Carlsbad Desalination Facility

Intake Effects Assessment

Draft March 3, 2005

Prepared for:

Poseidon Resources Corporation

Prepared by:

TENERA Environmental
971 Dewing Avenue #101, Lafayette CA 94549
(925) 962-9769, Fax (925) 962-9758

Table of Contents

Executive Summary ... ES-1

1.0 Introduction ... 1-1
1.1 Regulatory Setting ... 1-1
1.2 Report Organization ... 1-2

2.0 Project Description ... 2-1
2.1 Summary Description of Encina Power Station Operations ... 2-1
2.2 Summary Description of Desalination Facility ... 2-2

3.0 Project Environmental Setting ... 3-1
3.1 Agua Hedionda Lagoon ... 3-1
3.2 Southern California Bight and the Pacific Ocean ... 3-2
3.3 Source Water Fisheries Resources ... 3-4

4.0 Larval Entrainment Studies ... 4-1
4.1 Introduction ... 4-1
4.2 Methods ... 4-1
4.2.1 In-Plant Entrainment and Survival Sampling ... 4-1
4.2.2 Source Water Sampling ... 4-2
4.2.3 Laboratory Analysis ... 4-3
4.3 Taxon Profiles ... 4-3
4.3.1 CIQ Goby Complex ... 4-5
4.3.2 Combtooth Blennies ... 4-8
4.3.3 Northern Anchovy ... 4-11
4.4 Sampling Results ... 4-13
4.4.1 In-Plant Larval Abundance Estimates ... 4-13
4.4.2 Source Water Larval Abundance Estimates ... 4-14
4.4.3 In-Plant Larval Survival Results ... 4-18

5.0 Entrainment Impact Assessment ... 5-1
5.1 Entrainment Effects Model ... 5-1
5.2 Source Water Volume ... 5-5
5.3 *ETM* Modeling ... 5-9
5.3.1 Analysis Approach ... 5-9
5.3.2 Sources of Variance in *ETM* ... 5-10
5.3.3 *ETM* Results ... 5-10
5.3.4 Entrainment Effects Discussion ... 5-12

6.0 Literature Cited ... 6-1

List of Appendices

Appendix A. Survey Results

List of Tables

Table 2-1. Summary of EPS generating capacity and CWIS flows. 2-1

Table 3-1. Commercial nearshore finfish landings and value by year for nineteen nearshore finfish species and all commercial gear types except trawl. 3-6

Table 3-2. Average commercial landings, pounds, and value for nearshore finfish species over years 1989–1999, all gears except trawl. 3-6

Table 4-1. Total counts and mean concentrations of larval fishes from in-plant surveys collected June 16 and July 6, 2004. 4-14

Table 4-2. Total counts and mean concentrations of larval fishes and target invertebrates from source water surveys collected June 10, June 24, and July 6, 2004. 4-16

Table 4-3. Summary of larval fish data collected during in-plant survival studies from EPS discharge flows during June through November 2004. 4-19

Table 5-1. Volumes of the outer, middle, and inner segments of the Agua Hedionda Lagoon. 5-6

Table 5-2. Volumes of nearshore sampling blocks used in calculating source water abundances. 5-7

Table 5-3. Estimates of average daily populations of larval CIQ gobies, combtooth blennies, and northern anchovy based on the static source water volume and the maximum daily flow of desalination facility feedwater withdrawal. 5-10

Table 5-4. Estimates of average daily mortality (*PE*) calculated using the maximum desalination facility feedwater withdrawal rate for CIQ gobies, combtooth blennies, and northern anchovy. 5-11

Table 5-5. Estimates of maximum exposure to entrainment for populations of larval CIQ gobies, combtooth blennies, and northern anchovy. 5-11

Table 5-6. Estimates of P_m from *ETM* at maximum exposure for CDF entrainment from the EPS discharge flow and the incremental entrainment loss due to CDF operations at the average survival rate for populations of larval CIQ gobies, combtooth blennies, and northern anchovy. 5-13

List of Figures

Figure ES-1. Conceptual diagram of impingement and entrainment processes and their relationship to a generating station's once-through circulating water system with a desalination feedwater supply and return. ES-2

Figure 2-1. Schematic of intake and discharge of seawater for Poseidon's proposed Carlsbad Desalination Facility at Encina Power Station. 2-3

Figure 4-1. Source water plankton sampling stations including EPS entrainment station. 4-4

Figure 4-2. Comparison of larval fish concentrations among sampling areas in June and July 2004. 4-17

Figure 5-1. Nearshore sampling blocks used to calculate source water volumes. 5-8

Executive Summary

The purpose of this report is to assess the potential impingement and entrainment effects of the feedwater withdrawal of the proposed Carlsbad Desalination Facility (CDF) from the discharge of Cabrillo Power I LLC (Cabrillo) Encina Power Station (EPS) cooling water intake system. Impingement impacts are caused when organisms are trapped against screens, filters, or other mechanisms during the withdrawal of seawater through an intake system (**Figure ES-1**), and suffer damage or mortality as a result of pressure exerted from the flow of water. Entrainment effects occur when small planktonic organisms are drawn through the intake system (**Figure ES-1**), and suffer damage or mortality as a result of pressure changes, mechanical damage, temperature increases, or turbulence in the water flow.

To determine the potential effects resulting from seawater intake, a study was conducted to characterize the type and concentration of organisms within the source water for the EPS cooling water intake structure and the effects of CDF operations on the feedwater supply (diversion of 106 MGD of seawater discharged from the EPS cooling water discharge channel). This Intake Effects Assessment study is designed to address the following specific questions:

1. **Impingement Effect** – Will CDF operations contribute to the impingement effect (trapping of larger organisms on intake screens) of the EPS intake?

2. **Entrainment Losses** – What are the composition and abundance of fish species, *Cancer* spp. crabs, and spiny lobster that are entrained through the EPS cooling water intake structure (CWIS) and what proportion of these organisms would be susceptible to further entrainment by the CDF feedwater withdrawal?

3. **Effect on Source Populations in Aqua Hedionda Lagoon and the southern reaches of the Southern California Bight** – How might any additional losses of organisms due to desalination plant feedwater entrainment affect the source populations of the entrained species in Aqua Hedionda Lagoon and the southern reaches of the Southern California Bight?

4. **Significance of Entrainment Losses** – Are these losses ecologically or economically significant?

This study was undertaken in consideration of water code Section 13142(d) which provides that “independent baseline studies of the existing marine system should be conducted in the area that could be affected by a new or expanded industrial facility using seawater in advance of the carrying out of the development.” The cooling water intake structure (CWIS) is part of the EPS existing operations and is presently regulated under Section 316(b). The CDF's feedwater withdrawal does not include a CWIS. Therefore, it is not subject to intake regulation under the Federal Clean Water Act (CWA) Section 316(b). However, since the CDF will withdraw intake seawater from the power station discharge flow, this study was conducted consistent with the intent of Section 316(b), which requires that baseline conditions be established (USEPA 2004).

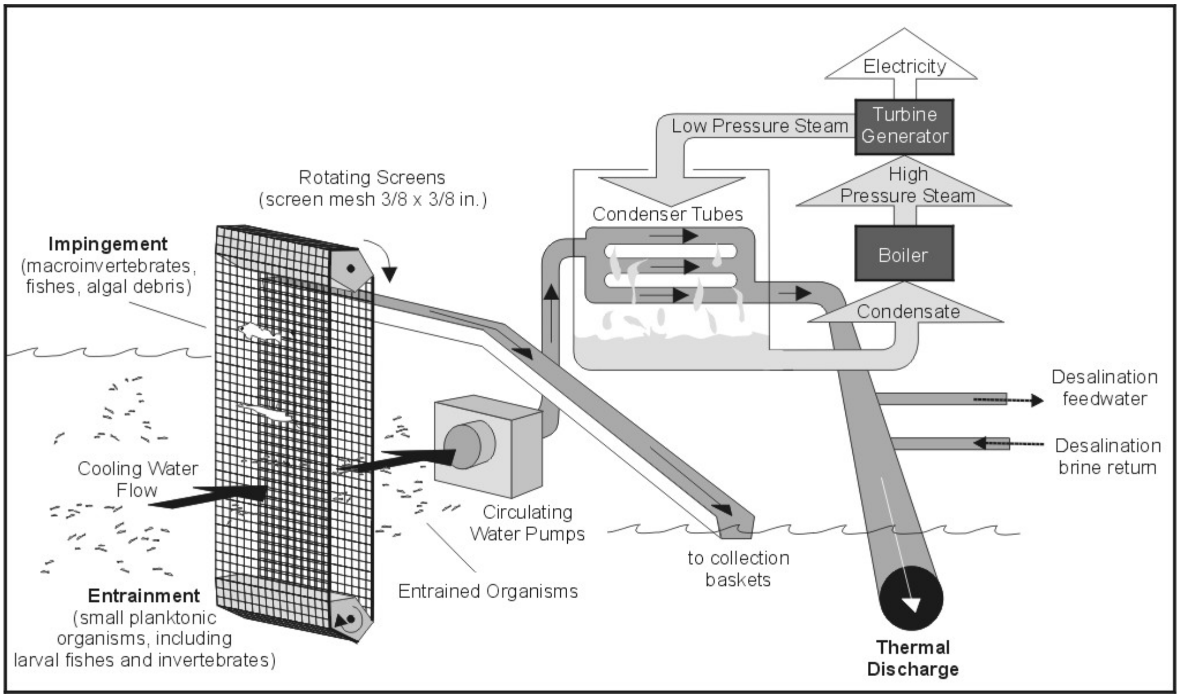


Figure ES-1. Conceptual diagram of impingement and entrainment processes and their relationship to a generating station's once-through circulating water system with a desalination feedwater supply and return

Study Overview

Entrainment sampling was conducted at an onshore point in the EPS discharge conduit before the cooling water is discharged. Bi-weekly samples have been collected since June 10, 2004 by pumping measured volumes of cooling water discharges through small-mesh nets. The preserved samples were sorted in the laboratory and the fishes and target invertebrates were identified to the lowest taxon practicable.

In general, entrainment effects are assessed using the Empirical Transport Model (*ETM*), as recommended and approved by the California Energy Commission (CEC), California Coastal Commission (CCC), Regional Water Quality Control Boards and other regulatory and resources agencies. This model, used for many other California intake effects studies, compares entrainment larval concentrations to source water larval concentrations to calculate the effects of larval removal on the standing stock of larvae in the defined source water. The *ETM* model results presented in this report are based on sampling results collected during the annual period when larval abundances are typically the highest. The source water volume used in the *ETM* calculations comprised a sub-area of the Southern California Bight and is described in Section 5.2 of this assessment. Source water volumes, cooling water volumes, larval concentrations, and larval durations were variables used in the *ETM* calculations. Conservative assumptions of maximum CDF volumes of 106 MGD were used for developing the estimates of potential losses due to CDF operations.

The CDF feedwater intake will not increase the volume, nor the velocity of the EPS cooling water intake nor will it increase the number of organisms entrained or impinged by the EPS CWIS. Therefore, the impingement effects of the EPS are not included in assessing the CDF intake effects. This assessment focuses on the effects of CDF's entrainment of organisms already entrained by the power station before they would be returned to the ocean in the cooling water discharge flow.

Results

The results of the Intake Effects Assessment study concluded the following:

Four taxa were found to comprise 95 percent of all of the fish larvae present in the EPS discharge flows from which the proposed CDF would withdraw its feedwater supply (see **Table 4-1**). They were combtooth blennies, gobies, kelpfishes, and garibaldi. The majority of these fishes were found to be common in an earlier 316(b) study of EPS entrainment effects (SDG&E 1980). Species with high commercial and recreational importance, such as California halibut, were uncommon (0.06 percent) in the EPS intake water. Generally less than one percent of all fish larvae become reproductive adults, including this small percentage of entrained halibut.

Impingement Effect

- The CDF operation does not require the EPS to increase the quantity of water withdrawn nor does it increase the velocity of the water withdrawn.

- The CDF will not have a separate direct lagoon or ocean intake and screening facilities, and will only use cooling water that is already screened by EPS's intake.

- Therefore, the CDF will not cause any additional impingement losses to the marine organisms impinged by the power plant.

Entrainment Losses

- Based on in-plant testing, the average observed entrainment mortality of EPS was 97.6 percent (2.4 percent survival). Living fish larvae entrained by the CDF would represent an incremental loss of approximately 0.01 to 0.28 percent of the power plant's source water supply of larvae.

Effect on Source Water Populations in the Southern California Bight

Fish larvae entrained by the desalination plant (gobies, combtooth blennies, and northern anchovy) represent an incremental loss of the EPS source water supply of larvae. The average observed entrainment mortality of the EPS was 97.6 percent (2.4 percent survival). Since 97.6 percent of the larvae are dead at the point of the desalination plant intake, the incremental loss on source water populations is the 2.4 percent survival rate times the desalination plant proportional entrainment for the most abundant species in the EPS discharge. These incremental effects range from 0.01 to 0.28 percent for these species. This small fraction of marine organisms lost to CDF entrainment would have no effect on the species' ability to sustain their populations because of their widespread distribution and high reproductive potential.

Significance of Entrainment Losses

- The most frequently entrained species are very abundant in the area of EPS intake, Aqua Hedionda Lagoon, and the Southern California Bight, and therefore, the actual ecological effects due to any additional entrainment from the CDF are insignificant.

- Species of direct recreational and commercial value constitute a very small fraction (less than 1 percent) of the entrained organisms and therefore, the operation of the CDF does not result in significant ecological impact.

- The incremental mortality due to CDF is 0.01 to 0.28 percent[1]. This assessment assumes 100 percent mortality of all organisms surviving the EPS upon withdrawal into the desalination facility.

- California Department of Fish and Game (2002) in their Nearshore Fishery Management Plan provides for sustainable populations with harvests of up to 60 percent of unfished adult stocks. The incremental entrainment ("harvest" of larval fishes from CDF operations at 106 MGD is slightly above 1 percent.

[1] The average survival rate was calculated from data collected during surveys that were not always coincident with source water sampling. By applying the highest survival rate (9.2 percent), the incremental mortality is only slightly above 1 percent (1.09 percent).

1.0 Introduction

Poseidon Resources, Inc. proposes to build and operate a seawater desalination facility at the Encina Power Station (EPS) in Carlsbad, California for the purpose of providing potable water to local and regional water distribution systems. The area of the Carlsbad Desalination Facility (CDF) site available for the construction of the facility totals approximately 4 acres. The CDF intake, pretreatment facilities, desalination facility building, and ancillary equipment will be configured to accommodate desalination facility production capacity of 50 MGD of potable water.

The source water for the desalination facility will be provided from the existing cooling water discharge conduit of the EPS. The facility will use a maximum of 106 MGD under full capacity operation. The power station withdraws cooling water from the Pacific Ocean via the Agua Hedionda Lagoon. The concentrate and the treated waste filter backwash water from the desalination facility will be discharged into the existing cooling water discharge conduit downstream of the point of interconnection for mixing with the cooling water discharge from the power station prior to its ultimate return to the ocean.

Since CDF will reuse the power station's cooling water discharge after its permitted use, the desalination facility will not require a new seawater intake or supply directly from the ocean. In addition, the EPS cooling water intake system (CWIS) also protects CDF's intake against impingement losses. Therefore, CDF intake operations will not result in incremental marine organism impingement.

1.1 Regulatory Setting

The EPS circulates water it withdraws from the Pacific Ocean and Agua Hedionda Lagoon (a man-made lagoon originally constructed as a cooling water forebay for the EPS) in a single pass through the power station's cooling water system that condenses freshwater steam used in power production back to recyclable boiler water. Because the quantity of cooling water withdrawn exceeds 50 MGD, the power station cooling water system's intake design, location, and capacity require a National Pollutant Discharge Elimination System (NPDES) permit approved by the San Diego Regional Water Quality Control Board (RWQCB) under Section 316(b) of the Federal Clean Water Act (FCWA).

Feedwater for the CDF will come directly from the cooling water discharge flow of the EPS. Although the proposed desalination facility's withdrawal of feedwater from the EPS cooling water discharge is not subject to 316(b) rules since the cooling water has already served its regulated purpose, Poseidon and Cabrillo Power I LLC both recognize that operation of the EPS cooling water intake, which creates the discharge flow, is subject to the EPA's Section 316(b) performance standards and rules.

In recognition of their common regulatory interests associated with their co-located projects, Poseidon and Cabrillo requested Tenera to study the potential entrainment effects of the CDF intake. This study was designed to collect information on the larval fishes and target invertebrates contained in CDF source water (the power station's cooling water discharge) that would be at risk to entrainment at the desalination facility's intake. The study was also designed to gather information on the larval fishes and target invertebrates in the power station's cooling water source and intake flows.

