Carlsbad Energy Center Project

Impact Assessment of Seawater Desalination for Industrial Water Use at the Carlsbad Energy Center Project

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Submitted to:

Mr. Tim Hemig
NRG Energy Inc.
1817 Aston Ave., Suite 104
Carlsbad, CA 92008

Prepared by:

TENERA Environmental
141 Suburban Rd., Suite A2, San Luis Obispo, CA 93401
805.541.0310, FAX: 805.541.0421

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Executive Summary

The proposed Carlsbad Energy Center Project (CECP) will use high-efficiency, combined-cycle power generation units with evaporative air cooling, thereby greatly reducing the overall use of seawater for once-through cooling at the Encina Power Station (EPS). The CECP will replace the existing Units 1, 2, and, 3 at EPS which together withdraw as much as 224 million gallons of seawater per day (mgd) from Agua Hedionda Lagoon (AHL) for cooling. A small volume of make-up water would be used for the operation of the CECP evaporative cooling system, and this would require pumping 4.32 mgd of seawater from the existing EPS intakes, some that would be purified into fresh water by a desalination process, and some that would be used for the dilution of the brine solution rejected from the desalination facility. This report analyzes the potential biological effects of the intake for the new CECP units on marine resources of AHL and vicinity.

When operated without the flow from EPS Units 4&5, the intake of 4.32 mgd will represent very little risk to marine organisms from entrainment and will present no risk from impingement due to the low intake approach velocities. The CECP process flows will result in an estimated total annual entrainment of 22.7 million fish larvae from AHL where the intake for the EPS and CECP is located. This estimate is based on data collected at the EPS intake during the 2004-2005 Impingement Mortality and Entrainment Characterization Study. Three taxa of fishes (gobies, combtooth blennies, and northern anchovies) would account for nearly 95% of all fish larvae entrained, with gobies representing more than 60% of the total. If operated 365 days of the year, the losses are estimated to represent less than 0.3% of the larval population of gobies and 0.2% of the population of combtooth blennies in AHL. Other fishes, including anchovies, halibut, and croakers had very low projected entrainment based on the Empirical Transport Model used for the analysis. The small fraction of marine organisms potentially lost due to CECP entrainment would have no effect on these populations. The most frequently entrained species are very abundant in the area of the EPS intake, AHL, and the Southern California Bight, and therefore, the actual ecological effects due to any additional entrainment from the CECP would not be significant.

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1.0 Introduction

The proposed Carlsbad Energy Center Project (CECP) will use high-efficiency, combined-cycle power generation units that will use evaporative air cooling that will greatly decrease the use of seawater for cooling. Once the CECP is in operation, the existing Encina Power Station's (EPS) Units 1, 2, and 3 will be decommissioned, but EPS Units 4&5 will continue to operate. Operation of Units 1, 2, and 3 requires up to 224 million gallons of seawater per day (mgd). There are several options being considered for the make-up water required for the operation of the CECP evaporative cooling system. One of the options is to use seawater pumped from the existing cooling water system that will then be desalinated before being used in the cooling system. The volume of seawater required for the system and for the dilution of the brine solution rejected from the desalination facility is 4.32 mgd. If the system is operated independently of Units 4&5, a reduction of greater than 98% in intake volume would be achieved as compared to the existing volume of seawater needed for cooling Units 1-3 at full operating capacity.

The CECP desalination unit would operate independently from the much larger Carlsbad Desalination Facility (CDF) also proposed for construction at the EPS site. The concentrate and the treated waste filter backwash water from the CECP desalination unit would be mixed with the cooling water discharge from EPS before it is returned to the ocean. Due to the low volumes of seawater anticipated for the desalination process, relative to the existing cooling water intake flows at EPS, there is a very low probability that significant impacts to the marine environment will occur as a result of impingement and entrainment of marine organisms. However, the following analysis will provide data to objectively examine this question as part of the environmental review process.

This study was undertaken in consideration of Water Code Section 13142.5(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 proposed intake for the CECP is not subject to regulations under the Federal Clean Water Act (CWA) Section 316(b) because of the relatively small volumes of ocean water involved. The CECP does not include a separate cooling water intake structure (CWIS). The intake for the CECP is part of the existing EPS CWIS that is presently regulated under Section 316(b). The CECP intake will be withdrawn from the EPS cooling water system and will not be taken directly from Agua Hedionda Lagoon. However, taking into consideration that the CECP will withdraw seawater from the power station cooling water flow, and would require water withdrawals independently of EPS Units 4&5, this assessment has been conducted consistent with the intent of Section 316(b), which requires that baseline conditions be established and potential impacts analyzed (U. S. Environmental Protection Agency 1977).

2.0 Analysis Approach

The approach for evaluating potential biological effects of the intake for the new CECP units is similar to that used in the EIR for the co-sited Poseidon Resources Carlsbad Desalination Facility Project (CDF) (Tenera Environmental 2005). Marine resources were evaluated in the CDF EIR in terms of impacts from both the source water intake (impacts on organisms drawn through the water intake system) and from the discharge of hypersaline water from the reverse osmosis process. In the present analysis, only the effects of water withdrawals necessary to support operation of the CECP will be addressed. The effects of adding hypersaline water into the cooling water discharge and subsequent dilution and dispersion will be evaluated in a separate document. The potential effects of impingement (trapping of larger organisms on intake screens) resulting from the operation of service water pumps will not be included in this analysis because the low intake volumes required for operation of the CECP desalination unit would result in very low approach velocities that would not cause any significant impingement of marine organisms.

Data on the concentrations of fish and invertebrate larvae entrained through the EPS cooling water intake system (CWIS) were collected as part of the CWA §316(b) Phase II Impingement Mortality and Entrainment Characterization Study (IM&E Study) conducted at the EPS from June 2004 through June 2005 (Tenera Environmental 2008). The numbers of larvae entrained were estimated using both the actual plant flow volumes that occurred during the study period and the maximum design flow rate of 857 mgd. Concentrations of larval organisms were also estimated from samples collected in the ocean immediately offshore from the EPS and in AHL, and these data were combined in the empirical transport model (ETM) to estimate the proportional mortality to the population due to entrainment. The ETM modeling approach used in the IM&E Study was also used in the CDF EIR. The model estimates were recalculated using a maximum intake flow for the CDF of 304 mgd which could occur if the facility were operating independently of the EPS. The same approach will be used for the CECP desalination facility by substituting the pump capacities necessary for CECP operation and recalculating the models using data from the IM&E Study.

3.0 Project Environmental Setting

The following sections describe the coastal environmental setting in the vicinity of the CECP that are relevant to the potential impacts from process water entrainment. The marine environment of Agua Hedionda Lagoon (AHL), is described first, followed by an overview of the nearshore zone, the southern California bight, and the major fisheries that occur in the region. An overview of the EPS, its environmental setting and special status wildlife species that occur in the area were described in Shaw Environmental and Tenera Environmental (2006).

3.1 Agua Hedionda Lagoon

The EPS is located on AHL, a natural lagoon that has been significantly enlarged by dredging. It was widened and increased in depth in 1954 primarily to provide a cooling water embayment for the power station. The lagoon extends 2.7 km (1.7 miles) inland and is up to 0.8 km (0.5 mile) wide. A railroad trestle and the Interstate Highway 5 bridge separate AHL into three interconnected segments: Outer, Middle, and Inner lagoons with surface areas of 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 Carlsbad Boulevard and allows tidal exchange of water with the ocean.

Circulation and input into AHL 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, part of the volume flows out through the entrance to the ocean while the remainder is pumped through EPS and discharged directly back to the ocean when the plant is operating. As a result of this daily tidal flushing and pumping from EPS, the lagoon is largely a marine environment. Although freshwater can enter the lagoon through Agua 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 AHL showed that it has good water quality and supports diverse infaunal, bird, and fish communities (MEC Analytical Systems 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 AHL. 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 Systems 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 with silversides, primarily jacksmelt and topsmelt, most abundant in the shallower Middle and Inner lagoons where water temperatures are warmest. 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 AHL (MEC Analytical Systems 1995) did not record any occurrences of the federally endangered tidewater goby (*Eucyclogobius newberryi*) that was once recorded from the lagoon. The presence of tidewater goby may predate the construction of the Outer Lagoon which created a direct connection with the ocean. The present 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

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

The Southern California Bight is delineated by Point Arguello to the north, the region below San Diego to the south, and inshore of the Santa Rosa Ridge. The circulation of the Bight is complex and dominated by the California Current rather than by local wind forcing. The California Current extends offshore a distance of about 400 km (249 mi) and to a depth of 300 m (984 ft). The average current speed is approximately 0.25 m/sec (0.8 ft/sec) and the greatest circulation occurs primarily during spring and summer (Hickey 1993). When the nearshore portion of this surface current periodically flows poleward, it is referred to as the Coastal Countercurrent. The Davidson Current or California Undercurrent also flows poleward and is characterized as being warmer, saltier, and having lower oxygen and higher phosphate concentrations than the California Current. Although the northerly countercurrent exists throughout the year at depths of 200–300 m (656–984 ft), it is strongest during the fall and winter months along the continental slope within 50 km (31 mi) 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 interrupts the supply of nutrients and affects 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 Niño oceanographic events, the currents can carry planktonic 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 into southern California during strong El Niño events.

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 (especially sand dollars, *Dendraster excentricus*) comprise the dominant invertebrate fauna. 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 species more typical of the outer coast can occasionally occur within AHL, 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 AHL. 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 AHL 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.

Commercial and sport fisheries are economically important in San Diego County. The estimated ex-vessel value of various nearshore commercial species landed in 2007 exceeded $3 million (**Table 3-1**). Species such as kelp bass, yellowtail, halibut, surfperch and white seabass are targeted by recreational fishers from commercial passenger fishing vessels (party boats), private skiffs, piers, and shore-based fishing.

Table 3-1. Nearshore commercial fishery species landed in San Diego County in 2007. Data from PacFIN—Pacific States Marine Fisheries Commission.

Common Name	Scientific Name	Revenue	Weight (lbs)
California spiny lobster	*Panulirus interruptus*	$2,129,898	210,565
Red sea urchin	*Strongylocentrotus franciscanus*	$388,642	627,153
California sheephead	*Semicossyphus pulcher*	$180,950	39,789
Common thresher shark	*Alopias vulpinus*	$136,039	168,399
Rock crab	*Cancer* spp.	$79,334	74,426
California halibut	*Paralichthys californicus*	$75,615	16,412
Miscellaneous fish	Miscellaneous fish	$53,844	80,910
White seabass	*Atractoscion nobilis*	$52,227	17,140
Other crab	Other crab	$22,182	18,583
Yellowtail	*Seriola lalandi*	$19,086	13,803
Pacific barracuda	*Sphyraena argentea*	$11,155	8,913
Unsp. Sea cucumbers	Unsp. Sea cucumbers	$10,627	6,800
Blackgill rockfish	*Sebastes melanostomus*	$10,493	7,659
Cabezon	*Scorpaenichthys marmoratus*	$4,932	956
Lingcod	*Ophiodon elongatus*	$3,232	1,274
Giant sea bass	*Stereolepis gigas*	$3,198	1,444
Soupfin shark	*Galeorhinus zyopterus*	$2,966	4,707
Leopard shark	*Triakis semifasciata*	$2,368	2,702
Unsp. Octopus	Unsp. Octopus	$1,614	1,361
Treefish	*Sebastes serriceps*	$1,399	439
Vermillion rockfish	*Sebastes miniatus*	$1,297	498
Pacific bonito	*Sarda chiliensis*	$1,076	434
Bocaccio	*Sebastes paucispinis*	$1,005	1,063
Unsp. Rockfish	Unsp. Rockfish	$791	311
Unsp. Squid	Unsp. Squid	$475	1,195
Chub mackerel	*Scomber japonicus*	$416	778
California scorpionfish	*Scorpaena gutatta*	$402	151
Gopher rockfish	*Sebastes carnatus*	$191	38
Grass rockfish	*Sebastes rastrelliger*	$59	10
		$3,195,513	

4.0 Larval Entrainment Analysis

This section describes the data sets used for analyzing potential effects from withdrawal of seawater from AHL for the CECP on marine fishes and target invertebrates that have planktonic larvae susceptible to entrainment. An overview of the sampling methods in the various studies is described along with profiles of the dominant species occurring in the source water.

4.1 Introduction

This study evaluates the potential impacts of the CECP intake system that will withdraw a maximum of 4.32 mgd from the EPS cooling water discharge flow. 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 system after they had passed through the mesh traveling screens and were entrained by the power station's CWIS.

The CECP entrainment analysis was designed to address the following questions:

- What are the species composition and abundance of larval fishes, Cancer crabs, and spiny lobster in the EPS cooling water system flow that could be entrained through the CECP intake?
- How might any losses due to entrainment affect the source populations of the entrained species in AHL and the southern reaches of the Southern California Bight?
- Are these losses ecologically or economically significant?

4.2 Data Description

This analysis uses existing information on the abundance and composition planktonic fish larvae and selected invertebrate larvae in AHL and vicinity. The data were obtained from a 13-month study of entrainment and impingement at EPS conducted from June 2004 through May 2005 (Tenera Environmental 2008).

The IM&E Characterization Study was designed and performed to comply with EPA's 2004 316(b) Phase II regulations. Originally, results were to be used in determining impingement mortality and entrainment from once-through cooling, evaluating potential fish protection technologies and operational measures at the facility, scaling potential restoration projects, and/or evaluating the benefits achieved in reducing IM&E at the facility. However, in March 2007, EPA suspended the Phase II regulations and directed administrators to determine compliance with 316(b) on a best professional judgment (BPJ) basis, although the study results provided data that could be used to evaluate the original objectives.

4.3 Methods

Data collection for the IM&E Characterization Study consisted of bi-weekly or monthly plankton sampling and laboratory processing of samples that included the sorting and identification of collected specimens. The data analysis included calculating the numbers of target organisms that would be entrained by the intake of water for the CECP, comparing larval densities among sites, and calculating effects on source water populations. The following sections describe the methods employed for each of these tasks.

Entrainment and source water sampling was conducted monthly from June 2004 through May 2005 except that two surveys were done in June 2004 separated by a two-week interval. The thirteen surveys provided a complete year of seasonal data for 2004–2005. The entire set of entrainment and source water stations (**Figure 4-1**) was sampled during each study period. All samples were collected over a single 24-hour survey period, with each period divided into four 6-hour sampling cycles. The sampling plan and detailed sampling procedures are included as appendices in the IM&E Characterization Study Report (Tenera Environmental 2008).

4.3.1 Entrainment Sampling

Samples for the IM&E Characterization Study were collected using methods and equipment similar to those developed and used by the California Cooperative Oceanic and Fisheries Investigation (CalCOFI) in their offshore larval fish studies (Smith and Richardson 1977). Entrainment samples were collected from a single station (**E1; Figure 4-1**) located in front of the EPS intakes. They were collected using a bongo frame with paired 0.71 m (2.33 ft) diameter openings each equipped with 335 µm (0.013 in) mesh plankton nets and codends. The use of a bongo frame design minimizes disturbance from the tow bridle compared to a three-point attachment design and allows each net to collect an unobstructed sample. The sampling platform was a 7.3 m (24-ft) research vessel with a side-mounted davit positioned for towing the nets. The start of each tow began approximately 30 m (98 ft) in front of the EPS intake structure along the southwest shore of the Outer Lagoon and proceeded in a northwesterly direction against the prevailing intake current, ending approximately 150 m (492 ft) from the intake structure. Because of the narrow constriction of the lagoon near the intakes there was a constant current flow toward the intake structure when pumps were operational and it was assumed that all of the water sampled at the entrainment station would have been drawn through the EPS CWS. Two replicate tows were collected consecutively at the entrainment station during each cycle. Concurrent surface water temperatures and salinities were measured with a digital probe (YSI Model 30).

