316(b) Entrainment Characterization Report for Potrero Power Plant Unit 3

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EXECUTIVE SUMMARY

The purpose of this report is to assess the entrainment effects of the Potrero Power Plant Unit 3 cooling water intake system (CWIS).

Results of this 316(b) entrainment characterization study have shown a low diversity of larvae in Bay water used by the Potrero Power Plant's CWIS. Bay goby larvae were the most abundant larval fish entrained at Potrero Power Plant during the course of this 316(b) study, comprising 35 percent of the estimated total entrainment of all fish larvae. Unidentified gobies made up 22 percent of the fish larvae, followed by northern anchovy (17 percent), Pacific herring (12 percent), and yellowfin goby (10 percent). The composition of unidentified gobies sampled in entrainment surveys is most likely arrow and cheekspot gobies—adults of both were abundant in trawl studies from within the study area.

This low diversity is characteristic of most other bays and estuaries. The projected fractional losses (mortality) of entrained larvae of the most abundant target species represent low potential impacts to the species' source water populations. These projected entrainment effects, which conservatively assume that Unit 3 cooling water pumps operate at 100 percent capacity and that there is 100 percent mortality of entrained organisms, are orders of magnitude below the 30 to 40 percent levels set by fishery management practice to maintain sustainable yields for many of California's stocks, and the current (2004–2005) 10 percent harvest quota for the San Francisco Bay herring fishery.

The field studies and data analyses presented in this report followed the Survey Protocol that was developed for the Potrero Power Plant in coordination with the Agency Working Group (AWG). The AWG was established under the auspices of the California Energy Commission (CEC) in 2002 when Mirant proposed to add a new unit, Unit 7, to its Potrero facility. The AWG included representatives from the California Department of Fish and Game, National Marine Fisheries Service, CEC, Mirant, and CEC and Mirant's consultants.

Findings of the completed entrainment study are presented graphically in the report using the results of February 2001–February 2002 entrainment and source water field studies (Section 3.0—*Entrainment and Source Water Sampling*). Entrainment sampling, as approved by the AWG, was conducted at the Potrero Power Plant intake, and source water sampling was conducted at near-field and far-field stations in San Francisco Bay south of the Oakland-San Francisco Bay Bridge. Source water volumes used in the calculation of entrainment effects were determined from hydrologic and biological data approved by the AWG.

The results of twenty-one 24-hour entrainment and source water surveys for larval fish and megalopal crabs show the following:

- Five taxa of larval fishes make up 96 percent of all of the entrained fish larvae, indicative of the Bay's naturally low diversity, which is typical of bays and estuaries.
- The only fish species of commercial value—northern anchovy, Pacific herring, and yellowfin goby—represented 17, 12, and 10 percent, respectively of the total estimated larval fish entrainment.
- The proportional entrainment estimates (*PE*) were low for bay goby, unidentified gobies, northern anchovy, Pacific herring, and yellowfin goby (see Section 4.0).
- Empirical Transport Model (*ETM)* estimates of P_m (probability of mortality due to entrainment) values, based on maximum period of entrainment risk, ranged from 0.3 percent to 0.5 percent. This range is well below both standard fishery management practices (30 to 40 percent) for sustainable harvests and the current (2004–2005) 10 percent harvest quota for the San Francisco herring fishery.
- *Cancer* spp. crab larvae were rarely found in the entrainment samples.

A summary of the estimated Unit 3 entrainment effects (February 2001–February 2002) for the most abundantly collected fishes is presented in Table ES-1. These values are based on analyses using the Empirical Transport Model (*ETM*), the Fecundity Hindcast (*FH*) model, and Adult Equivalent Loss (*AEL*) model (Section 4.0—*Cooling Water Intake System Impact Assessment*).

Table ES-1. Potrero Power Plant Unit 3 CWIS estimated total entrainment for abundant fishes and estimates based on Fecundity Hindcast (*FH*), Adult Equivalent Loss (*AEL*), and Empirical Transport Model (*ETM*) approaches using entrainment and source water larval concentrations and San Francisco Bay study area volume (February 2001–February 2002).

				ETM	
Taxa	**Total Entrainment**	**2*FH*[(a)] Estimate**	***AEL* Estimate**	**P_m [(b)] Estimate**	**P_m [(c)] Estimate**
bay goby	104,312,644	*	*	0.00133	0.00300
unidentified gobies	65,237,852	159,512	104,875	0.00107	0.00491
northern anchovy	49,302,228	6,276	11,620	0.00058	0.00321
Pacific herring	35,982,833	4,958	10,654	0.00134	0.00393
yellowfin goby	29,230,697	9,014	*	0.00195	0.00294

*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.
(b) P_m values calculated using average period of entrainment risk.
(c) P_m values calculated using maximum period of entrainment risk.

In summary, entrainment effects from the Potrero Power Plant CWIS are directly related to the small volume of the cooling water relative to the San Francisco Bay source water study area. The estimated effects are minimal because of the short average duration of exposure to entrainment for the taxa presented in this assessment. These conclusions are supported by results from the study's demographic models that indicate little potential for population-level effects. Economic losses due to entrainment of these species are low. The abundance of cancer crab megalopae was too low to estimate entrainment effects. Extremely low numbers of megalopal cancer crab species found at the intake stations provide assurance that population-level effects from entrainment would not occur to these species of crabs.

1.0 INTRODUCTION

The Potrero Power Plant (Plant) is located in an industrialized section of the City of San Francisco along the western shoreline of central San Francisco Bay, approximately two miles south of the Bay Bridge. Much of the surrounding waterfront has been developed to support large-scale shipping operations. The Plant was purchased by Mirant California, LLC (formerly Southern Energy Company) from Pacific Gas and Electric company in 1999.

In 2000, Mirant proposed to build and operate a 540 net megawatt combined-cycle power generation unit (Unit 7) at the existing Plant. Mirant submitted its Application for Certification (AFC) to the California Energy Commission (CEC) in May 2000. Entrainment and source water studies were conducted to estimate the effects of the existing Unit 3 and proposed Unit 7. The Unit 7 project was suspended in November 2003. The entrainment and source water data collected as part of the existing Unit 3 and proposed Unit 7 project have been analyzed to provide an assessment of only Unit 3 entrainment effects. The integrity of the entrainment and source water data is not affected because of the suspension of Unit 7. In other words, the data presented in this report for Unit 3 would have been collected and analyzed in the same manner whether or not Unit 7 was proposed.

Prior to this study, site-specific entrainment and impingement studies were conducted at the Plant from 1978–1979 (PG&E 1980). The information from these studies was used in conjunction with engineering and operating criteria to evaluate alternative intake technologies for the Plant in the 316(b) Demonstration Report (PG&E 1980). The conclusion of these studies and the regulatory agencies was that no alternative intake technologies or changes to the operations of the Plant were required to reduce impacts to entrained or impinged fish species.

1.1 Development of the 316(b) Survey Protocol

The CEC formed an Agency Working Group (AWG) to plan and direct the design and implementation of the 316(b) studies to assess the effects of the cooling water intake structure (CWIS) on the local larval fish and megalopal cancer crab populations. The AWG consisted of representatives of the CEC and their consultants (Drs. Noel Davis and Mike Foster), Mirant, Tenera Environmental, URS, the California Department of Fish and Game (CDFG), and the National Marine Fisheries Service (NMFS). The AWG members reviewed and commented on several drafts of the *Survey Protocol for Collection and Analysis of Validating and Baseline Data* (Survey Protocol). The Survey Protocol (Appendix A) was finalized and submitted to the CEC on December 19, 2000. Monthly reports describing the progress of intake, source water, otter and midwater trawls, and benthic sampling were submitted to the AWG. Working group meetings were scheduled to coincide with the completion of monthly data reports. These monthly reports contained data from the entrainment, source water, and trawl surveys for each month surveyed (January 2001 through February 2002).

The Survey Protocol was developed using information collected from previous Potrero Power Plant studies, CDFG studies, as well as federal 316(b) guidelines and input from the AWG. The AWG also specified the use of three modeling approaches to assess entrainment losses: (1) fecundity hindcast (*FH*), (2) empirical transport model (*ETM*), and (3) adult equivalent loss (*AEL*).

Larval fishes, megalopal cancer crabs, and European green crabs were selected by the AWG as the focus of the 316(b) entrainment study at the Plant. Fishes and *Cancer* spp. crabs were selected because of their role in the ecosystem and because some of them have commercial or recreational value. European green crabs, an introduced invasive species, were selected because of concerns regarding their presence in San Francisco Bay.

The AWG required assessment of entrainment effects of the most abundant taxa of larval fishes and all cancer crabs. This report presents the results of the three entrainment assessment models applied to the concentrations (no./1,000 m^3) of the most abundant fish taxa collected in the entrainment samples: bay goby, unidentified gobies, northern anchovy, Pacific herring, and yellowfin goby. Very few (less than 130) cancer crab larvae were collected from the intake and source water stations combined. Thus, concentrations of cancer crabs were too low to assess. The presence of larval European green crab was documented from both intake and source water collections.

1.2 Organization of the Report

This report is a summary and analysis of the entrainment and source water data collected from 2001–2002.

- Section 2.0—*Description of the Potrero Power Plant and Characteristics of the Source Water Body.* This section describes the Plant and its aquatic environmental setting, focusing on the various features of the power plant design and operations related to the facility's aquatic environment. Section 2.1 describes Unit 3 and its cooling water intake system. The aquatic environment in the vicinity of the Plant and the source water body study area are described in Section 2.2.

- Section 3.0—*Entrainment and Source Water Survey Results.* The entrainment and source water study experimental design, sampling and analysis methods, and results are presented in Section 3.0. The purpose of this study was to describe the composition and abundance of larval fishes and megalopal cancer crabs that are at risk of entrainment in the cooling water intake system (CWIS). This section presents the results of entrainment and source water data collected from 14 months of sampling (January 17, 2001–February 22, 2002).

- Section 4.0—*Impact Assessment.* This section evaluates the entrainment effects of the CWIS on abundant larval fishes. The assessment utilizes three different population effects models (except when life history data were not available). These models all assume 100 percent entrainment mortality. The three analytical techniques used are Empirical Transport Modeling (*ETM*), Adult Equivalent Loss (*AEL*), and Fecundity Hindcasting (*FH*). The AWG reviewed and approved the use of these methods to assess the potential impacts on entrained species' populations. Megalopal cancer crabs were not assessed because of the extremely low numbers collected during our study.

The report also contains five appendices. Appendix A is the Survey Protocol, Appendix B presents entrainment and source water survey data, Appendix C discusses the determination of source water body study area, Appendix D describes methodology for classifying larval rockfishes, and Appendix E describes the impact assessment models.

1.3 Literature Cited

Pacific Gas and Electric Company (PG&E). 1980. Potrero Power Plant Cooling Water Intake Structures 316(b) Demonstration. San Francisco, CA.

2.0 DESCRIPTION OF THE POTRERO POWER PLANT AND CHARACTERISTICS OF THE SOURCE WATER BODY

This section describes the Potrero Power Plant and its aquatic environmental setting, focusing on the various features of the power plant design and operations related to the facility's aquatic environment. Section 2.1 describes Unit 3 and its cooling water intake system. The aquatic environment in the vicinity of the Plant and the source water body study area are described in Section 2.2.

2.1 Potrero Power Plant

The Plant is located on approximately 20 acres in the City and County of San Francisco in an area zoned M-2 Heavy Industry on the waterfront south of the San Francisco business district (Figure 2-1). The power plant is surrounded by industrial and commercial uses to the north, west, and south. The shoreline of the San Francisco Bay comprises the eastern boundary of the site. Figure 2-2 provides an aerial perspective of the power plant from the northwest.

The Plant is located within a complex of shipping terminals and industrial and commercial land uses in an industrialized section of the southern San Francisco waterfront. All of the waterfront in the vicinity of the Plant has been modified or developed. The majority of the shoreline consists of piers, wharves, bulkheads, and a significant amount of filled areas. In many areas, including the entire eastern boundary of the Plant, the shoreline has been stabilized with rock, concrete riprap, or retaining walls.

The Plant site has been used for industrial purposes, primarily power generation, since 1881. A power generation facility was constructed on site in 1901. At the time the facility was constructed, the natural biological community was permanently altered. A significant portion of the site is on fill, which created land for industrial use. The entire 20-acre site is developed or paved.

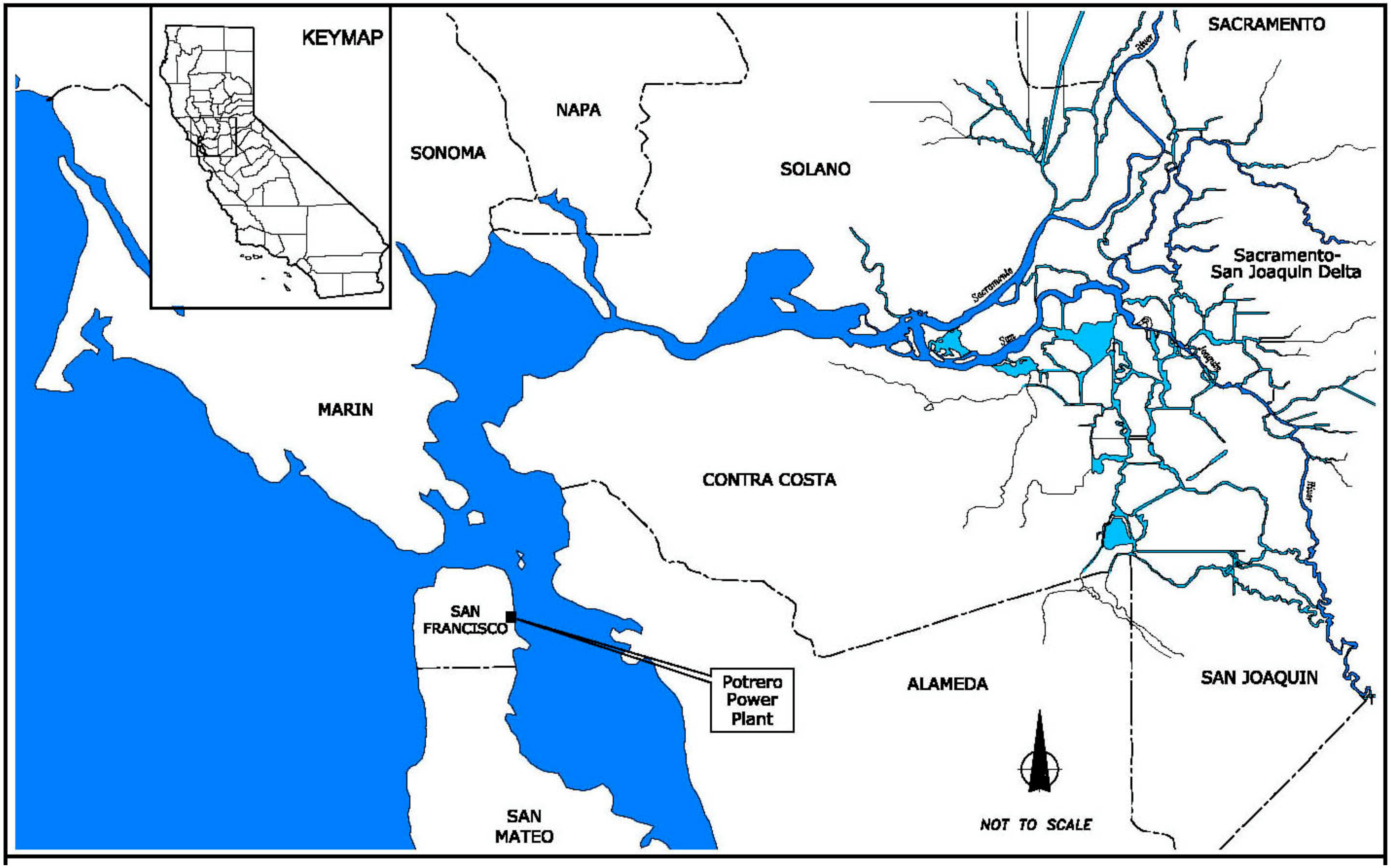

Figure 2-1. Location of the Potrero Power Plant in relation to San Francisco Bay-Delta.

Figure 2-2. Potrero Power Plant aerial perspective from the northwest (Source: URS).

The power plant consists of (1) Unit 3, a 206-MW steam turbine unit; (2) Units 4, 5, and 6, which are each 52-MW combustion turbine units; and (3) other ancillary equipment, including three fuel storage tanks. Units 4, 5, and 6 are used primarily to serve peaking loads, and Unit 3, which is fueled by natural gas, is used to serve intermediate loads.

Unit 3 uses a once-through cooling system. The major features of the intake include bar racks, traveling screens, and circulating water pumps (Figure 2-3). Water is withdrawn from San Francisco Bay through an intake structure near the northeastern corner of the site and is pumped to the Unit 3 condenser. The Unit 3 intake has screens equipped with woven wire with a mesh size of 3/8-inch. The intake operates with an approach velocity of 0.7 feet per second (fps) to the screens. Two intake screenwash pumps, each having a capacity of 1,800 gallons per minute (gpm) are used to rinse the intake screens (Table 2-1). Unit 3 is equipped with two circulating water pumps each with a maximum design flow capacity of 78,500 gpm. The design water flow for Unit 3 is 157,000 gpm circulating water and 3,600 gpm wash water; the Plant's total daily water withdrawal is 160,600 gpm (231.264 million gallons per day [mgd]). The cooling water is discharged directly back to the Bay through a shoreline outfall located south of the intake and directly east of Unit 3.

Table 2-1. Potrero Power Plant Unit 3 daily maximum design water flow.

Water Use	Daily Flow mgd (gpm)	Daily Flow m^3/day
Unit 3 cooling water (2 pumps total)	226 mgd (157,000 gpm)	855,806
Unit 3 screen wash water (2 pumps total)	5 mgd (3,600 gpm)	19,262
Plant total	**231 mgd (160,600 gpm)**	**875,068**

Source: NPDES Permit No. CA0005657 Tentative Order.

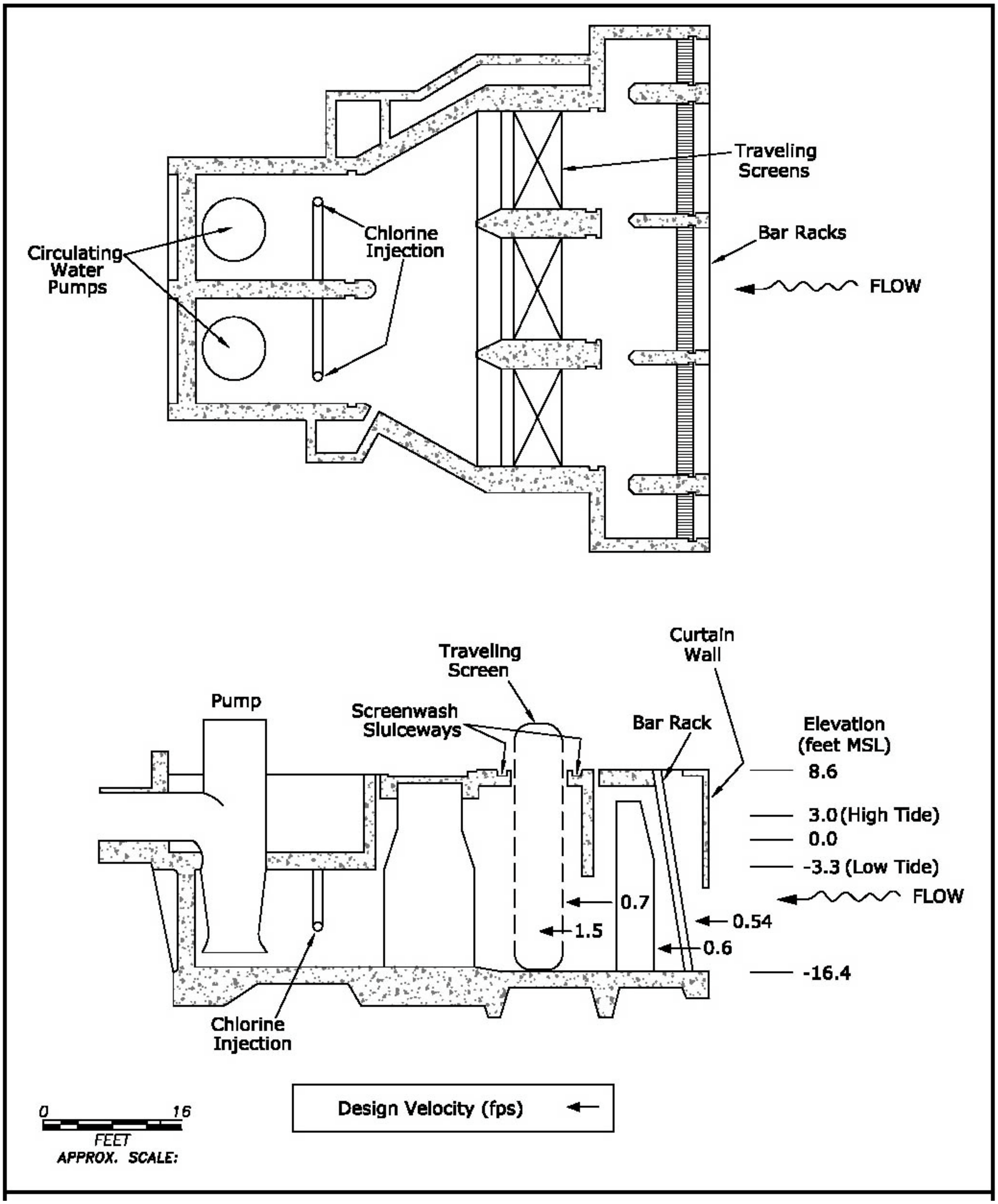

Figure 2-3. Plan and section schematic diagrams of Potrero Power Plant Unit 3 intake structure.

2.2 Aquatic Environment

The San Francisco Bay system, including the Bay and the Sacramento-San Joaquin Delta, forms the largest estuary on the west coast of North America. The Bay extends east from the Golden Gate Bridge and encompasses all waters between the bridge and Chipps Island near the confluence of the Sacramento and San Joaquin rivers. San Francisco Bay has a surface area of 1,126 square kilometers (km^2) (435 square miles [mi^2]) at mean tide and a volume of approximately 7.16 billion cubic meters (m^3) (235 billion cubic feet [ft^3]) (PG&E 1980a).
The primary influence on the flora and fauna in the region are the Pacific tides that flood and ebb semidiurnally (on a 25-hour cycle of two high and two low tides). The tidal prism (volume of water exchanged) ranges between 25 percent and 30 percent of the Bay's volume (Conomos and Peterson 1976).

The aquatic habitats of San Francisco Bay are also influenced by freshwater flows from a watershed area exceeding 165,000 km^2 (64,000 mi^2) (PG&E 1980a). The drainage basin of the Sacramento and San Joaquin rivers encompasses more than 90 percent of this area (PG&E 1980a). Freshwater enters the Bay through numerous creeks and small rivers. However, more than 90 percent of the freshwater flow into the Bay enters through the channels of the Sacramento and San Joaquin rivers. The influence of freshwater flow on aquatic habitats in the Bay varies by season and by proximity to the Sacramento and San Joaquin rivers. The ecological influence of these rivers' flows is generally confined to north San Francisco Bay and consequently has little to no influence in the Central Bay, where the Plant is located. The highest freshwater flows typically occur during the winter months (January through February); the lowest, during the summer (July through August) (PG&E 1980a).

The AWG approved the determination of the geographical extent of the Plant's source water body study area. Based on Central Bay's biological and water quality information, along with knowledge of the Bay's general currents and patterns of tidal exchange, it was determined that the Plant's source water body extended from the Oakland Bay Bridge south to the Hayward-San Mateo Bridge (see Appendix C for a description of the source water study area). A USGS model was used to determine the volume of the source water body study area. Based on the results of this model, the source water volume that is used in the *ETM* calculations is 2.907008×10^9 cubic meters (7.6795×10^{11} gallons).

Cooling water for the Plant is withdrawn from and discharged into the southwestern portion of Central San Francisco Bay. The Central Bay is the area of San Francisco Bay north of a line drawn between Hunters Point and the southern tip of Alameda Island, and south of a line drawn between Point San Pedro and Point San Pablo (PG&E 1980a). The Central Bay is 5.1 km

(3.2 mi) across from the Plant to the nearest point of land on Alameda Island (in a northerly direction). The opposite shore is more than 9.3 km (5.8 mi) across directly to the east of the power plant. Water depths are the greatest within 3.7 km (2.3 mi) of the western shoreline. The deepest region of the main channel is 2.3 km (1.4 mi) from the Plant, where its depth exceeds 18.3 m (60 ft). A shoal averaging around 7.6 m (25 ft) in depth extends out from the shore adjacent to the power plant for approximately 0.9 km (0.6 mi).

2.2.1 Physical Characteristics

The existing physical characteristics of the San Francisco Bay are described in the following four sections.

Currents

Currents in San Francisco Bay in the vicinity of the Plant are dominated by tidal action. Tides in the Bay Area are classified as mixed semidiurnal, with two flood tides and two ebb tides of unequal range occurring over a 25-hour period (PG&E 1998). The mean tidal range at the Plant is 4.6 ft. Currents measured at the National Oceanic and Atmospheric Administration (NOAA) station at Potrero Point range from 0 knot (kt) at slack tide to 2.3 kt at average maximum ebb tide and 2.5 kt at average maximum flood tide. Flood tides flow at 160° and ebb at 320° relative to north. In other words, incoming tides flow southward, outgoing tides flow northward towards the Golden Gate.

Salinity

Salinity in the San Francisco Bay near the Plant ranges between 12 parts per thousand (ppt) during the winter and 30 ppt during the summer based on Regional Monitoring Program data from 1993 to 1997 (Stations BB70 [Alameda] and BC10 [Yerba Buena Island]) (SFEI 1997). Salinities tend to be lower during the winter months due to heavy freshwater runoff. The yearlong average salinity is approximately 28 ppt (PG&E 1980a).

Although vertical salinity gradients are common in the northern part of San Francisco Bay, they are generally insignificant in the Central and Lower bays, varying by less than 3 ppt (PG&E 1980a; Baylosis et al. 1997). The Central Bay is much shallower than the North Bay and is not directly subject to the salinity gradients caused by freshwater flows from the Sacramento and San Joaquin rivers.

Temperature

Water temperatures in San Francisco Bay vary geographically, seasonally, and with depth and tidal influence. Ambient air temperature also affects water temperature.

Recent site-specific water temperature data were used in this evaluation. The San Francisco Bay water temperature is measured at the Unit 3 intake when the Plant is operating. Daily average temperatures recorded between November 1997 and April 2000 show water temperatures ranging from a minimum of 43.6°F to a maximum of 63.7°F, with an average of 55.7°F (Potrero Power Plant File).

Dissolved Oxygen

Dissolved oxygen (DO) values in the water near Potrero Point show a consistent pattern, with DO concentrations near 90 percent of saturated value most of the time. Because DO saturation is a function of temperature and salinity, the 90 percent saturation corresponds to DO values ranging from of 7.2 to 8.8 mg/L. The DO concentration averaged 8.5 mg/L in 15 surveys at Potrero Point from January to December 2000.

The DO concentration rises above the average value in the spring and drops below average in the fall. The highest values were 10.1 mg/L (107 percent saturation) in April 1999 and 9.8 mg/L (110 percent saturation) in April 2000. Values of DO greater than 100 percent (super saturation) can occur when the rate of oxygen production by photosynthesis is greater than the rate of oxygen consumption by other biota. The lowest DO levels typically occur in October and November. In November 1999, the DO was 7.0 mg/L (84 percent saturation). In 2000, the DO concentration was measured at 5.9 mg/L (74 percent saturation) in October and at 7.1 mg/L (84 percent) in November.

The concentration of DO in the Potrero area is usually uniform with depth. However, about 20 percent of the time, DO values at the surface are significantly higher than those at depth. For example, in March 2000, the DO level was 9.0 mg/L (96 percent) at the surface, and 7.1 mg/L (77 percent) at 8 m (26 ft).

2.2.2 Existing Aquatic Resources

The aquatic habitats in the vicinity of the Plant are characteristic of an enclosed bay marine environment. The benthic aquatic communities in the region are defined by depth and benthic substrate. Sediments such as gravel, sand, silt, shell debris, and mud underlie riprap, cement rubble, and metal debris in much of the nearshore area. Discarded rubber tires are also common. These materials are the result of filling the Bay and consequent shoreline stabilization, and also from dumping. The coverage of introduced hard substrates gradually gives way to the underlying sediments in offshore areas. Wharves, pilings, and seawalls are present throughout the Central Bay and provide hard surfaces for the attachment of plants and sessile invertebrates. The planktonic community that forms the base of the system's food web is found in the open-water areas of the Bay. The locations and extent of these habitat types are illustrated in Figure 2-4.

Aquatic Resource Surveys

The aquatic habitat in the vicinity of the Plant has been well studied. The most recent studies were conducted as specified by the Survey Protocol (Appendix A), which was approved by the AWG. These studies are listed below.

- An extensive survey of the benthic community in the area of the proposed offshore discharge and intake conducted in December 2000 (Tenera 2001a)
- A quantitative survey of the intertidal areas in the vicinity of the power plant conducted in February 2001 (Tenera 2001a)
- Monthly or weekly (during Pacific herring spawning) entrainment and source water larval fish and megalopal cancer crabs surveys beginning in January 2001 (Tenera 2001b and c)
- Monthly otter and midwater trawls conducted offshore of the power plant beginning in January 2001 (Tenera 2001a and c)

Reports were submitted to the AWG summarizing the results of the studies listed above. Monthly reports describing the collection and laboratory processing status of samples and results of data analyses were submitted to the AWG. In addition to these monthly reports, three major summary reports were submitted to the AWG. They include: (1) *Three-Month Report on the Benthic, Rocky Shoreline, and Trawl Surveys* (submitted to the AWG on May 4, 2001 and presented the final results of benthic and intertidal surveys and the first three months of trawl survey results); (2) *Construction and Thermal Impacts and First Quarter Larval Fish Assessment* report (submitted on June 29, 2001); and (3) *Six-Month Report on Larval Fish Surveys* (submitted to the AWG on September 14, 2001 and included data from the first six months of entrainment and source water surveys).

Publicly noticed AWG meetings were held to discuss the findings of the surveys. Input from the AWG during these meetings resulted in some changes to the sampling protocol (i.e., far-field source water station location changes, midwater trawl station location changes), while other changes were related to the analysis and presentation of data (i.e., separation of data by station, reordering species by abundance). In addition to the AWG meetings discussed above, Mirant and its consultants met with the staffs of the Bay Conservation and Development Commission (BCDC), Regional Water Quality Control Board (RWQCB), EPA, NMFS, and CDFG to discuss aquatic resource issues.

In addition to the studies associated with the Survey Protocol, the potential aquatic impacts resulting from the operation of the Plant cooling water system have been previously studied. In the 1970s, the Plant conducted fishery, benthic, and zooplankton studies to evaluate effects of the power plant's thermal discharge on the surrounding environment (PG&E 1973a). In 1978–1979, entrainment and impingement studies were conducted to evaluate potential impacts of the power plant's cooling water intake structures (PG&E 1980a). Additional studies were conducted in 1989–1990 to investigate potential thermal effects on fishes and invertebrates present in the vicinity of the power plant (PG&E 1991). In addition to these studies, thermal effects and entrainment and impingement studies were conducted at the Hunters Point Power Plant (located approximately 2 miles to the south) (PG&E 1973b, 1980b, 1991).

CDFG conducts ongoing monthly midwater and otter trawl surveys that began in 1980. Data from stations located in Central and South bays from 1980 through 1999 were used to provide long-term information on the distribution and abundance of the area's fish and invertebrate populations. CDFG also conducted monthly beach seine surveys at several stations in the Central and South bays from August 1980 through January 1987. Detailed descriptions of sampling methodologies for the past studies conducted at the power plants can be found in the Potrero Power Plant Unit 7 Application for Certification (Dames & Moore 2000). Sampling methodologies for the CDFG otter trawl, midwater trawl, and beach seine surveys are described in Baxter et al. (1999).

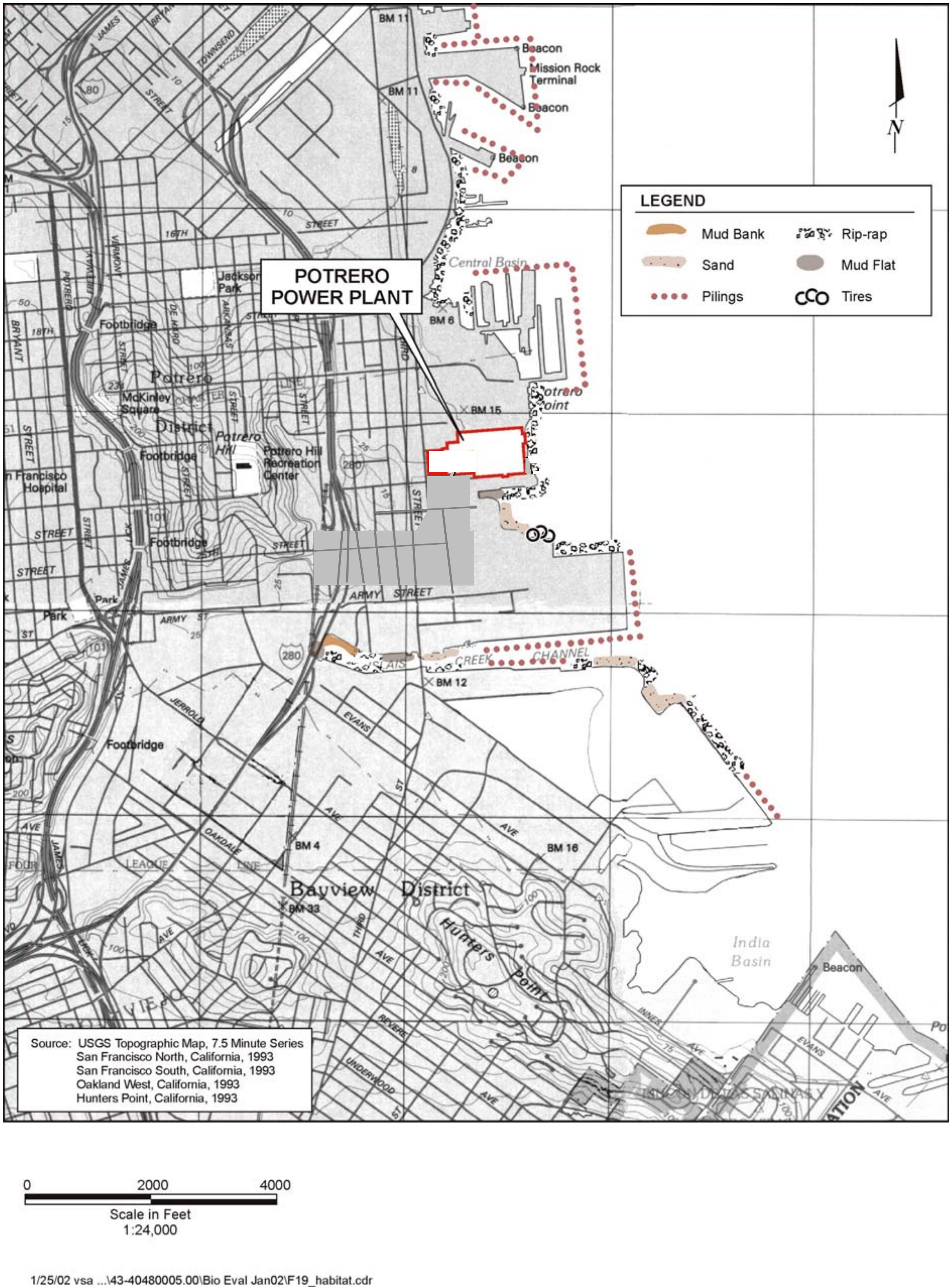

Figure 2-4. Location and extent of habitat types in the vicinity of Potrero Power Plant (Source: URS).

Intertidal Habitat

The intertidal habitat encompasses areas of the shoreline that are submerged during high tide and exposed during maximum low tides. Immediately south of the existing power plant, intertidal substrates are primarily mud and rock. Concrete rubble, metal debris, and discarded tires are common in this region. Intertidal areas along the northern shore of the discharge and the eastern boundary of the Plant property are primarily composed of concrete rubble and granite riprap overlaying sand, gravel, and shell debris.

Quantitative surveys of the rocky intertidal were conducted February 19 and 20, 2001 (Tenera 2001a). The purpose of the study was to determine the abundance and species composition of the plant and animal assemblages inhabiting the rocky intertidal zone near the Plant. The species found at sampling stations near the Plant are commonly found in similar habitat along south-central San Francisco Bay shorelines. Findings from other studies indicate that the diversity of intertidal organisms in the vicinity of the Plant are consistent with the general decline of diversity that occurs with increasing distance into the Bay, where relatively constant salinities of the outer coast are replaced by fluctuating wet and dry season salinities in the Bay.

All areas surveyed were characterized by a low diversity of algae and invertebrates. Invertebrate assemblages were composed of barnacles (mainly *Balanus* spp.), the clam *Pododesmus cepio*, and mussels *Mytilus galloprovencialis* (Tenera 2001a). Shorecrabs (species of *Pachygrapsus* and *Hemigrapsus*) were occasionally observed underneath cobbles. Large colonies of mussels line the power plant's shoreline discharge, where the plant's cooling water flows and temperatures favor their settlement and growth. One of the most abundant algal species was a red alga *Mastocarpus papillatus*. Another common species was *Gelidium coulteri*, as was rockweed *Fucus gardneri*. Many rocks and attached algae were covered with thin layers of diatoms (Tenera 2001a). Green sea lettuce (species of *Ulva* and *Enteromorpha*) and a filamentous alga *Ceramium* spp. were also common. Few of the larger foliose red algal groups (e.g., *Mazzaella* spp.) that are abundant on outer coasts were observed at the sampling stations (Tenera 2001a).

Although fishes were not collected as part of this intertidal study, a number of fish species, including sculpins, surfperch, and flatfishes, may occur in rocky areas of the intertidal zone. Hard substrate in the intertidal zone is also used for egg deposition by Pacific herring *Clupea pallasii*. The soft substrate located in the intertidal zone near the Plant provides limited habitat for benthic organisms (PG&E 1980a). Polychaete worms, crustaceans (primarily amphipods), and bivalve molluscs are the most common groups.

Subtidal Habitat

The subtidal habitat includes all waters of the Bay that remain submerged during the maximum extent of the lowest tide. Subtidal benthic habitats, comprised of unconsolidated sediments such as mud and sand, can support diverse and productive assemblages of invertebrates and fishes. Silty-mud sediments form the predominant bottom habitat in the shallow waters of San Francisco Bay (< 10 m [33 ft]), adjacent to the Plant. The benthic fauna includes both epifauna (invertebrates occurring mainly on the sediment surface) and infauna (burrowing or sessile invertebrates occurring mainly beneath the surface). Currents, substrate, depth, and relief are important factors influencing the composition and distribution of species within the subtidal zone.

The soft substrates of the subtidal zone are inhabited by a variety of benthic infauna and epibenthic invertebrates. A number of investigators had previously surveyed the benthic animal communities in the vicinity of the Plant (Dederian 1966, PG&E 1973a, Liu et al. 1975, Brown and Caldwell 1975). Numerous species of polychaete worms were reported within the soft sediments in the area, and amphipods were the dominant crustacean species. Several bivalve mollusk species were also reported to be widely distributed in the area (PG&E 1980a).

A survey of benthic organisms within the area of proposed intake and discharge structure construction was conducted on December 12 and 13, 2000. Nineteen stations were sampled, with three replicate samples collected at each station (see Appendix A–Survey Protocol, Figure 1 for station locations). Methods of collection, laboratory processing and all data were presented in *The Three-Month Report on the Benthic, Rocky Shoreline, and Trawl Surveys* (Tenera 2001a).

A total of 145 taxa was identified from the 57 benthic samples. Four taxa groups that included sponges, hydroids, and bryozoans were recorded as present. The 141 enumerated taxa included polychaete worms, oligochaete worms, nemertean worms, crustaceans (amphipods, tanaids), mussels, and echinoderms. Crustaceans and polychaetes were the two most abundant groups overall. Most taxonomic groups occurred at all stations.

A number of fish surveys were conducted in the vicinity of the Plant. PG&E studied the effects of the thermal discharge in 1971–1972 (PG&E 1973a) and again in 1989–1990 (PG&E 1991), and impingement and entrainment studies were conducted in 1978–1979 (PG&E 1980a). Ongoing CDFG midwater and otter trawls conducted in the Central and South bays also provide data on the fishes in this area. Results of these studies were summarized in the Unit 7 Application for Certification (Dames & Moore 2000).

In addition, as part of the Survey Protocol, monthly otter trawl surveys were conducted for one year in the vicinity of the Plant. The data from these surveys characterize the current fish, crab, and shrimp communities inhabiting this subtidal habitat. The data presented here cover the entire 12-month study period from January 2001 through December 2001 (Tenera 2001c). Otter trawl stations (see Appendix A–Survey Protocol, Figure 5 for station locations) were sampled monthly from January through December 2001. Results from all surveys and stations combined showed that bay goby *Lepidogobius lepidus* comprised 51 percent of the total catch, followed by speckled sanddab *Citharichthys stigmaeus* at 24 percent, and English sole *Parophrys vetulus* at 9 percent (Tenera 2001c). Dungeness crab *Cancer magister* and slender crab *Cancer gracilis* comprised the majority of the total number of crabs collected during the year-long survey (40 percent and 38 percent, respectively). Two species dominated the shrimp catch: black-tailed bay shrimp *Crangon nigricauda* at 71 percent and Stimpson's shrimp *Heptacarpus stimpsoni* at 15 percent (Tenera 2001c).

Wharves and pilings occupy a significant portion of the waterfront subtidal habitat along the western shoreline of Central San Francisco Bay, including the area north and south of the Plant (Figure 2-4). Wharves and pilings provide vertical structure for the attachment of algae and sessile invertebrates. Untreated pilings support communities that include mussels, barnacles, hydroids, tunicates, and wood-boring worms and clams. These communities in turn attract and provide food and shelter for invertebrates such as Cancrid and Majid crabs, as well as many fish species. Wharves and pilings also provide spawning substrate for Pacific herring.

Open Water

The open-water habitat of Central San Francisco Bay sustains a diverse community of planktonic and free swimming (nektonic) organisms. Planktonic forms, which may be plant or animal, drift in the Bay's currents and are only able to move short vertical distances on their own power. Nektonic organisms are free-swimming: fishes, crustaceans, and marine mammals.

Phytoplankton (planktonic plants) nourished by sunlight and the Bay's nutrients are the basis of primary production in the region. Phytoplankton communities consist primarily of two groups: diatoms and dinoflagellates. The abundance, distribution, and species composition of phytoplankton communities within the Bay undergo regular annual cycles. Concentrations of phytoplankton are generally the greatest in Bay waters between March and May (PG&E 1980a). While both diatoms and dinoflagellates make up these "blooms," diatoms are the dominant group throughout the year (PG&E 1980a).

Zooplankton abundance within the Bay also follows annual cycles. Many zooplankton species feed on phytoplankton, so peaks in abundance frequently occur following phytoplankton blooms. Zooplankters are divided into two groups: holoplankton and meroplankton. Holoplankton are composed of groups that remain adrift throughout their life cycle, and meroplankton remain within the plankton community only during their early life stages. Meroplankton are composed of the eggs and the larvae of fishes, crustaceans, polychaetes, mollusks, and other benthic organisms.

A larval fish and megalopal cancer crab survey was conducted to assess the effects of entrainment. Sampling, laboratory processing, and data analyses methodologies are described in Section 3.2. Results for the most abundant taxa are discussed in detail in Section 3.3 and presented by survey in Appendix B. Data from these surveys also serve to characterize the ichthyoplankton and megalopal cancer crabs inhabiting the area.

Four species and one taxon group comprised 94 percent of the annual average concentration of all fish taxa collected at the intake stations from February 27, 2001 through February 22, 2002: Bay goby *Lepidogobius lepidus*, Pacific herring, unidentified gobies, yellowfin goby *Acanthogobius flavimanus*, and northern anchovy *Engraulis mordax*. These same species and taxon comprised 96 percent of the annual average concentration of all fish taxa collected at all source water stations.

Very few cancer crab megalopae were collected during the study at the intake and source water stations (128 individuals total). Megalopae of the brown rock crab *Cancer antennarius*, yellow crab *Cancer anthonyi*, hairy rock crab *Cancer jordani*, slender crab *Cancer gracilis,* red rock crab *Cancer productus,* and a group of *Cancer* spp. megalopae that were only able to be identified to the genus level were collected during the study. Dungeness crab *Cancer magister* megalopae, easily distinguishable from other cancer megalopae, were not collected in any of the surveys. Low numbers (n = 11) of European green crab were collected at the intake and source water stations.

Data collected during the monthly midwater trawl surveys also help characterize the current fish communities inhabiting this open water habitat (see Appendix A–Survey Protocol, Figure 5 for station locations). Two species comprised 98 percent of the total number of fishes collected during all midwater trawl surveys from January through December 2001 at all stations combined: northern anchovy comprised 69 percent, and Pacific herring comprised 29 percent of the total. The majority of the Pacific herring were young-of-the-year fish ranging from 43 to 82 mm (1.7 to 3.2 in.) fork length. The majority of the northern anchovy measured between 78 to 117 mm (3.1 to 4.6 in.) fork length (Tenera 2001c).

A variety of marine and anadromous fish species inhabit the open water regions of San Francisco Bay, and many species have been collected in the Plant's otter and midwater trawls (see discussion in subtidal habitat section above). Surfperches, sculpins, and flatfishes are common demersal groups within the open waters of the Bay. Topsmelt *Atherinops affinis* and jacksmelt *Atherinopsis californiensis*, or silversides, are typically associated with the middle and upper regions of the water column, as are Pacific herring and northern anchovy. Pacific herring support the largest remaining commercial fishery in the Bay and are fished in the vicinity of the Plant. Nine fall-run sized Chinook salmon *Oncorhynchus tshawytscha* were collected at otter trawl stations during the one-year study. No winter-run or spring-run sized Chinook salmon or steelhead *Oncorhynchus mykiss* were collected.

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3.0 ENTRAINMENT AND SOURCE WATER SURVEY RESULTS

3.1 Introduction

The following sections present entrainment and source water data collected from 14 months of sampling (January 17, 2001–February 22, 2002). These studies focused on larval fishes and cancer crab megalopae whose adult populations might be affected by operation of the Plant's Unit 3 cooling water intake system (CWIS).

The studies were designed to specifically address the following questions:

- What are the species composition and abundance of larval fishes and cancer crab megalopae entrained by the Potrero Power Plant?
- What are the local species composition and abundance of entrainable larval fishes and cancer crab megalopae in the San Francisco Bay source water?
- What are the potential impacts of entrainment losses on larval fish and megalopal cancer crab populations due to operation of the power plant's cooling water intake system?

The Survey Protocol, developed in coordination with, and approved by the AWG focused on two groups of representative target organisms (larval fishes and cancer crab megalopae) to assess entrainment. From these groups, particular taxa were selected for further analyses on the basis of their sampled abundance. It was agreed that several assessment approaches would be applied to each analyzed taxon, where possible, to yield more robust and comparable impact assessments. A careful search was conducted during sample sorting for introduced European green crab *Carcinus maenas*, a species of concern for CDFG.

3.2 Methods

3.2.1 Intake Sample Collection

Two stations (E1 and E2) located in front of the Unit 3 intake structure were sampled to provide data used to estimate entrainment effects (Figure 3-1). Sample collection frequency (weekly or monthly) was specified in the Survey Protocol (Appendix A) and was based on the abundance of larval Pacific herring collected in the samples. Weekly intake station sampling began January 17, 2001, when larval Pacific herring were abundant, and continued through April 4, 2001, when concentrations of larval Pacific herring decreased. The sampling frequency was reduced to monthly beginning in April 2001 and continued at that frequency through November 2001. Sampling frequency increased to weekly beginning the first week of December 2001, when CDFG reported ripe Pacific herring adults entering the Bay. Weekly sampling continued through February 22, 2002 when one year of surveys had been conducted at all of the source water stations (Table 3-1).

Samples were collected by towing a bongo frame with 0.71-m (2.3-ft) diameter openings and rigged with two 335-µm white mesh plankton nets. Samples were collected over a continuous 24-hour period; each period was divided into six 4-hour sampling cycles. Two tows were conducted during each cycle. Sample collection methods were similar to those developed and used by the California Cooperative Oceanic and Fisheries Investigation (CalCOFI) in their larval fish studies (Smith and Richardson 1977), except that the bongo net was deployed and retrieved directly aft of the boat rather than off to one side. Deployment of the net aft of the boat was done for safety reasons. The size of the boat used at the Plant was smaller to allow for collections in relatively shallow waters in front of the intake. The CalCOFI boats, which sample in deeper offshore areas, and are rigged such that side deployment is practical and safe. The relatively slow speed of Mirant's boat and the use of the winch minimized problems of boat turbulence and net avoidance discussed by Smith and Richardson (1977). The bongo nets were lowered as close to the bottom as possible. Once the nets were at the correct depth, the boat was moved forward and the nets retrieved at an oblique angle (winch cable at a 45° angle). The winch retrieval speed was constant at approximately 1 ft/sec. Each net mouth was fitted with a calibrated flowmeter to record the volume of water filtered.

The target water volume filtered by both bongo nets combined was 40 m^3 (i.e., 20 m^3/net). The sample volume was checked when the nets reached the surface. If the target volume was not collected, the nets were placed back in the water and the tow repeated so that the targeted volume was reached. Upon successful completion of a tow, the nets were retrieved from the water and all of the collected material was rinsed into the ends (codends) of the nets. The contents of both nets were combined into a single, labeled jar (constituting one sample) immediately after collection, and were preserved in either ethanol (ETOH) or formalin. Each sample was given a serial number based on the location, date, time, and depth of collection. The information was logged onto a sequentially numbered data sheet that was used by the data management system to track the sample through laboratory processing, data analysis, and reporting.

Table 3-1. Potrero Power Plant intake and source water survey dates and numbers of samples collected by station.

Survey	Start Date	Station									Comments
		E1	E2	NF1	NF2	NF3	NF4	FF1	FF2	FF3	
1	01/17/01	12	12	11	11	11	0	*	*	*	NF4 not sampled because of time constraints; rough sea conditions resulted in longer plankton net washdown times at the other stations.
2	01/24/01	12	12	12	12	12	10	*	*	*	NF4 Cycle 4 not sampled because of time constraints; rough sea conditions resulted in longer plankton net washdown times at the other stations.
3	01/31/01	12	12	12	12	12	12	*	*	*	Plankton net # 1 was torn during the collection of Cycle 2. Samples were collected using only plankton net # 2 for Cycles 2 and 3.
4	02/07/01	12	12	12	12	12	10	*	*	*	NF4 Cycle 5 not sampled due to hazardous sea conditions.
								*	*	*	No samples collected for the week of February 12, 2001 due to mechanical problems with the boat.
5	02/23/01	10	10	10	10	10	10	*	*	*	Cycle 6 not sampled due to rough sea conditions.
6	02/28/01	12	12	12	10	12	10	12	12	10	NF2 and NF4 Cycle 1 not sampled due to schedule conflict. FF1 Cycle 4 sampled 24 hours after the rest of Cycle 4. FF3 Cycle 6 not sampled due to rough sea conditions.
7	03/07/01	12	12	12	12	12	12	12	12	12	All samples collected.
8	03/14/01	12	12	12	12	12	12	12	11	8	FF2 Replicate 2 and FF3 Replicates 1 and 2 not collected during Cycle 3 due to hazardous wind and sea conditions. FF3 Replicates 1 and 2 not collected during Cycle 4 due to hazardous wind and sea conditions.
9	03/21/01	2	2	2	2	2	2				Only one cycle collected from E1, E2, and NF1 through NF4 before the boat's power control cable failed.
10	03/27/01	12	12	12	11	10	10	6	8	4	NF2 Replicate #2 and NF3 and NF4 Replicates #1 and #2 during Cycle 3 and FF3 Replicates #1 and #2 during Cycle 1 not collected due to washdown pump failure. FF1 and FF3 Replicates #1 and #2 during Cycle 2 and FF1, FF2, and FF3 Replicates #1 and #2 during Cycles 3 through 5 not collected due to hazardous wind and sea conditions. An additional cycle was collected at FF1, FF2, and FF3 (2 samples/station) at the end of the normal sampling time period.
11	04/04/01	12	12	12	12	12	12	12	12	12	All samples collected.
12	05/22/01	12	12	12	12	12	12	12	12	12	All samples collected.
13	06/20/01	12	12	12	12	12	12	12	12	12	All samples collected.
14	07/11/01	12	12	12	12	12	12	12	12	12	All samples collected.
15	08/08/01	12	12	12	12	12	12	12	12	12	All samples collected.
16	09/12/01	12	12	12	12	12	12	8	8	6	FF3 Cycle 4 and FF1, FF2 and FF3 Cycles 5 and 6 not sampled due to mechanical problems with the boat.
17	10/10/01	12	12	12	12	12	12	12	12	10	FF3 Cycle 3 not sampled due to rough sea conditions.
18	11/07/01	12	12	12	12	12	12	12	12	12	All samples collected.
19	12/06/01	12	12	12	12	12	12	12	12	12	All samples collected.
20	12/12/01	12	12	12	12	12	12	12	12	12	All samples collected.
21	12/19/01	12	12	12	12	12	12	12	12	12	All samples collected.
22	12/28/01	12	12	12	12	12	12	12	12	12	All samples collected.
23	01/02/02	12	12	12	12	12	12	12	12	12	All samples collected.
24	01/10/02	12	12	12	12	12	12	12	12	12	All samples collected.

Table 3-1 (continued). Potrero Power Plant intake and source water survey dates and numbers of samples collected by station.

Survey	Start Date	Station									Comments
		E1	E2	NF1	NF2	NF3	NF4	FF1	FF2	FF3	
25	01/17/02	12	12	12	12	12	12	12	12	12	All samples collected.
26	01/23/02	12	12	12	12	12	12	12	12	12	All samples collected.
27	01/30/02	12	12	12	12	12	12	12	12	12	All samples collected.
28	02/06/02	12	12	12	12	12	12	12	12	12	All samples collected.
29	02/13/02	12	12	12	12	12	12	12	12	12	All samples collected.
30	02/21/02	12	12	12	12	12	12	12	12	12	All samples collected.

* Far-field source water station locations were finalized by the CEC on February 5, 2001. A second boat was rigged and far-field station collection began February 27, 2001.

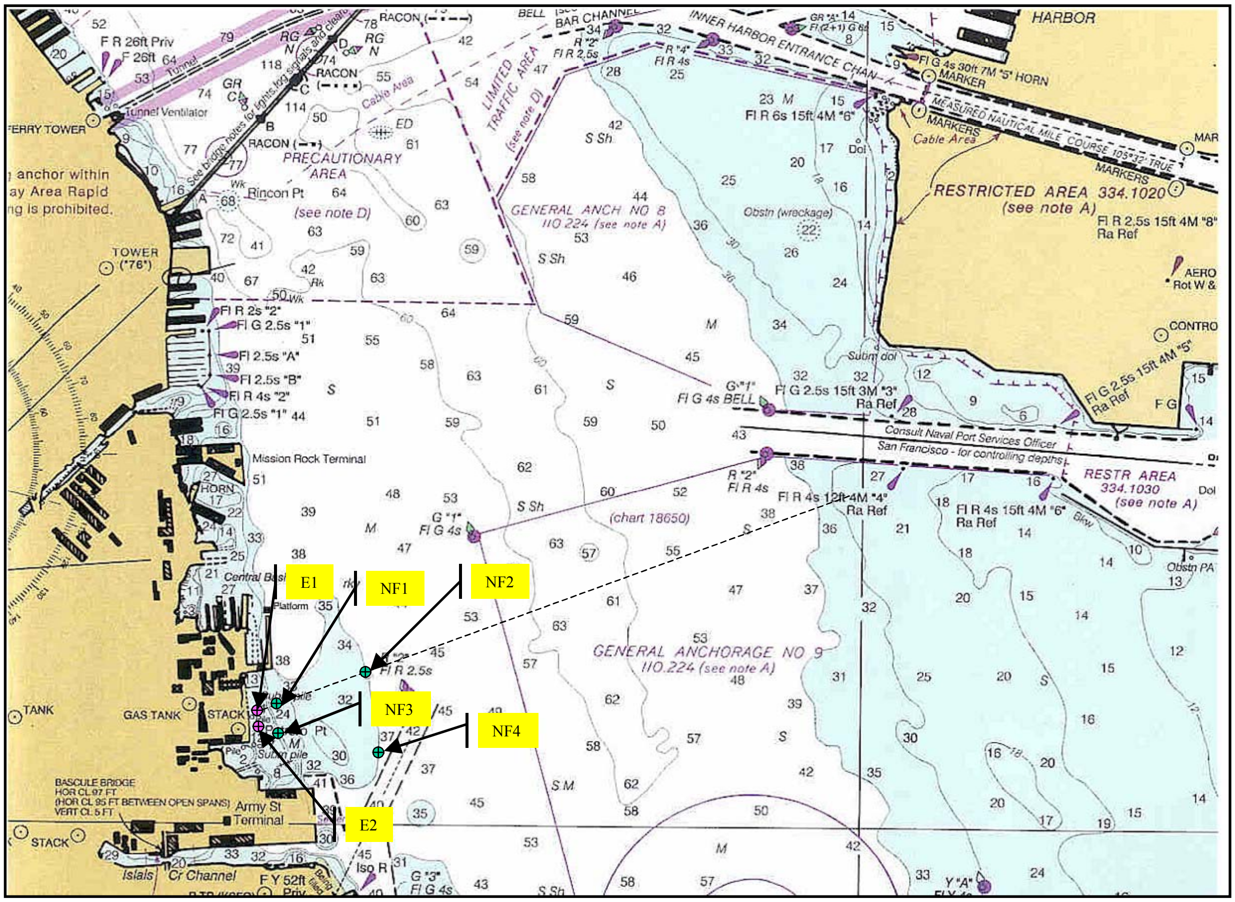


Figure 3-1. Locations of Potrero Power Plant intake (E1 and E2) and near-field (NF1–NF4) source water sampling stations.

3.2.2 Source Water Sample Collection

Source water station locations were chosen based on hydrological data (currents, tide, salinity) from U.S. Geological Service (USGS), biological data (species composition) from CDFG and other aquatic surveys in the area, and input from the AWG. A complete description of the source water determination is presented in Appendix C. Weekly source water sampling at the near-field stations began January 17, 2001 and was identical to the intake survey sample frequency described above. Near-field stations 1 and 3 (NF1 and NF3) were located approximately 100 yards (91 m) offshore of the intake stations and near-field stations 2 and 4 (NF2 and NF4) were located approximately 1,200 yards offshore of the intake stations (Figure 3-1).

Far-field station locations were agreed upon by the AWG on February 5, 2001. A larger boat was outfitted with sampling equipment and far-field stations were sampled beginning February 27, 2001 (Table 3-1) at the locations shown in Figure 3-2. The frequency of sample collection after February 27 was identical to the intake and near-field sampling schedules described above. Far-field Station 1 (FF1) was located south of the power plant near India Basin, FF2 was located south of Oyster Point, and FF3 was located just south of the San Mateo Bridge (Figure 3-2). Collection, preservation, and sample tracking methods for all source water survey samples were identical to the intake survey collection methods.

3.2.3 Laboratory Processing

Laboratory processing consisted of sorting, removing, identifying, and enumerating all larval fishes and megalopal stages of *Cancer* spp. and European green crabs. Sorting and identification accuracy was verified and maintained by Tenera Environmental's quality control (QC) program. All field and laboratory data were entered into a computer database that was verified for accuracy against the original data sheets. The numbers of samples processed in the laboratory from each intake and source water survey are shown in Table 3-2.

Figure 3-2. Locations of Potrero Power Plant far-field (FF1–FF3) source water sampling stations.

Table 3-2. The number of Potrero Power Plant intake and source water survey samples collected and processed in the laboratory.

Intake				Source Water			
Survey Serial Number	Date Collected	Samples Collected	# Processed	Serial Number	Date Collected	Samples Collected	# Processed
PPEAS0001	01/17/01	24	24	PPSWS0001	01/17/01	33	33
PPEAS0002	01/24/01	24	24	PPSWS0002	01/24/01	46	46
PPEAS0003	01/31/01	24	24	PPSWS0003	01/31/01	48	48
PPEAS0004	02/07/01	24	24	PPSWS0004	02/07/01	46	45*
PPEAS0005	02/23/01	20	20	PPSWS0005	02/23/01	40	40
PPEAS0006	02/27/01	24	24	PPSWS0006	02/27/01	78	78
PPEAS0007	03/08/01	24	24	PPSWS0007	03/07/01	84	84
PPEAS0008	03/15/01	24	24	PPSWS0008	03/14/01	79	79
PPEAS0009	03/21/01	4	4	PPSWS0009	03/21/01	8	8
PPEAS0010	03/27/01	24	24	PPSWS0010	03/27/01	61	61
PPEAS0011	04/05/01	24	24	PPSWS0011	04/04/01	84	84
PPEAS0012	05/22/01	24	24	PPSWS0012	05/22/01	84	84
PPEAS0013	06/20/01	24	24	PPSWS0013	06/20/01	84	84
PPEAS0014	07/11/01	24	24	PPSWS0014	07/11/01	84	84
PPEAS0015	08/08/01	24	24	PPSWS0015	08/08/01	84	84
PPEAS0016	09/12/01	24	24	PPSWS0016	09/12/01	70	70
PPEAS0017	10/10/01	24	24	PPSWS0017	10/10/01	82	82
PPEAS0018	11/07/01	24	24	PPSWS0018	11/07/01	84	84
PPEAS0019	12/06/01	24	24	PPSWS0019	12/05/01	84	84
PPEAS0020	12/12/01	24	0**	PPSWS0020	12/12/01	84	0**
PPEAS0021	12/19/01	24	0**	PPSWS0021	12/18/01	84	0**
PPEAS0022	12/28/01	24	0**	PPSWS0022	12/28/01	84	0**
PPEAS0023	01/02/02	24	24	PPSWS0023	01/02/02	84	84
PPEAS0024	01/10/02	24	24	PPSWS0024	01/09/02	84	84
PPEAS0025	01/17/02	24	24	PPSWS0025	01/16/02	84	84
PPEAS0026	01/23/02	24	24	PPSWS0026	01/23/02	84	84
PPEAS0027	01/30/02	24	24	PPSWS0027	01/30/02	84	84
PPEAS0028	02/06/02	24	24	PPSWS0028	02/05/02	84	84
PPEAS0029	02/13/02	24	24	PPSWS0029	02/12/02	84	84
PPEAS0030	02/21/02	24	24	PPSWS0030	02/20/02	84	84
TOTALS		696	624	TOTALS		2,187	1,934

*Note: One sample was voided during laboratory processing.

**Note: Samples from weekly surveys conducted from December 12-28, 2001 were not processed in the laboratory. Low concentrations of larval Pacific herring occurred in samples collected December 6, 2001 and also from samples collected January 2, 2002. Concentrations of larval Pacific herring increased the second week of January 2002, and all remaining weekly survey samples were processed.

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 and the higher taxonomic level of family include genus and species). Myomere and pigmentation patterns were used to identify many species; however, this can be problematic for some species. For example, sympatric members of the family Gobiidae share morphologic and meristic characters during early life stages (Moser 1996) making identification to the species level difficult. We grouped the gobies we were unable to identify to species into an "unidentified goby" category (i.e., unidentified Gobiidae). Rockfish can be identified to the genus, subgenus, or species level by relying on pigment patterns that change as the larvae develop, as described in Appendix D.

