Cabrillo Power I LLC
Encina Power Station

CLEAN WATER ACT SECTION 316(b) IMPINGEMENT MORTALITY AND ENTRAINMENT CHARACTERIZATION STUDY

Effects on the Biological Resources of Agua Hedionda Lagoon and the Nearshore Ocean Environment

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Executive Summary

The Encina Power Station (EPS) is a fossil-fueled steam electric power generating station that began operation in 1954. EPS is located in the City of Carlsbad, California, adjacent to Agua Hedionda Lagoon on the Pacific Ocean and approximately 30 miles north of the City of San Diego (**Figure S-1**). Cooling water is withdrawn from the Pacific Ocean via the Agua Hedionda Lagoon and circulated through the EPS cooling water system (CWS) to condense freshwater steam used in power production. The combined cooling and service water design flow is 857 million gallons per day (mgd) at full operating capacity. After passing through the plant, the warmed seawater is discharged to the ocean through a shoreline forebay and conveyance channel.

This report presents data from in-plant and source water field surveys performed for the EPS Impingement Mortality and Entrainment (IM&E) Characterization Study. This study was designed and performed to comply with EPA's 2004 316(b) Phase II regulations. Originally, results from the study 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.

This report is being submitted to provide the San Diego Regional Water Quality Control Board (SDRWQCB) with information that it can use in its determination in regards to 316(b) issues for EPS. Prior to the Phase II Rule, 316(b) decisions were based on precedents from case law and on USEPA's (1977) draft "Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500." As Section 316(b) requires that an intake technology employs the 'best technology available' (BTA) for minimizing 'adverse environmental impacts' (AEI) there are two steps in determining compliance:

1. Whether or not an AEI is caused by the intakes and, if so,
2. What intake structure represents BTA to minimize that impact.

The usual approach for a 316(b) demonstration would be to consider the question of BTA only if a determination has been made that a facility is causing an AEI. The purpose of this report is to assess the potential for AEI from the operation of the EPS cooling water intake system (CWIS). The two primary impacts of a once-through power plant CWIS are impingement of juvenile and adult life stages of fishes, shellfishes, and other organisms on screens at the openings to the CWIS, and entrainment of smaller organisms, usually larval forms of fishes and shellfishes, and other forms of plankton, through the CWIS. This report provides a characterization of the fish and invertebrate species subject to entrainment and impingement at the EPS, information on the levels of IM&E at the EPS, and a discussion on the level of significance of the IM&E losses.

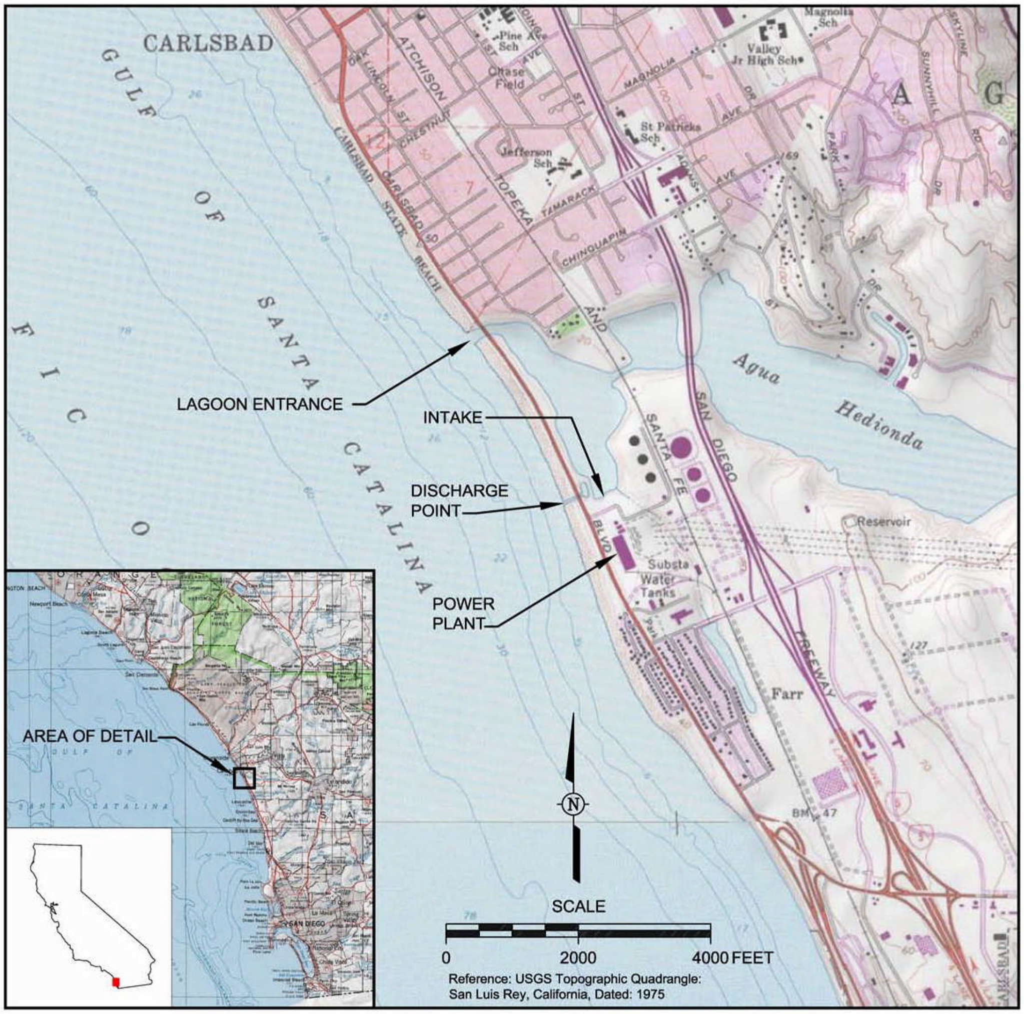


Figure S-1. Encina Power Station location map

A detailed IM&E sampling plan was developed for these IM&E studies and was previously submitted to the SDRWQCB in August 2004. The sampling plan was approved by the SDRWQCB and the sampling was conducted for one year starting in June 2004 and continuing to June 2005. The study included the following elements:

- Taxonomic identifications of all life stages of fishes, shellfishes, and any threatened or endangered species collected in the vicinity of the CWIS and are susceptible to IM&E.
- Characterization of all life stages of the target taxa in the vicinity of the CWIS and a description of the annual, seasonal, and diel variations in IM&E.
- Documentation of the current level of IM&E of all life stages of the target taxa.

The sampling methodologies and analysis techniques were derived from recent impingement and entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), and the Duke Energy South Bay Power Plant (Tenera 2004).

The information in this report is being submitted to assist in the evaluation of fish protection technologies and operational measures for EPS so that when the issues with the Phase II Rule are resolved, the plant will be prepared to move forward in a timely manner to comply with the Rule. The information is also important in evaluating the potential for adverse environmental impacts (AEI) potentially caused by impingement and entrainment. In support of this approach to compliance, the assessment of the IM&E study focuses on determining if impingement and entrainment losses pose any significant risk of AEI to the species and life stages of fish and shellfish impinged or entrained.

Detailed summaries of each component of the study are presented in the following sections. The following are brief summaries of the major findings of the study:

- The preliminary results from the IM&E sampling were used to identify 14 taxonomic groups or species of fishes and four taxonomic groups or species of shellfishes that were analyzed in greater detail in this report based on their abundances in the samples or importance to commercial or recreational fisheries. The process of identifying the group of fishes and shellfishes was done collaboratively with staff from the San Diego Regional Water Quality Control Board, California Department of Fish and Game, and National Marine Fisheries Service.
- The biological data and the actual cooling water flows measured from June 2004 through May 2005 from Units 1–5 were used to estimate that 3.63 billion fish larvae, and 162,000 target invertebrate larvae were entrained during the year. Two groups of fishes, gobies and blennies, comprised over 91% of the total entrainment.
- Data from sampling in the source waters of Agua Hedionda Lagoon and the nearshore areas around EPS were used to determine the potential effects on larval populations using a model that estimates the additional mortality on a population caused by entrainment. Except for the fishes that primarily inhabit the bay and harbor habitat of Agua Hedionda Lagoon where the intake is located, the estimated effects were very low and would not present any risk of AEI because these fishes are primarily associated with other habitats not affected by EPS entrainment.
- Due to the high estimated entrainment mortality for fishes resident in Agua Hedionda Lagoon, a series of special studies were done to determine the status of the adult populations. The results of the studies, comparisons with data from other similar lagoon habitats, and comparisons with previous entrainment data at EPS all indicated that the levels of entrainment were not resulting in AEI to these fish populations. In general, these fish groups are limited by available adult and not larval supply that is affected by entrainment.
- A total of 101 species of fishes, sharks and rays was impinged, with the top five species by numbers being topsmelt, shiner surfperch, deepbody anchovy, queenfish, and silversides. The top five species by weight were California butterfly ray, topsmelt, shiner surfperch, round stingray, and white seabass.

- The survey estimates from normal operations sampling and the samples collected during heat treatment operations were used to calculate that 4,358 kg (9,607 lb) of fishes were impinged during the June 2004 through May 2005 period with almost half of the biomass (2,035 kg [4,486 lb]) collected during the six heat treatments.
- The low level of impingement at EPS would not represent an AEI to fish or shellfish populations as the total losses are small relative to the total populations. Direct impingement losses (fish and macroinvertebrates) from both normal operations and tunnel heat treatments were equivalent to $4,749–$6,189 using 2005 commercial value data.
- No threatened or endangered fish or shellfish were collected during this or previous IM&E sampling at EPS.

Effects of Impingement and Entrainment

The withdrawal of water by once-through circulating water systems can affect biological resources of the source water body through two processes: impingement and entrainment. Most circulating water systems, including EPS, employ a primary screening device (‘bar rack’) to block larger objects from entering the circulating water system. A secondary screening system consists of an array of rotating screens with a mesh size of approximately 0.95 cm (⅜ inch). Fishes and other aquatic organisms large enough to be blocked by these screens become impinged if the intake velocity exceeds their ability to move away, or if they become entangled in debris that may be present in front of the CWIS. These organisms remain impinged until the screens are rotated and backwashed to remove them into a collection basket for disposal. Small planktonic organisms, including early life stages of larger organisms, pass through the screen mesh and are entrained into the circulating water flow. These organisms are exposed to velocity and pressure changes due to the circulating water pumps, increased temperatures and, in some cases, chlorine exposure through the plant’s condenser tubes. Although most individual organisms are killed by passage through the cooling water system (CWS), the goal of the studies is to determine if effects are significant at the population level for the affected species. The additional mortality rates imposed by the CWS on the high natural mortality rates of early life stages in most species typically cannot be measured directly in the natural population due to high natural variability in the ecosystem and must be modeled mathematically to estimate the potential impacts.

Entrainment and source water plankton net sampling was conducted monthly from June 2004 to June 2005 at both the intake station and at an array of source water stations. These entrainment and source water studies were designed to measure monthly variation in the species composition and abundance of larval fishes, cancer crabs, and spiny lobsters entrained by EPS and are used to estimate the source water populations at risk of entrainment.

The purpose of the impingement study was to characterize the juvenile and adult fishes and selected shellfishes (e.g., shrimps, crabs, lobsters, squid, and octopus) impinged by the power plant's CWIS. The sampling program was designed to provide current estimates of the abundance, taxonomic composition, diel periodicity, and seasonality of organisms impinged at EPS. In particular, the study focused on the rates (i.e., number or biomass of organisms per cubic meter of water flowing per time into the plant) at which various species of fishes and shellfishes were impinged. Impingement rates are subject to tidal and seasonal influences that vary on several temporal scales (e.g., hourly, daily, and monthly), while the rate of circulating water flow varies with power plant operations and can change at any time.

The species analyzed in this report are limited to those that were sufficiently abundant to provide reasonable assessment of impacts. For the purposes of this study, assessments were generally limited to the most abundant fishes and shellfishes that together comprised 90% of all larvae entrained and/or juveniles and adults impinged by the generating station. However, certain species that were not abundant in the samples but had particular fishery value, such as California halibut and California spiny lobster, were also reviewed.

Entrainment Results

A total of 20,601 larval fishes representing 41 taxa was collected from the EPS entrainment station during 13 monthly surveys in the 2004–2005 sampling period. 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. Larvae tended to be more abundant in samples collected at night than those collected during the day. Target shellfishes collected included only a single *Cancer* crab megalops and no larvae of spiny lobster, octopus or market squid.

Total annual entrainment was estimated to be 3.63×10^9 fish larvae from June 2004 through May 2005 using actual EPS cooling water flow for the calculations and 4.49×10^9 fish larvae during the 12 months using the maximum design flow for the EPS CWS. This equates to a 23.9% difference between the estimated entrainment using actual and design power plant intake flows. A summary of the annual numbers of the common larvae entrained by EPS, standardized by the actual volumes of cooling water utilized, are presented in **Table S-1**.

The highest entrainment occurred for larvae of lagoon species. Gobies and blennies, both small bottom-dwelling forms common in southern California lagoons, comprised the vast majority of entrained fish larvae at EPS. Entrainment losses represented nearly forty percent of the source water population of goby larvae and twenty percent of the blenny larvae (P_M value in **Table S-1**). These two species primarily inhabit the sheltered waters inside Aqua Hedionda Lagoon. The high losses result from the large volume of the water used by the CWIS relative to the volume of the lagoon. Despite these high losses other sampling associated with the study showed that adults of these species were abundant in the lagoon.

In contrast with these small, non-fishery species, that are primarily associated with the habitat inside Agua Hedionda Lagoon, species of fishery interest that are more broadly distributed across several habitats such as white croaker, white seabass, queenfish, and halibut had relatively few or no larvae entrained. As a result, these fishes incurred only small fractional losses (<2%) compared to source water populations or when projected to equivalent adults using demographic-based models.

Table S-1. Estimated numbers of common larval and post-larval fishes entrained and impinged at EPS based on actual cooling water flows from June 2004 through May 2005, and calculated equivalent adults or proportions of source water populations. Taxa include those that together comprised over 90% of individuals entrained or impinged, or were selected for fishery interest.

Taxon	Common name	Entrainment Estimate (Annual # Larvae)	*AEL* Estimate (Annual # Adults)	*FH* Estimate (Annual # Adults)	P_M (%)	Impingement (Annual #, All sources)	Impingement (Annual Biomass kg, All sources)
Fishes							
Atherinopsidae	silversides	7,936,121	–	–	–	68,519	449.74
Atractoscion nobilis	white seabass	0	–	–	–	2,102	408.12
Clevelandia ios, Ilypnus gilberti, Quietula y-cauda	CIQ goby complex	2,215,477,217	1,632,666	1,881,458	39.80	0	0.00
Cymatogaster aggregata	shiner surfperch	n/a	–	–	–	37,664	393.84
Engraulidae	anchovies	120,661,087	15,546	3,089	0.35	46,262	354.74
Genyonemus lineatus	white croaker	6,924,470	–	–	0.29	86	1.28
Hyperprosopon argenteum	walleye surfperch	n/a	–	–	–	5,586	248.55
Hypsoblennius spp.	blennies	1,098,083,615	2,450,084	575,354	19.40	807	4.69
Hypsypops rubicundus	garibaldi	29,287,646	–	–	14.42	5	1.90
Paralabrax spp.	sand basses	2,520,619	–	–	–	7,968	198.81
Paralichthys californicus	California halibut	3,752,551	–	4	0.32	612	15.44
Roncador stearnsii	spotfin croaker	9,554,139	–	–	1.57	1,351	80.76
Sardinops sagax	Pacific sardine	2,484,208	–	–	–	8,313	35.36
Seriphus politus	queenfish	6,746,448	–	–	0.90	9,479	70.43
Shellfishes							
Cancer spp.	Cancer crabs	162,150	–	–	–	961	5.22
Panulirus interruptus	Cal. spiny lobster	0	–	–	–	22	1.86
Loligo opalescens	market squid	0	–	–	–	0	0.00
Octopus spp.	octopus	0	–	–	–	497	69.46

Impingement Results

A total of 19,408 fishes representing 96 taxa was collected during normal operation impingement sampling at the EPS traveling screens during 52 weekly surveys in the 2004–2005 sampling period. These fishes had a combined weight of 351.7 kg (775 lb) which, when projected over a one-year period based on actual power plant flow rates, equaled losses of 2,323 kg (5,123 lb) of biomass for fish collected from both the traveling screens and bar racks. Coupled with a nearly equal amount of fish biomass collected during six tunnel shock treatments over the study, the total fish biomass from all plant mortality sources was estimated at 4,358 kg (9,608 lb) annually.

The highest impingement rates were for open-water fish species and least for bottom-dwelling species. The numerically most abundant fishes collected during the normal operations impingement sampling included topsmelt, shiner surfperch, deepbody anchovy, queenfish, salema, and slough anchovy. These six species comprised about 70% of all the fishes impinged during normal operations. Round stingray, bat ray and California butterfly ray were not abundant compared to other impinged species, comprising approximately 1% of the individuals, but they accounted for nearly 30% of the biomass due to their large individual size. Impingement rates for most species were generally higher during nighttime.

The numerically most abundant fishes collected during the tunnel shock sampling included deepbody anchovy, shiner surfperch, topsmelt, California grunion, Pacific sardine, and jacksmelt. These six species comprised about 80% of the total number of fishes collected during the tunnel shock surveys. The fishes with the greatest weight impinged during the tunnel shocks were white seabass, round stingray, deepbody anchovy, shiner surfperch, walleye surfperch, and spotted sand bass. The impingement of white seabass during heat shocks occurs due to releases of fishes from the Hubbs Sea World Research Institute in the days or weeks prior to the procedure. The impingement of these fishes has been significantly reduced by coordinating the releases so they do not occur in the period (2-3 weeks) directly before a tunnel shock.

Impact Analysis

The operation of the cooling water intake system during the 2004–2005 12-month study period resulted in an annual estimated impingement of 120,354 fish weighing 2,168 kg (4,780 lb), and an estimated 13,083 macroinvertebrates weighing 117 kg (258 lb) collected from the traveling screens during normal operations. In addition there were numerous “non-shellfish” invertebrate taxa such as small mollusks, hydroids, and other categories of non-edible invertebrates that were impinged mainly as a result of detachment from the bar racks and tunnel walls. Periodic heat treatment operations used to control the growth of fouling organisms on the tunnel walls resulted in losses of 94,991 fish weighing 2,034 kg (4,484 lb), and 1,384 shellfish weighing 19 kg (42 lb) during the study period. There are no source population estimates for impinged species with which to compare losses on a population level.

Impacts to SCB fish and invertebrate populations caused by the entrainment of planktonic larvae through the EPS CWIS can only be assessed indirectly through modeling. These impacts are additive with the direct impingement losses. Two taxa, CIQ goby complex and combtooth blennies, comprised 90% of all entrained fish larvae. Of the ten most abundant fish species entrained at EPS, only one (anchovies) has any direct commercial or recreational fishery value. All of the abundantly entrained species with the possible exception of garibaldi, *Hypsypops rubicundus*, can be considered forage species for larger predatory fishes, sea birds, or marine mammals. Approximately 40% of the 38 different fish taxa entrained belonged to species with some direct fishery value (e.g., anchovies, croakers, sand basses, California halibut) even though most of those were very infrequent in the samples. Because of their low abundance in the samples, most of these taxa were not modeled for potential impacts. An exception was California halibut, which was addressed because of its commercial and recreational fishery importance. Even with a total estimated annual entrainment of nearly 4 million larvae the power plant impacts to this species were negligible, amounting to a mean of four to six females at an age of 2.5 years.

The *ETM* procedure estimates the annual probability of mortality due to entrainment (P_M). It puts the entrainment estimate into context by comparing it with a known source population at risk of entrainment. The greatest P_M estimate for a target taxon was for the CIQ goby complex with a predicted fractional larval loss of 39.8%. The next greatest probabilities of mortality were for combtooth blennies (19.4%) and garibaldi (14.4%). The distance of shoreline potentially affected by entrainment is directly proportional to the estimate of time that the larvae are exposed to entrainment. All three of these species had local populations primarily located in the habitats of Agua Hedionda Lagoon, and most larvae were entrained at sizes that indicated they were recently hatched. Other modeled species with primarily nearshore (non-lagoon) distributions, such as white croaker and queenfish, had P_M estimates below 2%. Even in a heavily exploited commercial species these levels of additional mortality would be considered very low, especially when the populations of these species extend over a much larger geographic range than the extrapolated source water bodies. No invertebrate taxa were modeled for entrainment impacts due to the low abundance of the target taxa (e.g., spiny lobsters, *Cancer* crabs).

Compared to the IM&E study at EPS conducted by SDG&E in 1979–1980, goby larvae were approximately five times more abundant in the recent entrainment samples while combtooth blenny larvae were nearly twenty times more abundant. This may be attributed to a greater area of shallow mudflat habitat in AHL due to watershed erosion and sedimentation, and the addition of aquaculture float structures that provide potential habitat for combtooth blennies. Anchovy and croaker larvae were significantly more abundant in the earlier study, probably due to a cooler water climatic regime in the Southern California Bight (SCB) that favored increased populations of these taxa. Surfperches, topsmelt and anchovies were the most vulnerable taxa for impingement during both studies. Annual impingement of fish biomass (normal operations and heat treatments) was similar in both studies—approximately 4,202 kg (9,263 lb) in 2004–2005 compared to approximately 3,820 kg (8,421 lb) in 1979–1980.

The conclusion that the levels of entrainment and impingement at EPS are not resulting in any AEI to fish or shellfish populations is consistent with a recent review on population-level effects on harvested fish stocks (Newbold and Iovanna 2007). They modeled the potential effects of entrainment and impingement on populations of fifteen fish stocks that are targeted by either commercial or recreational fisheries using empirical data on entrainment and impingement, life history, and stock size. Their model indicated that the effects of theoretically removing all of the sources of power plant entrainment and impingement were very low for most species. They attributed the absence of large effects for most species to compensatory mechanisms that are probably acting on the populations at some level. If there is strong density dependence acting on these populations during the life stages from the period when they are vulnerable to entrainment as larvae through the age of maturity, then they concluded that there should be very little potential for population-level effects due to entrainment and impingement. The results for gobies from the studies conducted in AHL provide evidence of strong density dependence at recruitment which helps explain the apparent absence of any effects on local populations of this group despite the high levels of entrainment mortality.

1.0 Introduction

The Encina Power Station (EPS) is a fossil-fueled steam electric power generating station that began operation in 1954. EPS has been owned and operated by Cabrillo Power I LLC (Cabrillo Power) since May 22, 1999 and was previously owned by San Diego Gas and Electric Company (SDG&E). EPS is located in the City of Carlsbad, California, adjacent to the Agua Hedionda Lagoon on the Pacific Ocean and approximately 30 miles north of the City of San Diego. **Figure 1-1** depicts the location of the facility and the cooling water intake and discharge points relative to the shoreline. Cooling water is withdrawn from the Pacific Ocean via the Agua Hedionda Lagoon and circulated once through the EPS CWS to condense freshwater steam used in power production. The combined cooling and service water design flow is 857 million gallons per day (mgd) at full operating capacity. After passing through the plant, the heated seawater is discharged to the ocean through a shoreline forebay and conveyance channel.

Cooling water intake systems are regulated under Section 316(b) of the federal Clean Water Act. The U.S. Environmental Protection Agency (EPA) established new regulations for Section 316(b) that were published in the Federal Register on July 9, 2004 and became effective on September 7, 2004. The new regulations were applicable to large existing power plants (Phase II facilities) with daily cooling water volumes in excess of 50 mgd. Due to the design, location, operating characteristics of the EPS, and cooling water volume capacity that exceeds 50 mgd it is subject to these new regulations. The new regulations were challenged by a coalition of environmental groups and the case was heard by the Second U.S. Circuit Court of Appeals. The court rendered a decision in January 2007 that remanded several key components of the regulations back to the EPA. In March 2007 the EPA issued a memorandum suspending the rule and directing that all permits for Phase II facilities implement 316(b) on a case-by-case basis using “best professional judgment” (BPJ). The language of the memorandum was expanded and published in the Federal Register in July 2007 (Volume 72, 130:37107-37109).

The studies presented in this report were conducted in partial fulfillment of the requirements of the new regulations. With the suspension of the Phase II regulations, the results of the studies will be used to determine if impingement and entrainment losses pose any significant risk of adverse environmental impact (AEI) to the species and life stages of fish and shellfish impinged or entrained. The absence of any significant impacts would be a technically sound basis under BPJ for determining that the cooling water intake structure represents the best technology available for minimizing adverse environmental impacts. This would allow any additional requirements to further reduce impingement and/or entrainment to be deferred until issues with the Phase II Rule are resolved.

1.1 Background

1.1.1 Section 316(b) of the Clean Water Act

Section 316(b) of the Clean Water Act (CWA) requires that the location, design, construction, and capacity of cooling water intake structures (CWIS) reflect the best technology available (BTA) to minimize adverse environmental impacts (AEI) due to the impingement (IM) of aquatic organisms (i.e., fish, shellfish, and other forms of aquatic life) on intake structures and the entrainment (E) of eggs and larvae through cooling water systems. On July 9, 2004, the U.S. Environmental Protection Agency published the second phase of new regulations under §316(b) of the Clean Water Act (CWA) for cooling water intake structures (CWIS) that apply to existing facilities (Phase II facilities). The Phase II Final Rule went into effect in September 2004, and applies to existing generating stations with CWIS that withdraw at least 50 million gallons per day (mgd) from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. The regulations required all large existing power plants to reduce impingement mortality by 80–95% and to reduce the number of smaller aquatic organisms drawn through the cooling system by 60–90% when compared against a "calculation baseline". The water body type on which the facility is located, the capacity utilization rate, and the magnitude of the design intake flow relative to the waterbody flow determine whether a facility will be required to meet the performance standards for only impingement or both impingement and entrainment (IM&E). The final rule allowed these performance standards to be met through using the existing intake design, additional intake technologies, operational modifications, and restoration measures.

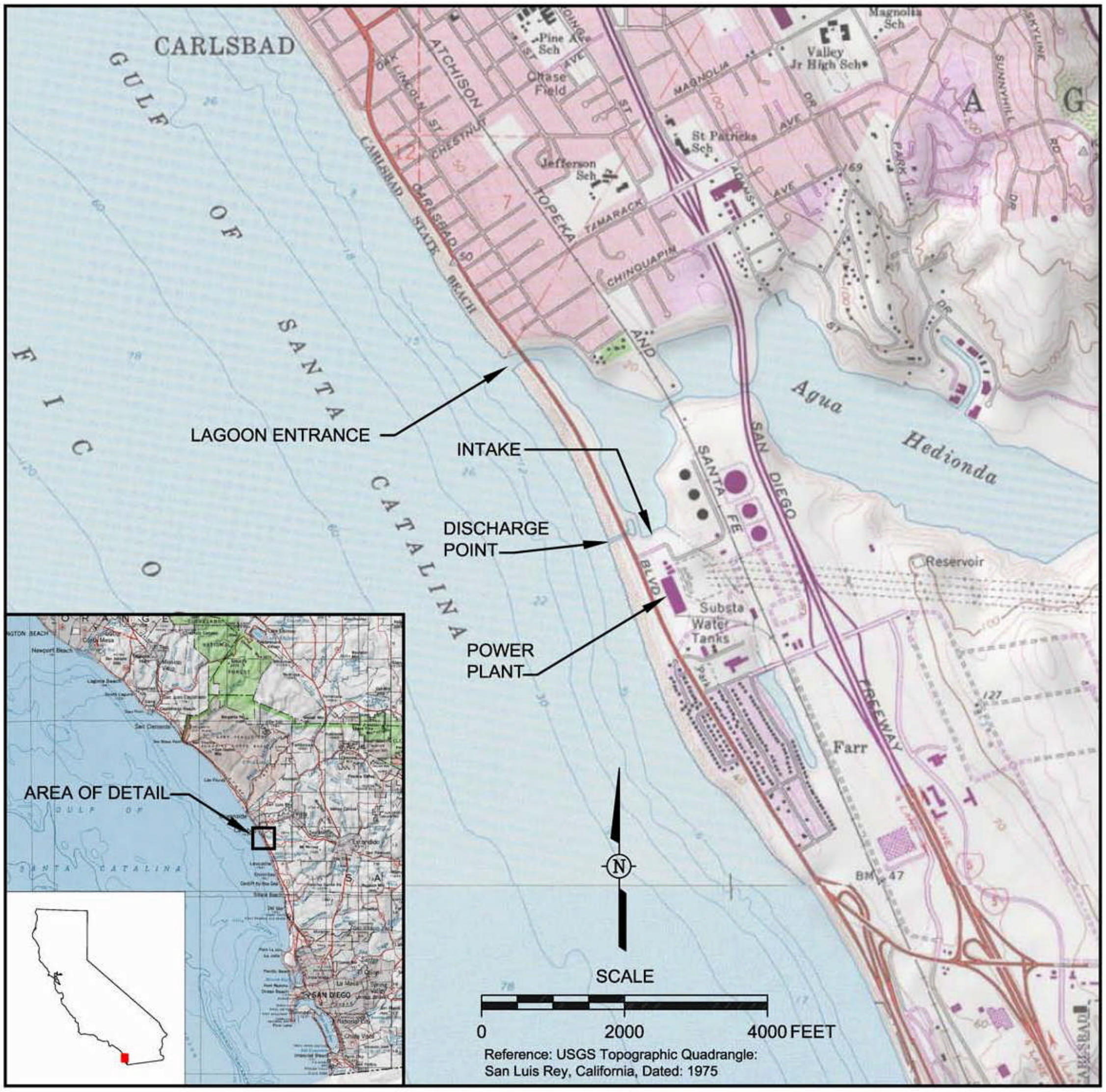


Figure 1-1. Encina Power Station location map

The Phase II regulations provided power plants with five options for meeting the performance standards, but unless a facility could show that it could meet the standards using the existing intake design or were installing one of the approved EPA technologies for IM&E reduction, it was required to submit information documenting its existing levels of IM&E. Existing data that may have previously been collected at the facility or a similar facility nearby could be used to document the levels of IM&E. The data were required to be submitted in an IM&E Characterization Study that was one component of the 316(b) Comprehensive Demonstration Study (CDS) required under the Phase II regulations. The impingement mortality component of the studies was not required if the through-screen intake velocity for a plant is less than or equal to 0.5 feet per second (ft/s) (15 centimeters [cm] per second). The entrainment characterization component was not required if a facility:

1. Has a capacity utilization rate of less than 15%;

2. Withdraws cooling water from a lake or reservoir, excluding the Great Lakes; or
3. Withdraws less than 5% of the mean annual flow of a freshwater river or stream.

Based on previously collected intake velocity measurements and plant operating characteristics, both of the IM&E components of the study were required at the EPS. Previous 316(b) entrainment and impingement studies were done at EPS (SDGE 1980) that are described in Section 1.2. Due to the time period since the original data were collected, a Study Plan for new IM&E studies was developed and submitted to the San Diego Regional Water Quality Control Board (SDRWQCB) in September 2004 (**Appendix A**). The sampling plan was approved by the SDRWQCB and the sampling was done for one year starting in June 2004 and continuing to June 2005. The study included the following elements:

- Taxonomic identifications of all life stages of fishes, shellfishes, and any threatened or endangered species collected in the vicinity of the CWIS and are susceptible to IM&E.
- Characterization of all life stages of the target taxa in the vicinity of the CWIS and a description of the annual, seasonal, and diel variations in IM&E.
- Documentation of the current level of IM&E of all life stages of the target taxa.

The goal of the study was to characterize the fishes and shellfishes affected by impingement and entrainment by the EPS CWIS. The studies examined losses at the EPS resulting from impingement of juvenile and adult fishes and shellfishes on traveling screens during normal operations and during heat treatment operations, and entrainment of ichthyoplankton and shellfishes into the cooling water intake system. The sampling methodologies and analysis techniques were derived from recent impingement and entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), and the Duke Energy South Bay Power Plant (Tenera 2004).

The study was completed prior to the publication of the Second U.S. Circuit Court of Appeals Decision on the 316(b) Phase II regulations issued on January 25, 2006. The Court decision was the result of a lawsuit brought against the EPA by several states, environmental groups, and power companies challenging multiple aspects of EPA's final Phase II rule. The decision supported the petitioners contention that EPA exceeded its authority in rejecting closed-cycle cooling, and selecting instead a range of technologies as BTA that were based on the agency's use of improper cost-benefit analysis. Nevertheless, the Court found that EPA may consider costs to determine what technologies are reasonably available. The Court also criticized the EPA's selection of the suite of technologies as BTA, remanding to the EPA the provision establishing BTA and requiring more explanation on the basis for the agency's decision or a new determination of BTA based on appropriate considerations. The Court also remanded to EPA certain provisions in the Phase II rule that set performance standards to be achieved through compliance measures, and provisions that allowed compliance through the use of restoration measured in lieu of BTA.

The EPA issued a memorandum to its Regional Offices dated March 20, 2007. This memorandum announced that EPA was withdrawing the 316(b) Phase II Rule for existing steam electric generating stations in its entirety based on the Court decision. The memorandum further directed EPA Regional Offices to implement 316(b) in NPDES permits on a "Best Professional Judgment" (BPJ) basis until the issues raised by the Court decision are resolved. EPA is currently considering several alternatives for responding to the Court decision and it may be several years before it is resolved either through further litigation and/or Rulemaking. The guidance in this memorandum was published in the Federal Register on July 9, 2007 (Volume 72, 130:37107-37109).

The information in this report is being submitted to assist in the evaluation of fish protection technologies and operational measures for EPS so that when the issues with the Phase II Rule are resolved, the plant will be in a position to move forward in a timely manner to comply with the Rule. The information is also important in evaluating the potential for AEI potentially caused by impingement and entrainment. In support of this approach to compliance, the assessment of the IM&E study focuses on determining if impingement and entrainment losses pose any significant risk of AEI to the species and life stages of fish and shellfish impinged or entrained. The AEI assessment in this report is based on previous EPA guidance on 316(b) (EPA 1977) and focuses on evaluating the following:

- Potential impacts that could pose a risk to populations of any impinged or entrained species.
- Impacts to the local commercial or recreational fishery.
- Any impacts to a protected species.

For entrained and juvenile species the analysis will provide estimates of adult losses for a representative set of commercial and recreational species. For forage species, estimates of the reductions to commercial and recreational species will be made due to the reduction in biomass as a result of impingement and entrainment. Demonstrating no significant risk of AEI would be a technically sound basis to defer requirements for reducing impingement and/or entrainment until issues with the Phase II Rule are resolved. The rationale and approach for the impact assessment in this report and the results and conclusions from our analysis are provided in Section 5.0.

1.2 Effects of Impingement and Entrainment: Overview

The withdrawal of water by once-through circulating water systems affects biological resources of the source water body through two processes: impingement and entrainment. Most circulating water systems employ some type of primary screening device ('bar rack') to block larger objects from entering the circulating water system. Smaller secondary screening systems generally consist of an array of rotating screens with a mesh size of approximately 0.95 cm (⅜ in) to 1.6 cm (⅝ in). Fishes and other aquatic organisms large enough to be blocked by these screens may become impinged on the screens if the intake velocity exceeds their ability to move away, or if they become entangled in debris that may be present in front of the CWIS. These organisms will remain impinged against the screens until the intake velocity is reduced so the organisms can move away or the screen is rotated and backwashed to remove them into a collection basket for disposal. Small planktonic organisms, including early life stages of larger organisms, pass through the screen mesh and are entrained into the circulating water flow. These organisms are exposed to velocity and pressure changes due to the circulating water pumps, increased temperatures and, in some cases, chlorine exposure through the plant's condenser tubes. Although most individual organisms are killed by passage through the CWIS, the ultimate goal of the studies is to determine if effects are significant at the population level for the affected species. The additional mortality rates imposed by the CWIS on the high natural mortality rates of early life stages in most species typically cannot be measured directly due to the high natural variability of the populations and the marine environment.

In 1980, San Diego Gas and Electric (SDGE) owned and operated the EPS. A 316(b) demonstration was conducted for the facility (SDGE 1980) as required at the time by the SDRWQCB. The study included descriptions of the facility, descriptions of the physical and biological environment of Agua Hedionda Lagoon and surroundings, studies of entrainment, impingement, and entrainment survival at the plant, and an environmental impact assessment that also evaluated the feasibility of alternative intake technologies to reduce IM&E.

A list of taxa ("critical species") that included 16 adult/juvenile fishes, 11 larval fishes, and one invertebrate zooplankton species, were selected based on six criteria and approved by the SDRWQCB for detailed study during the program. Some additional species that were found to be common in the subsequent sampling were also added to the list. The report reviewed the life histories of the critical species.

1.2.1 Entrainment

A one-year entrainment and source water characterization study was conducted beginning in 1979 as part of the 316(b) demonstration studies at the EPS. Plankton samples were collected monthly at five offshore stations using 505 and 335 micron mesh nets attached to a 2 ft diameter bongo net system. Collections were also made monthly in the Middle and Upper Lagoon segments and every two weeks in the Outer Lagoon using 1.6 ft diameter nets (505 and 335 micron mesh size). Entrainment samples were also collected every two weeks using a plankton pumping system in front of the intakes. Although most samples were collected during daylight hours some samples were occasionally taken in the evening or early morning hours.

Anchovies (primarily deep body and northern) were the most abundant larval forms in both the source water and entrainment samples, followed by croakers and sanddabs (**Table 1-1**). There were fewer fish eggs and more goby larvae in the entrainment samples whereas kelp and sand bass larvae were substantially more abundant in the combined source water samples from the Lagoon and offshore. Overall the average composition between the entrainment and source water data sets were very similar for the ten most abundant taxa. Only English sole, *Parophrys vetulus*, larvae were among the top ten entrainment taxa not represented in the top ten source water taxa.

Table 1-1. Average annual densities during 1979 of the ten most abundant larval fish taxa in source water and entrainment collections (335µ mesh nets).

Common Name	Taxon	Source Water concentration (mean per 100 m^3)	Entrainment concentration (mean per 100 m^3)
anchovies	Engraulidae	952.7	855.2
croakers	Sciaenidae	341.7	400.6
speckled sanddab	*Citharichthys* spp.	73.2	82.7
fish eggs	unidentified fish egg	33.8	20.2
gobies	Gobiidae	29.2	42.9
silversides	Atherinopsidae	8.3	10.8
wrasses	Labridae	6.4	4.0
combtooth blennies	*Hypsoblennius* spp.	6.1	5.7
sea basses	Serranidae	5.1	0.9
rockfishes	*Sebastes* spp.	2.8	2.5
English sole	*Parophrys vetulus*	0	1.9

Entrainment losses were calculated for each two-week sampling interval by multiplying the average plankton densities at the intake by the volume of cooling water drawn through the plant during that period. Annual, monthly, and daily rates were estimated by averaging the entrainment estimates for all sampling periods and calculating values for the indicated duration. Annual estimates for total zooplankton entrainment were 7.4×10^9 (505 µ net data) and 30.9×10^9 (335 µ net data) individuals. The copepod *Acartia tonsa* was the most abundant species in the entrainment collections.

Annual estimates of the abundance of ichthyoplankton entrained through the power plant were 4.15×10^9 (505µ net data) and 6.66×10^9 (335µ net data) individuals per year. Fish eggs comprised 98% and 86% of the total annual ichthyoplankton entrainment using the 505µ and 335µ net estimates, respectively. Through-plant entrainment mortality was assumed to be 100% for larvae and 60% for eggs based on survival experiments that were conducted. The report presented average annual densities of the critical species by net type and daily entrainment estimates for selected plankton groups.

Entrainment impacts were assessed by qualitative comparisons of entrainment losses to the estimated numbers of larvae in nearby source waters, comparisons of additional power plant mortality to natural mortality rates, entrainment probabilities based on current studies, and primary productivity studies. It was concluded that the entrainment of 1.82×10^7 fish larvae and eggs daily was small compared to the egg and larval concentrations measured in monthly plankton tows in the source water body. It was estimated that average daily losses of planktonic organisms amounted to about 0.2% of the plankton available within one day's travel time from the power plant by current transport. At the seaward entrance to Agua Hedionda Lagoon, a water parcel was estimated to have a 34% probability of entering the lagoon. The isopleth representing

10% probability of daily entrainment was calculated to lie near the northern and eastern extremities of Agua Hedionda Lagoon, and the 70% and 90% entrainment probability isopleths were calculated to be near the intakes and well within the southern third of the Outer Lagoon. The modeled isopleths shifted toward the seaward entrance on a flood tide and toward the Middle Lagoon on an ebb tide. Using the 70% entrainment probability isopleth to define intake effects, it was shown that the maximum extent of intake effects was about 305 m (1,000 ft) into the southern end of the Outer Lagoon segment. With natural mortality rates assumed to be 99% for egg and larval stages of most marine fish species it was concluded that additional mortality from the EPS was not significant. There was no modeling of entrainment impacts on larvae using demographic or proportional loss models. It was also concluded, based on results of light-dark bottle experiments, that entrainment effects on source water primary productivity were negligible.

1.2.2 Impingement

Impingement of fishes and shellfishes on the traveling screens and bar rack system of the EPS were monitored daily during normal operations for 336 consecutive days in 1979. The main method was to obtain abundance and weights from samples accumulated over two 12-hr periods (daylight and night) each day for all three screening systems at the plant. During this period there were a total of 79,662 fishes from 76 taxonomic categories weighing a total of 1,395 kg (3,076 lb) collected. The six highest-ranking fishes by numbers impinged were queenfish, deepbody anchovy, topsmelt, California grunion, northern anchovy, and shiner surfperch. These are all open water forms that occur in schools. These six species represented 82% of all fishes impinged during normal operations sampling.

There were also seven heat treatments conducted during the study period. Heat treatments are operational procedures designed to eliminate mussels, barnacles, and other fouling organisms growing in the cooling water conduit system. During a heat treatment, heated effluent water from the discharge is redirected to the intake conduit via cross-connecting tunnels until the water temperature rises to approximately 40.4°C (105°F) in the screenwell area. This water temperature is maintained for at least one hour, during which time all biofouling organisms, as well as fishes and shellfishes living within the CWS, succumb to the heated water. During heat treatment surveys, all material impinged onto the traveling screens is removed from the forebay. During the 1979 studies, the total weight of fishes impinged during these operations was 2,422 kg (5,340 lb). Over 90% of the fishes collected consisted of nine species: deepbody anchovy, topsmelt, northern anchovy, shiner surfperch, California grunion, walleye surfperch, queenfish, round stingray, and giant kelpfish. The numbers of fishes resident in the tunnels during heat treatments was greatest in winter and least in summer.

Shellfishes that ranked high in the total numbers impinged included yellow crab (*Cancer anthonyi*) with 2,540 individuals, swimming crab (*Portunus xantusii*) with 884, lined shore crab (*Pachygrapsus crassipes*) with 866, and market squid (*Loligo opalescens*) with 522. The yellow crab and market squid both have commercial fishery value whereas the other two species are small and are not fished commercially. California spiny lobster, the most valuable invertebrate in the local commercial fishery, was rare in the samples with only two individuals impinged during the entire year-long study period.

Most of the species removed by the power plant were widely distributed along the southern California and Baja California coasts and losses were considered small relative to these populations. On a local scale, it was calculated that the average daily power plant removal, including normal operations and heat treatment operations averaged throughout the year, was about 0.02% of the estimated standing crop in the local study area that extended along a shoreline distance of 3.6 miles out to a depth of 60 ft, comprising 1,211 acres. The removals also represented about 0.07% of local commercial fish landings by weight (excluding tuna) from the area between San Clemente and the Mexican border, and less than 7% of the recreational fishing landings by numbers annually in the area between Dana Point and the Mexican border.

1.2.3 Supplemental 316(b) Assessment Report–1997

The SDRWQCB issued Order 94-58 in 1994 requiring SDG&E to conduct additional analyses of data from the 316(b) study conducted in 1979–1980 (EA Science and Technology 1997). The supplemental analyses were completed in 1997. The purpose of the study was to further evaluate the effects of the EPS cooling water intake on the designated beneficial uses of Agua Hedionda Lagoon and the Southern California Bight using additional analysis methods.

Estimates of loss were calculated for 17 selected species that included the original 16 “critical species” identified in the original 316(b) report and also tidewater goby, the only endangered aquatic species likely to occur in the area. Estimates of adult equivalent loss were calculated for the three representative species with the highest estimates of entrainment or impingement loss: northern anchovy, topsmelt, and queenfish. The modeling used life stage-specific estimates of total mortality to calculate estimates of the number of individual adult fishes which would have resulted from the young lost to entrainment and impingement under the conservative assumption of equal survival.

In order to put the entrainment losses in perspective and evaluate the magnitude of potential impacts, the report considered the life history characteristics of each target species (reproductive ability, geographic distribution, migratory capabilities) as well as estimates of current population size or harvest by commercial or sport fishermen. Although the original report touched on these topics, the 1997 report went into greater detail to evaluate potential impacts. Impacts were considered at three levels: individual population, overall community, and designated beneficial uses of the source waterbody.

The report concluded that the potential for adverse impacts from the EPS CWIS on individual target species was small compared to the sizes of the existing populations and the effects of fisheries. It similarly concluded that operation of the EPS cooling water intake had not, and would not, adversely affect the continued maintenance of balanced aquatic communities or designated beneficial uses of AHL or the Pacific Ocean in the vicinity of the EPS. Finally, the report stated that since the existing intake was not causing any adverse environmental impacts as defined under the CWA 316(b) guidelines that were in effect in 1997, it should be designated as best technology available.

1.3 Study Design

A plan for IM&E studies that directly addressed the requirement of 316(b) was submitted to the SDRWQCB in September 2004 following the final publication of the new Rules in July 2004. The IM&E study plan was submitted as a first step in the facility's compliance with the new Phase II rule. The study plan was reviewed by the Board staff and their consultants, Tetra Tech Inc., and was approved contingent on responding to comments and questions submitted to EPS by the Board. Comments on the study plan were resolved and the studies continued through June 2005 under the direction of a Technical Advisory Group comprised of staff from the Board, state and federal resource agencies, EPS, and their consultants. The study design was based on a survey and compilation of available background literature, results of previously completed 316(b) intake studies, and circulating water system studies at other power plants.

Entrainment and source water plankton net sampling was conducted monthly from June 2004 to June 2005 at both the intake station and at an array of source water stations. These entrainment and source water studies were designed to measure monthly variation in the species composition and abundance of larval fishes, cancer crabs, and spiny lobsters entrained by EPS and were used to estimate the source water populations at risk of entrainment.

The purpose of the impingement study was to characterize the juvenile and adult fishes and selected shellfishes (e.g., shrimps, crabs, lobsters, squid, and octopus) impinged by the power plant's CWIS. The sampling program was designed to provide current estimates of the abundance, taxonomic composition, diel periodicity, and seasonality of organisms impinged at EPS. In particular, the study focuses on the rates (i.e., number or biomass of organisms per cubic meter of water flowing per time into the plant) at which various species of fishes and shellfishes are impinged. The impingement rate is subject to tidal and seasonal influences that vary on several temporal scales (e.g., hourly, daily, and monthly), while the rate of circulating water flow varies with power plant operations and can change at any time.

The organisms analyzed in this report are limited to those that were sufficiently abundant to provide reasonable assessment of impacts. For the purposes of this study, assessments were generally limited to the most abundant fish taxa that together comprised 90% of all larvae entrained and/or juveniles and adults impinged by the generating station. However, certain species that were not abundant in the samples but had particular fishery value, such as California halibut and California spiny lobster, were also reviewed.

1.4 Report Organization

Section 2 of this report describes the operational characteristics of EPS in greater detail, and provides an overview of the physical and biological environments in the vicinity of the power station. Methods and results of the entrainment and source water larval study are presented in Section 3 including assessments for each of the target taxa in separate subsections. A similar treatment of the impingement studies is presented in Section 4. Finally, a circulating water system impact assessment is presented in Section 5 that interprets the IM&E results in the context of resource populations. Seven appendices are also included with the report that include details on special support studies, sampling and processing procedures, and summarized data files.

2.0 Description of the Encina Power Station and Characteristics of the Source Water Body

The Encina Power Station (EPS) consists of five steam turbine generating units and a small gas turbine unit. The steam turbines units are primarily fueled by natural gas, but have the capability to be powered by fuel oil. Net generating capacity of the individual steam turbine units ranges from 104 megawatts (MW) to 315 MW (**Table 2-1**). The gas turbine has a net generating capacity of 16 MW. Units 1–3 began operating in the 1950s, the gas turbine was added in 1968, and Units 4 and 5 went on line in 1973 and 1978, respectively.

2.1 Description of the Encina Power Station Cooling Water System

Cooling water for each of the five steam electric generating units is supplied by two circulating water pumps (CWP) that range in capacity from 24,000 to 104,000 gallons per minute (gpm) (90.85–393.68 m^3/min) depending on the unit's generating potential and the associated cooling requirements. This water is primarily used to cool the plant's steam condensers, where steam is condensed back to water as part of the power production cycle. Each unit is also equipped with a number of smaller saltwater service pumps (SWSP) that supply water for a variety of purposes (cooling of small capacity heat exchangers, lubrication of rotating equipment, etc.). The quantity of cooling water circulated through the plant is dependent upon the number of units in operation. With all units in full operation, the cooling water flow through the plant is 2,253 m^3/min (595,200 gallons per minutes [gpm]) or 3,244,140 m^3/day (857 mgd) based on the manufacturer ratings for the circulating water and saltwater service pumps (**Table 2-1**).

Table 2-1. Encina Power Station generation capacity and cooling water flow volume.

Unit	Net Generating Capacity (MWe)	Circulating Water Flow m^3/min (gpm)	Service Water Flow m^3/min (gpm)	Daily Flow m^3/day (mgd)[1]
1	107	182 (48,000)	11 (3,000)	278,000 (73)
2	104	182 (48,000)	11 (3,000)	278,000 (73)
3	110	182 (48,000)	23 (6,000)	294,320 (78)
4	287	757 (200,000)	49 (13,000)	1,160,940 (307)
5	315	787 (208,000)	69 (18,200)	1,232,880 (326)
Gas Turbine[2]	16	–	–	–
Total	**939**	**2,090 (552,000)**	**163 (43,200)**	**3,244,140 (857)**

[1] Total flow including circulating water and saltwater service pumps.
[2] Gas turbine units do not utilize once-through cooling water sources.

2.1.1 Intake System

Cooling water for all five steam-generating units is supplied through a common intake structure located at the southern end of the outer segment of Agua Hedionda Lagoon, approximately 915 m (3,000 ft) from the opening of the lagoon to the ocean (**Figure 2-1**). Seawater entering the cooling water system passes through metal trash racks on the intake structure, with vertical bars that are spaced about 8.9 cm (3½ in) apart (**Figure 2-2**). The bars prevent large debris that could potentially clog or damage plant equipment from entering the system. The trash racks are cleaned periodically to remove impinged debris. Water velocity approaching the trash racks varies with the number of pumps that are in operation, water depth (tide level), and the quantity of debris impinged on the racks (percent occlusion). Approach velocity is measured annually as required by the power station's National Pollutant Discharge Elimination System (NPDES) Permit CA0001350. Most recently the approach velocity was measured on November 16, 2005. Average approach velocity at that time was 43 cm/sec (1.4 ft/sec). Tide level was 2.2 meters (7.1 feet) above MLLW at the time the measurements were made and eight of the ten CWP were in operation (Unit 4 was in the midst of an outage and its two pumps were shutdown). The cleanliness of the trash racks (percentage of the openings between bars occluded by debris) at that time is not known. Using the measured velocity and adjusting the flow volume to simulate maximum flow (all CWP and SWSP in operation) yields a calculated maximum approach velocity of 67.1 cm/sec (2.2 ft/sec) at the same tide height. Adjusting the tide height to mean sea level (MSL) provides a calculated approach velocity of 88.4 cm/sec (2.9 ft/sec) at maximum flow volume.

Behind the trash racks the intake tapers into two 3.7 m (12 ft) wide tunnels that further split into four 1.8 m (6 ft) wide inlet tunnels (**Figure 2-3**). Inlet tunnels 1 and 2 provide cooling water for Units 1, 2 and 3, while inlet tunnels 3 and 4 supply cooling water to Units 4 and 5, respectively. Vertical traveling water screens (TWS) are positioned immediately upstream of the CWP and SWSP to prevent fish and debris from entering the CWS and potentially clogging the condensers. There are two traveling screens for Units 1, 2 and 3, two screens for Unit 4, and three screens for Unit 5.

Each TWS consists of a continuous vertical belt of wire mesh panels through which the cooling water flows (**Figure 2-4**). The mesh size of the screens for Units 1–4 is 0.95 cm (⅜ in), while the mesh size for Unit 5 is 1.6 cm (⅝ in). Debris larger than the mesh is sieved from the flow stream and held on the screen panels until the TWS is placed in motion. The screens can be operated manually or activated automatically when a specified pressure differential is detected across the screens due to the accumulation of debris. When the specified pressure is detected, the screens rotate upward and the material on the screen is lifted out of the cooling water flow stream. A screen wash system (70–100 psi), located at the head of the screen, washes the debris from each screen panel into a trough, which empties into collection baskets where it is accumulated prior to disposal.

The velocity of the water as it approaches the traveling screens has a large effect on impingement and entrainment and varies depending on the number of pumps operating, tidal level, and cleanliness of the screen faces. Maximum approach velocities were calculated at high and low tide, with all pumps operating and clean screens, during the previous 316(b) study conducted in 1979 and 1980, and are presented in **Table 2-2**.

Table 2-2. Calculated maximum approach velocities in front of the Encina Power Station traveling screens with all CWP and SWSP in operation and 100 percent clean screens.

	Calculated Maximum Approach Velocity (cm/sec) [ft/sec]	
Unit Screen	**High Tide**	**Low Tide**
1	21.3 [0.7]	36.6 [1.2]
2	21.3 [0.7]	36.6 [1.2]
3	21.3 [0.7]	36.6 [1.2]
4	30.5 [1.0]	48.8 [1.6]
5	21.3 [0.7]	33.5 [1.1]

2.1.2 Discharge System

After passing through the traveling screens, the cooling water is pumped through the condensers of the individual generation units. At the condensers, heat is transferred from the steam exiting the plant’s turbines (passing over the outside of the condenser tubes) to the seawater (passing through the inside of the condenser tubes), condensing the steam back to water (condensate). Units 1–3 have dual-pass condensers (U-shaped tubes that pass through the condenser twice) made up of numerous aluminum-brass condenser tubes, each with an inside diameter (ID) of about 2.2 cm (⅞ in). Units 4 and 5 have single-pass condensers with 2.5 cm (1 in) ID tubes made of copper-nickel alloy.

When operating at full power, Units 1–5 transfer approximately 4,805 x 10^6 Btu/hr into the cooling water with a resultant temperature increase (delta-T) of about 10ºC (18ºF). Delta-T can vary, however, depending upon the individual units that are in operation (heat transfer characteristics differ between units), ambient seawater temperature, fluctuations in cooling water flow (due to tidal influences and debris clogging), and the cleanliness of each unit’s condenser. A maximum delta-T of 11ºC (20ºF) can be experienced under certain conditions.

Heated seawater exiting the condensers flows into a common discharge conduit that empties into an open discharge pond located to the west of the intake structure (**Figure 2-3**). Water from the discharge pond flows through a culvert under Carlsbad Blvd. and a discharge canal that leads across the beach and out into the ocean. The temperature of the cooling water discharged from Encina Power Station is regulated under the specifications of NPDES permit. The permit places limits on the chemical constituents and thermal characteristics of the plant’s discharge plume.

The terms of the permit specify that the temperature of the combined discharge shall not average more than 11.1ºC (20ºF) above that of the incoming water during any 24-hour period, and the combined discharge shall not, at any time, exceed 13.9ºC (25ºF) above that of the incoming lagoon water. A special provision to these discharge limitations is made to accommodate the higher discharge temperatures that result during heat treatment of the cooling water intake conduits (Section 2.1.3–*Biofouling Control*). The permit specifies that during heat treatment, heat added to the cooling water shall not cause the temperature of the combined discharge to the ocean to exceed 48.9ºC (120ºF), and that this maximum temperature shall not be maintained for more than two hours.

2.1.3 Biofouling Control

Cooling water entering the power plant contains a myriad of planktonic organisms that are too small to be filtered from the water flow by either the trash racks or the traveling screens. Some of these organisms can cause problems that, at a minimum, reduce the operating efficiency of the power plant and, at their worst, can require that the power plant be taken off line and shut down for maintenance. These organisms can be divided into two major groups, microfouling organisms, such as bacteria, fungi, and algae, and larger macrofouling organisms including barnacles, mussels (and other bivalves), and hydroids.

The primary problem caused by the microfouling organisms is the formation of a slime layer on the inner surface of the condenser tubes. This insulating microfouling layer interferes with heat transfer between the condenser tube and the cooling water flow. This decreases the efficiency of the condenser and degrades the power production capabilities of the plant. EPS uses periodic injections of the oxidizing biocide sodium hypochlorite (chlorine bleach) to control slime in the condenser tubes. Sodium hypochlorite is produced electrolytically at the plant from sodium chloride in the seawater. Seawater from the intake is pumped through each of two hypochlorinators, which are comprised of electrolytic cell modules arranged in series. The hypochlorite produced is fed into a holding tank where it is diluted with intake water. When needed, the sodium hypochlorite solution is injected to the cooling water conduit immediately upstream of the cooling water and saltwater service pump suctions for each unit. Each injection point is individually controlled, which allows each generating unit to be treated separately while the other units provide diluting water flow to the chlorinated discharge. Chlorination is conducted each day on a timed cycle for about five minutes per hour per unit. This method of chlorination results in a minimal chlorine residual in the cooling water being discharged to the ocean. In addition to the chlorine treatment, sodium bromide may be used as a chlorine enhancer.

Larger macrofouling organisms usually enter the CWS as larvae. Included within this group are a number of encrusting species, including barnacles and mussels that can attach themselves to the walls of the cooling water conduits. Once attached, they transform into a sessile stage and begin to feed and grow. These are hard-shelled animals that filter their food from the water that is passing by. The cooling water flow provides a continuous supply of food and the growth rates of these organisms within the CWS often far exceed the growth of the same species in the natural environment. If left unchecked, the biofouling layer formed by the aggregation of these organisms on the conduit walls and other submerged plant equipment can impede water flow within the system and interfere with the operation of pumps, valves, and other plant apparatus. In addition, as these macrofouling organisms increase in size, the force of the cooling water flow on their shells can detach them from the walls and carry them downstream to the condenser. Mussel and barnacle shells that exceed the 2.22–2.54 cm (⅞–1 inch) diameter of the condenser tubes can become lodged at the inlet ends of the tubes thereby blocking water flow through the tubes. As the number of clogged tubes increases, condenser performance decreases and, as a result, condenser operating temperatures and the temperatures of the discharged cooling water also increase. If the influx of tube-clogging debris continues, the condenser must be removed from service and cleaned.

Chlorination used at the concentration and duration applied by EPS to control microfouling is ineffective in the control of macrofouling organisms. Macrofouling organisms tend to be much more tolerant of chlorine than microfouling organisms. Mussels also have the ability to tightly close their shells if they detect harmful substances in the water and can remain closed for hours, or days. Chlorination at higher doses and/or applied continuously can effectively eliminate macrofouling but presents serious regulatory and environmental problems if the chlorine is not subsequently removed or deactivated prior to its discharge into the ocean.

As an alternative to chemical treatment, EPS uses heat treatments to control macrofouling. Heat treatment is performed by restricting the inlet cooling water flow and recirculating the condenser discharge water through the conveyance tunnels and condensers until the inlet water temperature has increased to the targeted treatment temperature. Recirculation of the cooling water is accomplished through a cross-over tunnel located approximately 36.6 m (120 ft) from the discharge, adjacent to the intake channel. The temperature is raised to 40.5ºC (105ºF) in the intake tunnels and then maintained for approximately two hours. This has proven to be adequate in killing the encrusting macrofouling organisms. Each time the cooling water passes through the condensers it picks up additional heat rejected from the steam cycle. Because the cooling water continues to circulate and the generating units continue to operate, the temperature in the discharge channel can reach 48.9ºC (120ºF). To maintain the treatment temperature at 40.5ºC during the treatment, and to prevent the continued build-up of heat in the system, additional lagoon water is blended into the recirculating flow as a corresponding volume of heated water is discharged to the Pacific Ocean. The targeted heat treatment duration is two hours while maintaining a treatment temperature of 48.9ºC in the intake conduits. This does not include the time required to reach the target temperature or the time necessary to return to a normal operating configuration. The total time required for the heat treatment procedure, including temperature buildup and cool-down, is approximately seven to nine hours. Because the input of cooling water is reduced during heat treatment due to recirculation, the plant's discharge flow rate is likewise reduced to approximately 7–45% of the maximum volume discharged during normal operation.

Following heat treatment some shells of the dead encrusting organisms begin to detach from the walls of the conduits and are carried downstream. Most mussels will lose their attachment over a period of days following treatment but barnacle shells are firmly attached and can take weeks or months to deteriorate and break away from the conduit walls. Shells smaller than the condenser tube diameter will pass through the system and be discharged into the ocean. Larger shells may be retained and removed by the traveling screens or, as in the case of fouling that occurs between the TWS and the condensers, may end up in the condensers where they are subsequently removed by cleaning. To reduce the need for condenser cleaning, heat treatments are optimally performed every five to eight weeks. This short growth period prevents most macrofouling organisms from attaining a size that will not allow them to pass through the condensers.

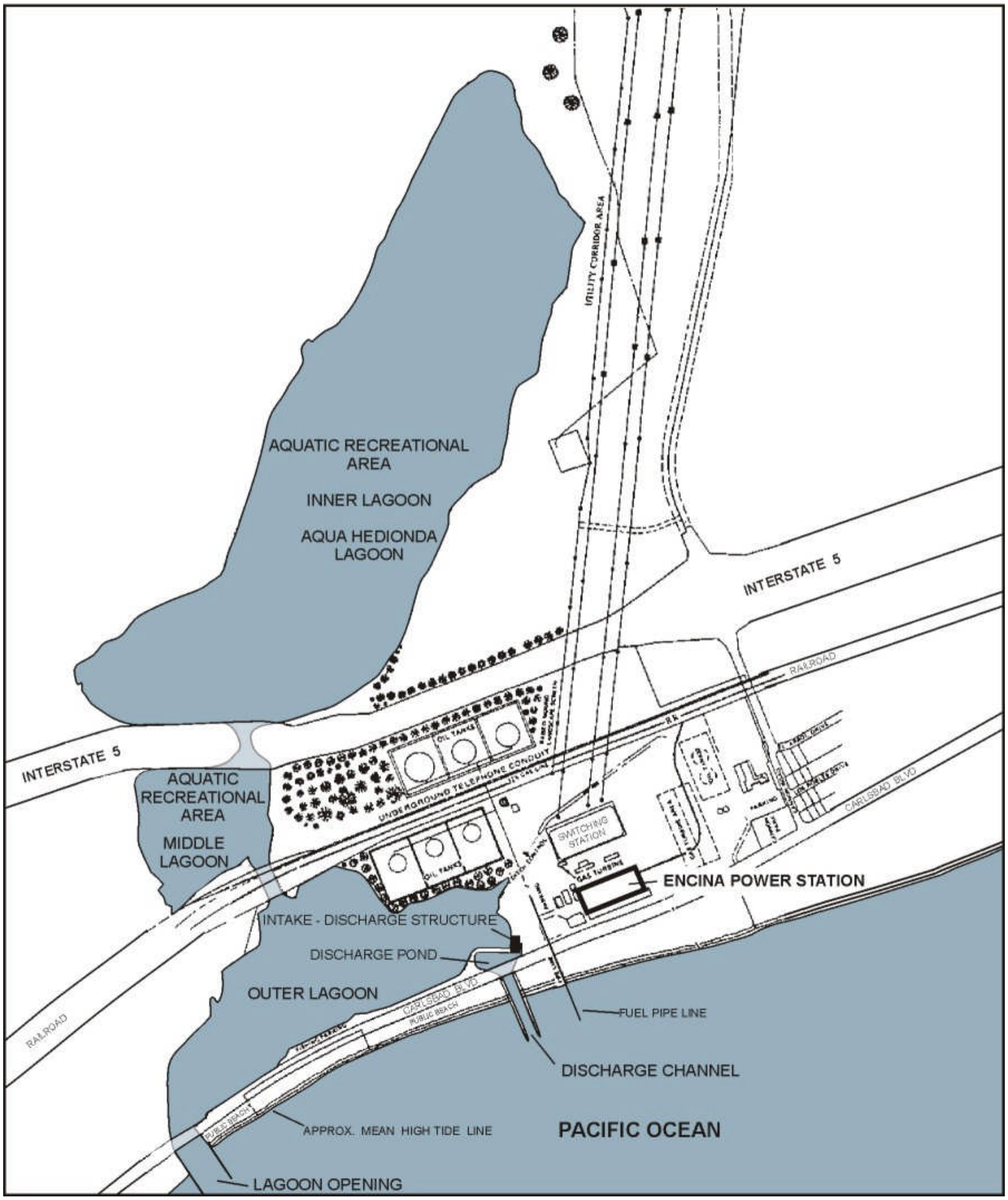


Figure 2-1. Location of Encina Power Station CWS in relation to Agua Hedionda Lagoon source water.

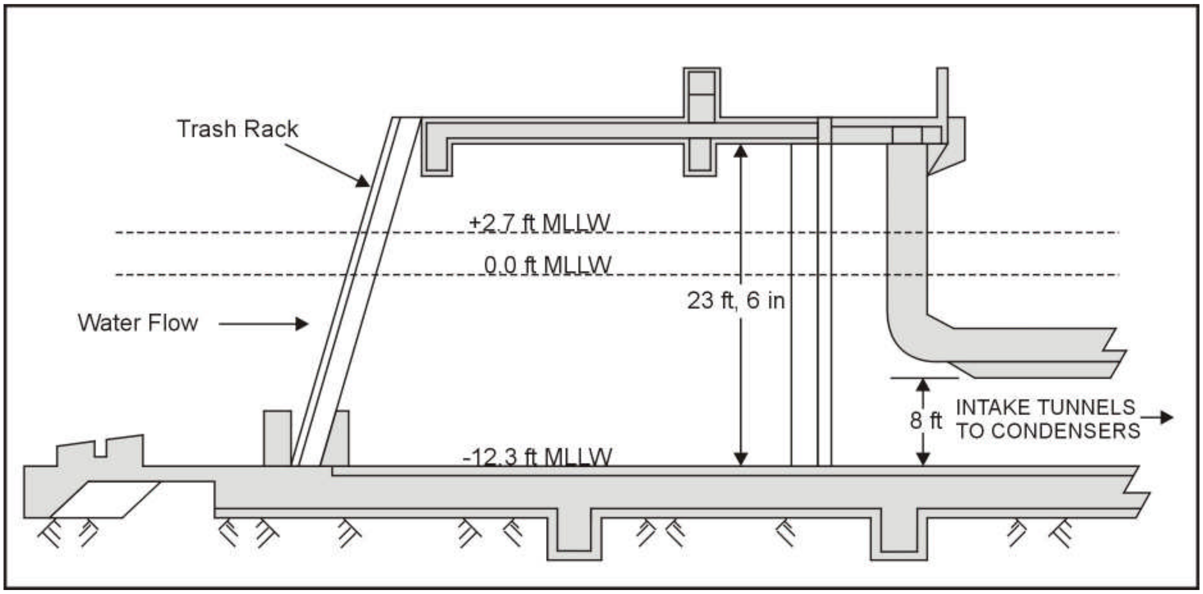


Figure 2-2. Longitudinal cross-section of Encina Power Station intake structure.

Note: No metric conversions provided for figure.

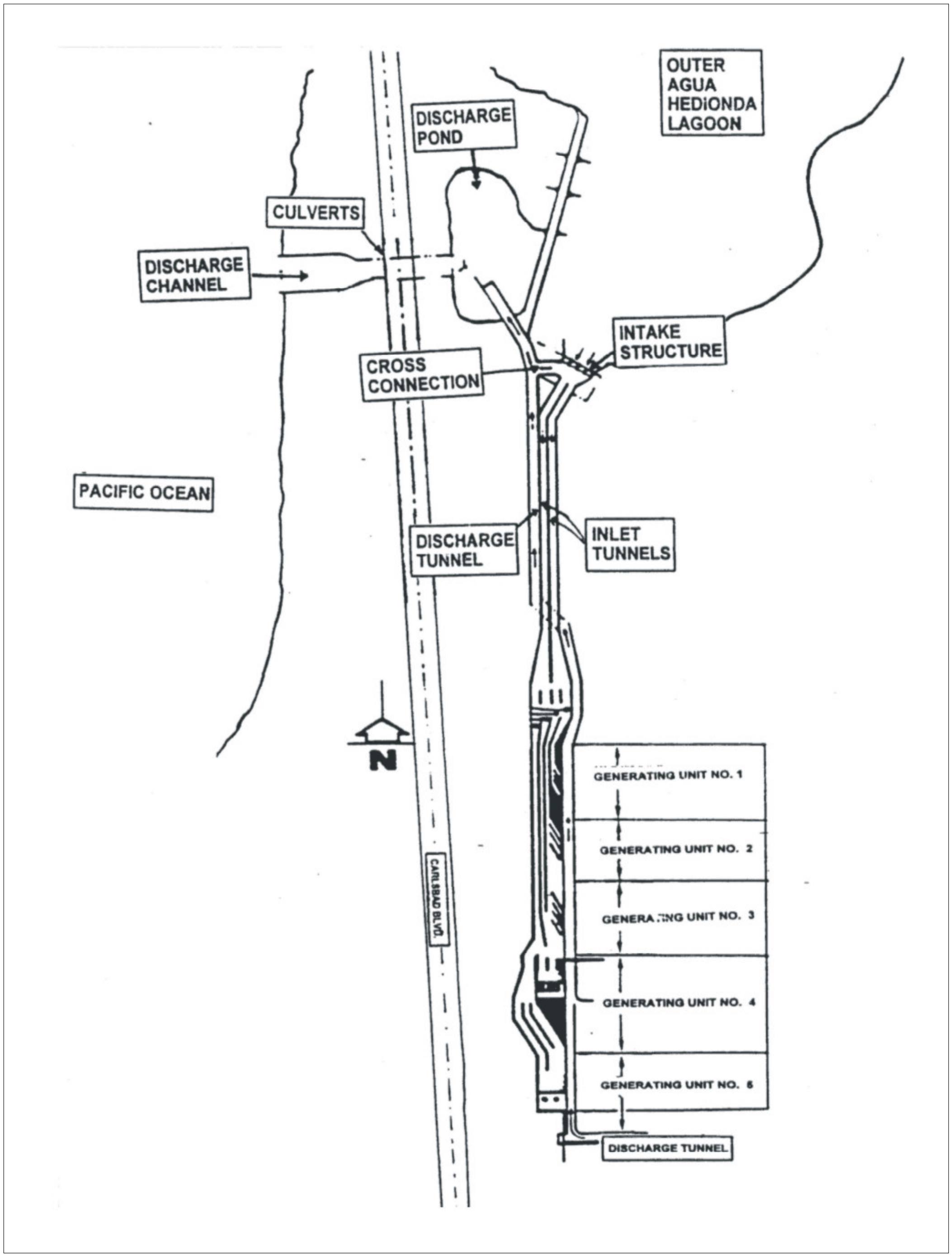


Figure 2-3. Schematic of Encina Power Station cooling water intake system.

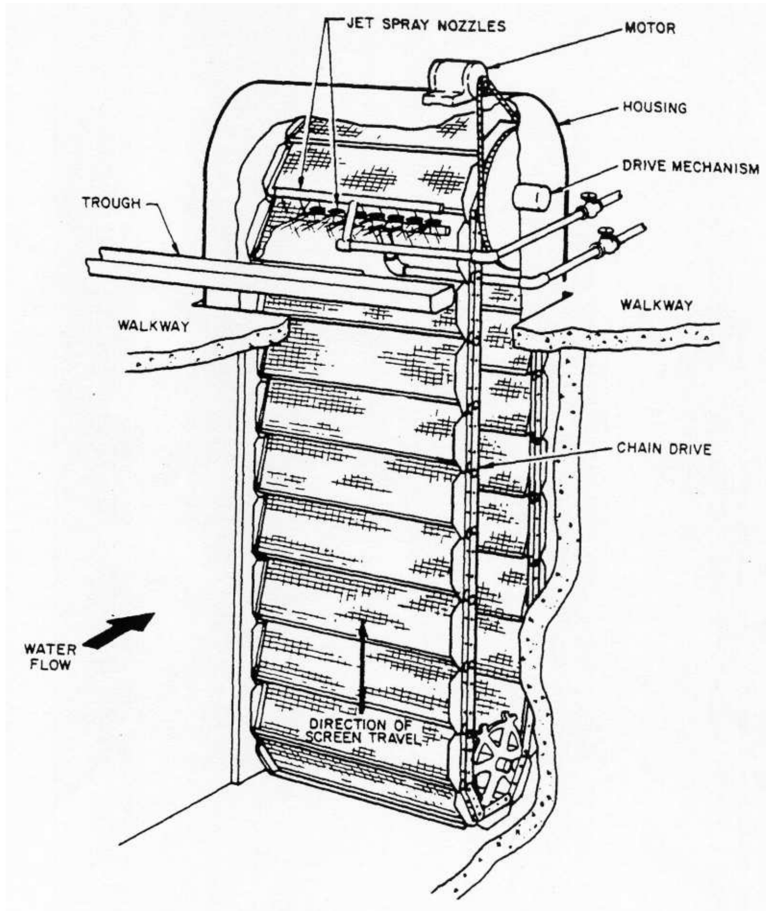


Figure 2-4. Diagram of traveling water screen similar to those in use at the Encina Power Station. Illustration from EPRI.

2.2 Environmental Setting

The aquatic environment surrounding EPS consists of Agua Hedionda Lagoon and its seasonal tributaries, and the open coastal waters of the Pacific Ocean. In the following description of the environmental setting, the physical environment will be characterized in terms of water body currents and tidal volumes relevant to the analysis of entrainment impacts, and the biological characteristics will be generally described with reference to previous environmental studies done at EPS.

2.2.1 Physical Description

Agua Hedionda Lagoon (AHL) is a coastal lagoon system consisting of three interconnected segments situated at the seaward end of the Agua Hedionda Creek drainage. It is located within the city limits of Carlsbad, California. It is one of several lagoons that are located along the southern California bight of the Pacific Ocean. Historically, AHL was a natural, seasonal estuary characterized by frequent closings of the lagoon mouth, especially in summer months. Wet and dry time periods play an important role in opening and closing southern California coastal lagoons (Elwany et al. 1999). Under normal conditions, floods control the opening of these lagoons. After large floods, lagoons stay open from one to three years. In the absence of floods, lagoons will remain closed unless their inlets are excavated. According to Bradshaw et al. (1976) AHL was first dredged from 1952 to 1954 in order to increase the lagoon volume to provide a cooling water source for EPS, thereby establishing a permanent opening and tidal connection with the nearshore coastal waters. In 1954, two rip-rap lined channels were completed that provided permanent connection with the ocean: a northernmost entrance channel over 91 m (300 ft) long with depth of 1.5 m (5 ft) below mean lower low water (MLLW), and a southern channel used to discharge water from the EPS.

The present lagoon system consists of three segments, the Outer, Middle, and Inner Lagoons (**Figure 2-5**). The Outer Lagoon is connected to the Pacific Ocean through an inlet channel formed by two jetties. The jetties are located west of the Coast Highway bridge and have lengths of about 107 m (350 ft) and 112 m (368 ft), north and south respectively. The distance between the centerline of the two jetties is about 74 m (243 ft). The lengths of the north and south discharge channel jetties are about 100 m (327 ft) and 115 m (376 ft), respectively. The absolute distance that the intake and discharge jetties extend from the shoreline varies somewhat with the changing location of the shoreline due to seasonal erosion and accretion of sand.

The coastal region of AHL is part of the Southern California Bight (SCB) whose nearshore is punctuated by headlands and submarine canyons. The SCB extends from Point Conception south to Cabo Colonet in Baja California about 120 miles south of the U.S.-Mexico border. The shelf in the vicinity of San Diego to AHL is relatively narrow, but widens somewhat off San Onofre, north of AHL. The headlands of Dana Point lie 31 mi northward, while Point Loma and the entrance to San Diego Bay is about 21 mi to the south, forming the continental landward extremes of the Gulf of Catalina part of the SCB. Further offshore, roughly 60 mi, Santa Catalina and San Clemente Islands delineate the westward boundary of the Gulf of Santa Catalina. Two submarine canyons are found nearby, the Carlsbad Canyon about one mi south and the La Jolla Canyon 16 mi south.

Ocean currents over the nearshore continental shelf are influenced by the poleward flow of the Southern California Countercurrent, a branch of the equatorward flowing California Current (Hickey 1993). The countercurrent is strongest in summer and winter, but either weak or absent in spring when flows of the California Current enter the SCB but turn equatorward rather than poleward. A detailed discussion of current patterns in the vicinity of AHL and EPS are presented in Section 2.2.1.3–*Coastal Source Water*.

2.2.1.1 Summary of Previous AH Studies

Several studies have previously been conducted to determine the effect of the operation of the cooling system of Encina Power Station on lagoon sedimentation (Ellis 1954, Bhogal and Costa 1989, EA Engineering Science and Technology 1997, Jenkins and Wasyl 2001). Studies to determine the impact on marine environments have been presented by Jenkins and Skelly (1998) and Jenkins et al. (1989). Elwany et al. (1999) described the oceanographic conditions (waves and tides) at Agua Hedionda Lagoon in detail. A bibliography of pertinent research on existing conditions and monitoring studies in the vicinity of Agua Hedionda Lagoon is given in Coastal Environments (1998).

The tidal prisms of the lagoon segments and volumes of water flowing through the AHL inlet were estimated by SDG&E (1980). The estimated flood volume was $2.0x10^6$ m^3 (1,600 acre-ft) comprised of the tidal prism of $1.25x10^6$ m^3 (1,000 acre-ft) and 0.75 $x10^6$ m^3 (600 acre-ft) of cooling water. The resulting ebb volume was calculated as $0.50x10^6$ m^3 (400 acre-ft).

As part of this 316(b) study, Dr. H. Elwany and other researchers at Coastal Environments determined the hydrodynamics of AHL, including estimates of inflow and outflow volumes, tidal prism, and residence time (**Appendix B**). Their estimates of inflow and outflow, corresponding to maximum power plant cooling volume, are similar to those measured by SDG&E (1980). They describe the dynamics of the flow in AHL during a period of over a month, June and early July 2005. Their measurements are used to estimate the inflows and outflows during the period of the present 316(b) study and the data are used in modeling potential impacts to fish and invertebrate populations.

2.2.1.2 Agua Hedionda Lagoon

The inlet to Agua Hedionda Lagoon serves as the source of coastal oceanic water for cooling the EPS. In general, this water flows through the Outer Lagoon to the power plant and to the Middle and Inner Lagoons of AHL during flood tide, while AHL itself is the source of cooling water during slack and ebb tidal conditions. Despite the relatively short residence time of “old water” in AHL, large populations of resident fishes are present.

SDG&E (1980) described the flood circulation into the lagoon at the entrance and measured velocities as high as 90 cm/s. As water enters the Outer Lagoon it flows clockwise along the northern bank and divides into three components: 1) a semi-permanent eddy responsible for sediment build-up, 2) a flow south towards the power plant intake and 3) a current that turns toward the Middle Lagoon. On ebb tide, currents coming out of the Inner Lagoon bifurcate at the entrance and flow toward the northern and southern ends. Ebb flows out of AHL were reported to be slower than inflows at 10 cm/s.

Elwany et al. (2005) measured changes in water level, velocity, salinity, and temperature in AHL between June 1, 2005 and July 7, 2005. The main purposes for this study were to determine the volumes of the three lagoon segments at mean sea level and to determine the volume of water that entered and left the lagoon daily, on average. In addition, the study described the general hydrodynamics of AHL, the volumes of the three lagoon segments at various elevations, the tidal prism, and the residence time of water in the three lagoon segments. The tidal prism was defined in this study as the volume of water in the lagoon between maximum and minimum water level per tidal cycle.

Bathymetric surveys of the Outer, Middle, and Inner Lagoons were conducted by the EPS in March 2005, November 2004, and May 2005, respectively. **Figure 2-5** shows the resulting bathymetric map of the lagoon. Additional figures in **Appendix B** (Appendix Figures B-1 through B-4) show the bathymetry of the Outer, Middle and Inner Lagoons. Lagoon depths ranged from about –12.8 m (–42 ft) (NGVD 29)[1], in the deepest portion of the Outer and Middle Lagoons, to about +3.0 m (+10 ft) NGVD along the shoreline of the Inner Lagoon. The channel leading from the Outer Lagoon to the Inner Lagoon was the deepest area of the lagoon.

The bathymetry of AHL in each lagoon segment was used to calculate the surface area, water volume and potential tidal prism at various elevations using ESRI ArcGIS® (**Table 2-3**). The surface area of the lagoon at +1.83 m (+6 ft) NGVD is about 144 ha (356 ac). The surface area of the lagoon is reduced to about 107 ha (264 ac) at mean low lower water (MLLW). At MLLW, the volume of water in the lagoon is about 2.16 million m^3 (1,750 acre-ft). The majority of the area and volume come from the large Inner Lagoon (**Figure 2-5** and **Appendix B**). The volume of AHL at mean sea level was estimated as 3.145 x 10^6 m^3 (2,550 acre-ft) for the three lagoon segments. The Outer, Middle and Inner Lagoon volumes were 1.247x10^6 m^3 (1,011 acre-ft), 0.350 x10^6 m^3 (284 acre-ft) and 1.547 x10^6 m^3 (1,255 acre-ft), respectively.

The potential tidal prism of the lagoon is defined as the volume of water in the lagoon between the maximum and minimum water levels, assuming the minimum water level to be –0.30 m (–1 ft) NGVD. The potential tidal prism definition assumes that the water level in the entire lagoon is the same, with no friction losses (i.e., no tidal muting). The potential tidal prism at mean sea level was estimated as approximately 370,000 m^3 (300 acre-ft), while at +1.83 m (+6 ft) NGVD it was nearly 2.59 million m^3 (2,100 acre-ft) (**Appendix B**). The tidal prism of the Inner Lagoon constituted the largest portion of the lagoon tidal prism.

In order to estimate the inflow, outflow and tidal prism (per tidal-cycle and daily) of AHL, four temporary data collection stations were established for a period of approximately one month from June 1, 2005 to July 7, 2005. Station S0 was located at the inlet to the Outer Lagoon, Station S2A was located in the northern portion of the Inner Lagoon, Station S2B was located at

[1] NGVD 29 (National Geodetic Vertical Datum 1929) measurements are +2.5 ft (0.7 m) MLLW in the vicinity of AHL.

the inlet to the Inner Lagoon, and Station S3 was located in the southeastern portion of the Inner Lagoon. Water level measurements were acquired at all four locations at five-minute intervals. Water velocities, temperature and conductivity were measured at Stations S0 and S2B (**Appendix B**).

The water level measurements showed only small variations between water level elevations at the four stations during neap tide; however there was a time lag between water level at the inlet and water level at the Inner Lagoon (<1 hour). During spring and mean tides, there is a short time lag and a variation in water elevation (~.08 m [0.25 ft]) between the inlet to the lagoon (Station S0) and the interior stations.

The highest water velocity measurements at Station S0 were +1.52 m/s (5 ft/sec) and –0.91 m/s (–3 ft/sec) during spring tide. Conductivity and temperature measurements showed little difference between Stations S0 and salinity fluctuated between about 31.5 and 34.0 PSU. During the first two weeks of June 2005 the temperature was about 20–22°C (68.0–71.6°F). In late June to early July, the temperature decreased and fluctuated significantly, ranging between 14 and 20°C (57.2–68.0°F). During the study, the cumulative tidal prism for the lagoon ranged from 215,860 m^3 (175 acre-ft) to 2.56 million m^3 (2,075 acre-ft). Water in the Middle and Outer Lagoons had fewer fluctuations and a much smaller tidal prism (about 61,000 to 370,000 m^3 [50 to 300 acre-ft]) than water in the large Inner Lagoon as it contains the majority of water in the lagoon. The tidal prism of the lagoon during the time period of the measurements varied from approximately 1.23 million m^3 (1,000 acre-ft during neap tide, 2.62 million m^3 (2,125 acre-ft) during spring tide, and 2.10 million m^3 (1,700 acre-ft) during mean tide.

A mathematical model was designed to compute the residence time of 'old' water in the lagoon during a tidal cycle. In the lagoon (total) after 5.0 tidal cycles or 2.6 days, the 'old' water is essentially flushed out of the lagoon. In the Inner Lagoon, 6.27 tidal cycles, or 3.2 days, are required to flush out the 'old' water. Due to water intake by the cooling system of the EPS, the outgoing flow through the inlet is less than the incoming flow through the inlet. **Appendix B** (Appendix Figures D-3 and D-4) show the lagoon inflow and outflow during the study period of June 1 through July 7, 2005. The mean reduction of the outflow water from the lagoon with respect to incoming water was about 51% per tidal cycle and 48% per day during the time period of the measurements.

As part of the description of the flow of water through the AHL, Elwany et al. (2005) estimated the incoming and outgoing water volumes at the major inlet of AHL for the period June 1, 2004 to May 31, 2005. Water level measurements conducted in the lagoon between June 1 and July 7, 2005 were used to establish the relationships of maximum and minimum water levels per tidal cycle, measured in feet, between the ocean at Scripps Pier, La Jolla, CA and the lagoon using linear regression analysis.

The relationships between lagoon and ocean water levels, shown in **Figure 2-6,** were as follows:

$$Wl_{max} = 0.97\ Wo_{max} + 0.0076 \qquad (1)$$

$$Wl_{min} = 0.69\ Wo_{min} - 0.37 \quad (2)$$

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

The measured ocean tides at Scripps Pier in La Jolla, CA, between June 1, 2004 and May 31, 2005 were used to estimate the maximum and minimum water levels in the lagoon using Equations 1 and 2, respectively. Using Equations 3 and 4 presented in **Appendix B** and the reported EPS cooling system hourly intake flows during the same time period (**Figure 2-7**), estimates were made regarding the incoming (inflow) and outgoing (outflow) flow rates per tidal cycle from the lagoon's major inlet (**Figure 2-8**). The length of a tidal cycle was variable depending on the tide phase.

The average daily estimated inflow and outflow through the lagoon's inlet between June 1, 2004 and May 31, 2005 was 4.11×10^6 m^3 (1.09×10^9 gal) and 1.80×10^6 m^3 (0.48×10^9 gal) corresponding to an average daily power plant intake flow of 2.31×10^6 m^3. A maximum daily inflow and outflow can be estimated, using these averages and the maximum power plant intake flow of 3.24×10^6 m^3 (1.09×10^9 gal) as 4.58×10^6 m^3 (1.09×10^9 gal) and 1.33×10^6 m^3 (1.09×10^9 gal).

2.2.1.3 Coastal Source Water

SDG&E (1980) reported an analysis of data from two current meters stationed offshore from the inlet to AHL in June, August and November 1979 that recorded currents at a depth of 3 m (10 ft) every 30 min. The two current meters were positioned 0.426 km (0.26 mi) and 1.036 km (0.64 mi) offshore. Median current speed at the offshore station was 10 cm/sec. Closer to shore, speeds were slower. Current directions at both stations showed reversals at tidal frequencies but a greater downcoast current was observed further offshore. Drifter studies showed a dominant trajectory of water directed towards the AHL inlet from the northwest (at an angle between 30 and 60 degrees toward the coastline).

During the present 316(b) study, a Sontek 1 MHz acoustic Doppler current meter (**Figure 2-9**) was deployed 0.8 km (0.5 mi) offshore from the entrance to AHL (33º08.5012'N, 117º21.1734'W) at a bottom depth of –15.8 m (–52 ft) MLLW, over the time period July 7, 2004 to July 12, 2005. The instrument was mounted in an anchored triangular frame with the instrument's reference point (piezoelectric ceramics) located about 0.5 m (1.6 ft) above the bottom and pointing upward. Data were collected for two minutes every half-hour in 20-1 m (0.3 ft) depth bins starting 0.7 m (2.3 ft) above the instrument. Water column average velocities were calculated every half-hour over the first 13 bins and represented average velocities from –0.610 m (–2 ft) MLLW to –14.1 m (–46.2 ft) MLLW.

Over the study period the average water column speed was 5.7 cm/sec (0.19 ft/sec). Cumulative water velocities were examined from July 2004 to June 2005 in units of km per month for 20 compass directions (**Figure 2-10)**. The dominant current directions over the time period were parallel to the coastline that runs approximately 328º to 148º T near EPS. Average water column velocities were rotated so that components orthogonal to the coastline could be estimated. These cumulative velocity components show a general downcoast and onshore displacement (**Figure 2-11**). The largest displacement occurred during November and the smallest during June (**Figure 2-12**).

The presentation of water current velocities as displacements per time period (e.g., per month) is relevant in the context of this 316(b) study of the entrainment of aquatic organisms. Larval transport to the power plant at AHL is estimated over the time period that the larvae of a particular species are floating in the plankton which is assumed to move at the same rate as the water mass.

The results of the present study showed predominately downcoast (equatorward) flow over the 15.9 m (52 ft) bottom depth. However, net upcoast flow occurred in April, June, July and December. Larger downcoast flows occurred during the fall 2004 and spring 2005 (March). These results are consistent with previous studies. Hickey (1993) reported a generally downcoast flow from a number of studies performed in the vicinity. Winant and Bratkovich (1981) measured equatorward flow in all seasons on the shelf (15 m [49.2 ft] to 60 m [197 ft] bottom depths) seaward of nearby Del Mar. Strongest downcoast flow occurred off Del Mar in winter (over 60 m bottom depth) or spring (15 m and 30 m bottom depths).

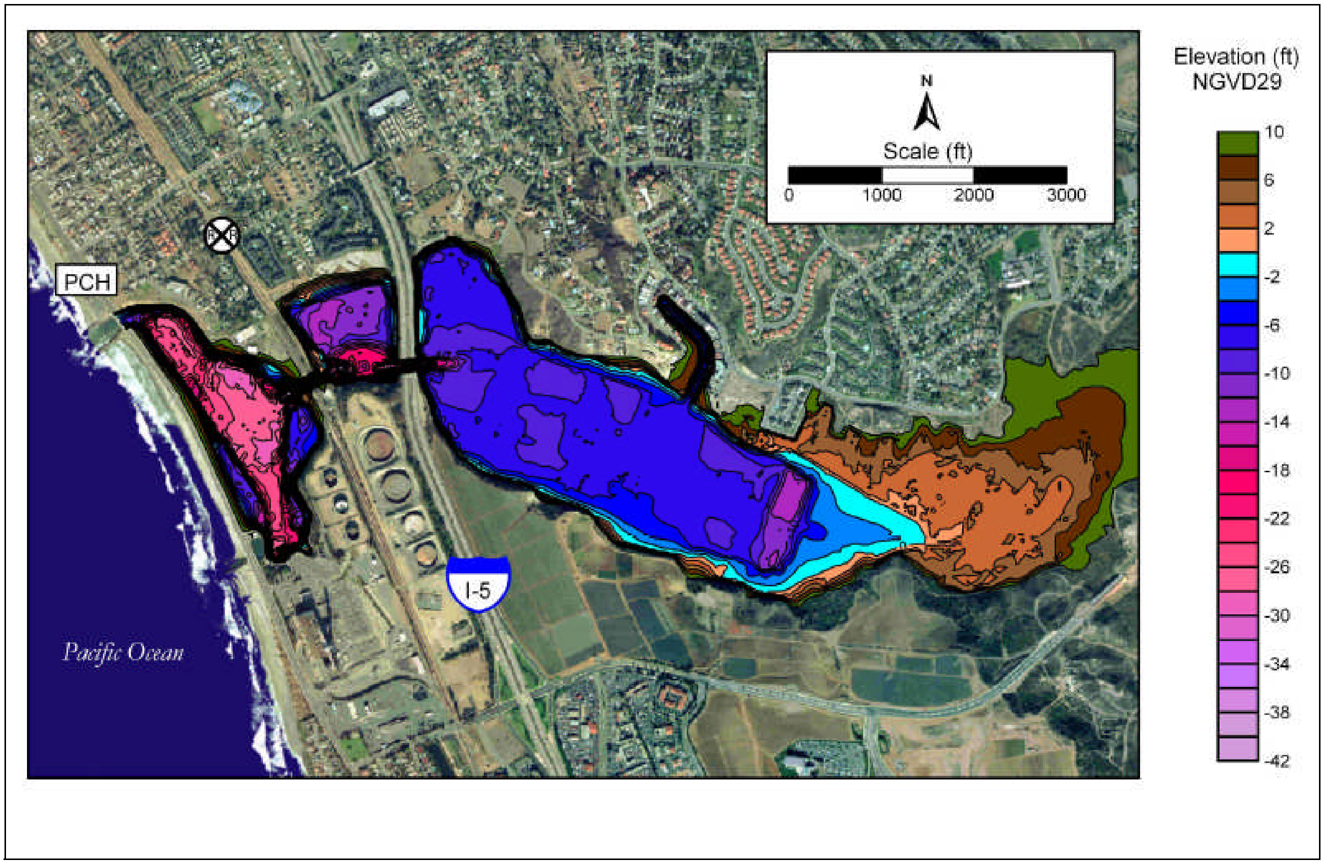


Figure 2-5. Bathymetry of Agua Hedionda Lagoon from a study by Elwany et al. (2005).

Note: Metric conversions not provided for figure.

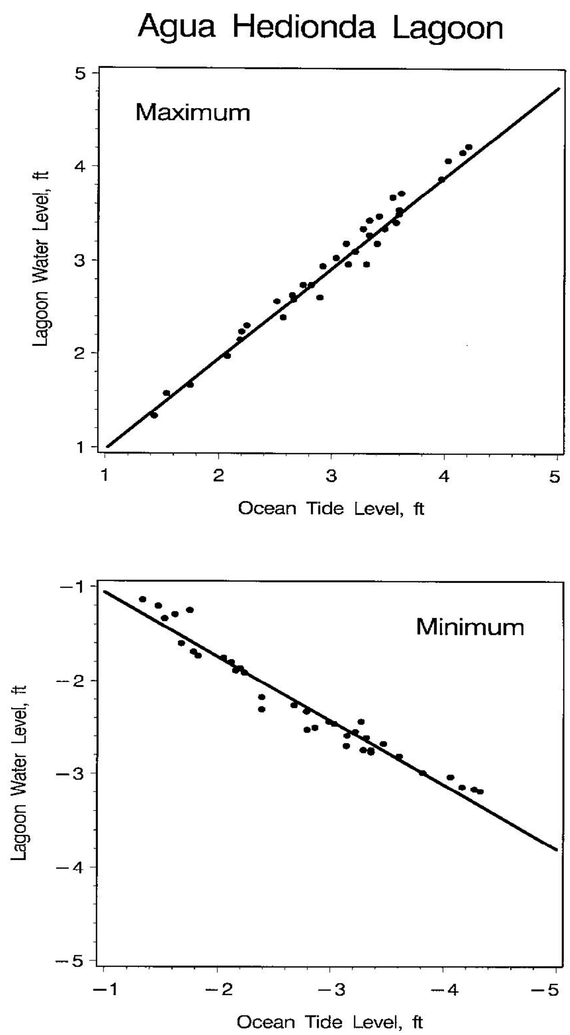


Figure 2-6. Relationship between maximum water level in the ocean and lagoon per tidal cycle (upper) and between minimum water level in the ocean at Scripps Pier, La Jolla, California and Agua Hedionda Lagoon (lower). Data from June 1 to July 7, 2005.

Note: Metric conversions not provided for figure.

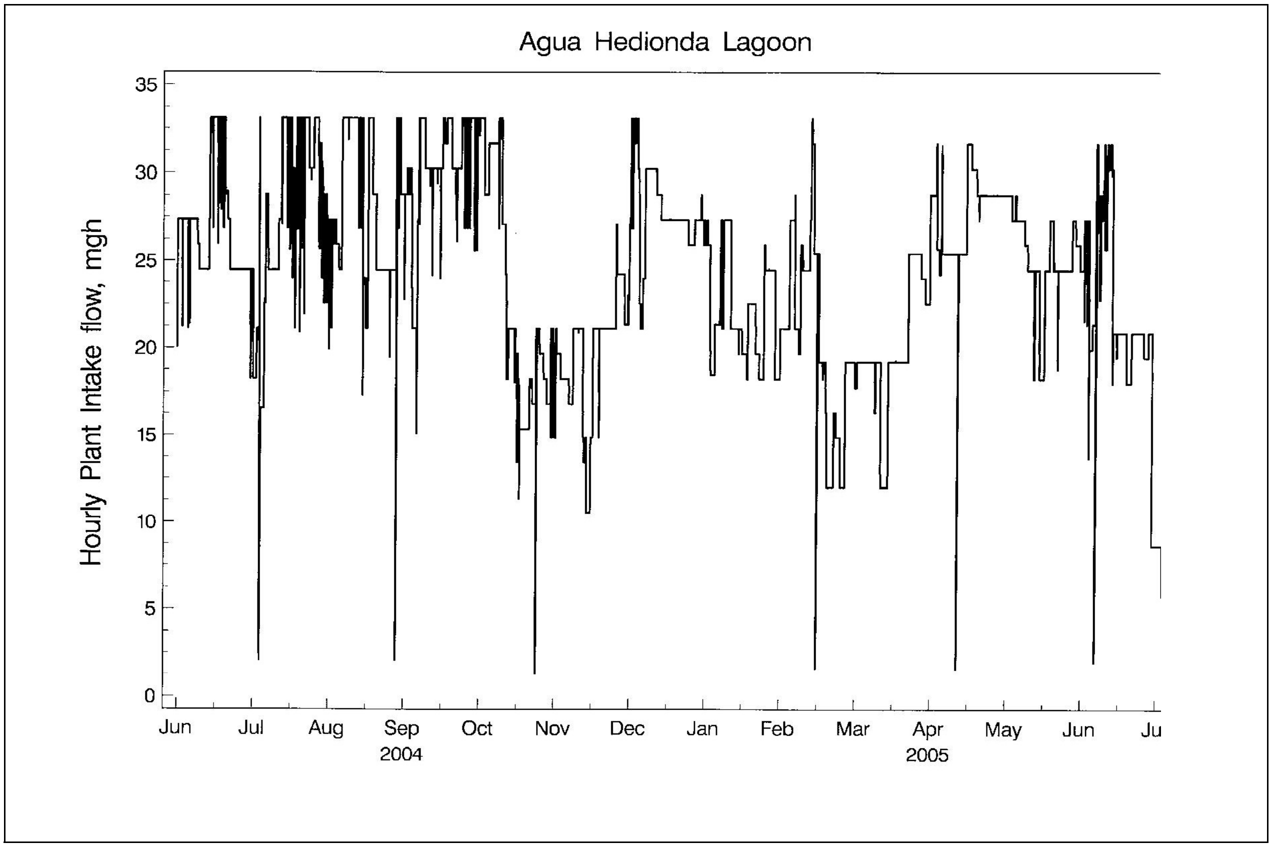


Figure 2-7. Hourly Encina Power Station intake flow (million gallons per hour) for the time period between June 1, 2004 and July 1, 2005.