Sampling began by lowering the bongo nets as close to the bottom as practical without contacting the substrate. Once the nets were near the bottom, the boat was moved forward, generally into any water currents, and the nets retrieved at an oblique angle (winch cable at approximately a 45 degree angle) to sample the widest strata of water depths possible at the

station. The winch retrieval speed was maintained at approximately 0.3 m/sec (1 ft/sec). Total time of each tow was approximately two minutes at a speed of approximately 0.5 m/s (1 knot) during which a combined volume of approximately 60 m^3 (15,851 gal) of water was filtered through both nets.

The water volume filtered was measured by calibrated flowmeters (General Oceanics Model 2030R) mounted in the openings of the nets. Flowmeters were maintained before and after each survey, and checked periodically during a survey to ensure that the impeller assembly was spinning freely. Flowmeters were calibrated quarterly by averaging the readings from ten replicate trials over a measured distance of 10 m (33 ft) and applying conversion factors supplied by the manufacturer. Accuracy of individual instruments differed by less than 5% between calibrations.

Once the nets were retrieved from the water, all of the collected material was rinsed into the end of the net. The contents of both nets were combined into one sample immediately after collection. Samples from the paired nets were not kept separate because they were not statistically independent samples and could not be used as replicates for analysis. The combined sample was placed into a labeled jar and preserved in 10% formalin. Each sample was given a unique serial number based on the location, date, time, and depth of collection, and all information was recorded on a sequentially numbered data sheet. The serial number was used to track the sample through the laboratory processing, data analysis, and reporting phases.

4.3.2 Source Water Sampling

Plankton samples were collected monthly at four source water stations in Agua Hedionda Lagoon and five nearshore stations adjacent to the EPS (**Figure 4-1**). The source water stations ranged in depth from approximately –1.8 m (–5.9 ft) MLLW at L3 and L4 in the Inner Lagoon to 34.1 m (–111.9 ft) MLLW at N5. The stations were stratified to include stations in the Inner, Middle and Outer Lagoon, and at varying distances upcoast, downcoast, and offshore from the lagoon mouth. This station array was chosen to include a range of depths and adjacent habitats that would characterize the larval fish composition in the source waters.

Source water sampling was conducted using the same methods and during the same time period described above for entrainment sampling, except that the stations sampled in the Middle and Inner Lagoons were sampled with a single 0.71 m (2.32 ft) diameter push net rather that the standard bongo net apparatus. The push net apparatus was used because of the shallow depths of the Middle and Inner Lagoons where a larger towed net was not practical. In both procedures, however, the target volumes for the oblique tows were 60 m^3 (2,119 ft^3) (2 minute tow at approximately 0.5 m/s (1 kt) for bongo and 4 minute tow for push net). A single tow was completed at each of the source water stations during each of the four 6-hr cycles. Entrainment samples at Station E1 were collected from the same vessel during sampling of the Outer Lagoon.

Surface water temperatures and salinities during the sampling were measured with a digital probe (YSI Model 30).

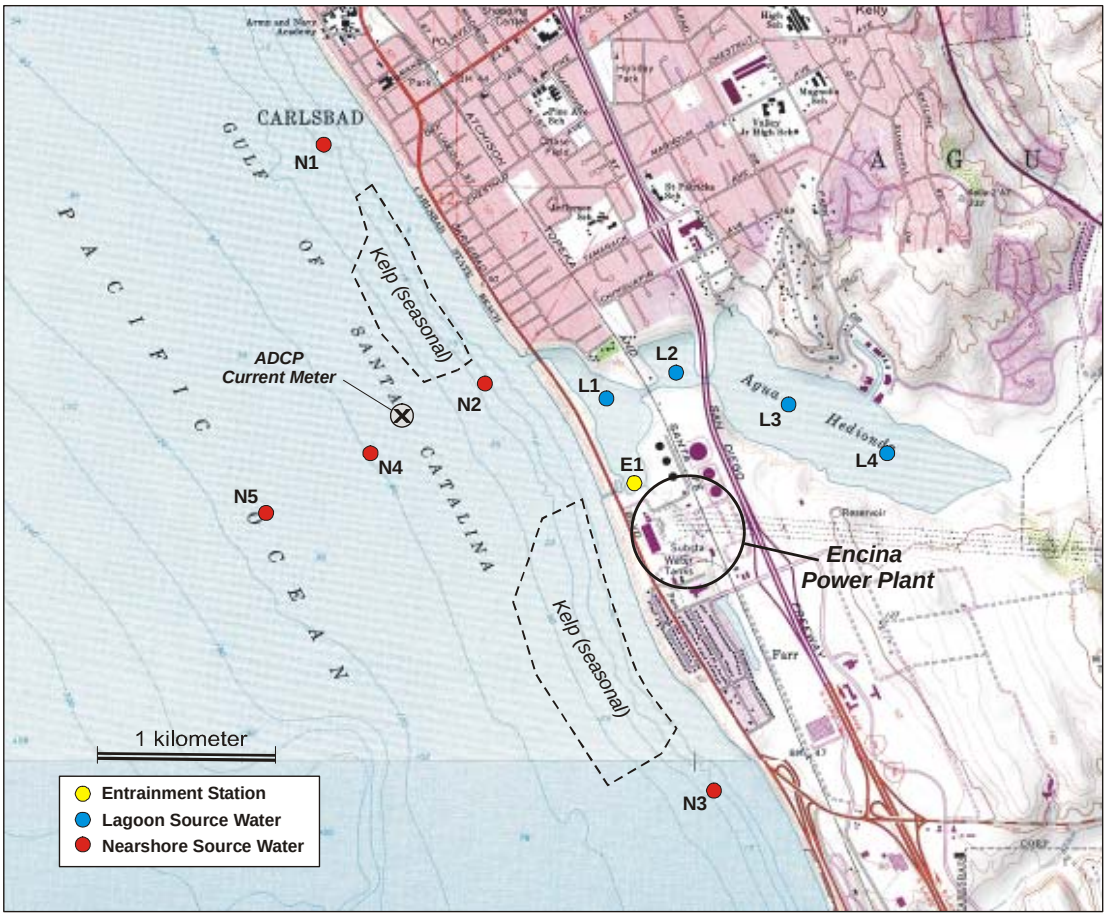

Figure 4-1. Location of Encina Power Station entrainment (E1) and source water (L1–L4; N1–N5) plankton stations.

4.3.3 Laboratory Analysis

Laboratory processing consisted 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. Larval fishes were identified to the lowest practical taxonomic level. Sorting and identification accuracy was 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.

4.3.4 Data Analysis

Estimates of daily larval entrainment for the sampling from June 2004 through May 2005 were calculated from data collected at entrainment station E1. Assessment of entrainment effects were limited to the most abundant fish taxa (target taxa). Estimates of entrainment loss, in conjunction with demographic data collected from the fisheries literature, were used in modeling entrainment effects on target taxa using adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*). Data for the same target taxa from sampling of the entrained larvae and potential source populations of larvae was used to calculate estimates of proportional entrainment (*PE*) that were used to estimate the probability of mortality (P_M) due to entrainment using the Empirical Transport Model (*ETM*). All three models (e.g., *AEL*, *FH*, and *ETM*) were used to assess effects of CECP intake losses. A detailed description of the analysis methods is presented in the IM&E Characterization Study Report (Tenera Environmental 2008).

An estimate of the volume of the daily outflow to the ocean from Agua Hedionda Lagoon was necessary for correctly calculating the proportional mortality estimates for the *ETM*. Water level measurements in the Agua Hedionda Lagoon conducted by Elwany et al. (2005) between June 1 and the July 7, 2005 were used to establish the relationships of maximum and minimum water levels per tidal cycle between the ocean at La Jolla (Scripp's Pier) and the lagoon using linear regression analysis:

$$Wl_{max} = 0.97\ Wo_{max} + 0.0076$$

$$Wl_{min} = 0.69\ Wo_{min} - 0.37$$

where Wl_{max} and Wl_{min} are the maximum and minimum water levels in the lagoon, and Wo_{max} and Wo_{min} are the maximum and minimum water levels in the ocean per tidal cycle respectively.

The measured maximum and minimum of each tidal cycle in ft (MLLW) at Scripps Pier, La Jolla, CA, between June 1, 2004 and July 31, 2005 were used to estimate the maximum and minimum water levels in the lagoon using these equations. A value of 0.78 m (2.56 ft) was subtracted from these values to estimate the time series of maximum and minimum lagoon levels in the NGVD reference.

Figure 4-2 shows the relationship between NGVD water level elevation and lagoon. A fourth degree polynomial was fit to estimate lagoon volume from tidal elevation. Outgoing water was computed as the volume difference between a tidal cycle's maximum elevation and following minimum elevation based on the estimated tidal data. The time-weighted average outgoing volume per cycle computed from 802 outgoing tidal cycles and 426 days was 1,497,500 m^3 (1,214 acre-ft) and the average daily outgoing flow was 2,819,000 m^3 (2,285 acre-ft). A report on the hydrodynamic studies is included as Appendix B in the IM&E Characterization Study Report (Tenera Environmental 2008).

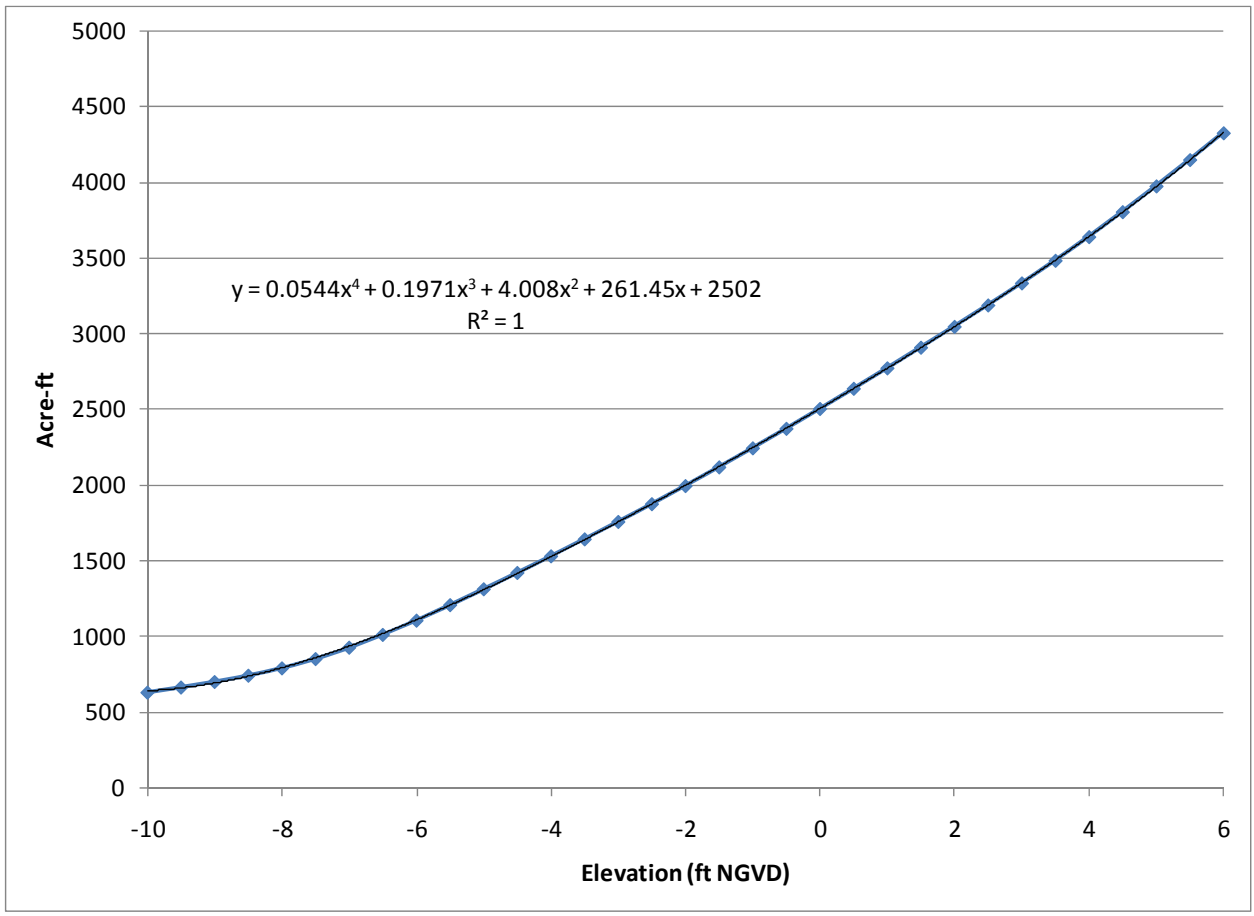

Figure 4-2. Relationship between water level in the lagoon and volume of the Agua Hedionda Lagoon. For reference, mean lower low water (MLLW) is -2.56 ft NGVD.

4.4 Sampling Results

4.4.1 IM&E Entrainment and Source Water Results

A total of 20,601 larval fishes representing 41 taxa was collected from the EPS entrainment station (E1) during 13 monthly surveys in the 2004–2005 sampling period (**Table 4-1**). Gobies (CIQ goby complex) and blennies comprised over 90% of all specimens collected, with anchovy larvae the third most abundant taxon at approximately 4%. The greatest concentrations of larval fishes, primarily gobies, occurred during the August 2004 survey and the fewest occurred in December 2004 (**Figure 4-3**). Larvae tended to be more abundant in samples collected at night than those collected during the day. Fish fragments and damaged fishes that could not be identified to species comprised a small fraction of the total catch. Of the target shellfishes

sampled, only one *Cancer* crab megalopa and no spiny lobster larvae were collected at the entrainment station.

Total annual entrainment was estimated to be 22.7 million fish larvae during the 12 months from June 2004 through May 2005 using the CECP process design flow of 4.32 mgd as the basis for the calculations (**Table 4-2**). The following three taxa were selected for detailed evaluation of entrainment effects based on their abundance in entrainment samples and/or importance as fishery species:

- CIQ goby complex (unidentified Gobiidae)
- combtooth blennies (*Hypsoblennius* spp.)
- anchovies (primarily *Engraulis mordax*)

These three taxa comprised nearly 95% of all entrained larvae (**Table 4-1**). In general, most of the larvae collected from the entrainment samples did not have any direct fishery value, and those with fishery value, such as California halibut, were in low abundance. The three groups of fishes were also the most abundant fish larvae in the source water (**Table 4-3).** No invertebrate taxa were evaluated for entrainment effects because only a single *Cancer* crab megalops was identified from the entrainment samples.

Table 4-1. Average concentration of larval fishes and target shellfishes in entrainment samples collected in Agua Hedionda Lagoon (Station E1), June 2004–May 2005.