Measurements of larval lengths, recorded as the length of the notochord, were taken on a representative sample of the larval fish taxa presented in the following sections. Approximately 300 fish from each of the most abundant taxon collected at the intake stations were measured using a digital imaging system and Optimus™ image analysis software. The 300 fish from each taxon were randomly selected based on their percentage frequency of occurrence in each survey. For example, if 20 percent of Pacific herring were collected from the intake station during a survey, then approximately 60 fish ($300 \times 0.20 = 60$) were measured from that survey. The total number of fish measured for each taxon did not exactly equal 300 because at least one or two larvae were measured from surveys that had less than one or two percent of the total for a taxon.

3.2.4 Data Analysis

Sample concentrations of larval fishes and megalopal *Cancer* spp. crabs, identified to the lowest taxonomic level practical, 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 larval fish taxa and target megalopal crabs from all processed surveys are presented in Appendix B and presented graphically in this section for the most abundant larval fishes. The graphs and the Appendix B tables include the data from the first five surveys that were collected before the far-field station locations were chosen. However, to determine the percent of the annual average concentration of larval fishes collected at intake and source water stations, data from the one-year period (February 27, 2001–February 22, 2002) were used because they represent one full year of sample collection at all stations. The mean survey concentration per 1,000 m^3 for the intake and source water stations found in Appendix B (Tables B-1 and B-2) were calculated as simple arithmetic averages of the sample concentrations for a survey for each species or taxa. The survey means were then averaged to obtain an annual mean concentration per 1,000 m^3 for the February 27, 2001–February 22, 2002 intake and source water stations.

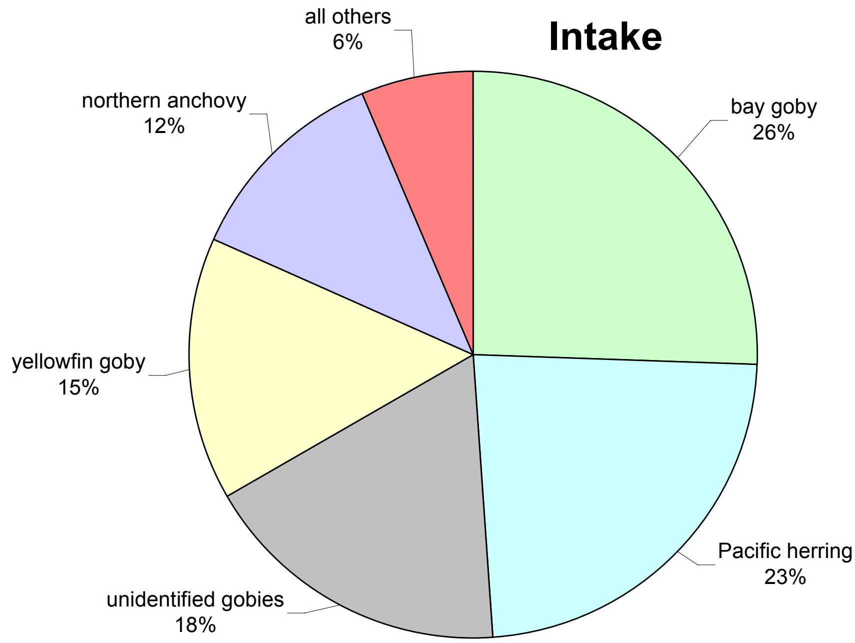
Data presented in Section 4.0 are entrainment estimates that were calculated using the mean survey concentrations and cooling water intake volumes. Although the daily cooling water volume used in all calculations was constant, the number of days within each survey period varied (i.e., 14 to ~28 days). Therefore, even though the annual average concentrations for two species may be equal, the annual entrainment estimates may differ because the survey with the highest concentration for one of the species had a larger number of days in the survey period than the survey with the highest concentration for the other species. Due to these differences in calculations, the rank order of abundance for annual mean concentration in Section 3.0 and the total entrainment estimate in Section 4.0 may be different. If the number of days in each survey period were the same, the rank order for the two estimates would also be the same. Since surveys were done every two weeks during the Pacific herring season, and monthly during the remainder of the year, if two species had equal annual average concentrations, the one with the higher concentration during the monthly surveys would have the higher entrainment estimate.

3.3 Intake and Source Water Results

Concentrations of larval fishes from each intake and source water survey are presented in Appendix B. Approximately 199,000 larval fishes were collected in plankton tows from the intake stations and all source water stations combined between January 17, 2001 and February 22, 2002 (Tables B-1 and B-2). Approximately 82 percent of the larval fishes were collected during the source water surveys (Table B-2), and 18 percent were collected at the intake stations (Table B-1). There were 71 fish taxa groups, six rockfish pigment groups, and three categories of larval fishes that could not be identified (fragments, damaged larvae, and whole unidentified larvae).

The percent composition of larval fishes (based on the annual average concentration) from intake and source water surveys from February 27, 2001–February 22, 2002 is shown in Figure 3-3. Four species and one taxon group comprised 94 percent of the annual average concentration of all fish taxa collected at the intake stations (Figure 3-3). Bay goby *Lepidogobius lepidus* was the most abundant larval fish species (26 percent), followed by Pacific herring *Clupea pallasii* (23 percent), unidentified gobies (18 percent), yellowfin goby *Acanthogobius flavimanus* (15 percent), and northern anchovy *Engraulis mordax* (12 percent). Four species and one taxon group comprised 96 percent of the annual average concentration of all fish taxa collected at all source water stations (Figure 3-3). Northern anchovy and unidentified gobies were the most abundant larval fish species (each comprised 24 percent), followed by Pacific herring (19 percent), yellowfin goby (18 percent), and bay goby (12 percent).

A total of only 128 megalopal cancer crabs and 11 megalopal European green crabs were collected from intake and source water surveys from January 17, 2001–February 22, 2002. Approximately 76 percent of the cancer crab megalopae were collected during the source water surveys (Tables B-1 and B-2). All cancer crab megalopae were identified to the lowest taxonomic level practical. Megalopae of the brown rock crab *Cancer antennarius*, yellow crab *Cancer anthonyi*, hairy rock crab *Cancer jordani*, slender crab *Cancer gracilis,* red rock crab *Cancer productus,* and a group of *Cancer* spp. megalopae that were only able to be identified to the genus level were collected during the 14-month study. The Dungeness crab *Cancer magister* megalopae, easily distinguishable from other *Cancer* spp. megalopae, were not collected in any of the surveys from January 17, 2001–February 22, 2002. Specimens identified in our laboratory as European green crab were sent to a taxonomic expert who verified our identification.



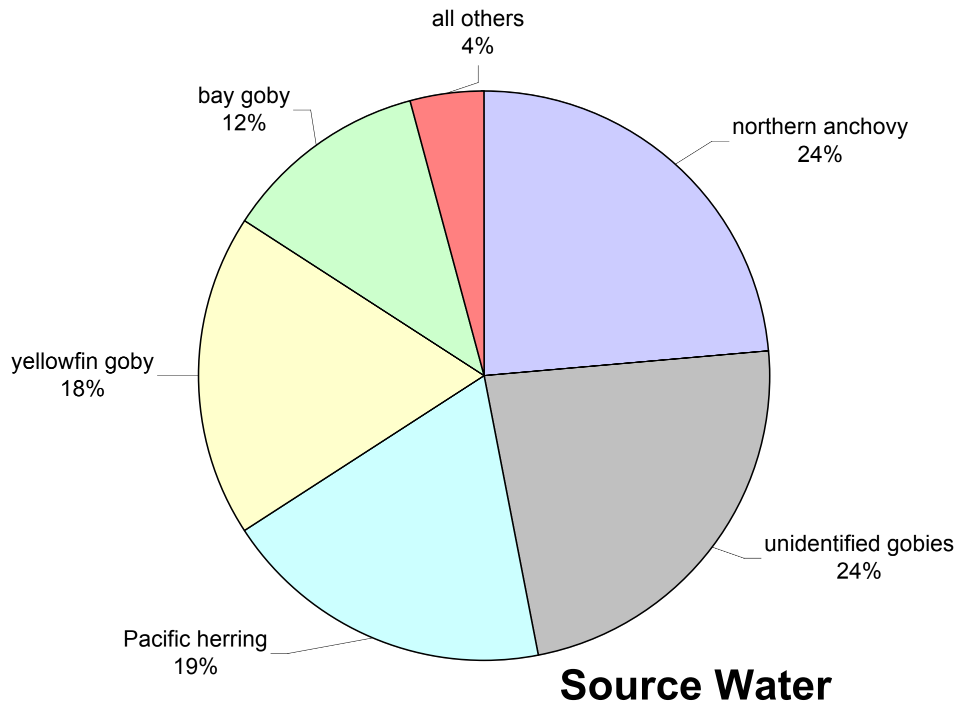


Figure 3-3. The percent composition of larval fishes collected at Potrero Power Plant intake and source water stations based on annual average concentrations from February 27, 2001–February 22, 2002.

Note: Source water values do not total 100 percent due to rounding.

3.3.1 All Fishes

The larval fish concentration (all taxa combined) at the Plant intake stations was generally highest during the winter and spring months (Figure 3-4). This is consistent with the reported spawning periods of two of the most abundant species collected (e.g., Pacific herring and yellowfin goby) (Moser 1996). The peak concentration of larval fishes occurred on February 22, 2002, and reflected high concentrations of larval Pacific herring.

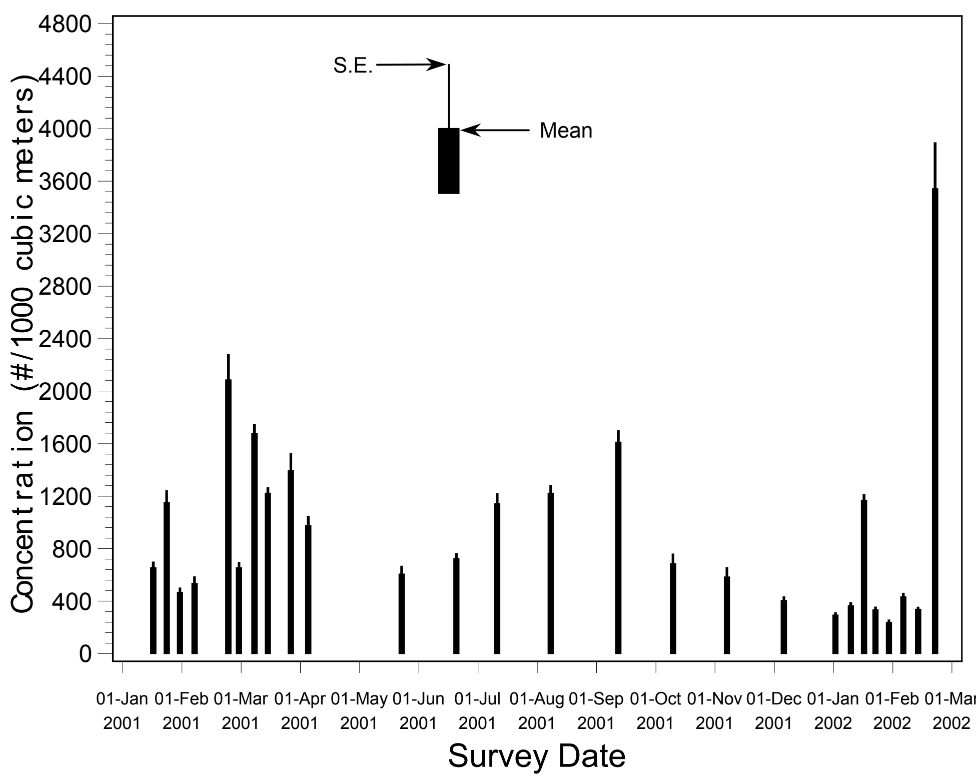


Figure 3-4. Mean larval fish concentrations for all taxa combined collected at the Potrero Power Plant intake stations (E1 and E2) from January 17, 2001–February 22, 2002.

Standard error indicated (+1 SE).

Larval fish concentrations at the intakes were compared to concentrations at all source water stations combined (Figure 3-5). Although the average monthly concentration at the source water stations was generally higher than the concentrations at the intake stations, the seasonal patterns of change in concentration were similar. The highest monthly average concentration occurred in August 2001 (3,971/1,000 m^3) at the source water stations mainly reflecting high concentrations of northern anchovy.

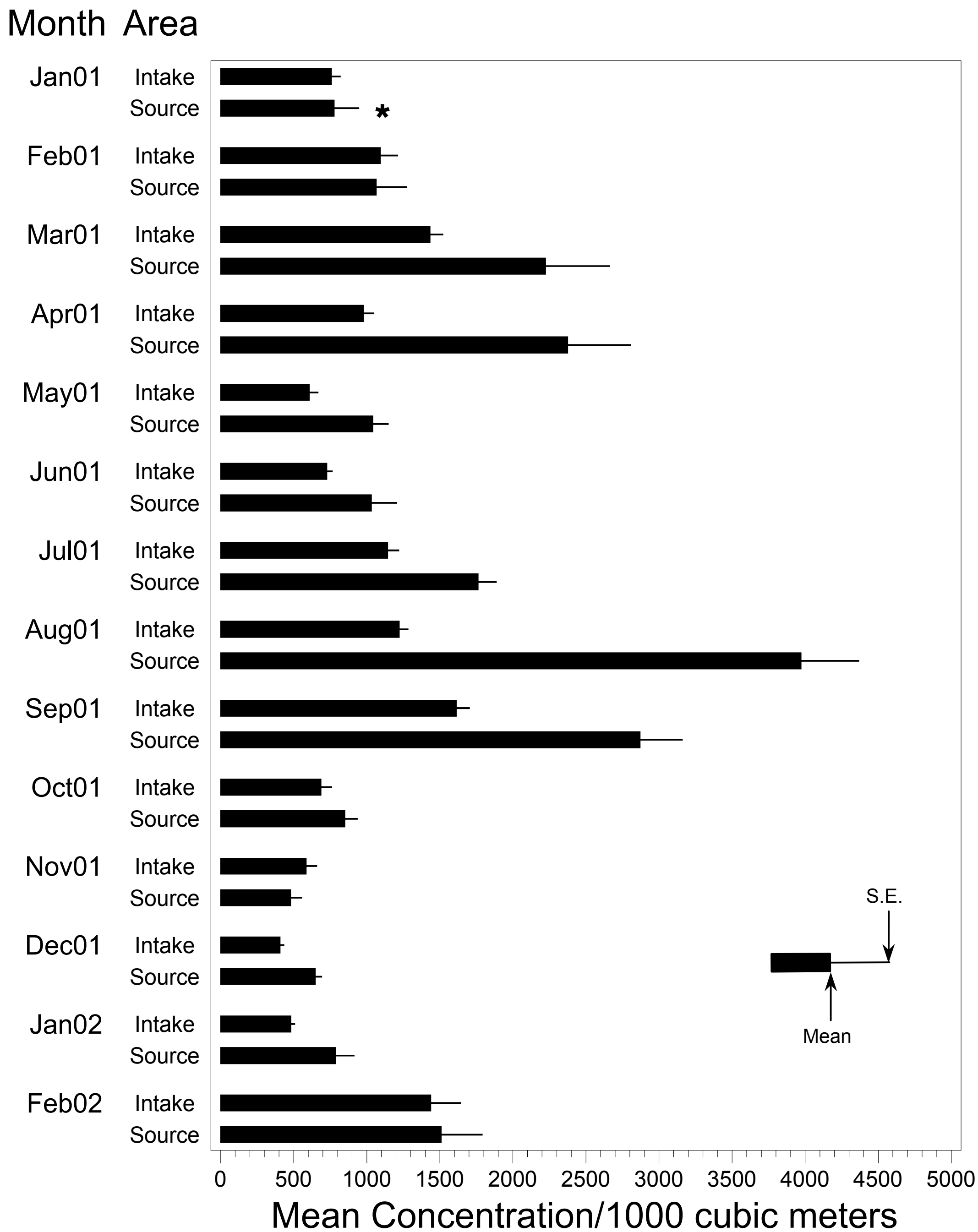


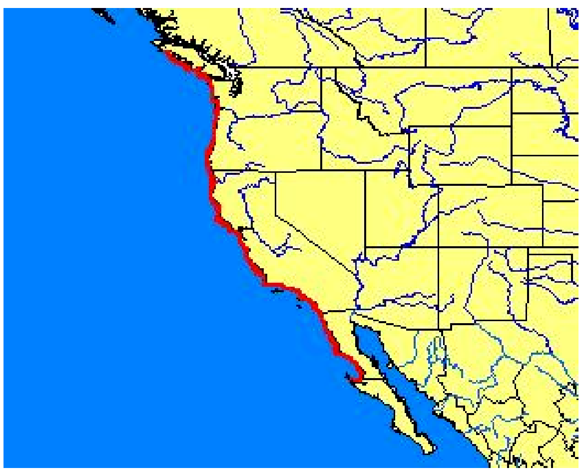
Figure 3-5. Monthly mean concentrations of larval fishes collected at the Potrero Power Plant intake and source water stations from January 17, 2001–February 22, 2002.

* Surveys at far-field stations started February 27, 2001.

Standard error indicated (+1 SE).

3.3.2 Bay Goby Lepidogobius lepidus

Photographer: Neil McDaniel



Distribution map for bay goby

Range: From Cedros Island, Baja California to Vancouver Island, British Columbia.

Life History: Size: to 108 mm (4.3 in.); age at maturity: one to two years old; fecundity: no information available; lifespan: seven plus years.

Habitat: Intertidal mudflats, shallow pools.

Fishery: None.

The bay goby *Lepidogobius lepidus* is a common bottom-dwelling inhabitant of bays and estuaries along the Pacific coast of North America. It ranges from Vancouver Island, British Columbia to Cedros Island, Baja California (Miller and Lea 1972). Bay goby was the most abundant fish species collected during the 2001 Potrero otter trawl study, comprising 51 percent of all fishes collected (Tenera 2002). They were the most abundant goby species (and the third most abundant fish species overall) collected during CDFG otter trawl surveys at Station 109 near the Plant from 1980–1999 (Baxter et al. 1999, CDFG unpublished otter trawl data).

The bay goby is generally considered a shallow-water marine species but may occur on mud and mud-sand substrata down to depths of 61 m (200 ft) (Miller and Lea 1972). They are common on intertidal mudflats where they remain in invertebrate burrows and shallow pools when the tide is out (Grossman 1979). Like many marine-estuarine species they are tolerant of variations in salinity and temperature. During population monitoring studies in the San Francisco Bay-Delta, bay goby occasionally (during periods of low Delta outflow) moved from marine waters upstream through the Carquinez Strait into the lower salinity waters of Suisun Bay (Baxter et al. 1999).

Reports differ on the longevity of bay goby. They are reported to live for about seven years, which is considered unusually long for a small fish species (Grossman 1979). Life span estimates of two to three years have been derived from length frequency data collected by CDFG.

Based on differences in ova size/development from fish collected during April and May off Hunters Point Power Plant in San Francisco Bay and in Moss Landing Harbor, bay goby have been characterized as asynchronous multiple spawners (Wang 1986). Most bay goby do not become reproductively mature until their second year, but a few mature during their first year (Wang 1986). Because bay goby use invertebrate burrows for predator avoidance and protection against dehydration during low tides, it is thought that this species, like many other goby species, may also use burrows for spawning (Grossman 1979, Wang 1986). No fecundity information is available for bay goby. Eggs are demersal, spherical/elliptical in shape, and have an adhesive anchoring point (Wang 1986).

Bay goby larvae occur with the larvae of arrow goby *Clevelandia ios*, cheekspot goby *Ilypnus gilberti*, and yellowfin goby *Acanthogobius flavimanus* in San Francisco Bay (Wang 1986, Grossman 1979). In a study by Wang (1986), the greatest abundance of bay goby larvae was collected in San Francisco Bay from November through May, with peak numbers occurring in April and May. The highest concentrations of larval bay goby within the San Francisco Bay system occurred between the Golden Gate Bridge and Angel Island (Wang 1986). Newly hatched larvae are small (3 mm [0.12 in.] or less) and nearly transparent (Wang 1986) and may have a planktonic life phase of 3 to 4 months (Grossman 1979, Wang 1986). Completion of the transformation stage (beginning of the juvenile phase) for bay goby larvae occurs around 29 mm (1.1 in.) (Moser 1996). Juveniles (and adults) occupy the burrows of blue mud shrimp *Upogebia pugettensis*, geoduck clams *Panope generosa* and other burrowing animals for shelter and predator avoidance (Grossman 1979).

Juvenile and adult bay goby growth was described by Grossman (1979). Growth is initially rapid, with 50 percent of their total growth (length) occurring within the first two years (Grossman 1979). Following this period of rapid growth, increases in length slow to about 6 mm (0.24 in.) per year (Grossman 1979).

Bay goby are thought to be an important food item in the diet of a variety of vertebrate and invertebrate predators. Their abundance, small size, and extended planktonic duration make bay goby larvae an important link in the food web of bay/estuarine systems (Wang 1986). Their abundance as juveniles and adults suggests that they remain an important forage species throughout all life stages. Pacific staghorn sculpin *Leptocottus armatus* and California halibut *Paralichthys californicus* are among the many fish predators of other adult gobies (Brothers 1975). It is assumed that these fishes and sharks and rays that inhabit estuarine systems also prey on bay gobies (Grossman 1979). Bay goby are also a prey item for birds (Reeder 1951, Grossman 1979). Due to their small size, bay goby are not harvested commercially for human consumption or targeted by recreational anglers (Wang 1986). There is no reference in the current literature of their harvest or use as bait.

Bay Goby Results

Concentrations of larval bay goby by survey are shown in Figure 3-6. Bay goby larvae comprised the largest percentage (26 percent) of the annual average concentration of larval fishes collected at the intake stations and 12 percent among the source water stations from February 27, 2001–February 22, 2002 (Figure 3-3). Bay goby larvae were collected at the Plant intake stations during all months of the study. The greatest concentrations of larvae at the intake stations occurred between June and December 2001, with the peak concentration (823/1,000 m^3) occurring in September 2001. Bay goby concentration was lowest (55/1,000 m^3) during the February 27, 2001 survey.

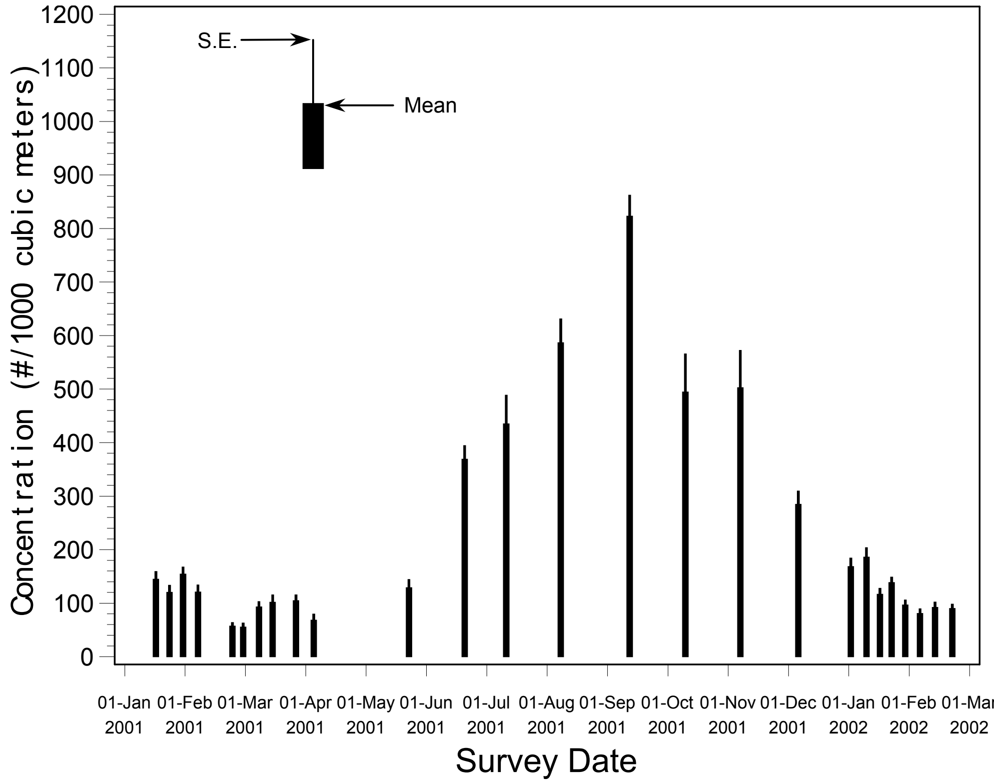


Figure 3-6. Mean concentrations of larval bay goby collected at the Potrero Power Plant intake stations from January 17, 2001–February 22, 2002.

Standard error indicated (+1 SE).

Lengths were recorded for a total of 308 larval bay goby collected at the Plant intake stations. The smallest bay goby larva measured from the intake stations was 2.4 mm (0.1 in.) notochord length (NL) (Figure 3-7). This is less than the estimated hatch length of approximately 3–3.2 mm NL reported in Moser (1996). Handling and preservation can lead to the shrinkage of larval tissues (Theilacker 1980), but smaller than reported hatch lengths could also result from natural variation of length at hatching. On average, bay goby larvae collected at the intake stations were 3.2 mm (0.1 in.) (*S.E.* = 0.02 mm), and the longest individual measured was 4.3 mm (0.2 in.). Bay goby larvae start to develop morphological characteristics of juveniles at 6.2 mm (0.2 in.) (Moser 1996) that may allow greater swimming ability. This increased swimming ability does not necessarily mean the larvae can avoid entrainment, but they may be able to select habitats where they are less susceptible to entrainment.

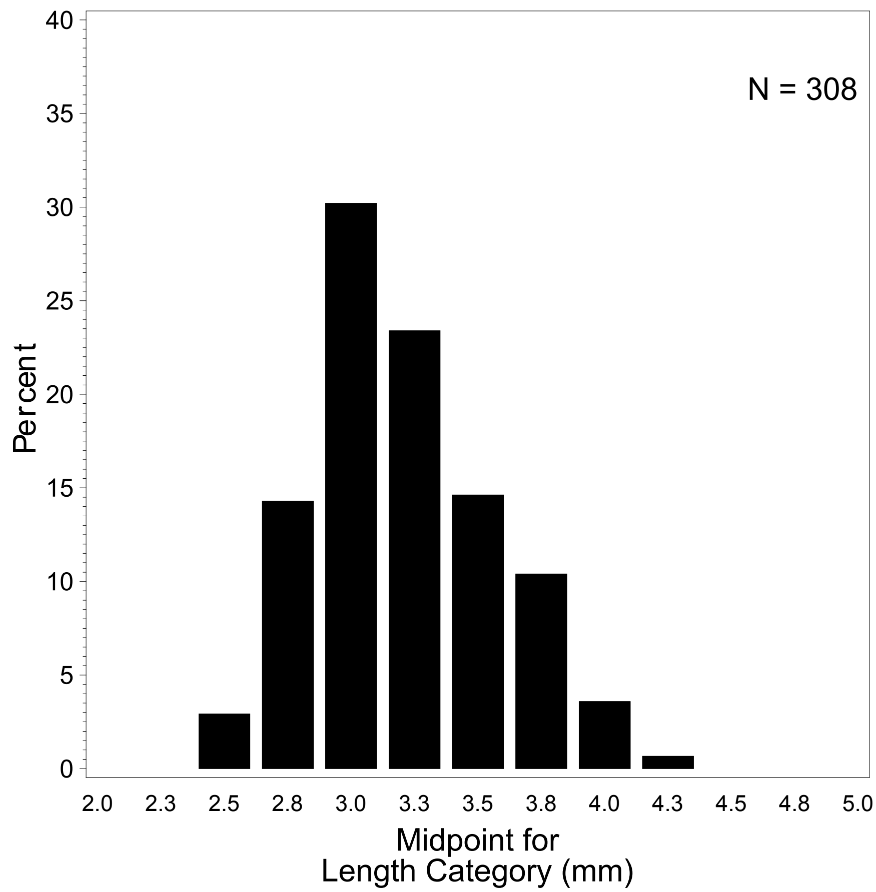


Figure 3-7. Length (mm) frequency distribution for larval bay goby collected at the Potrero Power Plant intake stations.

Larval bay goby were common, occurring in all months and areas sampled (Figure 3-8). Source water concentrations were generally lower than concentrations at the intake stations except in January, July, and December 2001. The highest concentrations of larval bay goby occurred in September 2001 (823/1,000 m^3) at the intake stations and in August 2001 (481/1,000 m^3) at the source water stations. The lowest concentrations (<70/1,000 m^3) in both areas occurred in April 2001.

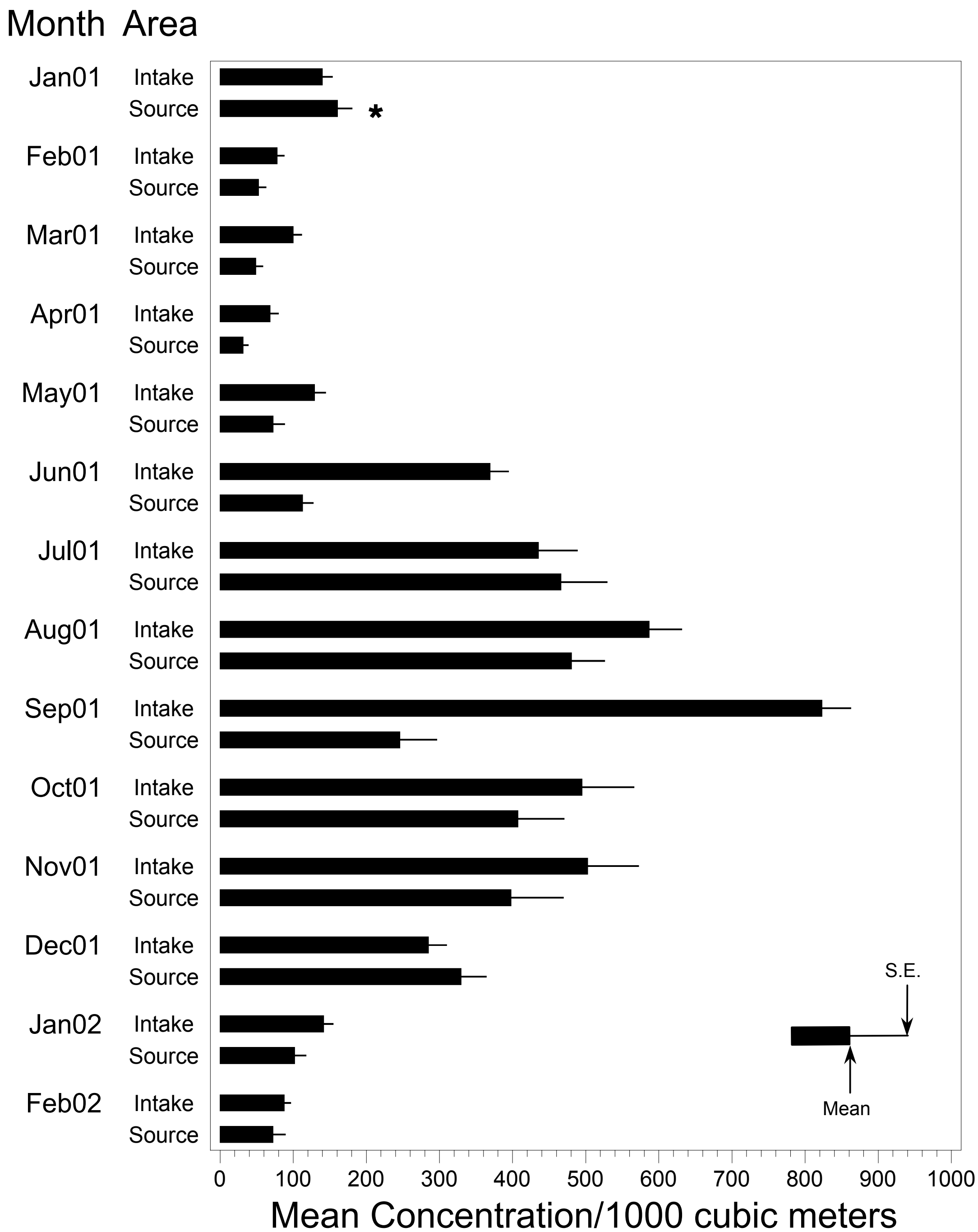
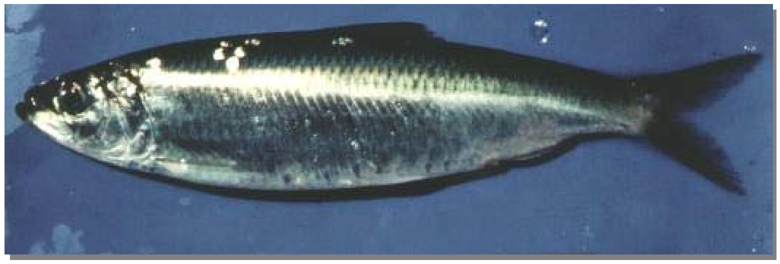


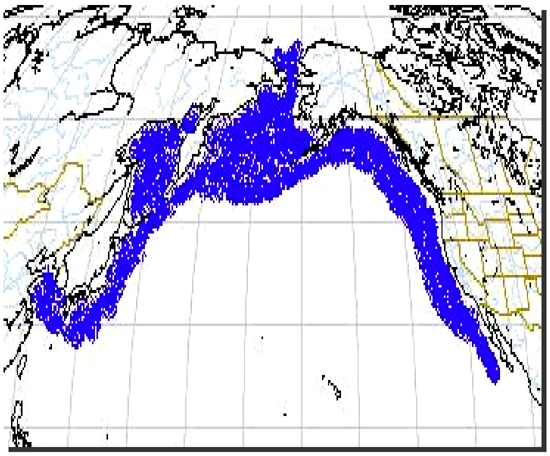
Figure 3-8. Monthly mean concentrations of larval bay goby collected at the Potrero Power Plant intake and source water stations from January 17, 2001–February 22, 2002.

* Surveys at far-field stations started February 27, 2001.

Standard error indicated (+1 SE).

3.3.3 Pacific Herring *Clupea pallasii*





Distribution map for Pacific herring

Range: From northern Baja California to Toyama Bay, Japan, westward to the Yellow Sea.

Life History: Size: up to 46 cm (18 in.) and 550 g (1.2 lb); Age at maturity: two to three years old; Fecundity: 4,000 to 130,000 eggs; Life span: variable (Alaska to 19 years, California to 11 years)

Habitat: A schooling species found near shore to hundreds of miles offshore; spawns in intertidal and sub-tidal zones in bays and estuaries.

Fishery: Commercial: valuable roe fishery; Recreational: small pier and shore angler fishery.

Pacific herring belong to the order Clupeiformes, which contains some of the world's most numerous and economically important fishes (e.g., herring, sardine, anchovy). The distribution of the Pacific herring extends from Baja California to the north Pacific and westward to Japan and the Yellow Sea (Miller and Lea 1972). In North America, Pacific herring range from Baja California north to arctic Alaska (PSMFC 1999) and are most abundant off Alaska and British Columbia. In California, most of the populations are found in the San Francisco and Tomales bay areas (Fitch and Lavenberg 1975). Pacific herring are found from nearshore areas to hundreds of miles off the coast (Love 1996).

Pacific herring are small, streamlined marine fishes, measuring up to 46 cm (18 in.) in length and weighing up to 550 g (1.2 lb) (PSMFC 1999). Fitch and Lavenberg (1975) report that in California they may live to 11 years of age and may exceed 30.5 cm (12 in.) in length. More recently, Leet et al. (2001) indicate that herring may live to nine to 10 years, but individuals older than seven years are rare. California Pacific herring reach first maturity at two years, and 100 percent are mature by three years at a length of 16.5 to 17.8 cm (6.5 to 7 in.) (Love 1996, Leet et al. 2001).

In California, spawning is known to occur in San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor (Leet et al. 2001). California's largest spawning population of Pacific herring occurs in San Francisco Bay (Leet et al. 2001). Fish begin entering protected coastal bays, estuaries, and shallow nearshore environments as early as two months (Eldridge 1977) to three weeks prior to spawning. Decreased salinity may be a cue to initiate spawning (Leet et al. 2001).

Males and females spawn simultaneously over a period of one to seven days (Miller and Schmidtke 1956). The fertilized eggs, broadcast mostly at night, are adhesive and commonly attach to eelgrass, algae, and other intertidal vegetation (Hardwick 1973) and to rocks, pilings and jetties. Thousands of females repeatedly deposit their eggs, which can result in egg masses from 10 to 15 layers thick (about 5 cm [2 in.]) (Love 1996). In large spawning runs, a 9-m (30-ft) wide band of herring eggs may span a distance of 20 miles (32.2 km) along the shoreline (Leet et al. 2001). Females are capable of spawning only once per season. Reilly and Moore (1986) report that fecundity within San Francisco Bay ranges from 8,000 to 44,000 eggs per female. After spawning, most herring return to the ocean (Eldridge 1977). The rate of egg development varies with surrounding water temperature; Pacific herring eggs commonly hatch within 10 to 14 days at 11.8° to 13.5° C (53.2° to 56.3° F) (Wang 1986). Egg mortality has been estimated to range from 20 percent (Hourston and Haegele 1980) to as high as 99 percent (Hardwick 1973, Leet et al. 2001).

Pacific herring early development is well described. The length at hatching is approximately 5.6 to 7.5 mm NL (0.2 to 0.3 in.) (Moser 1996). Shortly after hatching, and as the eyes become pigmented, the planktonic larvae move toward the surface. They tend to concentrate near the surface and can remain for a long time in the area of the spawning grounds. Some larvae, however, have been found several miles out to sea, drifting with the currents (Fitch and Lavenberg 1975). Stevenson (1962) cites Stevenson (1955), Outram (1958) and Tester (1948) to arrive at an estimate of larval herring mortality at 99.5 percent, with a range of 98.9 to 99.7 percent. It takes about 70 days (when they are approximately 26 mm [1.0 in.]) for the larvae to metamorphose into juveniles (Hay 1985). Metamorphosis is complete by 35 mm (1.4 in.) (Stevenson 1962). Juveniles range from 35 to 150 mm (1.4 to 5.9 in.), depending on geographical region (Reilly 1988).

Pacific herring are pelagic, and while some may remain in the bays and estuaries, most return to the ocean after spawning (Eldridge 1977). In the ocean, Pacific herring feed on copepods and euphausiids, but larval and juvenile herring in bays and estuaries are thought to feed on molluscan larvae and other zooplankton (Leet et al. 2001). Leet et al. (2001) also indicate that Pacific herring are a forage species for a diverse array of marine fishes, birds, and mammals (e.g., sturgeon, pelicans, and California sea lions).

The harvest of Pacific herring is a multi-million dollar industry in the United States, with most of the fish coming from Alaska, Washington, and California. In California, the largest herring spawning population utilizes San Francisco Bay. There are small fisheries in the Monterey and San Francisco area that target Pacific herring for bait and food, but the more valuable fishery involves herring eggs (roe).

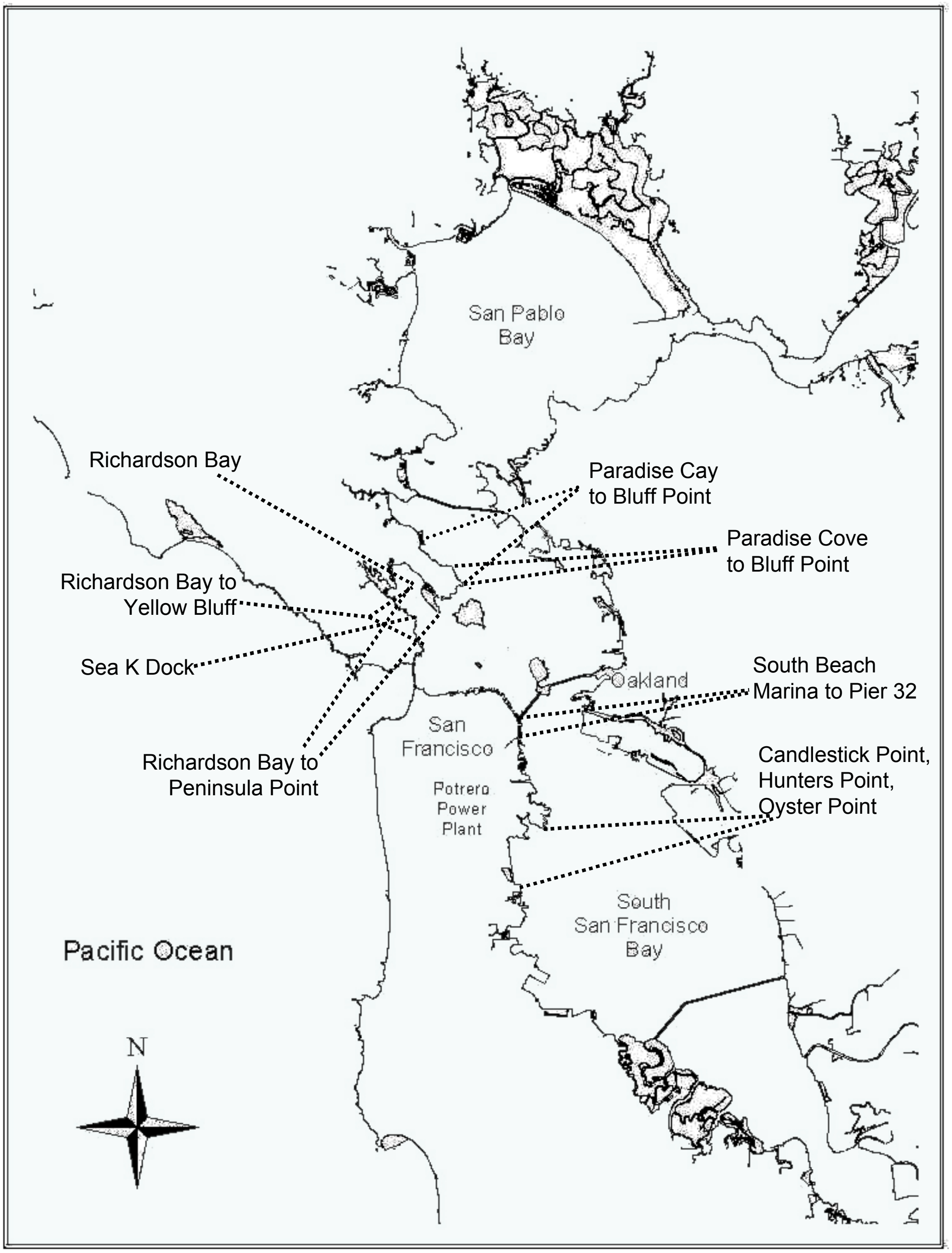
There is a lucrative export market for herring roe, especially for kazunoko kombu (roe-on-kelp) which is considered a delicacy in Japan. A limited number of roe-on-kelp permits are issued for this fishery in San Francisco Bay (11 permits for the 2000–2001 fishery and 10 permits for the 2001–2002 fishery) (Ashcraft and Peterson 2002). Leet et al. (2001) summarize the roe-on-kelp fishery efforts in San Francisco Bay:

> *. . . giant kelp is harvested from the Channel Islands off southern California or Monterey Bay, brought to San Francisco Bay, and suspended from floating rafts or longlines hung beneath piers. Rafts are positioned in locations where herring spawning is expected to occur and then anchored. . . . Suspended kelp is left in the water until egg coverage is sufficient, or spawning has ended.*

The eggs and kelp are harvested together, then salted, packed, and the vast majority is shipped directly to markets in Japan.

2000–2001 San Francisco Pacific Herring Spawning Characterization

The CDFG estimates Pacific herring spawning biomass each year based on the results of hydroacoustic and spawn surveys. Surveys were conducted from November 3, 2000 through March 30, 2001 (Watters and Oda 2001). Spawning locations for the 2000–2001 spawning season are shown in Figure 3-9. Results from the surveys estimated the total spawning biomass at 37,300 short tons (Table 3-3), which was greater than the previous year's estimate of 27,400 tons (Watters and Oda 2001). Two large schools of herring, which made up the majority of the spawning biomass for the season, were observed the week of January 15, 2001 (Plant sampling began January 17, 2001). One school was located in the South Bay and the other in the North Bay. The two schools combined and provided three gill net platoons with the remainder of their quotas the week of January 22, 2001. Four subsequent spawns, from February 5 through March 4, 2001 were believed to have been from this large school (Watters and Oda 2001).



Source: (after Watters and Oda 2001)

Figure 3-9. Locations of Pacific herring spawning events in San Francisco Bay during 2000–2001.

Table 3-3. Approximate spawning dates and preliminary estimates of spawning biomass of San Francisco Bay Pacific herring: 2000–2001.

Approximate Spawn Date(s)	Location(s)	Preliminary biomass estimate (short tons)
December 3, 2000	Richardson Bay eelgrass	100
December 15	Sea K dock – spot spawn	1
December 17	Paradise Cove — Bluff Pt.	200
December 20	San Francisco — South Beach marina to pier 32	700
January 3–8, 2001	Paradise Cove — Bluff Pt.	1,800
January 22–24	Paradise Cay — Bluff Pt.	33,000
February 5	Candlestick Pt., Hunter's Point, Oyster Point	included in Jan. 22–24 estimate
February 11	Richardson Bay eelgrass	included in Jan. 22–24 estimate
February 21–March 4	Richardson Bay eelgrass, marinas, east and west shorelines to Yellow Bluff and Peninsula Pt.	included in Jan. 22–24 estimate
March 27–28	Richardson Bay eelgrass	800
	Total	**37,300 short tons***

* These data were copied directly from source. Based on data shown only in the table, individual biomass estimates do not total 37,300 short tons.

Source: Watters and Oda 2001

2001–2002 San Francisco Bay Pacific Herring Spawning Characterization

Based on hydroacoustic and spawning field surveys (conducted from November 5, 2001 through early April 2002), CDFG estimated the 2001–2002 Pacific herring spawning biomass at 35,400 short tons (Table 3-4) (Oda et al. 2002). This value is slightly lower than the 2000–2001 season's estimate of 37,300 short tons. The approximate spawning date, locations and estimated biomass per spawning event are presented in Table 3-4, and the locations are shown in Figure 3-10.

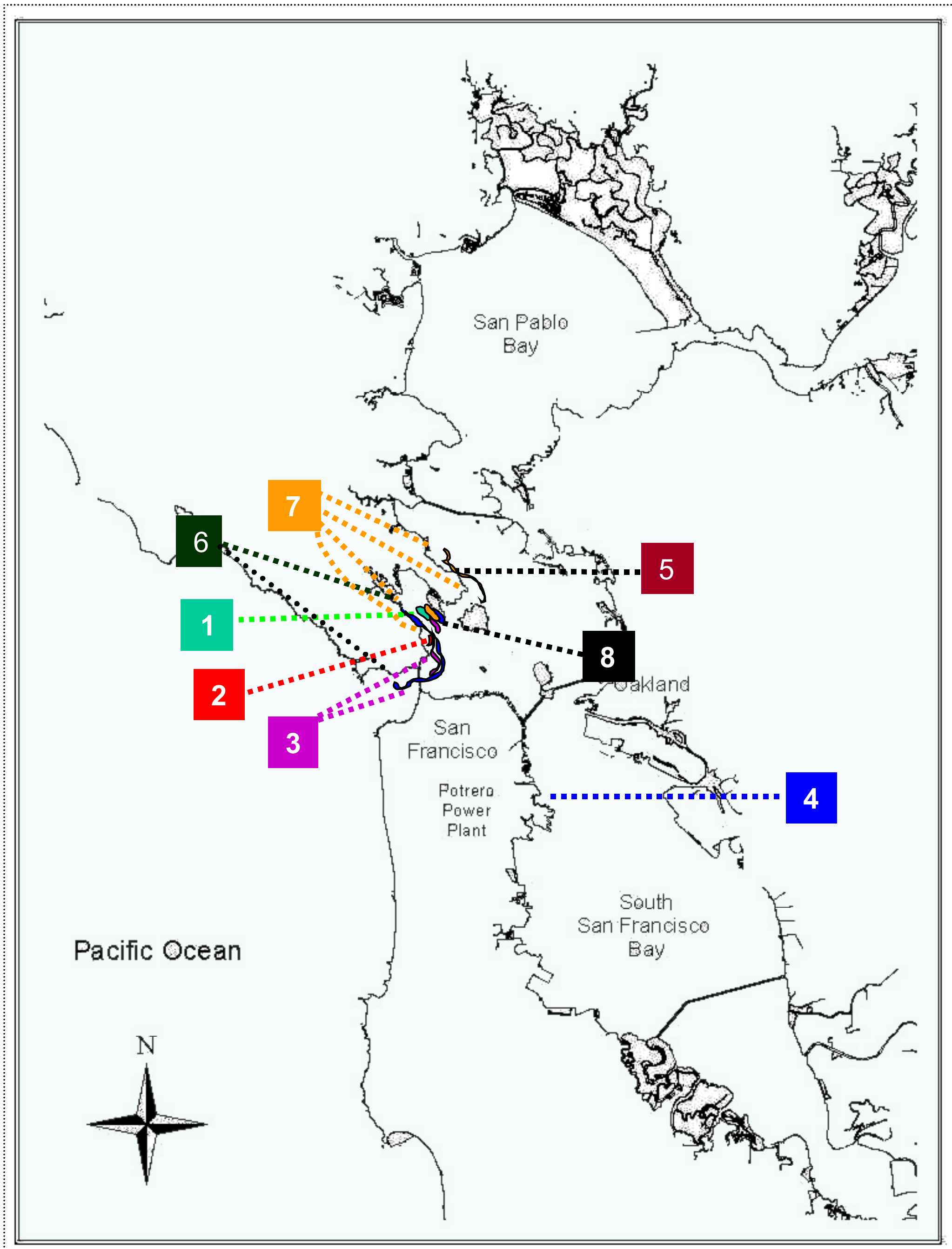
CDFG monitored the first school of Pacific herring in the Bay during the last week of November 2001 in the North Bay, with the first spawning occurring from November 24 to 27 in the Richardson Bay eelgrass bed (Oda et al. 2002). During the first and second weeks of December, herring schools were metered in portions of both the North and South bays. A large school of herring was located south of the Bay Bridge on December 12, 2001, and this school continued to increase in size through the end of the month. There was no evidence of spawning by this school during December. The first large spawning event (estimated biomass of 3,300 short tons) took place from January 3–7, 2002 in the North Bay. The school of herring in the South Bay diminished during the first two weeks of January 2002 followed by a subsequent increase and a spawning event (only a trace amount of biomass) at India Basin (near Hunters Point) on January 17. The largest seasonal spawning event took place in the North Bay starting on January 28, with an estimated biomass of 23,800 short tons (67 percent of the total season estimate) (Oda et al. 2002).

The December gill net fishery platoon only collected about 42 percent of its quota (542 short tons landed), while the odd and even gill net platoons collected a combined total of about 96 percent of their quota. The CDFG exploitation rate for herring during 2001–2002 was 9.3 percent, below the management goal of a maximum removal of 20 percent of the current biomass (Ashcraft and Peterson 2002).

Table 3-4. Approximate spawning dates and preliminary estimates of spawning biomass of San Francisco Bay Pacific herring: 2001–2002.

<table>
<tr><th>Approximate Spawn Date(s)</th><th>Location(s)</th><th>Preliminary biomass estimate (short tons)</th></tr>
<tr><td>November 24–27, 2001</td><td>Richardson Bay eelgrass bed</td><td>100</td></tr>
<tr><td>December 10–13</td><td>Sausalito: Horizons to seal statue & Horizons Restaurant</td><td>100</td></tr>
<tr><td>January 3–7, 2002</td><td>Richardson Bay eelgrass bed, Spinnakers to Lime Point, & Fort Baker</td><td>3,300</td></tr>
<tr><td>January 17</td><td>India Basin</td><td>trace</td></tr>
<tr><td>January 25</td><td>Point Chauncey</td><td>trace</td></tr>
<tr><td>January 28–?</td><td>East of Sausalito channel, Sausalito Park/Edgewater Marine, & Army Corp dock</td><td rowspan="2">23,800</td></tr>
<tr><td>February 3–5</td><td>Richardson Bay eelgrass bed, Spinnakers to at least Bonita Cove, Fort Baker, & Sausalito marinas</td></tr>
<tr><td>February 20–?</td><td>Richardson Bay eelgrass bed</td><td rowspan="2">7,700</td></tr>
<tr><td>February 23–27</td><td>Kiel Cove, Bluff Point to Paradise Cay, & Paradise/Sausalito marinas</td></tr>
<tr><td>March 1</td><td>Richardson Bay eelgrass bed</td><td>400</td></tr>
<tr><td></td><td>Total</td><td>35,400 short tons</td></tr>
</table>

Source: Oda et al. 2002



Source: After Oda et al. 2002 and presentation materials from the herring fishery public meeting April 4, 2002.

(1) Richardson Bay. (2) Sausalito Waterfront (3) Richardson Bay, Sausalito, Yellow Bluff, Ft. Baker, Golden Gate (4) India Basin (5) Point Chauncey (6) Richardson Bay and marina, Sausalito, Yellow Bluff, Ft. Baker, Pt. Diablo (7) Richardson Bay & marinas, Kiel Cove, Bluff Point, RTC, Paradise Beach, Paradise Cay (8) Richardson Bay

Figure 3-10. Locations of Pacific herring spawning events in San Francisco Bay during 2001–2002.

Pacific Herring Results

Concentrations of larval Pacific herring by survey are shown in Figure 3-11. Pacific herring larvae were collected at the Plant intake stations in 6 of the 14 months surveyed. They comprised 23 percent of the annual average concentration of all larval fish taxa collected at the intake stations compared to 19 percent among the source water stations from February 27, 2001–February 22, 2002 (Figure 3-3). Peak concentration (3,085/1,000 m^3) of herring larvae at the intake stations occurred during the February 21–22, 2002 survey.

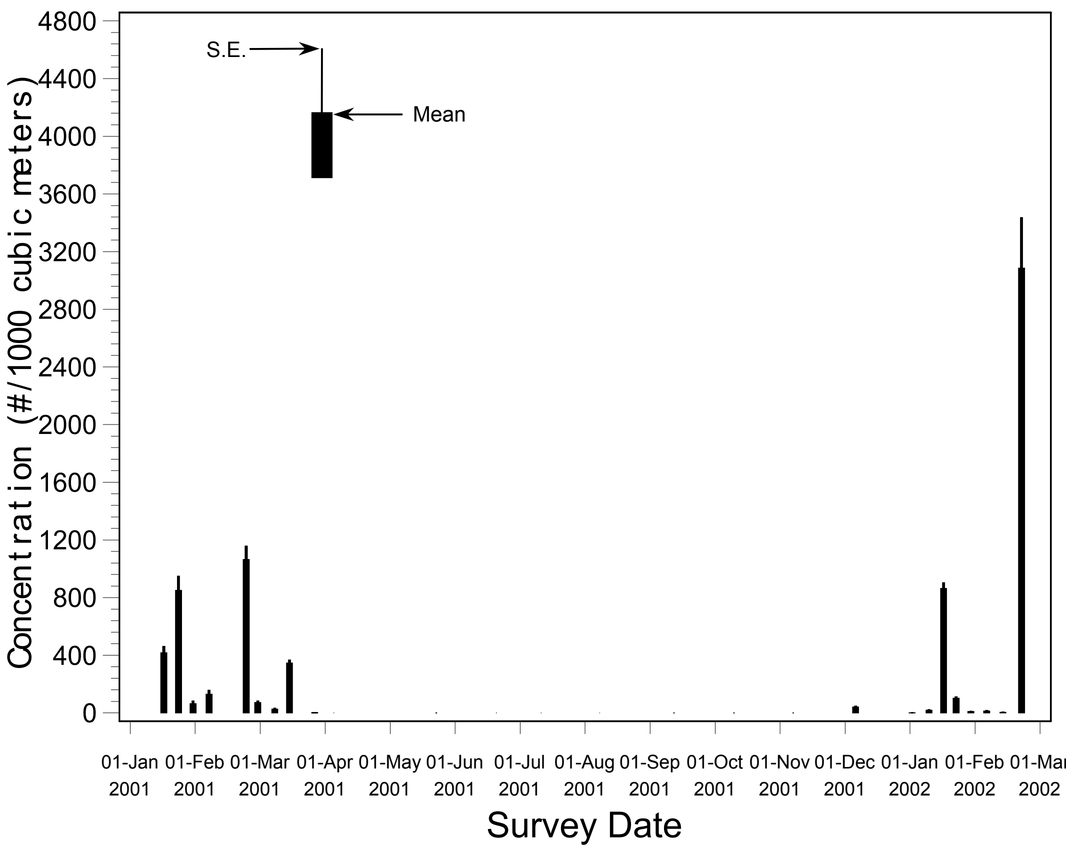


Figure 3-11. Mean concentrations of larval Pacific herring collected at the Potrero Power Plant intake stations from January 17, 2001–February 22, 2002.

Standard error indicated (+1 SE).

Lengths were recorded for 286 larval Pacific herring collected at the Plant intake stations (Figure 3-12). The smallest herring larva measured from intake station samples was 5.1 mm (0.2 in.) NL. This is less than the estimated hatch length of 5.6 to 7.5 mm NL (0.2 to 0.3 in.) reported in Moser (1996). Handling and preservation can lead to the shrinkage of larval tissues (Theilacker 1980), but the smaller length could also result from natural variation. On average, Pacific herring larvae collected at the Plant intake stations were 9.0 mm (0.4 in.) NL (*S.E.* = 0.1 mm) and the longest individual measured was 20.8 mm (0.8 in.) NL.

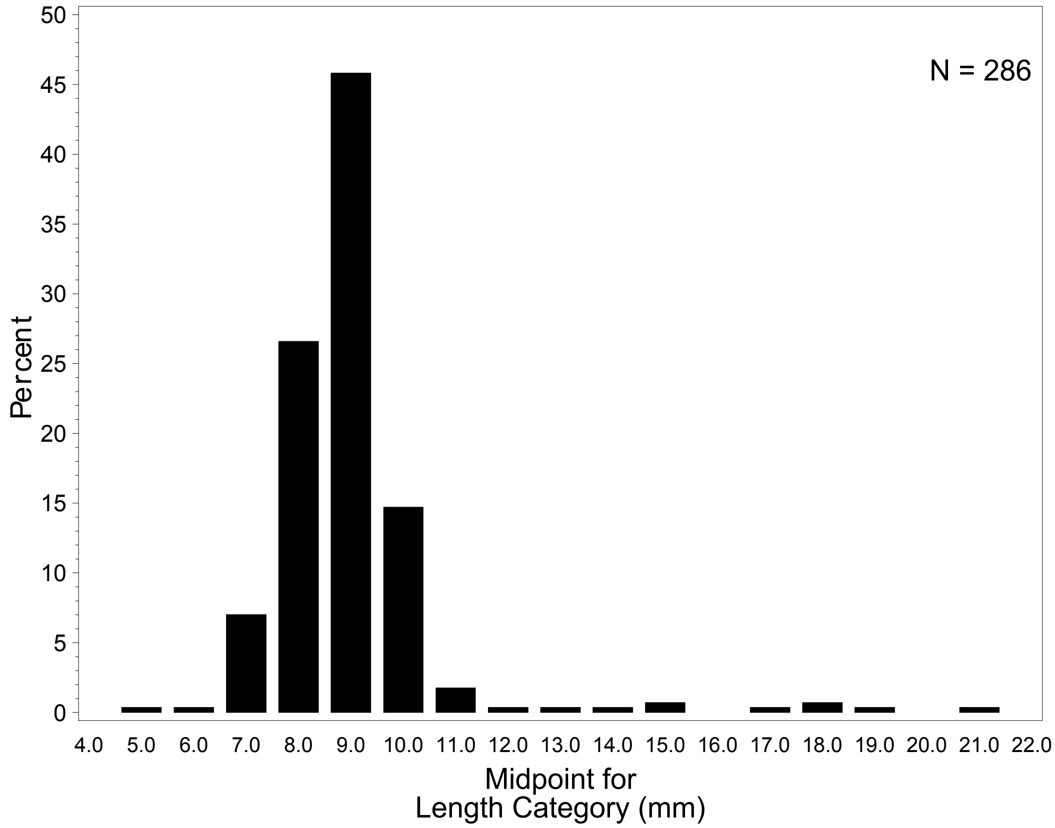


Figure 3-12. Length (mm) frequency distribution for larval Pacific herring collected at the Potrero Power Plant intake stations.

Herring larvae were collected at source water stations in 7 of the 14 months surveyed (Figure 3-13). Concentrations at source water and intake stations conform with the reported spawning period of December through March (Moser 1996). Herring larvae occurred in similar concentrations at the intake and source water stations in 5 of the months surveyed and occurred only at the source water stations in April 2001 (concentration = 3.3/1,000 m^3). Highest concentration at source water stations occurred in February 2002 (963/1,000 m^3).

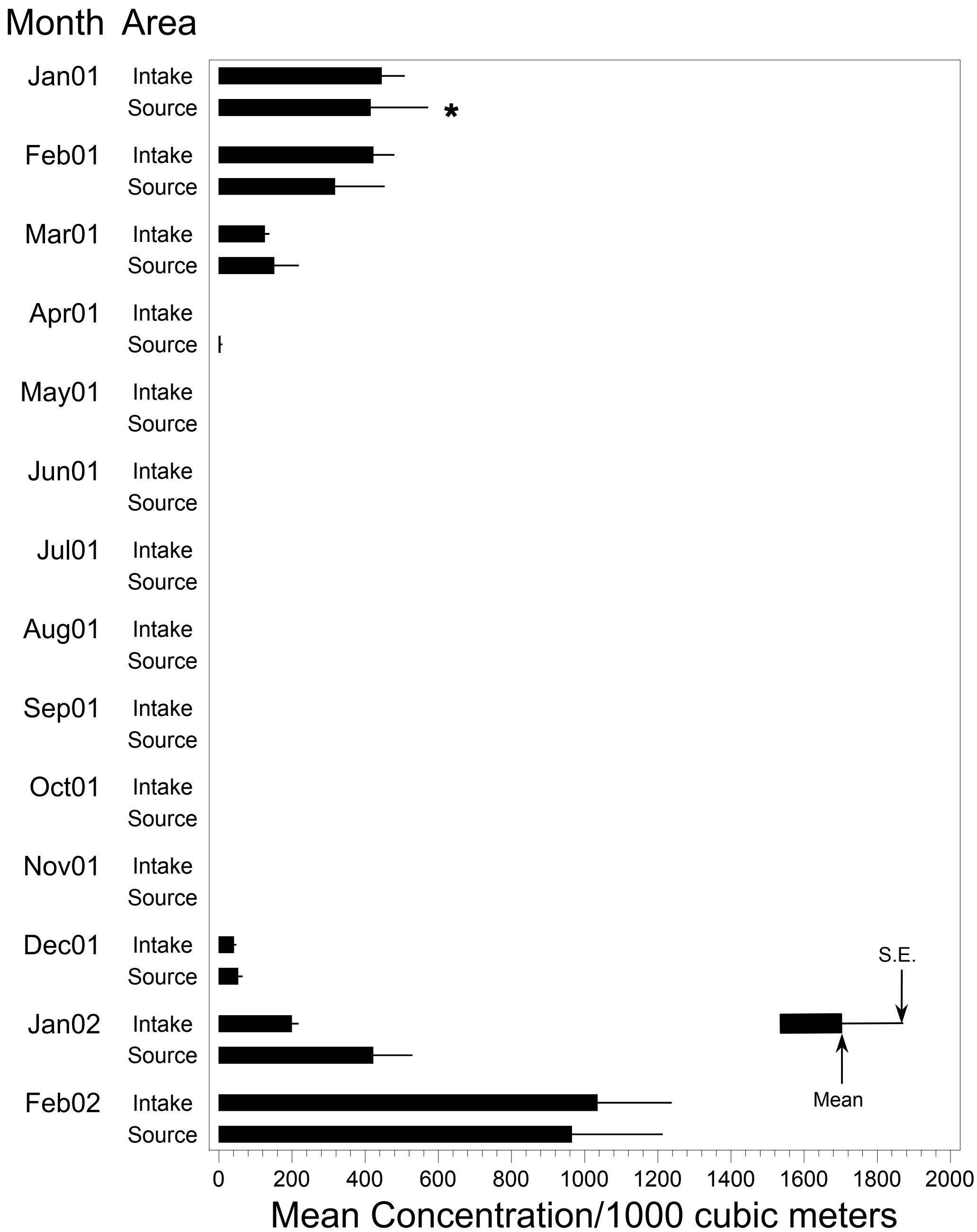


Figure 3-13. Monthly mean concentrations of larval Pacific herring collected at Potrero Power Plant intake and source water stations from January 17, 2001–February 22, 2002.