1.2 Report Organization

This report describes the proposed Poseidon desalination facility project and assesses the potential entrainment effects of the intake on source water resources through an assessment of the CDF feedwater intake's entrainment effects. Section 2.0 provides a description of the project and Section 3.0 describes the environmental setting. Section 4.0 presents the results of entrainment, source water, and larval survival studies. The analysis of entrainment impacts is presented in Section 5.0 and the literature cited in the report is listed in Section 6.0.

2.0 Project Description

2.1 Summary Description of Encina Power Station Operations

The Encina Power Station (EPS) consists of five steam turbine generating units and a small gas turbine unit. Generating capacity of the individual steam turbine units ranges from 104 to 315 megawatts (MW) (**Table 2-1**). The gas turbine has a generating capacity of 16 MW. Units 1-3 began operating in the 1950s, the gas turbine was added in 1968, and Units 4 and 5 went on line in 1973 and 1978, respectively.

Table 2-1. Summary of EPS generating capacity and CWIS flows.

Unit #	Date on Line*	Capacity (MW)	Number of CWP	Cooling Water Flow (gpm)**	Service Water Flow (gpm)**	Total (gpm)	Total (MGD)
1	1954	107	2	48,000	3,000	51,000	73
2	1956	104	2	48,000	3,000	51,000	73
3	1958	110	2	48,000	6,000	54,000	78
4	1973	287	2	200,000	13,000	213,000	307
5	1978	315	2	208,000	18,200	226,300	326
Gas turbine	1968	16	0	0	0	0	0
			Total:	**552,000**	**43,200**	**595,200**	**857**

* Encina Power Station NPDES Permit No. CA0001350, Order No. 2000-03, SDRWCB.
** Encina Power Station Supplemental 316(b) Report (EA Engineering, Science, and Technology 1997).

The power station utilizes a once-through cooling water system that draws water from the Pacific Ocean via the Agua Hedionda Lagoon. The power station uses a common intake structure located at the southwestern corner of the lagoon to provide cooling water for Units 1-5. The gas turbine is air-cooled and therefore does not use seawater for cooling purposes. Water entering the intake passes through trash racks (stationary panels of vertical steel bars on 3.5-inch centers) that prevent large debris from entering the system. Downstream of the trash racks, the water flow is diverted into a series of conduits that lead to each of the individual generating units (**Figure 2-1**). Each unit has two large circulating water pumps (CWP) that supply cooling water to each unit's condenser. Each unit is also equipped with smaller saltwater service pumps (SWSP) that provide water for cooling station equipment (pump motors, bearings, smaller heat exchangers, etc.). Vertical traveling screens are positioned immediately upstream of the CWPs and SWSPs to remove debris from the flow stream. Each traveling screen consists of a series of interconnected screen panels that are positioned perpendicular to the cooling water flow. As the water passes through the screens, debris is trapped on their surface. The screen panels (connected in a vertical loop) are drawn up out of the cooling water flow and later pass through a water spray system that cleans the debris from the screen and removes it from the cooling water system. The Unit 1-4 traveling screens are equipped with 3/8-inch mesh screen panels. The Unit 5 traveling screens are equipped with 5/8-inch mesh screen panels. Without the traveling screens, debris that had passed through the trash racks, and macrofouling debris (barnacles and mussels growing within the system) sloughed from the walls of the conduits, would travel downstream and clog the small tubes that make up the power station's condensers.

After passing through the traveling screens, the cooling water is pumped through the condensers of the individual generation units. At the condensers, heat is transferred from the steam exiting the power station's turbines (passing over the outside of the condenser tubes) to the seawater (passing through the inside of the condenser tubes), condensing the steam back to water (condensate). Heated seawater exiting the condensers flows into a common discharge conduit. The discharge conduit empties into an open discharge pond that is connected to the Pacific Ocean by a riprap-lined discharge outfall (**Figure 2-1**). The desalination facility intake piping will be connected to this discharge conduit.

The volume of cooling water passing through the power station at any given time is dependent upon the number of CWPs and SWSPs that are in operation. With all of the pumps in operation, the maximum permitted discharge volume is 857 MGD or about 595,000 gallons per minute (gpm) (2000 NPDES Permit No. CA0001350). As electrical demand varies, the number of generating units in operation and the number of cooling water pumps needed to supply those units will also vary. Over the first seven months of 2004, the daily volume of cooling water discharged by the EPS ranged from 288–795 MGD (not including equipment service water flows), with an average of 620 MGD for that period. Over the 20.5 year period (January 1980–mid 2000) used for modeling the impact of the desalination facility discharge, the average rate of cooling water flow was 550 MGD and ranged from 200–808 MGD. Therefore, the period selected for completion of this Intake Effects Assessment study is representative for the long-term operations of the power station.

2.2 Summary Description of Desalination Facility

The Carlsbad Desalination Facility key facilities include an intake facility, pretreatment facilities, reverse osmosis system, post-treatment system, and product water storage tank and transfer pump station. The CDF intake structure will consist of a pump station with a wet well connected to the south end of the power station's cooling water discharge conduit. The desalination facility seawater supply pumps will be located in the intake wet well and will pump seawater to the desalination facility. The intake pump station will include four duty pumps and one standby pump (25 percent redundant capacity). Four of the pumps will be constant-speed units and one will be equipped with a variable frequency drive. All of the pumps will have average/maximum capacity of 18,100 gpm/22,200 gpm, and will be equipped with high-efficiency motors.

The source water for the desalination facility will come from the power station's existing cooling water discharge conduit. The practical minimum flow for EPS was determined to be 163 MGD (Jenkins 2004), which is the volume pumped by one of the Unit 5 circulating water pumps. The potential effect of CDF entrainment is estimated based on maximum CDF design flows of 106 MGD.

The concentrate and the treated waste filter backwash water from the desalination facility will be discharged into the existing cooling water discharge outfall for mixing with the power station's cooling water discharge prior to its ultimate disposal to the ocean (**Figure 2-1**).

A more complete description of the desalination facility site is provided in the Encina Power Station Precise Development Plan (PDP). A regional map and a vicinity map indicating the location of the EPS are presented as Exhibits 1 and 2 of the PDP.

3.0 Project Environmental Setting

3.1 Agua Hedionda Lagoon

The Encina Power Station (EPS) is located on Agua Hedionda Lagoon, which is a man-made coastal lagoon that extends 2.7 km (1.7 miles) inland and is up to 0.8 km (0.5 mile) wide. The lagoon was constructed in 1954 to provide cooling water for the power station. A railroad trestle and the Interstate Highway 5 bridge separate Agua Hedionda Lagoon into three interconnected segments: Outer, Middle, and Inner lagoons. The surface areas of the Outer, Middle, and Inner lagoons are 26.7 (66 acres), 9.3 (23 acres), and 79.7 (197 acres) hectares, respectively. The lagoon is separated from the ocean by Carlsbad Boulevard and a narrow inlet 46 m (151 ft) wide and 2.7 m (9 ft) deep at the northwest end of the Outer Lagoon that passes under the highway and allows tidal exchange of water with the ocean.

Circulation and input into Aqua Hedionda Lagoon is dominated by semi-diurnal tides that bring approximately 2.0 million m^3 (528 million gallons) of seawater through the entrance to the Outer Lagoon on flood tides. Approximately half of this tidal volume flows into the Middle and Inner lagoons. On ebb tides this same tidal volume flows out through the entrance to the ocean. As a result of this tidal flushing, the lagoon is largely a marine environment. Although freshwater can enter the lagoon through Aqua Hedionda Creek, which drains a 7,500 hectare (18,500 acres) watershed, for most of the year freshwater flow is minimal. Heavy rainfall in the winter can increase freshwater flows and reduce salinity, especially in the Inner Lagoon.

A study on the ecological resources of Agua Hedionda showed that it has good water quality and supports diverse infaunal, bird, and fish communities (MEC Analytical 1995). Eelgrass was found in all three lagoon segments, but was limited to shallower depths in the Inner Lagoon because water turbidity reduces photosynthetic light penetration in deeper areas. The eelgrass beds provide a valuable habitat for benthic organisms that are fed upon by birds and fishes. Although eelgrass beds were less well developed in areas of the Inner Lagoon, the Inner Lagoon also provides a wider range of habitats, including mud flats, salt marsh, and seasonal ponds that are not found elsewhere in Aqua Hedionda. As a result bird and fish diversity was highest in the Inner Lagoon.

A total of 35 species of fishes was found during the 1994 and 1995 sampling conducted by MEC (MEC Analytical 1995). The Middle and Inner lagoons had more species and higher abundances than the Outer Lagoon. During the 1995 survey only four species were collected in the Outer Lagoon, compared to 14–18 species in the Middle and Inner lagoons. The sampling did not include any surveys of the rocky revetment lining the Outer Lagoon that would increase the abundance and number of species collected. Silversides (Atherinopsidae) and gobies (Gobiidae) were the most abundant fishes collected. Silversides, including jacksmelt and topsmelt, that occur in large schools in shallow waters where water temperatures are warmest were most abundant in the shallower Middle and Inner lagoons. Gobies were most abundant in the Inner Lagoon which has large, shallow mudflat areas that are their preferred habitat.

An assessment of the ecological resources of Agua Hedionda (MEC Analytical 1995) did not record any federally endangered tidewater goby *Eucyclogobius newberryi* that was once recorded from the lagoon. The record of the occurrence may not be accurate or may predate the construction of the Outer Lagoon that provided a direct connection with the ocean. The current marine environment in the lagoon would not generally support tidewater gobies because they prefer brackish water habitats. No other listed fish species were collected in the study.

3.2 Southern California Bight and the Pacific Ocean

Agua Hedionda Lagoon is tidally flushed through the small inlet in the Outer Lagoon by waters from the Pacific Ocean. The physical oceanographic processes of the southern California Bight that influence the lagoon include: tides, currents, winds, swell, temperature, dissolved oxygen, salinity, and nutrients through the daily tidal exchange of coastal seawater. Near the mouth of the lagoon the mean tide range is 3.7 ft (1.1 m) with a diurnal range of 5.3 ft (1.6 m). Waves breaking on the shore generally range in height from 2–4 ft (0.6–1.2 m), although larger waves (6–10 ft [1.8–3.0 m]) are not uncommon. Larger waves exceeding 15 ft (4.6 m) occur infrequently, usually associated with winter storms. Surface water in the local area ranges from a minimum of 57ºF (13.9ºC) to a maximum 72ºF (22.2ºC) with an average annual temperature between 63ºF (17.2ºC) and 66ºF (18.9ºC).

The circulation of the Bight is dominated by the California Current rather than by local wind forcing. The California Current extends offshore a distance of about 400 km and to a depth of 300 m. The average current speed is approximately 0.25 m/sec and circulation occurs primarily during spring and summer. When the nearshore portion of this surface current periodically flows poleward, it becomes the Coastal Countercurrent. The Davidson Current or California Undercurrent also flows poleward and is characterized by being warmer, saltier, and having low oxygen and high phosphate. Although this northerly countercurrent exists throughout the year at depths of 200–300 m, along the continental slope it is strongest during the fall and winter months and occurs within 50 km of the coast. The appearance of this current in the late summer and fall brings warm, saline, low dissolved oxygen water to Bight nearshore habitat and beaches. Bottom contours and submarine topography also influence the movement and mixing of water masses in the Bight, resulting in a complete turnover every 1–3 months.

El Niño events produce striking changes in the Bight's oceanographic conditions. They affect both physical factors (e.g., ocean temperatures) and indices of biological productivity (e.g., zooplankton densities). The El Niño events' alteration of regional currents and upwelling interrupt the supply of nutrients and the productivity of kelp forests and zooplankton populations that in turn support populations of fishes and shellfishes. The population changes can dramatically affect California's commercial and recreational fisheries harvests. During El Niños, the California Current can bring organisms into the Bight from the south, such as spiny lobster and California sheephead that normally have their centers of distribution off Baja California but can recruit heavily in southern California during strong El Niño events.

Circulation patterns within the Southern California Bight, the coastal ocean from Point Arguello to just south of San Diego and inshore of the Santa Rosa Ridge, are more complex than elsewhere off the west coast of the U.S. The equatorward California Current, a well-described eastern boundary current dominates flow in this region and is strongest during summer. The California Current branches shoreward and then poleward in the Southern California Bight, forming the Southern California Countercurrent (seasonal maximum in winter), and, at times, an eddy-like cyclonic circulation (i.e., the Southern California Eddy) whose seasonal maximum is summer to early fall. The California Undercurrent, also strongest in summer, similarly exhibits poleward flow over the continental slope in this region. The strongest equatorward winds are found during spring along most of the California coast. At this time, the California Current moves closer to shore and becomes increasingly jet-like, and flow is predominantly equatorward in the Southern California Bight. Thus, poleward flow in the Southern California Bight experiences a minimum during spring and a maximum in summer. Winds in the Southern California Bight are generally weaker but highly variable as compared to the rest of the California coast. In addition, upwelling events within the Bight tend to be limited to winter and early spring; local upwelling during summer, while strong elsewhere along the California coast, is minimal in the Southern California Bight due to a large reduction in wind stress. Temporally and spatially variable local winds, as well as eight nearshore islands and numerous coastal promontories, submarine canyons, basins, and ridges introduce complexity to these large-scale circulation patterns, particularly in the form of sub-mesoscale or small-scale eddies that are typically under 50 km in diameter.

The adults of larger fishes and other marine vertebrates are somewhat buffered from the effects of weather and other short-term physical fluctuations, and extremely long-lived organisms, such as many of the deep benthic fishes, may have populations that are nearly independent of normal short-term environmental fluctuations. Many of California's marine fishes have life history adaptations such as extended spawning seasons, multiple spawnings, migrations, and extreme longevity that reduce the harmful effects of short-term adverse environmental fluctuations and even limit the effects of El Niño events at the population level.

The outer coast has a diversity of marine habitats and includes zones of intertidal sandy beach, subtidal sandy bottom, rocky shore, subtidal cobblestone, subtidal mudstone, and water column. Organisms typical of sandy beaches include polychaetes, sand crabs, isopods, amphipods, and clams. Grunion utilize the beaches around EPS during their spawning season from March through August. Numerous infaunal species have been observed in subtidal sandy bottoms. Mollusks, polychaetes, arthropods, and echinoderms comprise the dominant invertebrate fauna. Sand dollars can reach densities of 1,200/m^2. Typical fishes in the sandy subtidal include queenfish, white croaker, several surfperch species, speckled sanddab, and California halibut. Also, California spiny lobster and *Cancer* spp. crabs forage over the sand. Many of the typically outer coast species can occasionally occur within Agua Hedionda Lagoon, carried there by incoming tidal currents.

The rocky habitat at the discharge jetty and on offshore reefs supports various kelps and invertebrates including barnacles, snails, sea stars, limpets, sea urchins, sea anemones, and mussels. Giant kelp (*Macrocystis*) forests are an important habitat-forming community in the area offshore from Agua Hedionda. Kelp beds provide habitat for a wide variety of invertebrates and fishes. The water column and kelp beds are known to support many fish species, including northern anchovy, jacksmelt, queenfish, white croaker, garibaldi, rockfishes, surfperches, and halibut.

Marine-associated wildlife that occur in the Pacific waters off Agua Hedionda Lagoon are numerous and include brown pelican, surf scoter, cormorants, western grebe, gulls, terns, and loons. Marine mammals, including porpoise, sea lions, and migratory gray whales, also frequent the adjacent coastal area.

3.3 Source Water Fisheries Resources

The Southern California Bight and Santa Maria Basin account for nearly 60 percent of California's recreational fisheries landings and about 5 percent of the total recreational landings in the continental U.S. (MMS 2001). However, the Bight's recreational fisheries harvest declined during the 1990s, while commercial landings increased slightly. Despite this fluctuation, commercial landings remained lower than recreational landings. According to the Marine Recreational Fisheries Statistics Survey (MRFSS) program, marine recreational fishing trips declined by 26.4 percent between 1993–1998 in southern California (MMS 2001). Private/rental boat trips declined 18.4 percent, charter/party boats declined 42.6 percent and shore fishing trips declined 21.4 percent. As reported by California Department of Fish and Game (CDFG), the recreational fishery annual landing of rockfishes from 1983–1989 averaged 2,008 metric ton (mt) (4,427,640 lb) compared to a commercial fishery average harvest of only 280 mt (617,400 lb). More recently, from 1993–1999, the average annual recreational landings declined to 806 mt (1,777,230 lb), while in the same period the commercial landings increased to an annual average of 431 mt (950,355 lb).

Recreational fishing activity is primarily conducted by fishers in areas close to shore. Nearshore finfishes were taken by angling or spear fishing from charter/party vessels, private/rental boats, beaches, (banks), and man-made structures such as piers and jetties. Commercial fishing activities generally occur further offshore.