Taxon	Common Name	Average Concentration (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Gobiidae (CIQ complex)	Gobies	2,222.93	12,763	61.95	61.95
Hypsoblennius spp.	blennies	1,107.67	5,838	28.34	90.29
Engraulidae	Anchovies	134.29	819	3.98	94.27
Hypsypops rubicundus	garibaldi	40.99	188	0.91	95.18
Typhlogobius californiensis	blind goby	24.65	148	0.72	95.90
Gibbonsia spp.	clinid kelpfishes	22.45	125	0.61	96.51
Labrisomidae.	labrisomid kelpfishes	17.65	81	0.39	96.90
Syngnathidae	pipefishes	16.06	83	0.40	97.30
Acanthogobius flavimanus	yellowfin goby	14.41	87	0.42	97.72
larvae, unid. fish fragment	unidentified larval fishes	9.65	56	0.27	98.00
Atherinopsidae	Silverside	9.18	54	0.26	98.26
larvae, unid. yolksac	unidentified yolksac larvae	8.36	39	0.19	98.45
Roncador stearnsii	spotfin croaker	8.33	42	0.20	98.65
Rimicola spp.	kelp clingfishes	7.92	43	0.21	98.86
Genyonemus lineatus	white croaker	7.04	44	0.21	99.07
Seriphus politus	Queenfish	5.50	29	0.14	99.21
Paraclinus integripinnis	reef finspot	4.95	31	0.15	99.36
Paralichthys californicus	California halibut	3.73	21	0.10	99.47
Sardinops sagax	Pacific sardine	2.66	16	0.08	99.54
Citharichthys spp.	sanddabs	2.24	14	0.07	99.61
Gillichthys mirabilis	longjaw mudsucker	2.14	13	0.06	99.67
Sciaenidae	croakers	1.86	11	0.05	99.73
Paralabrax spp.	sand basses	1.86	11	0.05	99.78
Hypsopsetta guttulata	diamond turbot	1.78	10	0.05	99.83
larvae, unid. post-yolksac	larval fishes	1.61	10	0.05	99.88
Pleuronectiformes	flatfishes	0.63	4	0.02	99.90
Heterostichus rostratus	giant kelpfish	0.54	3	0.01	99.91
Clinocottus analis	wooly sculpin	0.51	3	0.01	99.93
Stenobrachius leucopsarus	northern lampfish	0.37	2	0.01	99.94
Cheilotrema saturnum	black croaker	0.35	2	0.01	99.95
Scomber japonicus	Pacific mackerel	0.35	1	<0.01	99.95
Ophidiidae	cusk-eels	0.21	1	<0.01	99.96
Gobiesocidae	clingfishes	0.20	1	<0.01	99.96
Diaphus theta	California headlight fish	0.19	1	<0.01	99.96
Semicossyphus pulcher	California sheephead	0.19	1	<0.01	99.97
Menticirrhus undulatus	California corbina	0.18	1	<0.01	99.97
Haemulidae	grunts	0.18	1	<0.01	99.98
Labridae	wrasses	0.17	1	<0.01	99.98
Myctophidae	lanternfishes	0.16	1	<0.01	99.99
Symbolophorus californiensis	California lanternfish	0.16	1	<0.01	99.99
Oxyjulis californica	señorita	0.14	1	<0.01	100.00
			20,601		
Cancer spp. (megalops)	cancer crabs	0.17	1		

Table 4-2. Calculated annual entrainment of larval fishes and target shellfishes based on CECP flow of 4.32 mgd.

Taxon	Common Name	Annual Entrainment (Maximum Flow)	Std. Error (Max Flow)
Gobiidae (CIQ complex)	gobies	13,947,591	509,224
Hypsoblennius spp.	combtooth blennies	6,615,223	363,152
Engraulidae	anchovies	791,432	40,814
Hypsypops rubicundus	garibaldi	183,110	14,476
Gibbonsia spp.	clinid kelpfishes	149,295	9,454
Typhlogobius californiensis	blind goby	146,109	12,287
Acanthogobius flavimanus	yellowfin goby	106,066	8,605
Syngnathidae	pipefishes	97,680	8,119
Labrisomidae.	labrisomid kelpfishes	82,660	5,517
Atherinopsidae	silverside	63,783	3,350
larvae, unid. fish fragment	unidentified larval fishes	55,565	2,170
Roncador stearnsii	spotfin croaker	53,818	3,695
Rimicola spp.	kelp clingfishes	49,969	3,128
Genyonemus lineatus	white croaker	47,716	2,009
Paraclinus integripinnis	reef finspot	42,120	3,893
larvae, unid. yolksac	unid. yolksac larvae	40,325	2,245
Seriphus politus	queenfish	37,977	2,747
Paralichthys californicus	California halibut	24,595	1,330
Sardinops sagax	Pacific sardine	17,110	1,100
Gillichthys mirabilis	longjaw mudsucker	14,178	813
Paralabrax spp.	sand basses	13,988	533
Citharichthys spp.	sanddabs	13,358	1,110
Hypsopsetta guttulata	diamond turbot	12,456	760
larvae, unid. post-yolksac	larval fishes	11,607	903
Sciaenidae	croakers	10,907	838
Pleuronectiformes	flatfishes	3,752	539
Clinocottus analis	wooly sculpin	3,544	358
Heterostichus rostratus	giant kelpfish	3,006	339
Stenobrachius leucopsarus	northern lampfish	2,759	270
Cheilotrema saturnum	black croaker	2,340	292
Haemulidae	grunts	1,272	218
Ophidiidae	cusk-eels	1,243	235
Labridae	wrasses	1,217	209
Scomber japonicus	Pacific mackerel	1,180	295
Diaphus theta	California headlight fish	1,140	215
Semicossyphus pulcher	California sheephead	1,140	215
Myctophidae	lantern fishes	979	185
Symbolophorus californiensis	California lantern fish	979	185
Menticirrhus undulatus	California corbina	975	195
Oxyjulis californica	señorita	788	152
Gobiesocidae	clingfishes	566	157
Total		**22,655,519**	**627,340**
Cancer spp. (megalops)	cancer crabs	1,012	191

Table 4-3. Average concentration of larval fishes and target shellfishes in source water samples collected at in Agua Hedionda Lagoon and nearshore stations, June 2004–May 2005.

Taxon	Common Name	Nearshore		Lagoon	
		Average Concentration (per 1,000 m^3)	Total Count	Average Concentration (per 1,000 m^3)	Total Count
Fishes					
Engraulidae	anchovies	525.48	7,631	103.41	1,210
Hypsoblennius spp.	blennies	137.56	1,966	467.32	4,725
Gobiidae (CIQ complex)	gobies	69.12	921	2,718.58	30,270
Genyonemus lineatus	white croaker	64.66	921	4.25	54
larvae, unidentified yolksac	unid. yolksac larvae	45.82	678	3.12	32
Paralichthys californicus	California halibut	42.91	601	1.93	22
Paralabrax spp.	sand basses	24.88	372	0.68	8
Seriphus politus	queenfish	23.79	365	2.40	26
Sciaenidae	croaker	22.55	306	6.56	73
Citharichthys spp.	sanddabs	21.70	334	1.14	15
Roncador stearnsii	spotfin croaker	20.17	286	6.82	74
Gibbonsia spp.	clinid kelpfishes	19.29	277	16.74	182
Labrisomidae	labrisomid kelpfishes	16.36	219	35.30	366
Sardinops sagax	Pacific sardine	13.21	202	0.74	9
larval fish fragment	unid. larval fishes	10.50	145	15.02	174
Haemulidae	grunts	8.80	116	0.17	2
Scomber japonicus	Pacific mackerel	7.07	110	-	-
Hypsypops rubicundus	garibaldi	7.03	110	35.12	352
larval/post-larval fish unid.	larval fishes	6.81	93	1.36	16
Oxyjulis californica	senorita	5.55	79	0.75	8
Paralabrax nebulifer	barred sand bass	5.08	82	-	-
Sphyraena argentea	California barracuda	3.74	59	0.17	2
Xenistius californiensis	salema	3.61	55	0.30	3
Lepidogobius lepidus	bay goby	3.59	56	0.09	1
Stenobrachius leucopsarus	northern lampfish	3.26	51	-	-
Atherinopsidae	silversides	3.09	39	29.73	348
Pleuronichthys verticalis	hornyhead turbot	2.79	43	-	-
Umbrina roncador	yellowfin croaker	2.62	39	0.09	1
Ophidiidae	cusk-eels	2.61	37	0.09	1
Pleuronichthys ritteri	spotted turbot	2.51	34	0.17	2
Pleuronectidae unid.	flounders	2.28	35	0.08	1
Xystreurys liolepis	fantail sole	1.97	27	0.21	2
Hypsopsetta guttulata	diamond turbot	1.97	30	0.55	7
Rimicola spp.	kelp clingfishes	1.79	22	3.28	34
Peprilus simillimus	Pacific butterfish	1.78	28	-	-
Cheilotrema saturnum	black croaker	1.71	24	0.36	4
Semicossyphus pulcher	California sheephead	1.49	21	-	-
Diaphus theta	California headlight fish	1.46	24	-	-
Acanthogobius flavimanus	yellowfin goby	1.46	22	38.98	499
Pleuronectiformes	flatfishes	1.25	21	0.07	1
Menticirrhus undulatus	California corbina	1.21	16	0.47	5
Atractoscion nobilis	white seabass	1.18	18	0.08	1
Sebastes spp.	rockfishes	1.09	18	-	-
Girella nigricans	opaleye	1.06	16	-	-
Syngnathidae	pipefishes	1.02	13	5.31	53
Typhlogobius californiensis	blind goby	0.99	15	9.63	118
Trachurus symmetricus	jack mackerel	0.96	17	-	-
Halichoeres semicinctus	rock wrasse	0.95	15	-	-
Labridae	wrasses	0.83	11	-	-
Paraclinus integripinnis	reef finspot	0.81	14	2.88	31
Symphurus atricaudus	California tonguefish	0.77	11	-	-
Triphoturus mexicanus	Mexican lampfish	0.73	12	0.16	2
Nannobrachium spp.	lanternfishes	0.57	9	-	-

(table continued)

Table 4-3 (continued). Average concentration of larval fishes and target shellfishes in source water samples collected at in Agua Hedionda Lagoon and nearshore stations, June 2004-May 2005.

		Nearshore		Lagoon	
Taxon	**Common Name**	**Average Concentration (per 1,000 m^3)**	**Total Count**	**Average Concentration (per 1,000 m^3)**	**Total Count**
Medialuna californiensis	halfmoon	0.53	7	-	-
Gillichthys mirabilis	longjaw mudsucker	0.51	8	5.17	62
Chilara taylori	spotted cusk-eel	0.50	7	-	-
Heterostichus rostratus	giant kelpfish	0.50	7	-	-
Paralichthyidae	lefteye flounders & sanddabs	0.44	7	-	-
Parophrys vetulus	English sole	0.30	5	-	-
Myctophidae	lanternfishes	0.30	4	-	-
Hippoglossina stomata	bigmouth sole	0.29	5	-	-
Zaniolepis frenata	shortspine combfish	0.25	5	-	-
Ruscarius creaseri	roughcheek sculpin	0.22	3	-	-
Clupeiformes	herrings and anchovies	0.21	3	-	-
Gobiesocidae	clingfishes	0.18	3	0.64	7
Clupeidae	herrings	0.18	3	-	-
Lyopsetta exilis	slender sole	0.16	3	-	-
Pomacentridae	damselfishes	0.14	2	-	-
Rhinogobiops nicholsii	blackeye goby	0.14	2	-	-
Nannobrachium ritteri	broadfin lampfish	0.13	2	-	-
Cyclothone spp.	bristlemouths	0.13	2	-	-
Chromis punctipinnis	blacksmith	0.13	2	-	-
Icelinus spp.	sculpins	0.13	3	-	-
Anisotremus davidsonii	sargo	0.12	2	-	-
Sebastes jordani	shortbelly rockfish	0.10	2	-	-
Blennioidei	blennies	0.08	1	0.36	4
Clinidae	clinid kelpfishes	0.08	1	-	-
Chaenopsidae	tube blennies	0.07	1	-	-
Leptocottus armatus	Pacific staghorn sculpin	0.07	1	0.51	6
Cynoglossidae	tongue soles	0.07	1	-	-
Kyphosidae	sea chubs	0.07	1	-	-
Cyclothone acclinidens	benttooth bristlemouth	0.07	1	-	-
Hexagrammidae	greenlings	0.06	1	-	-
Bathylagus ochotensis	popeye blacksmelt	0.06	1	-	-
Hypsoblennius gentilis	bay blenny	0.05	1	-	-
Rimicola eigenmanni	slender clingfish	-	-	4.13	53
Clinocottus analis	wooly sculpin	-	-	0.31	4
Clinocottus spp.	sculpins	-	-	0.07	1
Semicossyphus pulcher	California sheephead	-	-	0.06	1
			16,763		**38,872**
Shellfishes					
Cancer spp. (megalops)	cancer crabs	9.29	158	0.17	2
Panulirus interruptus (phyllosome)	California spiny lobster	7.04	98	0.21	2
Cancer gracilis (megalops)	slender crab	2.93	48		

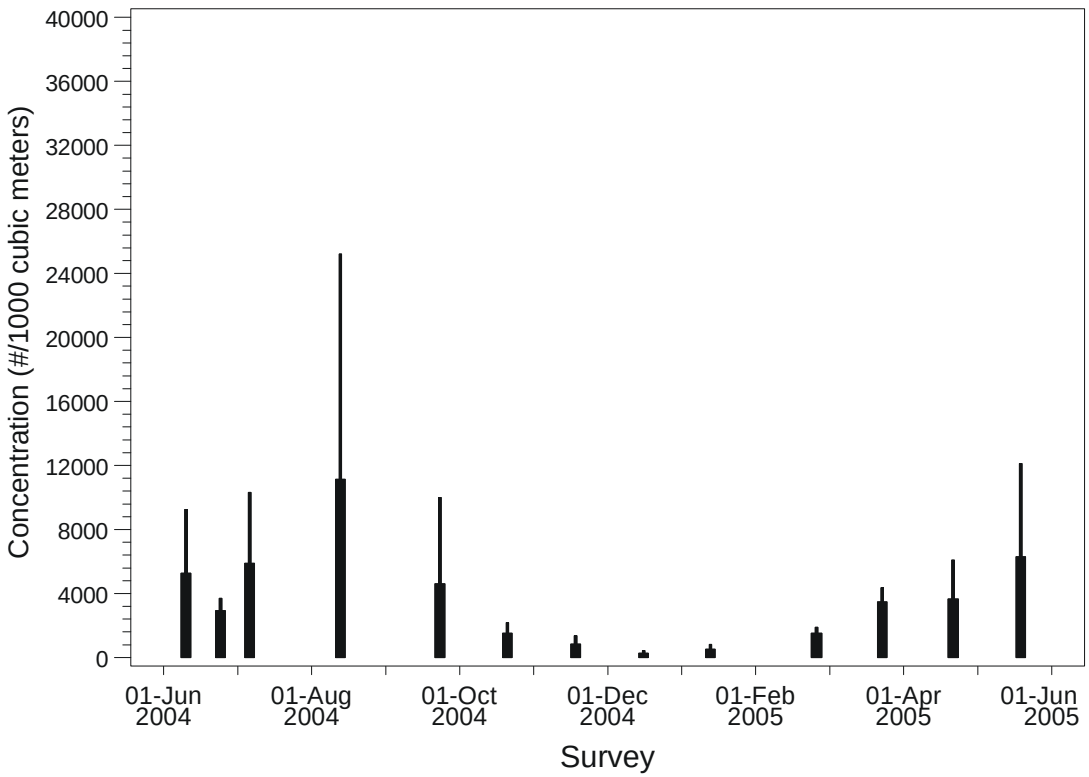

Figure 4-3. Mean concentration (# / 1,000 m^3 [264,172 gal]) and standard error of all larval fishes collected at EPS entrainment Station E1 during the 2004–2005 period.

4.5 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.

4.5.1 CIQ Goby complex (*Clevelandia ios, Ilypnus gilberti, Quietula y-cauda*)

Range: Vancouver Island, British Columbia to Gulf of California

Life History:

- Size up to 57 mm (2.1 in) (arrow goby); 64 mm (2.5 in) (cheekspot goby); 70 mm (2.75 in) (shadow goby)
- 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 (0.55-1.14 in) 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 are small, demersal fishes that are found worldwide in shallow tropical and subtropical environments. The family Gobiidae contains approximately 1,875 species in 212 genera (Nelson 1994; Moser 1996). Twenty-one goby species from 16 genera occur from the northern California border to south of Baja California (Moser 1996). In addition to the three species comprising the CIQ complex, there are at least five other common species in AHL and the adjacent nearshore waters: blackeye goby (*Rhinogobiops nicholsii*), yellowfin goby (*Acanthogobius flavimanus*), longjaw mudsucker (*Gillichthys mirabilis*), blind goby (*Typhlogobius californiensis*), and bay goby (*Lepidogobius lepidus*). The three species in the CIQ complex have been combined for analysis in the present study because it is not possible to distinguish between them at the small sizes typically collected in the plankton tows. The following section presents an overview of the family and life history characteristics of each of the three species.

4.5.1.1 Life History and Ecology

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 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. 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.

One of the most important characteristics of the goby family is their small size. 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).