*Note: Metric conversions not provided for figure***.**

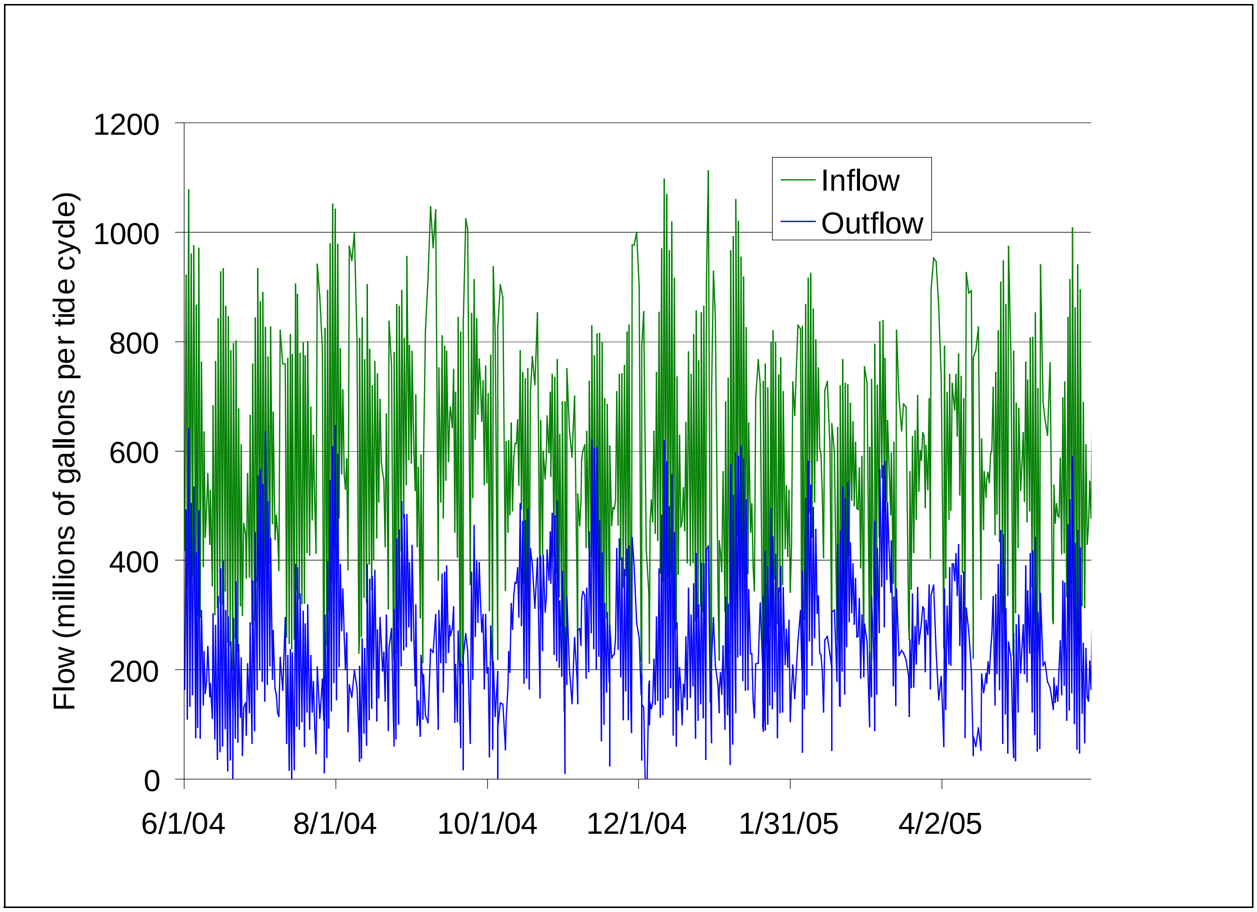


Figure 2-8. Estimated inflow and outflow through the Agua Hedionda Lagoon north jetty, June 1, 2004 through May 31, 2005.

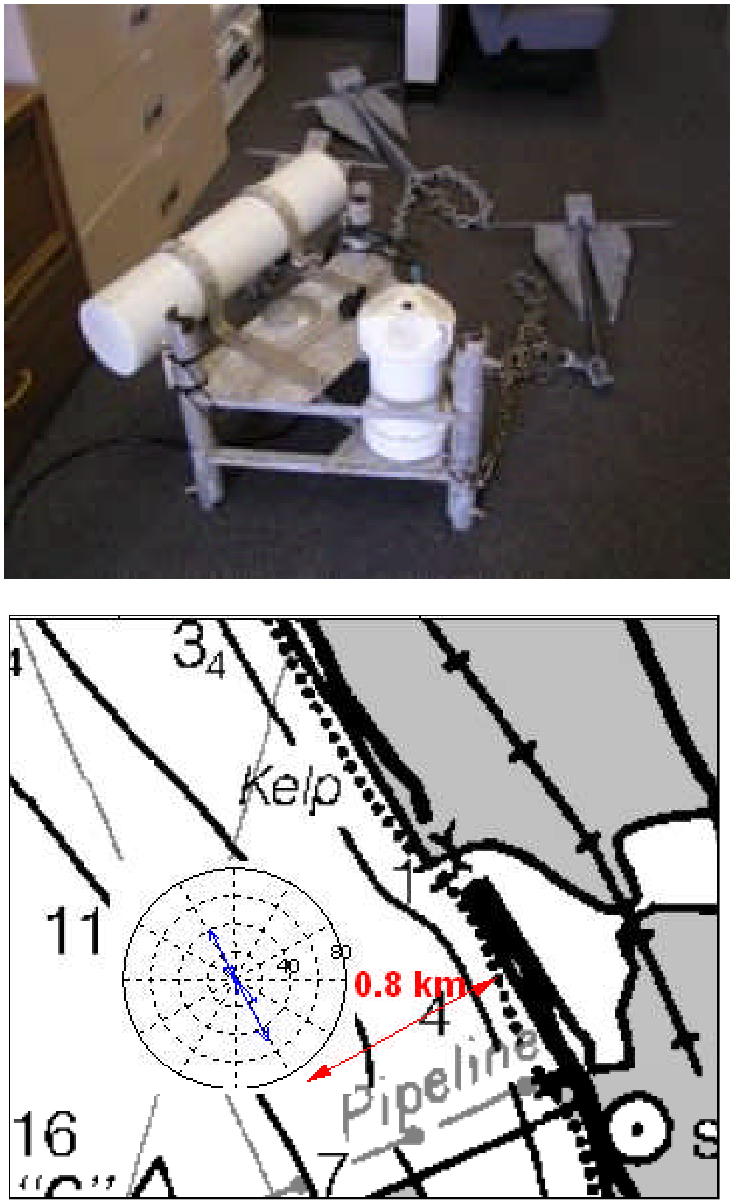


Figure 2-9. Acoustic Doppler current meter and battery in deployment frame (above) was positioned on the seafloor at –15.8 m (–52 ft) MLLW 0.8 km (0.5 mi) offshore the inlet to Agua Hedionda Lagoon, July 7, 2004 to July 12, 2005. The lower figure depicts an example of current velocities measured by the instrument over one month.

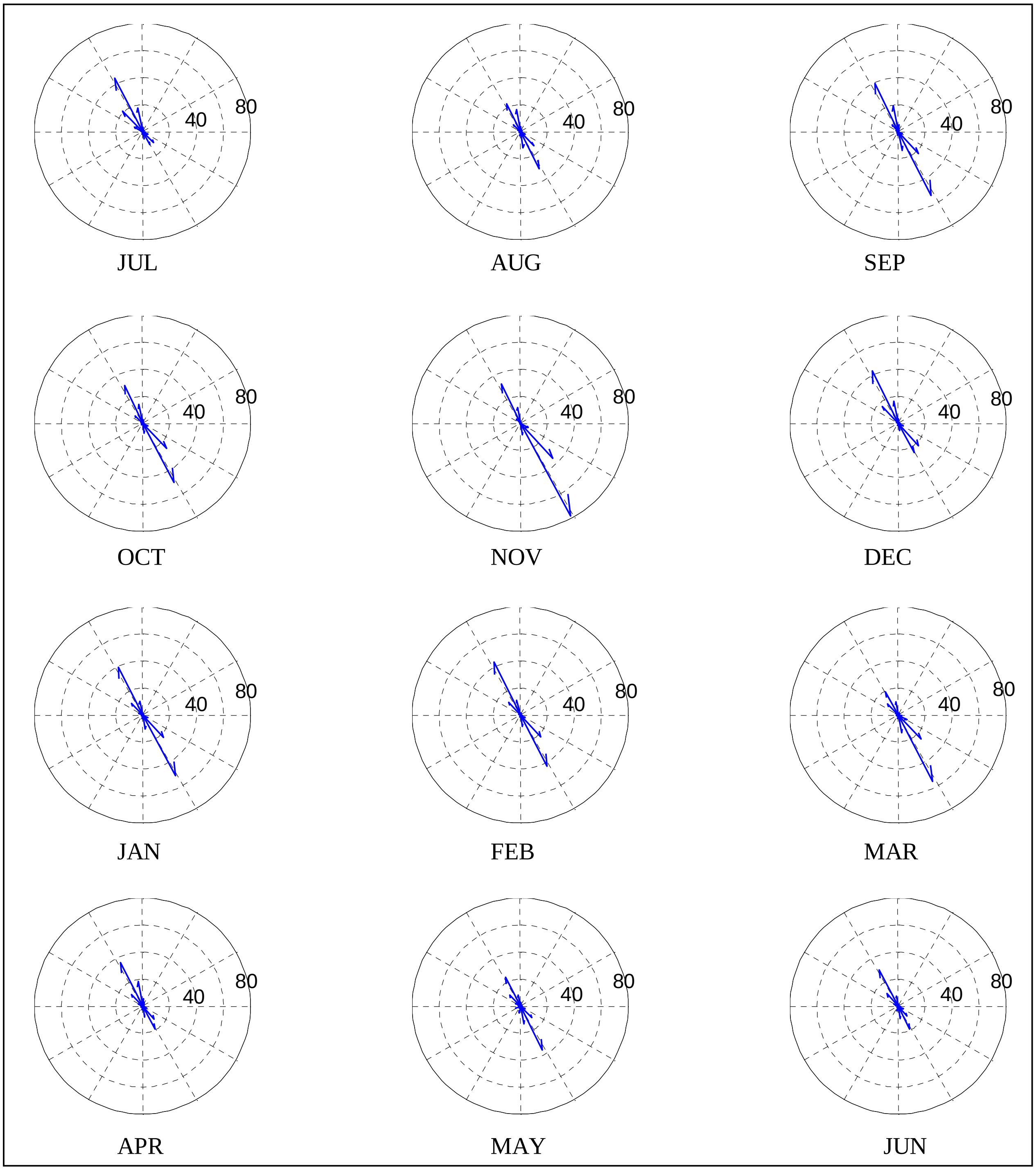


Figure 2-10. Cumulative excursions of water measured from July 2004 to June 2005 in km per month and by 20 compass directions. In each current rose, true north is upward; the coastline runs approximately 328º to 148º T near the Encina Power Station.

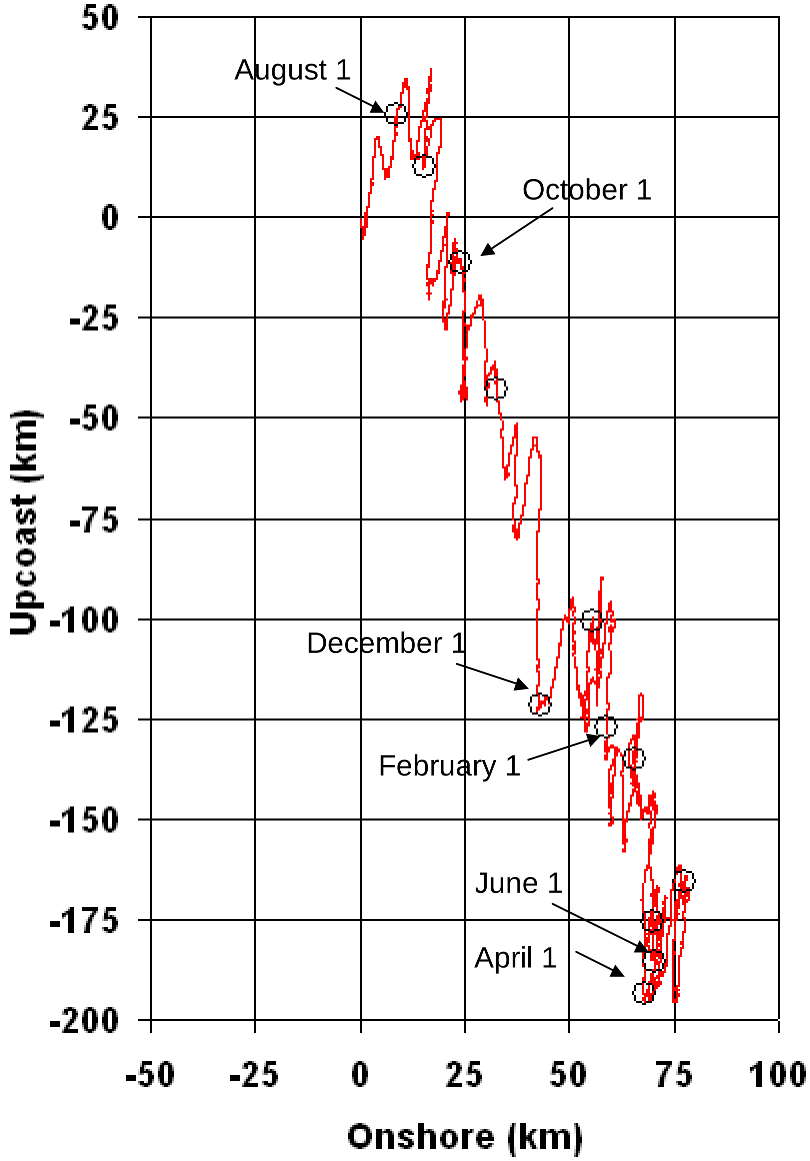


Figure 2-11. Cumulative current displacement measured by an uplooking acoustic Doppler current meter 0.5 mi (800 m) offshore the Encina Power Station, 33º08.5012'N 117º21.1734'W, –15.2 m (–50 ft) MLLW depth, 7 July 2004 (1000 hr) to 12 July 2005 (1000 hr).

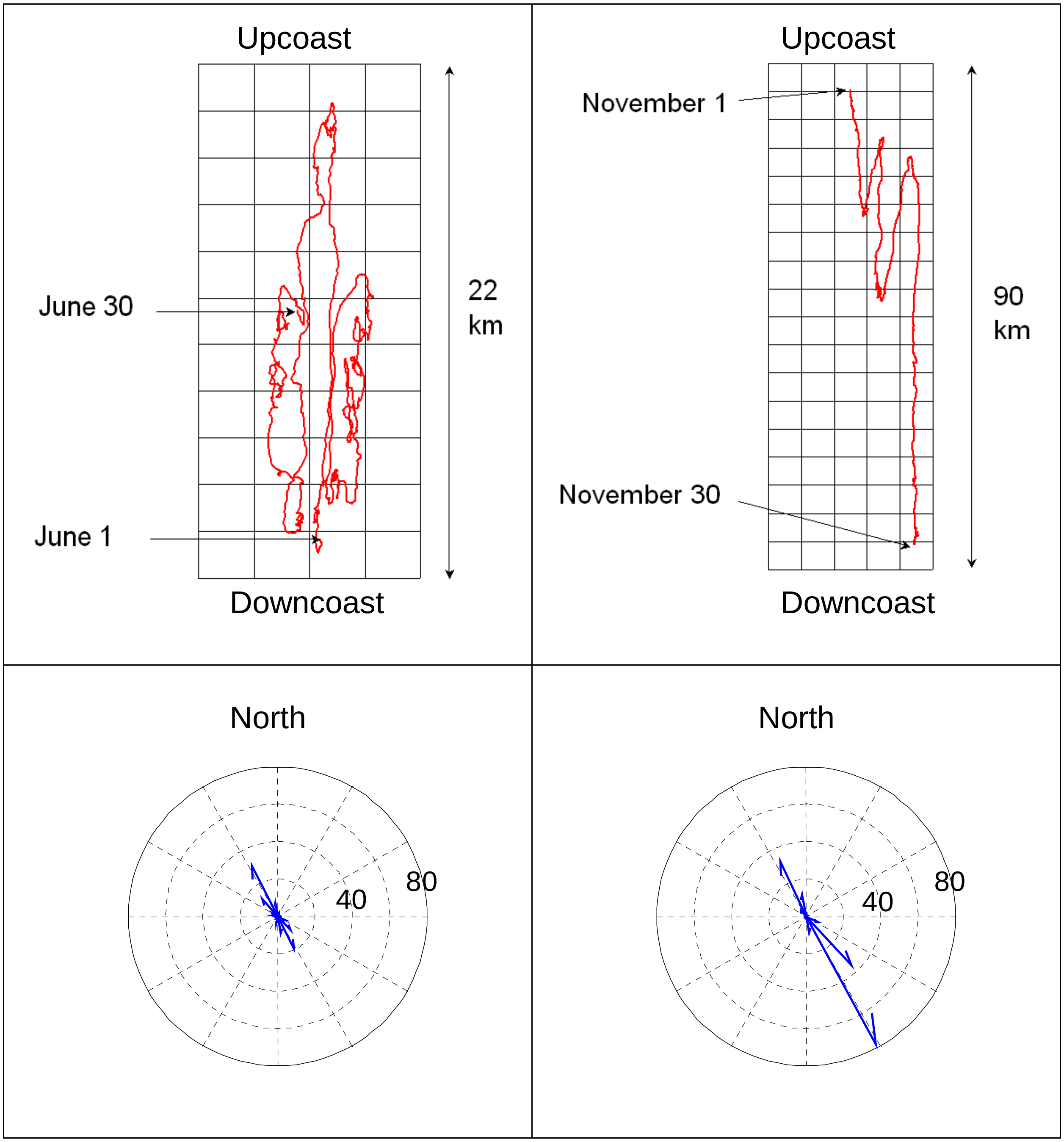


Figure 2-12. Cumulative monthly water column currents in June (2005) (left) and November 2004 (right) and 0.8 km offshore the inlet to Agua Hedionda Lagoon. Upper view is onshore and alongshore displacement orthogonal to the coastline. Below are corresponding compass roses, each divided into 20 bin directions.

Table 2-3. Surface area and volumes at contour lines, Agua Hedionda Lagoon. Reference elevation datum is NGVD29. Mean sea level (+0.06 m NGVD) areas and volumes are shaded.

Elevation (m)	Surface Area (hectares)				Volume (m^3 x 10^6)			
	Total	Outer	Mid	Inner	Total	Outer	Mid	Inner
1.83	144.417	22.646	10.771	111.000	5.323	1.636	0.531	3.156
1.68	141.139	22.503	10.677	107.959	5.105	1.602	0.514	2.989
1.52	138.632	22.377	10.583	105.672	4.892	1.568	0.498	2.826
1.37	135.692	22.262	10.487	102.943	4.683	1.534	0.482	2.667
1.22	130.224	22.156	10.390	97.678	4.480	1.500	0.466	2.514
1.07	122.552	22.054	10.291	90.207	4.288	1.466	0.450	2.371
0.91	118.547	21.952	10.190	86.405	4.104	1.433	0.435	2.236
0.76	116.144	21.851	10.084	84.209	3.925	1.399	0.419	2.106
0.61	112.623	21.749	9.973	80.901	3.751	1.366	0.404	1.981
0.46	110.520	21.646	9.855	79.020	3.581	1.333	0.389	1.859
0.30	109.559	21.538	9.736	78.285	3.413	1.300	0.374	1.739
0.15	108.545	21.425	9.615	77.506	3.247	1.267	0.359	1.620
0.06	107.748	21.350	9.539	76.859	3.145	1.247	0.350	1.547
0.00	107.260	21.304	9.493	76.463	3.082	1.235	0.345	1.503
-0.15	104.923	21.173	9.354	74.396	2.921	1.202	0.330	1.388
-0.30	102.915	21.027	9.223	72.665	2.762	1.170	0.316	1.276
-0.46	100.832	20.869	9.099	70.864	2.607	1.138	0.302	1.167
-0.61	98.456	20.699	8.976	68.782	2.455	1.107	0.289	1.060
-0.76	96.011	20.522	8.853	66.635	2.307	1.075	0.275	0.957
-0.91	93.748	20.342	8.733	64.674	2.162	1.044	0.262	0.857
-1.07	91.459	20.156	8.611	62.691	2.021	1.013	0.248	0.760
-1.22	89.753	19.962	8.493	61.297	1.883	0.983	0.235	0.665
-1.37	88.057	19.746	8.376	59.935	1.748	0.952	0.222	0.573
-1.52	86.292	19.507	8.257	58.527	1.615	0.922	0.210	0.483
-1.68	84.283	19.272	8.137	56.874	1.485	0.893	0.197	0.395
-1.83	80.937	19.025	8.015	53.897	1.359	0.864	0.185	0.310
-1.98	71.619	18.774	7.890	44.955	1.243	0.835	0.173	0.235
-2.13	65.128	18.534	7.761	38.834	1.139	0.806	0.161	0.171
-2.29	56.589	18.084	7.626	30.879	1.046	0.779	0.149	0.118
-2.44	42.916	17.675	7.482	17.759	0.970	0.751	0.138	0.081
-2.59	35.645	17.326	7.351	10.969	0.910	0.725	0.126	0.059
-2.74	31.208	16.972	7.208	7.028	0.859	0.699	0.115	0.045
-2.90	27.864	16.609	6.972	4.283	0.814	0.673	0.105	0.037
-3.05	26.349	16.295	6.548	3.506	0.773	0.648	0.094	0.031

2.3 Biological Description

The primary source water body for extracting cooling water for EPS is the Outer Lagoon in Agua Hedionda Lagoon. However, because of the large tidal exchange rate between the Outer Lagoon and the nearshore coastal waters off the Carlsbad area, and also the contiguous tidal connections with the Middle and Inner Lagoons, these waters must also be considered as part of the greater source water body for EPS. One of the most recent comprehensive studies on the biological characteristics of AHL was done by MEC Analytical (1995) in preparation for potential dredging within the lagoons. An earlier comprehensive study of lagoon and nearshore biological resources was done by SDG&E (1980) for the initial EPS 316(b) demonstration. A summary of the lagoon description and results of these studies are summarized in the following section. Tenera Environmental conducted additional sampling in 2005 in habitats of the lagoon that had not been adequately sampled for fishes in the previous studies, including the rock revetment around the margin of the Outer Lagoon and the intertidal mudflat habitats in the Middle and Inner Lagoons. The results of these studies are summarized in Section 2.3.1.2 and presented in full in Appendix C.

2.3.1.1 Summary of Previous AHL Biological Studies

Agua Hedionda Lagoon contains several specialized habitats, which are ideal for early stages of fish and invertebrate development. Habitats include open water, sand and mud substrates, eelgrass, rock revetment, pilings, and aquaculture grow-out floats. The lagoon environment offers calmer waters and higher productivity than adjacent coastal areas. Utilization of the lagoon is variable among species. There are permanent residents that utilize particular habitats in the lagoon for resting, feeding and spawning throughout their lifetime. There are also transient species whose adults use the lagoon for spawning seasonally and whose young subsequently utilize the area as a nursery ground. Habitat maps have been prepared for the lagoon environment (MEC 1993) and a reconnaissance survey in 1994 (MEC 1995) indicated that the previous maps were still generally valid.

Although this review concentrates mainly on finfishes due to their relevance to entrainment and impingement issues, other groups of organisms have been examined in previous studies. For example, Bradshaw et al. (1976) studied plankton populations in AHL and found zooplankton composition to be fairly uniform throughout the three sections of the lagoon. Density and distribution of zooplankton may be more closely influenced by tidal cycles than any other factors in this type of water system.

Saltmarsh vegetation and seasonal bird populations around AHL were also documented in earlier studies (MEC 1995). Salt marsh and tidal flats occur along the shores of the Middle and Inner Lagoons. The Middle Lagoon has narrow tidal flats along each shore; the widest flats occur along the north shore and at the eastern end of the south shore. The north shore has narrow tidal flats, and pickleweed occurred above mean high water in the northwest and northeast corners, and in scattered, small patches in between. The east shore has a narrow bank, and scattered small patches of pickleweed were scattered along this shore.

Mudflats were best developed at the east end of the Inner Lagoon, and have expanded in recent years due to extreme sedimentation. Sandy flats occur at the Bayshore Drive public access, and there are two beach areas along the southern shore of the Inner Lagoon that have expanded in size since the 1970s. The most extensive salt marsh occurred east of the Bayshore Drive public access and extended to the eastern end of the lagoon. This area is dominated by pickleweed, mudflat, tidal creeks, and non-tidal flats.

Eelgrass (*Zostera marina*) distribution was mapped by MEC (1995) and in the Outer Lagoon occurred primarily along the shoreline. Its distribution in the Outer Lagoon is largely controlled by the agency-approved limits of maintenance dredging in that section of the lagoon. Little eelgrass occurs near the inlet to the ocean, but it does occur, first in patches and then in larger beds, along the west and northeast shores. Eelgrass was well developed along the southeast shore. Eelgrass occurred to depths of –5.5 m (–18.0 ft) MSL in the Outer Lagoon. Eelgrass was found throughout most of the Middle Lagoon with the exception of the top of the sandbar, and in most of the channel between the Outer and Inner Lagoons. Substantial eelgrass occurred on the sandbars of the west Inner Lagoon, and in narrow bands along the shoreline. Similar to the Middle Lagoon, maximum depths in the west Inner Lagoon were about –2.4 to –2.7 m (–8 to –9 ft) MSL. However, the lower limit of eelgrass in the west Inner Lagoon only extended to about –1.2 to –1.5 m (–4 to –5 ft) MSL. Continuing further east, eelgrass thinned to non-continuous, patchy beds and no eelgrass was observed at the far eastern end of the lagoon.

Bradshaw et al. (1976) indicated that the distribution of eelgrass in Agua Hedionda Lagoon appears to be controlled by depth, substrate stability, and light availability. Light levels were considered the primary factor controlling the density of eelgrass relative to depth in the Middle Lagoon by Backman and Barilotti (1976). Because of the changes that have occurred in the lagoon due to sediment infilling over the last twenty years, it is reasonable that depth, substrate stability, and light all have contributed to the present distribution of eelgrass.

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, it was found to provide a wider range of habitats, including mud flats, salt marsh, and seasonal ponds than elsewhere in AHL. As a result, bird and fish diversity was highest in the Inner Lagoon.

The number of fish species in AHL was similar to that of other embayments examined by Horn and Allen (1978) with 55 fish species within a 120 hectare subtidal area. In the SDG&E (1980) impingement study, additional collections at the adjacent CWIS within EPS and lagoon collections by otter trawl yielded a total of 79 fish species. Other bays examined by Horn and Allen (1978) were: Anaheim Bay with 59 species in 53.0 ha (131.0 ac), Alamitos Bay with 43 species in 67.2 ha (166.1 ac), Elkhorn Slough with 69 species in 87.4 ha (216.0 ac), Bolinas Lagoon with 41 species in 109.3 ha (270.1 ac), and Newport Bay with 78 species in 175.2 ha

(432.9 ac). A positive linear logarithmic relationship of surface area to fish species diversity was indicated for all 13 embayments.

Lagoons provide important habitat for coastal marine and resident fishes. An important aspect of bays and estuaries is that they serve as nursery habitat for commercially and recreationally important coastal species such as California halibut (*Paralichthys californicus*) and diamond turbot (*Hypsopsetta guttulata*) (Allen 1982, 1988). AHL is primarily a marine lagoon but can be influenced by seasonal freshwater inflows from December through April. The southern end of the Inner Lagoon is influenced by runoff from Agua Hedionda Creek. Euryhaline species such as the California killifish (*Fundulus parvipinnis*), western mosquitofish (*Gambusia affinis*), and striped mullet (*Mugil cephalus*) occur in the Inner Lagoon. These waters may provide a necessary gradation from fresh to brackish water for some winter spawning fishes such as topsmelt that require variable salinities for normal egg and larval development.

The fish surveys during the MEC (1995) study were conducted during spring and summer. Temperatures ranged from 14.8 to 16.9°C (58.6–62.4°F) during the spring and 20.8 to 24.8°C (69.4–76.6°F) in the summer. Summer temperatures were up to 4°C (7.2°F) warmer in the Inner Lagoon than in the Outer Lagoon. Surface salinities ranged from 23 to 32.7 ppt, with the lower values in spring due to seasonal rainfall. Visibility ranged from approximately 2 to 4 ft (0.75 to 1.25 m) during the spring but was generally higher in the summer. Occasional phytoplankton blooms in nearshore and lagoon waters can severely decrease water clarity and deplete dissolved oxygen concentrations. Such conditions were particularly severe in AHL throughout much of summer 2005 (S. LePage, M-REP Consultants, pers. comm.).

Several types of fish sampling gear were used during the MEC (1995) study including otter trawl, beam trawl, and beach seine. A total of 35 species of fishes was found during the 1994 and 1995 sampling. 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 and 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 have increased the abundance and number of species collected (see following section). Silversides (Atherinopsidae) and gobies (Gobiidae) were the most abundant fishes collected. Silversides, including jacksmelt and topsmelt, that occur in large schools in shallow waters where water temperatures are warmest were most abundant in the shallower Middle and Inner Lagoons. Gobies were most abundant in the Inner Lagoon, which has large shallow mudflat areas that are their preferred habitat. The species composition generally reflected the open tidal exchange conditions with nearshore coastal waters, especially in the Outer Lagoon, with some of the more abundant marine species including the spotted sand bass (*Paralabrax maculatofasciatus*), barred sand bass (*P. nebulifer*), queenfish (*Seriphus politus*), shiner surfperch (*Cymatogaster aggregata*), giant kelpfish (*Heterostichus rostratus*), California halibut (*Paralichthys californicus*), and diamond turbot (*Hypsopsetta guttulata*).

No tidewater gobies (*Eucyclogobius newberryi*) were found during the study. This is a federally endangered species that was once recorded as occurring in the lagoon prior to lagoon modifications in the early 1950s. The present marine-influenced environment in the lagoon would not tend to support tidewater gobies because they prefer brackish water habitats. No other listed fish species were collected in the study.

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. California grunion utilize the beaches around EPS during spawning season from March through August. Numerous infaunal species occur in subtidal sandy bottoms with mollusks, polychaetes, arthropods, and echinoderms comprising the dominant invertebrate fauna. Sand dollars can reach densities of 1,200/m^2. Typical fishes in the sandy subtidal include queenfish, white croaker, several surfperch species, speckled sanddab, and California halibut. Also, California spiny lobster (*Panulirus interruptus*) and *Cancer* spp. crabs forage over the sand. Many of the typically outer coast species can occasionally occur within AHL, carried by incoming tidal currents.

The rocky habitat at the discharge canal and on offshore reefs supports various kelps and invertebrates including barnacles, snails, sea stars, limpets, sea urchins, sea anemones, mussels, crabs and spiny lobsters. Giant kelp (*Macrocystis*) forests are an important habitat-forming community in the area offshore from AHL and provide habitat for a wide variety of invertebrates and fishes. The kelp forests in coastal southern California support many fish species, including northern anchovy, jack smelt, queenfish, white croaker, garibaldi, rockfishes, surfperches, and halibut (North 1968). A 2004 study of the kelp forest habitat 2 km (1.2 mi) south of AHL quantified the abundances of 14 species of fishes and 13 species of macroinvertebrates (T. Anderson, SDSU, pers. comm.). Common fish species included jack mackerel (*Trachurus symmetricus*), señorita (*Oxyjulis californica*), shiner perch (*Cymatogaster aggregata*), and black surfperch (*Embiotoca jacksoni*). Common macroinvertebrate species included gorgonian (*Muricea californica*), purple sea urchin (*Strongylocentrotus purpuratus*), California spiny lobster, white sea urchin (*Lytechinus anamesus*).

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

2.3.1.2 Summary of Special Studies

The following studies were conducted by Tenera Environmental to provide additional interpretive data for the 2004-2005 larval fish entrainment studies at EPS. This section summarizes these studies—a complete data presentation can be found in **Appendix C**. The supplemental studies on fish in AHL were short-term in nature and the information was used to improve knowledge of adult/juvenile fish abundance, distribution and size composition that can be related to the source of entrained larvae. The studies were designed to sample specific habitats in the lagoon that were not sampled during earlier comprehensive fish studies by MEC Analytical (1995).

Gobies and blennies produce large numbers of larvae in AHL, yet the survey methods used in earlier studies likely underestimated their local adult population densities because the sampling equipment targeted larger fishes over soft substrates and seagrass habitats. Accurate density information on small cryptic fishes requires the use of enclosure sampling and/or the use of anesthetic solutions to ensure that all individuals are collected within a sampled area. Also, the earlier methods did not sample artificial habitats such as the breakwater areas along the western edge of the Outer Lagoon or aquaculture mussel floats below the tank farm.

In the present study, four methods were used to sample fishes in specific habitats (**Figure 2-13**). In the first method, divers counted fishes along 30 m x 2 m (98.4 ft x 6.6 ft) replicate transects at four rocky reef (rock shoreline armoring) sites around the perimeter of the Outer Lagoon. In order to conduct surveys during periods of best underwater visibility, counts were done within 2 hours of the maximum high tide for that day, or as long as current speed and visibility would allow data to be collected. A second survey method was used to sample cryptic fishes at the same sites. Using the measuring tape deployed for the visual counts, five 1.0 m^2 (10.8 ft^2) quadrats were randomly positioned along a transect. Quinaldine solution contained in 500 ml squirt bottles was injected into crevices and beneath cobbles to anesthetize any fishes within the quadrat area. Specimens were collected with hand nets and preserved for later identification and measurement in the laboratory.

Using a third method, cryptic fishes that reside within the aquaculture mussel floats in the Outer Lagoon were censused. A diver carrying a cylindrical net (6.4 mm [¼ inch] mesh) with a closed end encapsulated thirteen 2.4 m (8 ft) long mussel strands along with the associated float apparatus prior to harvest. Once the nets were in position, a harvesting barge lifted the mussel grow-out line out of the water and the netted strands were removed. The netted strands and float apparatus were checked for the presence of cryptic fish. All fish found were identified to species, counted, measured and returned.

Finally, a fourth sampling method targeted gobies and other small fishes that typically reside on the substrate or in burrows on intertidal mud and sandflat habitats. At each of nine sites around the Middle and Inner Lagoons, a circular enclosure (0.43 m^2 [4.6 ft^2]) constructed of plastic sheeting was used to sample the fishes during low tide periods. An average of five replicates was sampled parallel to shore at each site. A hinged sweep net with the hinge positioned in the center of the enclosure was unfolded through the enclosure to capture any fish using multiple passes. All fish captured were preserved for later identification and measurement in the laboratory.

The results of these studies were as follows: Along the rocky shoreline around the margin of the Outer Lagoon 17 species of fish were observed in the visual transects. The most abundant species observed, in order of decreasing density, were silversides (topsmelt), salema, barred sand bass, kelp bass, blacksmith, opaleye, northern anchovy, garibaldi, and black surfperch. The highest density of fishes (133 per transect) and the greatest number of species (12) occurred along the east channel separating the Outer and Middle Lagoons (Station F3). This station also had the deepest transect at 7.0 m (23 ft). The lowest density and fewest number of species occurred at the North Jetty. Barred sand bass were present at all stations and were equally abundant at the North Jetty and East Channel stations.

Five species of cryptic fishes were collected with mussel blennies (*Hypsoblennius jenkinsi*) being the most abundant species. The highest density of cryptic fishes ($3.2/m^2$) was found along the North Jetty breakwater (Station F1) and none was found near the power plant intakes on the east side of the lagoon (Station F4). This lack of cryptic, sedentary fishes in the southern end of the Outer Lagoon may have been due to the persistent phytoplankton blooms that occurred in AHL during summer 2005 that severely depleted dissolved oxygen. Examination of the aquaculture float lines revealed no cryptic fishes, although some blennies were present on collector lines brought ashore for processing. Although the aquafarm floats appear to be an excellent habitat for mussel blennies in particular, the prolonged low-oxygen conditions in summer months prior to sampling may have reduced blenny abundance.

Densities of gobies in the mudflat areas of the Middle and Inner Lagoons were higher in spring than in fall due to a greater abundance of newly settled individuals less than 25 mm (1 in) total length. Arrow goby (*Clevelandia ios*) was the most abundant species with densities of over $7/m^2$ in the eastern end of the Inner Lagoon (Station E9) in spring. Juvenile diamond turbot and California halibut were also captured during the intertidal study demonstrating the importance of the lagoon mudflats as nursery habitat.

Figure 2-13. Locations of visual fish transects and fish quadrat collections (F1–F4), aquaculture float sampling (A1), and intertidal enclosures (E1–E9). Epibenthic/surface larval fish tows (L3, L4) were conducted to measure potential differences in larval density as a function of water depth.

3.0 Entrainment and Source Water Larval Study Results

3.1 Introduction

The purpose of the EPS entrainment and source water studies was to evaluate the potential impacts of the circulating water intake system to the beneficial uses of the marine environment as required under 316(b) of the CWA (USEPA 1977, 2004). The data from the study will also be used in calculating baseline levels of entrainment that will be used to measure compliance with performance standards established in the Phase II regulations that became effective in September 2004. The SDRWQCB discussed the need for the additional information with a group of agency representatives and consultants who provided input on the design and implementation of the 316(b) studies at SBPP. It was agreed that the entrainment portion of the study should focus on the larval life stages of fishes, *Cancer* crabs, and California spiny lobster (*Panulirus interruptus*) that could pass through the 9 mm (⅜ in) mesh traveling screens of the EPS cooling water intakes and be entrained by the power plant's CWIS.

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

- What are the species composition and abundance of the larval fishes, *Cancer* crabs, and spiny lobster ("target species") entrained by EPS?
- What are the local species composition and abundance of the entrainable target species in the cooling water sources of Agua Hedionda Lagoon and the nearshore area adjacent to EPS?
- What are the potential environmental impacts of entrainment losses of target species populations due to operation of the CWIS?

Plankton samples collected in the intake channel near the EPS intake structures provided an estimate of the total number and types of the target organisms passing through the power plant's CWIS. Data collected from source water surveys were used to estimate the abundance of the larval populations at risk of entrainment. The estimates were used to provide an estimate of the fractional loss due to entrainment that can be translated into potential impacts on local fisheries or fish populations. The data used to calculate the volume of the source water in Agua Hedionda Lagoon is presented in **Appendix B**.

Many marine organisms have planktonic stages that can be entrained in circulating water intake systems. Particular taxa were selected in this study for further analyses based on their sampled abundance or economic or recreational value. Several approaches, where possible, were used in assessing the CWIS impacts on each taxon to yield more robust and comparable estimates of effects. The three assessment modeling techniques used were Adult Equivalent Loss (*AEL*), Fecundity Hindcasting (*FH*), and Empirical Transport Modeling (*ETM*), which are described in Section 3.2.3 below. For the purposes of modeling and calculations, through-plant mortality was assumed to be 100%. Although many marine organisms have planktonic eggs that are also entrained by the power plant's CWIS these were not counted in our samples. Egg mortality was considered in the *FH* assessment model for fishes with planktonic eggs. It was also factored into the *ETM* calculations by adding the duration of the egg stage to the duration of entrainment exposure calculated from the lengths of entrained larvae (see Section 3.2.3–*Data Analysis*).

Typically, local population estimates for small, non-use (fishes without commercial or recreational fishery value) fishes are not available. The assessments in this study benefited from a study on the fishes of Agua Hedionda Lagoon completed by MEC Analytical Systems (1995) and supplemental fish studies done by Tenera Environmental in conjunction with the present study (**Appendix C**). The information was used to assess effects on local populations and compare the results among models. For species with fishery value, commercial and recreational fishery data from the San Diego region was also used to evaluate potential entrainment and impingement effects.

3.1.1 Review of Previous Entrainment Study

In 1979, San Diego Gas and Electric (SDGE) owned and operated EPS. A 316(b) demonstration was conducted for the facility (SDGE 1980) as required at the time by the SDRWQCB. The study, done by Woodward-Clyde Consultants, included descriptions of the facility, descriptions of the physical and biological environment of Agua Hedionda Lagoon and surroundings, studies of entrainment, impingement, and entrainment survival at the plant, and an environmental impact assessment that also evaluated the feasibility of alternative intake technologies to reduce IM&E.

A list of selected taxa ('critical species') included 16 fish, 11 ichthyoplankton, and one zooplankton (**Table 3-1**) that were based on six criteria and approved by the SDRWQCB for detailed study during the program. Some additional species that were found to be common in the subsequent sampling were also added to the list. The report reviewed the life histories of the critical species.

3.1.1.1 Entrainment Study Procedures

A one-year entrainment and source water characterization study was conducted in 1979 as part of the 316(b) demonstration studies at EPS. Plankton samples were collected monthly at five offshore stations using 505 and 335 micron nets attached to a 61 cm (23.62 in) bongo net system. Collections were also made monthly in the Middle and Inner Lagoon and every two weeks in the Outer Lagoon using 0.5 meter (1.64 ft) diameter nets (505 µm and 335 µm). The procedures specified the use of a depressor weight connected to the towing apparatus but there was no indication at what depths the plankton samples were typically taken. Tows were targeted at 10 minutes at a speed of 2.8–3.7 km/h (1.5–2.0 kts). Entrainment samples were collected concurrently every two weeks using a plankton pumping system in front of the intakes. Although most samples were collected during daylight hours some were occasionally taken in the evening or early morning hours.

Table 3-1. ‘Critical species’ studied in 1979–1980 Encina 316(b) study.

‘Critical Species’	Common Name
Adult fish	
Engraulis mordax	northern anchovy
Atherinops affinis	topsmelt
Paralabrax clathratus	kelp bass
Paralabrax maculatofasciatus	spotted sand bass
Paralabrax nebulifer	barred sand bass
Cynoscion nobilis	white seabass
Menticirrhus undulatus	California corbina
Seriphus politus	queenfish
Amphistichus argenteus	barred surfperch
Hyperprosopon argenteum	walleye surfperch
Semicossyphus pulcher	California sheephead
Mugil cephalus	striped mullet
Citharichthys sordidus	Pacific sanddab
Paralichthys californicus	California halibut
Pleuronichthys verticalis	hornyhead turbot
Heterostichus rostratus	giant kelpfish
Ichthyoplankton	
Anchoa compressa	deepbody anchovy
Engraulis mordax	northern anchovy
Cottidae	sculpins
Serranidae	sea basses
Sciaenidae	croakers
Rhinogobiops nicholsii	blackeye goby
Gobiidae	gobies
Citharichthys stigmaeus	spotted sanddab
Paralichthys californicus	California halibut
Pleuronectidae	righteye flounders
Hypsopsetta guttulata	diamond turbot
Atherinopsidae	topsmelts
Zooplankton	
Acartia tonsa	copepod

3.1.1.2 Entrainment Study Results

Anchovies (primarily deepbody and northern) were the most abundant larval forms in both the source water and entrainment samples, followed by croakers and sanddabs (**Table 3-2**). There were fewer fish eggs and more goby larvae in the entrainment samples as compared to source water samples whereas kelp and sand bass larvae were substantially more abundant in the source water samples. Only English sole, *Parophrys vetulus*, was among the top ten entrainment taxa not represented in the top ten source water taxa. Overall the average composition between the two data sets was very similar when comparing the ten most abundant taxa.

Table 3-2. Average annual densities of the ten most abundant ichthyoplankton taxa per 100 m^3 (3,531 ft^3) in source water (lagoon and offshore stations combined) and entrainment (pump sampling) collections for 335 µm mesh nets during the 1979 316(b) study.

Taxon	Common Name	Source Water	Entrainment
Engraulidae	anchovies	952.7	855.2
Sciaenidae	croakers	341.7	400.6
Citharichthys spp.	speckled sanddab	73.2	82.7
unid. fish eggs	fish eggs	33.8	20.2
Gobiidae	gobies	29.2	42.9
Atherinopsidae	silversides	8.3	10.8
Labridae	wrasses	6.4	4.0
Hypsoblennius spp.	combtooth blennies	6.1	5.7
Serranidae	sea basses	5.1	0.9
Sebastes spp.	rockfishes	2.8	2.5
Parophrys vetulus	English sole	–	1.9

Entrainment losses were calculated for each two-week sampling interval by multiplying the average plankton densities at the intake by the volume of cooling water drawn through the plant during that period. Annual, monthly, and daily rates were estimated by averaging the entrainment estimates for all sampling periods and calculating value for the indicated duration. Annual estimates for total zooplankton entrainment were 7.4×10^9 (505 µm net data) and 30.9×10^9 (335 µm net data) individuals. The copepod *Acartia tonsa* was the most abundant species in the entrainment collections (**Table 3-3**).

Annual estimates of the abundance of ichthyoplankton entrained through the power plant were 4.15×10^9 (505 µm net data) and 6.66×10^9 (335 µm net data) individuals per year. Fish eggs comprised 98% and 86% of the total annual ichthyoplankton entrainment using the 505 µm and 335 µm net estimates, respectively. Through-plant entrainment mortality was assumed to be 100% for larvae and 60% for eggs based on survival experiments that were conducted. The report presented average annual densities of the critical species by net type and daily entrainment estimates for selected plankton groups. The daily entrainment estimates by net type are listed in the **Table 3-3**.

Entrainment impacts were assessed by qualitative comparisons of entrainment losses to the estimated numbers of larvae in nearby source waters, comparisons of additional power plant mortality to natural mortality rates, entrainment probabilities based on current studies, and primary productivity studies. It was concluded that the entrainment of 1.82×10^7 fish larvae and eggs daily was small compared to the egg and larval concentrations measured in monthly plankton tows in the source water body. It was estimated that average daily losses of planktonic organisms amounted to about 0.2% of the plankton available within one day's travel time from the power plant by current transport. Water at the seaward entrance to Agua Hedionda Lagoon was estimated to have a 34% probability of entering the lagoon. The 10% probability of entrainment isopleth was calculated to lie near the northern and eastern extremities of Agua

Hedionda Lagoon, and the 70% and 90% entrainment probability isopleths were calculated to be near the intakes and well within the southern third of the Outer Lagoon. The modeled isopleths shifted toward the seaward entrance on a flood tide and toward the Middle Lagoon on an ebb tide. Using the 70% entrainment probability isopleth to define intake effects, it was shown that the maximum extent of intake effects was about 304 m (1,000 ft) into the southern end of the Outer Lagoon segment. With natural mortality rates assumed to be 99% for egg and larval stages of most marine fish species it was concluded that additional mortality from EPS was not significant. There was no modeling of entrainment impacts on larvae using demographic models (Adult Equivalent Loss [*AEL*] and Fecundity Hindcasting [*FH*]), or proportional loss modeling (Entrainment Transport Modeling [*ETM*]). It was also concluded, based on light-dark bottle experiments, that entrainment effects on source water primary productivity were negligible.

Table 3-3. EPS daily entrainment estimates for two net sizes, 1979. Calculated using a daily plant cooling water capacity of 795 mgd.

Plankton Group	Daily Entrainment 335 µm	505 µm	Mean Percent of Total
Acartia tonsa (copepod)	$4.77x10^7$	$7.63x10^6$	41.2%
Fish eggs	$1.57x10^7$	$1.11x10^7$	19.9%
Decapoda	$1.32x10^7$	$4.44x10^6$	13.1%
Other Copepoda	$8.47x10^6$	$2.16x10^6$	7.9%
Other Crustacea	$6.95x10^6$	$2.70x10^6$	7.2%
Other Zooplankton	$5.68x10^6$	$4.55x10^5$	4.6%
Chaetognatha	$1.83x10^6$	$1.56x10^6$	2.5%
Fish larvae	$2.52x10^6$	$2.46x10^5$	2.1%
Mysidacea	$6.70x10^5$	$1.34x10^6$	1.5%
			100.0%

3.2 Methods and Station Locations

Data collection and analysis consisted of bi-weekly or monthly zooplankton sampling, the laboratory sorting and identification of collected specimens, and data analysis methods to compare larval densities among sites, calculate numbers of target organisms entrained through the EPS CWIS, and calculate effects on source water populations. The following sections describe the methods employed for each of these tasks.

3.2.1 Field Sampling

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 3-1**; **Table 3-4**) was sampled during each study period.

3.2.1.1 Entrainment Sampling

Sample collection methods and equipment were 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 3-1**) 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 sampling platform was a 24-ft research vessel (*R/V M-REP*) 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 intake structure 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. Samples were collected over a 24-hour period divided into four 6-hour cycles. 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° 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 codend. 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 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 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.

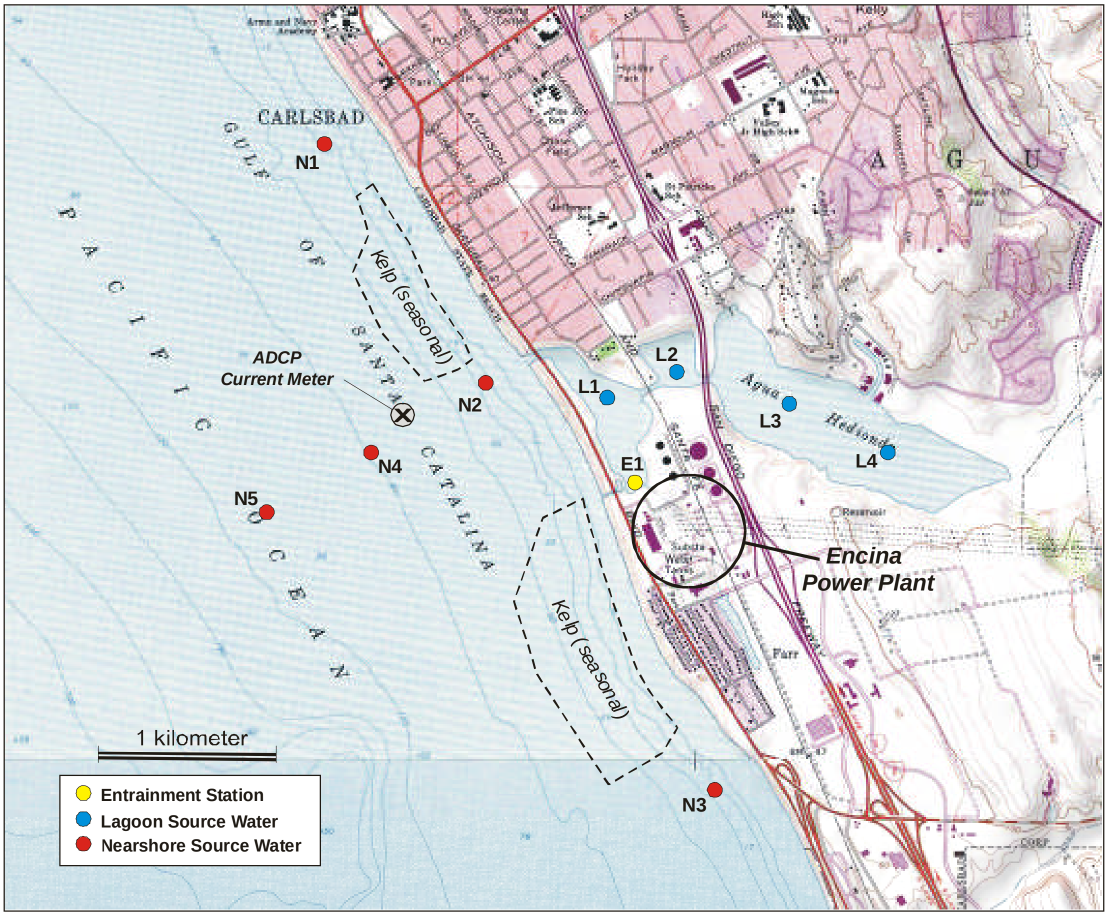


Figure 3-1. Location of Encina Power Station entrainment (E1) and source water (L1–L4; N1–N5) plankton stations.

3.2.1.2 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 3-1**). 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 lagoon. 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.

Table 3-4. Locations and depths of entrainment and source water plankton stations.

Station	Location	Latitude (N)	Longitude (W)	Depth below MLLW in meters (ft)
E1	EPS Intake – Outer AHL	33° 08.328	117° 20.283	3.4 (11.2)
L1	Outer AHL	33° 08.639	117° 20.422	3.0 (9.8)
L2	Middle AHL	33° 08.658	117° 20.105	6.1 (20.0)
L3	Inner AHL	33° 08.581	117° 19.725	1.8 (5.9)
L4	Inner AHL	33° 08.441	117° 19.391	1.8 (5.9)
N1	Nearshore	33° 09.376	117° 21.501	6.0 (19.7)
N2	Nearshore	33° 08.594	117° 20.994	8.8 (28.9)
N3	Nearshore	33° 07.430	117° 20.150	7.2 (23.6)
N4	Nearshore	33° 08.443	117° 21.269	17.6 (57.7)
N5	Nearshore	33° 08.245	117° 21.723	34.1 (111.9)

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. Concurrent surface water temperatures and salinities were measured with a digital probe (YSI Model 30).

3.2.2 Laboratory Analysis

Laboratory processing consisted of sorting (removing), identifying, and enumerating all larval fishes, megalopal stages of *Cancer* spp. crabs, and spiny lobster larvae (puerulus and phyllosome stages) from the samples. Juvenile specimens (not susceptible to entrainment) that were collected incidentally in the plankton sampling were separated in the laboratory from the samples but not included in the analysis. (A total of ten juvenile specimens of six species were collected from seven source water samples and none from any entrainment samples).

Sorting and identification accuracy was verified and maintained by Tenera Environmental's quality control (QC) program, which specified a minimum accuracy level of 90% for sorting and 95% for identification (**Appendix D**). A total of eight sorters and three taxonomists were involved in the processing of field samples. Mr. W. Watson of the Southwest Fisheries Science Center checked identifications of problematic specimens. The primary reference for identifications was Moser et al. (1996). All field and laboratory data were entered into a computer database which was verified for accuracy against the original data sheets.

Myomere counts and pigmentation patterns were used to identify larval fishes to the lowest taxonomic classification possible, which was usually the species level, but sometimes the genus or family level for certain groups. For example, many species of the family Gobiidae share morphologic and meristic characters during early life stages (Moser et al. 1996) making accurate identifications to the species level questionable. These include early larvae of the arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*). These three species were combined into an unidentified goby category referred to as the 'CIQ goby complex'. Larval combtooth blennies (*Hypsoblennius* spp.) can be easily distinguished from other larval fishes (Moser et al. 1996). However, the larvae of the three sympatric species that could occur in AHL cannot be distinguished from each other on the basis of morphometrics or meristics for some of the smaller sizes common in the samples. These combtooth blennies were grouped into an "unidentified combtooth blennies" category (i.e., *Hypsoblennius* spp.). Larvae from the three members of the silversides (family Atherinopsidae) that can occur in AHL (California grunion *Leuresthes tenuis*, jacksmelt *Atherinopsis californiensis*, and topsmelt *Atherinops affinis*) also cannot be easily distinguished at the smallest larval sizes and were therefore treated as a single group. Similarly, larvae for the deepbody anchovy *Anchoa compressa*) and slough anchovy (*Anchoa delicatissima*) are also very difficult to distinguish and were therefore combined into one group *Anchoa* spp. Also combined into this *Anchoa* spp. group were all small (2–3 mm [0.08-0.12 in]) Engraulidae (anchovy) individuals, as there were very few other species of this fish family identified from these samples.

Larvae were measured (notochord/standard lengths) to determine their length ranges in the entrainment samples. These estimates were used to calculate the time that the larvae were subject to entrainment. Up to 50 larvae from each survey of the most abundant taxa, or species with recreational or commercial fishery importance, were measured using a video capture system and Optimus™ image analysis software from each survey. Descriptive statistics on a random sample of 200 larvae were calculated from taxa with over 200 measurements and for all of the measurements from less abundant taxa. The statistics from these data were used to estimate the minimum, average, and maximum lengths of entrained larvae.

3.2.3 Data Analysis

Estimates of daily larval entrainment for the sampling from June 2004 through May 2005 at EPS were calculated from data collected at the entrainment station. Assessment of entrainment effects were limited to the most abundant fish taxa (target taxa) that together comprised 90% of all larvae entrained. 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*). In the EPS entrainment study each approach (e.g., *AEL*, *FH*, and *ETM*), as appropriate for each target taxon, was used to assess effects of power plant losses.

3.2.3.1 Demographic Approaches

Adult equivalent loss models evolved from impact assessments that compared power plant losses to commercial fisheries harvests and/or estimates of the abundance of adults. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare the numbers of impinged sub-adults and juveniles and entrained larval fishes to adults, it was necessary to convert all these losses to adult equivalents. Horst (1975) and Goodyear (1978) provided early examples of the equivalent adult model (*EAM*) to convert numbers of entrained early life stages of fishes to their hypothetical adult equivalency.

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. We used two different but related demographic approaches in assessing entrainment effects at EPS: *AEL*, which expresses effects as absolute losses of numbers of adults, and *FH*, which estimates the number of adult females at the age of maturity whose reproductive output has been eliminated by entrainment of larvae. Both approaches require an estimate of the age at entrainment. These estimates were obtained by measuring a representative number of larvae of each of the target taxa from the entrainment samples and using published larval growth rates to estimate the age at entrainment. The age at entrainment was calculated by dividing the difference between the size at hatching and the average size of the larvae from entrainment by a larval growth rate obtained from the literature. The size at hatching was estimated using the length at the 25th percentile. This value was used because of the large variation in size among larvae smaller than the average length. The large variation in hatch size justified using the length at the 25th percentile rather than the minimum length.

Age-specific survival and fecundity rates are required for *AEL* and *FH*. Adult-equivalent loss estimates require survivorship estimates from the age at entrainment to adult recruitment; *FH* requires egg and larval survivorship up to the age of entrainment plus estimates of fecundity. Furthermore, to make estimation practical, the affected population is assumed to be stable and stationary, and age-specific survival and fecundity rates are assumed to be constant over time. Each of these approaches provides estimates of adult fish losses, which ideally need to be compared to standing stock estimates of adult fishes.

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa considered in this assessment. These rates, when available, were inferred from the literature along with estimates of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported.

Because the accuracy of the estimated entrainment effects from *AEL* and *FH* will depend on the accuracy of age-specific mortality and fecundity estimates, lack of demographic information may limit the utility of these approaches.

The precursor to the *AEL* and *FH* calculations is an estimate of total annual larval entrainment. Estimates of larval entrainment at EPS were based on monthly sampling where E_T is the estimate of total entrainment for the study period and E_i is the monthly entrainment estimate. Estimates of entrainment for the study period were based on two-stage sampling designs, with days within periods, and cycles (four six-hour collection periods per day) within days. The within-day sampling was based on a stratified random sampling scheme with four temporal cycles and two replicates per cycle. Estimates of variation for each survey were computed from the four temporal cycles.

There were usually no estimates of variation available for the life history information used in the models. The ratio of the mean to standard deviation (coefficient of variation) was assumed to be 50% for all life history parameters used in the models.

Adult Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of the entrained or impinged organisms to project the loss of equivalent numbers of adults based on mortality schedules and age-at-recruitment. The primary advantage of this approach is that it translates power plant-induced early life-stage mortality into numbers of adult fishes that are familiar units to resource managers. Adult equivalent loss does not require source water estimates of larval abundance in assessing effects. This latter advantage may be offset by the need to gather age-specific mortality rates to predict adult losses and the need for information on the adult population of interest for estimating population-level effects (i.e., fractional losses).

Starting with the number of age class *j* larvae entrained E_j, it is conceptually easy to convert these numbers to an equivalent number of adults lost *AEL* at some specified age class from the formula:

$$AEL = \sum_{j=1}^{n} E_j S_j \qquad (1)$$

where

n = number of age classes from the average age at entrainment to adult recruitment;

E_j = estimated number of larvae lost in age class j; and

S_j = survival probability for the j th class to adulthood (Goodyear 1978).

Age-specific survival rates from the average age at entrainment to recruitment into the fishery must be included in this assessment method. We used a modified form of Equation 1 where the total entrainment was used having an average age a:

$$AEL = E_T \prod_{j=a}^{n} S_j \qquad (2)$$

where

E_T = annual estimate of larvae lost in all age classes.

The average age at entrainment was estimated from lengths of a representative sample of larvae measured from the entrainment samples. Literature-based hatch length and growth rate were used to estimate age from average length. For some commercial species, natural survival rates are known after the fish recruit into the commercial fishery. For the earlier years of development, this information is not well known for commercial species and may not exist for some non-commercial species.

*Fecundity Hindcasting (*FH*)*

The *FH* approach compares larval entrainment losses with adult fecundity to estimate the amount of adult female reproductive output eliminated by entrainment, hindcasting the numbers of adult females at the age of maturity effectively removed from the reproductively active population. The accuracy of these estimates of effects, as with those of the *AEL* above, is dependent upon accurate estimates of age-specific mortality from the egg and early larval stages to entrainment and accurate estimates of the total lifetime female fecundity. If it can be assumed that the adult population has been stable at some current level of exploitation and that the male:female ratio is constant and 50:50, then fecundity and mortality are integrated into an estimate of the loss of adults at the age of maturity by converting entrained larvae back into females (e.g., hindcasting) and multiplying by two.

A potential advantage of *FH* is that survivorship need only be estimated for a relatively short period of the larval stage (e.g., egg to larval entrainment). The method requires age-specific mortality rates and fecundities to estimate entrainment effects and some knowledge of the abundance of adults to assess the fractional losses these effects represent. This method assumes that the loss of the reproductive potential of a single female at the age of maturity is equivalent to the loss of two adult fish at the age of maturity, assuming a 50:50 male:female ratio.

In the *FH* approach, the total larval entrainment for a species, E_T, was projected backward from the average age at entrainment to estimate the number of females at the age of maturity that would produce over their lifetime the numbers of larvae seen in the entrainment samples. The estimated number of breeding females at the age of maturity, *FH*, whose fecundity is equal to the total loss of entrained larvae was calculated as follows:

$$FH = \frac{E_T}{TLF \bullet \prod_{j=1}^{n} S_j} \qquad (3)$$

where

E_T = total entrainment estimate;

S_j = survival rate from eggs to entrained larvae of the j^{th} stage ;

TLF = average total lifetime fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

The two key input parameters in Equation 3 are total lifetime fecundity *TLF* and survival rates S_j from spawning to the average age at entrainment. The average age at entrainment was estimated from lengths of a representative sample of larvae measured from the entrainment samples. Descriptions of these parameters may be limited for many species and are a possible limitation of the method. *TLF* was estimated in these studies using survivorship and fecundity tables that account for changes in fecundity with age. The data used in calculating *TLF* is described below for each taxon.

3.2.3.2 Empirical Transport Model (*ETM*)

The *ETM* calculations provide an estimate of the probability of mortality due to power plant entrainment. The calculations require not only the abundance of larvae entrained but also the abundance of the larval populations at risk of entrainment. Sampling at the cooling water intake is used to estimate the total number of larvae entrained for a given time period, while sampling in the lagoon and coastal waters around the EPS intake is used to estimate the source population for the same period.

On any one sampling day, the conditional entrainment mortality can be expressed as

$$PE_i = \frac{E_i}{N_i} \tag{4}$$

where

E_i = total numbers of larvae entrained during the i th survey; and

N_i = numbers of larvae at risk of entrainment, i.e., abundance of larvae in source water.

The values used in calculating *PE* are population estimates based on the respective larval concentrations and volumes of both the CWS flow and source water areas. The abundance of larvae at risk in various regions of the source water, R, summed over k stations during the i^{th} survey can be directly expressed as follows:

$$N_{R_i} = \sum_{k=1}^{n} V_{S_{R_k}} \cdot \overline{\rho}_{R_{ik}} \tag{5}$$

where $V_{S_{Rk}}$ is the static volume of the source water in region R at station k, and $\overline{\rho}_{Rik}$ denotes an estimate of the average larval concentration in the source water in region R for station k during survey i.

Three source water components were identified for EPS: 1) AHL where the EPS intake is located, 2) nearshore coastal water that is transported into the lagoon on incoming tides, and 3) AHL water that is transported out of the lagoon into nearshore coastal waters on outgoing tides. Each of these source water components operates on the time scale that larvae are subject to entrainment. Because the spatial scales of the components vary, the conditional mortality due to entrainment, *PE*, could not be expressed simply as in Equation 3. The calculation of *PE* is incorporated into the *ETM* calculation for estimating the total annual proportional mortality due to entrainment, P_M as follows:

$$P_M = 1 - \sum_{i=1}^{N} f_i \left(1 - \left[\frac{N_{E_i}}{\frac{N_{NS_i} - N_{NSOut_i}}{P_{S_i}} + N_{AH_i} + (N_{AHOut_i} \bullet q)}\right]\right)^q \qquad (6)$$

where

f_i = estimated fraction of total source water larval population present during the i th survey;

q = number of days the larvae are exposed to entrainment;

N_{E_i} = the estimated number of larvae entrained during the i^{th} survey;

N_{NS_i} = the estimated number of larvae in the nearshore sampled during the i^{th} survey;

P_{S_i} = the ratio of the length of the sampled nearshore area sampled during the i th survey to the total alongshore current displacement over the period of q days that the larvae could be exposed to entrainment;

N_{NSOut_i} = an adjustment for the outflow from AHL calculated using the average concentration from the nearshore sampling during the i^{th} survey and the outflow volume;

N_{AH_i} = the estimated number of larvae in AHL during the i^{th} survey; and

N_{AHOut_i} = an adjustment for the outflow from AHL calculated using the average concentration from AHL sampling during the i^{th} survey and the outflow volume.

The sizes of N_{NS}, N_{AH}, and N_E were calculated as the product of larval concentration and volume as in Equation 5. The estimate N_{NS} for the nearshore sampling area for each i^{th} survey used in the *ETM* calculations included nine areas (**Figure 3-2**) with component densities and volumes. The densities in areas N1–N5 were sampled and the densities in areas SW1–SW4 were interpolated using the sampled larval densities weighted by the inverse of distance squared as measured from the center of an unsampled area to the centers of the sampled areas. This was done to create a rectangular-shaped source water area with constant length that could be extrapolated using alongshore current displacement, otherwise the layout of the sampling locations would have required separate source water estimates for the offshore (N4 and N5) and alongshore station areas (N1, N2 and N3).

The sampled nearshore area, N_{NS}, for each i^{th} survey represents a proportion of the total nearshore source water potentially affected by entrainment over the number of days, q, that the larvae are exposed to entrainment. The proportion of the sampled nearshore area to the total source water, P_S, was estimated for each i^{th} survey using alongshore current displacement measured using a current meter deployed offshore from AHL (Section 2.2.1.3; Figures 2-9 through 2-12). The incorporation of P_S into the *ETM* model is typically defined by the ratio of the area or volume of the study grid to a larger area or volume containing the population of inference (Parker and DeMartini 1989). However, if an estimate of the larval (or adult) population in the larger area is available, then P_S can also be computed using an estimate of the proportion of the larval or adult population in the study area. If the distribution in the larger area is assumed to be uniform or the same as the nearshore sampling area, then the value of P_S for the proportion of the population will be the same as the proportion computed using area or volume. The current displacement measured over q days was used to estimate the distance alongshore that larvae could have been transported into the nearshore areas around AHL where they would be subject to entrainment. The ratio of the alongshore distance of the nearshore sampling area to the alongshore current displacement, P_S, was used to adjust the nearshore population estimate, N_{NS}, for the size of the total source water population.

The estimate of P_S, the proportion of the sampled source water population to the total source population did not include onshore current displacement that could result in the transport of larvae from offshore into the nearshore sampling area. Although this process does occur, as evidenced by the current data, a separate estimate of P_S that would account for onshore transport was not calculated because the water depths offshore from EPS drop off much more rapidly than other nearshore areas in southern California. Typically, a depth of 75 m has been used in extrapolating source water offshore (Parker and DeMartini 1989, MBC and Tenera Environmental 2005). This depth was based on Lavenberg et al. (1986) showing that ichthyoplankton transects in southern California shoreward of the 75 m (246 ft) depth were representative of the coastal zone.

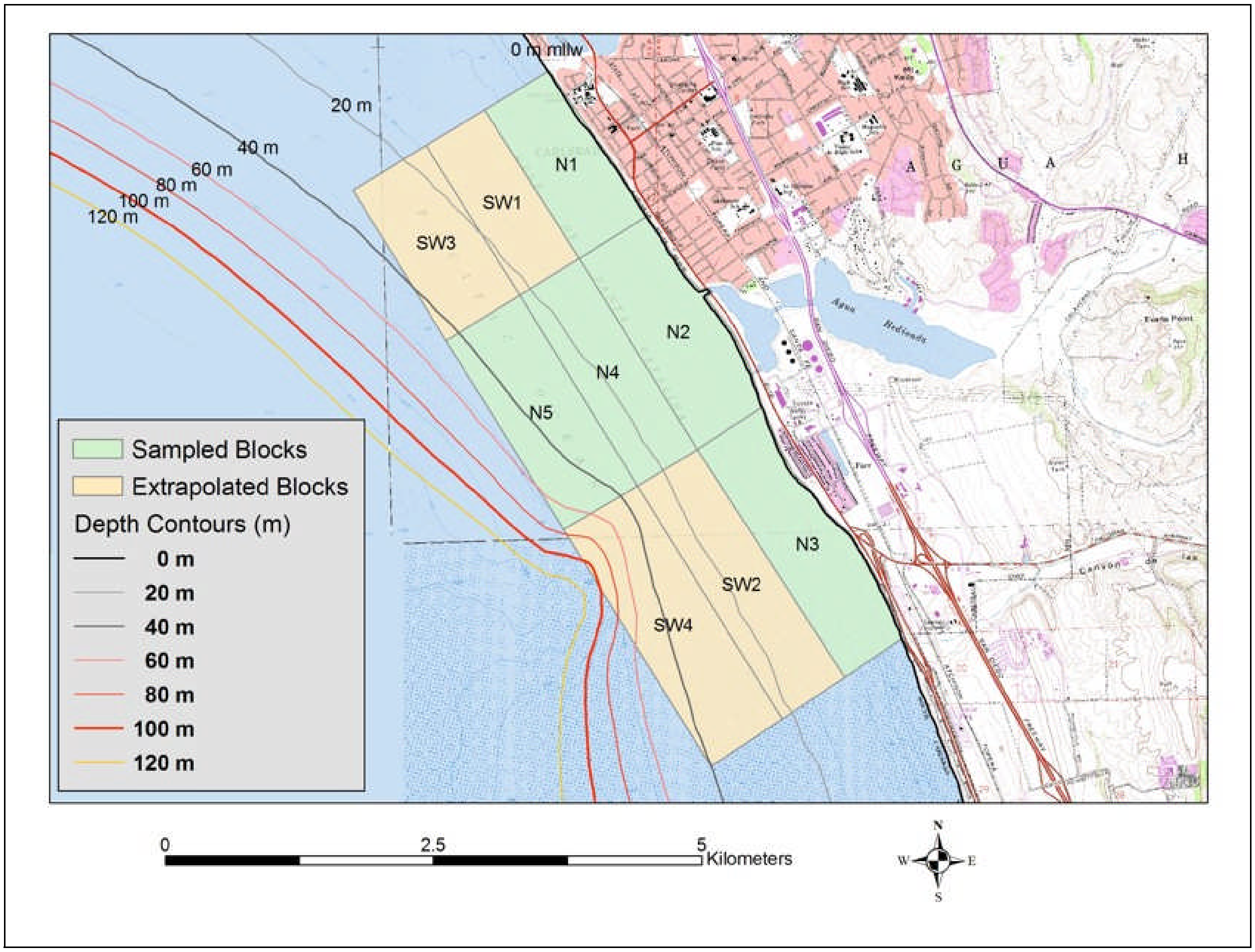


Figure 3-2. Bathymetry and boundaries of nearshore areas used in calculating average source water larval concentrations for the *ETM* analyses.

Larvae produced and resident in AHL that were potentially subject to entrainment, N_{AH}, were estimated for each i^{th} survey by combining the estimates from four stations located in the three lagoon segments into a total estimate for AHL that also included the concentrations measured at the entrainment station. In addition to the larvae present in the lagoon on the day that entrainment, N_E, was measured, larvae are continually being produced in the lagoon and transported into the nearshore due to tidal outflow. The outflow volume was multiplied by the concentration measured in the source water (N_{NSOut}) to account for water transported out into the nearshore on the day that the sampling occurred. N_{NSOu} was adjusted by P_S to account for this amount over a larval duration and subtracted from the nearshore source water population estimate. The average concentration from the nearshore sampling was used and this number was replaced by outflow estimated using the concentrations measured from AHL. This outflow volume is multiplied by the average concentration from AHL to estimate outflow of larvae into the nearshore (N_{AHOut}) over the period of larval exposure, including the day that sampling occurred.

Therefore, using Equation 6 to represent all three components of the source water *PE* was calculated as follows:

$$PE_i = \frac{N_{E_i}}{\frac{N_{NS_i} - N_{NSOut_i}}{P_{S_i}} + N_{AH_i} + (N_{AHOut_i} \bullet q)}. \tag{7}$$

To establish independent survey estimates, it was assumed that during each survey a new and distinct cohort of larvae is subject to entrainment. The number of days a taxon was exposed to entrainment was estimated by dividing a larval growth rate into the difference between the 25th and 95th percentile values of length measurements from the entrainment samples. Each of the monthly surveys was weighted by f_i and estimated as the proportion of the total population at risk during the i^{th} survey period. The weights are calculated as follows:

$$f_i = \frac{N_i}{N_{Total}}, \tag{8}$$

where N_i is the estimated fraction of the source population spawned during the i^{th} survey period, and N_{Total} is the total source population for the entire study period.

3.2.3.3 Dynamics of AHL Pertaining to Model

The numbers of fish larvae in the lagoon were estimated using the volume of the AHL at mean sea level. This volume was estimated from Elwany et al. (2005) and calculated in **Appendix B** as 3.148 x 10^6 m^3 (2,552 acre-ft) for the three lagoon segments. The Outer, Middle and Inner Lagoon volumes were 1.247 x 10^6 m^3 (1,011 acre-ft), 0.350 x 10^6 m^3 (284 acre-ft), and 1.547 x 10^6 m^3 (1,255 acre-ft) respectively.

As part of the description of the flow of water through AHL, Elwany et al. (2005) estimated the volume of the incoming and outgoing water at the AHL inlet for the period June 1, 2004 to May 31, 2005. Water level measurements conducted in the lagoon between June 1 and July 7, 2005 were used to establish the relationships of maximum and minimum water levels per tidal cycle, measured in feet, between the ocean at Scripps Pier, La Jolla, CA and the lagoon using linear regression analysis.

The relationships between lagoon and ocean water levels, shown in **Figure 2-6,** were as follows:

$$Wl_{max} = 0.97\ Wo_{max} + 0.0076 \tag{9a}$$

$$Wl_{min} = 0.69\ Wo_{min} - 0.37 \tag{9b}$$

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

The measured ocean tides at Scripps Pier, La Jolla, CA, between June 1, 2004 and May 31, 2005 were used to estimate the maximum and minimum water levels in the lagoon using equations 9a and 9b, respectively. Using Equations 3 and 4 presented in **Appendix B** and the reported EPS cooling system hourly intake flow (**Figure 2-7**) during the same time period, estimates were made regarding the incoming (inflow) and outgoing (outflow) water from the lagoon's major inlet (**Figure 2-8**).

The average daily estimated inflow and outflow thru the lagoon's inlet between June 1, 2004 and May 31, 2005 was 4.11×10^6 m^3 (3,333 acre-ft) and 1.80×10^6 m^3 (1,459 acre-ft) corresponding to an average daily power plant intake flow of 2.31×10^6 m^3 (1,874 acre-ft). Maximum daily inflow and outflow corresponding to a maximum power plant intake flow of 3.24×10^6 m^3 (2,627 acre-ft) is estimated as 4.58×10^6 m^3 (3,713 acre-ft) and 1.33×10^6 m^3 (1,078 acre-ft).

3.3 Entrainment and Source Water Results

3.3.1 Community Overview

3.3.1.1 Entrainment 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 3-5** and **Appendix E**). 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 3-3**). Larvae tended to be more abundant in samples collected at night than those collected during the day (**Figure 3-4**). 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 4.49 x 10^9 fish larvae during the 12 months from June 2004 through May 2005 using the EPS CWIS maximum design flows as the basis for calculations, and 3.63 x 10^9 fish larvae during the 12-month period calculated using the actual EPS flow rates recorded during the study period (**Table 3-6**). This equates to a 23.9% difference between the estimated entrainment using maximum and actual power plant intake flows.

The following eight 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*)
- garibaldi (*Hypsypops rubicundus*)
- white croaker (*Genyonemus lineatus*)
- queenfish (*Seriphus politus*)
- spotfin croaker (*Roncador stearnsii*)
- California halibut (*Paralichthys californicus*)

The four most abundant taxa comprised over 95% of all entrained larvae (**Table 3-5**). Although the other four taxa were collected in relatively low numbers they represented species with recreational or commercial fishery value. In general, most of the larvae collected from the entrainment samples did not have any recreational or commercial fishery value, and those with fishery value were in low abundance. None of the target invertebrate taxa was evaluated for entrainment effects because only a single *Cancer* crab megalops was identified from the entrainment samples.

Table 3-5. 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 3-6. Calculated annual entrainment of larval fishes and target shellfishes based on EPS maximum design flows and actual recorded flows, June 2004–May 2005.

Taxon	Common Name	Annual Entrainment (Maximum Flow)	Std. Error (Max Flow)	Annual Entrainment (Actual Flow)	Std. Error (Actual Flow)
Gobiidae (CIQ complex)	gobies	2,767,198,570	101,030,008	2,215,477,217	86,364,408
Hypsoblennius spp.	combtooth blennies	1,312,458,555	72,049,342	1,098,083,615	62,379,799
Engraulidae	anchovies	157,019,892	8,097,477	120,661,087	6,551,786
Hypsypops rubicundus	garibaldi	36,328,962	2,872,086	29,287,646	2,349,174
Gibbonsia spp.	clinid kelpfishes	29,620,060	1,875,599	18,192,742	1,162,809
Typhlogobius californiensis	blind goby	28,988,077	2,437,683	20,324,124	1,700,727
Acanthogobius flavimanus	yellowfin goby	21,043,508	1,707,240	12,590,127	1,057,808
Syngnathidae	pipefishes	19,379,619	1,610,753	16,530,546	1,390,890
Labrisomidae.	labrisomid kelpfishes	16,399,803	1,094,580	13,937,144	931,864
Atherinopsidae	silverside	12,654,500	664,630	7,936,121	419,868
larvae, unid. fish fragment	unidentified larval fishes	11,024,170	430,622	8,055,502	336,468
Roncador stearnsii	spotfin croaker	10,677,429	733,087	9,554,139	656,724
Rimicola spp.	kelp clingfishes	9,913,916	620,625	7,953,162	504,858
Genyonemus lineatus	white croaker	9,466,865	398,516	6,924,470	320,508
Paraclinus integripinnis	reef finspot	8,356,639	772,412	7,201,333	670,242
larvae, unid. yolksac	unid. yolksac larvae	8,000,516	445,456	6,578,080	370,110
Seriphus politus	queenfish	7,534,586	544,949	6,746,448	501,851
Paralichthys californicus	California halibut	4,879,725	263,926	3,752,551	223,985
Sardinops sagax	Pacific sardine	3,394,522	218,259	2,484,208	175,300
Gillichthys mirabilis	longjaw mudsucker	2,813,002	161,236	1,814,507	105,121
Paralabrax spp.	sand basses	2,775,286	105,724	2,520,619	94,986
Citharichthys spp.	sanddabs	2,650,151	220,150	1,855,512	155,988
Hypsopsetta guttulata	diamond turbot	2,471,214	150,706	1,770,451	100,989
larvae, unid. post-yolksac	larval fishes	2,302,748	179,221	1,760,888	135,949
Sciaenidae	croakers	2,164,020	166,322	1,695,162	141,027
Pleuronectiformes	flatfishes	744,368	106,852	519,811	72,825
Clinocottus analis	wooly sculpin	703,175	71,055	455,902	48,468
Heterostichus rostratus	giant kelpfish	596,406	67,172	393,522	45,546
Stenobrachius leucopsarus	northern lampfish	547,395	53,578	310,274	32,852
Cheilotrema saturnum	black croaker	464,305	57,915	392,460	49,352
Haemulidae	grunts	252,404	43,287	233,493	40,198
Ophidiidae	cusk-eels	246,537	46,591	149,892	28,997
Labridae	wrasses	241,401	41,400	223,314	38,446
Scomber japonicus	Pacific mackerel	234,086	58,521	193,720	48,676
Diaphus theta	California headlight fish	226,160	42,740	192,654	36,466
Semicossyphus pulcher	California sheephead	226,160	42,740	192,654	36,466
Myctophidae	lantern fishes	194,178	36,696	165,410	31,309
Symbolophorus californiensis	California lantern fish	194,178	36,696	165,410	31,309
Menticirrhus undulatus	California corbina	193,489	38,698	159,429	32,335
Oxyjulis californica	señorita	156,339	30,087	116,071	22,407
Gobiesocidae	clingfishes	112,198	31,118	90,331	25,219
		4,494,849,115		**3,627,641,744**	
Cancer spp. (megalops)	cancer crabs	200,698	37,928	162,150	31,311

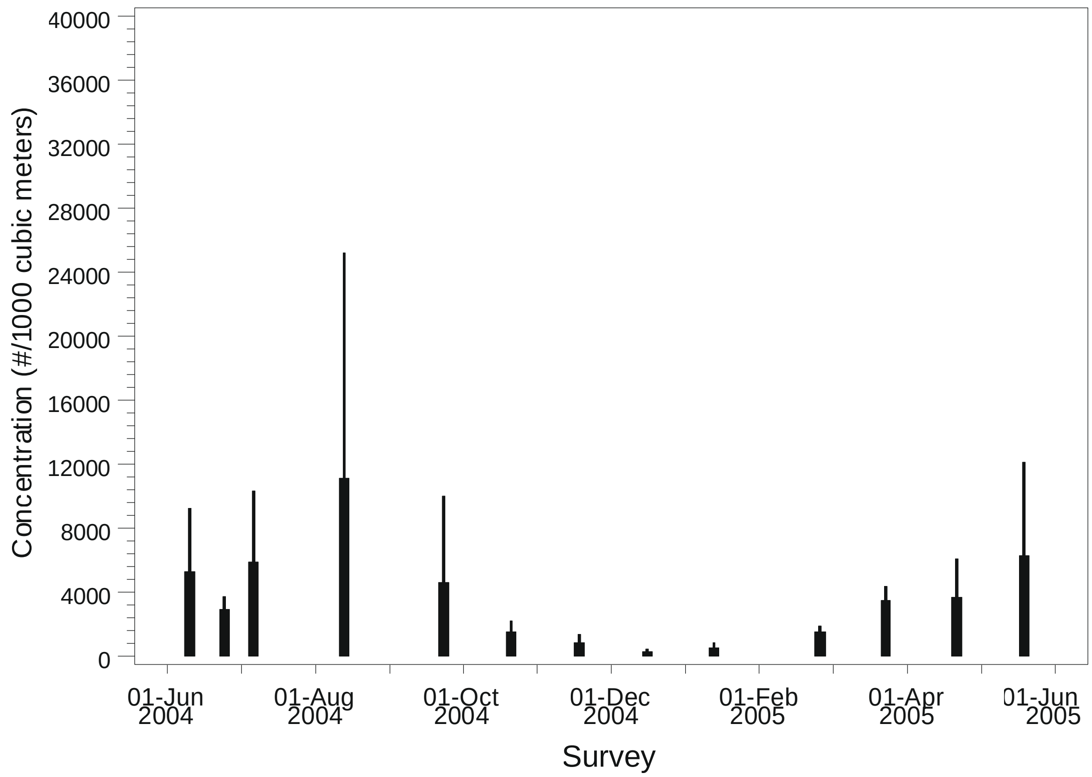


Figure 3-3. Mean concentration (# / 1,000 m^3 [264,172 gal]) and standard error of all larval fishes collected at EPS entrainment Station E1 during the 2004–2005 period.

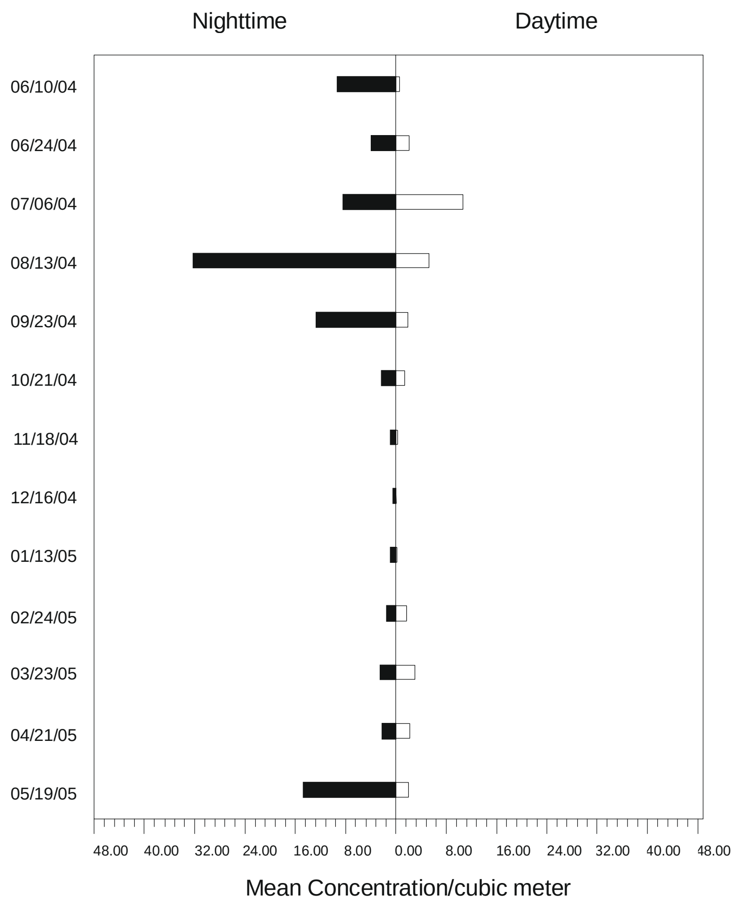


Figure 3-4. Mean concentration (#/1.0 m^3 [264 gal]) of all larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

3.3.1.2 Source Water Results

A total of 55,635 larval fishes representing 89 taxa was collected from the source water stations in Agua Hedionda Lagoon and the nearshore area adjacent to EPS during 13 monthly surveys (**Table 3-7** and **Appendix E)**. Approximately 70% of the source water larvae collected in the study came from the four stations in the Inner, Middle and Outer Lagoon with gobies (CIQ goby complex) comprising the bulk of those larvae. There were 47 taxa collected in the lagoon of which four were unique to the lagoon stations. The remaining 30% of the larvae were sampled at the five nearshore stations where anchovies (mainly *Engraulis mordax*) were the most abundant species. There were 85 taxa collected at the nearshore stations of which 42 were unique to the set of nearshore stations. Of the target shellfishes sampled, *Cancer* crab megalops and spiny lobster larvae were much more abundant at the nearshore stations than at the lagoon stations. Larval concentrations were highest in summer months and lowest in winter months, and generally followed a gradient from highest concentrations in the Inner Lagoon (mostly shallow mud substrate) to lowest concentrations at the group of nearshore stations (kelp forest and sand substrate) (**Figure 3-5**).

Table 3-7. 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
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 3-7 (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		

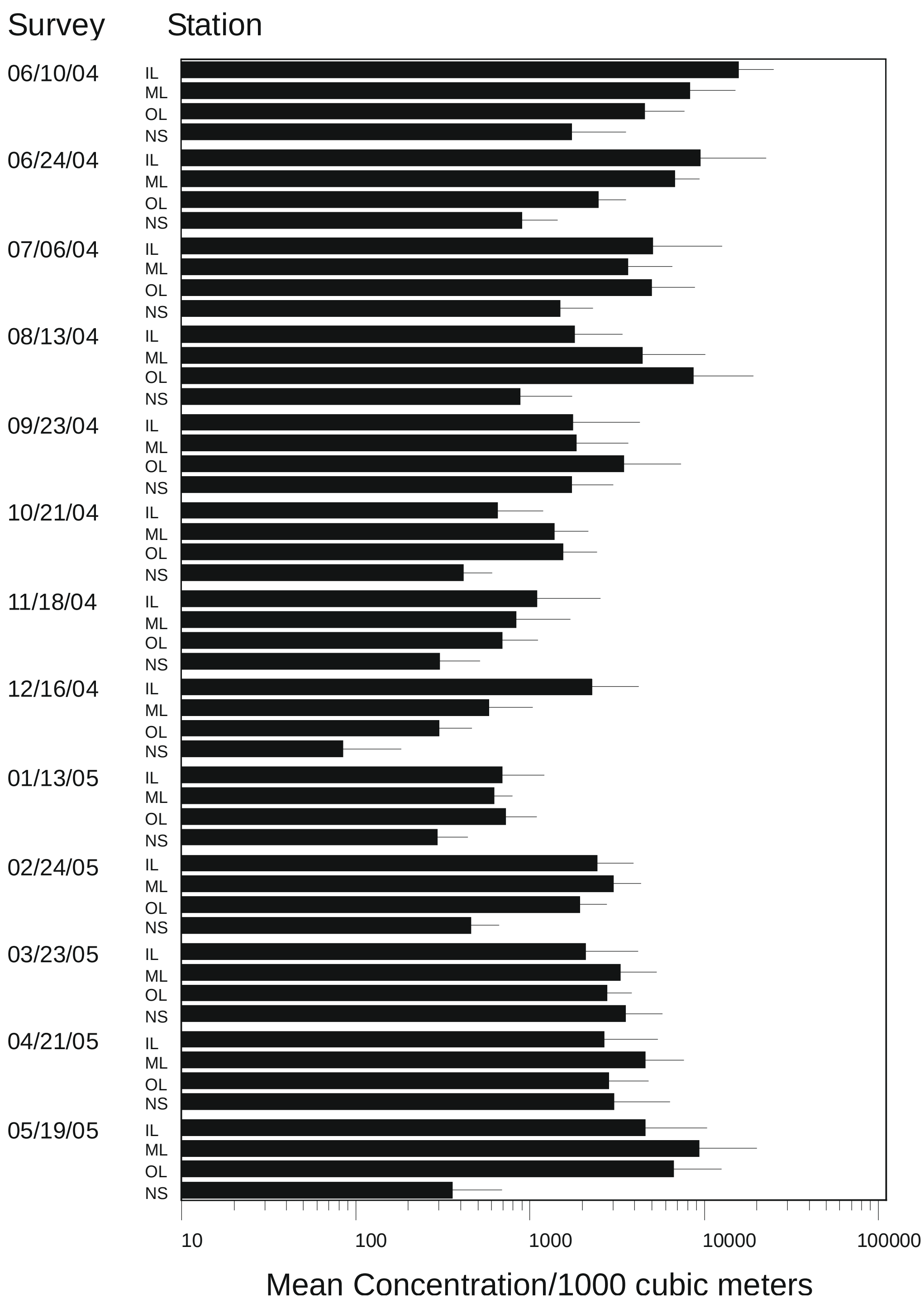
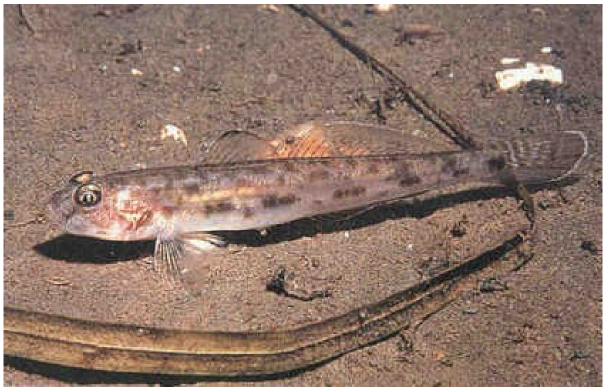


Figure 3-5. Mean concentration (# / 1,000 m^3 [264,172 gal]) and standard error of all larval fishes collected at source water stations in AHL and nearshore stations during the 2004–2005 period.

3.3.2 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.

3.3.2.1 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 (Moser 1996). The eyes of most gobies are relatively large and are a dominant feature of their blunt heads. Goby species are extremely variable in coloration. They range from the drab, cryptically colored species that inhabit mudflats to the striking, brightly colored species of tropical and subtropical reefs (Moser 1996).

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 (Moyle and Cech 1988). 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 et al. 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, including Elkhorn Slough (Cailliet et al. 1977), Anaheim Bay (MacDonald 1975) and Newport Bay (Allen 1982). 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 (W. Watson, Southwest Fisheries Science Center, pers. comm.) but those that were speciated in this study were subsequently combined into the CIQ complex for analysis.

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.

3.3.2.2 Sampling Results

CIQ complex goby larvae was the most abundant taxon collected at the entrainment station (**Table 3-5**). 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 3-6**). Entrainment estimates for each survey are presented in **Appendix F**. CIQ goby larvae were most abundant at the entrainment station during August and least abundant from December through January (**Figure 3-6**). 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 3-7**). 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.

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 3-8**). 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 et al. 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 3-9**).

3.3.2.3 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CWS 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. Total annual entrainment of CIQ goby larvae at EPS was estimated to be 2.21 billion using measured cooling water flow and 2.77 billion larvae using maximum cooling water flow for the June 2004 through May 2005 period (**Table 3-6**).

Fecundity Hindcasting (FH)

Annual entrainment estimates 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 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 3-8**). 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 was entrained through the EPS CWS for the 2004–2005 period ranged from a mean of 1,881,458 using the actual pump flow rates to 2,349,998 using a calculation based on maximum flows during the study period (**Table 3-9**).

Table 3-8. 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 3-9. Results of *FH* modeling for CIQ goby complex larvae based on a) actual flows and b) maximum flows. 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
a) Actual Flows					
FH Estimate	**1,881,458**	1,631,040	452,030	7,831,086	7,379,057
Total Entrainment	2,215,477,217	86,364,408	1,760,808	2,002,108	241,300
b) Maximum Flows					
FH Estimate	**2,349,998**	2,036,966	564,699	9,779,533	9,214,834
Total Entrainment	2,767,198,570	101,030,008	2,208,860	2,491,136	282,276

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 $0.93^{60\text{-}2.4} = 0.02$ 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 estimated number of adult CIQ gobies equivalent to the number of larvae entrained through the EPS CWS for the sampling period was 1,632,666 based on actual flows and 2,039,250 based on maximum flows (**Table 3-10**).

Table 3-10. Results of *AEL* modeling for CIQ goby complex larvae based on a) actual flows and b) maximum flows. 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
a) Actual Flows					
AEL Estimate	**1,632,666**	1,834,554	257,124	10,366,994	10,109,870
Total Entrainment	2,215,477,217	86,364,408	1,527,970	1,737,363	209,392
b) Maximum Flows					
AEL Estimate	**2,039,250**	2,291,244	321,199	12,946,922	12,625,723
Total Entrainment	2,767,198,570	101,030,008	1,916,775	2,161,725	244,949

Empirical Transport Model (ETM)

The larval duration used to calculate the *ETM* estimates for CIQ gobies was based on the lengths of entrained larvae. 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*) for the June 2004 – May 2005 period ranged from 0.00891to 0.10983 using the actual flows and from 0.01518 to 0.12744 using the maximum flows (**Table 3-11**). The largest estimates occurred during the August surveys 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 0.3980 with a standard error of 0.2692 using the actual flows and an estimate of 0.4700 with a standard error of 0.3169 using the maximum flows.