California ranks among the top five seafood producing states in the nation. The commercial landings at ports within southern and central California account for about 4 percent of the total U.S. catch. Los Angeles area ports rank among the top 10 ports in the U.S. in quantity and value of commercial catch (MMS 2001). The primary commercial fishing gears used in harvesting the 19 nearshore finfish species are hook-and-line and trap. Gill and trammel nets and trawls targeting other species occasionally take nearshore species in areas outside State waters. Landings have escalated from 23,586–448,149 kg (52,000–988,000 lb) from 1989–1995, with the number of fishers (live-fish fishers) from statewide rising from 70 to nearly 700 during the same period (MMS 2001). Presently, there are 1,014 nearshore and finfish trap permittees in California, with an estimated total fleet harvest capacity of more than 2,400 tons (or roughly 24 times the current harvest allocation for 2001). However, the number of commercial fishers that have landed nearshore species has declined from pre-1999 counts for all gear types. Other fisheries that use traps include “rock” and Dungeness crab, spiny lobster, and shrimp.

Trawlers fishing the Southern California Bight waters landed over 4 million lb of rockfishes (principally bocaccio and chilipepper rockfish) in response to a developing market for live and high-quality fresh fish. Fish buyers and consumers are willing to pay high prices for live and high-quality fresh fish products; $0.50/lb in 1989 for cabezon compared to $3.80/lb in 1999. This has markedly changed the revenue potential for this fishery over the last 10 or 12 years, as shown in **Table 3-1**. These findings and fisheries values are used to assess the fisheries value of any potential EPS entrainment losses.

Table 3-1. Commercial nearshore finfish landings and value by year for nineteen nearshore finfish species and all commercial gear types except trawl.

Year	Pounds landed	Value ($)	Value/Pound
1989	6,499,439	3,925,761	0.60
1990	7,563,254	4,735,678	0.63
1991	7,504,582	5,103,869	0.68
1992	6,704,447	5,002,397	0.75
1993	5,179,340	4,626,544	0.89
1994	1,595,987	1,833,840	1.15
1995	2,890,186	4,200,306	1.45
1996	2,740,887	4,411,758	1.61
1997	2,565,162	4,263,103	1.66
1998	2,346,037	4,405,981	1.88
1999	1,341,257	3,721,838	2.77

Source: CDFG 2002.

CDFG divides the nearshore commercial finfish fishery landings among nine major ports (**Table 3-2**). The ports with the highest average value for nearshore species landed in 1989–1999 were Morro Bay and Santa Barbara, with 23 and 24 percent, respectively, of the total average value. The maximum pounds landed by nearshore fishermen at each port indicates the fishing potential or harvest capacity of the fleet. As shown in **Table 3-2**, the maximum pounds landed in each port, 1989–1999, are two to three-times the average pounds landed for each respective port.

Table 3-2. Average commercial landings, pounds, and value for nearshore finfish species over years 1989–1999, all gears except trawl.

Port area	Average pounds	Average value ($)	Maximum pounds	Maximum value ($)	Average price/pound ($)
Eureka	532,033	307,324	1,265,270	630,733	0.58
Fort Bragg	734,402	606,060	1,840,338	1,255,252	0.83
Bodega Bay	232,582	189,761	457,413	346,121	0.82
San Francisco	311,855	345,948	696,561	753,339	1.11
Monterey	326,730	306,767	818,007	761,975	0.94
Morro Bay	649,702	1,057,894	1,305,903	2,122,196	1.63
Santa Barbara	511,007	1,077,989	999,544	2,140,046	2.11
Los Angeles	202,665	393,549	582,945	1,014,974	1.94
San Diego	127,442	212,469	345,815	520,265	1.67
Totals	**3,628,421**	**$4,497,761**	**8,311,796**	**$9,544,900**	

Source: CDFG 2002.

.

4.0 Larval Entrainment Studies

4.1 Introduction

The purpose of this study was to evaluate the potential impacts of the CDF's feedwater intake system that will withdraw a maximum of 106 MGD from the EPS cooling discharge flow. Although this study was not required by rule or regulation, it was undertaken in consideration of water code Section 13142(d).[2] The feedwater entrainment study focused on effects on larval fishes, Cancer crab megalops, and spiny lobster (*Panulirus interruptus*) larvae found in the EPS cooling water discharge after they had passed through the mesh traveling screens and were entrained by the power station's CWIS.

The CDF entrainment study was designed to specifically address the following questions:

- What are the species composition and abundance of larval fishes, Cancer crabs, and spiny lobster in the EPS cooling water discharge flow that could be entrained through the CDF feedwater intake, and

- How might any losses due to feedwater entrainment affect the source populations of the entrained species in Agua Hedionda Lagoon and the southern reaches of the Southern California Bight?

- Are these losses ecologically or economically significant?

4.2 Methods

4.2.1 In-Plant Entrainment and Survival Sampling

Samples were collected from EPS's discharge conduit just before the water flows into the power station's discharge pond. The samples were collected by pumping water through 4-inch diameter piping, a calibrated flow meter, and a recessed impeller pump. The pumped water was diverted either into a 335-µm (0.013-in.) mesh plankton net suspended in a tank or into a larval table which had a large panel constructed of 335-µm mesh net. The table was designed to allow collection of larvae in a low-flow system to minimize potential damage from abrasion so that larval survival could be assessed. The water was pumped into the larval table for 15 minutes and

[2] Water Code Section 13142(d) provides that "Independent baseline studies of the existing marine system should be conducted in the area that could be affected by a new or expanded industrial facility using seawater in advance of the carrying out of the development."

was then diverted into the tank for the next 30-minute period. Material collected in the tank was immediately preserved and returned to the laboratory for processing. During the first two surveys, samples were collected continually from about 16:30 hours until midnight; surveys 3–5 were collected over a 24-hour period. The number of larvae collected from both methods were used to determine composition and abundance of taxa in the samples.

After the 15-minute collection period, the water in the larval table was drained and all material was sorted to remove fish larvae. Initial observations of larval fish survival were recorded immediately after collection. All fish larvae that were alive were placed into numbered collection chambers and their condition for a period of at least 2 hours was monitored. The remaining sample material and any larvae that did not survive were preserved and returned to the laboratory for processing; larvae that were monitored were ultimately preserved and returned to the laboratory for identification.

4.2.2 Source Water Sampling

The EPS source water was partitioned into lagoon and nearshore sub-areas for modeling purposes; ten stations were chosen so that all source water community types would be represented. A total of five lagoon stations covering a depth of approximately 2–9 m (7–30 ft) were sampled; two within Inner Lagoon (L3 and L4), one within Middle Lagoon (L2), and two within Outer Lagoon (L1 and E1) (**Figure 4-1**). Five nearshore stations (N1–N5) covering a depth range of approximately 5–30 m (16–98 ft) were also sampled (**Figure 4-1**).

Sample collection methods for the deeper water nearshore (N1–N5) and Outer Lagoon (L1 and E1) stations were similar to those developed and used by the California Cooperative Oceanic and Fisheries Investigation (CalCOFI) in their larval fish studies. Two 335-µm mesh plankton nets with codends and flow meters were attached to a bongo net frame with two 0.71 m (2.33 ft) diameter openings. The nets were lowered from a boat as close to the bottom as practicable without contacting the substrate. Once the nets were near the bottom, the boat was moved forward and the nets retrieved at an oblique angle (winch cable at approximately a 45° angle) to sample the widest strata of water depths possible. The total time of each tow was approximately two minutes at a speed of about 1 knot. The volume of water filtered through each of the two nets was about 30 m^3 (1,060 ft^3). Once the nets were retrieved from the water, all of the material was rinsed into the codends, combined in a single labeled jar, and preserved in 10 percent formalin. Each sample was given a serial number based on the location, date, time, and depth of collection; this information was recorded on a sequentially numbered data sheet. The serial number was used to track the sample through laboratory processing, data analyses, and reporting.

Concurrent surface water temperatures and salinities measured with a digital probe at each station. A replicate tow was conducted at Station E1 in the same manner described above.

Sample collection methods were modified for sampling in the shallow source water areas of the Inner and Middle lagoons. Due to the shallow depth at the Inner Lagoon stations (L3 and L4) and the Middle Lagoon station (L2), samples were collected using a single plankton net that was suspended in the water off the front of a small boat. This net collected plankton from the upper 1.5 meters of the water column. During some lower tide periods the bottom of the net was about 1 meter from the lagoon bottom at some of these stations. Sample preservation and labeling was also identical for these samples.

All samples were collected over a 24-hour period, with each period divided into four 6-hour sampling cycles. All sources water samples were collected during the same four 6-hour periods as the CDF in-plant entrainment samples.

4.2.3 Laboratory Analysis

Laboratory processing consists of sorting (removing), identifying, and enumerating all larval fishes, megalopal stages of *Cancer* spp. crabs, and California spiny lobster larvae (phyllosome and puerulus stages) from the samples. Identification of larval fishes was done to the lowest taxonomic level practicable. Sorting and identification accuracy is verified and maintained by Tenera Environmental's quality control (QC) program. The identification of problematic specimens was verified by outside taxonomic experts. All field and laboratory data were entered into an Access® computer database that was verified for accuracy against the original data sheets.

4.3 Taxon Profiles

Based on abundances of larvae from the present study and those from an earlier entrainment study of larval fishes in the vicinity of EPS (SDG&E 1980), three taxa were chosen for detailed examination of entrainment effects: CIQ goby complex, combtooth blennies, and northern anchovy. The natural history and life history parameters of these taxa are described in the following sections as background for interpreting the results of the entrainment data.

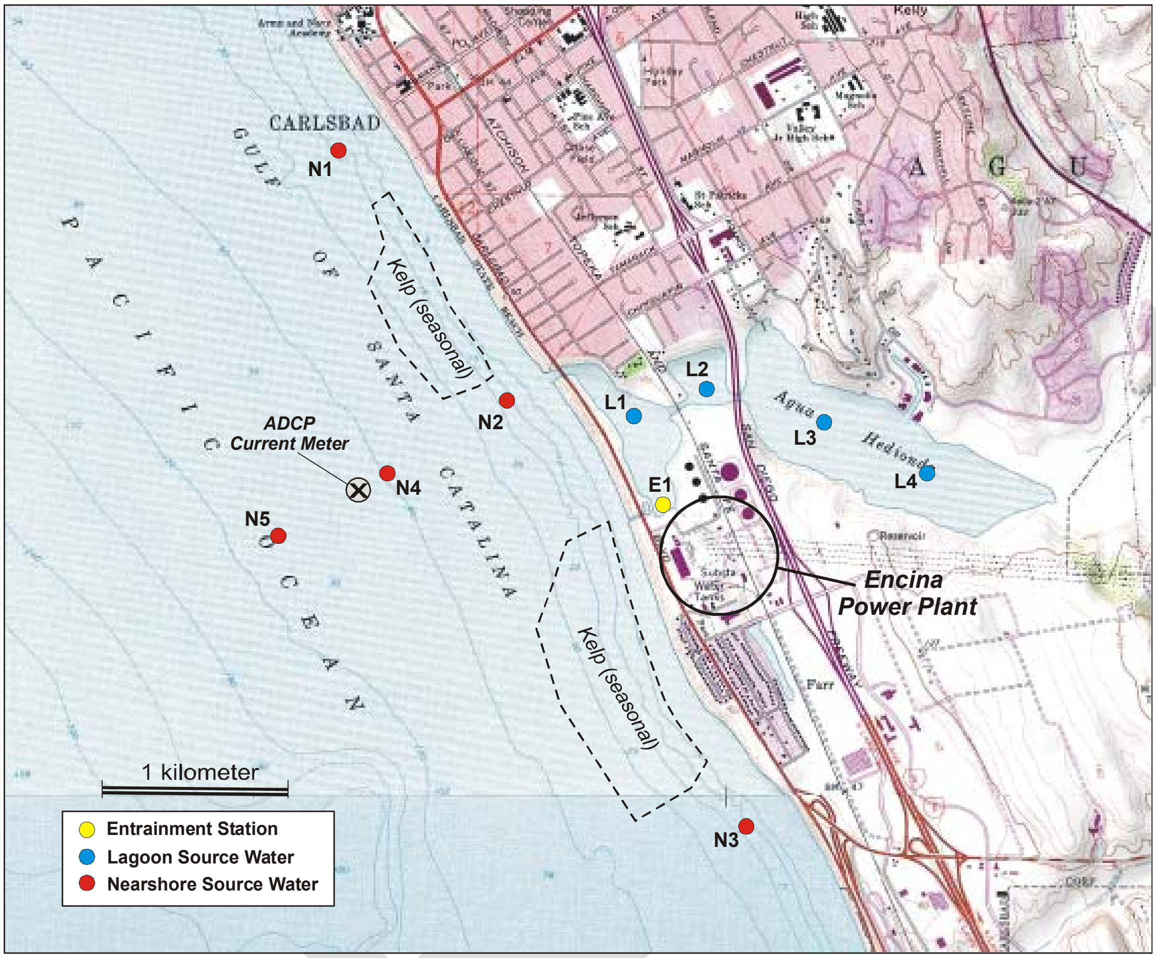
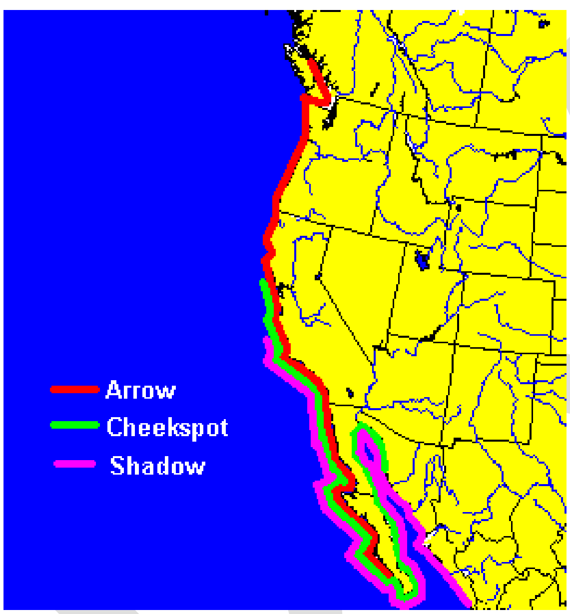


Figure 4-1. Source water plankton sampling stations including EPS entrainment station.

4.3.1 CIQ Goby Complex (*Clevelandia ios, Ilypnus gilberti, Quietula y-cauda*)



Distribution map for CIQ gobies.

Range: Vancouver Island, British Columbia to Gulf of California.

Life History: Size up to 50 mm (2 in);
Age at maturity from 0.7–1.5 yr;
Life span ranges from <3 yr (arrow goby) to 5 yr (shadow goby);
Spawns year-round in bays and estuaries; demersal, adhesive eggs with fecundity from 225–1,400 eggs per female with multiple spawning 2–5 per yr;
Juveniles from 14.0–29.0 mm are less than 1 yr old.

Habitat: Mud and sand substrates of bays and estuaries; commensally in burrows of shrimps and other invertebrates.

Fishery: None.

Gobies belong to a speciose family (Gobiidae) of small, demersal fishes that are found worldwide in shallow tropical and subtropical environments. The family contains approximately 1,875 species in 212 genera (Nelson 1994, Moser et al. 1996). Twenty-one goby species from 16 genera occur from the northern California border to south of Baja California (Moser et al. 1996) and six species were found in San Diego Bay during a five-year study (Allen 1999).

Members of the goby family share a variety of distinguishing characteristics. Their body shape is elongate and can be either somewhat compressed or depressed (Moser et al. 1996). Most members of the family lack both a lateral line and swim bladder (Moyle and Cech 1988). Gobies generally have two dorsal fins, the first consisting of 2–8 flexible spines and the second containing a spine and several segmented rays. Their caudal fin is rounded and their pelvic fins are typically joined to form a cup-like disc (Moser et al. 1996). The eyes of most gobies are relatively large and are a dominant feature of their blunt heads. Goby species are extremely variable in coloration. They range from the drab, cryptically colored species that inhabit mudflats to the striking, brightly colored species of tropical and subtropical reefs (Moser et al. 1996).

One of the most important characteristics of the goby family is their small size (1 to 3 inches). Due to their size and evolved tolerances for a variety of environmental conditions, gobies have been able to colonize habitats that are inaccessible to most other fishes. These include cracks and crevices in coral reefs, invertebrate burrows, mudflats, mangrove swamps, freshwater streams on oceanic islands, and inland seas and estuaries (Moyle and Cech 1988).

Three species of goby make up the CIQ complex: arrow goby *Clevelandia ios,* cheekspot goby *Ilypnus gilberti,* and shadow goby *Quietula y-cauda* (CIQ for *Clevelandia*, *Ilypnus* and *Quietula*). Arrow goby *Clevelandia ios* occupy the most northerly range of the three species, occurring from Vancouver Island, British Columbia to Baja California (Eschmeyer et al. 1983). The reported northern range limits of both cheekspot goby *Ilypnus gilberti* and shadow goby *Quietula y-cauda* are in central California with sub-tropical southern ranges that extend well into the Gulf of California (Robertson and Allen 2002). Their physiological tolerances reflect their geographic distributions with arrow goby being less able to withstand warmer temperatures compared to cheekspot goby. When exposed to temperatures of 32.1°C for three days in a laboratory experiment, no arrow goby survived but 95 percent of cheekspot goby survived (Brothers 1975). Gobies exposed to warm temperatures on mudflats can seek refuge in their burrows where temperatures can be several degrees cooler than surface temperatures.