Gobies generally occur in shallow marine habitats, however many members of the family are euryhaline and are able to tolerate very low salinities and even freshwater. A number of goby species also have the ability to survive out of the water by "breathing" air. The longjaw mudsucker can survive for days out of water if kept moist, and the mudskipper *Periopthalmus* spp. regularly leaves the water to forage for terrestrial insects among mangrove roots and exposed rocks. Gobies eat a variety of larval, juvenile, and adult crustaceans, mollusks, and insects. Many will also eat small fishes, fish eggs, and fish larvae.

Arrow goby *Clevelandia ios* occupy the most northerly range of the three species, occurring from Vancouver Island, British Columbia to Baja California (Eschmeyer and Herald 1983). The reported northern range limits of both shadow goby *Quietula y-cauda* and cheekspot goby *Ilypnus gilberti* are in central California with southern ranges that extend well into the sub-tropical 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 (89.9°F) for three days in a laboratory experiment, no arrow goby survived, but 95% 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 goby is the most abundant of the three species in bays and estuaries from Tomales Bay to San Diego Bay. It is also the most abundant of the three species in AHL. 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 43 km (26.7 mi) south of AHL. 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% 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 1996). Therefore, larval gobies collected during entrainment sampling that could not be identified to the species level were grouped into the 'CIQ' goby complex (for *Clevelandia*, *Ilypnus* and *Quietula*), or the family level 'Gobiidae' if specimens were damaged but could still be recognized as gobiids. Some larger larval specimens with well-preserved pigmentation patterns could be identified to the species level[1] but those that were speciated in this study were subsequently combined into the CIQ complex for analysis.

[1] W. Watson, Southwest Fisheries Science Center, pers. comm.

The reproductive biology of the three species in the CIQ complex is similar. Arrow goby typically mature sooner than the other two species, attaining 50% maturity in the population after approximately 8 mo as compared to 16–18 mo 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 1996). Hatched larvae are planktonic and the duration of the planktonic stage was estimated at 60 days for populations in Mission Bay located south of EPS in San Diego County (Brothers 1975). Arrow gobies mature more quickly and spawn a greater number of eggs at a younger age than either the cheekspot or shadow gobies. As with most fishes, fecundity is dependent on age and size of the female. Fecundity of gobies in Mission Bay ranged from 225–750 eggs per batch for arrow gobies, 225–1,030 eggs for cheekspot, and 340–1,400 for shadow, for a mean value of 615 per batch for the CIQ complex. Mature females for the CIQ complex deposit 2–5 batches of eggs per year.

CIQ complex larvae hatch at a size of 2–3 mm (0.08–0.12 in) (Moser 1996). Data from Mission Bay from Brothers (1975) were used to estimate an average growth rate of 0.16 mm/d (0.006 in/d) for the approximately 60 days from hatching to settlement. Brothers (1975) estimated a 60-day larval mortality of 98.3% for arrow goby larvae, 98.6% for cheekspot, and 99.2% 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 (0.39-0.59 in), depending on the species (Moser 1996), the juveniles settle into the benthic environment. For the Mission Bay populations mortality following settlement was 99% per year for arrow goby, 66–74% for cheekspot goby, and 62–69% for shadow goby. Few arrow gobies in the Mission Bay study exceeded 3 yr of age based on otolith records, whereas cheekspot and shadow gobies commonly lived for 4 yr (Brothers 1975).

There is no fishery for CIQ gobies and therefore no records on adult population trends based on landings data.

4.5.1.2 Sampling Results

CIQ complex goby larvae was the most abundant taxon collected at the entrainment station during the EPS IM&E Study conducted from June 2004 through June 2005 (**Table 4-1**). It was also the most abundant taxon at the lagoon source water stations and the third most abundant taxon at the combined nearshore source water stations (**Table 4-3**). CIQ goby larvae were most abundant at the entrainment station during August and least abundant from December through January (**Figure 4-4**). Peak abundances at source water stations generally occurred in summer months with CIQ goby larvae having highest concentrations in the Inner Lagoon stations, followed by Middle Lagoon, Outer Lagoon, and nearshore stations (**Figure 4-5**). Variation in abundance not only reflected differences in the habitats sampled but also the spawning periods for the three species comprising the CIQ complex. Brothers (1975) indicated that the peak spawning period for arrow goby occurs from November through April, while spawning in cheekspot and shadow goby is more variable and can occur throughout the year. The data for

CIQ gobies from each entrainment and source water survey are presented in **Appendix E** of the EPS IM&E Study (Tenera Environmental 2008).

There was no consistent relationship between daytime and nighttime larval abundances at the entrainment station, although overall concentrations tended to be higher at night (**Figure 4-6**). During July the larval concentrations were greater during daytime (Cycle 1, noon), but in the August survey they were greater at night (Cycle 3, midnight). The length-frequency distribution for a representative sample of CIQ goby larvae showed that the majority of the sampled larvae were recently hatched based on the reported hatch size of 2–3 mm (0.08-0.12 in) (Moser 1996)**.** A random sample of 200 CIQ goby larvae from all the surveys ranged in size from 1.9 to 6.4 mm (0.075 to 0.25 in) with a mean size of 2.8 mm (0.11 in) (**Figure 4-7**).

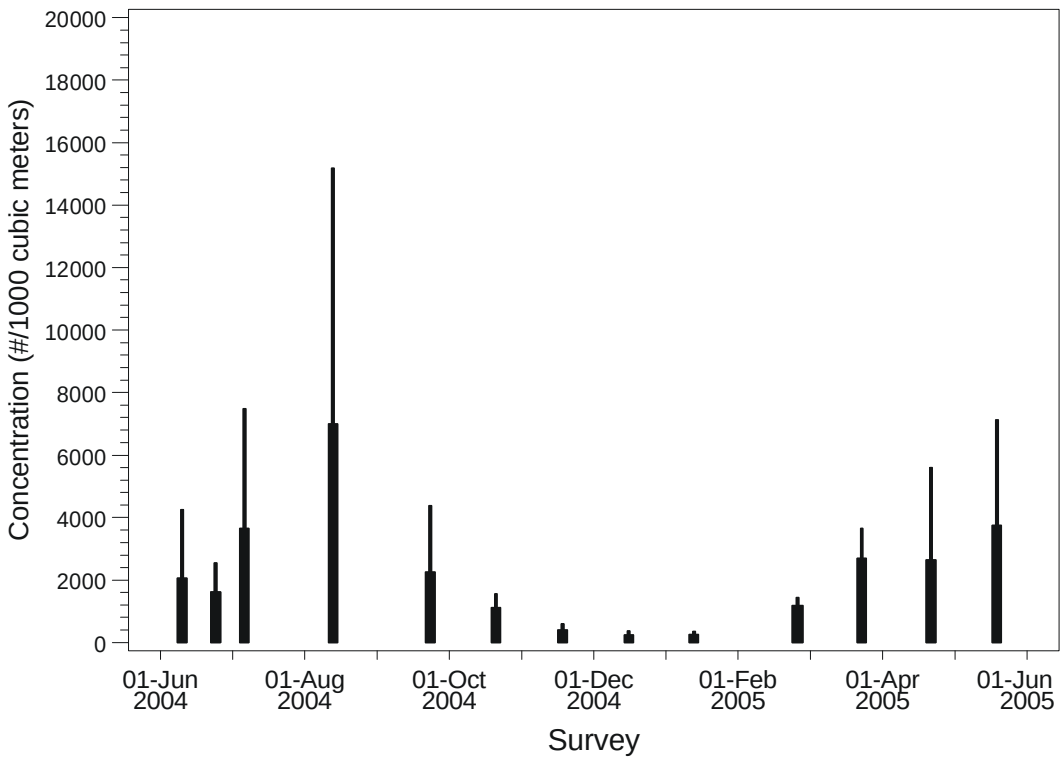

Figure 4-4. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of CIQ goby complex larvae at entrainment Station E1.

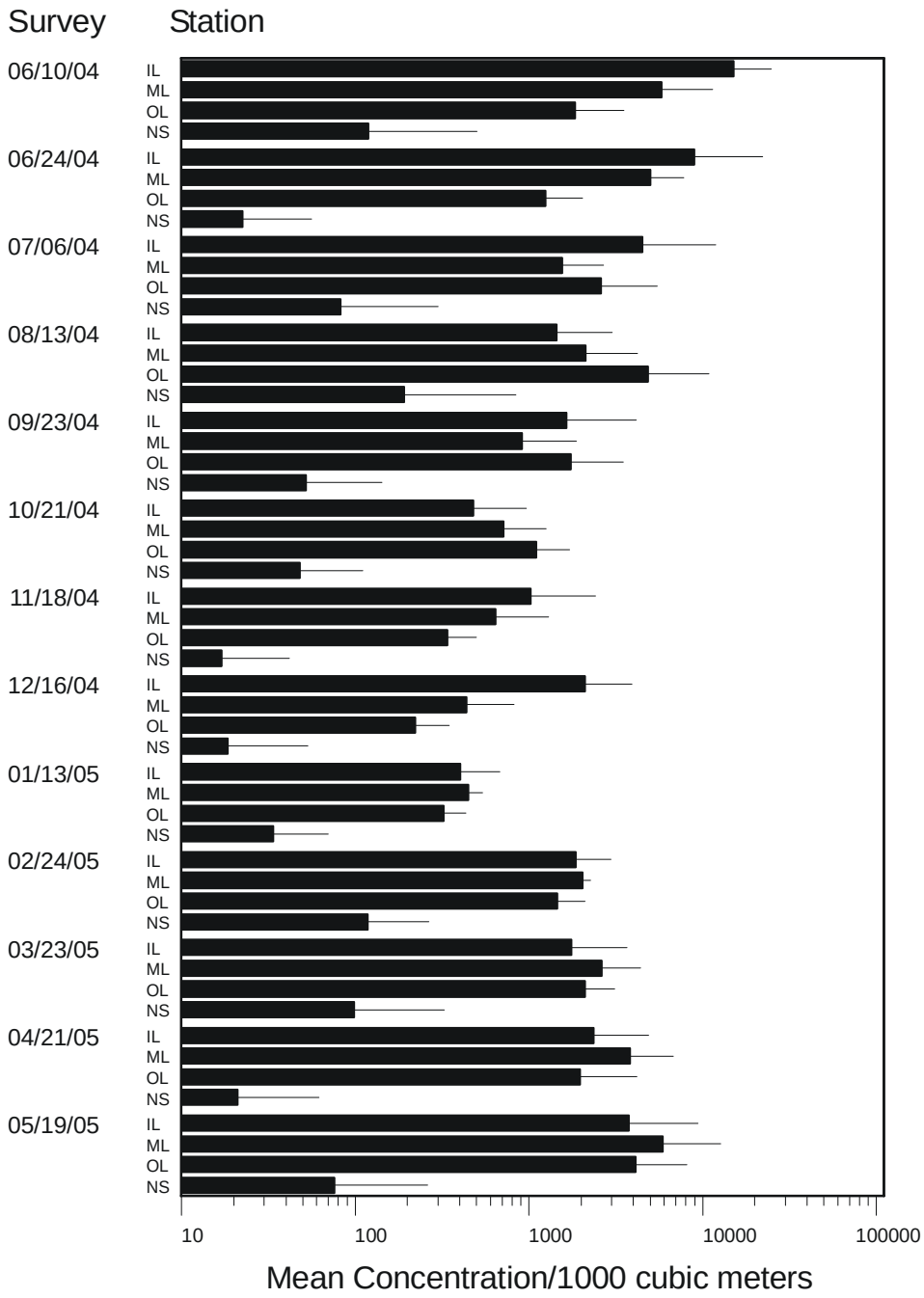

Figure 4-5. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of CIQ goby complex larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations. Note logarithmic abundance scale.

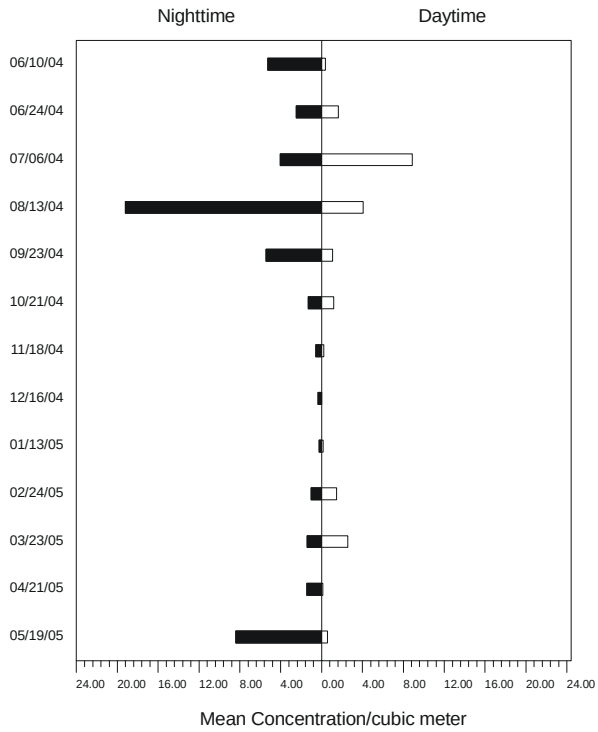

Figure 4-6 Mean concentration (#/1.0 m^3 [264 gal]) of CIQ goby complex larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

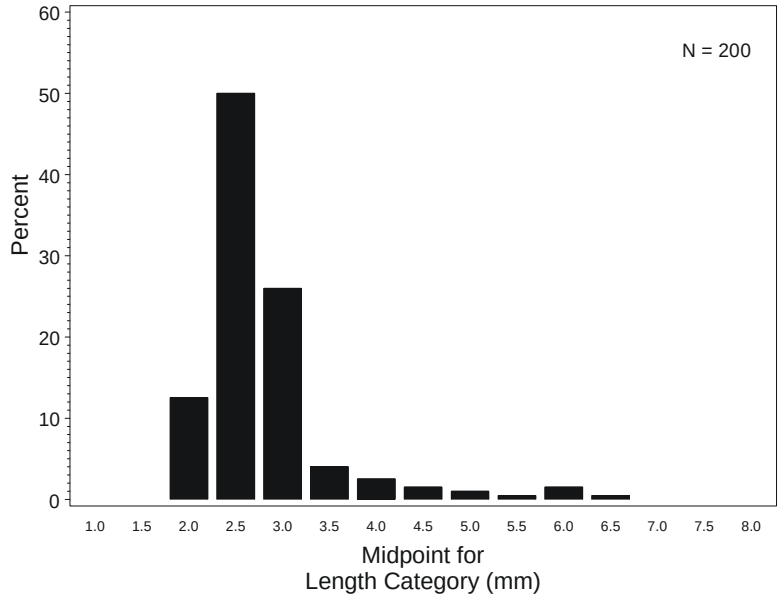

Figure 4-7. Length frequency of CIQ goby complex larvae at entrainment Station E1. Data from sub-samples of all surveys during 2004–2005.

4.5.1.3 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CECP intake effects on goby populations. A comprehensive comparative study of the three goby species in the CIQ complex by Brothers (1975) provided the necessary life history information for both the *FH* and *AEL* demographic models. Based on data collected from June 2004 through May 2005 period during the EPS IM&E Study, the total annual entrainment of CIQ goby larvae for the CECP process water was estimated to be 13.9 million (**Table 4-2**).

4.5.1.3.1 Fecundity Hindcasting (*FH*)

Annual entrainment estimates from the IM&E Study for CIQ gobies were used to estimate the number of females at the age of maturity needed to produce the number of larvae entrained during their lifetime. No estimates of egg survival for gobies were available, but because gobies deposit demersal egg masses (Wang 1986) and exhibit parental care, usually provided by the adult male, egg survival is generally high and was conservatively assumed to be 100%. Estimates of larval survival for the three species from Brothers (1975) were used to compute an average daily survival of 0.93. A larval growth rate of 0.16 mm/d (0.006 in/d) was estimated from transformation lengths reported by Brothers (1975) for the three species and an estimated transformation age of 60 d. The mean length and the length of the 25th percentile (2.4 mm [0.09 in]) of entrained larvae collected during the IM&E Study were used with the calculated growth rate to estimate that the mean age at entrainment was 2.4 d. Survival to the average age at entrainment was then estimated as $0.93^{2.4} = 0.84$. A survivorship table was constructed using data from Brothers (1975) and was used to estimate a total lifetime fecundity of 1,400 eggs (**Table 4-4**). Ages of at least 50% maturity averaged 1.67 years.