* Surveys at far-field stations started February 27, 2001.

Standard error indicated (+1 SE).

3.3.4 Unidentified Gobies Gobiidae

The family Gobiidae is composed of small, demersal fishes that are found worldwide in shallow tropical and subtropical environments (Moser 1996). The family contains around 1,875 species in 212 genera (Nelson 1994). Twenty-one goby species from 16 genera occur from the northern California border to south of Baja California (Moser 1996) and many of these species are common in the Potrero Power Plant study area (Miller and Lea 1972, Love et al. 1996). Adult cheekspot goby *Ilypnus gilberti*, yellowfin goby *Acanthogobius flavimanus* (an introduced species), and bay goby *Lepidogobius lepidus* were collected in the 2001 otter trawl surveys (Tenera 2002). Arrow goby *Clevelandia ios* juveniles were identified during the 1978–1979 Potrero Power Plant entrainment study (PG&E 1980). Adult bay goby, chameleon goby *Tridentiger trigonocephalus* (an introduced species), yellowfin goby, cheekspot goby, and arrow goby have been collected during 1980–1999 CDFG otter trawl surveys at Station 109 near the Plant (Baxter et al. 1999, CDFG unpublished otter trawl data).

Goby larvae look distinctly different from all other families of larval fishes in the study area. They are, however, similar to each other at all stages of their development, making them difficult to identify to species. In early developmental stages, the bay goby shares morphologic and meristic similarities with the arrow goby, and they are not easily separated. Moser (1996) indicates that arrow goby, cheekspot goby, and the shadow goby *Quietula y-cauda* (not found in the vicinity of the Plant) cannot be differentiated during any larval stage. Brothers (1975) reported difficulty in separating developed arrow and cheekspot goby that were less than 65 mm (2.6 in.) long. Several goby species are distinguishable at nearly all stages of larval development (e.g., yellowfin goby, longjaw mudsucker *Gillichthys mirabilis*, and blackeye goby *Coryphopterus nicholsii*). Larval gobies collected during Potrero Power Plant sampling that could not be identified to the species level were left at the family level (i.e., Gobiidae). Species comprising this group are likely arrow goby and cheekspot goby.

Members of the family Gobiidae share many life history characteristics. Adult gobies are oviparous and produce demersal eggs that are elliptical in shape, typically adhesive, and attached to a nest substratum at one end (Wang 1986, Matarese et al. 1989, Moser 1996). Most species that occur in San Francisco Bay inhabit burrows in mud flats and other shallow regions of bays and estuaries (Miller and Lea 1972). The fecundity of the arrow goby ranges from 750 to 1,000 eggs (Wang 1986) and spawning may occur multiple times per year (Brothers 1975). Goby larvae enter the plankton following hatching and remain in this pelagic phase until they transform and become benthic-oriented juveniles.

The duration of the planktonic phase varies greatly within the family and is not well described for most of the goby species in the study area. The period of entrainment risk used in the *ETM* model was estimated from larval arrow goby growth rates (Brothers 1975) and average reported lengths at hatching and early larval developmental stages (Moser 1996).

Unidentified Gobies Results

Concentrations of larval unidentified gobies by survey are shown in Figure 3-14. They comprised 18 percent of the annual average concentration of all larval fish taxa collected at the intake stations compared to 24 percent among the source water stations from February 27, 2001–February 22, 2002 (Figure 3-3). They were collected at the Plant intake stations in all months of the study. The greatest concentrations of larvae at the intake stations occurred between March and August 2001. The peak concentration (483/1,000 m^3) of unidentified goby larvae occurred in July 2001.

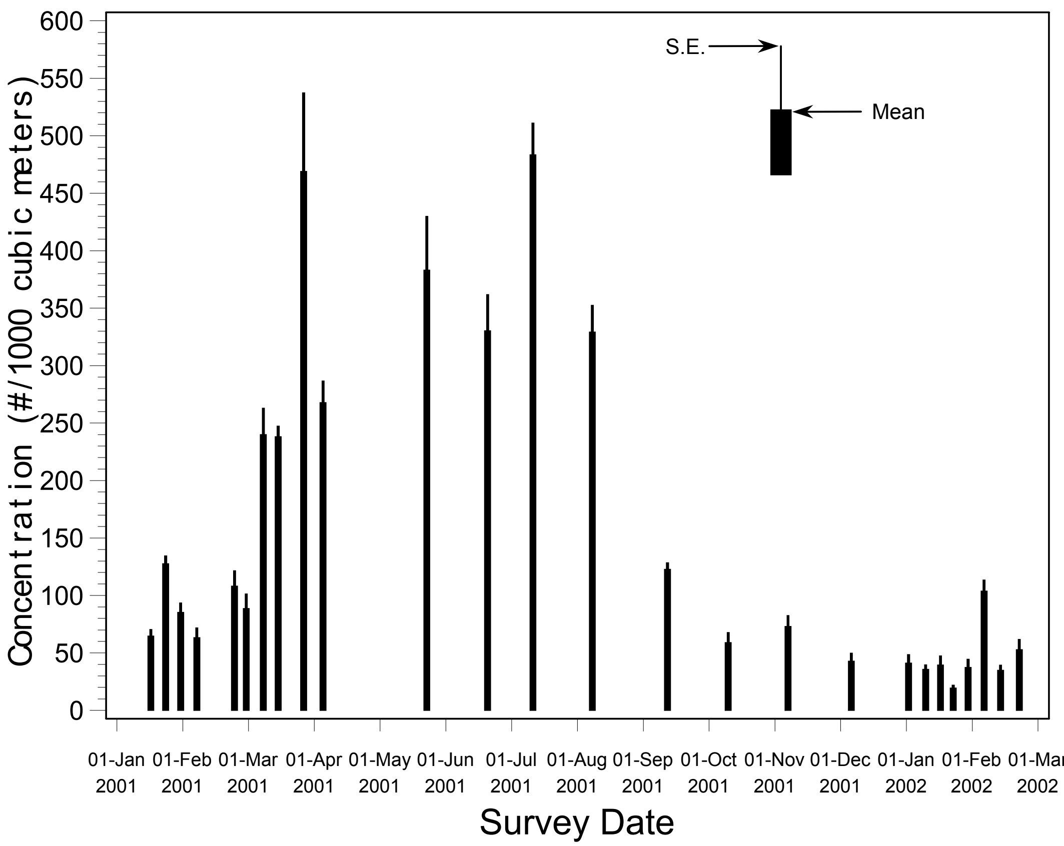


Figure 3-14. Mean concentrations of larval unidentified gobies collected at the Potrero Power Plant intake stations from January 17, 2001–February 22, 2002.

Standard error indicated (+1 SE).

Lengths were recorded for 311 larval unidentified gobies collected at the Plant intake stations. The smallest goby larva measured was 2.1 mm (0.08 in.) NL (Figure 3-15). This is very near the smallest reported hatch length (Moser 1996) for the likely members of this group (i.e., arrow and cheekspot gobies). On average, unidentified goby larvae collected at the intake stations were 4.1 mm (0.16 in.) NL (*S.E.* = 0.1 mm) and the longest individual measured was 23.0 mm (0.9 in.) NL. The majority of goby larvae entrained were in the early stages of larval development (88 percent were between 2 and 5 mm [0.08 and 0.2 in.] NL).

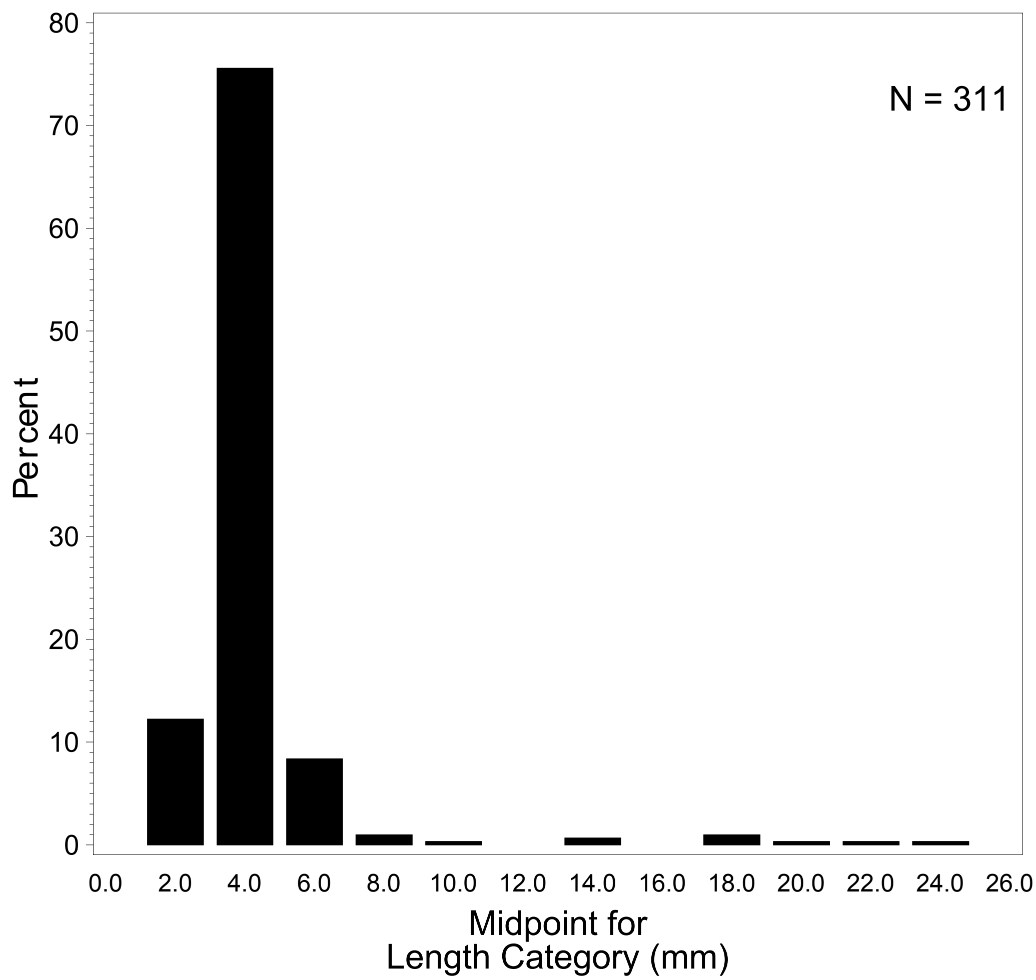


Figure 3-15. Length (mm) frequency distribution for larval unidentified gobies collected at the Potrero Power Plant intake stations.

Unidentified gobies were common in our samples, occurring in all months at both the intake and source water stations (Figure 3-16). During most months, they occurred in higher concentrations at source water stations than at intake stations. Peak source water station concentration occurred in April 2001 (1,050/1,000 m^3). Adult arrow goby and cheekspot goby are known to be abundant as adults near the vicinity of the Plant (Baxter et al. 1999, CDFG unpublished otter trawl data), but cannot be easily identified as larvae. The reported spawning periods of these two species (Moser 1996) are similar to the peak concentrations observed in our data.

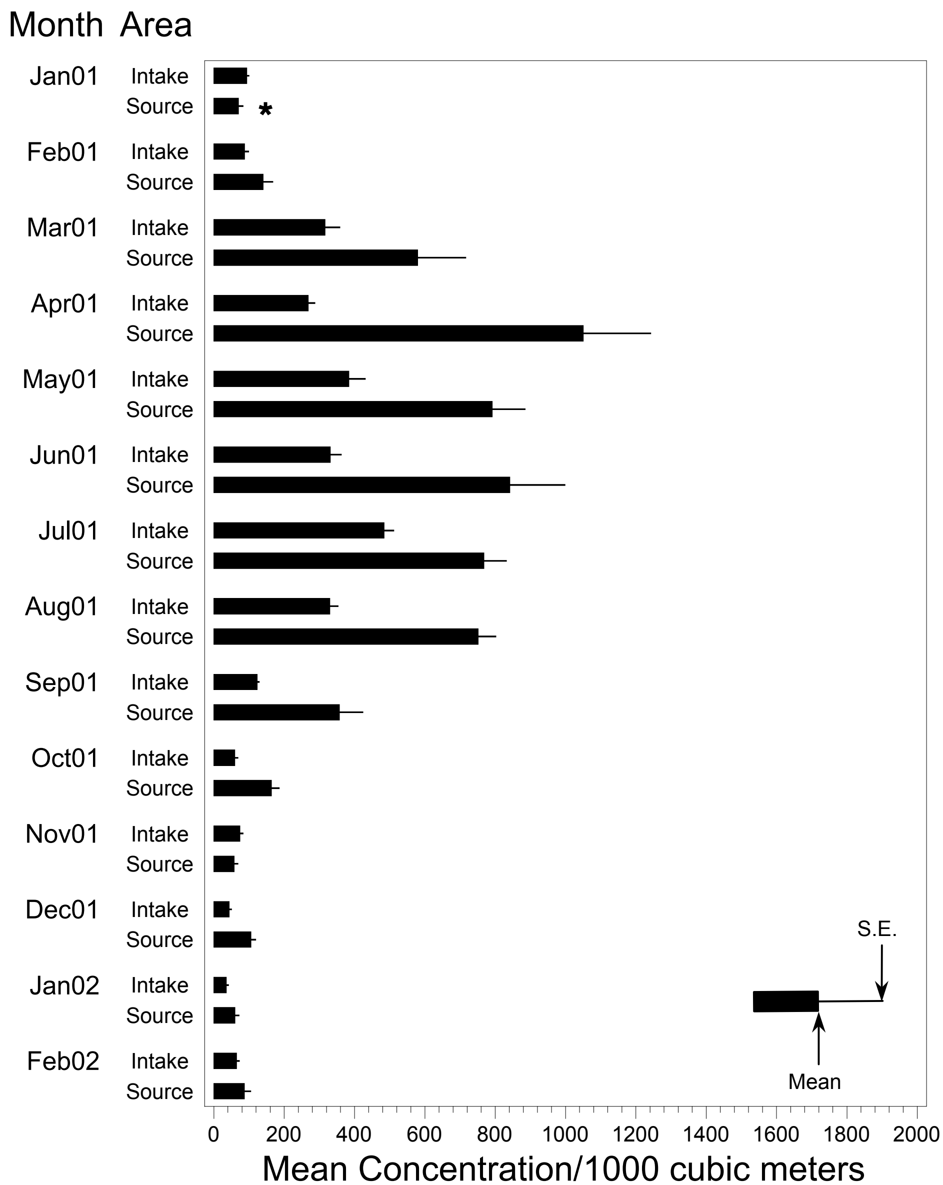


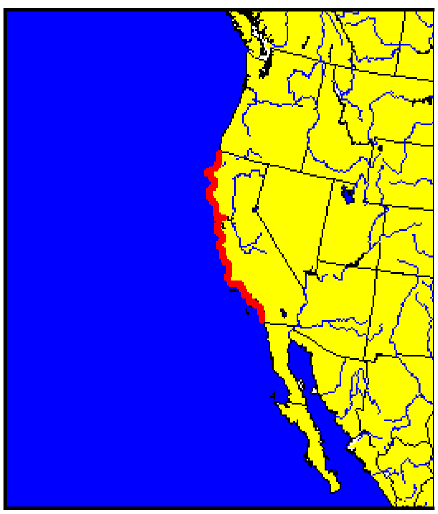
Figure 3-16. Monthly mean concentrations of larval unidentified gobies collected at Potrero Power Plant intake and source water stations from January 17, 2001–February 22, 2002.

* Surveys at far-field stations started February 27, 2001.

Standard error indicated (+1 SE).

3.3.5 Yellowfin Goby *Acanthogobius flavimanus*

(http://www.fish.metro.tokyo.jp/tokyowatching/tokyozukan/mahaze.htm)



Distribution map for yellowfin goby (California)

***Range*:** Worldwide, native species of Japan, South Korea, and China; introduced in San Francisco Bay and along California coast.

***Life History*:** Size: to 245 mm (9.5 in.); size at maturity: variable (see text); Fecundity: 6,000 and 32,000 eggs in Japan; Life span: variable, see text.

***Habitat*:** Shallow bays.

***Fishery*:** Commercial trap fishery; recreational hook-and-line fishery.

Yellowfin goby *Acanthogobius flavimanus* belong to the family Gobiidae. They are native to Japan, South Korea, and China, where they range from marine to fresh water (Brittan et al. 1963, Haaker 1979). This goby is catadromous in Japan, moving from fresh water to saline mudflats to spawn (Herbold and Moyle 1989). Yellowfin goby are an introduced (non-indigenous) species in the San Francisco Bay area and along the California coast.

The first documented collection of a yellowfin goby in California occurred in January 1963 in a midwater trawl from the San Joaquin River off Prisoner's Point, Venice Island. The fish was 155 mm (6 in.) total length (TL) and was entering its second year (Brittan et al. 1963). Wang (1986) suggests that yellowfin goby could have been introduced to the Sacramento-San Joaquin Delta as early as the 1950s. Explanations for its introduction into the Sacramento-San Joaquin

Delta include transport of adults in the fouled seawater system of ships (Brittan et al. 1963), transport of eggs or larvae in ballast water or on fouling organisms on ships' hulls (Haaker 1979), and import of eggs with oyster spat from Japan (Eschmeyer et al. 1983).

Adult yellowfin goby were widespread in the Bay and Delta by 1966 (Brittan et al. 1970) and are now well established throughout central and southern California (Eschmeyer et al. 1983). They are common throughout the Bay and Delta and have also been collected from Foster City Lagoon, Lake Merritt, and the salt ponds in Alviso; the Delta north of the Sacramento Ship Channel, and south to the Tracy Pumping Plant and the Stockton Deepwater Channel; the Delta-Mendota Canal at Newman, and the San Luis Reservoir in Merced County; and Contra Loma Reservoir in Contra Costa County (Brittan et al. 1970, McGinnis 1984, Cohen and Carlton 1995). Yellowfin goby have also been reported from Elkhorn Slough in Monterey County (Kukowski 1972), Tomales Bay, and Estero Americano in Baja California (Miller and Lea 1972), and one specimen was collected from Bolinas Lagoon (Brittan et al. 1970). They were collected in low numbers (less than 0.2 percent of the total number of fishes) by otter trawl during the 2001 Potrero Power Plant surveys (Tenera 2002). Adult yellowfin goby comprised 0.6 percent of the total number of fishes collected during CDFG otter trawl surveys at Station 109 from 1980–1999 (Baxter et al. 1999, CDFG unpublished otter trawl data).

Yellowfin goby are used differently over their native range compared with their introduced range in California. This goby is considered a delicacy in Japan (Eschmeyer et al. 1983), but in the Bay Area is primarily used as bait for striped bass (Cohen and Carlton 1995). Yellowfin goby supports a commercial trap fishery in the Bay and individual anglers collect it by hook-and-line (Cohen and Carlton 1995). From 1990–1999, CDFG landing data shows that 17,822 pounds of yellowfin goby (Market Category 487) were landed north of the San Francisco-Oakland Bay Bridge and 44 pounds were landed south of the Bay Bridge (CDFG unpublished yellowfin goby data). However, reliance on CDFG market category data has historically been problematic when discussing landings of a single species, since market categories are often composed of more than one species of fish. In San Francisco Bay, landings of yellowfin goby may be combined with those of the longjaw mudsucker.

The early life history of yellowfin goby is similar to other members of the family Gobiidae. Females are oviparous, laying demersal, adhesive eggs in burrows guarded by males until the planktonic larvae hatch (Moser 1996). Wang (1986) indicates that their larvae were collected in the Sacramento-San Joaquin estuary between December and July, corroborating Moser's (1996) report of spawning activity in winter and spring. Female yellowfin goby in Japan lay between 6,000 and 32,000 eggs and may be terminal spawners, with most dying after the eggs are released (Miyazaki 1940, cited in Wang 1986). Wang's (1986) fecundity estimate of 18,000 eggs per female falls within the range reported by Miyazaki (1940).

Yellowfin goby larvae are planktonic, initially remaining near the bottom before moving up into the water column (Jahn and Lavenberg 1986, Moser 1996). Yellowfin larvae hatch at 4.5 to 4.6 mm (approximately 0.18 in.), begin to have limited swimming ability between 6.7 to 8.5 mm (0.26 to 0.33 in.), and transform at around 16 to 18 mm (0.6 to 0.7 in.) (Moser 1996). Upon transformation they settle to the benthos and begin their juvenile life stage (Baker 1979).

Reported estimates for yellowfin goby longevity, age at maturity, and other demographic parameters vary in the scientific literature. Hoshino et al. (1993) indicate that yellowfin goby in Japan live to three years while Baker (1979) produced an estimate of four years in the San Francisco Bay Area. Age at maturity estimates range from less than one year (Baker 1979) to more than one year (Miyazaki 1940 [Japan], Middleton 1982 [Australia], Wang 1986 [California]) to as high as two to three years (Brittan et al. 1970 [California]).

No estimates of larval growth or survivorship have been reported for yellowfin goby. Brothers (1975) estimates a time period of 50 days from hatching to settlement for three sympatric gobies (arrow goby, cheekspot goby, and shadow goby) from Mission Bay, California. This estimate and estimates of hatch (4.6 mm; 0.2 in.) and transformation length (17 mm; 0.7 in.) derived from Moser (1996) were used to estimate a larval growth rate of 0.249 mm per day. Brothers (1975) also provided a finite mortality estimate of 0.983 for arrow goby *Clevelandia ios* over the two-month time period from egg laying through settlement. We used this mortality estimate for calculating yellowfin goby survivorship.

Yellowfin Goby Results

Concentrations of larval unidentified goby from each intake survey are shown in Figure 3-17. They comprised 15 percent of the annual average concentration of all larval fish taxa collected at the intake stations compared to 18 percent among the source water stations from February 27, 2001–February 22, 2002 (Figure 3-3). Yellowfin goby larvae were collected at the intake stations in 9 of the 14 months surveyed. The highest concentrations of larval yellowfin goby at the intake stations are consistent with reported winter and spring spawning periods (Moser 1996). The peak concentration of larval yellowfin goby at the intake stations (943/1,000 m^3) occurred during the March 8, 2001 survey.

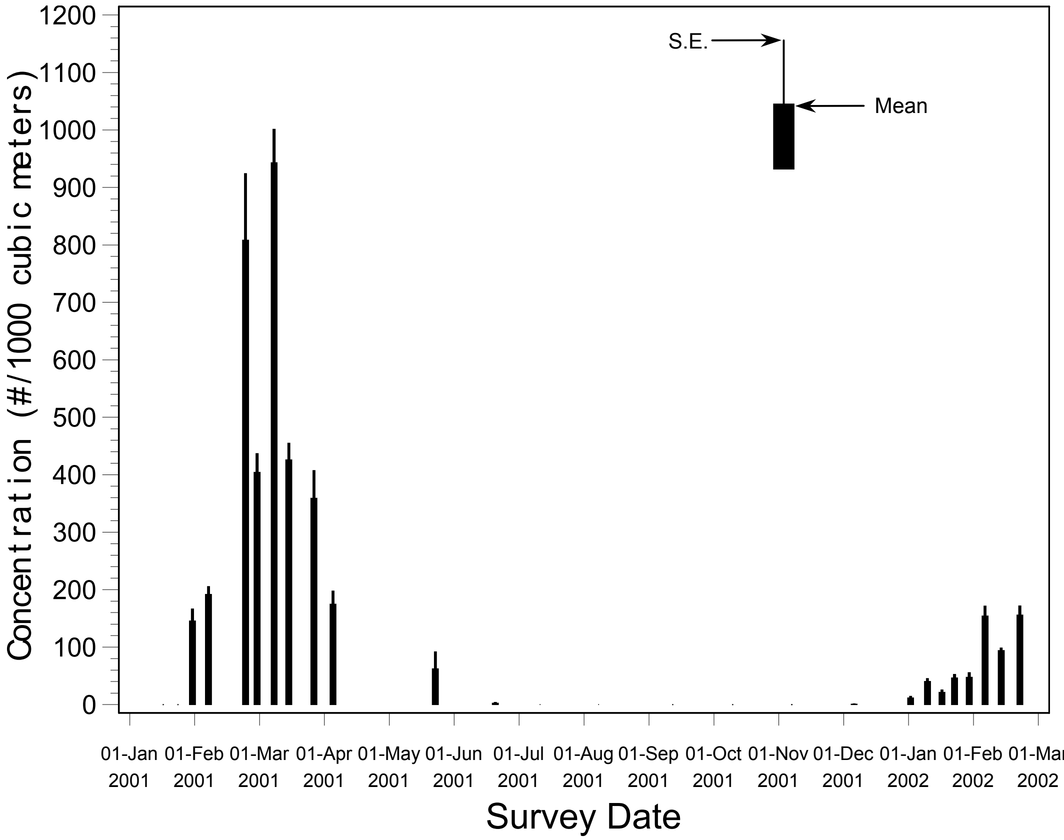


Figure 3-17. Mean concentrations of larval yellowfin goby collected at the Potrero Power Plant intake stations from January 17, 2001–February 22, 2002.

Standard error indicated (+1 SE).

Lengths were measured from 299 larval yellowfin goby collected at the Plant intake sampling stations. The smallest yellowfin goby larva measured was 3.7 mm (0.1 in.) NL (Figure 3-18). This is less than the estimated hatch length of 4.5 mm (0.2 in.) NL reported in Moser (1996). Handling and preservation can lead to the shrinking of larval tissues (Theilacker 1980), but smaller-than-reported hatch lengths could also result from natural variation of length at hatching. On average, yellowfin goby larvae collected at the intake stations were 5.4 mm (0.2 in.) NL (*S.E* = 0.03 mm) and the longest individual measured was 9.2 mm (0.4 in.) NL. The majority of yellowfin larvae collected at the intake stations were in the early stages of larval development.

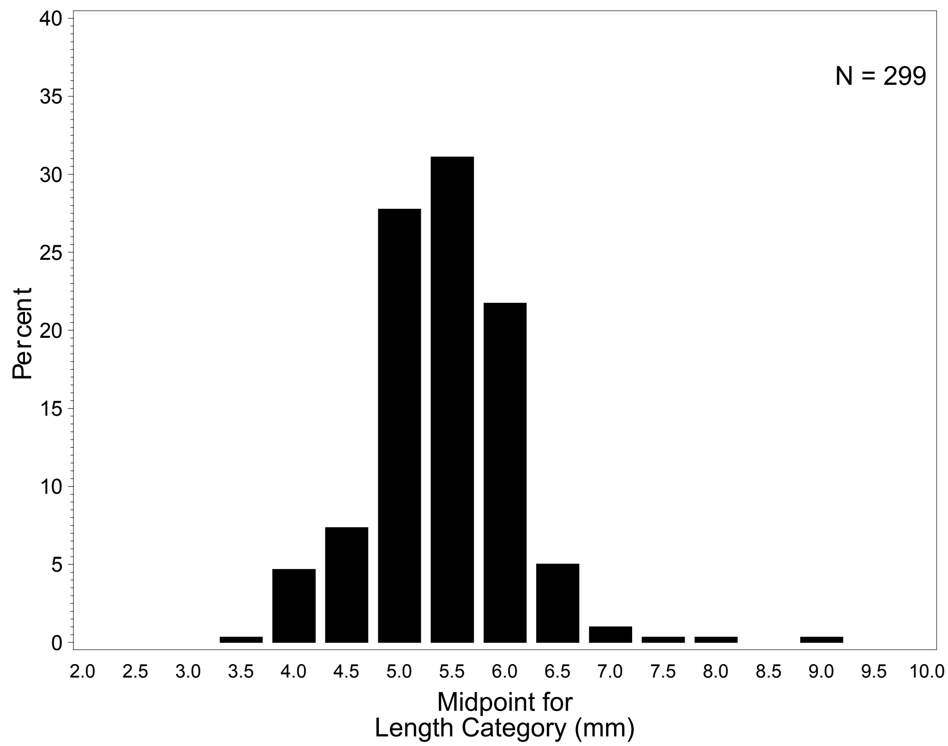


Figure 3-18. Length (mm) frequency distribution for larval yellowfin goby collected at the Potrero Power Plant intake stations.

Larval yellowfin goby were relatively common in our intake and source water samples. They were present in all months of the study period except November 2001 (Figure 3-19). The peak concentration (1,037/1,000 m^3) occurred during March 2001 at source water stations. High concentrations of larval yellowfin goby in our study area conform well to their reported spawning periodicity of winter through spring (Moser 1996).

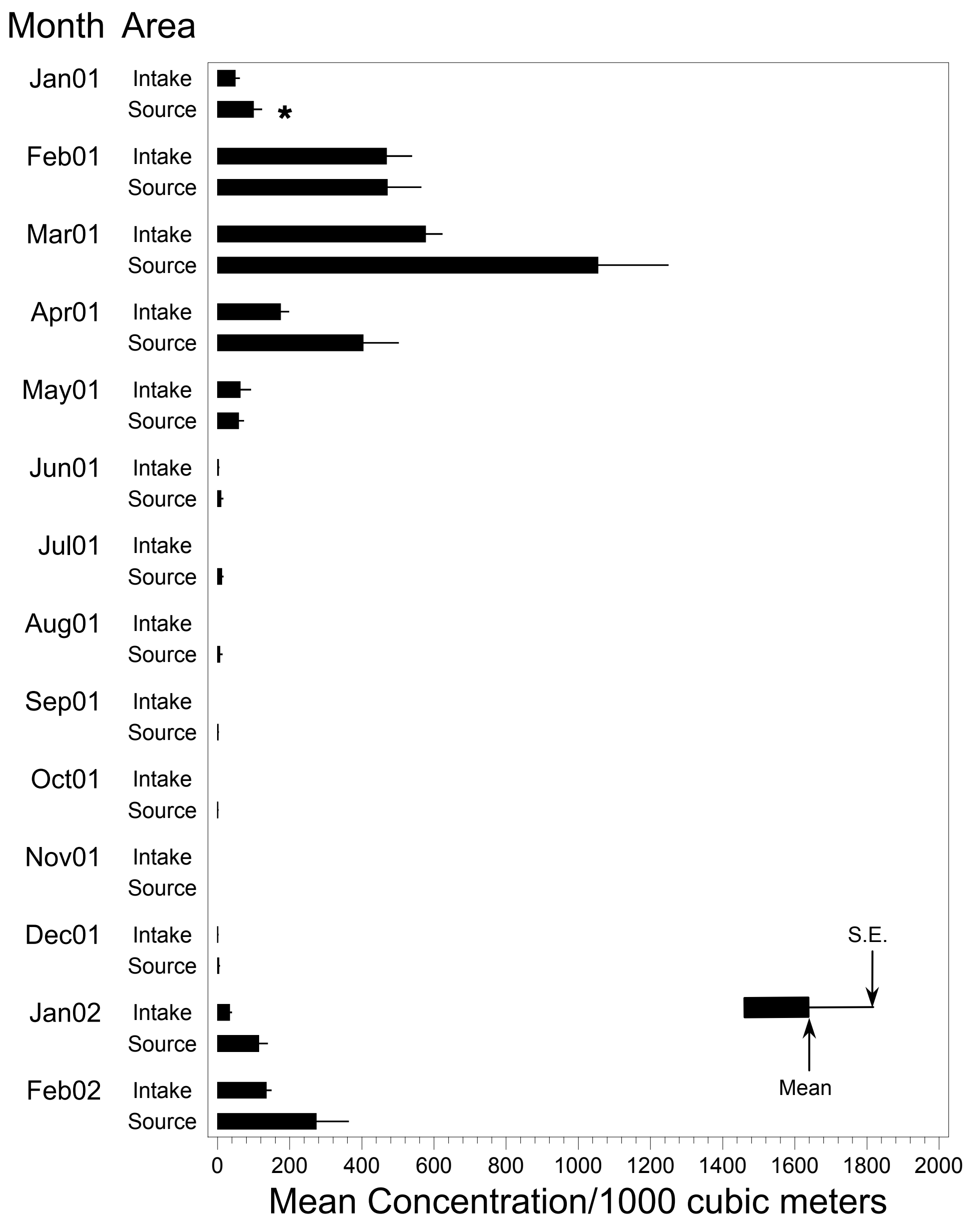
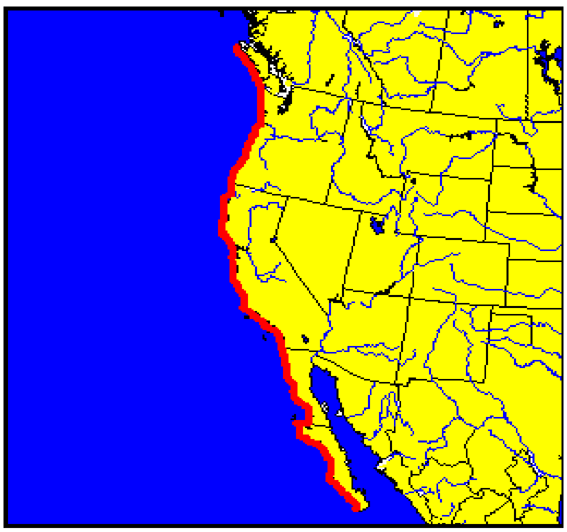


Figure 3-19. Monthly mean concentrations of larval yellowfin goby collected at Potrero Power Plant intake and source water stations from January 17, 2001–February 22, 2002.

* Surveys at far-field stations started February 27, 2001.

Standard error indicated (+1 SE).

3.3.6 Northern Anchovy Engraulis mordax



Distribution map for northern anchovy

Range: From British Columbia to southern Baja.

Life History: Size: to 229 mm (9 in.); Size at maturity: 152 mm (6 in.); Fecundity: spawn 2 to 3 times a year, releasing from 2,700 to 16,000 eggs per batch; Life span: to 7 years.

Habitat: Pelagic; found in surface waters down to depths of 300 m (1,000 ft).

Fishery: Commercial fishery for reduction, human consumption, live bait, dead bait.

The northern anchovy is one of the approximately 139 engraulids in the family Engraulididae (the anchovies) that occur in the one million square kilometers of the Eastern Pacific studied by CalCOFI between the Oregon-California border and the tip of Baja California (Moser 1996). Other representatives of this family that occur in central California waters are the deepbody anchovy *Anchoa compressa*, slough anchovy *Anchoa delicatissima*, and the anchoveta *Centengraulis mysticetu*s (Miller and Lea 1972, Eschmeyer et al. 1983, Love et al. 1996).

Three sub-populations of northern anchovy are recognized and managed separately along the Pacific coast of the United States (Lo 1985, PFMC 1990, 1998, Love 1996). The northern sub-population occurs from the northern limit of their range in British Columbia south to San Francisco, the central sub-population occurs from San Francisco to northern Baja California with the bulk of these fish found in the Southern California Bight, and the southern sub-population is found along the southern coast of Baja, the southern limit for this species. They range from the surface to depths of over 300 m (1,000 ft; Love 1996). Northern anchovy eggs and larvae have been collected 480 km (298 mi) from shore (Hart 1973) and the adults can exhibit extensive movements within their range (Love 1996). They tend to occur closer to the shoreline in the summer and fall and move offshore during the winter (Hart 1973).

Reproductive activity of northern anchovy varies within their range. Off southern and central California they can reach sexual maturity by the end of their first year at 110 to 130 mm (4.3 to 5.12 in.) TL, with all individuals maturing by four years of age and 152 mm (6 in.) TL (Hubbs 1925, Pike 1951, Clark and Phillips 1952, Daugherty et al. 1955, Hart 1973); off Oregon and Washington they do not mature until their third year (Love 1996). Leet et al. (2001) state that all northern anchovy are mature by two years and that the proportion of mature one-year-olds is temperature dependent and has been observed to range between 47 and 100 percent. In southern California, anchovy spawn year-round with peaks during late winter to spring (Love 1996, Moser 1996). In Oregon and Washington, spawning can occur from mid-June to mid-August (Love 1996).

Northern anchovy are multiple spawners and females spawn batches of eggs at intervals as short as 6 to 10 days (Schlotterbeck and Connally 1982, Love 1996, Leet et al. 2001). Spawning normally occurs at night in the upper layers of the water column (Hart 1973). An early estimate of northern anchovy fecundity (Baxter 1967) indicates an annual range of 20,000 to 30,000 eggs per female. More recent data from Love (1996) indicate that females can release from 2,700 to 16,000 eggs per batch, with annual fecundity as high as 130,000 eggs in southern California and around 35,000 eggs in northern populations. Parrish et al. (1986) and Butler et al. (1993) indicate that total annual fecundity varies with the age of the female from 20,000 to 30,000 eggs for a one-year-old female to more than 320,000 for a five-year-old. The eggs hatch within two to four days, depending on the water temperature, and release 2.5 to 3.0 mm (0.10 to 0.12 in.) long relatively undeveloped larvae (Hart 1973, Moser 1996). These larvae begin schooling at 11 to 12 mm (0.4 to 0.5 in.) and transform into juveniles at 35 to 40 mm (1.4 to 1.6 in.) in approximately 70 days (Hart 1973).

Northern anchovy in the central sub-population are harvested commercially in Mexico and California for human consumption, live bait, dead bait, and other commercial uses (PFMC 1998). Landings of northern anchovy in California between 1916 and 1997 varied from a low of 72 metric tons (MT) in 1926 to a high of 143,799 MT in 1975 (PFMC 1998). The non-reduction live-bait fishery is primarily centered in southern California and principally serves the sport fishing market. Northern anchovy have historically comprised the majority of the live-bait catch, but now Pacific sardine are landed in greater numbers; between 1996 and 1999 Pacific sardine comprised 72 percent of the live-bait catch (Leet et al. 2001). Although northern anchovy are fished throughout the state, commercial landings are usually made in San Francisco, Monterey, and Los Angeles.

Northern Anchovy Results

Concentrations of larval northern anchovy collected during intake surveys are shown in Figure 3-20. Northern anchovy larvae were collected at the Plant intake stations in all months of the study. They comprised 12 percent of the annual average concentration of all fish taxa collected at the intake stations compared to 24 percent among source water stations from February 27, 2001–February 22, 2002 (Figure 3-3). The greatest concentrations of larvae near the power plant occurred in March/April and in September 2001. The peak concentration (627/1,000 m^3) of northern anchovy occurred during the September 2001 survey.

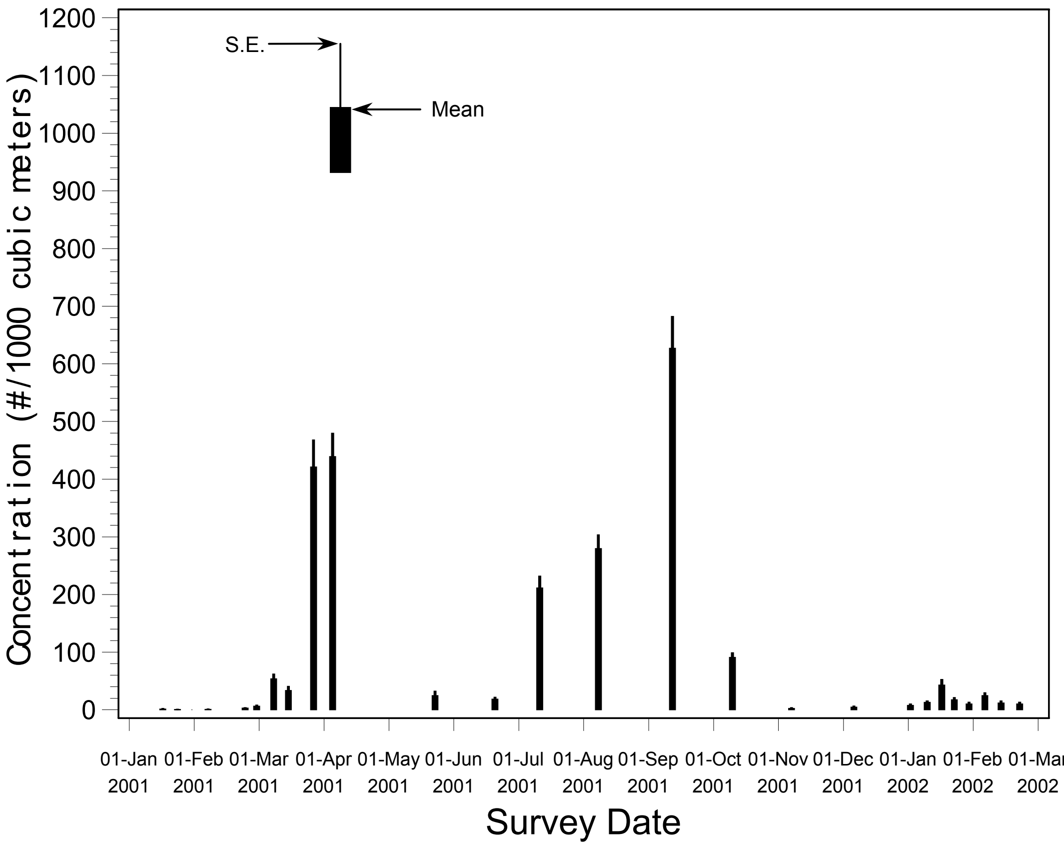


Figure 3-20. Mean concentrations of larval northern anchovy collected at the Potrero Power Plant intake stations from January 17, 2001–February 22, 2002.

Standard error indicated (+1 SE).

Lengths were recorded for 332 northern anchovy larvae collected at the Plant intake stations. The smallest anchovy larva measured was 2.1 mm (0.1 in.) NL (Figure 3-21). On average, anchovy larvae collected at the intake stations were 5.2 mm (0.2 in.) NL (*S.E.* = 0.22 mm) and the longest larva that was measured was 30.5 mm (1.2 in.) and was in the later stages of larval development. The majority of the northern anchovy larvae collected at the intake stations were in the early stages of larval development.

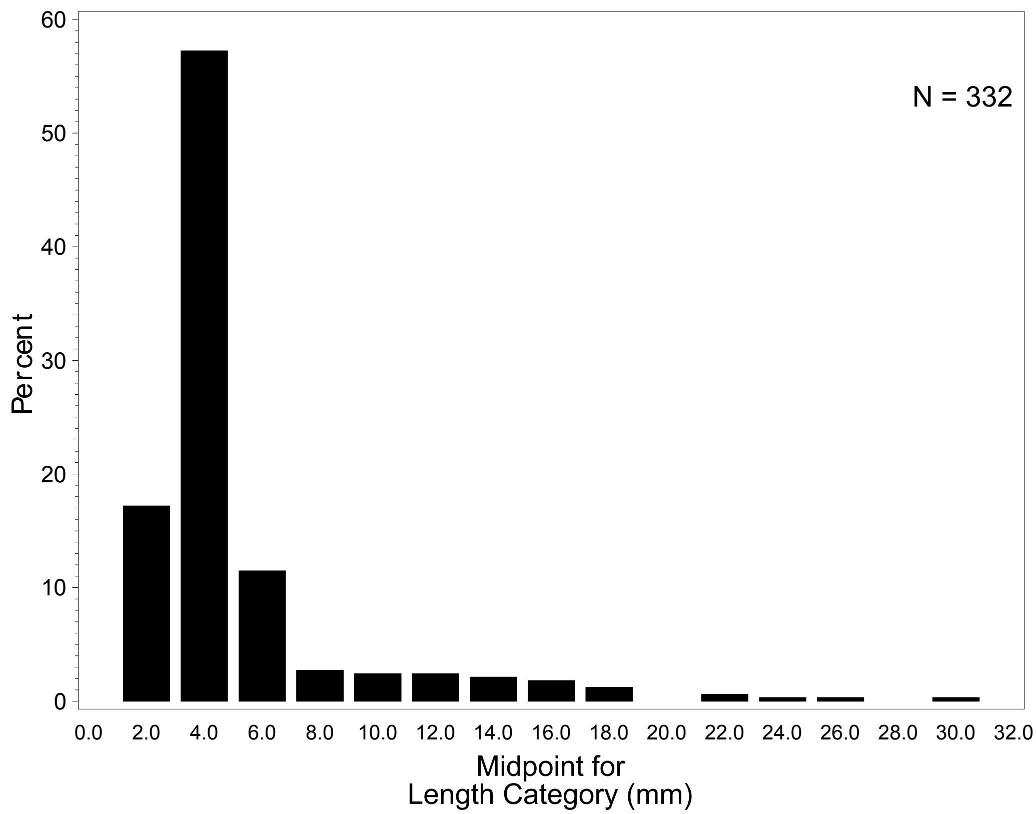


Figure 3-21. Length (mm) frequency distribution for larval northern anchovy collected at the Potrero Power Plant intake stations.

Northern anchovy larvae comprised 23 percent of the annual average concentration of all fishes collected at all source water stations combined from February 27, 2001–February 22, 2002 (Figure 3-3). Larval northern anchovy were common in our samples, occurring at intake and source water stations during all months sampled (Figure 3-22). During the periods with peak concentrations northern anchovy larvae were more abundant at the source water stations than the intake stations. Concentrations of larval northern anchovy peaked in August 2001 (2,709/1,000 m^3) at source water stations. This corroborates Love's (1966) reported spawning periodicity of February through April and July through September.

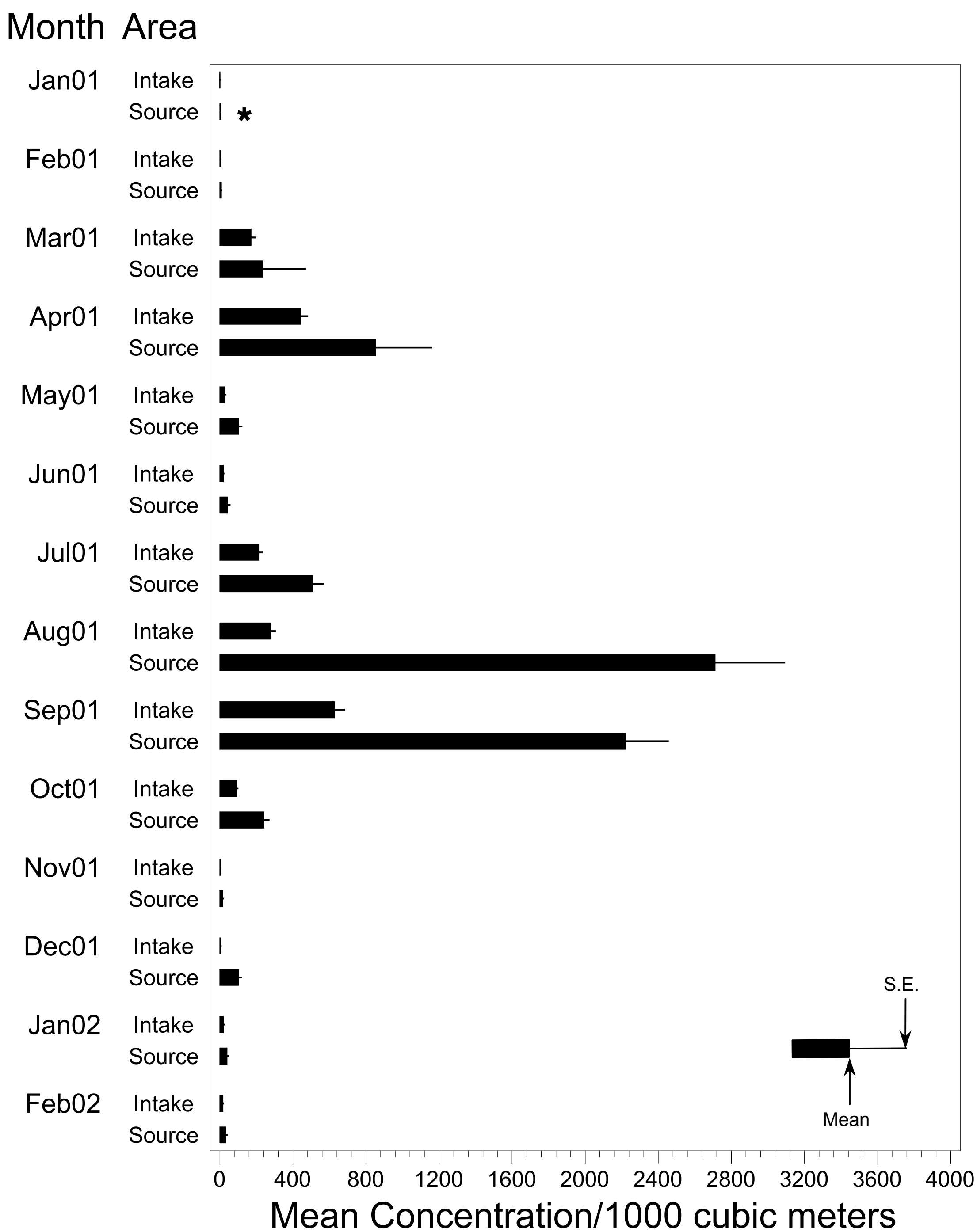


Figure 3-22. Monthly mean concentrations of larval northern anchovy collected at Potrero Power Plant intake and source water stations from January 17, 2001–February 22, 2002.

* Surveys at far-field stations started February 27, 2001.

Standard error indicated (+1 SE).

3.3.7 Cancer *Spp. Crabs*

Three species of rock crab are harvested commercially in California (brown rock crab, red rock crab, and yellow crab) and 85 to 95 percent of the catch is landed in southern California. There is a small sport fishery for rock crabs within San Francisco Bay (Baxter et al. 1999).

All species of cancer crabs share certain fundamental life history traits. Eggs are extruded from the ovaries through an oviduct and are carried in a sponge-like mass beneath the abdominal flap of the adult female. After a development period of several weeks, the eggs hatch and pre-zoea larvae emerge, beginning the planktonic life history phase. The planktonic larvae advance through six larval stages with successive increases in size: five zoea (not including the brief pre-zoea stage) and one megalopal. After several weeks as planktonic larvae, the crabs metamorphose into the first crab stage (first instar) and settle out to begin their benthic life history phase. Maturity is generally attained within one to two years. Females generally produce one or two batches per year, typically in winter. Fecundity per batch increases significantly with female body size (Hines 1991).

The brown rock crab *Cancer antennarius* is distributed in nearshore waters along the Pacific coast of North America from British Columbia to Mexico (Jensen 1995). Their range of peak abundance extends from San Francisco Bay to coastal areas south of the United States – Mexico border (Carroll and Winn 1989). The brown rock crab is a marine species that inhabits nearshore coastal regions but may also be found in sloughs and estuaries (Carroll and Winn 1989).

The yellow crab *Cancer anthonyi* occurs along the Pacific coast of North America from Humboldt Bay, California to Bahía Magdalena, Baja California (Jensen 1995). In the northern parts of their range, where rocky benthic substrata predominate, their distribution appears to be confined to bays, sloughs, and estuaries (Jensen 1995).

The hairy rock crab *Cancer jordani* is one of the smallest members of the family Cancridae. The species ranges from Baja California to Washington (Jensen 1995). Hairy rock crab occur from the intertidal zone down to depths of 104 m (340 ft; Garth and Abbott 1980). They are most often observed under rocks in the shallow waters of bays, but may also be found subtidally in the holdfasts of kelp.

Cancer Crab Results

Cancer crab megalopae were collected in very low numbers at the intake and source water stations (Table 3-5). Only 31 cancer crab megalopae were collected from the intake stations and

97 were collected at the source water stations from January 17, 2001–February 22, 2002 (Appendix B). Brown rock crab, yellow crab and hairy rock crab were all collected at the intake and source water stations. Slender crab (*n* = 5), megalopae that could not be identified to species (*n* = 6), and red rock crab (*n* = 1) were collected only at source water stations.

A total of 24 brown rock crab megalopae were collected at the intake stations from January 17, 2001–February 22, 2002 (Table 3-5 and Appendix B). They were collected in March (*n* = 4), April (*n* = 17), May (*n* = 2), and June 2001 (*n*=1) (Appendix B). A total of 66 megalopal brown rock crab were collected at source water stations from January 17, 2001–February 22, 2002 (Table 3-5 and Appendix B). Seventy-three percent of the total number of megalopal brown rock crab at source water stations were collected in April and June 2001 (*n* = 25 and 23, respectively) (Appendix B).

A total of five yellow crab megalopae were collected at the intake stations from January 17, 2001–February 22, 2002 (Table 3-5 and Appendix B). They were collected in February 2001 (*n* = 1) and April 2001 (*n* = 4). A total of 11 megalopal yellow crab were collected at source water stations from January 17, 2001 through February 22, 2002 (Table 3-5 and Appendix B). The majority (*n* = 7) were collected at source water stations in April 2001 (Appendix B).

A total of two hairy rock crab megalopae were collected at the intake stations from January 17, 2001–February 22, 2002 (Table 3-5 and Appendix B). They were both collected during March 2001 surveys (Appendix B). Eight hairy rock crab were collected at source water stations from January 17, 2001–February 22, 2002 (Table 3-5 and Appendix B). They were collected at source water stations in January, March, April, and June 2001 (Appendix B).

Table 3-5. The total number of cancer crab megalopae collected at intake and source water stations January 17, 2001–February 22, 2002.

Species	Intake Stations	Source Water Body Stations
Brown rock crab	24	66
Yellow crab	5	11
Hairy rock crab	2	8
Slender crab	0	5
Unidentified *Cancer* spp.	0	6
Red rock crab	0	1
Total	**31**	**97**

3.3.8 European Green Crab

The European green crab *Carcinus maenas* is an environmentally tolerant species that has become widely distributed outside of its native range following unintentional introductions. Its native range extends along the Atlantic coast of Europe and North Africa from Norway to Mauritania (Grosholtz 1996). Introduced populations occur in South Africa, Australia, and along both coasts of North America (WDFW 1999). It was not found along the Pacific coast until 1989/1990, when an established population was discovered in San Francisco Bay. Green crab were reported in Bodega Bay by 1993 and can now be found in every major bay and estuary between Monterey Bay and Humboldt Bay (Grosholtz 1996). They are most often found in the intertidal and shallow subtidal regions of estuaries, typically in depths of less than 6 m (20 ft) (Jensen 1995). They have been collected to depths of 10 m (33 ft) in San Francisco Bay (Cohen and Carlton 1995).

There is great concern over the expansion of the green crab along the Pacific coast of North America (Figure 3-23). Green crab predation on quahogs *Mercenaria mercenaria* is thought to have been a factor in the collapse of soft-shell clam fisheries along the Atlantic seaboard in the 1950s (WDFW 1999). The species has also become problematic for the east coast hard shell clam *Mya arenaria* fishery (Grosholtz 1996). In California, significant reductions in populations of the small clams *Nutricula* spp. and *Transennella* spp., the cumacean *Cumella vulgaris*, and the amphipod *Corophium* spp. have been attributed to green crabs (Grosholz 1996, Grosholz and Ruiz 1995). The species has also been documented preying on other crab species up to its own size. These crabs include young Dungeness crab and the yellow shore crab *Hemigrapsus oregonensis*. Green crabs are voracious predators of young oysters *Crassostrea gigas* and frequently recruit into oyster culture bags (Grosholz 1996). They are also a known intermediate host of an acanthocephalan worm *Profilcollis botulus*, which has been known to cause heavy mortalities in seabirds (WDFW 1999).

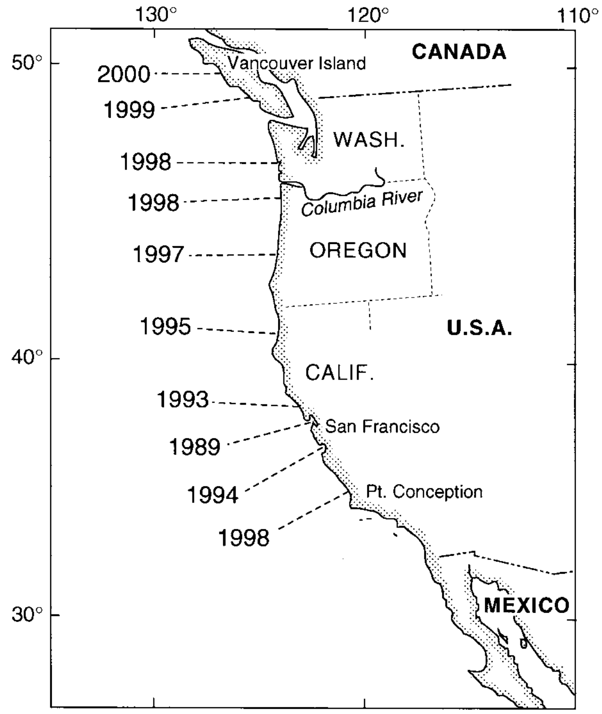


Figure 3-23. Distribution and dates of first collection of European green crab on the west coast of North America (after Yamada 2001).

Note: As of 2001, they range from Morro Bay, California to Vancouver Island.

European Green Crab Results

A total of two European green crab megalopae was collected at the intake stations during the January 17, 2001–February 22, 2002 surveys (Appendix B). They were collected in two surveys during late March and early April 2001. Nine European green crab were collected at source water stations from January 17, 2001–February 22, 2002. One was collected in February 2001, three were collected in March 2001, three were collected in April 2001 and two were collected in February 2002 (Appendix B).

3.4 Discussion

The purpose of this study was to describe the composition and abundance of larval fishes and megalopal cancer crabs that were at risk of entrainment in the cooling water intake system (CWIS). The occurrence of the megalopal life stage of the introduced European green crab was also documented.

Three of the five most abundant larval fish taxa (bay goby, unidentified gobies, and yellowfin goby) collected at the intake stations complete the majority of their lives within the confines of bays and estuaries. These gobies are primarily found in soft bottom bay and estuary habitats where they build burrows, reproduce, and complete their life cycles within a short distance of their hatching grounds. The other two species that make up the five most abundant fish taxa are Pacific herring and northern anchovy, which spend a greater portion of their lives in adjacent coastal pelagic waters.

The most abundant group of larval fishes collected at the Plant intake and in source water study stations was larval gobies (family Gobiidae). These small fishes are of no major sport or commercial importance (with the exception of yellowfin goby, which supports a small commercial bait fishery), and consequently the life histories of these species have been little studied. Love (1996) suggests a role in the trophic webs of nearshore ecosystems when he notes that some gobies are common prey of cormorants and sea lions.

The analysis of total larval fish concentration showed that average monthly source water concentrations were generally greater than average monthly intake station concentrations. Despite the differences in average monthly concentration, the seasonal patterns of change and composition of the samples for the most abundant taxa were very similar for the two areas. This indicated a well-mixed water body within the source water study area and/or a wide and fairly uniform distribution of adults and their progeny in the study area.

Peak larval fish concentrations at the intake stations occurred in February, March, and September 2001 and February 2002. The February peaks are consistent with the spawning season for many of the fishes in San Francisco Bay (e.g., Pacific herring). The peak in September is due to high concentrations of bay goby larvae. Unidentified goby larvae were found year-round, possibly reflecting the multiple species in this group and their spawning seasons. Northern anchovy are also reported to spawn all year with peak spawning occurring from February through April and July through September (Love 1996), which is consistent with our results.

Megalopal *Cancer* spp. were collected in such low numbers at the intake and source water stations that population effects are not only extremely unlikely, but the numbers were so small that the assessment models could not be used with any statistical reliability. Consequently, no further CWIS impact assessment was necessary for *Cancer* spp. megalopae.

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4.0 COOLING WATER INTAKE SYSTEM IMPACT ASSESSMENT

This assessment on the effects of entrainment by Potrero Power Plant Unit 3 cooling water intake system (CWIS) is based on 12 months of data collected from February 27, 2001 through February 22, 2002. This time period was chosen because it encompasses the time when all source water and intake stations were sampled; far-field station locations were not finalized by the AWG until February 2001. Entrainment occurs when organisms smaller than the openings in the traveling screens (e.g., larval fishes) are drawn into the CWIS with the cooling water. For the purposes of this study we conservatively assume that mortality of entrained organisms is 100 percent, and that Unit 3's cooling water and screen wash pumps will operate at maximum flow 24 hours per day, 7 days per week, with no scheduled or unscheduled maintenance outages.

Three methods for assessing CWIS effects on larval fishes were described in the Potrero Power Plant Survey Protocol (Appendix A), which was approved by the AWG and submitted to the CEC in December 2000. They were empirical transport modeling (*ETM*), and the demographic modeling approaches of fecundity hindcasting (*FH*), and adult equivalent loss (*AEL*). The statistical derivations of these models and example calculations are given in Appendix E—Model Parameterization. Two reports were submitted to the CEC and the AWG that contained estimates of *ETM* as well as results from *FH* and *AEL* (where applicable) from data collected during the first three months and the first six months of this study (Tenera 2001a and b). This report contains estimates of *ETM*, as well as results from *FH* and *AEL* (where applicable) for Unit 3 from data collected from one year of surveys.

Data collected in entrainment and source water plankton surveys were compiled in one of two ways for the three modeling approaches used in the impact assessment of each taxon (Table 4-1). The 21 surveys from February 27, 2001–February 22, 2002 were used to calculate an estimate of annual entrainment that was used in the *AEL* and *FH* models to estimate equivalent adult losses and losses to reproductive potential, respectively. These data were combined with monthly source water survey data to calculate *ETM*. Entrainment abundance data were combined with concurrent source water abundance estimates to calculate proportional entrainment (*PE*), an estimate of the daily conditional mortality in the source water population due to entrainment. Mean survey concentrations used to estimate *PE* were calculated by treating each cycle as a stratum and computing a mean and variance for each cycle. These values were then combined to compute estimates of the mean and variance for each survey; treating the *n* for each station cycle as a weight using the standard calculations for stratified sampling (Snedecor and Cochran 1967).

Table 4-1. Data used to parameterize models for estimating impacts.

Impact Assessment Approach	Type of Data Employed	Data Collection Period Used	Number of Surveys Included
Fecundity Hindcast (*FH*)	Entrainment Abundance	February 27, 2001–February 22, 2002	21
Adult Equivalent Loss (*AEL*)	Entrainment Abundance	February 27, 2001–February 22, 2002	21
Empirical Transport Model (*ETM*)	Entrainment Abundance and Source Water Abundance	February 27, 2001–February 22, 2002	21

Length frequency data from samples of the five target larval fish taxa at the two intake stations were used to estimate the period of time that the larvae were exposed to entrainment. A sample of approximately 300 larvae from each taxon was measured with a digital imaging system (see Section 3.0 for length data). The cumulative percentages of each 0.1-mm size class were used to calculate the upper and lower bounds on the central 95 percent of the measurements. The upper and lower values of 95 percent of the measurements were used to produce an estimate of the maximum period of exposure (days) to entrainment using either a calculated or a literature-based growth rate (mm/day). The mean length of all of the measurements and the lower value of the central 95 percent of the measurements were used to calculate an estimate of the average period of exposure.

