to the absence of any published larval mortality information (Table 4-2). The low estimated number of entrained bluegill/redear sunfishes (n=1,771) was less than the fecundity values of bluegill and redear; therefore, *FH* and *AEL* values were not computed (Table 4-2).

The species composition of larval fishes collected during the 2008–2009 BARDP entrainment and source water sampling was consistent with published life history information for species found in Suisun Bay, along with documented collections from other studies conducted in Suisun Bay (PG&E 1981, Moyle 2002, Tenera 2009, IEP/CDFG survey results). The estimated small annual loss of adult prickly sculpin and bluegill/redear sunfishes is unlikely to affect adult populations. Entrainment of longfin/delta smelts occurred during the sensitive fish period of January through June when these larvae are normally present in the vicinity of Mallard Slough. BARDP entrainment of these listed species would require Endangered Species Act consultation with USFWS and CDFG for delta smelt and CDFG for longfin smelt.

4.4 Literature Cited

Bennett, William A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science, 3(2). Retrieved from: http://escholarship.org/uc/item/0725n5vk.

Contra Costa Water District. 1999. Letter dated January 6, 1999, to Matt Vandenberg (USFWS) from Richard Denton (CCWD) transmitting the 1998 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2000a. Letter dated January 14, 2000, to Stephanie Brady (USFWS) from Richard Denton (CCWD) transmitting the 1999 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2000b. Letter dated December 29, 2000, to Karen Miller (USFWS) from Richard Denton (CCWD) transmitting the 2000 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2001. Letter dated December 21, 2001, to Karen Miller (USFWS) from Richard Denton (CCWD) transmitting the 2001 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2003. Letter dated March 12, 2003, to Daniel Buford (USFWS) from Richard Denton (CCWD) transmitting the 2002 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2004. Letter dated March 25, 2004, to Daniel Buford (USFWS) from Richard Denton (CCWD) transmitting the 2003 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2005. Letter dated January 26, 2005, to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2004 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2006. Letter dated February 16, 2006, to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2005 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2007. Letter dated February 17, 2007 to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2006 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2008. Letter dated February 29, 2008 to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2007 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Contra Costa Water District. 2009. Letter dated February 27, 2009 to Ryan Olah (USFWS) from Leah Orloff (CCWD) transmitting the 2008 Annual Reporting for the Biological Opinion on Delta Smelt for the Los Vaqueros Project.

Emig, J.W. 1966. *In* A. Calhoun, ed. Inland fisheries management. Sacramento: California Department of Fish and Game.

Moyle, P. 2002. Inland Fishes of California, University of California Press, Berkeley CA, 2002.

Pacific Gas and Electric Company (PG&E). 1981. Pittsburg Power Plant Cooling Water Intake Structures 316 (b) Demonstration. Prepared by Ecological Analysts, Inc. PG&E. San Francisco, California.

Tenera Environmental (Tenera). 2009. Entrainment and Impingement Monitoring Plan for IEP Annual Report November 2007 – October 2008 for the Contra Costa and Pittsburg Power Plants. Submitted to Mirant Delta, LLC. Pittsburg, California.

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin estuary and adjacent waters, California: a guide to the early life histories. IEP Technical Report 9. Sacramento (CA): California Dept. of Water Resources.

Wang, J.C.S. and R. Brown. 1991. Early life stages and early life history of the delta smelt, *Hypomesus transpacificus*, in the Sacramento-San Joaquin Estuary, with comparison of early life stages of the longfin smelt, *Spirinchus thaleichthys*. IEP Technical Report 28. Sacramento (CA): California Dept. of Water Resources.