The estimated numbers of female gobies at the age of maturity whose lifetime reproductive output that would be lost due to entrainment by the CECP based on the data collected during the EPS IM&E Study was estimated at 11,845 using the maximum daily CECP flow of 4.32 mgd (**Table 4-5**).

Table 4-4. Total lifetime fecundity estimates for three goby species based on a life table in Brothers (1975).

Species	Age	N	% Mature	Fecundity	Spawns	No. Eggs	Eggs per Spawner	TLF
Clevelandia ios	0	500						
	1	100	81	450	1.5	54,675	547	
	2	4	100	700	2.0	5,600	56	**603**
Ilypnus gilberti	0	500						
	1	80	10	260	0	0		
	2	51	71	480	1.5	26,071	511	
	3	14	99	720	3.0	29,938	587	
	4	2	100	900	3.0	5,400	106	**1,204**
Quietula y-cauda	0	500						
	1	74	23	410	0	0		
	2	50	87	620	1.5	4,0455	809	
	3	26	99	840	2.5	54,054	1081	
	4	7	100	1,200	3.0	25,200	504	**2,394**
							Mean	**1,400**

Table 4-5. Results of *FH* modeling for CIQ goby complex larvae based on CECP process intake volume of 4.32 mgd. The upper and lower estimates are based on a 90% confidence interval of the mean. *FH* estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Parameter	Mean	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH Estimate	11,845	10,294	2,836	49,479	46,644
Total Entrainment	13,947,591	1,018,449	10,422	13,268	2,846

4.5.1.3.2 Adult Equivalent Loss (*AEL*)

The parameters required for formulation of *AEL* estimates include larval survival from entrainment to settlement and survival from settlement to the average age of reproduction for a mature female. Larval survival from entrainment through settlement was estimated as $0.93^{60-2.4} = 0.02$ using the same daily survival rate used in formulating *FH*. Brothers (1975) estimated that mortality in the first year following settlement was 99% for arrow, 66–74% for cheekspot, and 62–69% for shadow goby. These estimates were used to calculate a daily survival of 0.995 that was used to estimate a finite survival of 0.21 for the first year following settlement. Daily survival through the average female age of 2.21 years from life table data for the three species was estimated as 0.994 and was used to calculate a finite survival of 0.21.

The number of adult CIQ gobies that were lost due to entrainment by the CECP based on the data collected during the 2004–2005 IM&E Study was estimated at 10,278 using the maximum daily CECP flow of 4.32 mgd (**Table 4-6**).

Table 4-6. Results of *AEL* modeling for CIQ goby complex larvae based on CECP flow of 4.32 mgd. The upper and lower estimates are based on a 90% confidence interval of the mean. *AEL* estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Parameter	Mean	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
AEL Estimate	10,278	11,567	1,614	65,448	63,834
Total Entrainment	13,947,591	1,018,449	9,044	11,513	2,469

4.5.1.3.3 Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for CIQ gobies was based on the lengths of entrained larvae collected during the 2004–2005 IM&E Study. The difference between the lengths of the 25th and 95th percentiles was used with a growth rate of 0.16 mm/d (0.006 in/d) to estimate that CIQ goby larvae were vulnerable to entrainment for a period of 11.5 days.

CIQ gobies larvae were present in the entrainment and source water samples throughout the year. The monthly estimates of proportional entrainment (*PE*) based on data collected during the IM&E Study ranged from 0.00006 to 0.00054 (**Table 4-7**). The largest estimates occurred during the August survey with the largest proportion of the source population also occurring during that survey (f_i = 0.186 or 18.6%). The values in the table were used to calculate a P_M estimate of 0.00296 with a standard error of 0.00423.

Table 4-7. *ETM* data for CIQ goby larvae based on CECP process flow volume of 4.32 mgd.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i
10-Jun-04	0.00008	0.00088	0.11600
24-Jun-04	0.00013	0.00168	0.03160
6-Jul-04	0.00033	0.00366	0.07955
13-Aug-04	0.00054	0.00576	0.18595
23-Sep-04	0.00033	0.00301	0.06335
21-Oct-04	0.00024	0.00101	0.04577
18-Nov-04	0.00013	0.00103	0.02347
16-Dec-04	0.00006	0.00053	0.02729
13-Jan-05	0.00007	0.00026	0.03878
24-Feb-05	0.00007	0.00029	0.14489
23-Mar-05	0.00024	0.00122	0.11674
21-Apr-05	0.00039	0.00520	0.03690
19-May-05	0.00028	0.00288	0.08971
P_M	**0.00296**		
Std. Error	0.00423		

4.5.2 Combtooth blennies (*Hypsoblennius* spp.)

Gerald Allen

Range:

- Bay blenny—Monterey Bay to Gulf of California.
- Mussel blenny—Morro Bay to Magdalena Bay Baja California and the northern Gulf of California
- Rockpool blenny—Morro Bay to Magdalena Bay

Life History:

- Size: bay blenny to 14.7 cm TL (5.8 in), mussel blenny to 13 cm (5.1 in), rockpool blenny to 17 cm (6.8 in)
- Age at maturity: all species ≈0.5 yr
- Life span: bay blenny ≈7 yr, mussel blenny <6 yr, rockpool blenny >8 yr
- Fecundity: bay blenny 500–1,500 eggs, mussel blenny 200–2,000 eggs, rockpool blenny 700-1,700 eggs

Habitat:

- Bay blenny—soft bottom in bays and estuaries, associated with submerged aquatic vegetation and mussels on mooring buoys; to 24 m (80 ft)
- Mussel blenny—empty worm tubes and barnacle tests on pilings, mussel beds, crevices in shallow rock reefs; to 21 m (70 ft)
- Rockpool blenny—under rocks, in crevices on shallow rock reefs; to 18 m (60 ft)

Fishery: None

Combtooth blennies comprise a large group of subtropical and tropical fishes that inhabit inshore rocky habitats throughout much of the world. 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. Three species of the genus *Hypsoblennius* occur in the vicinity of EPS: 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 (Love et al. 2005).

4.5.2.1 Life History and Ecology

Combtooth blennies are all relatively small fishes that typically grow to a total length of less than 200 mm (7.9 in) (Moser 1996). Their bodies are generally elongate and without scales. Dorsal fins are often continuous and contain more soft rays than spines (Moyle and Cech 1988). Coloration in the group is quite variable, even among individuals of the same species (Stephens et al. 1970).

The three species of *Hypsoblennius* found in California waters are morphologically similar as early larvae (Moser 1996, Ninos 1984). For this reason most *Hypsoblennius* identified in the EPS IM&E Study samples were identified as *Hypsoblennius* spp. Certain morphological features (e.g., preopercular spines) develop at larger sizes and allow taxonomists to identify some older larvae to the species level. The mussel blenny is common in AHL and life history information for this species was used to model entrainment impacts on this group.

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.

The California 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 appears to have general habitat requirements and may inhabit a variety of intertidal and subtidal areas. They are commonly found in mussel beds and on encrusted floats, buoys, docks, and even fouled boat hulls. Bay blennies are also typically found in bays as the common name implies and are tolerant of estuarine conditions. They are among the first resident fish species to colonize new or disturbed marine habitats such as new breakwaters or mooring floats after the substrate is first colonized by attached invertebrates (Stephens et al. 1970, Moyle and Cech 1988). Rockpool blennies are mainly found along shallow rocky shorelines, along breakwaters, and in shallow kelp forests along the outer coast.

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. Blennies are oviparous and lay demersal eggs that are attached to the nest substrate by adhesive pads or filaments. Males tend the nest and developing eggs. Females spawn 3–4 times over a period of several weeks. 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. 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).

Larvae are pelagic and average approximately 2.7 mm (0.11 in) in length two days after hatching (Stephens et al. 1970). The planktonic phase for *Hypsoblennius* spp. larvae may last for 3 months. Captured larvae released by divers have been observed to use surface water movement and near-surface currents to aid swimming (Ninos 1984). After release the swimming larvae orient to floating algae, bubbles on the surface, or the bottoms of boats or buoys. The size at settlement ranges from 12–14 mm (0.5–0.6 in). After the first year mussel and bay blenny averaged 40 and 45 mm (1.6 and 1.8 in) total length, respectively (Stephens et al. 1970). 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. Mussel blennies grow to 13 cm (5.1 in) and have a life span of 3–6 years. Male and female growth rates are similar.

Juvenile and adult combtooth blennies are omnivores and eat both algae and a variety of invertebrates, including limpets, urchins, and bryozoa (Stephens 1969, Love 1996). They are preyed on by spotted sand bass, kelp bass, giant kelpfish, and cabezon (Stephens et al. 1970).

There is no fishery for combtooth blennies and therefore no records on adult population trends based on landings data.

4.5.2.2 Sampling Results

Combtooth blenny larvae was the second most abundant taxon collected in the entrainment samples and source water samples during the EPS IM&E Study conducted from June 2004 through June 2005 (**Tables 4-1** and **4-3**). They were most abundant from May through September and least abundant from October through April (**Figure 4-8**) with maximum concentrations at the entrainment station in August 2004 (3,900 per 1,000 m^3). Concentrations of larval blennies in the source water were generally greatest in the Outer and Middle Lagoon and least at the nearshore stations (**Figure 4-9**), and substantially greater in night samples than those collected during the day (**Figure 4-10**). The number of larval combtooth blennies collected during each entrainment and source water survey is presented **Appendix E** of the EPS IM&E Study (Tenera Environmental 2008).

The length frequency distribution for a random sample of 200 combtooth blenny larvae from all the surveys during the IM&E Study ranged in size from 1.8 to 3.3 mm (0.07 to 0.13 in) with a mean size of 2.3 mm (0.09 in) (**Figure 4-11**). The size range for the entrainment samples indicate that the majority of the larvae were recently hatched based on a reported hatching size of 2.1 mm (0.08 in) (Moser 1996).

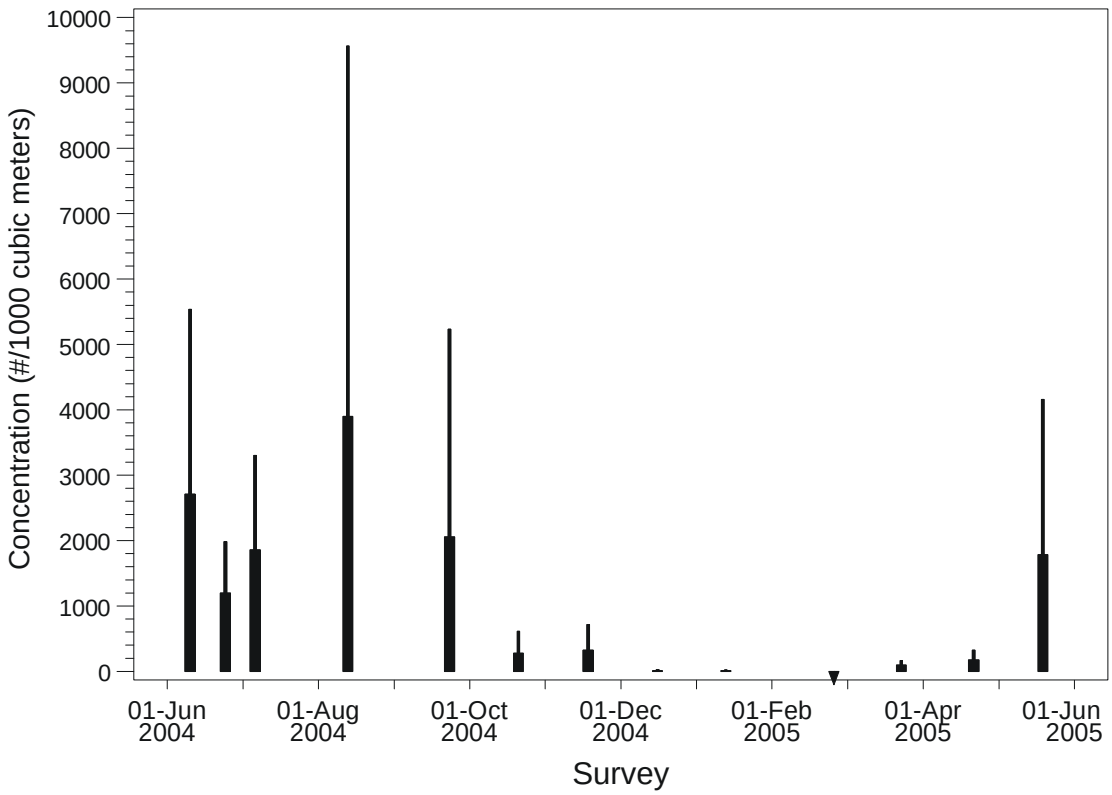

Figure 4-8. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of combtooth blenny larvae at entrainment Station E1. Note: Downward pointing triangle indicates survey with no larvae collected.

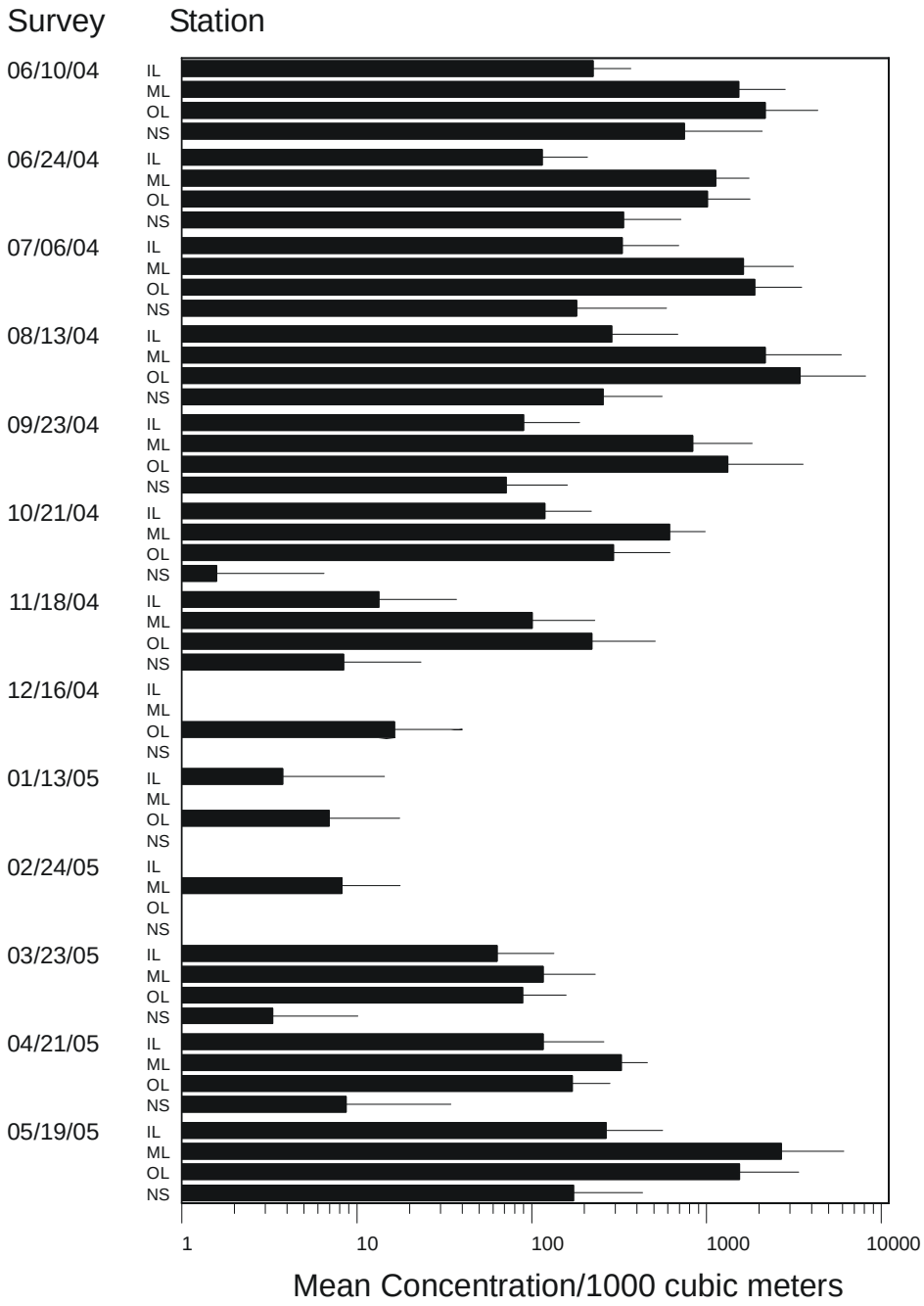

Figure 4-9. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of combtooth blenny larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations. Note logarithmic abundance scale.