Data from the 21 surveys completed from February 27, 2001–February 22, 2002 were used to estimate larval fish concentration (no./m^3) at the Potrero Power Plant CWIS. These estimates were multiplied by the maximum Unit 3 intake volume (m^3) (see Table 2-1 for cooling water and screen wash water volumes) to provide estimates of total entrainment for the sampling period. Similarly, larval fish concentrations estimated from samples collected in the San Francisco Bay source water study area were used to estimate local larval fish abundance. By comparing the number of larvae withdrawn by the power plant to the number available (i.e., at risk to entrainment), an estimate of the mortality due to entrainment (i.e., proportional entrainment or *PE*) can be generated for each taxon or species. These estimates of mortality are combined in the *ETM* to provide an estimate of the annual probability of mortality due to entrainment (P_m). This can be used to determine CWIS effects as well as the potential for long-term population declines. Fishery harvest data and other forms of stock assessments, when available, provide the context required to interpret P_m.
In assessing CWIS effects for potential population-level impacts on harvested species, P_m is a source of mortality that is added to harvest losses.

4.1 Entrainment Effects Assessment

For this report, we have focused our assessment of entrainment effects on the five most abundant fish taxa from samples collected at intake stations from February 27, 2001–February 22, 2002. No analyses of CWIS effects were conducted for species of megalopal cancer crabs or European green crab because not enough were collected to provide for meaningful analyses.

Results from the sampling for the one-year period showed that four species and one taxon of larval fish comprised 96 percent of all the entrained larvae. The rank order and percentage composition for annual entrainment estimates differ from the rank order and percentages in Section 3.0 that are based on annual average concentration (no./1,000 m^3). See Section 3.2.4–Data Analysis for further discussion. Estimated entrainment from February 27, 2001–February 22, 2002 shows that the five most abundant taxa in rank order were bay goby *Lepidogobius lepidus* (35 percent), unidentified gobies (22 percent), northern anchovy *Engraulis mordax* (17 percent), Pacific herring *Clupea pallasii* (12 percent), and yellowfin goby *Acanthogobius flavimanus* (10 percent) (Table 4-2). Three of these species, Pacific herring, northern anchovy, and yellowfin goby are commercially or recreationally important species. Concentrations (no./1,000 m^3) for all fish taxa collected during intake and source water sampling are presented by survey in Appendix B (Tables B-1 and B-2).

Table 4-2. Estimates of total larval fish entrainment based on Potrero Power Plant Unit 3 maximum cooling water and screen wash water volumes[1] (February 27, 2001–February 22, 2002).

Common Name	Taxon	Estimated Annual # of Entrained Larvae	Standard Error	Percent of Total Entrainment (%)
Fishes				
bay goby	*Lepidogobius lepidus*	104,312,644	3,358,684	35.12
gobies	Gobiidae unid.	65,237,852	2,124,330	21.97
northern anchovy	*Engraulis mordax*	49,302,228	2,047,913	16.60
Pacific herring	*Clupea pallasii*	35,982,833	2,513,057	12.12
yellowfin goby	*Acanthogobius flavimanus*	29,230,697	1,425,890	9.84
white croaker	*Genyonemus lineatus*	6,281,538	301,083	2.12
California halibut	*Paralichthys californicus*	1,594,402	183,278	0.54
Pacific staghorn sculpin	*Leptocottus armatus*	933,538	84,013	0.31
speckled sanddab	*Citharichthys stigmaeus*	656,840	117,795	0.22
herrings and anchovies	Clupeiformes	466,877	102,489	0.16
larval fishes, damaged	larval fish - damaged	357,748	100,080	0.12
Pacific sand lance	*Ammodytes hexapterus*	315,914	38,581	0.11
rockfishes*	*Sebastes* spp. V_De	279,688	57,853	0.09
sand sole	*Psettichthys melanostictus*	279,656	38,867	0.09
flounders	Pleuronectidae unid.	242,949	57,379	0.08
diamond turbot	*Hypsopsetta guttulata*	196,164	73,690	0.07
larval fishes	larval/post-larval fish, unid.	190,943	84,032	0.06
croakers	Sciaenidae unid.	134,360	49,296	0.05
pipefishes	*Syngnathus* spp.	120,780	50,318	0.04
jacksmelt	*Atherinopsis californiensis*	97,341	26,302	0.03
monkeyface eel	*Cebidichthys violaceus*	73,393	30,439	0.02
silversides	Atherinidae unid.	62,648	35,476	0.02
sculpins	*Oligocottus* spp.	61,773	28,471	0.02
pricklebacks	Stichaeidae unid.	60,643	31,775	0.02
bay pipefish	*Syngnathus leptorhynchus*	45,588	32,374	0.02
smelts	Osmeridae unid.	38,698	33,376	0.01
Pacific sanddab	*Citharichthys sordidus*	36,462	18,191	0.01
sculpins	Cottidae unid.	34,732	16,836	0.01
blackeye goby	*Coryphopterus nicholsi*	33,936	28,045	0.01
northern lampfish	*Stenobrachius leucopsarus*	31,386	16,671	0.01
English sole	*Parophrys vetulus*	31,075	17,176	0.01
cabezon	*Scorpaenichthys marmoratus*	22,687	18,608	0.01
rockfishes	*Sebastes* spp. VD	21,694	17,125	0.01
snailfishes	Cyclopteridae unid.	21,161	21,161	0.01
queenfish	*Seriphus politus*	18,775	18,775	0.01
rock sole	*Pleuronectes bilineatus*	17,449	10,802	0.01
sculpins	*Clinocottus* spp.	17,082	9,935	0.01
topsmelt	*Atherinops affinis*	16,586	16,586	0.01
longjaw mudsucker	*Gillichthys mirabilis*	15,723	15,723	0.01
clinid kelpfishes	*Gibbonsia* spp.	15,692	15,692	0.01
blennies	*Hypsoblennius* spp.	15,316	15,316	0.01
flatfishes	Pleuronectiformes unid.	13,400	7,890	<0.01
rockfishes	*Sebastes* spp. V	9,751	6,931	<0.01
clingfishes	*Gobiesox* spp.	6,166	6,166	<0.01
lefteye flounders & sanddabs	Paralichthyidae unid.	5,730	5,730	<0.01
giant kelpfish	*Heterostichus rostratus*	5,377	5,377	<0.01
greenlings	Hexagrammidae unid.	5,377	5,377	<0.01
lingcod	*Ophiodon elongatus*	5,226	5,226	<0.01
rockfishes	*Sebastes* spp. V_D_	4,820	4,820	<0.01
sculpins	*Artedius* spp.	4,783	4,783	<0.01
butter sole	*Pleuronectes isolepis*	4,498	4,498	<0.01
snailfishes	*Liparis* spp.	4,216	4,216	<0.01
gunnels	Pholididae unid.	4,014	4,014	<0.01
codfishes	Gadidae	3,936	3,936	<0.01
brown Irish lord	*Hemilepidotus spinosus*	3,505	3,505	<0.01
sanddabs	*Citharichthys* spp.	3,433	3,433	<0.01
Total Fishes		296,991,723		

*See Appendix D for an explanation of the letter codes used to denote the pigment groupings of larval rockfishes.

(1) Unit 3 maximum cooling water and screen wash water volume equals 875,068 m^3/day (160,600 gpm).

4.2 Assessment Models

4.2.1 Empirical Transport Model

The calculation of *ETM*, presented in the Survey Protocol (Appendix A), requires that several parameters be obtained for each taxon being modeled. These include estimates of the number of entrained larvae, the number of larvae in the source water population at risk to entrainment, and an estimate of the period of time that the larvae are subject to entrainment. The number of larvae entrained was estimated by multiplying estimates of intake station concentrations by the maximum volume of the power plant's intake. The number of source water larvae at risk was estimated by multiplying estimated source water population concentrations by the estimated volume of the source water (see Appendix C for a discussion of the source water volume calculation). Proportional entrainment estimates for each survey were computed by dividing the entrainment estimate by the source water population estimate. These estimates were then applied to days preceding the survey to conform to the assumption that the *PE* estimate corresponds to a single cohort spawned prior to the survey date. The entrainment estimates used to calculate the fraction of larvae collected during the survey period were treated as point estimates and extrapolated to the days on either side of the survey. Although these fractions, f_i, were used to weight the *PE* estimates for each survey in the *ETM* calculation, the periods used to calculate the f_i do not correspond exactly to the *PE* survey periods.

The length of time that larval fishes are in the plankton and subject to entrainment is important in *ETM* calculations. The duration of risk to entrainment for fish larvae was determined from their estimated age based on the average size entrained. Total larval duration from settlement to transformation into juveniles is not an appropriate time scale for estimating the duration of entrainment risk. The risk to entrainment diminishes as the larvae develop by increasing in both size and swimming ability. Therefore, a more appropriate measure of the duration of entrainment risk is obtained by estimating the average larval age at entrainment. Length measurements taken from representative samples of the larval fish taxa collected at the intake stations and growth rates reported in the literature were used to estimate the number of days that the larvae for a specific taxon were at risk of entrainment.

The minimum and maximum lengths used in computing larval fish durations were based on the central 95 percent of the length distribution for a taxon. Dropping the lengths of the top and bottom percentiles eliminated measurements that may have represented outlier values. Estimates of larval growth rates (mm/day) were calculated from 95 percent of the length distribution to estimate the number of days the larvae were exposed to entrainment risk. Estimated growth rates and their sources from the literature are presented in the following impact assessment sections for each taxon. The average duration of entrainment risk for a taxon was calculated from the bottom 5^{th} percentile value to the mean value, while the maximum duration was calculated from the bottom 5^{th} percentile value to the 99^{th} percentile value. These values are reported in the following sections for each taxon as the mean and maximum lengths.

AWG members provided direction on the selection of the source water study area. Once the source water study area was determined (AWG meeting on August 27, 2001) a U.S. Geological Service (USGS) online interactive tool was used to calculate the volume of the source water study area. A description of the method used to determine the source water volume is presented in Appendix C.

4.2.2 Demographic Approaches for Estimating Entrainment Effects

Entrainment losses were also assessed from total larval entrainment at Potrero Power Plant 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 four of the most abundant 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 percent was used to estimate the sample variance for all of the life history parameters.

4.3 Individual Taxa Results

4.3.1 Bay Goby

Bay goby was the most abundant larval fish entrained at Potrero Power Plant during the course of this study and comprised 35 percent of the estimated total entrainment of all fish larvae (Table 4-2). The annual estimate of Potrero Power Plant Unit 3 entrainment for February 27, 2001–February 22, 2002 was 104,312,644 larvae (*S.E.* =3,358,684).

No species-specific larval survivorship estimates were available for bay goby. Although larval survival data were available from other species of gobies, survival of later stages through adulthood were not applicable to a longer-lived species such as bay goby. The estimated annual mortality used for arrow goby from Brothers (1975) for the first year was approximately 91 percent, and 99 percent thereafter. Applying these mortality estimates, which were used to parameterize the *FH* and *AEL* models for unidentified gobies, to bay goby resulted in a very low finite survival for the stages from recruitment through the average age of a mature adult. Since this would result in potentially large underestimates of *AEL*, an estimate of *AEL* was not attempted. Similarly, an estimate of *FH* for this species was not calculated due to the absence of any species-specific fecundity data for bay goby.

Empirical Transport Model (ETM)

The average length of bay goby larvae from intake station samples (n=308), along with the minimum and maximum lengths of the central 95 percent of the length frequency distribution, were used to estimate the period of entrainment risk for bay goby. There are no reported larval growth rates for bay goby, but a growth rate of 0.22 mm per day was calculated by using the size difference between hatch length (2.85 mm, 0.1 in.) and transformation length (26.5 mm, 1.0 in.) (Moser 1996, Wang 1986) divided by an average planktonic duration of three to four months (105 days) from Grossman (1979). The length range of 2.6 to 3.9 mm (0.10 to 0.15 in.) NL for the central 95 percent of bay goby larvae measured from the intake stations (n=308) was used to estimate a maximum period of entrainment risk of 5.8 days, while the average period of entrainment risk based on the mean length of 3.2 mm (0.13 in.) NL was estimated as 2.6 days.

Estimates of P_m for bay goby from the *ETM* were low and ranged from 0.001 (*S.E.* = 0.037) for the average duration of larval exposure (2.58 days) to 0.003 (*S.E.* = 0.055) for the maximum duration of larval exposure (5.81 days) (Table 4-3). Thus, between 0.1 and 0.3 percent of the standing stock of larval bay goby in the San Francisco Bay source water study area could be removed due to entrainment.

Bay goby larvae were collected during all of the surveys, but the largest fraction of the entrained population was collected during September 2001 (f_i = 0.21) (Table 4-4). Proportional entrainment estimates ranged from a low of 0.00026 in December 2001 to a peak of 0.0099 in June 2001. The estimates were close to the volumetric ratio of cooling water and source water of 0.0006 (0.06 percent) for many of the surveys.

Table 4-3. Empirical transport model (*ETM*) estimates of conditional entrainment mortality (P_m) of bay goby based on entrainment risk durations calculated from mean and maximum lengths of entrained larvae.

Entrainment Exposure (days)	P_m Estimate	P_m Std. Error	P_m +2 Std. Errors	P_m -2 Std. Errors
2.58	0.00133	0.03695	0.07522	-0.07256
5.81	0.00300	0.05500	0.11300	-0.10700

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Table 4-4. Estimate of proportional entrainment (*PE*) of bay goby.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i	f_i Std. Error
28-Feb-01	0.00048	0.00008	0.00188	0.00012
8-Mar-01	0.00051	0.00007	0.00531	0.00022
15-Mar-01	0.00077	0.00011	0.00577	0.00027
27-Mar-01	0.00058	0.00008	0.01044	0.00035
5-Apr-01	0.00066	0.00012	0.00639	0.00028
23-May-01	0.00054	0.00008	0.04036	0.00080
20-Jun-01	0.00099	0.00008	0.06075	0.00096
11-Jul-01	0.00028	0.00004	0.07140	0.00158
8-Aug-01	0.00037	0.00003	0.12177	0.00204
12-Sep-01	0.00090	0.00007	0.20881	0.00204
10-Oct-01	0.00036	0.00006	0.15266	0.00237
7-Nov-01	0.00038	0.00006	0.11768	0.00284
6-Dec-01	0.00026	0.00003	0.09523	0.00219
2-Jan-02	0.00037	0.00004	0.05103	0.00092
10-Jan-02	0.00044	0.00005	0.01209	0.00040
17-Jan-02	0.00040	0.00005	0.00863	0.00032
23-Jan-02	0.00044	0.00004	0.00663	0.00022
30-Jan-02	0.00047	0.00006	0.00676	0.00021
6-Feb-02	0.00039	0.00006	0.00516	0.00020
13-Feb-02	0.00041	0.00005	0.00514	0.00021
21-Feb-02	0.00031	0.00004	0.00611	0.00021

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Fecundity Hindcast Model (FH)

We did not estimate the number of reproductively active females required to produce the bay goby larvae entrained at Potrero Power Plant. No species-specific fecundity estimates were available from the literature with which to parameterize the model. Therefore, an *FH* estimate of breeding females was not calculated for this species.

Adult Equivalent Loss (AEL)

We did not estimate the number of equivalent adults that would have resulted from the bay goby larvae entrained at Potrero Power Plant. There are no species-specific estimates of bay goby survivorship from the juvenile stages through adulthood. Therefore, an *AEL* estimate of adult equivalents was not calculated for this species.

Summary

Bay goby have neither commercial nor recreational fishery value. There are no fishery or population data that can be used to compare harvest mortality rates to entrainment mortality rates or to provide some context for the *ETM* results. The *ETM* estimates of P_m indicate that the power plant may entrain an average of 0.1 percent (*S.E.* = 3.7) to a maximum of 0.3 percent (*S.E.* = 5.5) of bay goby larvae from the San Francisco Bay source water study area during a particular year. Based on the *ETM* results, the bay goby population of the San Francisco Bay source water study area would not be adversely affected by the Potrero Power Plant Unit 3 CWIS.

4.3.2 Unidentified Gobies

The annual estimate of entrainment for unidentified gobies for the February 27, 2001–February 22, 2002 period was 65,237,852 larvae (*S.E.* = 2,124,330). The unidentified gobies comprised around 22 percent of the fish larvae entrained, the second highest percentage of any group (Table 4-2).

The taxonomic composition of the family grouping analyzed here is not known, but it is likely that the majority of larvae collected are from the species of adult gobies found in abundance in the vicinity of the study area. In addition, these would be the gobies that we know we cannot distinguish as species during their early life stages. Thus, the likely candidates for membership in this group are arrow and cheekspot gobies; both are abundant in trawls from within the study area (Baxter et al. 1999, CDFG unpublished otter trawl data, Tenera 2002) and cannot be easily distinguished from one another as larvae (Moser 1996) or juveniles (Brothers 1975).

This finding brings out an important point in the application of the assessment models. Although we can analyze the proportional loss of a taxonomic group such as unidentified gobies, it is not possible to assign the significance of these losses to a population unless we can identify the species. However, we may still have a high degree of assurance that a species will be unaffected by entrainment if we find that the entrainment losses of an unidentified taxon to which it may belong are proportionally low compared to our estimates of the source water population.
In addition, even though a species may be one of several in a taxonomic group, our estimate of CWIS effects is still valid if the relative proportion of each species in the unidentified group of species is the same among entrainment and source water samples.

Empirical Transport Model (ETM)

The average length of unidentified goby larvae from intake station samples (n=311), along with the minimum and maximum lengths of the central 95 percent of the length frequency distribution, were used to estimate the period of entrainment risk for unidentified gobies. A larval growth rate of 0.24 mm per day, estimated from data reported by Brothers (1975), was used to estimate entrainment risk duration for unidentified gobies. The length range of 2.5 to 10.2 mm (0.1 to 0.4 in.) for the central 95 percent of unidentified goby larvae measured from the intake stations was used to estimate a maximum period of entrainment risk of 32.6 days, while the average period of entrainment risk based on the mean length of 4.1 mm (0.2 in.) was estimated as 7.1 days.

The February 27, 2001–February 22, 2002 annual estimates of P_m for unidentified gobies based on both the mean and maximum estimated durations of entrainment risk were low and ranged from 0.001 (*S.E.* = 0.033) for the average duration of larval exposure (7.1 days) to 0.005 (*S.E.* = 0.070) for the maximum duration of larval exposure (10.2 days) (Table 4-5). Thus, between 0.1 and 0.5 percent of the standing stock of larval unidentified gobies in the San Francisco Bay source water study area could be removed due to entrainment. These values represent the annual probability of increased mortality due to entrainment to the unidentified goby source population of larvae by Potrero Power Plant Unit 3.

Estimates of *PE* for unidentified gobies were highest in November 2001 and early February 2002 (Table 4-6). The estimates for many of the surveys were less than but close to the volumetric ratio of cooling water to source water of 0.0006 (0.06 percent). The largest proportions (f_i) of unidentified goby larvae were collected from May–September 2001 (Table 4-6).

Table 4-5. Empirical transport model (*ETM*) estimates of conditional entrainment mortality (P_m) for unidentified gobies based on entrainment risk durations calculated from mean and maximum lengths of entrained larvae.

Entrainment Exposure (days)	P_m Estimate	P_m Std. Error	P_m +2 Std. Errors	P_m -2 Std. Errors
7.1	0.00107	0.03319	0.06745	-0.06532
10.2	0.00491	0.07022	0.14535	-0.13553

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Table 4-6. Estimate of proportional entrainment (*PE*) of unidentified gobies.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i	f_i Std. Error
28-Feb-01	0.00016	0.00003	0.00505	0.00035
8-Mar-01	0.00021	0.00003	0.01982	0.00075
15-Mar-01	0.00015	0.00001	0.02263	0.00059
27-Mar-01	0.00020	0.00003	0.06050	0.00235
5-Apr-01	0.00008	0.00001	0.04348	0.00187
23-May-01	0.00015	0.00002	0.21286	0.00290
20-Jun-01	0.00012	0.00001	0.13441	0.00255
11-Jul-01	0.00019	0.00001	0.11660	0.00176
8-Aug-01	0.00013	0.00001	0.15178	0.00180
12-Sep-01	0.00012	0.00001	0.10556	0.00136
10-Oct-01	0.00011	0.00002	0.03351	0.00056
7-Nov-01	0.00039	0.00006	0.02519	0.00065
6-Dec-01	0.00012	0.00002	0.02253	0.00059
2-Jan-02	0.00020	0.00004	0.01530	0.00050
10-Jan-02	0.00017	0.00002	0.00408	0.00021
17-Jan-02	0.00022	0.00005	0.00358	0.00023
23-Jan-02	0.00013	0.00002	0.00211	0.00017
30-Jan-02	0.00016	0.00003	0.00280	0.00020
6-Feb-02	0.00037	0.00005	0.00713	0.00031
13-Feb-02	0.00016	0.00002	0.00609	0.00026
21-Feb-02	0.00015	0.00003	0.00498	0.00029

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Fecundity Hindcast Model (FH)

The larval entrainment estimate for unidentified gobies over the February 27, 2001–February 22, 2002 sampling period (Table 4-2) was used to estimate the number of breeding females needed to produce the number of larvae entrained. Several species could comprise the taxonomic assemblages of the unidentified goby. We chose to use demographic data describing arrow goby to parameterize our *FH* model because as an adult it is abundant in the study area (CDFG unpublished otter trawl data,) and it is one of the gobies whose larvae we cannot identify to species (Moser 1996).

Egg survival was assumed to be high since goby egg masses are adhesive and typically attached to walls of burrows and similar bottom substrata (Wang 1986). In addition, there are no reported estimates of egg survival for arrow goby in the literature. Adult male gobies typically care for the developing eggs (Brothers 1975), and hatching success, therefore, is probably also high. For purposes of model calculations, egg survival is assumed to be 100 percent. Brothers (1975) calculated a larval mortality rate for arrow goby of 98.3 percent for the two-month larval duration. This translates to a daily survival of $(1\text{-}0.983)^{6/365.25} = 0.935$ (the value for survival was estimated using an exponent of 6/365.25 because there are six two-month periods within a year). Survival to entrainment was then estimated using the mean number of days to entrainment (7.1 days) as $0.935^{7.1} = 0.62$. A batch fecundity estimate of 875 eggs was used based on estimates for arrow goby from Wang (1986) and Brothers (1975). Brothers (1975) reports that arrow gobies may spawn multiple times during the year, so an estimate of two spawns per year was used in the *FH* calculations (875 eggs/spawn × 2 spawns/year = 1,750 eggs). Brothers (1975) states that mortality after the first year is high and a large percentage of the females are reproductive during the first year. Therefore, values for longevity and age at maturity of 2.0 years and 0.5 year, respectively, were used in the model. The number of adult females hindcast from the annual entrainment estimate for the February 27, 2001–February 22, 2002 period was 79,756 (90 percent C.I. = 30,093 to 211,375; Table 4-7).

Table 4-7. Estimates of female adult unidentified goby losses based on larval entrainment estimates using the fecundity hindcast (*FH*) model for February 2001–February 2002.

Parameter	Estimate	Std. Error	Lower Estimate	Upper Estimate	Range
FH estimate	79,756	47,255	30,093	211,375	181,282
Entrainment	65,237,900	2,124,330	75,484	84,028	8,544
Larval survival	0.6232	0.1870	49,705	130,643	80,938
# Eggs/year	1,750	525	48,690	130,643	81,953
Longevity	2.00	0.60	43,094	165,934	122,839
Maturation	0.50	0.15	70,590	101,300	30,710

Note: Estimates from upper and lower 90 percent confidence intervals result from varying the value of the corresponding parameter in the model.

Sensitivity analysis showed that the uncertainty of our *FH* estimate was attributed to the model parameters of average longevity, fecundity, and larval survival, in that order.

Adult Equivalent Loss (AEL)

The values required for computing *AEL* estimates for unidentified gobies include larval survival from entrainment to settlement and survival from settlement to age 1.25 years, the average age of reproductive female adults between ages 0.5 and 2.0 years used in the *FH* model. Larval survival from entrainment to settlement (50 days from hatching) was estimated as 0.056 ($0.935^{50-7.1} = 0.056$) using the same daily survival rate used in formulating *FH*. Brothers (1975) estimated that annual mortality through the first year (after settlement) was approximately 91 percent, and 99 percent thereafter. Therefore, the daily survival rate through the first year was estimated as 1-0.91, while daily survival through the average female age of 1.25 years used in *FH* was estimated as $0.987 = (1\text{-}0.99)^{(1/(456.56-365.25))}$. Survival estimates for these two periods were 0.09 and 0.316, respectively. The estimated number of equivalent adults corresponding to our entrainment estimate for the February 2001–February 2002 period was 104,875 (90 percent C.I. = 44,537 to 246,957; Table 4-8).

Table 4-8. Estimates of adult unidentified goby losses due to entrainment using the adult equivalent loss (*AEL*) model for February 2001–February 2002.

Parameter	Estimate	Std. Error	Lower Estimate	Upper Estimate	Range
AEL estimate	104,875	54,602	44,537	246,957	202,420
Total entrainment	65,237,900	2,124,330	99,258	110,493	11,235
Early larval survival	0.0565	0.0169	64,025	171,790	107,765
Early juvenile survival	0.0900	0.0270	64,025	171,790	107,765
Pre-recruit survival	0.3162	0.0949	64,025	171,790	107,765

Note: Estimates from upper and lower 90 percent confidence intervals result from varying the value of the corresponding parameter in the model.

Summary

The species of gobies that may comprise this taxon have neither commercial nor recreational fishery value and there is little information on their ecological role in the community. There are no fishery or population data that can be used to compare harvest mortality rates to entrainment mortality rates or provide context for the *ETM*, *FH*, or *AEL* results. The *ETM* estimates of P_m indicate that the power plant may annually entrain an average of 0.1 percent (*S.E.* = 3.3) to a maximum of 0.5 percent (*S.E.* = 7.0) of unidentified goby larvae from the San Francisco Bay source water study area (Table 4-5).

The context for the estimates of P_m are the *FH* and *AEL* results that showed that the mortality due to entrainment may be equivalent to the loss of approximately 80,000 adult females or 105,000 adults, respectively. The 2*FH* estimate of approximately 160,000 adult equivalents differs from the *AEL* estimate of approximately 105,000. This difference reflects the uncertainty in the life history values used in the *FH* and *AEL* models and the importance of aligning the models so that results can be compared. The *AEL* model used a daily survival rate for age 1 year and older fishes that is lower than the survival rate for younger fishes (Brothers 1975). This reduces the numbers of adult fishes in the older age classes that are being extrapolated by the *AEL* model. Both the *2FH* and *AEL* estimates indicate a low risk to the widely distributed populations of these gobies in the San Francisco Bay source water study area. See further discussion in Section 4.4.

4.3.3 Northern Anchovy

Northern anchovy larvae ranked third in annual entrainment abundance at Potrero Power Plant and comprised about 17 percent of all fish larvae entrained (Table 4-2). The annual estimate of entrainment (February 27, 2001–February 22, 2002) was 49,302,228 larvae (*S.E.* = 2,047,913).

Empirical Transport Model (ETM)

The average length of northern anchovy larvae from intake station samples (n=332), along with the minimum and maximum lengths of the central 95 percent of the length frequency distribution, were used to estimate the period of entrainment risk for northern anchovy. A larval growth rate of 0.49 mm per day (Methot 1981) was used to calculate entrainment risk duration. The length range of 2.7 to 17.0 mm NL (0.1 to 0.7 in.) for the central 95 percent of the length-frequency distribution was used to estimate a maximum period of entrainment risk of 29.2 days, while the average period of entrainment risk based on the mean length of 5.2 mm (0.2 in.) NL was estimated as 5.3 days.

Estimates of conditional mortality (P_m) of northern anchovy larvae due to entrainment in the Potrero Power Plant Unit 3 CWIS were low. They ranged from 0.0006 (*S.E.* = 0.0251) for the duration to an average larval size at entrainment (5.3 days), to 0.0032 (*S.E.* = 0.0571) for the duration to the maximum larval size at entrainment (29.2 days) (Table 4-9). Thus, between 0.06 and 0.32 percent of the standing stock of larval northern anchovy in the San Francisco Bay source water study area could be removed due to entrainment.

Proportional entrainment estimates ranged from 0.00001 (December 2001) to 0.00040 (mid-March 2001) and were close to the volumetric ratio of cooling water and source water of 0.0006 (0.06 percent) for many of the surveys (Table 4-10). The highest *PE* estimates occurred during surveys in March 2001. Northern anchovy larvae were collected during all of the surveys, but the largest proportion (f_i = 0.285) of the entrained larvae was collected during the September 2001 survey.

Table 4-9. Empirical transport model (*ETM*) estimates of conditional entrainment mortality (P_m) for northern anchovy based on entrainment risk durations calculated from mean and maximum lengths of entrained larvae.

Entrainment Exposure (days)	P_m Estimate	P_m Std. Error	P_m +2 Std. Errors	P_m -2 Std. Errors
5.26	0.00058	0.02509	0.011731	-0.011089
29.24	0.00321	0.05705	0.11731	-0.11089

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Table 4-10. Estimate of proportional entrainment (*PE*) of northern anchovy.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i	f_i Std. Error
28-Feb-01	0.00027	0.00008	0.00039	0.00005
8-Mar-01	0.00023	0.00004	0.00512	0.00033
15-Mar-01	0.00040	0.00010	0.00526	0.00036
27-Mar-01	0.00028	0.00006	0.05535	0.00215
5-Apr-01	0.00016	0.00003	0.06895	0.00223
23-May-01	0.00007	0.00002	0.19033	0.00316
20-Jun-01	0.00013	0.00003	0.01053	0.00057
11-Jul-01	0.00013	0.00001	0.04457	0.00122
8-Aug-01	0.00003	0.00000	0.12332	0.00206
12-Sep-01	0.00011	0.00001	0.28497	0.00372
10-Oct-01	0.00012	0.00001	0.16905	0.00321
7-Nov-01	0.00005	0.00003	0.02166	0.00053
6-Dec-01	0.00001	0.00001	0.00188	0.00016
2-Jan-02	0.00006	0.00002	0.00302	0.00019
10-Jan-02	0.00011	0.00002	0.00156	0.00012
17-Jan-02	0.00026	0.00006	0.00374	0.00035
23-Jan-02	0.00019	0.00004	0.00276	0.00028
30-Jan-02	0.00007	0.00002	0.00162	0.00016
6-Feb-02	0.00019	0.00004	0.00227	0.00020
13-Feb-02	0.00009	0.00003	0.00214	0.00020
21-Feb-02	0.00020	0.00007	0.00151	0.00017

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Fecundity Hindcast Model (FH)

The entrainment abundance estimate for larval northern anchovy over the one-year (February 27, 2001–February 22, 2002) sampling period (Table 4-2) was used to estimate the number of breeding females needed to produce the number of larvae entrained. The values required for calculating *FH* for northern anchovy were available from the literature since they have been extensively studied and are a commercially harvested species. Butler et al. (1993) modeled annual fecundity (Table 4-11a), and egg and larval survivorship (Table 4-11b) of northern anchovy. Their best estimate is derived by fitting the range of mortality estimates from field collections to the assumption of a stable and stationary population age structure. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage (Table 4-11b).

Clark and Phillips (1952) report age at sexual maturity as one to two years. Similarly, Leet et al. (2001) report that 47 to 100 percent of one-year-olds may be mature in a given year, while all are mature by two years. We used a mid-value of 1.5 years that assumed the reported range corresponds to 99 percent of a normal distribution. For longevity, Hart (1973) reports a value of seven years, but Leet et al. (2001) states that northern anchovy in the fished population rarely exceed four years of age. A value of four years was used to represent the most likely reproductive life span. The reproductive life span (Table 4-11a) was used to estimate an average annual fecundity of 147,622 eggs over the four-year period using the data presented in Butler et al. (1993).

Table 4-11. Survivorship of northern anchovy: a) Age-specific fecundity schedule (M_x = natality rate) and b) stage-specific life-history parameters (Z = instantaneous mortality rate; S = finite survival rate) modified from Butler et al. (1993).

a)

Age (yr)	Spawns/year	Eggs/batch	M_x
1	5.3	4,238	22,460
2	11.9	7,860	93,539
3	19.2	10,132	194,538
4	23.5	11,913	279,951
5	23.5	13,939	327,567
6	23.5	13,939	327,567
7	23.5	13,939	327,567

b)

Stage	Z_{best}	Stage duration (d)	Age (d)	S_{best}
Egg	0.231	2.9		0.512
Yolk-sac larva	0.366	3.6	6.5	0.268
Early larva	0.286	12	18.5	0.046
Late larva	0.072	45	63.5	0.039
Early juvenile	0.014	62	125.5	0.417
Late juvenile	0.004	80	205.5	0.703
Pre-recruit	0.003	287	492.5	0.411
Early adult	0.002	1000	1492.5	0.123

The number of adult females hindcast from the estimated total larvae during the sampling period from February 2001–February 2002 was 3,138 (90 percent C.I. = 855 to 11,514; Table 4-12).

Table 4-12. Estimates of female adult northern anchovy losses based on larval entrainment estimates using the fecundity hindcast (*FH*) model for February 2001–February 2002.

Parameter	Estimate	Standard Error	Lower 90% Confidence Interval	Upper 90% Confidence Interval	Absolute Range
FH estimate	3,138	2,480	855	11,514	10,659
Entrainment estimate	49,302,200	2,047,910	2,923	3,352	429
Egg survival	0.5118	0.1535	1,916	5,140	3,224
Yolk-sac survival	0.2678	0.0803	1,916	5,140	3,224
Larval survival	0.6213	0.1864	1,950	5,140	3,190
# Eggs/year	147,622	44,287	1,916	5,140	3,224
Longevity (years)	4.0	1.20	1,553	8,328	6,775
Maturation (years)	1.5	0.45	2,543	5,084	2,541

Note: Estimates from upper and lower 90 percent confidence intervals result from varying the value of the corresponding parameter in the model.

Sensitivity analysis showed that the uncertainty of our *FH* estimate was attributed to the model parameters of average lifespan, fecundity, and survivorship in that order (Table 4-12).

Adult Equivalent Loss (AEL)

The larval entrainment estimate for northern anchovy for the one-year (February 2001–February 2002) sampling period (Table 4-2) was used to estimate the number of equivalent adults needed to produce the estimated number of larvae entrained. Stage-specific instantaneous mortality rates used to compute finite survival were estimated from the life table (Table 4-11b) produced by Butler et al. (1993). Butler et al. 1993 apportioned survivorship to recruitment into several developmental stages. *AEL* was estimated for the average age of sexually mature females (2.75 years) used in *FH* model estimates. The duration of the early larval stage was calculated using the reported duration (12 days) from Butler et al. (1993) and subtracting the average age at entrainment (5.3 days). The estimated number of equivalent adults corresponding to the number of larvae that would have been entrained by the Potrero Power Plant Unit 3 CWIS during the sampling period was 11,620 (90 percent C.I. = 547 to 246,889; Table 4-13).

Table 4-13. Estimates of adult northern anchovy losses due to entrainment using the adult equivalent loss (*AEL*) model for February 2001–February 2002.

Parameter	Estimate	Standard Error	Lower 90% Confidence Interval	Upper 90% Confidence Interval	Absolute Range
AEL estimate	11,620	21,589	547	246,889	246,342
Entrainment estimate	49,302,200	2,047,910	10,826	12,414	1,588
Early larval survival	0.1457	0.0437	7,094	19,034	11,940
Late larval survival	0.0393	0.0118	7,094	19,034	11,940
Early juvenile survival	0.4172	0.1252	7,094	19,034	11,940
Juvenile survival	0.7033	0.2110	7,094	16,523	9,429
Pre-recruit survival	0.4108	0.1232	7,094	19,034	11,940
Early adult	0.3413	0.1024	7,094	19,034	11,940

Note: Estimates from upper and lower 90 percent confidence intervals result from varying the value of the corresponding parameter in the model.

Summary

ETM estimates of P_m indicate that entrainment impacts represents losses due to entrainment of 0.06 to 0.32 percent of the northern anchovy source water larval population. Results from the *FH* and *AEL* models do not match the relationship of $2FH \cong AEL$ ($2FH$ = 6,276 and AEL = 11,620). This may be due to lower survival for yolk-sac larvae used in the *FH* model that is applied to a large proportion of the larval duration from hatching to entrainment. Using the higher survival estimate would have resulted in an increased *FH* estimate. The 2*FH* and *AEL* estimates, in combination with the *ETM* results, indicate a low risk to northern anchovy populations in San Francisco Bay source water study area. See further discussion in Section 4.4.

4.3.4 Pacific Herring

Pacific herring larvae ranked fourth in estimated annual entrainment abundance at Potrero Power Plant and comprised about 12 percent of all fish larvae entrained in the CWIS (Table 4-2). The annual estimate of entrainment (February 27, 2001–February 22, 2002) was 35,982,833 larvae (*S.E.* = 2,513,057). The high percentage and rank abundance of herring larvae are a result of their high concentrations in February 2002.

Empirical Transport Model (ETM)

The average length of Pacific herring larvae from intake station samples (n=286), along with the minimum and maximum lengths of the central 95 percent of the length frequency distribution, were used to estimate the period of entrainment risk for Pacific herring. The larval growth rate used to calculate the period of entrainment risk was based on data presented by Stevenson (1962) for larvae between 8 and 20 mm (0.3 and 0.8 in.). The average growth rate of 0.52 mm per day from his data is consistent with the rate reported by Alderdice and Hourston (1985) of 0.48 to 0.52 mm per day for the first 15 days after hatching. Based on these estimates, a larval growth rate of 0.50 mm per day was used to calculate a maximum period of entrainment risk of 14.5 days based on a length range of 6.8 to 14.1 mm (0.3 to 0.6 in.) for the central 95 percent of Pacific herring larvae measured from the intake stations. The mean length of 9.0 mm (0.4 in.) was used to calculate an average period of entrainment risk of 4.4 days.

Longer exposure to entrainment increases the conditional larval mortality caused by operation of the CWIS. Based on the above, the average entrainment risk duration of 4.4 days was used to calculate a P_m estimate of 0.001 (*S.E.* = 0.037), while the maximum duration of 14.5 days was used to calculate a P_m estimate of 0.004 (*S.E.* = 0.063) (Table 4-14). Thus, between 0.1 and 0.4 percent of the standing stock of larval Pacific herring in the San Francisco Bay source water study area could be removed by entrainment.

Larval Pacific herring did not occur at the intake stations during the May through November 2001 surveys (Table 4-15). Estimates of *PE* ranged from 0 to 0.00033 with the highest value occurring during the first week of February 2002. Estimates of *PE* for many of the surveys were close to the volumetric ratio of cooling water to source water of 0.0006 (0.06 percent), reflecting the widespread and abundant distribution of herring larvae in the source water. The largest proportion of larval Pacific herring was collected during the February 21, 2002 survey (f_i = 0.559).

Table 4-14. Empirical transport model (*ETM*) estimates of conditional entrainment mortality (P_m) for Pacific herring based on entrainment risk durations calculated from mean and maximum lengths of entrained larvae.

Entrainment Exposure (days)	P_m Estimate	P_m Std. Error	P_m +2 Std. Errors	P_m -2 Std. Errors
4.40	0.00134	0.03681	0.07496	-0.07228
14.48	0.00393	0.06275	0.12943	-0.12158

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Table 4-15. Estimate of proportional entrainment (*PE*) of Pacific herring.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i	f_i Std. Error
28-Feb-01	0.00013	0.00003	0.04637	0.00356
8-Mar-01	0.00007	0.00002	0.01262	0.00085
15-Mar-01	0.00031	0.00004	0.05291	0.00213
27-Mar-01	0.00022	0.00010	0.06292	0.00242
5-Apr-01	0	0	0.00020	0.00001
23-May-01	0	0	0	0
20-Jun-01	0	0	0	0
11-Jul-01	0	0	0	0
8-Aug-01	0	0	0	0
12-Sep-01	0	0	0	0
10-Oct-01	0	0	0	0
7-Nov-01	0	0	0	0
6-Dec-01	0.00023	0.00005	0.02163	0.00114
2-Jan-02	0.00005	0.00005	0.01914	0.00105
10-Jan-02	0.00024	0.00007	0.00343	0.00043
17-Jan-02	0.00014	0.00001	0.12710	0.00443
23-Jan-02	0.00016	0.00002	0.07716	0.00299
30-Jan-02	0.00008	0.00003	0.01228	0.00080
6-Feb-02	0.00033	0.00011	0.00291	0.00032
13-Feb-02	0.00008	0.00006	0.00195	0.00028
21-Feb-02	0.00032	0.00004	0.55938	0.01294

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Fecundity Hindcast Model (FH)

The larval entrainment estimate for Pacific herring over the February 2001–February 2002 sampling period (Table 4-2) was used to estimate the number of breeding females needed to produce the number of larvae entrained. Pacific herring spawn once per season and each female produces from 4,000 to 130,000 eggs (Wang 1986). Reilly and Moore (1986) report a range in San Francisco Bay of 7,000 to 40,000 with an average annual fecundity of 20,000 to 25,000 eggs. Therefore, an annual fecundity estimate of 22,500 eggs was used in computing *FH*. Although Fitch and Lavenberg (1975) report that herring may live to eleven years of age, Leet et al. (2001) indicate that fish older than seven years are rare. An estimate of longevity from Leet et al. (2001) of seven years and an estimate of 2.5 years for the age where approximately 50 percent of the females are reproductively mature from Love (1996) were also used in computing *FH*.

An estimate of egg survival of 0.40 used in the model was based on a range of estimates of egg mortality available in the literature: 20 percent (Hourston and Haegele 1980) and 99 percent

(Hardwick 1973, Leet et al. 2001). Survival of the larvae from hatching to entrainment was estimated using a daily survival rate of 0.927 ($1\text{-}0.995^{1/70} = 0.927$) based on a larval mortality of 99.5 percent (Stevenson 1962). Survival to entrainment was then estimated using the mean number of days to entrainment (4.4 days) as $0.927^{4.4} = 0.7167$. These life history parameters were used in the *FH* model to estimate a loss of 2,479 reproductive females (90 percent C.I. = 757 to 8,123; Table 4-16) from the entrainment estimate for Pacific herring larvae.

Table 4-16. Estimates of female adult Pacific herring losses are based on larval entrainment estimates using the fecundity hindcast (*FH*) model for February 2001–February 2002.

Parameter	Estimate	Standard Error	Lower 90% Confidence Interval	Upper 90% Confidence Interval	Absolute Range
FH estimate	2,479	1,789	757	8,123	7,366
Entrainment estimate	35,982,800	2,513,060	2,194	2,764	570
Egg survival	0.4000	0.1200	1,514	4,061	2,548
Larval survival	0.7167	0.2150	1,777	4,061	2,284
# Eggs/year	22,500	6,750	1,514	4,061	2,548
Longevity (years)	7.00	2.10	1,244	6,291	5,047
Maturation (years)	2.50	0.75	2,038	3,841	1,802

Note: Estimates from upper and lower 90 percent confidence intervals result from varying the value of the corresponding parameter in the model.

Sensitivity analysis showed that the uncertainty of our *FH* estimate was attributed to the model parameters of average longevity, fecundity, and egg survivorship, in that order (Table 4-16).

Adult Equivalent Loss (AEL)

The estimate of larval entrainment abundance for Pacific herring over the February 2001–February 2002 sampling period (Table 4-2) was used to estimate the number of equivalent adults that the entrained larvae represent. Survivorship of Pacific herring larvae from the average age at entrainment (4.4 days) to the estimated end of the larval period of 70 days (Hay 1985) was estimated using the same daily survival rate of 0.927 used to calculate *FH*. Survival from post-larvae to the average age of a mature female (4.75 years) in the population was calculated using an estimate of 50 percent annual adult mortality or $Z = –0.69$ from Hourston and Haegele (1980). The estimated number of equivalent adults (male and female) corresponding to the number of larvae that could be entrained by the Potrero Power Plant Unit 3 CWIS was 10,654 (90 percent C.I. = 5,252 to 21,612; Table 4-17).

Table 4-17. Estimates of adult Pacific herring losses due to entrainment using the adult equivalent loss (*AEL*) model for February 2001–February 2002.

Parameter	Estimate	Standard Error	Lower 90% Confidence Interval	Upper 90% Confidence Interval	Absolute Range
AEL estimate	10,654	4,581	5,252	21,612	16,360
Entrainment estimate	35,982,800	2,513,060	9,430	11,878	2,448
Early larval survival	0.0070	0.0021	6,504	17,452	10,948
Pre-recruit survival	0.0424	0.0127	6,504	17,452	10,948

Note: Estimates from upper and lower 90 percent confidence intervals result from varying the value of the corresponding parameter in the model.

Sensitivity analysis showed that the uncertainty of our *AEL* estimate was attributed to the model parameters of survivorship (Table 4-17).

Summary

Empirical transport model estimates of P_m indicate that larval entrainment losses could represent 0.1 to 0.4 percent of the larval population of Pacific herring in the San Francisco Bay source water study area. The results from the *FH* and *AEL* models do not exactly match the relationship of $2FH \cong AEL$ ($2FH$=4,958 and AEL=10,654). Differences between the two estimates reflect uncertainties in the parameter values used to calculate the *FH* and *AEL* models and could be due primarily to the use of a single adult mortality rate from recruitment through adult lifestages in the *AEL* model. Mortality of juvenile herring is probably higher than the adult mortality used in the model; higher juvenile mortality would result in a reduction of the *AEL* estimate. The 2*FH* and *AEL* estimates, in combination with the *ETM* results, indicate a low risk to Pacific herring populations in the San Francisco Bay source water study area. See further discussion in Section 4.4.

The CDFG had a peer review of their commercial Pacific herring fishery management in 2003. The review and reported finding submitted to the Fish and Game Commission suggested that the San Francisco Bay population is currently about 20 percent of its unfished level, and that the harvest strategy be re-evaluated. The age composition of the catch has shifted towards younger and therefore less fecund individuals. It was the opinion of the peer reviewers that the current harvest rate appears too aggressive, and a lower harvest rate of 10 to 15 percent was recommended. The estimated Potrero Power Plant entrainment loss based on the *AEL* estimate of 10,654 adults represents less than 0.03 percent by weight of the 2001–2002 San Francisco Bay Pacific herring harvest. The entrainment estimates of Pacific herring larvae are insignificant to the source water body population and to the San Francisco Bay herring fishery.

4.3.5 Yellowfin Goby

Yellowfin goby larvae ranked fifth in annual entrainment abundance at Potrero Power Plant and comprised about 10 percent of all fish larvae entrained in the CWIS (Table 4-2). The annual estimate of entrainment (February 27, 2001–February 22, 2002) was 29,230,697 larvae (*S.E.* = 1,425,890; Table 4-2).

Empirical Transport Model (ETM)

The average length of yellowfin goby larvae from intake station samples (*n*=299), along with the minimum and maximum lengths of the central 95 percent of the length frequency distribution, were used to estimate the period of entrainment risk for yellowfin goby. There are no reported larval growth rates for yellowfin goby, but a growth rate of 0.25 mm per day was calculated by using the size difference between hatch and transformation lengths (12.45 mm; 0.5 in.) derived from Moser (1996) and dividing it by a planktonic duration of 50 days cited for three other bay-dwelling goby species (Brothers 1975). This growth rate was used with the range of the central 95 percent of the measurements (4.0 to 6.6 mm NL; 0.2 to 0.3 in. NL) to calculate an estimate of 10.6 days for the maximum duration of entrainment risk. The growth rate and mean length of 5.4 mm (0.2 in.) NL were used to calculate an average duration of entrainment risk of 5.7 days.

The annual estimates (February 2001–February 2002) of conditional mortality (P_m) for yellowfin goby based on both the mean and maximum estimated durations of entrainment risk were small. The average entrainment risk duration of 5.7 days was used to calculate a P_m estimate of 0.002 (*S.E.* = 0.036), while the maximum duration of 10.6 days was used to calculate a P_m estimate of 0.003 (*S.E.* = 0.048) (Table 4-18). Thus, between 0.2 and 0.3 percent of the standing stock of larval yellowfin goby in the San Francisco Bay source water study area could be removed by entrainment (Table 4-18).

Estimates of proportional entrainment (*PE*) for yellowfin goby were highest in February, March, and May 2001 (Table 4-19). The estimates for many of the surveys were close to the volumetric ratio of cooling water to source water (0.0006 or 0.06 percent). The largest proportion (f_i) of yellowfin goby larvae was collected during the March 8, 2001 survey, and nearly 50 percent of the total collected for the study occurred during the three surveys that month (Appendix B).

Table 4-18. Empirical transport model (*ETM*) estimates of conditional entrainment mortality (P_m) for larval yellowfin goby based on entrainment risk durations calculated from mean and maximum lengths of entrained larvae.

Entrainment Exposure (days)	P_m Estimate	P_m Std. Error	P_m +2 Std. Errors	P_m -2 Std. Errors
5.7	0.00195	0.03595	0.07385	-0.06995
10.6	0.00294	0.04778	0.09851	-0.09262

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Table 4-19. Estimate of proportional entrainment (*PE*) of yellowfin goby.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i	f_i Std. Error
28-Feb-01	0.00024	0.00003	0.06803	0.00412
8-Mar-01	0.00030	0.00002	0.19957	0.00444
15-Mar-01	0.00009	0.00001	0.15262	0.00376
27-Mar-01	0.00015	0.00002	0.15629	0.00443
5-Apr-01	0.00013	0.00002	0.07773	0.00351
23-May-01	0.00033	0.00016	0.18748	0.00542
20-Jun-01	0.00008	0.00005	0.02837	0.00351
11-Jul-01	0	0	0.00079	0.00014
8-Aug-01	0	0	0	0
12-Sep-01	0	0	0	0
10-Oct-01	0	0	0	0
7-Nov-01	0	0	0	0
6-Dec-01	0.00006	0.00006	0.00034	0.00009
2-Jan-02	0.00005	0.00001	0.00567	0.00036
10-Jan-02	0.00015	0.00002	0.00791	0.00042
17-Jan-02	0.00005	0.00001	0.00690	0.00041
23-Jan-02	0.00011	0.00002	0.00767	0.00047
30-Jan-02	0.00008	0.00001	0.01109	0.00065
6-Feb-02	0.00012	0.00002	0.02556	0.00125
13-Feb-02	0.00016	0.00001	0.02823	0.00108
21-Feb-02	0.00019	0.00002	0.03575	0.00125

Note: All calculations based on Unit 3 maximum daily cooling water and screen wash water volume = 875,068 m^3 and San Francisco Bay study area source water volume = 2,907,008,000 m^3.

Fecundity Hindcast Model (FH)

The values required to estimate *FH* for yellowfin goby were substituted from reported life histories of other gobiid species (Brothers 1975, Wang 1986). No estimates of egg mortality for gobies were available. Goby egg masses are typically attached in burrows that are guarded by the male (Wang 1986, Moser 1996) so egg survival is probably high and is assumed to be 100 percent for the purpose of this analysis. Larval yellowfin goby survivorship estimates were also not available from the literature. Therefore, we used an estimate of 98.3 percent larval arrow goby mortality over two months from Brothers (1975) to calculate a daily survival estimate of 0.935 ($[1-0.983]^{6 / 365.25} = 0.935$) for yellowfin goby. Survival to entrainment was then estimated using the average number of days to entrainment (5.7 days) as $0.935^{5.7} = 0.683$. A batch fecundity estimate of 19,000 eggs was derived from Miyazaki (1940) and Wang (1986). Baker (1979) estimates longevity at 4 years, while Hoshino et al. (1993) reported a value of 3.5 years. An average age at maturity (1.3 years) was computed from Baker (1979), Brittan et al. (1970), Middleton (1982), and Wang (1986). The estimate of longevity was adjusted to a value of 2.3 years to account for the observation by Miyazaki (1940) that yellowfin goby may be terminal spawners and probably deposit a single egg batch per lifetime.

The estimated number of yellowfin goby larvae entrained over the one-year period from February 27, 2001–February 22, 2002 (Table 4-2) was used to calculate the number of breeding females needed to produce the number of larvae entrained. The number of adult females needed to produce the number of larvae entrained was 4,507 (90 percent C.I. = 1,056 to 19,244; Table 4-20). We were unable to locate any estimates of adult standing stock of yellowfin goby that could be used to provide some context for these estimates.

Table 4-20. Estimates of female adult yellowfin goby losses based on larval entrainment estimates using the fecundity hindcast (*FH*) model for February 2001–February 2002.

Parameter	Estimate	Standard Error	Lower 90% Confidence Interval	Upper 90% Confidence Interval	Absolute Range
FH estimate	4,507	3,977	1,056	19,244	18,188
Entrainment estimate	29,230,700	1,425,890	4,145	4,869	723
Larval survival	0.6827	0.2048	3,077	7,383	4,306
# Eggs/year	19,000	5,700	2,752	7,383	4,631
Longevity (years)	2.30	0.68	1,851	36,467	34,617
Maturation (years)	1.30	0.38	3,031	22,263	19,232

Note: Estimates from upper and lower 90 percent confidence intervals result from varying the value of the corresponding parameter in the model.

The sensitivity analysis shows that the uncertainty of our *FH* estimate was attributed to the model parameters of average longevity, maturation, and fecundity, in that order.

Adult Equivalent Loss (AEL)

The formulation of *AEL* requires estimates of survival from settlement to maturity. No survival estimates were available from the literature for these life stages of yellowfin goby. Therefore, we did not estimate *AEL* for this species.

Summary

Yellowfin goby are a species introduced to California from Japan and are utilized in the San Francisco Bay area primarily as bait for striped bass (Cohen and Carlton 1995). Other than the dominant position they have taken in many of the habitats where they have become established, there is little information on their ecological role in the community. Catch data from the commercial bait fishery were used to provide context for the *ETM* and *FH* results. The P_m estimates indicate that the power plant may annually entrain an average of 0.2 percent up to a maximum of 0.3 percent of yellowfin goby larvae from the San Francisco Bay source water study area. These estimates can be interpreted as the incremental mortality due to entrainment (P_m) and based on the *FH* results may be equivalent to the loss of approximately 4,500 adult females from the reproducing population. The *ETM* and *FH* estimates indicate a low risk to yellowfin goby population of the San Francisco Bay source water study area.

4.4 Summary of Entrainment Effects

The concentrations of larval fishes collected at the Potrero Power Plant intake stations were used to estimate entrainment losses of the Unit 3 CWIS both by estimating the fractional larval entrainment loss to the adult population and by extrapolating entrained larvae to a representative number of adults. Three different population models were employed to assess the potential impact of entrainment losses: empirical transport model (*ETM*), fecundity hindcast (*FH*), and adult equivalent loss (*AEL*). Results from each of the models are summarized for the most abundant fish taxa in Table 4-21. The lack of some life history information for bay goby and yellowfin goby precluded an analysis using all three models for those species. Cancer crabs were not assessed because their numbers were too low to provide statistically sound estimates.

Table 4-21. Summary of Potrero Power Plant Unit 3 CWIS estimated entrainment for abundant fishes based on Fecundity Hindcast (*FH*), Adult Equivalent Loss (*AEL*), and Empirical Transport Model (*ETM*) approaches using entrainment and source water larval concentrations and San Francisco Bay source water study area volume (February 2001–February 2002).

Taxa	Total Entrainment	2*FH* Estimate	*AEL* Estimate	*ETM* P_m (a) Estimate	*ETM* P_m (b) Estimate
bay goby	104,312,644	*	*	0.00133	0.00300
unidentified gobies	65,237,852	159,512	104,875	0.00107	0.00491
northern anchovy	49,302,228	6,276	11,620	0.00058	0.00321
Pacific herring	35,982,833	4,958	10,654	0.00134	0.00393
yellowfin goby	29,230,697	9,014	*	0.00195	0.00294

Taxa	*FH* Estimate	Total Entrainment	Egg Survival	Yolk-sac Survival	Larval Survival	Average Lifespan (years)	Age at Maturation (years)	Eggs/year
bay goby	*	104,312,644	*	*	*	*	*	*
unidentified gobies	79,756	65,237,852	*	*	0.6232	2.00	0.50	1,750
northern anchovy	3,138	49,302,228	0.5118	0.2678	0.6213	4.00	1.50	147,622
Pacific herring	2,479	35,982,833	0.4000	*	0.7167	7.00	2.50	22,500
yellowfin goby	4,507	29,230,697	*	*	0.6827	2.30	1.30	19,000

Taxa	*AEL* Estimate	Total Entrainment	Early Larval Survival	Late Larval Survival	Early Juvenile Survival	Late Juvenile Survival	Pre-Recruit Survival	Early Adult Survival
bay goby	*	104,312,644	*	*	*	*	*	*
unidentified gobies	104,875	65,237,852	0.0565	*	0.0900	*	0.3162	*
northern anchovy	11,620	49,302,228	0.1457	0.0393	0.4172	0.7033	0.4108	0.3413
Pacific herring	10,654	35,982,833	0.0070	*	*	*	0.0424	*
yellowfin goby	*	29,230,697	*	*	*	*	*	*

*Unavailable information or value that could not be computed.
(a) P_m values calculated using average period of entrainment risk.
(b) P_m values calculated using maximum period of entrainment risk.

The *PE* values for each source water survey used in the *ETM* are estimates of the daily mortality due to entrainment for each survey. The *PE* estimates for many of the surveys are close in value to the ratio of cooling water intake to source water volumes. One of the original applications of the *ETM* model suggested that an estimate of P_m could be derived from entrainment densities alone by using the ratio of the entrainment volume to the source water and assuming uniform distribution and entrainment risk of larvae (Boreman et al. 1978). This approach was suggested for freshwater lakes or rivers of closed source water volumes and uniform larval distributions. In this sense, most marine systems with large tidal exchange and vast ocean currents are termed "open" systems in contrast to "closed" freshwater systems that have less variability and fewer input and output parameters.

The San Francisco Bay source water as defined in this study has aspects of a "closed" *ETM* model system. Tidal and wind driven currents transport and mix the distribution of the Bay's planktonic larvae, especially in the shallow nearshore areas where sampling occurred. As source water distributions become more uniform, the calculation of *ETM* and estimates of P_m become a function of the duration of entrainment exposure. The estimates of P_m that were calculated using the average period of larval exposure were similar for each of the five most abundant fish species (taxa) entrained because their larval duration periods only varied from approximately three to seven days. The estimates for all of the fish taxa were similar and did not appear to vary based on the duration of exposure. For example, the estimates based on the maximum duration of exposure for bay goby and northern anchovy are similar even though they represented the range of exposures (6 to 29 days, respectively). This may indicate that factors such as larval behavior and habitat differences between intake and source water stations are important in estimating P_m.

The average lengths of the fishes measured from the intake station samples indicated that, on average, exposure to entrainment occurs over a relatively short time period (three to seven days) during development. The low concentrations of larger larval fishes in later developmental stages may indicate larval behavior (e.g., settlement to benthic habitats or migration into deeper areas away from the intakes) that reduces their risk to entrainment as they develop.

The low magnitude of the *ETM* estimates are supported by the population model results of the low numbers of individuals impacted listed in Table 4-21. The model results for Pacific herring indicate that the P_m estimates of 0.1 to 0.4 percent losses correspond to a theoretical loss of approximately 4,960 to 10,650 adults (Table 4-21). P_m estimates for northern anchovy were 0.06 to 0.32 percent and correspond to a theoretical loss of 6,280 to 11,620 adults (Table 4-21). Yellowfin goby P_m estimates were 0.2 to 0.3 percent and correspond to estimated adult losses of approximately 9,010 (Table 4-21). Bay goby P_m estimates were 0.1 to 0.3 percent (Table 4-21). The demographic models for unidentified gobies indicate that the P_m estimates of 0.1 to 0.5 percent losses correspond to a theoretical loss of approximately 159,510 to 104,880 adults (Table 4-21).

For those species with both *FH* and *AEL* estimated losses, the model results can be compared directly using the relationship $2FH = AEL$. This conversion requires that ages of *AEL* and *FH* individuals are equal and that a 50:50 sex ratio exists in the population. While the results for the three taxa with both *FH* and *AEL* estimates were not in close agreement with the $2FH = AEL$ relationship, the confidence intervals for the two estimates using one standard error overlap indicate that the differences would not be statistically significant. The differences between the $2FH$ and *AEL* estimates reflect the uncertainty in the model parameters. In the case of unidentified gobies, the estimates are limited by the uncertainty in the taxonomic composition of this group. The model assumption that the parameters are representative for the time period of collection may not hold for a taxonomic group, such as unidentified gobies, whose composition may change through the year due to variations in the reproductive cycles among the species within the group. Additionally, the *FH* and *AEL* models used generalized larval mortality information that may not accurately represent larval survival rates for a single species.

The impacts of entrainment on source water populations can be evaluated by estimating the fractional losses to the population attributable to the CWIS. Estimated entrainment losses were extrapolated to potential losses to the source water fishery using *FH* and *AEL* estimates and data on commercial landings for the San Francisco Bay area. CDFG landing data for yellowfin goby and northern anchovy were obtained for 1999, 2000, and 2001 (CDFG 2000, 2001, 2002) (Table 4-22). The value of Pacific herring roe catches were obtained from CDFG for the 2000–2001 and 2001–2002 commercial herring season (Ashcraft 2002) (Table 4-22). In addition to the Pacific herring roe fishery, northern anchovy and yellowfin goby are taken in a commercial trap fishery and sold as baitfish. While bay goby and other unidentified gobies may be taken as incidental catch in this fishery, they are not otherwise commercially or recreationally important. As a result there are no fishery data for these taxa, and no estimates of standing stocks in San Francisco Bay that can be used with the model results. To convert the *FH* and *AEL* estimates to units of biomass, average weights per fish were obtained from the literature for yellowfin goby, Pacific herring, and northern anchovy.

While the bait fishery for yellowfin goby is very small, the fishery for Pacific herring is valuable (Table 4-23). Pacific herring are taken as whole fish, but the most valuable fishery is for herring roe and herring roe on kelp. The fishery data for herring roe reflect landings of whole fish that are sold into the herring roe market. Therefore, the estimated cost per kilogram is based on the whole fish that are sold into herring roe fishery.

Table 4-22. Weight (kg) and value ($) of landings for yellowfin goby and northern anchovy landed in San Francisco Bay Area ports for 1999, 2000, and 2001.

Year		Yellowfin goby	Northern anchovy
1999	Weight (kg)	124	45,222
	Value ($)	743	13,015
2000	Weight (kg)	75	116,482
	Value ($)	285	63,435
2001	Weight (kg)	37	8,059
	Value ($)	103	4,374
Average cost per kg ($)		$4.79	$0.48

Source: CDFG 2000, 2001, 2002-Final California Commercial Landings for 1999, 2000, 2001.

Table 4-23. San Francisco Bay herring roe fishery prices for gill net-caught fish.

Season	Base price*/ton**	Base price/lb.	Base price/kg	Average roe %	Ex-vessel price/ton	Ex-vessel price/lb.	Ex-vessel price/kg.
2000-2001	700	0.35	0.77	13.5	910	0.46	1.01
2001-2002	500	0.25	0.55	15.9	795	0.40	0.88
Average	600	0.30	0.66		853	0.43	0.95

Source: Ashcraft 2002.
* Price in U.S. dollars.
** Short tons are used (2,000 lb/ton).

While no estimates of average weight were available from the literature, data on yellowfin goby were available from field collections from other estuaries in California. The U.S. Fish and Wildlife Service Southern California Habitat Conservation Division conducted fish monitoring in San Diego and Mission bays from 1988 to 1992. Summary data from the Mission Bay surveys showed that six yellowfin goby weighed a total of 183 g (0.4 lb), or an average of 30.5 g (0.07 lb) per fish (USFWS http://swr.ucsd.edu/hcd/cummb.htm). Using this average value, the 2*FH* estimate is equal to 275 kg (606 lb) (9,014 × 30.5 = 275 kg).