Table 3-11. *ETM* data for CIQ goby larvae based on actual and maximum daily cooling water flows. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		Maximum Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0.01884	0.07027	0.02277	0.08475	0.11600
24-Jun-04	0.02890	0.11076	0.03590	0.13735	0.03160
6-Jul-04	0.06809	0.27212	0.08262	0.32838	0.07955
13-Aug-04	0.10983	0.47389	0.12744	0.54871	0.18595
23-Sep-04	0.07170	0.24957	0.07750	0.26921	0.06335
21-Oct-04	0.03223	0.05658	0.05301	0.09253	0.04577
18-Nov-04	0.01958	0.05349	0.03101	0.08434	0.02347
16-Dec-04	0.01226	0.0383	0.01518	0.04709	0.02729
13-Jan-05	0.00891	0.01371	0.01571	0.02342	0.03878
24-Feb-05	0.00940	0.01556	0.01556	0.02564	0.14489
23-Mar-05	0.03661	0.08619	0.05419	0.1273	0.11674
21-Apr-05	0.08833	0.4196	0.10369	0.49206	0.03690
19-May-05	0.05236	0.19698	0.07051	0.26494	0.08971
P_M	**0.3980**		**0.4700**		
Std. Error	0.2692		0.3169		

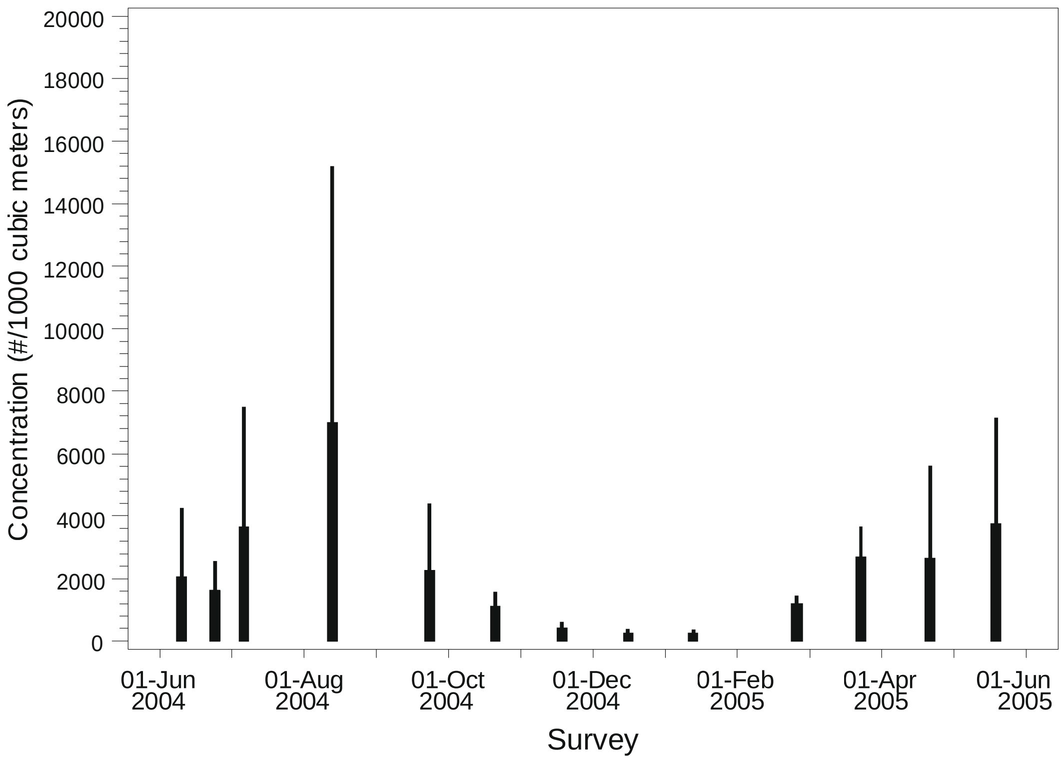


Figure 3-6. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of CIQ goby complex larvae at entrainment Station E1.

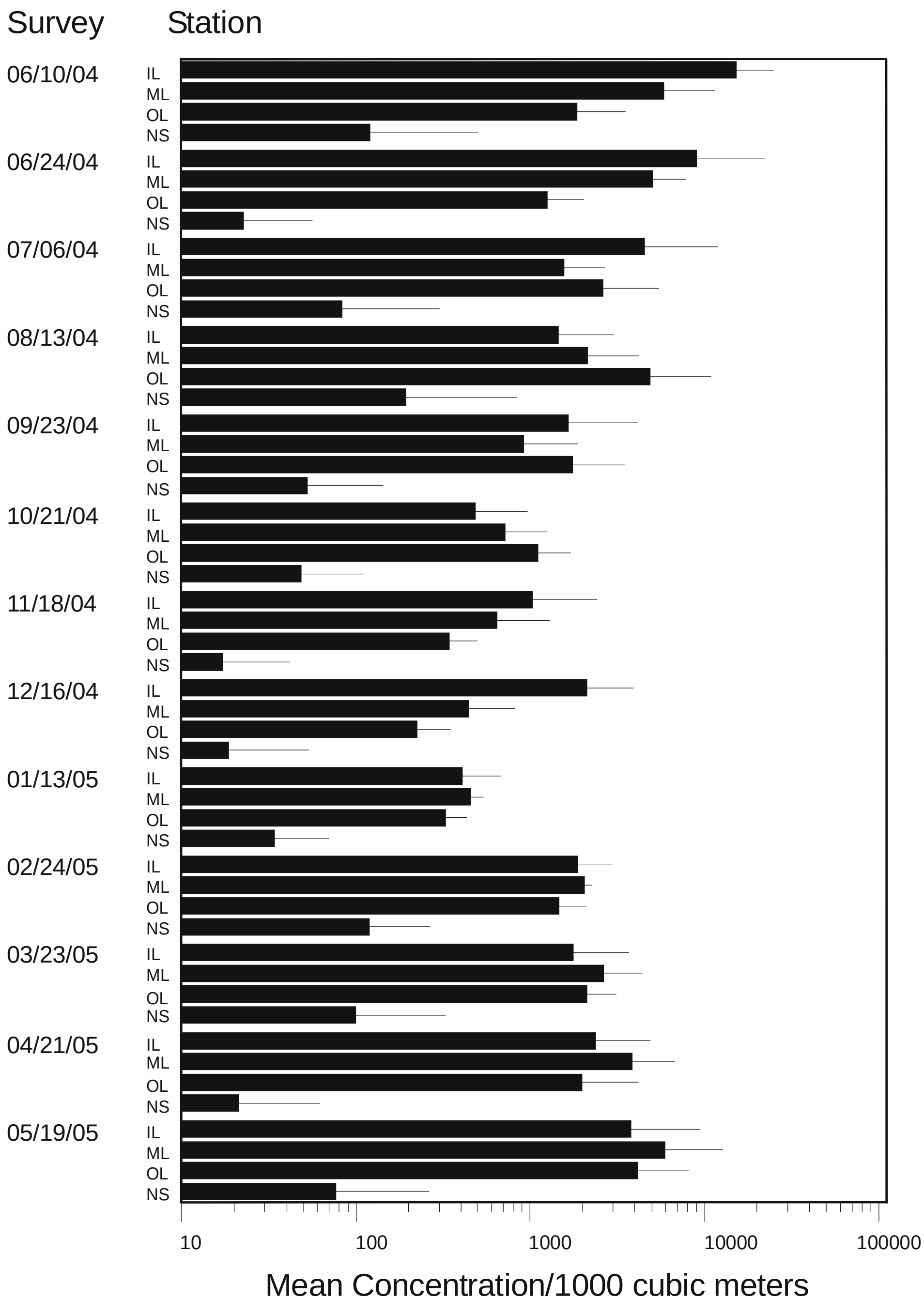


Figure 3-7. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of CIQ goby complex larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods. Note logarithmic abundance scale.

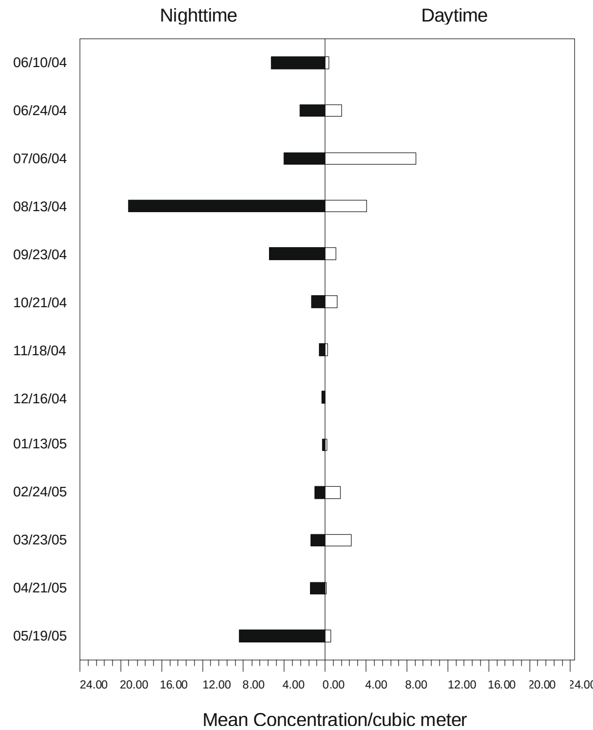


Figure 3-8. Mean concentration (#/1.0 m^3 [264 gal]) of CIQ goby complex larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

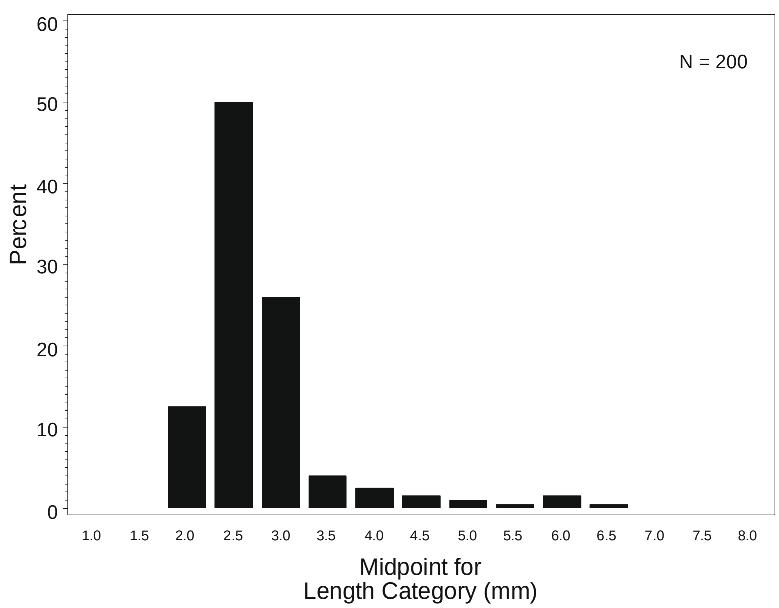


Figure 3-9. Length frequency of CIQ goby complex larvae at entrainment Station E1. Data from sub-samples of all surveys in 2004–2005.

3.3.3 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).

3.3.3.1 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 316(b) plankton collections 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 (Stephens et al. 1970). They are commonly found in mussel beds and on encrusted floats, buoys, docks, and even fouled boat hulls (Stephens 1969, Stephens et al. 1970). Bay blennies are also typically found in bays as the common name implies and are tolerant of estuarine conditions (Stephens et al. 1970). 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 (Stephens et al. 1970). Blennies are oviparous and lay demersal eggs that are attached to the nest substrate by adhesive pads or filaments (Moser 1996). Males tend the nest and developing eggs. Females spawn 3–4 times over a period of several weeks (Stephens et al. 1970). Males guard the nest aggressively and will often chase the female away, however, several females may occasionally spawn with a single male. The number of eggs a female produces varies proportionately with size (Stephens et al. 1970). The mussel blenny spawns approximately 500 eggs in the first reproductive year and up to 1,500 eggs by the third year (Stephens et al. 1970).

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 (Stephens et al. 1970, Love 1996). 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 (Stephens 1969, Stephens et al. 1970, Miller and Lea 1972). Mussel blennies grow to 13 cm (5.1 in) and have a life span of 3–6 years (Stephens et al. 1970, Miller and Lea 1972). 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.

3.3.3.2 Sampling Results

Combtooth blenny larvae were the second most abundant taxon collected in the entrainment samples and source water samples (**Tables 3-5** and **3-7**). They were most abundant from May through September and least abundant from October through April (**Figure 3-10**) 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 3-11**), and substantially greater in night samples than those collected during the day (**Figure 3-12**). The number of larval combtooth blennies collected during each entrainment and source water survey is presented in **Appendix E**.

The length frequency distribution for a random sample of 200 combtooth blenny larvae from all surveys 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 3-13**). 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).

3.3.3.3 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CWS 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). Total annual entrainment of combtooth blenny larvae at EPS was estimated at 1.10 billion using measured cooling water flow and at 1.31 billion larvae using maximum cooling water flow for the June 2004 through May 2005 period (**Table 3-6**).

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 (Stephens et al. 1970), 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 3-12**) 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 3-12. 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 through the EPS CWS for the June 2004 through May 2005 period was 573,354 based on actual flows and 685,288 based on maximum flows (**Table 3-13**). 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 3-13. Results of *FH* modeling for combtooth blenny larvae based on a) actual flows, and b) maximum flows. 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
a) Actual Flows					
FH Estimate	**573,354**	497,606	137,528	2,390,306	2,252,778
Total Entrainment	1,098,083,615	62,379,799	519,775	626,933	107,159
b) Maximum Flows					
FH Estimate	**685,288**	594,668	164,411	2,856,379	2,691,968
Total Entrainment	1,312,458,555	72,049,342	623,403	747,172	123,769

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 as 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 through the EPS CWS for the sampling period was 2,450,084 based on actual flows and 2,928,405 based on design maximum flows (**Table 3-14**).

Table 3-14. Results of *AEL* modeling for combtooth blenny larvae based on a) actual flows and b) maximum flows. 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
a) Actual Flows					
AEL Estimate	**2,450,084**	3,003,954	326,035	18,411,836	18,085,800
Total Entrainment	1,098,083,615	62,379,799	2,221,126	2,679,042	457,916
b) Maximum Flows					
AEL Estimate	**2,928,405**	3,590,150	389,742	22,003,161	21,613,419
Total Entrainment	1,312,458,555	72,049,342	2,663,956	3,192,854	528,897

Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for combtooth blenny was based on the lengths of entrained larvae. 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 for the June 2004 – May 2005 period varied among surveys and ranged from 0 to 0.42268 using the actual flows and from 0 to 0.74564 using the maximum flows during the period (**Table 3-15**). 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 0.1940 with a standard error of 0.1415 using the actual flows and an estimate of 0.2279 with a standard error of 0.1656 using the maximum flows.

Table 3-15. *ETM* data for combtooth blenny larvae based on actual and maximum daily cooling water flows. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		**Maximum Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0.05923	0.02255	0.07156	0.02716	0.29923
24-Jun-04	0.03048	0.01432	0.03786	0.01773	0.12245
6-Jul-04	0.03815	0.05152	0.04630	0.06220	0.13375
13-Aug-04	0.12766	0.12137	0.14813	0.14012	0.26395
23-Sep-04	0.15965	0.29549	0.17257	0.31857	0.05771
21-Oct-04	0.15218	0.37091	0.25027	0.60328	0.00319
18-Nov-04	0.09596	0.25147	0.15199	0.39395	0.00523
16-Dec-04	0.25382	0.32000	0.31413	0.39380	0.00035
13-Jan-05	0.42268	0.98886	0.74564	1.65570	0.00004
24-Feb-05	0	0	0	0	0.00001
23-Mar-05	0.08658	0.09164	0.12817	0.13460	0.00327
21-Apr-05	0.06001	0.09815	0.07043	0.11515	0.00885
19-May-05	0.06105	0.07780	0.08222	0.10456	0.10197
P_M	**0.1940**		**0.2279**		
Std. Error	0.1415		0.1656		

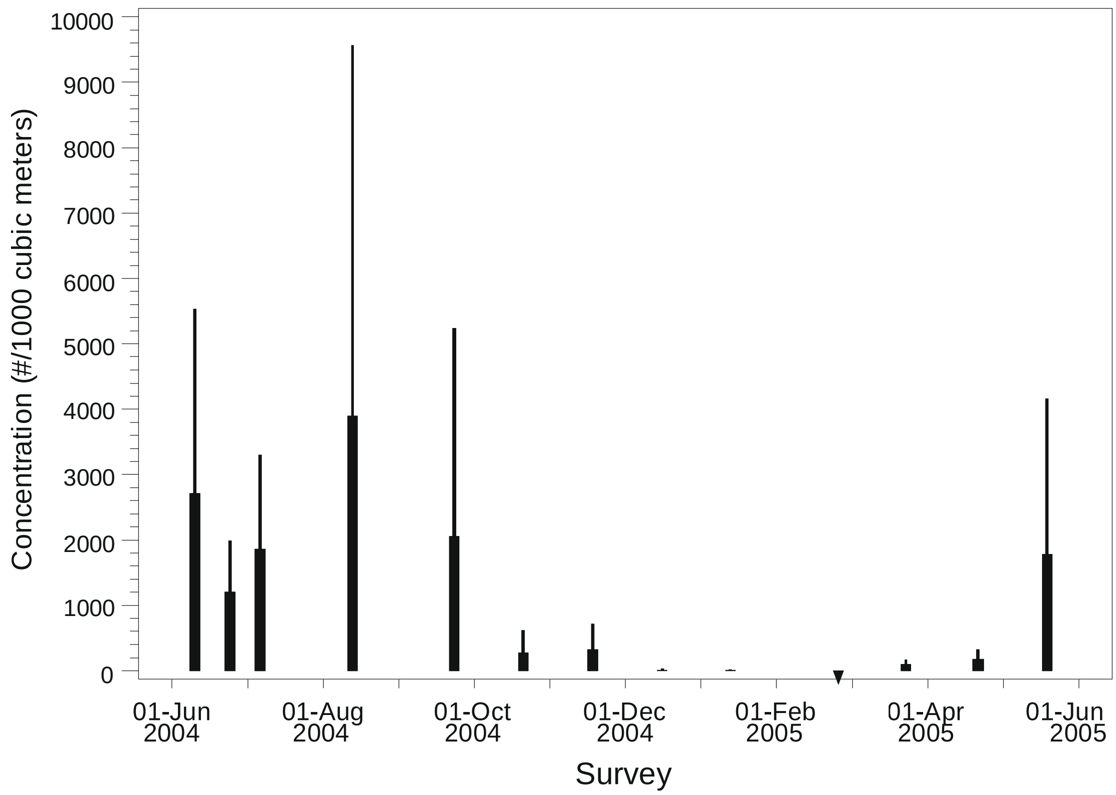


Figure 3-10. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of combtooth blenny larvae at entrainment Station E1.

Note: Downward pointing triangle indicates survey with no larvae collected.

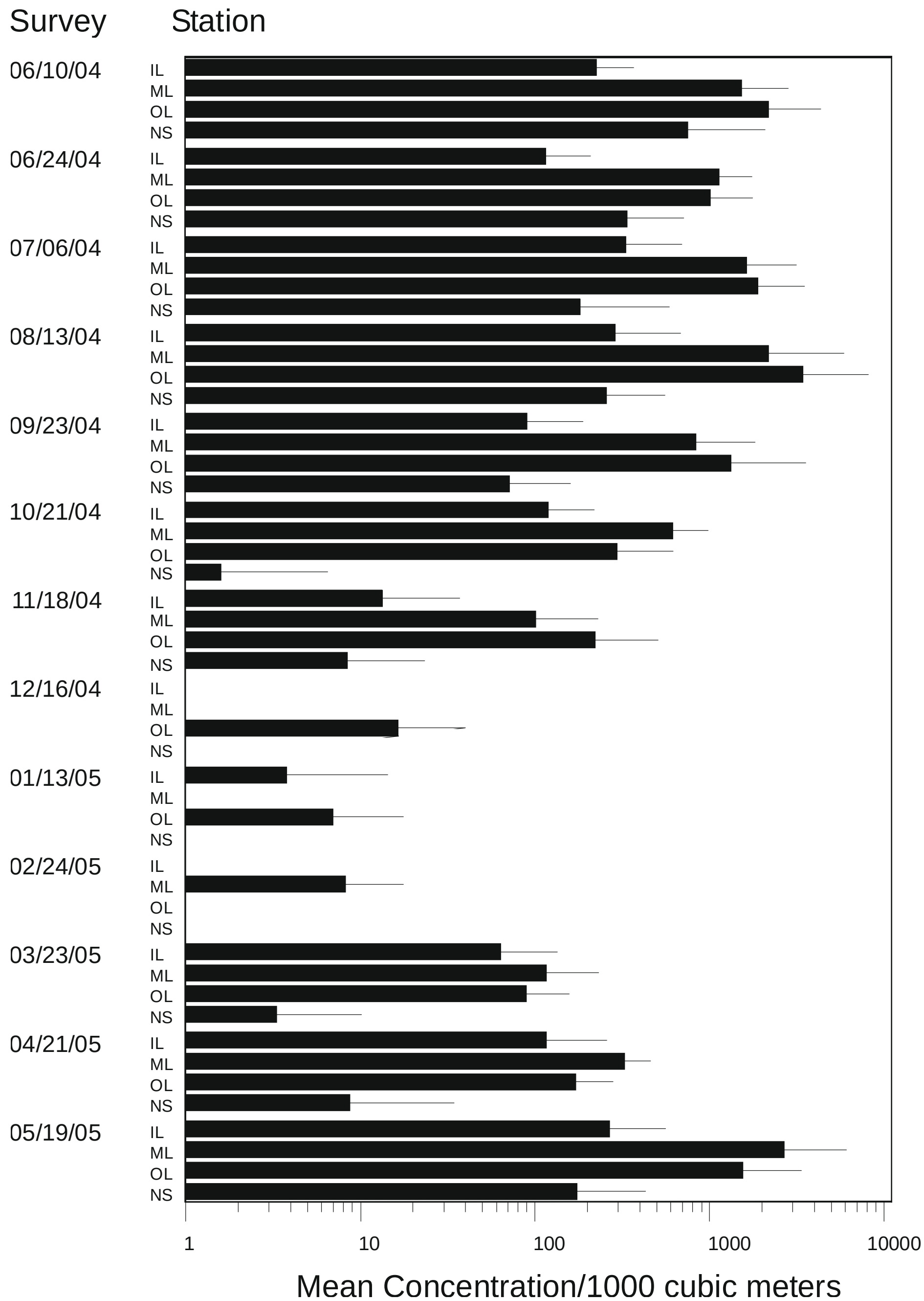


Figure 3-11. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of combtooth blenny larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods.

Note logarithmic scale for mean concentration.

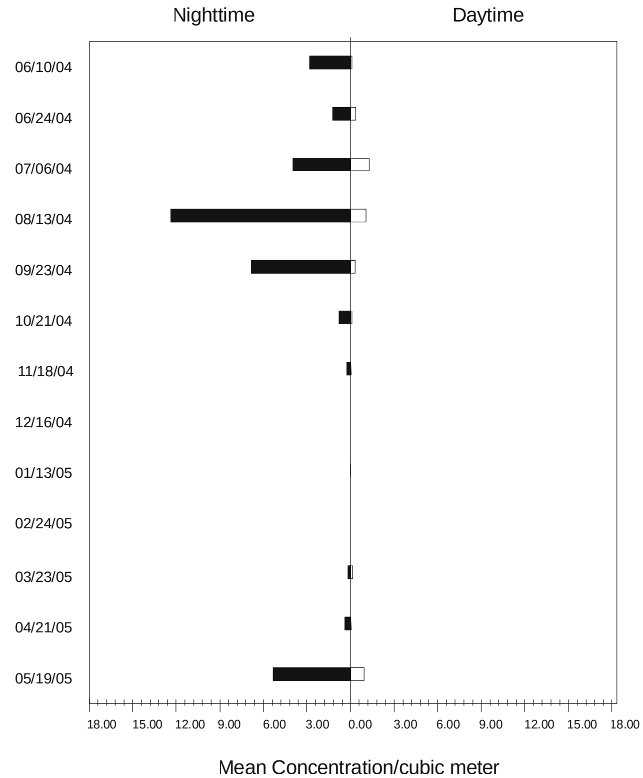


Figure 3-12. Mean concentration (#/1.0 m^3 [264 gal]) of combtooth blenny larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

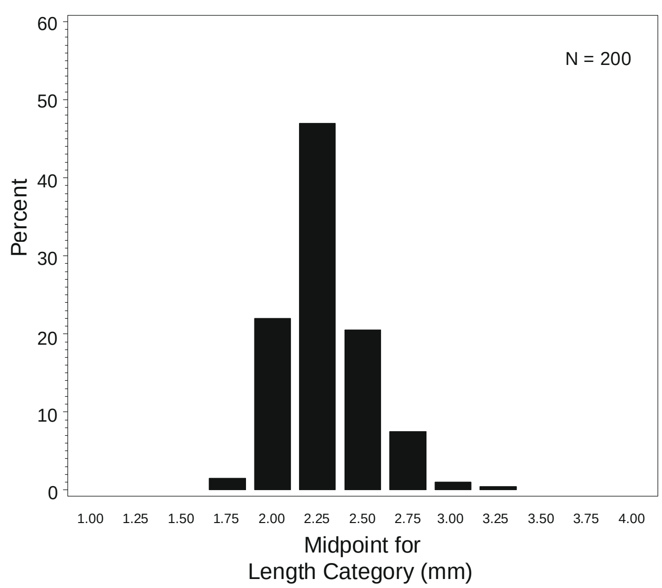


Figure 3-13. Length frequency of combtooth blenny larvae at entrainment and all source water stations combined. Data from sub-samples of all surveys in 2004–2005.

3.3.4 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 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).

3.3.4.1 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 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 (MBC 1987). 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, MBC 1987). Most spawning occurs at night and is completed by dawn (Hunter and Macewicz 1980). 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 northern anchovy egg hatches in two to four days, has a larval phase lasting approximately 70 days, and undergoes transformation into a juvenile at about 35-40 mm (Hart 1973, MBC 1987, 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 appropriate phytoplankton species (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 (Frey 1971, Hunter and Macewicz 1980). Maximum size is about 230 mm (9 in) and 60 g (2.1 ounces) (Fitch and Lavenberg 1971, Eschmeyer et al. 1983). 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 (Fitch and Lavenberg 1971). 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° Fare avoided by juveniles and adults (Brewer 1974).

3.3.4.2 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 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.

3.3.4.3 Sampling Results

Engraulid larvae (predominantly northern anchovy) were the third most abundant taxon at the entrainment station with a mean concentration of 134 per 1,000 m^3 (264,172 gal) over all the surveys (**Table 3-5**). 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 3-14**). 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 3-15**)**.** The nearshore station group generally had the highest 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**.

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 3-16**)**.** The length frequency distribution of measured northern anchovy larvae show a distribution strongly skewed toward recently hatched larvae (**Figure 3-17**) 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 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).

3.3.4.4 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CWS effects on Engraulidae (northern anchovy) larvae. Total annual entrainment at EPS was estimated at 120.7 million using measured cooling water flow and at 157.0 million larvae using maximum cooling water flow for the June 2004 through May 2005 period (**Table 3-6**).

Fecundity Hindcasting (*FH*)

The entrainment estimate for northern anchovy for the June 2004 through May 2005 sampling period was used to estimate the number of breeding females at the age of maturity needed to produce the estimated number of larvae entrained. 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 3-16**). 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 3-16. 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	0.231	2.9		0.512	0.142
Yolk-sac larva	0.366	3.6	6.5	0.093	0.240
Early larva	0.286	12	18.5	0.032	0.071
Late larva	0.0719	45	63.5	0.039	0.427
Early juvenile	0.0141	62	125.5	0.417	0.239
Late Juvenile	0.0044	80	205.5	0.703	0.033
Pre-recruit	0.0031	287	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 3-17** 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 3-17. 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 was entrained through the EPS CWS for the June 2004 through May 2005 period was 3,089 based on actual flows and 4,019 based on design maximum flows (**Table 3-18**). The range of estimates based on the 90% confidence intervals show that the variation in our 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 3-18. Results of *FH* modeling for anchovy larvae based on a) actual flows and b) maximum flows. 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
a) Actual Flows					
FH Estimate	**3,089**	2,680	741	12,873	12,132
Total Entrainment	120,661,087	6,551,786	2,813	3,365	552
b) Maximum Flows					
FH Estimate	**4,019**	3,487	965	16,748	15,783
Total Entrainment	157,019,892	8,097,477	3,678	4,360	682

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 (**Table 3-16**). 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 estimated number of adult northern anchovies equivalent to the number of larvae entrained through the EPS CWS for the sampling period was 15,456 based on actual flows and 20,113 based on design maximum flows (**Table 3-19**).

Table 3-19. Results of *AEL* modeling for anchovy larvae based on a) actual flows and b) maximum flows. 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
a) Actual Flows					
AEL Estimate	**15,456**	17,897	2,300	103,840	101,540
Total Entrainment	**120,661,087**	6,551,786	14,075	16,836	2,761
b) Maximum Flows					
AEL Estimate	**20,113**	23,288	2,994	135,102	132,108
Total Entrainment	**157,019,892**	8,097,477	18,407	21,819	3,412

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 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 period ranged from 0 to 0.04037 using the actual flows and from 0 to 0.05437 using the maximum flow volumes (**Table 3-20**). 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 0.0035 with a standard error of 0.0025 using the actual flows and an estimate of 0.0045 with a standard error of 0.0032 using the maximum flows.

Table 3-20. *ETM* data for northern anchovy larvae based on actual and maximum daily cooling water flows. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		**Maximum Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0.00044	0.00054	0.00054	0.00065	0.02259
24-Jun-04	0.00048	0.00163	0.00059	0.00202	0.00187
6-Jul-04	0.00108	0.00206	0.00131	0.00248	0.02319
13-Aug-04	0.00070	0.00189	0.00081	0.00219	0.01464
23-Sep-04	0.00005	0.00017	0.00005	0.00018	0.03618
21-Oct-04	0.00008	0.00023	0.00014	0.00037	0.01157
18-Nov-04	0.00074	0.00305	0.00117	0.00477	0.01404
16-Dec-04	0	0	0	0	0.00011
13-Jan-05	0.00005	0.00032	0.00009	0.00053	0.00834
24-Feb-05	0.00070	0.00297	0.00117	0.00481	0.01230
23-Mar-05	0.00024	0.00050	0.00035	0.00072	0.42247
21-Apr-05	0.00042	0.00119	0.00049	0.00139	0.42965
19-May-05	0.04037	0.09825	0.05437	0.13220	0.00305
P_M	**0.0035**		**0.0045**		
Std. Error	0.0025		0.0032		

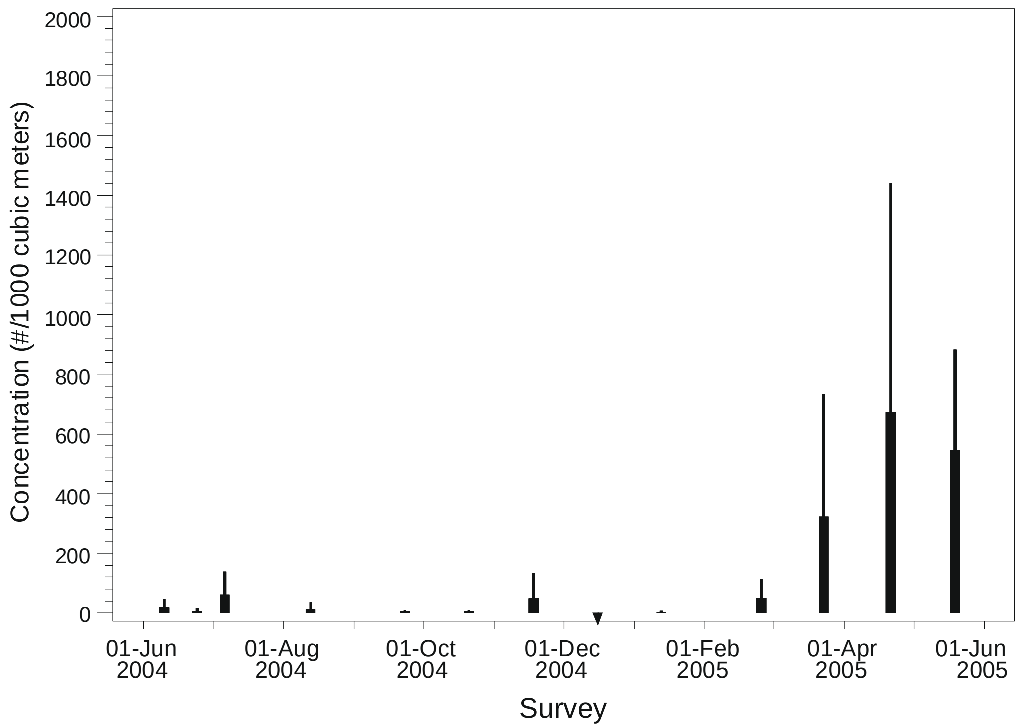


Figure 3-14. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of anchovy larvae at entrainment Station E1.

Note: Downward pointing triangle indicates survey with no larvae collected.

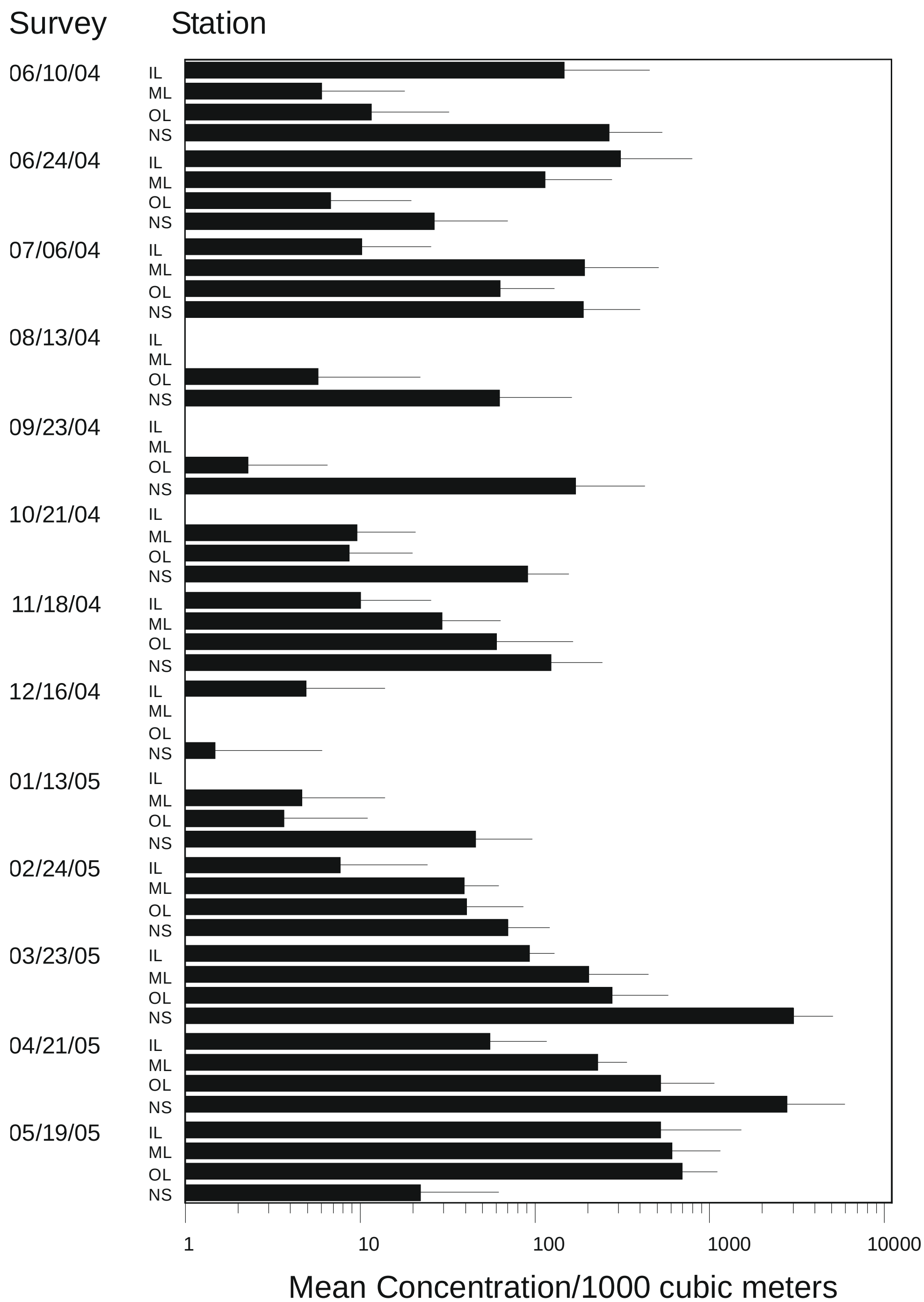


Figure 3-15. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of anchovy larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods.

Note logarithmic abundance scale.

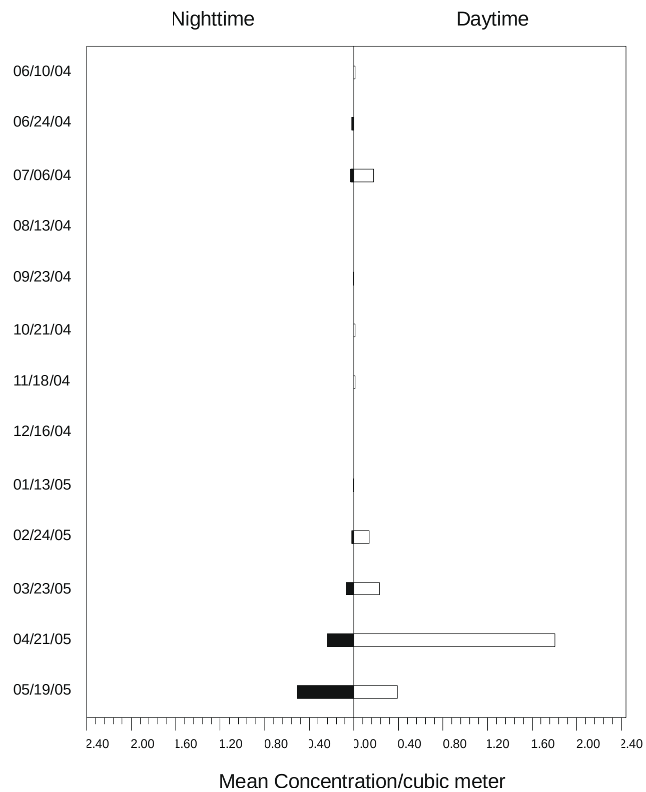


Figure 3-16. Mean concentration (#/1.0 m^3 [264 gal]) of anchovy larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

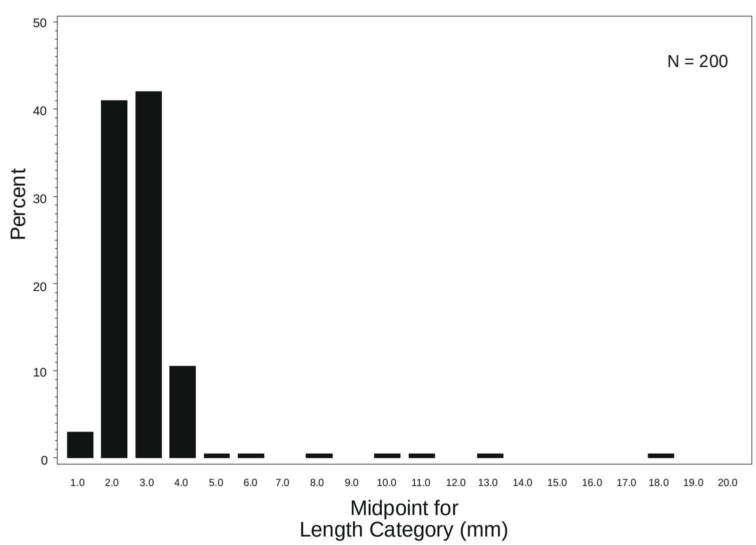
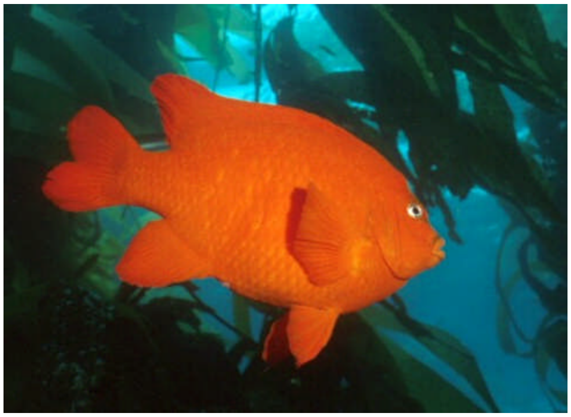


Figure 3-17. Length frequency of anchovy larvae at entrainment Station E1. Data from sub-samples of all surveys in 2004–2005.

3.3.5 Garibaldi (*Hypsypops rubicundus*)



Jay Carroll

Range: Monterey Bay, California, to southern Baja California and Guadalupe Island, Mexico.

Life History:

- Size up to 38.1 cm TL (15 in)
- Age at first maturity 3-6 yr in males and 6 yr in females
- Life span to 17 yr (29 yr in captivity)
- Spawns in spring and summer primarily in bays and shallow rocky areas; demersal, adhesive eggs with fecundity of 15,000-88,000 eggs per female

Habitat: Occurs over rocky bottoms in clear water, often near crevices, small caves, and in kelp; to 29 m (95 ft).

Fishery: None; protected by California state law.

Garibaldi (*Hypsypops rubicundus*) ranges from Monterey Bay, California to southern Baja California and Guadalupe Island (off northern central Baja California) in Mexico, but is not abundant north of Santa Barbara (Fitch and Lavenberg 1975). They are one of two common species of damselfishes (Family Pomacentridae) found off southern California, the other being the blacksmith (*Chromis punctipinnis*). Garibaldi is the California state marine fish and is fully protected by the State.

3.3.5.1 Life History and Ecology

Garibaldi occurs over rocky bottoms in clear water, often near crevices and small caves, from the intertidal zone (as juveniles) to depths of 29 m (95 ft). They occur on the outer coast, around islands, and in protected bays and harbors (Fitch and Lavenberg 1975), typically as individuals (adults defend a territory all year) but occasionally in loose aggregations. They attain a maximum length up to 38.1 cm TL (15 in) although few are larger than 30.5 cm (12 in). Males are larger than females at a given age (Limbaugh 1964). Males begin to mature at about 3 yr but females may not reproduce until age 5–6 yr.

Garibaldi spawn from March through October (Love 1996), and the female deposits demersal adhesive eggs in a nest that the male has prepared by clearing off all growth except calcareous tubes and filamentous red algae. Males defend algal nests within permanent territories (10–15 m^2 [107–161 ft^2]) on which females deposit eggs (Clarke 1970). Males that guard nesting areas with sparse algal cover tend to be less likely to court passing females (Sikkel 1995). DeMartini et al. (1994) measured mean batch fecundity at 12,546 eggs with an average of 35 eggs per gram of body weight. Some nests may contain up to 190,000 eggs deposited by several females (Fitch and Lavenberg 1975). Female garibaldi in southern California were estimated to spawn about 24 times during their 144-day spawning season (DeMartini et al. 1994). Females preferentially approach nests with eggs in the early stages of development prior to or in the absence of male courtship and are more likely to spawn in such nests than in empty nests or nests with only eggs in the advanced stages of development (Sikkel 1989). Eggs in the early stages of development are bright yellow and turn gray as development proceeds. Eggs hatch in 12–23 days (Sikkel 1989) depending on temperature. Larvae are primarily neustonic, initially ca. 2.2 mm (0.09 in) in length and attain flexion at ca 3.5 mm (0.14 in) (Moser 1996). Transformation occurs at a length of ca 5–10 mm (0.19–0.39 in) and settlement has been noted to occur at approximately 20 mm SL (0.79 in). Larval duration ranges from 18–22 days (mean of 20 days) based on daily incremental marks on otoliths in recently settled individuals (Wellington and Victor 1989).

As juveniles garibaldi feed on planktonic crustaceans such as copepods, amphipods, and isopods (Clarke 1970). As adults they are typically carnivorous feeding a variety of invertebrates including sponges, sea anemones, bryozoans, worms, crustaceans, clams and mussels, snail eggs, and their own eggs. Field observations and experiments during the mating phase show that brood-guarding males usually cannibalize older clutches if the older eggs are exposed to empty nest space (Sikkel 1994a). Males nearly always cannibalize the entire brood when they receive only a single clutch, and the probability of cannibalism of last clutches increases with brood age (Sikkel 1994b). Garibaldi are only active during the day and shelter in holes in the reef at night (Clarke 1970). Juvenile garibaldi are preyed upon by larger fishes such as kelp bass, and adult garibaldi are preyed upon by sharks, giant sea bass, moray eels, and sea lions.

3.3.5.2 Sampling Results

Garibaldi larvae ranked as the fourth most abundant species of larvae entrained with an average concentration across all surveys of 41 per 1,000 m^3 (264,172 gal), but comprised less that 1% of all entrained larvae (**Table 3-5**). Garibaldi larvae were very seasonal in abundance at all stations and were present only from April through August (**Figure 3-18**). The greatest abundance at the entrainment station occurred during early June with mean concentrations of 275 larvae per 1,000 m^3 (264,172 gal). Source water larvae were typically most abundant at the Middle and Outer Lagoon sampling stations, but also occurred in the Inner Lagoon and at the nearshore stations (**Figure 3-19**). Larvae were significantly more abundant in the nighttime samples than in the daytime samples (**Figure 3-20**). A sample of 198 garibaldi larvae from all surveys ranged in size from 1.9 to 3.3 mm (0.075 to 0.13 in) with a mean size of approximately 2.6 mm (0.1 in) (**Figure 3-21**).

3.3.5.3 Modeling Results

The following section present the results for empirical transport modeling of CWS effects on garibaldi larvae. Total annual entrainment at EPS was estimated at 29 million using measured cooling water flows and at 36 million larvae using maximum cooling water flows for the June 2004 through May 2005 period (**Table 3-6**). Life history information on garibaldi was insufficient to parameterize the *AEL* or *FH* models.

Empirical Transport Model (*ETM*)

A larval growth rate of 0.29 mm/day (0.01 in/day) for garibaldi was estimated from Wellington and Victor (1989) and used with the difference in the lengths of the 25th (2.4 mm) and 95th

percentiles (3.1 mm [0.12 in]) of the measurements to estimate that the larvae were exposed to entrainment for a period of approximately 2.2 days.

Garibaldi larvae were absent from entrainment samples from September through March. The monthly estimates of proportional entrainment (*PE*) for garibaldi for the June 2004 – May 2005 period ranged from 0 to 0.14528 using the actual flows and from 0 to 0.19366 using maximum flows (**Table 3-21**). The largest estimate was calculated for the April survey using actual flows and for the May survey using the maximum flows, but the largest proportion of the source population was present during the first survey in June 2004 (f_i = 0.625 or 62.5%). Garibaldi larvae were present in six of the 12 surveys. The values in the table were used to calculate a P_M estimate of 0.1442 with a standard error of 0.3115 using actual flows and an estimate of 0.1753 with a standard error of 0.3777 using the maximum flows.

Table 3-21. *ETM* data for garibaldi larvae based on actual and maximum daily cooling water flows. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		**Maximum Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0.06453	0.03775	0.07797	0.0455	0.62469
24-Jun-04	0.05705	0.02888	0.07085	0.03577	0.05168
6-Jul-04	0.03231	0.04608	0.03922	0.05558	0.17163
13-Aug-04	0.11489	0.12829	0.13331	0.14847	0.04004
23-Sep-04	0	0	0	0	0
21-Oct-04	0	0	0	0	0
18-Nov-04	0	0	0	0	0
16-Dec-04	0	0	0	0	0
13-Jan-05	0	0	0	0	0
24-Feb-05	0	0	0	0	0
23-Mar-05	0	0	0	0	0
21-Apr-05	0.14528	0.3425	0.17053	0.40196	0.01825
19-May-05	0.14379	0.17011	0.19366	0.22888	0.09371
$\boldsymbol{P_M}$	**0.1442**		**0.1753**		
Std. Error	0.1455		0.1764		

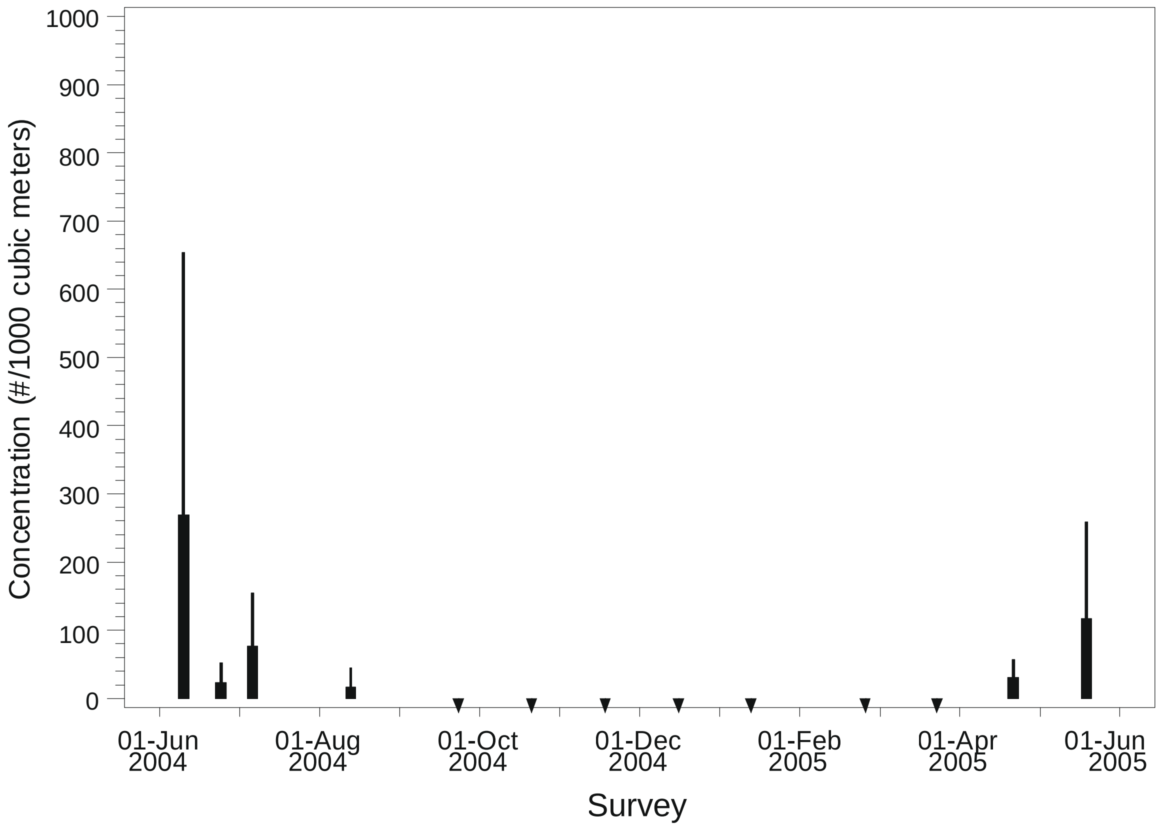


Figure 3-18. Comparison among surveys of mean concentration (#/1,000 m^3) of garibaldi larvae at entrainment Station E1.

Note: Downward pointing triangle indicates survey with no larvae collected.

Figure 3-19. Mean concentration (#/1,000 m^3]) and standard error of garibaldi larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods.

Note logarithmic abundance scale.

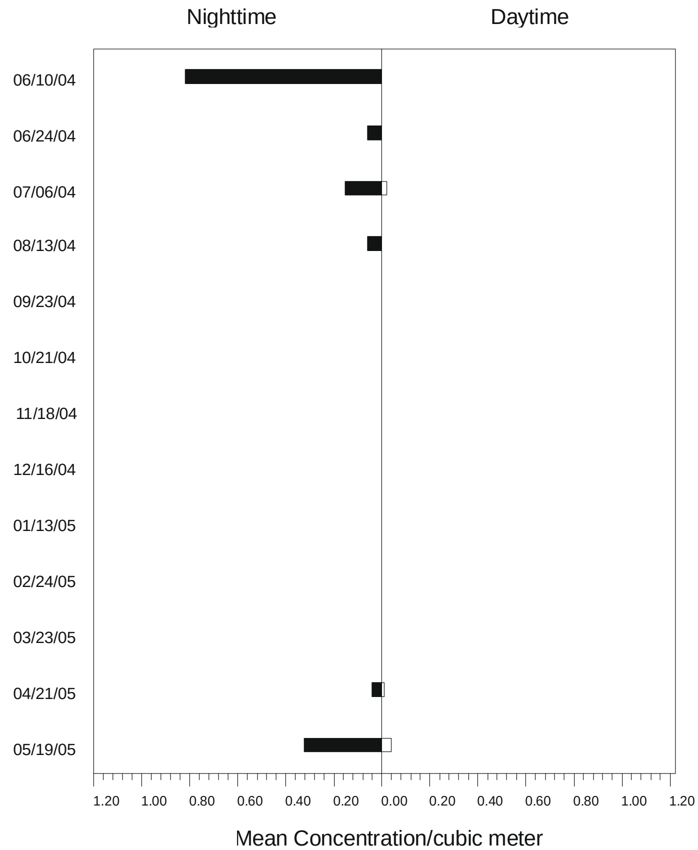


Figure 3-20. Mean concentration (#/1.0 m^3 [264 gal]) of garibaldi larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

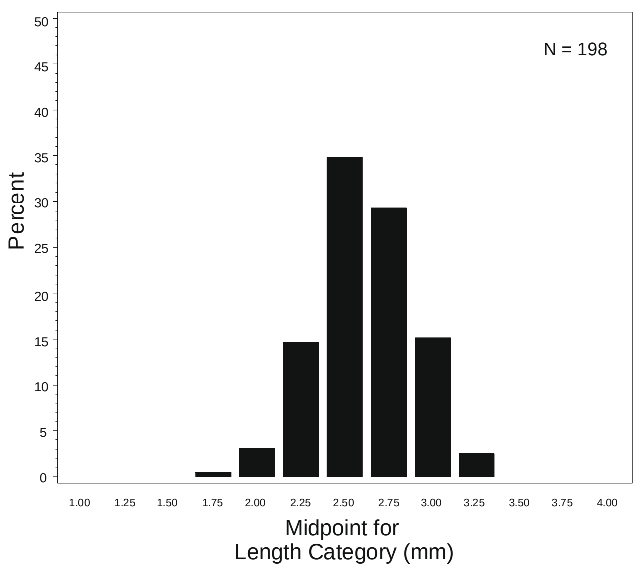


Figure 3-21. Length frequency of garibaldi larvae at entrainment Station E1. Data from sub-samples of all surveys in 2004–2005.

3.3.6 White croaker (*Genyonemus lineatus*)

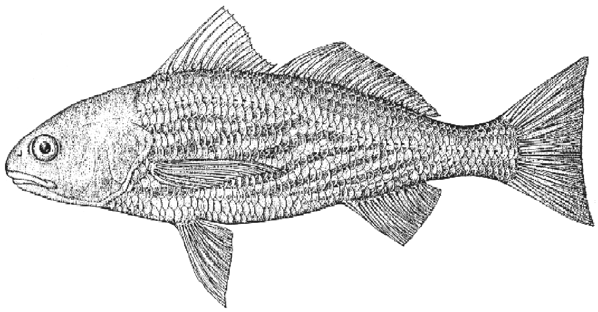


Illustration from NOAA

Range: British Columbia to southern Baja California

Life History:
- Size up to 41 cm SL (16.25 in)
- Age at maturity 1–4 yr
- Life span to 13 yr
- Spawns throughout the year with a peak season in January–March; multiple broadcast spawners with external fertilization; batch fecundity of 15-80 thousand eggs per female

Habitat: Sand and mud bottoms over the open coast from the surf zone to depths of 238 m (781 ft).

Fishery: Sport and commercial fishery.

White croaker (*Genyonemus lineatus*) range from Magdalena Bay, Baja California, north to Vancouver Island, British Columbia (Miller and Lea 1972). They are one of eight species of croakers (Family Sciaenidae) found off California. The other croakers include: white seabass (*Atractoscion nobilis*), black croaker (*Cheilotrema saturnum*), queenfish (*Seriphus politus*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), and shortfin corvina (*Cynoscion parvipinnis*). All but shortfin corvina are known to occur in AHL.

3.3.6.1 Life History and Ecology

The reported depth range of white croaker is from near the surface to depths of 238 m (781 ft) (Love et al. 2005); however, in southern California, Allen (1982) found *Genyonemus* over soft bottoms between 10 and 130 m (33 and 427 ft), and it was collected most frequently at 10 m (33 ft). It is nocturnally active, and is considered a benthic searcher that feeds on a wide variety of benthic invertebrate prey. Adults feed on polychaetes and crustaceans, while juveniles feed during the day in midwater on zooplankton (Allen 1982).

White croakers are oviparous broadcast spawners. They mature between about 130 and 190 mm TL (5.1 and 7.5 in), between their first to fourth year; approximately 50% spawn at age one year (Love 1996). About one-half of males mature by 140 mm TL (5.5 in), and one-half of females by 150 mm TL (5.9 in), and all fish are mature by 190 mm TL (7.5 in) in their third to fourth year (Love et al. 1984). Off Long Beach, white croaker spawn primarily from November through August, with peak spawning from January through March (Love et al. 1984). However, some spawning can occur year-round. Batch fecundities ranged from about 800 eggs in a 155 mm (6.1 in) female to about 37,200 eggs in a 260 mm (10.2 in) female, with spawning taking place as often as every five days (Love et al. 1984). In their first and second years, females spawn for three months for a total of about 18 times per season. Older fish spawn for about four months and about 24 times per season (Love et al. 1984). Some older fish may spawn for seven months. The nearshore waters from Redondo Beach to Laguna Beach are considered an important spawning center for this species (Love et al. 1984). A smaller spawning center occurs off Ventura.

Newly hatched white croaker larvae are 1–2 mm SL (0.04-0.08 in) and not well developed (Watson 1982). Larvae are principally located within 4 km (2.5 miles) from shore, and as they develop tend to move shoreward and into the epibenthos (Schlotterbeck and Connally 1982). Murdoch et al. (1989b) estimated a daily larval growth rate of 0.20 mm/day (0.008 in/day). Maximum reported size is 414 mm (16.3 in) (Miller and Lea 1972), with a life span of 12–15 years (Frey 1971, Love et al. 1984). White croakers grow at a fairly constant rate throughout their lives, though females increase in size more rapidly than males from age 1 (Moore 2001). No mortality estimates are available for any of the life stages of this species.

White croaker are primarily nocturnal benthic feeders, though juveniles may feed in the water column during the day (Allen 1982). Important prey items include polychaetes, amphipods, shrimps, and chaetognaths (Allen 1982). In Outer Los Angeles Harbor, Ware (1979) found that important prey items included polychaetes, benthic crustaceans, free-living nematodes, and zooplankton. Younger individuals feed on holoplankonic crustaceans and polychaete larvae. White croaker may move offshore into deeper water during winter months (Allen and DeMartini 1983); however, this pattern is apparent only south of Redondo Beach (Herbinson et al. 2001).

3.3.6.2 Population Trends and Fishery

Annual relative abundance of white croaker in impingement samples at southern California power plants showed decreases during the strong El Niño events of 1982-83, 1986-87, and 1997-98 as compared with non-El Niño years (Herbinson et al. 2001).

White croaker is an important constituent of the commercial and sport fisheries of California. Prior to 1980, most of the croaker catch was in southern California. However, since 1980, the majority of the commercial catch occurred in central California, and has been attributed to the entrance of Southeast Asian refugees into the fishery (Moore and Wild 2001). Most of the recreational catch is still in southern California from piers, breakwaters, and private boats.

Before 1980, statewide white croaker landings averaged 685,000 lb annually, exceeding 1,000,000 lb in several years (Moore and Wild 2001). High landings in 1952 corresponded with the collapse of the Pacific sardine fishery. Since 1991, landings averaged 461,000 lb and steadily declined to an all-time low of 142,500 lb in 1998. State-wide landings by recreational fishermen aboard commercial passenger fishing vessels (CPFVs) averaged about 12,000 fish per year from 1990 to 1998, with most of the catch in southern California. Most white croaker are caught by gillnet and hook-and-line (Moore and Wild 2001). In 2005 there was a reported 0.33 MT landed in San Diego County for a value of $1,022 (PacFIN database).

3.3.6.3 Sampling Results

White croaker was the fifteenth most abundant taxon in the entrainment samples with a mean concentration of 7.0 larvae per 1,000 m^3 (264,172 gal), and comprised only about 0.2% of all of the larvae collected at the entrainment station (**Table 3-5**). They were most abundant at the nearshore stations ranking fourth overall with a mean concentration of 64.7 larvae per 1,000 m^3 (264,172 gal) (**Table 3-7**). Peaks in abundance occurred during February and they were absent in the June and July surveys at the entrainment station (**Figure 3-22**). There was no consistent difference between daytime and nighttime abundance in the entrainment samples. Monthly concentrations in the source water were typically greatest at the nearshore stations with a gradient of declining abundance toward the Inner Lagoon (**Figure 3-23**). The number of larval white croaker collected during each entrainment and source water survey is presented in **Appendix E**.

The length frequency distribution of the 44 white croaker larvae collected from the entrainment samples (**Figure 3-24**) was skewed toward recently-hatched larvae based on the reported hatch length of 1–2 mm (0.04-0.08 in) (Watson 1982). The mean, maximum, and minimum sizes for the measurements were 2.0, 4.1, and 1.2 mm (0.08, 0.16, and 0.05 in), respectively.

3.3.6.4 Modeling Results

The following section presents the results for empirical transport modeling of CWS effects on white croaker larvae. No age-specific estimates of survival for later stages of development were available from the literature for white croaker, therefore no estimates of *FH* or *AEL* were calculated. Total annual entrainment at EPS was estimated at 6.92 million using measured cooling water flow and at 9.47 million larvae using maximum cooling water flow for the June 2004 through May 2005 period (**Table 3-6**).

Empirical Transport Model (ETM)

Only 44 white croaker larvae were collected and measured from the entrainment samples. In order to obtain a larger sample size to describe the sizes of entrained larvae, length frequency data on white croaker from entrainment samples collected for the Huntington Beach Generating Station between September 2003 and August 2004 (MBC and Tenera Environmental 2004) were used in estimating the period that the larvae are exposed to entrainment. The 25th (2.1 mm [0.08 in]) and 95th (7.0 mm [0.28 in]) percentile values from the measurements were used with a larval growth rate of 0.20 mm/day (0.008 in/day) from Murdoch et al. (1989b) to estimate that the larvae were exposed to entrainment for a period of approximately 24.3 days. The duration of the planktonic egg stage, 2.2 d, was added to the period for the larvae to estimate a total period of exposure of 26.5 d.

The monthly estimates of proportional entrainment (*PE*) for white croaker for the June 2004 – May 2005 period ranged from 0 to 0.00072 using the actual flows and from 0 to 0.00084 using the maximum flows (**Table 3-22**). The largest estimate was calculated for the April survey, but the largest proportion of the source population was present during the September survey (f_i = 0.354 or 35.4%). The results show that while white croaker larvae were present in the source water during all of the surveys they only were collected during eight of the entrainment surveys. The values in the table were used to calculate a P_M estimate of 0.0029 with a standard error of

0.0025 and an estimate of 0.0039 with a standard error of 0.0034 using the maximum flow volumes.

Table 3-22. *ETM* data for white croaker larvae based on actual and maximum daily cooling water flows. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		**Maximum Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0	0	0	0	0.00001
24-Jun-04	0	0	0	0	0.00187
6-Jul-04	0	0	0	0	0.00989
13-Aug-04	0.00028	0.00172	0.00033	0.00199	0.02103
23-Sep-04	0.00006	0.00055	0.00007	0.00059	0.35414
21-Oct-04	0	0	0	0	0.03043
18-Nov-04	0.00007	0.00087	0.00012	0.00137	0.07183
16-Dec-04	0.00032	0.00519	0.00040	0.00636	0.00574
13-Jan-05	0.00016	0.00082	0.00029	0.00138	0.04775
24-Feb-05	0.00017	0.00068	0.00028	0.00111	0.13805
23-Mar-05	0.00004	0.00022	0.00005	0.00032	0.26954
21-Apr-05	0.00072	0.00271	0.00084	0.00318	0.04449
19-May-05	0	0	0	0	0.00523
P_M	**0.0029**		**0.0039**		
Std. Error	0.0025		0.0034		

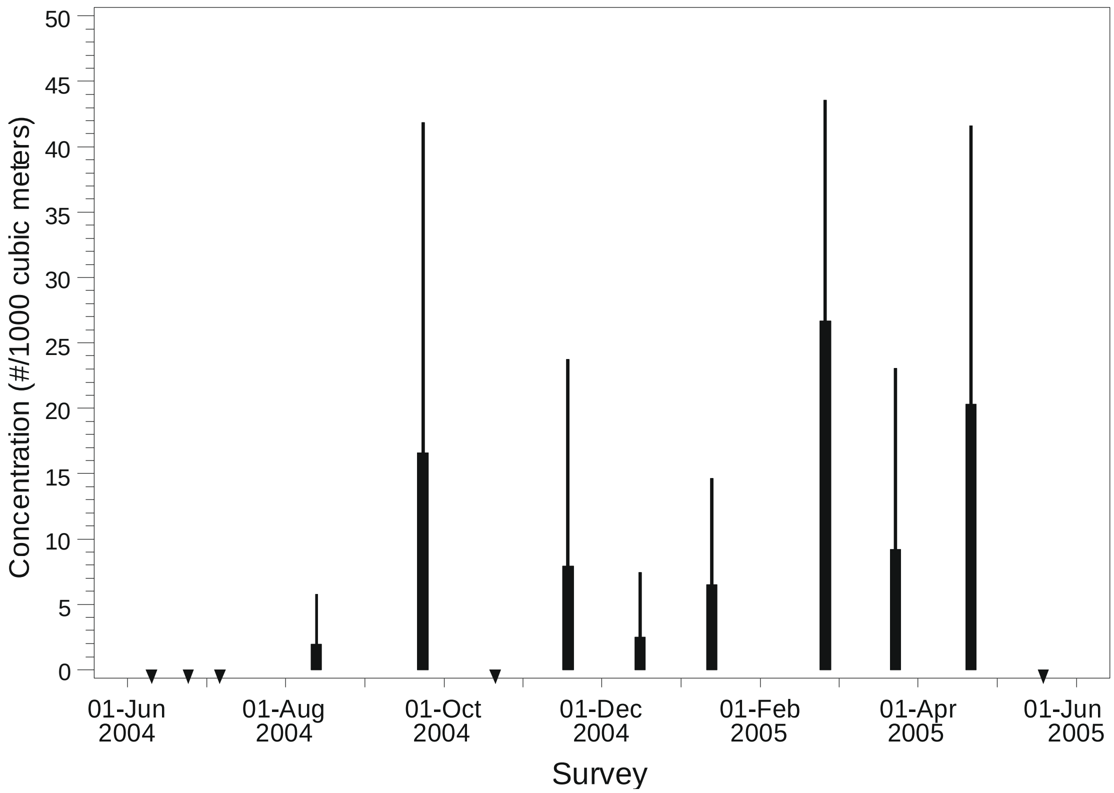


Figure 3-22. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of white croaker larvae at entrainment Station E1.

Note: Downward pointing triangle indicates survey with no larvae collected.

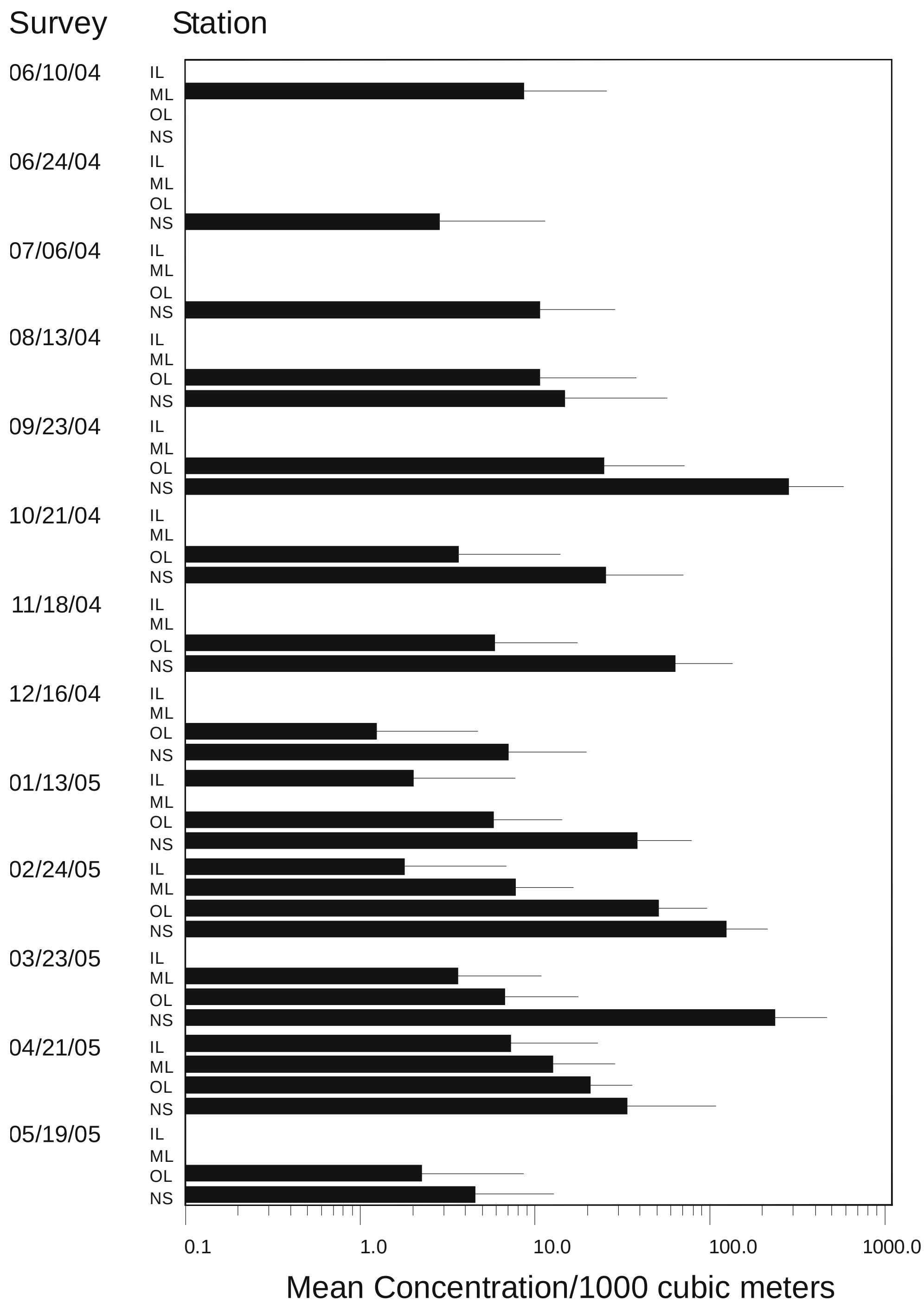


Figure 3-23. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of white croaker larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods.

Note logarithmic abundance scale.

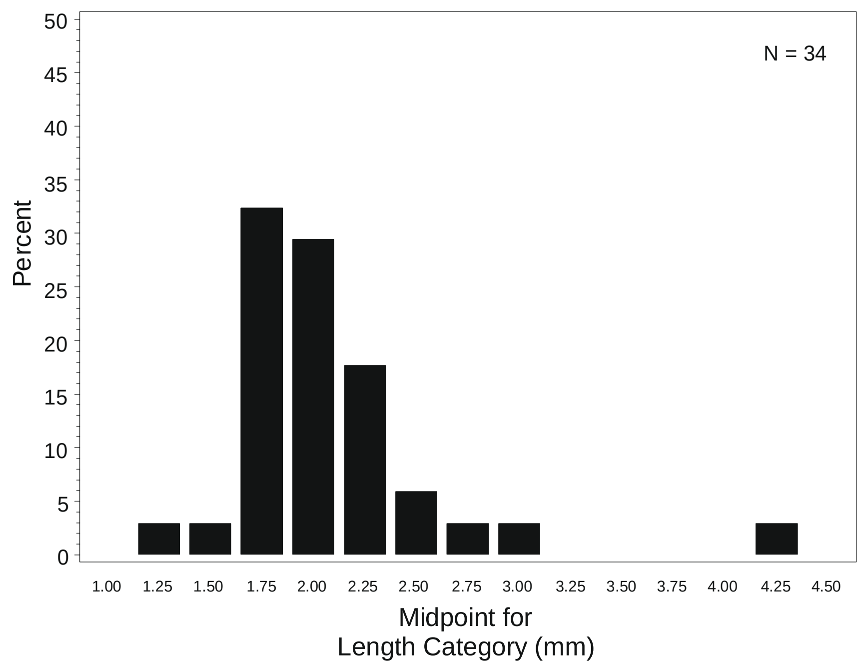


Figure 3-24. Length frequency of white croaker larvae at entrainment Station E1. Data from sub-samples of all surveys in 2004–2005.

3.3.7 Queenfish (*Seriphus politus*)

Milton Love

Range: British Columbia to southern Gulf of California

Life History:
- Size up to 30.5 cm TL (12 in)
- Age at maturity from 1−2 yrs
- Spawns multiple times March through October; pelagic eggs with annual fecundity ranging from 60,000 to 2.3 million eggs.

Habitat: Over sand and mud bottoms in bays and outer coast from the surf zone to depths of 181 m (594 ft).

Fishery: Recreational and commercial fisheries; recreational fishery landings averaged 311,000 per year 2000–2004.

Queenfish (*Seriphus politus*) range from Vancouver Island, British Columbia to southern Gulf of California (Love et al. 2005). Queenfish are common in southern California, but rare north of Monterey. They are one of eight species of croaker or 'drums' (Family Sciaenidae) found off California. The other croakers include: white seabass (*Atractoscion nobilis*), black croaker (*Cheilotrema saturnum*), white croaker (*Genyonemus lineatus*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), and shortfin corvina (*Cynoscion parvipinnis*). All but shortfin corvina are known to occur in AHL.

3.3.7.1 Life History and Ecology

The reported depth range of queenfish is from the surface to depths of about 181 m (594 ft) (Love et al. 2005). In southern California, Allen (1982) found queenfish mainly over soft bottoms at 10–70 m (33–230 ft), with highest abundance occurring at the 10 m stratum. Queenfish form dense, somewhat inactive, schools close to shore during the day, but disperse to feed in midwater after sunset (Hobson and Chess 1976). In a study of queenfish off northern San Diego County, DeMartini et al. (1985) found that adults of both sexes made onshore and offshore migrations, but immature fish generally remained within 2.5 km (1.5 miles) of shore at night. Queenfish are active throughout the night, feeding several meters off the seafloor either in small schools or individually.

Queenfish mature at 10.5–12.7 cm TL (4.1–5.0 in) (DeMartini and Fountain 1981, Love 1996), during their first spring or second summer. Maximum reported size is 30.5 cm TL (12 in) (Miller and Lea 1972). Immature individuals grow at a rate of about 2.5 mm/day, while early adults grow about 1.8 mm/day (0.07 in/day) (Murdoch et al. 1989a). Mortality rate estimates are unavailable for this species.

Queenfish is a summer spawner. Goldberg (1976) found queenfish to enter spawning condition in April and spawn into August, while DeMartini and Fountain (1981) recorded spawning as early as March. Spawning is asynchronous among females, but there are monthly peaks in intensity during the waxing (first quarter) of the moon (DeMartini and Fountain 1981). They also stated that mature queenfish spawn every 7.4 days, on average, regardless of size. Duration of the spawning season is a function of female body size, ranging from three months (April–June) in recruit spawners to six months (March–August) in repeat spawners (>13.5 cm SL [5.3 in]). Based on the spawning frequency and number of months of spawning, these two groups of spawners can produce about 12 and 24 batches of eggs during their respective spawning seasons (DeMartini and Fountain 1981). Demartini (1991) noted the relationship between declines in fecundity, gonadal and somatic condition of queenfish in southern California, and the crash in planktonic production during the 1982–84 El Niño event.

Goldberg (1976) found no sexually mature females less than 14.8 cm SL (5.8 in) in Santa Monica Bay. This differs from the findings of DeMartini and Fountain (1981) who found sexually mature females at 10.0–10.5 cm SL (3.9-4.1 in) off San Onofre at slightly greater than age-1. Batch fecundities in queenfish off San Onofre ranged from 5,000 eggs in a 10.5 cm (4.1 in) female to about 90,000 eggs in a 25 cm (9.8 in) fish. The average-sized female (14 cm [5.5 in], 42 g [1.5 ounces]) had a potential batch fecundity of 12,000–13,000 eggs. Parker and DeMartini (1989) estimated the average batch fecundity to be 12,700 for queenfish collected over a five-year period. Based on a female spawning frequency of 7.4 days, a 10.5-cm (4.1 in) female that spawns for three months (April–June) can produce about 60,000 eggs per year, while a 25cm (9.8 in) female that spawns for six months (March through August) can produce nearly 2.3 million eggs per year (DeMartini and Fountain 1981).

Queenfish feed mainly on crustaceans, including amphipods, copepods, and mysids, along with polychaetes and fishes (Quast 1968, Hobson and Chess 1976, Hobson et al. 1981, Feder et al. 1974). They are a forage species that is probably consumed by a wide variety of larger piscivorous fishes such as halibut, kelp bass, Pacific bonito, Pacific mackerel, and sharks as well as sea lions and cormorants.

3.3.7.2 Population Trends and Fishery

Queenfish was the most abundant sciaenid impinged at five southern California generating stations from 1977 to 1998, and accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). Annual abundance fluctuated from year to year, with notable declines during the strong El Niño events of 1982–83, 1986–87, and 1997–98. However, abundance remained relatively high throughout the over 20-year study period. Queenfish was also one of the three most abundant species of soft-bottom associated fishes in southern California along with white croaker and northern anchovy during a 1982–1984 trawl study (Love et al. 1986).

There are both recreational and commercial fisheries for queenfish. Recreational fishers landed an average of 311,000 queenfish per year from 2000 through 2004, with the greatest estimated landings of 942,000 (40 metric tons) occurring in 1992 (RecFIN database). No specific landings for queenfish are reported in the commercial landings statistics for San Diego County during the 1995–2005 time period (PacFIN database), although they may be included in other landings groups such as unspecified croakers.

3.3.7.3 Sampling Results

Queenfish larvae were the sixteenth most abundant taxon collected from the entrainment station with an average annual density of 5.5 larvae per 1,000 m^3 (264,172 gal) (**Table 3-5**). They comprised 0.14% of the larvae collected at the entrainment station, 0.07% from the lagoon source water, and 2.18% from the nearshore source water. This species was found in the entrainment samples collected in June, August, September and October with a peak abundance of over 50 larvae per 1,000 m^3 (264,172 gal) during September 2004 (**Figure 3-25**). Queenfish larvae were found at the source water stations during the same period of the year mainly at the nearshore and outer lagoon stations (**Figure 3-26**). The number and density of larval queenfish collected during each entrainment and source water survey is presented in **Appendix E**.

The 29 queenfish larvae in the entrainment samples from all surveys ranged in length from 1.6 to 7.2 mm (0.06 to 0.28 in) with a mean length of 4.0 mm (0.16 in) (**Figure 3-27**). Hatch length of queenfish is approximately 2.9 mm (0.11 in) (Moser 1996).

3.3.7.4 Modeling Results

The following sections present the results for empirical transport modeling of entrainment effects on queenfish larvae. Demographic model estimates of entrainment effects (*FH* and *AEL*) were not calculated because of the absence of information on life history parameters necessary for model calculations. Total annual entrainment at EPS was estimated at 6.7 million using measured cooling water flow and at 7.5 million larvae using maximum cooling water flow for the June 2004 through May 2005 period (**Table 3-6**).

Empirical Transport Model (ETM)

Only 29 queenfish larvae were collected and measured from the entrainment samples. As a result, length frequency data on queenfish from entrainment samples collected for the Huntington Beach Generating Station between September 2003 and August 2004 (MBC and Tenera Environmental 2004) were used in estimating the period that the larvae are exposed to entrainment. The 25^{th} (3.8 mm [0.15 in]) and 95^{th} (7.7 mm [0.3 in]) percentile values from the measurements were used with a larval growth rate for white croaker of 0.20 mm/day (0.008 in/day) from Murdoch et al. (1989b) to estimate that the larvae were exposed to entrainment for a period of approximately 19.4 days. The duration of the planktonic egg stage, 2.2 d, was added to the period for the larvae to estimate a total period of exposure of 21.6 d.

The monthly estimates of proportional entrainment (*PE*) for queenfish for the June 2004 – May 2005 period ranged from 0 to 0.00370 using the actual flows, and from 0 to 0.00608 using the maximum flows during the period (**Table 3-23**). The largest estimate was calculated for the October survey, and the largest proportion of the source population was present during the September survey (f_i = 0.441 or 44.1%). Queenfish larvae were collected from entrainment samples from four of the entrainment surveys and from seven surveys from the source water samples. The values in the table were used to calculate a P_M estimate of 0.009 with a standard error of 0.0055 using the actual flows during the sampling period and an estimate of 0.0102 with a standard error of 0.0062 using the maximum flows.

Table 3-23. *ETM* data for queenfish larvae based on actual and maximum daily cooling water flows. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		Maximum Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0.00029	0.00099	0.00035	0.00119	0.15001
24-Jun-04	0	0	0	0	0.23205
6-Jul-04	0	0	0	0	0.12955
13-Aug-04	0.00190	0.01025	0.00220	0.01185	0.03996
23-Sep-04	0.00064	0.00438	0.00070	0.00472	0.44080
21-Oct-04	0.00370	0.02183	0.00608	0.03561	0.00522
18-Nov-04	0	0	0	0	0
16-Dec-04	0	0	0	0	0
13-Jan-05	0	0	0	0	0
24-Feb-05	0	0	0	0	0
23-Mar-05	0	0	0	0	0
21-Apr-05	0	0	0	0	0.00242
19-May-05	0	0	0	0	0
P_M	**0.0090**		**0.0102**		
Std. Error	0.0055		0.0062		

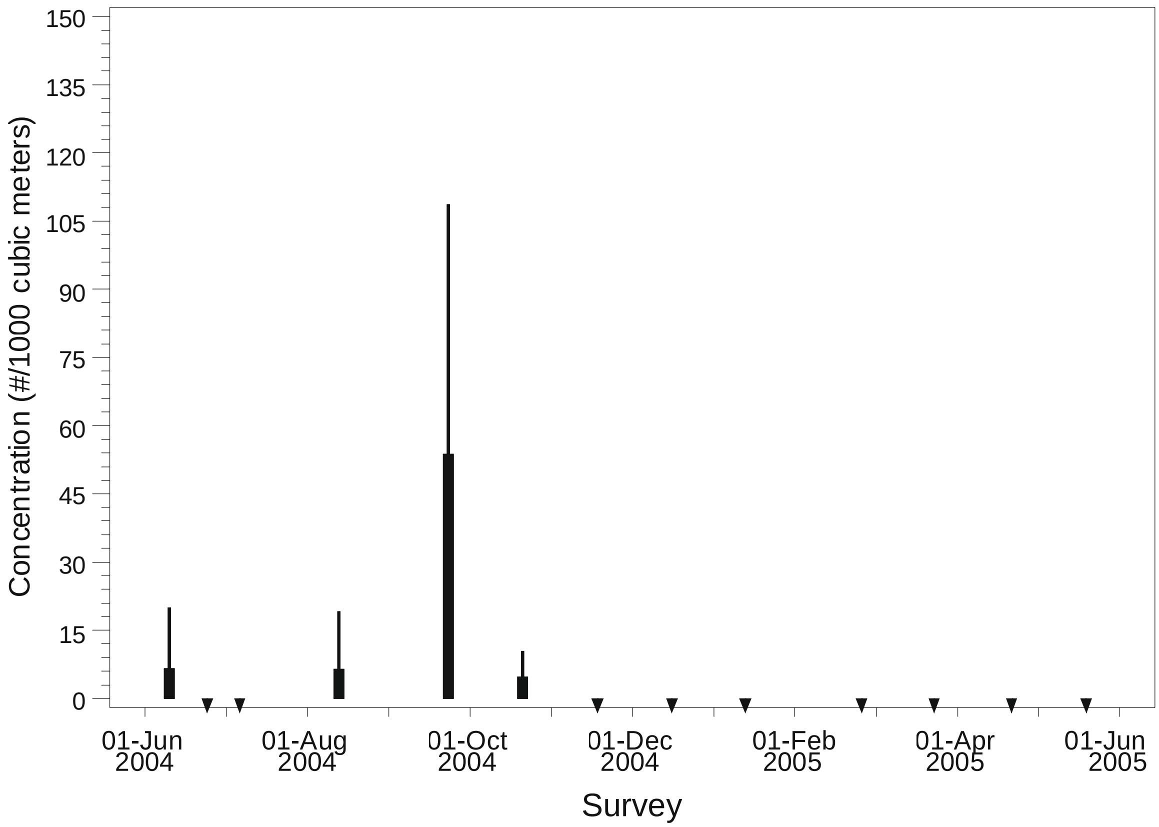


Figure 3-25. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of queenfish larvae at entrainment Station E1.

Note: Downward pointing triangle indicates survey with no larvae collected.

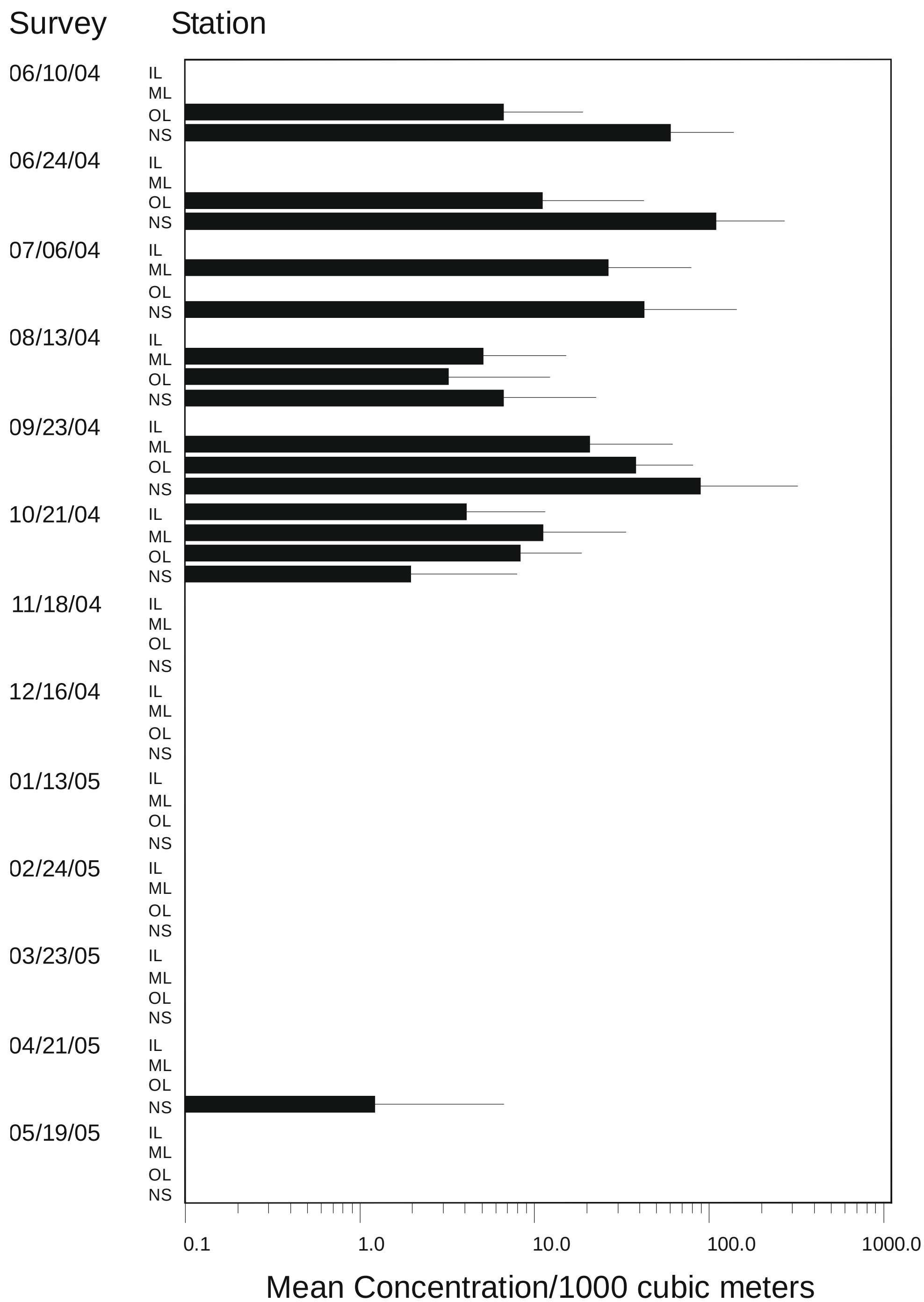


Figure 3-26. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of queenfish larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods.

Note logarithmic abundance scale.

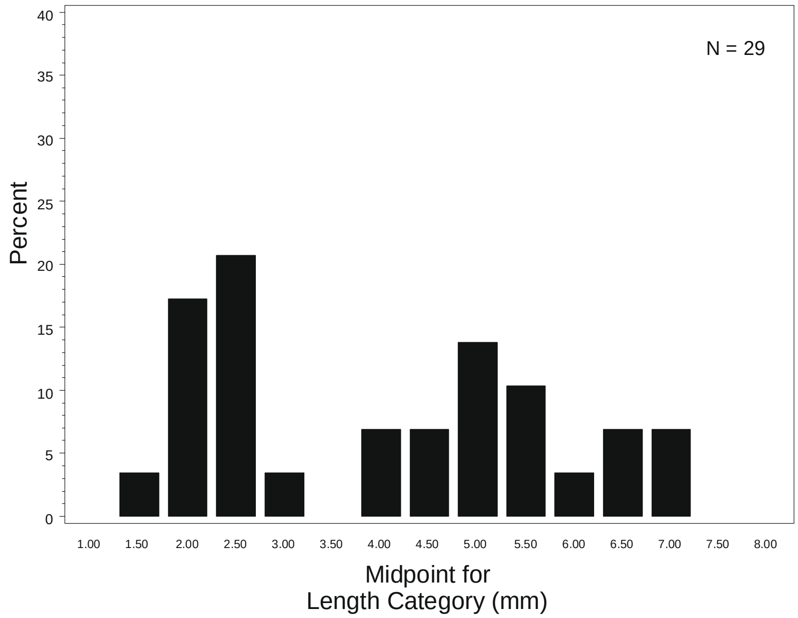


Figure 3-27. Length frequency of queenfish larvae at entrainment Station E1. Data from all surveys in 2004–2005.

3.3.8 Spotfin croaker (*Roncador stearnsii*)

Range: Point Conception, California to Mazatlan, Mexico including the Gulf of California

Life History:

- Size up to 68.6 cm (27 in)
- Size at maturity 23 cm (9 in) at 2 yrs of age for males, and 32 cm (12.6 in) at 3 yrs for females
- Life span to at least 10 years
- Broadcast spawner inshore with peak larval abundances June through September; pelagic eggs

Habitat: Sand bottoms from surf zone to 22 m (73 ft).

Fishery: Sport fishery only in southern California; variable annual catches average approx. 12,000 fish per year.

Spotfin croaker (*Roncador stearnsii*) (Family Sciaenidae) ranges from Mazatlan, Mexico to Point Conception, California, including the Gulf of California and occurs in depths ranging from the surf zone to 17 m (Miller and Lea 1972). Seven species of croaker, in addition to spotfin croaker, are common to the Southern California Bight (SCB). These include white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), yellowfin croaker (*Umbrina roncador*), white seabass (*Atractoscion nobilis*), California corbina (*Menticirrhus undulatus*), black croaker (*Cheilotrema saturnum*), and shortfin corvina (*Cynoscion parvipinnis*) (Miller and Lea 1972). Two other croakers [orangemouth corvina (*Cynoscion xanthulus*) and bairdiella (*Bairdiella icistia*)] are believed to be restricted in California to the Salton Sea.

Pondella and Allen (2000) noted a predominantly coastal distribution throughout the SCB, indicated by an absence in samples from the California Channel Islands. Allen (1985) indicated spotfin croaker to be a common member of the open-coast sandy-beach ichthyofauna, with seasonal occurrences in bays and harbors within the SCB. Love et al. (1984) observed distributions of spotfin croaker in the 6.1 m (20 ft) isobath over soft-substrate, with diminishing abundances with increasing depth. Limbaugh (1955) observed sporadic occurrences of spotfin croaker in the rocky bottom/kelp bed biotope. Valle and Oliphant (2001) noted spotfin croaker prefer depressions in the sandy bottom in water depths greater than 3 m (9.8 ft).

3.3.8.1 Life History and Ecology

Spotfin croaker is an oviparous broadcast spawner with pelagic eggs and larvae (Moser 1996). Gonosomatic index (GSI [gonad weight expressed as percent of whole body weight]) peaked for both sexes in June (Miller et al. in prep b), while peak larval abundances were observed from June to September (Moser 1996). Although usually found in small groups (< 5 individuals), observations have been made of large aggregations (> 50 individuals; Feder et al. 1974). Initially thought to migrate offshore to spawn (Valle and Oliphant 2001), recent observations within the SCB indicate an inshore spawning ground based on seasonal fluctuations in catch per unit effort and GSI (Miller et al. in prep b). Within spawning aggregations, gender ratios were significantly skewed towards males with nearly a 10:1 male to female ratio (Miller et al. in prep b). In groups not exhibiting reproductive activity (high GSI), the gender ratio is nearly 1:1 (Miller et al. in prep b). Valle and Oliphant (2001) estimated males to mature at two years old and 228.5 mm SL (8.9 in), while females mature, on average, in their third year and 317.4 mm SL (12.5 in).

At hatching, spotfin croaker yolk sac larvae are less than 1.9 mm (0.07 in) long, flexion occurs at 5–6 mm (0.19–0.24 in), and transformation at about 13 mm (0.5 in) long (Moser 1996). Miller and Lea (1972) indicate the maximum length for spotfin croaker at 68.6 cm SL (2.7 in). Joseph (1962) estimated the maximum age for spotfin croaker at ten years using scale aging. Spotfin croaker exhibit the greatest growth rate between the first and second years, with a mean increase of 100 mm SL (3.9 in), quickly tapering off to under 30 mm SL (1.2 in) per year after age five (Joseph 1962). No information on variation in growth by gender or mortality estimations is available for spotfin croaker.

Spotfin croaker feeds primarily on benthic invertebrates commonly found in sandy environments, such as clams and polychaetes, but also mysids (Joseph 1962). This species of croaker migrates seasonally as indicated by individuals tagged near Los Angeles, California and subsequently recaptured near Oceanside, California (Valle and Oliphant 2001). California corbina (*Menticirrhus undulatus*), another member of the croaker family, is frequently encountered with spotfin croaker due to the strong similarities in habitat preferences between the two species (Miller et al. in prep b). Within southern California, spotfin croaker populations are historically known to exhibit “runs” (Valle and Oliphant 2001) when they form large aggregations, principally during spawning season (Miller et al. in prep b). Notably absent during the majority of the year near Seal Beach, California, spotfin croaker abundance rises dramatically between April and August, with peaks in abundance typically occurring in June (Miller et al. in prep b).

3.3.8.2 Population Trends and Fishery

Spotfin croaker is the least frequently impinged croaker at coastal generating stations within the SCB (Herbinson et al. 2001). Since 1977, four of the five generating stations built by Southern California Edison within the SCB have reported spotfin croaker in impingement samples (Herbinson et al. 2001). Based on these impingement samples, spotfin croaker populations in southern California have been low since 1983, although their abundance was less than all other croakers, except white seabass (Herbinson et al. 2001). Nearshore gillnet sampling within the SCB has indicated a general rise in abundance, corresponding to a general rise in sea surface temperatures (Miller et al. in prep b).

Spotfin croaker has been reserved for recreational angling within California State waters since 1915, with a ban on the use of nets imposed in 1909 and a ban on commercial sale in 1915 (Valle and Oliphant 2001). Incidental catches were possible in the nearshore gillnet fishery for white seabass, which was closed in 1992 by legislative action. Recreational angling, specifically surf-fishing, continues, as anglers enjoy greater success during periods of dense aggregations, such as spawning periods. There was an average of approximately 12,000 fish caught annually in southern California from 2000 through 2005 based on information from the RecFIN database.

3.3.8.3 Sampling Results

Spotfin croaker larvae had the thirteenth highest mean density of all taxa collected in the entrainment samples for the period of June 2004 through May 2005 with a mean density of 8.3 larvae per 1,000 m^3 (264,172 gal) (**Table 3-5**). It was more abundant in the combined source water samples with a concentration of 20.2 larvae per 1,000 m^3 (**Table 3-7**). Spotfin croaker larvae occurred almost exclusively in summer and early fall surveys and were mostly absent during other times of the year (**Figure 3-28**). They were most abundant in the source water samples at the outer AHL and nearshore stations (**Figure 3-29**). The numbers of larval spotfin croaker collected during each entrainment and source water survey are presented in **Appendix E**.

Most of the spotfin croaker larvae sampled were slightly larger than 2 mm (0.08 in), indicating that they were recently hatched. Moser (1996) reported the hatch length at 2.1 mm (0.08 in). The length frequency distribution of 45 spotfin croaker larvae ranged from a minimum of 1.3 mm (0.05 in) to a maximum of 4.5 mm (0.18 in) with a mean size of 2.2 mm (0.09 in).

3.3.8.4 Modeling Results

The following sections present the results for empirical transport modeling of entrainment effects on spotfin croaker larvae. Demographic model estimates of entrainment effects (*FH* and *AEL*) were not calculated because of the absence of information on life history parameters necessary for model calculations. Total annual entrainment at EPS was estimated to be 9.5 million using measured cooling water flow and 10.7 million larvae using maximum cooling water flow for the June 2004 through May 2005 period (**Table 3-6**).