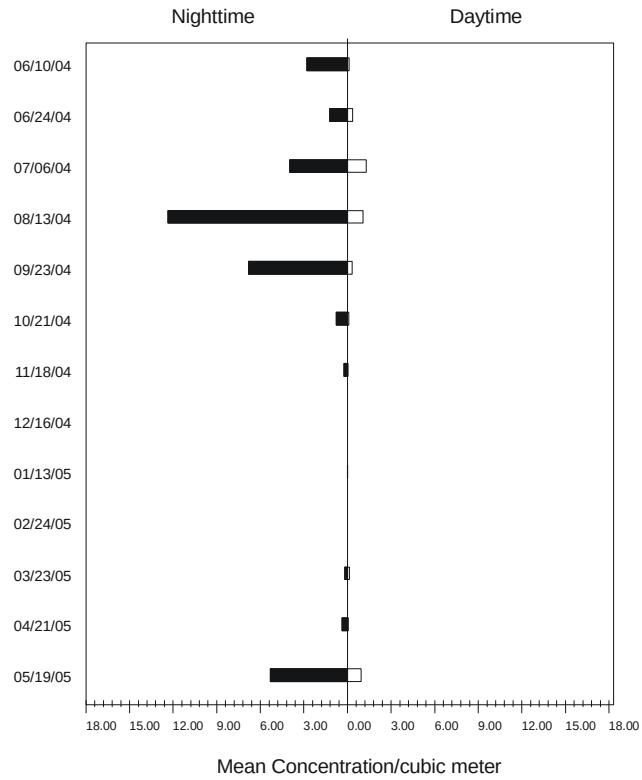

Figure 4-10. Mean concentration (#/1.0 m^3 [264 gal]) of combtooth blenny larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

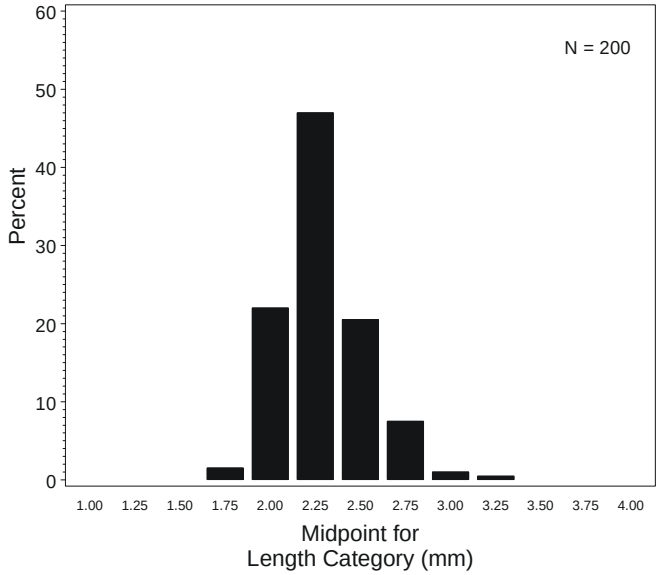

Figure 4-11. Length frequency of combtooth blenny larvae at entrainment and all source water stations combined. Data from sub-samples of all surveys during 2004–2005.

4.5.2.3 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CECP intake effects on combtooth blennies. There was very little species-specific life history information available for combtooth blennies. Larval survival was estimated using data from Stephens (1969) and Stevens and Moser (1982), and there was enough other information on reproduction to calculate an *FH* estimate, but not to calculate an *AEL* estimate. Larval growth was estimated from information from Stevens and Moser (1982). Based on data collected during the IM&E Study from June 2004–May 2005, the total annual entrainment of combtooth blenny larvae for the CECP process water was estimated to be 6.6 million (**Table 4-2**).

4.5.2.3.1 Fecundity Hindcasting (*FH*)

The annual entrainment estimates for combtooth blenny larvae were used to estimate the number of females at the age of maturity needed to produce this number of larvae over their lifetimes. No estimates of egg survival for combtooth blenny were available, but because egg masses are attached to the substrate and guarded by the male, egg survival is probably high and was conservatively assumed to be 100%. The mean length for larval combtooth blenny larvae in entrainment samples was 2.3 mm (0.09 in). A larval growth rate of 0.20 mm/day (0.008 in/d) was derived from growth rates using data in Stevens and Moser (1982). The mean length and the length at the 25th percentile (2.1 mm [0.08 in]) were used with the growth rate to estimate that the mean age at entrainment was 0.7 days. A daily survival rate of 0.89 computed from data in Stephens (1969) was used to calculate survival to the average age at entrainment as $0.89^{0.7} = 0.91$. A quadratic equation was used to estimated adult survival S at age in days x using Figure 17 in Stephens (1969):

$$S = 8.528 \times 10^{-8} x^2 - 3.918 \times 10^{-4} x + 0.4602 \qquad (10)$$

An adult survivorship table (**Table 4-8**) was constructed using the survival equation based on Stephens (1969) and information about eggs from Stephens (1969; Table 3) on *H. gentilis*, *H. gilberti* and *H. jenkinsi* to estimate a lifetime fecundity of 2,094 eggs.

Table 4-8. Survivorship table for adult combtooth blenny from data in Stephens (1969) showing spawners (L_x) surviving to the age interval and numbers of eggs spawned annually (M_x). The total lifetime fecundity was calculated as the sum of L_xM_x divided by 1,000.

Age (yr)	L_x	M_x	L_xM_x
0.5	1,000	367	366,667
1.5	693	633	438,624
2.5	443	1,067	472,794
3.5	252	1,533	386,465
4.5	119	2,000	237,915
5.5	44	2,500	109,973
6.5	27	3,000	81,415
		TLF =	**2,094**

The estimated numbers of female combtooth blennies at the age of maturity (0.5 years) whose lifetime reproductive output was entrained by the CECP intake based on the data collected during the 2004–2005 IM&E Study was estimated at 3,454 based on an intake volume of 4.32 mgd (**Table 4-9**). The range of estimates based on the 90% confidence intervals shows that the variation in the estimate of entrainment abundance had much less of an effect on the variation of the *FH* estimate, by an order of magnitude, than the life history parameters used in the model.

Table 4-9. Results of *FH* modeling for combtooth blenny larvae based on CECP intake volume of 4.32 mgd. The upper and lower estimates are based on a 90% confidence interval of the mean. *FH* estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Parameter	Mean	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH Estimate	3,454	3,015	822	14,521	13,699
Total Entrainment	6,615,223	726,305	2,830	4,078	1,248

4.5.2.3.2 Adult Equivalent Loss (*AEL*)

The parameters required for formulation of *AEL* include larval survival from entrainment to settlement and survival from settlement to the average age of reproduction for a mature female. Larval survival from entrainment through settlement at 50 days was estimated as $0.89^{(50-0.7)} = 0.003$ using the same daily survival rate used in formulating *FH*. Juvenile and adult survival was calculated from observed age group abundances in Stephens (1969). Daily survival through the average female age of 2.7 years for the three species was estimated at 0.99 and was used to calculate a finite survival of 0.79.

The estimated number of adult combtooth blennies equivalent to the number of larvae entrained by the CECP intake flow based on the data collected during the 2004–2005 IM&E Study was estimated at 14,760 based on an intake volume of 4.32 mgd (**Table 4-10**).

Table 4-10. Results of *AEL* modeling for combtooth blenny larvae based on CECP process intake volume of 4.32 mgd. The upper and lower estimates are based on a 90% confidence interval of the mean. *AEL* estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Parameter	Mean	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
AEL Estimate	14,760	18,150	1,953	111,577	109,624
Total Entrainment	6,615,223	726,305	12,094	17,426	5,332

4.5.2.3.3 Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for combtooth blenny was based on the lengths of entrained larvae collected during the IM&E Study. The difference between the lengths of the 25th and 95th percentiles was used with a growth rate of 0.20 mm/day (0.008 in/d) to estimate that combtooth blenny larvae were vulnerable to entrainment for a period of about 2.7 days.

The monthly estimates of proportional entrainment (*PE*) for combtooth blennies based on data collected during the June 2004–May 2005 IM&E Study varied among surveys and ranged from 0 to 0.00279 (**Table 4-11**). The largest estimate was calculated for the January survey, but the largest proportion of the source population was present during the early June survey (f_i = 0.299 or 29.9%). The values in the table were used to calculate a P_M estimate of 0.00122 with a standard error of 0.00190.

Table 4-11. *ETM* data for combtooth blenny larvae based on CECP process flow volume of 4.32 mgd.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i
10-Jun-04	0.00035	0.00029	0.29923
24-Jun-04	0.00019	0.00018	0.12245
6-Jul-04	0.00023	0.00066	0.13375
13-Aug-04	0.00071	0.00155	0.26395
23-Sep-04	0.00083	0.00360	0.05771
21-Oct-04	0.00106	0.00623	0.00319
18-Nov-04	0.00074	0.00438	0.00523
16-Dec-04	0.00138	0.00419	0.00035
13-Jan-05	0.00279	0.01942	0.00004
24-Feb-05	0	0	0.00001
23-Mar-05	0.00060	0.00135	0.00327
21-Apr-05	0.00034	0.00119	0.00885
19-May-05	0.00040	0.00111	0.10197
P_M	**0.00122**		
Std. Error	0.00190		

4.5.3 Anchovies (Engraulidae)

Range: British Columbia to southern Baja California

Life History:

- Size: to 248 mm (9.7 in.)
- Age at maturity: 1–2 yr
- Fecundity: multiple spawning at 6-10 day intervals peaking in late winter and spring, releasing from 2,700 to 16,000 eggs per batch;
- Life span: 4–5 yr (up to 7 yr)

Habitat: Pelagic from surface to depths of 310 m (1,017 ft)

Fishery: Commercial fishery for fish meal reduction, human consumption, and bait (live and frozen)

Three species of anchovy (Family Engraulidae) are known to inhabit AHL and EPS nearshore areas: northern anchovy (*Engraulis mordax*), deepbody anchovy (*Anchoa compressa*) and slough anchovy (*Anchoa delicatissima*). This analysis of entrainment effects on anchovies will concentrate on life history aspects of the northern anchovy because all of the Engraulid larvae collected that were large enough to be positively identified were northern anchovies. Almost half of the specimens could be identified only to the family level (Engraulidae) including very small specimens still in their recently-hatched yolk-sac stage and some specimens that were damaged to an extent that did not allow positive identification to the species level. No *Anchoa* larvae of any size were positively identified in the entrainment samples although adult deepbody anchovy were common in the EPS impingement samples.

Northern anchovy range from Cape San Lucas, Baja California to Queen Charlotte Island, British Columbia, and offshore to 480 km (298 miles) (Hart 1973). They are most common from Magdalena Bay, Baja California to San Francisco Bay and within 157 km (98 miles) of shore (Hart 1973, MBC Applied Environmental Sciences 1987). Northern anchovy is one of four species of anchovies (Family Engraulidae) that occurs off California (Miller and Lea 1972). Deepbody anchovy and slough anchovy are found in the vicinity of EPS, while the anchoveta (*Cetengraulis mysticetus*) has been recorded from southern California but is considered rare north of Magdalena Bay, Baja California.

Three genetically distinct subpopulations are recognized for northern anchovy; (1) Northern subpopulation, from northern California to British Columbia; (2) Central subpopulation, off southern California and northern Baja California; and (3) Southern subpopulation, off southern Baja California (Emmett et al. 1991).

4.5.3.1 Life History and Ecology

The reported depth range of northern anchovy is from the surface to depths of 310 m (1,017 ft) (Davies and Bradley 1972). Juveniles are generally more common inshore and in estuaries. Eggs are elliptical and occur from the surface to about 50 m (164 ft), while larvae are found from the

surface to about 75 m (246 ft) in epipelagic and nearshore waters (Garrison and Miller 1982). Northern anchovy larvae feed on small planktonic organisms such as dinoflagellates, rotifers, and copepods (MBC Applied Environmental Sciences 1987). Juveniles and adults feed mainly at night on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971, Hart 1973, Allen and DeMartini 1983).

Northern anchovy spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978). Most spawning takes place within 100 km (62 miles) of shore. On average, female anchovies off southern California spawn every 7–10 days during peak spawning periods, approximately 20 times per year (Hunter and Macewicz 1980). Most spawning occurs at night and is completed by dawn. Anchovies are all sexually mature by age two, and the fraction of the population that is sexually mature at one year of age can range from 47 to 100% depending on the water temperature during development (Bergen and Jacobsen 2001). Love (1996) reported that they release 2,700–16,000 eggs per batch, with an annual fecundity of up to 130,000 eggs per year in southern California. Parrish et al. (1986) and Butler et al. (1993) stated that the total annual fecundity for one-year old females was 20,000-30,000 eggs, while a five-year old could release up to 320,000 eggs per year.

The eggs from northern anchovy eggs hatch in two to four days following spawning. The larval phase lasts approximately 70 days, and the larvae undergo transformation into juveniles at about 35-40 mm (Hart 1973, Moser 1996). Larvae begin schooling at 11 to 12 mm SL (0.43 to 0.47 in) (Hunter and Coyne 1982). Northern anchovy reach 102 mm (4 in) in their first year, and 119 mm (4.7 in) in their second (Sakagawa and Kimura 1976). Larval survival is strongly influenced by the availability and density of the phytoplankton species they utilize as food (Emmett et al. 1991). Storms and strong upwelling reduce larval food availability, and strong upwelling may transport larvae out of the Southern California Bight (Power 1986). However, strong upwelling may benefit juveniles and adults. Growth in length is most rapid during the first four months, and growth in weight is most rapid during the first year (Hunter and Macewicz 1980, PFMC 1983). They mature at 78 to 140 mm (3.1 to 5.5 in) in length, in their first or second year. Maximum size is about 230 mm (9 in) and 60 g (2.1 ounces). Maximum age is about seven years (Hart 1973), though most live less than four years (Fitch and Lavenberg 1971).

Northern anchovy are random planktonic feeders, filtering plankton as they swim. They feed mostly on larval crustaceans, but also on fish eggs and larvae (Fitch and Lavenberg 1971). Numerous fish and marine mammal species feed on northern anchovy. Elegant tern and California brown pelican reproduction is strongly correlated with the annual abundance of this species (Emmett et al. 1991). Temperatures above 25°C (77°F) are avoided by juveniles and adults (Brewer 1974).

4.5.3.2 Population Trends and Fishery

Northern anchovy are fished commercially for reduction (e.g., fish meal, oil, and paste) and live or frozen bait. 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 populations increased dramatically following the collapse of the Pacific sardine (*Sardinops sagax*) fishery, suggesting competition between these two species (Smith 1972).