The average weight of a Pacific herring caught in the 2001–2002 fishery was 104 g (0.2 lb) (Ashcraft 2002). Using an estimate of 104 g, the 2*FH* and *AEL* estimates for Pacific herring are equal to 516 and 1,108 kg (1,138 and 2,443 lb), respectively (2*FH* = 4,958 × 104 g = 516 kg) (*AEL* = 10,654 × 104 g = (1,108 kg).

We estimate that a 2.75-year old northern anchovy (male/female combined) is 134.2 mm standard length (SL) and weighs 25 g (0.06 lb), using data from Mallicoate and Parrish (1981) and Collins (1969), in Sakagawa and Kimura (1976). An age of 2.75 years was selected to align with *AEL* and *FH* estimates for this species (see Section 4.3.3). Using this estimated weight of 25 g, the 2*FH* and *AEL* estimates are equal to 157 and 291 kg (346 and 642 lb), respectively (2*FH* = 6,276 × 25 g = 157 kg) (*AEL* = 11,620 × 25 g = 291 kg).

The landing weights and market prices of these commercial fisheries were used to estimate the value per kilogram of entrained larvae expressed as adults (*AEL* and *FH* estimates). Assuming all of the adults would have been caught, 2*FH* and *AEL* estimates showed that economic losses would have totaled approximately $1,882.06 and $1,192.06, respectively (Table 4-24). The 2*FH* dollar value includes all three species and the *AEL* estimate includes dollar values for Pacific herring and northern anchovy.

In summary, entrainment effects from the Potrero Power Plant CWIS are directly related to the small volume of the cooling water relative to the San Francisco Bay source water study area. The estimated effects are minimal because of the short average duration of exposure to entrainment for the taxa presented in this assessment. These conclusions are supported by results from the study's demographic models that indicate little potential for population-level effects. Economic losses due to entrainment of these species are low. The abundance of cancer crab megalopae was too low to estimate entrainment effects. Extremely low numbers of megalopal cancer crab species found at the intake stations provide assurance that population-level effects from entrainment would not occur to these species of crabs.

Table 4-24. Approximate values of estimated losses due to entrainment at the Potrero Power Plant for selected groups of fishes (February 2001–February 2002).

Taxa	Total Estimated Entrainment	*2FH* Estimate	*AEL* Estimate	Average weight (kg) per fish	Estimated cost ($) per kg	Approximate Value ($) of Losses due to Entrainment *2FH*	Approximate Value ($) of Losses due to Entrainment *AEL*
bay goby	104,312,644	*	*	*	*	*	*
unidentified gobies	65,237,852	159,512	104,875	*	*	*	*
northern anchovy	49,302,228	6,276	11,620	0.0250	0.48[a]	75.31	139.44
Pacific herring	35,982,833	4,958	10,654	0.1040	0.95[b]	489.85	1,052.62
yellowfin goby	29,230,697	9,014	*	0.0305	4.79[a]	1,316.90	*
Total						**1,882.06**	**1,192.06**

Values are given in U.S. dollars.
* Unavailable information or value that could not be computed.
[a] Values calculated from San Francisco Bay port area landings (Table 4-22).
[b] Values calculated from 2000-2001 and 2001-2002 herring season landings (Table 4-23).

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Potrero Power Plant Unit 3
316(b) Entrainment Characterization Report

Appendix A

Potrero Power Plant Unit 7 Project

Survey Protocol for Collection and Analysis of Baseline Data

Potrero Power Plant Unit 7 Project

Survey Protocol for Collection and Analysis of Validating and Baseline Data

December 19, 2000

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SURVEY PROTOCOL AND SCHEDULE FOR COLLECTION AND ANALYSIS OF VALIDATING AND BASELINE DATA POTRERO POWER PLANT UNIT 7 PROJECT

The California Energy Commission (CEC)'s staff has determined that Southern Energy California (SECAL)'s application for the Potrero Plant Power Unit 7 Project is data adequate in the area of marine biological resources based on existing site information. The staff has requested that SECAL validate the results of certain studies that were used in the application to assess potential impacts on marine resources in the area of the project and provide additional baseline biological data. The staff, in concert with consulting agency representatives, provided SECAL with the following general guidance regarding aquatic surveys they required for the Unit 7 project.

Survey Objective

It is intended that the CEC's requested surveys provide updated information with which to evaluate the potential impacts of the proposed Potrero Power Plant Unit 7 Project.

Survey Protocols

The CEC staff and consulting agency representatives requested that three categories of marine resources be resurveyed to validate previous study results, provide baseline data, and assess potential impacts of the Potrero Power Plant (PP). In an addendum to the agreement with SECAL, the CEC requested that SECAL conduct surveys of the site's:

- benthic infauna according to a survey plan previously submitted on August 31, 2000, approved by CEC management staff at a meeting on October 5, 2000, and amended on December 1, 2000. The original benthic survey plan has been expanded at the CEC's request to include a survey of the intertidal habitat in the vicinity of the Potrero PP. The shoreline habitat in the area of potential construction and associated disturbance will be surveyed for species composition and percent cover information.

- juvenile and adult fishes using otter trawl and midwater trawl methods comparable to previous Pacific Gas and Electric Company (PG&E) and California Department of Fish and Game (CDFG) surveys in the area, and

- larval fishes and cancer and European green crab megalops as part of a 316(b) resource assessment of cooling water intake system (CWIS) effects patterned after those recently completed for the Moss Landing Power Plant Modernization Project.

The CEC provided SECAL the following guidance, which is incorporated as required into the survey protocols for the collection and analysis of validating and baseline biological resource data.

Organization of this Report

This report is divided into three sections: benthic and intertidal survey, trawl surveys, and 316 (b) resource assessment. Information about ongoing and previous studies is provided at the beginning of each section, followed by a discussion of the proposed study design.

BENTHIC AND ROCKY SHORELINE INTERTIDAL SURVEY

BENTHIC AND ROCKY SHORELINE INTERTIDAL SURVEY

Objectives

The objectives for the benthic and intertidal surveys are to provide updated information on the benthic community near the new outfall and in the immediate vicinity of the power plant and to characterize the intertidal algal and invertebrate communities in the immediate vicinity of the power plant's proposed intake and discharge construction activities.

Introduction

The San Francisco Bay subtidal habitat harbors an abundant and diverse assemblage of invertebrate organisms in its bottom sediments (e.g., bivalves, polychaete worms, and amphipod crustaceans). These sediment-dwelling organisms, known as infauna, provide food for a variety of epibenthic invertebrate predators, fin fishes, and marine mammals. Temporary sediment disturbance and warmer water temperatures associated with the construction and operation of the Potrero Power Plant's proposed offshore discharge could potentially affect the project site's benthic habitat. Neither the anticipated construction disturbances nor the projected offshore discharge temperature are expected to result in long-term impacts on the abundance or reproductive characteristics of the area's infaunal populations. The proposed study is designed to quantitatively sample the subtidal habitat to verify the findings of previous studies and to update a biological baseline for the potentially affected habitat.

Benthic assemblages in San Francisco Bay respond to many types of physical, chemical, and biological fluctuations. The Bay experiences natural fluctuations due to variations in freshwater flows, salinity, and sedimentation, as well as historic and recurring human influences, including nutrient and organic enrichment and contamination. It is difficult to identify a benthic response to disturbances when contamination commonly co-occurs with many of these other environmental factors (Nichols, 1979; Peterson et al., 1996; Swartz et al., 1986; and Spies et al., 1988). Additionally, most of the benthic species that currently inhabit the Bay are non-native species (Cohen and Carlton, 1995). Therefore, much information about the changes in benthos in space and time and the corresponding changes in environmental and contaminant factors is required in order to observe consistent patterns and trends (Luoma and Carter, 1991).

Currently, the Potrero Power Plant (Potrero PP) discharges heated water from a shoreline structure. Excess discharge temperatures dissipate in the surface layers of the receiving water due to buoyancy and mixing, and decrease along the shoreline with distance from the outfall.

Tidal currents are a major factor influencing the orientation of the surface thermal plume. During the ebb tide the surface plume is oriented to the north; during the flood tide it is oriented to the south. The wharves and pilings to the north and south of the discharge modify the orientation of the plume.

The study's primary objective is to provide a current description of the benthic habitat. The updated information has been requested by the CEC's staff. The proposed survey will provide baseline data to evaluate benthic community changes that might result from modifications to the design and location of the power plant's cooling water intake and discharge structures.

Ongoing and Previous Studies — Benthic Survey

Regional Monitoring Program Base Program Monitoring Sites (SFEI, 1999)

Monitoring of trace substances in benthic indicator species in the Bay-Estuary began in 1993 and is ongoing. In an effort to capture seasonal variability, samples are taken three times a year: during the rainy season (March–April), during a period of declining Delta outflow (May–June), and during the dry season (August–September). Two dozen sampling stations are located throughout the Bay-Estuary and at its major tributaries, from the mouths of the Guadalupe River and Coyote Creek in the extreme southern portions of the Bay, to the confluence of the Sacramento and San Joaquin rivers. Most stations are located as far as possible from the influence of local contaminant sources to be as representative as possible of "background" contaminant concentrations. Other stations are close to wastewater outfalls or creek mouths for comparison purposes. Water samples have also been collected during the spring at two upstream locations at Rio Vista (Sacramento River) and Manteca (San Joaquin River). Researchers at the U.S. Geological Survey in Menlo Park participate by collecting monthly water quality and phytoplankton data. The U.S. Geological Survey in Sacramento also participates by measuring suspended sediments in water using continuous samplers. These measurements, made at different time scales than those in the base program, are used to describe Bay-Estuary water conditions, thus providing a context for interpreting the Regional Monitoring Program (RMP) contaminant data.

Samples are analyzed for five general parameters:

- conventional water quality data (such as salinity, dissolved oxygen, and temperature),
- chemical constituents (such as metals, pesticides, and other synthetic hydrocarbons),
- water toxicity (effect on laboratory organisms),

- sediment characteristics (such as particle size), sediment chemistry, and sediment toxicity (effect on laboratory organisms), and
- contaminant bioaccumulation in transplanted shellfish.

More than 100 individual chemical parameters are analyzed in water, sediment, and shellfish two to three times per year. Water and sediment samples are also used to conduct toxicity tests on selected organisms.

Benthic infauna samples have been collected at a large number of sampling locations throughout San Francisco Bay and the Sacramento-San Joaquin Delta Estuary since the 1970s. The samples, collected with a Ponar sediment sampler, are analyzed for the fauna retained on 1.0-millimeter (mm) and 0.5-mm mesh screens, and the particle size of sediments. Various chemical constituents in the samples, such as trace metals and pesticides are also analyzed. The stations sampled in this study fall well outside the influence of the existing Potrero PP thermal discharge, in terms of both depth and distance offshore. However, identifying truly unimpacted reference locations within the Bay is probably not possible, and no other nearby bay has characteristics similar to the San Francisco Bay that could serve as a true reference location for biological comparisons. Therefore, "ambient" reference locations must be identified from the existing benthic monitoring data. An ambient reference benthic assemblage is defined as:

> A sample taken of organisms currently inhabiting the least-contaminated areas of the Bay. This sample must include species known (from studies elsewhere) to inhabit uncontaminated sediments, but must not include very many species known to inhabit contaminated sediments. These assemblages should exhibit natural fluctuations in species composition and abundance in response to changes in salinity and sediment type.

Several studies of benthic species responses to contamination in San Francisco Bay have been published, including Filice (1959), Nichols (1979), Chapman et al. (1987), Lee et al. (1994), and Hunt et al. (1998). Additionally, studies of benthic responses to contamination in other locations have been used to identify the types and abundances of benthic organisms one might expect to find in unimpacted and impacted areas in the Bay. The use of literature as an initial step avoids the common assumption that if sediments are contaminated then the benthos must be impacted.

Indicators of Salinity and Sediment Type

Several benthic assemblages have been identified from data collected between 1994 and 1996 (Thompson et al., 1997) that generally reflect differences in salinity and sediment types in San Francisco Bay. Examples of species that indicate environmental conditions are the amphipod

Corophium spincorne, which occurs only in salinities below about 5 practical salinity units (psu), and the closely related amphipod *Corophium insidiosum*, which occurs only in Central Bay salinities above 30 psu. The worm *Heteropodarke* sp. is found only in high salinity and sandy sediments.

Indicators of Ambient Reference and Impacted Conditions

Impacted and unimpacted infaunal assemblages in the Bay have been identified from regional monitoring results using classification and ordination analysis. The analyses clearly distinguished the distinctly different assemblages of Central San Francisco Bay and the Delta Estuary and also contaminated sub-assemblages of each assemblage. Contaminated assemblages were characterized by reduced numbers of species and individuals and by the presence of indicator species (e.g., *Streblospio benedicti*). In the Central Bay, data from the sampling sites for the Bay Area Dischargers Associations (BADA), Local Effects Monitoring Program (LEMP), City and County of San Francisco (CCSF), and East Bay Municipal Utility District (EBMUD) were classified as part of the Central Bay assemblage. These data could not be distinguished from Central Bay samples collected away from the BADA discharges. The analyses also could not distinguish impacted or unimpacted assemblages in the sample data. Regional monitoring results have demonstrated sediment contamination at all monitoring sites. The widespread nature of this sediment contamination makes it difficult to locate reference areas for use in control and impact study designs.

Proposed Study Design — Benthic and Intertidal Survey

Benthic infauna samples will be collected in a manner that enables the comparison of results from an RMP benthic station off Islais Creek. These samples are comprised of primarily sedentary invertebrate organisms that burrow in or live on the surface of sediments. The nature of the shallow mud-bottom habitat results in a high degree of spatial and temporal variation in the fauna; therefore several benthic replicate samples will be collected at each station. A single survey will be conducted in December 2000, weather permitting.

The proposed benthic study design will resample areas designated as reference sample locations in previous studies of the Potrero PP thermal discharge. The station locations are considered reference stations because they represent areas that are beyond the influence of the discharge thermal plume. However, there is no reasonable way to select reference locations that duplicate all other influential sediment characteristics and water quality conditions between the reference stations and project study locations. The proposed benthic study is designed to provide sediment and infaunal data that will adequately describe subtidal habitat in the affected project area, particularly at the sites of the proposed offshore pipelines and diffusers.

The rocky shoreline intertidal habitat near the immediate vicinity of the Potrero PP will be characterized by sampling a combination of the attached organisms large enough to reliably field-identify using vertical and horizontal transects depending on the substrate and distribution of the species.

Benthic Sample Collection Methods

Figure 1 portrays the 19 proposed benthic sampling locations. At each station three samples will be collected using a 6-inch × 6-inch Ponar grab sampler. A fourth sediment sample will be collected at each station and analyzed for particle grain size distribution. Lead weights will be added to or removed from the outside of the grab as appropriate to the sediment type in order to control depth of penetration. If the appropriate substrate for grab sampling is not encountered, the sampling location will be modified to allow for sample collection. An incomplete grab closure will result in rejection of the sample. If the condition of the grab sample is acceptable[1], the grab jaws are opened, and the sediment is placed into a five-gallon plastic bucket.

The sample is sieved through two screens stacked on top of each other. The top screen has a 1-mm mesh size, and the smaller screen retains animals in its 0.5-mm mesh. The material retained in each screen is gently washed into separate labeled sample jars. A wash bottle with seawater is used to rinse material into the sample jar. Forceps are used to remove any organisms remaining on the screens; these organisms are subsequently placed into the sample jar. Seawater is filtered out from the sample jars through a 0.25-mm Nitex mesh and replaced with a volume of isotonic $MgCl_2$ a third greater than the volume of the sample. The sample is set aside for 15 to 30 minutes, then the $MgCl_2$ is replaced with 10 percent buffered formalin solution. As a final step, two to three drops of stain (rose bengal solution) are added to the sample for ease of organism removal. The preserved samples will be returned to the laboratory for sorting and identification to the lowest practical taxonomic level.

[1] The sample is accepted if the sampler is completely closed, there is no evidence of sediment washout through the doors, sediment is evenly distributed in the grab, surface of the sediment is minimally disturbed, and the overall depth of sediment in the sample is appropriate for the sediment type.

FIGURE 1: BENTHIC SAMPLING STATIONS

Rocky Shoreline Characterization Methods

The rocky shoreline intertidal habitat near the immediate vicinity of the Potrero PP will be characterized by sampling either vertical or horizontal transects, depending on the distribution of the species in the area. Quadrats that are ¼-meter square will be randomly positioned and sampled along transect lines. Transect lengths and numbers of quadrats per transect will be selected in the field to sufficiently characterize the area. Algae and attached invertebrates will be measured for percent cover, and conspicuous motile invertebrates will be identified and counted. Areawide photographs of the area and closeup pictures of the sample sites will be taken during the survey.

Benthic Data Analysis

The benthic study will be a one-time single survey. Community structure is known to vary between stations due to sediment types and other physical factors. Sediment grain size and other physical factors will be used to stratify the 19 benthic grab sampling stations. Cluster analysis will be used to construct a dendrogram plot of the station that would be inspected for trends with respect to the RMP Islais Creek Station. If clusters of stations based on sediment grain size can be identified from the RMP station and current studies, these groups of stations will be used to estimate the similarity among sampling periods. The error term from the bootstrap estimate would measure spatial variation among samples and not temporal variation estimated for trawl studies.

The combined data will be analyzed with multivariate methods to describe community structure infaunal composition. The principal population parameters that reflect the overall health of the benthic community within Central San Francisco Bay will be computed from samples collected at each station over the duration of the study. Species similarity analyses, such as Bray-Curtis analysis, will be performed on grab sampling results to test the degree of overlap in benthic community microstructure between surveys and stations. Results from the species similarity tests will be displayed in a dendrogram plot of the 19 stations and inspected for trends with respect to the RMP Islais Creek Station data. Abundance data for each taxon will also be used to compute grab sample Principal Component Analysis (PCA) scores.

These community parameters are explained below.

Abundance. The type and abundance of benthic organisms reflect the quality of the biological community in which they live. While information on abundance is necessary, abundance information alone gives no indication of the types of organisms in the environment. This population parameter is best used in conjunction with other parameters such as diversity and number of species.

Number of Species. The total number of species will be recorded in all replicate samples at each individual station. Spatial variability (mean number of species among stations) will also be recorded.

Diversity (H'). The Shannon-Wiener diversity index will be used to measure the distribution of individual organisms in the sample. If all individuals are of the same species, the diversity index is 0.

Evenness (J'). The Pielou evenness index will be used to measure the evenness of the community. When all species have equal abundances in the community, evenness is at a maximum (J' = 1.00).

Dominance. Dominance will be measured in two ways. The first measure used will be Simpson's index (C'). The index increases with decreasing diversity in the sample and is heavily weighted toward the most common species.

The second dominance measure used will be the Swartz dominance index (Sw). The index is defined as the minimum number of species that account for 75 percent of all individual organisms collected in a sample.

Infaunal Index. The Infaunal Trophic Index (ITI) will be computed by comparing the abundance of four soft-bottom benthic groups. The groups are distinguished by feeding behavior and consist of Group I (suspension feeders), Group II (surface-detritus feeders), Group III (surface deposit feeders), and Group IV (sub-surface detritus feeders). The ITI ranges between 0 and 100.

When the index values are above 58, the sediments are relatively clean (Groups I and II dominate). When Groups III and IV dominate, lower indices indicate that the sediments are high in organics.

Species Richness (d). Species richness will be determined using the Margalef species richness index (d). The index measures the number of species relative to the number of individuals in a sample. If only one species is present then *d* is 0.00.

Deliverables

A report regarding the findings of this study will be prepared. The report will characterize the existing subtidal benthic habitat and its biological resources in the vicinity of the Potrero PP. The report will also contain a complete list of the numbers of individuals of each species collected at each of the current study's stations as well as the mean grain size and percentage of sand, silt, and clay at each station. It will also compare this study's results with those collected at the RMP's Islais Creek Station. The report shall be provided to Energy Commission staff no later than 90 days after collection of the samples.

The report will also contain information regarding the rocky shoreline habitat in the immediate vicinity of the Potrero PP. The report will characterize the composition and abundance of algal and attached invertebrate species and conspicuous motile invertebrate species encountered during the survey. Species abundance and distribution will be portrayed using histograms and maps.

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TRAWL SURVEYS

TRAWL SURVEYS

Objective

The objective of the trawl surveys is to provide updated information on fish populations near the proposed new circulating cooling water outfall.

Ongoing and Previous Studies — Trawl Surveys

An Evaluation of the Effects of the Cooling Water Discharges on the Beneficial Uses of Receiving Waters at Potrero Power Plant (PG&E, 1973)

The following section is a summary of a report prepared by PG&E (1973) in response to a requirement by the Regional Water Quality Control Board.

Biological field investigations were designed to sample a cross section of biota that could be affected by the thermal plume at Potrero PP. These investigations included studies of fishes, benthic organisms, and zooplankton. Otter trawls were used to sample fishes associated with bottom substrates, floating and sinking gill nets collected free-swimming fishes throughout the water column, a benthic grab device was used to sample bottom-dwelling invertebrates, and a filter-pump system was used to assess zooplankton survival.

Thermal Effects on Fishes

A fish population study was conducted at the Potrero Power Plant to address questions about the effects of the thermal discharge on fish communities and their distributions. The study was designed to "(1) qualitatively classify the fish with respect to their temperature preference on the basis of their abundance, (2) qualitatively classify the power plant with respect to its associated fish in order to determine possible ecotypic situations, (3) quantitatively determine relationships between fish catch parameters and temperature, and (4) quantitatively determine differences in the fishing gear used" (PG&E, 1973).

Station Locations

Five sampling locations along the western shoreline of Central San Francisco Bay were selected for the study of thermal discharge effects on fishes in the vicinity of the Potrero Power Plant.

Stations were sampled in quarterly periods from November 1971 through August 1972. The locations were designated F-1 through F-5, as shown in Figure 2. Stations F-1 and F-2 were control stations (ambient temperature) located 503 meters (m) (1,650 feet [ft]) and 335 m (1,100 ft), north of the Unit 3 discharge, respectively. Station F-3 was located 122 m (400 ft) north of the Unit 3 discharge and was affected by the discharge thermal plume under certain conditions. Station F4 and F5 were discharge stations. Station 4 was located in the center of the Unit 3 discharge and Station 5 was located in the center of the Unit 1 and 2 discharge. The water temperature at the discharge stations (F4 and F5) was continuously around 5.6° C (10° F) above ambient. Station F3 was located in a transitional zone between ambient and discharge temperatures, where water temperatures at times reached 1.7° C (3° F) above ambient.

Methods

Three capture methods were used to sample fish species that occur throughout the water column. Otter trawls were used to sample demersal fishes (discussed below) and two variations of set gill nets (floating and sinking) were used to sample fishes within the water column. Temperature profiles were taken at the surface during the first and second sampling periods and at the surface, bottom, and depths of 0.61 m (2 ft), 1.5 m (5 ft), and 3 m (10 ft) during the third and fourth sampling periods.

Otter Trawl Sampling

Fishes were collected using a 4.9-m (16-foot) (footrope) nylon shrimp net with otter doors to spread the net opening. The net was constructed of 3.2-centimeter (cm) (1-¼ inch) mesh, except for the codend where 2.5-cm (1-in.) mesh was used. The net was deployed and retrieved by hand. Tows were approximately 91 m (100 yds) in length and were conducted at a speed of 1.5 knots. Following each tow, fishes, invertebrates, and detritus were removed from the codend and the organisms were placed in labeled plastic bags.

Processing

Catch Processing

Processing of samples occurred on shore. Sample number, date, time, station location, sampling gear, and temperature profiles were recorded. Fishes were separated by species, and their total lengths (cm) were measured and recorded. The combined weight of all individuals within a species was recorded. The total abundance and species composition of fishes are shown in Table 1.

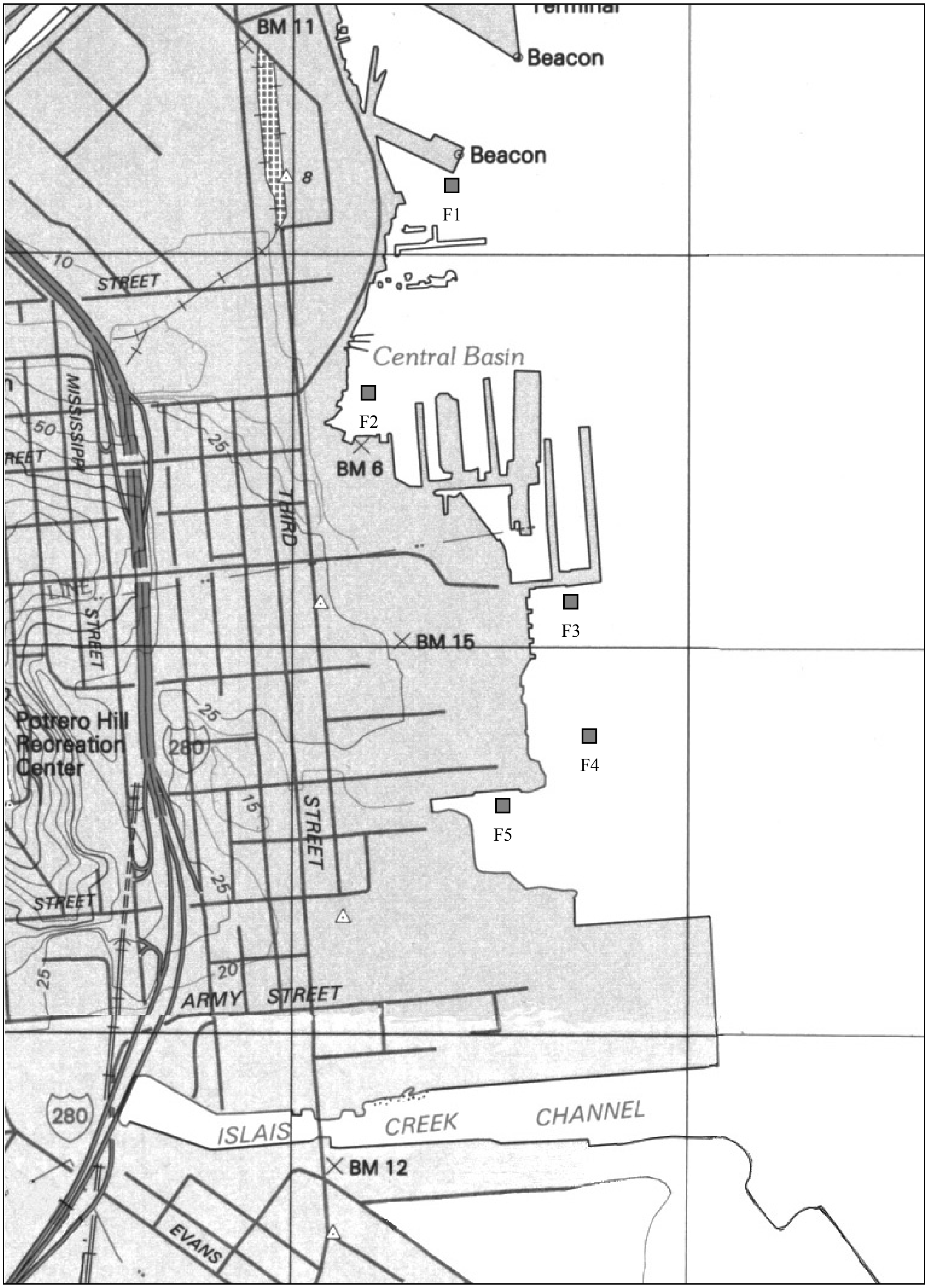

Figure 2. Station locations from fish sampling in 1971 – 1972.

Table 1. Abundance and Species Composition of Top 15 Fish Species Collected at the Potrero Power Plant Fish Sampling Stations, 1971–1972.

Species Scientific name	First Sampling Period	Second Sampling Period	Third Sampling Period	Fourth Sampling Period	Total
English sole *Parophrys vetulus*	89	328	730	144	1,291
Shiner perch *Cymatogaster aggregata*	159	300	156	171	786
Jacksmelt *Atherinopsis californiensis*	0	28	106	8	142
Pacific staghorn sculpin *Leptocottus armatus*	8	19	39	20	86
Dwarf perch *Micrometrus minimus*	61	1	7	12	81
White seaperch *Phanerodon furcatus*	22	22	10	26	80
Pacific sanddab *Citharichthys sordidus*	7	56	10	0	73
Starry flounder *Platichthys stellatus*	7	19	13	13	52
Bigmouth sole *Hippoglossina stomata*	0	0	0	37	37
Goby unid. *Gobiidae*	0	0	0	35	35
Striped bass *Morone saxatilis*	1	8	9	8	26
Threadfin shad *Dorosoma petenense*	1	2	0	12	15
Pacific herring *Clupea pallasi*	0	12	0	0	12
Specklefin midshipman *Porichthys myriaster*	0	0	0	10	10
Brown rockfish *Sebastes auriculatus*	2	3	3	1	9
Total	357	798	1,083	497	2,735

Source: PG&E, 1973

Data Processing

Data collected from the three gear types used in the fish population study included:

- numbers of fishes collected,
- numbers of species collected,
- total weight of each species (combined individuals),

- total length of each fish, and
- water temperature(s).

The weights and lengths of fishes captured during a sampling effort were averaged for analysis. Data were analyzed using two-way analysis of variance. The underlying assumptions for this statistical method were accepted (normality and equal variance), although the paucity of replications made these assumptions unverifiable. Data were analyzed to determine simultaneous differences between sampling stations (indicating possible thermal discharge effects) for all stations, gear types, and for each fish catch parameter. Differences between gear types for each station and fish catch parameter were also analyzed. The hypothesis that all sample means were equal was tested against an alternate hypothesis that all sample means were not equal. The Potrero PP thermal plume area of influence was not static; it shifted during the year because of the action of currents, wind, and tidal action. Some sample stations may have been thermally influenced during one sampling period but not during others. This confounded the classification of fish species according to temperature affinity. The distribution and abundance of fishes varied spatially within the study area and vertically within the water column.

Data Analysis

Qualitative Analysis

During the fish population study at Potrero and Hunters Point, a total of 2,789 fishes representing 33 different taxa were collected. English sole (*Parophrys vetulus*) were the most numerous fish species caught, comprising 46.3 percent of the total. Shiner perch (*Cymatogaster aggregata*) accounted for 28.2 percent of the total, and jacksmelt (*Atherinops affinis*) comprised 5.1 percent of the total.

Data for the study were arranged according to the temperature difference (ΔT) above the ambient temperature regardless of other fish catch parameters. The station location was used as a criterion for temperature grouping when temperature data were not available. Forty-five percent of all fishes captured during the study at Potrero PP (17.9 fish caught per unit effort) were caught in what was categorized as ambient temperature water (that is, 0° above ambient [°C or °F]). Transitional temperature range areas (1.9 to 3.8 °C [3.5 to 6.8 °F] above ambient) accounted for 25.3 percent of the total catch (29.6 fish caught per unit effort). Finally, 29 percent of all fishes captured during the study (11.4 fish caught per unit effort) were taken from discharge temperatures (4.3 to 6.6 °C [7.8 to 11.8 °F] above ambient). Of the total fishes collected during the study, 28.2 fish per unit effort were categorized into a thermal temperature range by station location (instead of temperature data).

Seventy-seven percent of the total species collected during the study were taken from ambient temperature ranges, 50 percent were associated with transitional areas, and 73.1 percent were caught in discharge temperatures. Of the 73.1 percent of the species that occurred in discharge temperature ranges, more than half (53.9 percent) were also collected in ambient temperature ranges and 38.5 percent were collected in transitional temperature ranges. Results indicate that eurythermal fishes (or fish species) are associated with the Potrero PP.

Angler Use and Catch Composition in the Vicinity of the Discharge of Potrero Power Plant (Steitz, 1975)

Purpose

This report presented information gathered from the Potrero Power Plant during the four-month creel census program at six Pacific Gas and Electric Company (PG&E) thermal power plants. The program was undertaken to supplement the thermal studies program with additional biological descriptions of thermal impact areas, and to provide some specific information regarding sport fishing at Potrero PP.

Methods

Creel census at the Potrero PP was conducted from June 28 through October 24, 1974. The four-month sampling period was stratified into two successive two-month sampling periods. Sampling dates were randomly selected with the restriction that each day of the week was to be sampled at least once at each power plant during the sampling period.

The shoreline adjacent to the thermal discharge was divided into survey zones. Survey zones were established at the power plant for the purpose of delineating the influence of the thermal plume as related to its configuration at various tidal stages, and analyzing this influence with respect to angler success, catch composition, and possible angler use patterns.

All sampling was conducted within a legal California fishing day, beginning one-half hour before sunrise, and ending one-half hour after sunset. Bi-hourly use counts were used to provide estimates of fishing pressure as well as to supply additional information regarding specific recreational uses at areas adjacent to the power plant.

Only shore anglers were interviewed during the sampling period. The following information was recorded: number of anglers in the party, total time fished (to the nearest half-hour), total fish species caught, number of fishes kept and released by the fish species, zip code, and time of interview. At the time of the interview, the census taker also recorded the following information:

air temperature, wind velocity and direction, a general rating for the weather (subjective scale), and the plant zone in which the interview took place. The tidal stage and generating load were also recorded.

Potrero Power Plant Thermal Effects Assessment, 1989–1990 (PG&E, 1991)

PG&E conducted studies to determine the potential impacts of the thermal plume from the Potrero PP discharge on the receiving water's fish, algal, and macroinvertebrate populations. These studies, conducted from November 1989 through October 1990, were done to fulfill a requirement of the plant's National Pollutant Discharge Elimination System (NPDES) permit renewal process.

The purpose of these studies was to characterize fish, macroinvertebrate, benthic, and algal communities inhabiting the waters in and near the vicinity of the Potrero PP discharge and to document the response of these organisms to discharge temperatures. Information was gathered on trends in abundance and geographic distribution for the above-listed communities within the influence of the thermal discharge and in reference areas unaffected by the thermal plume. Biological field studies included:

- fishery surveys to characterize the species composition, relative abundance, and distribution of juvenile and adult fishes and macroinvertebrate species,
- angling surveys of recreational fisherman,
- Pacific herring shallow subtidal and intertidal spawning and egg development surveys, and
- shallow subtidal and intertidal benthic invertebrate and algal surveys.

Monthly Fishery Collections

Monthly fishery surveys were conducted from November 1989 through October 1990 in the vicinity of the Potrero PP. Sampling stations were located in areas contacted by the thermal plume (discharge stations) and in areas not affected by the warm-water discharge (reference stations). During each survey a total of five crab trap stations, three otter trawl stations, and four small-mesh gill net stations were sampled. The locations of all of the stations are presented in Figure 3. Sampling typically occurred during the daytime with additional collections at night to assess diel variation in fish use patterns and test the efficiency of the collection gear. Multiple

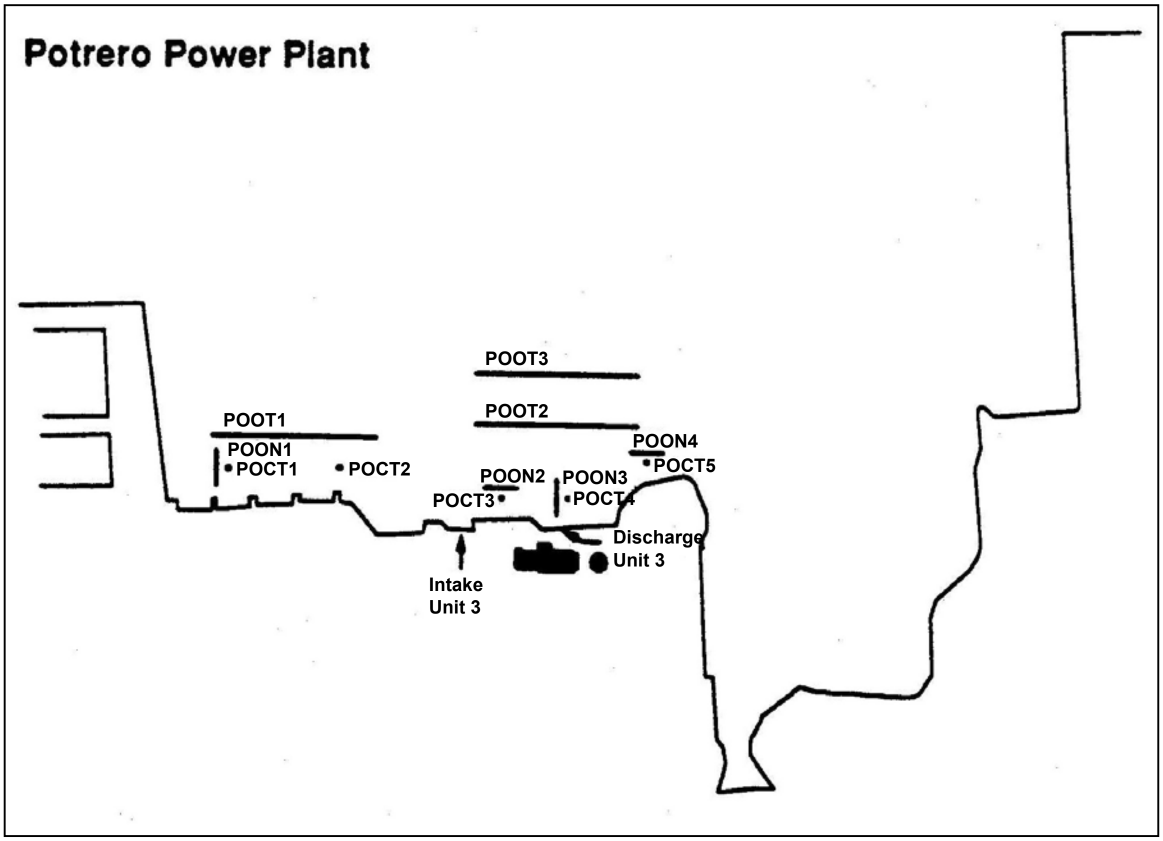

Figure 3. Locations of otter trawl (POOT), gill net (POON), and crab trap (POCT) stations during the 1989-90 Potrero PP Thermal Effects Assessment (PG&E, 1991).

collections were made with each sampling gear during all of the surveys to allow for calculations of catch-per-unit-effort (CPUE) rates.

Fishes were collected through out the year in the vicinity of Potrero PP. Ninety-six percent of all fishes (n=18,794) were collected in otter trawls and the remaining 4 percent (n=743) were collected in gill nets.

Monthly Otter Trawl Survey Methods

Otter trawls were conducted at three stations (Figure 3) each month near the Potrero PP. A semi-balloon otter trawl, measuring 16 feet wide at the mouth and 4 feet tall, was used to collect organisms near the bottom of the water column. Single spreader boards attached to each side of the net kept the mouth of the net open during the trawl. The upper section of the net was constructed of ¾-inch-square mesh and the lower section contained an inner line of 1/8-inch woven mesh.

The net was lowered to the bottom and towed for the full length of the station. Once the net was retrieved, organisms were sorted by hand and placed into a holding container. All fishes were identified to the lowest taxonomic level possible, counted, and the total lengths of the first 50 individuals of a species were recorded. Cancer crabs were identified to species, measured (maximum carapace width), and sexed. All other crabs were identified to the Genus level and counted. All bay shrimp (*Crangon nigromaculata*) were identified and counted, while other shrimps were separated into groups. Water temperatures were measured at the surface and near the bottom with a Yellow Springs Instrument temperature probe.

Monthly Otter Trawl Survey Results

A total of 18,794 fishes representing 36 taxa were collected in otter trawl surveys. Eight species comprised the top 97 percent of all taxa collected (Table 2). Sixty-nine percent of the most abundant fishes were represented by two species: bay goby (*Lepidogobius lepidus*) (39 percent) and northern anchovy (*Engraulis mordax*) (30 percent). The remainder of the top 97 percent (28 percent) of fishes were represented by the following six species: unidentified gobies (Family Gobiidae) (8 percent), shiner perch (*Cymatogaster aggregata*) (7 percent), speckled sanddab (*Citharichthys stigmaeus*) (5 percent), Pacific staghorn sculpin (*Leptocottus armatus*) (3 percent), English sole (*Parophrys vetulus*) (3 percent), and white croaker (*Genyonemus lineatus*) (2 percent). Nearly 50 percent of the most abundant species collected were members of one Family—Gobiidae. The remaining species listed above have either commercial or recreational importance.

Table 2. Number and Seasonal Distribution of the Most Abundant Fishes Collected in Monthly Otter Trawl Samples at the Potrero Power Plant: November 1989 – October 1990.

Fishes	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total (% Comp)
bay goby	20	40	9	1,633	19	1,694	2,340	868	514	183	42	6	7,368 (39%)
northern anchovy	372	2	0	6	8	0	83	149	1,160	2,020	996	782	5,578 (30%)
unidentified goby	54	299	190	0	317	53	137	12	45	50	81	190	1,428 (8%)
shiner perch	91	382	136	23	107	2	38	174	179	70	80	20	1,302 (7%)
speckled sanddab	94	275	90	73	119	61	71	74	32	30	45	10	974 (5%)
Pacific staghorn sculpin	2	5	6	11	48	18	66	147	329	4	1	0	636 (3%)
English sole	2	12	27	27	116	52	198	169	25	0	0	0	628 (3%)
white croaker	1	0	1	5	31	4	29	34	143	114	4	1	367 (2%)

Source: PG&E, 1991

CPUE rates for fishes were compared between stations. No significant differences (P>0.05) were detected in the CPUE rates for fishes collected at sampling stations located directly offshore of the discharge and the reference station location (Table 3).

Table 3. Average CPUE Rates for Fishes Collected in Otter Trawls near the Potrero Power Plant: November 1989 – October 1990.

Station	Average CPUE Rate
PO-OT1 (reference)	38.4
PO-OT2 (closest to discharge)	44.6
PO-OT3	38.9

Source: PG&E, 1991

Five genera and nine species of macroinvertebrates (total n=5,685) were collected in otter trawls from the vicinity of Potrero PP. Eighty-eight percent of the total catch was dominated by bay shrimps *Crangon* spp. Three species of cancer crabs (slender crab [*Cancer gracilis*], red rock crab [*Cancer productus*], and brown rock crab [*Cancer antennarius*]) and the spider crab (*Pyromaia tuberculata*) were also collected in otter trawls. Nudibranchs, ctenophores, and gastropods were collected but were neither identified to species nor counted.

CPUE rates for macroinvertebrates were compared between stations. No significant differences (P>0.05) were detected in the CPUE rates for macroinvertebrates collected at sampling stations located directly offshore of the discharge and the reference station locations (Table 4).

Table 4. Average CPUE Rates for Macroinvertebrates Collected in Otter Trawls near the Potrero Power Plant: November 1989 – October 1990.

Station	Average CPUE Rate
PO-OT1 (reference)	11.9
PO-OT2 (closest to discharge)	13.5
PO-OT3	11.5

Source: PG&E, 1991

Herring Fishery and Management

Pacific herring have been commercially harvested from bays and estuaries in California since at least the mid-1800s (Spratt, 1981; Barnhart, 1988). The species was considered an important food fish during the California Gold Rush, and by 1875 San Francisco Bay supported a well-established gillnet fishery (Love, 1996; CDFG, 1998). Records of Pacific herring catches were poorly documented prior to 1916 (when tabulation of annual landings by CDFG began); however, the annual harvest was reported to be small (Spratt, 1981; Barnhart, 1988). A fresh food fishery also exists in San Francisco Bay and Tomales Bay but is relatively minor. The bulk of the fishing effort for herring in California involves harvest of the species for roe products.

The CDFG has assessed the status of the spawning population of Pacific herring in San Francisco Bay since the inception of the sac-roe fishery in 1973. Published results of this research are presented in Administrative reports through the 1992-1993 season (CDFG, 1997). The objective of the CDFG Pacific Herring Research Project is to furnish data to the CDFG commission for the long-term management of the sac-roe and roe-on-kelp fisheries in California.

A number of assessment methods are used by the CDFG project to determine the annual status of the herring population. Estimates of the size of the spawning population (biomass) have been a key source of information used in managing the fishery. The predominant assessment methods for biomass estimates include hydroacoustic (acoustic) and spawn escapement surveys (Spratt, 1981). Biological data, such as year-class composition, age structure, sex ratio, potential recruitment levels, and young-of-the-year abundance are obtained from mid-water trawl surveys and used in evaluating the general condition of the population. The information obtained from these annual surveys, along with data on historic trends in oceanic conditions and herring populations, is used to regulate the commercial harvest of Pacific herring throughout California.

Spawning Biomass Estimates

Spawn Survey

The spawn surveys of San Francisco Bay were conducted mainly within the Central and South Bays, bounded by the Richmond-San Rafael Bridge to the north, the Golden Gate Bridge to the west, and the San Mateo Bridge to the south. The majority of the spawn surveys have taken place north of Candlestick Point. The surveys were conducted up to four days per week, from November through March. Project personnel searched for spawning activity by boat, usually at low tide. Observations of feeding marine birds and mammals and the presence of milt in the water aided in locating the spawning areas (Watters and Oda, 1997).

The estimated biomass (tons) of spawning adult herring is calculated from the estimated number of eggs spawned. Herring spawn in subtidal and intertidal locations, as well as on pier pilings. Unique sampling techniques and conversion factors are used for each type of spawn in order to determine the best estimate of the total number of eggs spawned. A description of each sampling technique follows. The methodology has remained the same for subtidal and intertidal sampling since the 1984 - 1985 season (Spratt, 1988).

Subtidal Spawns

As the herring move into the shallows to spawn, they deposit their adhesive eggs on beds of vegetation. To estimate the number of eggs spawned in a subtidal location, it is necessary to determine the density of the vegetation. In potential spawning areas, prior to the spawn, divers collected three random vegetation samples (1 square meter [m^2] each) from a number of stations. The samples consisted primarily of the red alga *Gracilaria* spp. and eelgrass (*Zostera marina*). The estimated vegetation density for each station was obtained by averaging the densities of the three samples.

The search for subtidal spawning locations involved towing a weighted rake along the bottom to collect vegetation and checking it for eggs. This same technique was used to collect the egg and vegetation samples. Once the spawn was located, the boundaries were determined and mapped. The area of the entire spawn was then calculated from the recorded dimensions. Samples were collected every 9,000 m^2, with a minimum of three random samples collected for small spawns, and at least ten samples collected for spawns >93,000 m^2.

Laboratory processing involved sub-sampling at least 10 grams (g) from each sample. Each sample was rinsed of debris, dried, and weighed. The number of eggs were either counted or weighed (1 g = 750 eggs) and the vegetation re-weighed. The number of eggs per kilogram (kg) of vegetation was averaged for all samples. The estimate for the total number of eggs in the spawn was calculated by the following formula:

Total eggs = (mean eggs/kg vegetation) × (kg vegetation/area) × (area)

Intertidal Spawns

The search for intertidal herring spawns involved checking the shoreline for exposed eggs. Once the spawn area was located, a random segment of shoreline was selected from which three random samples (1 m^2) were taken. The spawn area, with adjustments made for topographical effects, was determined from chart or rangefinder measurements.

Laboratory processing involved counting or weighing the eggs from each sample to determine the eggs/m^2, from which an average for all samples was obtained. The estimate for the total number of eggs in the spawn was calculated by the following formula:

Total eggs = (mean eggs/m^2) × (spawn area) × (correction factor for topography)

Pier Piling Spawns

Pier piling spawns were not sampled randomly. Instead, one-m^2 samples were collected approximately every 274 to 457 m (900 to 1,500 feet) along the entire length of the spawn. The area of the spawn was calculated one of two ways. One method was to measure the depth of the spawn on pilings and multiply it by the length of the pier. The second method was to multiply the depth of the spawn by the number of pilings spawned upon, multiplied by the piling circumference. The estimate for the total number of eggs in the spawn was calculated by multiplying the spawn area by the average number of eggs per m^2.

Hydroacoustic Surveys

Hydroacoustic surveys, using sound transmission, are used to determine the size and density of herring schools to estimate spawning stock biomass. Hydroacoustic surveys have been used in San Francisco Bay since the 1982 – 1983 spawning season. Many variations in the collection methods and data analysis have occurred since that time. Methods for hydroacoustic surveys from the most recent CDFG Administrative Report (Pacific Herring, *Clupea pallasi*, Spawning Population Assessment for San Francisco Bay, 1992 - 1993) (CDFG, 1997) were discussed in the Potrero PP AFC.

Report on the 1980-1995 Fish, Shrimp, and Crab Sampling in the San Francisco Estuary, California (CDFG, 1999)

The Bay-Delta Division of the CDFG has conducted a long-term monitoring study of the San Francisco Estuary since February of 1980. The plan for this study was designed by the Interagency Ecological Program (IEP) in 1979, of which CDFG is a member, and subsequently approved by the State Water Resources Control Board (SWCRB). The stated objective of the study was "to determine the effects of freshwater outflow from the delta on the abundance of marine and estuarine fishes, shrimps, and crabs and use this knowledge to understand the timing of freshwater flow that is necessary for their well-being." The report presents a summary of the results (1980 to 1995) of ongoing efforts to collect biological and physical data about the San Francisco Estuary. Data on the abundance and distribution of selected organisms are presented and described in the report. Detailed analyses of the data were not presented as a part of this report.

Materials and Methods

Data was collected through a regimen of three general types of sampling surveys.

- open water,
- shore, and
- ringnet.

The sampling surveys were conducted on a monthly basis. In addition to biological data collected during these surveys, physical water parameters were measured/collected at each station during each survey.

Open Water

Open water sampling began February 1980 and has continued on a monthly basis since. Initially, 35 sampling stations were established within the Estuary (Figure 4). These were located over benthic habitats of varying depths from the South Bay (near the Dumbarton Bridge) to the main channels of the Sacramento (near Sherman Island) and San Joaquin (near Antioch) rivers. Seven open water stations were added to the survey in 1988, four were added in 1990, and six in 1994 for a total of 52 stations. Station 109 was located in the vicinity of the Potrero PP.

Open water stations were sampled using three different gears:

- bottom trawls (otter),
- midwater trawls, and
- plankton nets (discontinued in 1989).

Otter trawl gear was used for sampling benthic macroinvertebrates and demersal fishes. The net headrope measured 4.9 m, and the net body was constructed of 2.5-cm stretched mesh with a 1.3-cm stretched-mesh codend. Tows were made against the current and were approximately 5 minutes in duration. To ensure that the net remained in contact with the bottom throughout the tow, 5 feet of cable was paid out for every 1 foot of water depth (scope of 5:1). Measurement of the length of each tow was typically accomplished using Loran-C (for surveys after May 1981). A 70 percent door spread (3.4 m) was assumed when calculating the width of the net mouth when being towed. The bottom area sampled was calculated as the product of door spread and tow length. Midwater and plankton net sampling methods were summarized in the Potrero PP AFC.

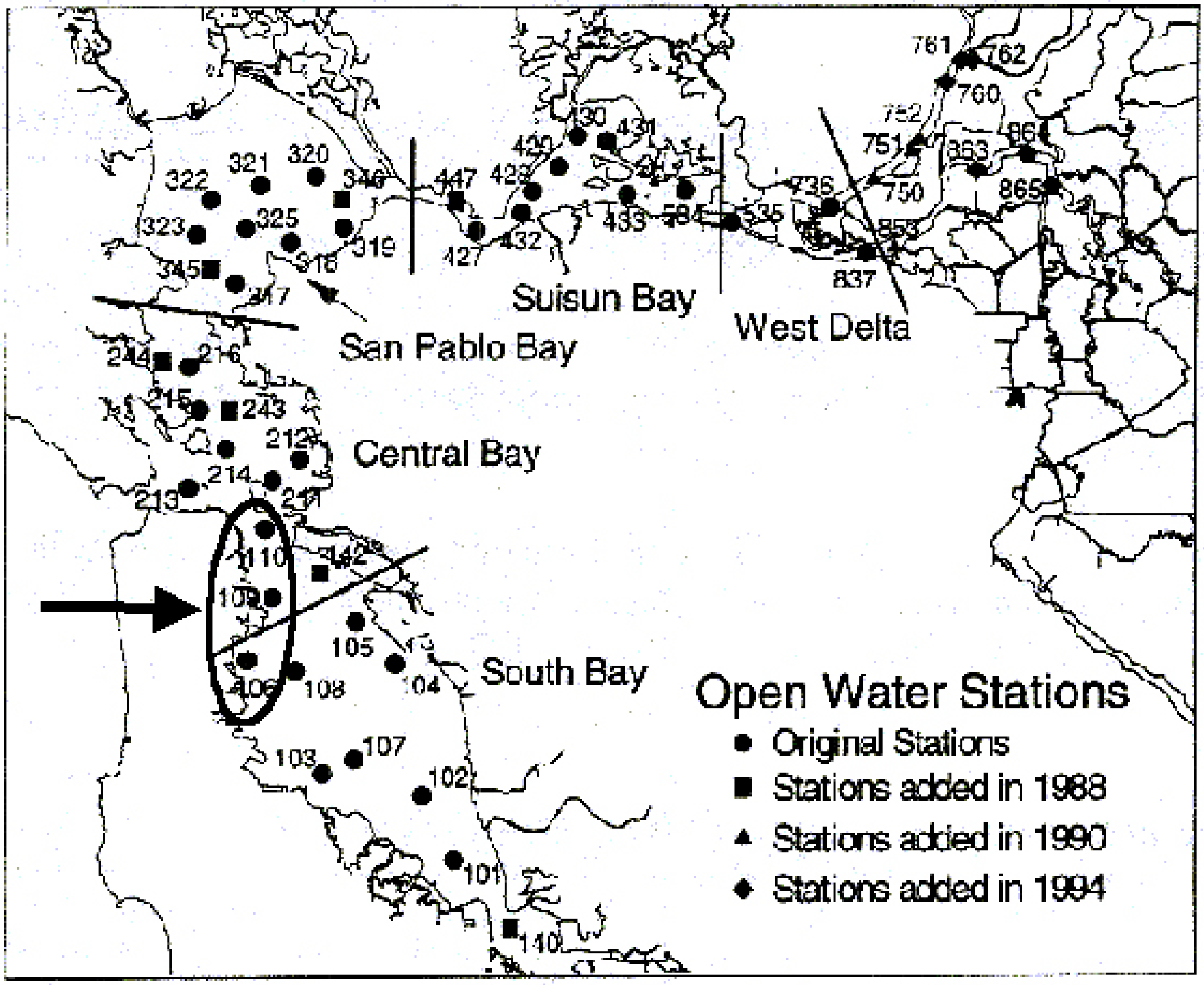

Figure 4. Station locations of the CDFG open water surveys (CDFG, 1999).

Shore Sampling and Ringnets

Shore sampling was conducted using a beach seine at 27 stations within San Francisco and San Pablo bays. Shore sampling began in August 1980 and continued monthly until January 1987. Two shore sampling stations were located in the Central Bay south of Bay Bridge. Station 177 was the shore sampling station nearest to the Potrero PP and was located south of the Potrero PP near India Basin/Hunters Point. Shore sampling methods were described in the Potrero PP AFC.

A survey of crab abundance was conducted from May 1982 until December 1993 using ringnets. Nine sampling stations were established initially, however three ringnet stations were added in 1990, and five were added in 1994. No ringnet stations were located in the Central Bay south of the Bay Bridge. Ringnet sampling methods were described in the Potrero PP AFC.

Temperature and Salinity

Measurements of both specific conductance and temperature were taken at each station on all surveys. During open water sampling water temperature and specific conductance are currently measured with a CTD device every 0.5 second during descent to the bottom and retrieval. From 1981 to February 1990 water temperature and specific conductance was measured with a digital water quality monitor at 1-m or 2-m depth intervals, depending on the water depth at the station. Prior to 1981, only surface water temperatures were recorded during open water sampling. Surface water samples were collected in a bucket and the temperature was measured immediately to 0.1 °C. Specific conductance was measured for each sample in the laboratory and converted to a salinity value (at 25 °C). Temperature and specific conductance were measured using the same procedure used for surface water samples.

Catch Processing

Fishes and *Cancer* crabs collected by trawling were separated from the detritus and identified to species. Shrimp were also separated from the detritus for identification and measurement. Fishes were measured to the nearest mm fork length (FL) or total length (TL). If a great number of any species was captured, a sub-sample of up to 50 randomly selected individuals were measured. Small individuals of several species were not counted or measured because they were considered too small to be fished effectively with the mesh size used. A minimum size cut-off (for counting) was established for the selected species. All *Cancer* crabs were sexed (when size permitted) and a maximum carapace width measurement (to nearest mm) was recorded for up to 30 randomly selected individuals of each species. A sub-sample of up to 0.94 L of the total volume of shrimp sorted from each otter trawl sample were fixed in 10 percent formalin for laboratory processing and identification.

Proposed Study Design — Trawl Surveys

Otter trawl samples will be collected at a total of six stations (Figure 5). One station (OT1) is located north of the Potrero PP in the Central Basin. Two stations (OT2 and OT3) are located to the north of the proposed outfall, and two stations (OT4 and OT5) will cover the area of the new discharge. Station OT6 is located south of proposed discharge in an area of approximately the same bathymetric contours as the new discharge. Midwater trawl samples will be collected along three trawl tracks (Figure 5). Station MT1 is located in the Central Basin, north of the Potrero PP, Station MT2 covers the area of the proposed discharge, and Station MT3 is located south of the proposed discharge. These sampling locations were selected to include both stations near the proposed outfall and otter trawl stations sampled in the 1989-1990 PG&E study (PG&E, 1991). The stations will be sampled on a monthly basis (concurrent with the CDFG trawling, if possible) at approximately 30-day intervals allowing for weather and sea conditions. Inasmuch as the composition of fish species found in the previous surveys were influenced by the power plant's discharge temperatures or flow, it will be important for comparative purposes to sample the present day fish assemblage under similar operating conditions. The monthly surveys will be conducted for three months beginning January 2001[2] through November 2001. Sampling will occur during the daytime generally between the hours of 9 a.m. to 4 p.m., consistent with the sampling time of the previous surveys. Each otter trawl track will be repeated beginning with the first trawl track one hour after the first set of replicate samples has been collected. Each of the midwater trawl stations will be sampled once per month. The location of each trawl track's start and finish will be located as closely as possible using differentially corrected GPS navigation equipment.

Sample Collection Methods

Otter trawl and midwater trawl samples will be collected using sampling gear and methods similar to those used in the previous PG&E surveys and in the ongoing CDFG surveys. The otter trawl net's headrope will measure approximately 16 feet (4.9 m), and the net body will be constructed of 1-inch (2.5-cm) stretched mesh with a ½-inch (1.3-cm) stretched-mesh codend. The otter trawl will be towed against any prevailing current (or in the opposite direction of the

[2] Trawl data from the first three months of collection will be compared to data collected in the 1989-1990 PG&E thermal effects studies (PG&E, 1991). If the comparison shows that fish populations are essentially the same, the level of effort (frequency) of sampling will be discontinued. Note: Discontinuation of the study will be approved by the Working Group.

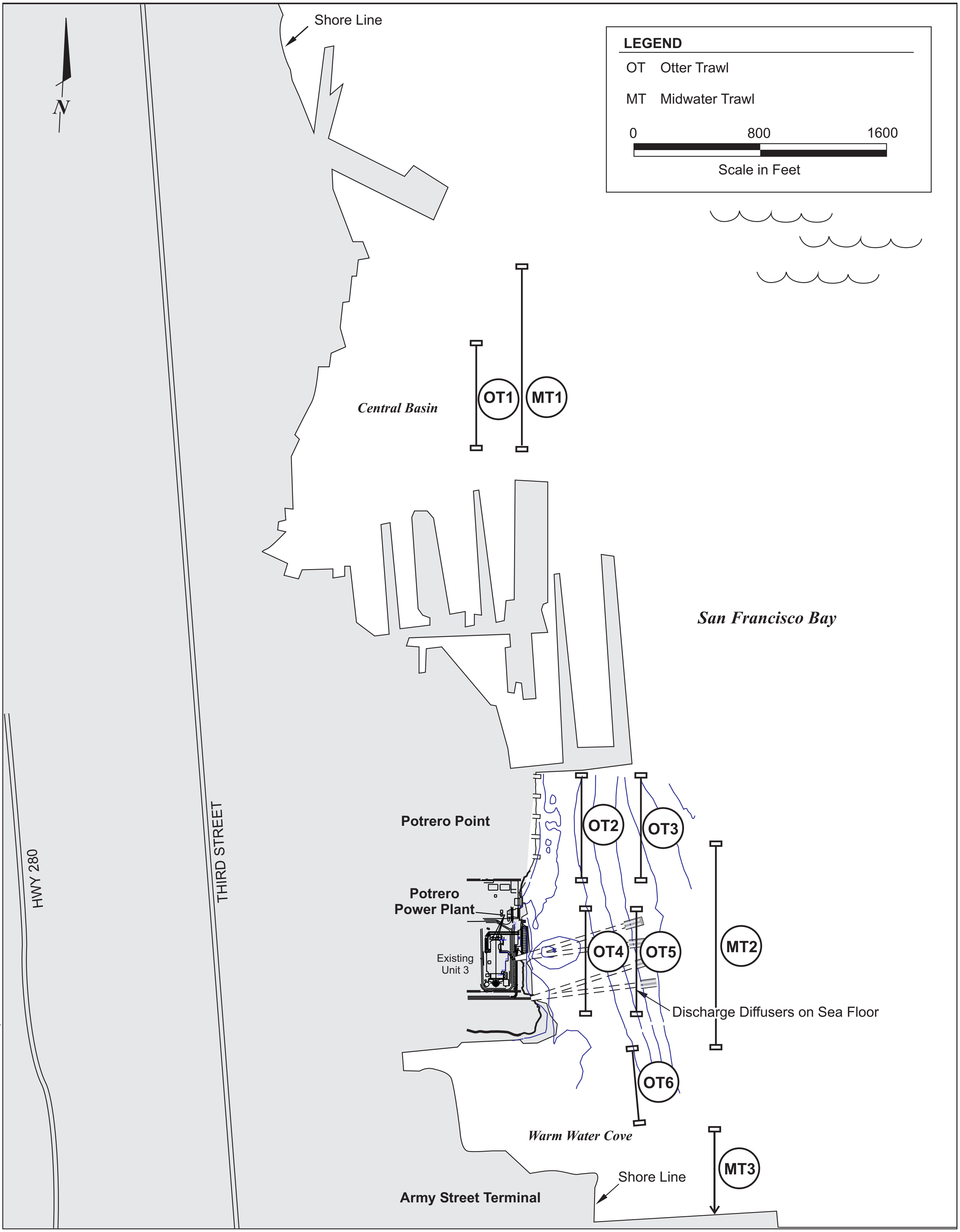

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FIGURE 5:
FIGURE TRAWL STATIONS

predicted tide) for approximately 5 minutes after the trawl has reached the bottom. Tow tracks are approximately 91 m (100 yds) in length at a speed of 1.5 knots. Following each tow, fishes, selected invertebrates, and detritus will be removed from the codend. A shipboard fathometer will be used to monitor bottom depth and type to maintain sampling consistency. Using real-time fathometer readouts, 5 feet of tow cable will paid out for every 1 foot of water depth (scope of 5:1) to ensure that the otter trawl net remains in contact with the bottom throughout the tow. Measurement of the length of each tow will be accomplished using global positioning system (GPS) navigation equipment and will be recorded along with each sample's field collection data and identification number. The beginning and ending times of each trawl net sample will be recorded along with measured water quality information such as temperature, salinity, dissolved oxygen, pH, and turbidity.