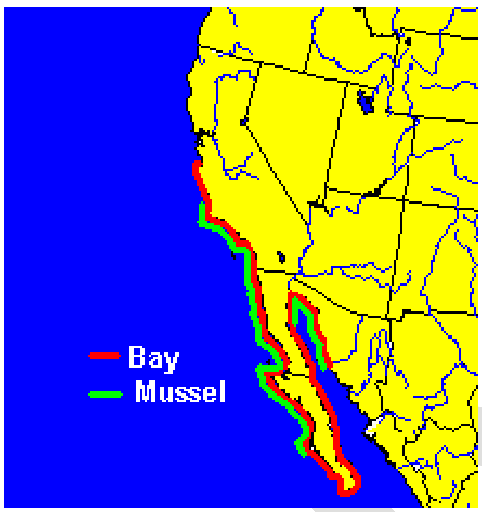
All three species have overlapping ranges in the San Diego region and occupy similar habitats. Arrow, cheekspot, and shadow gobies are all present in Agua Hedionda Lagoon (MEC 1995). The life history of the arrow goby was reviewed by Emmett et al. (1991) and the comparative ecology and behavior of all three species were studied by Brothers (1975) in Mission Bay, approximately 44 km (27.3 mi) south of Agua Hedionda Lagoon. Arrow goby is the most abundant of the three species in bays and estuaries from Tomales Bay to San Diego Bay, including Elkhorn Slough (Calliet et al. 1977), Anaheim Bay (MacDonald 1975) and Newport Bay (Allen 1982). The species inhabits burrows of ghost shrimps *Neotrypnea* spp. and other burrowing invertebrates. In a 5-year study of fishes in San Diego Bay, approximately 75 percent of the estimated 4.5 million (standing stock) gobies were juveniles (Allen et al. 2002).

Myomere counts, gut proportions, and pigmentation characteristics can be used to identify most fish larvae to the species level. However, the arrow, cheekspot, and shadow gobies cannot be differentiated with complete confidence at most larval stages (Moser et al. 1996). Therefore, larval gobies that could not be identified to the species level were grouped into the unidentified "CIQ" goby complex. Some larger larval specimens with well-preserved pigmentation patterns could be identified to the species level (W. Watson, Southwest Fisheries Science Center, pers. comm.).

The reproductive biology is similar among the three species. Arrow goby typically mature sooner than the other two species, attaining 50 percent maturity in the population after approximately 8 months as compared to 16–18 months for cheekspot and shadow gobies. Mature females for all three of these species are oviparous and produce demersal eggs that are elliptical in shape, typically adhesive, and attached to a nest substratum at one end (Matarese et al. 1989, Moser et al. 1996). Hatched larvae are planktonic and the duration of the planktonic stage was estimated at 60 days for populations in Mission Bay (Brothers 1975). Arrow goby mature more quickly and spawn a greater number of eggs at a younger age than either the cheekspot or shadow gobies. Fecundity is dependent on age and size of the female. For the Mission Bay populations of gobies, Brothers (1975) found that measured fecundity ranged from 225–750 eggs per batch for arrow goby (depending on adult size), 225–1,030 eggs for cheekspot, and 340–1,400 for shadow, for a mean value of 615 per batch for the complex. Mature females for the complex deposit 2–5 batches of eggs per year.

Larvae from the CIQ gobiid complex hatch at a size of 2–3 mm (Moser et al. 1996). Data from Brothers (1975) were used to estimate an average growth rate of 0.16 mm/d for the approximately 60-day period from hatching to settlement. Brothers (1975) estimated a 60-day larval mortality of 98.3 percent for arrow goby larvae, 98.6 percent for cheekspot, and 99.2 percent for shadow. These values were used to estimate average daily survival at 0.93 for the three species. Once the larvae transform at a size of approximately 10–15 mm SL, depending on the species (Moser et al. 1996), the juveniles settle into the benthic environment. For the Mission Bay populations mortality following settlement was 99 percent per year for arrow goby, 66–74 percent for cheekspot goby, and 62–69 percent for shadow goby. Few arrow goby in the Mission Bay study exceeded 3 years of age based on otolith records, whereas cheekspot and shadow gobies commonly lived for 4 years (Brothers 1975).

4.3.2 Combtooth Blennies (*Hypsoblennius* spp.)



Distribution map for combtooth blennies.

Range: Bay blenny terey Bay to Gulf of California.
Mussel blenny—Mor Magdalena Bay, ia California and the nor ulf of California.

Size: bay blenny to 15 cm (5.9 in), nussel cm (5.1 in);
Age at species 0.5 yr;
ife bay bl y 6 yr., mussel blenny 5 yr.
ty: bay blenny 300–3,000 eggs, mussel 200–2,000 eggs.

H: Bay blenny—soft bottom in bays and estu , associated with submerged aquatic vege ation and mussels on mooring buoys; to a depth of 9 m (30 ft),
Mussel blenny—empty worm tubes and barnacle tests on pilings, mussel beds, crevices in shallow rock reefs; to 12 m (40 ft).

Fishery: No commercial or recreational fishery.

Combtooth blennies are a prominent group among the subtropical and tropical fish fauna that inhabit inshore rocky habitats throughout much of the world. They are members of the family Blenniidae within the order Blennioidei. The family Blenniidae, the combtooth blennies, contains about 345 species in 53 genera (Nelson 1994, Moser 1996). They derive their common name from the arrangement of closely spaced teeth in their jaws.

Combtooth blennies are all relatively small fishes that typically grow to a total length of less than 200 mm (7.9 in.) (Eschmeyer et al. 1983). Most have blunt heads that are topped with some arrangement of cirri (Moyle and Cech 1988). Their bodies are generally elongate and without scales. Dorsal fins are often continuous and contain more soft rays than spines. Coloration in the group is quite variable, even among individuals of the same species.

Blennies inhabit a variety of hard substrates in the intertidal and shallow subtidal zones of tropical and subtropical marine habitats throughout the world. They may occur to depths of 24 m (80 ft) but are more frequently found in water depths of less than 5 m (15 ft) (Love 1996). Combtooth blennies are common in rocky tidepools, reefs, breakwaters, and on pier pilings. They are also frequently observed on encrusted buoys and boat hulls. Combtooth blennies are omnivores and eat both algae and a variety of invertebrates, including limpets, urchins, and bryozoa (Stephens 1969, Love 1996).

Combtooth blennies are represented along the California coast by three members of the genus *Hypsoblennius*: bay blenny *H. gentilis*, rockpool blenny *H. gilberti*, and mussel blenny *H. jenkinsi*. These species co-occur throughout much of their range although they occupy different habitats. The bay blenny is found along both coasts of Baja California and up the California coast to as far north as Monterey Bay (Miller and Lea 1972, Robertson and Allen 2002). The rockpool blenny occurs from Magdalena Bay, Baja California to Point Conception, California (Miller and Lea 1972, Stephens et al. 1970). The range of the mussel blenny extends from Morro Bay to Magdalena Bay, Baja California and in the northern Gulf of California (Tenera 2001, Robertson and Allen 2002). In Agua Hedionda Lagoon the only *Hypsoblennius* species recorded is the bay blenny, although the sampling methods did not include inspections of piling habitats and aquaculture floats where mussel blennies would be expected. No rockpool blenny habitat occurs in the lagoon, so the *Hypsoblennius* spp. complex designation in the present study was used to describe only bay and mussel blenny species.

Mussel and bay blennies have different habitat preferences. The mussel blenny is only found subtidally and inhabits mussel beds, the empty drill cavities of boring clams, barnacle tests, or in crevices among the vermiform snail tubes *Serpulorbis* spp. (Stephens 1969, Stephens et al. 1970). They generally remain within one meter of their chosen refuge (Stephens et al. 1970). The bay blenny is usually found subtidally but appear to have general habitat requirements and may inhabit a variety of intertidal and subtidal areas (Stephens et al. 1970). They are commonly found in mussel beds and on encrusted floats, buoys, docks, and even fouled boat hulls (Stephens 1969, Stephens et al. 1970). Bay blenny are often found in bays and are tolerant of nearly estuarine conditions. They are among the first fish species to colonize new or disturbed marine habitats such as new breakwaters or mooring floats after recolonization by attached invertebrates (Stephens et al. 1970, Moyle and Cech 1988).

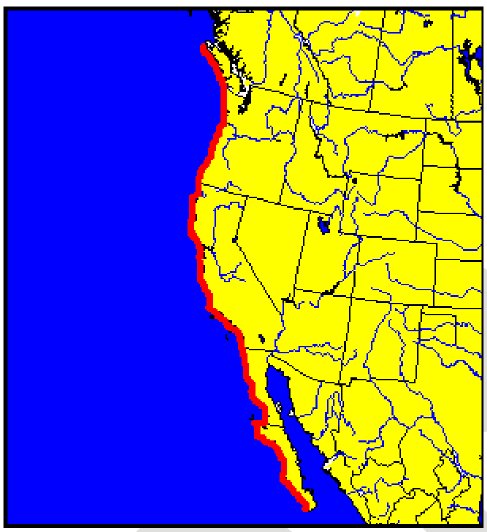
Bay blenny grow to a slightly larger size and live longer than mussel blenny, reaching a size of 15 cm (5.9 in.) and living for 6–7 years (Stephens 1969, Stephens et al. 1970, Miller and Lea 1972). Mussel blenny grow to 13 cm (5.1 in.) and have a life span 3–6 years (Stephens et al. 1970, Miller and Lea 1972). Male and female growth rates are similar. Female blennies mature quickly and reproduce within the first year, reaching peak reproductive potential in the third year

(Stephens 1969). The spawning season typically begins in the spring and may extend into September (Stephens et al. 1970). Blennies are oviparous and lay demersal eggs that are attached to the nest substrate by adhesive pads or filaments (Moser et al. 1996). Males are responsible for tending the nest and developing eggs. Females spawn 3–4 times over a period of several weeks (Stephens et al. 1970). Males guard the nest aggressively and will often chase the female away, however, several females may occasionally spawn with a single male. The number of eggs a female produces varies proportionately with size (Stephens et al. 1970). The mussel blenny spawns approximately 500 eggs in the first reproductive year and up to 1,500 eggs by the third year (Stephens et al. 1970). Total lifetime fecundity may be up to 7,700 eggs (Stephens 1969).

Larvae are pelagic and average 2.7 mm (0.1 in.) in length two days after hatching at a size of 2.3–2.6 mm (0.9–1.0 in.) (Stephens et al. 1970, Moser 1996). The planktonic phase for *Hypsoblennius* spp. larvae may last for 3 months (Stephens et al. 1970, Love 1996). *Hypsoblennius* larvae are visual swimmers (Ninos 1984). Captured larvae released by divers have been observed to use surface water movement and near-surface currents to aid swimming. After release the swimming larvae orient to floating algae, bubbles on the surface, or the bottoms of boats or buoys. The overall swimming speed was measured at 17 cm/s (0.33 kt) for rockpool blenny and 14.8 cm/s (0.28 kt) for mussel blenny (Ninos 1984). Size at settlement ranges from 12–14 mm (0.5–0.6 in). After the first year mussel and bay blennies averaged 40 and 45 mm (1.6 and 1.8 in.) total length, respectively (Stephens et al. 1970).

Stephens (1969) estimated the survival for mussel blenny from egg to settling (50 days) at 0.31. This is a rough estimate based on assumptions of population size and fecundity. To check the estimate we recalculated mortality for half year intervals using the predicted age group abundance based on 1,284 fish in Stephens (1969) study. Blenny daily larval survival was estimated as 0.8875 using a computed adult daily survival from Stephens (1969) of 0.9983. Adult survival was computed by fitting an exponential mortality function to observed field abundances of ages 0.52, 1, 2, 3, 4, 5, and 6 yr fish. The larval survival was then estimated using N_0 equal to the estimated lifetime fecundity of 3,281. A larval growth rate of 0.198 mm/d for mussel blenny was determined by regression of the growth equation; $Y_t = 1.2845\ e^{3.92*(1-e^\wedge -0.0177t)}$ (Stevens and Moser 1982) determined for 300+ days growth to 60–65 mm SL.

4.3.3 Northern Anchovy (*Engraulis mordax)*



Distribution map for northern anchovy.

Range: From British C[illegible] to southern Baja.

[illegible]ry: Size: to 229 mm (9 in.); Size at maturity: 152 [illegible] Fecundity: spawn 2 to 3 times a year, [illegible]leasin[illegible] 16,000 eggs per batch; Life [illegible] years.

[illegible]t: Pelagic; found in surface waters down to depths o[illegible] m (1,000 ft).

Fis[illegible]. Commercial fishery for reduction, human cons[illegible]mption, live bait, dead bait.

The northern anchovy is one of the approximately 139 engraulids in the family Engraulidae (the anchovies) that occur in the CalCOFI study area (Moser 1996). The CalCOFI study area covers more than one million square kilometers between the Oregon-California border and the tip of Baja California extending from around 3–400 nautical miles offshore (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 U.S. (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 animals 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 110–130 mm (4.3–5.12 in.) TL, with all individuals maturing by four years of age and 152 mm (6 in.) TL (Clark and Phillips 1952, 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 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 six to ten 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 indicates an annual range of 20,000–30,000 eggs per female (Baxter 1967). More recent data from Love (1996) indicate that females can release from 2,700–16,000 eggs per batch, with annual fecundity as high as 130,000 eggs in southern California and around 35,000 eggs per year 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 20,000–30,000 eggs for a one-year old female to more than 320,000 for a five-year old. The eggs hatch within 2–4 days, depending on the water temperature, and release 2.5–3.0 mm (0.10–0.12 in.) long relatively undeveloped larvae (Hart 1973, Moser 1996) that begin schooling at 11–12 mm (0.4–0.5 in.) and transform into juveniles at 35–40 mm (1.4–1.6 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.

This species is collected for both live bait and also for reduction (to make fish meal, oil, and paste). This species is the most important bait fish in southern California, and is also used in Oregon and Washington as bait for sturgeon (*Acipenser* spp.), salmonids (*Oncorhynchus* spp.), and other species (Emmett et al. 1991).

Northern anchovy is part of the coastal pelagic species (CPS) group that is managed under the Pacific Council's CPS fishery management plan (FMP). Northern anchovy are divided into northern, central and southern sub-populations. The central sub-population used to be the focus of large commercial fisheries in the U.S. and Mexico. Most of this sub-population is located in the Southern California Bight, between Point Conception, California and Point Descanso, Mexico.

California landings of northern anchovy reported by Pacific Coast Fisheries Information Network (PacFIN) totaled 11,752 mt in 2000; 9,187 mt in 2001; and 4,650 mt in 2002. In the San Diego region, northern anchovy landings for 2002 and 2003 were 5 and 14 mt valued at $3,150 and $8,103 respectively. The Orange/Los Angeles County landings for the same years were 1,206 and 206 mt valued at $103,315 and $30,645 respectively.

4.4 Sampling Results

The following sections present results for larval fishes and target invertebrates collected during two in-plant surveys and three source water surveys conducted during June and July 2004. It should be noted that the spring and summer months represent the period of greatest larval abundance for many fishes and therefore any annual mean abundances calculated from our spring-summer data would be overestimates. During the rest of the year, the larval abundance is expected to be significantly lower. The species composition occurring in the source water area is not expected to change substantially though the year. Results are also presented for eleven larval fish survival studies conducted from June through November 2004.

4.4.1 In-Plant Larval Abundance Estimates

A total of 1,648 fish larvae was collected during two in-plant surveys conducted on June 16 and July 6, 2004 (**Table 4-1**). Four taxa comprised 95 percent of all of fish larvae in the EPS discharge flows from which the proposed CDF would withdraw its feedwater supply. They were combtooth blennies, CIQ gobies, labrisomid kelpfishes, and garibaldi. Gobies and blennies combined accounted for nearly 72 percent of the larvae identified in the discharge flows.

Species with high commercial and recreational importance, such as California halibut, were shown to be very uncommon in the EPS intake flows. Target invertebrate larvae were not collected in the in-plant samples. Data from each in-plant survey are shown in **Appendix A, Table A-1**.

Table 4-1. Total counts and mean concentrations (#/1,000 m^3) of larval fishes from in-plant surveys collected June 16 and July 6, 2004.