Empirical Transport Model (ETM)

Only 45 spotfin croaker larvae were collected and measured from the entrainment samples. As a result, length frequency data on queenfish from entrainment samples collected for the Huntington Beach Generating Station between September 2003 and August 2004 (MBC and Tenera Environmental 2004) were used in estimating the period that the larvae are exposed to entrainment. The 25^{th} (1.9 mm [0.075 in]) and 95^{th} (3.8 mm [0.15 in]) percentile values from the measurements were used with a larval growth rate for white croaker of 0.20 mm/day (0.008 in/day) from Murdoch et al. (1989b) to estimate that the larvae were exposed to entrainment for a period of approximately 9.2 days. The duration of the planktonic egg stage, 2.2 d, was added to the period for the larvae to estimate a total period of exposure of 11.4 d.

Spotfin croaker larvae were only present from June through September in the entrainment samples. The monthly estimates of proportional entrainment (*PE*) for the June 2004 – May 2005 period ranged from 0 to 0.00269 using the actual flows and from 0 to 0.00300 using the maximum flows (**Table 3-24**). Spotfin croaker larvae were collected from samples from five of the entrainment surveys and from six surveys from the source water samples. The largest estimates occurred during both the July and September surveys, and the largest proportion of the source population was present during the September survey (f_i = 0.332 or 33.2%). The values in the table were used to calculate a P_M estimate of o.0157 with a standard error of 0.0163 using the actual flows and an estimate of 0.0177 with a standard error of 0.0183 using the maximum flow volumes.

Table 3-24. *ETM* data for spotfin croaker larvae based on actual and maximum daily cooling water flows. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		**Maximum Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0.00011	0.00028	0.00013	0.00033	0.27272
24-Jun-04	0.00012	0.00047	0.00014	0.00058	0.15573
6-Jul-04	0.00247	0.00761	0.00300	0.00915	0.17050
13-Aug-04	0.00064	0.00298	0.00074	0.00344	0.06863
23-Sep-04	0.00269	0.0077	0.00290	0.00831	0.33239
21-Oct-04	0	0	0	0	0
18-Nov-04	0	0	0	0	0
16-Dec-04	0	0	0	0	0
13-Jan-05	0	0	0	0	0
24-Feb-05	0	0	0	0	0
23-Mar-05	0	0	0	0	0
21-Apr-05	0	0	0	0	0.00003
19-May-05	0	0	0	0	0
$\boldsymbol{P_M}$	**0.0157**		**0.0177**		
Std. Error	0.0163		0.0183		

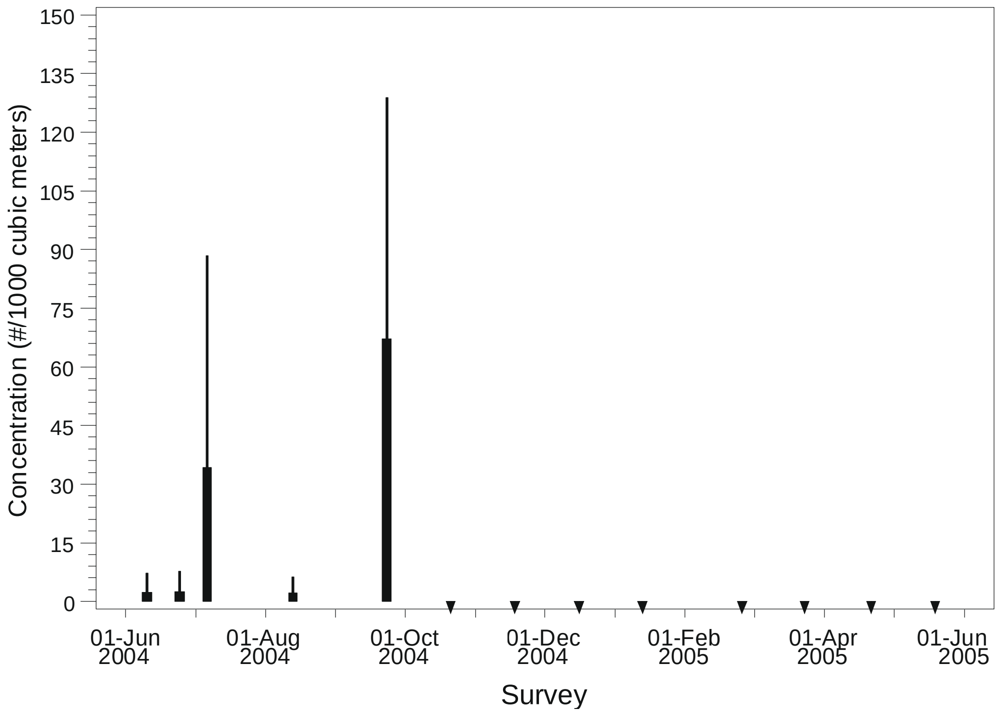


Figure 3-28. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of spotfin croaker larvae at entrainment Station E1.

Note: downward pointing triangle indicates survey with no larvae collected.

Figure 3-29. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of spotfin croaker larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods.

Note logarithmic abundance scale.

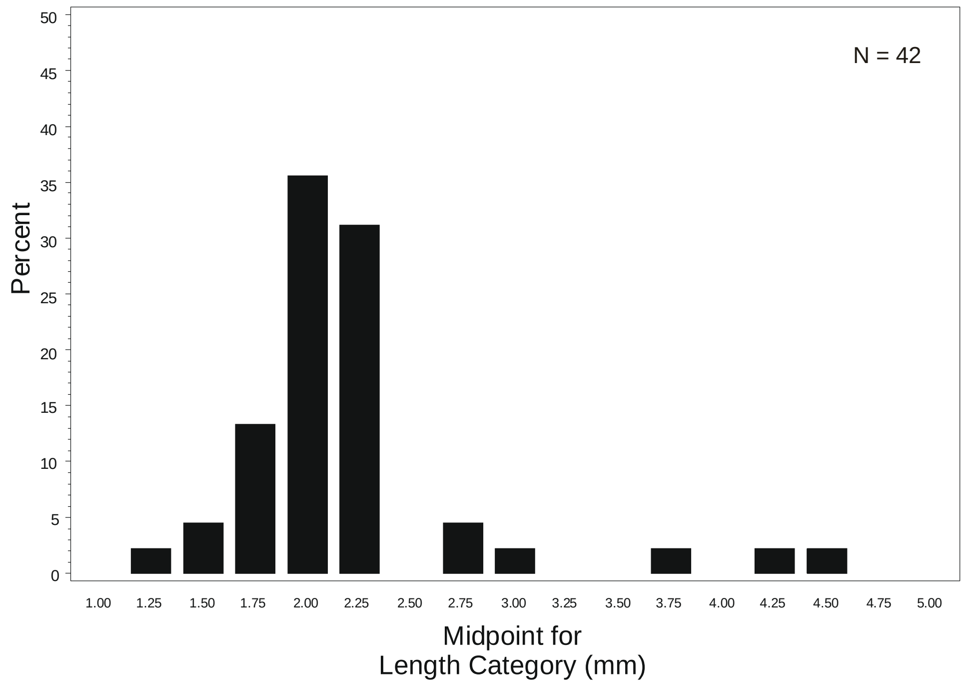


Figure 3-30. Length frequency of spotfin croaker larvae at entrainment Station E1. Data from all surveys in 2004–2005.

3.3.9 California halibut (*Paralichthys californicus*)

Range: northern Washington to southern Baja California

Life History:
- Size up to 152 cm (5 ft)
- Age at first maturity ~2 yr (20 cm TL [7.9 in]) in males and ~3 yr (43 cm TL [16.9 in]) in females
- Life span up to 30 yrs
- Spawns generally February–August in bays and estuaries; pelagic eggs; female spawns multiple times per season and may release from 5–50 million eggs/season

Habitat: Sand bottoms from the surf zone to 281 m (922 ft).

Fishery: Sport and commercial fishery in southern and central California; minimum legal size is 56 cm TL (22 in).

California halibut (*Paralichthys californicus*) is an important part of California's commercial and recreational fisheries (Leet et al. 2001; Starr et al. 1998). It ranges from northern Washington to southern Baja California and is found from very shallow nearshore waters in bay nursery grounds to depths of at least 281 m (922 ft) (Love et al. 2005; Haaker 1975).

3.3.9.1 Life History and Ecology

Juveniles and adults typically occur on sandy sediments at depths less than 30 m (98 ft) but sometimes concentrate near rocks, algae, or Pacific sand dollar (*Dendraster excentricus*) beds (Feder et al. 1974). As with other flatfishes, they frequently lie buried or partially buried in the sediment. Newly settled and juvenile halibut often occur in unvegetated shallow embayments and occasionally on the outer coast, suggesting that bays are an important nursery habitat for this species (Leet et al. 2001).

California halibut is a broadcast spawner with eggs being fertilized externally. The spawning season is generally thought to extend from February to August with most spawning occurring in May (Frey 1971) although some fall spawning may also occur. The average number of eggs per spawn is 313,000–589,000 with an average reproductive output of approximately 5.5 million eggs per spawning season (Caddell et al. 1990). During spawning season females may release eggs every 7 days and the largest individuals may produce in excess of 50 million eggs per year (Caddell et al. 1990). Captive specimens were observed to spawn at least 13 times per season. Halibut eggs are 0.7–0.8 mm (0.027–0.03 in) in diameter (Ahlstrom et al. 1984) and are most abundant in the water column in less than 75 m (246 ft) depths and within 6.5 km (47 miles) from shore (Leet et al. 2001).

Upon hatching, the larvae (1.6–2.1 mm NL [0.06-0.08 in] [Moser 1996]) are pelagic (Frey 1971), and most abundant between Santa Barbara, California, and Punta Eugenia, Baja California Sur (Ahlstrom and Moser 1975) from January through April and June through August (Moser 1996). California halibut have a pelagic larval stage of 20–29 days (Gadomski et al.

1990). Larval transformation occurs at a length of ca. 7.5–9.4 mm SL (0.29-0.37 in) (Moser 1996) at which time the young fish settle to the bottom, generally in bays but also occasionally in shallow substrates along the open coast (Haugen 1990). Kramer (1991) found that 6–10 mm (0.24-0.39 in) California halibut larvae grew <0.3 mm/day (0.11 in/day), while larger 70–120 mm (2.75-4.7 in) halibut grew about 1.0 mm/day (0.04 in/day). In a laboratory study, California halibut held at 16°C (60.8°F) grew to a length of 11.1 mm ± 2.61 (SD) (0.44 in ± 0.1) in 2 mo from an initial hatch length of 1.9 mm (0.075 in) (Gadomski et al. 1990). After settling in the bays, the juveniles may remain there for about 2 years until they emigrate to the outer coast. Males mature at 2–3 years and 20–23 cm SL (7.87-9.05 in); females mature at 4–5 years and 38–43 cm SL (14.96-16.93 in) (Fitch and Lavenberg 1971; Haaker 1975). Males emigrate out of the bays when they mature (i.e. at 20 cm [7.87 in]) but females migrate out as subadults at a length of about 25 cm (9.8 in) (Haugen 1990). Subadults remain nearshore at depths of 6–20 m (19.7-65.6 ft) (Clark 1930; Haaker 1975). California halibut may reach 152 cm (58.9 in) and 33 kg (73 lb) (Eschmeyer et al. 1983). Individuals may live as long as 30 years (Frey 1971).

California halibut feed during both day and night, but show a preference for daytime feeding (Haaker 1975). The species is an ambush feeder, typically lying partially buried in the sand until prey approaches. They prey on Pacific sardine, anchovies, squid, and other nektonic nearshore fish species (Leet et al. 2001). Small halibut in bays eat small crustaceans and become increasingly piscivorous with size. Other similar species of flatfishes such as sand sole and bigmouth sole may compete with California halibut within their range (Haugen 1990). Because of an extensive overlap in diet, habitat, geographic and bathymetric distributions, and probable foraging behavior, the California lizardfish may be the most important potential competitor of medium-sized California halibut (Allen 1982).

3.3.9.2 Population Trends and Fishery

It appears that the size of the California halibut population may be limited by the availability of shallow-water nursery habitat, and a long-term decline in landings corresponds to a decline in these habitats in southern California associated with dredging and filling of bays and wetlands (Leet et al. 2001). A fishery-independent trawl survey for halibut conducted in the early 1990s estimated that the southern California biomass was 3,130 metric tons (3,450 tons) (3.9 million adult fish) and the central California biomass was 1,043 metric tons (1,150 tons) (0.7 million fish).

California halibut have a high commercial and recreational fishery value. The fishery for California halibut was reviewed by Leet et al. (2001) and recent catch statistics are available through the PSMFC PacFIN (commercial) and RecFIN (recreational) databases. Historically, halibut have been commercially harvested by three principal gear types: otter trawl, set gill and trammel net, and hook and line. Presently there are numerous gear, area, and seasonal restrictions that have been imposed on the commercial halibut fishery for management purposes. Since 1980 the commercial catch has averaged approximately one million pounds per year statewide. In southern California (San Diego, Orange and Los Angeles counties) the average annual commercial catch and ex-vessel revenue from California halibut for the years 2000–2004 was approximately 56,000 lb and $202,000 respectively. During this time the greatest catches were in 2000 (82,225 lb) and the least were in 2003 (38,113 lb). PacFIN records indicate that 14.3 MT of halibut worth $106,554 was landed in San Diego County in 2005.

3.3.9.3 Sampling Results

California halibut was the eighteenth most abundant taxon collected from the entrainment station (average concentration of 3.7 larvae per 1,000 m^3 [264,172 gal]; **Table 3-5**) and sixth most abundant at the nearshore source water stations (average concentration of 42.9 larvae per 1,000 m^3; **Table 3-7**). The larvae occurred in low numbers at the entrainment station in all but the late June and early July 2004 surveys (**Figure 3-31**). They were more abundant at the nearshore stations than at the lagoon stations and were mostly absent at the Inner and Middle Lagoon stations (**Figure 3-32**). The numbers of larval California halibut collected during each entrainment and source water survey are presented in **Appendix E**.

The length frequency distribution of nineteen California halibut larvae from the entrainment samples showed a range of small sizes (**Figure 3-33**) dominated by recently hatched larvae, based on the reported hatch length of 1.6–2.1 mm (0.06-0.08 in) (Moser 1996). The mean, maximum, and minimum sizes for the measurements were 2.6, 4.8, and 1.7 mm (0.1, 0.19, and 0.07 in), respectively.

3.3.9.4 Modeling Results

The following sections present the results for demographic and empirical transport modeling of entrainment effects on California halibut larvae. The available information on late larval and post-larval survival rates was insufficient to forecast adult equivalent losses, but enough information was available from the literature to estimate equivalent adult reproductive output using the fecundity hindcasting approach. Total annual entrainment at EPS was estimated at 3.8 million using measured cooling water flows and at 4.9 million larvae using maximum cooling water flows for the June 2004 through May 2005 period (**Table 3-6**).

Fecundity Hindcasting (FH)

The annual entrainment estimate for California halibut larvae was used to estimate the number of breeding females needed to produce this number of larvae. Egg survival for California halibut was 0.50 based on laboratory studies on fertilization success (Gadomski et al. 1990). The mean length for larval California halibut in entrainment samples was 2.1 mm (0.08 in). A larval growth rate of 0.186 mm/d (0.007 in/day) was derived from laboratory growth rates from first feeding larvae to the flexion stage over a period of 21 days (Gadomski and Peterson 1988). Since only 19 larvae were collected in the entrainment samples, length frequency data on California halibut from entrainment samples collected for the Huntington Beach Generating Station between September 2003 and August 2004 (MBC and Tenera Environmental 2004) were used in estimating the age at entrainment. The mean length (2.1 mm [0.08 in]) and the length at the 25th percentile (1.4 mm [0.06 in]) from these data were used with the growth rate (0.186 mm/d [0.007

in/day]) to estimate the mean age at entrainment of 3.5 d. A daily survival rate of 0.96 from Kramer (1991) was used to calculate survival to the average age at entrainment (0.86). A survivorship table was constructed using data from Caddell et al. (1990), MacNair et al. (2001), Hobbs et al. (1990) and Love and Brookes (1990) to estimate a total lifetime fecundity of 2.00 million eggs. Love and Brooks (1990) expressed the proportion of mature females at age *x* years as

$$P_x = \frac{1}{1+e^{-1.52x+6.56}} . \tag{11}$$

Hobbs et al. (1990) used the following relationship for female length in millimeters and weight in grams at age *x*,

$$Length_x = 1440\left[1-e^{(-0.0118x-0.0852)}\right];\ W_L = 7.811\times10^{-5}\,L^{3.048} . \tag{12}$$

Female weight at age was estimated using Equation 12. An annual number of eggs spawned per age *x* female was estimated by multiplying the average of two natural condition spawns in Caddell et al. (1990), i.e. 5,460,000 and 7,657,000, normalized by the weight at age to that of age 6 females. The estimated total lifetime fecundity was the sum of the product of the relative number of females at age, beginning at age 2, estimated using exponential mortality rate of Z=0.68 per year (MacNair et al. 2001), times proportion mature times eggs (**Table 3-25**).

Love and Brookes (1990) report that the age of female maturity is 4.3 years. However, the survivorship table analysis corresponded to age 2.5, the mid-interval of the 2 year olds. The number of California halibut at the age of maturity of 2.5 years whose lifetime reproductive output was entrained through the EPS CWS for the June 2004 through May 2005 period was estimated to be that of four to six females (**Table 3-26**).

Table 3-25. Fecundity and survivorship table for adult female California halibut from data in Caddell et al. (1990), MacNair et al. (2001), Hobbs et al. (1990) and Love and Brookes (1990) showing spawners (L_x) surviving to the beginning of 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 5,000.

Age (yr)	P_x	$Length_x$ (mm)	W_L (g)	L_x	M_x	L_xM_x
2	0.029	396	644	5,000	23,031	115,156,083
3	0.119	512	1,413	2,533	209,415	530,466,656
4	0.382	615	2,475	1,283	1,176,078	1,509,265,847
5	0.739	707	3,782	650	3,473,609	2,258,344,248
6	0.928	789	5,275	329	6,087,878	2,005,187,394
7	0.983	861	6,897	167	8,432,714	1,407,136,170
8	0.996	925	8,594	85	10,645,763	899,964,365
9	0.999	983	10,320	43	12,820,398	549,072,613
10	1.000	1,034	12,037	22	14,962,658	324,651,024
11	1.000	1,079	13,716	11	17,051,287	187,432,517
12	1.000	1,119	15,333	6	19,062,907	106,158,961
13	1.000	1,155	16,874	3	20,978,956	59,187,658
14	1.000	1,187	18,328	1	22,786,689	32,569,288
15	1.000	1,215	19,689	1	24,478,549	17,725,254
					TLF =	**2,000,464**

Table 3-26. Results of *FH* modeling for California halibut larvae based on a) actual flows and b) maximum flows. 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
a) Actual Flows					
FH Estimate	**4**	4	1	18	17
Total Entrainment	3,752,551	223,985	4	5	1
b) Maximum Flows					
FH Estimate	**6**	5	1	24	23
Total Entrainment	4,879,725	263,926	5	6	1

Empirical Transport Model (*ETM*)

Only 19 California halibut larvae were collected and measured from the entrainment samples. As a result, length frequency data on halibut from entrainment samples collected for the Huntington Beach Generating Station between September 2003 and August 2004 (MBC and Tenera Environmental 2004) were used in estimating the period that the larvae are exposed to entrainment. The 25th (1.4 mm [0.06 in]) and 95th (6.8 mm [0.27 in]) percentile values from the measurements were used with a larval growth rate of 0.186 mm/day (0.007 in) from Gadomski and Peterson (1988) to estimate that the larvae were exposed to entrainment for a period of approximately 28.9 days. The planktonic egg stage of 2.2 d was added to this value for a total period of exposure to entrainment of 31.1 d.

Although California halibut larvae were present in the source water during all of the surveys they were not collected at the entrainment station during two of the surveys. The monthly estimates of proportional entrainment (*PE*) for the June 2004 – May 2005 period ranged from 0 to 0.0107 using the actual flows and from 0 to 0.00188 using the maximum flows (**Table 3-27**). The largest estimate occurred during the January survey, and the largest proportion of the source population was present during the September survey (f_i = 0.362 or 36.2%). The values in the table were used to calculate a P_M estimate of 0.0032 with a standard error of 0.0023 using the actual flows during the sampling period and an estimate of 0.0042 with a standard error of 0.003 based on the maximum flows.

Table 3-27. *ETM* data for California halibut larvae based on actual and maximum daily cooling water volumes. The *PE* estimates incorporate all three components of the source water shown in Equation 7.

	Actual Flows		Maximum Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
10-Jun-04	0.00013	0.00065	0.00016	0.00079	0.03876
24-Jun-04	0	0	0	0	0.03912
6-Jul-04	0	0	0	0	0.25640
13-Aug-04	0.00009	0.00069	0.00010	0.00080	0.08947
23-Sep-04	0.00008	0.00069	0.00009	0.00075	0.36188
21-Oct-04	0.00020	0.00146	0.00033	0.00236	0.04843
18-Nov-04	0.00015	0.00170	0.00024	0.00265	0.01426
16-Dec-04	0.00062	0.01013	0.00077	0.01241	0.00498
13-Jan-05	0.00107	0.00608	0.00188	0.01038	0.00915
24-Feb-05	0.00020	0.00156	0.00033	0.00256	0.04461
23-Mar-05	0.00005	0.00046	0.00008	0.00067	0.06386
21-Apr-05	0.00100	0.00550	0.00117	0.00645	0.01923
19-May-05	0.00054	0.00421	0.00072	0.00567	0.00985
$\boldsymbol{P_M}$	**0.0032**		**0.0042**		
Std. Error	0.0023		0.0030		

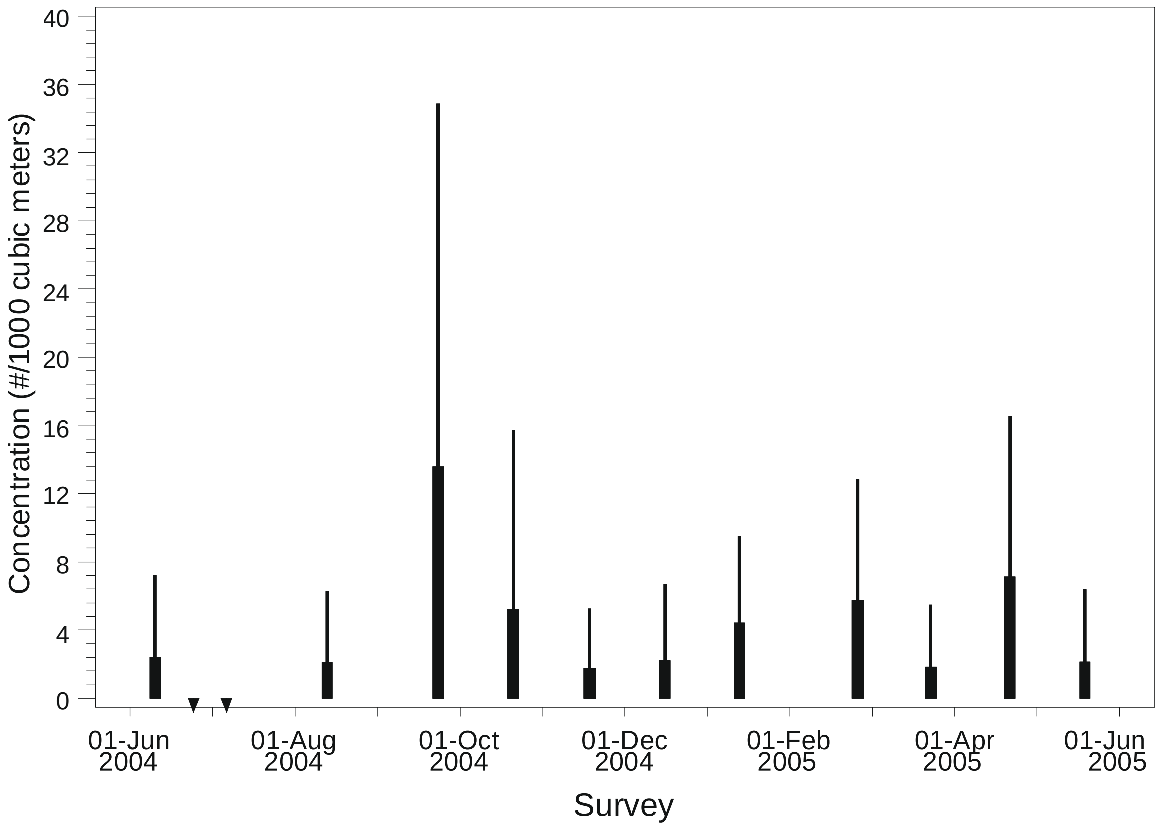


Figure 3-31. Comparison among surveys of mean concentration (#/1,000 m^3 [264,172 gal]) of California halibut larvae at entrainment Station E1.

Note: Downward pointing triangle indicates survey with no larvae collected.

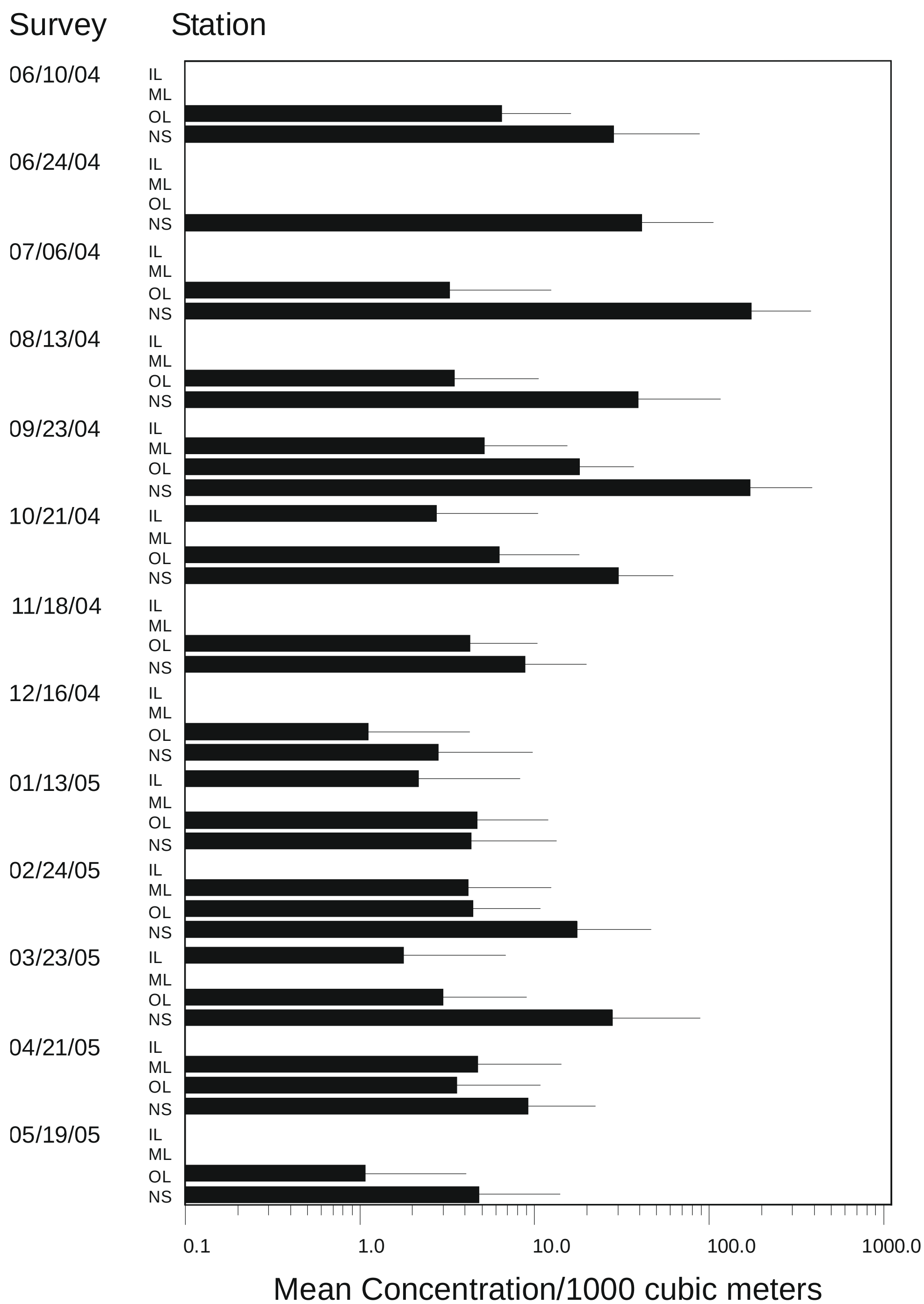


Figure 3-32. Mean concentration (#/1,000 m^3 [264,172 gal]) and standard error of California halibut larvae at Agua Hedionda Lagoon (inner, middle, and outer) and nearshore source water stations during the 2004 and 2005 sampling periods.

Note logarithmic abundance scale.

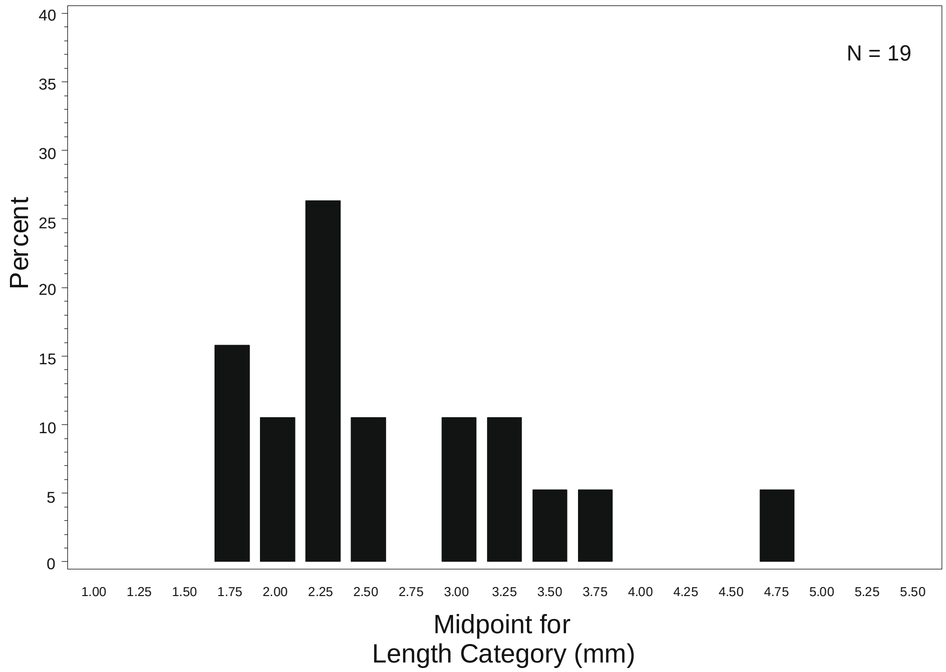


Figure 3-33. Length frequency of California halibut larvae at entrainment Station E1. Data from sub-samples of all surveys in 2004–2005.

4.0 Impingement Study Results

4.1 Introduction

The purpose of the EPS impingement study was to evaluate the potential impacts of the operation of the cooling water intake structure as required under Section 316(b) of the CWA (USEPA 1977). The SDRWQCB reviewed the need for and design of the studies with representatives of Cabrillo Power, Tenera Environmental, U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game (CDFG), and other agencies. The group reviewed and approved the final 316(b) Cooling Water Intake Effects Entrainment and Impingement Sampling Plan (**Appendix A**).

The impingement study was designed to specifically address the following questions:

- What are the species composition and abundance of the juvenile and adult fishes and shellfishes impinged by EPS?
- What are the potential impacts of impingement losses on populations of fishes and shellfishes due to operation of the CWIS?

An earlier study of impingement of fishes and invertebrates was conducted from February 4, 1979 to January 4, 1980 (SDG&E 1980). Each 24-hour period was divided into two 12-hour periods, roughly separated into a daylight and nighttime sample. All material impinged during the two 12-hour periods was rinsed from the traveling screens and collected in ¼ inch mesh liners that had been placed in the metal collection baskets. The fishes and invertebrates were removed from the impinged debris and then identified, counted, and measured. All the data from each 12-hour period was recorded separately. Organisms impinged on the bar racks were processed in the same manner at the end of the entire 24-hour period. During this study a total of 76 taxa of fishes and 45 taxa of macro-invertebrates totaling 85,943 individuals and weighing 1,548 kg (3,414 lb) was impinged during the surveys conducted during normal operations. Of this material, about 90% of the weight was from fishes and 10% from invertebrates. The numerically most abundant fishes impinged during normal operations surveys were queenfish, deepbody anchovies, topsmelt, California grunion, northern anchovy, and shiner surfperch (**Table 4-1**). These six species comprised about 82% of all the individuals collected, but only about 47% of the overall weight of the collected fishes. The most abundant shellfishes were rock crabs, swimming crabs, striped shore crabs, and squid.

Sampling was also conducted during the seven heat treatment events that occurred during this same approximate 12-month period. During the heat treatments the heated discharge water is diverted back through the CWS to kill all organisms that are growing on the conduits. All fishes and invertebrates that are living in the water within this area are killed and end up as impinged organisms. A record was also made of the identity, number, and measurement of all fishes and shellfishes impinged during these heat treatments using the sample procedures used during the normal operation surveys. A total of 108,102 fishes weighing 2,422 kg (5,341 lb) was collected during these seven heat treatments. The most abundant fishes collected during heat treatment surveys were deepbody anchovy, topsmelt, northern anchovy, shiner surfperch, California grunion, and walleye surfperch. These six species comprised about 88% of all the fishes collected during the heat treatments. The most abundant shellfishes found were unidentified crabs, striped shore crabs, and rock crabs.

Table 4-1. Number and weight (grams) of the 'critical fish species' collected during normal operations and seven heat treatment surveys at EPS, February 1979 – January 1980 (from SDG&E 1980).

		Normal Operations		Heat Treatments	
Species	**Common Name**	**# Impinged**	**Weight impinged (g)**	**# Impinged**	**Weight impinged (g)**
Seriphus politus	queenfish	18,681	91,314	3,485	96,320
Anchoa compressa	deepbody anchovy	13,299	64,323	23,142	182,179
Atherinops affinis	topsmelt	10,915	112,340	21,788	166,058
Leuresthes tenuis	California grunion	8,583	33,770	9,671	81,708
Engraulis mordax	northern anchovy	7,434	14,573	19,567	93,981
Cymatogaster aggregata	shiner surfperch	6,545	53,258	12,326	275,549
Hyperprosopon argenteum	walleye surfperch	1,877	50,405	8,305	522,797
Anchoa delicatissima	slough anchovy	1,758	4,106	464	1,405
Phanerodon furcatus	white surfperch	1,751	16,991	604	8,609
Urolophus halleri	round stingray	1,626	185,896	1,685	404,237
Paralichthys californicus	California halibut	1,215	57,128	329	52,995
Heterostichus rostratus	giant kelpfish	1,046	14,912	1,421	36,212
Xenistius californiensis	salema	538	2,244	161	1,389
Paralabrax nebulifer	barred sand bass	189	15,309	518	26,724
Menticirrhus undulatus	California corbina	117	9,263	29	4,634
Amphistichus argenteus	barred surfperch	83	1,853	166	15,946
Mugil cephalus	striped mullet	73	44,730	10	5,593
Paralabrax maculatofasciatus	spotted sand bass	73	10,857	616	87,360
Paralabrax clathratus	kelp bass	34	502	568	38,505
Cynoscion nobilis	white seabass	25	226	13	833
Citharichthys sordidus	Pacific sanddab	-	-	-	-
Semicossyphus pulchra	California sheephead	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	-	-	-	-
	Total Above Fishes	**75,862**	**784,000**	**104,868**	**2,103,034**
	Total Other Fishes	3,800	611,200	3,610	322,517
	Total Invertebrates	6,281	153,200	1,682	49,884*

* - only includes weights of counted invertebrates from Table 7-12.1

The total abundance and weight of the 22 'critical fish species' impinged during the seven heat treatment surveys was higher than the total during the normal operation surveys (**Table 4-1**). These 22 species comprised the majority of the numbers of fishes collected during both normal operations and heat treatments. The weight of the 'critical fish species' collected during normal operations was only slightly higher than the overall weight of the other fish species during those surveys. The majority of the weight of impinged fishes during heat treatments was due to the 'critical fish species' group. The total number and weight of the shellfishes was generally much less than that of the fishes during both normal operations and heat treatments.

4.2 Methods

The following sections provide information on impingement sample collection and field processing done from June 2004 through June 2005, and also on methods used to assess impingement impacts. The impingement sampling program was designed to provide current estimates of the abundance, taxonomic composition, diel periodicity, and seasonality of organisms impinged at EPS. This was accomplished by calculating the rates (i.e., number or biomass of organisms per cubic meter of water flowing per time into the plant) at which various species of fishes and selected shellfishes (crab, shrimp, lobster, squid, octopus, etc.) were impinged. Impingement rates are subject to tidal and seasonal influences that vary on several temporal scales (e.g., hourly, daily, and monthly) while the rate of circulating water flow varies with power plant operations.

4.2.1 Sampling

The EPS has one intake structure that withdraws water from the Agua Hedionda Lagoon. Seawater entering the CWS passes through metal trash racks (bar racks) on the intake structure. Behind the trash racks, the intake tapers into two and then four tunnels (**Figure 2-3**), which provide cooling water for five steam-generating units (Units 1–5). The seawater then goes through vertical traveling screens. Units 1–4 each have two traveling screens with a mesh size of 0.95 cm (⅜ in), and Unit 5 has three screens with a mesh size of 1.6 cm (⅝ in).

All material that passed through the bar racks but was larger than the traveling screen mesh was impinged and was subsequently rinsed from the screens when the screens were rotated for cleaning. A high-pressure wash system (70-100 psi) located at the head of the screens was used to wash the material into a sluiceway that emptied into metal collection baskets, where the material accumulated until disposal. The traveling screens were operated either manually or automatically when a specified pressure differential was detected across the screens due to the accumulation of debris.

Impingement sampling at EPS was conducted during a 24-hr period one day each week from June 24, 2004 through June 15, 2005. Each sampling period was divided into six approximately 4-hr cycles. Before each weekly sampling effort, all of the screens were rotated and rinsed clean of any impinged material. Nets (0.5 cm (¼ in) mesh size) were placed into each metal basket during impingement sampling for ease of collection of impinged material.

During each cycle the traveling screens remained stationary for a period of approximately 3.5 hr. Screens for Units 1–4 were rotated and rinsed for 35 minutes and screens for Unit 5 were rotated and rinsed for 30 min (approximate time for one complete revolution of the screens). This rinse period allowed the entire traveling screen to be rinsed of all material that had been impinged since the last screen wash cycle. In a few instances during impingement collections, the screen wash system started automatically due to a high differential pressure prior to the end of the cycle. The material that was rinsed from the screens during the automatic screen washes was combined with the material collected at the end of that cycle. All debris and organisms rinsed from each set of traveling screens were kept separate.

All fishes and selected shellfishes collected at the end of each 4-hr cycle were removed from the debris and then identified and counted. Individual weights and lengths of bony fishes, sharks and rays were recorded (standard length [SL] for the bony fishes, total length [TL] for the sharks, and disc width [DW] for the rays). Any mutilated fishes were identified if possible, and the total weight recorded by taxa. No length measurements were recorded for mutilated fishes. Carapace width was measured for crabs, total length was measured for shrimps and mantle length was measured for cephalopod mollusks. Weight was also recorded for these shellfishes. Other macroinvertebrates, including hydroids, anemones, sea jellies, barnacles, worms, brittlestars, bryozoans, tunicates, gastropods, and bivalves, were not enumerated or weighed but were only recorded as present when found in the impinged material.

During periods when many fishes or shellfishes were impinged during a single cycle, a maximum of 50 individuals of any one taxa from each traveling screen set were measured and weighed. All lengths were recorded to the nearest 0.1 mm and all weights to the nearest 0.1 g. The condition (alive, dead, or mutilated) of the organisms and the amount and type of impinged debris was also recorded. In addition, the operating status of the circulating water pumps and traveling screens was also recorded. All data were recorded on sequentially numbered data sheets, verified, and subsequently entered into a computer database (MS Access™).

Impingement sampling was also conducted during heat treatment operations. Procedures for heat treatment involved clearing and rinsing the traveling screens prior to the start of the heat treatment procedure. At the end of the heat treatment procedure, normal pump operation was resumed and the traveling screens were rinsed until no more fish were collected on the screens or live fish were found amongst the debris collected. Processing of the samples followed the same procedures used for normal impingement sampling. Six heat treatments were performed and sampled during the one-year study.

A quality control (QC) program was implemented to ensure the correct identification; enumeration, length, and weight measurements of the organisms were recorded on the data sheet. QC surveys were conducted on regular impingement sampling quarterly and one heat treatment was selected for a QC survey. Two cycles were randomly chosen for QC re-sorts to verify that all the collected organisms were removed from the impinged material and processed correctly.

A log containing hourly observations of the operating status (on or off) of the ten circulating water pumps for the entire study period was obtained from the power plant's operation staff. This provided a record of the volume of circulating water pumped through the plant, which was used to calculate impingement rates.

4.2.2 Data Analysis

To estimate taxa-specific impingement rates, the cooling water flow during each of the six cycles of the 24-hr survey was first calculated. The total time for each cycle (generally 4 hr) was multiplied by the manufacturer's rated flow of each of the pumps that had operated during the cycle. Each unit has two circulating water pumps with the following flow rates: Units 1, 2, and 3 pumps–90.9 m^3/min/pump (24,000 gpm), Unit 4 pumps–378.5 m^3/min/pump (100,000 gpm) and Unit 5 pumps–393.7 m^3/min/pump (104,000 gpm). In addition each unit has one service water pump except for Unit 3, which has two service pumps. The service pumps have the following flow rates: Units 1, 2, and 3 pumps–11.4 m^3/min/pump (3,000 gpm), Unit 4 pump–49.2 m^3/min/pump (13,000 gpm) and Unit 5 pump–68.9 m^3/min/pump (18,200 gpm). During periods when the units were undergoing maintenance and not operational during sampling, water flows for those pumps were not added into the total for that cycle as impinged organisms were not collected from those units. The cooling water flow rate for each cycle (obtained from the plant's operator pump logs showing which pumps were operating and manufacturer's rated flow for each operating pump) was then used to calculate an average daily impingement rate and associated standard error per volume of cooling water for each taxa for the three sets of traveling screens (Units 1–5). **Figure 2-7** presents the pump flow volume during the study period. Although many of the impinged fishes were juveniles, for analysis purposes it was assumed that they were all adults and that none of the impinged organisms survived.

An adjustment was made to the total weight of each taxa to compensate for any mutilated fishes that were collected and not weighed. The average weight of non-mutilated individuals of a given taxa collected in each cycle was assigned to any mutilated individuals in that cycle. This adjusted weight was then used in all biomass calculations.

The estimated daily impingement rate was used to calculate estimated weekly, monthly, and annual impingement. The days between the impingement collections were assigned to a weekly survey period by setting the collection day as the median day within the period and assigning the days on either side of the collection date to the closest adjacent sampling day to create a weekly survey period. In most cases, the weekly survey periods were 7 d, but in a few instances the survey period varied from 5-9 d in length. The total calculated flow for each weekly survey period was multiplied by the taxon-specific impingement rate calculated from the daily sampling to obtain estimates of the weekly impingement rates of both counts and biomass for each taxon. Finally, the estimated abundance and biomass impingement rate for each survey period was summed to determine monthly and annual estimates of impingement for each taxon for the yearlong study period. In addition, the maximum flow rate, assuming all pumps were operating continuously, was used to calculate the maximum possible, or "worst-case scenario" impingement rates.

Organisms collected on the bar racks were added to the total number and biomass of organisms impinged for each survey, but were not included in the impingement rate calculations. Data collected during heat treatment operations was summed for each heat treatment survey. This data was kept independent of the normal impingement data and is presented separately.

Data for all impinged taxa are presented in this report, but a subset of the taxa was selected for more detailed analysis. This included fishes that comprised the top 90% of the total abundance and biomass impinged during normal impingement sampling plus any taxon that was commercially or recreationally important and in the top 95% of the total abundance or biomass. The impinged commercially or recreationally important shellfishes that were in the top 90% of the total abundance or biomass are also discussed in more detail in the following sections.

4.3 Fish Impingement Results

4.3.1 Fish Community Overview

A total of 19,408 fishes representing 96 taxa was collected during normal operation impingement sampling at the EPS traveling screens during the 52 weekly surveys from June 24, 2004 through June 15, 2005 (**Table 4-2** and **Appendix G**). These fishes had a combined weight of 351.7 kg (775.3 lb). The greatest fish impingement rate (both in numbers and biomass) was seen during the January and February 2005 surveys (**Figure 4-1)**. Impingement of all fishes was generally higher during nighttime cycles (Cycles 4-5, 8pm – 4am) than the daytime cycles (Cycles 1–2, 0800– 1600 hrs) (**Figures 4-2** and **4-3**). There was also a total of 34 fishes weighing 22.2 kg (48.4 lb) collected from the bar racks during the 52 surveys. During the six heat treatments completed from June 2004 through June 2005, a total of 94,991 fishes (71 taxa) weighing 2,035 kg (4,486 lb) was collected. The July 2004 and June 2005 heat treatments had the greatest number of fishes but the largest weight of fishes was seen during the February and June 2005 heat treatments (**Figures 4-4**).

The numerically most abundant fishes collected during the normal operations impingement sampling included topsmelt, shiner surfperch, deepbody anchovy, queenfish, salema, and slough anchovy (**Table 4-2**). These six species comprised about 70% of all the fishes impinged during normal operations. The fish taxa with the greatest weight impinged during normal operations were California butterfly ray, topsmelt, shiner surfperch, speckled midshipmen, walleye surfperch, and round stingray. The numerically most abundant fishes collected during the heat treatment sampling included deepbody anchovy, shiner surfperch, topsmelt, California grunion, Pacific sardine, and jacksmelt. These six species comprised about 80% of the total number of fishes collected during the heat treatment surveys. The fishes with the greatest weight impinged during the heat treatments were white seabass, round stingray, deepbody anchovy, shiner surfperch, walleye surfperch, and spotted sand bass (**Table 4-2**).

The survey information was combined with the circulating water pump (CWP) data to generate annual impingement estimates. **Table 4-3** presents the estimated abundance and weight of the fishes and shellfishes annually impinged during normal operations at the traveling screens and bar racks based on maximum flow and reported flow recorded at EPS during the impingement survey days. As the plant did not operate all the CWPs every hour during the year, the estimated number of organisms impinged during maximum flows was greater than during reported flows.

The annual estimated number and weight of impinged fishes and shellfishes collected during normal operations (traveling screens and bar racks) and heat treatments were combined and are presented in **Table 4-4**. The top eight most abundant fish taxa based on the overall estimated numbers impinged at maximum CWS flow were topsmelt, shiner surfperch, deepbody anchovy, queenfish, unidentified silversides, slough anchovy, salema, and California grunion. These taxa comprised about 75% of the estimated number that would be impinged if all the pumps were run every hour of every day for a year. The fishes with the highest weight estimated to be impinged with full CWS flow for an entire year were California butterfly ray, topsmelt, shiner surfperch, round stingray, white seabass, walleye surfperch, deepbody anchovy, and speckled midshipman. They comprised about 64% of the total weight estimated to have been impinged if the plant had sustained maximum flow of all pumps for an entire year.

The fishes that were ranked in the top 90th percentile by abundance and biomass were identified. The fishes that were ranked in high abundance in both abundance and biomass, and the taxa that were commercially or recreationally important were selected for detailed evaluation of impingement effects. This resulted in the selection of the nine following taxa:

- anchovies (primarily two *Anchoa* species)
- silversides (Atherinopsidae)
- shiner surfperch (*Cymatogaster aggregata*)
- queenfish (*Seriphus politus*)
- walleye surfperch (*Hyperprosopon argenteum*)
- sand basses (*Paralabrax maculatofasciatus* and *P. nebulifer*)
- Pacific sardine (*Sardinops sagax*)
- spotfin croaker (*Roncador stearnsii*)
- white seabass (*Atractoscion nobilis*)

Table 4-2. Number and weight of fishes, sharks, and rays impinged during normal operation and heat treatment surveys at EPS from June 2004 to June 2005.

			Normal Operations Sample Totals				Heat Treatment	
	Taxon	Common Name	Sample Count	Sample Weight (g)	Bar Rack Count	Bar Rack Weight (g)	Sample Count	Sample Weight (g)
1	*Atherinops affinis*	topsmelt	5,242	42,299	10	262	15,696	67,497
2	*Cymatogaster aggregata*	shiner surfperch	2,827	28,374	-	-	18,361	196,568
3	*Anchoa compressa*	deepbody anchovy	2,079	11,606	2	21	23,356	254,266
4	*Seriphus politus*	queenfish	1,304	7,499	2	17	929	21,390
5	*Xenistius californiensis*	salema	1,061	2,390	-	-	1,577	6,154
6	*Anchoa delicatissima*	slough anchovy	1,056	3,144	-	-	7	10
7	Atherinopsidae	silverside	999	4,454	-	-	2,105	8,661
8	*Hyperprosopon argenteum*	walleye surfperch	605	23,962	1	21	2,547	125,434
9	*Engraulis mordax*	northern anchovy	537	786	-	-	92	374
10	*Leuresthes tenuis*	California grunion	489	2,280	-	-	7,067	40,849
11	*Heterostichus rostratus*	giant kelpfish	344	2,612	-	-	908	9,088
12	*Paralabrax maculatofasciatus*	spotted sand bass	303	4,604	-	-	1,536	107,563
13	*Sardinops sagax*	Pacific sardine	268	1,480	-	-	6,578	26,266
14	*Roncador stearnsii*	spotfin croaker	182	8,354	2	3,000	106	17,160
15	*Paralabrax nebulifer*	barred sand bass	151	1,541	-	-	1,993	32,759
16	*Gymnura marmorata*	Calif. butterfly ray	146	60,629	1	390	70	36,821
17	*Phanerodon furcatus*	white surfperch	144	4,686	-	-	53	823
18	*Strongylura exilis*	California needlefish	135	6,025	-	-	158	11,899
19	*Paralabrax clathratus*	kelp bass	111	680	-	-	976	13,279
20	*Porichthys myriaster*	specklefin midshipman	103	28,189	-	-	218	66,860
21	unidentified chub	unidentified chub	96	877	-	-	7	44
22	*Paralichthys californicus*	California halibut	95	1,729	-	-	21	4,769
23	*Anisotremus davidsoni*	sargo	94	1,662	-	-	963	68,528
24	*Urolophus halleri*	round stingray	79	20,589	-	-	1,090	300,793
25	*Atractoscion nobilis*	white seabass	70	11,295	6	872	1,618	332,056
26	*Hypsopsetta guttulata*	diamond turbot	66	10,679	1	85	112	24,384
27	*Micrometrus minimus*	dwarf surfperch	57	562	-	-	-	-
28	*Syngnathus spp.*	pipefishes	55	161	-	-	56	90
29	*Atherinopsis californiensis*	jacksmelt	54	1,152	-	-	4,468	45,152
30	*Myliobatis californica*	bat ray	50	19,899	4	5,965	132	68,572
31	*Menticirrhus undulatus*	California corbina	43	1,906	-	-	16	4,925
32	*Amphistichus argenteus*	barred surfperch	43	1,306	-	-	34	2,528
33	*Fundulus parvipinnis*	California killifish	43	299	-	-	16	41
34	unidentified fish, damaged	unid. damaged fish	36	1,060	1	70	8	262
35	Ictaluridae	catfish unid.	35	4,279	-	-	-	-
36	*Leptocottus armatus*	Pacific staghorn sculpin	32	280	-	-	5	26
37	*Sphyraena argentea*	California barracuda	29	397	-	-	46	1,667
38	*Lepomis cyanellus*	green sunfish	29	1,170	-	-	-	-
39	*Umbrina roncador*	yellowfin croaker	28	573	-	-	127	22,399
40	*Lepomis macrochirus*	bluegill	20	670	-	-	-	-
41	*Ophichthus zophochir*	yellow snake eel	18	5,349	-	-	51	17,303
42	*Citharichthys stigmaeus*	speckled sanddab	17	62	-	-	1	30
43	*Brachyistius frenatus*	kelp surfperch	16	182	-	-	17	598
44	*Cheilotrema saturnum*	black croaker	15	103	-	-	288	9,029
45	*Embiotoca jacksoni*	black surfperch	14	1,240	-	-	69	5,367
46	*Genyonemus lineatus*	white croaker	12	171	-	-	9	79

(table continued)

Table 4-2 (continued). Number and weight of fishes, sharks, and rays impinged during normal operation and heat treatment surveys at EPS from June 2004 to June 2005.

			Normal Operations Sample Totals				Heat Treatment	
	Taxon	**Common Name**	**Sample Count**	**Sample Weight (g)**	**Bar Rack Count**	**Bar Rack Weight (g)**	**Sample Count**	**Sample Weight (g)**
47	*Platyrhinoidis triseriata*	thornback	11	4,731	1	1,500	-	-
48	*Chromis punctipinnis*	blacksmith	10	396	-	-	151	4,431
49	unidentified fish	unidentified fish	10	811	-	-	-	-
50	*Porichthys notatus*	plainfin midshipman	9	1,792	-	-	-	-
51	*Hermosilla azurea*	zebra perch	9	1,097	-	-	62	3,518
52	*Micropterus salmoides*	large mouth bass	9	27	-	-	-	-
53	*Trachurus symmetricus*	jack mackerel	7	7	-	-	15	702
54	*Hypsoblennius gentilis*	bay blenny	7	37	-	-	440	2,814
55	*Heterostichus* spp.	kelpfish	7	48	-	-	-	-
56	Engraulidae	anchovies	6	3	-	-	-	-
57	*Anchoa* spp.	anchovy	6	27	-	-	-	-
58	*Peprilus simillimus*	Pacific butterfish	5	91	-	-	1	33
59	*Rhacochilus vacca*	pile surfperch	4	915	-	-	-	-
60	*Sebastes atrovirens*	kelp rockfish	4	40	-	-	-	-
61	*Pleuronichthys verticalis*	hornyhead turbot	4	190	-	-	2	251
62	*Pylodictis olivaris*	flathead catfish	4	480	-	-	-	-
63	Pleuronectiformes unid.	flatfishes	4	62	-	-	-	-
64	*Syngnathus leptorhynchus*	bay pipefish	3	9	-	-	-	-
65	*Hypsoblennius gilberti*	rockpool blenny	3	16	-	-	8	77
66	*Mustelus californicus*	gray smoothhound	3	1,850	-	-	22	19,876
67	*Cheilopogon pinnatibarbatus*	smallhead flyingfish	3	604	-	-	-	-
68	*Ameiurus natalis*	yellow bullhead	3	220	-	-	-	-
69	*Lepomis* spp.	sunfishes	3	196	-	-	-	-
70	*Girella nigricans*	opaleye	2	346	-	-	355	30,824
71	*Rhinobatos productus*	shovelnose guitarfish	2	461	2	6,200	-	-
72	*Acanthogobius flavimanus*	yellowfin goby	2	55	-	-	-	-
73	*Scomber japonicus*	Pacific mackerel	2	10	-	-	15	880
74	*Hypsoblennius* spp.	blennies	2	11	-	-	113	489
75	*Hypsoblennius jenkinsi*	mussel blenny	2	17	-	-	175	946
76	*Paralabrax* spp.	sand bass	2	2	-	-	6	19
77	*Scorpaena guttata*	Calif. scorpionfish	2	76	-	-	-	-
78	*Hyporhamphus rosae*	California halfbeak	2	23	-	-	1	-
79	*Symphurus atricaudus*	California tonguefish	2	15	-	-	-	-
80	*Tilapia* spp.	tilapias	2	7	-	-	-	-
81	*Sarda chiliensis*	Pacific bonito	2	1,010	-	-	2	540
82	*Albula vulpes*	bonefish	2	1,192	-	-	1	900
83	Sciaenidae unid.	croaker	2	3	-	-	17	1,212
84	*Oxylebius pictus*	painted greenling	1	5	-	-	-	-
85	*Lyopsetta exilis*	slender sole	1	26	-	-	-	-
86	*Citharichthys sordidus*	Pacific sanddab	1	1	-	-	-	-
87	*Gibbonsia montereyensis*	crevice kelpfish	1	8	-	-	-	-
88	*Pleuronichthys ritteri*	spotted turbot	1	7	-	-	13	2,745
89	*Gillichthys mirabilis*	longjaw mudsucker	1	34	-	-	-	-
90	*Dorosoma petenense*	threadfin shad	1	3	-	-	-	-
91	*Porichthys* spp.	midshipman	1	200	-	-	-	-
92	*Cynoscion parvipinnis*	shortfin corvina	1	900	-	-	-	-

(table continued)

Table 4-2 (continued). Number and weight of fishes, sharks, and rays impinged during normal operation and heat treatment surveys at EPS from June 2004 to June 2005.

			Normal Operations Sample Totals				Heat Treatment	
	Taxon	**Common Name**	**Sample Count**	**Sample Weight (g)**	**Bar Rack Count**	**Bar Rack Weight (g)**	**Sample Count**	**Sample Weight (g)**
93	*Mugil cephalus*	striped mullet	1	3	-	-	5	3,854
94	*Paraclinus integripinnis*	reef finspot	1	4	-	-	4	12
95	*Hyperprosopon* spp.	surfperch	1	115	-	-	7	552
96	*Ameiurus nebulosus*	brown bullhead	1	100	-	-	-	-
97	*Micropterus dolomieu*	smallmouth bass	1	150	-	-	-	-
98	*Citharichthys* spp.	sanddabs	-	-	-	-	1	3
99	*Triakis semifasciata*	leopard shark	-	-	-	-	2	688
100	*Medialuna californiensis*	halfmoon	-	-	-	-	53	1,864
101	*Torpedo californica*	Pacific electric ray	-	-	1	3,750	-	-
102	Scorpaenidae	scorpionfishes	-	-	-	-	2	64
103	*Halichoeres semicinctus*	rock wrasse	-	-	-	-	1	33
104	*Hypsypops rubicundus*	garibaldi	-	-	-	-	5	1,897
105	*Seriola lalandi*	yellowtail jack	-	-	-	-	21	978
106	*Dasyatis dipterura*	diamond stingray	-	-	-	-	2	1,468
107	*Heterodontus francisci*	horn shark	-	-	-	-	1	850
108	Zoarcidae	eelpouts	-	-	-	-	1	17
			19,408	**351,672**	**34**	**22,152**	**94,991**	**2,034,900**

Table 4-3. Calculated annual impingement of fishes, sharks, and rays based on EPS maximum flows and actual flows during normal operation surveys from June 2004 to June 2005.

			Maximum flow rate basis				Actual flow rate basis				Bar rack impingement	
	Taxon	Common Name	Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Weight (g)
1	*Atherinops affinis*	topsmelt	55,176	7,012	477,267	68,702	28,840	3,767	233,437	34,341	70	1830
2	*Cymatogaster aggregata*	shiner surfperch	26,506	2,689	300,068	34,418	19,303	2,024	197,272	21,678	-	-
3	*Anchoa compressa*	deepbody anchovy	20,833	3,157	135,216	20,501	13,915	2,259	79,668	11,514	14	147
4	*Seriphus politus*	queenfish	11,568	1,386	68,156	10,153	8,536	1,116	48,923	7,931	14	115
5	*Anchoa delicatissima*	slough anchovy	11,211	4,077	33,692	15,528	5,000	2,010	14,729	7,645	-	-
6	Atherinopsidae	silverside	10,198	2,624	46,649	10,901	6,857	1,979	30,372	8,035	-	-
7	*Xenistius californiensis*	salema	9,533	3,393	20,754	7,082	6,933	2,732	15,588	5,744	-	-
8	*Hyperprosopon argenteum*	walleye surfperch	6,623	1,751	276,928	79,508	3,032	866	122,967	39,161	7	147
9	*Engraulis mordax*	northern anchovy	4,778	1,282	7,368	1,625	3,835	1,128	5,530	1,226	-	-
10	*Leuresthes tenuis*	California grunion	3,963	594	19,037	2,990	3,077	454	3,077	2,135	-	-
11	*Paralabrax maculatofas.*	spotted sand bass	3,910	778	59,213	14,560	1,779	385	30,692	8,194	-	-
12	*Heterostichus rostratus*	giant kelpfish	2,793	461	21,335	3,568	2,345	408	17,649	3,127	-	-
13	*Sardinops sagax*	Pacific sardine	2,344	403	13,949	1,690	1,735	359	9,096	1,135	-	-
14	*Paralabrax nebulifer*	barred sand bass	2,156	455	19,188	4,540	1,130	226	11,230	2,968	-	-
15	unidentified chub	unid. chub	1,746	916	15,832	8,437	838	446	7,606	4,108	-	-
16	*Roncador stearnsii*	spotfin croaker	1,700	455	83,903	35,219	1,231	353	42,602	18,092	14	21,000
17	*Phanerodon furcatus*	white surfperch	1,411	225	51,760	14,552	860	146	24,193	7,275	-	-
18	*Gymnura marmorata*	Cal. butterfly ray	1,321	132	581,992	71,334	914	91	351,686	42,603	7	2,730
19	*Paralabrax clathratus*	kelp bass	1,203	219	7,382	1,456	554	111	3,289	727	-	-
20	*Strongylura exilis*	Cal. needlefish	1,173	153	59,304	9,622	895	120	36,949	5,904	-	-
21	*Anisotremus davidsonii*	sargo	992	155	16,510	5,431	603	94	9,355	3,305	-	-
22	*Paralichthys californicus*	California halibut	954	192	18,504	4,476	591	105	10,668	2,380	-	-
23	*Porichthys myriaster*	midshipman	888	98	245,274	31,495	713	80	194,289	24,590	-	-
24	*Fundulus parvipinnis*	California killifish	779	386	5,615	3,090	369	188	2,672	1,505	-	-
25	*Hypsopsetta guttulata*	diamond turbot	735	91	118,470	19,617	420	54	67,812	11,142	7	595
26	*Atractoscion nobilis*	white seabass	724	140	119,954	30,746	442	85	69,962	17,493	42	6,105
27	Ictaluridae	catfish unid.	708	352	87,489	54,747	339	171	41,926	26,656	-	-
28	*Urolophus halleri*	round stingray	696	124	185,157	44,163	510	83	129,583	27,211	-	-
29	*Micrometrus minimus*	dwarf surfperch	615	178	6,035	1,707	268	89	2,573	848	-	-
30	*Lepomis cyanellus*	green sunfish	534	221	20,796	8,079	190	43	2,231	1,244	-	-
31	*Atherinopsis californiensis*	jacksmelt	516	161	10,341	3,138	339	98	7,517	2,341	-	-
32	*Syngnathus spp.*	pipefishes	469	75	1,331	398	375	61	1,105	365	-	-

Table 4-3.(continued) Calculated annual impingement of fishes, sharks, and rays based on EPS maximum flows and actual flows during normal operation surveys from June 2004 to June 2005.

			Maximum flow rate basis				Actual flow rate basis				Bar rack impingement	
	Taxon	Common Name	Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Weight (g)
33	*Menticirrhus undulatus*	California corbina	452	151	19,581	12,307	191	75	8,682	6,191	-	-
34	*Amphistichus argenteus*	barred surfperch	444	157	13,864	7,231	211	79	5,658	3,559	-	-
35	*Myliobatis californica*	bat ray	429	58	177,308	33,107	330	46	125,302	20,852	28	41,755
36	unidentified fish, damaged	unid. damaged fish	381	91	12,530	4,868	240	57	9,228	3,513	7	490
37	*Lepomis macrochirus*	bluegill	331	169	10,399	6,734	162	82	5,090	3,288	-	-
38	*Leptocottus armatus*	Pac. staghorn sculpin	286	74	2,551	695	216	55	1,897	504	-	-
39	*Umbrina roncador*	yellowfin croaker	251	69	5,785	3,488	170	49	2,859	1,748	-	-
40	*Sphyraena argentea*	California barracuda	245	58	3,558	2,027	269	109	10,542	4,035	-	-
41	*Brachyistius frenatus*	kelp surfperch	217	87	2,306	847	114	45	1,271	460	-	-
42	*Ophichthus zophochir*	yellow snake eel	214	42	65,618	14,945	111	24	34,071	8,366	-	-
43	*Citharichthys stigmaeus*	speckled sanddab	180	52	643	187	109	32	406	124	-	-
44	*Embiotoca jacksoni*	black surfperch	127	31	14,381	7,593	99	23	9,970	4,996	-	-
45	*Chromis punctipinnis*	blacksmith	124	34	3,655	1,292	79	21	2,790	1,063	-	-
46	*Micropterus salmoides*	large mouth bass	115	53	345	165	65	30	195	93	-	-
47	*Cheilotrema saturnum*	black croaker	109	31	822	439	96	28	629	289	-	-
48	*Genyonemus lineatus*	white croaker	104	33	1,468	801	77	25	1,202	679	-	-
49	*Platyrhinoidis triseriata*	thornback	104	27	43,446	14,790	67	18	28,953	11,149	7	10,500
50	unidentified fish	unid. fish	89	30	7,284	5,883	67	23	5,961	4,904	-	-
51	*Hermosilla azurea*	zebra perch	86	31	9,263	5,738	56	21	7,608	4,823	-	-
52	*Porichthys notatus*	plainfin midshipman	76	38	16,617	8,882	60	31	12,177	6,586	-	-
53	*Pylodictis olivaris*	flathead catfish	70	31	8,359	3,973	34	15	4,020	1,934	-	-
54	*Trachurus symmetricus*	jack mackerel	68	33	75	38	50	25	51	24	-	-
55	*Heterostichus* spp.	kelpfish	66	52	453	370	51	40	348	285	-	-
56	*Hypsoblennius gentilis*	bay blenny	61	21	308	134	45	16	232	107	-	-
57	Engraulidae	anchovies	57	39	27	18	43	30	20	13	-	-
58	*Anchoa* spp.	anchovy	53	23	246	116	39	17	179	83	-	-
59	*Peprilus simillimus*	Pacific butterfish	47	20	773	388	34	14	602	336	-	-
60	*Rhacochilus vacca*	pile surfperch	44	21	11,110	6,656	26	13	6,366	3,903	-	-
61	Pleuronectiformes unid.	flatfishes	44	25	453	359	28	16	387	318	-	-
62	*Ameiurus natalis*	yellow bullhead	40	17	2,966	1,256	20	9	1,505	640	-	-
63	*Lepomis* spp.	sunfishes	39	22	3,121	2,314	20	12	1,540	1,136	-	-
64	*Pleuronichthys verticalis*	hornyhead turbot	37	17	1,517	862	29	13	1,299	762	-	-

Table 4-3.(continued) Calculated annual impingement of fishes, sharks, and rays based on EPS maximum flows and actual flows during normal operation surveys from June 2004 to June 2005.

	Taxon	Common Name	Maximum flow rate basis				Actual flow rate basis				Bar rack impingement	
			Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Weight (g)
65	*Sebastes atrovirens*	kelp rockfish	34	20	338	210	28	17	280	174	-	-
66	*Mustelus californicus*	gray smoothhound	32	20	19,800	15,052	13	10	7,766	7,404	-	-
67	*Hypsoblennius* spp.	blennies	32	22	146	96	21	15	97	64	-	-
68	*Syngnathus leptorhynchus*	bay pipefish	28	15	81	45	21	11	60	33	-	-
69	*Hypsoblennius gilberti*	rockpool blenny	28	15	144	78	17	10	90	52	-	-
70	*Acanthogobius flavimanus*	yellowfin goby	27	16	729	452	14	8	370	230	-	-
71	*Tilapia* spp.	tilapia	26	15	86	54	15	9	49	30	-	-
72	*Cheilopogon pinnatibar.*	spotted flyingfish	23	12	4,563	2,666	21	11	4,305	2,519	-	-
73	*Scorpaena guttata*	Cal. scorpionfish	22	14	821	537	10	7	386	283	-	-
74	*Albula vulpes*	bonefish	21	13	12,760	7,472	8	6	5,005	3,676	-	-
75	*Sarda chiliensis*	Pacific bonito	21	14	10,712	7,290	13	9	6,813	4,673	-	-
76	*Hypsoblennius jenkinsi*	mussel blenny	19	13	147	100	13	9	109	80	-	-
77	*Hyporhamphus rosae*	California halfbeak	19	18	214	198	15	14	165	153	-	-
78	*Ameiurus nebulosus*	brown bullhead	19	17	1,890	1,749	9	9	909	852	-	-
79	*Rhinobatos productus*	shovelnose guitarfish	18	12	4,244	2,918	14	9	3,164	2,187	14	43,400
80	*Girella nigricans*	opaleye	18	17	3,086	2,858	15	14	2,626	2,441	-	-
81	*Symphurus atricaudus*	California tonguefish	18	12	137	92	11	8	82	58	-	-
82	*Micropterus dolomieu*	smallmouth bass	16	15	2,395	2,217	8	7	1,152	1,080	-	-
83	Sciaenidae unid.	croaker	16	10	19	17	14	9	19	17	-	-
84	*Scomber japonicus*	Pacific mackerel	15	10	73	53	14	9	68	50	-	-
85	*Paralabrax* spp.	sand bass	15	10	15	10	14	9	14	9	-	-
86	*Lyopsetta exilis*	slender sole	12	11	313	290	7	6	175	163	-	-
87	*Dorosoma petenense*	threadfin shad	12	11	41	38	7	6	24	22	-	-
88	*Gillichthys mirabilis*	longjaw mudsucker	12	11	409	379	6	6	202	190	-	-
89	*Cynoscion parvipinnis*	shortfin corvina	11	10	9,647	8,932	4	5	3,784	4,394	-	-
90	*Citharichthys sordidus*	Pacific sanddab	11	10	5	5	4	5	2	2	-	-
91	*Hyperprosopon* spp.	surfperch	11	10	1,219	1,128	4	5	495	550	-	-
92	*Pleuronichthys ritteri*	spotted turbot	10	9	65	60	6	6	42	39	-	-
93	*Gibbonsia montereyensis*	crevice kelpfish	10	9	79	73	7	6	56	52	-	-
94	*Mugil cephalus*	striped mullet	8	7	27	25	7	6	24	22	-	-
95	*Porichthys* spp.	midshipman	8	7	1,608	1,489	7	6	1,400	1,297	-	-
96	*Paraclinus integripinnis*	reef finspot	8	7	28	26	7	6	25	23	-	-

Table 4-3.(continued) Calculated annual impingement of fishes, sharks, and rays based on EPS maximum flows and actual flows during normal operation surveys from June 2004 to June 2005.

	Taxon	Common Name	Maximum flow rate basis				Actual flow rate basis				Bar rack impingement	
			Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Abundance Std. Error	Weight (g)	Weight Std. Error	Abundance	Weight (g)
97	*Oxylebius pictus*	painted greenling	7	7	35	32	7	6	33	31	-	-
98	*Citharichthys* spp.	sanddabs	-	-	-	-	-	-	-	-	-	-
99	*Triakis semifasciata*	leopard shark	-	-	-	-	-	-	-	-	-	-
100	*Medialuna californiensis*	halfmoon	-	-	-	-	-	-	-	-	-	-
101	*Torpedo californica*	Pacific electric ray	-	-	-	-	-	-	-	-	7	26,250
			194,333		**3,651,179**		**120,354**		**2,168,422**		**238**	**155,065**

Table 4-4. Calculated overall annual impingement of fishes, sharks, and rays from all sources combined (normal operations [traveling screens and bar racks] and heat treatments) based on EPS maximum flows and actual flows, June 2004–June 2005.

			Maximum Flow		Actual Flow	
	Taxon	Common Name	Abundance	Weight (g)	Abundance	Weight (g)
1	*Atherinops affinis*	topsmelt	70,942	546,594	44,606	302,764
2	*Cymatogaster aggregata*	shiner surfperch	44,867	496,636	37,664	393,840
3	*Anchoa compressa*	deepbody anchovy	44,203	389,629	37,285	334,081
4	*Seriphus politus*	queenfish	12,511	89,662	9,479	70,429
5	Atherinopsidae	silverside	12,303	55,310	8,962	39,033
6	*Anchoa delicatissima*	slough anchovy	11,218	33,702	5,007	14,739
7	*Xenistius californiensis*	salema	11,110	26,909	8,510	21,742
8	*Leuresthes tenuis*	California grunion	11,030	59,886	10,144	55,273
9	*Hyperprosopon argenteum*	walleye surfperch	9,177	402,509	5,586	248,549
10	*Sardinops sagax*	Pacific sardine	8,922	40,215	8,313	35,362
11	*Paralabrax maculatofasciatus*	spotted sand bass	5,446	166,777	3,315	138,255
12	*Atherinopsis californiensis*	jacksmelt	4,984	55,493	4,807	52,669
13	*Engraulis mordax*	northern anchovy	4,870	7,742	3,927	5,904
14	*Paralabrax nebulifer*	barred sand bass	4,149	51,947	3,123	43,989
15	*Heterostichus rostratus*	giant kelpfish	3,701	30,423	3,253	26,737
16	*Atractoscion nobilis*	white seabass	2,384	458,115	2,102	408,122
17	*Paralabrax clathratus*	kelp bass	2,179	20,661	1,530	16,568
18	*Anisotremus davidsonii*	sargo	1,955	85,039	1,566	77,884
19	*Roncador stearnsii*	spotfin croaker	1,820	122,063	1,351	80,762
20	*Urolophus halleri*	round stingray	1,786	485,950	1,600	430,376
21	unidentified chub	unid. chub	1,753	15,875	845	7,650
22	*Phanerodon furcatus*	white surfperch	1,464	52,583	913	25,016
23	*Gymnura marmorata*	California butterfly ray	1,398	621,543	991	391,238
24	*Strongylura exilis*	California needlefish	1,331	71,203	1,053	48,848
25	*Porichthys myriaster*	specklefin midshipman	1,106	312,133	931	261,148
26	*Paralichthys californicus*	California halibut	975	23,273	612	15,437
27	*Hypsopsetta guttulata*	diamond turbot	854	143,448	539	92,790
28	*Fundulus parvipinnis*	California killifish	795	5,656	385	2,713
29	Ictaluridae	catfish unid.	708	87,489	339	41,926
30	*Micrometrus minimus*	dwarf surfperch	615	6,035	268	2,573
31	*Myliobatis californica*	bat ray	589	287,635	490	235,629
32	*Lepomis cyanellus*	green sunfish	534	20,796	190	2,231
33	*Syngnathus spp.*	pipefishes	525	1,421	431	1,195
34	*Hypsoblennius gentilis*	bay blenny	501	3,121	485	3,045
35	*Amphistichus argenteus*	barred surfperch	478	16,392	245	8,186
36	*Menticirrhus undulatus*	California corbina	468	24,505	207	13,607
37	*Cheilotrema saturnum*	black croaker	397	9,851	384	9,658
38	unidentified fish, damaged	unid. damaged fish	396	13,282	255	9,980
39	*Umbrina roncador*	yellowfin croaker	378	28,185	297	25,258
40	*Girella nigricans*	opaleye	373	33,910	370	33,449
41	*Lepomis macrochirus*	bluegill	331	10,399	162	5,090
42	*Sphyraena argentea*	California barracuda	291	5,225	315	12,209
43	*Leptocottus armatus*	Pacific staghorn sculpin	291	2,577	221	1,924
44	*Chromis punctipinnis*	blacksmith	275	8,086	230	7,221
45	*Ophichthus zophochir*	yellow snake eel	265	82,921	162	51,374
46	*Brachyistius frenatus*	kelp surfperch	234	2,904	131	1,869
47	*Embiotoca jacksoni*	black surfperch	196	19,748	168	15,337

(table continued)

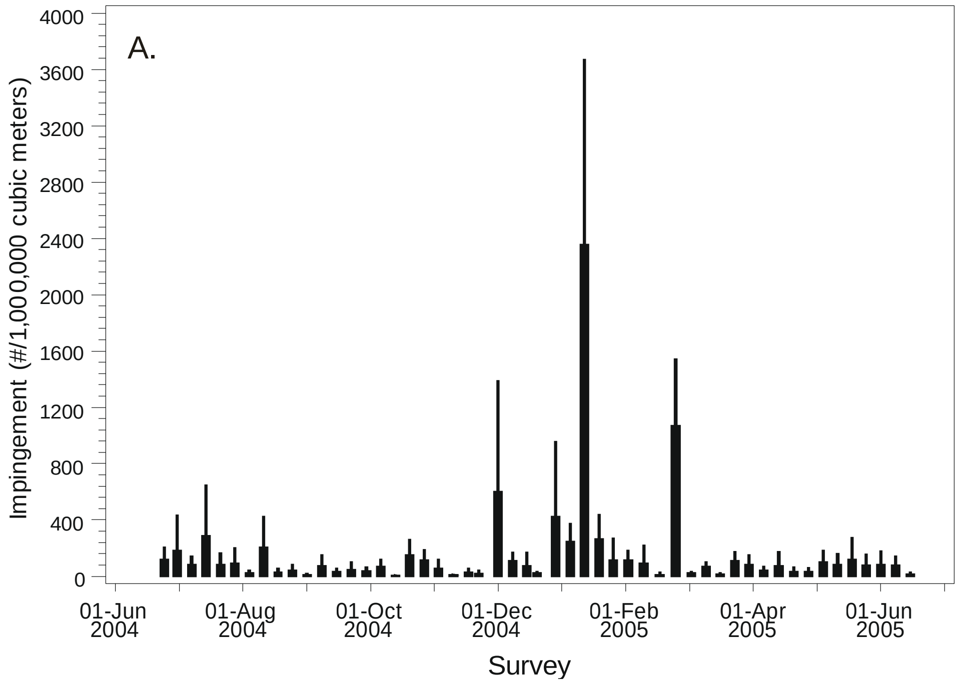
Table 4-4 (continued). Calculated overall annual impingement of fishes, sharks, and rays from all sources combined (normal operations [traveling screens and bar racks] and heat treatments) based on EPS maximum flows and actual flows, June 2004–June 2005.

			Maximum Flow		Actual Flow	
	Taxon	**Common Name**	**Abundance**	**Weight (g)**	**Abundance**	**Weight (g)**
48	*Hypsoblennius jenkinsi*	mussel blenny	194	1,093	188	1,055
49	*Citharichthys stigmaeus*	speckled sanddab	181	672	110	435
50	*Hermosilla azurea*	zebra perch	148	12,781	118	11,126
51	*Hypsoblennius* spp.	blennies	145	636	134	587
52	*Micropterus salmoides*	large mouth bass	115	345	65	195
53	*Genyonemus lineatus*	white croaker	113	1,546	86	1,281
54	*Platyrhinoidis triseriata*	thornback	111	53,946	74	39,453
55	unidentified fish	unidentified fish	89	7,284	67	5,961
56	*Trachurus symmetricus*	jack mackerel	83	777	65	753
57	*Porichthys notatus*	plainfin midshipman	76	16,617	60	12,177
58	*Pylodictis olivaris*	flathead catfish	70	8,359	34	4,020
59	*Heterostichus* spp.	kelpfish	66	453	51	348
60	Engraulidae	anchovies	57	27	43	20
61	*Mustelus californicus*	gray smoothhound	54	39,676	35	27,642
62	*Anchoa* spp.	anchovy	53	246	39	179
63	*Medialuna californiensis*	halfmoon	53	1,864	53	1,864
64	*Peprilus simillimus*	Pacific butterfish	48	806	35	636
65	*Rhacochilus vacca*	pile surfperch	44	11,110	26	6,366
66	Pleuronectiformes unid.	flatfishes	44	453	28	387
67	*Ameiurus natalis*	yellow bullhead	40	2,966	20	1,505
68	*Lepomis* spp.	sunfishes	39	3,121	20	1,540
69	*Pleuronichthys verticalis*	hornyhead turbot	39	1,769	31	1,550
70	*Hypsoblennius gilberti*	rockpool blenny	36	221	25	167
71	*Sebastes atrovirens*	kelp rockfish	34	338	28	280
72	Sciaenidae unid.	croaker	33	1,231	31	1,231
73	*Rhinobatos productus*	shovelnose guitarfish	32	47,644	28	46,564
74	*Scomber japonicus*	Pacific mackerel	30	953	29	948
75	*Syngnathus leptorhynchus*	bay pipefish	28	81	21	60
76	*Acanthogobius flavimanus*	yellowfin goby	27	729	14	370
77	*Tilapia* spp.	tilapia	26	86	15	49
78	*Sarda chiliensis*	Pacific bonito	23	11,252	15	7,353
79	*Cheilopogon pinnatibarbatus*	spotted flyingfish	23	4,563	21	4,305
80	*Pleuronichthys ritteri*	spotted turbot	23	2,810	19	2,787
81	*Albula vulpes*	bonefish	22	13,660	9	5,905
82	*Scorpaena guttata*	California scorpionfish	22	821	10	386
83	*Seriola lalandi*	yellowtail jack	21	978	21	978
84	*Paralabrax* spp.	sand bass	21	33	20	32
85	*Hyporhamphus rosae*	California halfbeak	20	214	16	165
86	*Ameiurus nebulosus*	brown bullhead	19	1,890	9	909
87	*Hyperprosopon* spp.	surfperch	18	1,771	11	1,047
88	*Symphurus atricaudus*	California tonguefish	18	137	11	82
89	*Micropterus dolomieu*	smallmouth bass	16	2,395	8	1,152
90	*Mugil cephalus*	striped mullet	13	3,881	12	3,878
91	*Lyopsetta exilis*	slender sole	12	313	7	175
92	*Dorosoma petenense*	threadfin shad	12	41	7	24
93	*Gillichthys mirabilis*	longjaw mudsucker	12	409	6	202

(table continued)

Table 4-4 (continued). Calculated overall annual impingement of fishes, sharks, and rays from all sources combined (normal operations [traveling screens and bar racks] and heat treatments) based on EPS maximum flows and actual flows, June 2004–June 2005.

			Maximum Flow		Actual Flow	
	Taxon	**Common Name**	**Abundance**	**Weight (g)**	**Abundance**	**Weight (g)**
94	*Paraclinus integripinnis*	reef finspot	12	40	11	37
95	*Cynoscion parvipinnis*	shortfin corvina	11	9,647	4	3,784
96	*Citharichthys sordidus*	Pacific sanddab	11	5	4	2
97	*Gibbonsia montereyensis*	crevice kelpfish	10	79	7	56
98	*Porichthys* spp.	midshipman	8	1,608	7	1,400
99	*Oxylebius pictus*	painted greenling	7	35	7	33
100	*Torpedo californica*	Pacific electric ray	7	26,250	7	26,250
101	*Hypsypops rubicundus*	garibaldi	5	1,897	5	1,897
102	*Triakis semifasciata*	leopard shark	2	688	2	688
103	Scorpaenidae	scorpionfishes	2	64	2	64
104	*Dasyatis dipterura*	diamond stingray	2	1,468	2	1,468
105	*Citharichthys* spp.	sanddabs	1	3	1	3
106	*Halichoeres semicinctus*	rock wrasse	1	33	1	33
107	*Heterodontus francisci*	horn shark	1	850	1	850
108	Zoarcidae	eelpouts	1	17	1	17
			289,562	**5,841,143**	**215,583**	**4,358,386**



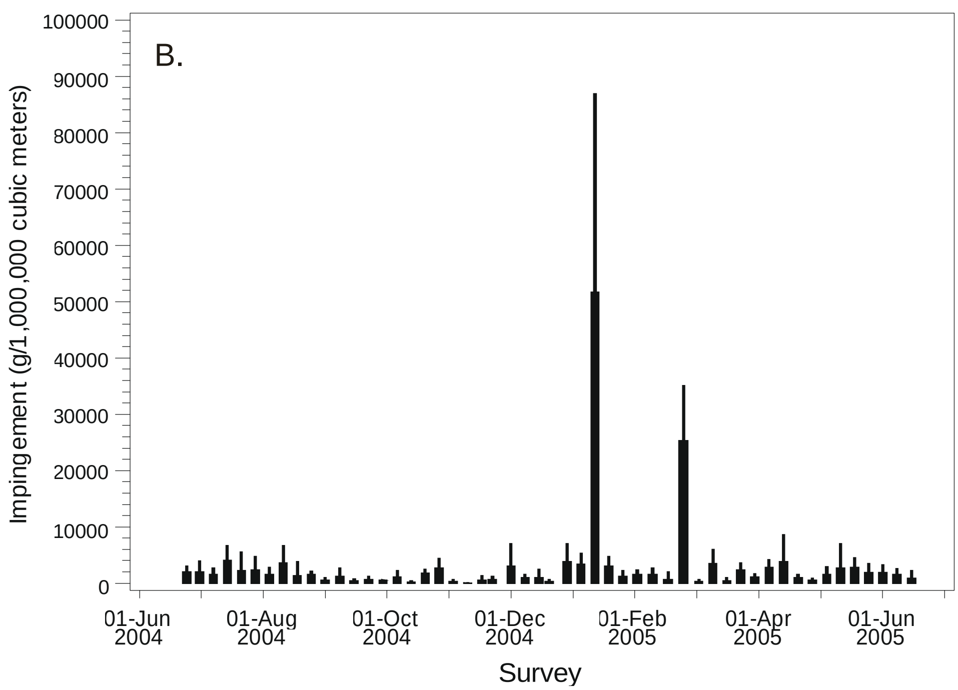


Figure 4-1. Mean concentration and standard error of all fish impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

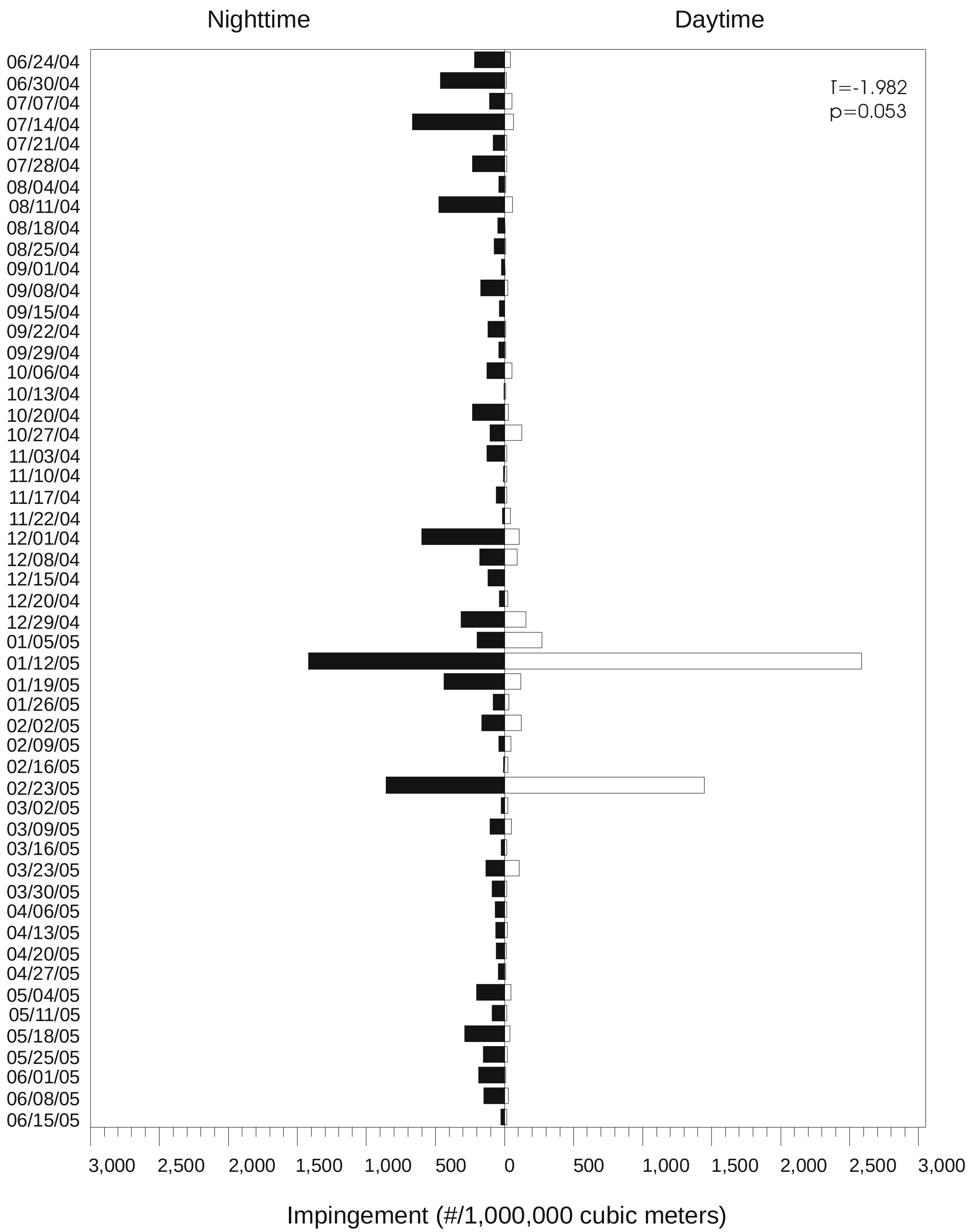


Figure 4-2. Abundance (#/10^6 m^3) of all fish impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples .

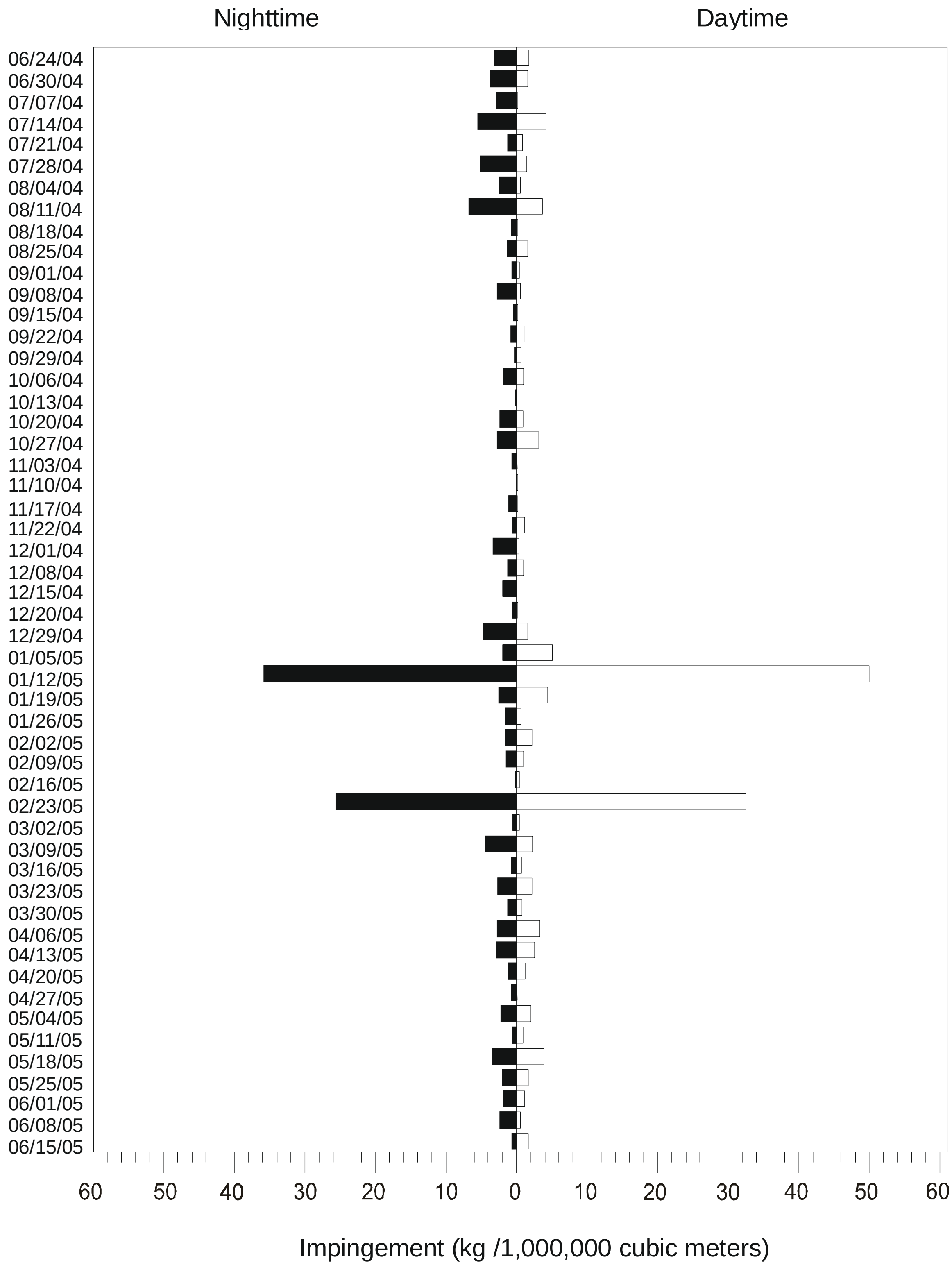


Figure 4-3. Biomass (kg/10^6 m^3) of all fish impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

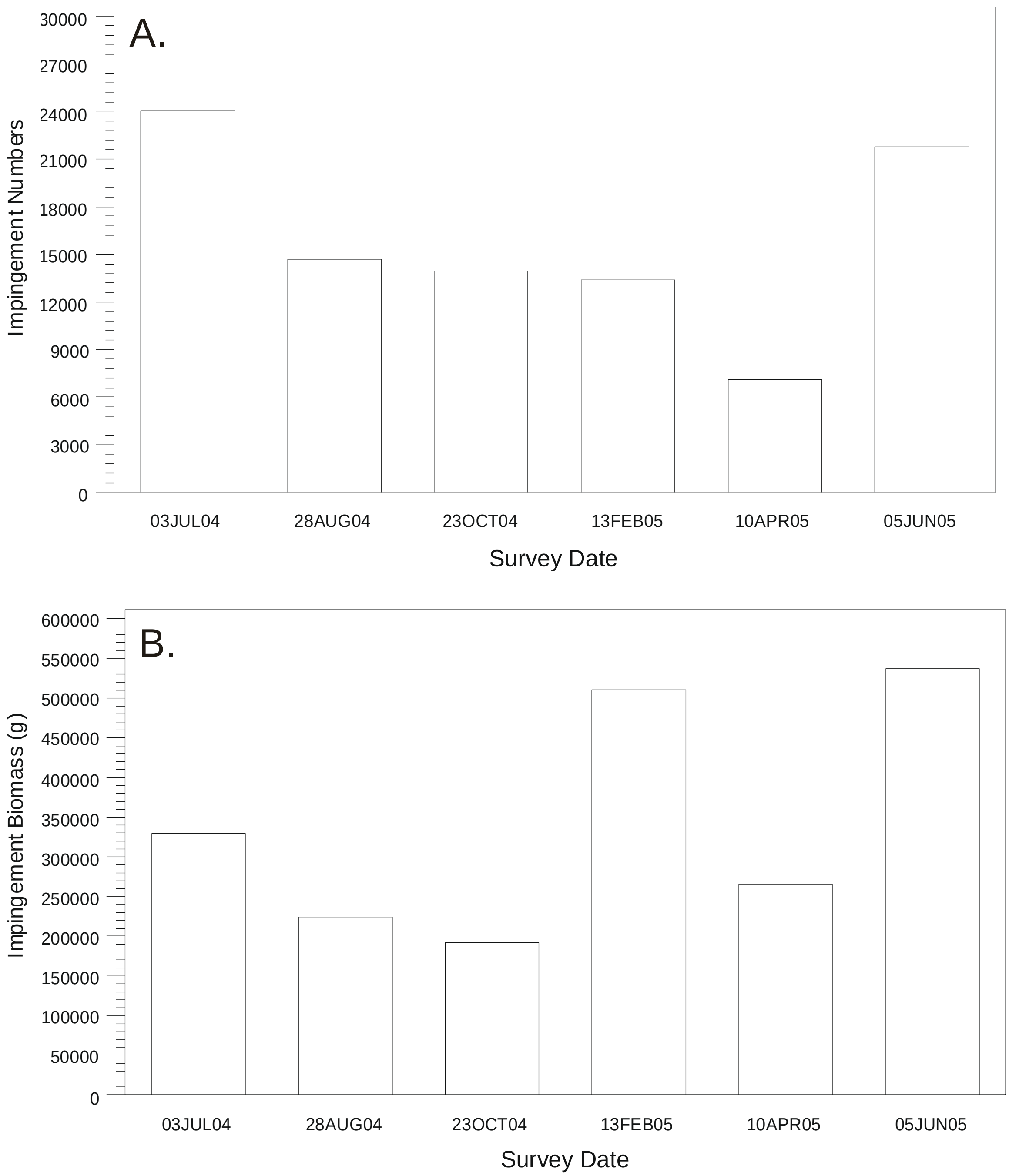


Figure 4-4. A) abundance, and B) biomass of all fish impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

4.3.2 Anchovies (Engraulidae)

Four species of anchovies (family Engraulidae) occur off of California (Miller and Lea 1972). Slough anchovy (*Anchoa delicatissima)*, deepbody anchovy (*Anchoa compressa),* and northern anchovy (*Engraulis mordax)* are found in the vicinity of the EPS, while the anchoveta (*Cetengraulis mysticetus*) is considered rare north of Magdelena Bay, Baja California. Northern anchovy larvae were abundant in plankton samples collected as part of the entrainment portion of the present study and it was the only larval engraulid that could be positively identified to the species level. Numerous engraulid larvae were collected that were recently hatched and these specimens did not have enough distinct characteristics to allow them to be positively identified to species level. The life history characteristics of northern anchovy are presented in Section 3.3.4 of this report.