Specifications for the custom-made CDFG midwater trawl net have been requested from CDFG. The midwater trawl will be towed with the current and retrieved obliquely. Measurement of the length of each tow will be accomplished using GPS navigation equipment and will be recorded along with each sample's field collection data and identification number. The beginning and ending times of each trawl net sample will be recorded, along with measured water quality information such as temperature, salinity, dissolved oxygen, pH, and turbidity.

Fishes, *Cancer* crabs, and shrimps collected by trawling will be separated from the detritus and identified to species, counted and measured. Other invertebrate species will be identified to the lowest practical taxonomic level and counted.

Fishes will be measured to the nearest mm fork length (FL) or total length (TL). If a great number of any species are captured, a sub-sample of up to 50 randomly selected individuals will be measured. Small individuals of several species will be identified if possible and counted. However if these individuals are considered too small to be fished effectively with the mesh size used, then they will not be included in concentration analysis. A minimum size cut-off (for measuring) will be established for the selected species. All *Cancer* crabs will be sexed (when size permits) and a maximum carapace width (CW) measurement (to nearest mm) will be recorded for up to 30 randomly selected individuals of each species. A sub-sample of up to 0.94 L of the total volume of shrimp sorted from each otter or midwater trawl sample will be fixed in 10 percent formalin for laboratory processing and identification.

Data Analysis

Species similarity analyses between the 1989 - 1990 survey and CDFG Station 109 data and the current survey will be performed on trawl study results to test the degree of similarity between the three sampling periods. The choice of (dis)similarity index and variable transformation for the analysis will be based on the need for comparing the composition of the taxa between the two periods and not necessarily the need to compare their absolute abundances. Absolute abundances could be affected by many factors including changes in sampling protocols between the two survey periods. The choice of index affects how abundant, rare, or missing taxa are weighted. Standardizing the data or transformation to logarithms can also be used to reduce the effects of very abundant taxa on the index. One potential solution for addressing the differences in sampling protocols between periods would be to reduce the data to presence/absence and compute a qualitative measure of similarity.

The characteristics of different (dis)similarity indices have been considered by many authors (e.g., Orloci, 1975; Digby and Kempton, 1987; van Tongeren, 1987). The sensitivity of similar indices to sample total dominant species and species richness was considered by van Tongeren (1987). The potential differences between sampling protocols for the two periods would most likely affect the total abundances in the samples and the abundances of the dominant species. The results of van Tongeren (1987) indicate that the chord distance and coefficient of community would be the most appropriate measures of similarity for quantitative data and the coefficient of community would be the most appropriate measures of similarity for qualitative or presence/absence data. The details of models for data comparison, model criteria and parameters of statistical comparison (CL, Type I and Type II error rates) will be specified through the CEC technical committee process.

The comparison of trawl net sample results will be based on monthly samples from the current study period and the 5-month period (bracketing the current 3-month period) from the 1989 - 1990 study and CDFG Station 109. The multiple samples will also allow for calculation of an error term for the estimate, but the smaller sample size will limit its usefulness in the assessment.

Interannual variation in seasonal changes in species composition could confound a comparison of the same three calendar months from different years. Therefore, the samples from the 5-month period from 1989 - 1990 and CDFG Station 109 that bracket the current 3-month survey period will be randomly sampled to obtain a bootstrap similarity estimate. The bootstrap estimate will also provide a measure of the error due to interannual variation associated with our similarity estimate. The multiple samples will also allow for calculation of an error term for the estimate.

Deliverables

Beginning in February 2001 and continuing for three months, results of monthly trawl surveys shall be provided to California Energy Commission staff. These monthly reports will include species composition and abundance data collected from monthly otter and midwater trawls.

A report regarding the findings of the three months of sample collection (January 2001-March 2001) will be submitted to the CEC on or before April 1, 2001. The report will characterize the existing fish, *Cancer* crab, and shrimp populations in the vicinity of the Potrero PP. It will also compare this study's results with those collected in the Potrero PP 1989 - 1990 thermal effects assessment (PG&E, 1991) and with data from CDFG surveys at Station 109. This three-month summary report will also contain a review of applicable thermal effects. Based on the results of the trawl studies, a determination will be made whether the proposed project construction will affect listed species or adversely affect Essential Fish Habitat. Similarity between station catch data from the current study will be analyzed to determine whether the number of stations could be reduced for the remainder of the sampling program.

A final report, containing species composition and abundance data from all stations, will be submitted to the CEC one month after completion of the sampling.

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316(b) RESOURCE ASSESSMENT

316(b) RESOURCE ASSESSMENT

Objective

The objective of the proposed 316(b) Resource Assessment is to determine whether the proposed Cooling Water Intake Structure (CWIS) represents best technology available to minimize the potential impacts of the proposed new circulation cooling water intake on aquatic life. Data from this study will also be used to assess any potential effects on sensitive fish species and to species managed under the Coastal Pelagic Species and West Coast Groundfish Fisheries Management Plans.

Ongoing and Previous Studies — 316(b) Assessment

Potrero Power Plant Cooling Water Intake Structures, 316(b) Demonstration (PG&E, 1980)

Entrainment Effects: Larval Fishes and Macroinvertebrates

The objective of the Potrero PP entrainment abundance and survival studies was to estimate the number and taxa of organisms exposed to the plant's cooling water system. The entrainment abundance and survival studies focused on the early life stages of fishes (ichthyoplankton) and selected invertebrates (amphipods, isopods, cumaceans, tanaids, mysids, decapods, and chaetognaths). The species composition, length (ichthyoplankton only), and the seasonal and diel patterns of entrainment were also determined.

The numbers of entrained ichthyoplankton and invertebrates were estimated by sampling a portion of the cooling water flow once a week for 12 months (March 1978 to March 1979). Samples were collected at Unit 3 and the observed densities were used in estimating total numbers of ichthyoplankton and macroinvertebrates entrained at Units 1 and 2, and the old proposed Unit 7. The densities collected at Unit 3 were believed to be representative of densities from the other units. The discharge area was also sampled. It was expected (and tests confirmed) that the discharge, rather than the intake, would provide a more accurate representation of the densities of entrained organisms. The organisms were more uniformly distributed due to the turbulent transit through the plant.

Methods

Entrainment samples were collected from filtering water pumped from the Unit 3 discharge conduit. Samples were collected during one 24-hour period per week, except during January 28, through February 17, 1979 (peak entrainment season of Pacific herring) when two 24-hour periods per week were sampled. The 24-hour period was divided into eight 3-hour sampling blocks. Eight 3-hour samples were collected during the 24-hour period.

All entrainment samples were processed in the laboratory. Ichthyoplankton and macroinvertebrates were sorted from all weekly samples until June 6, 1978. After this date, macroinvertebrates were sorted from biweekly samples (their densities were found to fluctuate less than ichthyoplankton). Samples were divided with a plankton splitter prior to invertebrate processing. A chi-square goodness-of-fit test was used to assess the accuracy of the splits; it was determined that the difference in replications was never significant ($\alpha = 0.05$). Ichthyoplankton continued to be sorted from weekly samples. Organisms were identified, counted, and their life stages noted. Total lengths of fish larvae and juveniles were measured to the nearest millimeter. Although all fish eggs were counted, only northern anchovy eggs were identified.

Results

An estimated 387 million fish larvae were entrained in the year-long study at Potrero PP between March 1978 and March 1979. The maximum densities were in late December through March. Mean daily densities (for the year) ranged from 0.008 per cubic meter (m^3) to over 8.0/m^3. No diel patterns were observed for the major taxa entrained. Pacific herring *Clupea pallasi* and gobies (Gobiidae) made up 90.8 percent of the fishes entrained at Units 1, 2, and 3. Other species entrained included northern anchovy (*Engraulis mordax*) (9.05 million), white croaker (*Genyonemus lineatus*) (2.74 million), Pacific staghorn sculpin (*Leptocottus armatus*) (2.00 million), and silversides (Atherinidae) (1.89 million). Twenty other taxa representing 1.5 million larvae and juveniles included sculpin (Cottidae) (0.37 million), kelpfish (Clinidae) (.031 million), rockfish (*Sebastes* spp.) (0.16 million), smelt (Osmeridae) (0.12 million), and bay pipefish (*Syngnathus leptorhynchus*) (0.11 million). English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), cabezon (*Scorpaenichthys marmoratus*), plainfin midshipman (*Porichthys notatus*), pricklebacks (Stichaeidae), and greenlings (Hexagrammidae) were entrained in much lower numbers. Representing 4.8 percent of the total were 18.52 million unidentified fish larvae and juveniles.

Pacific herring were the most abundantly entrained fish. An estimated 195 million (50.4 percent of the total) were entrained at Units 1 and 2 (85 million) and Unit 3 (110 million). Larvae were entrained from November through March, with the greatest densities from mid-January to late February (up to 6.0/m^3). Fifty-seven percent of the larvae were entrained during the day. The mean total length of Pacific herring larvae was 6.8 mm (0.27 inch). They ranged in size from 3 to 30 mm (0.12 to 1.18 inch) with 96 percent measuring less than 9 mm (0.35 inch). Pacific herring eggs are adhesive, and they are deposited on suitable vegetation and substrate. The eggs, therefore, were not entrained.

Gobies were the second most abundantly entrained larval and juvenile fishes. Approximately 156 million gobies were entrained at Units 1 and 2 (64 million) and Unit 3 (92 million) constituting 40.4 percent of the total ichthyoplankton entrained. Although no goby larvae were identified to the species level unequivocally, juveniles of three species, were reportedly entrained: arrow goby, bay goby, and yellowfin goby. Peak densities occurred in February and March.

Northern anchovy were the third most commonly entrained larvae and juvenile fish, although they constituted only 2.3 percent of the total. Approximately 3.7 million larvae were entrained at Units 1 and 2 and 5.3 million at Unit 3. Northern anchovy yolk-sac larvae were entrained only in September, with low densities of less than $0.014/m^3$. Larvae were entrained during most of the year, except from June through August, with the highest densities in April (up to $0.23/m^3$). Juveniles were rarely entrained. Fifty-one percent of northern anchovy larvae were entrained during the day. The mean total length of northern anchovy larvae was 12.9 mm (0.51 inch). They ranged in size from 2 to 59 mm (0.08 to 2.32 inches) with over 60 percent measuring between 6 and 15 mm (0.24 and 0.59 inch).

Of the macroinvertebrates examined in entrainment samples from March 1978 to March 1979, amphipods were the most abundant. An estimated total of 2.4 billion were entrained at Units 1 and 2 and 3.4 billion at Unit 3. *Corophium insidiosum* was the most abundantly entrained amphipod at an estimated 1.7 billion for Units 1, 2, and 3. Other abundantly entrained amphipod species were *Jassa falcata*, *Ampelisca milleri*, *Stenothoe valida*, and *Caprella equilibra*.

The second most abundantly entrained macroinvertebrates were decapod larvae. Blue mud shrimp larvae *Upogebia puggettensis* were entrained in the greatest number, estimated at over 570 million at Units 1, 2, and, 3. Five families of true crab (Brachyura) larvae were entrained; the pea crab was the most abundantly entrained at an estimated 209 million, followed by the spider crab at 140 million, the shore crab (133 million), *Cancer* crab (56 million) and the pebble crab (32 million). True shrimp (Caridea) were also entrained, but in much lower numbers. An estimated 2.7 million bay shrimp (*Crangon* spp.) and 3.0 million oriental shrimp (*Palaemon macrodactylus*) were entrained. Of the true shrimp entrained, approximately 20 million could not be identified to species level.

Estimated counts of the most commonly entrained fishes and macroinvertebrates are summarized in Tables 5 and 6, respectively.

Table 5. Estimated Numbers of Selected Ichthyoplankton Entrained at the Potrero PP under Actual Pump Operation: March 1978 – March 1979[(a)].

Taxon		Units 1 and 2		Unit 3		Units 1, 2, and 3		Percentage Composition [(d)]
Common Name	Scientific Name	Total Number Entrained [(b)] (millions)	Standard Error [(c)] (millions)	Total Number Entrained (millions)	Standard Error (millions)	Total Number Entrained (millions)	Standard Error (millions)	
Fish Larvae and Juveniles								
Pacific herring	*Clupea pallasi*	84.61	20.18	110.53	25.08	195.14	44.63	50.40
Gobies	*Gobiidae* [(e)]	64.25	10.62	92.01	15.28	156.26	25.90	40.38
Northern anchovy	*Engraulis mordax*	3.71	0.76	5.32	1.09	9.03	1.85	2.34
White croaker	*Genyonemus lineatus*	1.13	0.13	1.62	0.18	2.75	0.31	0.71
Pacific staghorn sculpin	*Leptocottus armatus*	0.83	0.13	1.17	0.19	2.00	0.33	0.52
Silversides	*Atherinidae*	0.77	0.22	1.11	0.32	1.88	0.55	0.49
Unidentified sculpin	Cottidae	0.15	0.04	0.22	0.06	0.37	0.10	0.10
Kelpfish	Clinidae	0.13	0.02	0.18	0.03	0.31	0.06	0.08
Rockfish	*Sebastes* spp.	0.07	0.01	0.09	0.02	0.16	0.03	0.04
Unidentified smelt	Osmeridae	0.05	0.02	0.07	0.02	0.12	0.04	0.03
Bay pipefish	*Syngnathus leptorhynchus*	0.05	0.01	0.07	0.02	0.11	0.03	0.03
Cabezon	*Scorpaenichthys marmoratus*	0.03	0.02	0.04	0.03	0.07	0.04	0.02
Starry flounder	*Platichthys stellatus*	0.03	0.01	0.04	0.02	0.07	0.03	0.02
Plainfish midshipman	*Porichthys notatus*	0.03	0.01	0.03	0.01	0.06	0.03	0.02
Pricklebacks	Stichaeidae	0.02	0.01	0.03	0.02	0.06	0.03	0.02
Greenlings	Hexagrammidae	0.02	0.01	0.03	0.01	0.05	0.02	0.01
English sole	*Parophrys vetulus*	0.01	<0.01	0.02	0.01	0.03	0.01	0.01
Others [(f)]		0.03	--	0.04	--	0.07	--	0.02
Unidentified		7.72	1.20	10.80	1.69	18.52	2.87	4.79

Source: PG&E, 1980

(a) See Appendix D of PG&E, 1980 for data for other taxa collected.
(b) Computed using Equation 3-4 from PG&E, 1980.
(c) Computed using Equation 3-5 and 3-9 from PG&E, 1980.
(d) Percentage composition based on estimates of total numbers entrained at Units 1 and 2 and Unit 3.
(e) Includes identified and unidentified gobies.
(f) Standard error not computed.

Table 6. Estimated Numbers of Selected Macroinvertebrates Entrained at the Potrero PP under Actual Pump Operation: March 1978 – March 1979 [(a)].

Taxon		Units 1 and 2		Unit 3		Units 1, 2, and 3	
Common Name	Scientific Name	Total Number Entrained [(b)] (millions)	Standard Error [(c)] (millions)	Total Number Entrained (millions)	Standard Error (millions)	Total Number Entrained (millions)	Standard Error (millions)
Opossum shrimp	Mysidacea						
	Neomysis mercedis	3.1	1.1	4.3	1.5	7.4	2.6
	Neomysis kadiakensis	1.1	0.3	1.5	0.4	2.5	0.8
	Acanthomysis macropis	5.0	0.6	7.0	0.9	12.0	1.5
	Unidentified Mysidacea	4.6	1.3	6.5	1.8	11.2	3.1
Cumaceans	Cumacea						
	Cumella vulgaris	20.0	3.0	27.8	4.3	47.9	7.2
	Eudorella pacifica	3.7	2.1	5.1	3.0	8.8	5.0
	Lamprops spp.	3.2	1.3	4.2	1.8	7.4	3.1
	Unidentified Cumacea	2.0	1.1	2.9	1.6	4.9	2.8
Tanaids	Tanaidacea						
	Leptochelia dubia	8.8	2.2	11.5	3.1	20.3	5.3
	Anatanais normani	3.7	0.5	4.9	0.6	8.6	1.1
	Unidentified Tanaidacea	1.3	0.4	1.7	0.6	3.1	1.1
Isopods	Isopoda						
	Limnoria tripunctata	3.3	0.5	4.6	0.7	7.9	1.2
	Limnoria quadripunctata	1.6	0.6	2.2	0.9	3.8	1.5
	Epicaridea	2.9	0.8	4.0	1.1	6.9	1.9
Amphipods	Amphipoda						
	Corophium spp. [(d)]	973.2	98.2	1,352.8	143.6	2,326.4	242.9
	Corophium insidiosum	693.2	59.1	971.9	85.1	1,665.2	144.0
	Jassa falcata	279.5	44.6	393.0	64.1	672.5	108.6
	Ampelisca milleri	213.9	45.8	283.2	66.6	497.1	113.1
	Stenothoe valida	63.5	11.3	82.5	15.0	146.0	26.2
	Caprella spp. [(e)]	87.6	9.3	118.8	11.8	206.4	20.8
	Caprella equilibra	58.4	8.2	79.7	10.7	138.1	18.9
Decapods	Decapoda						
True Shrimps	Caridea						
Bay Shrimp	*Crangon* spp.	1.1	0.5	1.6	0.8	2.7	1.3
Oriental Shrimp	*Palaemon macrodactylus*	1.2	0.5	1.8	0.7	3.0	1.2
	Unidentified Caridea	8.0	1.7	11.4	2.4	19.4	4.1
True Crabs	Brachyura						
Spider Crabs	Majidae	57.2	5.4	70.4	8.3	127.6	13.5
Cancer Crabs	Cancridae [(f)]	22.8	4.2	32.2	6.1	55.0	10.4
	Cancer spp.	21.9	4.0	30.9	5.7	52.8	9.7
Rock crab	*C. antennarius*	0.8	0.5	1.1	0.7	1.9	1.2
Red Rock crab	*C. productus*	2.7	0.6	3.5	0.9	6.2	1.5
Slender crab	*C. gracilis*	1.1	0.5	1.6	0.7	2.7	1.2
Pebble crabs	Xanthidae	13.2	6.4	18.5	9.2	31.7	15.6
Pea crabs	Pinnotheridae	85.4	16.9	121.2	24.5	206.6	41.5
Shore crabs	Grapsidae	54.2	16.2	76.7	23.2	130.9	39.4
Anomurans	Anomura						
Ghost Shrimp	*Callianassa* sp.	7.3	1.6	10.4	2.4	17.8	4.0
Blue mud shrimp	*Upogebia pugettensis*	234.8	48.0	337.7	69.0	572.5	116.9
Hermit crab	*Pagurus* sp.	1.5	1.4	2.1	2.0	3.6	3.4
Chaetognaths	Chaetognatha						
Arrow worm	*Sagitta euneritica*	38.6	8.4	55.6	12.1	94.2	20.4

(a) See Appendix D of PG&E, 1980 for data for other taxa collected. *Source: PG&E, 1980*
(b) Computed using Equation 3-4 from PG&E, 1980.
(c) Computed using Equations 3-5 and 3-9 from PG&E, 1980.
(d) Includes identified and unidentified *Corophium* spp.
(e) Includes identified and unidentified *Caprella* spp.
(f) Includes identified and unidentified *Cancer* spp.

Proposed Study Design — 316(b) Resource Assessment

Previous studies of the Potrero Power Plant CWIS surveyed the numbers of organisms taken in the cooling water withdrawal that were impinged on the intake screens and that were entrained through the screens. The present study design is proposed to only re-survey the source water organisms at risk to entrainment and not those currently being impinged on the facility's existing intake screens. The new project proposes to significantly improve the current intake facility by installing finer-mesh inclined screens. The proposed new facility is expected to significantly lower impingement rates by reducing the amount of debris that might entangle fish and lowering the intake approach velocities. The intake facility is being improved so greatly that the results from impingement studies of the existing facility would not reflect impingement rates of the new facility. Validation of the power plant's previous CWIS studies will be based on a re-survey and a comparison of the source water larval fishes and *Cancer* crabs megalops presently at the site at risk to entrainment.

This study is designed to quantify the composition and abundance of source water and entrained larval fishes and cancer and European green crab (*Carcinus maenas*) megalops in the area of the Potrero PP. Planktonic fish eggs will not be sorted from samples. Although many marine fish eggs are described, the taxonomy remains difficult and is very time consuming.

Entrainment and source water samples will be collected in the vicinity of the Potrero PP (Figure 6). Two entrainment stations (stations E1 and E2, Figure 6) will be sampled: Station E1 is located off of the existing intake, and Station E2 is located off of the proposed intake location. The locations of the eight source water stations (stations S1 through S8) are shown in Figure 6. The stations are located offshore of the intake along transect lines crossing the Central Bay.

Sample Collection Methods

Sample collection methods are similar to those developed and used by the California Cooperative Oceanic and Fisheries Investigation (CalCOFI) in their larval fish studies (Smith and Richardson, 1977). Samples will be collected by towing a bongo frame with two 0.71 m-diameter openings each equipped with 335-micrometer (µm) mesh plankton nets and codends. The water volume filtered will be measured by calibrated flowmeters mounted in the openings of the nets. At all stations except the source water channel stations (Stations S3 and S7), the bongo nets are lowered as close to the bottom as possible, based on a depth reading from an echosounder mounted on the boat. Once the nets are as close to the bottom as possible, the boat is moved forward and the nets retrieved at an oblique angle (with the winch cable at a 45 degree angle). The winch retrieval speed is maintained at approximately 1 foot per second after the correct angle on the towline is achieved.

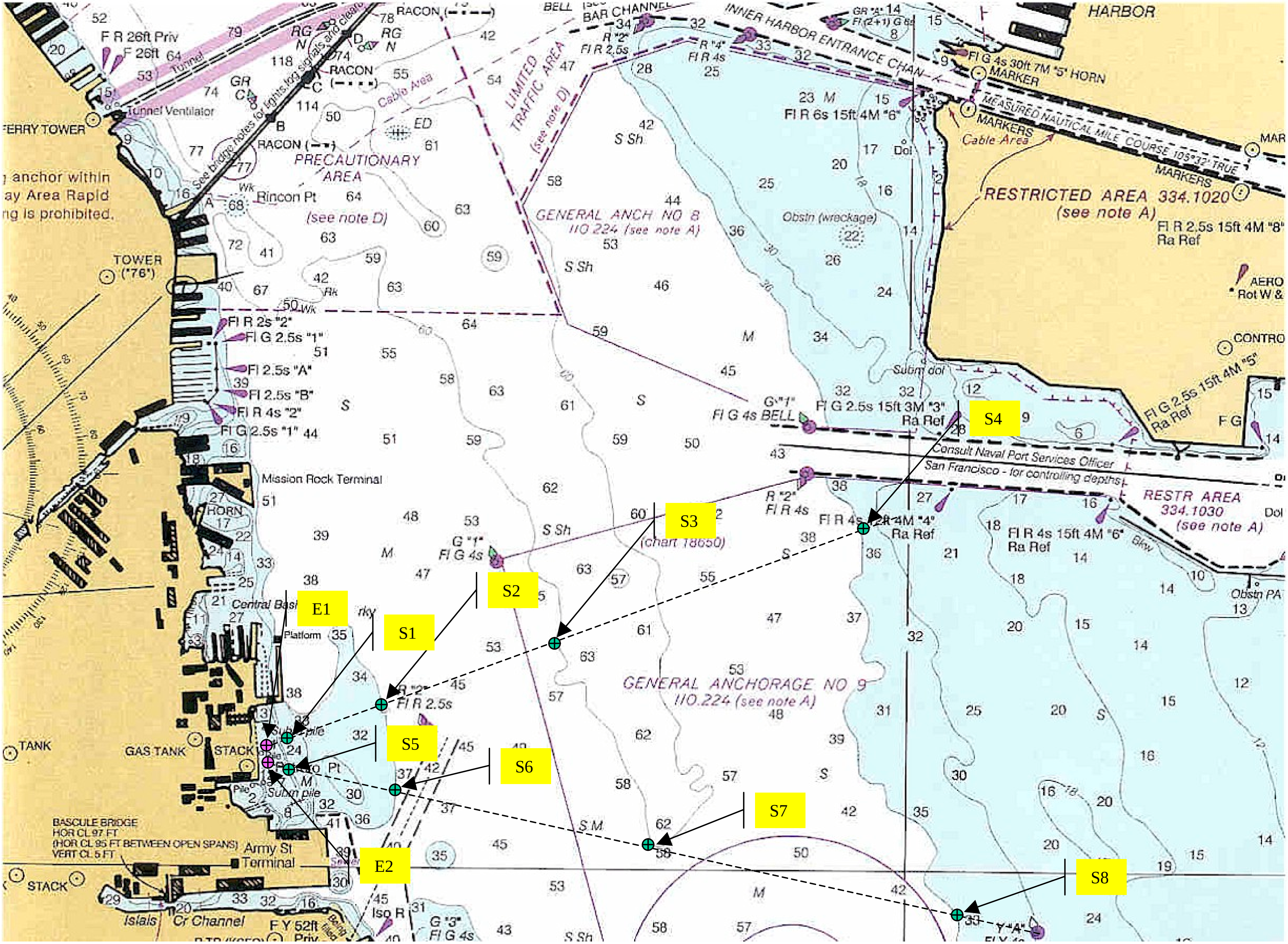

Figure 6. Entrainment and source water sampling stations.

Samples will be collected over a continuous 24-hour period, with each period divided into six 4-hour sampling cycles. Two replicated tow samples using paired bongo nets are collected during each cycle. The samples in the bongo net are combined for a single tow replicate. The samples collected in the bongo net are combined for a single tow replicate.

The target combined volume of water filtered by both nets will be approximately 40 m^3 (20 m^3 per net). The sample volume is checked when the nets reached the surface. If the sample volume is approximately double (80 m^3 total), indicating possible flowmeter failure, the sample is voided and the tow repeated. If the target volume is not collected, the oblique tow method is repeated until the targeted volume is reached. The nets are then retrieved from the water, and all of the sample is rinsed into the codends.

The contents of both nets are combined into one sample immediately after collection. The sample is placed into a labeled jar and is preserved in ethanol (ETOH). Preservation in ETOH will allow specimen identifications to be genetically validated, checked for age, and measured for growth studies should the need arise. Each sample is given a serial number based on the location, date, time, and depth of collection. In addition, that information is logged onto a sequentially numbered data sheet. The sample's serial number is used to track it through laboratory processing, data analyses, and reporting.

Entrainment and Source Water Sampling Frequency

The entrainment and source water sampling will occur monthly (except during herring spawning season) until a year of data are collected. During herring spawning season, the frequency of sample collection will increase to weekly for a two- to three-month period during peak spawning. Samples will be collected from ten locations as shown in Figure 6 for one year, from January 2001 through December 2001.

Laboratory Processing

Laboratory processing will remove all larval fishes and the megalopal stages of *Cancer* spp. and European green crabs (*Carcinus maenas*) from the samples. Fish eggs will not be sorted from the samples. Although many marine fish eggs are described, the taxonomy is difficult and very time consuming. Larval fishes and all species of cancer crab megalops and the megalopal stage of *Carcinus maenas* will be identified to the lowest taxonomic level possible by Tenera's in-house taxonomists. In addition, the lifestage of larvae will be identified on the data sheet. A laboratory quality control (QC) program for all levels of laboratory sorting and taxonomic identification will be applied to all samples. The QC program will also incorporate the use of outside taxonomic experts to provide taxonomic QC and resolve taxonomic uncertainties.

Laboratory data sheets will be coded with species or taxon codes. These codes will be verified with species/taxon lists and signed off by the data manager. The data will be entered into a computer database for analysis.

Data Analysis

The volume of the source water to be used in the proportional entrainment calculations will be determined by examining physical data (i.e., salinity and current data) and fish guilds identified from CDFG survey results. A separate report is being prepared for the Working Group for discussion and approval of source water definitions and sampling rationale.

Species similarity analyses between the 1978 - 1980 survey and the current survey will be done on entrainment study results to test the degree of similarity between the two sampling periods. The choice of (dis)similarity index and variable transformation for the analysis will be based on the need for comparing the composition of the taxa between the two periods and not necessarily the need to compare their absolute abundances. Absolute abundances could be affected by many factors, including changes in sampling protocols between the two survey periods. The choice of index affects how abundant, rare, or missing taxa are weighted. Standardizing the data or transformation to logarithms can also be used to reduce the effects of very abundant taxa on the index. One potential solution for addressing the differences in sampling protocols between periods would be to reduce the data to presence/absence and compute a qualitative measure of similarity.

The characteristics of different (dis)similarity indices have been considered by many authors (e.g., Orloci, 1975; Digby and Kempton, 1987; van Tongeren, 1987). The sensitivity of similar indices to sample total dominant species and species richness was considered by van Tongeren (1987). The potential differences between sampling protocols for the two periods would most likely affect the total abundances in the samples and the abundances of the dominant species. The results of van Tongeren (1987) indicate that the chord distance and coefficient of community would be the most appropriate measures of similarity for quantitative data and the coefficient of community would be the most appropriate measures of similarity for qualitative or presence/absence data. The details of models for data comparison, model criteria and parameters of statistical comparison (CL, Type I and Type II error rates) will be specified through the CEC technical committee process.

The comparison of entrainment study results will include weekly or monthly samples collected over a 3-month period with a comparable period from the 1978 - 1980 study. Interannual variation could affect a comparison of the same three months between years. Therefore, the samples from the 5-month period from 1978 - 1980 that bracket the current 3-month survey period will be randomly sampled to obtain a bootstrap similarity estimate. The bootstrap estimate will also provide a measure of the error due to interannual variation associated with the similarity estimate for this analysis.

The species composition and abundance of larval fishes collected in entrainment and source water sampling will be compared to the results from 1978 - 1980 impingement survey of the Potrero PP CWIS. Based on findings from other power plants, these comparisons are expected to show a relatively low degree of similarity between the species of fish entrained and those impinged.

Deliverables

Beginning in March 2001 and continuing each month until sample collection and processing is completed, results of monthly entrainment and source water surveys shall be provided to CEC staff. These monthly reports will include species composition and abundance data of samples processed to date.

A report regarding the findings of the first three months of sample collection (January 2001-March 2001) will be submitted to the CEC on or before July 1, 2001. The lag time from the time of collection to the report submittal date is due to the amount of time required to process plankton samples. The report will characterize the existing larval fish and *Cancer* crab megalops collected in entrainment and source water samples. The report will contain the first three months of proportional entrainment calculations. It will also compare this study's results with those collected in the 1978 - 1979 Potrero PP 316(b) resource assessment (PG&E, 1980). This three-month summary report will also contain a review of applicable thermal effects literature, and potential effects on sensitive species or species managed under the Coastal Pelagic Species and West Coast Groundfish Management Plans. Similarity between the two entrainment stations and among the source water stations data will be analyzed to determine whether the number of stations could be reduced for the remainder of the sampling program.

A final report, containing species composition and abundance data from all stations, proportional entrainment calculations, and discussions of potential impacts, will be submitted to the CEC approximately 90 days after sampling is completed.

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Potrero Power Plant Unit 3
316(b) Entrainment Characterization Report

Appendix B

Entrainment and Source Water Survey Results

Table B-1. Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant intake stations E1 and E2 (all cycles combined): Surveys 1 – 30; January 17, 2001 - February 22, 2002.

			Survey 1		Survey 2		Survey 3		Survey 4		Survey 5	
			Jan. 17-18, 2001		Jan. 24-25		Jan. 31-Feb. 1		Feb. 7-8		Feb. 23-24	
			N=24		N=24		N=24		N=24		N=20	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Clupea pallasii	Pacific herring	9,909	622	416.34	1,268	850.31	93	64.07	200	128.00	1,394	1063.20
Lepidogobius lepidus	bay goby	7,874	193	144.31	183	120.04	219	153.98	198	120.56	73	56.96
Acanthogobius flavimanus	yellowfin goby	5,783	-	-	-	-	204	145.43	302	191.49	1,022	808.11
Gobiidae unid.	gobies	5,547	91	64.50	197	127.51	121	85.26	101	63.32	148	108.10
Engraulis mordax	northern anchovy	3,397	2	1.34	1	0.47	-	-	1	0.71	4	2.79
Genyonemus lineatus	white croaker	1,070	5	3.67	3	2.00	1	0.78	13	8.00	7	5.97
larval fish fragment, unid.	larval fishes, fragment	227	4	2.90	29	18.53	6	4.08	11	6.72	16	10.24
Leptocottus armatus	Pacific staghorn sculpin	223	9	6.63	8	5.76	18	12.42	16	9.62	10	8.20
Clupeiformes	herrings and anchovies	155	5	3.56	48	37.26	1	0.56	8	5.25	13	9.71
Paralichthys californicus	California halibut	103	-	-	-	-	-	-	-	-	2	1.44
Ammodytes hexapterus	Pacific sand lance	75	-	-	-	-	-	-	8	4.35	21	15.86
Psettichthys melanostictus	sand sole	50	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	47	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	44	1	1.03	6	3.31	-	-	-	-	4	2.88
larval fish - damaged	larval fishes, damaged	33	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	32	-	-	-	-	2	1.56	2	1.45	1	0.63
Sciaenidae unid.	croakers	21	1	0.62	-	-	-	-	2	1.35	-	-
Atherinopsis californiensis	jacksmelt	20	-	-	-	-	1	0.62	-	-	-	-
Clupeidae unid.	herrings	15	15	6.89	-	-	-	-	-	-	-	-
larval/post-larval fish, unid.	larval fishes	15	1	0.69	1	0.62	-	-	1	0.62	-	-
Cebidichthys violaceus	monkeyface eel	12	-	-	-	-	2	1.24	-	-	-	-
Hypsopsetta guttulata	diamond turbot	11	-	-	-	-	-	-	-	-	-	-
Oligocottus spp.	sculpins	11	1	0.84	-	-	1	0.72	-	-	-	-
Syngnathus spp.	pipefishes	10	-	-	1	0.76	-	-	-	-	-	-
Cottidae unid.	sculpins	8	1	0.69	-	-	1	0.56	-	-	2	1.44
Pleuronectes bilineatus	rock sole	6	-	-	2	1.20	-	-	-	-	-	-
Atherinidae unid.	silversides	5	1	0.69	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	5	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	5	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	5	-	-	-	-	-	-	-	-	-	-
Stichaeidae unid.	pricklebacks	5	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	4	1	0.49	-	-	-	-	-	-	1	0.88
Sebastes spp. VD	rockfishes	4	-	-	1	0.69	1	0.62	-	-	-	-
Clinocottus spp.	sculpins	3	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	3	1	0.46	1	0.70	-	-	-	-	-	-
Osmeridae unid.	smelts	3	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	3	-	-	-	-	-	-	1	0.54	-	-
Coryphopterus nicholsi	blackeye goby	2	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	2	-	-	-	-	-	-	1	0.63	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	2	1	0.82	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	2	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	2	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	1	-	-	-	-	-	-	-	-	-	-
Bathymasteridae unid.	ronquils	1	1	0.90	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	1	-	-	-	-	-	-	-	-	-	-
Gadidae	codfishes	1	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Hemilepidotus spinosus	brown Irish lord	1	-	-	-	-	-	-	-	-	-	-
Heterostichus rostratus	giant kelpfish	1	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	1	-	-	-	-	-	-	-	-	-	-
Liparis spp.	snailfishes	1	-	-	-	-	-	-	-	-	-	-
Ophiodon elongatus	lingcod	1	-	-	-	-	-	-	-	-	-	-
Pholididae unid.	gunnels	1	-	-	-	-	-	-	-	-	-	-
Pleuronectes isolepis	butter sole	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	1	1	0.57	-	-	-	-	-	-	-	-
Sebastes spp. V_D_	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Seriphus politus	queenfish	1	-	-	-	-	-	-	-	-	-	-
	Total Fish Counts:	34,771	957		1,749		671		865		2,718	
Megalopal Crabs												
Cancer antennarius	brown rock crab	24	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi	yellow crab	5	-	-	-	-	-	-	1	0.78	-	-
Cancer jordani	hairy rock crab	2	-	-	-	-	-	-	-	-	-	-
Carcinus maenas	European green crab	2	-	-	-	-	-	-	-	-	-	-
	Total Crab Counts:	33	0		0		0		1		0	

(*continued*)

Table B-1 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant intake stations E1 and E2 (all cycles combined): Surveys 1–30; January 17, 2001–February 22, 2002.

			Survey 6 Feb. 28-Mar. 1 N=24		Survey 7 Mar. 8-9 N=24		Survey 8 Mar. 15-16 N=24		Survey 9 Mar. 21 N=4		Survey 10 Mar. 27-28 N=24	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Clupea pallasii	Pacific herring	9,909	107	72.11	43	26.36	519	345.25	Incomplete		2	1.41
Lepidogobius lepidus	bay goby	7,874	85	55.41	145	92.81	149	101.64	Survey		156	104.39
Acanthogobius flavimanus	yellowfin goby	5,783	591	403.86	1,468	942.75	610	425.76			526	358.79
Gobiidae unid.	gobies	5,547	130	88.54	372	240.00	344	238.21			702	468.85
Engraulis mordax	northern anchovy	3,397	10	6.41	85	53.80	52	33.67			634	420.92
Genyonemus lineatus	white croaker	1,070	14	9.76	472	294.58	56	38.46			31	20.17
larval fish fragment, unid.	larval fishes, fragment	227	16	12.33	18	11.81	31	22.04			40	26.70
Leptocottus armatus	Pacific staghorn sculpin	223	2	1.59	16	9.50	7	4.67			6	4.23
Clupeiformes	herrings and anchovies	155	5	3.08	6	4.15	42	28.18			-	-
Paralichthys californicus	California halibut	103	1	0.60	9	5.69	-	-			1	0.85
Ammodytes hexapterus	Pacific sand lance	75	2	1.56	2	1.14	-	-			-	-
Psettichthys melanostictus	sand sole	50	1	0.81	2	1.22	1	0.61			6	4.71
Citharichthys stigmaeus	speckled sanddab	47	1	0.78	-	-	-	-			-	-
Sebastes spp. V_De	rockfishes	44	1	0.72	2	1.25	1	0.73			3	1.93
larval fish - damaged	larval fishes, damaged	33	4	2.74	-	-	1	0.61			3	1.89
Pleuronectidae unid.	flounders	32	2	1.46	2	1.42	-	-			1	0.64
Sciaenidae unid.	croakers	21	1	0.92	-	-	-	-			-	-
Atherinopsis californiensis	jacksmelt	20	2	1.44	-	-	-	-			-	-
Clupeidae unid.	herrings	15	-	-	-	-	-	-			-	-
larval/post-larval fish, unid.	larval fishes	15	-	-	1	0.70	-	-			-	-
Cebidichthys violaceus	monkeyface eel	12	1	0.72	1	0.72	2	1.33			2	1.53
Hypsopsetta guttulata	diamond turbot	11	-	-	-	-	-	-			-	-
Oligocottus spp.	sculpins	11	-	-	-	-	2	1.34			1	0.81
Syngnathus spp.	pipefishes	10	-	-	-	-	-	-			-	-
Cottidae unid.	sculpins	8	-	-	-	-	-	-			-	-
Pleuronectes bilineatus	rock sole	6	-	-	-	-	-	-			-	-
Atherinidae unid.	silversides	5	-	-	-	-	-	-			-	-
Citharichthys sordidus	Pacific sanddab	5	-	-	-	-	-	-			-	-
Parophrys vetulus	English sole	5	-	-	-	-	-	-			-	-
Stenobrachius leucopsarus	northern lampfish	5	1	0.69	1	0.55	-	-			-	-
Stichaeidae unid.	pricklebacks	5	-	-	-	-	1	0.73			2	1.38
Pleuronectiformes unid.	flatfishes	4	-	-	-	-	-	-			1	0.60
Sebastes spp. VD	rockfishes	4	-	-	-	-	-	-			-	-
Clinocottus spp.	sculpins	3	-	-	-	-	-	-			-	-
Hexagrammidae unid.	greenlings	3	-	-	-	-	-	-			-	-
Osmeridae unid.	smelts	3	-	-	-	-	-	-			-	-
Scorpaenichthys marmoratus	cabezon	3	-	-	-	-	-	-			-	-
Coryphopterus nicholsi	blackeye goby	2	-	-	-	-	-	-			1	0.70
Gibbonsia spp.	clinid kelpfishes	2	-	-	-	-	-	-			-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	2	-	-	-	-	-	-			1	0.60
Sebastes spp. V	rockfishes	2	-	-	-	-	-	-			-	-
Syngnathus leptorhynchus	bay pipefish	2	-	-	-	-	-	-			-	-
Artedius spp.	sculpins	1	-	-	-	-	1	0.61			-	-
Atherinops affinis	topsmelt	1	-	-	-	-	-	-			-	-
Bathymasteridae unid.	ronquils	1	-	-	-	-	-	-			-	-
Citharichthys spp.	sanddabs	1	-	-	1	0.49	-	-			-	-
Cyclopteridae unid.	snailfishes	1	-	-	-	-	-	-			-	-
Gadidae	codfishes	1	-	-	1	0.56	-	-			-	-
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	-	-			-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-			1	0.64
Hemilepidotus spinosus	brown Irish lord	1	-	-	-	-	-	-			-	-
Heterostichus rostratus	giant kelpfish	1	-	-	-	-	-	-			-	-
Hypsoblennius spp.	blennies	1	-	-	-	-	-	-			-	-
Liparis spp.	snailfishes	1	1	0.80	-	-	-	-			-	-
Ophiodon elongatus	lingcod	1	-	-	-	-	-	-			-	-
Pholididae unid.	gunnels	1	1	0.76	-	-	-	-			-	-
Pleuronectes isolepis	butter sole	1	-	-	-	-	-	-			-	-
Sebastes spp. V_D	rockfishes	1	-	-	-	-	-	-			-	-
Sebastes spp. V_D_	rockfishes	1	-	-	-	-	1	0.61			-	-
Seriphus politus	queenfish	1	-	-	-	-	-	-			-	-
	Total Fish Counts:	34,771	979		2,647		1,820				2,120	
Megalopal Crabs												
Cancer antennarius	brown rock crab	24	-	-	-	-	-	-			4	2.52
Cancer anthonyi	yellow crab	5	-	-	-	-	-	-			-	-
Cancer jordani	hairy rock crab	2	-	-	1	0.70	-	-			1	0.81
Carcinus maenas	European green crab	2	-	-	-	-	-	-			1	0.70
	Total Crab Counts:	33	0		1		0				6	

(*continued*)

Table B-1 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant intake stations E1 and E2 (all cycles combined): Surveys 1–30; January 17, 2001–February 22, 2002.

			Survey 11 Apr. 4-5 N=24		Survey 12 May 23-24 N=24		Survey 13 Jun. 20-21 N=24		Survey 14 Jul. 11-12 N=24		Survey 15 Aug. 8-9 N=24	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Clupea pallasii	Pacific herring	9,909	-	-	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	7,874	91	68.04	163	128.96	492	368.82	576	434.95	894	586.27
Acanthogobius flavimanus	yellowfin goby	5,783	228	174.52	77	62.09	3	2.34	-	-	-	-
Gobiidae unid.	gobies	5,547	372	267.76	503	383.14	428	330.39	643	483.30	490	329.20
Engraulis mordax	northern anchovy	3,397	610	439.27	30	24.33	24	18.41	274	211.28	423	279.58
Genyonemus lineatus	white croaker	1,070	30	22.16	1	0.73	-	-	-	-	-	-
larval fish fragment, unid.	larval fishes, fragment	227	6	4.06	3	2.48	3	2.23	1	0.81	8	5.43
Leptocottus armatus	Pacific staghorn sculpin	223	1	0.65	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	155	1	0.60	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	103	-	-	1	0.64	3	2.15	8	6.03	21	14.15
Ammodytes hexapterus	Pacific sand lance	75	-	-	-	-	1	0.76	-	-	-	-
Psettichthys melanostictus	sand sole	50	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	47	-	-	-	-	-	-	1	0.57	2	1.47
Sebastes spp. V_De	rockfishes	44	2	1.42	2	1.39	-	-	-	-	-	-
larval fish - damaged	larval fishes, damaged	33	-	-	-	-	-	-	1	0.68	3	1.94
Pleuronectidae unid.	flounders	32	-	-	-	-	-	-	2	1.55	1	0.70
Sciaenidae unid.	croakers	21	-	-	-	-	-	-	3	2.08	-	-
Atherinopsis californiensis	jacksmelt	20	-	-	-	-	1	0.71	-	-	-	-
Clupeidae unid.	herrings	15	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish, unid.	larval fishes	15	-	-	-	-	-	-	-	-	3	2.21
Cebidichthys violaceus	monkeyface eel	12	-	-	1	0.77	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	11	-	-	-	-	-	-	-	-	4	2.89
Oligocottus spp.	sculpins	11	-	-	1	0.73	-	-	-	-	-	-
Syngnathus spp.	pipefishes	10	-	-	-	-	-	-	-	-	2	1.49
Cottidae unid.	sculpins	8	-	-	-	-	-	-	-	-	-	-
Pleuronectes bilineatus	rock sole	6	-	-	-	-	-	-	-	-	-	-
Atherinidae unid.	silversides	5	-	-	1	0.83	1	0.77	1	0.68	-	-
Citharichthys sordidus	Pacific sanddab	5	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	5	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	5	-	-	-	-	-	-	-	-	-	-
Stichaeidae unid.	pricklebacks	5	1	0.71	1	0.73	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	4	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	4	-	-	-	-	-	-	-	-	-	-
Clinocottus spp.	sculpins	3	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	3	-	-	-	-	-	-	-	-	-	-
Osmeridae unid.	smelts	3	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	3	-	-	-	-	-	-	-	-	-	-
Coryphopterus nicholsi	blackeye goby	2	-	-	1	0.82	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	2	-	-	-	-	-	-	1	0.75	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	2	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	2	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	2	-	-	1	0.75	-	-	-	-	1	0.74
Artedius spp.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	1	-	-	-	-	1	0.76	-	-	-	-
Bathymasteridae unid.	ronquils	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	1	-	-	-	-	-	-	-	-	1	0.76
Gadidae	codfishes	1	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	1	0.72	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Hemilepidotus spinosus	brown Irish lord	1	-	-	-	-	-	-	-	-	-	-
Heterostichus rostratus	giant kelpfish	1	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	1	-	-	-	-	-	-	-	-	1	0.55
Liparis spp.	snailfishes	1	-	-	-	-	-	-	-	-	-	-
Ophiodon elongatus	lingcod	1	-	-	-	-	-	-	-	-	-	-
Pholididae unid.	gunnels	1	-	-	-	-	-	-	-	-	-	-
Pleuronectes isolepis	butter sole	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D_	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Seriphus politus	queenfish	1	1	0.77	-	-	-	-	-	-	-	-
	Total Fish Counts:	34,771	1,343		786		958		1,511		1,854	
Megalopal Crabs												
Cancer antennarius	brown rock crab	24	17	13.50	2	1.40	1	0.91	-	-	-	-
Cancer anthonyi	yellow crab	5	4	2.97	-	-	-	-	-	-	-	-
Cancer jordani	hairy rock crab	2	-	-	-	-	-	-	-	-	-	-
Carcinus maenas	European green crab	2	1	0.75	-	-	-	-	-	-	-	-
	Total Crab Counts:	33	22		2		1		0		0	

(*continued*)

Table B-1 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant intake stations E1 and E2 (all cycles combined): Surveys 1–30; January 17, 2001–February 22, 2002.

			Survey 16 Sep. 12-13 N=24		Survey 17 Oct. 10-11 N=24		Survey 18 Nov. 7-8 N=24		Survey 19 Dec. 6-7 N=24		Survey 20 Dec. 12-13 N=24	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Clupea pallasii	Pacific herring	9,909	-	-	-	-	-	-	67	39.80	Not Sorted	
Lepidogobius lepidus	bay goby	7,874	1,217	822.82	682	494.50	646	502.31	410	284.48		
Acanthogobius flavimanus	yellowfin goby	5,783	-	-	-	-	-	-	1	0.67		
Gobiidae unid.	gobies	5,547	182	122.65	82	58.88	92	73.14	64	42.76		
Engraulis mordax	northern anchovy	3,397	934	626.91	123	90.90	3	2.47	7	4.74		
Genyonemus lineatus	white croaker	1,070	-	-	17	12.85	5	3.88	27	17.24		
larval fish fragment, unid.	larval fishes, fragment	227	2	1.45	1	0.66	3	2.36	5	3.75		
Leptocottus armatus	Pacific staghorn sculpin	223	-	-	-	-	-	-	7	4.38		
Clupeiformes	herrings and anchovies	155	1	0.49	-	-	-	-	1	0.54		
Paralichthys californicus	California halibut	103	29	19.23	22	16.09	-	-	-	-		
Ammodytes hexapterus	Pacific sand lance	75	-	-	-	-	-	-	-	-		
Psettichthys melanostictus	sand sole	50	-	-	-	-	-	-	-	-		
Citharichthys stigmaeus	speckled sanddab	47	17	10.35	7	4.98	-	-	4	2.36		
Sebastes spp. V_De	rockfishes	44	-	-	-	-	-	-	3	2.08		
larval fish - damaged	larval fishes, damaged	33	7	5.02	2	1.50	-	-	-	-		
Pleuronectidae unid.	flounders	32	2	1.31	3	2.39	-	-	-	-		
Sciaenidae unid.	croakers	21	-	-	-	-	-	-	2	1.28		
Atherinopsis californiensis	jacksmelt	20	-	-	-	-	-	-	-	-		
Clupeidae unid.	herrings	15	-	-	-	-	-	-	-	-		
larval/post-larval fish, unid.	larval fishes	15	-	-	3	2.53	1	0.92	1	0.67		
Cebidichthys violaceus	monkeyface eel	12	-	-	-	-	-	-	-	-		
Hypsopsetta guttulata	diamond turbot	11	5	2.89	1	0.70	1	0.78	-	-		
Oligocottus spp.	sculpins	11	-	-	-	-	-	-	-	-		
Syngnathus spp.	pipefishes	10	-	-	-	-	-	-	3	1.98		
Cottidae unid.	sculpins	8	-	-	-	-	-	-	1	0.65		
Pleuronectes bilineatus	rock sole	6	-	-	-	-	-	-	-	-		
Atherinidae unid.	silversides	5	-	-	-	-	-	-	-	-		
Citharichthys sordidus	Pacific sanddab	5	-	-	-	-	-	-	-	-		
Parophrys vetulus	English sole	5	-	-	-	-	-	-	-	-		
Stenobrachius leucopsarus	northern lampfish	5	-	-	-	-	-	-	-	-		
Stichaeidae unid.	pricklebacks	5	-	-	-	-	-	-	-	-		
Pleuronectiformes unid.	flatfishes	4	-	-	-	-	-	-	-	-		
Sebastes spp. VD	rockfishes	4	-	-	-	-	-	-	1	0.66		
Clinocottus spp.	sculpins	3	-	-	-	-	-	-	-	-		
Hexagrammidae unid.	greenlings	3	-	-	-	-	-	-	-	-		
Osmeridae unid.	smelts	3	-	-	-	-	-	-	2	1.34		
Scorpaenichthys marmoratus	cabezon	3	-	-	-	-	1	0.71	-	-		
Coryphopterus nicholsi	blackeye goby	2	-	-	-	-	-	-	-	-		
Gibbonsia spp.	clinid kelpfishes	2	-	-	-	-	-	-	-	-		
Paralichthyidae unid.	lefteye flounders & sanddabs	2	-	-	-	-	-	-	-	-		
Sebastes spp. V	rockfishes	2	-	-	-	-	-	-	-	-		
Syngnathus leptorhynchus	bay pipefish	2	-	-	-	-	-	-	-	-		
Artedius spp.	sculpins	1	-	-	-	-	-	-	-	-		
Atherinops affinis	topsmelt	1	-	-	-	-	-	-	-	-		
Bathymasteridae unid.	ronquils	1	-	-	-	-	-	-	-	-		
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-		
Cyclopteridae unid.	snailfishes	1	-	-	-	-	-	-	-	-		
Gadidae	codfishes	1	-	-	-	-	-	-	-	-		
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	-	-	-	-		
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-		
Hemilepidotus spinosus	brown Irish lord	1	-	-	-	-	-	-	-	-		
Heterostichus rostratus	giant kelpfish	1	-	-	-	-	-	-	-	-		
Hypsoblennius spp.	blennies	1	-	-	-	-	-	-	-	-		
Liparis spp.	snailfishes	1	-	-	-	-	-	-	-	-		
Ophiodon elongatus	lingcod	1	-	-	-	-	-	-	-	-		
Pholididae unid.	gunnels	1	-	-	-	-	-	-	-	-		
Pleuronectes isolepis	butter sole	1	-	-	-	-	-	-	-	-		
Sebastes spp. V_D	rockfishes	1	-	-	-	-	-	-	-	-		
Sebastes spp. V_D_	rockfishes	1	-	-	-	-	-	-	-	-		
Seriphus politus	queenfish	1	-	-	-	-	-	-	-	-		
	Total Fish Counts:	34,771	2,396		943		752		606			
Megalopal Crabs												
Cancer antennarius	brown rock crab	24	-	-	-	-	-	-	-	-		
Cancer anthonyi	yellow crab	5	-	-	-	-	-	-	-	-		
Cancer jordani	hairy rock crab	2	-	-	-	-	-	-	-	-		
Carcinus maenas	European green crab	2	-	-	-	-	-	-	-	-		
	Total Crab Counts:	33	0		0		0		0			

(*continued*)

Table B-1 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant intake stations E1 and E2 (all cycles combined): Surveys 1–30; January 17, 2001–February 22, 2002.

			Survey 21 Dec. 19-21 N=24		Survey 22 Dec. 28-31 N=24		Survey 23 Jan. 1-2, 2002 N=24		Survey 24 Jan. 10-11 N=24		Survey 25 Jan. 17-18 N=24	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Clupea pallasii	Pacific herring	9,909	Not Sorted		Not Sorted		1	0.77	28	18.44	1,085	862.96
Lepidogobius lepidus	bay goby	7,874					211	168.34	280	185.97	143	116.40
Acanthogobius flavimanus	yellowfin goby	5,783					14	11.41	58	40.14	27	21.11
Gobiidae unid.	gobies	5,547					51	41.12	55	35.62	49	39.45
Engraulis mordax	northern anchovy	3,397					10	7.74	19	12.88	52	42.97
Genyonemus lineatus	white croaker	1,070					50	39.47	83	57.39	33	27.14
larval fish fragment, unid.	larval fishes, fragment	227					-	-	2	1.40	6	4.88
Leptocottus armatus	Pacific staghorn sculpin	223					8	6.41	5	3.17	37	29.93
Clupeiformes	herrings and anchovies	155					-	-	-	-	5	3.47
Paralichthys californicus	California halibut	103					-	-	1	0.70	-	-
Ammodytes hexapterus	Pacific sand lance	75					-	-	-	-	-	-
Psettichthys melanostictus	sand sole	50					1	0.73	2	1.39	1	1.03
Citharichthys stigmaeus	speckled sanddab	47					10	7.85	-	-	4	3.42
Sebastes spp. V_De	rockfishes	44					2	1.50	2	1.51	3	2.24
larval fish - damaged	larval fishes, damaged	33					3	2.64	-	-	7	5.77
Pleuronectidae unid.	flounders	32					-	-	3	2.04	2	1.40
Sciaenidae unid.	croakers	21					-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	20					-	-	-	-	2	1.75
Clupeidae unid.	herrings	15					-	-	-	-	-	-
larval/post-larval fish, unid.	larval fishes	15					1	0.93	-	-	1	0.70
Cebidichthys violaceus	monkeyface eel	12					-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	11					-	-	-	-	-	-
Oligocottus spp.	sculpins	11					-	-	-	-	3	2.03
Syngnathus spp.	pipefishes	10					2	1.54	2	1.09	-	-
Cottidae unid.	sculpins	8					-	-	-	-	2	1.39
Pleuronectes bilineatus	rock sole	6					-	-	-	-	-	-
Atherinidae unid.	silversides	5					-	-	-	-	1	0.78
Citharichthys sordidus	Pacific sanddab	5					2	1.51	2	1.48	1	0.70
Parophrys vetulus	English sole	5					1	0.93	-	-	4	3.27
Stenobrachius leucopsarus	northern lampfish	5					1	0.96	-	-	1	0.81
Stichaeidae unid.	pricklebacks	5					-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	4					-	-	-	-	-	-
Sebastes spp. VD	rockfishes	4					-	-	-	-	-	-
Clinocottus spp.	sculpins	3					-	-	2	1.49	-	-
Hexagrammidae unid.	greenlings	3					-	-	-	-	-	-
Osmeridae unid.	smelts	3					-	-	1	0.83	-	-
Scorpaenichthys marmoratus	cabezon	3					-	-	1	0.67	-	-
Coryphopterus nicholsi	blackeye goby	2					-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	2					-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	2					-	-	-	-	-	-
Sebastes spp. V	rockfishes	2					-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	2					-	-	-	-	-	-
Artedius spp.	sculpins	1					-	-	-	-	-	-
Atherinops affinis	topsmelt	1					-	-	-	-	-	-
Bathymasteridae unid.	ronquils	1					-	-	-	-	-	-
Citharichthys spp.	sanddabs	1					-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	1					-	-	-	-	-	-
Gadidae	codfishes	1					-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	1					-	-	-	-	-	-
Gobiesox spp.	clingfishes	1					-	-	-	-	-	-
Hemilepidotus spinosus	brown Irish lord	1					-	-	-	-	-	-
Heterostichus rostratus	giant kelpfish	1					-	-	-	-	-	-
Hypsoblennius spp.	blennies	1					-	-	-	-	-	-
Liparis spp.	snailfishes	1					-	-	-	-	-	-
Ophiodon elongatus	lingcod	1					-	-	-	-	-	-
Pholididae unid.	gunnels	1					-	-	-	-	-	-
Pleuronectes isolepis	butter sole	1					-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	1					-	-	-	-	-	-
Sebastes spp. V_D_	rockfishes	1					-	-	-	-	-	-
Seriphus politus	queenfish	1					-	-	-	-	-	-
	Total Fish Counts:	34,771					368		546		1,469	
Megalopal Crabs												
Cancer antennarius	brown rock crab	24					-	-	-	-	-	-
Cancer anthonyi	yellow crab	5					-	-	-	-	-	-
Cancer jordani	hairy rock crab	2					-	-	-	-	-	-
Carcinus maenas	European green crab	2					-	-	-	-	-	-
	Total Crab Counts:	33					0		0		0	

(*continued*)

Table B-1 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant intake stations E1 and E2 (all cycles combined): Surveys 1–30; January 17, 2001–February 22, 2002.

			Survey 26 Jan. 23-24 N=24		Survey 27 Jan. 30-31 N=24		Survey 28 Feb. 6-7 N=24		Survey 29 Feb. 13-14 N=24		Survey 30 Feb. 21-22 N=24	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Clupea pallasii	Pacific herring	9,909	139	100.83	12	9.08	17	13.28	4	3.51	4,308	3085.12
Lepidogobius lepidus	bay goby	7,874	194	138.51	134	96.61	112	80.64	110	91.99	118	89.92
Acanthogobius flavimanus	yellowfin goby	5,783	63	46.35	65	47.58	219	154.02	106	94.06	199	155.84
Gobiidae unid.	gobies	5,547	27	19.25	52	37.40	139	103.73	41	34.75	71	52.82
Engraulis mordax	northern anchovy	3,397	24	17.28	15	9.86	33	24.59	13	11.73	14	9.98
Genyonemus lineatus	white croaker	1,070	3	1.94	25	19.27	30	21.41	56	44.79	108	81.77
larval fish fragment, unid.	larval fishes, fragment	227	-	-	2	1.64	1	0.76	4	3.48	9	6.76
Leptocottus armatus	Pacific staghorn sculpin	223	12	9.08	12	8.56	10	7.74	12	10.14	27	18.47
Clupeiformes	herrings and anchovies	155	-	-	-	-	2	1.69	7	6.43	10	6.87
Paralichthys californicus	California halibut	103	-	-	1	0.66	-	-	2	1.63	2	1.47
Ammodytes hexapterus	Pacific sand lance	75	-	-	1	0.97	1	0.87	27	22.67	12	9.07
Psettichthys melanostictus	sand sole	50	1	0.70	2	1.71	5	3.60	8	7.21	20	15.66
Citharichthys stigmaeus	speckled sanddab	47	-	-	-	-	1	0.69	-	-	-	-
Sebastes spp. V_De	rockfishes	44	-	-	7	4.76	2	1.64	2	1.48	1	0.70
larval fish - damaged	larval fishes, damaged	33	-	-	1	0.69	1	0.80	-	-	-	-
Pleuronectidae unid.	flounders	32	-	-	-	-	1	0.92	2	1.55	6	4.76
Sciaenidae unid.	croakers	21	-	-	-	-	12	8.88	-	-	-	-
Atherinopsis californiensis	jacksmelt	20	-	-	-	-	2	1.39	1	1.04	11	7.16
Clupeidae unid.	herrings	15	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish, unid.	larval fishes	15	-	-	-	-	-	-	1	0.75	-	-
Cebidichthys violaceus	monkeyface eel	12	-	-	1	0.59	1	0.73	-	-	1	0.80
Hypsopsetta guttulata	diamond turbot	11	-	-	-	-	-	-	-	-	-	-
Oligocottus spp.	sculpins	11	-	-	-	-	-	-	1	0.65	1	0.61
Syngnathus spp.	pipefishes	10	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	8	-	-	-	-	-	-	-	-	1	0.73
Pleuronectes bilineatus	rock sole	6	-	-	-	-	4	2.85	-	-	-	-
Atherinidae unid.	silversides	5	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	5	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	5	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	5	-	-	-	-	1	0.89	-	-	-	-
Stichaeidae unid.	pricklebacks	5	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	4	-	-	-	-	1	0.63	-	-	-	-
Sebastes spp. VD	rockfishes	4	-	-	-	-	1	0.89	-	-	-	-
Clinocottus spp.	sculpins	3	-	-	-	-	-	-	1	1.09	-	-
Hexagrammidae unid.	greenlings	3	-	-	-	-	-	-	1	0.88	-	-
Osmeridae unid.	smelts	3	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	3	-	-	-	-	-	-	-	-	-	-
Coryphopterus nicholsi	blackeye goby	2	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	2	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	2	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	2	-	-	-	-	-	-	1	0.71	1	0.77
Syngnathus leptorhynchus	bay pipefish	2	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	1	-	-	-	-	-	-	-	-	-	-
Bathymasteridae unid.	ronquils	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	1	-	-	-	-	-	-	-	-	-	-
Gadidae	codfishes	1	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Hemilepidotus spinosus	brown Irish lord	1	1	0.57	-	-	-	-	-	-	-	-
Heterostichus rostratus	giant kelpfish	1	-	-	-	-	-	-	1	0.88	-	-
Hypsoblennius spp.	blennies	1	-	-	-	-	-	-	-	-	-	-
Liparis spp.	snailfishes	1	-	-	-	-	-	-	-	-	-	-
Ophiodon elongatus	lingcod	1	-	-	1	0.85	-	-	-	-	-	-
Pholididae unid.	gunnels	1	-	-	-	-	-	-	-	-	-	-
Pleuronectes isolepis	butter sole	1	-	-	-	-	1	0.73	-	-	-	-
Sebastes spp. V_D	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D_	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Seriphus politus	queenfish	1	-	-	-	-	-	-	-	-	-	-
	Total Fish Counts:	34,771	464		331		597		401		4,920	
Megalopal Crabs												
Cancer antennarius	brown rock crab	24	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi	yellow crab	5	-	-	-	-	-	-	-	-	-	-
Cancer jordani	hairy rock crab	2	-	-	-	-	-	-	-	-	-	-
Carcinus maenas	European green crab	2	-	-	-	-	-	-	-	-	-	-
	Total Crab Counts:	33	0		0		0		0		0	

(*continued*)

Table B-2. Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant source water stations (NF 1–4 and FF 1–3): Surveys 1–30, January 17, 2001–February 22, 2002.