Taxon	Common Name	Total Count	Percent	Cum. Percent	Mean Concentration (#/1,000 m^3)
Hypsoblennius spp.	combtooth blennies	766	46.48%	46.48%	1,119.89
CIQ gobies	CIQ goby complex	426	25.85%	72.33%	630.94
Labrisomidae unid.	labrisomid kelpfishes	205	12.44%	84.77%	291.66
Hypsypops rubicundus	garibaldi	174	10.56%	95.33%	230.14
Rimicola spp.	kelp clingfishes	13	0.79%	96.12%	17.54
Gibbonsia spp.	clinid kelpfishes	12	0.73%	96.84%	16.38
Engraulidae	anchovies	12	0.73%	97.57%	15.83
Gobiesocidae unid.	clingfishes	8	0.49%	98.06%	10.15
Sciaenidae	croakers	8	0.49%	98.54%	11.38
Blennioidei	blennies	7	0.42%	98.97%	9.21
Atherinopsidae	silversides	6	0.36%	99.33%	7.36
larval/post-larval fish unid.		3	0.18%	99.51%	3.50
Heterostichus rostratus	giant kelpfish	1	0.06%	99.58%	1.14
Syngnathus spp.	pipefishes	1	0.06%	99.64%	0.92
Paralichthys californicus	California halibut	1	0.06%	99.70%	1.28
Chaenopsidae unid.	clinids	1	0.06%	99.76%	0.92
Labridae	wrasses	1	0.06%	99.82%	1.28
larvae, unidentified yolksac		1	0.06%	99.88%	2.45
Typhlogobius californiensis	blind goby	1	0.06%	99.94%	1.96
Agonidae unid.	poachers	1	0.06%	100.00%	2.19
Total		1,648			

4.4.2 Source Water Larval Abundance Estimates

This section presents the data collected from three source water surveys conducted on June 10, June 24, and July 6, 2004. The source water sampling was divided into lagoon and nearshore station groups. A total of 27,029 larval fishes was collected from all surveys and source water stations combined (**Table 4-2**). Two taxa comprised 84 percent of the total number of larval fishes collected from all surveys and source water stations combined: CIQ gobies (65 percent) and combtooth blennies (19 percent). Data for each of the three source water surveys are shown in **Appendix A, Table A-2**.

A total of 22,279 fish larvae was collected from all lagoon stations and surveys combined (**Table 4-2**). CIQ gobies and combtooth blennies comprised approximately 94 percent of the total number of larvae collected. The mean concentration of CIQ goby larvae from all stations and surveys combined was approximately 4,900/1,000 m^3 and the mean concentration of combtooth blennies was approximately 1,200/1,000 m^3 (**Table 4-2**). Two larval spiny lobsters were also collected in the samples; no other target invertebrate larvae were collected.

Nearshore stations had a greater number of taxa than the lagoon stations although the total number of larval fishes at the nearshore stations (*n* = 4,750) was significantly less than the total number at the lagoon stations (*n* = 22,279) (**Table 4-2**). Combtooth blennies were the most abundant taxon at nearshore stations, followed by croakers, anchovies, unidentified yolksac larvae, and California halibut. The category of unidentified yolksac larvae which ranked fourth in the nearshore samples was comprised of several species of larvae in the size range of 1.5–2.0 mm in length from the families Labridae, Serranidae, Haemulidae, and Scombridae. Four species of target invertebrates were collected in the samples: California spiny lobster (*n* = 93), yellow rock crab (*Cancer anthonyi*, *n* = 31), brown rock crab (*Cancer antennarius*, *n* = 4), and slender crab (*Cancer gracilis*, *n* = 2).

A comparison among areas showed that anchovies and croakers were more abundant in the nearshore samples (**Figure 4-2**). CIQ gobies, which were very abundant in the lagoon and in-plant samples, were one to two orders of magnitude less abundant in the nearshore samples (**Figure 4-2**).

Table 4-2. Total counts and mean concentrations (#/1,000 m^3) of larval fishes and target invertebrates from source water surveys collected June 10, June 24, and July 6, 2004.

Taxon	Common Name	Total Count	Percent	Cum. Percent	AH Lagoon Mean Concentration (#/1,000 m3)	AH Count	Nearshore NS Mean Concentration (#/1,000 m3)	NS Count
CIQ gobies.	CIQ goby complex	17,674	65.39%	65.39%	4,898.44	17,417	74.32	257
Hypsoblennius spp.	combtooth blennies	5,061	18.72%	84.11%	1,197.05	3,616	421.71	1,445
Engraulidae	anchovies	906	3.35%	87.47%	82.54	281	158.15	625
Sciaenidae unid.	croakers	817	3.02%	90.49%	26.75	87	209.31	730
larvae, unidentified yolksac		516	1.91%	92.40%	13.37	40	132.66	476
Labrisomidae unid.	labrisomid kelpfishes	510	1.89%	94.28%	98.89	330	56.08	180
Hypsypops rubicundus	garibaldi	455	1.68%	95.97%	114.96	352	27.93	103
Paralichthys californicus	California halibut	282	1.04%	97.01%	1.21	4	80.86	278
Paralabrax spp.	sand basses	176	0.65%	97.66%	0.00	0	47.55	176
Scomber japonicus	Pacific mackerel	81	0.30%	97.96%	0.50	1	21.32	80
Syngnathus spp.	pipefishes	68	0.25%	98.21%	20.26	64	1.06	4
Gibbonsia spp.	clinid kelpfishes	65	0.24%	98.45%	6.58	20	13.64	45
larval/post-larval fish unid.		53	0.20%	98.65%	0.53	2	14.78	51
Sphyraena argentea	California barracuda	43	0.16%	98.81%	0.00	0	11.08	43
Citharichthys stigmaeus	speckled sanddab	33	0.12%	98.93%	0.30	1	9.24	32
Oxyjulis californica	senorita	32	0.12%	99.05%	0.53	2	8.16	30
Xenistius califoriensis	salema	31	0.11%	99.16%	0.00	0	8.61	31
Rimicola spp.	kelp clingfishes	24	0.09%	99.25%	6.66	22	0.65	2
Peprilus simillimus	butterfish	21	0.08%	99.33%	0.00	0	5.81	21
Haemulidae	grunts	19	0.07%	99.40%	0.00	0	4.72	19
Genyonemus lineatus	white croaker	18	0.07%	99.47%	0.48	2	4.47	16
Atherinopsidae	silversides	17	0.06%	99.53%	4.59	17	0.00	0
Typhlogobius californiensis	blind goby	17	0.06%	99.59%	4.08	12	1.35	5
Xystreurys liolepis	fantail sole	14	0.05%	99.64%	0.62	2	3.71	12
Pleuronichthys verticalis	hornyhead turbot	13	0.05%	99.69%	0.00	0	3.28	13
Trachurus symmetricus	jack mackerel	13	0.05%	99.74%	0.00	0	3.13	13
Sardinops sagax	Pacific sardine	12	0.04%	99.79%	0.00	0	3.35	12
Semicossyphus pulcher	California sheephead	8	0.03%	99.82%	0.17	1	1.76	7
Labridae	wrasses	7	0.03%	99.84%	0.00	0	2.28	7
Paraclinus spp.	blenny	7	0.03%	99.87%	0.00	0	1.42	7
Pleuronichthys ritteri	spotted turbot	4	0.01%	99.88%	0.00	0	1.14	4
Blennioidei	blennies	3	0.01%	99.89%	0.56	2	0.35	1
Diaphus theta	California headlight fish	3	0.01%	99.90%	0.00	0	0.80	3
Girella nigricans	opaleye	3	0.01%	99.91%	0.00	0	0.72	3
Gobiesox spp.	clingfishes	3	0.01%	99.93%	1.03	3	0.00	0
Heterostichus rostratus	giant kelpfish	3	0.01%	99.94%	0.27	1	0.80	2
Clupeiformes	herrings and anchovies	2	0.01%	99.94%	0.00	0	0.64	2
Medialuna californiensis	halfmoon	2	0.01%	99.95%	0.00	0	0.56	2
Paralichthyidae unid.	flatfishes	2	0.01%	99.96%	0.00	0	0.35	2
Pleuronichthys spp.	turbots	2	0.01%	99.97%	0.00	0	0.45	2
Anisotremus davidsonil	sargo	1	<0.01%	99.97%	0.00	0	0.22	1
Citharichthys sordidus	longfin sanddab	1	<0.01%	99.97%	0.00	0	0.28	1
Citharichthys spp.	sanddabs	1	<0.01%	99.98%	0.00	0	0.28	1
Clinidae unid.	clinid kelpfishes	1	<0.01%	99.98%	0.00	0	0.33	1
Clupeidae unid.	herrings	1	<0.01%	99.99%	0.00	0	0.24	1
Gobiesocidae unid.	clingfishes	1	<0.01%	99.99%	0.00	0	0.29	1
Halichoeres semicinctus	rock wrasse	1	<0.01%	99.99%	0.00	0	0.27	1
Myctophidae unid.	lanternfishes	1	<0.01%	100.00%	0.00	0	0.40	1
Triphoturus mexicanus	Mexican lampfish	1	<0.01%	100.00%	0.00	0	0.28	1
	Total	27,029				22,279		4,750
Invertebrates								
Panulirus interruptus (phyllosome)	California spiny lobster	93	71.54%	71.54%	0.61	2	28.14	91
Cancer anthonyi (megalops)	yellow crab	31	23.85%	95.38%	0.00	0	8.35	31
Cancer antennarius (megalops)	brown rock crab	4	3.08%	98.46%	0.00	0	1.27	4
Cancer gracilis (megalops)	slender crab	2	1.54%	100.00%	0.00	0	0.45	2
	Total	130				2		128

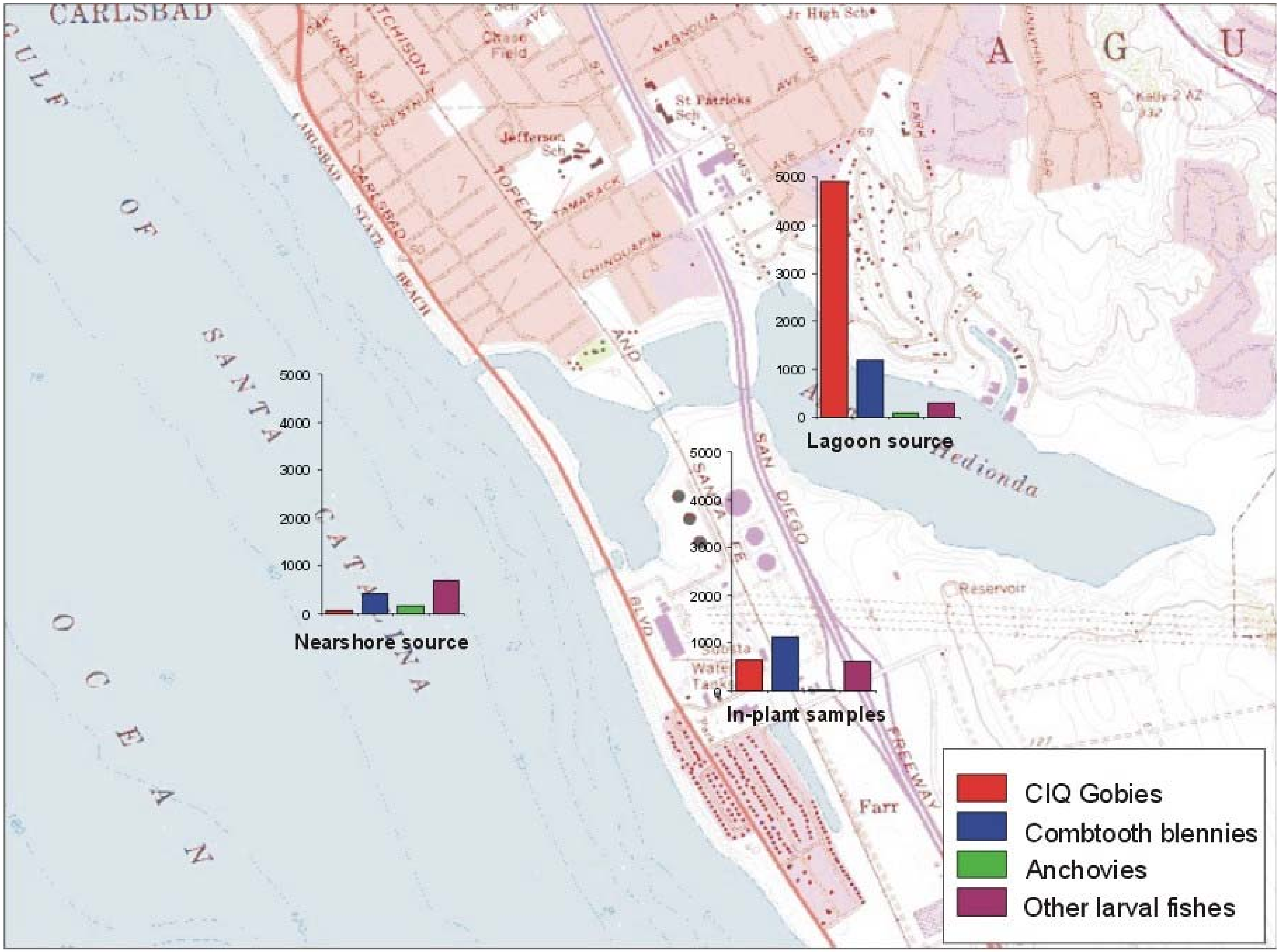


Figure 4-2. Comparison of larval fish concentrations among sampling areas in June and July 2004.

4.4.3 In-Plant Larval Survival Results

Eleven surveys to estimate the survival of larval fishes in the EPS discharge flow were conducted from June through November 2004. Surveys conducted on June 16 and July 6 were completed during late afternoon and evening hours. Beginning with the July 20, 2004 survey, samples were collected over a continuous 24-hour period. The average volume of water filtered per sample during surveys collected on June 16 and July 6, 2004 was 13 m^3, and the average volume of water filtered per sample for surveys collected from July 20 through November 30, 2004 was approximately 10 m^3. In general, the volume of water filtered during the larval fish survival sampling was approximately 0.0005 percent of the average volume of cooling water (550 MGD) pumped by EPS.

A total of 1,989 fishes was collected from the eleven surveys (**Table 4-3**). Larvae that were alive immediately after collection were placed in separate containers and observed for up to three hours after collection. Approximately half of the larvae continued swimming for up to two hours after collection while the others died between 0.5−1.5 hours after collection. The species of larvae that survived entrainment and sampling were CIQ gobies, combtooth blennies, and unidentified clingfishes. The highest concentration of larval fishes (2,444/1,000 m^3) was collected July 6, 2004, the lowest concentration (93/1,000 m^3) was collected on October 21, 2004.

The average survey percent survival ranged from 0 percent (November 2 survey) to 9.2 percent (November 30 survey) (**Table 4-3**). The overall average percent survival based on an average of survival data from each sample containing fish (n=223 out of a 291 total surveys) is 2.40 percent with a standard deviation of 11.22. The average percent survival based on each survey's (n=11) average survival data is 2.71 with a standard deviation of 11.24 among survival averages for the 11 surveys. The surviving larvae that enter the CDF will be retained on the desalination facility's pretreatment filters, which could be either granular media facilities or membrane filters. The retained organisms will be removed from the pretreatment filters with the filter media backwash.

Table 4-3. Summary of larval fish data collected during in-plant survival studies from EPS discharge flows during June through November 2004.

Date Collected	Number of Samples[1]	Total Volume Filtered (m^3)	Average Larval Fish Concentration (#/1,000 m^3) per Survey[2] (standard deviation in parenthesis)	Total # Larvae Collected	Total # Alive upon Collection	Average % Survival per Survey[3] (standard deviation in parenthesis)
6/16/2004	8	117	1,289.4 (754.2)	140	2	1.8 (4.7)
7/06/2004	9	112	2,443.8 (875.0)	276	13	4.3 (4.1)
7/20/2004	30	301	1,053.3 (674.6)	315	7	1.6 (4.0)
8/13/2004	30	339	564.4 (632.9)	192	2	0.005 (0.02)
8/26/2004	32	284	415.4 (350.9)	112	1	0.6 (3.2)
9/09/2004	31	342	2,027.5 (2,246.4)	590	4	0.5 (1.8)
9/23/2004	30	344	668.8 (1,134.6)	200	2	1.2 (5.5)
10/21/2004	31	347	93.0 (123.9)	31	1	5.9 (24.3)
11/02/2004	30	257	182.3 (161.9)	47	0	0
11/18/2004	30	271	132.9 (166.7)	34	2	4.6 (13.8)
11/30/2004	30	216	264.5 (291.6)	52	4	9.2 (24.2)

1. The number of samples per survey increased beginning July 20, 2004 when the duration of sampling increased to cover 24-hour periods.
2. The average larval fish concentration per survey was calculated by summing the individual sample concentrations and dividing by the number of samples in each survey.
3. The average percent survival per survey was calculated by summing the individual sample survival percentages and dividing by the number of samples containing fish larvae in each survey.

5.0 Entrainment Impact Assessment

The preliminary entrainment effects of the CDF were estimated using an assessment method developed by the U.S. Fish and Wildlife Service (Boreman et al. 1978) that Tenera has recently adapted and used for similar entrainment impact assessments at a number of California ocean- and bay-sited intake structures. These case studies include, in chronological order beginning in 1995, Diablo Canyon Power Plant, Moss Landing Power Plant, Morro Bay Power Plant, San Francisco Bay's Potrero Power Plant, and San Diego's South Bay Power Plant. Because the data are preliminary and sampling has only occurred during the summer season of 2004, the results cannot be generalized over an entire year, but are indicative of the magnitude of potential effects of water withdrawals.