4.3.2.1 Sampling Results

Three anchovy species: deepbody, slough, and northern, were impinged during the study. A total of 3,684 anchovies was impinged during the normal impingement surveys, of which 2,079 were deepbody, 1,056 were slough, 537 were northern, and 12 were recorded as *Anchoa* spp. or Engraulidae since they could not be identified to the species level. The impinged anchovies had a combined total weight of 15.6 kg (34.4 lb) in the 52 weekly surveys (**Table 4-2**). Anchovies combined were the second most abundant fish taxa impinged and had the eighth highest biomass. Large spikes in abundance occurred in some weeks during December through February but the remainder of the weekly surveys had low but consistent levels of impingement (**Figure 4-5**). Abundance and biomass were typically greater in most surveys during nighttime cycles, although the two surveys with the highest numbers and biomass (January and February 2005) had the majority of fishes impinged during the daytime cycles (**Figures 4-6** and **4-7**). A total of 23,455 anchovies weighing 254.7 kg (561.5lb) was impinged in the heat treatments (**Figure 4-8**), with a peak in their abundance being during the summer surveys. Nearly all of the impinged specimens were deepbody anchovy during both normal operation and heat treatment surveys. Lengths ranged from 19 to 169 mm (0.75 to 6.7 in), with a mean length of 76.1 mm (3.0 in) (**Figure 4-9; Appendix G**).

4.3.2.2 Annual Impingement Estimates

Based on the impinged abundance and biomass of anchovies from weekly surveys and actual CWS flow during the year-long study, the impingement abundance of all species of anchovies combined (not including bar rack or heat treatment mortality) was calculated as 22,832 individuals, approximately 61% of which were deepbody anchovy, 22% slough anchovy, and the remainder northern anchovy (**Table 4-3**). The estimated biomass of anchovies impinged during the year, based on actual flows, was calculated as 100.1 kg (220.7 lb). Under maximum CWS flow, the impinged numbers and biomass of anchovies would have increased 62% and 76% respectively, assuming that impingement was directly proportional to flow rate. The total annual impingement including normal operations, heat treatments and the few individuals impinged on the bar racks was 46,301 and 354.9 kg (782 lb) using actual flows and 60,401 and 431.3 kg (951 lb) using maximum flows (**Table 4-4**).

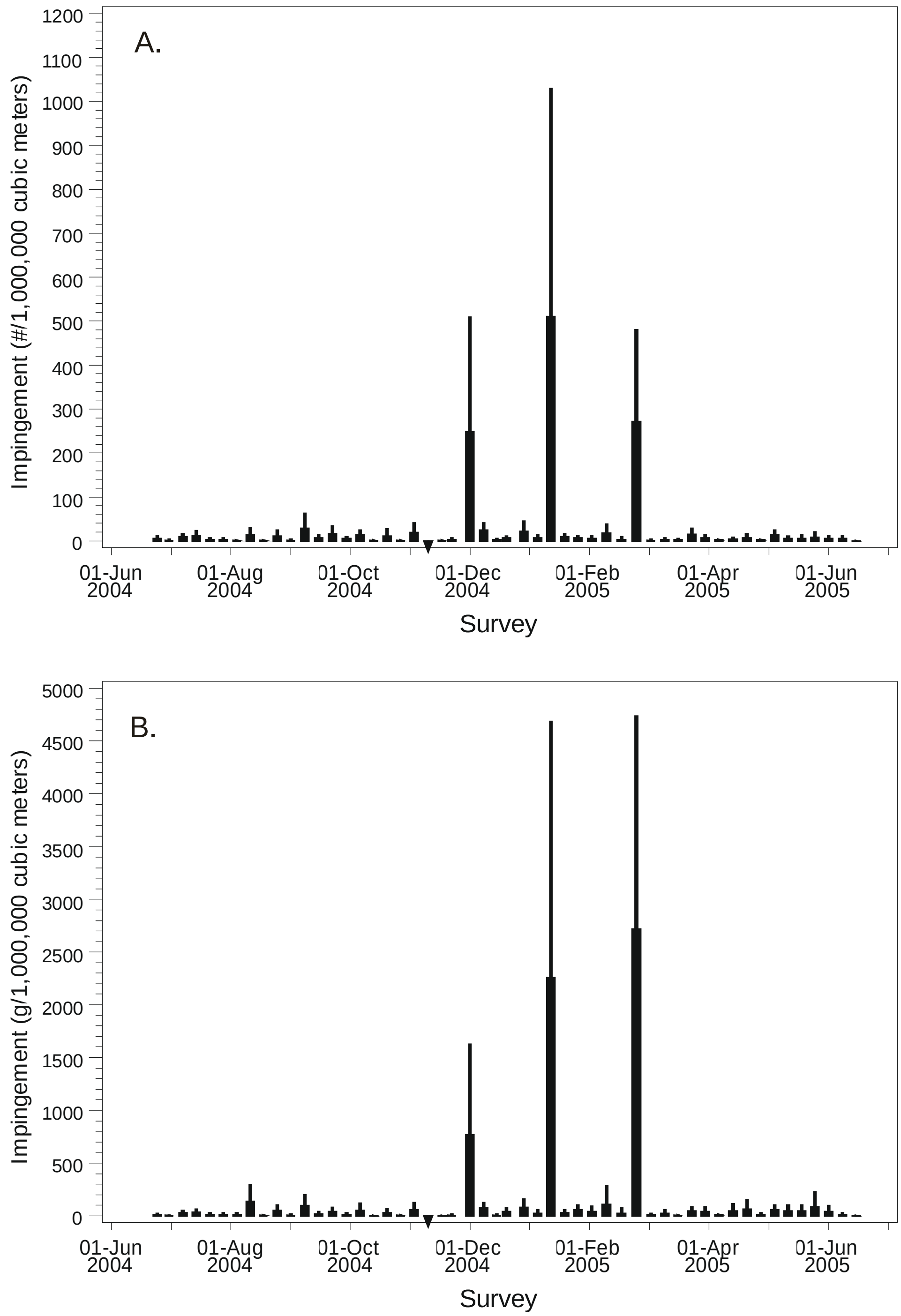


Figure 4-5. Mean concentration and standard error of anchovies impinged at EPS Units 1–5 from June 2004 through June 2005 (n=52 surveys); A) abundance, and B) biomass. *Note: Downward pointing triangle indicates survey with no larvae collected.*

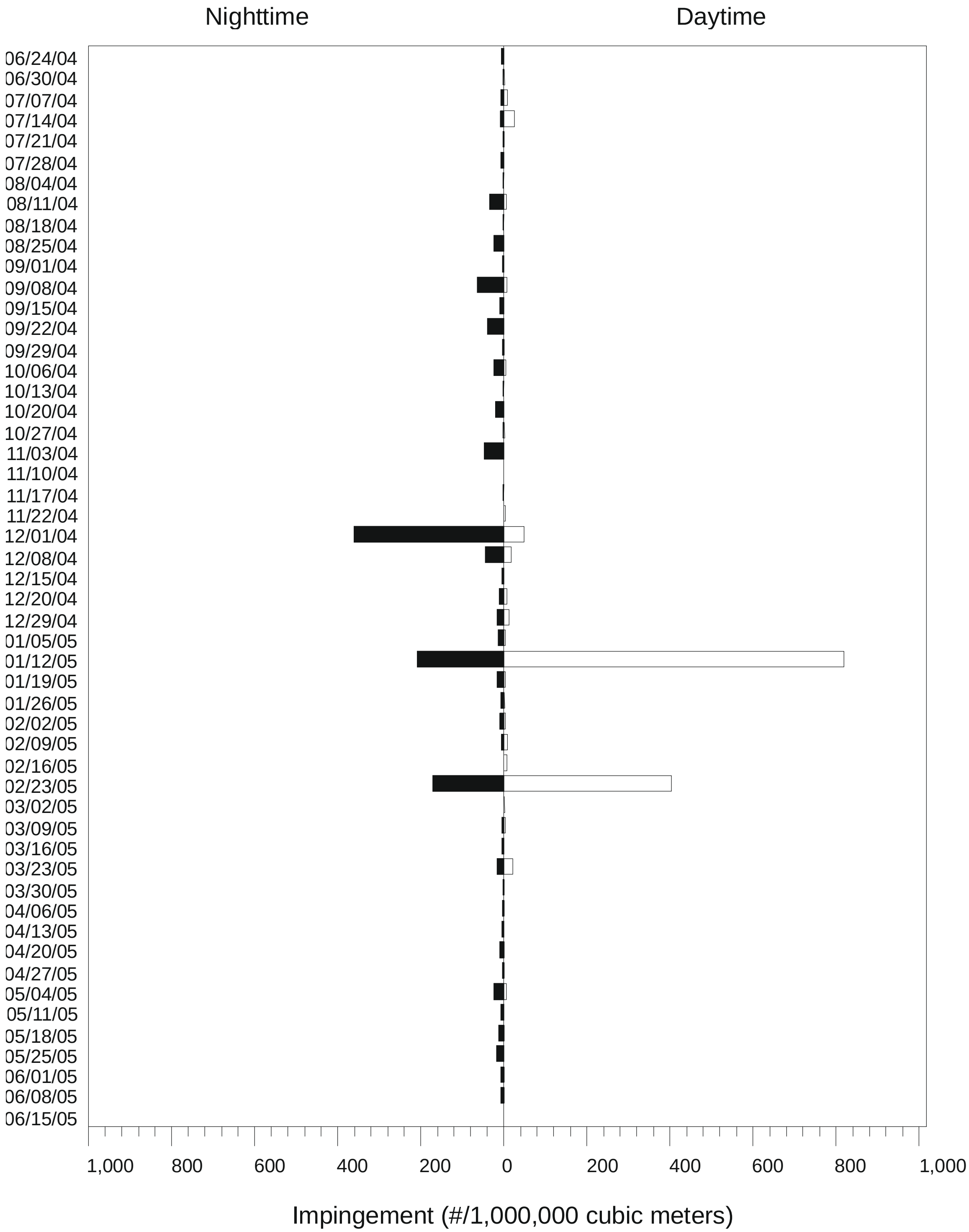


Figure 4-6. Abundance (#/10^6 m^3) of anchovies impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

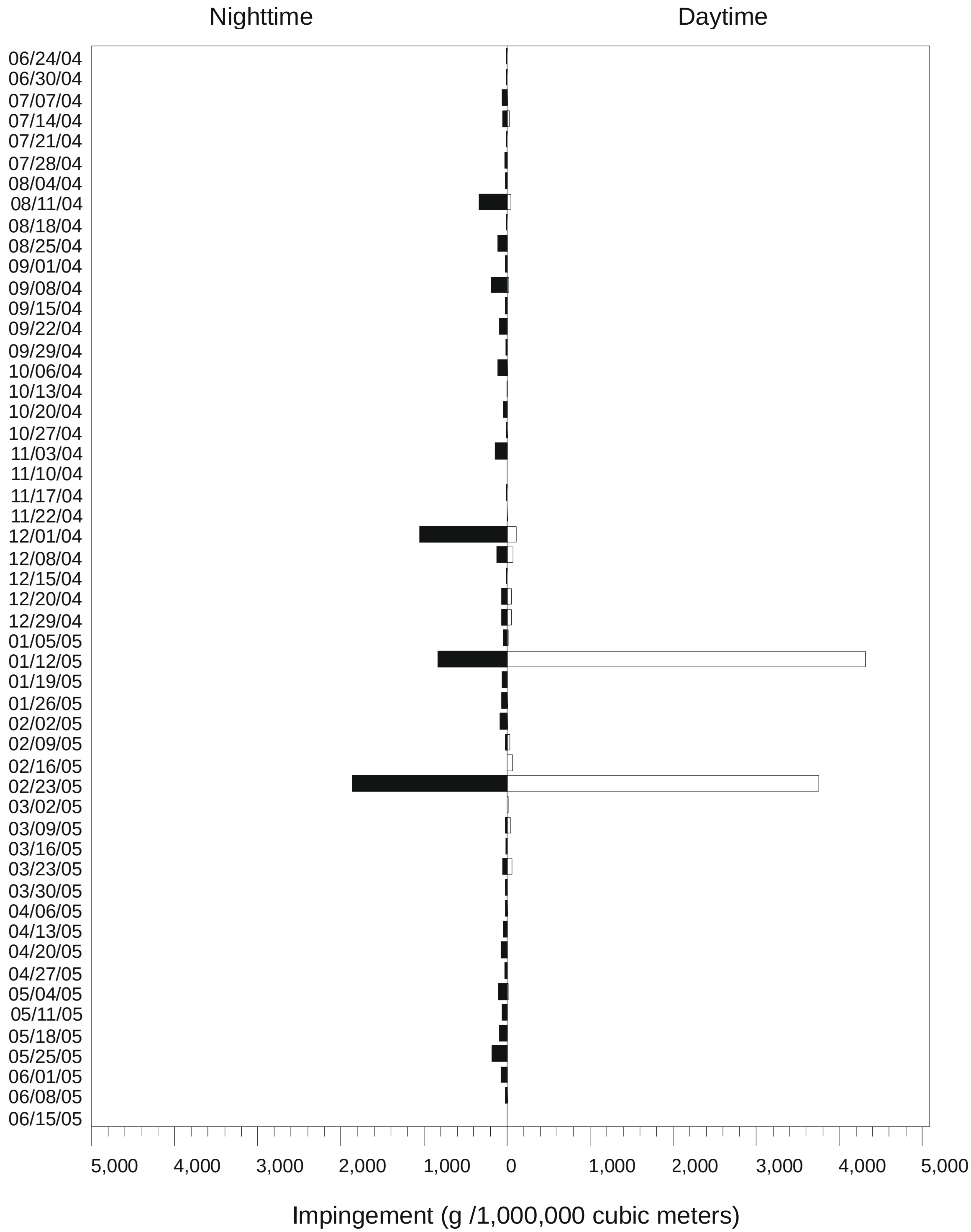


Figure 4-7. Biomass (g/10^6 m^3) of anchovies impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

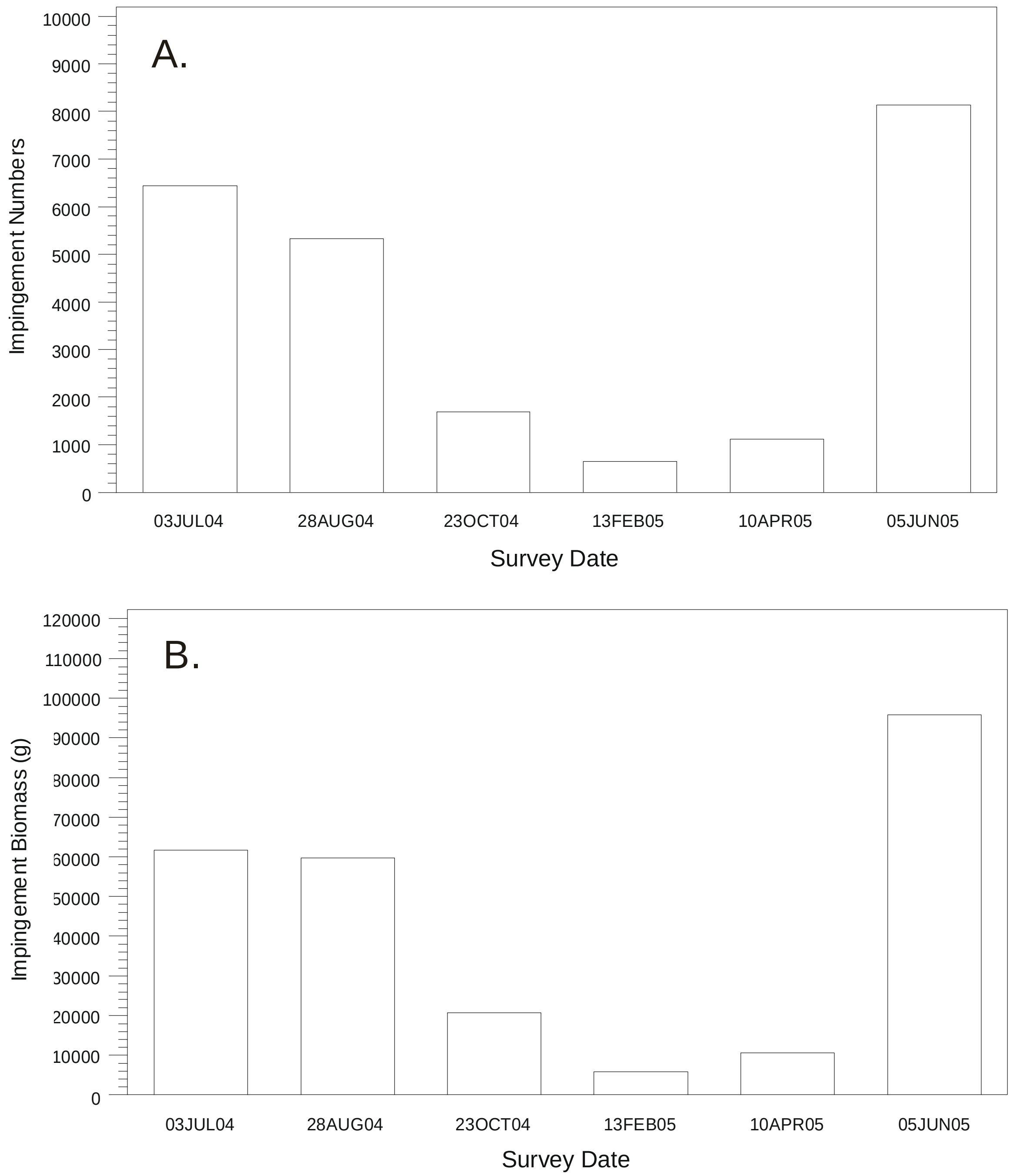


Figure 4-8. A) abundance, and B) biomass of anchovies impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

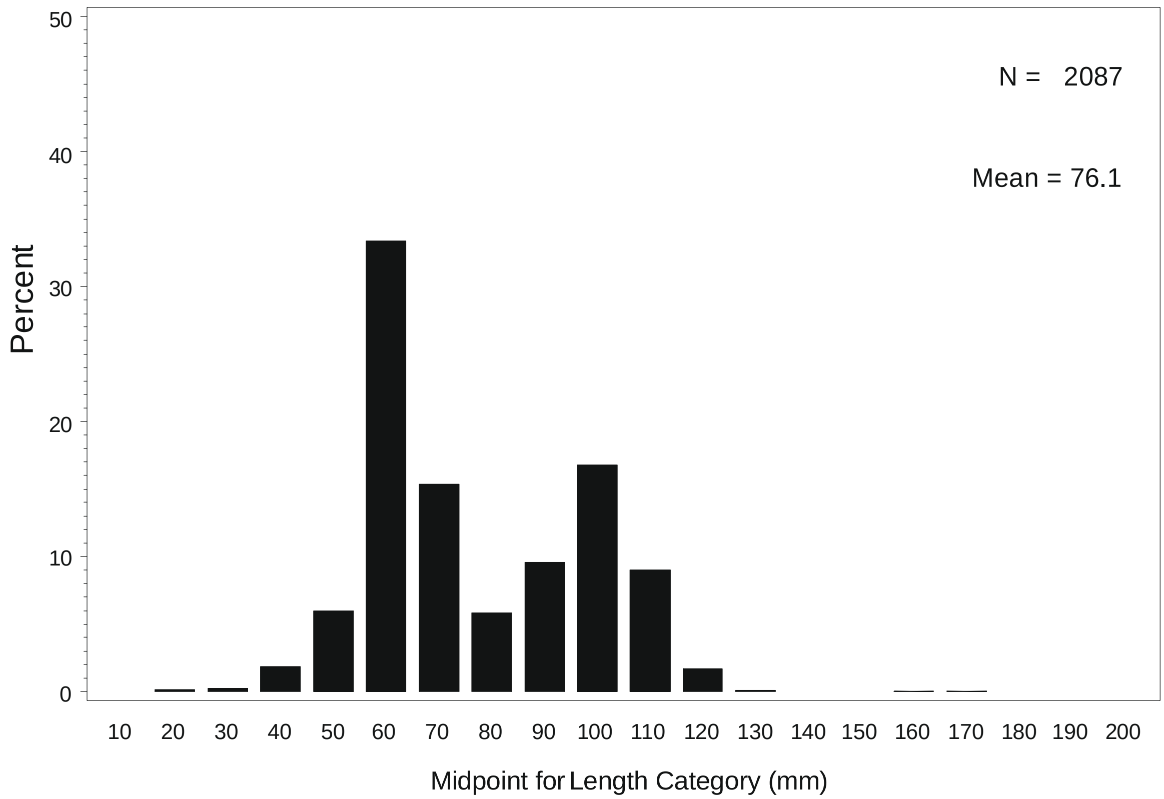


Figure 4-9. Size frequency distribution of anchovies from EPS Units 1–5 impingement samples.

4.3.3 Silversides (Atherinopsidae)

Jamie Siler

Range:
- Topsmelt-Vancouver Island, British Columbia, to southern Baja California and the upper Gulf of California
- Jacksmelt-Yaquina Bay, Oregon through Gulf of California
- Grunion-San Francisco to southern Baja California

Life History*:*
- Size up to 19 cm (7.5 in) (grunion); 37 cm (14.5 in) (topsmelt); 44cm (17 in) (jacksmelt)
- Age at maturity from 2–3 yr all species
- Life span to 4 yr (grunion); 8 yr (topsmelt); 10 yr (jacksmelt)
- Spawn from February to June (topsmelt); October to March (jacksmelt); February to September (grunion) with fecundity ranging from 1,000 (topsmelt)–3,000 (grunion) eggs

Habitat*:* Bays, estuaries, nearshore surface waters to depths of 9-29 m (30-95 ft).

Fishery: Incidental commercial and limited recreational take on hook and line or with nets.

Three species of silversides (family Atherinopsidae) occur in California ocean waters and in the vicinity of the EPS: topsmelt (*Atherinops affinis)*, jacksmelt (*Atherinopsis californiensis)*, and the California grunion (*Leuresthes tenuis)*. Topsmelt are found from Vancouver Island British Columbia, to the Gulf of California, (Miller and Lea 1972), with a disjunct distribution in the northern gulf (Robertson and Allen 2002). Jacksmelt are found in estuaries and coastal marine environments from Yaquina Bay, Oregon to the Gulf of California (Eschmeyer et al. 1983, Robertson and Allen 2002). California grunion are found from San Francisco to Magdalena Bay, Baja California (Miller and Lea 1972) but are most abundant from Point Conception southward (Love 1996).

4.3.3.1 Life History and Ecology

These schooling fishes are very common in estuaries, kelp beds, and along sandy beaches. Although mostly observed on the surface, topsmelt have been seen to depths of 9 m (30 ft) (Love 1996). Jacksmelt have been observed at depths of 29 m (95 ft). Grunion are usually seen from just behind the surf line to depths of about 18 m (60 ft).

In a five-year study of fishes in San Diego Bay, topsmelt ranked second in abundance and fifth in biomass, comprising about 23% of the individuals and 9% of the total weight (Allen 1999). Topsmelt were captured in all samples with peak abundances generally occurring in April due to heavy recruitment of young-of-the-year (YOY). Topsmelt occurred in a wide size range over the study and were represented by four age classes. Typically, YOY and juvenile topsmelt primarily occupied the intertidal zone while adult fish also occupied nearshore and midwater channel sub-habitats. Topsmelt and grunion were collected in the 1979–80 impingement study conducted at

EPS, comprising 13.7 and 10.8% respectively of total number of fishes collected (SDG&E 1980).

Adult topsmelt mature within 2–3 years to an approximate length of 10–15 cm (4–6 in) and can reach a length of 37 cm (14.5 in). They have a life expectancy of up to eight years (Love 1996). Jacksmelt is the largest member of the three species of the silverside that occur in California with adults reaching a maximum length of 44 cm (17 in) (Miller and Lea 1972). The fish reach maturity after two years at a size range of 18–20 cm (7.0–7.8 in) SL, and can live to a maximum age of nine or ten years (Clark 1929). Grunion reach 19 cm (7.5 in) in length, with a life span of up to four years. They mature at one year old at a length of approximately 12–13 cm (5 in).

The spawning activity of topsmelt corresponds to changes in water temperature (Middaugh et al. 1990). In Newport Bay, topsmelt spawn from February to June peaking in May and June (Love 1996). Females deposit the eggs on marine plants and other floating objects where fertilization occurs (Love 1996). Fecundity is a function of female body size with individuals in the 110–120 mm range spawning approximately 200 eggs per season, and fish 160 mm or greater spawning 1,000 eggs per season (Fronk 1969). The spawning season for jacksmelt is from October through March (Clark 1929), with peak activity from January through March (Allen et al. 1983). Individuals may spawn multiple times during the reproductive season and reproductive females have eggs of various sizes and maturities present in the ovary (Clark 1929). Fecundity has not been well documented but is possibly over 2,000 eggs per female (Emmett et al. 1991). Females lay eggs on marine plants and other floating objects where fertilization by males occurs (Love 1996). The spawning activity of grunion is quite different from the other silversides. Spawning occurs only three or four nights following each full or new moon, and then only for 1–3 hours immediately after the high tide, from late February to early September (peaking late March to early June) (Love 1996). The female swims onto the beach and digs into the wet sand, burying herself up to her pectoral fins or above. The male or males curve around her with vents touching her body, and when the female lays her eggs beneath the sand, males emit sperm, which flows down her body and fertilizes the eggs (Love 1996). Females spawn four to eight times per season at about 15-day intervals, producing 1,000–3,000 eggs.

4.3.3.2 Fishery and Population Trends

A limited fishery exists for silversides, which are marketed fresh for human consumption or for bait (Leet et al. 2001). The commercial fishery for silversides has been conducted with a variety of gear. Historically, set-lines have been used in San Francisco Bay for jacksmelt, and during the 1920s beach nets, pulled ashore by horses, were used at Newport Beach (Leet et al. 2001). Commercial catches of jacksmelt have varied sharply over the past 80 years fluctuating from more than two million pounds in 1945 to 2,530 pounds in 1998 and 1999 (Leet et al. 2001). Silversides are an incidental fishery and the large fluctuations in the catch records reflect demand, not actual abundances (Leet et al. 2001). The commercial use of grunion is limited as this species forms a minor portion of the commercial “smelt” catch (Leet et al. 2001). Grunion are taken incidentally in bait nets and other round haul nets, and limited quantities are used as live bait, though no commercial landings have been reported (Leet et al. 2001). In the 1920s, the recreational fishery was showing signs of depletion, and a regulation was passed in 1927 establishing a closed season of three months, April through June. The fishery improved, and in 1947, the closure was shortened to April through May. Both topsmelt and jacksmelt are caught by sport fishers from piers and along shores. Sport fishermen may take grunion by hand only, and no holes may be dug in the beach to entrap them (Leet et al. 2001). Recent catch estimates of silversides by recreational anglers in southern California were 49,000 fish in winter 2005. Catch estimates averaged 267,000 fish from 2000–2004 (RecFIN 2005).

4.3.3.3 Sampling Results

Silversides were the most abundant fish impinged and had the second highest biomass (**Table 4-2**). Three silverside species, topsmelt, grunion, and jacksmelt, were impinged during the study. Of the 6,784 silversides, there were 5,242 topsmelt, 489 grunion, 54 jacksmelt, and 999 others that could not be identified to the species level and were recorded as Atherinopsidae. The impinged silversides had a combined total weight of 50.2 kg (110.7 lb) in the 52 weekly surveys. An additional 10 topsmelt were collected from the bar racks, weighing 262 g (0.6 lb). Impingement of silversides occurred year-round, peaking late December through late February (**Figure 4-10**). Time of day was not a significant factor in the impingement of silversides with approximately equal numbers and biomass occurring in both day and night cycles (**Figure 4-11** and **4-12**). The majority of impinged biomass was recorded during one survey in January 2005. Topsmelt were the most abundant silverside collected in the heat treatments (53.5%), followed by grunion (24.1%) and jacksmelt (15.2%). A total of 29,336 individuals weighing 162.2 kg (357.6 lb) was impinged in the heat treatment surveys with the highest abundance and biomass occurring during the October 2004 heat treatment (**Figure 4-13**). Lengths of impinged silversides ranged from 18 to 325 mm SL (0.71 to 12.8 in) with a mean length of 84.4 mm (3.3in) (**Figure 4-14; Appendix G**).

4.3.3.4 Annual Impingement Estimates

The estimated annual impingement abundance for silversides using actual CWS flows (not including bar rack or heat treatment mortality) was 39,113 individuals, weighing 274.4 kg (604.9 lb) (**Table 4-3**). Estimated bar rack impingement abundance was 70 individuals, weighing 1.8 kg (4.0 lb). The estimated annual impingement abundance would increase to 69,853 individuals (±10,392 std. error), weighing 553.3 kg (1,219.8 lb) (±85.7 kg std. error) using maximum CWS flows. All sources of impingement combined resulted in an estimated mortality of 68,519 individuals weighing 449.7 kg (991.4 lb) using actual CWS flows and 99,259 individuals weighing 717.3 kg (1,581 lb) using maximum flows (**Table 4-4**).

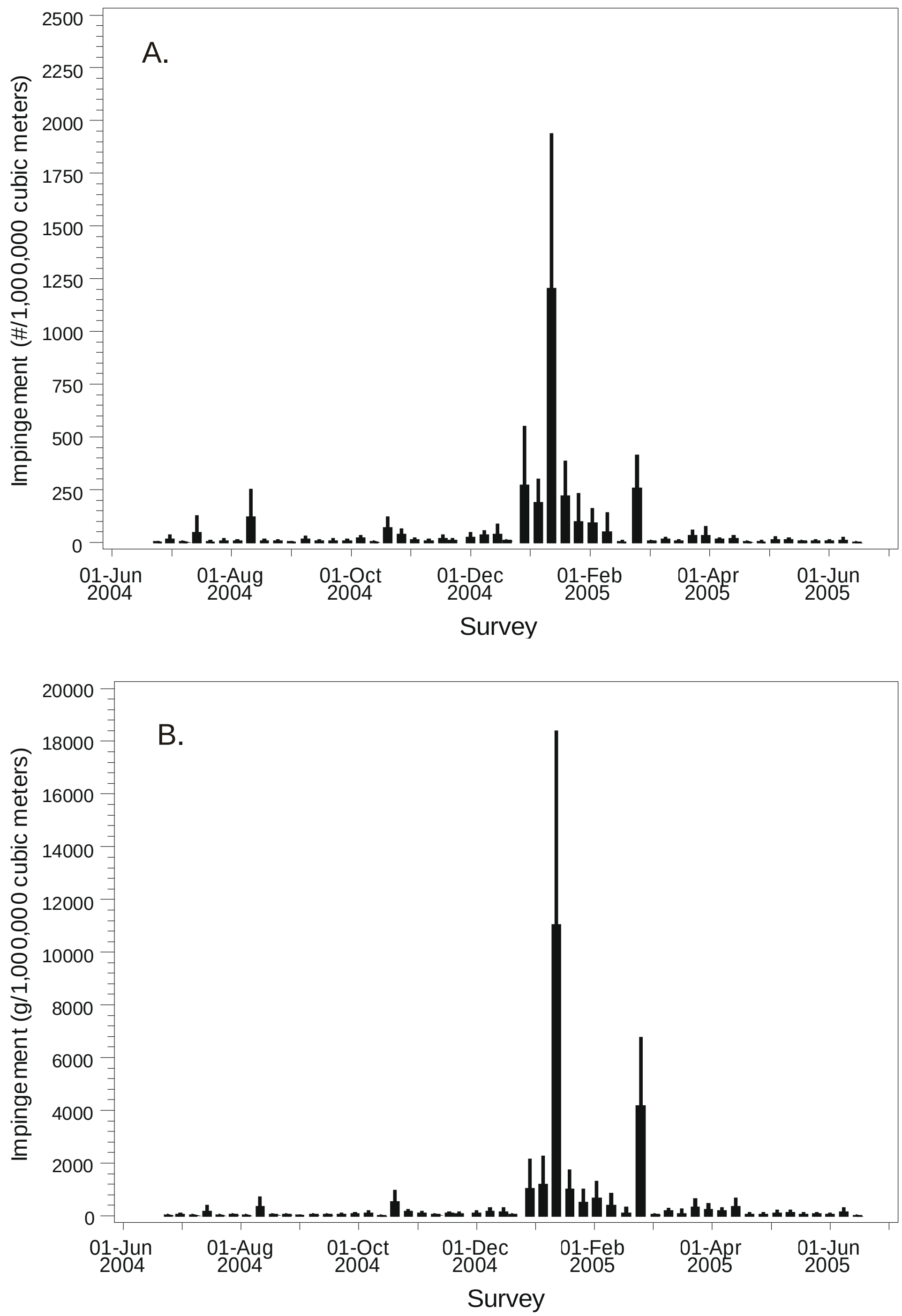


Figure 4-10. Mean concentration and standard error of silversides impinged at EPS Units 1–5 from June 2004 through June 2005 (n=52 surveys): A) abundance, and B) biomass.

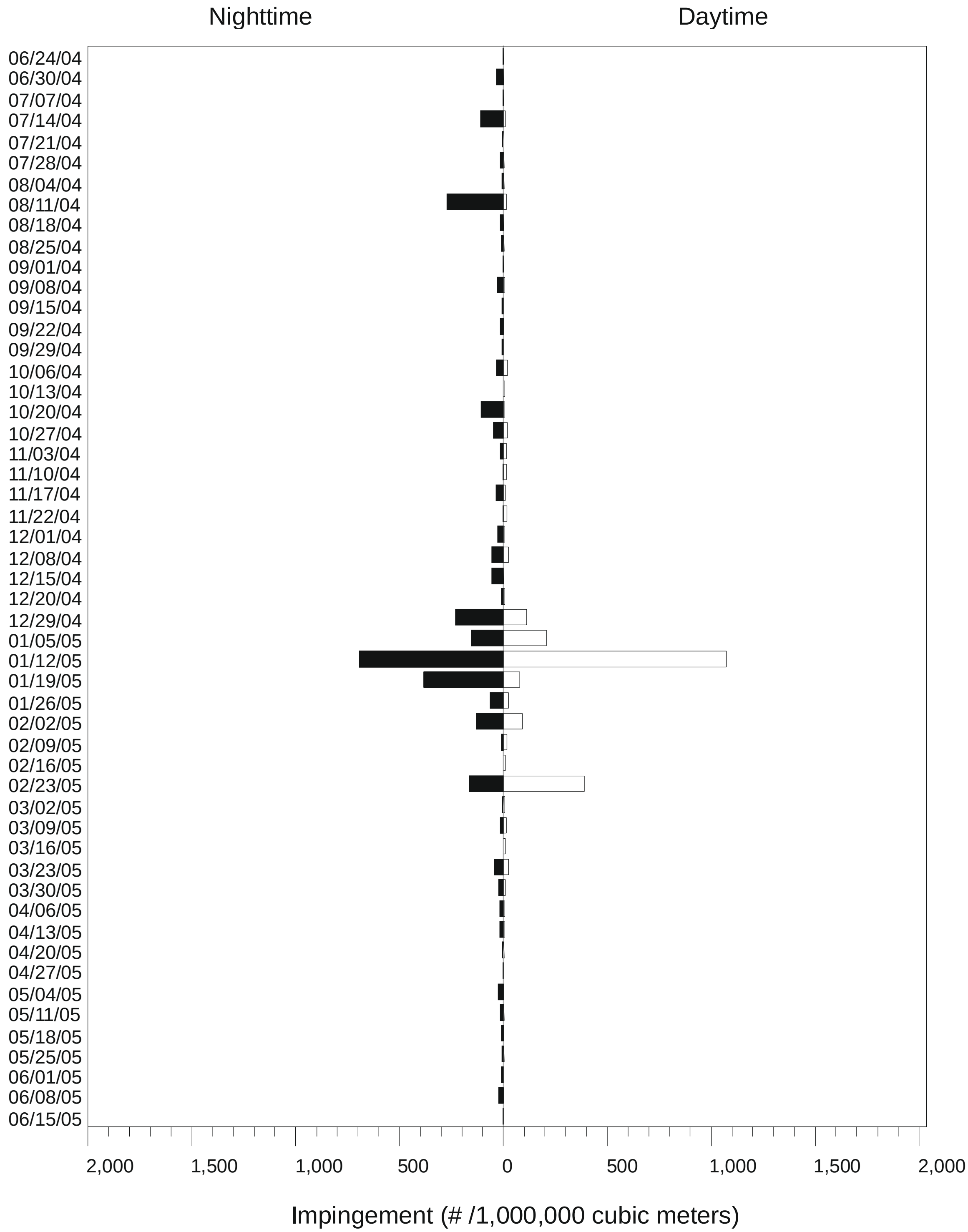


Figure 4-11. Abundance (#/10^6 m^3) of silversides impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

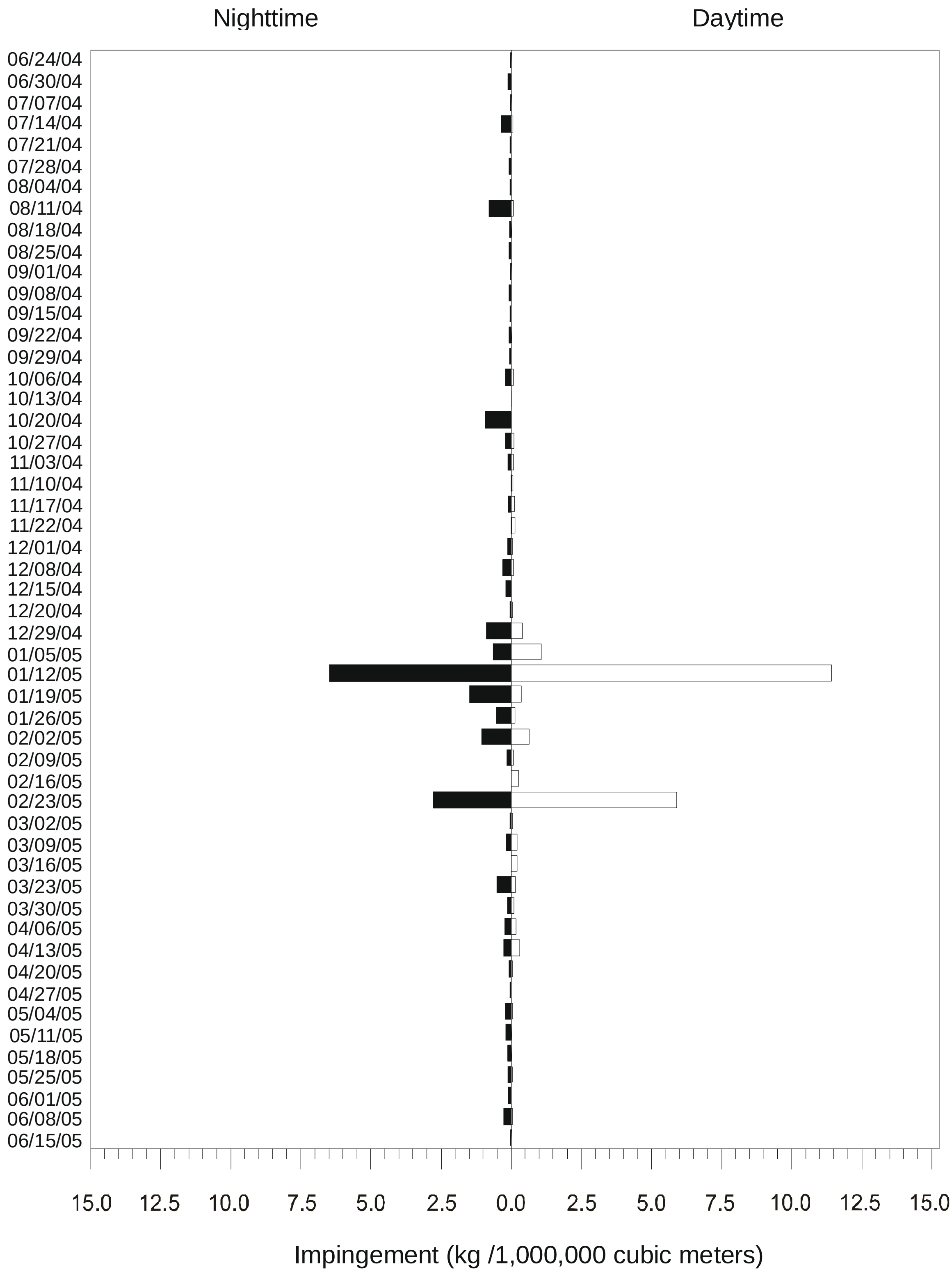


Figure 4-12. Biomass (kg/10^6 m^3) of silversides impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

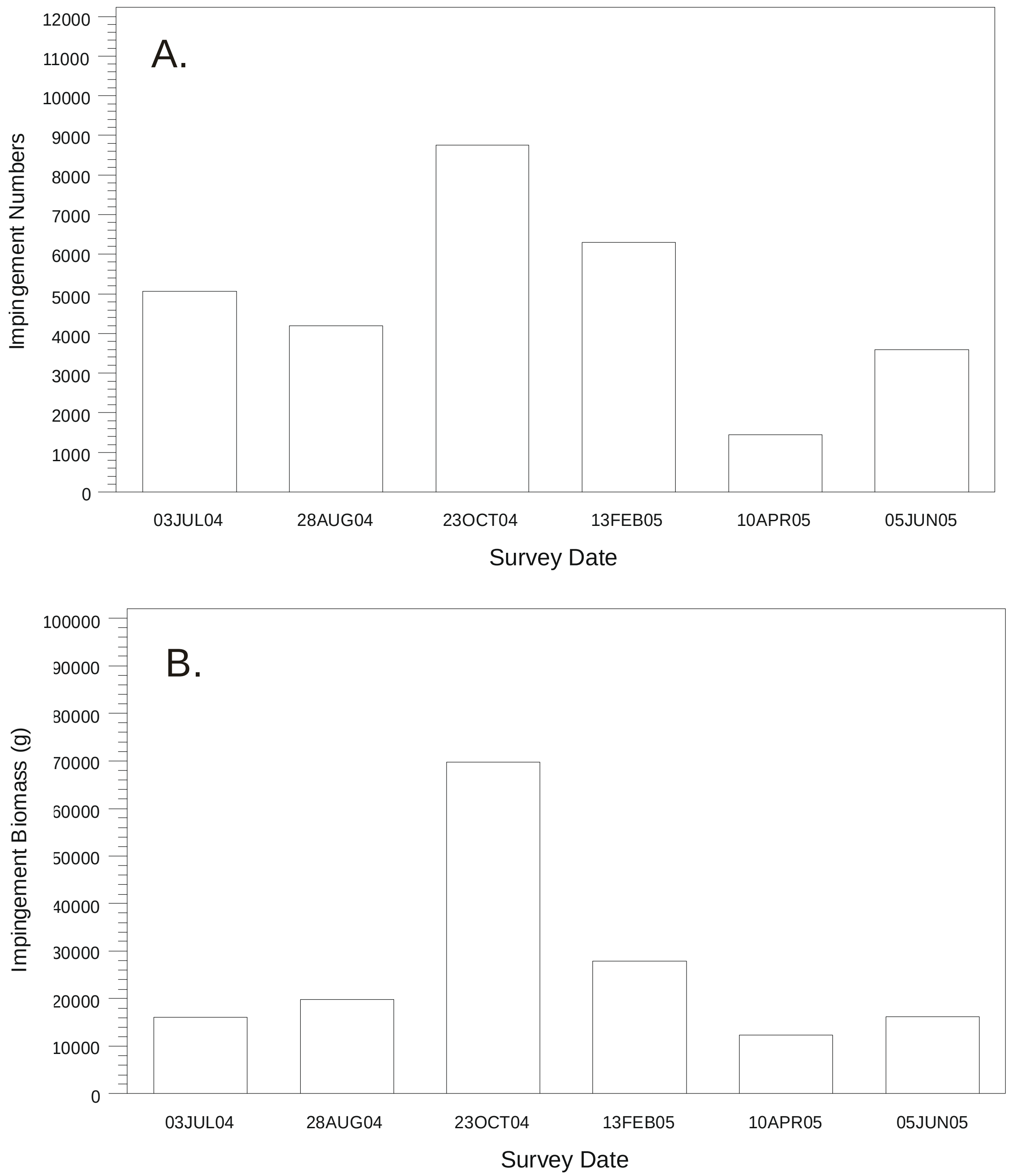


Figure 4-13. A) abundance, and B) biomass of silversides impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

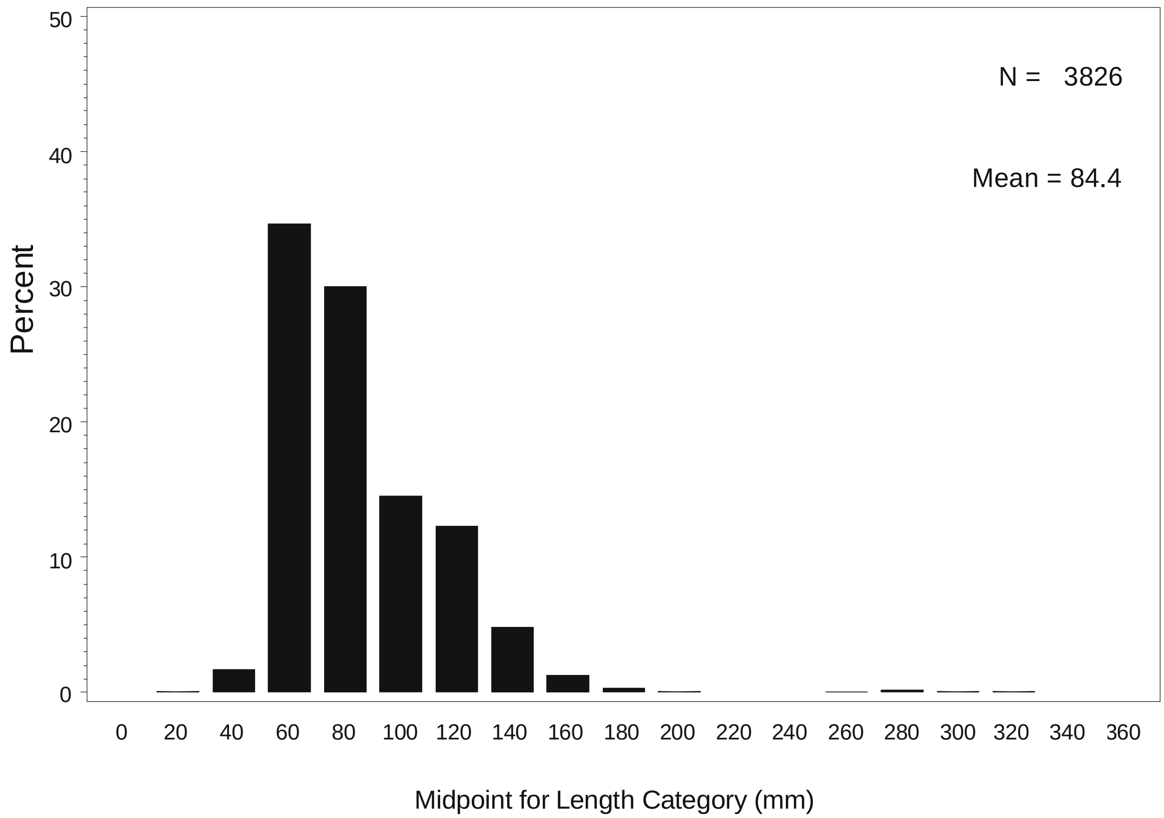


Figure 4-14. Size frequency distribution of silversides from EPS Units 1–5 impingement samples.

4.3.4 Shiner Surfperch (*Cymatogaster aggregata*)

Range: San Quentin Bay, Baja California, to Port Wrangell Alaska

Life History:
- Size up to 18 cm (7 in)
- Size at maturity 9.3 cm (3.6 in)
- Livebearers with up to 25 embryos
- Life span: to 6 yr

Habitat: bays, near eelgrass and kelp beds, oil platforms, piers, and jetties.

Fishery: Taken both recreationally and commercially; minor commercial value as bait.

Nineteen of the twenty species of surfperch (family Embiotocidae) found in California occur in inshore coastal waters (Miller and Lea 1972), and southern California is the center of distribution for many of the species (Bane and Robinson 1970).

Distributed from Port Wrangell, Alaska to San Quintin Bay, Baja California, *Cymatogaster aggregata* exhibits the widest range of the embiotocids (Miller and Lea 1972). Love (1996) reports that they are more common south of British Columbia. Bane and Robinson (1970) attributes this wide range to its euryhaline and eurythermal characteristics. Although they have been taken in water as deep as 146 m (480 ft) they are common at 61 m (200 ft) and abundant at depths less than 15 m (50 ft) (Love 1996). Love (1996) states that they are found in a wide variety of environments including quiet bays and backwaters, eelgrass and kelp beds, oil platforms, piers, jetties and occasionally the tidal zones of coastal streams. They form loose schools by day and disperse at night.

4.3.4.1 Life History and Ecology

Love (1996) summarized the life history of the shiner surfperch. Adults can reach 18 cm (7 in) in length and live to at least 6 years old. Surfperch are viviparous, giving birth to free swimming young. Females mature within the first year when they are approximately 9.3 cm (3.6 in) long and may contain up to 25 embryos (Wilson and Millemann 1969). Bane and Robinson (1970) reported on their reproductive cycle. Males are sexually mature at birth. Fertilization does not occur at the time of mating. After spawning females will carry spermatozoa in their oviduct until the eggs are mature. Fertilization occurs in winter for populations near San Diego (Love 1996). Odenweller (1975) found that birth in the Anaheim bay population of shiner surfperch occurs primarily in May. Wilson and Millemann (1969) found that embryo size was directly related to the size of the female.

Sport fishery catch estimates of shiner surfperch in the southern California region from 1999 to 2003 ranged from 2,000 to 20,000 annually with a mean of 11,000 fish (RecFIN 2005). For

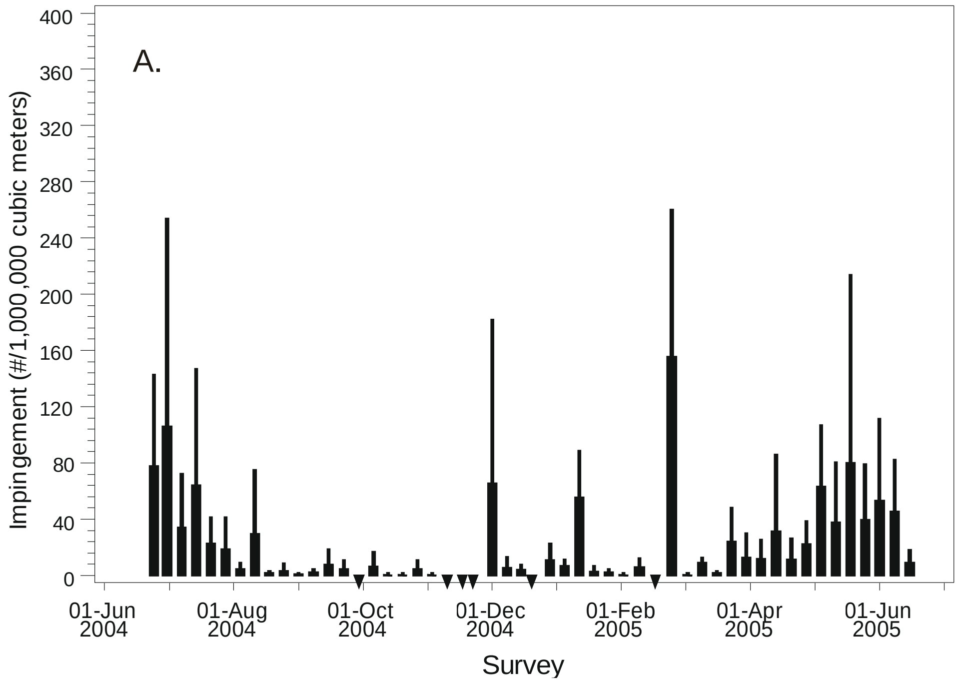
2003, CDFG estimates an average recreational take of 121.6 metric tons of shiners from 1999 to 2001. The PacFIN database does not distinguish among individual species of surfperch (PacFIN 2005). Commercial landings for surfperches in general from 1999 to 2003 ranged from 22.4 to 34.2 metric tons for the entire state (PacFIN 2005). CDFG (2003) noted that the commercial fishery of shiner surfperch averaged 22.5 metric tons per year in all of California from 1999 to 2001.

4.3.4.2 Sampling Results

Shiner surfperch were the second most abundant fish impinged at EPS with the third highest biomass during normal operation surveys. A total of 2,827 shiner surfperch with a total weight of 28.4 kg (62.6 lb) was impinged at EPS during the study (**Table 4-3**). Except for periodic high abundances in winter months, most shiner surfperch were impinged from April through August (**Figure 4-15**). Shiners were significantly more abundant in impingement collections at night than during the day, although more were impinged during the day in a few of the weekly surveys (**Figures 4-16** and **4-17**). A total of 18,361 individuals weighing 196.6 kg (433.4 lb) was collected in the heat treatments with the greatest biomass collected in the April 2005 treatment and highest numbers occurring in the July 2004 treatment (**Figure 4-18**). Impinged shiners ranged in length from 11 to 228 mm SL (0.4 to 9.0 in), with an average length of 70.3 mm (2.8 in) (**Figure 4-19; Appendix G**).

4.3.4.3 Annual Impingement Estimates

Based on the impinged abundance and biomass of shiner surfperch the estimated annual impingement abundance of shiner surfperch using actual CWS flow (not including heat treatment mortality) was 19,303 individuals, weighing 197.3 kg (435.0 lb) (**Table 4-3**). At maximum CWS flow the estimated annual impingement abundance of this species was 26,506 individuals, weighing 300.1 kg (661.7 lb). When all sources of impingement mortality were combined, it was estimated that during actual flows a total of 37,664 shiner surfperch weighing 393.8 kg (868.2 lb) were impinged (**Table 4-4**). If the plant operated at maximum flow for the entire year, the annual estimates of impingement increase to 44,867 individuals with a combined weight of 496.6 kg (1,095 lb).



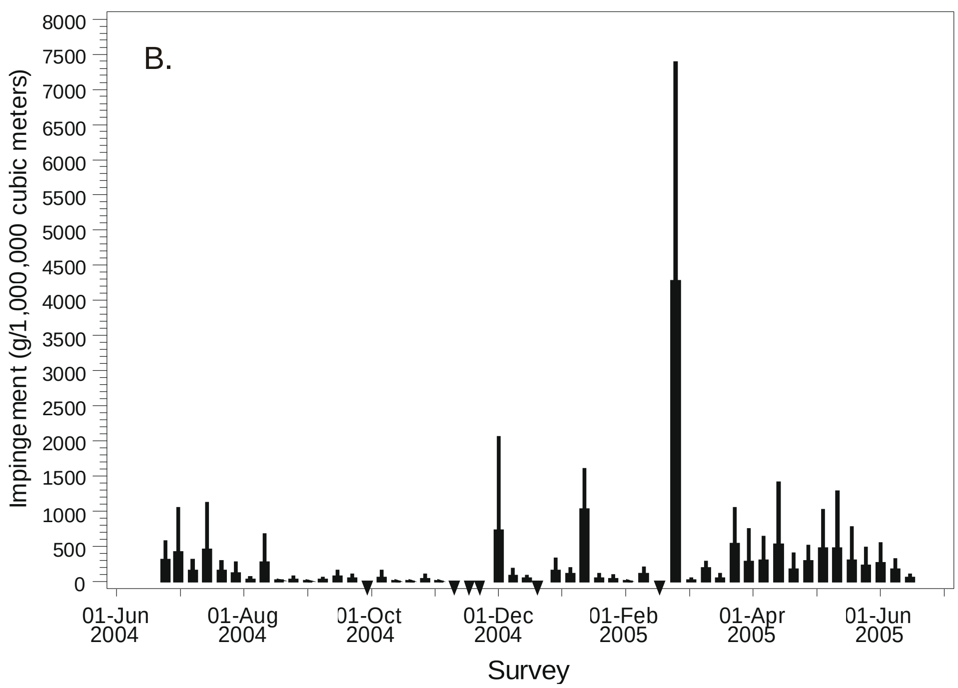


Figure 4-15. Mean concentration and standard error of shiner surfperch impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

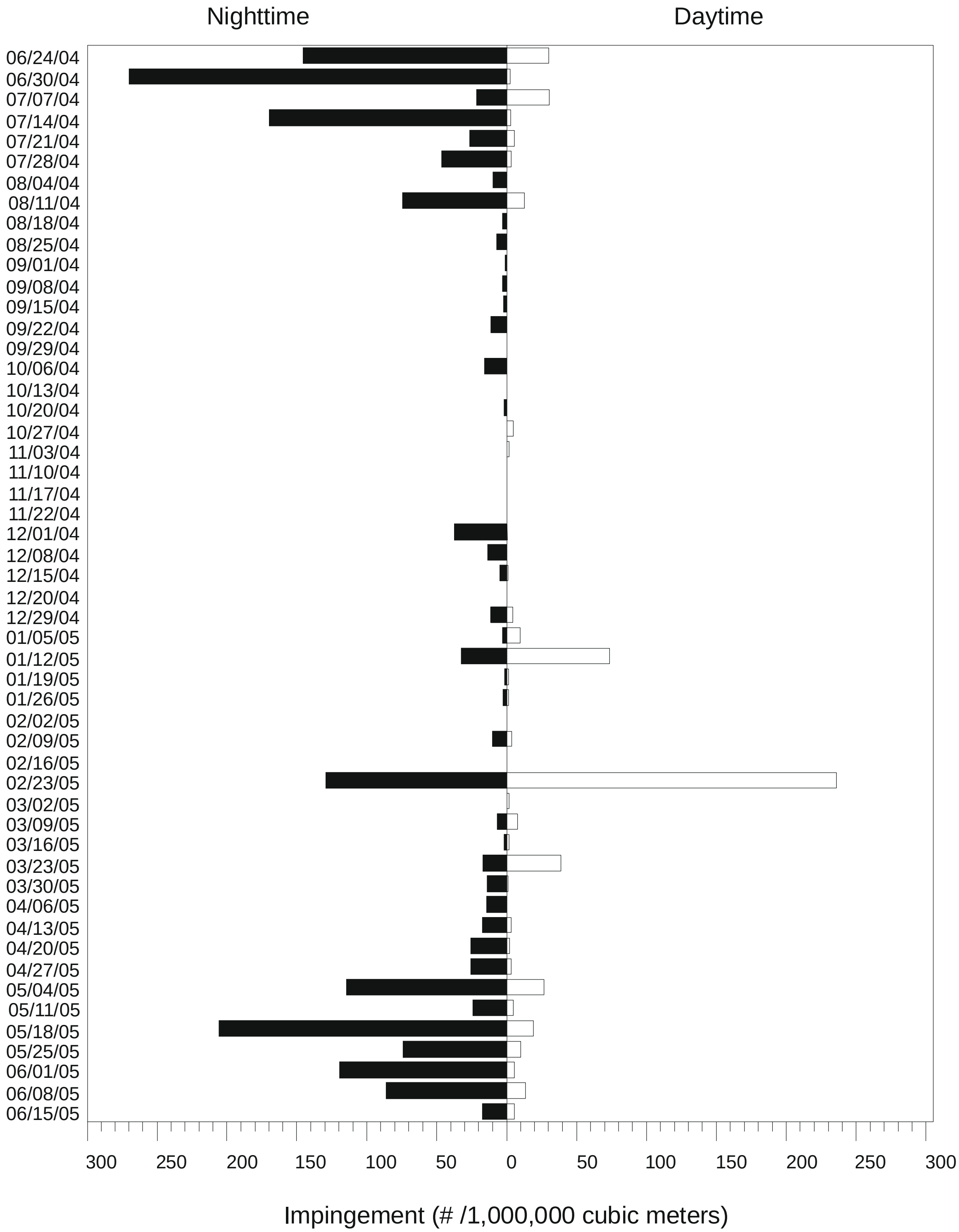


Figure 4-16. Abundance (#/10^6 m^3) of shiner surfperch impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

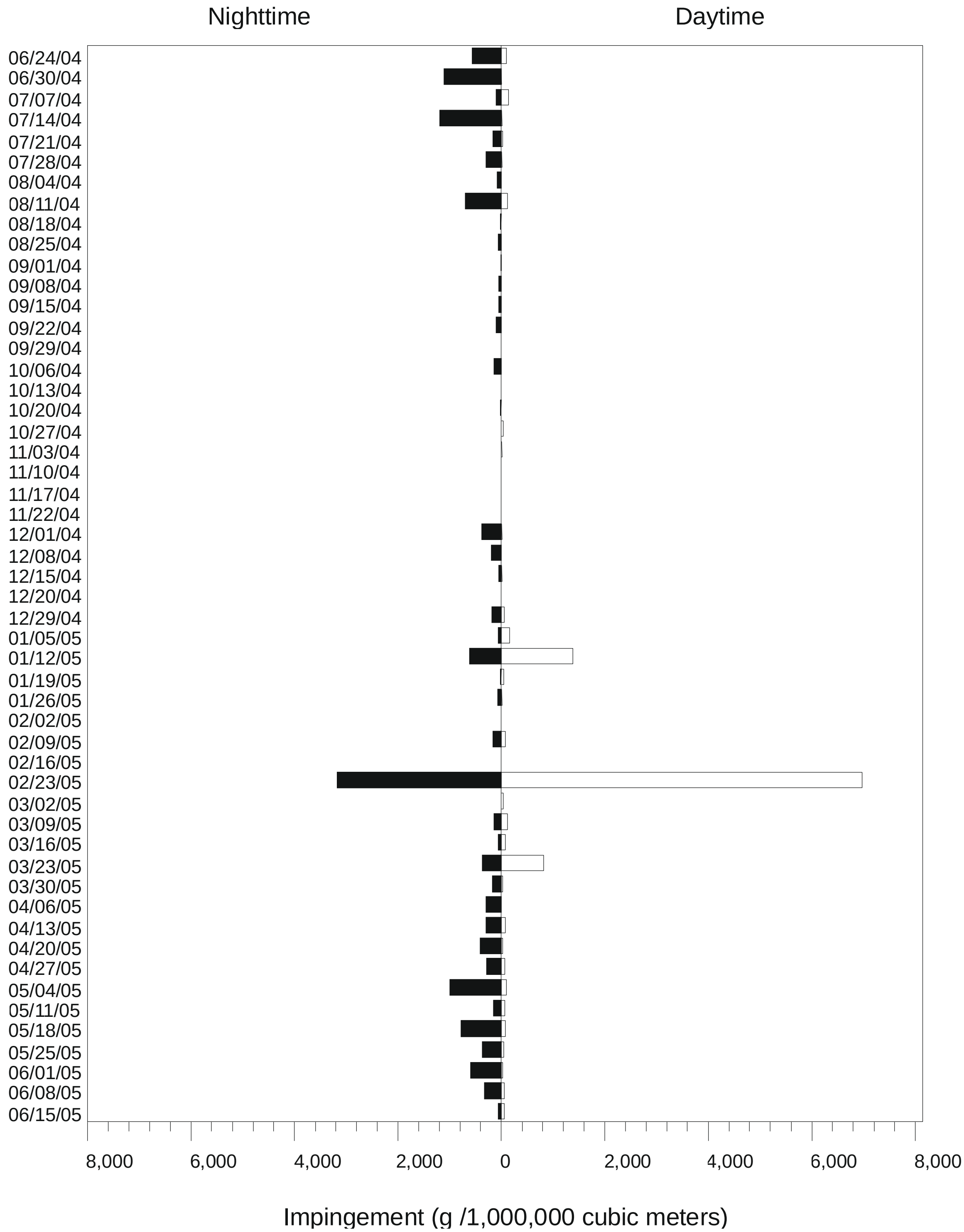


Figure 4-17. Biomass (g/10^6 m^3) of shiner surfperch impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

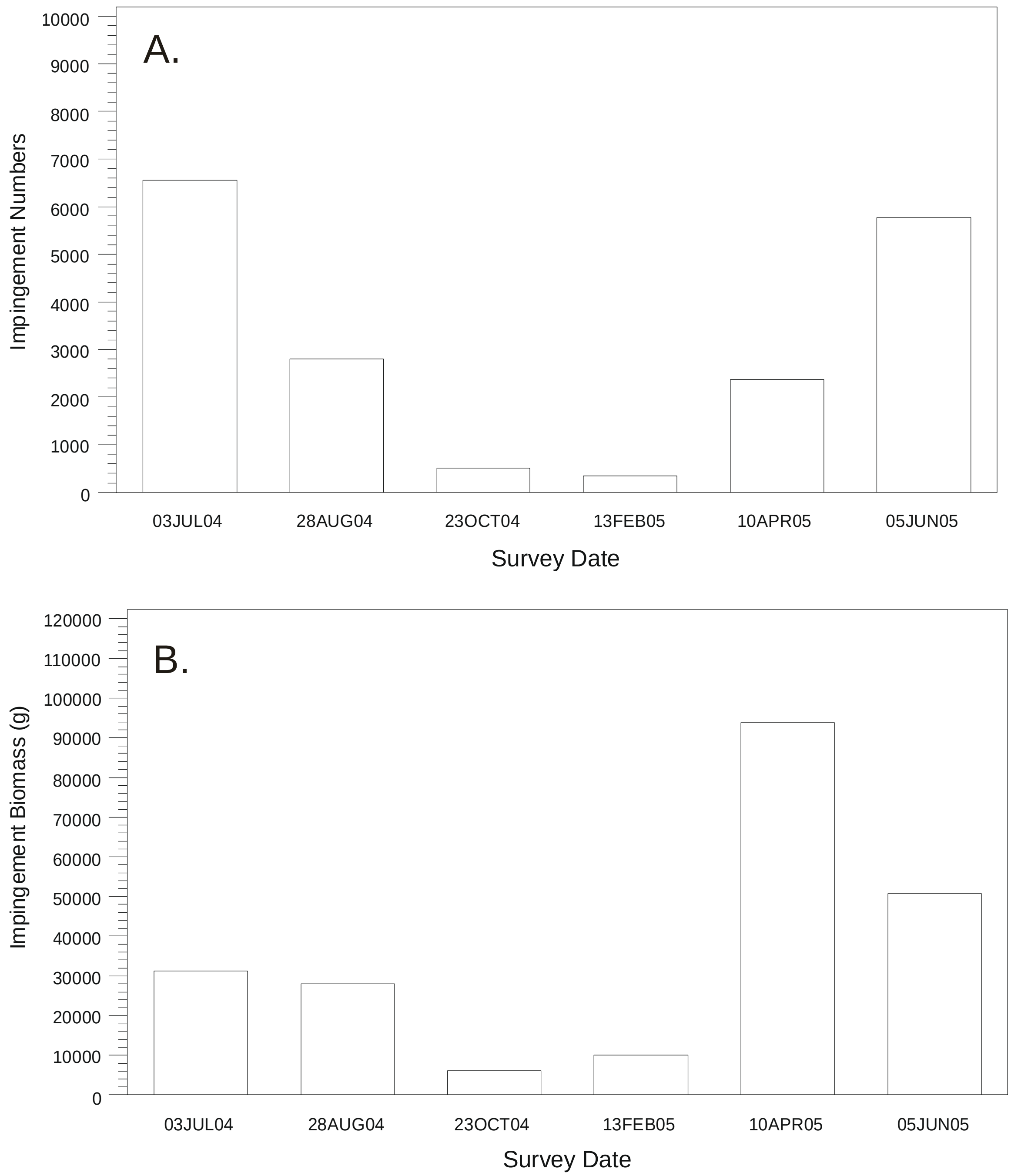


Figure 4-18. A) abundance, and B) biomass of shiner surfperch impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

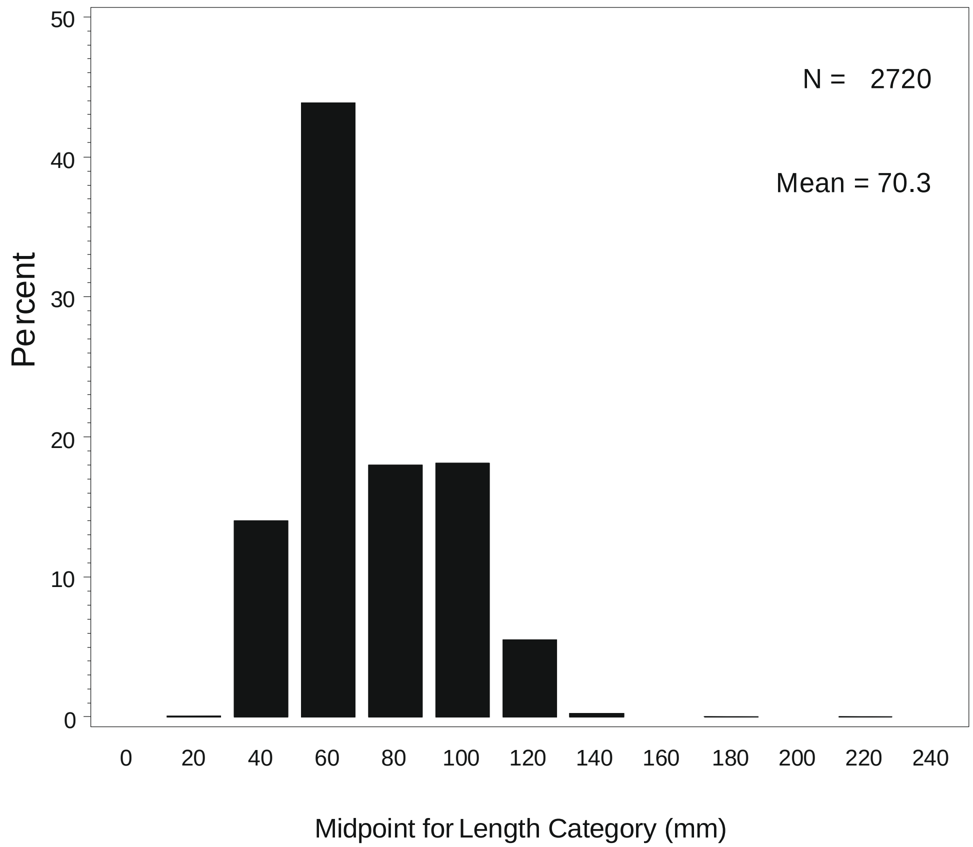


Figure 4-19. Size frequency distribution of shiner surfperch from EPS Units 1–5 impingement samples.

4.3.5 Queenfish (*Seriphus politus*)

Queenfish (*Seriphus politus*) is one of eight species of croakers (family Sciaenidae) found off of the California coast. Queenfish was the most abundant sciaenid impinged at five generating stations in southern California from 1977 to 1998, and accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). A study of the fish composition of Aqua Hedionda Lagoon in 1995 observed queenfish as one of the more abundant fish in the lagoon (MEC 1995). Queenfish were the most abundant species of fish collected in the 1979-80 impingement study conducted at the EPS, comprising 23.4% of the total number of fishes collected. Queenfish larvae were abundant in plankton samples collected as part of the entrainment impact portion of the present study, and their life history is presented in Section 3.3.7 of this report.

4.3.5.1 Sampling Results

A total of 1,304 queenfish was collected in the normal impingement sampling at EPS weighing 7.5 kg (16.5 lb) with 2 additional fish weighing 17 g (0.04 lb) collected from the bar racks (**Table 4-2**). Queenfish numbers were significantly more abundant at night than during the day (**Figure 4-21**) although greater numbers and biomass were impinged during daytime cycles in some weeks, and biomass was found not to be significantly different between night and day cycles (**Figure 4-22**). A total of 929 individuals was collected during heat treatments, weighing 21.4 kg (47.2 lb) (**Table 4-2**). The peak in abundance during heat treatment surveys was during April 2005, while the peak in biomass was impinged during the heat treatment in August 2004 (**Figure 4-2.3**). Lengths of the measured individuals ranged from 22 to 499 mm SL (0.9 to 19.6 in SL), with a mean length of 73.7 mm (**Figure 4.24; Appendix G**). Queenfish were the fourth most abundant species of fish impinged during the year-long survey with the seventh highest biomass of all fish species collected (**Table 4-2**).

4.3.5.2 Annual Impingement Estimates

Based on the impinged abundance and biomass of queenfish, the estimated annual impingement using actual CWS flow was 8,536 individuals weighing 48.9 kg (107.8 lb) (**Table 4-3**). Estimated bar rack impingement was 14 individuals, weighing 0.1 kg (0.22 lb). Under maximum CWS flow the estimated annual impingement abundance would increase to 11,568 individuals, weighing 68.2 kg (150.4 lb). The estimated annual impingement of queenfish from all sources based on actual CWS flows was 9,479 individuals weighing 70.4 kg (155.2 lb) (**Table 4-4**). Under maximum CWS flows the estimated impingement mortality from all sources would be 12, 511 individuals having a combined weight of 89.7 kg (197.8 lb).

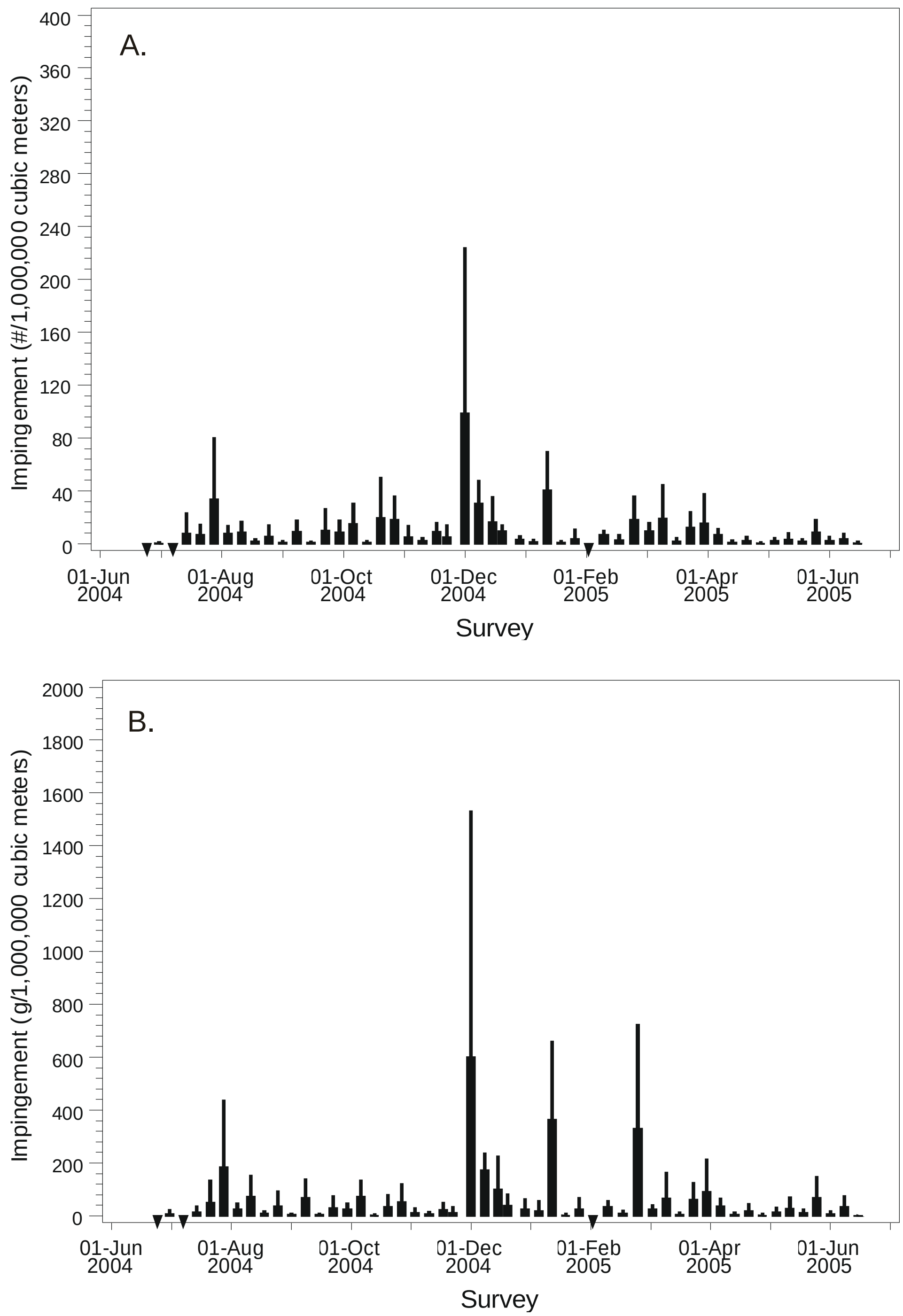


Figure 4-20. Mean concentration and standard error of queenfish impinged at EPS Units 1–5 from June 2004 through June 2005 (n=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

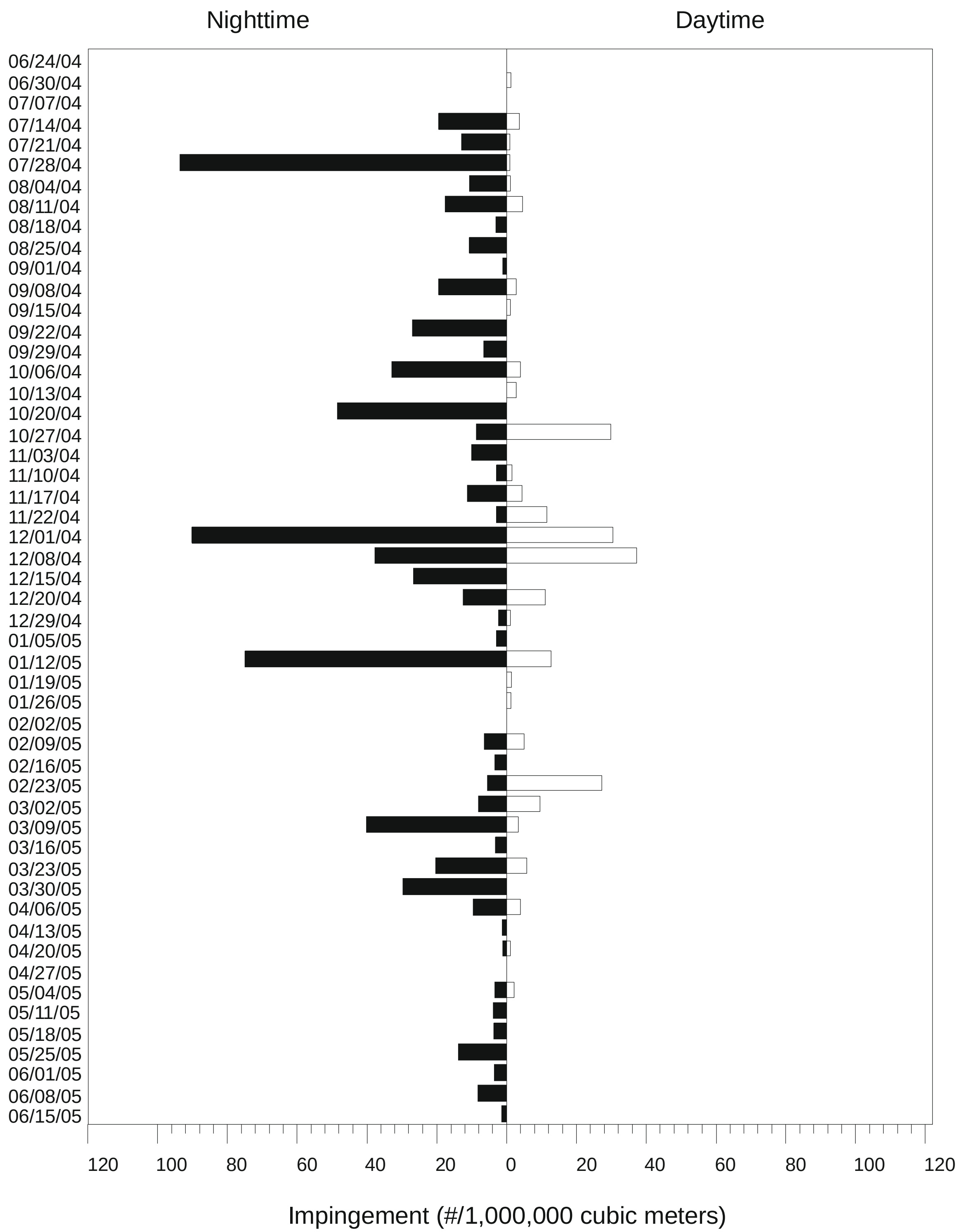


Figure 4-21. Abundance (#/10^6 m^3) of queenfish impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

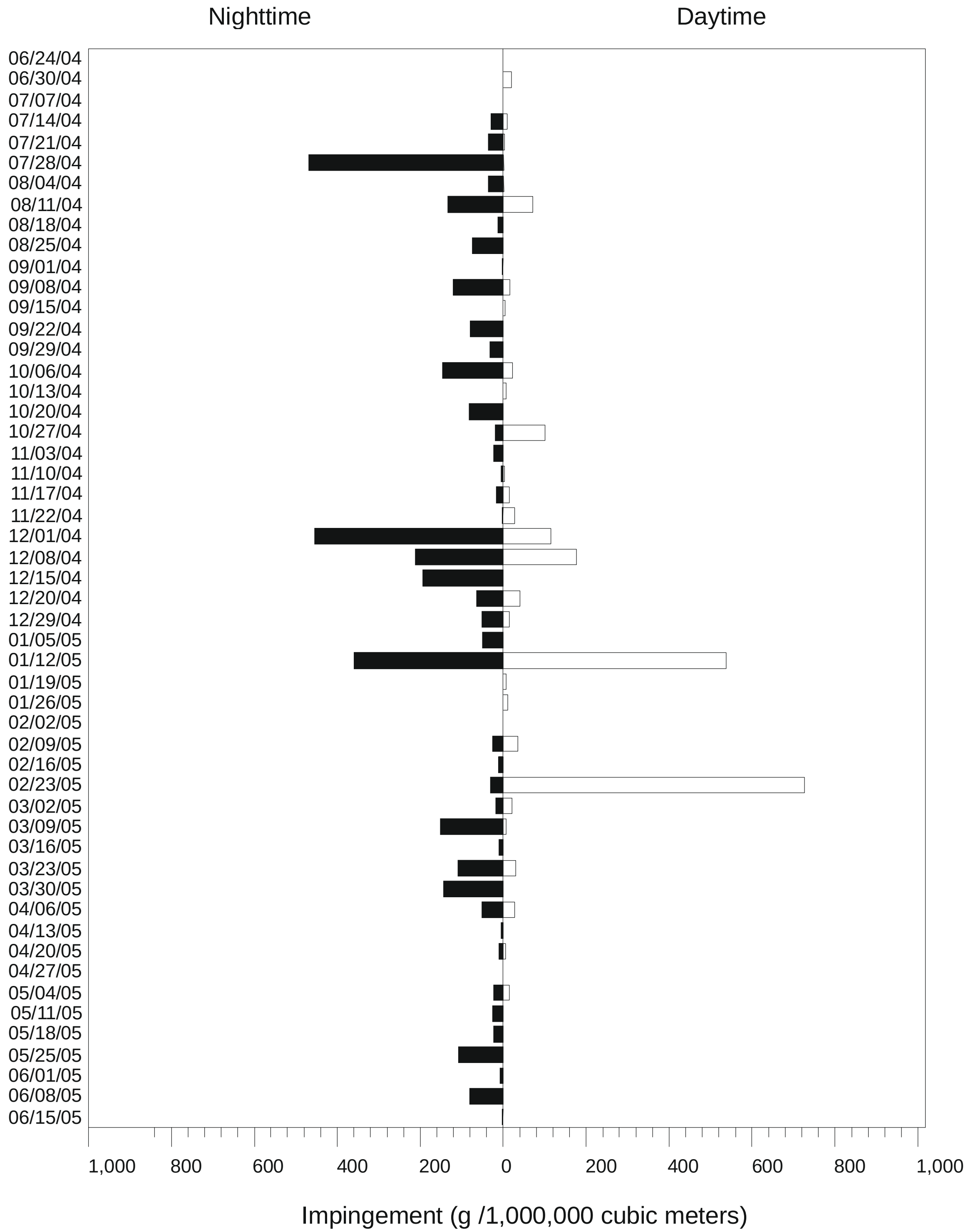


Figure 4-22. Biomass (g/10^6 m^3) of queenfish impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

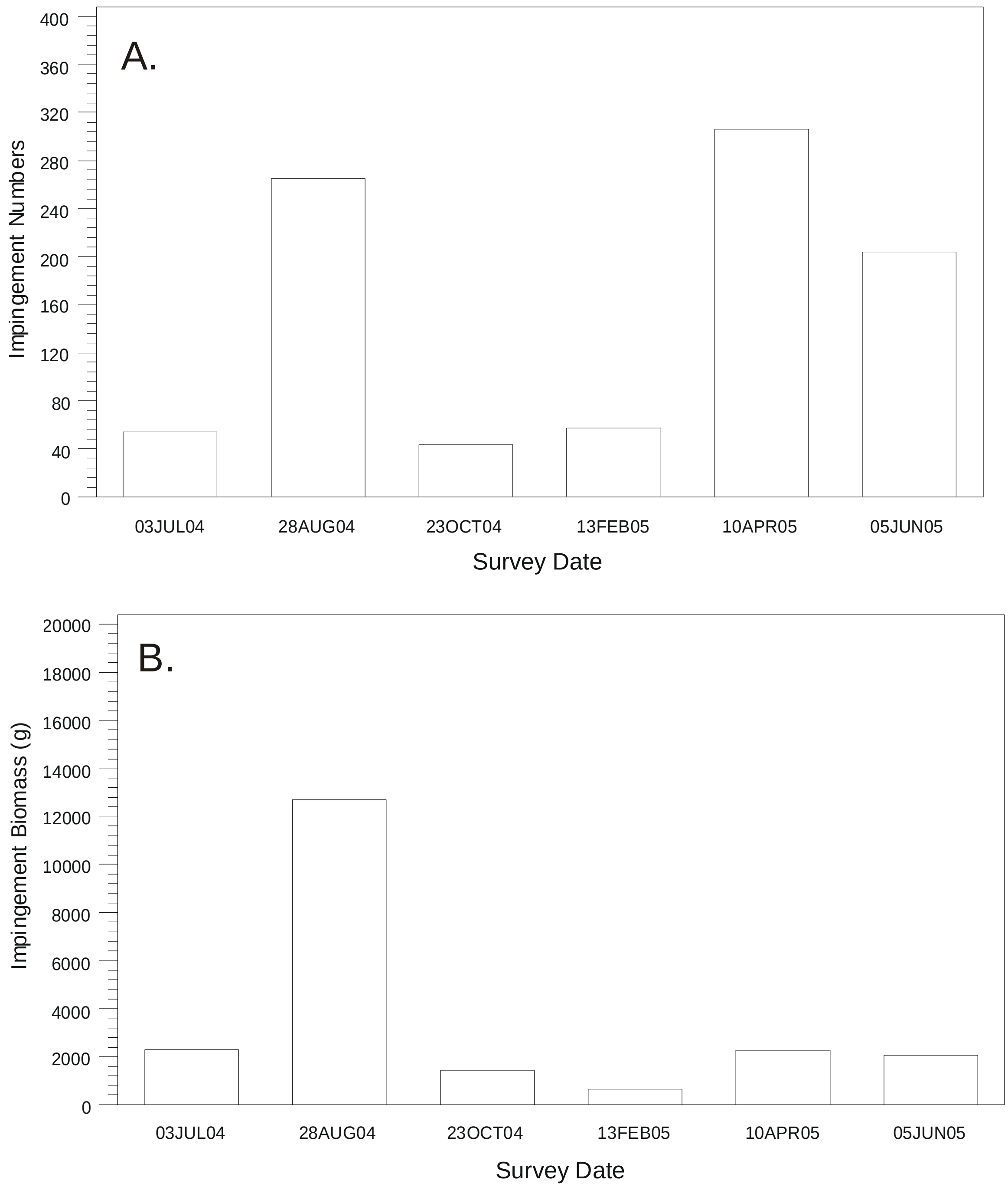


Figure 4-23. A) abundance, and B) biomass of queenfish impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

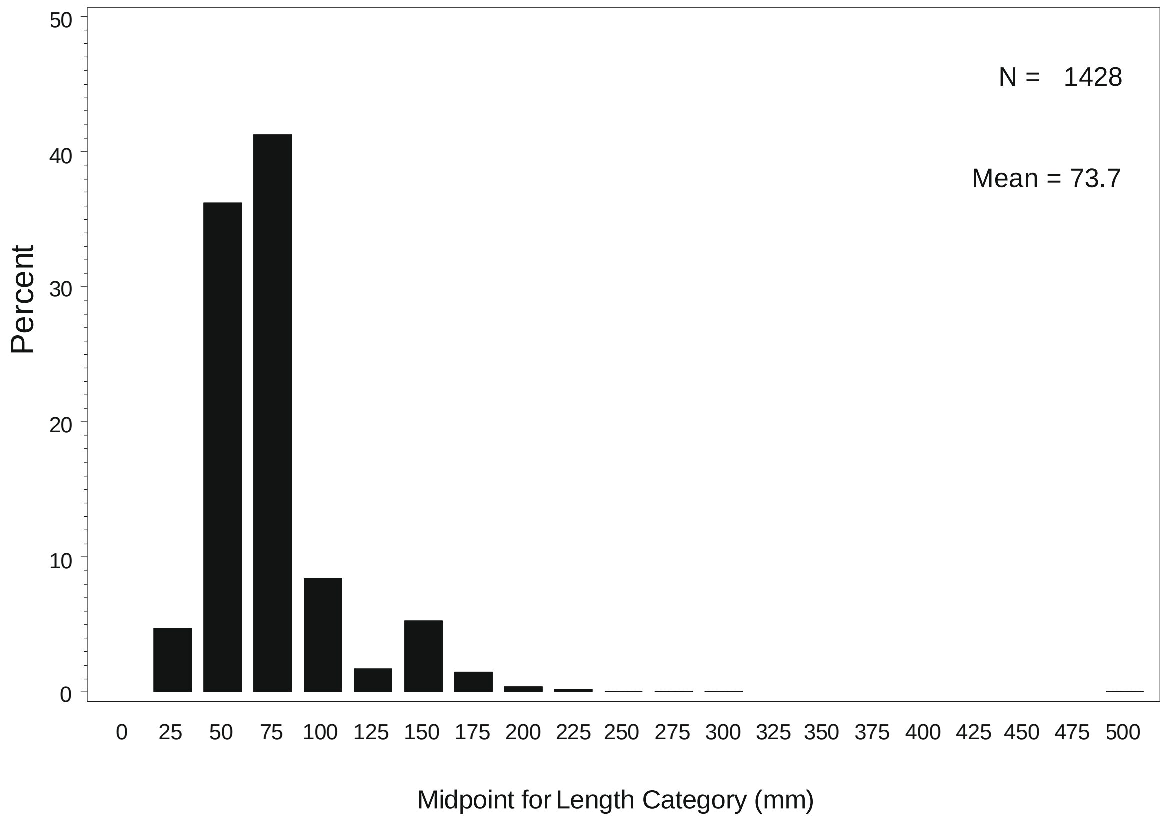


Figure 4-24. Size frequency distribution of queenfish from EPS Units 1–5 impingement samples.

4.3.6 Walleye Surfperch (*Hyperprosopon argenteum*)

Range: Vancouver Island, British Columbia to Central Baja California, Mexico

Life History:
- Size up to 30.2 cm (12.0 in)
- Size at maturity ca. 11.3 cm (4.5 in)
- Life span to 6 yr
- Fecundity up to 19 per litter

Habitat: Along sandy beaches, jetties, kelp beds and other sand-rock margins; moving onto reefs at night.

Fishery: Commercial and sport fishing allowed but primarily caught by sport fishers.

Twenty of the 23 surfperch (family Embiotocidae) species are found off the California coast, and 17 of these occur in the San Diego region (Love et al. 2005). Eight species were identified during the impingement study at EPS including shiner surfperch (*Cymatogaster aggregata)*, walleye surfperch (*Hyperprosopon argenteum)*, white surfperch (*Phanerodon furcatus)*, dwarf surfperch (*Micrometrus minimus)*, barred surfperch (*Amphistichus argenteus)*, kelp surfperch (*Brachyistius frenatus)*, black surfperch (*Embiotoca jacksoni)*, and pile perch (*Rhacochilus vacca)*.

Walleye surfperch range from Vancouver Island, British Columbia to Punta San Rosarito in central Baja California, Mexico, including Guadalupe Island (Miller and Lea 1972). Love (1996) states that they are common from Washington southward and are even more abundant off of California. They are most common at depths down to 9.0 m (30 ft) but have been recorded to a maximum depth of 181.4 m (600 ft) (Love 1996).

4.3.6.1 Life History and Ecology

Adults can reach 30.2 cm (12.0 in) in length and live about 6 years (Love 1996). Walleye mature during their first year at a length of 11.0 cm (4.5 in). While males mature faster than females, females grow faster and live longer than males. Walleye spawn in November and release their offspring between April and June. Females are viviparous and may produce up to 19 young per litter (Love 1996), although Eschmeyer and Herald (1983) state that litters typically range from 5 to 12 individuals.

No commercial fishery for walleye surfperch exists in the San Diego area (PacFIN), but they are recreationally fished. Sport fishery catch estimates of walleye surfperch in the southern California region from 1999 to 2003 ranged from 15,000–107,000 annually with a mean of 59,600 fish (RecFIN 2005). CDFG (2001) noted that the sport fishery has recently averaged 112,000 fish per year in all of California, which agrees with estimates from RecFIN (2005) of about 110,750 fish per year in 1995–2002 for all of California.

4.3.6.2 Sampling Results

Walleye surfperch were the eighth most abundant fish taxa collected during the year-long study at EPS during normal operations, with the fourth highest biomass of all the fishes impinged during normal operations (**Table 4-2**). A total of 605 walleye surfperch individuals with a total weight of 24.0 kg (52.9 lb) was impinged (**Table 4-2**). One additional walleye surfperch was collected from the bar racks, weighing 0.02 kg (0.04 lb). These individuals were primarily collected from late December to June, with being impinged in a single survey (January 5, 2005) (**Figure 4-25**). Although they were found with greater frequency during night impingement cycles, the greatest abundance and biomass during some surveys occurred during the daytime (**Figures 4-26** and **4-27**). A total of 2,547 individuals weighing 125.4 kg (276.5 lb) was impinged during the heat treatment surveys (**Table 4-2**). Walleye surfperch were more common in the heat treatment surveys from October 23 2004 to June 5, 2005, but most were collected in one survey in February 2005 (**Figure 4-28**). Impinged individuals ranged in length from 20 to 225 mm SL (0.8 – 8.9 in) with a mean length of 113 mm SL (4.5 in) (**Figure 4-29; Appendix G**).

4.3.6.3 Annual Impingement Estimates

The estimated annual impingement abundance and biomass of walleye surfperch under actual CWS flows was 3,032 individuals, weighing 123.0 kg (271.2 lb) (**Table 4-3**). Under maximum CWS flows the estimate increases to 6,623 individuals, weighing 276.9 kg (610.6 lb) (**Table 4-3**). Combining data from normal operations, heat treatment and bar rack the total estimated annual impingement mortality under actual CWS flows was 5,586 walleye surfperch weighing 248.5 kg (547.8 lb) (**Table 4-4**). Under maximum flows the annual estimates of impingement increase to 9,177 individuals with a combined weight of 402.5 kg (887.4 lb).