		Total	Survey 1 Jan. 17-18, 2001 N=33		Survey 2 Jan. 24-25 N=46		Survey 3 Jan. 31-Feb. 1 N=48		Survey 4 Feb. 7-8 N=45		Survey 5 Feb. 23-24 N=40	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Gobiidae unid.	gobies	36,016	183	85.03	184	65.11	178	60.61	302	96.41	347	124.54
Engraulis mordax	northern anchovy	35,539	7	3.72	14	4.83	3	1.04	13	3.91	30	10.56
Clupea pallasii	Pacific herring	34,128	472	227.37	2,824	939.74	115	39.99	344	109.60	2,128	785.09
Acanthogobius flavimanus	yellowfin goby	30,410	-	-	210	72.30	575	199.03	477	154.94	1,951	711.95
Lepidogobius lepidus	bay goby	19,155	343	167.53	438	150.69	470	161.58	231	73.21	180	63.89
Genyonemus lineatus	white croaker	3,802	13	6.72	30	8.93	6	2.21	29	8.37	60	21.23
larval fish fragment, unid.	larval fishes, fragment	973	3	1.91	26	8.98	19	6.23	65	21.47	37	13.01
Leptocottus armatus	Pacific staghorn sculpin	856	15	6.64	21	7.29	47	14.81	22	6.85	58	20.11
Clupeiformes	herrings and anchovies	601	34	12.47	13	3.77	5	1.52	53	18.29	63	20.07
Ammodytes hexapterus	Pacific sand lance	477	-	-	-	-	-	-	239	67.27	93	31.58
Paralichthys californicus	California halibut	231	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	200	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	152	-	-	1	0.27	3	1.12	26	7.33	5	1.65
Psettichthys melanostictus	sand sole	149	-	-	-	-	-	-	-	-	3	1.06
Citharichthys stigmaeus	speckled sanddab	122	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	120	5	2.35	2	0.61	9	3.34	6	1.77	11	3.79
Hypsopsetta guttulata	diamond turbot	111	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	larval fishes, damaged	95	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish, unid.	larval fishes	87	2	1.01	2	0.57	1	0.34	2	0.59	5	1.57
Cebidichthys violaceus	monkeyface eel	58	-	-	1	0.24	-	-	4	1.09	2	0.77
Sciaenidae unid.	croakers	55	1	0.37	6	1.86	1	0.33	2	0.52	-	-
Syngnathus spp.	pipefishes	41	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	36	1	0.57	-	-	4	1.21	9	2.64	3	0.91
Osmeridae unid.	smelts	34	-	-	-	-	-	-	20	5.07	-	-
Atherinidae unid.	silversides	30	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	23	-	-	4	1.02	1	0.51	2	0.50	3	1.12
Sebastes spp. VD	rockfishes	21	2	0.99	4	1.35	-	-	-	-	2	0.72
Syngnathus leptorhynchus	bay pipefish	21	-	-	1	0.38	-	-	-	-	-	-
Bathymasteridae unid.	ronquils	19	-	-	-	-	1	0.29	1	0.25	1	0.35
Parophrys vetulus	English sole	19	-	-	-	-	-	-	8	2.04	1	0.39
Citharichthys sordidus	Pacific sanddab	18	1	0.43	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	15	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	13	1	0.38	-	-	2	0.68	-	-	2	0.73
Clinocottus analis	wooly sculpin	12	-	-	-	-	-	-	1	0.26	4	1.64
Hemilepidotus spinosus	brown Irish lord	12	-	-	1	0.34	1	0.38	1	0.32	-	-
Gillichthys mirabilis	longjaw mudsucker	11	1	0.38	-	-	-	-	-	-	-	-
Oligocottus spp.	sculpins	11	1	0.43	-	-	1	0.35	3	0.84	-	-
Pleuronectes bilineatus	rock sole	9	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D_	rockfishes	9	-	-	-	-	1	0.39	-	-	-	-
Stichaeidae unid.	pricklebacks	9	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	8	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	7	-	-	-	-	-	-	-	-	1	0.20
Cyclopteridae unid.	snailfishes	7	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	6	-	-	-	-	-	-	-	-	-	-
Liparis spp.	snailfishes	6	1	0.49	-	-	-	-	2	0.59	2	0.75
Microgadus proximus	Pacific tomcod	6	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	6	-	-	-	-	-	-	1	0.24	1	0.34
Sebastes spp.	rockfishes	6	-	-	1	0.31	-	-	2	0.55	2	0.68
Stenobrachius leucopsarus	northern lampfish	6	-	-	-	-	-	-	-	-	-	-
Clinocottus spp.	sculpins	5	-	-	-	-	-	-	-	-	-	-
Pholididae unid.	gunnels	5	-	-	-	-	-	-	-	-	-	-
Cottus asper	prickly sculpin	4	-	-	-	-	-	-	-	-	1	0.39
Sebastes spp. V_D	rockfishes	4	1	0.48	-	-	-	-	-	-	1	0.46
Syngnathidae unid.	pipefishes	4	-	-	-	-	-	-	-	-	-	-
Ammodytidae	sand lances	3	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	3	-	-	-	-	-	-	1	0.25	-	-
Coryphopterus nicholsi	blackeye goby	3	-	-	-	-	-	-	-	-	-	-
Gadidae	codfishes	3	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	3	-	-	-	-	-	-	-	-	-	-
Brosmophycis marginata	red brotula	2	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	2	-	-	-	-	-	-	-	-	-	-
Platichthys stellatus	starry flounder	2	-	-	-	-	-	-	-	-	-	-
Pleuronectes isolepis	butter sole	2	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	2	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	2	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	1	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	1	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	1	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	1	-	-	-	-	-	-	-	-	-	-
Hemilepidotus spp.	Irish lord	1	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	1	-	-	-	-	-	-	1	0.29	-	-
Odontopyxis trispinosa	pygmy poacher	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Stellerina xyosterna	pricklebreast poacher	1	-	-	-	-	-	-	-	-	-	-
	Total Fish Counts:	163,817	1,087		3,783		1,443		1,867		4,997	
Megalopal Crabs												
Cancer antennarius	brown rock crab	66	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi	yellow crab	11	-	-	-	-	-	-	-	-	-	-
Carcinus maenas	European green crab	9	-	-	-	-	-	-	-	-	-	-
Cancer jordani	hairy rock crab	8	2	0.74	-	-	-	-	-	-	-	-
Cancer spp.	cancer crabs	6	-	-	-	-	-	-	-	-	-	-
Cancer gracilis	slender crab	5	-	-	-	-	-	-	1	0.27	-	-
Cancer productus	red rock crab	1	-	-	-	-	-	-	-	-	1	0.47
	Total Crab Counts:	106	2		0		0		1		1	

(*continued*)

Table B-2 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant source water stations (NF 1–4 and FF 1–3): Surveys 1–30, January 17, 2001–February 22, 2002.

		Total	Survey 6 Feb. 27-Mar. 1 N=78		Survey 7 Mar. 3-9 N=84		Survey 8 Mar. 14-16 N=79		Survey 9 Mar. 21 N=8		Survey 10 Mar. 27-29 N=61	
Taxon	Common Name	Total Count	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.	Count	Mean Conc.
Fishes												
Gobiidae unid.	gobies	36,016	887	171.88	1,965	342.04	2,405	485.62	Incomplete		2,595	686.39
Engraulis mordax	northern anchovy	35,539	36	7.21	417	71.73	127	25.13	Survey		1,685	453.09
Clupea pallasii	Pacific herring	34,128	825	162.36	585	112.61	1,620	332.60			7	1.90
Acanthogobius flavimanus	yellowfin goby	30,410	2,605	509.77	5,536	944.62	7,159	1433.97			2,696	730.93
Lepidogobius lepidus	bay goby	19,155	176	34.68	331	54.98	194	39.03			205	53.07
Genyonemus lineatus	white croaker	3,802	57	11.13	1,575	265.80	170	33.05			152	38.03
larval fish fragment, unid.	larval fishes, fragment	973	60	11.42	88	15.49	140	29.79			17	4.42
Leptocottus armatus	Pacific staghorn sculpin	856	24	4.70	39	6.83	53	10.63			9	2.23
Clupeiformes	herrings and anchovies	601	24	4.58	84	16.03	243	50.46			-	-
Ammodytes hexapterus	Pacific sand lance	477	16	3.11	13	2.17	-	-			1	0.21
Paralichthys californicus	California halibut	231	-	-	27	4.75	1	0.22			8	2.10
Atherinopsis californiensis	jacksmelt	200	6	1.20	6	1.06	1	0.17			5	1.24
Pleuronectidae unid.	flounders	152	7	1.25	20	3.61	1	0.19			4	0.97
Psettichthys melanostictus	sand sole	149	4	0.83	17	2.90	-	-			1	0.26
Citharichthys stigmaeus	speckled sanddab	122	-	-	1	0.15	-	-			-	-
Sebastes spp. V_De	rockfishes	120	8	1.51	6	0.97	5	0.99			2	0.42
Hypsopsetta guttulata	diamond turbot	111	-	-	-	-	-	-			-	-
larval fish - damaged	larval fishes, damaged	95	-	-	-	-	56	10.70			-	-
larval/post-larval fish, unid.	larval fishes	87	1	0.18	1	0.15	3	0.58			4	1.25
Cebidichthys violaceus	monkeyface eel	58	2	0.38	3	0.48	4	0.74			10	2.35
Sciaenidae unid.	croakers	55	-	-	1	0.15	-	-			-	-
Syngnathus spp.	pipefishes	41	-	-	-	-	-	-			-	-
Cottidae unid.	sculpins	36	3	0.56	6	1.02	2	0.45			2	0.46
Osmeridae unid.	smelts	34	1	0.28	-	-	3	0.53			-	-
Atherinidae unid.	silversides	30	3	0.53	-	-	4	0.77			1	0.24
Sebastes spp. V	rockfishes	23	-	-	2	0.32	-	-			-	-
Sebastes spp. VD	rockfishes	21	3	0.66	2	0.30	-	-			1	0.20
Syngnathus leptorhynchus	bay pipefish	21	-	-	-	-	-	-			-	-
Bathymasteridae unid.	ronquils	19	-	-	2	0.39	1	0.21			2	0.50
Parophrys vetulus	English sole	19	-	-	5	0.89	-	-			-	-
Citharichthys sordidus	Pacific sanddab	18	-	-	-	-	-	-			1	0.28
Artedius spp.	sculpins	15	-	-	4	0.74	3	0.59			1	0.26
Scorpaenichthys marmoratus	cabezon	13	-	-	-	-	1	0.21			-	-
Clinocottus analis	wooly sculpin	12	-	-	2	0.40	-	-			1	0.27
Hemilepidotus spinosus	brown Irish lord	12	-	-	-	-	-	-			-	-
Gillichthys mirabilis	longjaw mudsucker	11	-	-	-	-	-	-			1	0.24
Oligocottus spp.	sculpins	11	1	0.20	2	0.34	-	-			-	-
Pleuronectes bilineatus	rock sole	9	-	-	-	-	-	-			2	0.54
Sebastes spp. V_D_	rockfishes	9	-	-	-	-	-	-			-	-
Stichaeidae unid.	pricklebacks	9	1	0.23	1	0.20	1	0.21			-	-
Gobiesocidae unid.	clingfishes	8	-	-	-	-	-	-			-	-
Artedius lateralis	smoothhead sculpin	7	-	-	1	0.18	1	0.23			1	0.19
Cyclopteridae unid.	snailfishes	7	-	-	-	-	-	-			-	-
Hypsoblennius spp.	blennies	6	-	-	-	-	-	-			-	-
Liparis spp.	snailfishes	6	-	-	-	-	-	-			1	0.25
Microgadus proximus	Pacific tomcod	6	-	-	4	0.64	-	-			-	-
Pleuronectiformes unid.	flatfishes	6	-	-	-	-	-	-			-	-
Sebastes spp.	rockfishes	6	-	-	-	-	-	-			1	0.26
Stenobrachius leucopsarus	northern lampfish	6	-	-	3	0.56	-	-			-	-
Clinocottus spp.	sculpins	5	-	-	-	-	-	-			-	-
Pholididae unid.	gunnels	5	2	0.37	2	0.30	-	-			-	-
Cottus asper	prickly sculpin	4	-	-	1	0.15	-	-			-	-
Sebastes spp. V_D	rockfishes	4	-	-	-	-	-	-			-	-
Syngnathidae unid.	pipefishes	4	-	-	-	-	-	-			-	-
Ammodytidae	sand lances	3	-	-	-	-	3	0.61			-	-
Citharichthys spp.	sanddabs	3	-	-	-	-	-	-			-	-
Coryphopterus nicholsi	blackeye goby	3	-	-	-	-	-	-			-	-
Gadidae	codfishes	3	-	-	2	0.35	-	-			-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	3	-	-	-	-	-	-			-	-
Brosmophycis marginata	red brotula	2	-	-	-	-	1	0.16			-	-
Ilypnus gilberti	cheekspot goby	2	-	-	-	-	-	-			-	-
Platichthys stellatus	starry flounder	2	-	-	1	0.16	-	-			-	-
Pleuronectes isolepis	butter sole	2	-	-	-	-	-	-			2	0.41
Pleuronichthys spp.	turbots	2	-	-	-	-	-	-			-	-
Pleuronichthys verticalis	hornyhead turbot	2	-	-	-	-	-	-			1	0.20
Atherinops affinis	topsmelt	1	-	-	-	-	-	-			-	-
Chaenopsidae unid.	tube blennies	1	-	-	-	-	-	-			-	-
Clevelandia ios	arrow goby	1	-	-	-	-	-	-			-	-
Engraulidae	anchovies	1	-	-	-	-	-	-			-	-
Hemilepidotus spp.	Irish lord	1	-	-	-	-	-	-			-	-
Hexagrammidae unid.	greenlings	1	-	-	-	-	-	-			-	-
Odontopyxis trispinosa	pygmy poacher	1	-	-	-	-	-	-			-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-			-	-
Sebastes spp. V_	rockfishes	1	-	-	-	-	-	-			-	-
Stellerina xyosterna	pricklebreast poacher	1	-	-	1	0.15	-	-			-	-
	Total Fish Counts:	163,817	4,752		10,756		12,202				7,419	
Crabs												
Cancer antennarius	brown rock crab	66	-	-	-	-	-	-			6	1.60
Cancer anthonyi	yellow crab	11	1	0.24	-	-	-	-			-	-
Carcinus maenas	European green crab	9	1	0.19	2	0.34	1	0.20			-	-
Cancer jordani	hairy rock crab	8	-	-	-	-	2	0.41			1	0.27
Cancer spp.	cancer crabs	6	-	-	-	-	1	0.17			-	-
Cancer gracilis	slender crab	5	-	-	1	0.15	-	-			-	-
Cancer productus	red rock crab	1	-	-	-	-	-	-			-	-
	Total Crab Counts:	106	2		3		4				7	

(*continued*)

Table B-2 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant source water stations (NF 1–4 and FF 1–3): Surveys 1–30, January 17, 2001–February 22, 2002.

			Survey 11 Apr. 4-6 N=84		Survey 12 May 22-24 N=84		Survey 13 Jun. 20-22 N=84		Survey 14 Jul. 11-13 N=84		Survey 15 Aug. 8-10 N=84	
Taxon	Common Name	Total Count	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.
Fishes												
Gobiidae unid.	gobies	36,016	4,938	1049.54	3,905	790.89	4,176	840.67	3,848	767.33	4,245	750.68
Engraulis mordax	northern anchovy	35,539	4,050	851.42	502	101.99	205	41.44	2,578	506.35	14,961	2709.22
Clupea pallasii	Pacific herring	34,128	15	3.27	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	30,410	1,942	402.85	286	57.43	46	9.24	55	11.28	35	5.86
Lepidogobius lepidus	bay goby	19,155	159	31.13	367	72.27	581	112.53	2,225	465.76	2,583	480.05
Genyonemus lineatus	white croaker	3,802	92	17.46	2	0.35	2	0.45	1	0.20	-	-
larval fish fragment, unid.	larval fishes, fragment	973	132	28.19	9	1.96	17	3.27	17	3.11	57	10.43
Leptocottus armatus	Pacific staghorn sculpin	856	3	0.61	-	-	-	-	-	-	1	0.17
Clupeiformes	herrings and anchovies	601	15	3.08	-	-	-	-	-	-	-	-
Ammodytes hexapterus	Pacific sand lance	477	1	0.14	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	231	5	0.95	2	0.44	10	2.05	18	3.51	41	7.72
Atherinopsis californiensis	jacksmelt	200	8	2.03	45	10.03	99	19.91	12	2.11	3	0.44
Pleuronectidae unid.	flounders	152	-	-	-	-	2	0.37	2	0.42	5	0.97
Psettichthys melanostictus	sand sole	149	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	122	-	-	-	-	-	-	-	-	3	0.57
Sebastes spp. V_De	rockfishes	120	4	0.76	3	0.61	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	111	-	-	1	0.21	4	0.86	8	1.74	44	8.17
larval fish - damaged	larval fishes, damaged	95	4	0.94	-	-	1	0.20	3	0.50	13	2.21
larval/post-larval fish, unid.	larval fishes	87	8	1.73	-	-	4	0.82	-	-	17	3.27
Cebidichthys violaceus	monkeyface eel	58	2	0.36	19	3.30	-	-	-	-	-	-
Sciaenidae unid.	croakers	55	3	0.58	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	41	-	-	-	-	7	1.35	1	0.20	2	0.29
Cottidae unid.	sculpins	36	1	0.21	1	0.24	-	-	-	-	-	-
Osmeridae unid.	smelts	34	7	1.18	-	-	-	-	-	-	-	-
Atherinidae unid.	silversides	30	9	1.93	5	0.85	1	0.16	2	0.43	1	0.19
Sebastes spp. V	rockfishes	23	-	-	1	0.19	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	21	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	21	-	-	2	0.48	-	-	1	0.24	3	0.45
Bathymasteridae unid.	ronquils	19	5	0.86	-	-	2	0.30	1	0.21	-	-
Parophrys vetulus	English sole	19	1	0.20	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	18	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	15	2	0.36	-	-	-	-	1	0.25	-	-
Scorpaenichthys marmoratus	cabezon	13	1	0.20	-	-	-	-	-	-	-	-
Clinocottus analis	wooly sculpin	12	2	0.32	1	0.22	-	-	-	-	-	-
Hemilepidotus spinosus	brown Irish lord	12	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	11	-	-	1	0.13	1	0.17	-	-	-	-
Oligocottus spp.	sculpins	11	-	-	-	-	-	-	-	-	-	-
Pleuronectes bilineatus	rock sole	9	3	0.69	-	-	-	-	-	-	-	-
Sebastes spp. V_D_	rockfishes	9	-	-	-	-	-	-	-	-	-	-
Stichaeidae unid.	pricklebacks	9	-	-	3	0.53	1	0.20	-	-	-	-
Gobiesocidae unid.	clingfishes	8	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	7	2	0.36	-	-	-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	7	1	0.24	2	0.34	1	0.21	-	-	-	-
Hypsoblennius spp.	blennies	6	-	-	-	-	-	-	-	-	4	0.67
Liparis spp.	snailfishes	6	-	-	-	-	-	-	-	-	-	-
Microgadus proximus	Pacific tomcod	6	1	0.14	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	6	-	-	-	-	-	-	-	-	1	0.15
Sebastes spp.	rockfishes	6	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	6	-	-	-	-	-	-	-	-	-	-
Clinocottus spp.	sculpins	5	-	-	-	-	-	-	-	-	-	-
Pholididae unid.	gunnels	5	-	-	-	-	-	-	-	-	-	-
Cottus asper	prickly sculpin	4	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	4	-	-	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	4	-	-	-	-	-	-	-	-	2	0.37
Ammodytidae	sand lances	3	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	3	-	-	-	-	-	-	-	-	-	-
Coryphopterus nicholsi	blackeye goby	3	-	-	-	-	-	-	2	0.34	-	-
Gadidae	codfishes	3	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	3	-	-	-	-	-	-	1	0.17	-	-
Brosmophycis marginata	red brotula	2	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	2	-	-	-	-	-	-	-	-	-	-
Platichthys stellatus	starry flounder	2	-	-	-	-	-	-	-	-	-	-
Pleuronectes isolepis	butter sole	2	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	2	2	0.36	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	2	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	1	-	-	-	-	1	0.20	-	-	-	-
Chaenopsidae unid.	tube blennies	1	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	1	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	1	-	-	-	-	-	-	-	-	-	-
Hemilepidotus spp.	Irish lord	1	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	1	-	-	-	-	-	-	-	-	-	-
Odontopyxis trispinosa	pygmy poacher	1	-	-	1	0.15	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Stellerina xyosterna	pricklebreast poacher	1	-	-	-	-	-	-	-	-	-	-
	Total Fish Counts:	163,817	11,418		5,158		5,161		8,776		22,021	
Crabs												
Cancer antennarius	brown rock crab	66	25	5.18	9	1.69	23	4.67	-	-	-	-
Cancer anthonyi	yellow crab	11	7	1.54	2	0.37	-	-	-	-	-	-
Carcinus maenas	European green crab	9	3	0.58	-	-	-	-	-	-	-	-
Cancer jordani	hairy rock crab	8	2	0.45	-	-	1	0.19	-	-	-	-
Cancer spp.	cancer crabs	6	3	0.58	1	0.15	1	0.21	-	-	-	-
Cancer gracilis	slender crab	5	1	0.24	-	-	-	-	-	-	-	-
Cancer productus	red rock crab	1	-	-	-	-	-	-	-	-	-	-
	Total Crab Counts:	106	41		12		25		0		0	

(*continued*)

Table B-2 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant source water stations (NF 1–4 and FF 1–3): Surveys 1–30, January 17, 2001–February 22, 2002.

			Survey 16 Sep. 12-13 N=70		Survey 17 Oct. 10-12 N=82		Survey 18 Nov. 7-9 N=84		Survey 19 Dec. 5-7 N=84		Survey 20 Dec. 12-15 N=84	
Taxon	Common Name	Total Count	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.
Fishes												
Gobiidae unid.	gobies	36,016	1,425	315.44	800	160.43	288	57.20	577	104.53	Not Sorted	
Engraulis mordax	northern anchovy	35,539	7,685	1683.09	1,151	231.14	68	13.71	556	101.82		
Clupea pallasii	Pacific herring	34,128	-	-	-	-	-	-	282	51.24		
Acanthogobius flavimanus	yellowfin goby	30,410	4	0.96	2	0.39	-	-	18	3.41		
Lepidogobius lepidus	bay goby	19,155	1,263	275.46	2,112	416.72	1,932	397.61	1,752	329.17		
Genyonemus lineatus	white croaker	3,802	7	1.77	62	12.68	12	2.44	202	34.64		
larval fish fragment, unid.	larval fishes, fragment	973	13	3.01	20	4.13	1	0.19	24	4.26		
Leptocottus armatus	Pacific staghorn sculpin	856	-	-	2	0.31	-	-	64	11.93		
Clupeiformes	herrings and anchovies	601	-	-	-	-	-	-	4	0.67		
Ammodytes hexapterus	Pacific sand lance	477	-	-	-	-	-	-	-	-		
Paralichthys californicus	California halibut	231	91	20.01	17	3.48	4	0.73	-	-		
Atherinopsis californiensis	jacksmelt	200	-	-	-	-	1	0.24	1	0.23		
Pleuronectidae unid.	flounders	152	-	-	4	0.70	1	0.22	-	-		
Psettichthys melanostictus	sand sole	149	-	-	1	0.26	-	-	-	-		
Citharichthys stigmaeus	speckled sanddab	122	65	13.99	38	8.34	3	0.51	1	0.22		
Sebastes spp. V_De	rockfishes	120	-	-	-	-	-	-	6	1.04		
Hypsopsetta guttulata	diamond turbot	111	38	8.66	12	2.58	4	0.78	-	-		
larval fish - damaged	larval fishes, damaged	95	2	0.42	3	0.74	3	0.60	2	0.37		
larval/post-larval fish, unid.	larval fishes	87	15	3.19	13	2.92	1	0.22	-	-		
Cebidichthys violaceus	monkeyface eel	58	-	-	-	-	-	-	-	-		
Sciaenidae unid.	croakers	55	-	-	20	4.29	4	0.75	9	1.63		
Syngnathus spp.	pipefishes	41	-	-	1	0.24	7	1.37	12	2.07		
Cottidae unid.	sculpins	36	-	-	-	-	-	-	1	0.20		
Osmeridae unid.	smelts	34	-	-	-	-	-	-	-	-		
Atherinidae unid.	silversides	30	-	-	1	0.25	1	0.20	1	0.19		
Sebastes spp. V	rockfishes	23	-	-	-	-	-	-	-	-		
Sebastes spp. VD	rockfishes	21	-	-	-	-	-	-	2	0.35		
Syngnathus leptorhynchus	bay pipefish	21	3	0.74	8	1.72	-	-	3	0.59		
Bathymasteridae unid.	ronquils	19	-	-	-	-	-	-	-	-		
Parophrys vetulus	English sole	19	-	-	-	-	-	-	-	-		
Citharichthys sordidus	Pacific sanddab	18	-	-	-	-	-	-	2	0.35		
Artedius spp.	sculpins	15	-	-	-	-	-	-	-	-		
Scorpaenichthys marmoratus	cabezon	13	-	-	-	-	2	0.34	2	0.45		
Clinocottus analis	wooly sculpin	12	-	-	-	-	-	-	-	-		
Hemilepidotus spinosus	brown Irish lord	12	-	-	-	-	-	-	-	-		
Gillichthys mirabilis	longjaw mudsucker	11	-	-	-	-	-	-	2	0.31		
Oligocottus spp.	sculpins	11	-	-	-	-	-	-	-	-		
Pleuronectes bilineatus	rock sole	9	-	-	-	-	-	-	-	-		
Sebastes spp. V_D_	rockfishes	9	-	-	-	-	-	-	-	-		
Stichaeidae unid.	pricklebacks	9	-	-	-	-	-	-	-	-		
Gobiesocidae unid.	clingfishes	8	-	-	-	-	-	-	-	-		
Artedius lateralis	smoothhead sculpin	7	-	-	-	-	-	-	-	-		
Cyclopteridae unid.	snailfishes	7	-	-	-	-	-	-	-	-		
Hypsoblennius spp.	blennies	6	2	0.40	-	-	-	-	-	-		
Liparis spp.	snailfishes	6	-	-	-	-	-	-	-	-		
Microgadus proximus	Pacific tomcod	6	-	-	-	-	-	-	-	-		
Pleuronectiformes unid.	flatfishes	6	-	-	-	-	-	-	-	-		
Sebastes spp.	rockfishes	6	-	-	-	-	-	-	-	-		
Stenobrachius leucopsarus	northern lampfish	6	-	-	-	-	-	-	-	-		
Clinocottus spp.	sculpins	5	-	-	-	-	-	-	-	-		
Pholididae unid.	gunnels	5	-	-	-	-	-	-	-	-		
Cottus asper	prickly sculpin	4	-	-	-	-	-	-	-	-		
Sebastes spp. V_D	rockfishes	4	-	-	-	-	-	-	-	-		
Syngnathidae unid.	pipefishes	4	-	-	1	0.18	-	-	1	0.13		
Ammodytidae	sand lances	3	-	-	-	-	-	-	-	-		
Citharichthys spp.	sanddabs	3	-	-	-	-	-	-	1	0.13		
Coryphopterus nicholsi	blackeye goby	3	-	-	-	-	-	-	1	0.16		
Gadidae	codfishes	3	-	-	-	-	-	-	-	-		
Paralichthyidae unid.	lefteye flounders & sanddabs	3	-	-	-	-	-	-	-	-		
Brosmophycis marginata	red brotula	2	-	-	-	-	-	-	-	-		
Ilypnus gilberti	cheekspot goby	2	-	-	-	-	-	-	-	-		
Platichthys stellatus	starry flounder	2	-	-	-	-	-	-	-	-		
Pleuronectes isolepis	butter sole	2	-	-	-	-	-	-	-	-		
Pleuronichthys spp.	turbots	2	-	-	-	-	-	-	-	-		
Pleuronichthys verticalis	hornyhead turbot	2	-	-	-	-	-	-	-	-		
Atherinops affinis	topsmelt	1	-	-	-	-	-	-	-	-		
Chaenopsidae unid.	tube blennies	1	-	-	1	0.21	-	-	-	-		
Clevelandia ios	arrow goby	1	-	-	-	-	-	-	1	0.19		
Engraulidae	anchovies	1	-	-	1	0.17	-	-	-	-		
Hemilepidotus spp.	Irish lord	1	-	-	-	-	-	-	-	-		
Hexagrammidae unid.	greenlings	1	-	-	-	-	-	-	-	-		
Odontopyxis trispinosa	pygmy poacher	1	-	-	-	-	-	-	-	-		
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-		
Sebastes spp. V_	rockfishes	1	-	-	-	-	-	-	-	-		
Stellerina xyosterna	pricklebreast poacher	1	-	-	-	-	-	-	-	-		
	Total Fish Counts:	163,817	10,613		4,270		2,332		3,527			
Crabs												
Cancer antennarius	brown rock crab	66	-	-	-	-	-	-	2	0.37		
Cancer anthonyi	yellow crab	11	-	-	-	-	-	-	-	-		
Carcinus maenas	European green crab	9	-	-	-	-	-	-	-	-		
Cancer jordani	hairy rock crab	8	-	-	-	-	-	-	-	-		
Cancer spp.	cancer crabs	6	-	-	-	-	-	-	-	-		
Cancer gracilis	slender crab	5	-	-	-	-	-	-	-	-		
Cancer productus	red rock crab	1	-	-	-	-	-	-	-	-		
	Total Crab Counts:	106	0		0		0		2			

(*continued*)

Table B-2 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant source water stations (NF 1–4 and FF 1–3): Surveys 1–30, January 17, 2001–February 22, 2002.

			Survey 21 Dec. 18-21 N=84		Survey 22 Dec. 28-31 N=84		Survey 23 Jan. 2-4, 2002 N=84		Survey 24 Jan. 9-11 N=84		Survey 25 Jan. 16-18 N=84	
Taxon	Common Name	Total Count	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.
Fishes												
Gobiidae unid.	gobies	36,016	Not Sorted		Not Sorted		334	61.91	330	63.39	257	53.40
Engraulis mordax	northern anchovy	35,539					206	38.23	185	35.62	237	49.78
Clupea pallasii	Pacific herring	34,128					23	4.46	119	23.00	8,768	1847.80
Acanthogobius flavimanus	yellowfin goby	30,410					350	66.98	418	79.37	571	120.30
Lepidogobius lepidus	bay goby	19,155					703	136.42	667	126.82	417	87.13
Genyonemus lineatus	white croaker	3,802					307	59.91	192	38.50	127	27.53
larval fish fragment, unid.	larval fishes, fragment	973					6	1.10	2	0.34	65	15.90
Leptocottus armatus	Pacific staghorn sculpin	856					47	8.90	65	12.04	90	17.78
Clupeiformes	herrings and anchovies	601					-	-	1	0.21	40	8.23
Ammodytes hexapterus	Pacific sand lance	477					-	-	-	-	-	-
Paralichthys californicus	California halibut	231					-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	200					1	0.18	2	0.45	3	0.60
Pleuronectidae unid.	flounders	152					29	5.85	4	0.76	4	0.90
Psettichthys melanostictus	sand sole	149					4	0.80	10	1.82	3	0.61
Citharichthys stigmaeus	speckled sanddab	122					2	0.46	1	0.26	4	0.79
Sebastes spp. V_De	rockfishes	120					8	1.50	-	-	7	1.53
Hypsopsetta guttulata	diamond turbot	111					-	-	-	-	-	-
larval fish - damaged	larval fishes, damaged	95					-	-	-	-	3	0.69
larval/post-larval fish, unid.	larval fishes	87					2	0.38	-	-	2	0.49
Cebidichthys violaceus	monkeyface eel	58					-	-	-	-	1	0.25
Sciaenidae unid.	croakers	55					-	-	-	-	1	0.21
Syngnathus spp.	pipefishes	41					4	0.74	1	0.21	4	0.88
Cottidae unid.	sculpins	36					-	-	-	-	-	-
Osmeridae unid.	smelts	34					-	-	-	-	1	0.24
Atherinidae unid.	silversides	30					-	-	-	-	-	-
Sebastes spp. V	rockfishes	23					1	0.20	-	-	-	-
Sebastes spp. VD	rockfishes	21					1	0.14	-	-	1	0.24
Syngnathus leptorhynchus	bay pipefish	21					-	-	-	-	-	-
Bathymasteridae unid.	ronquils	19					-	-	-	-	1	0.26
Parophrys vetulus	English sole	19					-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	18					2	0.43	7	1.45	4	0.90
Artedius spp.	sculpins	15					-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	13					-	-	-	-	-	-
Clinocottus analis	wooly sculpin	12					-	-	-	-	-	-
Hemilepidotus spinosus	brown Irish lord	12					-	-	4	0.77	2	0.36
Gillichthys mirabilis	longjaw mudsucker	11					1	0.16	-	-	1	0.20
Oligocottus spp.	sculpins	11					-	-	-	-	-	-
Pleuronectes bilineatus	rock sole	9					-	-	1	0.17	1	0.15
Sebastes spp. V_D_	rockfishes	9					-	-	-	-	2	0.42
Stichaeidae unid.	pricklebacks	9					-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	8					-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	7					-	-	-	-	-	-
Cyclopteridae unid.	snailfishes	7					-	-	1	0.21	-	-
Hypsoblennius spp.	blennies	6					-	-	-	-	-	-
Liparis spp.	snailfishes	6					-	-	-	-	-	-
Microgadus proximus	Pacific tomcod	6					-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	6					-	-	1	0.19	1	0.22
Sebastes spp.	rockfishes	6					-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	6					-	-	-	-	2	0.36
Clinocottus spp.	sculpins	5					-	-	1	0.19	-	-
Pholididae unid.	gunnels	5					-	-	-	-	-	-
Cottus asper	prickly sculpin	4					-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	4					-	-	1	0.21	1	0.19
Syngnathidae unid.	pipefishes	4					-	-	-	-	-	-
Ammodytidae	sand lances	3					-	-	-	-	-	-
Citharichthys spp.	sanddabs	3					-	-	-	-	1	0.19
Coryphopterus nicholsi	blackeye goby	3					-	-	-	-	-	-
Gadidae	codfishes	3					-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	3					-	-	-	-	-	-
Brosmophycis marginata	red brotula	2					-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	2					1	0.21	-	-	1	0.27
Platichthys stellatus	starry flounder	2					-	-	-	-	-	-
Pleuronectes isolepis	butter sole	2					-	-	-	-	-	-
Pleuronichthys spp.	turbots	2					-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	2					1	0.21	-	-	-	-
Atherinops affinis	topsmelt	1					-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	1					-	-	-	-	-	-
Clevelandia ios	arrow goby	1					-	-	-	-	-	-
Engraulidae	anchovies	1					-	-	-	-	-	-
Hemilepidotus spp.	Irish lord	1					-	-	-	-	-	-
Hexagrammidae unid.	greenlings	1					-	-	-	-	-	-
Odontopyxis trispinosa	pygmy poacher	1					-	-	-	-	-	-
Oxylebius pictus	painted greenling	1					-	-	-	-	-	-
Sebastes spp. V_	rockfishes	1					-	-	1	0.20	-	-
Stellerina xyosterna	pricklebreast poacher	1					-	-	-	-	-	-
	Total Fish Counts:	163,817					2,033		2,014		10,623	
Crabs												
Cancer antennarius	brown rock crab	66					-	-	-	-	-	-
Cancer anthonyi	yellow crab	11					-	-	-	-	-	-
Carcinus maenas	European green crab	9					-	-	-	-	-	-
Cancer jordani	hairy rock crab	8					-	-	-	-	-	-
Cancer spp.	cancer crabs	6					-	-	-	-	-	-
Cancer gracilis	slender crab	5					1	0.24	-	-	-	-
Cancer productus	red rock crab	1					-	-	-	-	-	-
	Total Crab Counts:	106					1		0		0	

(*continued*)

Table B-2 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and megalopal *Cancer* and *Carcinus* crabs collected at Potrero Power Plant source water stations (NF 1–4 and FF 1–3): Surveys 1–30, January 17, 2001–February 22, 2002.

			Survey 26 Jan. 23-25 N=84		Survey 27 Jan. 30- Feb. 1 N=84		Survey 28 Feb. 5-7 N=84		Survey 29 Feb. 12-14 N=84		Survey 30 Feb. 20-22 N=84	
Taxon	Common Name	Total Count	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.	Ct.	Mean Conc.
Gobiidae unid.	gobies	36,016	219	44.19	352	72.28	416	85.07	332	67.25	528	105.25
Engraulis mordax	northern anchovy	35,539	137	27.54	227	44.82	196	39.84	194	40.10	69	14.84
Clupea pallasii	Pacific herring	34,128	942	191.76	177	36.05	61	11.99	61	12.77	14,760	2866.68
Acanthogobius flavimanus	yellowfin goby	30,410	612	121.85	849	179.09	1,964	389.26	856	182.08	1,193	247.88
Lepidogobius lepidus	bay goby	19,155	464	94.42	310	62.30	313	61.76	322	67.28	417	86.51
Genyonemus lineatus	white croaker	3,802	26	5.15	89	19.18	150	30.55	206	45.98	233	49.60
larval fish fragment, unid.	larval fishes, fragment	973	11	2.27	3	0.58	9	1.94	25	4.92	107	21.88
Leptocottus armatus	Pacific staghorn sculpin	856	49	10.29	46	9.39	43	9.19	76	16.23	82	16.29
Clupeiformes	herrings and anchovies	601	8	1.70	1	0.19	2	0.45	5	1.05	6	1.24
Ammodytes hexapterus	Pacific sand lance	477	-	-	2	0.43	8	1.61	80	17.85	24	4.92
Paralichthys californicus	California halibut	231	1	0.26	-	-	1	0.19	4	0.91	1	0.23
Atherinopsis californiensis	jacksmelt	200	1	0.17	-	-	1	0.21	1	0.20	4	0.79
Pleuronectidae unid.	flounders	152	4	0.90	2	0.45	5	1.00	10	2.20	13	2.90
Psettichthys melanostictus	sand sole	149	2	0.37	9	1.95	30	6.52	21	4.75	44	9.04
Citharichthys stigmaeus	speckled sanddab	122	1	0.24	1	0.26	2	0.39	-	-	-	-
Sebastes spp. V_De	rockfishes	120	4	0.96	12	2.42	7	1.47	8	1.77	7	1.47
Hypsopsetta guttulata	diamond turbot	111	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	larval fishes, damaged	95	2	0.35	-	-	3	0.63	-	-	-	-
larval/post-larval fish, unid.	larval fishes	87	-	-	1	0.16	-	-	2	0.46	1	0.20
Cebidichthys violaceus	monkeyface eel	58	-	-	3	0.56	1	0.21	-	-	6	1.31
Sciaenidae unid.	croakers	55	-	-	5	1.20	2	0.36	-	-	-	-
Syngnathus spp.	pipefishes	41	-	-	-	-	-	-	1	0.22	1	0.20
Cottidae unid.	sculpins	36	-	-	2	0.45	-	-	-	-	1	0.18
Osmeridae unid.	smelts	34	-	-	1	0.25	-	-	1	0.28	-	-
Atherinidae unid.	silversides	30	-	-	-	-	1	0.24	-	-	-	-
Sebastes spp. V	rockfishes	23	-	-	2	0.44	3	0.59	3	0.64	1	0.21
Sebastes spp. VD	rockfishes	21	-	-	1	0.20	2	0.39	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	21	-	-	-	-	-	-	-	-	-	-
Bathymasteridae unid.	ronquils	19	-	-	-	-	-	-	1	0.21	1	0.18
Parophrys vetulus	English sole	19	2	0.42	-	-	-	-	1	0.17	1	0.25
Citharichthys sordidus	Pacific sanddab	18	-	-	-	-	-	-	1	0.22	-	-
Artedius spp.	sculpins	15	-	-	-	-	1	0.15	-	-	3	0.59
Scorpaenichthys marmoratus	cabezon	13	-	-	-	-	-	-	2	0.44	-	-
Clinocottus analis	wooly sculpin	12	-	-	-	-	-	-	-	-	1	0.21
Hemilepidotus spinosus	brown Irish lord	12	-	-	1	0.28	1	0.18	1	0.22	-	-
Gillichthys mirabilis	longjaw mudsucker	11	-	-	-	-	1	0.20	-	-	2	0.37
Oligocottus spp.	sculpins	11	-	-	1	0.27	1	0.21	-	-	1	0.20
Pleuronectes bilineatus	rock sole	9	1	0.22	1	0.20	-	-	-	-	-	-
Sebastes spp. V_D_	rockfishes	9	-	-	3	0.58	3	0.62	-	-	-	-
Stichaeidae unid.	pricklebacks	9	-	-	-	-	-	-	-	-	2	0.39
Gobiesocidae unid.	clingfishes	8	-	-	-	-	-	-	-	-	8	1.42
Artedius lateralis	smoothhead sculpin	7	-	-	-	-	-	-	1	0.24	-	-
Cyclopteridae unid.	snailfishes	7	1	0.24	-	-	-	-	-	-	1	0.16
Hypsoblennius spp.	blennies	6	-	-	-	-	-	-	-	-	-	-
Liparis spp.	snailfishes	6	-	-	-	-	-	-	-	-	-	-
Microgadus proximus	Pacific tomcod	6	-	-	1	0.20	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	6	-	-	-	-	1	0.23	-	-	-	-
Sebastes spp.	rockfishes	6	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	6	-	-	-	-	-	-	-	-	1	0.18
Clinocottus spp.	sculpins	5	1	0.27	1	0.20	-	-	2	0.55	-	-
Pholididae unid.	gunnels	5	-	-	-	-	-	-	-	-	1	0.21
Cottus asper	prickly sculpin	4	-	-	1	0.16	1	0.18	-	-	-	-
Sebastes spp. V_D	rockfishes	4	-	-	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	4	-	-	-	-	-	-	-	-	-	-
Ammodytidae	sand lances	3	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	3	-	-	-	-	-	-	-	-	-	-
Coryphopterus nicholsi	blackeye goby	3	-	-	-	-	-	-	-	-	-	-
Gadidae	codfishes	3	-	-	1	0.24	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders & sanddabs	3	-	-	1	0.29	-	-	1	0.17	-	-
Brosmophycis marginata	red brotula	2	-	-	-	-	-	-	-	-	1	0.23
Ilypnus gilberti	cheekspot goby	2	-	-	-	-	-	-	-	-	-	-
Platichthys stellatus	starry flounder	2	-	-	-	-	-	-	-	-	1	0.25
Pleuronectes isolepis	butter sole	2	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	2	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	2	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	1	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	1	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	1	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	1	-	-	-	-	-	-	-	-	-	-
Hemilepidotus spp.	Irish lord	1	1	0.26	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	1	-	-	-	-	-	-	-	-	-	-
Odontopyxis trispinosa	pygmy poacher	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	1	0.20	-	-	-	-	-	-
Sebastes spp. V_	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Stellerina xyosterna	pricklebreast poacher	1	-	-	-	-	-	-	-	-	-	-
	Total Fish Counts:	163,817	2,489		2,107		3,229		2,218		17,522	
Crabs												
Cancer antennarius	brown rock crab	66	-	-	-	-	-	-	1	0.24	-	-
Cancer anthonyi	yellow crab	11	-	-	-	-	-	-	1	0.24	-	-
Carcinus maenas	European green crab	9	-	-	-	-	-	-	1	0.25	1	0.19
Cancer jordani	hairy rock crab	8	-	-	-	-	-	-	-	-	-	-
Cancer spp.	cancer crabs	6	-	-	-	-	-	-	-	-	-	-
Cancer gracilis	slender crab	5	-	-	-	-	-	-	1	0.28	-	-
Cancer productus	red rock crab	1	-	-	-	-	-	-	-	-	-	-
	Total Crab Counts:	106	0		0		0		4		1	

Potrero Power Plant Unit 3
Entrainment Characterization Report

Appendix C

Determination of Source Water Volume

Potrero Power Plant Unit 3
316(b) Entrainment Characterization Report

Appendix C

Determination of Source Water Volume

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Potrero Power Plant Unit 3
Entrainment Characterization Report

Determination of Source Water Volume

The results of three entrainment effects models were used to assess potential cooling water intake system (CWIS) impact. The three population models of entrainment effects selected for the assessment were the empirical transport model (*ETM*), the fecundity hindcast (*FH*) model, and the adult equivalent loss (*AEL*) model. The formulation and application of these three models are discussed in detail in Section 4.0 and Appendix E. An example of the use of all three methods is presented in Appendix E.

In brief, the *ETM* model compares the estimated number of organisms by species entrained to the estimated number of individuals of the same species at risk to entrainment that are found in the source water body. Both the estimated number of individuals entrained and in the source water body are the products of the species' average concentration in either the volume of cooling water withdrawn or the source water volume, respectively. The cooling water volume is determined by the design capacity of Potrero Power Plant Unit 3 cooling water and screenwash pumps and annual hours of operation. The model's source water volume is the hydrographic volume of water in an estimated area at risk to entrainment and CWIS effects. In general, the source water area should correspond to the source water sampling locations used to estimate species concentrations.

The published literature describing the geographical patterns in the distribution of San Francisco Bay fish species and the hydrographic estimates of San Francisco Bay volumes using tidal datum and bathymetric survey results was used to determine area and volume of the Potrero Power Plant source water study area. The abundances and distributions of fish species reported in the California Department of Fish and Game's (CDFG) comprehensive survey report from 1980–1995 (Baxter et al. 1999) at locations shown in Figure C-1 were used to guide the preliminary selection of the source water study area as well as locate the source water biological sampling stations. The CDFG survey findings indicate that salinity is the predominant factor in the abundance and distribution of the Bay's species, as seen in Figure C-2. A relatively gradual transition occurs between salinity and the most abundant species (catch per unit effort) in the range of 25 to 30 parts per thousand (ppt). A noticeable break occurs between 15 and 20 ppt as anadromous and freshwater species begin to dominate the fewer number of species in the lower salinity range. Figure C-3, also taken from the CDFG report, illustrates the seasonal distribution of the Bay's salinity differences that, as shown in Figure C-1, would be expected to closely predict the distribution and abundance of Bay species. Seasonally, the oceanic and delta outflows strongly influence salinities in the area north and south of Treasure Island and across the Berkeley shallows. Salinities above 18 ppt are typical of the Central and South bays during the majority of the year. However, salinities in the polyhaline Central and South bay regions vary among wet and dry seasons and years (Figure C-3). The report's breakdown of species distributions by sampling locations — rivers and streams, Delta, Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Ocean — provides strong evidence that the Central Bay region is hydrographically and biologically distinct from the South Bay region, and the Central Bay is an appropriate designation of the Potrero Power Plant's source water volume.

At the August 27, 2001 meeting of the Agency Working Group (AWG), AWG members and outside consultants suggested that the area south of the Hayward-San Mateo Bridge, referred to as "South Bay," was biologically distinct from the majority of the project's source water area. The AWG recommend that the "South Bay" volume not be included in the source water volume and that an area north of the Bay Bridge be investigated biologically for possible addition to the source water volume. The AWG's general view that a significantly different fauna exists in the lower end of the Bay was analyzed using principal components (PCA) and similarity analyses. The sample results of a similarity analysis of the CDFG 1980–1995 survey database of the San Francisco Bay, shown in Figures C-4 and C-5, generally support the AWG's view. The sample plots of PCA scores for the 1989 (below normal outflow) and 1993 (above normal outflow) indicate both a degree of dissimilarity of sampling locations 101, 102, and 140 south of the Hayward-San Mateo Bridge to stations north of the bridge, and a broad similarity among these stations north of the bridge to the Berkeley Marina. Based both on the dissimilarity of the "South Bay" stations and on the similarities among the Central Bay stations, it was agreed that the source water study area should extend from the Hayward-San Mateo Bridge to a line running from the Berkeley Marina to the shoreline at the west end of the Oakland Bay Bridge.

Based on the Central Bay's biological and water quality information along with knowledge of the Bay's general currents and patterns of tidal exchange, the geographical extent of the project's source water was determined, in concurrence with the AWG, to extend from the Oakland Bay Bridge south to the Hayward-San Mateo Bridge. Tenera's initial effort to compute the volume of the source water area (Oakland Bay Bridge south to the end of the Bay) relied on survey findings and computational methods found in a 1966 University of California publication by the Sanitary Engineering Laboratory (SERL). Dr. Smith[1] of the United States Geological Survey (USGS) advised Tenera to use the SERL Report No. 65-10 (Selleck et al. 1966) as the best reference available to determine the dynamic and static volumes of different sections of the San Francisco Bay. In this report the Bay is divided into approximately 30 sections of computed

[1] Richard E. Smith, US Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025 MS-496, Phone: (650) 329-4516, email: resmith@usgs.gov.

volume. By combining appropriate sections, Tenera computed the volume of a source water area defined in the SERL report as Central and South bays. These areas also correspond to the southern half of the area defined as Central Bay by the CDFG in their survey report to the Interagency Ecological Program (IEP) fisheries (Baxter et al. 1999). The Central Bay includes CDFG midwater and otter trawl stations 110, 109 and 142. The preliminary volume for this proposed source water study area was calculated to be 4.9603E $\times 10^{11}$ gallons.

Dr. Smith also advised Tenera at the time that he and his staff at USGS were developing an internet accessible interactive tool[2] that would compute San Francisco Bay volumes based on the most recent USGS bathymetric surveys. He strongly recommended the use of this tool, which had recently become available, in place of the SERL method. The use of this new tool was discussed by the AWG at their August 27, 2001 meeting. Following AWG approval, Tenera re-calculated the initial estimates of source water volume using the USGS San Francisco Bay interactive tool. The revised source water calculations using the USGS volumes replace the earlier SERL calculations in all of Tenera's *ETM* model runs presented in this report. The USGS model results are illustrated in Figure C-6, the original source water area and volume (Oakland Bay Bridge to the end of the Bay), and Figure C-7, the source water area and volume to be subtracted (Hayward-San Mateo Bridge to the end of the Bay). These figures show the areas used in the USGS model calculations, the resulting volumes, and information documenting the model runs. Based on these results, the source water volume that was used in the *ETM* calculations presented in this report is 2.907008×10^9 cubic meters (7.6795×10^{11} gallons).

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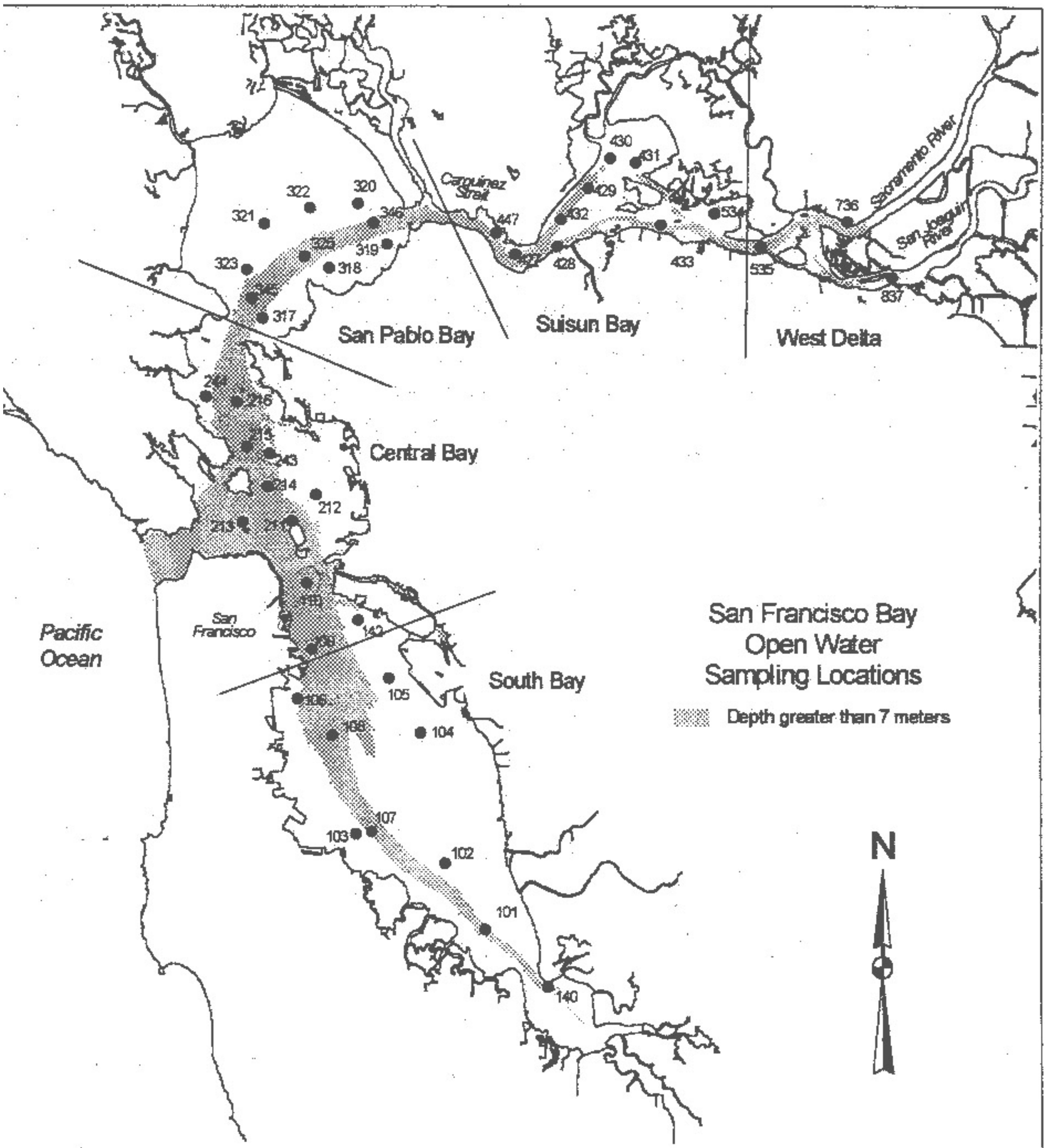
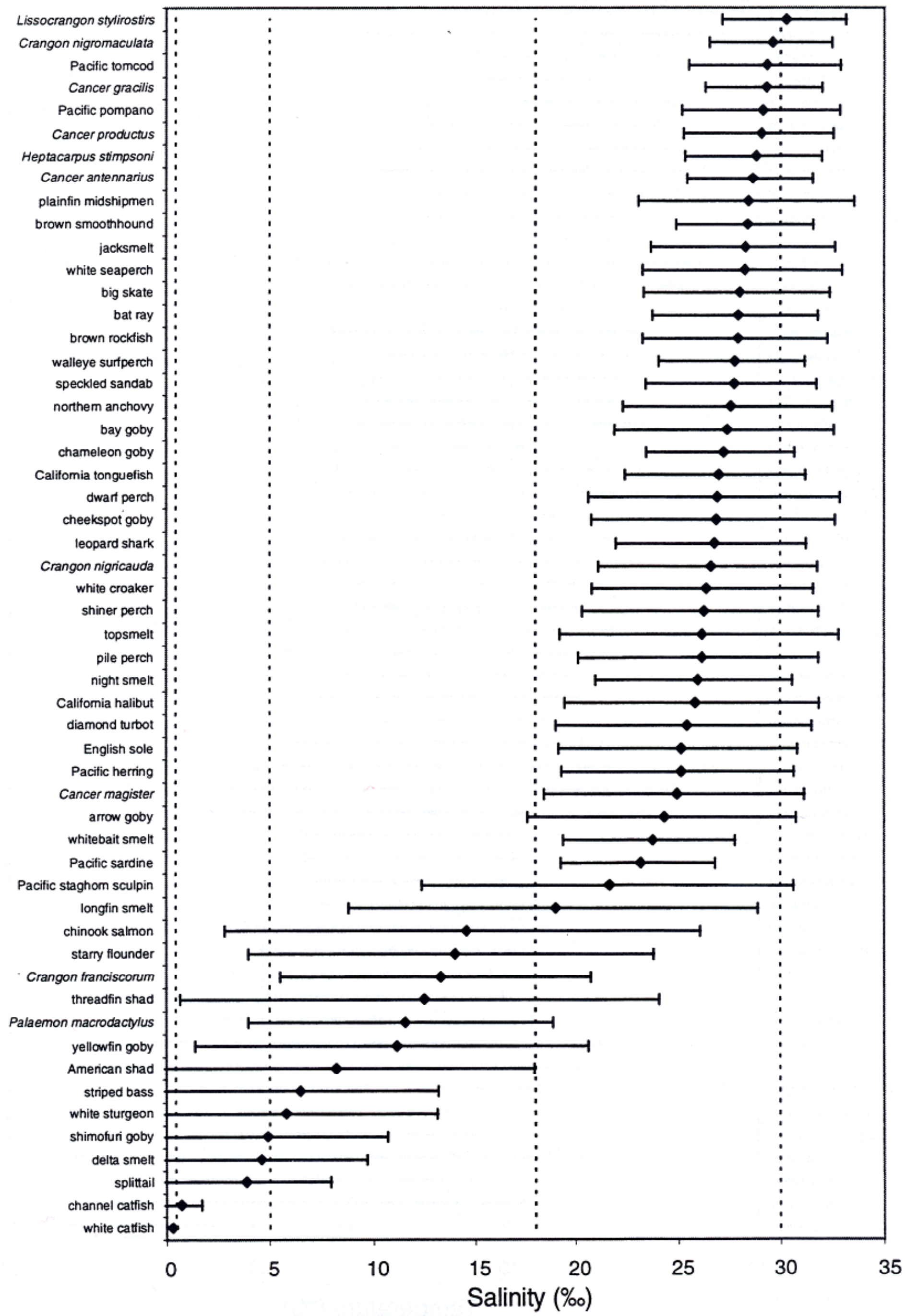
[2] http://sfports.wr.usgs.gov/Bathy/1990s/IWA_SDS_index.html



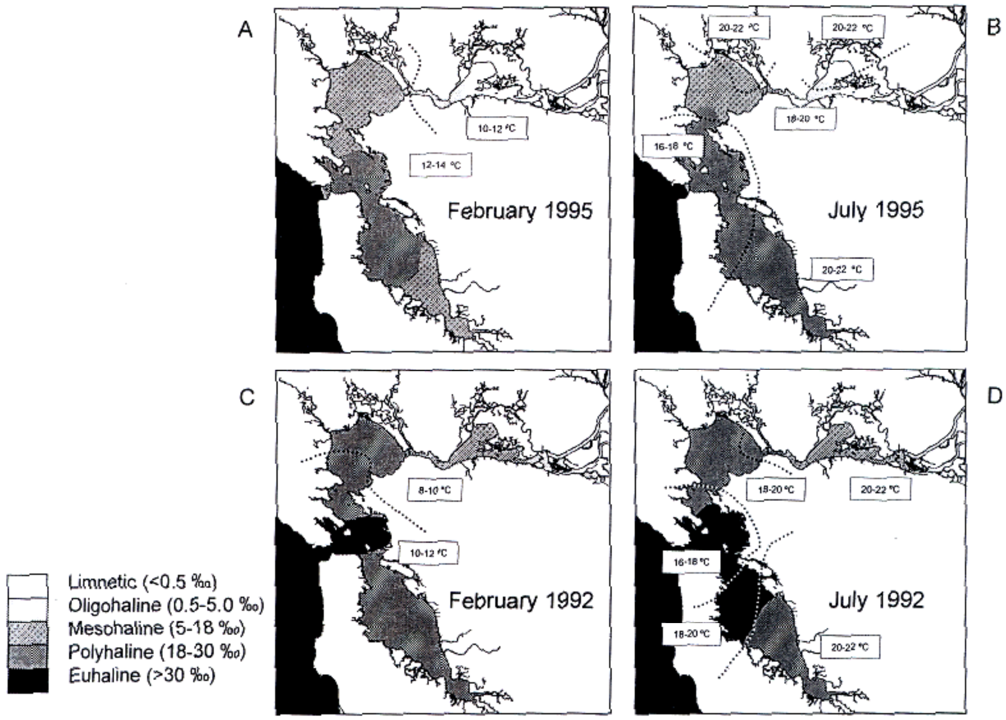
Source: Baxter et al. 1999.

Figure C-1. California Department of Fish and Game San Francisco Bay survey station locations.



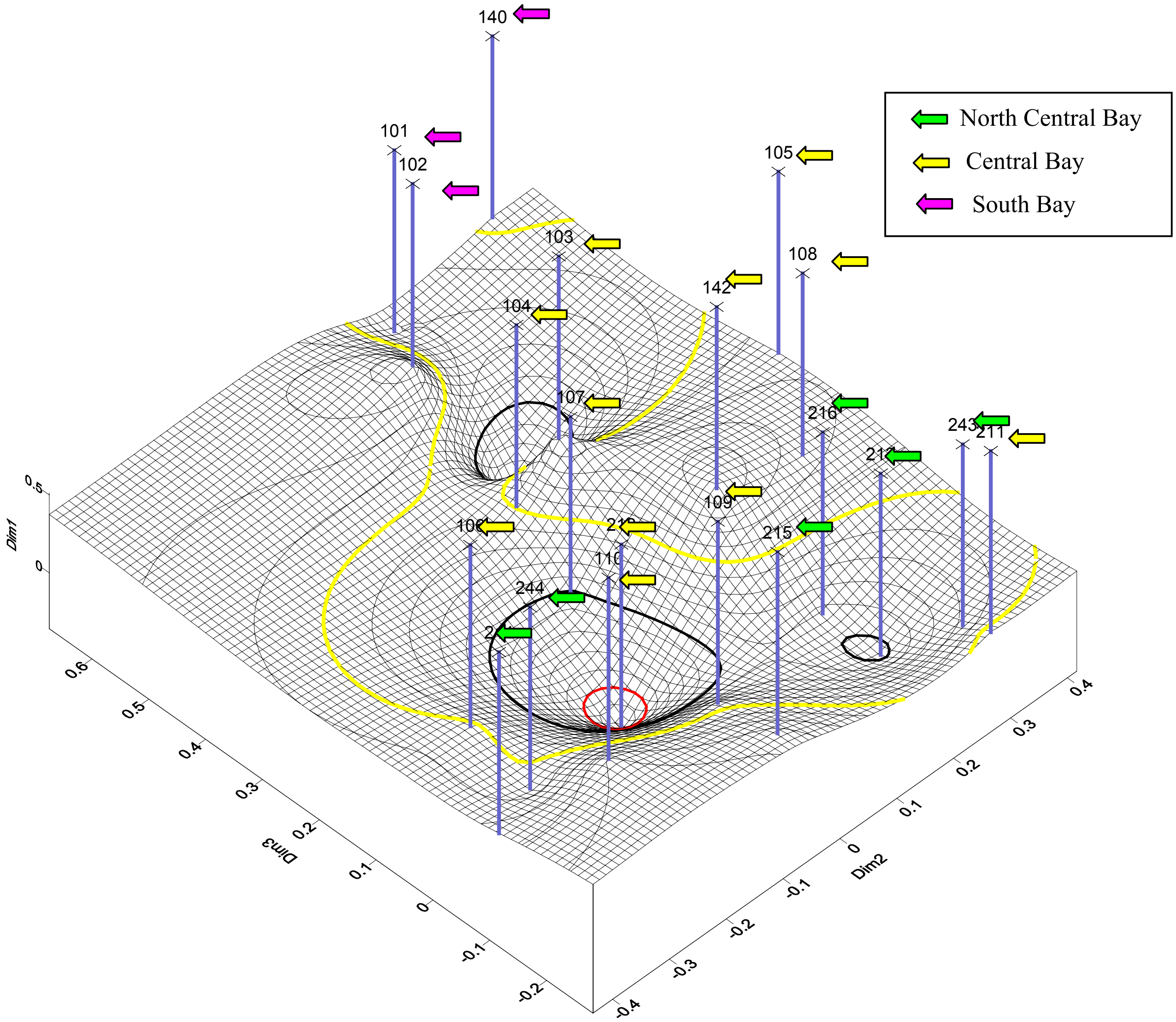
Source: Baxter et al. 1999

Figure C-2. Mean salinity (o/oo) ± standard deviation for the 54 most commonly collected species of fishes, shrimps, and crabs.