In order to assess any potential effects of the desalination facility feedwater withdrawal on local fishery resources, Tenera selected three taxa: CIQ goby complex, combtooth blennies, and northern anchovy. These taxa were some of the most commonly entrained species in the CDF in-plant surveys or were species (northern anchovy) that may have been of interest to fishery managers. Larvae of species with high value to sport and commercial fisheries such as California halibut were entrained in such low numbers that any effects on source water populations of these species could not be modeled. The number of entrained halibut was approximately 0.06 percent of the total number of EPS-entrained larvae. Generally less than one percent of all fish larvae become reproductive adults, including this small percentage of entrained halibut.

The following sections describe the model, source water volume used in the model, life history data relevant to the model, and the model results. The proposed desalination facility feedwater intake cannot increase the volume of the EPS cooling water intake nor increase the number of organisms entrained or impinged by the CWIS. Therefore any potential impingement effects of the EPS are not included in assessing the CDP's intake. The assessment focuses on the effects of CDF entraining EPS-entrained organisms before they would be returned to the ocean in the cooling water discharge flow.

5.1 Entrainment Effects Model

The Empirical Transport Model (*ETM*) used in this report for assessing effects of the desalination facility is based on principles used in fishery management. To determine the effects of fishing on a population, a fishery manager needs an estimate of the number of fishes in the population and the number of fishes being *removed* by the fishery. With these two pieces of information the mortality due to fishing can be estimated as the ratio of the number caught to the number in the population. If the two estimates used to calculate the fishing mortality were daily averages, the resulting mortality estimate would be identical to the estimate of proportional entrainment (*PE*) used in the *ETM* model, which is the ratio of the entrained larvae to the larvae in the source water body. Both the fishing mortality and *PE* estimate mortality for a single day need to be expanded to estimate the total effects on the population. We can use a small lake that is stocked with 1,000 sterile fish as a simple example of how these estimates could be expanded to the population level, in this case the population of fishes in the lake. If the managers of the lake recorded the numbers of fishes caught each day at the lake and the total numbers of days fished they would be able to very easily compute the numbers of fish remaining in the lake at the end of the month assuming there were no other sources of mortality. But if they only censused the fishermen on the day after they stocked the lake with the 1,000 fish they would have to use that estimate of the number of fish caught to estimate the mortality and the number of fish in the lake at the end of the month. If they recorded that 10 fish were caught on the day of their census that would compute to a daily mortality rate due to fishing of 1 percent (10/1000 = 0.01). At the end of that day of fishing there would be 990 fish left in the lake, and the 1 percent fishing mortality would be applied on subsequent days to an increasingly diminishing population. Therefore, if fishing occurred on 20 of the 30 days during the month the estimated number of fishes left in the lake at the end of the month would be 818 ($[1-0.01]^{20}$), not 800 (1000-[20*10]).

Instead of censusing fisherman, the number of days that the larvae are subject to entrainment, or the number of days the desalination facility is operating, is estimated using the size range of the larvae entrained. This number of operating days is then combined, as shown above, with the entrainment mortality (*PE*) to estimate the total mortality due to entrainment for a study period. These estimates for each study period can then be combined to calculate the average proportional mortality due to entrainment for an entire year.

The *ETM* has been proposed by the U.S. Fish and Wildlife Service (Boreman et al. 1978) to estimate mortality rates resulting from cooling water withdrawals by power plants. The *ETM* model provides an estimate of incremental mortality (a conditional estimate in absence of other mortality [Ricker 1975]) imposed on local larval populations by using an empirical measure of proportional entrainment (*PE*) rather than relying solely on demographic calculations. Proportional entrainment (*PE*) (an estimate of the daily mortality) to the source water population from entrainment is expanded to predict regional effects on appropriate adult populations using the *ETM*, as described below.

Variations of this model have been discussed in MacCall et al. (1983) and have been used to assess impacts at a southern California power plant (Parker and DeMartini 1989). The *ETM* has also 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. Empirical transport modeling permits the estimation of 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. Tenera's *ETM* modeling approach described below uses a *PE* approach that is similar to the method described by MacCall et al. (1983) and used by Parker and DeMartini (1989) in their final report to the California Coastal Commission (Murdoch et al. 1989) for the San Onofre Nuclear Generating Station (SONGS). This estimate can then be summarized over appropriate blocks of time in a manner similar to that of the *ETM*.

The general equation to estimate *PE* for a day on which entrainment was sampled is:

$$\hat{PE} = \frac{\hat{N}_{Ei}}{\hat{N}_{Si}}$$

where

$\hat{N}_{Ei}$ = estimated number of larvae entrained during the day in survey i, calculated as (estimated density of larvae in the water entrained that day) $\times$ (design specified daily cooling water intake volume),

$\hat{N}_{Si}$ = estimated number of larvae in the source water that day in survey i (estimated density of larvae in the souce water that day) $\times$ (source water volume).

A source water volume is used because, 1) cooling water flow is measured in volume per time, and 2) biological sampling measures larval concentration in terms of numbers per sample volume. Entrained numbers of larvae are estimated using the volume of water withdrawn. A source population is similarly estimated using the source water volume. If one assumes that larval concentrations at the point of entrainment are the same as larval concentrations in the source population volume then it follows that:

$$\hat{PE} = \frac{\hat{V}_{Ei}}{\hat{V}_{Si}},$$

where

$\hat{V}_{Ei}$ = design specified daily cooling water intake volume,

$\hat{V}_{Si}$ = estimated source water volume.

The ratio of daily entrainment volume to source volume can thus serve as an estimate of daily mortality. The *PE* value is estimated for each larval duration period over the course of a year by using a source water estimate from an advection model described below.

If larval entrainment mortality is constant throughout the period and a larva is susceptible to entrainment over a larval duration of *d* days, then the proportion of larvae that escape entrainment in period *i* is:

$$(1-\hat{PE}_i)^{\hat{d}} .$$

A larval duration of 23 days from hatching to entrainment was calculated from growth rates using the length representing the upper 99th percentile of the length measurements from larval CIQ gobies collected from entrainment samples during 316(b) studies (Tenera 2004). The value for *d* was computed by dividing an estimate of growth rate into the change in length based on this 99th percentile estimate. The minimum size used for computing the larval duration was determined after removing the smallest 1 percent of the values.

It is possible that aging was biased, even though standard lengths of larval fishes (i.e., measurements of minimum, mean, and maximum), and larval growth rates were applied to estimate the ages of the entrained larvae. It was assumed that larvae shorter than the minimum length were just hatched and therefore, aged at zero days. Subsequent ages were estimated using this length. Other reported data for various species suggest that hatching length can be either smaller or larger than the size estimated from the samples, and indicate that the smallest observed larvae represent either natural variation in hatch lengths within the population or shrinkage following preservation (Theilacker 1980). The possibility remains that all larvae from the observed minimum length to the greatest reported hatching length (or to some other size) could have just hatched, leading to overestimation of ages for all larvae.

Sixteen larval duration periods over the course of a year were used to estimate larval mortality (P_M) due to entrainment using the following equation

$$\hat{P}_M = \frac{1}{16}\sum_{i=1}^{16} 1-(1-\hat{PE}_i)^{\hat{d}}$$

where

$\hat{PE}_i$ = estimate of proportional entrainment for the *i*th period and

$\hat{d}$ = the estimated number of days of larval life.

The estimate of the population-wide probability of entrainment ($\hat{PE}_i$) is the central feature of the *ETM* approach (Boreman et al. 1981, MacCall et al. 1983). If a population is stable and stationary, then $\hat{P}_M$ estimates the effects on the fully-recruited adult age classes when uncompensated natural mortality from larva to adult is assumed.

Assumptions associated with the estimation of P_M include the following:

1) lengths and applied growth rate of larvae accurately estimate larval duration,
2) a source population of larvae is defined by the region from which entrainment is possible,
3) source water volume adequately describes the population, and
4) the currents used to calculate the source water volume are representative of other years.

The ratio of daily entrainment volume to source volume will serve as an estimate of daily mortality. The *ETM* method estimates the source population using an estimate of the source volume of water from which larvae could possibly be entrained. It has been noted that if some members of the target group lie outside the sampling area, the *ETM* will overestimate the population mortality (Boreman et al. 1981).

Recent work by Largier (2003) showed the value of advection and diffusion modeling in the study of larval dispersal, which is central to the *ETM* method. Ideally, three components could be considered in estimating entrainable populations: advection, diffusion, and biological behavior. An *ad hoc* approach, developed by the Technical Working Group during the Diablo Canyon Power Plant (DCPP) 316(b) study (Tenera 2000b), modeled the three components using a single offshore current meter. For the present analysis, lagoon and coastal source water populations were treated separately. Larval populations in the Agua Hedionda lagoon were computed using the lagoon segment volumes, described below. Nearshore populations were defined using the *ad hoc* approach developed by the DCPP Technical Working Group.

5.2 Source Water Volume

Agua Hedionda Lagoon is comprised of three segments: "outer", "middle", and "inner". The lagoon segments were originally dredged to a mean depth of 2.4 m (8 ft) relative to mean water level (MWL) in 1954 (MEC 1995). The horizontal areas of the outer, middle, and inner segments at MHW are 267,000 m^2 (66 acres), 110,000 m^2 (27 acres) and 1,200,000 m^2 (295 acres), respectively (**Table 5-1**). The tidal prism of the outer segment was calculated as 246,696 m^3 (200 acre ft) and for the middle and inner segments as 986,785 m^3 (800 acre ft) (SDG&E 1980). The individual volumes of the middle and inner tidal prisms were estimated as 82,860 m^3 and 903,925 m^3 using weighting by areas. The volumes of the three segments below mean water level were computed as the volume below mean high water minus half the tidal prism (**Table 5-1**).

Table 5-1. Volumes of the outer, middle, and inner segments of the Agua Hedionda Lagoon.

	Design Depth (m re: MWL)	Area (m^2 re: MHW)	Volume (m^3 re: MHW)	Volume (MWL) (m^3 MHW-.5 Prism)
Outer	2.4	267,000	791,356	668,006
Middle	2.4	110,000	326,027	284,597
Inner	2.4	1,200,000	3,556,656	3,104,696
Total		**1,577,000**	**4,674,039**	**4,057,299**

Figure 5-1 shows the sampling blocks used to calculate nearshore source water volume. Sampling done in five (the "N" blocks) of the nine blocks was assumed to be representative of alongshore and offshore variation in abundances and therefore the volume from all nine blocks was used in calculating source water abundances. The volumes for these sampling blocks were calculated from bathymetric data for the coastal areas around Carlsbad using ArcGIS software. The total volume in these nine blocks was estimated as 283,303,115 m^3 (**Table 5-2**).

SDG&E (1980) described a three-month deployment (June, August, and November 1979) of two Endeco current meter seaward of the outer lagoon entrance. Highest current speeds occurred further offshore, with 10.06 cm/s being the average current speed. The furthest offshore station was over a bottom depth of about 24.4 m (80 ft) at California State plane 355,800 N and 6,625,000 E. The meter was set –3 m below the surface. SCCWRP (1993) reported similar current speeds with median offshore currents at Carlsbad of 8.6 cm/s in winter and 7.0–9.5 cm/s in summer from a mid-depth position over a 45 m bottom from 1979–1990.

Table 5-2. Volumes of nearshore sampling blocks used in calculating source water abundances.

Block	Depth (m re: MWL)	Area (m^2 re: MHW)	Volume (m^3 re: MHW)
N1	-5.3	1,195,366	5,959,236
N2	-6.4	1,653,677	9,840,181
N3	-5.6	1,775,546	9,247,259
SW1	-14.8	1,055,516	15,633,525
N4	-18.5	1,359,040	25,081,478
SW2	-17.9	1,711,379	30,499,399
SW3	-27.8	1,312,832	36,386,864
N5	-38.5	1,661,891	63,329,174
SW4	-42.8	2,046,985	87,325,998
Total		**13,772,232**	**283,303,115**

The three months of currents reported in SDG&E (1980) were rotated to the coastline direction at the Encina Power Station (36 degrees W of N). The average current vector components were 1.702 cm/s downcoast and 0.605 cm/s offshore.

A current meter was placed in the nearshore between Stations N4 and N5. The data from the meter was used to characterize currents in the nearshore area that would directly affect the dispersal of planktonic organisms that could be entrained by the power plant. The data were used to define the size of the nearshore component of the source water by using the current speed and the estimated larval durations of the entrained organisms.

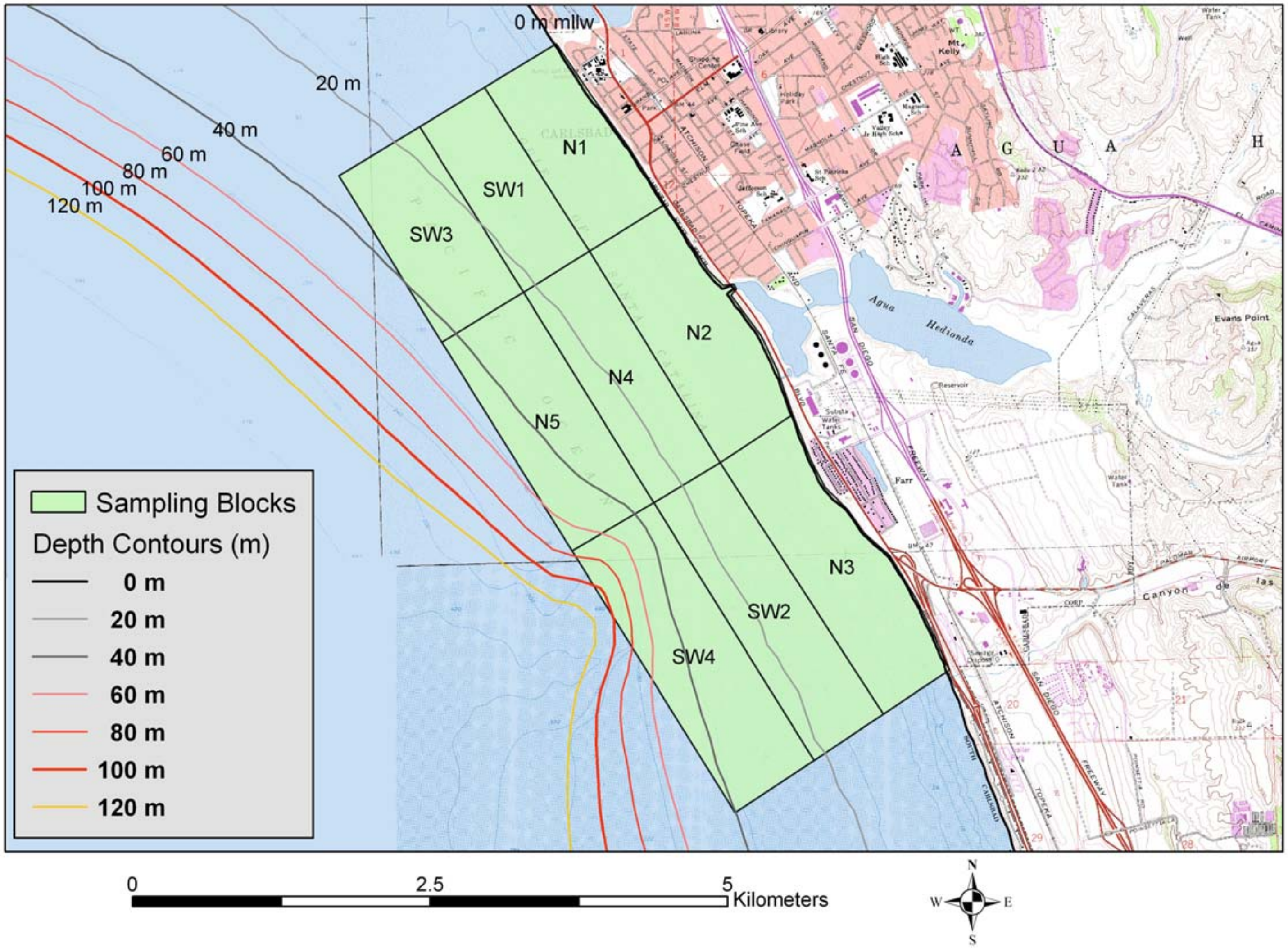


Figure 5-1. Nearshore sampling blocks used to calculate source water volumes.

5.3 ETM Modeling

5.3.1 Analysis Approach

The effect of the proposed CDF operations on source water populations of larval fishes was evaluated in three steps. First, by computing estimates of the incremental mortality that could result from the desalination facility feedwater withdrawal over a one-day period, second by using the incremental mortality to estimate mortality over the period that the larvae are exposed to water withdrawals, and finally by placing these estimates into context based on empirical data of the number of larvae that survive EPS entrainment and are alive at the point of feedwater withdrawal by the proposed desalination facility.