Estimates of the central subpopulation averaged about 325,679 metric tons (359,000 tons) from 1963 through 1972, then increased to over 1.54 metric tons (1.7 million tons) in 1974, then declined to 325,679 metric tons (359,000 tons) in 1978 (Bergen and Jacobsen 2001). Anchovy biomass in 1994 was estimated at 391,904 metric tons (432,000 tons). The stock is thought to be stable, and the size of the anchovy resource is largely dependent on natural influences such as ocean temperature. There have not been any landings of northern anchovy in San Diego County recorded in the PacFIN database since 1996 when 144,242 kg (318,000 lb) were landed. In 2004 there were 147,417 kg (325,000 lb) landed in the Los Angeles area, 2,753 metric tons (3,035 tons) in the Santa Barbara area, and 3,892 metric tons (4,290 tons) in the Monterey area for a total value of $750,000.

The anchovy live bait fishery is monitored by CDFG through the submission of Live Bait Logs. Live bait logs have been at different times either mandated by state law, or submitted to the CDFG on a voluntary basis. In the early 1990s sardine became more prevalent in the bait fishery, and quotas were imposed on their annual take pursuant to management efforts to recover the sardine population off California. In 1995, CDFG lifted quotas restricting the quantity of sardines that the live bait industry could harvest (PFMC 2005). The sardine population along the California Coast was increasing toward a “recovered” level, as anchovy showed a decline, and sardines became the preferred live bait over anchovy. With the sardine quota lifted, the level of scrutiny on the harvest of the live bait industry lessened. Accurate levels of harvest for northern anchovy alone are difficult to ascertain due to the multi-species nature of the live bait fishery.

The ratio of anchovy to sardine in the southern California live bait harvests shifts significantly as the populations of these two fish expand and contract over periods of years or decades (PFMC 2005). Much of the early reported harvest consisted of anchovy, following the collapse of the sardine fishery in the 1940s. Through the years of 1994 to 2004, the proportion of anchovy in the total reported harvest ranged from a high of 58% in 1994 to a new low in 2004 of 5%. The proportion of sardine ranged from a low of 42% in 1994, to a new high of 95% in 2004.

4.5.3.3 Sampling Results

Engraulid larvae (predominantly northern anchovy) was the third most abundant taxon at the entrainment station during the EPS IM&E Study conducted from June 2004–June 2005 with a mean concentration of 134 per 1,000 m^3 (264,172 gal) over all the surveys (**Table 4-1**). Although 61% of the engraulid larvae collected were positively identified as northern anchovy, the remaining specimens were newly hatched, or in some cases damaged to the extent that they could not be positively identified past the family level. Therefore, all specimens were combined into the Engraulidae category for analysis. Their abundance was highly seasonal with over 90% of the larvae in the entrainment samples occurring from March through May (**Figure 4-12**). There was a broader temporal distribution of the larvae in the monthly source water samples than

in the entrainment samples although peak abundances still tended to occur in March–May and lowest abundances in December (**Figure 4-13).** The nearshore station group generally had higher concentrations of anchovy larvae compared to the lagoon stations. The number of larval anchovies collected during each entrainment and source water survey is presented in **Appendix E** of the EPS IM&E Study (Tenera Environmental 2008).

The larvae tended to be more abundant in the day entrainment samples as compared to the night samples when comparing the concentrations in Cycle 1 (noon) to Cycle 3 (midnight) (**Figure 4-14).** The length frequency distribution of northern anchovy larvae measured from the 2004–2005 surveys show a distribution strongly skewed toward recently hatched larvae (**Figure 4-15**) based on the reported hatch length of 2–3 mm (0.08-0.12 in) (Moser 1996). There was a small proportion of larger larvae in the samples ranging from 5 to18 mm (0.19 to 0.7 in). A random sample of 200 anchovy larvae from the entrainment samples from all of the IM&E Study surveys ranged in size from 1.2 to 18.0 mm (0.05 to 0.7 in) with a mean size of approximately 2.9 mm (0.11 in).

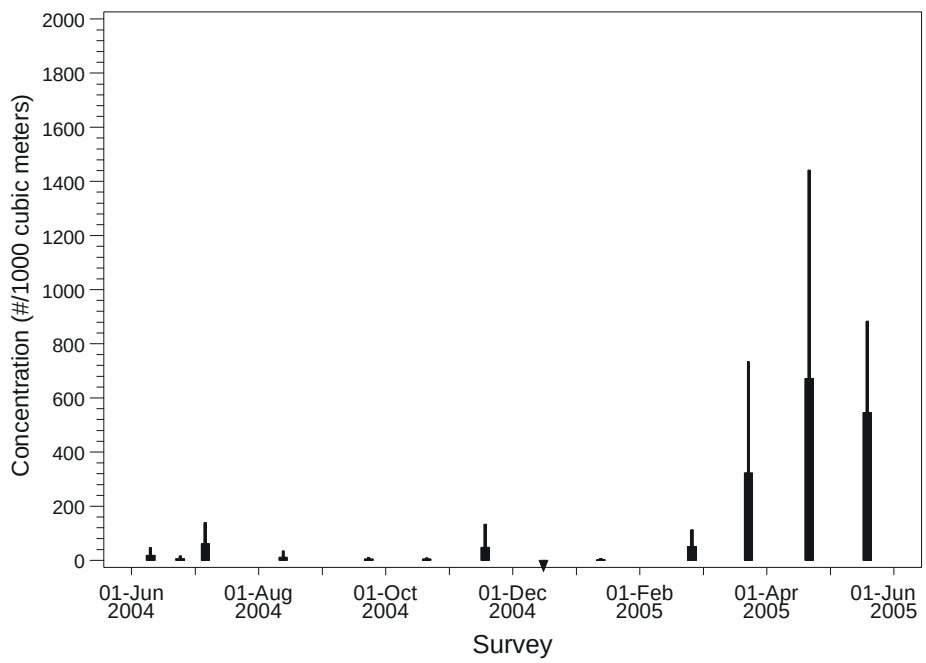

Figure 4-12. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of anchovy larvae at entrainment Station E1. Note: Downward pointing triangle indicates survey with no larvae collected.

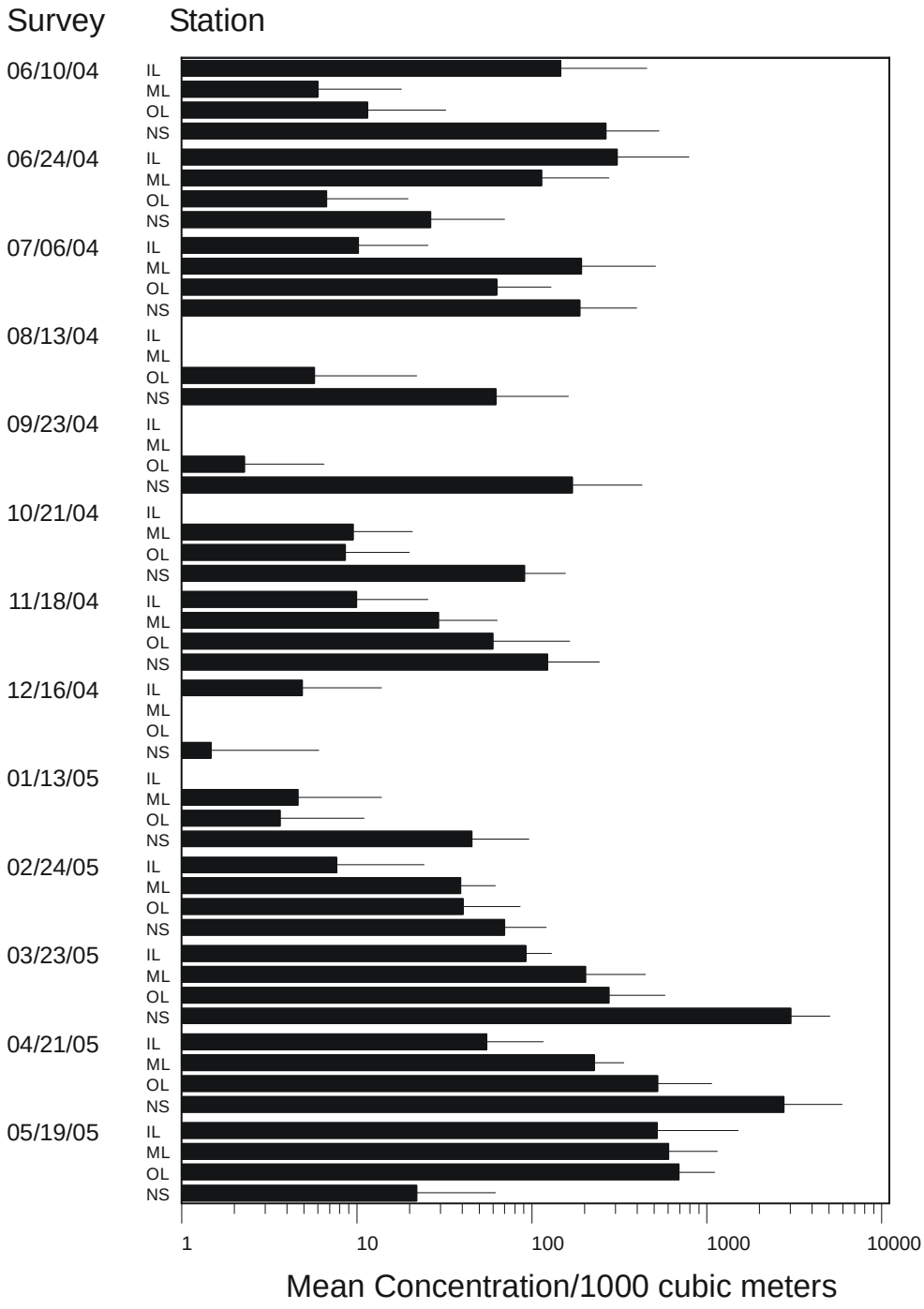

Figure 4-13. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of anchovy larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations. Note logarithmic abundance scale.

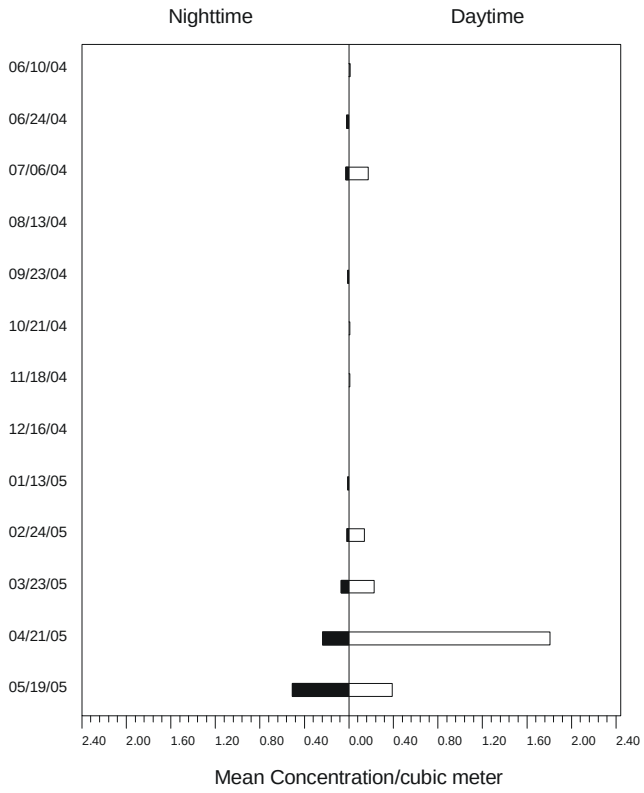

Figure 4-14. Mean concentration (#/1.0 m^3 [264 gal]) of anchovy larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

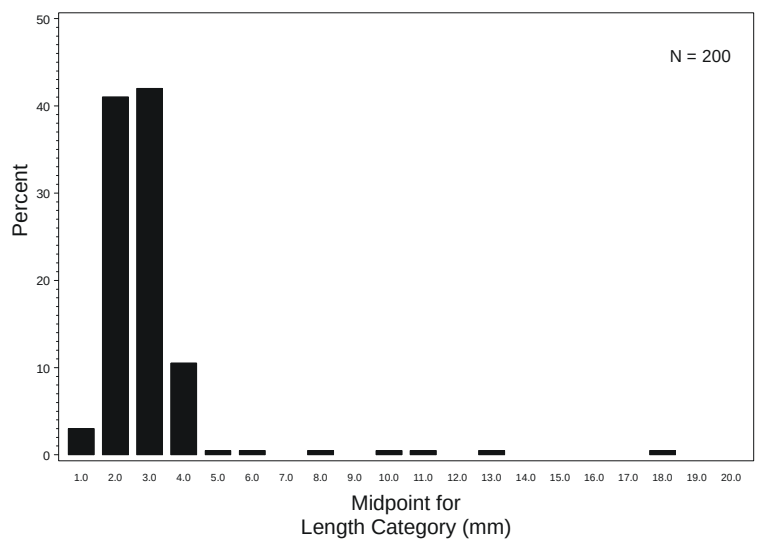

Figure 4-15. Length frequency of anchovy larvae at entrainment Station E1. Data from sub-samples of all surveys during 2004–2005.

4.5.3.4 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CECP intake effects on Engraulidae (northern anchovy) larvae. Based on data collected from June 2004–May 2005 during the EPS IM&E Study, the total annual entrainment of anchovy larvae for the CECP process water was estimated to be 0.8 million (**Table 4-2**).

4.5.3.4.1 Fecundity Hindcasting (*FH*)

The annual entrainment estimate for northern anchovy for the June 2004–May 2005 IM&E Study was used to estimate the number of breeding females at the age of maturity needed to produce the estimated number of larvae entrained by the CECP intake. Butler et al. (1993) modeled annual fecundity and egg and larval survivorship for northern anchovy. Their "best" estimate can be derived by fitting the range of mortality estimates from field collections to the assumption of a stable and stationary population age structure. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage (**Table 4-12**). Fish at the mean age of entrainment include yolk sac, early and late stage larvae. Therefore, survival estimates for all three stages were combined to obtain a finite survival value of 0.47 up to the mean age at entrainment (2.1 days), which was calculated by dividing the difference between the mean length (2.9 mm [0.11 in]) and the value of the 25th percentile (2.1 mm [0.08 in]) using a larval growth rate of 0.41 mm d^{-1} (0.02 in d^{-1}).

Table 4-12. Stage-specific life history parameters for northern anchovy (*Engraulis mordax*) modified from Butler et al. (1993). Z = instantaneous daily mortality; S = finite survival rate.

Stage	Z_{best}	Stage duration (d)	Age (d)	S_{best}	CV_{best}
Egg	0.2310	2.9		0.512	0.142
Yolk-sac larva	0.3660	3.6	6.5	0.093	0.240
Early larva	0.2860	12.0	18.5	0.032	0.071
Late larva	0.0719	45.0	63.5	0.039	0.427
Early juvenile	0.0141	62.0	125.5	0.417	0.239
Late Juvenile	0.0044	80.0	205.5	0.703	0.033
Pre-recruit	0.0031	287.0	492.5	0.411	0.088

Clark and Phillips (1952) report age at sexual maturity as 1–2 years. Similarly, Leet et al. (2001) report that 47 to 100% of one-year olds may be mature in a given year while all are mature by two years. For modeling purposes we used a mid-value of 1.5 years. For longevity, Hart (1973) reports a value of seven years, but Leet et al. (2001) states that northern anchovy in the fished

population rarely exceed four years of age. The survivorship table in **Table 4-13** was used to estimate an average annual fecundity of 163,090 over the seven-year period using the data presented in Butler et al. (1993).

Table 4-13. Survivorship table for adult northern anchovy (*Engraulis mordax*) from Butler et al. (1993) showing spawners (L_x) surviving at the start of age interval and numbers of eggs spawned annually (M_x). The total lifetime fecundity (TLF) was calculated as the sum of L_xM_x divided by 1,000.

Age (yr)	L_x	M_x	L_xM_x
1	1,000	22,500	22,500,000
2	468	93,500	43,800,000
3	216	195,000	42,000,000
4	102	280,000	28,600,000
5	48	328,000	15,700,000
6	22	328,000	7,210,000
7	10	328,000	3,280,000
		TLF =	**163,090**

The estimated numbers of 1.5 year old adult female northern anchovies whose lifetime reproductive output would be entrained by the CECP based on the data collected during the 2004–2005 IM&E Study was estimated at 20 based on a flow volume of 4.32 mgd (**Table 4-14**). The range of estimates based on the 90% confidence intervals show that the variation in the estimate of entrainment had much less of an effect on the variation of the FH estimate than the life history parameters used in the model.