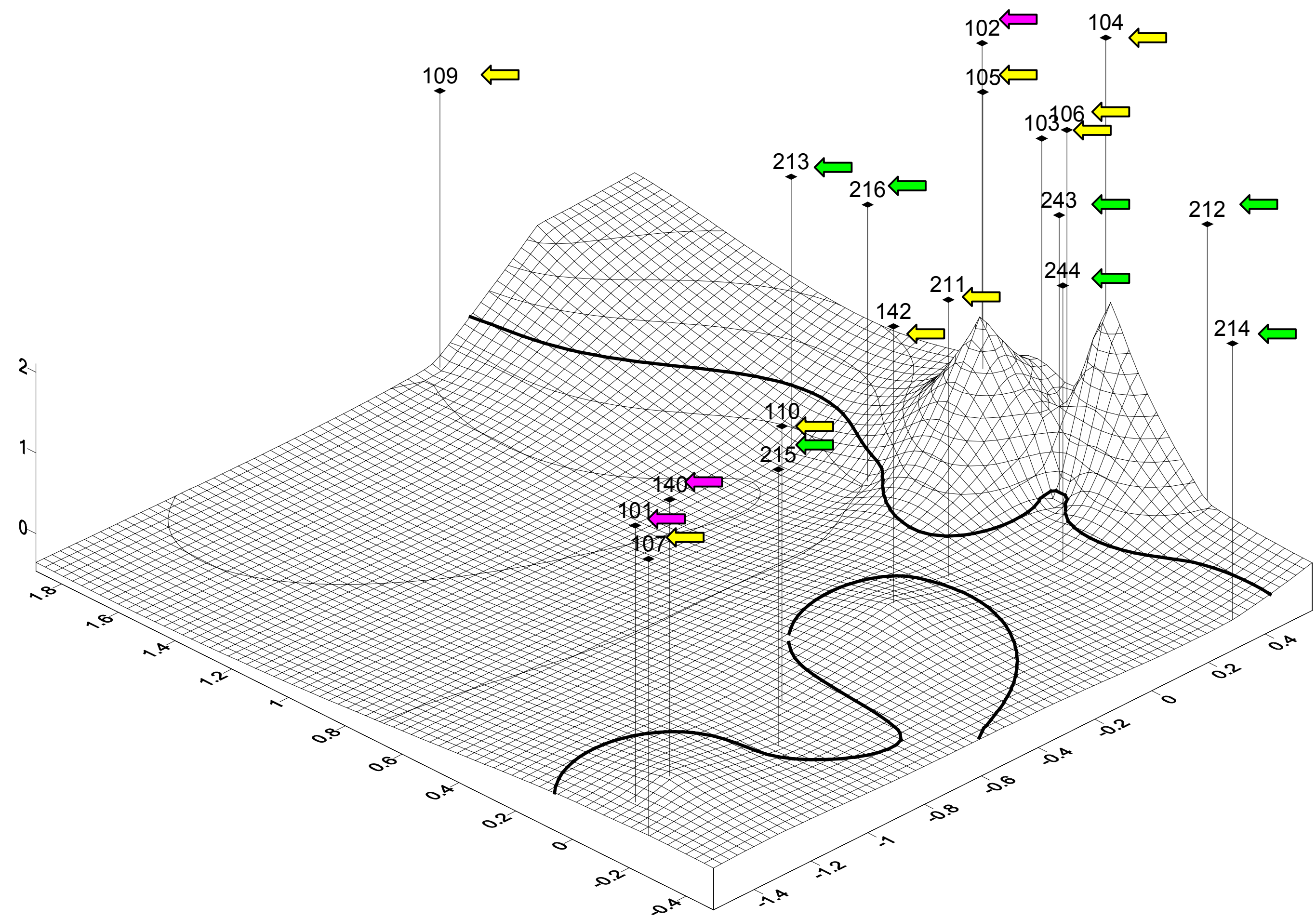
Source: Baxter et al. 1999.

Figure C-3. Isohalines and isotherms for winters and summers of “wet” (1995) and “dry” (1992) years: (A) February 1995, (B) July 1995, (C) February 1992, and (D) July 1992.



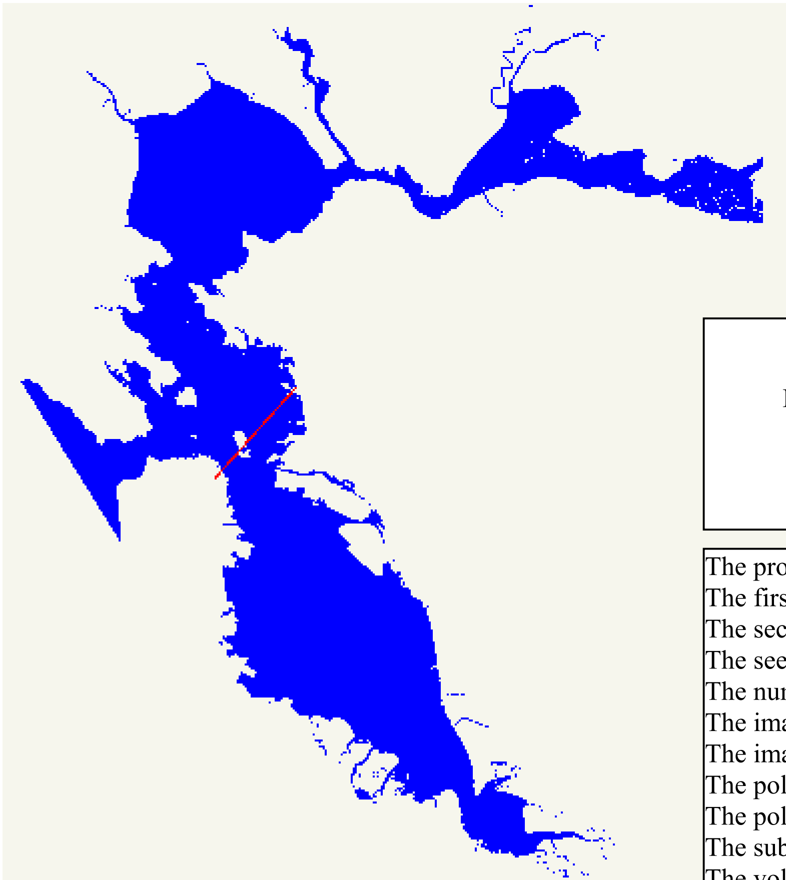
Data Source: CDFG Fish Survey 1980 – 1995 Sampling in the San Francisco Estuary Database for Technical Report 63, November 1999.

Figure C-4. Similarity analysis of species collected in CDFG surveys in 1989.



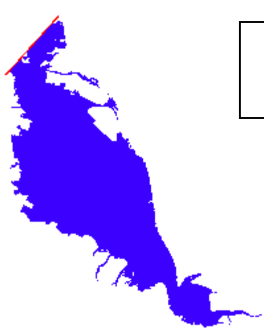
Data Source: CDFG Fish Survey 1980–1995 Sampling in the San Francisco Estuary Database for Technical Report 63, November 1999.

Figure C-5. Similarity analysis of species collected in CDFG surveys in 1993.



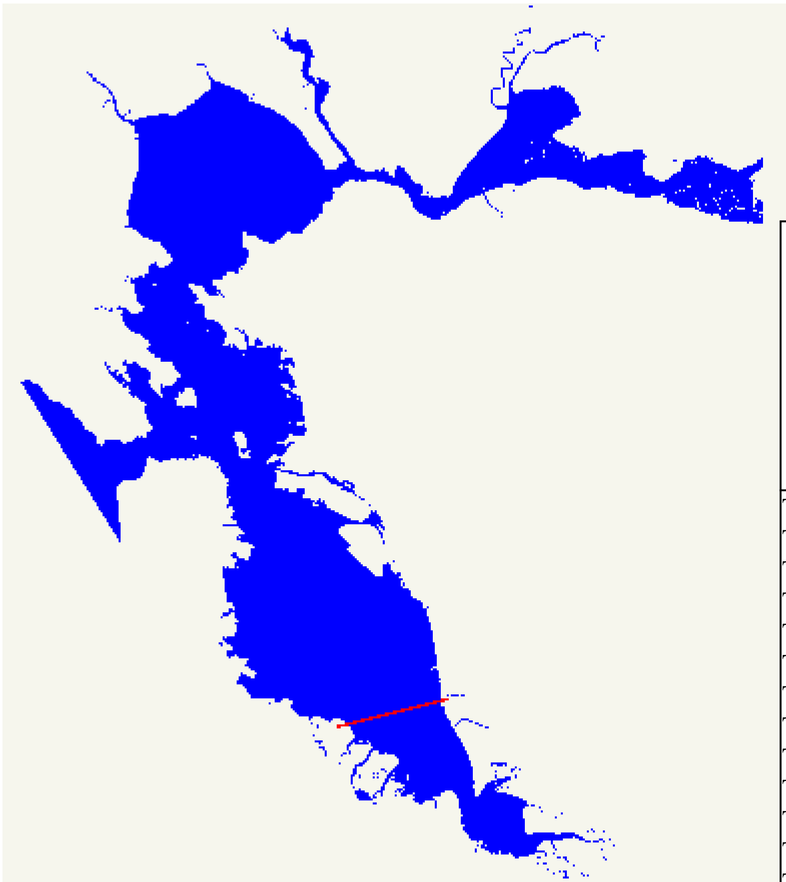
CENTRAL BAY SOURCE WATER
Data set: mhhw1k
Bounded surface area: 0.517270E+09 sq. m.
Total data volume: 0.957007E+10 cu. m.
Barriered volume: 0.340159E+10 cu. m.
(Or: 0.35544 of total volume.)

The process ID is: 35367
The first line point is: (214, 474)
The second line point is: (294, 385)
The seed point is: (298, 562)
The number of polygon sides is: 1
The image width is: 789
The image height is: 882
The polygon x-coordinates are: 69
The polygon y-coordinates are: 361
The submit class is: Line Tool
The volume control logic is: TRUE
The axis control logic is: REL
The text control logic is: FALSE
The bathy file is: mhhw1k
The upper bound is: 0
The lower bound is: 0
Reference USGS Interactive Tool,
http:/sfports.wr.usgs.gov



Barriered Area

Figure C-6. Central Bay volume.



SOUTH BAY VOLUME
\Data set: mhhw1k
Bounded surface area: 0.120480E+09 sq. m.
Total data volume: 0.957007E+10 cu. m.
Barriered volume: 0.494582E+09 cu. m.
(Or: 0.05168 of total volume.)

The process ID is: 34808
The first line point is: (336, 722)
The second line point is: (445, 695)
The seed point is: (417, 725)
The number of polygon sides is: 1
The image width is: 789
The image height is: 882
The polygon x-coordinates are: 69
The polygon y-coordinates are: 359
The submit class is: Line Tool
The volume control logic is: TRUE
The axis control logic is: REL
The text control logic is: FALSE
The bathy file is: mhhw1k
The upper bound is: 0
The lower bound is: 0
SOURCE: USGS Interactive Tool,
http:/sfports.wr.usgs.gov

Shadow of Barriered Volume

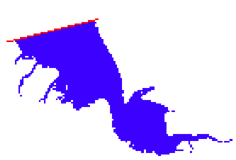


Figure C-7. South Bay volume.

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Appendix D

Identification of Larval Rockfish

APPENDIX D

IDENTIFICATION OF LARVAL ROCKFISH

Many rockfish species are closely related, and the larvae share many morphological and meristic characteristics, making it difficult to visually identify them to species (Moser et al. 1977, Moser and Ahlstrom 1978, Baruskov 1981, Kendall and Lenarz 1987, Moreno 1993, Nishimoto in prep.). Identification of larval rockfish to the species level relies heavily on pigment patterns that change as the larvae develop (Moser 1996). Of the 59 *Sebastes* spp. known from California marine waters (Lea et al. 1999), at least five can be reliably identified to the species level as larvae (Laidig et al. 1995, Yoklavich et al. 1996): blue rockfish *Sebastes mystinus*, shortbelly rockfish *S. jordani*, cowcod *S. levis*, bocaccio *S. paucispinis*, and stripetail rockfish *S. saxicola*. Other species within this genus can only be resolved to broad sub-generic groupings based on pigment patterns; these larvae were grouped using information provided by Nishimoto (in preparation) (Table D-1).

Table D-1. Preflexion larval rockfish pigment groups from Nishimoto (in preparation).

The code for each group is based on the following letter designations:	
V_ = long series of ventral pigmentation (starts directly at anus)	De = elongating series of dorsal pigmentation; scattered melanophores after continuous ones stop)
V = short series of ventral pigmentation (starts 3-6 myomeres after anus)	d = develops dorsal pigmentation (1-2 or scattered melanophores)
D_ = long series of dorsal pigmentation (4 or more in a continuous line) extending to above anus	P = pectoral blade pigmentation
D = short series of dorsal pigmentation (4 or more in a continuous line) not extending to anus	p = develops pectoral pigmentation (1-2 or scattered melanophores)

LETTER CODE	SPECIES	COMMON NAME
V_P	**Long ventral series, no dorsal, pectoral pigment**	
	S. chlorostictus	greenspotted
	S. ensifer	swordspine
V_D	**Long ventral series, short dorsal series, no pectoral pigment**	
	S. saxicola	stripetail
V_D_	**Long ventral series, long dorsal series, no pectoral pigment**	
	S. atrovirens	kelp
	S. chrysomelas	black and yellow
	S. maliger	quillback
	S. nebulosus	China
	S. semicinctus	halfbanded
V_De or **V_DeP** or **V_dep**	**Long ventral series, elongating dorsal series, pectoral pigment**	
	S. auriculatus	brown
	S. carnatus	gopher
	S. caurinus	copper
	S. dalli	calico
	S. rastrelliger	grass
V	**Short ventral series, no dorsal series, no pectoral pigment**	
	S. aleutianus	rougheye
	S. alutus	Pacific ocean perch
	S. brevispinis	silvergrey
	S. crameri	darkblotched
	S. diploproa	splitnose
	S. elongatus	greenstriped
	S. macdonaldi	Mexican
	S. miniatus	vermilion
	S. nigrocinctus	tiger
	S. proriger	redstripe
	S. rosaceus	rosy
	S. ruberrimus	yelloweye
	S. serriceps	treefish
	S. umbrosus	honeycomb
	S. wilsoni	pygmy
	S. zacentrus	sharpchin
VP	**Short ventral series, no dorsal series, various patterns of pectoral pigmentation**	
	S. constellatus	starry
	S. eos	pink
	S. goodei	chilipepper
	S. helvomaculatus	rosethorn
	S. levis	cowcod
	S. melanostomus	blackgill
	S. paucispinis	bocaccio
	S. rosenblatti	greenblotched
	S. rubrivinctus	flag
Vdp	**Short ventral series, develops dorsal series, develops various patterns of pectoral pigmentation** (at younger stages can be confused with V above due to lack of dorsal and pectoral pigmentation)	
	S. entomelas	widow
	S. flavidus	yellowtail
	S. melanops	black
	S. mystinus	blue
	S. rufus	bank
	S. serranoides	olive
VD	**Short dorsal series, short dorsal series**	
	S. aurora	aurora
	S. babcocki	redbanded
	S. gilli	bronzespotted
	S. hopkinsi	squarespot
	S. jordani	shortbelly
	S. ovalis	speckled
	S. pinniger	canary
Species without descriptions or illustrations		
	S. philipsi	chameleon

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Appendix E

Model Parameterization

Appendix E1
Estimating Total Entrainment

A general form can be written for summing entrainment over stations at an intake or entrainment site using cycles within a day and days within time periods. Let

i = period $(i = 1, \ldots, N)$;

j = day within period $(j = 1, \ldots, N_i)$;

k = cycle within day $(k = 1, \ldots, N_{ij})$;

l = station $(l = 1, \ldots, N_{ijk})$;

m = volume at station within cycle $(m = 1, \ldots, N_{ijkl})$.

The total larval entrainment at an intake source can be expressed as

$$E_T = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \rho_{ijkl} V_{ijkl} \tag{A1}$$

where

ρ_{ijkl} = density of larvae at the *l*th station within the *k*th cycle on the *j*th day in the *i*th time period;

V_{ijkl} = volume of water passing the at the *l*th station within the *k*th cycle on the *j*th day in the *i*th time period.

This summation assumes that stations represent the total intake volume of the power plant. It also assumes that the larval density in the volume of water passing a station is constant over time and space over any cycle. An estimate of the total larval entrainment can be made by taking n_{ijkl} samples of the N_{ijkl} volumes passing a station as

$$\hat{E}_T = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \frac{V_{ijkl}}{n_{ijkl}} \sum_{m=1}^{n_{ijkl}} \rho_{ijklm} \tag{A2}$$

If we also assume that entrainment volume is constant and the same at all stations then

$$\hat{E}_T = \sum_{i=1}^{N} V_{ijkl} \sum_{j=1}^{N_i} \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \frac{1}{n_{ijkl}} \sum_{m=1}^{n_{ijkl}} \rho_{ijklm} \tag{A3}$$

Strata will be defined as the stations and cycles with constant N_{ij} and N_{ijk}. In addition, we sample n_i days of the N_i possible during a period so that

$$\begin{aligned} \hat{E}_T &= \sum_{i=1}^{N} N_i N_{ij} N_{ijk} V_{ijkl} \frac{1}{n_i} \sum_{j=1}^{n_i} \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \left(\frac{1}{N_{ij} N_{ijk} n_{ijkl}} \right) \sum_{m=1}^{n_{ijkl}} \rho_{ijklm} \\ &= \sum_{i=1}^{N} V_i \frac{1}{n_i} \sum_{j=1}^{n_i} \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \left(\frac{1}{N_{ij} N_{ijk} n_{ijkl}} \right) \sum_{m=1}^{n_{ijkl}} \rho_{ijklm} \end{aligned} \tag{A4}$$

where

$$V_i = \sum_{j=1}^{N_i} \sum_{l=1}^{N_{ij}} \sum_{k=1}^{N_{ijk}} V_{ijkl}$$

If only one day per period is sampled Equation A4 can be expressed as

$$\begin{aligned} \hat{E}_T &= \sum_{i=1}^{N} V_i \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \left(\frac{1}{N_{ij} N_{ijk} n_{ijkl}} \right) \sum_{m=1}^{n_{ijkl}} \rho_{ijklm} \\ &= \sum_{i=1}^{N} V_i \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \left(\frac{1}{N_{ij} N_{ijk}} \right) \hat{\rho}_{ijkl} \end{aligned} \tag{A5}$$

with estimated variance

$$\widehat{Var}\left(\hat{E}_T\right) = \sum_{i=1}^{N} V_i^2 \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ijk}} \left(\frac{1}{N_{ij} N_{ijk}} \right)^2 \left(1 - \frac{n_{ijkl}}{N_{ijkl}} \right) \frac{\widehat{Var}\left(\rho_{ijkl}\right)}{n_{ijkl}} \tag{A6}$$

where

$$\hat{Var}\left(\rho_{ijkl}\right)=\frac{\sum_{m=1}^{n_{ijkl}}\left(\rho_{ijklm}-\bar{\rho}_{ijkl}\right)^{2}}{\left(n_{ijkl}-1\right)};$$

$$\bar{\rho}_{ijkl}=\frac{\sum_{m=1}^{n_{ijkl}}\rho_{ijklm}}{n_{ijkl}}.$$

Estimates of E_T based on Equation A5 will be used in *FH* and *AEL* calculations to estimate annual effects of entrainment on fish stocks. Equation A6 will underestimate the true variance because it does not include within-period variance. In practice, we ignore the finite population correction, $\left(1-\frac{n_{ijkl}}{N_{ijkl}}\right)$ because N_{ijkl} is large. Estimators similar to Equation A5 and Equation A6 are used for calculating survey period estimates of intake and source populations for use in *ETM* calculations.

Appendix E2
Estimating Proportional Entrainment
and the *ETM* Calculations

The Empirical Transport Model (*ETM*) is used to estimate the total mortality probability for larvae from power plant entrainment. The estimate is based on periodic estimates of the probability of entrainment mortality based on daily samples. In the following calculations we assume all larvae entrained die. Generally, sampling takes place over the course of a year so that larval mortality of various species is estimated.

The daily probability of entrainment can be defined as

$$PE_i = \frac{\text{abundance of entrained larvae}_{\text{i}}}{\text{abundance of larvae in source population}_{\text{i}}}$$
$$= \text{probability of entrainment in } i\text{th time period } \left(i = 1,\ldots,N\right).$$

In turn, the daily probability can be estimated and expressed as

$$PE_i = \frac{\hat{E}_i}{\hat{R}_i} \qquad \text{(B1)}$$

where

$\hat{E}_i$ = estimated abundance of larvae entrained in the ith time period $\left(i = 1,\ldots,N\right)$;

$\hat{R}_i$ = estimated abundance of larvae at risk of entrainment from the source population in the ith time period $\left(i = 1,\ldots,N\right)$.

Estimating Daily Entrainment

The estimate of total Potrero Power Plant entrainment on day j in period i can be expressed from equation (A4) as

$$\hat{E}_{ij} = \sum_{k=1}^{6}\sum_{l=1}^{2} V_{ijkl}\,\frac{1}{2}\sum_{m=1}^{2}\rho_{ijklm} \qquad \text{(B2)}$$
$$= V_{ij}\sum_{k=1}^{6}\sum_{l=1}^{2}\left(\frac{1}{24}\right)\sum_{m=1}^{2}\rho_{ijklm}$$

with associated variance

$$Var\left(\hat{E}_{ij}\middle|E_{ij}\right) = V_{ij}^{\,2}\sum_{k=1}^{6}\sum_{l=1}^{2}\left(\frac{1}{24}\right)^2\left(1-\frac{2}{N_{ijkl}}\right)S^2_{\rho_{ijkl}} \qquad \text{(B3)}$$

which can be estimated by

$$\hat{V}ar\left(\hat{E}_{ij}\right) = V_{ij}^{\,2}\sum_{k=1}^{6}\sum_{l=1}^{2}\left(\frac{1}{24}\right)^2\left(1-\frac{2}{N_{ijkl}}\right)s^2_{\rho_{ijkl}}\ . \qquad \text{(B4)}$$

The finite population correction [i.e., $\left(1-\frac{2}{N_{ijk}}\right)$] can be ignored because N_{ijkl} is exceedingly large. Only one day is sampled per period. The period estimated entrainment and variance are

$$\hat{E}_{i} = V_{i}\sum_{k=1}^{6}\sum_{l=1}^{2}\left(\frac{1}{24}\right)\sum_{m=1}^{2}\rho_{ijklm} \qquad \text{(B5)}$$

$$\hat{V}ar\left(\hat{E}_{i}\right) = V_{i}^{2}\sum_{k=1}^{6}\sum_{l=1}^{2}\left(\frac{1}{24}\right)^2 s^2_{\rho_{ijkl}}\ . \qquad \text{(B6)}$$

Estimating Numbers of Larvae at Risk

With the defined and agreed-upon sources of central San Francisco Bay (S) larvae (source water study area larvae), the daily abundance of larvae at risk can be estimated by

$$\hat{R}_{ij} = V_S \cdot \hat{\rho}_{S_{ij}} \qquad \text{(B7)}$$

where V_S denotes daily exchanged and static volumes at central San Francisco Bay (S), and $\hat{\rho}$ denotes an estimate of average density in each respective source water bodies. The variance of Expression B7 can be written as

$$Var\left(\hat{R}_{ij} \mid R_{ij}\right) = V_S^2 \cdot Var\left(\hat{\bar{\rho}}_{S_{ij}} \mid \bar{\rho}_{S_{ij}}\right) \tag{B8}$$

The individual variances within Formula B8 describe temporal-spatial variance in density within the source population during the day of sampling. Seven source water locations are sampled in central San Francisco Bay. Ideally, tow samples would be collected randomly through time and space during a sampling day over a potential source population. However, practical limitations due to sampling a large area required a directed and fixed time and location sampling scheme. Our source water estimates of population and variance are made for each period using only one day, i.e. $\hat{R}_i = \hat{R}_{ij}$ and $\hat{V}ar\left(\hat{R}_i\right) = Var\left(\hat{R}_{ij} \mid R_{ij}\right)$.

Period Entrainment and *ETM* Calculations

By dividing estimated period entrainment (B5) by the corresponding source population (B7) an estimate of entrainment mortality can be written as

$$\hat{P}E_i = \frac{\hat{E}_i}{\hat{R}_i} \tag{B9}$$

Variance for the Estimate of PE_i

The variance for the period estimate of $\hat{P}E_i$ can be expressed as

$$Var\left(\hat{P}E_i \middle| PE_i\right) = Var\left(\frac{\hat{E}_i}{\hat{R}_{ij}} \middle| E_i, R_i\right).$$

Assuming zero covariance between the entrainment and source and using the delta method (Seber 1982), the variance of an estimator formed from a quotient (like $\hat{P}E_i$) can be effectively approximated by

$$Var\left(\frac{A}{B}\right) \approx Var(A)\left(\frac{\partial\left[\frac{A}{B}\right]}{\partial A}\right)^2 + Var(B)\left(\frac{\partial\left[\frac{A}{B}\right]}{\partial B}\right)^2.$$

The delta method approximation of $Var(\hat{PE}_i)$ is shown as

$$Var\left(\hat{PE}_i\right) = Var\left(\frac{\hat{E}_i}{V_S \cdot \hat{\bar{\rho}}_{S_i}}\right)$$

which by the Delta method can be approximated by

$$\hat{Var}\left(\hat{PE}_i\right) \approx \hat{Var}\left(\hat{E}_i\right)\left(\frac{1}{V_S \cdot \hat{\bar{\rho}}_{S_i}}\right)^2 + \hat{Var}\left(V_S \cdot \bar{\rho}_{S_i}\right)\left(\frac{-\hat{E}_i}{V_S \cdot \left(\hat{\bar{\rho}}_{S_i}\right)^2}\right)^2 \tag{B10}$$

and is equivalent to

$$= PE_i^2\left[CV\left(\hat{E}_i\right)^2 + CV\left(V_S \cdot \hat{\bar{\rho}}_{S_i}\right)^2\right]$$

where

$$\hat{R}_i = V_S \cdot \hat{\bar{\rho}}_{S_{ij}} \quad \text{and}$$

$$CV\left(\hat{\theta}\middle|\theta\right) = \frac{\hat{Var}\left(\hat{\theta}\middle|\theta\right)}{\hat{\theta}^2}.$$

Regardless of whether the species has a single spawning period per year or multiple overlapping spawnings the estimate of total larval entrainment mortality can be expressed by

$$\hat{P}_M = 1 - \sum_{i=1}^{N} \hat{f}_i\left(1 - \hat{PE}_i\right)^q \tag{B11}$$

where

q = number of days of larval life, and

$\hat{f}_i$ = estimated annual fraction of total larvae hatched during the *i*th survey period.

Formula (B11) is based on the total probability law where

$$P\left(A\right) = \sum_{i=1}^{N} P\left(A\middle|B_i\right) \cdot P\left(B_i\right).$$

In the above example, the event A is larval survival and event B is hatching with $P(B)$ estimated by $\hat{f}_i$ where

$$\hat{f}_i = \frac{\hat{E}_i}{\hat{E}_T},$$

where $\hat{E}_i$ = estimated entrainment for the *i*th survey period. Then based on the Delta method

$$\begin{aligned}
\hat{V}ar(\hat{f}_i) &= \hat{V}ar\left[\frac{\hat{E}_i}{\hat{E}_T}\right] \\
&= \hat{V}ar\left[\frac{\hat{E}_i}{\hat{E}_i + \sum_{j\neq i}^{N} \hat{E}_j}\right] \\
&= \hat{f}_i^{\,2}(1-\hat{f}_i)^2\left[\frac{\hat{V}ar(\hat{E}_i)}{\hat{E}_i^{\,2}} + \frac{\hat{V}ar(\hat{E}_T)}{\hat{E}_T^{\,2}}\right].
\end{aligned}$$

The estimates of PE_i and f_i and their respective variance estimates can be combined in an estimate of the variance for $\hat{P}_M$ following the Delta method (Seber 1982) for variance and covariance as follows:

$$\begin{aligned}
\hat{V}ar(\hat{P}_M) &= \hat{V}ar\left(1 - \sum_{i=1}^{N} \hat{f}_i(1-\hat{P}E_i)^q\right) \\
&= \hat{V}ar\left(\sum_{i=1}^{N} \hat{f}_i(1-\hat{P}E_i)^q\right) \\
&= \sum_{i=1}^{N}\left[Var(\hat{f}_i)(1-\hat{P}E_i)^{2q}\right] \\
&\quad + \sum_{i=1}^{N}\left[Var(\hat{P}E_i)(\hat{f}_i q(1-\hat{P}E_i)^{q-1})^2\right] \\
&\quad + 2\sum_{i=1}^{N}\sum_{j>i}^{N}\operatorname{cov}\left(\hat{f}_i,\hat{f}_j\right)(1-\hat{P}E_j)^q(1-\hat{P}E_i)^q \qquad \text{where}
\end{aligned}$$

$$\operatorname{cov}\left(\hat{f}_i,\hat{f}_j\right) = \left(\frac{1}{\hat{E}_T}\right)^2\left[\hat{f}_i\hat{f}_j Var\left(\sum_{g\neq i,j}^{N}\hat{E}_g\right) + \hat{f}_i\left(1-\hat{f}_j\right)\hat{E}_i + \hat{f}_j\left(1-\hat{f}_i\right)\hat{E}_j\right].$$

Appendix E3
Demographic Model Calculations

Fecundity Hindcasting (FH)

The estimated total larval entrainment for a species ($\hat{E}_T$) was used to estimate the number of breeding females needed to produce the number of larvae entrained. The estimated number of breeding females ($\widehat{FH}$) whose fecundity was equal to the estimated total loss of entrained larvae is calculated as follows:

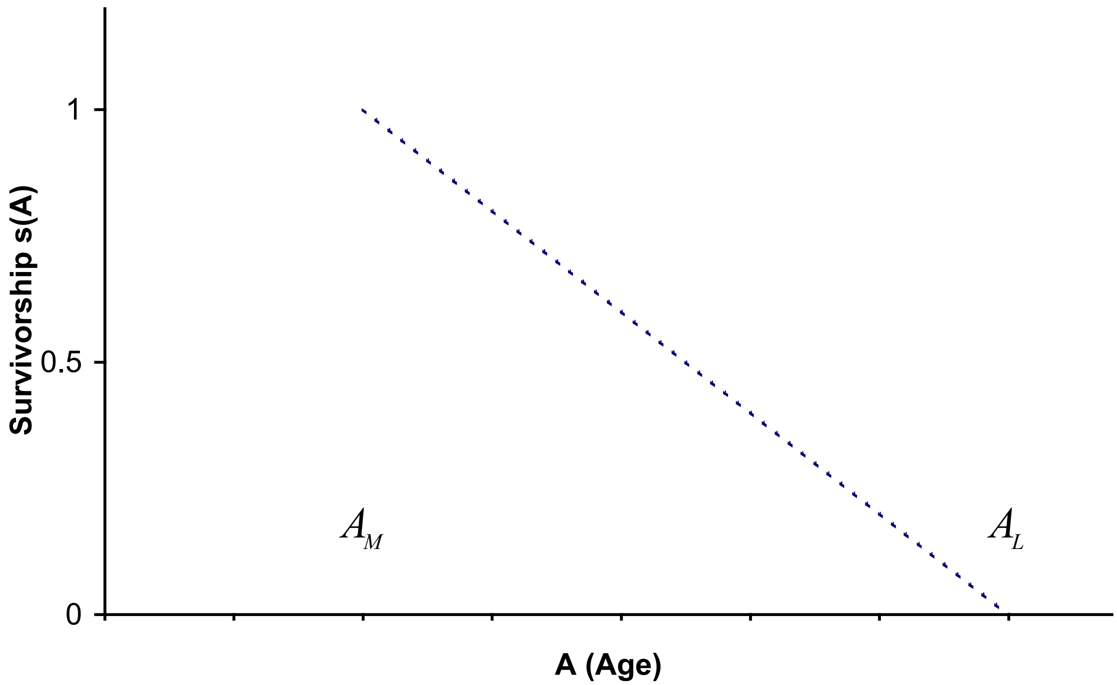
$$\widehat{FH} = \frac{\hat{E}_T}{\widehat{TLF} \cdot \prod_{i=1}^{n} S_i} \tag{C1}$$

where

n = number of larval stages vulnerable to entrainment,
$\hat{E}_T$ = estimated total entrainment,
S_i = survival rate from eggs to larvae of the ith stage, and
$\widehat{TLF}$ = estimated total life time fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

Equation C1 is based on the simplified case of a single synchronized spawning by a species. For species with overlapping or continuous spawning, larval abundance would have to be specified by week and age class (i.e., $\hat{E}_{ij}$). However, we used the mean size of all larvae entrained to estimate a representative age of larvae, and then estimated a survival rate to this representative age. Two input parameters in Equation C1 that may not be available for many species, and thus may limit the method, are lifetime fecundity (TLF) and survival rates (S_i) from spawning to entrainment.

In practice, survival was estimated by either one or several age classes, depending on the data source, to the estimated age at entrainment. The expected total lifetime fecundity $E(TLF)$ was approximated by modeling a linear survivorship for a female once she reached the age of maturity, and using a constant number of eggs produced per year.



The number of eggs produced per year was approximated as the average number of eggs per year. Thus

$$
\begin{aligned}
TLF &= \int_{A_M}^{A_L} F(A)s(A)\,dA \\
&= \overline{F}\int_{A_M}^{A_L} \frac{A_L - A}{A_L - A_M}\,dA \\
&= \overline{F}\left(\frac{A_L - A_M}{2}\right)
\end{aligned}
$$

where

$s(A)$ = survivorship of a female;

$F(A)$ = eggs produced;

A_M = age of maturity; and

A_L = age at death.

In other words,

$$
\begin{aligned}
\widehat{TLF} &= \text{Estimated Total Lifetime Fecundity} \\
&= \text{Average eggs/year} \cdot \text{Average number of years of reproductive life} \\
&= \text{Average eggs/year} \cdot \left(\frac{\text{Longevity - Age at maturation}}{2} \right).
\end{aligned}
\tag{C2}
$$

The expected length of reproductive life was approximated as the midpoint between the times of maturation and longevity. The approximation of linear survivorship between these events implies uniform survival. For exploited species such as northern anchovy and sardine, the expected number of years of reproductive life may be much less than predicted using this assumption.

Simulation, comparing exponential survival, shows that the calculation of $\widehat{TLF}$ will be negatively biased for species with short reproductive lifespans, and positively biased for those with longer durations.

The variance of $\widehat{FH}$ was approximated by the Delta method (Appendix E2) (Seber 1982):

$$
\widehat{Var}(\widehat{FH}) = (\widehat{FH})^2 \left[CV^2(\hat{E}_T) + \sum_{j=1}^{n} CV^2(\hat{S}_j) + CV^2(\hat{\bar{F}}) + \left(\frac{\widehat{Var}(A_L) + \widehat{Var}(A_M)}{(A_L - A_m)^2} \right) \right]
$$

where

$CV(\hat{E}_T)$ = CV of estimated entrainment (estimated by CV($\hat{\hat{\mathrm{I}}}$) when available),
$CV(\hat{S}_j)$ = CV of estimated survival of eggs and larvae up to entrainment,
$CV(\hat{\bar{F}})$ = CV of estimated average annual fecundity,
A_M = age at maturation, and
A_L = age at maturity.

The behavior of the estimator for FH appears log-linear, suggesting that an approximate confidence interval can be based on the assumptions that ln($\widehat{FH}$) is normally distributed and uses the pivotal quantity

$$
Z = \frac{\ln \widehat{FH} - \ln FH}{\sqrt{\dfrac{\widehat{Var}(\widehat{FH})}{\widehat{FH}^2}}}.
$$

A 90% confidence interval for *FH* was estimated by solving for *FH* and setting Z equal to

+/-1.645, i.e.

$$\hat{FH} \cdot e^{-1.645\sqrt{\frac{\hat{Var}(\hat{FH})}{\hat{FH}^2}}} \quad \text{to} \quad \hat{FH} \cdot e^{+1.645\sqrt{\frac{\hat{Var}(\hat{FH})}{\hat{FH}^2}}}.$$

Adult Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of entrained or impinged organisms to forecast the loss of equivalent numbers of adults. Starting with the number of age class *j* larvae entrained ($\hat{E}_j$), it is conceptually easy to convert these numbers to an equivalent number of adults lost ($\hat{AEL}$) at some specified age class from the formula:

$$\hat{AEL} = \sum_{j=1}^{n} \hat{E}_j \hat{S}_j \qquad \text{(C3)}$$

where

$n =$ number of age classes,
$\hat{E}_j =$ estimated number of larvae lost in age class j, and
$\hat{S}_j =$ survival rate for the jth age class to adulthood (Goodyear 1978).

Age-specific survival rates from larval stage to recruitment into the fishery (through juvenile and early adult stages) must be included in this assessment method. For some commercial species, survival rates are known for adults in the fishery; but for most species, age-specific larval survivorship has not been well described.

When age-specific survival rates from larval stage to recruitment into the fishery were available, *AEL* was calculated using survival from the average age of the entrained larvae. This age was calculated by dividing the average larval length at entrainment (minus hatch length) by a literature-based growth rate. Age-specific survivorship for any interval of time (t) was then calculated following the formula (Ricker 1975)

$$\frac{N_t}{N_0} = e^{-Zt}$$

where

$N_t =$ number of animals in the population at time t,
$N_0 =$ number of animals in the population at time $t = 0$,
$\frac{N_t}{N_0} = S$ (finite survivorship to time t),
$e = 2.71828...$(base of the natural log), and
$Z =$ instantaneous mortality rate.

Survivorship to recruitment, to an adult age, was apportioned into several age stages, and AEL was calculated using the total entrainment as

$$\hat{AEL} = \hat{E}_T \prod_{j=1}^{n} \hat{S}_j \tag{C4}$$

where

$n =$ number of age classes from entrainment to recruitment and
$\hat{S}_j =$ survival rate from the beginning to end of the jth age class.

The variance of $\hat{AEL}$ can be estimated using a Taylor series approximation (Delta method of Seber 1982) as

$$\hat{Var}(\hat{AEL}) = \hat{AEL}^2 \left(CV^2(\hat{E}_T) + \sum_{j=1}^{n} CV^2(\hat{S}_j) \right). \tag{C5}$$

An alternative analysis would be to compare $\hat{AEL}$ with the size of the adult population of interest or with fishery harvest data. This method converts numbers of adult losses into fractional loss of the population of interest (e.g., stock assessment). However, information describing adult stocks is limited for many species, and independent field estimates of survival from time of entrainment to adulthood are not available for some species. For some species where such information is unavailable, we can estimate this parameter by assuming a stationary population where an adult female must produce two adults (i.e., one male and one female). Overall survival (S_T) can then be estimated from total lifetime fecundity (TLF) by the quantity

$$\hat{S}_T = \frac{2}{\hat{TLF}} = \hat{S}_{egg} \cdot \hat{S}_{larvae} \cdot \hat{S}_{adult},$$

which leads to

$$\hat{S}_{adult} = \frac{2}{\widehat{TLF} \cdot \hat{S}_{egg} \cdot \hat{S}_{larvae}}. \qquad \text{(C6)}$$

Substituting Equation 11 into the overall form of the *AEL* equation where

$$\widehat{AEL} = \hat{E}_T \cdot \hat{S}_{adult} \qquad \text{(C7)}$$

yields

$$\widehat{AEL} = \frac{2(\hat{E}_T)}{\hat{S}_{egg} \cdot \hat{S}_{larva} \cdot \widehat{TLF}}$$

where

$$\widehat{AEL} \equiv 2\widehat{FH}\ . \qquad \text{(C8)}$$

Without independent adult survival rates and assuming a 50:50 sex ratio, $\widehat{AEL}$ and $\widehat{FH}$ are deterministically related according to Equation 13, with an associated standard error of $\widehat{SE}(\widehat{AEL}) = 2\widehat{SE}(\widehat{FH})$. Equation 13 should be aligned so that the average female age is also the age of recruitment used in computing $\widehat{AEL}$. This alignment is accomplished by solving the simple exponential survival equation (Ricker 1975)

$$N_t = N_0 \cdot e^{-Z(t-t_0)}$$

by substituting numbers of either equivalent adults or hindcast females, their associated ages, and mortality rates into the equation where,

$N_t =$ number of adults at time t,
$N_0 =$ number of adults at time t_0,
$Z =$ instantaneous rate of natural mortality, and
$t =$ age of hindcast animals (FH) or extrapolated age of animals (AEL).

This allows for the alignment of ages in either direction such that $2FH \equiv AEL$ since they are either hindcast or extrapolated to the same age.

The estimates of mortality calculated from the *AEL* and *FH* approaches can be compared for the same time periods for taxa where independent estimates are available for (1) survival from entrainment to recruitment into the fishery and (2) entrainment back to hatching. These comparisons serve as a method of cross-validation for the demographic approaches to impact assessment.

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Appendix E4 — Attachment

Example Model Calculations for Pacific Herring

EXAMPLE MODEL CALCULATIONS FOR PACIFIC HERRING

The three methods for assessing cooling water system (CWS) effects on larval fishes and megalopal cancer crabs described in the Survey Protocol (Appendix A) were empirical transport modeling (*ETM*), fecundity hindcasting (*FH*), and adult equivalent loss (*AEL*). The *FH* and *AEL* models are demographic approaches that rely almost entirely on life history information for their formulation. An estimate of the relative ages of the larvae that is used to determine the duration of exposure to entrainment is the only life history information needed for calculating the *ETM*. We used estimates of larval growth rates to determine the relative age. While this is an advantage of the *ETM*, all of the models require some estimate of the source water population for their interpretation. This appendix describes how life history information from the scientific and technical literature was used to parameterize these models for Pacific herring *Clupea pallasii*.

1.0 Empirical Transport Model

The empirical transport model (*ETM*) has been proposed by the U.S. Fish and Wildlife Service to estimate mortality rates resulting from cooling water withdrawals at power plants (Boreman et al., 1978, 1981). The original concept of the *ETM* was that mortality due to the power plant could be estimated as the ratio of the cooling water volume to the volume of water occupied by the population. Variations of this model have been discussed in MacCall et al. (1983) and used to assess impacts (Parker and DeMartini 1989). The *ETM* has been used to assess impacts at the Salem Nuclear Generating Station in Delaware Bay, New Jersey (PSE&G, 1993) as well as other power stations along the East Coast. The *ETM* approach was also used at Diablo Canyon (Tenera 2000a), Moss Landing (Tenera 2000b) and Morro Bay (Tenera 2001) power plants in California. Our approach to the *ETM* is similar to Parker and DeMaritini (1989) presented in the final report to the California Coastal Commission (Murdoch et al. 1989) for the San Onofre Nuclear Generating Station on the coast of southern California. The *ETM* permits the estimation of annual conditional mortality due to entrainment while accounting for the spatial and temporal variability in distribution and vulnerability of each life stage to power plant withdrawals. The generalized form of *ETM* incorporates many time-, space-, and age-specific estimates of mortality as well as information regarding spawning periodicity and duration, most of which are limited or unknown for the marine taxa being investigated.

In the Potrero Power Plant study, the purpose of the *ETM* calculations was to estimate the probability of mortality of larvae associated with power plant entrainment. The calculations required estimates of both the abundance of larvae entrained and the abundance of the larval populations at risk of entrainment. Sampling at the cooling water intakes was used to estimate the number of larvae entrained. At the Potrero Power Plant, the larval source population was been defined *a priori* as those larvae in the San Francisco Bay source water study area.

On any one sampling day, the conditional, or proportional, entrainment mortality (PE) can be expressed as

$$\hat{PE}_i = \frac{\hat{E}_i}{\hat{R}_i} \tag{1}$$

where E_i = total number of larvae entrained on the *i*th survey day $(i = 1,\ldots,L)$; R_i = number of larvae at risk of entrainment, i.e., abundance of larvae in the San Francisco Bay source water study area. PE is an estimate of the conditional mortality on the source water population due to entrainment that includes no other sources of mortality. For a detailed explanation of conditional mortality see Ricker (1975).

The entrainment estimate used in calculating PE can be expressed as

$$\hat{E}_i = V_E \cdot \hat{\bar{\rho}}_{E_i} \tag{2}$$

where V_E is the plant's cooling water intake volume during the *i*th survey and $\bar{X}_{E_i}$ is the average larval entrainment density during the survey. With the larval source populations defined *a priori*, the abundance of larvae at risk can be expressed as

$$\hat{R}_i = V_S \cdot \hat{\bar{\rho}}_{S_i} \tag{3}$$

where V_S is the source water study area volume in San Francisco Bay (S) and $\bar{\rho}_{S_i}$ is the average larval density in the source population during the *i*th survey.

The estimates of the larval densities in entrainment ($\bar{\rho}_{E_i}$) and San Francisco Bay source water study area ($\bar{\rho}_{S_i}$) are computed from the samples collected over a 24-hour sampling period at two entrainment stations and up to seven source water stations. Data from the two entrainment stations sampled during the January 17, 2002 survey are presented in **Table 1** to show how the estimate of $\bar{\rho}_{E_i}$ is calculated. Density estimates (ρ_{ijk}) from the k^{th} tow, during the j^{th} cycle*station within the i^{th} survey are calculated by dividing the number of the Pacific herring larvae in the tow by the measured volume of the water filtered by the net. The mean density for the cycle*station ($\overline{\rho}_{ij}$) and the cycle*station variance ($S^2_{\rho_{ij}}$) for the j^{th} cycle*station within the i^{th} survey are computed as follows, where $n_{ij} = 2$ tows for most cycle*station:

$$\overline{\rho}_{ij} = \frac{\sum_{l=1}^{n_{ij}} \rho_{ijk}}{n_{ij}},$$

$$S^2_{\rho_{ij}} = \frac{\sum_{l=1}^{n_{ij}} \left(\rho_{ijk} - \overline{\rho}_{ij}\right)^2}{\left(n_{ij} - 1\right)}.$$

Table 1. Data from entrainment stations for January 17, 2002 survey.

Cycle	Station	Replicate	Volume	Count	Density	Mean	Variance	Cycle n	Survey n
1	E01	A	47.84	33	0.6898	0.6474	0.0036	2	24
		B	42.97	26	0.6051				
2	E01	A	60.75	46	0.7572	0.5634	0.0751	2	24
		B	48.70	18	0.3696				
3	E01	A	51.73	45	0.8699	0.7806	0.0159	2	24
		B	40.50	28	0.6914				
4	E01	A	48.77	6	0.1230	0.1224	0.0000	2	24
		B	41.04	5	0.1218				
5	E01	A	65.35	26	0.3979	0.5578	0.0512	2	24
		B	55.73	40	0.7177				
6	E01	A	49.26	94	1.9082	1.8135	0.0179	2	24
		B	58.76	101	1.7189				
1	E02	A	45.14	24	0.5317	0.5189	0.0003	2	24
		B	53.35	27	0.5061				
2	E02	A	59.67	88	1.4748	1.2826	0.0739	2	24
		B	51.36	56	1.0903				
3	E02	A	54.08	44	0.8136	0.7638	0.0050	2	24
		B	47.62	34	0.7140				
4	E02	A	44.51	9	0.2022	0.1860	0.0005	2	24
		B	47.11	8	0.1698				
5	E02	A	53.63	49	0.9137	0.6153	0.1780	2	24
		B	63.10	20	0.3170				
6	E02	A	52.28	126	2.4101	2.5038	0.0175	2	24
		B	50.82	132	2.5974				
Survey Density Estimates						0.8630	0.0015		
Survey Entrainment Estimates (Volume = 875,429 m^3)						755,464	1,168,251,686		

Estimates of the mean and variances for the survey are calculated using the following formulas for stratified sampling treating all of the station-cycle combinations within a survey as individual strata:

$$\bar{\rho}_{E_i} = \sum_{i=1}^{j} \bar{\rho}_{ij} \frac{n_{ij}}{\sum n_{ij}},$$

$$\hat{S}^2_{\rho_{E_i}} = \sum_{i=1}^{j} \left(\frac{n_{ij}}{\sum n_{ij}} \right)^2 \frac{\hat{S}^2_{ij}}{n_{ij}}.$$

All of the replicates in the example based on Table 1 were collected for each of the cycle-station combinations. The same set of calculations is done for the source water stations to obtain estimates of $\bar{\rho}_{S_i}$ and $S^2_{S_i}$. Using these estimates and combining Equations (1–3), the probability of entrainment for larvae in the source population during the i^{th} sampling day can be estimated by

$$\hat{P}E_i = \frac{\left(\hat{E}_i\right)}{\left(V_S \cdot \bar{\rho}_{S_i}\right)}. \qquad (4)$$

The estimates of $\hat{P}E_i$ from each survey are used in the model to estimate the annual probability of entrainment mortality (P_M).

The manner of incorporating the individual estimates of $\hat{P}E_i$ into the *ETM* depends on the nature of the entrainment process and on the nature of the spawning and hatching sequence of the fish species. In the case where there are multiple non-overlapping spawnings, the *ETM* calculations can be formulated as the population-wide larval mortality ($\hat{P}_M$) due to entrainment:

$$\hat{P}_M = 1 - \sum_{i=1}^{L} f_i \left(1 - \hat{P}E_i\right)^q \qquad (5)$$

where f_i = fraction of the spawning for the total study period that occurred during the i^{th} survey, and q is equal to the larval duration for that species. The period of time in days (q) that the larvae were exposed to entrainment was estimated by applying a daily larval growth rate to the mean and maximum larval lengths from entrainment samples. The period of time that the larvae were exposed to entrainment was estimated as follows:

$$\textit{Entrainment Exposure (days)} = (\textit{Mean Length (mm)} - \textit{Minimum Length (mm)}) / \textit{growth rate (mm/days)} \tag{6}$$

Equation (5) assumes the population-wide probability of entrainment is the essence of the *ETM* approach of MacCall et al. (1983). If this population is stable and stationary, then $\hat{P}_M$ is also an indicator of the effects on the fully recruited age classes when no compensatory natural mortality is assumed.

The calculation of *ETM*, illustrated in Equations 1 to 6, requires that several parameters be obtained for each taxon being modeled. These include estimates of the number of larvae entrained, the number of larvae in the source water population at risk to entrainment, and an estimate of the period of time that the larvae were subject to entrainment. The period of time that the larvae were exposed to entrainment was estimated by applying a daily larval growth rate to the mean and maximum larval lengths from entrainment samples.

The data used to calculate $\hat{P}_M$ for Pacific herring are shown in **Table 2**. Estimates of the number of larvae in the source water population at risk to entrainment and the number of larvae entrained were used to calculate $\widehat{PE}$ for each survey. The *PE* estimates from each survey were weighted by the fraction (f_i) of the total study period entrainment that is subject to entrainment during survey period *i*. A sample of Pacific herring larvae measured from the entrainment stations had a mean length of 9.0 mm and a range from 5.1 to 20.8 mm. The larval growth rate used to calculate the period of entrainment risk was based on data presented by Stevenson (1962) for larvae between 8 – 20 mm. The average growth rate of 0.52 mm per day from his data is consistent with the rate reported by Alderdice and Hourston (1985) of 0.48 – 0.52 mm per day for the first 15 days after hatching. Based on these estimates, a larval growth rate of 0.50 mm per day was used to calculate the period of entrainment risk based on a length range of 6.8 – 14.1 mm for the central 95 percent of Pacific herring larvae measured from the entrainment stations. The period of time that the larvae were exposed to entrainment was estimated as follows:

$$\textit{Entrainment Exposure (days)} = (\textit{Mean Length (mm)} - \textit{Minimum Length (mm)}) / \textit{growth rate (mm/days)} \tag{7}$$

The mean length of 9.0 mm was used to calculate an average period of entrainment risk of 4.4 days using Equation 7 as follows:

$$(9.0\ mm - 6.8\ mm) / 0.50\ mm/day = 4.4\ days$$

These estimates were used to calculate an estimate of $P_m = 0.0011$ for Pacific herring.

Table 2. *ETM* data and example calculations for Pacific herring *Clupea pallasii.*

Survey Date	Daily Entrainment Estimate	Daily Entrainment Std. Error	Daily Source Estimate	Daily Source Std. Error	PE_i Estimate	Fraction of Entrainment for Survey (f_i)	Days (q)	$=f_i(1-PE_i)^q$
28-Feb-01	63,130	9,097	471,969,216	70,141,794	0.00013	0.046368	4.4	0.04634
8-Mar-01	23,078	4,556	327,359,672	68,719,718	0.00007	0.012616	4.4	0.01261
15-Mar-01	302,246	18,376	977,985,320	111,711,708	0.00031	0.052912	4.4	0.05284
27-Mar-01	1,238	68	5,625,446	2,560,565	0.00022	0.062916	4.4	0.06286
5-Apr-01	0	0	9,516,787	5,080,580	0	0.000205	4.4	0
23-May-01	0	0	0	0	0	0	4.4	0
20-Jun-01	0	0	0	0	0	0	4.4	0
11-Jul-01	0	0	0	0	0	0	4.4	0
8-Aug-01	0	0	0	0	0	0	4.4	0
12-Sep-01	0	0	0	0	0	0	4.4	0
10-Oct-01	0	0	0	0	0	0	4.4	0
7-Nov-01	0	0	0	0	0	0	4.4	0
6-Dec-01	34,842	6,034	148,953,575	13,606,492	0.00023	0.021635	4.4	0
2-Jan-02	674	674	12,970,899	2,408,152	0.00005	0.019141	4.4	0.01914
10-Jan-02	16,144	4,453	66,862,189	8,315,009	0.00024	0.003425	4.4	0.00342
17-Jan-02	755,464	34,180	5,371,580,491	260,285,244	0.00014	0.127095	4.4	0.12702
23-Jan-02	88,273	9,660	557,458,478	38,409,264	0.00016	0.077161	4.4	0.07711
30-Jan-02	7,945	2,447	104,807,406	15,994,801	0.00008	0.012278	4.4	0.01227
6-Feb-02	11,625	3,053	34,867,385	6,977,850	0.00033	0.002912	4.4	0.00291
13-Feb-02	3,075	2,024	37,116,042	4,615,018	0.00008	0.001953	4.4	0.00195
21-Feb-02	2,700,802	307,156	8,333,473,924	472,132,046	0.00032	0.559383	4.4	0.55859
						Total P_m Estimate =		**0.00134**

2.0 Fecundity Hindcasting

The Fecundity Hindcast (*FH*) model estimates the number of females whose reproductive output is lost due to Potrero Power Plant entrainment. The calculation of *FH* requires several life history values for each taxon. These values are the age at entrainment, the egg and larval survival to entrainment, and lifetime fecundity for each taxon. Lifetime fecundity (*TLF*) is calculated from estimates of annual fecundity applied to the average number of years a mature female is reproductive as

$$TLF = \overline{Eggs / year} \bullet (\frac{Longevity - Maturation}{2}) \tag{8}$$

The estimate of *FH* is computed using F_T in the following formula:

$$FH = \frac{\hat{E}_T}{\hat{T}LF \prod_{j=1}^{n} \hat{S}_j}, \tag{9}$$

where S_j represents the survival of the *j* life stages up through entrainment. The life stages could include eggs, yolk-sac, and later larval stages depending upon the life history of the taxa.

The larval entrainment estimate (E_T) of 35,982,833 (Std. Error = 2,513,057) for Pacific herring over the February 2001–February 2002 sampling period was used in calculating an estimate of *FH*. This estimate is calculated using the formula presented in Appendix E1. An annual fecundity estimate of 22,500 eggs was used in computing *FH* based on a letter from CDFG citing a range of 20,000 to 25,000 from Reilly and Moore (1986) (P. Wolf, CDFG, December 26, 2001). Although Fitch and Lavenberg (1975) report that herring may live to eleven years of age, Leet et al. (2001) indicate that fish older than seven years are rare. An estimate of longevity from Leet et al. (2001) of seven years and an estimate of 2.5 years for the age where approximately 50 percent of the females are reproductively mature from Love (1996) were also used in computing *FH*.

The estimate of 40 percent egg survival used in the model was based on a range of estimates of egg mortality available in the literature: 20 percent (Hourston and Haegele 1980) and 99 percent (Hardwick 1973, Leet et al. 2001). Larval mortality from hatching through recruitment at 70 days was estimated by Stevenson (1962) to be 99.5 percent. This value was used to calculate a daily survival rate of 0.927 as follows:

$$0.927 = (1 - 0.995)^{(1/70)}.$$

This estimate assumes that daily survival is constant over the 70-day period and that it is representative of survival during the earliest larval stages through entrainment. Survival to entrainment was then estimated as follows:

$$0.716 = 0.927^{4.4},$$

where 4.4 is the estimated average age in days of the entrained larvae; the same estimate used in calculating *ETM*.

These life history parameters were used in the *FH* model to estimate a loss of 2,479 reproductive females as follows:

$$FH = 2,479 = \frac{35,982,833}{0.4000 \cdot 0.7167 \cdot \left[22,500 \cdot \frac{(7\text{-}2.5)}{2}\right]}.$$

3.0 Adult Equivalent Loss

The Adult Equivalent Loss (*AEL*) model uses survival of the various life stages from entrainment through maturity to estimate the number of adults that the larvae lost due to Potrero Power Plant entrainment represent. The calculation of *AEL* requires survival estimates for the various life stages from entrainment through recruitment to adulthood for each taxon being modeled. Survival rates are not available for many of the taxa we collected, and survival rates for specific life stages are even less common. In taxa where survival rates are not available for all life stages, survival rates are applied across a number of stages. For example, in Pacific herring a single estimate of larval survival was applied over the period from entrainment through settlement (70 days) and a juvenile survival rate was applied from settlement to maturity. This assumes that these survival rates apply to all of the various larval, juvenile, and pre-recruit stages. In general, *AEL* would be calculated as follows if survival rates for all the various life stages were available:

$$AEL = (E_T)\,(S_{Early\ Larvae})\,(S_{Late\ Larvae})\,(S_{Early\ Juv})\,(S_{Late\ Juv.})\,(S_{Pre\text{-}Recruits}) \qquad (10)$$

The larval entrainment estimate (E_T) of 35,982,833 (Std. Error = 2,513,057) for Pacific herring over the February 2001–February 2002 sampling period was used in calculating an estimate of *AEL*. This estimate is calculated using the formula presented in Appendix E1. Survivorship of Pacific herring larvae from the average age at entrainment (4.4 days) to the estimated end of the larval period of 70 days (Hourston and Haegele 1980) was calculated using the same daily survival rate of 0.927 used to calculate *FH*. Larval survival from age at entrainment (4.4 days) through recruitment (70 days) was estimated as follows by compounding the daily survival:

$$0.00698 = 0.927^{(70\text{-}4.4)}.$$

Survival from post-larvae to the average age of a mature female in the population (4.75 years) was using the exponential survival equation from Ricker (1975):

$$S_t = e^{-Zt}. \tag{11}$$

Survival was calculated to be 0.042442 using an annual mortality rate of 50 percent adult mortality (*Z* = -0.69) from Hourston and Haegele (1980) as follows:

$$0.04244 = e^{-0.69(4.75-(70/365.25))}.$$

The *AEL* model (Equation 10) was adjusted for the available survival values as follows:

$$AEL = (E_T)\ (S_{Larvae})\ (S_{Adult}),$$

and used to calculate an estimate of the equivalent number of adults represented by the larvae lost due to Potrero Power Plant entrainment as follows:

$$\widehat{AEL} = 10,654 = 35,982,833 \times 0.00698 \times 0.04244$$

4.0 Model Comparison

Both $\widehat{FH}$ and $\widehat{AEL}$ can be compared with the size of the adult population of interest or with fishery harvest data. This method converts numbers of adult losses into fractional loss of the population of interest (e.g., stock assessment). However, information describing adult stocks is, and independent field estimates of survival are not available for many species.

The level of uncertainty associated with $\widehat{FH}$ and $\widehat{AEL}$ can be evaluated by assuming a stationary population where an adult female must produce two adults (i.e., one male and one female) over its lifetime. Overall survival (N_T) can then be estimated from total lifetime fecundity ($\bar{F}_T$) by the quantity

$$\hat{N}_T = 2 = \widehat{TLF} \times \hat{S}_{Before} \times \hat{S}_{After}, \tag{12}$$

where the value for survival is partitioned into two sources that combine all of the egg, larval, juvenile, and adult stages from the two models: $\hat{S}_{Before}$ accounts for survival in *FH* up to entrainment, and $\hat{S}_{After}$ for survival in *AEL* from entrainment through maturity. Reformulating the *FH* and *AEL* model equations to solve for $\hat{S}_{Before}$ and $\hat{S}_{After}$, respectively, gives us

$S_{Before} = \dfrac{\hat{E}_T}{\widehat{FH} \times \widehat{TLF}}$ and $S_{After} = \dfrac{\widehat{AEL}}{\hat{E}_T}$. Substituting these values into Equation 12 gives us

$$\widehat{N}_T = 2 = \widehat{TLF}\left(\frac{\widehat{E}_T}{\widehat{FH}\cdot\widehat{TLF}}\right)\left(\frac{\widehat{AEL}}{\widehat{E}_T}\right),$$

which after elimination yields

$$\widehat{AEL} \equiv 2\cdot\widehat{FH}\ . \tag{13}$$

Without independent adult survival rates, and assuming a 50:50 sex ratio and a stationary population, $\widehat{AEL}$ and $\widehat{FH}$ are deterministically related according to Equation 13. To compare $\widehat{AEL}$ and $\widehat{FH}$ the models should be aligned so that the average female age used in *FH* is also the age of recruitment used in computing *AEL*. In our calculations we use the average age of an adult female from *FH* as the age of the average adult in the *AEL* to ensure that the models are extrapolated to the same age. The magnitude of the difference from the relationship of $\widehat{AEL} \equiv 2\cdot\widehat{FH}$ reflects the level of uncertainty associated with the life history parameters.

Differences between the two estimates using the results for Pacific herring from the *FH* and *AEL* models probably reflect uncertainties in the parameter values used in the calculations. One source of uncertainty is the use of a single mortality rate from recruitment through adult life stages in the *AEL* model. Mortality of juvenile herring is probably higher than the adult mortality used in the model; higher juvenile mortality would result in a reduction of the *AEL* estimate.

Another possibility is that $\widehat{TLF}$ is overestimated resulting in an underestimate of $\widehat{FH}$. The expected length of reproductive life was approximated as the midpoint between the times of maturation and longevity. This approximation was based on the assumption of linear survivorship between these events. For exploited species such as northern anchovy and sardine, the expected number of years of reproductive life may be much less than predicted using this assumption. Simulation, comparing exponential survival, shows that the calculation of $\widehat{TLF}$ will be negatively biased for species with short reproductive lifespans, and positively biased for those with longer durations.

APPENDIX E REFERENCES

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