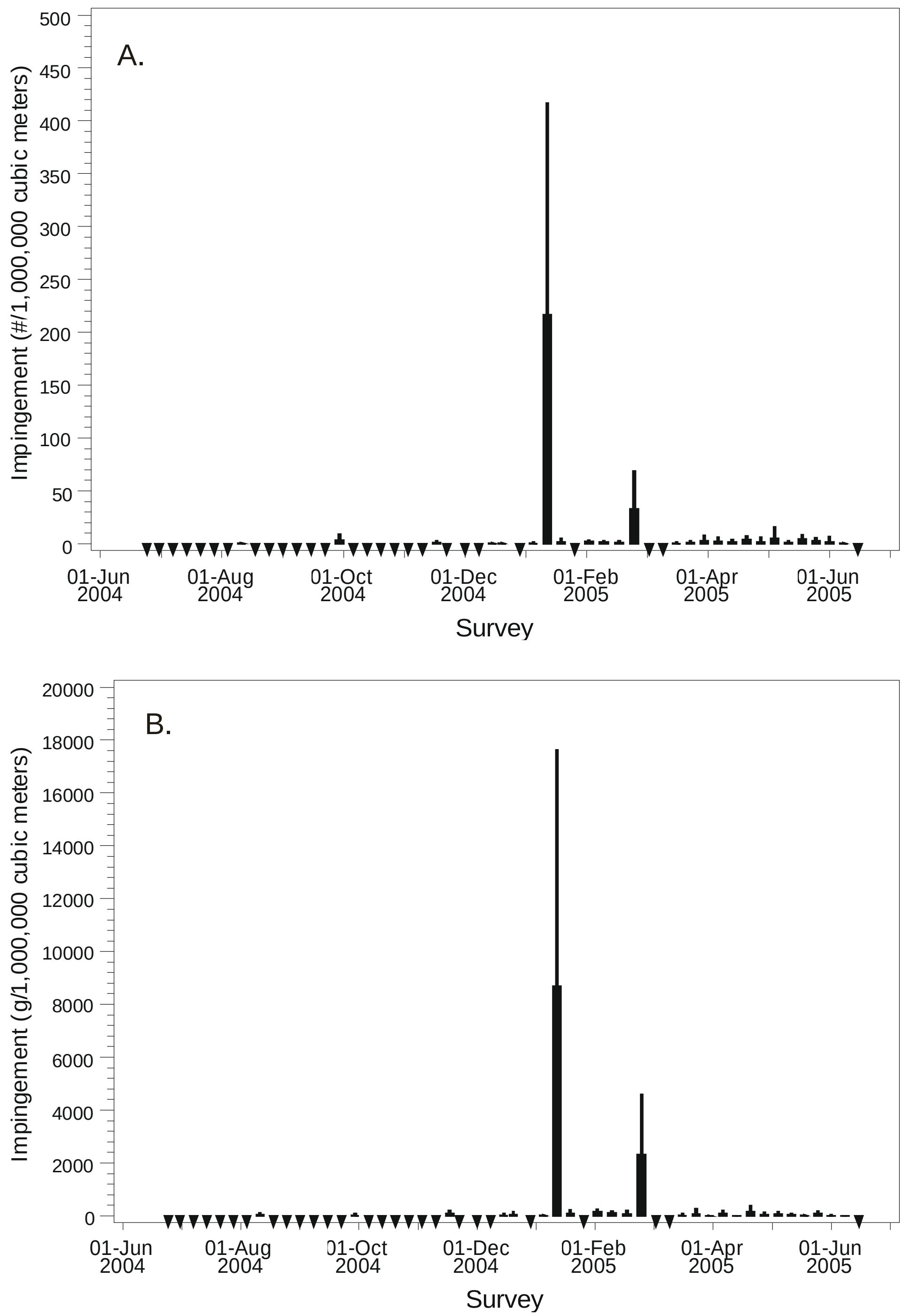


Figure 4-25. Mean concentration and standard error of walleye surfperch impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

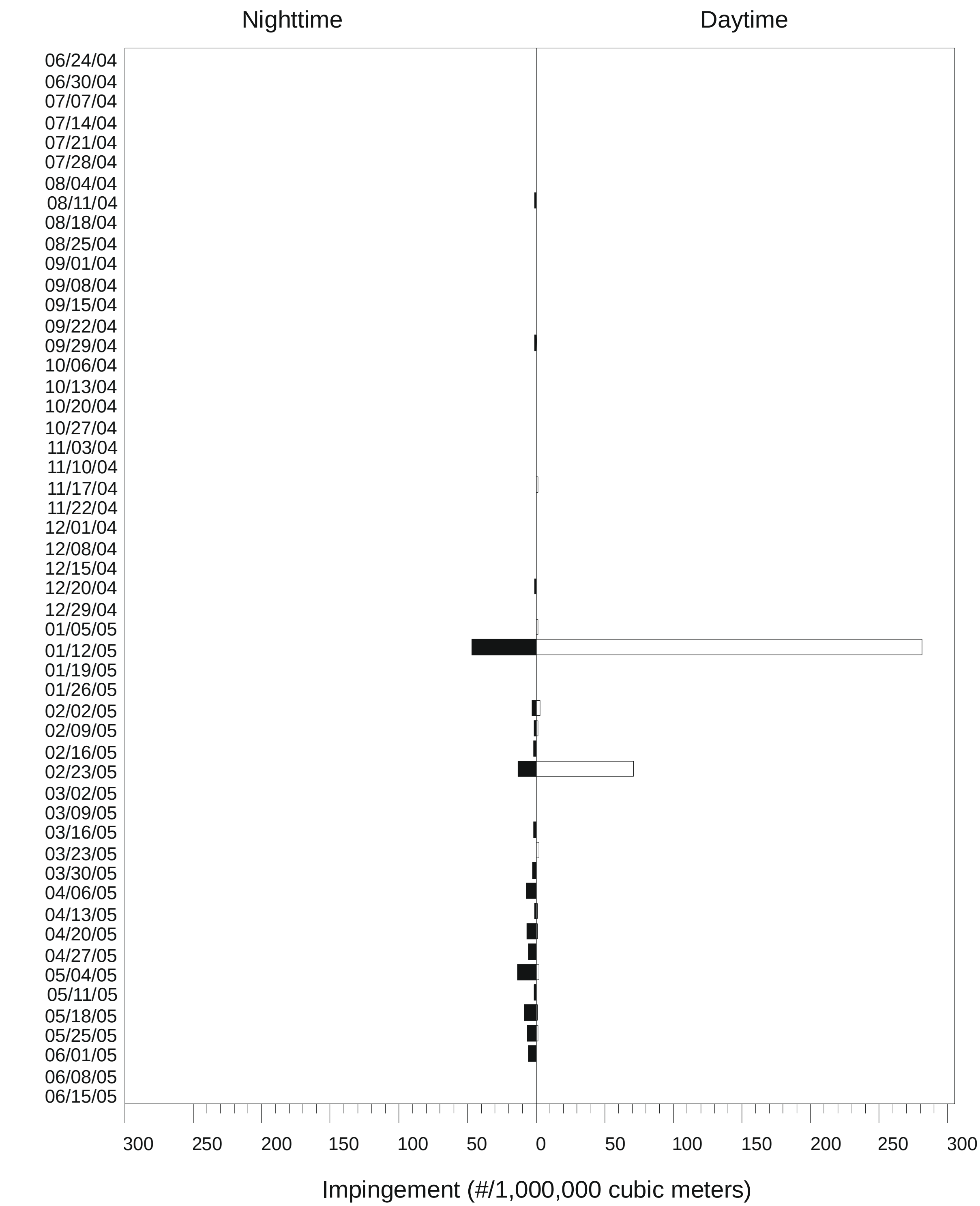


Figure 4-26. Abundance (#/10^6 m^3) of walleye surfperch impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

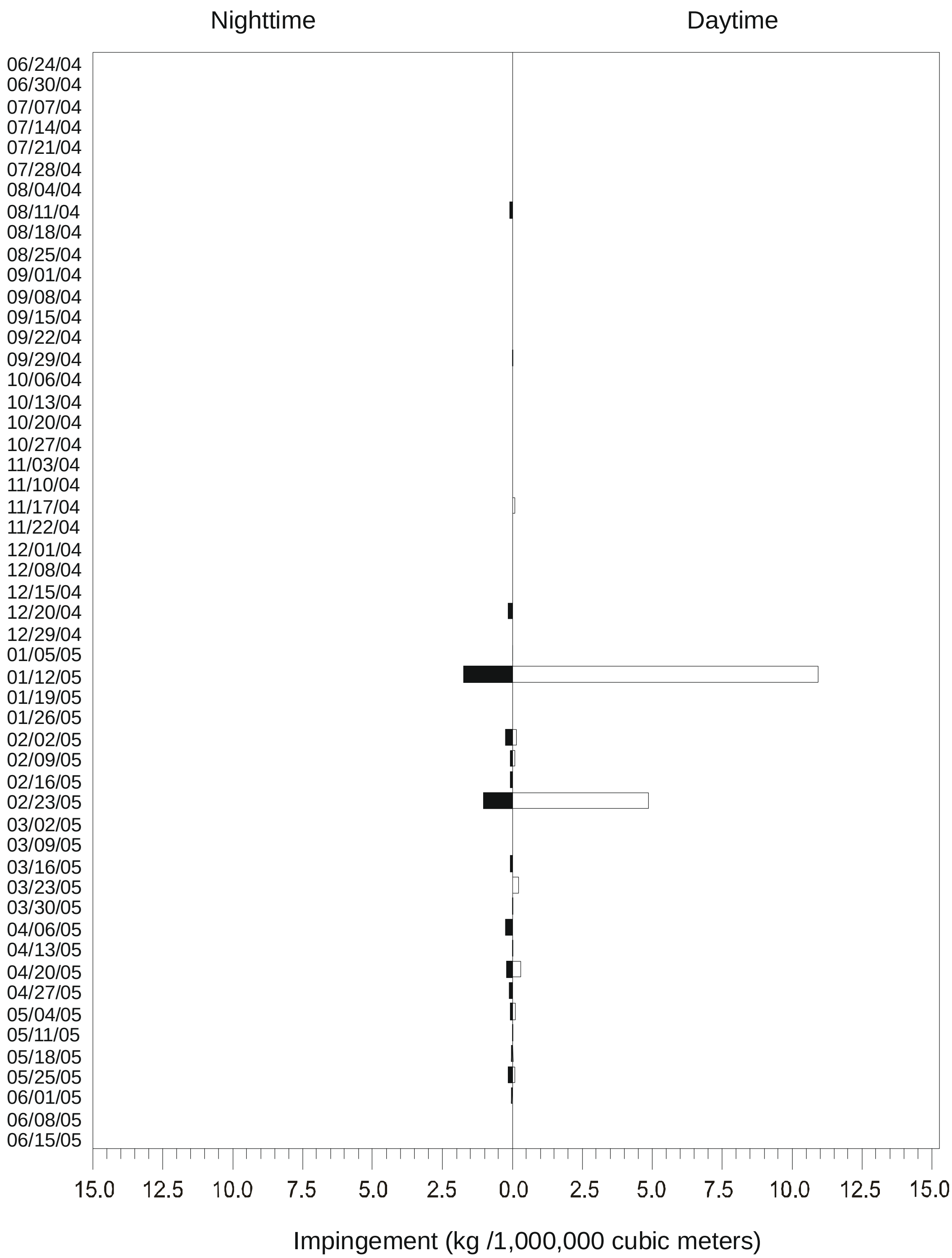


Figure 4-27. Biomass (kg/10^6 m^3) of walleye surfperch impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

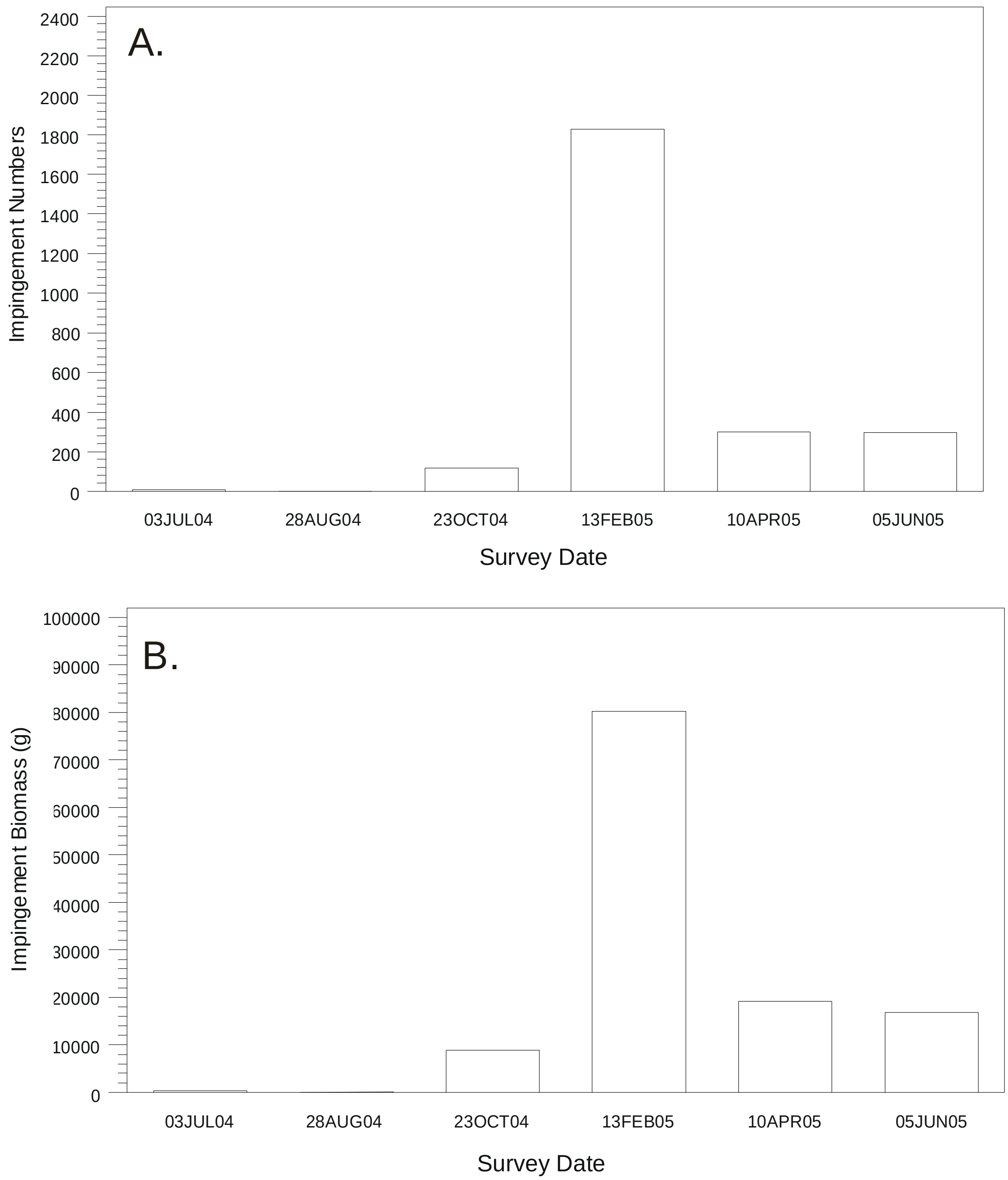


Figure 4-28. A) abundance, and B) biomass of walleye surfperch impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

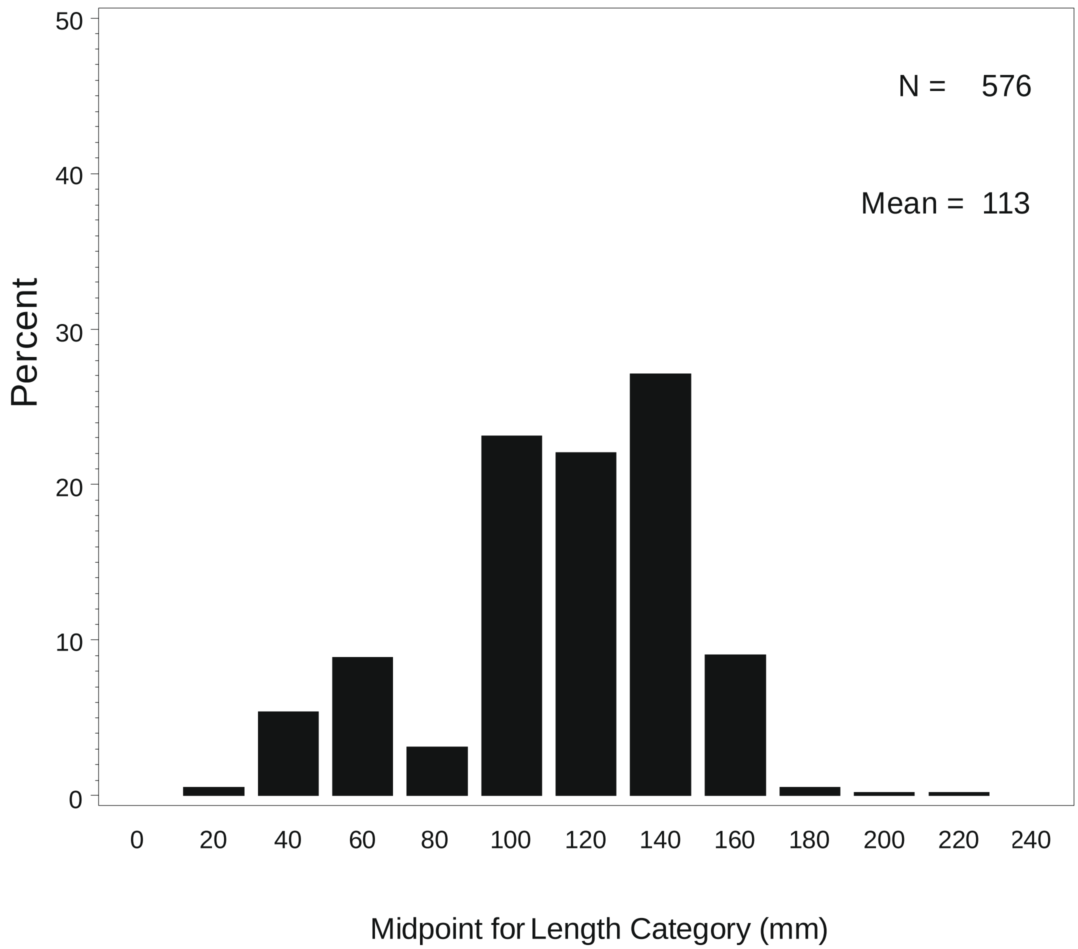
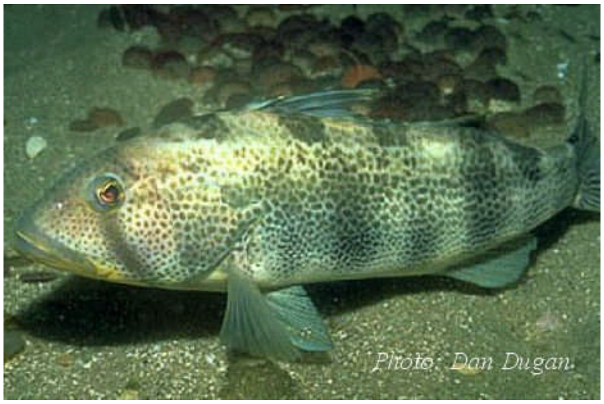


Figure 4-29. Size frequency distribution of walleye surfperch from EPS Units 1–5 impingement samples.

4.3.7 Sand Basses (*Paralabrax* spp.)



Range:

- Spotted: Monterey, California to Mazatlan, Mexico, including the Gulf of California
- Barred: Santa Cruz south to Bahia Magdelena, Baja California
- Kelp: Washington south to Bahia Magdalena, Baja California

Life History:

- Size to 56 cm (22 in) (spotted); 69 cm (27 in) (barred); 72 cm (28.5 in) (kelp)
- Age at maturity >1 to 5 yr, all species
- Life span to 14 yr (spotted); 24 yr (barred); 34 yr (kelp)
- Spawning occurs April to November for barred and kelp bass, June to August for spotted; fecundity up to 185,00 eggs/ year

Habitat: shallow water rock-sand ecotone; nearshore sand flats, near kelp beds, rocky areas, and bays.

Fishery: Sport fishery only; no commercial fishery allowed.

Three species of basses, family Serranidae, genus *Paralabrax*, occur in the San Diego region and were collected in the EPS impingement abundance study: spotted sand bass (*P. maculatofasciatus)*, barred sand bass (*P. nebulifer)*, and kelp bass (*P. clathratus)*. Spotted sand bass are found from Monterey, California to Mazatlan, Mexico, including the Gulf of California; barred sand bass are found from Santa Cruz to Bahia Magdalena; and kelp bass are found from the mouth of the Columbia River in Washington to Bahia Magdalena, Baja California (Miller and Lea 1972). However, Love (1996) reports that spotted sand bass are not common north of Newport Bay in southern California and Leet et al. (2001) states that barred and kelp bass are rare north of Point Conception.

4.3.7.1 Life History and Ecology

The life history of the spotted sand bass was summarized by Love (1996). Adults can reach 56 cm (22 in) in length and live to at least 14 years of age. Females mature within the first year and approximately one-half are mature when they are approximately 15 cm (6 in) long. Males reach maturity at approximately 3 yr with about half of the males being mature at 18 cm (7 in). Some individuals in the populations are protogynous, changing sex from female to male as they grow. Spawning in California populations occurs from June through August. Leet et al. (2001) summarized the life history of barred and kelp sand bass. Adult barred sand bass can reach 69 cm (27 in) and can live to 24 years of age. Adult kelp bass can reach 72 cm (28.5 in) and live to at least 34 years of age. Barred and kelp sand bass reach sexual maturity between 18 and 27 cm (7 to 10.5 in), at about 3–5 years of age. Barred and kelp sand bass form large breeding aggregations in deeper waters and spawn from April through November, peaking in summer months. All three species are multiple spawners (Oda et al. 1993).

In a study of *Paralabrax* fecundity by DeMartini (1987), the number of eggs ranged over a factor of 15 from about 12,000 eggs in a 447 g fish to >185,000 eggs in a 2,625 g fish. The smallest fish, a 148 g sand bass, contained 16,500 eggs. Sample females contained a mean $\pm$ 1 S. E. of 760 $\pm$ 80 eggs per gram of ovary and 70 $\pm$ 12 eggs per gram of ovary-free body weight. All three species are capable of daily spawning (Oda et al. 1993). However, not all fish captured in the Oda et al. (1993) study demonstrated evidence of daily spawning: 32% of the *P. clathratus* females (n = 84), 20% of the *P. maculatofasciatus* females (n = 79), and 31% of the *P. nebulifer* females (n = 81) showed evidence of spawning on two consecutive days. There was no statistically significant difference in the average size of specimens that exhibited evidence of daily spawning, compared to those that had spawned the day before collection. A standard weight female (ca. 700 g [ovary-free weight] and 300 mm SL) was calculated to average 81,000 eggs per batch. This estimate of batch fecundity for *Paralabrax* is higher than that reported by DeMartini (1987) and may indicate the variation possible in these species of *Paralabrax*.

Kelp bass are found associated with structure, such as kelp or rocks, from the subtidal zone to depths of 61 m (200ft) (Love 1996). They are typically found in water less than 21 m (70 ft) (Leet et al. 2001). Spotted sand bass are found in back bays and lagoons, were there is extensive cover (Love 1996). They have been taken in water as deep as 61 m (200 ft), however they are usually found shallower than 6.1 m (20 ft) (Love 1996). Barred sand bass are found at the sand-rock interface, and are commonly observed at artificial reefs. Barred sand bass have been taken in water as deep as 183 m (600 ft), but are usually found in water shallower than 27 m (90 ft);

4.3.7.2 Fishery and Population Trends

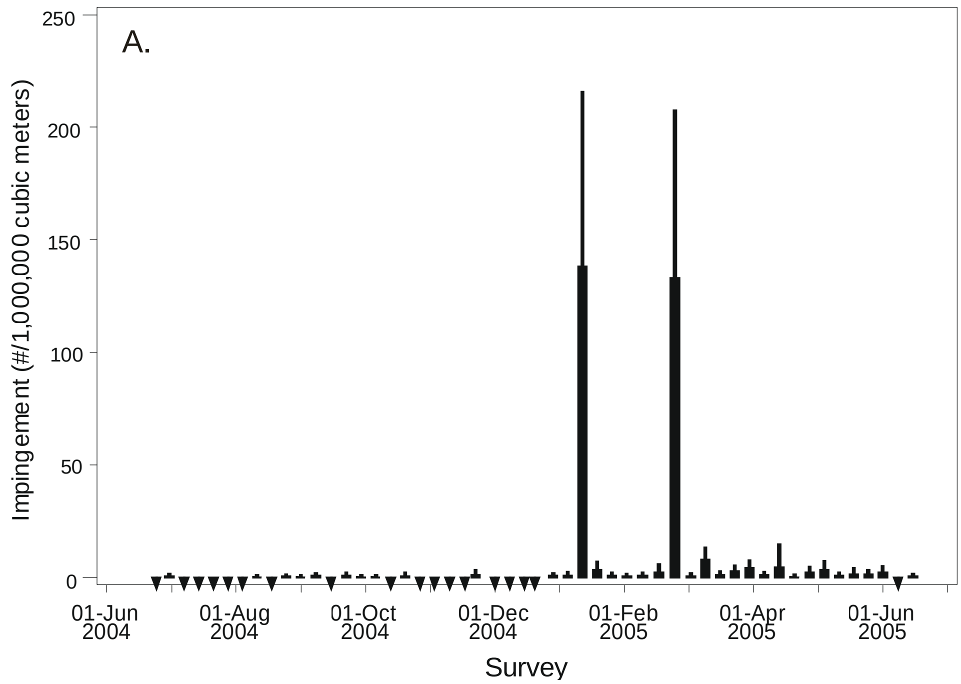
Barred and kelp bass are two of the most important recreational fishes in southern California (Leet et al. 2001). Sport fishery catch estimates of spotted sand bass in the southern California region from 2000 to 2004 ranged from 10,000 to 74,000 fish, with an average of 49,400 fish caught annually (RecFIN 2006). Catch estimates of kelp bass in southern California ranged from 291,000 to 587,000 fish from 2000 to 2004, with an average of 424,400 fish caught annually. Barred sand bass catch estimates ranged from 695,000 to 1,130,000 fish caught annually, with an average of 917,000 fish caught annually (RecFIN 2006).

4.3.7.3 Sampling Results

A total of 567 sand bass was impinged during the normal impingement surveys (**Table 4-2**). Of these, 303 were spotted, 151 were barred, 111 were kelp and 2 could not be identified to the species level and were recorded as *Paralabrax* spp. These impinged sand bass had a combined total weight of 6.8 kg (15.0 lb) (**Table 4.2**). *Paralabrax* spp. combined were the ninth most abundant fish impinged and had the thirteenth highest biomass of the impinged fish. Sand bass were impinged throughout the year, but the peak in sand bass impingement abundance was in January and February, with the peaks in biomass being in January, February, April, and June (**Figures 4-30 and 4-31**). Most sand bass were impinged during two surveys (January 12 and February 23, 2005). Sand basses were more frequent during the nighttime impingement cycles but there was no substantial difference in overall numbers or biomass between day and night samples throughout the year (**Figures 4-31** and **4-32**). Sand bass were also collected during all heat treatments, peaking in numbers during the June 5, 2005 survey (**Figure 4-33**). A total of 4,511 sand bass was impinged in the heat treatments, weighing 153.6 kg (338.6 lb) (**Table 4-2**). Of these fish, 1,536 were spotted, 1,993 were barred, 976 were kelp and 6 could only be identified to *Paralabrax* spp. Lengths ranged from 28 to 358 mm SL (1.1 to 14.1 in SL), with a mean length of 81.3 mm SL (3.2 in) (**Figure 4-34; Appendix G**). Although the majority of *Paralabrax* spp. were small, they were assumed to be reproductively mature adults for the purposes of this assessment.

4.3.7.4 Annual Impingement Estimates

The estimated annual impingement of sand bass under normal operations using actual CWS flows was 3,477 individuals, weighing 45.2 kg (99.6 lb) (**Table 4-3**). Under maximum CWS flows the estimates increase to 7,274 individuals, weighing 85.8 kg (189.2 lb) (**Table 4-3**). When all sources of impingement mortality are combined, the annual impingement of sand basses under actual CWS flows was 7,988 individuals weighing 198.8 kg (438.3 lb) (**Table 4-4**). Under maximum flows the estimated number was 11,795 individuals weighing 239.4 kg (527.8 lb).



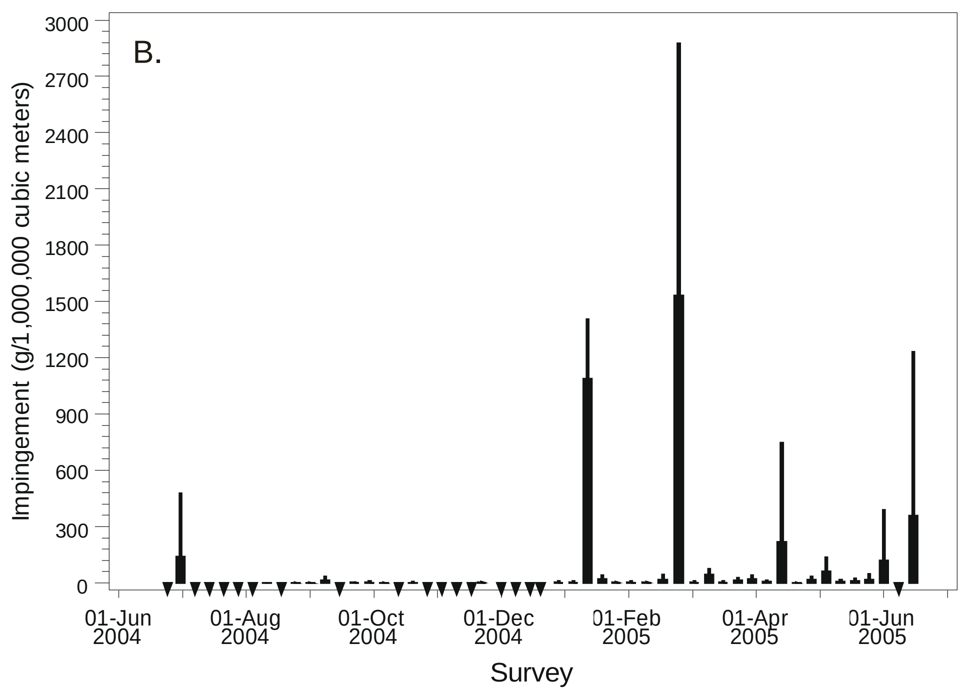


Figure 4-30. Mean concentration and standard error of sand basses impinged at EPS Units 1–5 from June 2004 through June 2005 (n=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

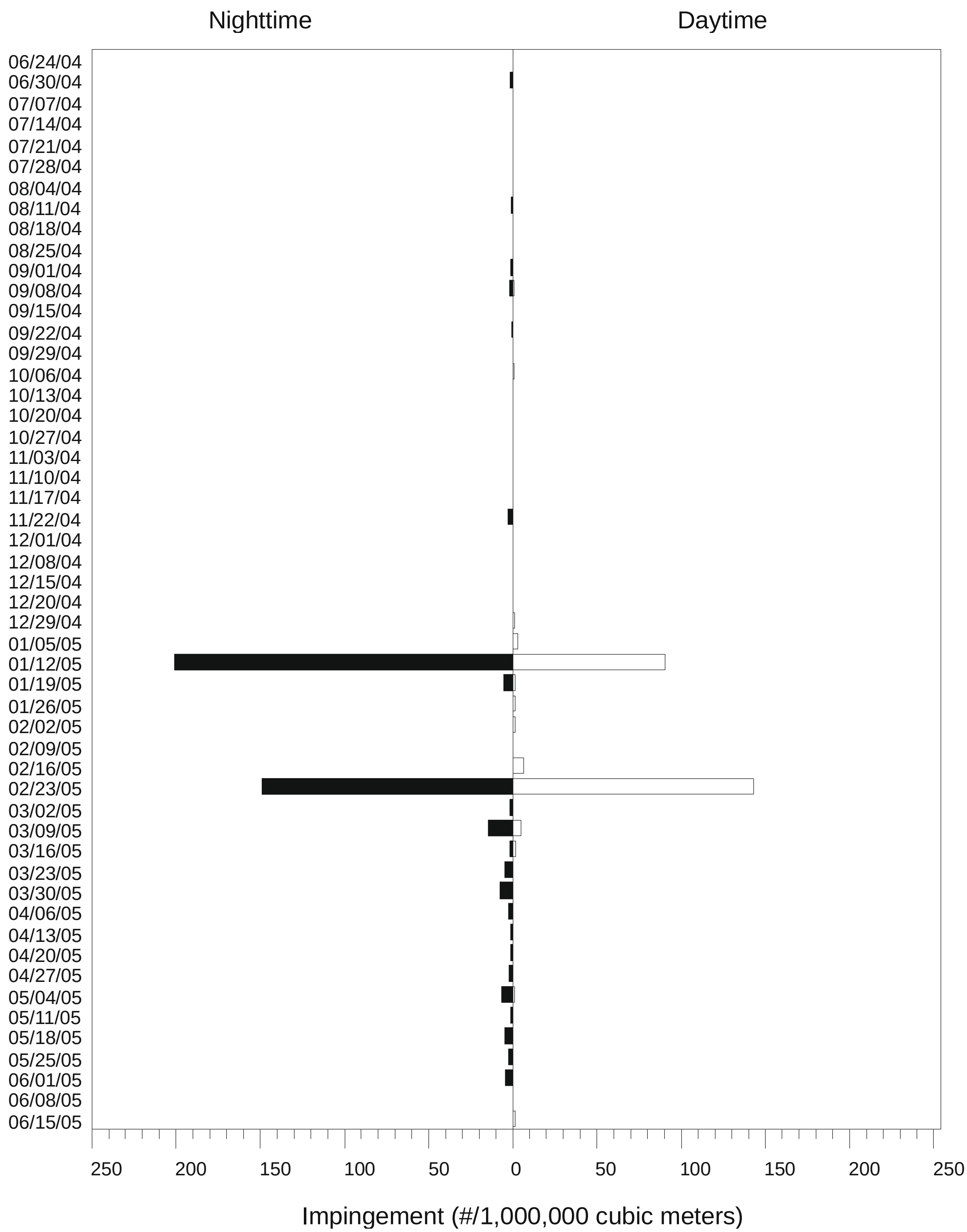


Figure 4-31. Abundance (#/10^6 m^3) of sand basses impinged at EPS Units 1−5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

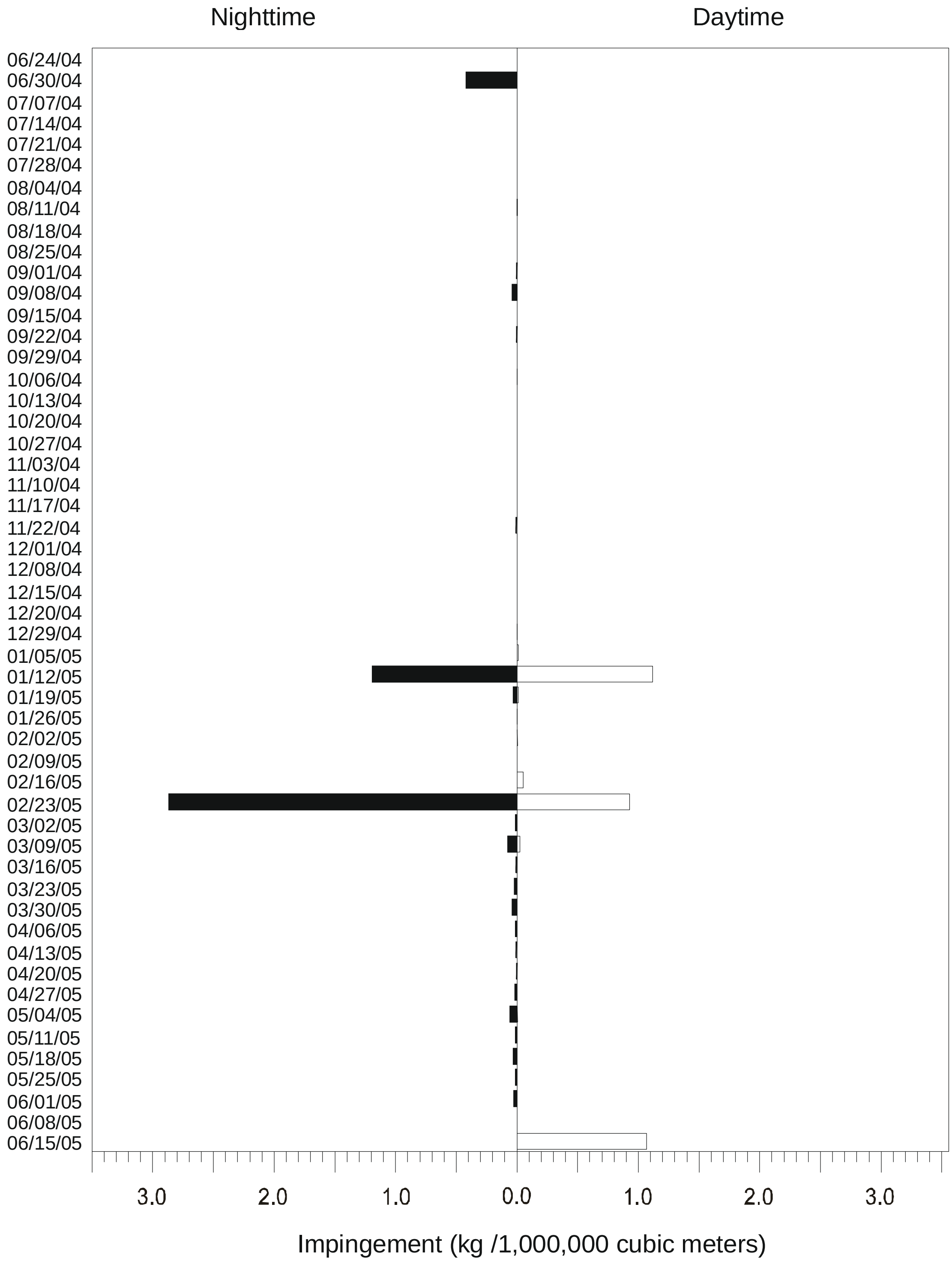


Figure 4-32. Biomass (kg/10^6 m^3) of sandbasses impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

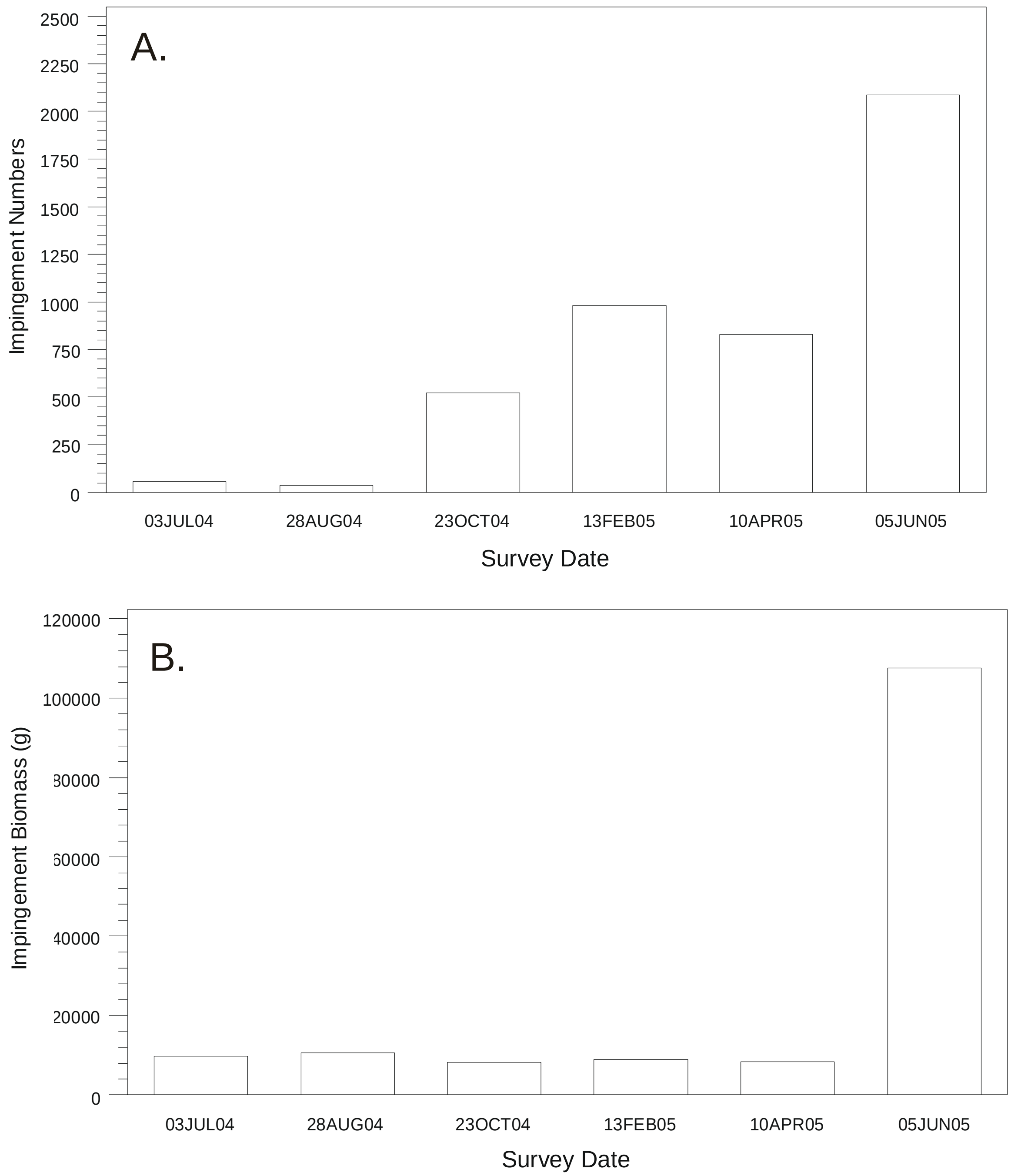


Figure 4-33. A) abundance, and B) biomass of sandbasses impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

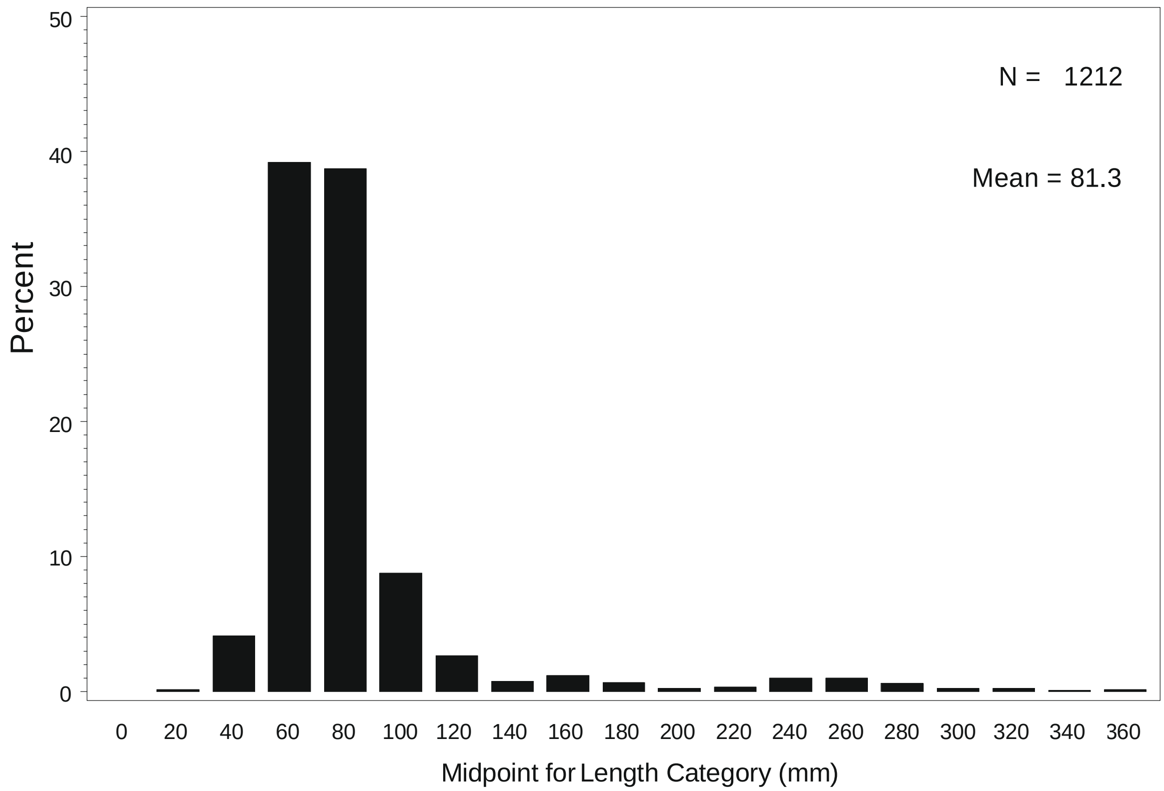
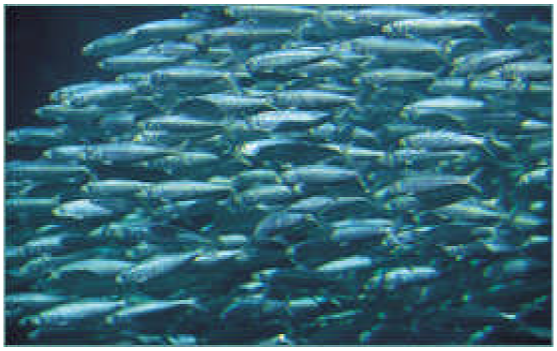


Figure 4-34. Size frequency distribution of sand basses from EPS Units 1–5 impingement samples.

4.3.8 Pacific Sardine (*Sardinops sagax*)



Monterey Bay Aquarium

Range: Kamchatka, Russia, southeast Alaska to Guaymas, Mexico, and Peru to Chile

Life History:
- Size up to 41 cm (16 in)
- Age at maturity less than one year
- Life span to 13 yr
- Spawning occurs year-round with a fecundity of 200,000 eggs/yr

Habitat: schools over continental shelf, often near shore.

Fishery: Commercial and sport fishery.

Pacific sardines are small pelagic schooling fish that are members of the herring family (Clupeidae). Pacific sardines occur in coastal areas from Kamchatka, Russia and southeast Alaska to Guaymas, Mexico, and from Peru and Chile in the southern hemisphere. Pacific sardines are often found in schools with other pelagic forage species such as anchovy, mackerel, and hake (Leet et al. 2001).

4.3.8.1 Life History and Ecology

Pacific sardines can grow to 410 mm (16 cm), but typically are less then 300 mm (12 cm). Fitch and Lavenberg (1971) indicated that Pacific sardine can live to 25 yr, but longevity is more likely about 13 yr according to Butler et al. (1993). Reproduction is temperature dependent, and the spawning biomass may move north during El Niño years. Size at maturity also may be temperature dependent, with 50% of females maturing at about 16 cm standard length (SL) in southern California (Macewicz et al. 1996) and 50% of the females maturing at about 13 cm off Ensenada, Baja California Norte, Mexico in 1958 during an El Niño year (Ahlstrom 1960). Butler et al. (1996) reported that fish less than 1 year old were sexually mature.

Spawning occurs year-round with a summer and fall peak (Love 1996). Estimates from previous studies of sardine fecundity range widely. Hart (1973) estimated 30,000–65,000 eggs/batch with large individuals producing 200,000 eggs/yr. Fitch and Lavenberg (1971) reported an estimate of sardine fecundity of 90,000–200,000 eggs/yr. Lo et al. (1996) estimated an average batch fecundity of 24,282 (CV=11%). The highest estimates of annual fecundity from Butler et al. (1993) indicate that Pacific sardine fecundity ranged from 146,754 eggs/two-yr-old female to as many as 2,156,600 eggs for ten-yr and older females.

Age and growth characteristics of Pacific sardine at all life stages have been well described. Larval growth estimated from otoliths has been measured in several temperature regimes (Miller 1952), from which we are able to derive an approximate larval growth rate of 0.24 mm/day. Growth of the adults has been described with a von Bertalanffy growth function (Von

Bertalanffy growth function: L_∞=205.4 mm ± 1.6 mm SE, k=1.19 ± 0.04 SE, t_0 = 0) by Butler et al. (1996).

Pacific sardine are among the few fishes with age- and stage-specific mortality estimates from the egg stage through later life stages reported in the scientific literature. Instantaneous egg mortality has been estimated as 0.13/d off of Oregon with a CV=243% (Barnes et al. 1992). Lo et al. (1996) produced a similar estimate of embryonic (yolk-sac) mortality of 0.12/d, but with a CV=97%. Butler et al. (1993) modeled the demography of Pacific sardine from the egg stage through the late adult stages with estimates of instantaneous daily natural mortality, the estimated duration of each stage, and daily fecundity (**Table 4-5**). Deriso et al. (1996) modeled the annual fishing mortality of Pacific sardine for the years 1983–1995. The natural adult mortality rate in fished populations has been assumed to be 0.4/yr (Murphy 1966; MacCall 1979).

Sardines school over the continental shelf and often near shore. Each year sardines migrate northward early in summer and return south in fall, migrating farther with each year of life. The timing and extent of these migrations are complex and may be affected by oceanographic conditions. Age stratification of the adult population does appear to occur over a latitudinal gradient, with the larger, older fish occurring farther north (Hart 1973).

4.3.8.2 Fishery and Population Trends

The sharp decline of the Pacific sardine population in the mid-1940's led to the demise of the world's largest commercial fishery and to the establishment of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program (originally named the Cooperative Sardine Research Program) in 1947 (Moser 1996). In 1999, CDFG issued a press release (January 15, 1999) indicating that the Pacific sardine resource had fully recovered. The sport fisheries catch estimates for Pacific sardine for southern California was 452,000 fish in 2003 and 808,000 fish in 2004 (RecFin 2005). Average commercial catches of Pacific sardine for 2001–2004 was 184,029,382 pounds for all gear types in the Pacific region (PacFIN 2005). Records from the CDFG commercial fishery database (CDFG 2005) indicate that in 2004 there were 44.5 MT of sardine was landed in the San Diego Region (primarily at the port of Oceanside) with an ex-vessel value of $26,428.

4.3.8.3 Sampling Results

A total of 268 Pacific sardines was impinged during normal operations impingement surveys (**Table 4-2**). They had a combined weight of 1.5 kg (3.3 lb). They were most abundant from July to August and late December to early February (**Figure 4-35**). Sardines were most frequently collected during nighttime impingement cycles although both numbers and biomass were greater in the daytime during some weeks of the year (**Figures 4-36** and **4-37**). A total of 6,578 individuals weighing 26.3 kg (58.0 lb) was collected in the heat treatment surveys (**Table 4-2**). The overall size of impinged Pacific sardine ranged from 35 to 242 mm SL (1.4 to 9.5 in) with a mean length of 84.8 mm SL (3.3 in) (**Figure 4-39; Appendix G**).

4.3.8.4 Annual Impingement Estimates

The estimated annual impingement of Pacific sardines under actual CWS flows during normal operations was 1,735 individuals weighing 9.1 kg (20.1 lb). Under maximum CWS flows, the estimated annual impingement rates was 2,344 individuals weighing 13.9 kg (30.6 lb). When all sources of impingement mortality (normal operations, bar racks and heat treatments) are combined, the annul estimate of impingement based on actual CWS water flow was 8,313 individuals weighing 35.4 kg (78.0 lb). Under maximum CWS flow the estimated impingement mortality from all sources was 8,922 individuals weighing 40.2 kg (88.6lb).

Table 4-5. Life table for Pacific sardine (*Sardinops sagax*): a) Age-specific fecundity schedule (M_x=natality rate; L_x=survivorship) and b) stage-specific survivorship schedule (Z=instantaneous daily mortality; S=finite survival rate) modified from Butler et al. (1993).

a) Age-specific fecundity

Age (yr)	M_x	L_x	M_xL_x
1	0	1,000	0
2	146,754	670	98,325,180
3	388,188	449	174,296,412
4	599,640	301	180,491,640
5	849,490	202	171,596,980
6	1,167,457	135	157,606,695
7	1,487,528	91	135,365,048
8	1,617,450	61	98,664,450
9	1,887,025	41	77,368,025
10	2,156,600	27	58,228,200
11	2,156,600	18	38,818,800
12	2,156,600	12	25,879,200
13	2,156,600	8	17,252,800

b) Stage-specific survivorship

Stage	Z_{min}	Z_{best}	Z_{max}	Duration (d)	Cumulative	Duration (d)	S_{max}	S_{best}	S_{min}	CV_{best}
Egg	0.3100	0.7200	2.1200	3		3	0.4607	0.1653	0.0050	0.4595
Yolk-sac larva	0.3940	0.6698	0.9710	3	6	3	0.2948	0.1254	0.0493	0.3264
Early larva	0.1423	0.2417	0.3502	11	17	7.26	0.356	0.173	0.0788	0.267
Survivorship from egg to entrainment:								**0.0036**		
Early larva	0.1423	0.2417	0.3502	11	17	3.74	0.587	0.4047	0.270	0.131
Late larva	0.0570	0.0964	0.1390	35	52	35	0.1360	0.0343	0.0077	0.6243
Early juvenile	0.0290	0.0560	0.0810	25	77	25	0.4843	0.2466	0.1320	0.2381
Juvenile I	0.0116	0.0197	0.0285	50	127	50	0.5599	0.3734	0.2405	0.1425
Juvenile II	0.0023	0.0040	0.0058	110	237	110	0.7765	0.6440	0.5283	0.0642
Juvenile III	0.0016	0.0028	0.0040	146	383	146	0.7917	0.6644	0.5577	0.0587
Juvenile IV	0.0012	0.0022	0.0032	170	553	170	0.8155	0.6880	0.5804	0.0569
Pre-recruit	0.0006	0.0011	0.0015	175	728	175	0.9003	0.8249	0.7691	0.0265
Survivorship from entrainment to recruitment:								**0.0003**		

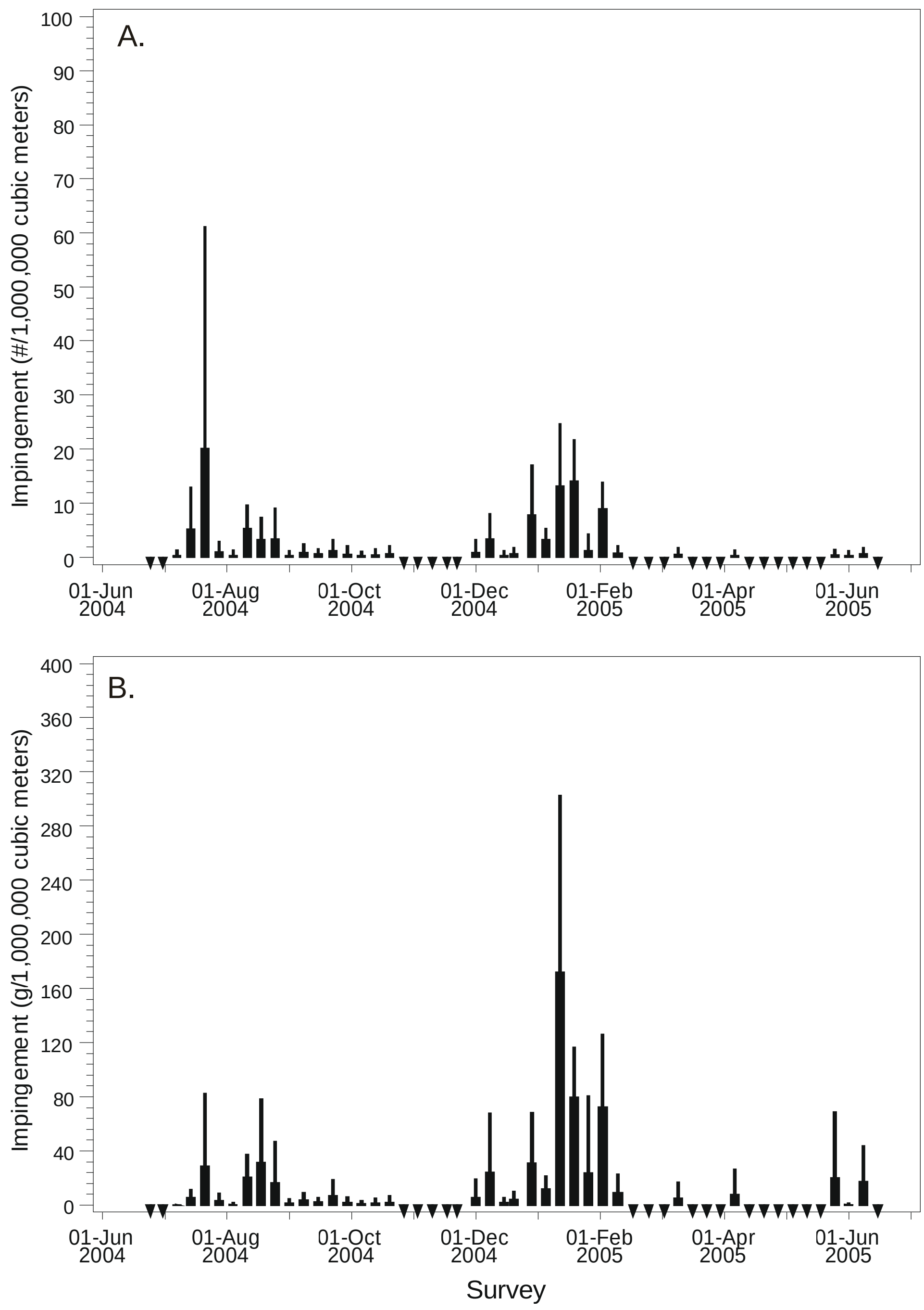


Figure 4-35. Mean concentration and standard error of Pacific sardine impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

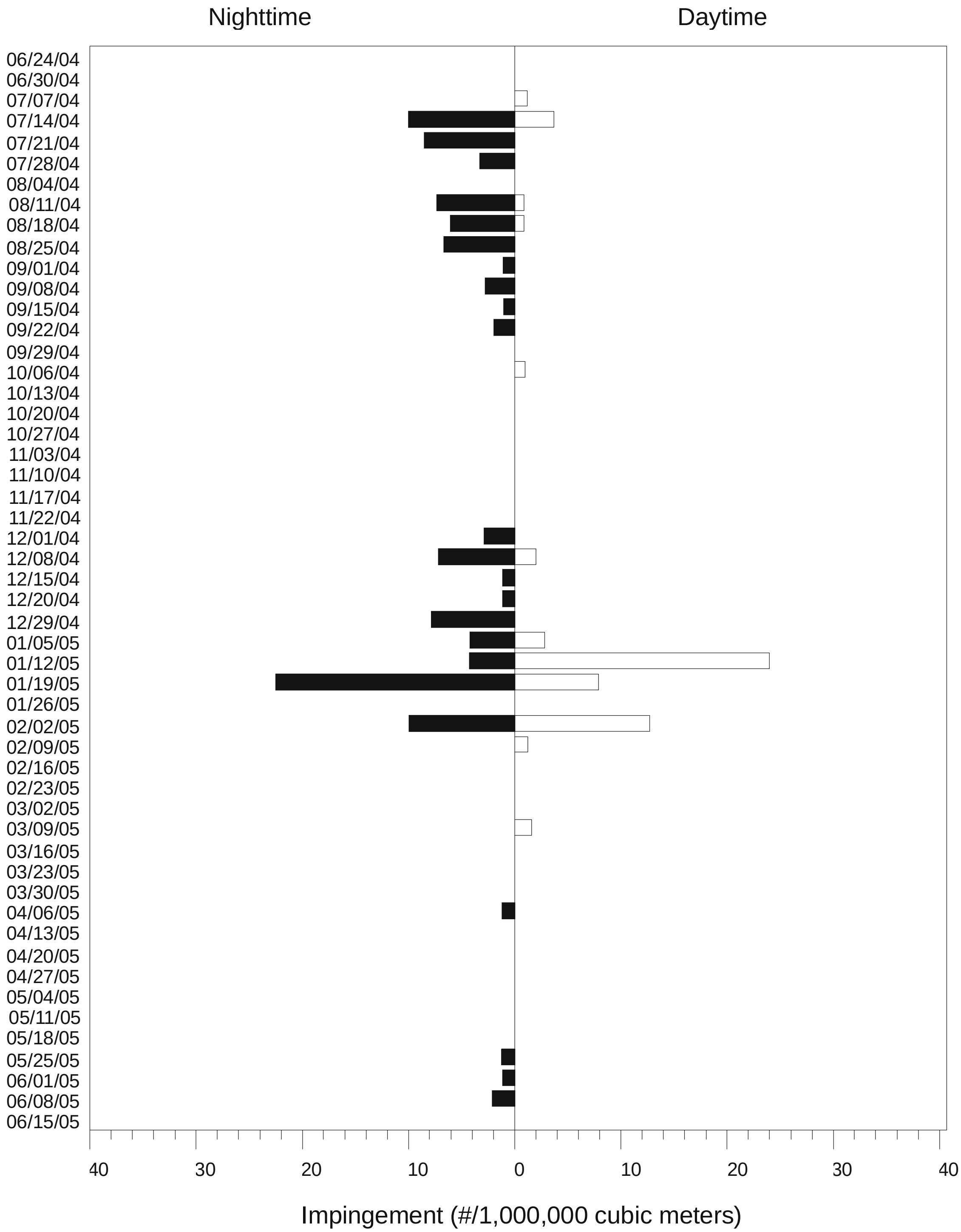


Figure 4-36. Abundance (#/10^6 m^3) of Pacific sardine impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

Figure 4-37. Biomass (g/10^6 m^3) of Pacific sardine impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

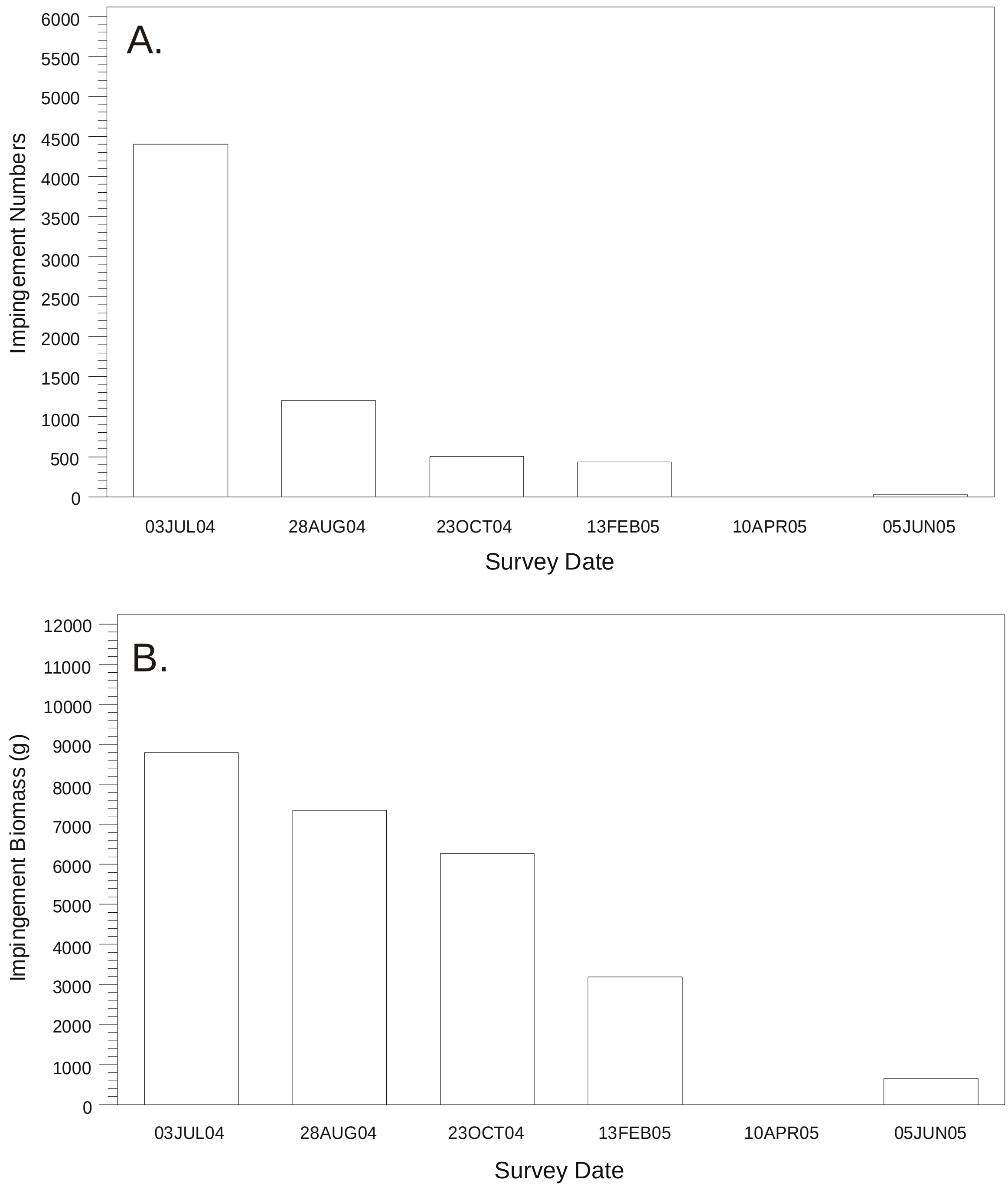


Figure 4-38. A) abundance, and B) biomass of Pacific sardine impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

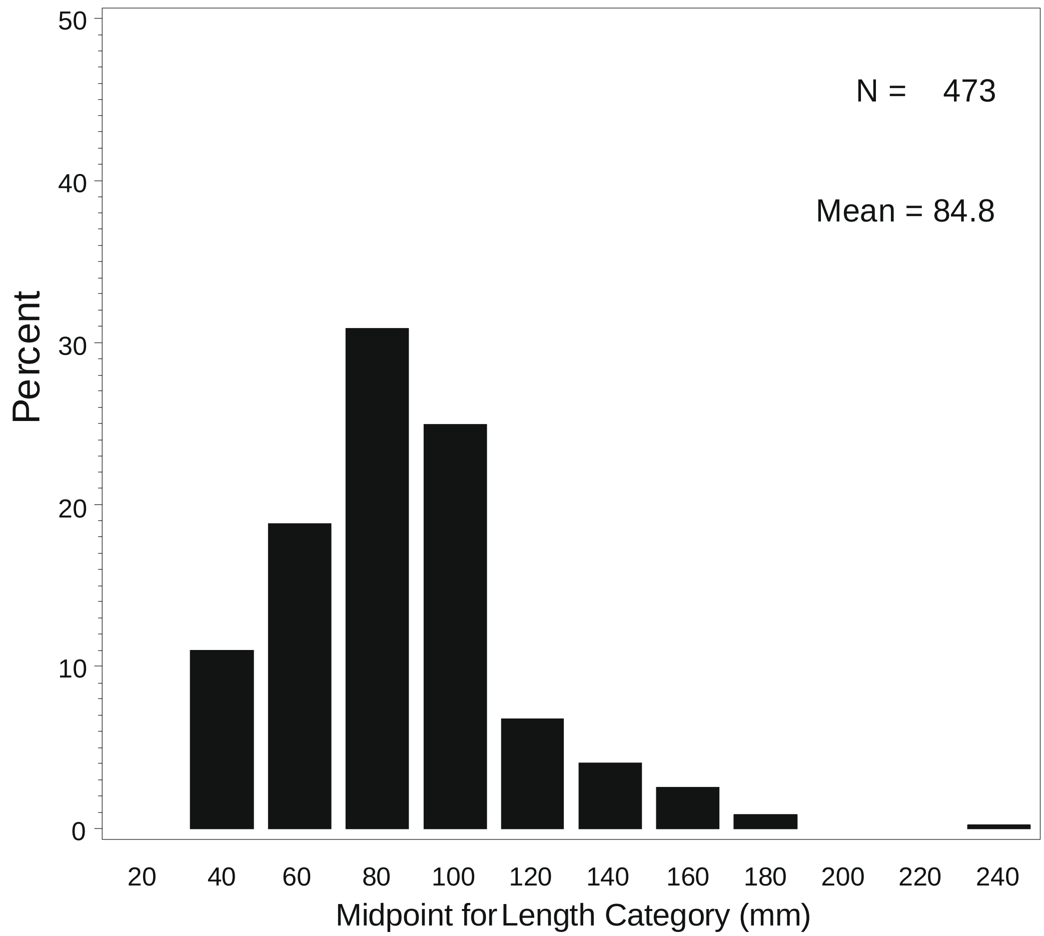


Figure 4-39. Size frequency distribution of Pacific sardine from EPS Units 1–5 impingement samples.

4.3.9 Spotfin Croaker (*Roncador stearnsii*)

Spotfin croaker (*Roncador stearnsii*) is one of the eight members of the croakers (Family Sciaenidae) found off of the California coast.. Spotfin croaker larvae were abundant in plankton samples collected as part of the entrainment impact portion of the present study, and their life history is presented in Section 3.3.8 of this report.

4.3.9.1 Sampling Results

A total of 182 spotfin croaker was collected in the normal impingement sampling at EPS weighing 8.4 kg (18.5 lb) with an additional 2 collected from the bar racks weighing 3.0 g (0.01 lb) (**Table 4-2**). Spotfin croaker was the fourteenth most abundant taxa impinged during the yearlong survey and ranked eleventh in total biomass of all species collected. The numbers of spotfin croaker were significantly greater in nighttime samples, particularly in June and July 2004 (**Figure 4-41**), but the presence of a few larger individuals impinged during some daytime samples contributed to more biomass being impinged during daytime cycles (**Figure 4-42**). A total of 106 individuals was collected during heat treatments, weighing 17.2 kg (37.9 lb) (**Table 4-2)**. The greatest number of spotfin croakers collected during heat treatment surveys were seen in June 2005, with the highest biomass in February 2005 (**Figure 4-43**). Standard lengths of the measured individuals ranged from 33 – 555 mm (1.3 – 21.9 in SL) with a mean length of 103 mm (4.1 in) (**Figure 4-44; Appendix G**).

4.3.9.2 Annual Impingement Estimates

The estimated annual impingement of spotfin croaker under normal operations using actual CWS flows was 1,231 individuals weighing 42.6 kg (94.0 lb). Estimated bar rack impingement was 14 individuals, weighing 21.0 kg (46.3 lb) (**Table 4-3**). Under maximum CWS flow estimated annual impingement increases to 1,700 individuals weighing 83.9 kg (185.0 lb) (**Table 4-3**). Combining all sources of impingement mortality, estimated annual impingement of spotfin croaker under actual CWS flows was 1,351 individuals weighing 80.8 kg (178.1 lb) (**Table 4-4**). Under maximum CWS flows the estimate was 1,820 spotfin croaker weighing 122.1 kg (269.2 lb).

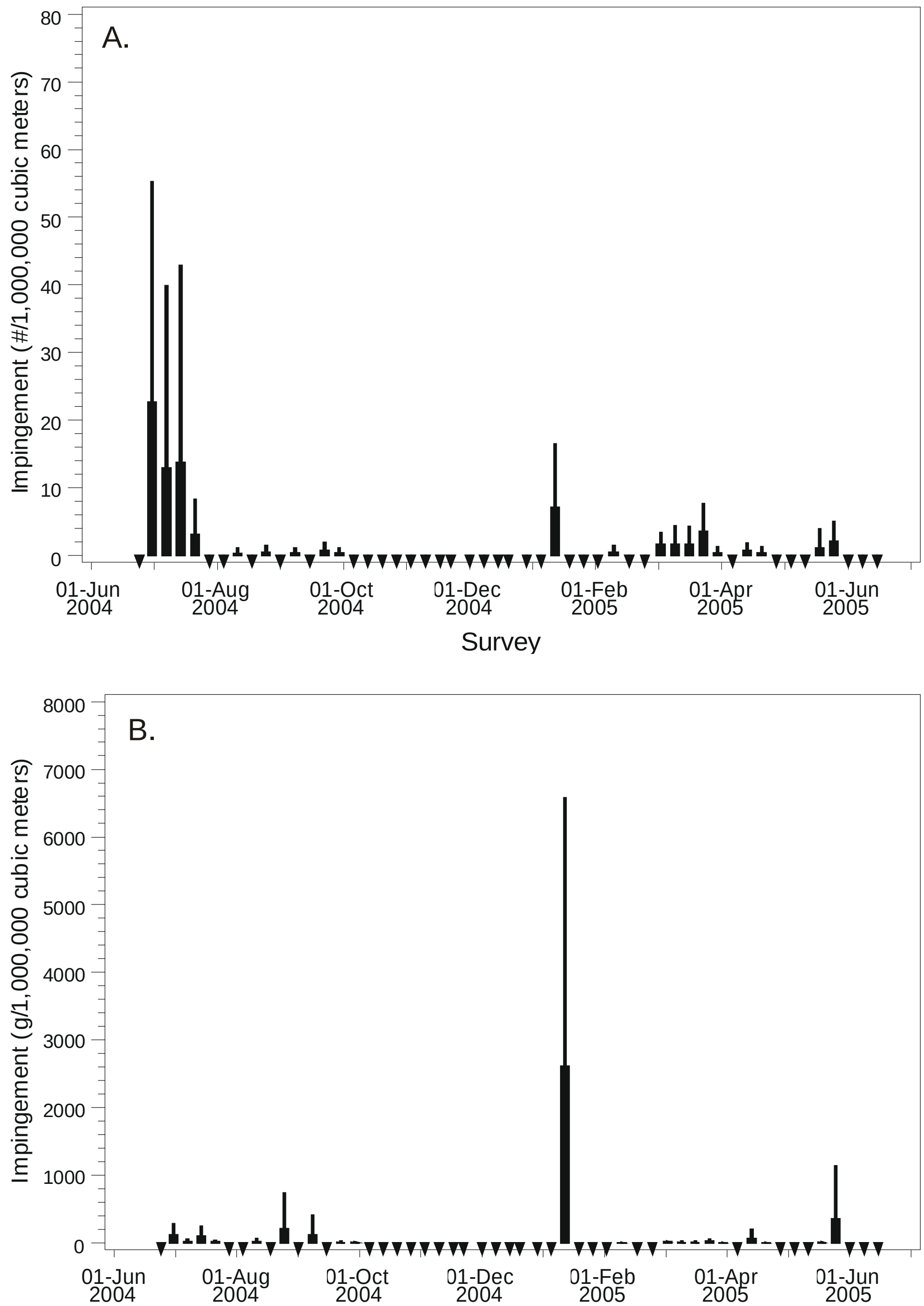


Figure 4-40. Mean concentration and standard error of spotfin croaker impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

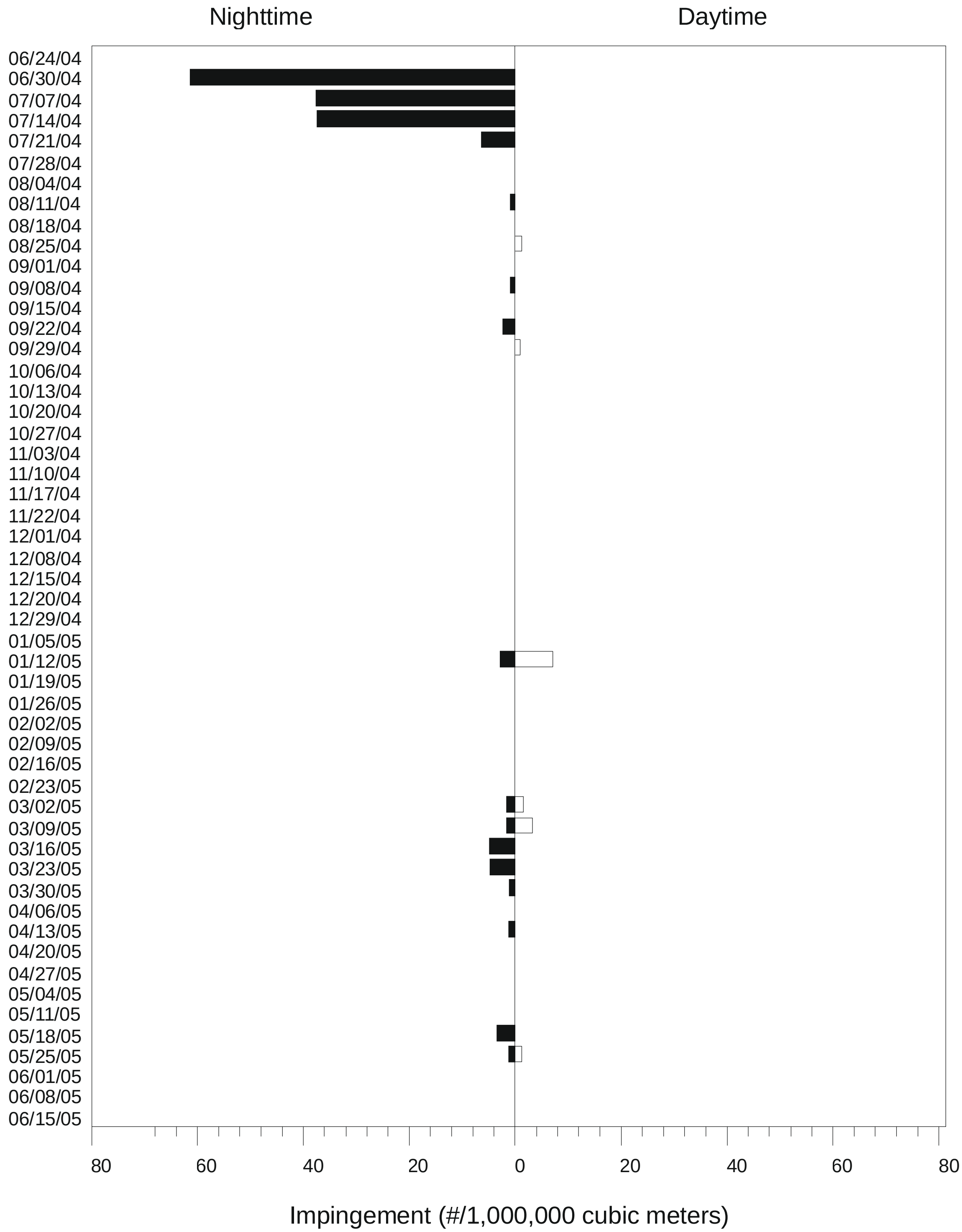


Figure 4-41. Abundance (#/10^6 m^3) of spotfin croaker impinged at EPS Units 1−5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

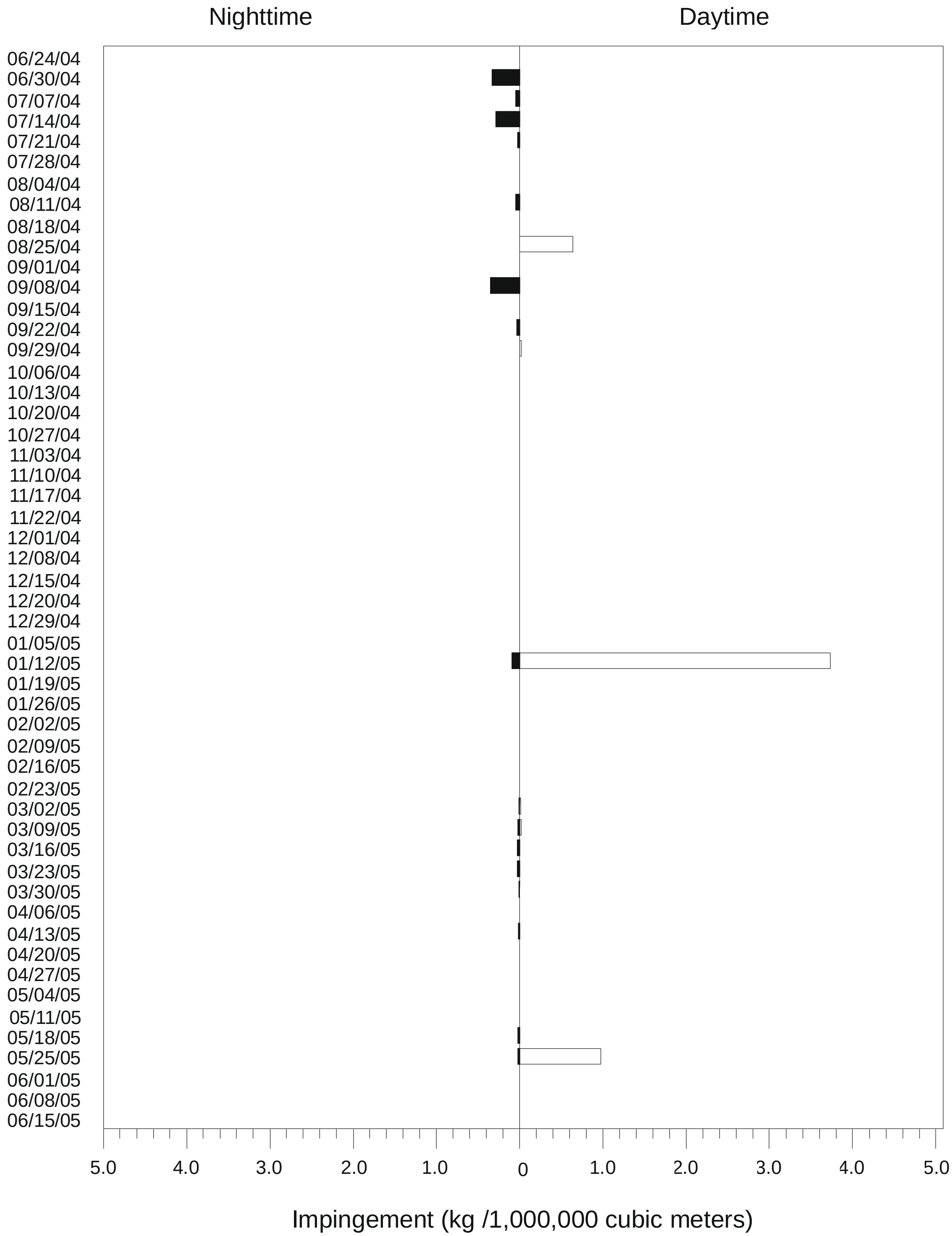


Figure 4-42. Biomass (kg/10^6 m^3) of spotfin croaker impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

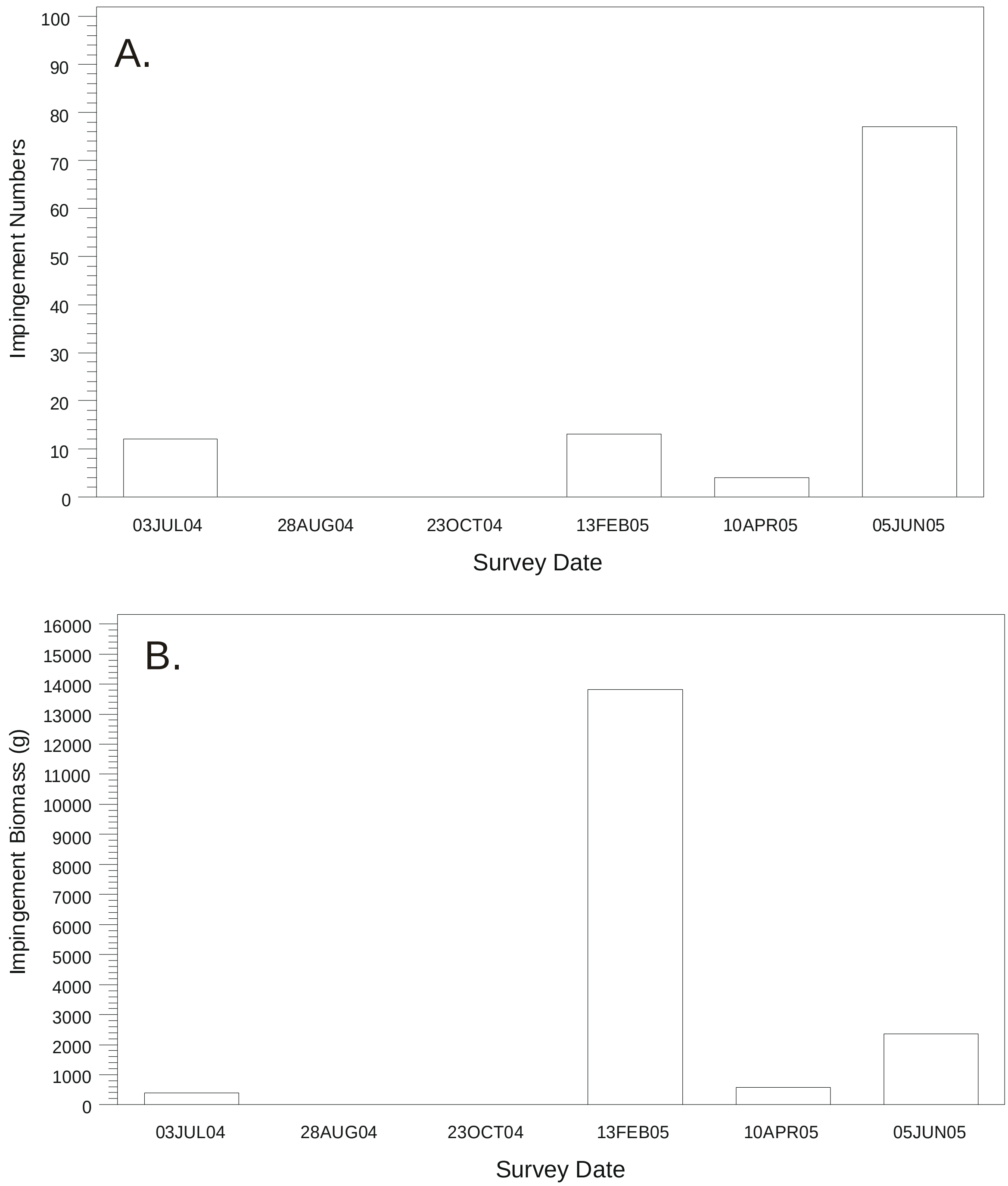


Figure 4-43. A) abundance, and B) biomass of spotfin croaker impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

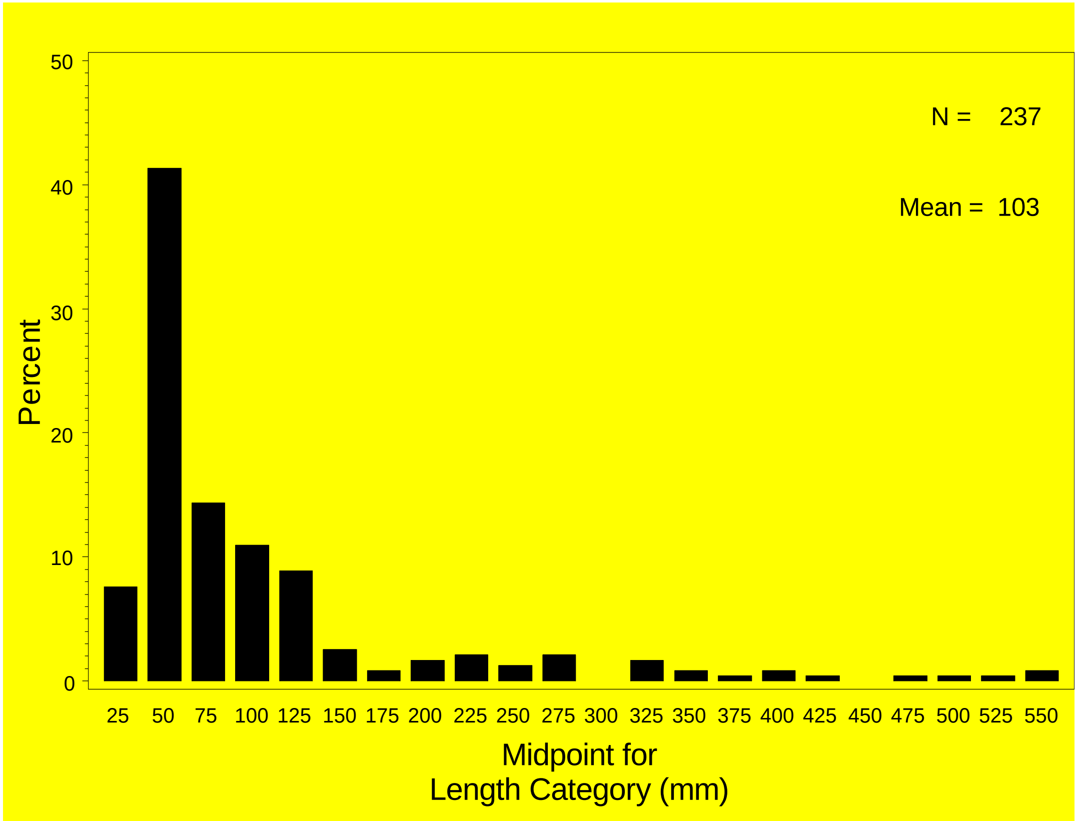


Figure 4-44. Size frequency distribution of spotfin croaker from EPS Units 1–5 impingement samples.

4.3.10 White Seabass (*Atractoscion nobilis*)

Hubbs-SeaWorld

Range: Juneau, Alaska to Magdalena Bay, Baja California, including the Gulf of California

Life History:

- Size to 166 cm (65.4 in)
- Size at maturity to 71.1 cm (28 in)
- Fecundity up to 1,500,000 eggs per yr
- Life span to 27 yr

Habitat: Very young fish live in drift algae behind the surf line, juveniles are in bays and shallow coastal waters near kelp or rock; adults tend to be near reefs or kelp beds.

Fishery: Sport and commercial fishery; stock replenishment in southern California through culturing facilities and grow-out pens.

White seabass is one of the eight members of the croakers (Family Sciaenidae) found off of the California coast. The white seabass is the largest croaker in California and the only member of the genus *Atractoscion.*

White seabass have been found from Juneau, Alaska to Magdalena Bay, Baja California, and the Gulf of California (Miller and Lea 1972). However, Love (1996) reported that they are not common north of Point Conception. Franklin (1997) examined white seabass DNA and concluded that the white seabass stock in the Eastern Pacific is composed of three components: northern, southern and Sea of Cortez.

4.3.10.1 Life History and Ecology

White seabass can be found as deep as 122 m (400 ft) (Miller and Lea 1972). Adults can reach 166 cm (65.4 in) in length and live to at least 27 years (Love 1996). A 71 cm (28 in.) white seabass (the minimum legal size) was determined to be five years old and weighed about 3 kg (7 lb) (Thomas 1968), however, recent growth data from CDFG (2003) suggest that minimum legal size may be obtained by the third year. Fifty percent of females are sexually mature at 71 cm (28 in) while half of males reach maturity at approximately 61 cm (24 in).

Spawning occurs from April through August, with a peak in May and June. White seabass are multiple spawners with individuals releasing eggs every 3 weeks for 4–5 months (Orhun 1989). Eggs are free-floating for 3 days before hatching, and the total larval duration is approximately 35-37 days (Bartley et al. 1995). Fecundity has been determined from artificial propagation attempts (CDFG 1994). Batch fecundity, the number of eggs released by one female at a single time, has ranged from 0.76 million to 1.5 million eggs, and has varied as a function of mean female body weight. Mortality estimates were developed by Kent and Ford (1990) as 0.258 (1 to 2 yr old) and 0.117 (3 to 4 yr old).

In a study of young-of-the-year (YOY) populations in Long Beach Harbor, Allen and Franklin (1992) found that no YOY white seabass were collected in the 93 tows made in protected bays, however, they tended to be concentrated in semi-protected and exposed coasts among various species of drift algae, clumps of sessile invertebrates, and debris of terrestrial origin. The highest abundances were found in July. Older juveniles occupy bays and shallow coastal waters, often near kelp or rocks. Adults are usually found near reefs or kelp beds, and in winter many move into deep water (36.6-106.7 m) (Love 1996). Seasonally, white seabass were most abundant in coastal power plant entrainment samples in winter with lowest abundances in spring, and a secondary peak in June (Herbinson et al. 2001).

Juvenile white seabass feed on mysid shrimps and adults are known to feed on northern anchovy (*Engraulis mordax*); market squid (*Loligo opalescens*); Pacific sardine (*Sardinops sagax*); blacksmith (*Chromis punctipinnis*); silversides (Atherinopsidae species); and pelagic red crab (*Pleuroncodes planipes*) (Thomas 1968).

Commercial fishermen have recorded numerous instances of sea lion and shark predation on adult white seabass caught in nets (Fitch and Lavenberg 1971). Studies to identify the predators of white seabass eggs, larvae, and juveniles have not been done. Hypothetically, predators would include all piscivorous fishes such as kelp and sand bass (*Paralabrax clathratus* and *P. nebulifer*). In laboratory tanks, white seabass larvae are cannibalistic and must be graded by size. This behavior probably takes place in the wild.

4.3.10.2 Population Trends and Fishery

Declining stocks of white seabass due to overfishing have resulted in the development of a hatchery release program to replenish stocks of this valuable sport species. In a survey of private boaters at launch ramp facilities from 1978 to 1982, it was found that only six to 16% of white seabass were of legal size (Vojkovich and Crooke 2001). Populations of white seabass have been low since 1977 but declined dramatically from 1980 to 1982 and have never recovered to previous levels (Herbinson et al. 2001). In 1983, the California legislature created the Ocean Resources Enhancement and Hatchery Program (OREHP). The purpose of this program was to research artificial propagation, rearing, stocking, and distribution of economically important species of fish south of Point Arguello. By 1999, more than 375,000 juvenile white seabass had been released off southern California, and it is estimated that 17,500 of those may have survived to legal size or larger (Vojkovich and Crooke 2001). Since 1999, commercial and recreational catches of white seabass have increased north of Point Conception; possibly indicating a recent northward shift in the stock due to warmer waters brought up during the El-Niño/Southern Oscillation (ENSO) of 1997–1998. Fishery-independent data from gill net surveys indicate a significant increase in 0 to 4 year old white seabass from 1995–2001 (Allen et al. 2001). The largest recruitment during this period occurred in 1999 when a large number of one and two year old fish were caught. This was probably a result of a strong year class associated with the ENSO of 1997–1998.

Sport fishery catch estimates of white seabass in the southern California region from 1995 to 2004 ranged from 3,000 to 29,000 fish annually with a mean of 16,182 fish (RecFIN 2005). Commercial catch estimates in San Diego County for 2005 were 26.8 MT valued at $140,612 (PacFIN 2005).

4.3.10.3 Sampling Results

A total of 70 white seabass was collected in the normal impingement sampling at EPS weighing 11.3 kg (24.9 lb) with an additional 6 collected from the bar racks weighing 0.87 kg (1.9 lb) (**Table 4-2**). The peak in abundance and biomass during normal operation impingement was seen in January and February (**Table 4-45**). White seabass was impinged during both day and night sampling periods with the greatest numbers occurring in daytime samples (**Figure 4-46**). Biomass followed the same trends in diel abundances as numerical abundance (**Figure 4-47**). A total of 1,618 individuals weighing 332.1 kg (732.2 lb) was collected during heat treatments (**Figure 4-48)** with the highest abundance and biomass being during the February heat treatment survey. Lengths of the measured individuals ranged from 36–441 mm (1.4–17.4 in), with a mean length of 224 mm (8.8 in) (**Table 4-49**).

4.3.10.4 Annual Impingement Estimates

The estimated annual impingement of white seabass during normal operations and using actual CWS flows was 442 individuals weighing 70.0 kg (154.2 lb) (**Table 4-3**). Estimated bar rack impingement was 42 individuals, weighing 6.1 kg (13.5 lb) (**Table 4-3**). Under maximum CWS flows the estimated annual impingement abundance would increase to 724 individuals weighing 120.0 kg (264.6 lb) (**Table 4-3**). When all sources of impingement at EPS are combined, the estimated mortality using actual CWS flows was 2,102 individuals weighing 408.1 kg (899.7 lb) and using maximum flows was 2,384 individuals weighing 458.1 kg (1,010 lb) (**Table 4-4**).