The estimate of daily incremental mortality, or proportional entrainment (*PE*), was computed as the ratio of the number of larvae in the water withdrawn by the proposed facility to the number of larvae in the surrounding source water. The estimate of the number of larvae in the water withdrawn is calculated using the average concentration of larvae from samples that were collected inside the EPS cooling water intake system at a point close to the location where the desalination facility would withdraw its water. The average concentration and variance were calculated for the in-plant surveys conducted on June 16 and July 6, 2004. The average concentration and variance from these two surveys were then used to calculate estimates of the average in-plant concentration and variance. The average variance from the two surveys was used since it best reflected the level of variation among samples over a 24-hr period. The average concentration was multiplied by desalination facility's maximum feedwater withdrawal volume of 401,254 m^3/day (106 MGD), to simulate effects under maximum operating conditions. A total maximum withdrawal volume of 106 MGD (as compared to average withdrawal of 104 MGD) was used as a worst case volume, under a scenario where maximum backwash water volumes would be used during a period of maximum RO production. Similar calculations were used to estimate the source water populations of larvae that would be affected by the proposed CDF operations. Average concentrations of larval fishes from stations in the inner, middle, and outer segments of Aqua Hedionda Lagoon, and stations in the ocean directly offshore from EPS were calculated from the three surveys conducted on June 10, June 24, and July 6, 2004. The average concentrations were multiplied by the volume estimates for each of the water body segments and then combined to estimate the average source water population.

5.3.2 Sources of Variance in *ETM*

The major sources of variance in *ETM* results have been shown to include variance in estimates of larval entrainment concentrations, source water concentrations, and larval duration, in this order. Variance in estimates of entrainment and source water concentrations of fish larvae is due to spatial differences among stations, day and night diurnal changes, and temporal changes between surveys.

5.3.3 *ETM* Results

Estimates of desalination intake and source water populations for the three fish taxa evaluated in this report are presented in **Table 5-3**.

Table 5-3. Estimates of average daily populations (standard error in parentheses) of larval CIQ gobies, combtooth blennies, and northern anchovy based on the static source water volume and the maximum daily flow of desalination facility feedwater withdrawal.

Fish Group	Number of Larvae: Source Population Estimate (standard error in parentheses)		Number of Larvae: Condition: Maximum Flow 401,254 m^3/day (106 MGD) (standard error in parentheses)	
CIQ gobies	46,244,071	(80,910,286)	253,167	(186,428)
Combtooth blennies	124,387,723	(236,319,771)	449,362	(230,202)
Northern anchovy	45,137,821	(54,839,090)	6,352	(13,194)

The estimate of incremental mortality, or proportional entrainment (*PE*), was calculated using the estimates of the number of larvae in the source water and water withdrawn by the proposed desalination facility shown in **Table 5-3**. The estimates of *PE* ranged from 0.01 percent for northern anchovy to 0.55 percent for CIQ gobies (**Table 5-4**). The differences among fish taxa result from the distributions of the larvae in the source water. CIQ gobies and combtooth blennies, with higher estimated daily mortality, are primarily distributed in Aqua Hedionda Lagoon, whereas northern anchovy occur in both the lagoon and in the ocean waters offshore.

Table 5-4. Estimates of average daily mortality (*PE*) (standard error in parentheses) calculated using the maximum desalination facility feedwater withdrawal rate for CIQ gobies, combtooth blennies, and northern anchovy.

Fish Group	Estimates of average daily mortality (*PE*) (standard error in parentheses) Feedwater Volume – Maximum Flow 401,254 m^3/day (106 MGD)
CIQ gobies	0.55% (2.08)
Combtooth blennies	0.36% (0.87)
Northern anchovy	0.01% (0.05)

The second step in the assessment is to compute the effects on a cohort of larvae based on estimates of the number of days the larvae would be exposed to the effects of desalination facility water withdrawals. The total mortality was estimated using an Empirical Transport Model (*ETM*) (Boreman et al. 1978, 1981) that expands the estimate of daily mortality over the number of days the larvae from a single cohort, or batch of larvae, would be exposed to entrainment. The length of exposure was estimated from data collected on these fishes during similar studies at the South Bay Power Plant in San Diego Bay (60 km [37.3 mi] south of EPS), and the Huntington Beach Generating Station in Huntington Beach (80 km [49.7 mi] northwest of EPS). The average and maximum lengths of the larvae collected from these studies were used with estimated larval growth rates to estimate age of the larvae when entrained (**Table 5-5**). These estimates would be expected to change as site-specific data on larval lengths are collected from EPS intake and discharge flows.

Table 5-5. Estimates of maximum exposure (in days) to entrainment for populations of larval CIQ gobies, combtooth blennies, and northern anchovy.

Fish Group (Source)	Days at Risk based on Maximum Length at Entrainment
CIQ gobies (SBPP)	22.9
Combtooth blennies (SBPP)	16.1
Northern anchovy (HBGS)	40.9

The estimated effects of withdrawal for desalination operations on a single cohort of larvae were calculated using the *ETM* as

$$P_M = 1 - (1 - PE)^{duration},$$

where P_m is the proportional level of mortality resulting from the water withdrawals by the proposed desalination facility.

5.3.4 Entrainment Effects Discussion

The role of turbulence and temperature and how larvae are affected were not evaluated at the EPS. It is noted that mortality from entrainment through the cooling water intake structure may be primarily due to pressure and turbulence in the water flow, rather than temperature increases resulting from the cooling operation. Since the desalination plant feedwater will be subject to the same turbulence whether or not the EPS is operating, it is reasonable to estimate incremental mortality for the heated and unheated desalination scenarios using the survival data presented in Table 5-6.

Although combtooth blennies had higher *PE* estimates, CIQ gobies had higher estimates of P_m because their larvae were exposed to entrainment for a longer period of time (either from multiple spawnings or one species or different species spawning at different times) (**Table 5-6**). Adult CIQ gobies and combtooth blennies are very common in Aqua Hedionda Lagoon and these levels of mortality would not be expected to result in any population-level effects because these fishes are adapted to estuarine environments where large percentages of their larvae are exported into nearshore areas during tidal flushing. Gobies are abundant in the shallow mudflat and eelgrass habitats that are common in the middle and inner lagoons (MEC 1995).
A significant proportion of the CIQ goby larvae in the outer lagoon at the point of entrainment likely originated in the inner and middle lagoon segments and would be exported from the lagoon system on the following tidal cycle. Adult combtooth blennies are common in outer lagoon habitats including rock jetties, docks, pilings, and aquaculture floats, as well as some sandy areas in the lagoon. It is therefore not surprising that large numbers of the larvae occur in the EPS intake flows and consequently in discharge flows to be used by the proposed desalination facility. The estimates for northern anchovy are much lower than the other two taxa because they are more common in the nearshore areas than the lagoon. In fact, the estimates for northern anchovy are very conservative because these fish are distributed over a large area and therefore the estimate of their source water population would be much larger than the estimate used in the calculation of *PE*.

Both living and dead fish larvae entrained by CDF at flows of 106 MGD from the EPS discharge flow represent a loss of 11.8 percent of EPS's source water supply of larvae, using the maximum loss value modeled (CIQ gobies) (**Table 5-6**). Based on in-plant testing, the average observed entrainment mortality of EPS from the 223 survival samples that contained fish was 97.6 percent (2.4 percent survival). Since 97.6 percent of the larvae are dead at the point of CDF intake, CDF's incremental effect on source water populations of CIQ gobies, combtooth blennies, and northern anchovy is 2.4 percent of the species source water entrainment losses.[3] These incremental effects range from 0.28 percent for CIQ gobies to 0.01 percent for northern anchovy (**Table 5-6**). The incremental mortality assumes 100 percent mortality of all organisms surviving the EPS upon withdrawal into the desalination facility.

Table 5-6. Estimates of P_m from *ETM* at maximum exposure for CDF entrainment from the EPS discharge flow and the incremental entrainment loss due to CDF operations at the average survival rate (2.4 percent) for populations of larval CIQ gobies, combtooth blennies, and northern anchovy.

	P_m based on Maximum Length at Entrainment	**Estimate when applying the overall average survival estimate of 2.4 percent[1]**
	CDF Entrainment from EPS Discharge Flow	**Incremental Entrainment Loss Due to CDF Operations**
Fish Group	**Maximum flow - 106 MGD ($401,254\ m^3$/day)**	**Maximum flow - 106 MGD ($401,254\ m^3$/day)**
CIQ gobies	11.8%	0.28%
Combtooth blennies	5.7%	0.14%
Northern anchovy	0.6%	0.01%

1. The overall average percent survival (2.4 percent with a standard deviation of 11.22) was based on an average of each sample that contained fish (n=223).

In the unlikely event that the CDF were to operate at 106 MGD while the EPS was not operating, the estimated larval fish entrainment loss would be no more than 11.8 percent of the total number of larvae in the facility's source water.

Significance of Entrainment Losses

Whether the EPS is operating or not, the small fraction of marine organisms lost to CDF entrainment would have no effect on the species' ability to sustain their populations because of their widespread distribution and high reproductive potential. The most frequently entrained

[3] The average survival rate was calculated from data collected during surveys that were not always coincident with source water sampling. By applying the highest survey survival rate (9.2 percent), the incremental mortality is only slightly above 1 percent (1.09 percent).

species are very abundant in the area of EPS intake, Aqua Hedionda Lagoon, and the Southern California Bight, and therefore, the actual ecological effects due to any additional entrainment from the CDF are insignificant. Species of direct recreational and commercial value constitute a very small fraction (less than 1 percent) of the entrained organisms and therefore, the operation of the CDF does not result in significant ecological impact. California Department of Fish and Game (2002) in their Nearshore Fishery Management Plan provides for sustainable populations with harvests of up to 60 percent of unfished adult stocks. The incremental entrainment ("harvest") effect of larval fishes from CDF operations at 106 MGD is approximately 1 percent and would have no effect on the source water populations. Generally less than one percent of all fish larvae become reproductive adults.

6.0 Literature Cited

Allen, L. G. 1982. Seasonal abundance, composition, and productivity of the littoral fish assemblage in upper Newport Bay, California. Fish Bull., U. S. 80 (4): 769-790.

Allen, L. G., A. M. Findlay, and C. M. Phalen. 2002. Structure and standing stock of the fish assemblages of San Diego Bay, California from 1994 to 1999. Bull. So. Cal. Acad. Sci. 101(2): 49-85.

Baxter, J. L. 1967. Summary of biological information on the northern anchovy, *Engraulis mordax* Girard. California Cooperative Oceanic Fishery Investigations Report 11:110-116. *In*: Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: a Guide to the Early Life Histories. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Tech. Report 9.

Boreman, J., C. P. Goodyear, and S. W. Christensen. 1978. An empirical transport model for evaluating entrainment of aquatic organism by power plants. United States Fish and Wildlife Service. FWS/OBS-78/90, Ann Arbor, MI.

Boreman, J., C. P. Goodyear, and S. W. Christensen. 1981. An empirical methodology for estimating entrainment losses at power plant sites on estuaries. Trans. Amer. Fish Society 110: 253-260.

Brothers, E. B. 1975. The comparative ecology and behavior of three sympatric California gobies. Ph.D. Thesis, University of California at San Diego.

California Department of Fish and Game. 2002. Nearshore fishery management plan. http://www.dfg.ca.gov/mrd/nfmp/entire.html

Calliet, G. M., B. Antrim, D. Ambrose, S. Pace, and M. Stevenson. 1977. Species composition, abundance and ecological studies of fishes, larval fishes, and zooplankton in Elkhorn Slough. pp. 216-386 *in* J. Nybakken, G. Calliet, and W. Broenkow (eds.). Ecological and hydrographic studies of Elkhorn Slough, Moss Landing Harbor and nearshore coastal waters, July 1974 to June 1976. Moss Landing Marine Lab, Moss Landing, CA.

EA Engineering, Science, and Technology. 1997. Encina Power Plant Supplemental 316(b) Assessment Report. San Diego Gas and Electric, San Diego, CA.

Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundances of fishes and invertebrates in west coast estuaries. Volume II: Species life history summaries. ELMR Report No. 8. NOAA/NOS, Strategic Environmental Assessments Division. Rockville, MD, 329 pp.

Eschmeyer, W. N., E. S. Herald and H. Hamann. 1983. Field Guide to the Pacific Coast Fishes of North America. Peterson Field Guide. Houghton Mifflin Company. 336 pp.

Fronk, R. H. 1969. Biology of *Atherinops affinis littoralis* Hubbs in Newport Bay. MS Thesis, Univ. Calif. Irvine. 106 pp.

Goodyear, C. P. 1979. Entrainment impact estimates using the equivalent adult approach. United States Fish and Wildlife Service, FWS/OBS-78/65, Ann Arbor, MI.

Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180. 740 pp.

Jenkins, S.A. 2004. Hydrodynamic Modeling of Dispersion and Dilution of Concentrated Seawater Produced by the Ocean Desalination Project at the Encina Power Plant, Carlsbad, CA Part II: Saline Anomalies Due to Theoretical Extreme Case Hydraulic Scenarios.

Largier, J. L. 2003. Considerations in estimating larval dispersal distances from oceanographic data. Ecological Applications, 13(1) Supplement, 2003, pp. S71–S89

Lo, N. C. H. 1985. Egg production of the central stock of northern anchovy, *Engraulis mordax*, 1951-1982. Fishery Bulletin 83:137-150.

Love, M. 1996. Probably more than you want to know about fishes of the Pacific Coast. Really Big Press, Santa Barbara, CA. 381 pp.

Love, M. S., A. Brooks, D. Busatto, J. Stephens, and P. A. Gregory. 1996. Aspects of the life histories of the kelp bass, *Paralabrax clathratus*, and barred sand bass, *P. nebulifer*, from the Southern California bight. Fish Bulletin 94:472-481.

MacCall, A. D., K. R. Parker, R. Leithiser, and B. Jessee. 1983. Power plant impact assessment: a simple fishery production model approach. Fishery Bulletin 81:613-619.

Matarese, A. C., A. W. Kendall Jr., D. M. Blood, and B. M. Vintner. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. NOAA Tech. Rept. NMFS 80, 652 pp.

MacDonald, C. K. 1975. Notes on the family Gobiidae from Anaheim Bay. pp. 117-121 *in* E. D. Lane and C. W. Hill (eds.). The marine resources of Anaheim Bay. Calif. Dept. Fish and Game, Fish Bull. 165.

Marine Review Committee (MRC). 1989. Technical Report to the California Coastal Commission. Section D. Adult Equivalent Loss.

MEC Analytical Systems. 1995. 1994 and 1995 field survey report of the ecological resources of Agua Hedionda Lagoon. Prepared for San Diego Gas and Electric Co., Carlsbad, CA. 47 pp.

Miller, D. J. and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish and Game, Fish Bull. 157. 249 pp.

Minerals Management Service (MMS). 2001. Draft EIR OCS Oil and Gas Leasing Program: 2002-2007. October 2001. Vol. I & II.

Moser, H. G., W. Watson, S. R. Charter, D. A. Ambrose and E. M. Sandknop. 1996. The Early Stages of Fishes in the California Current Region. California Cooperative Oceanic Fisheries Investigations, Atlas No. 33. Allen Press Inc., Lawrence, Kansas.

Moyle, P. B. and Cech. 1988. Fishes: An Introduction to Ichthyology. Department of Wildlife and Fisheries Biology, U.C. Davis. Prentice Hall, Englewood Cliffs, N.J.

Nelson, J. S. 1994. Fishes of the World, 3rd Ed. John Wiley and Sons, Inc., New York. 600 pp.

Ninos, M. 1984. Settlement and metamorphosis in *Hypsoblennius* (Pisces, Blenniidae). Ph.D. Thesis, University of Southern California. 86 pp.

Pacific Fishery Management Council (PFMC). 1990. Sixth Amendment to the Northern Anchovy Fishery Management Plan. Portland, Oregon. 68 pp.

Pacific Fishery Management Council (PFMC). 1998. Amendment 8 (to the Northern Anchovy Fishery Management Plan) incorporating a name change to: The Coastal Pelagic Species Fishery Management Plan. Portland, Oregon.

Parker, K. R. and E. DeMartini. 1989. Adult-equivalent loss. *In*: Technical Report to the California Coastal Commission. Marine Review Committee, Inc. p. 56.

Public Service Electric and Gas Company (PSE&G). 1993. Appendix I—Modeling. Permit No. NJ0005622. Prepared by Lawler, Matusky, and Skelly Engineers, Pearl River, NY. Comments on NJPDES Draft. 82 pp.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. J. Fish. Res. Board Canada 91:382.

Robertson, D. R. and G. R. Allen. 2002. Shorefishes of the tropical eastern Pacific: an information system. Smithsonian Tropical Research Institution, Balboa, Panamá.