Table 4-14. Results of *FH* modeling for anchovy larvae based on CECP flow volume of 4.32 mgd. The upper and lower estimates are based on a 90% confidence interval of the mean. *FH* estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Parameter	Mean	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH Estimate	20	18	5	85	80
Total Entrainment	791,432	81,628	17	24	7

4.5.3.4.2 Adult Equivalent Loss (*AEL*)

The parameters required for formulation of *AEL* estimates include larval survival from entrainment to settlement and survival from settlement to the average age of reproduction for a mature female. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage. The early larval stage survival was adjusted to the mean age at entrainment (2.1 days) and used to calculate a finite survival through age 12 d of 0.019 using the daily survival rates for yolk sac and early stage larvae. The other finite survival rates from Butler et al. (1993) were used to estimate the number of adults of age 3.03 years, the average age of a mature female in the population. The number of adult northern anchovies equivalent to the number of larvae entrained by the CECP based on the data collected during the 2004–2005 period was estimated at 42 based on a CECP process flow of 4.32 mgd (**Table 4-15**).

Table 4-15. Results of *AEL* modeling for anchovy larvae based on CECP flow volume of 4.32 mgd. The upper and lower estimates are based on a 90% confidence interval of the mean. *AEL* estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Parameter	Mean	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
AEL Estimate	42	48	6	281	275
Total Entrainment	791,432	81,628	35	49	14

4.5.3.4.3 Empirical Transport Model (*ETM*)

A larval growth rate of 0.41 mm/day (0.02 mm/day) for northern anchovies was estimated from Methot and Kramer (1979) and used with the difference in the lengths of the 25th and 95th percentiles of the measurements made on larvae collected during the IM&E Study to estimate that the larvae were exposed to entrainment for a period of approximately 4.8 days. The duration of the planktonic egg stage, 2.9 d, was added to the period for the larvae to estimate a total period of exposure of 7.7 d.

The monthly estimates of proportional entrainment (*PE*) for anchovies for the June 2004–May 2005 IM&E Study ranged from 0 to 0.00024 using the CECP process flow of 4.32 mgd (**Table 4-16**). The largest estimate was calculated for the May survey, but the largest proportion of the source population was present during the April survey (f_i = 0.429 or 42.9%). The values in the table were used to calculate a P_M estimate of 0.00002 with a standard error of 0.00004.

Table 4-16. *ETM* data for northern anchovy larvae based CECP process flow volume of 4.32 mgd.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i
10-Jun-04	<0.00001	0.00001	0.02259
24-Jun-04	<0.00001	0.00002	0.00187
6-Jul-04	0.00001	0.00003	0.02319
13-Aug-04	<0.00001	0.00003	0.01464
23-Sep-04	0	0	0.03618
21-Oct-04	0	0	0.01157
18-Nov-04	0.00001	0.00005	0.01404
16-Dec-04	0	0	0.00011
13-Jan-05	<0.00001	0.00001	0.00834
24-Feb-05	0.00001	0.00005	0.01230
23-Mar-05	<0.00001	0.00001	0.42247
21-Apr-05	<0.00001	0.00002	0.42965
19-May-05	0.00024	0.00152	0.00305
P_M	**0.00002**		
Std. Error	0.00004		

5.0 Discussion and Conclusions

5.1 Entrainment Effects

The overall impact of the CECP in terms of water withdrawals from Agua Hedionda Lagoon (AHL) will be a net reduction in volume of at least 18% below recent levels, with actual reductions depending on the future operating levels of EPS Units 4&5. This percentage is based on a comparison of actual flows recorded in 2004–2005 for all EPS units combined, the decommissioning of Units 1–3 when the CECP begins to generate power, and a 4.32 mgd flow necessary to supply a projected desalination plant to be used for process water. The potential entrainment impacts of the 4.32 mgd withdrawals on fish populations, however, were modeled as a stand-alone project, without considering the overall benefits of decommissioning EPS Units 1–3. When operated without the flow from EPS Units 4&5, the intake of 4.32 mgd will represent very little risk to marine organisms from entrainment and will present no risk from impingement due to the low intake approach velocities.

The CECP process flows will result in an estimated total annual entrainment of 22.7 million fish larvae from AHL where the intake for the EPS and CECP is located. This estimate is based on data collected at the EPS intake during the 2004-2005 Impingement Mortality and Entrainment Characterization Study (IM&E Study) (Tenera Environmental 2008). Three taxa of fishes (gobies, combtooth blennies, and northern anchovies) accounted for nearly 95% of all fish larvae entrained, with gobies representing more than 60% of the total. The projected annual entrainment of gobies of 13.9 million larvae due to the CECP process flow of 4.32 mgd, if operated 365 days of the year, is estimated to represent a loss to the population of less than 0.3% based on the same Empirical Transport Model (*ETM*) used in the analysis of the IM&E Study data (**Table 5-1**). Combtooth blennies had the next highest larval entrainment estimate at 6.6 million, resulting in an effect on the local population of less than 0.2%, while northern anchovy entrainment and population losses would be negligible at the projected CECP flow rates. Other species, including target invertebrates such as spiny lobster and Cancer crabs, had very low projected entrainment.

Table 5-1. Summary of modeling estimates for CECP entrainment flows at 4.32 mgd.

Fish Group	Estimated Annual Larval Entrainment (millions)	Adult Equivalents (2**FH*)	Adult Equivalents (*AEL*)	*ETM* estimate (P_M)
CIQ gobies	13.9	23,690	10,278	0.29%
Combtooth blennies	6.6	6,908	14,760	0.19%
Northern anchovy	0.8	40	42	<0.01%
Other species	1.3	–	–	–

5.2 Significance of Entrainment Losses

Gobies and combtooth blennies are very common in AHL and these levels of mortality would not be expected to result in any measurable population-level effects because these fishes are adapted to estuarine environments where large percentages of their larvae are regularly 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. A significant proportion of the CIQ goby larvae in the outer lagoon at the point of entrainment 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 were collected in the entrainment samples and would be entrained by the intake for the proposed CECP 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 in the lagoon. In fact, the estimates for northern anchovy are very conservative because these fish are distributed over a very large area and therefore the estimate of their source water population would be much larger than the estimate used in the calculation of *PE* which only considered areas alongshore and not further offshore where they may be more abundant (**Figure 5-1**).

The CIQ goby complex had the highest estimated entrainment at 13.9 million larvae annually (Table 5-1), and as resident fishes in AHL would be expected to be impacted to a greater extent than other fishes that occupy a variety of habitats. The source water sampling for the IM&E Study found that the highest concentrations of larval gobies occurred in the Inner Lagoon and lowest concentrations in the nearshore zone, forming a gradient of abundance (**Figure 4-5**). Monthly densities were typically several thousand per 1,000 m^3 in the Inner and Middle Lagoons, over 1,000 per 1,000 m^3 in the Outer Lagoon, and less than 100 per 1,000 m^3 in the nearshore zone. Similar but slightly lower concentrations were measured in the earlier 316(b) study done in 1979 (SDGE 1980), with goby concentrations averaging almost 500 per 1,000 m^3 in the lagoon samples and 30 per 1,000 m^3 in the nearshore samples. The higher densities during the IM&E Study indicate that the goby population in AHL has probably increased over time and has not been adversely affected by the operation of EPS even with the infilling of the Middle and Inner Lagoons and development of sandbars at the western edge of the Inner Lagoon (MEC 1995) which probably resulted in a reduction in total habitat area in recent years.

Fishes, such as CIQ gobies that are primarily restricted to coastal embayments such as AHL are at greatest risk due to entrainment by the CECP intake. In an ecological resource assessment of AHL in 1994–1995 (MEC 1995) gobies were found to be most abundant in the Inner Lagoon with densities in the samples that approached 5 per m^2 in April 1995. Similar sampling in July 1994 yielded substantially lower densities, reflecting the seasonal nature of goby recruitment in the lagoon. Adult and juvenile sampling in 2005 during the IM&E Study used enclosures to specifically capture cryptic fishes, and the resulting density estimates were greater than those from the earlier sampling using trawls. For example, arrow gobies of all sizes averaged nearly 20

per m^2 in the Inner and Middle Lagoon shoreline sampling, yielding an estimate of 200,000/ha (one hectare = 2.47 acres) of this species alone, whereas previous trawling yielded densities of less than 5 per m^2 for all gobies. With an estimated combined habitat area between the +1 ft and –4 ft MLLW elevations in the Middle and Inner Lagoons of 18.56 ha (45.9 acres) (based on 1995 bathymetry), the enclosure sampling yielded an extrapolated estimate of 3.8 million gobies in the lagoon. Reproductive individuals would only comprise a fraction of this estimate but would still be capable of producing large numbers of larvae as evidenced by the large entrainment of those larvae.

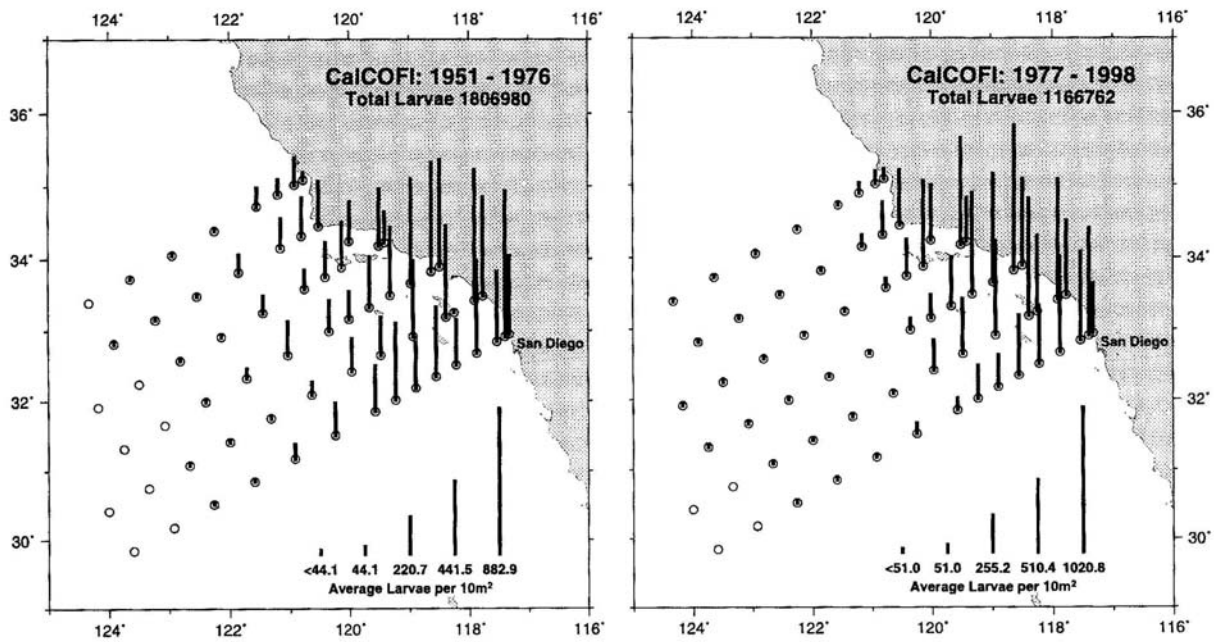

Figure 5-1. Distribution and abundance of northern anchovy larvae (*Engraulis mordax*) at permanent stations sampled in the CalCOFI study in the Southern California Bight from 1951 through 1998 (from Moser et al. 2001).

Other studies have also measured high densities of adult gobies in southern California bays and lagoons. MacDonald (1975) found densities of 4–5 per m^2 in Anaheim Bay in winter, although concentrations of up to 20 per m^2 were found in some individual burrows. Restoration efforts and subsequent monitoring in Batiquitos Lagoon 7 km (4.3 mi) south of AHL from 1997–2001 measured goby densities from 0.3 to 1.6 per m^2 annually (Merkel and Associates 2002).

The data from the IM&E Study and other sources indicate that even with the reductions in goby larvae due to entrainment by the EPS, the lagoon habitat continues to sustain a thriving population of gobies. This is evidenced not only by the large larval concentrations that are over 70 times that of the nearshore source water, but also by a census of the local juvenile and adult population. In a lagoon or bay such as AHL that is significantly affected by tidal exchange, many of the larvae are inevitably lost to the system due to export by outgoing tidal currents. The

hydrodynamic study of AHL showed that all of water in the lagoon was turned over within 6.3 tidal cycles or 3.2 days (Tenera Environmental 2008; Appendix B), which, in the absence of behavioral mechanisms to allow larval retention, would result in the loss of all of the goby larvae from the lagoon before they developed to the stage when they recruit into their adult habitat after 60 days (Brothers 1975). Fishes and other organisms that inhabit lagoons with strong tidal currents have behavioral adaptations that cause larvae to migrate toward the bottom or move to areas with less current and minimize export (Barlow 1963, Pearcy and Myers 1974, Brothers 1975) or, in larger systems, have mechanisms that allow some larvae to return to the estuary after a period of development in offshore waters.

The expected larval losses to gobies due to entrainment by the CECP intake were assessed using both population and demographic models. The ETM population-loss model estimated a loss of 0.29 percent of the larval population. This equates to approximately 11,000 adults from the estimated AHL population if the losses of larvae translated directly to losses at the adult level. This estimate is bracketed by the two estimates from the demographic models (**Table 5-1**). All of the approaches for projecting larval losses to the adult population assume that there is available habitat to support the additional production, which is not usually the case in the example of substrate-oriented or territorial species like gobies. In contrast, species that live in open water environments, such as anchovies, are generally not limited by habitat availability but by other factors such as food availability, oceanographic conditions, or predation. In AHL where there is a limited amount of benthic habitat, density–dependent mortality may be a substantial factor affecting post-settlement recruits (Brothers 1975). The large decreases in numbers of gobies in 2005 between the spring and late-summer surveys and the increasing mean length in the collected fishes reflects this high mortality rate. Therefore, projections of larval losses to the adult population likely overestimate actual adult losses. The limited habitat area in AHL coupled with the short generation times of gobies (1–3 years) explains why the population densities in AHL are similar to other bays and lagoons in southern California that have no additional mortality from once-through industrial cooling systems. The alignment of the results from the population-level and demographic modeling efforts increases the level of certainty associated with the results.

Based on the results indicating that the cooling water intake from EPS (design cooling water intake volume = 857 mgd) has not affected populations of CIQ gobies in AHL that would be most susceptible to entrainment effects, there would be no effects expected from the much smaller CECP intake (4.32 mgd). In terms of potential economic losses resulting from goby entrainment, there are no direct impacts because gobies have no fishery value, except the occasional use of larger specimens as bait by recreational anglers. Although larval reductions could have some effect on the trophic structure of the source water through the loss of available forage for predators, any potential effects would not be measurable due to the high natural variation in the system and the unknown compensatory response of other species present in the lagoon and nearshore environment.

The small fraction of marine organisms of other fishes potentially lost due to CECP entrainment would have no effect on these populations because of their widespread distribution and high reproductive potential. The most frequently entrained species are very abundant in the area of the EPS intake, AHL, and the Southern California Bight, and therefore, the actual ecological effects due to any additional entrainment from the CECP would not be significant. Species of direct recreational and commercial value constitute a very small fraction (less than 1%) of the entrained organisms and therefore, the operation of the CECP does not result in a significant ecological impact. California Department of Fish and Game in their Nearshore Fishery Management Plans provide for sustainable populations with harvests of up to 60% of unfished adult stocks. The incremental "harvest" effect of larval fishes from CECP operations at 4.3 mgd is less than 0.1% and would therefore have no significant effect on the source water populations. Generally fewer than 1% or less of all fish larvae become reproductive adults in a stable age population.

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