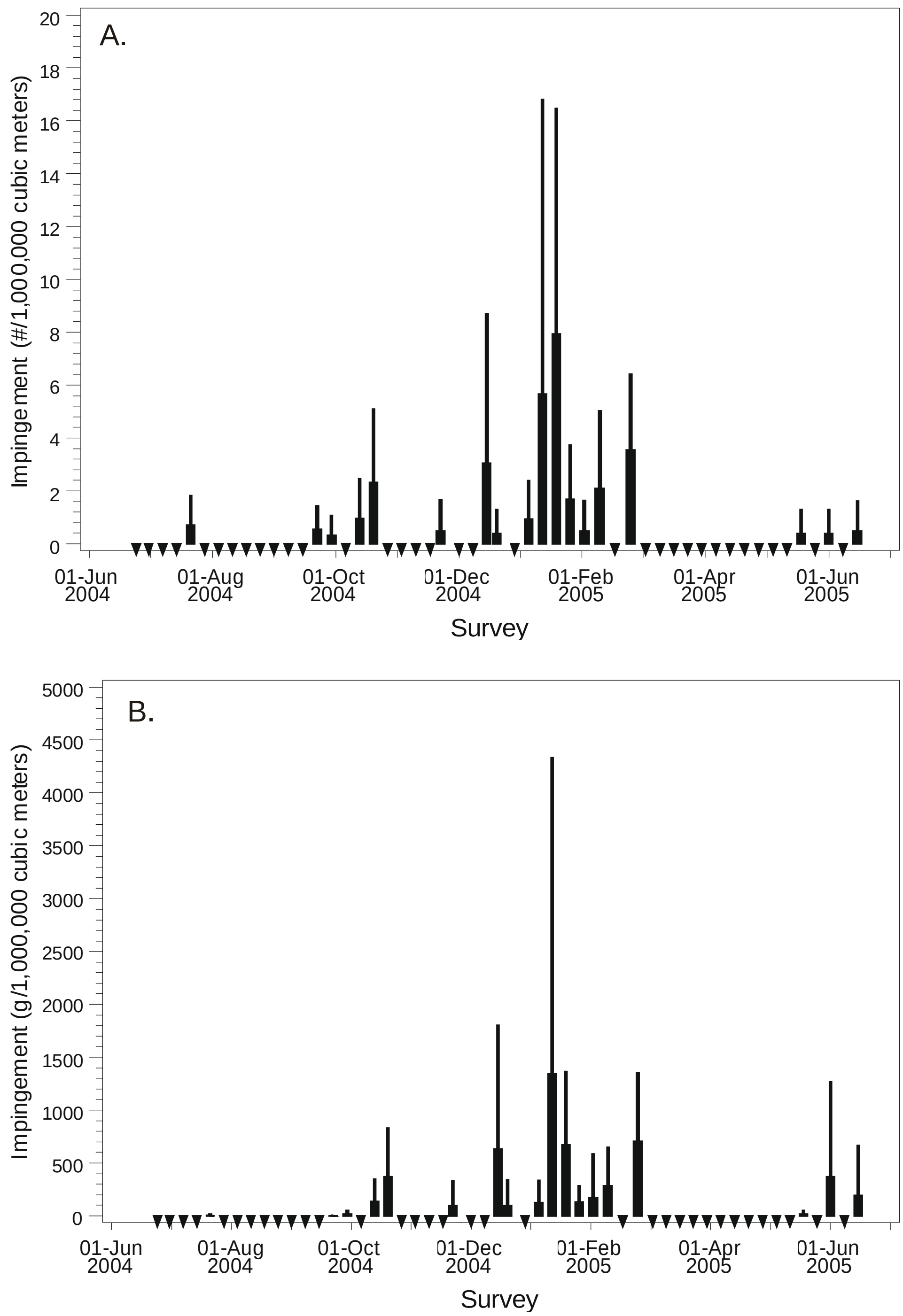


Figure 4-45. Mean concentration and standard error of white seabass impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

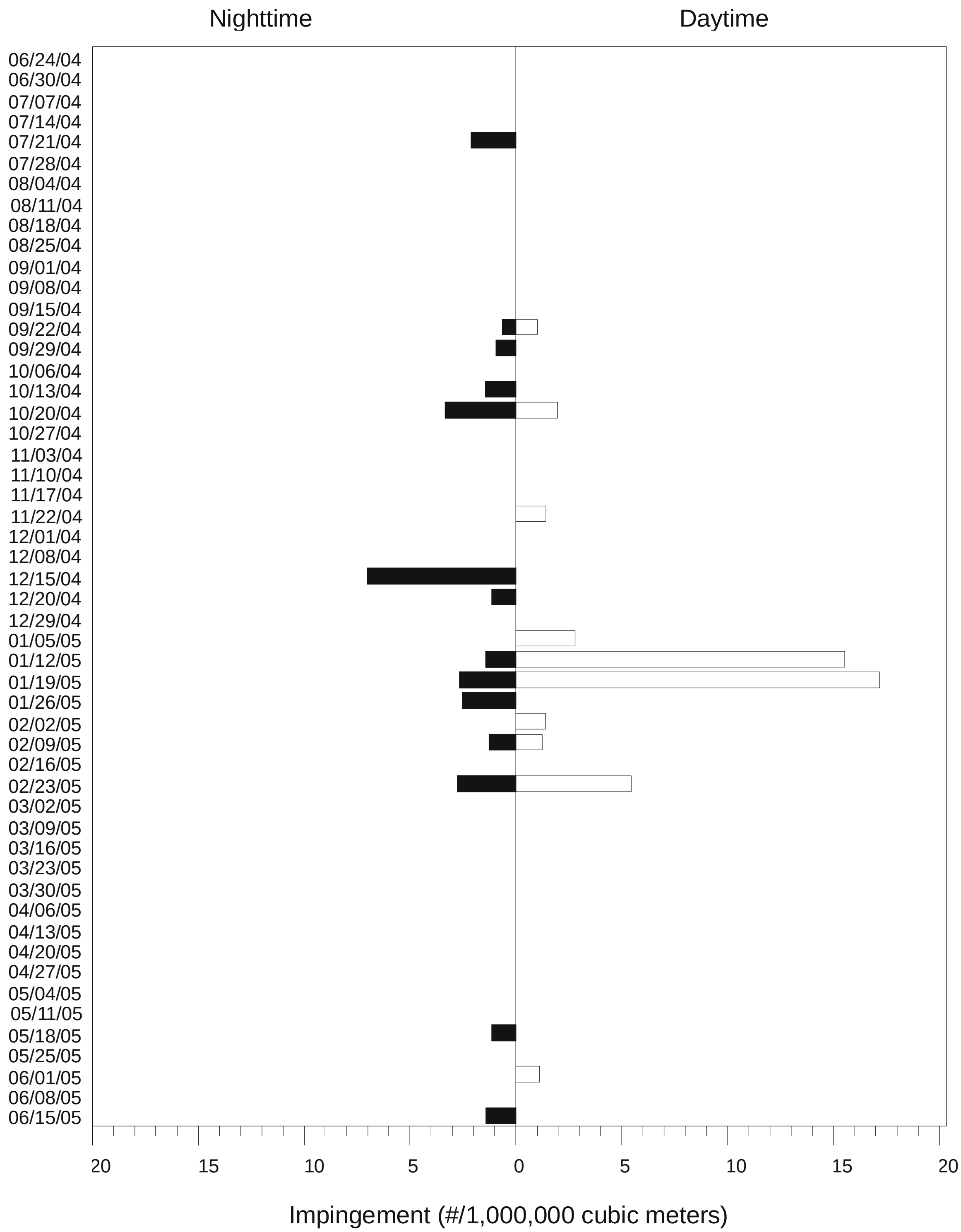


Figure 4-46. Abundance (#/10^6 m^3) of white seabass impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

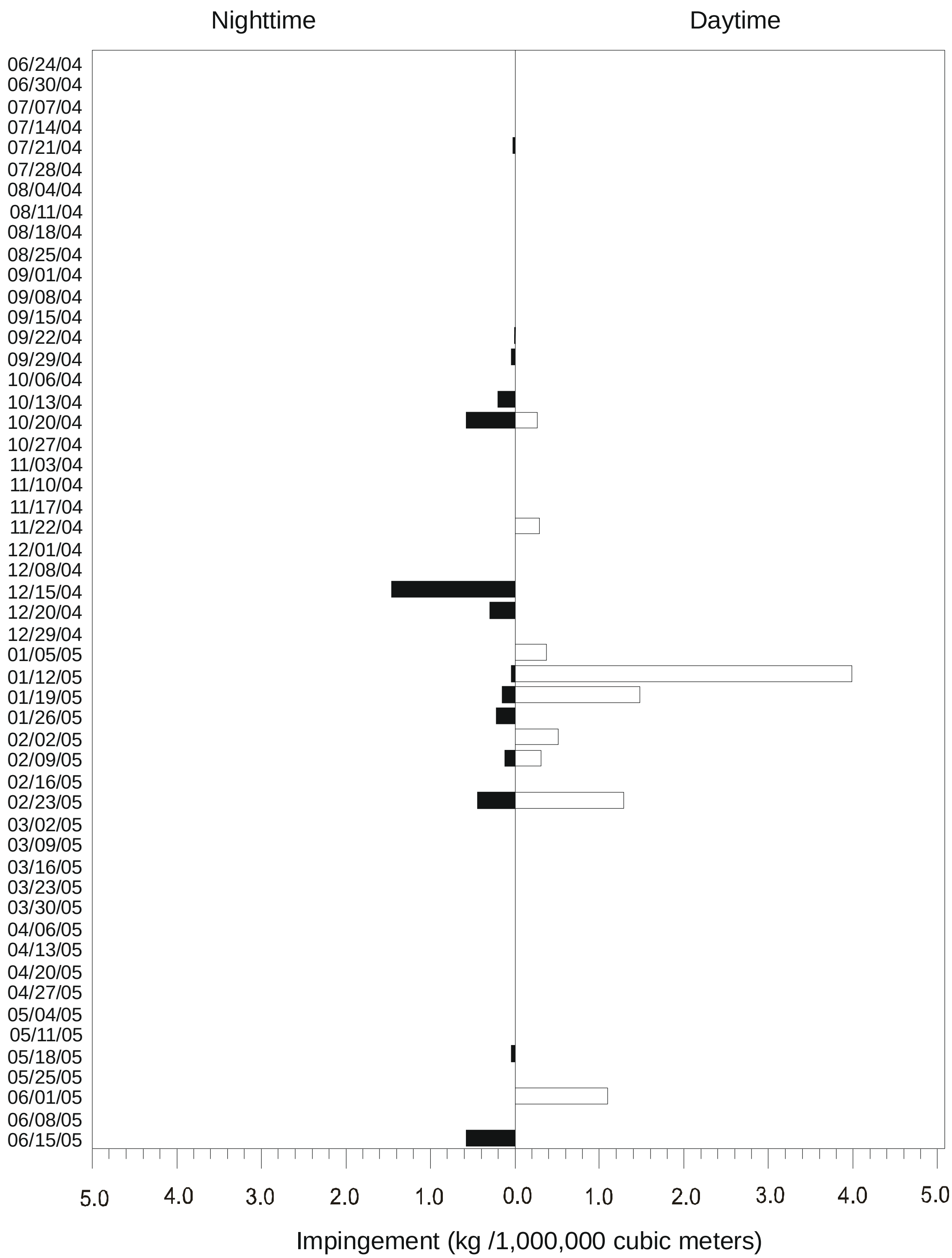


Figure 4-47. Biomass (kg/10^6 m^3) of white seabass impinged at EPS Units 1–5 from June 2004 through June 2005 during two 4-hr nighttime samples and two 4-hr daytime samples.

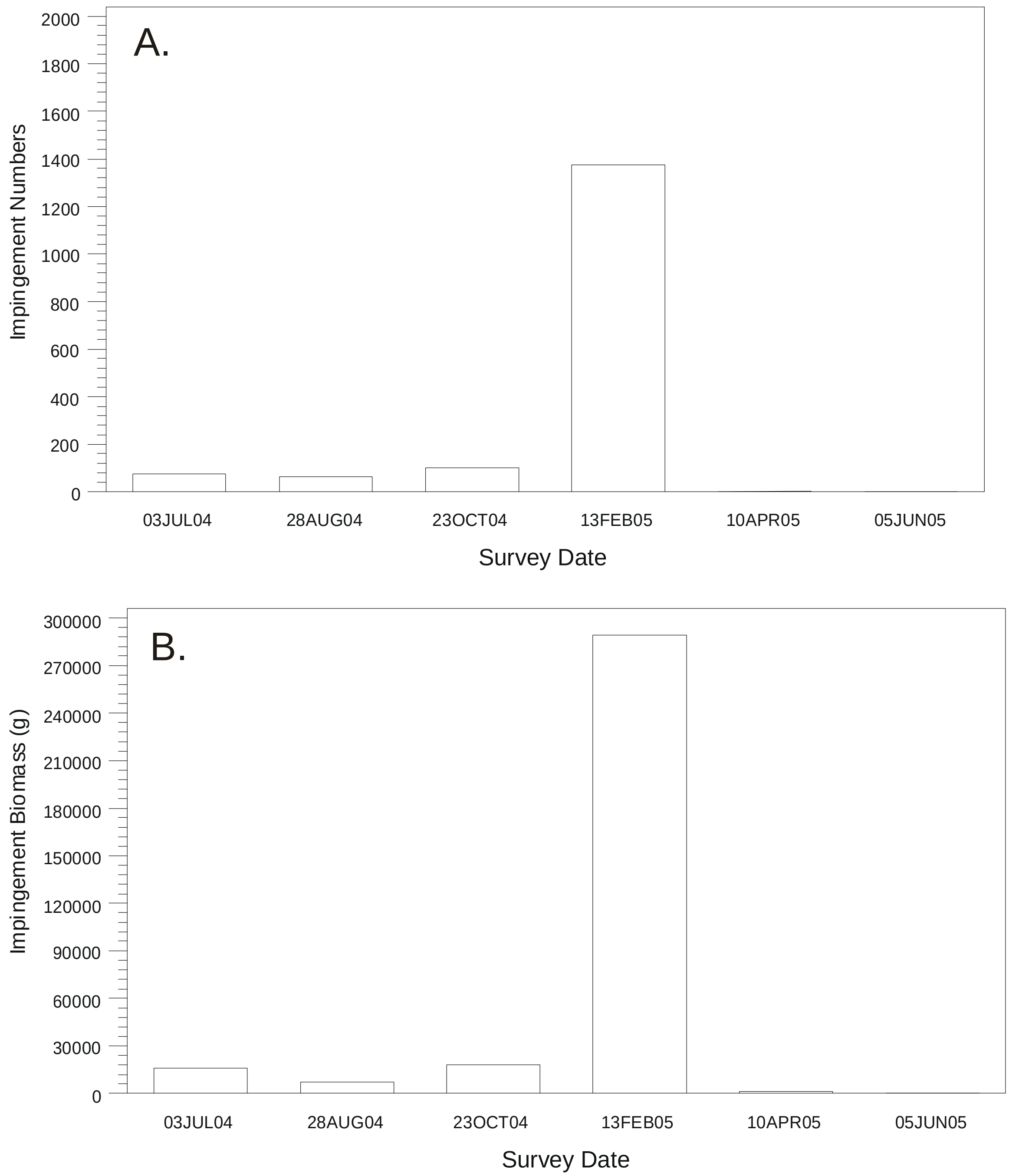


Figure 4-48. A) abundance, and B) biomass of white seabass impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (n=6 surveys).

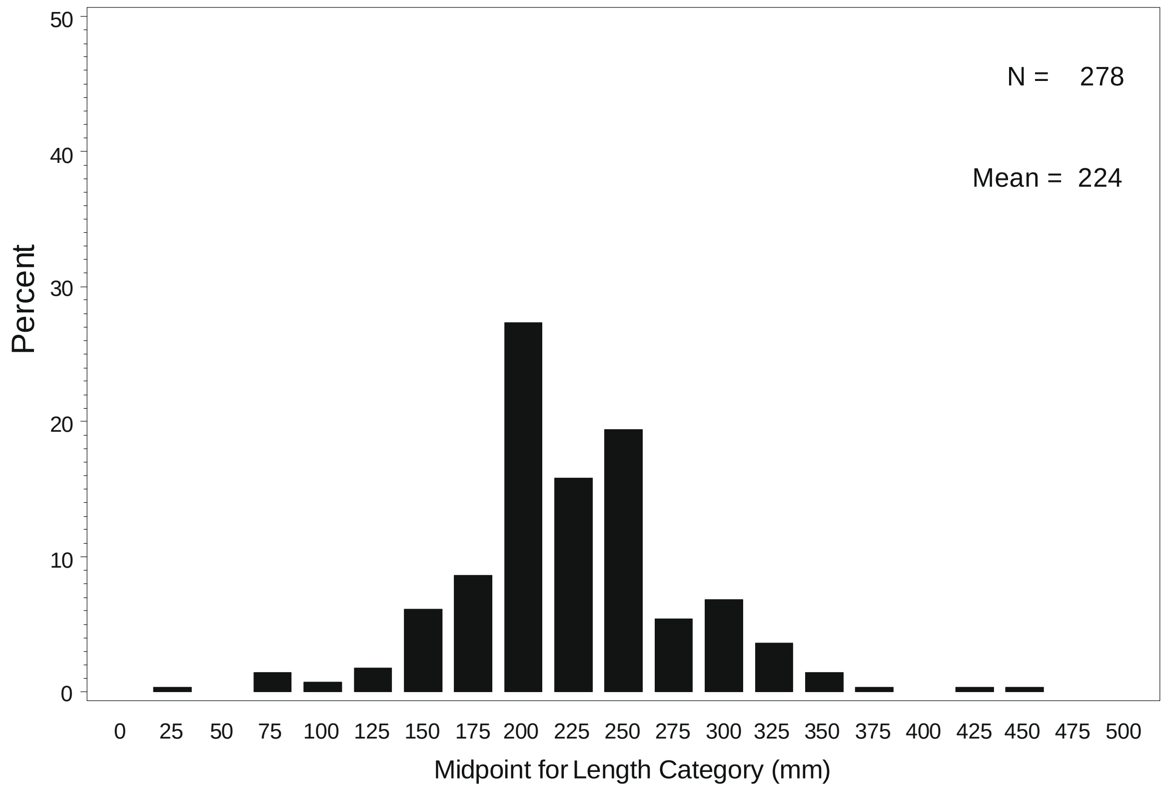


Figure 4-49. Size frequency distribution of white seabass from EPS Units 1–5 impingement samples.

4.4 Shellfish Impingement Results

4.4.1 Community Overview

A total of 1,985 shellfishes (36 taxa) was collected during normal operation impingement sampling at the EPS during the 52 weekly surveys from June 24, 2004 through June 15, 2005 (**Table 4-6** and **Appendix G)**. The combined weight of these shellfishes was 17.2 kg (38.0 lb). There were only two shellfishes with a combined weight of 0.5 kg (1.1 lb) removed from the bar racks during the 52 surveys. During the six heat treatments completed from June 2004 through June 2005, a total of 1,384 shellfishes weighing 19.9 kg (43.9 lb) was collected.

The most abundant shellfishes collected during the normal operations impingement sampling were three crab species: Xantus' swimming crab, striped shore crab, and unidentified shore crab (**Table 4-6**). These three species comprised about 89% of all the shellfishes impinged during normal operations. The invertebrate taxa with the greatest weigh impinged during normal operations were octopus, Xantus' swimming crab, and striped shore crab (**Table 4-6**). The most abundant shellfishes collected during the heat treatment sampling included red rock crab and striped shore crab (**Table 4-6**). These two species comprised about 72% of the total number of shellfishes collected during the heat treatment surveys. The shellfishes with the greatest weight impinged during the heat treatments were octopus, striped shore crab, and red rock crab (**Table 4-6**).

The estimated number and biomass of the shellfishes annually impinged during normal operations at EPS are presented in **Table 4-7**. The combined annual impingement estimates for all sources of mortality (traveling screens, bar racks, and heat treatments) based on maximum and reported flow of the CWS pumps are found in **Table 4-8**. The three most abundant shellfishes impinged based on all sources combined and maximum flow were Xantus' swimming crab (7,268), striped shore crab (7,229), and unidentified shore crab (5,044). This comprised about 86% of the total number estimated to be impinged during maximum flow at EPS. The most abundant shellfishes based on weight were octopus (two taxa: 130.4 kg [287.5 lb]), Xantus' swimming crab (45.7 kg [100.8 lb]) and striped shore crab (30.6 kg [67.5 lb]).

The following four taxa of shellfish were selected for detailed evaluation of impingement effects based on their abundance in the normal and heat treatment samples and/or importance as fishery species:

- cancer crabs (*Cancer spp.*)
- California spiny lobster (*Panulirus interruptus*)
- market squid (*Loligo opalescens*)
- octopus (*Octopus* spp.)

Table 4-5. Number and weight of shellfishes impinged during normal operation and heat treatment surveys at EPS from June 2004 to June 2005.

			Normal Operations Sample Totals				Heat Treatment	
	Taxon	**Common Name**	**Sample Count**	**Sample Weight (g)**	**Bar Rack Count**	**Bar Rack Weight (g)**	**Sample Count**	**Sample Weight (g)**
1	*Portunus xantusii*	Xantus' swimming crab	699	4,423	-	-	59	443
2	*Pachygrapsus crassipes*	striped shore crab	655	2,786	-	-	494	3,101
3	*Pachygrapsus* spp.	shore crab	418	822	-	-	1	2
4	*Octopus* spp.	octopus	36	6,909	-	-	76	6,309
5	*Cancer productus*	red rock crab	26	222	-	-	502	2,876
6	*Pugettia* spp.	kelp crabs	24	53	-	-	1	26
7	*Loligo opalescens*	market squid	24	264	-	-	-	-
8	*Cancer* spp.	cancer crabs	23	57	-	-	36	87
9	*Pugettia producta*	northern kelp crab	11	20	-	-	11	46
10	*Pyromaia tuberculata*	tuberculate pea crab	11	18	-	-	19	-
11	*Octopus bimaculatus*	Calif. two-spot octopus	8	1,108	-	-	91	5,464
12	*Taliepus nuttallii*	globose kelp crab	6	3	-	-	-	-
13	*Cancer antennarius*	brown rock crab	4	11	-	-	27	170
14	*Loxorhynchus crispatus*	moss crab	4	2	-	-	-	-
15	Brachyuran unid.	unidentified crab	4	271	-	-	-	-
16	*Hemigrapsus oregonensis*	yellow shore crab	3	6	-	-	-	-
17	*Cancer jordani*	hairy rock crab	3	16	-	-	18	86
18	*Pugettia richii*	cryptic kelp crab	2	12	-	-	-	-
19	*Lophopanopeus* spp.	black-clawed crabs	2	9	-	-	26	27
20	*Blepharipoda occidentalis*	spiny mole crab	2	12	-	-	-	-
21	*Panulirus interruptus*	Calif. spiny lobster	2	96	-	-	9	1,223
22	*Callianassa californiensis*	ghost shrimp	2	3	-	-	-	-
23	Caridean unid.	unidentified shrimp	2	35	-	-	1	-
24	*Lophopanopeus frontalis*	crestleg crab	2	1	-	-	-	-
25	*Loxorhynchus* spp.	spider crabs	1	-	1	0.5	-	-
26	Majidae	spider crabs	1	2	-	-	6	20
27	*Crangon* spp.	bay shrimp	1	21	-	-	-	-
28	Hippolytidae unid.	hippolytid shrimps	1	-	-	-	-	-
29	*Podochela hemphilli*	Hemphill's kelp crab	1	3	-	-	-	-
30	*Cancer magister*	Dungeness crab	1	-	-	-	1	18
31	*Pandalus platyceros*	spot shrimp	1	2	-	-	-	-
32	*Pelia tumida*	dwarf teardrop crab	1	2	-	-	-	-
33	*Callinectes* spp.	Swimming crab	1	14	-	-	-	-
34	*Rhithropanopeus harrisii*	Harris mud crab	1	18	-	-	-	-
35	*Cycloxanthops novemdentatus*	ninetooth pebble crab	1	3	-	-	-	-
36	*Sicyonia ingentis*	Ridgeback rock shrimp	1	16	-	-	-	-
37	*Pandalus* spp.	unidentified shrimp	-	-	-	-	1	1
38	*Crangon nigromaculata*	spotted bay shrimp	-	-	-	-	1	4
39	*Pilumnus spinohirsutus*	retiring hairy crab	-	-	-	-	4	5
40	*Dosidicus gigas*	jumbo squid	-	-	1	500	-	-
			1,985	**17,241**	**2**	**501**	**1,384**	**19,909**

Table 4-6. Calculated annual impingement of shellfishes based on EPS maximum flows and actual flows during normal operations surveys from June 2004–June 2005.

		Maximum flow rate basis				Actual flow rate basis			
	Taxon	**Abundance**	**Abundance Std. Error**	**Weight (g)**	**Weight Std. Error**	**Abundance**	**Abundance Std. Error**	**Weight (g)**	**Weight Std. Error**
1	*Portunus xantusii*	7,209	756	45,263	4,436	4,492	464	28,299	2,830
2	*Pachygrapsus crassipes*	6,735	1,683	27,517	4,159	4,395	1,060	18,635	2,920
3	*Pachygrapsus* spp.	5,043	4,662	9,921	9,179	2,745	2,636	5,396	5,189
4	*Octopus* spp.	559	125	101,779	23,094	272	62	49,346	11,486
5	*Cancer productus*	282	89	2,481	974	168	52	1,448	571
6	*Pugettia* spp.	244	45	550	151	165	31	365	103
7	*Cancer* spp.	217	90	508	247	156	69	388	197
8	*Loligo opalescens*	190	45	2,193	539	162	39	1,770	440
9	*Pugettia producta*	127	42	214	83	75	31	121	55
10	*Octopus bimaculatus*	108	51	16,842	13,943	58	26	8,341	6,804
11	*Pyromaia tuberculata*	100	43	151	71	70	23	133	54
12	*Taliepus nuttallii*	52	21	25	11	38	17	19	9
13	Brachyuran unid.	47	22	3,102	2,305	27	13	1,795	1,334
14	*Loxorhynchus crispatus*	37	18	21	11	28	13	17	9
15	*Cancer antennarius*	36	19	115	76	22	15	53	39
16	*Blepharipoda occidentalis*	35	25	166	109	19	13	95	64
17	*Cancer jordani*	32	16	165	101	16	9	93	64
18	Caridea unid.	24	12	473	19	14	9	251	196
19	*Cancer magister*	22	20	-	-	15	14	-	-
20	*Callianassa californiensis*	21	16	30	381	9	6	12	9
21	*Hemigrapsus oregonensis*	21	14	43	29	20	14	40	27
22	*Lophopanopeus* spp.	20	13	98	80	11	8	43	40
23	*Pugettia richii*	18	12	127	109	9	7	53	54
24	*Panulirus interruptus*	16	11	747	503	13	9	640	451
25	*Lophopanopeus frontalis*	14	13	6	5	14	13	6	5
26	*Loxorhynchus* spp.	13	12	1	1	6	6	1	1
27	*Crangon* spp.	13	12	263	243	7	6	146	135
28	*Rhithropanopeus harrisii*	13	12	226	210	7	6	126	117
29	*Cycloxanth. novemdenta.*	11	10	29	27	6	6	16	15
30	*Podochela hemphilli*	11	10	32	30	7	7	22	21
31	*Pandalus platyceros*	11	10	19	18	4	5	8	9
32	*Sicyonia ingentis*	11	10	171	159	4	5	67	78
33	Hippolytidae unid.	9	8	-	-	7	6	-	-
34	Majidae	8	8	15	14	6	6	11	10
35	*Callinectes* spp.	8	7	106	98	7	7	100	92
36	*Pelia tumida*	7	6	13	12	7	6	13	12
		21,323		**213,414**		**13,083**		**117,870**	

Table 4-7. Calculated overall annual impingement of shellfishes from all sources combined (normal operations [traveling screens and bar racks] and heat treatments) based on EPS maximum flows and reported flows, June 2004–June 2005.

			Maximum Flow		Actual Flow	
	Taxon	**Common Name**	**Abundance**	**Weight (g)**	**Abundance**	**Weight (g)**
1	*Portunus xantusii*	Xantus' swimming crab	7,268	45,706	4,551	28,742
2	*Pachygrapsus crassipes*	striped shore crab	7,229	30,618	4,889	21,736
3	*Pachygrapsus* spp.	shore crab	5,044	9,924	2,746	5,399
4	*Cancer productus*	red rock crab	784	5,357	670	4,324
5	*Octopus* spp.	octopus	635	108,088	348	55,656
6	*Cancer* spp.	cancer crabs	253	596	192	475
7	*Pugettia* spp.	kelp crabs	245	576	166	391
8	*Octopus bimaculatus*	Calif. two-spot octopus	199	22,305	149	13,805
9	*Loligo opalescens*	market squid	190	2,193	162	1,770
10	*Pugettia producta*	northern kelp crab	138	261	86	168
11	*Pyromaia tuberculata*	tuberculate pea crab	119	151	89	133
12	*Cancer antennarius*	brown rock crab	63	286	49	224
13	*Taliepus nuttallii*	globose kelp crab	52	25	38	19
14	*Cancer jordani*	hairy rock crab	50	251	34	178
15	Brachyura unid.	unidentified crab	47	3,102	27	1,795
16	*Lophopanopeus* spp.	black-clawed crabs	46	125	37	70
17	*Loxorhynchus crispatus*	moss crab	37	21	28	17
18	*Blepharipoda occidentalis*	spiny mole crab	35	166	19	95
19	*Panulirus interruptus*	California spiny lobster	25	1,970	22	1,863
20	Caridea unid.	unidentified shrimp	25	473	15	251
21	*Cancer magister*	Dungeness crab	23	18	16	18
22	*Callianassa californiensis*	ghost shrimp	21	30	9	12
23	*Hemigrapsus oregonensis*	yellow shore crab	21	43	20	40
24	*Loxorhynchus* spp.	spider crabs	20	5	13	4
25	*Pugettia richii*	cryptic kelp crab	18	127	9	53
26	Majidae	spider crabs	14	35	12	31
27	*Lophopanopeus frontalis*	crestleg crab	14	6	14	6
28	*Crangon* spp.	bay shrimp	13	263	7	146
29	*Rhithropanopeus harrisii*	Harris mud crab	13	226	7	126
30	*Cycloxanthops novemdentatus*	ninetooth pebble crab	11	29	6	16
31	*Podochela hemphilli*	Hemphill's kelp crab	11	32	7	22
32	*Pandalus platyceros*	spot shrimp	11	19	4	8
33	*Sicyonia ingentis*	Ridgeback rock shrimp	11	171	4	67
34	Hippolytidae unid.	hippolytid shrimps	9	-	7	-
35	*Callinectes* spp.	crab	8	106	7	100
36	*Pelia tumida*	dwarf teardrop crab	7	13	7	13
37	*Pilumnus spinohirsutus*	retiring hairy crab	4	5	4	5
38	*Pandalus* spp.	unidentified shrimp	1	1	1	1
39	*Crangon nigromaculata*	spotted bay shrimp	1	4	1	4
40	*Dosidicus gigas*	jumbo squid	1	500	1	500
Totals			**22,714**	**233,326**	**14,474**	**137,782**

4.4.2 Cancer crabs (*Cancer spp.*)

Range:
- Red rock crab: Kodiak Island to central Baja California
- Brown rock crab: northern Washington to central Baja California
- Dungeness crab: Alaska to Santa Barbara, rare south of Point Conception
- Hairy rock crab: Washington to Baja California

Life History:
- Size to 20 cm (8 in) (Red); 16 cm (6.5 in) (brown); 4 cm (1.5 in) (hairy); 23 cm (9 in) (Dungeness)
- Age at maturity: 2 yr (Dungeness)
- Life span to 6 yr (Pacific); 8 yr (Dungeness)
- Spawning occurs in winter; Fecundity: size dependant, from 500,000 to 4.0 million eggs

Habitat: Intertidal to 91 m (300 ft), sand and rocky bottoms.

Fishery: Commercial fishery for Dungeness crab (*C. magister*) and Rock crabs (*C. antennarius, C. productus,* and *C. anthonyi* combined). No fishery for *C. jordani*.

Crabs of the genus Cancer are widely distributed in the coastal waters of the west coast of North America. Four species of Cancer crabs were collected in the impingement survey: red rock crab (*Cancer productus),* brown rock crab (*C. antennarius),* hairy rock crab (*C. jordani),* and Dungeness crab (*C. magister)*. Red rock crabs range from Kodiak Island to Central Baja California; and brown rock crabs range from northern Washington to central Baja California. The Dungeness crab ranges from Alaska to Santa Barbara, but is rare south of Point Conception (Leet et al. 2001). The hairy rock crab ranges from Neah Bay, Washington to Bahia de Tortuga, Baja California (Jensen 1995).

4.4.2.1 Life History and Ecology

All species of Cancer crabs share certain fundamental life history traits. Maturity is generally attained within 1–2 years. Mature females mate while in the soft shell molt condition and extrude fertilized eggs onto the abdominal pleopods. Females generally produce one or two batches per year, typically in winter. Red rock crabs can grow to 20 cm (8 in) in carapace width. Brown rock crabs are sexually mature at 8 cm (3 in) and can grow to over 16 cm (6.5 in) across the carapace. They may live up to 6 years of age. Sexual maturity of Dungeness crabs is reached at the end of the second year, when they are about 10 cm (4 in) across. Females reach a maximum size of 18 cm (7 in) and males, 23 cm (9 in). Males may live as long as 6 to 8 years. One of the smallest Cancer species, hairy rock crab males reach a maximum size of 3.9 cm (1.5 in) and females grow to 1.95 cm (0.7 in) (Jensen 1995). The main determinant of brood size and reproductive output in brachyuran crabs is body size, and the range of egg production in Cancer crabs generally reflects this relationship (Hines 1991). Dungeness crab females may carry from 500,000 to up to 2.0 million eggs per brood. The next largest species, red rock crab, produces up to 877,000 eggs per brood. Other *Cancer* spp. females may carry 4.0 million eggs, dependant upon size of the female and her molt stage (Leet et al. 2001).

Cancer crabs are common in intertidal and shallow subtidal habitats on both rock and sand substrate down to about 91 m (300 ft). Brown and red rock crabs prefer rocky or reef-like habitat. Juvenile Dungeness crabs settle in shallow coastal waters, tidal flats, and estuaries, living on beds of eelgrass and other aquatic vegetation. Adult Dungeness crabs have be found down to depths of 750 ft (Leet et al. 2001).

4.4.2.2 Fishery and Population Trends

Of the nine species known to occur in the northeast Pacific, four species contribute to economically significant fisheries. Dungeness crab has the highest economic value among these, and three species of rock crabs (yellow rock crab *C. anthonyi, C. antennarius, and C. productus*) comprise the remainder of the catches. Rock crabs are fished along the entire California coast with crab pots, though some landings are reported from set gill nets and trawls as well (CDFG 2004). The rock crab fishery is most important in southern California (from Morro Bay south), where most of the landings occur, and of lesser importance in northern areas of California where a fishery for the more desirable Dungeness crab takes place. Most rock crabs are landed alive for retail sale by fresh fish markets. The commercial harvest has been difficult to assess on a species-by-species basis because the fishery statistics are combined into the general “rock crab” category. From 1991 through 1999 state-wide rock crab landings (including claws) averaged 1.2 million lb/year (Parker 2001).

Recent catch statistics from the PSMFC PacFIN (commercial) database were examined for the years 2000–2005 for San Diego County (http://www.psmfc.org/pacfin/woc.html). The average annual commercial catch and ex-vessel revenue for rock crab for this period was approximately 164,063 lb and $179,528, respectively. The 2005 catch of 47.4 MT was valued at $107,722.

4.4.2.3 Sampling Results

Four Cancer crab species were impinged during the study. Of the 57 Cancer crabs impinged during the normal impingement surveys, there were 26 red, 4 brown, 3 hairy, 1 Dungeness, and 23 others that could not be identified to the species level and were recorded as *Cancer* spp. The impinged Cancer crabs had a combined total weight of 0.3 kg (0.67 lb) (**Table 4-6**) in the 52 weekly surveys. Cancer crabs combined were the fourth most abundant taxon of shellfish impinged and had the fifth highest biomass. Cancer crabs were the most abundant shellfish impinged in the heat treatment surveys, with a total of 584 crabs impinged weighing 3.2 kg (7.1 lb) (**Table 4-6**). Of these crabs, 502 were red, 27 were brown, 18 were hairy, 1 was Dungeness, and 36 were could not identified to the species level.

Cancer crabs were impinged in surveys from late September through June, with most being collected in the winter surveys (**Figure 4-50**). Cancer crabs were also collected in five of the six heat treatment surveys, with most being collected in one survey in June 2005 (**Figure 4-51**).

4.4.2.4 Annual Impingement Estimates

The estimated annual impingement of Cancer crabs under normal operations using actual CWS flows was 377 individuals weighing 2.0 kg (4.4 lb) (**Table 4-7**). Under maximum CWS flow the estimate was 589 individuals weighing 3.3 kg (7.3 lb). Combining all three sources of impingement at EPS the estimate was 961 individuals weighing 5.2 kg (11.5 lb) using actual and 1,173 weighing 6.5 kg (14.3 lb) under maximum flow (**Table 4-8**).

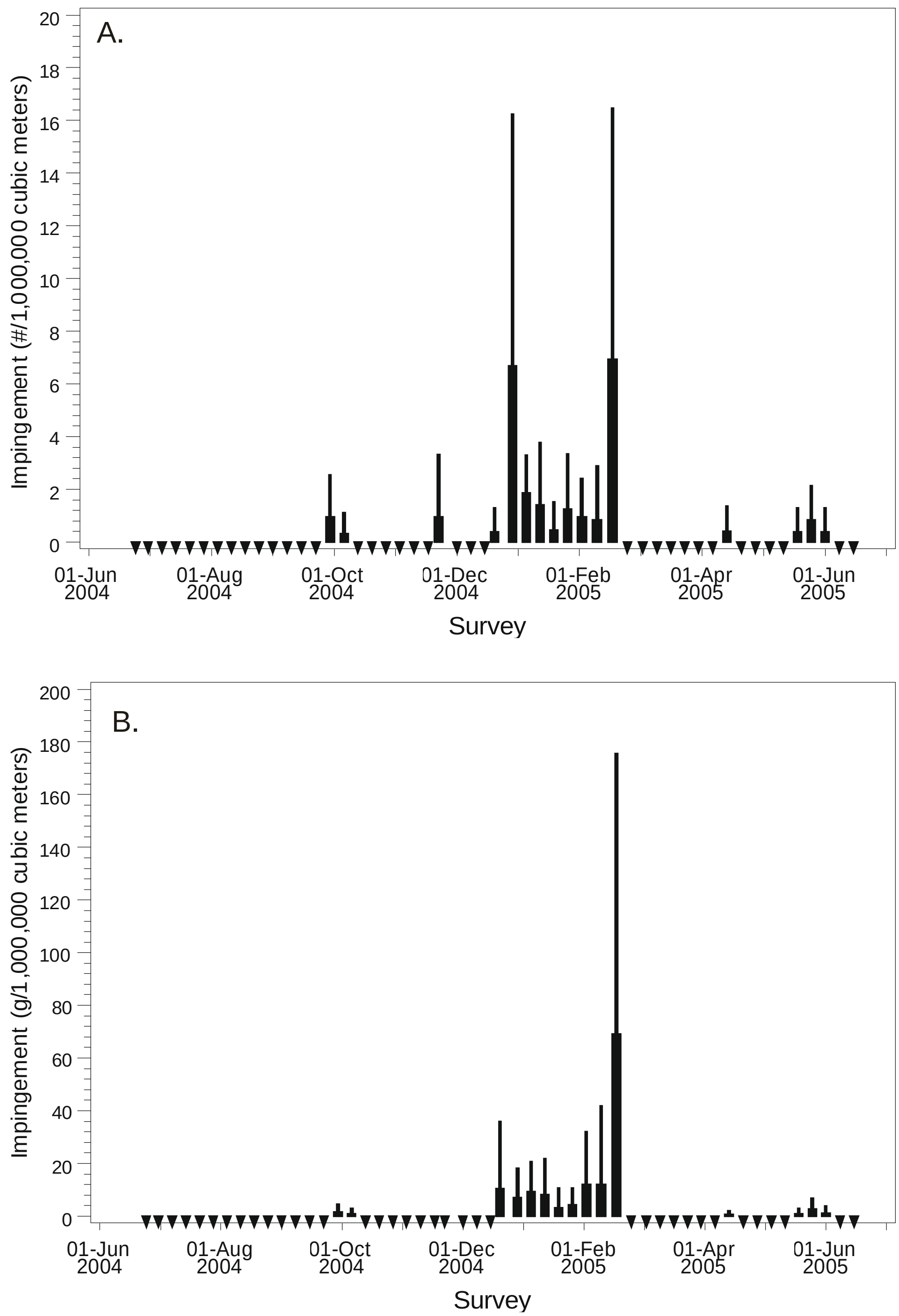


Figure 4-50. Mean concentration and standard error of Cancer crabs impinged at EPS Units 1–5 June 2004 through June 2005 (n=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

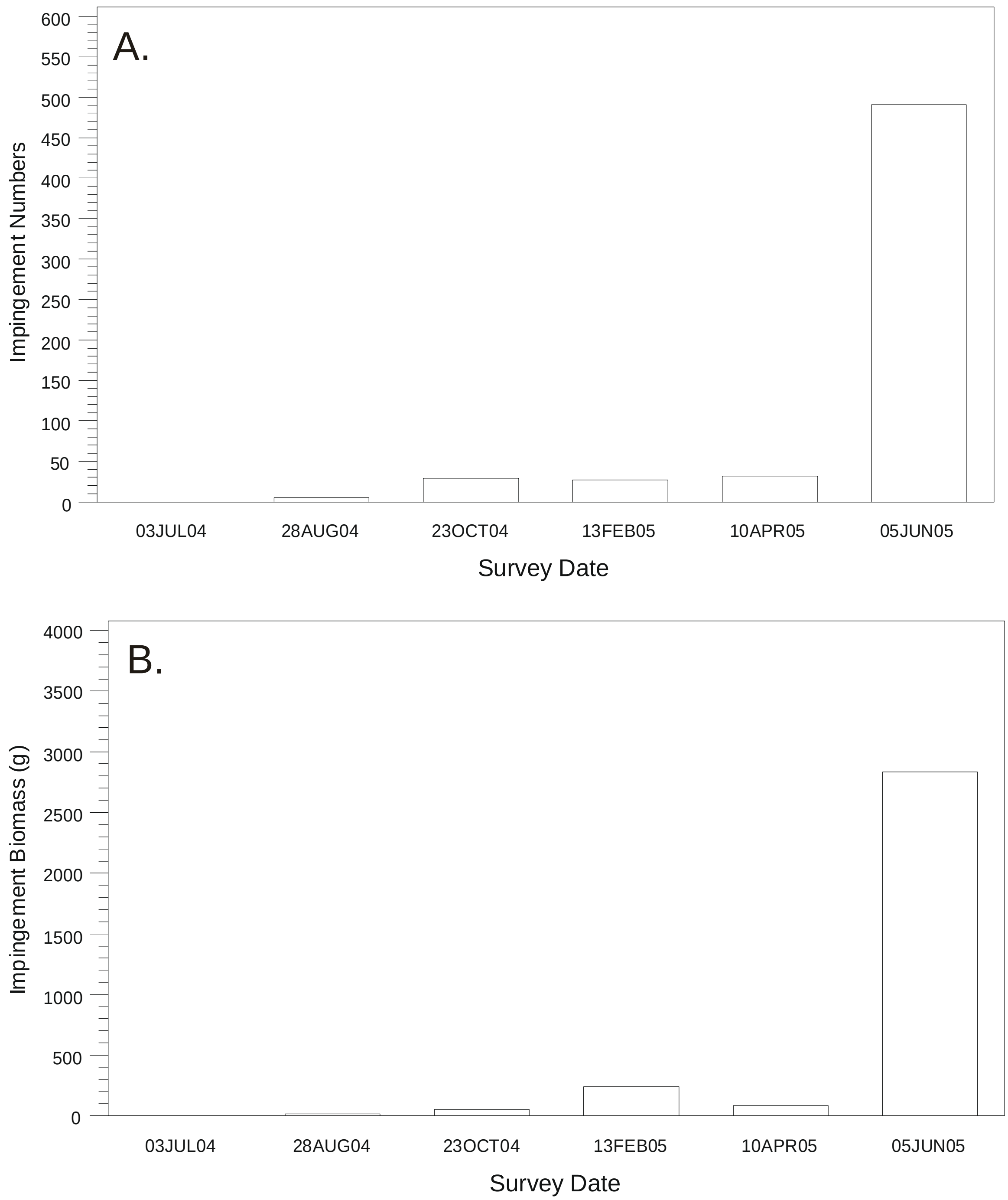


Figure 4-51. A) abundance, and B) biomass of Cancer crabs impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

4.4.3 California Spiny Lobster (*Panulirus interruptus*)

Range: From Monterey Bay, California to southern Baja California and northern Gulf of California, Mexico

Life History:
- Size to 75 cm (2.5 ft) total length
- Age at maturity 3 to 9 yr
- Life span from 20 to 30 yr
- Spawns March through August with a fecundity of 50,000–800,000 eggs

Habitat: Nearshore surfgrass beds and rocky habitat in depths from intertidal to 75 m (0–245 ft).

Fishery: Commercial and recreational fishery throughout range.

The California spiny lobster *Panulirus interruptus* inhabits coastal waters of the Pacific Southwest from Monterey Bay, California, to Manzanillo, Mexico (Leet et al. 2001), with the majority of the population being found between Point Conception and central Baja California (Lindberg 1955, Johnson 1960). There is an isolated population in the northern waters of the Gulf of California (Duffy 1973).

4.4.3.1 Life History and Ecology

Adult lobsters usually inhabit rocky areas from the intertidal zone to depths of 73 m (240 ft) (Leet et al. 2001). Lobsters make an annual offshore-onshore migration stimulated by water temperature and an increase in wave action. In winter months, male and female lobsters are found in depths of 15 m (50 ft) or greater. Mating occurs in November through May (Leet et al. 2001) while the lobsters are offshore. Starting in late March through May they move onshore into depths of less than 9 m (30 ft). They generally migrate in small groups after dark.

Spawning occurs from March through August with primary activity during May, June, and July (Allen 1916). Females move inshore and release 50,000–800,000 eggs (Shaw 1986). The female extrudes the eggs which are fertilized by sperm released from a tar-like spermatophore deposited by the male on the under side of the female’s sternum (Leet et al. 2001). The female attaches the fertilized eggs to the pleopods at the tail, where they develop for 9–10 wk before hatching (Leet et al. 2001).

The larval development of spiny lobster, described by Johnson (1956), is protracted and complex compared to other crustaceans. There are 11 pelagic stages with the first stages or phyllosomes being transparent, with dorsoventrally flattened bodies and long spider-like legs. The average body length is 1.4 mm (0.06 in) for stage I phyllosomes and 29 mm (1.1 in) for stage IV phyllosomes. Only 3% of larvae survive to reach stage IV. During the larval period, the phyllosomes drift with the prevailing currents feeding on other planktonic organisms. After 5–9 months, the phyllosome larvae metamorphose into stage XI, the puerulus stage. Here the animal resembles the adult form, although the body is still transparent and the second antennae are three times the length of the body. The puerulus actively swims inshore where it settles to the bottom if the habitat is suitable. The larvae are commonly found in surf grass, *Phyllospadix torreyi*. The puerulus stage lasts approximately 60–90 d. Ten days after settling, the puerulus become fully pigmented and begins life as a benthic juvenile. Most juvenile lobsters spend their first two years in nearshore surf grass beds, mussel beds, or shallow rocky crevices.

Approximately 90% of females are sexually mature when they have a 69 mm (2.7 in) carapace length (CL) (Shaw 1986). Males mature at 3–6 yr and females mature at 5–9 yr. Growth rates are highly variable depending on food resources, water temperature, size, and sex of the animal. Males tend to grow faster and live longer than females. Males reach the minimum legal harvest CL of 83 mm (3.3 in) in 7–10 yr and females after 12 yr. Lobsters shelter in crevices or holes during daylight hours to avoid a variety of predators including sheephead, cabezon, kelp bass, octopus, California moray eel, giant sea bass, rockfishes, leopard shark, and horn shark. At night lobsters leave the safety of the den to search for food. Being omnivores, they consume algae and a wide variety of fish and invertebrates such as snails, mussels, sea urchins, and clams, as well as injured or newly molted lobsters.

4.4.3.2 Fishery and Population Trends

Spiny lobsters have been commercially fished in southern California since the 1800s. Fishermen use weighted wire mesh boxes or "traps" baited with fish or crushed mussels to attract the lobsters. The traps are usually clustered around rocky outcrops or along depth contours of less than 30 m (100 ft). Seasonal landings in California between 1916 and 2001 varied from a peak in 1950 of 423,412 kg (933,449 lb) to a low in 1942 of 76,486 kg (168,641 lb) (Shaw 1986, CDFG 2004). San Diego County is located in the central portion of the spiny lobster range where up to 60% of California landings occur. The average landings for San Diego County in 2000–2005 were 112,243 kg (247,450 lb) (PacFIN). Annual revenue generated by lobster landings in San Diego County during this period averaged $1,667,371 (PacFIN) and the 2005 catches were 111.4 MT valued at $1.81 million. Estimated annual landings of spiny lobster for all of California from 2000–2005 averaged 338,779 kg (746,867 lb) (PacFIN). There is also a substantial sport fishery. Lobsters are taken by skin divers and scuba divers, as well as with hoop nets. Although there are little data, it is estimated that annual sport take is equal to half of the commercial catch (Frey 1971). Fluctuations in landings can be due to factors other than population such as weather events like El Nino or La Nina. Based on the proportion of short and legal lobsters taken, CDFG believes that the lobster population in California is well managed and in a healthy status.

4.4.3.3 Sampling Results

A total of 2 spiny lobsters, with a combined weight of 0.1 kg (0.22 lb), was impinged during normal impingement surveys during the entire one-year study (**Table 4-6**). No lobster were impinged on the bar racks. These two lobsters were found during late September and late January surveys (**Figure 4-52**). Nine spiny lobsters were impinged in the heat treatment surveys, weighing 1.2 kg (2.6 lb) (**Figure 4-6**). They were collected in the heat treatments surveys from July 2004 to February 2005, with the most being collected during the August survey (**Figure 4-**

53). Their lengths ranged from 21 to 211 mm TL (0.83 to 8.31 in TL) with a mean length of 162.3 mm TL (6.4 in) (**Appendix G**).

4.4.3.4 Annual Impingement Estimates

The estimated impingement of California spiny lobster under normal operations using actual CWS flows was 13 individuals weighing 0.6 kg (1.3 lb) (**Table 4-7**). Under maximum CWS flows the estimate increased to 16 individuals weighing 0.7 kg (1.5 lb) (**Table 4-7**). When all sources of loss due to the operation of the EPS CWS were combined (normal operations, bar racks and heat treatment), the annual loss based on actual CWS flow was 22 individuals weighing 1.9 kg (4.1 lb.) and 25 individuals weighing of 2.0 kg (4.3 lb) under maximum CWS flows (**Table 4-8**).

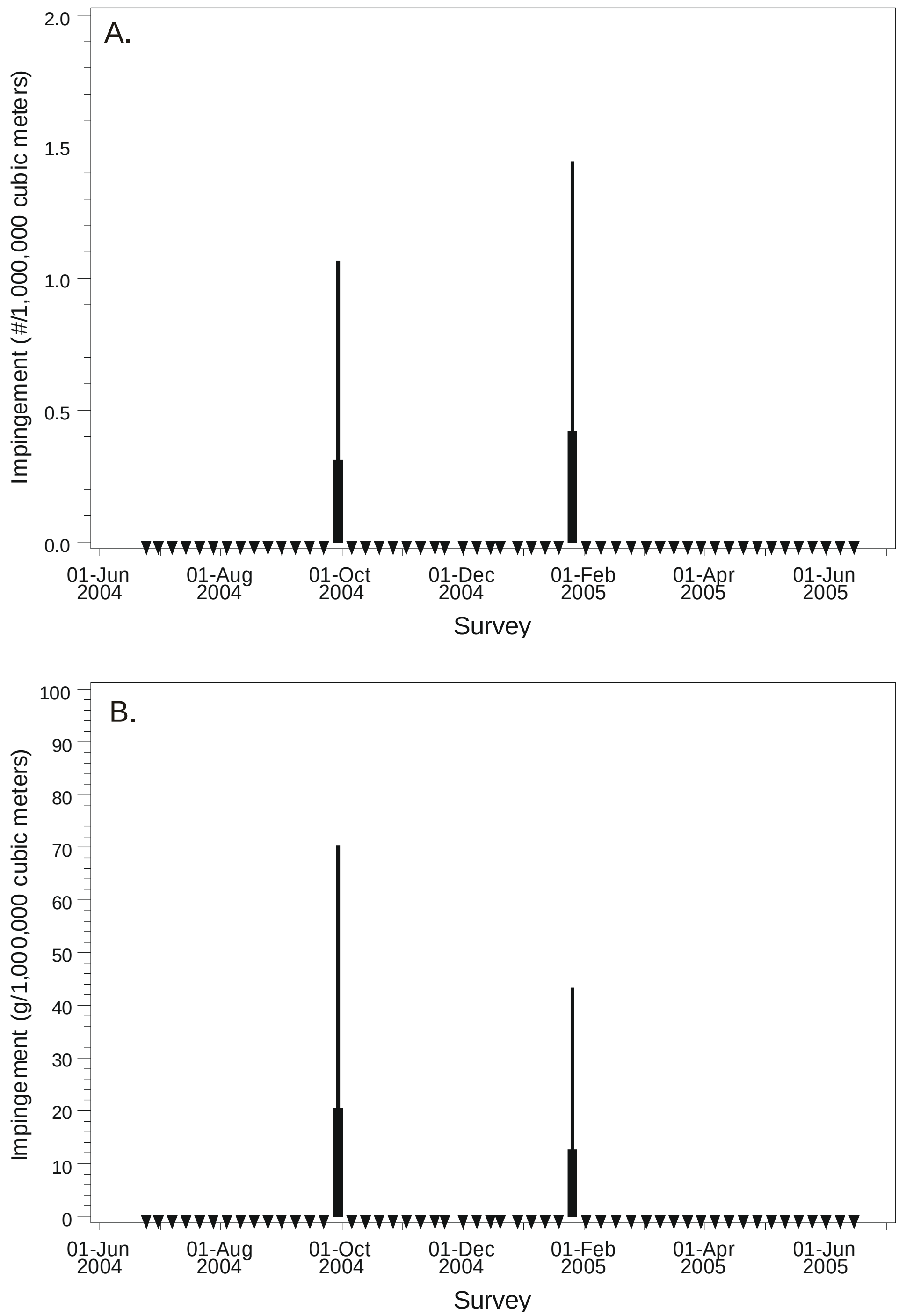


Figure 4-52. Mean concentration and standard error of California spiny lobster impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

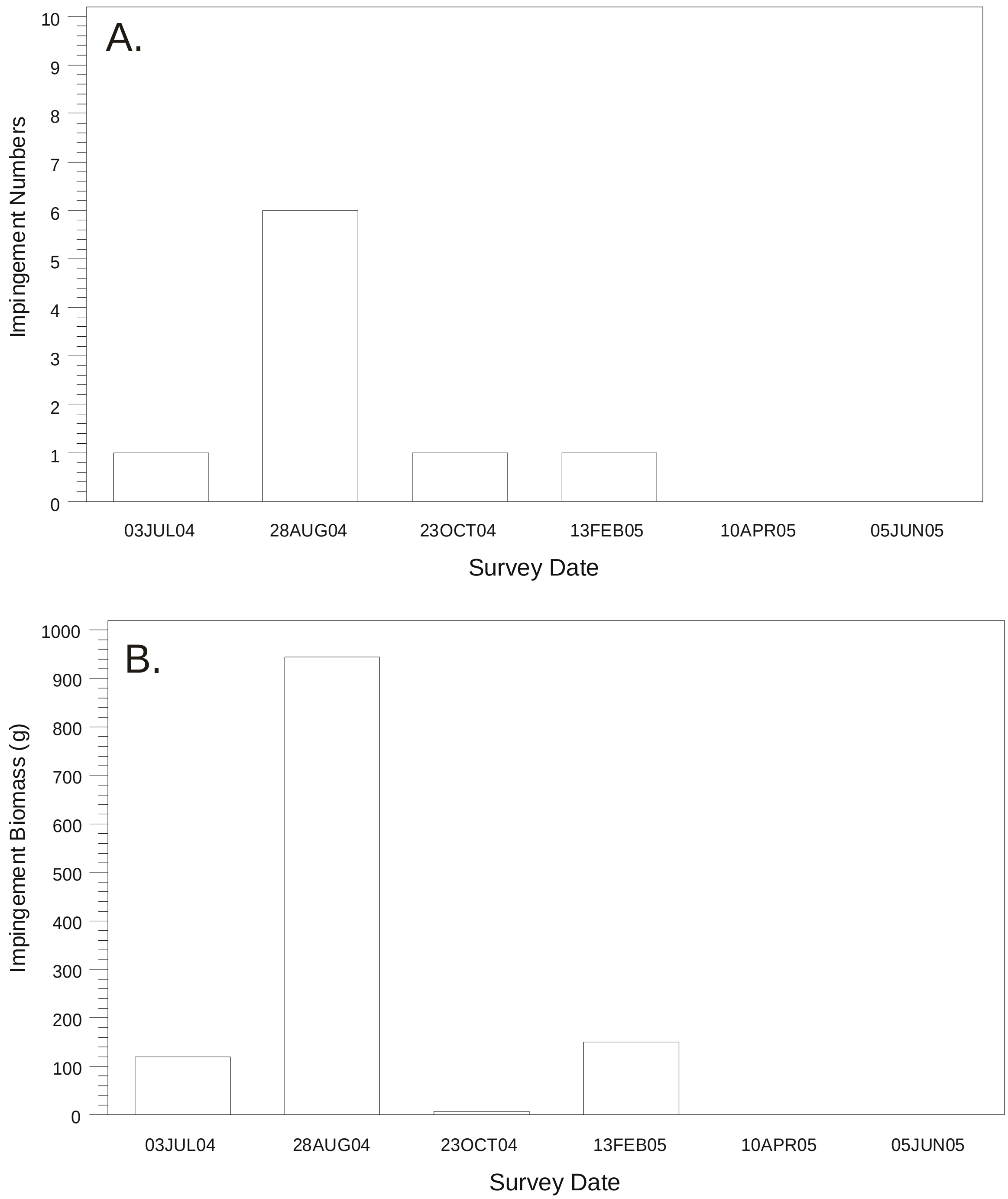


Figure 4-53. A) abundance, and B) biomass of California spiny lobster impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (n=6 surveys).

4.4.4 Market Squid (*Loligo opalescens*)

Range: From southern Alaska to Isla Guadalupe, Mexico

Life History:
- Size to 275 mm (11 in) (males) (not including tentacles) and to approximately 200 mm (8 in) (females)
- Life span <1 yr
- Spawn year-round with fecundity of about 180–300 eggs encased in a capsule, may extrude 20–30 capsules

Habitat: Pelagic, living in coastal waters but returning to shallow inshore waters to spawn.

Fishery: Commercial, marketed for human consumption or sold as bait.

The market squid is a member of the family Loliginidae in the order Decapoda that also contains octopus. Market squid range from southern Alaska to Isla Guadalupe, Mexico, and Bahía Asuncíon, Baja California, but are most common from British Columbia southward (Morris et al. 1980). Several other species of *Loligo* occur in the Pacific Ocean, but are generally found in deeper water (Leet et al. 2001).

4.4.4.1 Life History and Ecology

Market squid are pelagic, living in coastal waters and moving to semi-sheltered bays and other locations with suitable substrata (sand or mud bottoms) to spawn in depths ranging from just below the intertidal down to 180 m (540 ft) (Fields 1965, Kato and Hardwick 1975).

Male market squid can reach 275 mm (11 in) in dorsal mantle length (DML), and females can attain 200 mm (8 in) DML (UCLA 1999). Growth of squid in the southern California bight was found to be related to water temperature and productivity (Jackson and Domeier 2003). Male and female market squid reach maturity at around 70–80 mm (ca. 3 in) DML in as little as six months (Butler et al. 1999) At 15 mm (0.6 in) DML, squid are reported to be approximately 50 days old. Recent age estimates indicate that the market squid may complete their life cycle in less than one year (Butler et al. 1999).

Market squid spawn year-round from San Francisco to Baja California, but exhibit two spawning peaks annually (Starr et al. 1998). Spawning activity begins in the southern California population in December and continues through March. In Monterey Bay, they begin spawning in April and continue through November (McInnis and Broenkow 1978, Morris et al. 1980). Both male and female squid are terminal spawners and die after spawning.

The female produces from 180–300 eggs encased in a cylindrical capsule and may extrude 20–30 capsules during a spawning event (Starr et al. 1998, FWIE 1999). Macewicz et al. (2000) estimated around 5,500 eggs per spawning female per year. Egg cases are attached with thin stalks to the bottom substratum (Fields 1965). Subsequent layers can then be deposited until large clusters are formed (Starr et al. 1998). Egg cases have been observed in depths ranging from 3–180 m (10–590 ft) (FWIE 1999) and the eggs hatch in 15–90 d, depending on water temperature (Fields 1965, Yang et al. 1986).

The majority of fishing for market squid has shifted from Monterey Bay to southern California since the 1980's (Zeidberg et al. 2006). Approximately 90% of the seasonal harvest of market squid in California occurs south of Point Conception (Leet et al. 2001). Large fluctuations in annual landings are thought to be correlated with changes in ocean climate that affect market squid reproduction and survival. Annual commercial landings of market squid landed in California during 2000–2005 averaged 69.8 million kg (153.8 million lb) with an average annual valued of $23,188 (PacFIN). Very few market squid were landed in San Diego during this period, with the majority being landed during 2001 (10,965 kg [24,174 lb] valued at $4,623) with none being reported to have been landed in 2000, 2003, and 2004 (PacFIN).

4.4.4.2 Sampling Results

A total of 24 market squid weighing 0.3 kg (0.67 lb) was collected during the normal operations impingement sampling (**Table 4-6**). They were ranked as the fifth most abundant invertebrate impinged based on both abundance and biomass. No squid were collected on the bar racks or in the heat treatment surveys. Squid were only impinged from September through January, with the most individuals being seen during October (**Figure 4-54**). Lengths ranged from 47–129 mm ML (1.9 –5.1 in) (**Appendix G**).

4.4.4.3 Annual Impingement Estimates

The estimated annual impingement of market squid under normal operations and actual CWS flows was 162 individuals weighing 1.8 kg (4.0 lb) (**Table 4.4-1**). Under maximum CWS flows the estimate was 190 individuals weighing 2.2 kg (4.9 lb).

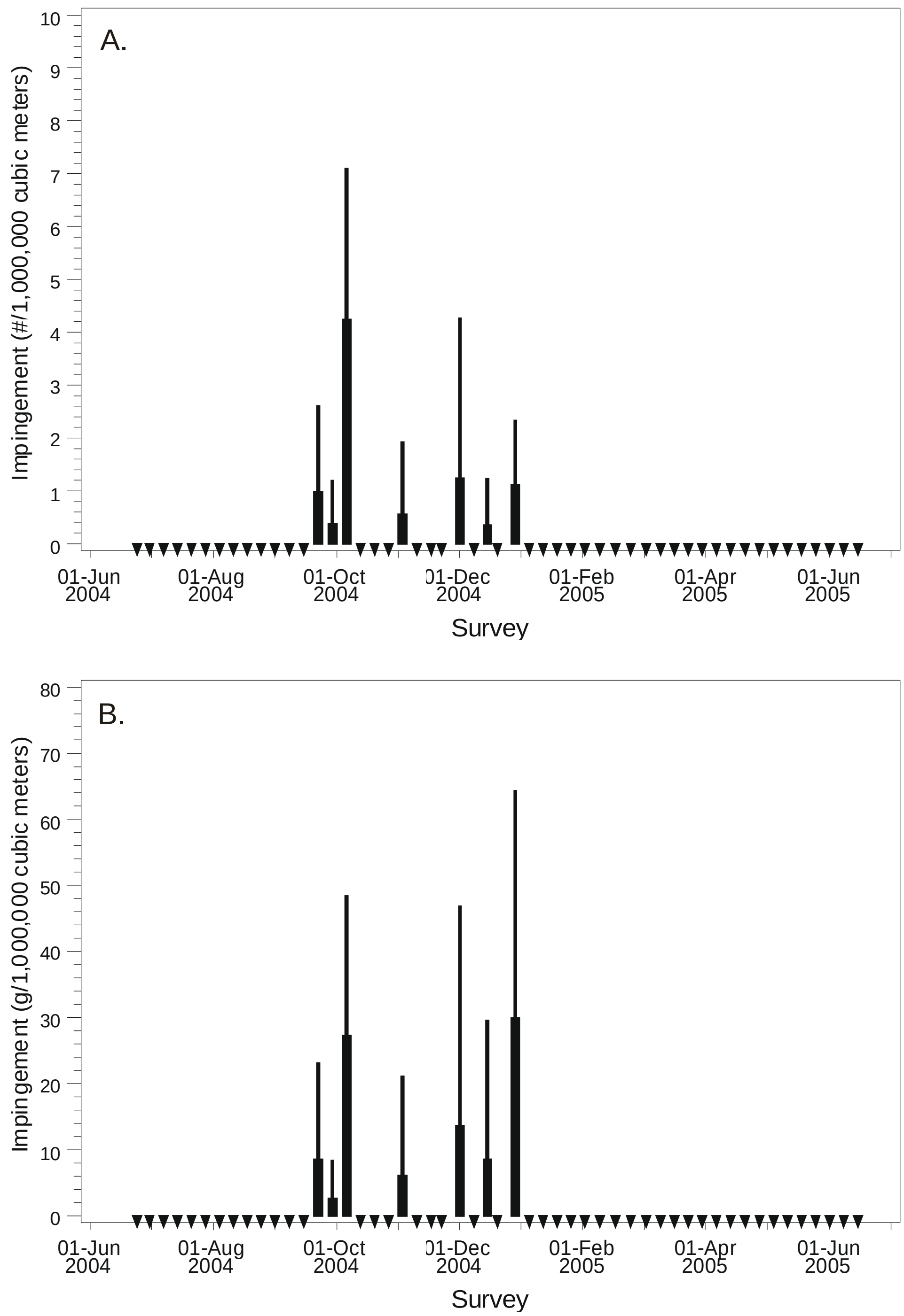


Figure 4-54. Mean concentration and standard error of market squid impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

4.4.5 Two-spotted Octopus (*Octopus* spp.)

Range: *O. bimaculoides*: San Simeon (San Luis Obispo Co.) to Ensenada, Baja California;
O. bimaculatus: Santa Barbara to Gulf of California

Life History:

- Size: Dorsal mantle length from 5–20 cm (2.0– 7.9 in) at maturity
- Life span varies with species, approximately 0.5–3 years
- Spawn late-winter to early-summer; fecundity varies with species and size

Habitat: *O. bimaculoides* found from the Middle and low intertidal zones and mud flats to the subtidal, on rocks or in kelp beds, to depths of 20 m; *O. bimaculatus* from the lower intertidal zone to 50 m.

Fishery: Commercial and recreational.

The two-spotted octopus group consists of two similar species: *Octopus bimaculoides* and *O. bimaculatus*. *Octopus bimaculoides* occurs from San Simeon (San Luis Obispo Co.) to Ensenada, Baja California, and *O. bimaculatus* has a more southerly distribution extending into the Gulf of California (Morris et al. 1980).

4.4.5.1 Life History and Ecology

Octopus occur from the middle intertidal zone to depths of 20–50 m (66–164 ft). *O. bimaculatus* occupies holes and crevices in a wide range of hard substrate habitats (Ambrose 1988). They can also shelter in large gastropod shells or discarded bottles and cans.

Morris et al. (1980) summarized the life history of *O. bimaculoides*. Two-spotted octopuses begin laying eggs primarily from January through May. Females lay their eggs under rocks from late winter to early summer, and brood them continuously from 2–4 mo until hatching. MacGinitie and MacGinitie (1968) report that female *O. bimaculoides* weighing approximately 0.5 lb will lay approximately 600 eggs. At Santa Catalina Island, with an average octopus size of 260 g (0.6 lb) (71 mm [2.8 in] mantle length [ML]), the average clutch size was approximately 20,000 eggs (Ambrose 1981). The eggs are attached by slender stalks, are about 0.5 in. long and 1/6 inch in diameter. The young remain on the bottom after hatching, often moving into the intertidal.

Octopus are commercially and recreationally fished. Commercial landings in California for all octopus averaged 4,332 kg (9,550 lb) annually from 2000–2005, peaking at 11,110 kg (24,500 lb) in 2002 (PacFIN). The average annual landing of octopus in San Diego during this period was 74.4 kg (161 lb), and the 2005 catch of 0.1 MT was valued at $339 (PacFIN).

4.4.5.2 Sampling Results

A total of 44 octopuses weighing 8.0 kg (17.6 lb) was collected from impingement samples (**Table 4-6**). They were the third most abundant invertebrate impinged and the most abundant in biomass (**Table 4-6**). Most of the octopi were impinged during normal operations surveys were found in one survey in late February (**Figure 4-55**). A total of 167 individuals weighing 11.8 kg (26.0 lb) was impinged in the heat treatment surveys (**Figure 4-6**). Most octopuses collected during the heat treatment surveys were seen in October 2004 (**Figure 4-56**).

4.4.5.3 Annual Impingement Estimates

The estimated annual impingement of octopus during the normal operation surveys using actual CWS flows was 330 individuals weighing 57.7 kg (127.2 lb) (**Table 4-7**). Under maximum CWS flows, the estimated annual impingement was 667 individuals weighing 118.6 kg (261.5 lb) (**Table 4-7**). When all sources of impingement mortality were combined, the annual estimate of impingement during actual and maximum flow was 348 and 834 individuals weighing 69.5 kg (153.2 lb) and 130.4 kg (287.5 lb), respectively (**Table 4-8**).

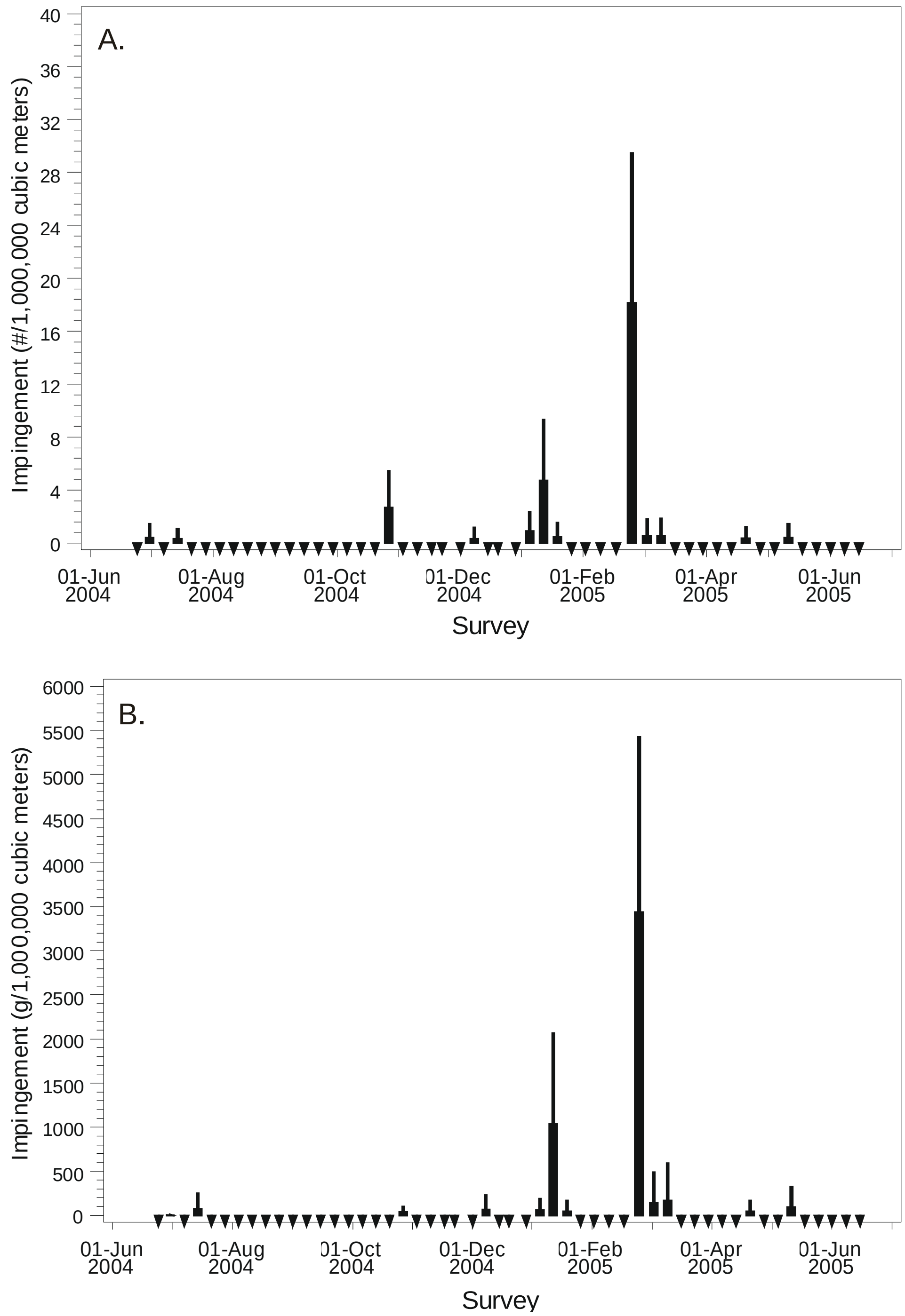


Figure 4-55. Mean concentration and standard error of octopus impinged at EPS Units 1–5 from June 2004 through June 2005 (*n*=52 surveys): A) abundance, and B) biomass.

Note: Downward pointing triangle indicates survey with no larvae collected.

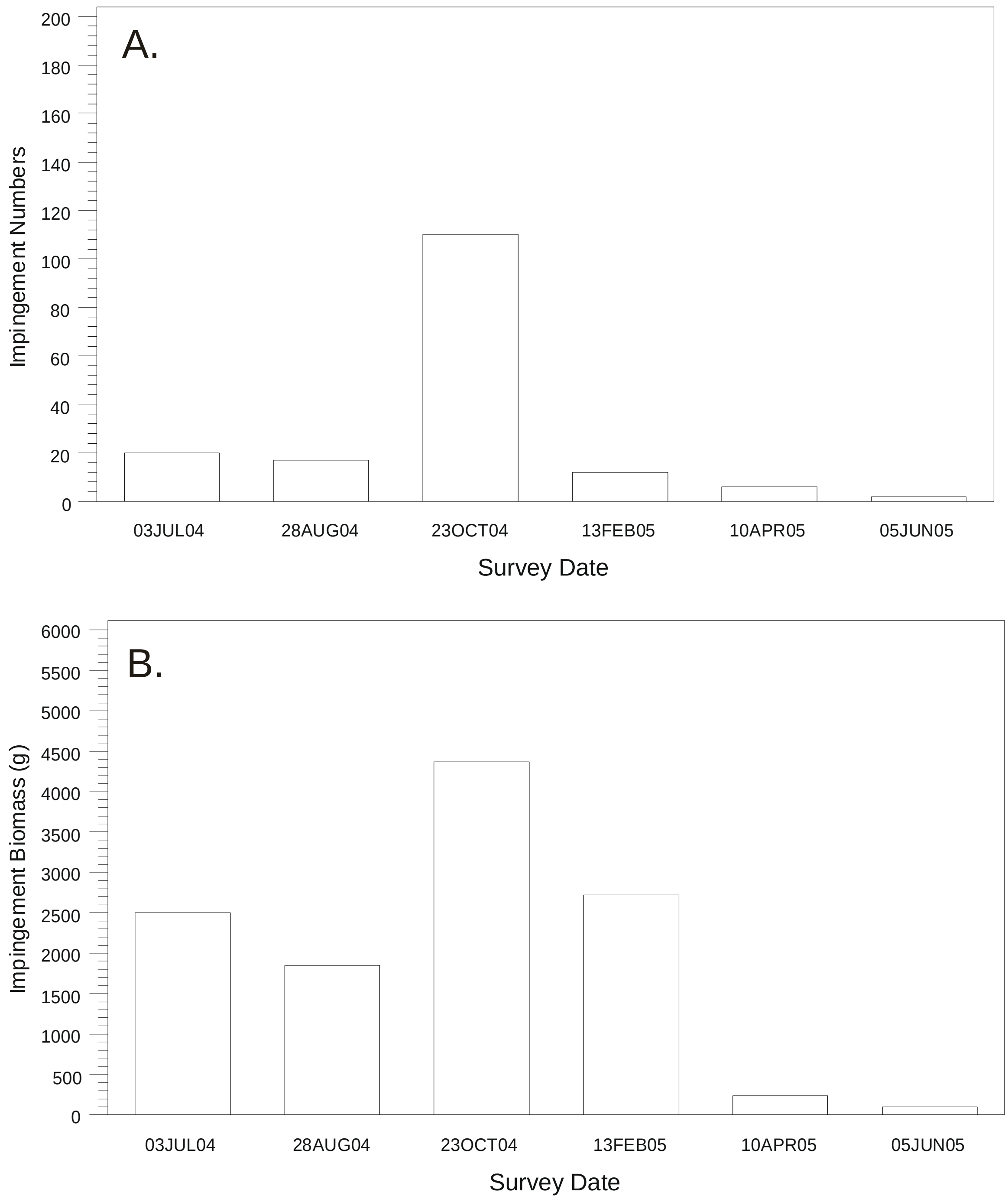


Figure 4-56. A) abundance, and B) biomass of octopus impinged during heat treatments at EPS Units 1–5 from July 2004 through June 2005 (*n*=6 surveys).

5.0 Impact Assessment of the EPS Cooling Water System

5.1 Impact Assessment Overview: Data and Approach

Section 316(b) of the Clean Water Act regulates cooling water intake systems at electrical generating facilities, and requires the location, design, construction, and capacity of cooling water intake structures reflect the best technology available (BTA) for minimizing adverse environmental impacts (AEI). In 2004, EPA published Phase II 316(b) regulations for existing power plants, which established performance standards for reducing entrainment by 60–90% and impingement mortality by 80–95%. However, the Phase II regulations were suspended by EPA in 2007. On May 20, 2007, EPA sent a memorandum to regional administrators informing them that the Phase II rule should be considered suspended, and that "*…all permits for Phase II facilities should include conditions under Section 316(b) of the Clean Water Act developed on a Best Professional Judgment basis. See 40 CFR 401.14.*" As written, the Clean Water Act does not specify required cooling water intake system (CWIS) technologies or methods by which EPA must make its determinations under Section 316(b).

Prior to the publication of the Phase II regulations in 2004, regulators relied on EPA's (1977) draft guidelines for evaluating adverse impacts of cooling water intake structures to determine compliance with Section 316(b). Since the new Phase II regulations were based on performance standards for reducing entrainment and impingement and did not explicitly rely on determining whether existing levels represented an adverse environmental impact (AEI), EPA determined that the "*…performance standards reflect the best technology available for minimizing adverse environmental impacts determined on a national categorical basis.*" Although AEI was not intended to be used in assessing compliance under the new regulations, the potential for AEI was still considered in determining the types of plants and water bodies where the new performance standards would apply. Plants with low capacity factors and low cooling water volumes were considered to be BTA since their cooling systems had a low potential for AEI.

In its 1977 draft guidance document, EPA stated that "*Adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact.*" EPA further stated in the document that "*Regulatory agencies should clearly recognize that some level of intake damage can be acceptable if that damage represents a minimization of environmental impact.*"

The 2004–2005 EPS IM&E study was performed to determine if the existing intake and its operations results in AEI. Entrainment and impingement losses were measured by collecting samples within the EPS (IM) and in front of the cooling water system intake (E). The impact assessment puts the measured losses into context of the marine ecological setting at the facility.

5.1.1 CWIS impacts

There are three general types of effects associated with intake structures utilizing once-through cooling designs: (1) thermal effects, (2) impingement effects, and (3) entrainment effects. Thermal effects are caused by waste heat rejected from condenser cooling flows and are regulated under Section 316(a) of the Clean Water Act and the *Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays of California (California Thermal Plan)*. Entrainment occurs when small planktonic organisms are drawn into the CWIS and subsequently pass through it. Organisms large enough to become trapped on the intake screening system are said to be impinged.

In discussing the potential effects of the EPS CWIS on fish and shellfish populations the life history of the species in the community needs to be considered. For example, several fish species in the nearshore coastal areas around EPS have early life stages that are not susceptible to entrainment. Live-bearers, such as surfperches, and some sharks and rays, produce young that are fully developed and too large to be affected by entrainment. In addition, for fishes with entrainable life stages, the period of time that they are vulnerable to entrainment may be relatively short. As the results for EPS show, many species are only vulnerable to entrainment for a few days when they are newly hatched since their swimming ability increases rapidly with age and development. Although some species spawn in the water column and have free-floating eggs, others such as gobies, which were the most abundant taxon entrained, others have demersal eggs that are not subject to entrainment. Also, with increased age young post larval fishes begin searching for adult habitat, usually on the bottom, where they are not susceptible to entrainment. From the standpoint of impingement effects, gobies are generally not susceptible to impingement after transformation to the juvenile life stage because they are bottom-dwelling species that typically do not move up into the water column. This is also true of many flatfishes which are bottom-dwellers and also tend to be strong swimmers. Even fish species that swim in the water column are generally not susceptible to impingement as they mature because they are able to swim against the slow approach velocity of the cooling water inflow.

5.1.2 Review of IM&E Sampling Approach

The Phase II 316(b) regulations required that IM&E studies include "*Documentation of current impingement mortality and entrainment of all life stages of fish, shellfish, and any protected species identified previously and an estimate of impingement mortality and entrainment to be used as the calculation baseline.*" For the purposes of this study the term 'shellfish' was defined as commercially and recreationally important species of crustaceans (crabs, lobsters, shrimp, etc.) and mollusks (squid and octopus) that are harvested on a regular basis from the coastal areas surrounding the EPS. This definition does not include organisms such as clams, mussels, and other crustaceans and mollusks that may only be harvested occasionally for recreational purposes. This definition was used because 'shellfish' could also be considered as including all species of shelled invertebrates, including zooplankton, and clarification of the term was not provided in the regulations.

The Rule's entrainment performance standard focuses on addressing impacts to fish and shellfish rather than lower tropic levels such as phyto- and zooplankton. EPA recognized the low vulnerability of phyto- and zooplankton in its 1977 draft 316(b) guidance (EPA 1977). There are several reasons why there is a low potential for impacts to phyto- and zooplankton and why the EPA decided to focus on potential effects on fish and shellfish. The reasons include:

- The extremely short generation times of most holoplanktonic organisms; on the order of a few hours to a few days for phytoplankton and a few days to a few weeks for zooplankton;
- Both phyto- and zooplankton have the capability to reproduce continually depending on environmental conditions; and
- The most abundant phyto- and zooplankton species along the California coast have populations that span the entire Pacific or in some cases all of the world's oceans. For example, *Acartia tonsa*, one of the common copepod species found in the nearshore areas of California is distributed along the Atlantic and Pacific coasts of North and South America and the Indian Ocean.

Relative to the large abundances of phyto- and zooplankton, larval fishes make up a small fraction of the total numbers of organisms present in seawater. The EPA has correctly focused on potential impacts on fishes and shellfishes because they are more susceptible to entrainment effects for the following reasons:

- They have much shorter spawning seasons relative to phyto- and zooplankton. In many species, spawning occurs only once during the year;
- Unlike phyto- and zooplankton that may be distributed over large oceanic areas, most fishes are restricted to the narrow shelf along the coast and in some cases have specific habitat requirements that further restrict their distribution; and
- Unlike many phyto- and zooplankton, there is a greater likelihood of mortality due to entrainment in larval fishes, since many lower tropic level organisms are not soft bodied as is the case for finfish and are better able to tolerate passage through the cooling system.

The impingement and entrainment sampling was therefore focused on fishes and shellfishes as required in the new 316(b) Phase II regulations. All of the fishes and shellfishes collected during the impingement sampling were counted and identified, while fish larvae, megalops stages of Cancer crabs, phyllosome larvae of spiny lobster, and squid larvae were identified and counted from the entrainment samples. The new 316(b) Phase II regulations provided latitude for focusing on the set of species that could be accurately quantified and that would provide the necessary detail to support development of other aspects of the CDS. The target group of organisms that were included in the entrainment sample processing was agreed to by the Technical Advisory Group that included staff from the SDRWQCB and other resource agencies.

The specific taxa (species or group of species) that were included in the assessment were limited to the taxa that were sufficiently abundant to provide reasonable assessments of impacts. For the purposes of this study plan, the taxa analyzed in the assessment were limited to the most abundant taxa that together comprised 90–95% of all larvae entrained and/or juveniles and adults impinged by the generating station. The most abundant taxa were used in the assessment because they provide the most robust and reliable estimates for the purpose of assessing impacts. Since the most abundant organisms may not necessarily be the organisms that experience the greatest effects on the population level, the data were also carefully examined to determine if additional taxa should be included in the assessment. For example, this might include commercially or recreationally important taxa, taxa with limited habitats, and any threatened or endangered fish or shellfish species. No listed species were entrained or impinged at the EPS during the study and among the species with few entrained larvae only California halibut was included in the assessment because of its commercial and recreational fishery importance.

Results for individual taxa from the impingement and entrainment sampling need to be combined, where possible, to evaluate the combined effects of the CWIS. This is done by extrapolating the numbers of adult and juvenile fishes impinged to the same age used in the adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*) models for the entrainment data. The age used in the *AEL* and *FH* modeling was the average age of reproductive females in the population. Unfortunately, the life history information necessary for the modeling is unavailable for most species so combined assessments were only possible for northern anchovy.

5.1.3 Approaches for Assessment of CWIS impacts

Due to the suspension of the 316(b) Phase II rule, state and federal permit writers have been directed to implement Section 316(b) on a case-by-case basis using "best professional judgment". In the case of the EPS, the permit applicant is obligated to provide the San Diego RWQCB with the "best information reasonably available" to assist it in fulfilling its decision-making responsibility. To make Section 316(b) decisions, permit writers have relied on precedent from other cases and on USEPA's (1977) draft "Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500."

As is clear from the statute, the permit writer must consider two basic issues in making a finding that an intake technology employs the BTA for minimizing AEI:

- Whether or not an AEI is caused by the intake and, if so,
- What intake structure represents BTA to minimize that impact.

The usual approach for a 316(b) demonstration would be to consider the question of BTA only if a determination has been made that a facility is causing an AEI.

5.1.3.1 Adverse Environmental Impact (AEI) Standard

Since there are no regulations defining AEI, permit decisions must be based on the USEPA's AEI interpretations provided in guidance documents issued since the 1970's. In those documents, the USEPA has indicated that assessment of AEI should be based on an evaluation of population level effects, not just losses of individual organisms. In its 1975 Draft BTA Guidelines, the USEPA stated that "[a]dverse environmental impacts occur when the ecological function of the organism(s) of concern is impaired or reduced to a level which precludes maintenance of existing populations...". Additionally, in the 1976 Development Document, released in conjunction with the EPA's previous Section 316(b) rules, the USEPA said that "the major impacts related to cooling water use are those affecting the aquatic ecosystems. Serious concerns are with population effects that…may interfere with the maintenance or establishment of optimum yields to sport or commercial fish and shellfish, decrease populations of endangered organisms, and seriously disrupt sensitive ecosystems."

The USEPA (1977) draft guidelines acknowledge that the determination of the extent of AEI when it is occurring is difficult to assess. They stated that "Adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact. The exact point at which adverse aquatic impact occurs at any given plant site or water body segment is highly speculative and can only be estimated on a case-by-case basis."

Due to the obvious difficulties with determining the extent of AEI, the document (USEPA 1977) provides some general guidelines. These involve determining the "relative biological value of the source water body zone of influence for selected species and determining the potential for damage by the intake structure" based on the following considerations of the value of a given area to a particular species:

- principal spawning (breeding) ground;
- migratory pathways;
- nursery or feeding areas;
- numbers of individuals present; and
- other functions critical during the life history.

Following this general approach provided by the USEPA (1977), additional criteria can be evaluated that are specific to the marine environment around the EPS that are directly applicable to the present 316(b) study:

- distribution (pelagic, subtidal, nearshore subtidal & intertidal);
- range, density, and dispersion of population;
- population center (source or sink);

- magnitude of effects;
- long-term abundance trends (e.g., fishery catch data);
- long-term environmental trends (climatological or oceanographic); and
- life history strategies (e.g., longevity and fecundity).

By assessing the relative value of each of these criteria for a particular taxon, we will be able to better assess the extent of the impact that the loss of these animals has on the local environment and the population at large.

5.1.4 Relating Measured Impacts to Source Populations

The criteria used to evaluate the potential for AEI need to be placed into a larger context using the characteristics of the source water and the biological community. This assessment focuses on a set of species that were collected during the study in adequate abundances to provide reasonable confidence in the estimates of entrainment and impingement effects. These species were also selected to be broad enough to include representatives from the different habitats and species groups present in the source water. As previously discussed (Section 5.1.1), not all of the fishes and shellfishes in the source water are subject to entrainment or impingement, and only a few species occur in high abundance in both entrainment and impingement samples. These differences in the vulnerability to entrainment and impingement occur due to different life histories of the species, and the differences in habitat preferences and behavior that may occur at different life stages. The potential magnitude of the losses due to entrainment and impingement depend on many factors but specifically this assessment focuses on the distribution of the species and their habitats to determine which species are at greatest risk. The extreme case of highest risk would occur for a rare or endangered species with a distribution that was limited to Agua Hedionda Lagoon (AHL). Conversely, larvae for species such as northern lampfish that occurs to depths of 2,900 m (9,500 ft) were entrained at the EPS, but the primary distribution for this species is the outer coastal waters from Baja California to the Bering Sea and Japan (Miller and Lea 1972). The distribution of larval northern lampfish collected by CalCOFI from 1951-19898 is presented in **Figure 5-1** (Moser et al. 2001). The larvae for these and other species that are transported from far offshore into AHL where they are subject to entrainment are not likely to contribute to an adult population that occurs further offshore.

Data on water current flow and direction collected during the study were used to estimate the spatial extent of the effective source populations of larvae for modeling entrainment effects. The larval durations for the species analyzed for this report indicated that the source for some of the larvae was most likely from inside AHL. The larval durations estimated for blennies and garibaldi were both less than three days reflecting the high likelihood that the sources of the larvae are the fouling communities and breakwater habitats in the Outer Lagoon. The estimated duration for CIQ gobies was longer at 11.5 days probably due to the predominant habitat for gobies being the Middle and Inner Lagoons. The longer duration is probably due to the time it takes for the larvae to be transported out of the inner lagoon segments as a result of tidal currents combined with their behavioral tendency to resist transport by seeking quieter water microhabitats. Although the larval duration for northern anchovy was only 4.8 days, the source population for the larvae extend throughout the Southern California Bight (SCB) with peak larval abundances in the outer shelf areas (**Figure 5-2**) (Moser et al. 2001). The estimated larval durations for the other species analyzed from the entrainment sampling were consistent with their distribution in the nearshore areas inside and outside AHL. The estimates of larval duration and the composition of the fishes collected during the entrainment and impingement sampling indicate that AHL and the surrounding nearshore habitats are the logical focus for examining the potential effects of entrainment and impingement.

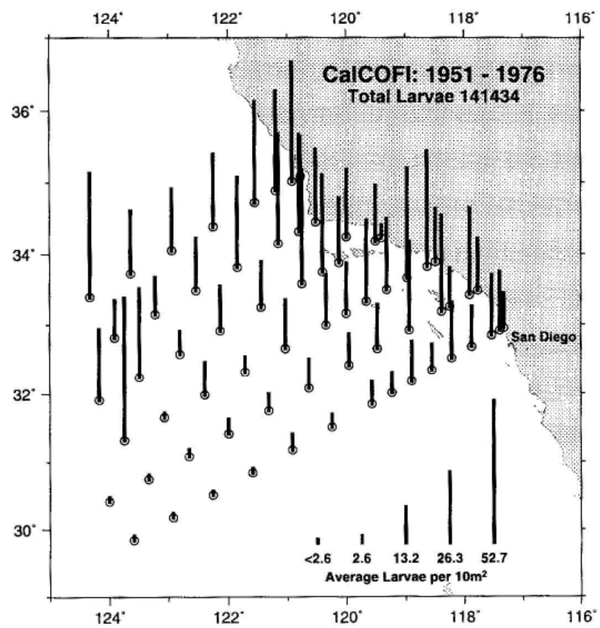


Figure 5-1. Distribution and abundance of northern lampfish larvae (*Stenobrachius leucopsarus*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

The location of the EPS intake structure inside AHL makes the fishes and other organisms that utilize that area more susceptible to the potential effects of entrainment and impingement. CWIS effects from EPS will have less effect on fishes that are primarily associated with other habitats or have distributions that extend far offshore. The following criteria from the list in the previous section can be used to focus the assessment on species with adult and larval distributions that would place them at greatest risk to entrainment and impingement effects:

- distribution (pelagic, subtidal, nearshore subtidal & intertidal),
- range, density, and dispersion of population; and
- population center (source or sink).

These criteria relate directly to the habitats associated with the fish and shellfish potentially affected by entrainment and impingement. This approach to classification has been taken in recent studies of marine fishes of California (Horn and Allen 1978, Allen 1985, Allen and Pondella 2006) and will be used to organize the taxa included in this assessment. We have simplified the more detailed categorization of habitats used by Allen and Pondella (2006) which included several habitats used to define deeper offshore areas. These deeper offshore habitat types can be combined for the purposes of our assessment since the taxa associated with those habitats are generally not at risk due to entrainment and impingement and were collected in very low numbers. The habitats defined by Allen and Pondella (2006) have been simplified for this assessment to the following habitat types:

- bays, harbors, and estuaries;
- subtidal and intertidal rocky reefs and kelp beds;
- coastal pelagic;
- continental shelf and slope; and
- deep pelagic including deep bank and rocky reefs.

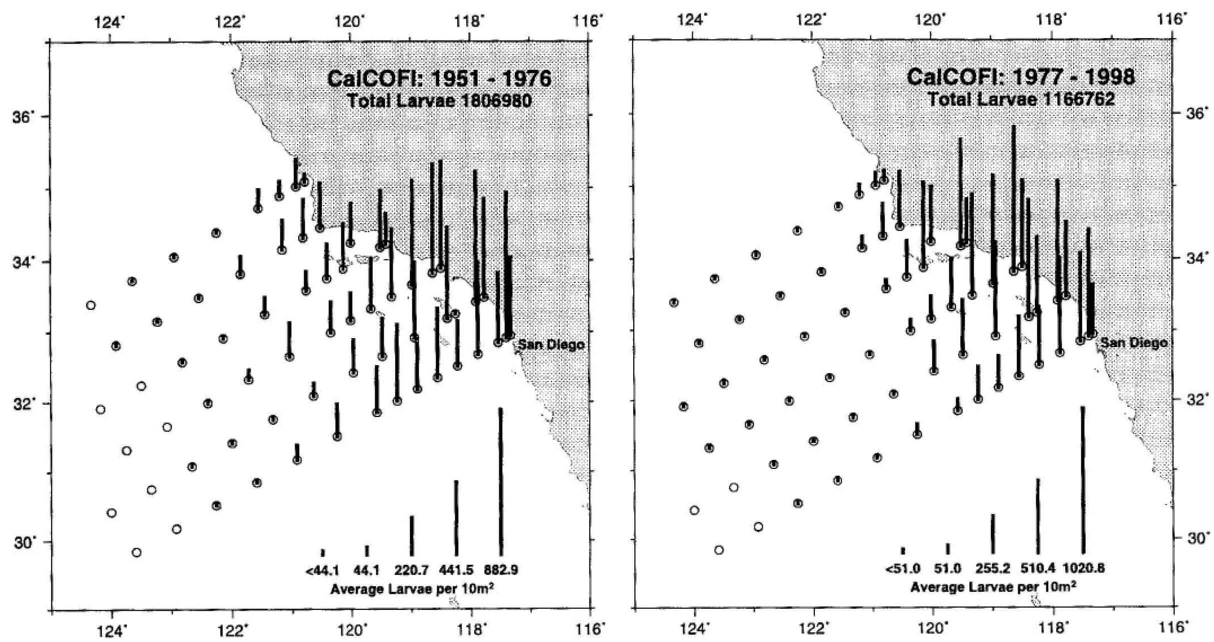


Figure 5-2. Distribution and abundance of northern anchovy larvae (*Engraulis mordax*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

The taxa included in this assessment were categorized into these habitat types (**Table 5-1**). Taxa that occur in more than one habitat were included in the habitat group that best reflected the primary distribution for the taxa or if a primary habitat cannot be identified. This raises an important point in regards to impact assessment. Taxa that occupy several different habitats will be at less risk from power plant impacts especially if at least one of the habitats is not directly affected by entrainment and impingement. For example, garibaldi occur along the rock jetties that border the Outer Lagoon which places them directly at risk to entrainment and impingement, but they also occur in rocky reef areas outside of the lagoon where they are not at risk. As previously discussed, the risk of impacts to northern anchovy is very low since their primary habitat is not directly affected by the power plant and they are widely distributed.

This approach to assessing AEI is consistent with a recent trend in fisheries management towards ecosystem-based management (Larkin 1996, Link 2002, Mangel and Levin 2005). This approach recognizes that commercial fishing stocks can only be protected if the habitats and other components of the ecosystem are protected. An ecosystem-based approach also addresses other human activities in addition to fishing and the environmental factors that affect an ecosystem, the response of the ecosystem, and the outcomes in terms of benefits and impacts on humans. In this context it will help identify the habitats most at risk to CWIS effects and help identify a broader context for the effects relative to the entire ecosystem. If restoration were to be allowed as a compliance alternative, this approach to assessment would focus the restoration scaling with the appropriate species from the identified habitats.

Table 5-1. Habitat associations for taxa included in assessment of CWIS effects at the EPS. Primary habitat in bold, upper case and secondary habitat in lower case. Taxa also designated as to whether they are targeted by a sport (S) or commercial (C) fishery.

		Fishery	**Habitats**			
Scientific name	**Common name**	**S-Sport, C-Comm.**	**bays, harbors**	**reefs, kelp beds**	**coastal pelagic**	**shelf**
Gobiidae unid.	CIQ goby complex		**X**			
Hypsoblennius spp.	combtooth blennies		**X**	x		
Engraulidae unid.	anchovies	C	x		**X**	
Hypsypops rubicundus	garibaldi		x	**X**		
Roncador stearnsii	spotfin croaker	S				**X**
Atherinopsidae unid.	silversides		x	**X**	x	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Seriphus politus	queenfish	S			**X**	x
Paralichthys californicus	California halibut	S, C	x			X
Paralabrax spp.	sand and kelp basses	S	x	**X**		
Sardinops sagax	Pacific sardine	C			**X**	
Cymatogaster aggregata	shiner surfperch		**X**	x		
Hyperprosopon argenteum	walleye surfperch	S	x	**X**		x
Atractoscion nobilis	white seabass	S, C			**X**	x
Cancer spp.	cancer crabs	S, C	x	x		**X**
Panulirus interruptus	California spiny lobster	S, C		**X**		
Loligo opalescens	market squid	S, C			**X**	
Octopus spp.	two-spotted octopus	S, C		**X**		

5.2 Summary of Entrainment and Impingement Results

Summaries of the entrainment and impingement study results are followed by tables combining the sampling and modeling results for all the taxa included in the assessment and tables with estimated economic losses for those taxa.

5.2.1 Entrainment

A total of 20,601 larval fishes representing 41 taxa was collected from the EPS entrainment station (E1) during 13 surveys in the 2004–2005 sampling period. This yielded a total annual entrainment estimate of 4.49 x 10^9 fish larvae from June 2004 through May 2005 using the EPS CWIS maximum flows as the basis for calculations, and 3.63 x 10^9 larvae using actual EPS flows during the same time period, a 23.9% difference. Calculations based on actual flows yielded an estimate of nearly 10 million fish larvae per day entrained through the EPS CWS.

An earlier study of entrainment at EPS in 1979 (SDGE 1980) measured the concentrations of larval fishes, fish eggs, and various groups of invertebrate zooplankton in the cooling water supply. Total zooplankton entrainment estimates were 7.4 x 10^9 organisms annually (based on 505 μ mesh sampling nets) and 30.9 x 10^9 organisms annually (335 μ mesh) with the copepod *Acartia tonsa* the most abundant invertebrate. (Estimates were presumably based on maximum EPS pump flows, although this was not clearly stated in the report). The total annual ichthyoplankton entrainment estimates were 4.2 x 10^9 and 6.7 x 10^9 individuals annually for the 505 μ mesh and 335 μ mesh, respectively, with 86% of the total consisting of fish eggs. The entrained abundance of fish larvae from February 1979 through January 1980 was estimated at 0.92 x 10^9 individuals, which was approximately one-quarter of the total numbers estimated during the 2004–2005 survey.

The greatest concentrations of larval fishes during the 2004–2005 study occurred in August 2004 and the fewest occurred in December 2004. Gobies (CIQ goby complex) and blennies, both largely found in lagoons, bays and estuaries, comprised over 90% of all larval specimens collected, with anchovy larvae the third most abundant taxon at approximately 4%. The CIQ goby complex is comprised of up to three species that are common in southern California bays and estuaries (arrow, shadow, and/or cheekspot gobies) but cannot be reliably identified to the species level as young larvae. Although some larger specimens could be positively identified, all gobies of these three species were grouped for analysis. There were very few fish fragments or damaged fishes in the collections.

The fish taxa that were the focus of the analysis have varied distributions and life histories. They include fishes that occur in estuarine and enclosed bay habitats (e.g., gobies), in coastal nearshore habitats (e.g., kelp bass), and in coastal open ocean habitats (e.g. queenfish). As expected, the most abundantly sampled species were those with adult populations that spawned in lagoon environments and the least abundant were outer coast species, such as flatfishes or croakers, that do not typically spawn directly in lagoons, even though juveniles of the species may eventually migrate into lagoon habitats as they develop. One unexpected result was the lack of deepbody and slough anchovy larvae (*Anchoa* spp.) in the entrainment samples even though deepbody, in particular, were abundant in the impingement samples and the larvae have been found in other southern California bays (Tenera Environmental 2004). The cause of this apparent lack of spawning is not known. The engraulid larvae from AHL that could be identified to species were almost entirely northern anchovy, a species that was also common in impingement samples. In general, most of the entrained larvae could be classified as belonging to forage species for predatory fishes and seabirds, and relatively few of the entrained larvae were from species that have significant sport or commercial fisheries, such as basses (Serranidae), white seabass (Sciaenidae), or California halibut.