Schlotterbeck, R. E. and D. W. Connally. 1982. Vertical stratification of three nearshore southern California larval fishes (*Engraulis mordax*, *Genyonemus lineatus*, and *Seriphus politus*). Fishery Bulletin. 80(4):895-902.

San Diego Gas and Electric (SDG&E). 1980. Encina Power Plant cooling water intake system demonstration. Prepared for California Regional Water Quality Control Board, San Diego Region.

Southern California Coastal Water Research Project (SCCWRP) 1993. 1992-1993 Annual Report. http://www.sccwrp.org/pubs/annrpt/92-93/contents.htm.

Stephens, J. S. Jr. 1969. Growth, longevity, and the effect of size on the biology of certain Blennioid fishes. Final Report. National Science Foundation GB 5940. 83 pp.

Stephens, J. S. Jr., R. K. Johnson, G. S. Key and J. E. McCosker. 1970. The comparative ecology of three sympatric species of California blennies of the genus *Hypsoblennius* Gill (Teleostomi, Blenniidae). Ecol Monogr. 40(2):213-233.

Tenera, Inc. 2000a. Moss Landing Power Plant Modernization Project 316(b) Resource Assessment. Prepared for Duke Energy Moss Landing, LLC, Oakland, CA.

Tenera, Inc. 2000b. Diablo Canyon Power Plant 316(b) Demonstration Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera, Inc. 2001. Morro Bay Power Plant Modernization Project 316(b) Resource Assessment. Prepared for Duke Energy Morro Bay, LLC, Oakland, CA.

Tenera, Inc. 2004. South Bay Power Plant cooling water system effects on San Diego Bay Volume II: Compliance with Section 316(b) Clean Water Act for the South Bay Power Plant. Prepared for Duke Energy South Bay LLC, Chula Vista, CA.

Theilacker, G. H. 1980. Changes in body measurements of larval northern anchovy, *Engraulis mordax*, and other fishes due to handling and preservation. Fishery Bulletin 78:685-692.

U.S. Environmental Protection Agency (USEPA). 2004. Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities.

Carlsbad Desalination Facility Intake Effects Assessment

Appendix A

Survey Results

Table A-1. Counts and mean concentrations (#/1,000 m^3) of larval fishes collected from in-plant surveys conducted on June 16, 2004 and July 6, 2004.

		Survey:	1		2	
		Start Date:	06/16/04		07/06/04	
		Sample Count:	17		19	
Taxon	Common Name	Total Count	Survey Count	Average Conc. (#/1,000 m^3)	Count	Average Conc. (#/1,000 m^3)
Hypsoblennius spp.	combtooth blennies	766	391	1,077.969	375	1,161.821
CIQ gobies	CIQ goby complex	421	85	247.022	336	998.596
Labrisomidae unid.	labrisomid kelpfishes	205	71	188.562	134	394.753
Hypsypops rubicundus	garibaldi	174	89	237.839	85	222.442
larval fish fragment	unidentified larval fishes	27	6	16.500	21	54.377
Rimicola spp.	kelp clingfishes	13	2	5.044	11	30.040
Gibbonsia spp.	clinid kelpfishes	12	0	0.000	12	32.768
Engraulis mordax	northern anchovy	11	1	1.838	10	27.147
Gobiesocidae unid.	clingfishes	8	0	0.000	8	20.301
Blennioidei	blennies	7	0	0.000	7	18.421
Sciaenidae unid.	croaker	6	1	2.801	5	14.069
Quietula y-cauda	shadow goby	5	0	0.000	5	16.262
Atherinidae unid.	silversides	4	4	10.521	0	0.000
larval/post-larval fish unid.	larval fishes	3	3	6.992	0	0.000
Atherinops affinis	topsmelt	2	2	4.191	0	0.000
Agonidae unid.	poachers	1	0	0.000	1	4.386
Chaenopsidae unid.	tube blennies	1	1	1.838	0	0.000
Engraulidae	anchovies	1	1	2.674	0	0.000
Heterostichus rostratus	giant kelpfish	1	0	0.000	1	2.288
Labridae	wrasses	1	1	2.558	0	0.000
larvae, unidentified yolksac	unidentified yolksac larvae	1	1	4.902	0	0.000
Paralichthys californicus	California halibut	1	1	2.558	0	0.000
Roncador stearnsi	spotfin croaker	1	1	1.838	0	0.000
Seriphus politus	queenfish	1	0	0.000	1	4.049
Syngnathus spp.	pipefishes	1	1	1.838	0	0.000
Typhlogobius californiensis	blind goby	1	1	3.922	0	0.000
	Total	1,675	663		1,012	

Table A-2. Counts and mean concentrations (#/1,000 m^3) of larval fishes and target invertebrates collected during source water surveys conducted on June 10, June 24, and July 6, 2004.

			June 10, 2004			
		Total Survey	Station: Lagoon N=24		Station: Nearshore N=20	
Taxon	Common Name	Count	Count	Conc.	Count	Conc.
CIQ gobies.	CIQ goby complex	8,694	8,545	6953.4	149	118.1
Hypsoblennius spp.	combtooth blennies	2,334	1,398	1505.3	936	748.0
Engraulis mordax	northern anchovy	286	8	7.8	278	206.0
Labrisomidae unid.	labrisomid kelpfishes	279	192	178.0	87	73.4
Hypsypops rubicundus	garibaldi	257	173	179.1	84	66.6
Engraulidae	anchovies	134	54	48.6	80	54.2
Roncador stearnsi	spotfin croaker	107	2	1.7	105	84.1
larvae, unidentified yolksac		94	10	10.4	84	66.7
Seriphus politus	queenfish	84	3	3.3	81	60.0
Sciaenidae unid.	croakers	71	23	19.4	48	33.5
Gibbonsia spp.	clinid kelpfishes	47	11	11.4	36	29.6
Paralichthys californicus	California halibut	42	3	2.6	39	28.3
larval fish fragment		36	25	21.4	11	8.5
Scomber japonicus	Pacific mackerel	33	1	1.5	32	25.6
Paralabrax clathratus	kelp bass	28	0	0.0	28	20.1
Syngnathus leptorhynchus	bay pipefish	22	19	17.5	3	2.4
Oxyjulis californica	senorita	13	2	1.6	11	7.3
Trachurus symmetricus	jack mackerel	13	0	0.0	13	9.4
Paralabrax spp.	sand bass	11	0	0.0	11	8.7
Haemulidae	grunts	10	0	0.0	10	6.7
larval/post-larval fish unid.		8	1	0.8	7	4.9
Sphyraena argentea	California barracuda	8	0	0.0	8	6.5
Typhlogobius californiensis	blind goby	8	4	3.5	4	3.2
Paraclinus spp.	clinid	7	0	0.0	7	4.3
Semicossyphus pulcher	California sheephead	7	1	0.5	6	4.2
Atherinops affinis	topsmelt	6	6	4.7	0	0.0
Cheilotrema saturnum	black croaker	6	0	0.0	6	4.8
Citharichthys stigmaeus	speckled sanddab	5	0	0.0	5	3.6
Quietula y-cauda	shadow goby	5	5	3.6	0	0.0
Menticirrhus undulatus	California corbina	4	0	0.0	4	3.0
Atherinopsidae	silverside	3	3	2.3	0	0.0
Rimicola spp.	kelp clingfishes	3	3	3.3	0	0.0
Sardinops sagax	Pacific sardine	3	0	0.0	3	2.0
Atractoscion nobilis	white seabass	2	0	0.0	2	1.5
Clupeiformes	herrings and anchovies	2	0	0.0	2	1.9
Genyonemus lineatus	white croaker	2	2	1.4	0	0.0
Girella nigricans	opaleye	2	0	0.0	2	1.4
Heterostichus rostratus	giant kelpfish	2	1	0.8	1	1.0
Medialuna californiensis	halfmoon	2	0	0.0	2	1.7
Syngnathus spp.	pipefishes	2	2	2.1	0	0.0
Blennioidei	blennies	1	1	0.7	0	0.0
Clinidae unid.	clinid kelpfishes	1	0	0.0	1	1.0
Diaphus theta	California headlight fish	1	0	0.0	1	0.8
Gobiesocidae unid.	clingfishes	1	0	0.0	1	0.9
Hypsoblennius gentilis	bay blenny	1	0	0.0	1	0.6
Umbrina roncador	yellowfin croaker	1	0	0.0	1	0.7
Invertebrates						
Cancer gracilis (megalops)	slender crab	2	0	0.0	2	1.3
Panulirus interruptus (phyllosome)	California spiny lobster	1	0	0.0	1	0.8
	Totals:	12,691	10,498		2,193	

Table A-2 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and target invertebrates collected during source water surveys conducted on June 10, June 24, and July 6, 2004.

		June 24, 2004				
		Total Survey	Station: Lagoon N=24		Station: Nearshore N=19*	
Taxon	Common Name	Count	Count	Conc.	Count	Conc.
CIQ gobies	CIQ goby complex	5,064	5,042	4,491.2	22	22.5
Hypsoblennius spp.	combtooth blennies	1,161	836	763.9	325	335.3
Engraulidae	anchovies	145	143	123.7	2	1.7
Seriphus politus	queenfish	131	5	3.7	126	109.0
Labrisomidae unid.	labrisomid kelpfishes	128	81	71.5	47	48.1
Hypsypops rubicundus	garibaldi	67	61	58.8	6	5.7
Roncador stearnsi	spotfin croaker	67	1	0.9	66	63.6
larvae, unidentified yolksac	unidentified yolksac larvae	51	6	6.1	45	40.0
Paralichthys californicus	California halibut	45	0	0.0	45	40.9
Paralabrax clathratus	kelp bass	43	0	0.0	43	37.0
larval fish fragment	unidentified larval fishes	31	21	20.7	10	8.7
Xenistius californiensis	salema	31	0	0.0	31	25.8
Engraulis mordax	northern anchovy	28	1	0.9	27	24.7
Umbrina roncador	yellowfin croaker	24	0	0.0	24	21.9
Sciaenidae unid.	croakers	18	1	0.8	17	15.9
Syngnathus leptorhynchus	bay pipefish	17	17	15.3	0	0.0
Peprilus simillimus	Pacific butterfish	15	0	0.0	15	12.8
Citharichthys stigmaeus	speckled sanddab	11	0	0.0	11	10.0
Gibbonsia spp.	clinid kelpfishes	11	6	5.4	5	6.9
Atractoscion nobilis	white seabass	9	0	0.0	9	8.4
Scomber japonicus	Pacific mackerel	9	0	0.0	9	7.4
Paralabrax spp.	sand bass	8	0	0.0	8	7.0
Sphyraena argentea	California barracuda	8	0	0.0	8	6.6
larval/post-larval fish unid.		5	0	0.0	5	4.6
Quietula y-cauda	shadow goby	5	5	4.5	0	0.0
Atherinops affinis	topsmelt	4	4	3.7	0	0.0
Cheilotrema saturnum	black croaker	4	0	0.0	4	3.8
Haemulidae	grunts	4	0	0.0	4	3.3
Menticirrhus undulatus	California corbina	4	0	0.0	4	4.1
Genyonemus lineatus	white croaker	3	0	0.0	3	2.8
Gobiesox spp.	clingfishes	3	3	3.1	0	0.0
Pleuronichthys verticalis	hornyhead turbot	3	0	0.0	3	2.6
Rimicola spp.	kelp clingfishes	3	3	2.8	0	0.0
Syngnathus spp.	pipefishes	3	2	2.0	1	0.8
Oxyjulis californica	senorita	2	0	0.0	2	2.0
Paralabrax nebulifer	barred sand bass	2	0	0.0	2	1.7
Blennioidei	blennies	1	1	0.9	0	0.0
Citharichthys sordidus	Pacific sanddab	1	0	0.0	1	0.8
Citharichthys spp.	sanddabs	1	0	0.0	1	0.8
Diaphus theta	California headlight fish	1	0	0.0	1	0.8
Girella nigricans	opaleye	1	0	0.0	1	0.8
Heterostichus rostratus	giant kelpfish	1	0	0.0	1	1.4
Pleuronichthys spp.	turbots	1	0	0.0	1	0.8
Triphoturus mexicanus	Mexican lampfish	1	0	0.0	1	0.8
Typhlogobius californiensis	blind goby	1	0	0.0	1	0.8
Invertebrates						
Panulirus interruptus (phyllosome)	California spiny lobster	71	0	0.0	71	64.8
Cancer antennarius (megalops)	brown rock crab	3	0	0.0	3	3.1
Cancer anthonyi (megalops)	yellow crab	2	0	0.0	2	2.4
	Totals:	7,252	6,239		1,013	

* 20 samples were collected; one was voided during laboratory processing.

Table A-2 (continued). Counts and mean concentrations (#/1,000 m^3) of larval fishes and target invertebrates collected during source water surveys conducted on June 10, June 24, and July 6, 2004.

		July 6, 2004				
		Total Survey	Station: Lagoon N=24		Station: Nearshore N=20	
Taxon	Common Name	Count	Count	Conc.	Count	Conc.
CIQ gobies	CIQ goby complex	3,903	3,817	3,240.1	86	82.4
Hypsoblennius spp.	combtooth blennies	1,565	1,382	1,322.0	183	181.2
larvae, unidentified yolksac		371	24	23.6	347	291.3
Engraulis mordax	northern anchovy	229	15	14.6	214	168.4
Paralichthys californicus	California halibut	195	1	1.1	194	173.4
Hypsypops rubicundus	garibaldi	131	118	106.9	13	11.4
Sciaenidae unid.	croaker	110	8	7.9	102	99.7
Labrisomidae unid.	labrisomid kelpfishes	103	57	47.2	46	46.8
Roncador stearnsi	spotfin croaker	87	35	34.6	52	47.5
Engraulidae	anchovies	84	60	52.1	24	19.5
Seriphus politus	queenfish	55	5	4.4	50	42.2
Paralabrax spp.	sand bass	50	0	0.0	50	40.5
larval fish fragment		44	3	2.9	41	35.9
larval/post-larval fish unid.		40	1	0.8	39	34.9
Scomber japonicus	Pacific mackerel	39	0	0.0	39	30.9
Paralabrax clathratus	kelp bass	34	0	0.0	34	27.6
Sphyraena argentea	California barracuda	27	0	0.0	27	20.1
Syngnathus leptorhynchus	bay pipefish	24	24	23.9	0	0.0
Rimicola spp.	kelp clingfishes	18	16	13.8	2	2.0
Citharichthys stigmaeus	speckled sanddab	17	1	0.9	16	14.0
Oxyjulis californica	senorita	17	0	0.0	17	15.2
Umbrina roncador	yellowfin croaker	14	0	0.0	14	11.4
Xystreurys liolepis	fantail sole	14	2	1.8	12	11.1
Genyonemus lineatus	white croaker	13	0	0.0	13	10.6
Cheilotrema saturnum	black croaker	12	2	1.7	10	9.3
Pleuronichthys verticalis	hornyhead turbot	10	0	0.0	10	7.3
Sardinops sagax	Pacific sardine	9	0	0.0	9	8.1
Typhlogobius californiensis	blind goby	8	8	8.8	0	0.0
Gibbonsia spp.	clinid kelpfishes	7	3	3.0	4	4.4
Labridae	wrasses	7	0	0.0	7	6.8
Peprilus simillimus	Pacific butterfish	6	0	0.0	6	4.7
Atractoscion nobilis	white seabass	5	0	0.0	5	3.6
Haemulidae	grunts	5	0	0.0	5	4.1
Pleuronichthys ritteri	spotted turbot	4	0	0.0	4	3.4
Quietula y-cauda	shadow goby	3	3	2.6	0	0.0
Atherinops affinis	topsmelt	2	2	1.6	0	0.0
Menticirrhus undulatus	California corbina	2	2	1.9	0	0.0
Paralichthyidae unid.	lefteye flounders & sanddabs	2	0	0.0	2	1.0
Anisotremus davidsonil	sargo	1	0	0.0	1	0.7
Atherinopsidae	silverside	1	1	0.8	0	0.0
Atherinopsis californiensis	jacksmelt	1	1	0.8	0	0.0
Blennioidei	blennies	1	0	0.0	1	1.1
Clupeidae unid.	herrings	1	0	0.0	1	0.7
Diaphus theta	California headlight fish	1	0	0.0	1	0.8
Halichoeres semicinctus	rock wrasse	1	0	0.0	1	0.8
Myctophidae unid.	lanternfishes	1	0	0.0	1	1.2
Pleuronichthys spp.	turbots	1	0	0.0	1	0.5
Semicossyphus pulcher	California sheephead	1	0	0.0	1	1.1
Invertebrates						
Cancer anthonyi (megalops)	yellow crab	29	0	0.0	29	22.7
Panulirus interruptus (phyllosome)	California spiny lobster	21	2	1.8	19	18.8
Cancer antennarius (megalops)	brown rock crab	1	0	0.0	1	0.7
	Totals:	7,327	5,593		1,734	