One species that had a relatively high entrainment rate in spring and summer months was garibaldi, a large member of the damselfish family. Garibaldi are common throughout southern California and are associated with artificial substrates in bays and harbors, and natural rock reefs along the outer coast and islands. In AHL, adult females attach their eggs in discrete patches to rock surfaces around the margin of the lagoon. As the eggs hatch the larvae are immediately susceptible to entrainment before they develop a strong ability to swim.

Of the target shellfishes sampled, only one *Cancer* crab megalopa and no spiny lobster larvae were collected at the entrainment station. The target invertebrate taxa were selected based on their direct economic value as fishery species, and it was clear from the sampling results that such larvae are not routinely subject to mortality from EPS power plant entrainment. Although many of the other planktonic organisms that pass through the CWS were not quantified in this study, they typically represent taxa that are very widespread and numerous along the entire coast either as larvae of benthic organisms, such as barnacle nauplii, or living an entirely planktonic existence throughout their life cycle, such as copepods. As noted earlier, a single species of copepod was found to be numerically dominant in the entrainment collections from the 1979–1980 study.

5.2.2 Impingement

A total of 19,408 fishes weighing 351.7 kg (775.3 lb) and 1,985 shellfishes weighing 17.2 kg (38.0 lb) was collected during normal operation impingement sampling at the EPS traveling screens during 52 weekly surveys from June 24, 2004 through June 15, 2005 (**Tables 4-2** and **4-6**). There were also 34 fishes weighing 22.2 kg (48.4 lb) and two shellfishes weighing 0.5 kg (1.1 lb) collected from the bar racks during the same period. Six heat treatments of the conduits were completed from June 2004 through June 2005, and 94,991 fishes weighing 2,035 kg (4,486 lb) and 1,384 shellfishes weighing 19.9 kg (43.9 lb) were collected. The combined counts from all plant mortality sources were used to estimate a maximum annual impingement of 289,562 fishes weighing 5,841 kg (12,877 lb) and 22,714 shellfishes weighing 233 kg (514 lb) using the maximum CWS flows, and a best estimate of actual impingement of 215,583 fishes weighing 4,358 kg (11,069 lb) and 14,474 shellfishes weighing 138 kg (304 lb) using the actual CWS flows measured during the sampling period. Nine taxa were examined in detail that included fishes comprising the top 90th percentile in both abundance and biomass, or fishes with commercial or recreational fishery importance that were in the top 90th percentile of abundance or biomass.

The earlier 316(b) impingement study (SDGE 1980) was conducted for 336 consecutive days from February 1979 through January 1980. Totals of 79,662 fishes and 6,281 shellfishes weighing 1,395 kg (3,075 lb) and 153 kg (337 lb), respectively, were collected during normal impingement sampling. During the sampling period there were seven heat treatments with 108,478 fishes weighing 2,426 kg (5,348 lb) being collected. Although the average losses measured during heat treatments were similar between the two studies (**Table 5-2**), the results from normal operation impingement suggest that the total abundances of fishes in AHL that are subject to impingement have increased over the 25 years since the first study was done. Data on shellfishes were not compared because of the differences in sampling protocols for shellfishes between the two studies.

Table 5-2. Average daily abundances of fishes collected during normal operations (unadjusted for plant flow) and heat treatment impingement surveys during the 1979-1980 and 2004–2005 surveys.

	Average Daily Fish Abundance Normal Operations		Average Fish Abundance Heat Treatments	
Study Period	**Numbers**	**Biomass in kg (lb)**	**Numbers**	**Biomass in kg (lb)**
1979–1980	237	4.1 (9.0)	15,497	346.5 (763.9)
2004–2005	373	6.8 (15.0)	15,832	339.2 (747.8)

Results from the two studies also show similar species composition including topsmelt, shiner surfperch, deepbody anchovy, queenfish, and slough anchovy (**Tables 4-1** and **4-2**). One noticeable difference, however, was a much higher number of salema in 2004–2005. Salema are distributed from Monterey Bay south to Peru and are considered a warmer water species. Impingement rates for salema at other generating stations in southern California have also increased since 1979, possibly due to generally warmer water temperatures and frequent El Niño conditions in the 1980s and 1990s (MBC and K. Herbinson, unpublished data).

The results also showed that heat treatments caused a significant fraction of the total annual impingement mortality. Under maximum CWS flows they accounted for 33% and 35% of the total impingement abundance and biomass of fishes, respectively, and under actual CWS flows they accounted for 44% and 47% of the total impingement abundance and biomass, respectively (**Tables 4-2** and **4-4**). The percentage of the total is higher for biomass since larger fishes are probably able to maintain their position in the tunnels under normal operating conditions but are killed during heat treatments when they become trapped in the tunnels prior to the warm water circulation procedure. This also results in differences in composition between heat treatment and normal operations impingement. Fishes that are generally strong swimmers such as Pacific sardine, barred sand bass, white seabass, and jacksmelt were collected in much higher abundances during heat treatment surveys. Also, fishes that use the fouling community inside the intake as habitat, such as bay and mussel blennies, were collected almost exclusively during heat treatments.

The shellfishes impinged during heat treatments contributed a much smaller percentage of the total estimated impingement—6% and 10% of the total estimated impingement under maximum and actual flows, respectively (**Tables 4-6** and **4-8**). Most shellfishes are unable to avoid impingement once they enter the CWIS. Therefore, there were fewer differences between impingement types for shellfishes and finfishes. There were some exceptions however, with octopuses and rock crabs both more abundant during heat treatments than normal impingement.

The combined annual estimates for entrainment and impingement based on actual flow rates and maximum flow rates are shown in **Tables 5-3** and **5-4**. The estimated valuation of these losses based on commercial fishery prices for equivalent weight are presented in **Table 5-5**.

Table 5-3. Summary of entrainment and impingement impacts on selected fishes and shellfishes. Values are estimates based on actual flow rates during the sampling period.

Taxon	Entrainment (Annual Larval #)	*AEL* (Estimated Annual Mean)	*2FH* (Estimated Annual Mean)	P_M	Impingement (Annual #, All sources)	Impingement (Annual Biomass (kg), All sources)
Fishes						
CIQ goby complex	2,215,477,217	1,632,666	3,762,916	0.398	0	0
combtooth blennies	1,098,083,615	2,450,084	1,150,708	0.194	832	4.85
anchovies	120,661,087	15,456	6,178	0.004	46,301	354.92
garibaldi	29,287,646	–	–	0.144	5	1.90
spotfin croaker	9,554,139	–	–	0.016	1,351	80.76
silversides	7,936,121	–	–	–	68,519	449.74
white croaker	6,924,470	–	–	0.003	86	1.28
queenfish	6,746,448	–	–	0.009	9,479	70.43
California halibut	3,752,551	–	8	0.003	612	15.44
sand basses	2,520,619	–	–	–	7,987	198.84
Pacific sardine	2,484,208	–	–	–	8,313	35.36
shiner surfperch	0	–	–	–	37,664	393.84
walleye surfperch	0	–	–	–	5,586	248.55
white seabass	0	–	–	–	2,102	408.12
Shellfishes						
Cancer crabs	162,150	–	–	–	962	5.22
California spiny lobster	0	–	–	–	22	1.86
market squid	0	–	–	–	162	1.77
octopus	0	–	–	–	497	69.46

Table 5-4. Summary of entrainment and impingement impacts on selected fishes and shellfishes. Values are estimates based on maximum design flow rates during the sampling period.

Taxon	Entrainment (Annual Larval #)	*AEL* (Estimated Annual Mean)	*2FH* (Estimated Annual Mean)	P_M	Impinge-ment (Annual #, All sources)	Impinge-ment (Annual Biomass (kg), All sources)
Fishes						
CIQ goby complex	2,767,198,570	2,039,250	4,699,996	0.470	0	0
combtooth blennies	1,312,458,555	2,928,405	1,370,576	0.228	876	5.07
anchovies	157,019,892	20,113	8,038	0.005	60,402	431.34
Garibaldi	36,328,962	–	–	0.176	5	1.90
spotfin croaker	10,677,429	–	–	0.018	1,820	122.06
silversides	12,654,500	–	–	–	99,259	717.28
white croaker	9,466,865	–	–	0.004	113	1.55
queenfish	7,534,586	–	–	0.010	12,511	89.66
California halibut	4,879,725	–	12	0.004	975	23.27
sand basses	2,775,286	–	–	–	11,795	239.42
Pacific sardine	3,394,522	–	–	–	8,922	40.22
shiner surfperch	0	–	–	–	44,867	496.64
walleye surfperch	0	–	–	–	9,177	402.51
white seabass	0	–	–	–	2,384	458.12
Shellfishes						
Cancer crabs	200,698	–	–	–	1,172	6.51
California spiny lobster	0	–	–	–	25	1.97
market squid	0	–	–	–	190	2.19
octopus	0	–	–	–	834	130.39

Table 5-5. Approximate dollar value of estimated entrainment and impingement losses for selected taxonomic groups of fishes at EPS for the study period using actual and maximum CWS flow volumes.

					Actual Flow	Maximum Flow
Taxon	**Source for Fishery Data**	**Landings (MT)**	**Ex-vessel Value ($)**	**Cost ($) per kg**	**Value ($) of Estimated Losses**	**Value ($) of Estimated Losses**
Finfish						
CIQ goby complex	n.a.	n.a.				
combtooth blennies	n.a.	n.a.				
anchovies	–	–		$0.48	$207.46	$255.31
garibaldi	protected species					
spotfin croaker	not sold commercially					
silversides	n.a.	n.a.		$0.55	$247.36	$394.50
white croaker	PacFIN '05 SD	0.33	$1,022	$3.13	$4.01	$4.85
queenfish	PacFIN '05 SMt ocrk	5.59	$9,992	$1.79	$125.89	$160.27
California halibut	PacFIN '05 SD	14.3	$106,554	$7.45	$429.42	$644.95
sand basses	not sold commercially					
Pacific sardine	CDFG '04 SD	44.5	$26,428	$0.59	$20.86	$23.73
shiner surfperch	PacFIN '05 LA srfp	0.2	$403	$2.02	$793.59	$1,000.73
walleye surfperch	PacFIN '05 LA srfp	0.2	$403	$2.02	$500.83	$811.06
white seabass	PacFIN '05 SD	26.8	$140,612	$5.25	$2,141.29	$2,403.63
				Total Finfish	**$4,471**	**$5,699**
Shellfishes						
Cancer crabs	PacFIN '05 SD	47.4	$107,722	$2.27	$11.86	$14.79
Calif. spiny lobster	PacFIN '05 SD	111.4	$1,813,926	$16.28	$30.29	$32.08
market squid	PacFIN '05 LA	31,561	$18,781,573	$0.60	$1.05	$1.30
octopus	PacFIN '05 SD	0.1	$339	$3.39	$235.47	$442.02
				Total Shellfish	**$279**	**$490**
				GRANDTOTAL	**$4,749**	**$6,189**

Values for each species are based on landings data from the Pacific States Marine Fisheries Commission (PSMFC) Pacific Fisheries Information Network (PacFIN) internet database of 2005 landings and California Department of Fish and Game (2005), Final Commercial Landings for 2004. SD is San Diego, SMt is Santa Monica Bay, LA is Los Angeles, ocrk is other croaker, srfp is surfperch.

Northern anchovy was based on live bait value from Leet et al. (2001) as $440 per ton.

5.3 Assessment of Taxa by Habitat Type

The following sections present assessments for taxa from the five habitat types simplified from Allen and Pondella (2006). A general discussion of the habitat and the potential risk to the habitat due to EPS operation will be followed by discussion of the specific impacts to the fishes and shellfishes included in the assessment for each habitat type (**Table 5-1**).

5.3.1 Background Information on Oceanographic Setting and Population Trends

Water temperatures and current patterns have a significant effect on marine faunal composition. Understanding the nature of the variability in these physical factors is essential for explaining long-term population trends for many marine species. The Southern California Bight is the transition zone between the cool temperate Oregonian fauna, from the north and the warm temperate San Diegan fauna from the south. This transition is caused by the geology and oceanic current structure of the region. The source of cold water is the California Current, the eastern branch of the North Pacific Gyre. The strength of the California Current varies on many time frames. On a multi-decadal scale it oscillates between a warm and cold phase referred to as the Pacific Decadal Oscillation (PDO). During the warm phase the PDO is relatively weaker than average, while during the cold phase it is stronger than average. This multi-decadal oscillation has had a significant effect of the Southern California Bight (SCB) and the most pertinent debate concerns when it will switch back to a cold phase (Bogard et al. 2000, Durazo et al. 2001, Lluch-Belda et al. 2001). During the cold phase, the bight is colder than average and dominated by the Oregonian fauna. The opposite is the case for the warm phase; the bight is warmer than average and dominated by the San Diegan fauna. There have been three transitions in the PDO over the last century. The most recent oscillation of the PDO caused a regime shift starting in the late 1970’s that was completed by the end of the 1982–1984 El Niño, the largest El Niño recorded at that time (Stephens et al. 1984, Holbrook et al. 1997). The transition culminated with the 1982–1984 El Niño that effectively extirpated the Oregonian fauna from the Southern California Bight.

The strength of the PDO varies annually and the most important phenomenon with respect to this variation is the El Niño Southern Oscillation (ENSO). This oscillation consists of two components, El Niño and La Niña periods. El Niño causes the California Current to weaken and move offshore as warm subtropical water moves into the bight. The rebound from this event is the shift to La Niña, which in effect is manifested as a strengthening of the California Current and generally cooler water in the bight. Either phase of an ENSO generally lasts 1–2 years, depending upon their strength, and are particularly important for understanding fish dynamics in the SCB for a variety of reasons. First, in the El Niño phase, the bight is warmed and vagile warm-water fishes and invertebrates immigrate or recruit into the region (Lea and Rosenblatt 2000, Pondella and Allen 2001). Cold water forms migrate out of the region, move into deeper (cooler) water or are extirpated. During the La Niña phase, the SCB usually, but not always, is cooler than normal, and we observe an increase in cold temperate (Oregonian fauna) organisms through the same processes. Highly mobile organisms will immigrate or emigrate from the bight during these periods; and on smaller spatial scales less vagile organisms may exhibit offshore versus onshore movements. However, the resident fauna tends not to be altered on such short time frames when compared to the magnitude of the PDO.

In the decade prior to this study there were three major events that affected the California Current System that need to be explained in order to understand the oceanographic setting of this study period. The first was the 1997–98 El Niño, the strongest recorded event of its kind. This was followed by a series of four cold water years (1999–2002) including the strongest La Niña on record (Schwing et al. 2000, Goericke et al. 2005). The possible return to the cold water phase of the PDO did not occur since 2003–2004 was described as a 'normal' year (Goericke et al. 2005). This normal year turned out to be the beginning of an extended warm phase that has persisted through 2006 (Peterson et al. 2006, **Figure 5-3**). Thus, the oceanographic context for this study can best be described as a warm phase of the PDO that has persisted for three years. Prior to this warm phase were four unusually cool years.

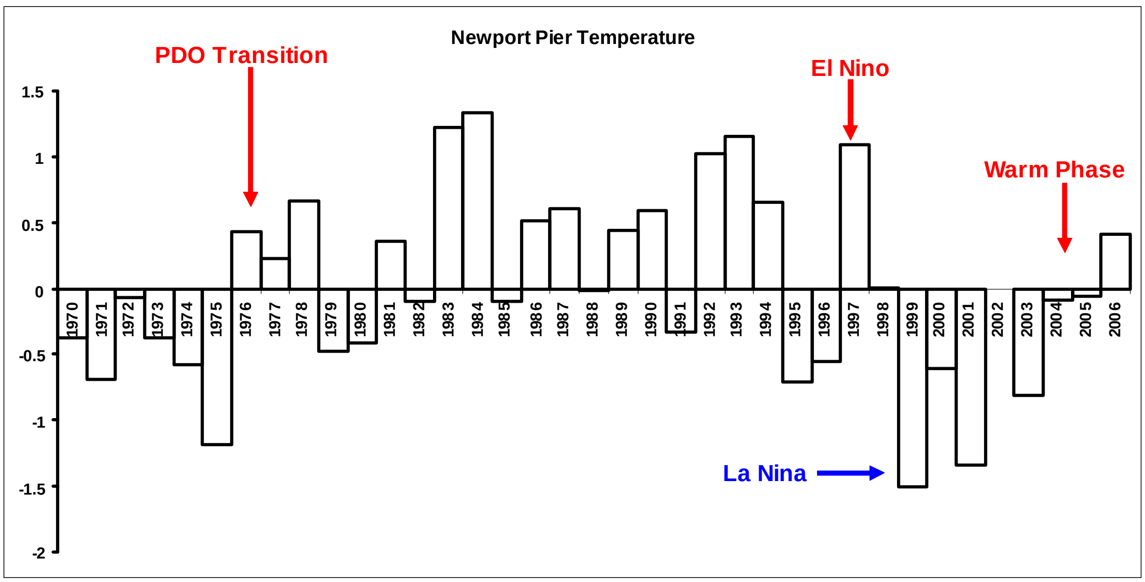


Figure 5-3. Sea surface temperature anomalies for Newport Pier, California. Values are ± the long-term average (1925-2006).

To determine the current population status of fishes and invertebrates in the SCB requires placing this data into an appropriate long-term context. From an oceanographic standpoint, the influences that were associated with change over time are the PDO, the ENSO, and the associated ocean temperature changes. These oceanographic metrics are interconnected with each other and have effects in the SCB on varying time scales. In order to understand the responses of organisms in the SCB to these various environmental metrics, it is important to realize the general trends for the region (Brooks et al. 2002) and that each taxon may have a unique response to these metrics based upon its life history characteristics and evolution.

In addition, to the real time responses these organisms have to oceanographic parameters, anthropogenic influences also have significant effects. Currently, the most extensively studied anthropogenic effects are related to over fishing and the various management actions associated with fishing. In the SCB, all of the top-level predators (with the exception of marine mammals) were over fished during the last seven decades (Ripley 1946, Love et al. 1998, Allen et al. *in press*, Pondella and Allen *in review*). The effects on fisheries were also species specific, as the effort, type of fishery and associated management actions vary case by case. Some fishes were reserved for recreational anglers (e.g. kelp bass, barred sand bass etc.) as they were historically over fished by commercial fishers (Young 1963); others were primarily commercial species (e.g. anchovies); while others are extracted by both fisheries (e.g. California halibut). Fishery data may or may not reflect actual population trends due to socioeconomic considerations such as market value, effort, management actions, etc. Fishery independent monitoring programs produce the best population time series metrics and also allow non-commercial species to be evaluated.

5.3.2 Habitat Associations

Most entrained larvae were from species found associated with the bay and harbor habitat where the intake is located (**Table 5-6**). The larvae for species, such as gobies and blennies, are found in the same habitats occupied by the adults. The larvae from other entrained taxa were from fishes associated with kelp bed and reef habitats and coastal pelagic habitats that are found in nearshore areas outside of AHL where the EPS intake is located. The fewest number of taxa were from fishes associated with deep pelagic habitats. Although almost 45 percent of the taxa were from fishes associated with shelf and slope habitats further offshore, these taxa were collected in very low numbers relative to the fishes from nearshore habitats. This would be expected since onshore currents may transport the larvae of these taxa onshore, but they occur in much greater abundances offshore where the adult habitat is located. Most significant to the assessment of impacts is that only about 5% of the larvae entrained were targeted by sport or commercial fishing.

Since impingement affects juvenile and adult stages of fishes and shellfishes, there are greater percentages of species associated with the types of habitats in close proximity to the intakes than found from the entrainment data (**Table 5-6**). For example, no species from deep pelagic habitats were collected and by far the greatest abundance of fishes were associated with the bay-harbor habitat most at risk to impingement. The percentage is much greater than found among the fishes in the entrainment samples since the larvae from the taxa are directly produced in AHL where they are subject to entrainment.

Table 5-6. Percent of fish larvae entrained (abundance and number of taxa) or adults/juvenile fishes impinged (biomass and number of taxa) associated with general habitat types and fisheries.

Attributes	Entrained % of taxa	Entrained % of abundance	Impinged % of taxa	Impinged % of biomass
Habitat Association				
Bays, Harbors	34.21	97.03	50.00	69.03
Rocky reef, Kelp	44.74	33.44	33.96	41.26
Coastal pelagic	23.68	4.08	28.30	32.10
Continental shelf / slope	44.74	0.91	16.98	17.10
Deep pelagic	10.53	0.02	0.00	0.00
Fishery				
Sport	36.84	1.22	52.83	62.38
Commercial	26.32	4.22	31.13	24.57
None	57.89	95.37	40.57	35.61

Note: Species may have more than one associated habitat or fishery.

5.3.2.1 Bay and Harbor Habitats

This habitat type includes, bay, harbors and estuaries that are either entirely marine and largely influenced by tidal movement of seawater, or estuarine areas where freshwater input results in lower salinity seawater in some areas of the habitat. Bays and harbors in the areas around EPS include AHL where the plant is located, Oceanside Harbor and Buena Vista Lagoon to the north, and Batiquitos, San Elijo and San Dieguito Lagoons to the south. Characteristic fishes from these habitats include deepbody anchovy, bay pipefish, bay blenny, round stingray and diamond turbot (Allen and Pondella 2006). There are wetland habitats associated with all of the coastal lagoons and characteristic fishes from this habitat include slough anchovy, barred pipefish, shadow and arrow goby, and longjaw mudsucker (Allen and Pondella 2006). The largest percentage of the fishes collected during the entrainment and impingement sampling had some dependency on bay and harbor habitats during at least some stage of their life, and this habitat is the primary habitat for the most abundant fishes collected during entrainment sampling: CIQ gobies and combtooth blennies (**Tables 5-3** and **5-4**). While CIQ gobies are almost totally confined to these habitats, one species of combtooth blenny, the rockpool blenny (*Hypsoblennius gilberti*), also inhabits shallow intertidal and subtidal rocky reef habitats. The only fish from the impingement sampling included in the assessment that is primarily associated with bay and harbor habitats is shiner surfperch. Assessments of these three species are presented in the following sections.

CIQ Goby Complex

The CIQ goby complex had the highest estimated entrainment at 2.2 billion larvae annually (actual flows), the highest projected adult losses (1.6–3.8 million annually), and the highest estimated fractional losses of larvae at nearly 40% of the source population (**Table 5-3**). Using the maximum design flows, the estimated entrainment increases to 2.8 billion larvae with projected adult losses of 2.0–4.7 billion fish (**Table 5-4**). Impingement of gobies was negligible.

This section discusses entrainment mortality in relation to the abundance and distribution of source water populations.

Highest concentrations of larval gobies occurred in the Inner Lagoon and lowest concentrations in the nearshore zone, forming a gradient of abundance (**Figure 3-7**). Mean densities fluctuated throughout the year according to the peak spawning season with the highest concentrations in summer and lowest in winter. 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 in the recent study indicate that the goby population in AHL has probably increased over time and has not been adversely affected by the operation of EPS. The higher densities are noteworthy since infilling of the Middle and Inner Lagoons and development of sandbars at the western edge of the Inner Lagoon (MEC 1995) have contributed to a reduction in total habitat area in recent years.

Adult and juvenile (post-settlement) populations of gobies are concentrated in coastal embayments such as AHL, and in nearby Batiquitos Lagoon, Mission Bay and San Diego Bay. Their larvae are dispersed by tidal flushing and transported in coastal waters by prevailing currents (Horn and Allen 1978, Brothers 1975). 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 $5/m^2$ in April 1995. Even though gobies were relatively abundant in the samples, the sampling methods likely underestimated their true densities because of the selectivity of the sampling gear that was biased toward larger specimens. Most of the gobies in the higher density samples were comprised of unidentified juveniles (nearly 90%) although most of these were probably juvenile arrow gobies, which were also the dominant goby species of the larger size classes. Similar sampling in July 1994 yielded substantially lower densities, reflecting the seasonal nature of goby recruitment in the lagoon. Spatially, densities of gobies declined rapidly into the Middle and Outer Lagoon stations as compared to the Inner Lagoon, being approximately 100-fold less abundant near the lagoon mouth.

Adult and juvenile sampling in 2005 (present 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 $20/m^2$ in the Inner and Middle Lagoon shoreline sampling, yielding an estimate of 200,000/ha of this species alone, whereas previous trawling yielded densities of less than $5/m^2$ 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 (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.

Other studies have also measured high concentrations of gobies in southern California bays and lagoons. MacDonald (1975) found densities of 4–5/m^2 in Anaheim Bay in winter, although concentrations of up to 20/m^2 were found in some individual burrows. Restoration efforts and subsequent monitoring in Batiquitos Lagoon 7 km south of AHL from 1997–2001 measured goby densities from 0.3 to 1.6/m^2 annually using enclosure sampling devices (Merkel and Associates 2002). Adult densities in the same areas ranged from 0.01 to 0.05/m^2 based on data from a large bottom seine, demonstrating the differences in density estimates between sampling methods.

Even with a substantial fraction of the source larval production in AHL cropped by power plant entrainment, the lagoon habitat continues to sustain a thriving population of gobies, as 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 (**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. In addition, detailed hydrodynamic modeling of tidal processes indicates that exchange rates can vary considerably within the lagoon (Fischer et al. 1979), especially in the Middle and Inner Lagoon where the majority of the goby habitat is located. Larvae that are transported into coastal waters can provide genetic exchange between estuarine areas along the coast by moving back into bays with incoming tidal currents (Dawson et al. 2002). However, most of these exported larvae experience much higher mortality rates in the open ocean than those that are retained in their natal estuaries. Although the intake and discharge of EPS increases the export rate of larvae from AHL over natural transport, it mainly affects the outer lagoon where larvae are less abundant, and many of these larvae would be lost to the system even under natural conditions.

Demographic-based estimates of projected losses assume that there is available habitat to support the additional production in the source water area, 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 adult equivalents based on larval entrainment 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 results indicate that even with the projected loss of nearly 50 percent of the larval source water population due to entrainment there is little measurable effect on the adult population of gobies.

In terms of potential economic losses resulting from CIQ 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. Larval reductions could have some effect on the trophic structure of the source water through the loss of available forage for predators. However, 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.

Combtooth Blennies

Combtooth blennies (*Hypsoblennius* spp.) had an estimated entrainment of approximately one billion larvae annually, with projected adult losses of 1.2 to 2.5 million based on the actual flows during the study period and 1.4 to 2.9 million lost based on the maximum flows. Estimated fractional losses of larvae were approximately 19% of the source population of larvae (**Table 5-3**) and increased to 23% using the design flows (**Table 5-4**). Impingement of combtooth blennies from all sources was negligible. This section discusses entrainment mortality in relation to the abundance and distribution of source water populations.

Adult and juvenile (post-settlement) populations of combtooth blennies are concentrated in coastal areas and harbors that have rock structure (either natural or artificial), pier pilings, or other fouled surfaces that provide protective habitats. The aquaculture floats in outer AHL that are used to culture mussels and oysters provide an extensive potential habitat area for mussel blennies (*H. jenkinsi*) and the rock revetments around the lagoon provide habitat for *H. gilberti* and *H. gentilis*. The kelp forest environment offshore of EPS also provides potential habitat for combtooth blennies. An assessment of ecological resources in AHL in 1994–1995 (MEC 1995) recorded combtooth blennies only as infrequent in trawl samples, but this would be expected because of their cryptic habits and general lack of susceptibility to trawl or seine sampling. The only species captured was bay blenny, which tends to occupy benthic and eelgrass habitats, and the highest densities were in the west Inner and Middle Lagoons ($0.02/m^2$). Special studies completed in spring and summer of 2005 (**Appendix C**) were intended to improve estimates of the local post-settlement population by specifically sampling cryptic habitats, but only a few blenny specimens were recorded during sampling. One factor that may have contributed to the low numbers was a persistent plankton bloom or “red tide” throughout the summer months of 2005 that may have induced widespread mortality by decreasing the oxygen content of the seawater. Qualitative observations have revealed that blennies can be common on both the mussel floats and collector lines in the aquaculture facility, and several adults were collected from the rock rip-rap areas earlier in the season as brood stock for larval survival experiments. These observations, and the fact that blenny larvae were more abundant in the Outer Lagoon samples than in any other source water areas (**Figure 3-11**), suggests that artificial habitats in the Outer Lagoon can support high densities of adult blennies.

Mean larval densities fluctuated throughout the year according to the peak spawning season with high densities in spring and summer and very few, if any, in winter. Highest densities exceeded 1,000 per 1,000 m^3 in the Outer Lagoon. Lower concentrations were measured in the earlier 316(b) study done in 1979 (SDG&E 1980), with averages of 67 per 1,000 m^3 in the lagoon samples and 48 per 1,000 m^3 in the nearshore samples. The increase in larval production in AHL over this time period may reflect the establishment and expansion of the aquaculture operations that provide additional habitat for these fishes. The comparison with previous study results for blennies contrasts with the results for gobies that showed only slightly increased densities in the recent study. Whereas the habitat for gobies has declined slightly since the previous study, the habitat for blennies has increased significantly due to the placement of artificial habitat in the Outer Lagoon.

Even with a substantial fraction of the source larval production cropped by power plant entrainment, the AHL lagoon habitat continues to sustain a thriving population of combtooth blennies adults as evidenced by the prolific larval concentrations that are over 70 times that of the nearshore source water. As with the gobies, blenny larvae would also be significantly affected by tidal exchange with many of the early larvae lost to the system due to export by outgoing tidal currents. The fact that much of the available blenny habitat in AHL is in the Outer Lagoon in direct proximity to the EPS intake structure means that larvae hatching from the demersal egg masses have a high probability of entrainment. This has resulted in the relatively high P_M estimate of 0.19 for this group of species. The estimated age of the entrained blenny larvae used in the *ETM* calculations, 2.7 d, was much less than the larval duration of 3 months reported by Stephens et al. (1970). This duration is also shorter than the estimated duration of goby larvae, 11.5 d, which were probably transported out of the Middle and Inner Lagoons, and is further evidence that the source of the blenny larvae is the Outer Lagoon.

Similar to the gobies, the demographically-based estimates of projected losses (*FH* and *AEL*) assume that there is available habitat to support additional adult densities in the source water area, which is probably limiting in AHL, even though artificial habitat is present. Therefore, projections of adult equivalents based on the larval entrainment likely overestimate actual adult losses. Blennies also have relatively short generation times of 1–2 years and attain peak reproductive potential in the third year (Stephens 1969) suggesting that adult populations are adapted to recover quickly from environmental perturbations. Since their abundance in AHL is closely associated with the presence of artificial substrates, populations in the natural reef environments of the outer kelp forest likely benefit from established adult populations in AHL with some export occurring naturally out of the lagoon mouth from tidal currents.

In terms of potential economic losses resulting from combtooth blenny entrainment, there are no direct losses because blennies have no fishery value. As with gobies, larval reductions could have some effect on the trophic structure of the source water through the increased loss of available forage for predators, but any potential effects could not be measured directly due to the high natural variation in the system.

Shiner surfperch

The annual estimated impingement of shiner surfperch (*Cymatogaster aggregata*) under normal operations was 19,303 individuals weighing 197.3 kg (435 lb) based on actual CWS flows (not including bar rack or heat treatment mortality) (**Table 4-3**). The estimated annual impingement abundance using maximum CWS flows was 26,506 individuals weighing 300.1 kg (662 lb). The total annual impingement including normal operations, heat treatments and individuals impinged on the bar racks was 44,867 individuals weighing 496.6 kg (1,095 lb) using maximum flows and 37,664 individuals weighing 393.8 kg (868 lb) using actual flows (**Tables 5-3** and **5-4**). As noted earlier, surfperches are not subject to entrainment because females bear fully developed young.

Shiner surfperch were less abundant in the 1979–1980 impingement study. The estimated annual impingement of shiner perch during normal operations was 7,100 and an average of 1,761 individuals was collected during each of the seven heat treatments (Tables 7.4-3 and 7.12-1 SDG&E 1980). An average of 3,060 shiner surfperch was collected per heat treatment during the 2004–2005 study. Shiner surfperch mainly occur in protected coastal bays and estuaries such as AHL and would be expected to have decreased in abundance over time if EPS impingement was having a significant effect on the populations. The results show increased impingement of shiner surfperch between the 1979–1980 and 2004–2005 studies providing evidence that the AHL population has not been significantly affected by EPS impingement.

Sport fishery catch estimates of shiner surfperch in the southern California region from 1999 to 2003 ranged from 2,000 to 20,000 annually with a mean of 11,000 fish (RecFIN 2005). For 2003, CDFG estimated an average recreational take of 121.6 metric tons of shiners from 1999 to 2001 which is considerably higher than the RecFIN estimates. Shiner surfperch are caught and sold as bait in northern California, but low abundances resulted in more restrictions on the fishery in recent years with no reported catches in 2003 and 2004. Commercial catches of only 96 kg (211 lb) and 279 kg (616 lb) were reported statewide in 2001 and 2002, respectively (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing). An average price per kg of $2.02 for unspecified surfperch from the 2005 PacFIN database was used to estimate that the total cost of the impingement losses was $1,000 using maximum flows and $794 using actual flows (**Table 5-5**).

Summary

The greatest impacts resulting from the EPS CWIS occur to organisms that are primarily associated with bay, harbor, and estuarine habitats. Most of these organisms are affected through entrainment since the juveniles and adults of species such as gobies and blennies occupy habitats within the lagoon where they are less susceptible to the effects of impingement. Although the CWIS affects the larval supply for these species, the results indicate that the limiting factor for these populations is probably the available habitat in AHL since larval abundances appear to have increased since the previous 316(b) study was completed. The habitat is not unique as it was partially constructed to accommodate the EPS intake. As a result the entrance to AHL is regularly dredged by the plant to maintain open flow with the ocean. This circulation helps maintain the water quality in AHL and may partially explain why the larval concentrations for many of the taxa are similar or have increased since the previous 316(b) study. The habitat within AHL is not unique as there are several similar habitat areas located in close proximity to AHL. These also provide additional sources of larvae for recruitment into the lagoon. These factors all contribute to a low potential for any adverse environmental impacts (AEI) to bay and harbor species.

5.3.2.2 Rocky Reef and Kelp Bed Habitats

Physical structure and food resources are essential factors in promoting fish abundance and diversity. Shallow rocky reefs and the giant kelp (*Macrocystis* spp.) forests often associated with them provide both factors. Both occur in the shallow nearshore areas directly offshore from EPS. Artificial structures such as harbor breakwaters in the Outer Lagoon and at Oceanside Harbor, and emplaced artificial fishing reefs north of Oceanside are also significant resources for fishes associated with these habitats. Common species in these assemblages include kelp bass, barred sand bass, black perch, opaleye, halfmoon, California sheephead, señorita, garibaldi, salema and zebraperch (Stephens et al. 2006). Although the presence and extent of giant kelp affects the abundance of some reef fishes, many other factors can also affect their distributions, and it is not unusual to find many of the species characteristic of kelp bed habitats in other shallow water locations. Common species of fishes and target invertebrates that are typically associated with rocky reef habitats and were entrained or impinged at EPS included garibaldi (*Hypsypops rubundicus*), sea basses (*Paralabrax* spp. [includes kelp bass, *P. clathratus*, spotted sand bass, *P. maculatofasciatus*, and barred sand bass, *P. nebulifer*]), silversides (Family Atherinopsidae), California spiny lobster (*Panulirus interruptus*) and octopus (*Octopus* spp.) (**Table 5-1**).

Garibaldi

Total annual entrainment of garibaldi larvae at EPS was estimated at 29 million larvae using measured cooling water flows and 36 million larvae using maximum cooling water flows for the June 2004 through May 2005 period (**Tables 5-3** and **5-4**). Garibaldi larvae were present in 6 of the 12 entrainment surveys, being absent in samples taken from September through March. No estimates of adult equivalents based on larval entrainment were developed due to the lack of mortality rate information and other life history data necessary for the demographic modeling. However, *ETM* modeling was done based on a comparison of source water and entrainment densities and yielded a P_M estimate of 0.144 (14.4%) using the actual CWS flows and an estimate of 0.176 (17.6%) using the maximum flows. No adult or juvenile garibaldi were impinged during normal pump operations, but five specimens were collected during the intake tunnel heat treatments. The species ranked very low in the 1979–1980 entrainment survey with a mean entrainment density of 0.0015 larvae per 1,000 m^3.

Garibaldi are common throughout southern California and are associated with artificial substrates in bays and harbors, and natural rock reefs along the outer coast and islands. As noted earlier, garibaldi larvae had a relatively high entrainment rate in spring and summer because the adult females deposit their eggs in discrete nests to rock surfaces around the margin of the lagoon. When the eggs hatch the larvae are immediately susceptible to entrainment before they develop a strong ability to swim.

As a protected species under CDFG fishery regulations, there is no take of garibaldi in California. Therefore, it has no direct commercial or recreational fishery value. At small sizes it can function as a minor forage species for some types of larger predatory fishes, and may be consumed by seals at larger sizes. Perhaps its most notable value to humans, and the main reason for its protected status, is its striking bright orange color and obvious visibility that makes it a subject for underwater photography and observation by skin and scuba divers, coupled with its territorial behavior and susceptibility to spearfishing. Garibaldi can normally be seen in spring and summer in shallow rocky areas around harbors and marinas as they guard nesting territories.

The reductions in larval density caused by EPS entrainment losses are difficult to translate into adult equivalents because the population is probably limited to some degree by the availability of suitable nest sites and the territorial nature of the species during breeding season. Quantitative observations of garibaldi in the Outer Lagoon (**Appendix C**) during August 2005 recorded densities of 7 fish per 30 m x 2 m transect along the North Jetty, 2 fish per transect in front of the EPS intake, and 1 per transect along the east channel leading into the Middle Lagoon. Based on the distribution of hard substrate in the lagoon, it would not be an overestimate to conclude that several hundred garibaldi could be present in AHL, especially during the peak of breeding season in June and July. Any reductions in overall abundance of the population as a result of increased larval mortality related to EPS operation would be spread throughout the greater source water body and not localized in AHL. Based on the earlier entrainment study in 1979 when garibaldi larvae were relatively rare in samples, it is evident that the local population has increased considerably and now utilizes the artificial substrate in the lagoon for spawning to a much greater degree than previously. Some of the increase may reflect the long-term protected status of the species from sport or commercial collections in California.

Silversides

Three species of silversides (Atherinopsidae) were impinged during the study: topsmelt, jacksmelt, and California grunion. The annual estimated impingement based on actual CWS flows of all species of silversides (not including bar rack or heat treatment mortality) was 39,113 individuals weighing 274 kg (605 lb) (**Table 4-3**). The estimated annual impingement abundance using maximum CWS flows was 69,853 individuals, weighing 553 kg (1,220 lb). Topsmelt was the most abundant silverside collected in the heat treatments (53.5%), followed by grunion (24.1%) and jacksmelt (15.2%). A total of 29,336 individuals weighing 162 kg (358 lb) was impinged in the heat treatment surveys with the highest abundance and biomass occurring during the October 2004 heat treatment. The total annual impingement including normal operations, heat treatments and bar racks was 68,519 and 449.7 kg (991 lb) using actual flows and 99,259 and 717.3 kg (1,581 lb) using maximum flows (**Tables 5-3** and **5-4**).

Earlier impingement surveys done in 1979 (SDGE 1980) yielded the same relative abundance of topsmelt as in the present study, but grunion were considerably more abundant than jacksmelt compared to the 2004–2005 results (**Table 5-7**). The total impingement of 166 kg was less than the 274 kg estimated during the most recent survey, but silversides are schooling fishes and high variation in their spatial distribution and temporal occurrence would be expected.

Silverside larvae comprised 0.26% of the larvae entrained through EPS annually, which yielded an annual estimate of 7,936,121 larvae based on actual flows and 12,654,500 based on maximum flows (**Tables 5-3** and **5-4**). A detailed analysis of the adult equivalents represented by these larvae, or the proportion of the source water population potentially affected by entrainment was not done because the species was neither abundant enough nor had significant fisheries for consideration. However, topsmelt are multiple spawners and can produce several thousand eggs annually, so the annual larval entrainment would roughly represent the reproductive output of several thousand females.

Table 5-7. Summary of impingement results for silversides from normal operations impingement surveys from February 1979 – January 1980 (from SDG&E 1980). Totals for 336 days of sampling were used to compute daily averages that were then used to compute annual impingement totals.

Species	Abundance	Weight (kg)	Average Daily Abundance	Average Daily Weight (kg)	Annual Estimated Abundance	Annual Estimated Weight (kg)	Percent Composition
topsmelt	10,915	112.3	32	0.33	11,857	122.0	55.9%
California grunion	8,583	33.8	26	0.10	9,324	36.7	43.9%
jacksmelt	40	7.0	0	0.02	43	7.6	0.2%
Totals					**21,224**	**166.3**	

A limited fishery exists for silversides, which are marketed fresh for human consumption or used as bait (Leet et al. 2001). Commercial catches of jacksmelt have varied sharply over the past 80 years fluctuating from more than two million pounds in 1945 to 2,530 pounds in 1998 and 1999 (Leet et al. 2001). Silversides are an incidental fishery and the large fluctuations in the catch records reflect demand, not actual abundances (Leet et al. 2001). The commercial catch of grunion is limited as this species forms a minor portion of the commercial "smelt" catch (Leet et al. 2001). In the 1920s, the recreational fishery was showing signs of depletion, and a regulation was passed in 1927 establishing a closed season of three months, April through June. The fishery improved, and in 1947, the closure was shortened to April through May where it presently remains. Both topsmelt and jacksmelt are caught by sportfishers from piers and along shores. Sport fishermen may take grunion by hand only, and no holes may be dug in the beach to entrap them (Leet et al. 2001). Recent catch estimates of silversides by recreational anglers in southern California were 49,000 fish in winter 2005. Catch estimates averaged 267,000 fish from 2000–2004 (RecFin 2005).

From 2001 through 2004 there were no reported landings of silversides from the San Diego area ports (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing). Over the same period a total of 24,430 kg (53,858 lb) worth $41,944 or $1.72 per kg were landed in Los Angeles area ports. Using the dollar value of $0.55 from the 2004 commercial landings data, the estimated total dollar loss due to impingement of silversides from all sources was $395 using maximum flows and $247 using actual flows(**Table 5-5**). These estimates are very conservative because the calculations assume that the impinged silversides were all fishery-sized individuals. The results showed that only a small number of the impinged silversides were greater than 160 mm (6.3 in).

Sand Basses

Barred sand bass and kelp bass are two of the most important recreationally fished species in southern California (Leet et al. 2001). Barred sand bass catch estimates ranged from 695,000 to 1,130,000 fish annually, with an average of 917,000, while kelp bass catches ranged from 291,000 to 587,000 fish in 2000–2004, with an average of 424,400 fish caught annually (RecFin 2006). Catch estimates of spotted sand bass in the southern California region during the same period ranged from 10,000 to 74,000 fish, with an average of 49,400 fish caught annually. Commercial fishing for sand basses is not allowed in California.

All three species were present in fish samples from AHL (MEC 1995), and fish observations conducted in the Outer Lagoon in 2005 (**Appendix C**) recorded barred sand bass along the North Jetty at densities up to 15 per 60 m^2 transect and kelp bass at 9.5 per transect. Most of the individuals recorded in these studies were juveniles or subadults, although sport fishers catch legal-sized adult fishes in the lagoon off the north and west jetties.

Sand bass larvae were scarce in entrainment samples with only 11 larvae (1.86 per 1,000 m^3) collected during the year-long study (**Table 3-5**). This, however, yielded an extrapolated entrainment of approximately 2.5 million larvae annually for actual cooling water flow rates. Using maximum design flows, the estimate increased to 2.7 million larvae entrained annually. Nearshore densities were considerable higher at 24.99 per 1,000 m^3, indicating that the source water kelp forests and adjacent sand bottom habitats are the preferred spawning habitat for this group. Sand basses are capable of daily spawning during their reproductive season and an average-sized female can release well over 100,000 eggs (Oda et al. 1993). Because of their relatively low larval entrainment rate compared to other taxa, a detailed analysis of entrainment effects was not done for this taxon.

All three species, primarily juveniles, were impinged during normal flow conditions and heat treatment operations. A total of 567 sand bass with a combined weight of 6.8 kg (15.0 lb) was collected during the weekly impingement surveys (**Table 4-2**). Of these, 303 were spotted, 151 were barred, 111 were kelp, and 2 could not be identified to the species level and were recorded as *Paralabrax* spp. Sand basses were impinged throughout the year, but the peak abundance was in January and February. Most were collected during heat treatments, with a total of 4,511 individuals weighing 153.6 kg (338.6 lb) (**Table 4-2**). Of these fish, 1,536 were spotted, 1,993 were barred, 976 were kelp, and 6 could only be identified to *Paralabrax* spp. Lengths ranged from 28 to 358 mm SL (1.1 to 14.1 in SL), with a mean length of 81.3 mm SL (3.2 in).

The estimated annual impingement of sand bass under normal operations using actual CWS flows was 3,477 individuals, weighing 45.2 kg (99.6 lb) (**Table 4-3**). Under maximum CWS flow rates the estimate increased to 7,274 individuals weighing 85.8 kg (189.2 lb) (**Table 4-3**). When all sources of impingement mortality are combined, the annual impingement of sand basses under actual CWS flows and heat treatments was estimated at 7,987 individuals weighing 198.8 kg (438.3 lb) (**Table 5-3**) for an average weight per fish of approximately 25 g (.05 lb). The mean length of sand basses impinged during normal operations was 81 mm (3.2 in). Using the maximum flows, the estimated impingement increased to 11,795 individuals weighing 239.4 kg (528 lb) (**Table 5-4**).

Sand basses were less abundant in the 1979–1980 impingement study (SDG&E 1980) during heat treatment surveys with an average of 243 fishes per survey compared with 751 fishes per survey in the 2004–2005 study (**Table 5-8**). Although large variations in abundance among years would be expected in AHL for fishes that mainly utilize the area as juveniles, there has also been a generally increasing trend in the recreational fishery coastwide since the 1970s, especially for barred and spotted sand bass (Leet et al. 2001).

Although substantial numbers of sand basses are impinged annually during EPS operations most of these are juveniles less than 1 year old. In terms of potential impacts to local fisheries, few of these juveniles would survive to retainable fishery size (12 in TL under present CDFG regulations) which are at least 5–6 yr old (Young 1963). Therefore, the combination of entrainment and impingement is unlikely to produce any measurable impacts on populations of sand basses in the vicinity. Because commercial fishing for this group of fishes has been illegal in California since 1953, the dollar value of the estimated impingement losses was not calculated.

Table 5-8. Summary of impingement results for sand basses from normal operations impingement surveys from February 1979 – January 1980. Totals for 336 days of sampling were used to compute daily averages that were then used to compute annual impingement totals. From Tables 7.4-3 and 7.4-6 (SDG&E 1980).

Species	Abundance	Weight (kg)	Average Daily Abundance	Average Daily Weight (kg)	Annual Estimated Abundance	Annual Estimated Weight (kg)	Percent Composition
barred sand bass	189	15.3	0.56	0.05	205	16.6	63.9%
spotted sand bass	73	10.9	0.22	0.03	79	11.8	24.7%
kelp bass	34	0.5	0.10	0.00	37	0.5	11.5%
Totals					**322**	**29.0**	

Walleye surfperch

The estimated annual impingement abundance of walleye surfperch (*Hyperprosopon argenteum*) under normal operations was 3,032 individuals weighing 123.0 kg (271.2 lb) based on actual

CWS flows (**Table 4-3**). Using maximum CWS flows the estimate increased to 6,623 individuals weighing 276.9 kg (610.6 lb). The estimated annual impingement from all sources based on actual CWS flows was 5,586 individuals weighing 248.5 kg (547.8 lb) (**Table 5-3**). Under maximum flows the annual estimate of total impingement increased to 9,177 individuals with a combined weight of 402.5 kg (887.4 lb) (**Table 5-4**). Surfperches are not subject to entrainment because females bear fully-developed young.

Walleye surfperch was the eighth most abundant fish collected during normal operations impingement surveys during the 1979–1980 study with a total estimated annual impingement of 2,039 individuals (Table 7.4-3 in SDG&E 1980). It was the sixth most abundant species during heat treatment surveys with an average of 1,186 individuals per survey (Table 7.12-1 in SDG&E 1980). Although their total abundance during normal impingement surveys was greater during the 2004–2005 study, they were less abundant during heat treatment surveys with an average abundance of only 425 individuals (**Table 4-2**).

No commercial fishery for walleye surfperch exists in the San Diego area (PacFIN), but they are fished recreationally. Sport fishery catch estimates in the southern California region from 1999 to 2003 ranged from 15,000–107,000 annually with a mean of 59,600 fish (RecFIN 2005). CDFG (2001) noted that the sport fishery has recently averaged 112,000 fish per year in all of California, which agrees with estimates from RecFIN (2005) of about 110,750 fish per year from 1995–2002 for all of California. Reported commercial landings of walleye surfperch from 2001 through 2004 were very low and almost exclusively from northern California ports (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing). An average price per kg of $2.02 for unspecified surfperch from the 2005 PacFIN database was used to estimate that the total cost of the impingement losses under actual flows was $501 and under maximum flows was $813 (**Tables 5-5** and **5-6**).

California spiny lobster

Impingement of California spiny lobster (*Panulirus interruptus*) at EPS was very low during the study, and no larvae were collected in the entrainment samples. Two spiny lobsters, with a combined weight of 0.1 kg (0.22 lb), were impinged during normal operations surveys and nine lobsters weighing a total of 1.2 kg (2.6 lb) were impinged in the heat treatment surveys (**Table 4-5**). Their body lengths ranged from 21 to 211 mm TL (0.83 to 8.31 in TL) with a mean length of 162.3 mm TL (6.4 in). When all sources of loss due to the operation of the EPS CWS were combined (normal operations, bar racks and heat treatment), the annual loss based on actual CWS flow was 22 individuals weighing 1.9 kg (4.1 lb.) and 25 individuals weighing of 2.0 kg (4.3 lb) based on maximum CWS flows (**Table 5-3** and **5-4**).

Spiny lobsters have been commercially fished in southern California since the 1800s and San Diego County is located in the central portion of the spiny lobster range where up to 60% of California landings occur. The average annual landings from San Diego County in 2000–2005 were 112,243 kg (247,450 lb) with an average annual value of $1,667,371 (PacFIN) and the 2005 catches were 111.4 MT valued at $1.81 million. Estimated annual landings of spiny lobster for all of California from 2000–2005 averaged 338,779 kg (746,867 lb) (PacFIN database). There is also a substantial sport fishery. Lobsters are taken by skin divers and scuba divers, as well as with baited hoop nets. It is estimated that annual sport take is equal to half of the commercial catch (Frey 1971). Based on the proportion of short and legal lobsters taken, CDFG believes that the lobster population in California is well-managed and in a healthy status.

Despite EPS being adjacent to a nearshore kelp forest area where spiny lobsters are abundant, the impact of the EPS CWS on this species is minimal. The total impingement biomass of spiny lobsters from all sources was equivalent to only a few legal-sized individuals. Total estimated losses during actual flow were valued at $30 based on 2005 prices or $32 using the maximum flows (**Table 5-5**). Although juvenile lobsters occur in the Outer Lagoon along the rip-rap structure around the lagoon margin, the population is mainly concentrated in deeper nearshore areas where they are not affected by impingement or entrainment.

Two-spotted Octopus

The estimated annual impingement abundance of two-spotted octopus (*Octopus bimaculatus / O. bimaculoides*) under normal operations was 330 individuals weighing 26.1 kg (58 lb) based on actual CWS flows (**Table 4-6**). The estimated annual impingement from all sources based on actual CWS flows was 497 individuals weighing 69.5 kg (153 lb) (**Table 5-3**). Under maximum flows the annual estimate of total impingement increased to 834 weighing 130.4 kg (287 lb) (**Table 5-4**). No octopus larvae were collected during entrainment surveys.

The total dollar value of the impingement losses was very low. The reported commercial catch from Los Angeles and San Diego area ports of octopus from 2002 through 2004 totaled 1,791 kg (3,948 lb) worth $4,870 (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing). A 2005 catch of 0.1 MT in the San Diego region was valued at $339 (PacFIN). This value per kg resulted in total estimated CWS losses from the 2004–2005 study of $235 to $442 (**Table 5-5**).

Summary

Species that inhabit rocky reef and kelp habitats are directly affected by the EPS CWIS due to the rocky habitat surrounding the Outer Lagoon. Other similar habitats occur in the shallow nearshore areas near the plant and at other sites with rock jetties such as Oceanside Harbor. Recruitment from these other areas probably helps maintain the populations of these species since their abundances have increased or remained similar to abundances measured during the previous 316(b) study for the species included in the assessment. Garibaldi appear to have increased in abundance over time and are more likely to be limited by available habitat than larval supply since the adults are highly territorial (Clarke 1970). The annual losses due to entrainment and impingement of species associated with rock reefs and kelp habitats were low in comparison to the fishery take for these species. The results and comparisons with the previous study indicate a low potential for any adverse environmental impacts (AEI) to rocky reef and kelp bed species.

5.3.2.3 Coastal Pelagic Habitats

The most extensive type of nearshore habitat outside AHL is coastal pelagic habitat, which in the expanded definition used for this assessment also includes the surfzone and nearshore soft bottom habitats. Most of the shallow water areas around AHL are sand bottom with relatively few hard bottom relief features. This is the main habitat type in close proximity to the entrance to AHL and as a result many of the species entrained or impinged are characteristic of the coastal pelagic zone. These mainly included northern anchovy, Pacific sardine, white croaker, queenfish, white seabass, and market squid. Some of these species, such as northern anchovy and white croaker, can be considered habitat generalists because they are also be found in bays and a variety of other shallow water locations (Allen and Pondella 2006). Juveniles of most of these species also tend to be abundant in the shallower depths of the habitat range as demonstrated by the small size distributions collected from impingement data.

Anchovies

Three species of anchovy (Family Engraulidae) are known to inhabit AHL and the nearshore areas around the EPS: northern anchovy (*Engraulis mordax*), deepbody anchovy (*Anchoa compressa*) and slough anchovy (*Anchoa delicatissima*). Entrainment effects were largely restricted to northern anchovy because all of the Engraulid larvae collected that were large enough to be positively identified were northern anchovies. Almost half of the larval anchovy specimens could only be identified to the family level (Engraulidae) because many were still in their recently-hatched yolk-sac stage and some 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 very common in the EPS impingement samples. All three species of anchovies were collected in the impingement samples during normal operations and heat treatments.

Engraulid larvae (predominantly northern anchovy) were the third most abundant taxon at the entrainment station with a mean concentration of 134 per 1,000 m^3 over all the surveys (**Table 3-5**). Their abundance was highly seasonal with over 90% of the larvae in the entrainment samples occurring from March through May. There was a broader temporal distribution of the larvae in the monthly source water samples although peak abundances still tended to occur in March–May with the lowest abundances occurring in December**.** The nearshore station group generally had higher concentrations of anchovy larvae than the lagoon stations. The earlier study at EPS in 1979 (SDG&E 1980) recorded Engraulid larval densities of approximately 86 per 1,000 m^3 in the entrainment samples, which was about 2/3 of the density found during the 2004–2005 sampling.

Total annual entrainment at EPS for the June 2004 through May 2005 period was estimated at 120.7 million using actual cooling water flows and 157.0 million larvae using maximum cooling water flows. The projected adult losses were 6,000 to 15,000 annually as a result of entrainment mortality under actual operating flows, and estimated fractional losses of larvae of approximately 0.4% of the source population (**Table 5-3).** Projected adult losses increased to 8,000 to 20,000 annually with estimated fractional losses of larvae at 0.5% of the population using the design flows (**Table 5-4**).

Impingement mortality from all sources was about eight times greater than the estimated entrainment mortality for anchovies of all species, including deepbody and slough anchovies, amounting to over 46,000 individuals and 355 kg (783 lb) annually using actual flows, and 60,401 individuals weighing 431 kg (951 lb) using maximum flows (**Tables 5-3** and **5-4**). The annual estimated impingement under normal operations based on actual CWS flows of all species of anchovies (not including bar rack or heat treatment mortality) was calculated as 22,832 individuals weighing 100.1 kg (220.7 lb) (**Table 4-3**). The estimate increased to 36,932 individuals weighing 176.5 kg (389 lb) when they were calculated using maximum CWS flows (**Table 4-4**).

Anchovies were less abundant in the 1979–1980 impingement study than in the 2004–2005 sampling (**Table 5-9**). Deepbody anchovy was the most abundant species in both studies but slough anchovies made up a larger portion of the total catch of anchovies in the 2004–2005 study (21%). The total annual impingement estimates (actual CWS flows) of deepbody anchovy during normal operations from both studies were remarkably similar (14,447 and 13,915 from **Table 4-3**). Both deepbody and slough anchovies are resident in AHL and would be expected to decrease if EPS impingement was having a significant cumulative effect on the populations over time. Northern anchovy move into coastal estuaries and embayments as juveniles but primarily inhabit open coastal waters from the surface to depths of 310 m (1,017 ft) (Davies and Bradley 1972). As the result, their abundances can show considerable variation from year-to-year as is shown in the estimates from the two studies.

Table 5-9. Summary of impingement results for anchovies from normal operations impingement surveys from February 1979 – January 1980. Totals for 336 days of sampling were used to compute daily averages that were then used to compute annual impingement totals. From Tables 7.4-3 and 7.4-6 in SDG&E (1980).

Species	Abundance	Weight (kg)	Average Daily Abundance	Average Daily Weight (kg)	Annual Estimated Abundance	Annual Estimated Weight (kg)	Percent Composition
deepbody anchovy	13,299	64.3	40	0.19	14,447	69.8	59.1%
slough anchovy	1,758	4.1	5	0.01	1,910	4.5	7.8%
northern anchovy	7,434	14.6	22	0.04	8,076	15.9	33.1%
Totals					**24,432**	**90.2**	

From the standpoint of a direct economic impact, anchovy losses from impingement and entrainment at EPS comprises an insignificant loss in comparison to the overall population size of these species. Northern anchovy are fished commercially for reduction (e.g., fish meal, oil, and paste) but the live or frozen bait market is the primary target of the nearshore fishery. Along with Pacific sardine it is the most important bait fish in southern California, and is usually collected in open-water purse seines. Slough and deepbody anchovy are not typically harvested because their occurrence in shallow bay environments makes them difficult to capture commercially. Total anchovy harvest and exploitation rates have been below theoretical levels for maximum sustainable yield, and the stock is thought to be relatively stable (Bergen and Jacobsen 2001). The size and fluctuations of the anchovy resource is largely dependent on natural influences such as ocean temperature and current patterns. Live bait catches are monitored by the California Department of Fish and Game (CDFG), but the nature of the mixed species composition between anchovy and sardine, and the conversion of recorded “scoops” of bait to pounds landed present some problems in tracking the fishery (PMFC 2005). 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, although CDFG retains records of bait catches during this period. In 2004, there were 147,417 kg (325,000 lb) landed in the Los Angeles area, 2,753,000 kg (6.07 million pounds) in the Santa Barbara area, and 3,892,000 kg (8.58 million pounds) in the Monterey area for a total value of $750,000 (approximately $0.05 per pound). Based on these values the direct value of EPS impingement losses of northern anchovy total $39 to $47 using actual and maximum flows, respectively. Anchovies are sold as live bait at a considerably higher price than frozen or reduced product, but even at these higher rates ($0.48 per kg) the total losses from projected entrainment or impingement would not exceed several hundred dollars (**Table 5-5**).

Anchovy are an important forage species for predatory fishes (white seabass, sand basses) and seabirds (brown pelicans and various species of terns including the endangered least tern). Any indirect impacts of losses of potential forage species would be difficult to measure although the P_M values from the ETM calculations suggest that impacts to the source water larvae amount to about 0.4% of the local nearshore northern anchovy population and would be significantly less based on the actual distribution of this species which can extend offshore and along the entire coast of California.

White croaker

White croaker was the fifteenth most abundant taxon in the entrainment samples with a mean concentration of 7.0 larvae per 1,000 m^3, and comprised only about 0.2% of all of the larvae collected at the entrainment station (**Table 3-5**). Total annual entrainment was estimated at 6.92 million using measured cooling water flows and 9.47 million larvae using maximum cooling water flows (**Tables 5-3** and **5-4**). No age-specific estimates of survival for later stages of development were available from the literature for white croaker, therefore no estimates of *FH* or *AEL* were calculated. White croaker larvae were present in the source water during all of the surveys but were only present during eight of the entrainment surveys. They are known to occur more frequently in nearshore and shelf areas of the SCB than in shallow bays or lagoons and their larval distributions near EPS reflected this difference. When the *ETM* model was applied to the sampling results for this species, the monthly estimates of proportional entrainment (*PE*) for the June 2004 – May 2005 period ranged from 0 to 0.00072, with a P_M estimate of 0.0029 (0.29%). Using the maximum flows, *PE* estimates ranged from 0 to 0.00084 and the P_M estimate increased to 0.0039 (0.39%). Very few white croaker were impinged during either the heat treatments or normal operations and the resulting estimate for annual impingement was 86 individuals using the actual flows and increased to 113 individuals using the maximum flows (**Table 4-2**).

Impacts to white croaker and queenfish at San Onofre Nuclear Generating Station (SONGS), 32 km (20 mi) northwest of EPS, were reviewed by EPA (2004b) and were substantially greater than impacts measured at EPS in the present study, This was due to the offshore intake location and greater cooling water volume at SONGS. In a normal (non-El Niño) year, an estimated 57 tons of fish of all species were killed per year through impingement when all units were in operation (Murdoch et al. 1989b). Unit 1, which accounted for about 20% of total losses, was taken out of operation in November 2002. The estimates included approximately 350,000 juvenile white croaker, which represents approximately 33,000 adults weighing 3.5 tons. Within 3 km of SONGS, the density of queenfish and white croaker in shallow-water samples decreased by 34% and 36%, respectively comparing before and during power plant operation. Queenfish declined by 50–70% in deepwater samples. In contrast, relative abundances of bottom-dwelling adult queenfish and white croaker increased in the vicinity of SONGS. Increased numbers of these and other bottom-dwelling species were believed to be related to the SONGS discharges which result in increased circulation including nutrients, which in turn may support elevated numbers of prey items for bottom fish.

White croaker is an important constituent of sport fisheries in California and is also caught commercially. Most white croaker are caught by gillnet and hook-and-line (Moore and Wild 2001). Since 1991, commercial landings averaged 461,000 lb statewide but steadily declined to a low of 142,500 lb in 1998. In 2005 there was a reported 0.33 MT landed in San Diego County for a value of $1,022 (PacFIN database). State-wide landings by recreational fishermen aboard commercial passenger fishing vessels (CPFVs) averaged about 12,000 fish per year from 1990 to 1998, with most of the catch from southern California. The recreational fishery in southern California from 2000 to 2005 had landings in the range of 20-40 MT per year (RecFIN data). Using the dollar value of $3.13 from the 2005 commercial landings data, the estimated total dollar loss due to impingement of white croaker from all sources was less than $5 using the maximum flows or the actual flows (**Table 5-5**).

Based on the estimates of entrainment and impingement losses it is unlikely that EPS had any effect on the source water population of white croaker.

Queenfish

Total annual entrainment of queenfish at EPS was estimated at 6.7 million larvae using measured cooling water flows and at 7.5 million larvae using maximum cooling water flows (**Tables 5-3** and **5-4**). It was the sixteenth most abundant taxon collected from the entrainment station with an average annual density of 5.5 larvae per 1,000 m^3. They comprised 0.14% of the larvae collected at the entrainment station and 2.18% of the nearshore source water larvae. There was insufficient life history information available to develop equivalent adult loss estimates from the larval entrainment data. Queenfish larvae were collected from entrainment samples from four of the entrainment surveys and from seven of the source water surveys. A P_M estimate of 0.009

indicated that, overall, approximately 1% of the source water larval population of queenfish was lost due to entrainment through EPS. Using the maximum flows, *PE* estimates ranged from 0.00608 and the P_M estimate increased to 0.010.

Queenfish was the fourth most abundant species of fish impinged during the study with the seventh highest biomass of all fish species collected. The estimated annual impingement of queenfish from all sources based on actual CWS flows was 9,479 individuals weighing 70.4 kg (155.2 lb) (**Table 5-3**). Under maximum CWS flows, the estimated impingement mortality from all sources was 12,511 individuals having a combined weight of 89.7 kg (197.8 lb) (**Table 5-4**). A total of 1,304 queenfish weighing 7.5 kg (16.5 lb) was collected in the normal impingement sampling at EPS, with 2 additional fish collected from the bar racks (**Table 4-2**). A total of 929 individuals weighing 21.4 kg (47.2 lb) was collected during heat treatments. Queenfish was the most abundant fish collected during normal operations surveys during the 1979–1980 impingement study (SDGE 1980). The estimated annual impingement during that study was 18,784 and an average of 498 individuals were collected during each of the seven heat treatments. The levels of impingement measured during the 2004-2005 study were less than the levels measured during the 1979–1980.

Queenfish was the most abundant croaker impinged at five southern California generating stations from 1977 to 1998, and accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). Annual abundance fluctuated from year to year, with notable declines during the strong El Niño events of 1982–83, 1986–87, and 1997–98. However, abundances remained relatively high over the 22-year study period. Queenfish was also one of the three most abundant species of soft-bottom associated fishes in southern California, along with white croaker and northern anchovy, during a 1982–1984 trawl study (Love et al. 1986). They typically occur at depths of 10–70 m (33–230 ft), with highest abundance occurring at the 10 m stratum (Allen 1982). Adult queenfish may move close to shore during the day, and disperse to feed in midwater after sunset (Hobson and Chess 1976), but immature fish generally remained within 2.5 km (1.5 miles) of shore at night (DeMartini et al. 1985). Their abundance in AHL depends on many factors and would be expected to show considerable variation from year-to-year and also over shorter time periods. The results from the study in 1994–1995 showed low densities of adult queenfish present during the July 1994 survey and no fishes in the April 1995 surveys (MEC 1995). This difference in the results for the two impingement studies may reflect the high variation in abundance for this species but also declines in abundance throughout the bight associated with increased ocean temperatures.

There are both recreational and commercial fisheries for queenfish. Recreational fishers landed an average of 311,000 queenfish per year from 2000 through 2004, with the greatest estimated landings of 942,000 (40 metric tons) occurring in 1992 (RecFIN database). From 2001 through 2004 most of the statewide reported landings for queenfish were from Los Angeles and San Diego area ports (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing). Over this period a total of 5,594 kg (12,333 lb) worth $9,992 or $1.79 per kg were landed statewide. This dollar value was used to estimate the total dollar loss due to impingement of queenfish from all sources at $126 using actual flows and $160 using maximum flows **(Table 5-5)**. These estimates are very conservative because the calculations assume that the impinged queenfish were all fishery-sized individuals. The results showed that only a small number of the impinged queenfish were greater than 150 mm (5.9 in) (**Figure 4-24**). Combining the projected loss estimates from the entrainment and impingement analyses, it is apparent that mortality from EPS has an insignificant effect on the queenfish population in comparison to the bight-wide distribution and annual fishery for this species.

Pacific sardine

The estimated annual entrainment of Pacific sardine (*Sardinops sagax*) was 2,484,208 larvae based on actual CWS flows and 3,394,522 larvae using maximum CWS flows (**Tables 5-3** and **5-4**). No analysis was done to convert these larval numbers into equivalent adults because of the relatively low numbers entrained. The estimated annual impingement abundance under normal operations at EPS was 1,735 individuals weighing 9.1 kg (20.1 lb) based on actual CWS flows and 2,344 individuals weighing 13.9 kg (30.6 lb) using maximum CWS flows (**Table 4-3**). The estimated annual impingement from all sources based on actual CWS flows was 8,313 individuals weighing 35.4 kg (78.0 lb) (**Table 5-3**). Under maximum flows the annual estimate of total impingement increased to 8,922 individuals weighing 40.2 kg (88.6lb) (**Table 5-4**). Approximately 90% of the Pacific sardines impinged during normal operations surveys were less that 100 mm (4 in) and generally less than one year old.

Pacific sardine was not collected during the previous impingement or entrainment surveys at EPS in 1979. A sharp decline of the Pacific sardine population in the mid-1940's due to a combination of overfishing and changing oceanographic conditions led to the demise of one of the world's largest commercial fisheries and resulted in the establishment of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program in 1947 (Moser 1996). In 1999, CDFG declared that the Pacific sardine resource had fully recovered. Sport fishery catch estimates for Pacific sardine for southern California was 452,000 fish in 2003 and 808,000 fish in 2004 (RecFin 2005). In addition, smaller individuals are caught by purse seine in mixed schools with northern anchovies and sold as live bait. From 2001 through 2004 a total of 128,191 metric tons (141,306 tons) were landed in the ports of Los Angeles and San Diego with a total value of $12,600,000 (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing). Records from the CDFG commercial fishery database (CDFG 2005) indicate that in 2004 there were 44.5 MT of sardine landed in the San Diego Region (primarily at the port of Oceanside) with an ex-vessel value of $26,428. Based on these values a conservative estimate of the cost of the impingement losses of Pacific sardine was only $21 using the actual flows or $24 using the maximum flows, assuming all of the fishes were of commercial size (**Table 5-5**). If losses are based on the price paid for live bait then the costs would be proportionately higher, but still insignificant.

White seabass

The estimated annual impingement abundance of white seabass (*Atractoscion nobilis*) under normal operations was 442 individuals weighing 70.0 kg (154.2 lb) based on the actual CWS flows (**Table 4-3**). Using maximum CWS flows the estimate increased to 724 individuals weighing 120.0 kg (264.6 lb). The estimated annual impingement from all sources based on actual CWS flows was 2,102 individuals weighing 408.1 kg (899.7 lb) (**Table 5-3**). Under maximum flows the annual estimate of total impingement increased to 2,384 individuals weighing 458.1 kg (1,010 lb) (**Table 5-4**). There were no white seabass larvae collected in the entrainment samples.

White seabass was much less abundant in the 1979–1980 impingement study with an annual estimate of only 27 fishes during normal operations and 13 fishes during all seven heat treatments (SDG&E 1980). Data from impingement studies at other southern California power plants show that populations of white seabass have been low since 1977 but declined dramatically from 1980 to 1982 and have never recovered to previous levels (Herbinson et al. 2001). Declining stocks of white seabass due to overfishing has led to the development of a hatchery release program to replenish stocks of this valuable sport species. A hatchery operated by the Hubbs-SeaWorld Research Institute (HSWRI) is located on the northern shoreline of the Outer Lagoon and has contributed to increases in commercial and recreational catches of white seabass in the SCB since 1999.

The HSWRI releases a portion of their hatchery-raised white seabass juveniles into AHL several times throughout the year. A comparison of release dates and EPS heat treatment dates showed a positive correlation between numbers of hatchery releases and heat treatment impingement of white seabass (**Table 5-10**). A total of 1,375 white seabass (85% of fish collected in all heat treatment surveys combined) were collected during heat treatment survey 4 on February 13, 2005. In the 30 days prior to this survey over 31,000 white seabass were released into the lagoon. For the period January 14 through February 4, 2005, the estimated average weight of the released fish was 134.9 grams, while the average weight in heat treatment survey 4 was 210.3 grams. The release date closest to this survey was February 4, when 6,312 white seabass were released with an estimated average weight of 103.5 grams. Sonic tag tracking of these fish has shown that many will stay in the lagoon for several months before moving into the open ocean (D. Jirsa, HSWRI, personal communication). As a result of these observations, EPS plant and HSWRI staff will coordinate future heat treatments and hatchery releases to ensure that impingement is minimized.

Sport fishery catch estimates of white seabass in the southern California region from 1995 to 2004 ranged from 3,000 to 29,000 fish annually with a mean of 16,182 fish (RecFIN 2005). Reported commercial catch from Los Angeles and San Diego area ports from 2001 through 2004 totaled 302,429 kg (666,741 lb) worth $1,170,808 (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing). The PacFIN database from San Diego County listed a 2005 catch of 26.8 MT valued at $140,612. Based on these values a conservative estimate of the cost of the impingement losses of white seabass range from $2,141 to $2,404 depending on plant flows (**Table 5-5**).

Table 5-10. Comparison of the number of white seabass impinged during EPS heat treatment surveys and white seabass released 30 days prior to the surveys in the Agua Hedionda Outer Lagoon by Hubbs-SeaWorld Research Institute.

Heat Treatment Survey	Date	White seabass impinged		# Releases 30 days prior	White seabass released	
		# Fish	Weight (g)		# Fish	Weight (g)
1	Jul 3, 2004	75	213.9	2	1,052	177.6
2	Aug 28,2004	64	116.0	1	1,537	99.0
3	Oct 23, 2004	100	180.7	2	6,019	398.1
4	Feb 13, 2005	1,375	210.3	9	31,056	1214.3
5	Apr 10, 2005	3	336.8	0	0	0
6	Jun 5, 2005	1	344.8	1	504	73.9

Market Squid

The estimated annual impingement of market squid (*Loligo opalescens*) under normal operations and actual CWS flows was 162 individuals weighing 1.8 kg (4.0 lb) (**Table 4-6**). Under maximum CWS flows the estimate was 190 individuals weighing 2.2 kg (4.9 lb). In comparison, an estimated annual total of 13,909 market squid weighing 13.9 kg (31 lb) were collected during the 1979–1980 impingement study (SDG&E 1980). Impingement of market squid was lower during heat treatment surveys in both studies with no squid being collected in the 2004–2005 study and only 99 market squid collected during all seven heat treatment surveys in the 1979–1980 study.

No market squid paralarvae were collected during entrainment sampling. Market squid hatch from egg masses as small squid with strong swimming abilities that would typically enable them to avoid entrainment.

The total dollar value of the impingement losses was very low. The reported commercial catch from Los Angeles and San Diego area ports of market squid from 2002 through 2004 totaled 46,372,810 kg (102,234,560 lb) worth $15,705,111 (source: commercial landings reported at www.dfg.ca.gov/mrd/fishing), resulting in total estimated CWS losses from the 2004–2005 study of just over one dollar (**Table 5-5**).

Summary

In summary, the coastal pelagic habitat is extensive within the southern California bight, and most of the common fish species that are part of this assemblage have wide-ranging distributions. Commercial or sport fisheries target many of these species and their populations are generally sensitive to large-scale oceanographic influences. The largest effect of the EPS CWIS on species in this particular marine habitat type occurs as a result of the white seabass hatchery in AHL. Coordinating the releases of the juvenile fish with heat treatments operations at the plant should eliminate this source of mortality. Impacts to other species would be expected to be low since they are not resident in AHL and have distributions that extend far beyond the limits of the source water used in estimating entrainment losses.

5.3.2.4 Shelf Habitats

Shelf habitats include several different habitats from Allen and Pondella (2006) including inner, middle, and outer shelf, and shallow slope habitats. The abundance, biomass, and other population attributes of the fish assemblages in these habitats increase from the inner to outer shelf (Allen 2006). Allen attributed this gradient to the increased variability in ocean conditions on the inner shelf due to runoff, pollution, and a variety of other factors. A variety of flatfishes and other species dominate the fish assemblages on the soft mud and sandy bottoms in these habitats. Fishes characteristic of the inner and middle shelf include white croaker, California halibut, bay goby, California tonguefish, bigmouth sole, hornyhead turbot, and California skate (Allen and Pondella 2006). Fishes characteristic of the outer shelf and slope include plainfin midshipman, Pacific sanddab, pink seaperch, curlfin turbot, Dover sole, longspine thornyhead, and California rattail (Allen and Pondella 2006).

The fishes from these habitats support a variety of commercially and recreationally important fishery species including rock and Dungeness crab fisheries. The species caught by commercial fisheries in these habitats are broadly categorized as groundfish and are jointly managed by the California Department of Fish and Game (CDFG), and the Pacific Fishery Management Council (PFMC) and NOAA Fisheries. Two periods of rapid growth in groundfish landings have been identified (Mason 2004). The first period was during the early 1940s when demand due to World War II led to increased landings with Dover sole as the most abundant component of the catch. The second period of increase occurred in the 1970s leading to the largest groundfish landing on record in the late 1970s and early 1980s with rockfishes, Dover sole, and sablefish being the largest components of the catch. Through the 1990s there was a general decline in landings. Mason (2004) identified market demand, variability in ocean conditions, and effects of exploitation as the three primary factors contributing to the changes in groundfish landings.

Spotfin Croaker

Spotfin croaker was selected for specific analysis because it is a recreationally fished species that was entrained and impinged at EPS, although in relatively low abundances. Spotfin croaker larvae had the thirteenth highest mean density of all taxa collected in the entrainment samples for the period of June 2004 through May 2005 with a mean density of 8.3 larvae per 1,000 m^3 (264,172 gal) (**Table 3-5**). It was more abundant in the source water samples with a concentration of 20.2 larvae per 1,000 m^3 and occurred almost exclusively in summer and early fall surveys being mostly absent during other times of the year (**Table 3-7**). Total annual entrainment at EPS was estimated at 9.5 million using measured cooling water flows and 10.7 million using maximum cooling water flows (**Tables 5-3** and **5-4**). There was insufficient life history information available to develop *AEL* estimates from the larval entrainment data, but the *ETM* modeling was used to estimate that 0.016, or slightly less than 2% of the source population was lost due to entrainment, which increased to 0.018 using maximum design flows (**Tables 5-3** and **5-4**).

A total of 182 spotfin croaker weighing 8.4 kg (18.5 lb) were collected in the normal impingement sampling at EPS, with an additional 2 specimens collected from the bar racks (**Table 4-2**). It was the fourteenth most abundant taxa impinged during the yearlong survey and ranked eleventh in total biomass of all species collected. A total of 106 individuals weighing 17.2 kg (37.9 lb) were collected during the six heat treatments. The total impingement was estimated at 1,351 fishes weighing 80.8 kg (178 lb) using actual flows and 1,820 fishes weighing 122.1 kg (269 lb) using design flows (**Tables 5-3** and **5-4**). Spotfin croaker was much less abundant in the 1979–1980 study with an annual impingement estimate of only 36 fishes during normal operations and 10 fishes during all seven heat treatments (SDG&E 1980).

Spotfin croaker is the least frequently impinged croaker at coastal generating stations within the SCB (Herbinson et al. 2001). Since 1977, four of the five generating stations built by Southern California Edison have reported spotfin croaker in impingement samples (Herbinson et al. 2001). Based on these impingement samples, spotfin croaker populations in southern California have been low since 1983 (Herbinson et al. 2001). More recently, nearshore gillnet sampling within the SCB has indicated a general rise in abundance, corresponding to an increase in sea surface temperatures (Miller et al. in prep b).

Spotfin croaker has been reserved for recreational angling within California State waters since 1915, with a ban on the use of nets imposed in 1909 and a ban on commercial sale in 1915 (Valle and Oliphant 2001). Incidental catches, however, did occur in the nearshore gillnet fishery for white seabass, which was closed in 1992 by legislative action. Recreational angling, specifically surf-fishing, continues as anglers enjoy greater success during periods of dense aggregations, such as spawning periods. There was an average of approximately 12,000 fish caught annually in southern California from 2000 through 2005 based on information from the RecFIN database. Because there is no commercial market for spotfin croaker, there is no specific wholesale value per pound associated with this species.

Although the estimated numbers of spotfin croakers impinged annually amounts to approximately 10% of annual reported recreational landings, the impinged fishes at EPS are typically juveniles with a mean size of approximately 100 mm (4 in) whereas the typical sport-caught fish would be at least 9 in for males and 12 in for females which are the approximate sizes at maturity in the population (Love 1996). The difference in ages between impinged fishes (ca. +1 yr) and sport-caught fishes (ca. >3 yr) would yield a substantial reduction in adult equivalents. The increase in impingement abundance from the previous study also indicate that it is unlikely that the combined entrainment or impingement from EPS measurably affects local populations of spotfin croaker in the source water area.

California halibut

California halibut was selected for detailed analysis because they have a high commercial and recreational fishery value. The fishery for California halibut was reviewed by Leet et al. (2001) and recent catch statistics are available through the PSMFC PacFIN (commercial) and RecFIN (recreational) databases. Historically, halibut have been commercially harvested by three principal gear types: otter trawl, set gill and trammel net, and hook and line. Presently there are numerous gear, area, and seasonal restrictions that have been imposed on the commercial halibut fishery for management purposes. Since 1980 the commercial catch has averaged approximately one million pounds per year statewide. In southern California (San Diego, Orange and Los Angeles counties) the average annual commercial catch and ex-vessel revenue from California halibut for the years 2000–2004 was approximately 56,000 lb and $202,000 respectively. During this time the greatest catches were in 2000 (82,225 lb) and the least were in 2003 (38,113 lb). It appears that the size of the California halibut population may be limited by the availability of shallow-water nursery habitat, and a long-term decline in landings corresponds to a decline in these habitats in southern California associated with dredging and filling of bays and wetlands (Leet et al. 2001).

During the 2004–2005 study, only 19 California halibut larvae were collected and measured from the entrainment samples (**Table 3-5**). The larvae occurred in low numbers at the entrainment station in all but the late June and early July 2004 surveys. They were more abundant at the nearshore stations than at the lagoon stations and were mostly absent at the Inner and Middle Lagoon stations (**Figure 3-32**). Total annual entrainment of California halibut at EPS was estimated at 3.7 million and 4.9 million larvae using actual and maximum design cooling water flows, respectively, for the June 2004 through May 2005 period (**Tables 5-3** and **5-4**). Applying the *FH* demographic model to these data, it was estimated that the lifetime reproductive output of 8-12 females was entrained through the EPS CWS for the June 2004 through May 2005 period (**Tables 5-3** and **5-4**). The *ETM* model results were used to calculate a P_M estimate of 0.003, indicating an entrainment mortality of less than 0.5% of the source water larval population (**Tables 5-3**). Using the maximum flows, the P_M estimate increased slightly to 0.004 (**Tables 5-4**).

California halibut ranked twenty-second on the list of fishes impinged during normal operations with a total of 95 individuals weighing 1.7 kg (3.7 lb) (**Table 4-2**). These were all juvenile fishes that averaged approximately 120 mm TL (4.7 in). Fewer individuals were collected during heat treatment operations (21) but these were slightly larger fishes with a combined weight of 4.8 kg (10.5 lb). These numbers were extrapolated to estimate that approximately 600–975 California halibut weighing a total of 15.4–23.3 kg (34–51 lb) were impinged during normal and heat treatment operations using actual and design flows, respectively (**Tables 5-3** and **5-4**). The total revenue value of impingement losses, if calculated on estimated annual biomass and an ex-vessel value of $7.45 per pound would be approximately $430 using the actual flows or $645 using the maximum flows (**Table 5-5**).

Newly settled and juvenile halibut often occur in shallow embayments and occasionally on the outer coast, suggesting that bays are an important nursery habitat for this species (Leet et al. 2001). Juveniles were collected in all segments of AHL during a resources survey in 1994–1995 (MEC 1995), and they were also present during fish studies done in 2005 (**Appendix C**). With an AHL bottom area of approximately 107 ha (264 ac), which was defined as the lagoon surface area at mean lower low water, the density estimates from the comprehensive MEC (1995) surveys were used to calculate a total abundance of over 25,000 juvenile halibut potentially utilizing AHL annually (**Table 5-11**). The calculated annual impingement abundance in 2004–2005 represents approximately 2% of this total.

Table 5-11. Estimated abundance of juvenile California halibut present in AHL from beam trawl and beach seine sampling done in 1994–1995 by MEC (1995). Benthic area is the surface area of each lagoon segment at the +0.0 MLLW tide level (Elwany et al. 2005).

	Outer Lagoon	Middle Lagoon	Inner Lagoon	Total AHL
Benthic area (ha)	21.30	9.49	76.46	107.26
Average density per m^2	0.0023	0.0136	0.0313	
Estimated Abundance	479	1,293	23,933	**25,705**

All estimates of entrainment and impingement effects on California halibut point to a minimal impact of the EPS on this species. Although AHL is a suitable nursery habitat for juvenile halibut, the primary spawning area in the source water region appears to be in the nearshore areas where larval abundances exceeded lagoon abundances by over a factor of ten. Coupled with the primarily benthic habitat preference of California halibut which minimizes impingement risk, there is no overall risk of AEI to halibut from EPS operation.

Cancer crabs

Cancer crabs (primarily yellow, brown, and red rock crab) are fished both commercially and recreationally in southern California. Dungeness or market crab is also a commercially fished species but is more common in central and northern California and is generally not found in SCB commercial catches. The slender crab and hairy crab, also members of the family Cancridae, are not part of the fishery due to their small size. Recent catch statistics for rock crab from the PSMFC PacFIN (commercial) database for the years 2000–2005 for San Diego County showed an average annual commercial catch and ex-vessel revenue of 164,063 lb and $179,528, respectively. The 2005 catch of 47.4 MT was valued at $107,722 for a cost per kg of $2.27.

Both the entrainment of advanced larval stages and the impingement of juveniles and adults was very low during 2004–2005. Only a single cancer crab megalops was collected in the entrainment samples, which yielded an annual estimate of 162,150 megalops under actual flow conditions. Cancer crabs can produce several hundred thousand to several million eggs annually (Hines 1991), so the estimated entrainment represents the reproductive output of a very small number of crabs. Of the 57 Cancer crabs impinged during the normal impingement surveys, there were 26 red, 4 brown, 3 hairy, 1 Dungeness, and 23 others that could not be identified to the species level and were recorded as *Cancer* spp. (**Table 4-5**). Cancer crabs were the most abundant type of shellfish impinged in the heat treatment surveys, with a total of 584 crabs weighing 3.2 kg (7.1 lb). Of these crabs, 502 were red, 27 were brown, 18 were hairy, 1 was Dungeness, and 36 could not be identified to the species level.

The estimated annual impingement of Cancer crabs from all sources under normal operations using actual CWS flows was 962 individuals weighing 5.2 kg (11.5 lb) (**Table 5-3**). Using design flows the estimate was 1,172 weighing 6.5 kg (14.3 lb) (**Table 5-4**). The direct loss for the actual impingement biomass based on 2005 commercial values was $12- $15 using the actual and design CWS flows (**Table 5-5**).

Summary

In summary, the shelf habitat is extensive within the southern California bight, and most of the common fish species that are part of this assemblage have wide-ranging distributions. Many of the fishes in this habitat are targeted by commercial or sport fisheries and their populations are generally sensitive to large-scale oceanographic influences. Impacts to species from this habitat would be expected to be low since they are not resident in AHL and have distributions that extend far beyond the limits of the source water used in estimating entrainment losses.

5.3.2.5 Deep Pelagic Habitats

Deep pelagic habitats include several different habitats from Allen and Pondella (2006) including deep slope, deep bank, and deep rocky reef habitats. This category also includes open ocean pelagic habitats. Some of these habitats are extremely productive and the fishes inhabiting these areas are the basis of large commercial fisheries. The fisheries in the areas outside the three-mile limit of California state waters are federally managed by the PFMC. Fishes characteristic of the deep shelf, bank and slope habitats include Pacific hake, splitnose rockfish, rex sole, sablefish, blackgill rockfish, and shortspine thornyhead. Several different species of rockfishes dominate the fish assemblages on the deep reef, shelf and canyon habitats including bocaccio, chilipepper, and greenspotted, greenstripe, rosethorn, and pinkrose rockfishes. Fishes characteristic of open ocean pelagic habitats include swordfish, striped marlin, several species of shark, albacore, and bluefin, bigeye, and yellowfin tuna. Although the fishes characteristic of these habitats occasionally occur closer to shore their primary habitats are offshore in open water or at deep ocean depths.

Fishes from these habitats are not at risk due to entrainment or impingement by the EPS CWIS. No fishes or shellfishes characteristic of this habitat type were collected during impingement sampling. The larvae from these habitats are subject to entrainment, but once the larvae are transported into nearshore areas the likelihood of them maturing to adults is probably very low due to the unique adaptations many of these species have to life in deep water habitats which do not occur close to shore. One species from these habitats that was collected during entrainment samples was northern lampfish. This species is characteristic of an offshore species that occurs to depths of 2,900 m (9,500 ft) but also occurs in midwater (Neighbors and Wilson 2006) where its larvae are subject to onshore currents that result in transport into nearshore waters where the larvae are subject to entrainment. The primary distribution for this species is the outer coastal waters where it larvae are in higher abundances (**Figure 5-1**) and therefore it was not included in this assessment.

5.4 Summary of Cooling Water System Effects

Impacts to SCB fish and invertebrate populations caused by the entrainment of planktonic larvae through the EPS CWIS can only be assessed indirectly through modeling. These impacts are additive with the direct impingement losses. Two taxa, CIQ goby complex and combtooth blennies, comprised 90% of all entrained fish larvae. Of the ten most abundant fish species entrained at EPS, only one (anchovies) has any direct commercial or recreational fishery value. All of the abundantly entrained species with the possible exception of garibaldi, *Hypsypops rubicundus*, can be considered forage species for larger predatory fishes, sea birds, or marine mammals. Approximately 40% of the 38 different fish taxa entrained belonged to species with some direct fishery value (e.g., anchovies, croakers, sand basses, California halibut) even though most of those were in very low abundance in the samples and as a result were not assessed for potential impacts. An exception was California halibut, which was included in the assessment because of its commercial and recreational fishery importance. Even with a total estimated annual entrainment of nearly 4 million larvae the power plant impacts to this species were negligible, amounting to the loss of four to six females at the age of maturity.

The *ETM* procedure estimates the annual probability of mortality due to entrainment (P_M). It puts the entrainment estimate into context by comparing it with a known source population at risk of entrainment. The greatest P_M estimate for a target taxon was for the CIQ goby complex with a predicted fractional larval loss of 39.8% (**Table 5-1**). The next greatest probabilities of mortality were for combtooth blennies (19.4%) and garibaldi (14.4%). The distance of shoreline potentially affected by entrainment is directly proportional to the estimate of time that the larvae are exposed to entrainment. All three of these species had local populations primarily located in the habitats of Agua Hedionda Lagoon, and most larvae were entrained at sizes that indicated they were recently hatched. Other modeled species with primarily nearshore (non-lagoon) distributions, such as white croaker and queenfish, had P_M estimates below 1%. Even in a heavily exploited commercial species these levels of additional mortality would be considered very low, especially when the populations of these species extend over a much larger geographic range than the extrapolated source water bodies. No invertebrate taxa were modeled for entrainment impacts due to the low abundance of the target taxa (e.g., spiny lobsters, *Cancer* crabs).

Compared to the IM&E study conducted by SDG&E in 1979–1980, goby larvae were approximately five times more abundant in the recent entrainment samples while combtooth blenny larvae were nearly twenty times more abundant. These increases are probably the result of increases in habitat for these two taxa. In the case of gobies, the shallow mudflat habitat in AHL has increased due to watershed erosion and sedimentation. The addition of floats and barges from aquaculture operations provides large surface area for fouling communities utilized by blennies for habitat. Anchovy and croaker larvae were significantly more abundant in the earlier study, perhaps due to the cooler water climatic regime in the SCB during that period that favored these taxa. Surfperches, topsmelt and anchovies were the most vulnerable taxa for impingement during both studies. Annual impingement of fish biomass (normal operations and heat treatments) was similar in both studies—approximately 4,202 kg (9,263 lb) in 2004–2005 compared to approximately 3,820 kg (8,421 lb) in 1979–1980.

Key findings of the entrainment study are as follows:

- No State- or Federally-listed threatened or endangered species were entrained in the year-long study.
- Annual entrainment losses of equivalent adults were projected for CIQ gobies (3.76 million using *FH* and 1.63 million using *AEL*), combtooth blennies (1.15 million using *FH* and 2.45 million using *AEL*), anchovies (6,000 for *FH* and 15,456 using *AEL*), and California halibut (less than 10 using the *FH* modeling approach).
- Fish larval entrainment losses were from 14–40% of the source water populations for species that lived mainly within the Agua Hedionda Lagoon system, but less than 2% for most other species that occurred in nearshore areas outside of the lagoon. Approximately 40% of the taxa entrained through EPS had some direct value to sport or commercial fishers, although most were entrained in very low abundance.
- The five most abundantly entrained fish species (CIQ gobies, combtooth blennies, anchovies, garibaldi, and clinid kelpfishes) represented fishes mainly from the bay and harbor habitat (gobies and blennies), but also rocky reef (garibaldi and kelpfishes) and coastal pelagic habitats (anchovies). All of these species could be considered abundant in the SCB. The only entrained target shellfish larvae were Cancer crabs, which are also widely distributed in nearshore zones in the SCB.

The following is a summary of impingement impacts:

- No State- or Federally-listed threatened or endangered species were impinged in the year-long study.
- A total of 101 species of fishes, sharks and rays was impinged, with the top five species by numbers being topsmelt, shiner surfperch, deepbody anchovy, queenfish, and silversides. The top five species by weight were California butterfly ray, topsmelt, shiner surfperch, round stingray, and white seabass.
- Direct impingement losses (fish and macroinvertebrates) from both normal operations and tunnel heat treatments were equivalent to $4,749–$6,189 using 2005 commercial value data.
- The most abundantly impinged fish species are also considered fairly abundant throughout the SCB.

5.4.1 IM&E Losses Relative to 1977 EPA AEI Criteria

The USEPA (1977) provided some general guidelines to determine the "relative biological value of the source water body zone of influence for selected species and the potential for damage by the intake structure" based on the following considerations of the value of a given area to a particular species:

- principal spawning (breeding) ground;
- nursery or feeding areas;
- migratory pathways;
- numbers of individuals present; and
- other functions critical during the life history.

The area in which the EPS intake structure is located does not include any essential fish or invertebrate habitat such as kelp forest, rocky reef or eelgrass. It is located in the outer segment of Agua Hedionda Lagoon that was largely constructed as a source of cooling water for the plant. Similar coastal lagoons are located north and south of the plant. Fishes in the vicinity of the AHL intake structure are part of the bay and harbor and rocky reef zone fish assemblages characteristic of the Southern California Bight as defined by Allen and Pondella (2006). These include gobies, blennies, silversides, garibaldi, anchovy, white croaker, California halibut, and walleye and shiner surfperch. In regards to the AEI criteria, the habitat is not unique as a spawning area for these particular fishes because they are widespread in southern California. Although many species utilize AHL as a spawning and nursery area, including silversides (e.g. submerged aquatic vegetation), garibaldi (e.g. embayments with vertical rock faces of shallow reefs or constructed breakwalls), and California halibut (e.g. shallow mudflat with submerged vegetation), the Outer Lagoon where the intake is located is not the principal spawning area for any species.

The issue in the EPA guidelines of fish migratory pathways relative to intake location primarily concerns anadromous fishes and situations where power plant intake locations are on or near rivers that may function as narrow migratory corridors for certain species. Because the EPS intakes are located in AHL, this issue is not of concern for any of the species that were impinged. In addition, most of the impinged species are year-round residents and not highly migratory although some, such as northern anchovy and California halibut may exhibit some seasonal onshore-offshore movements but these would not be affected by the EPS CWIS.

The other points of concern relative to intake location and fish distribution are numbers of individuals present and other functions critical during the life history (i.e., high concentrations of individuals present in the area for reasons other than spawning, recruitment or migration). This may include a circumstance where, for example, prevailing currents or the proximity to certain bathymetric features attracts prey items for a predatory species and thus results in high concentrations of a species that may subsequently be at risk of impingement. None of the data collected during this study suggests that there are any species that are especially vulnerable to impingement or entrainment due to their behavior at any stage in their life history. This includes all common species as well as any special status species designated for protection under state or federal statutes.

No federal/state threatened or endangered fish/shellfish species were identified in entrainment and impingement samples collected from EPS. This is consistent with the previous entrainment and impingement study (SDG&E 1980).

5.4.2 IM&E Losses Relative to Other AEI Criteria

Additional criteria that were evaluated because they were specific to the marine environment around EPS included:

- distribution (pelagic, subtidal, nearshore subtidal & intertidal);
- range, density, and dispersion of population;
- population center (source or sink);
- magnitude of effects;
- long-term abundance trends (e.g., fishery catch data);
- long-term environmental trends (climatological or oceanographic); and
- life history strategies (e.g., longevity and fecundity).

These criteria were used in assessing the effects of individual taxa and to place the estimated effects into a larger context using the characteristics of the source water and the biological community. The separation of the taxa on the basis of habitat allowed us to focus on the groups most at risk due to entrainment and impingement. Taxa with larvae that are transported from nearshore or offshore areas into AHL where they are subject to entrainment are less at risk than taxa that occur in the vicinity of the intake where all life stages are vulnerable to both entrainment and impingement. Gobies and blennies both primarily occur in the protected bay and harbor habitats that occur in AHL and as a result are at greatest risk to any CWIS effects. Also, taxa that occur in several different habitats will be less at risk than taxa that only occur in habitats directly affected by the AHL intake. Most of the taxa included in the assessment, with the exception of gobies, did not have limited habitat associations that would place them at risk to entrainment. Finally, the entire distribution of the population is also important, especially for species that may be more limited to bay and harbor areas where they are not only subject to CWIS effects from EPS, but other impacts associated with nearshore coastal environments such as pollution. As a result, fishes such as Pacific sardine and northern anchovy that are distributed across large coastal areas, and California halibut, white seabass, and the croakers (white croaker, spotfin croaker, and queenfish) that are distributed across the shelf will be less at risk than species with more limited distributions.

The criteria of distribution, range, habitat, and population center all need to be considered relative to the magnitude of the effects. The greatest attention should be placed on fishes or shellfishes with limited distribution in the habitat directly affected by the intake, such as gobies. Other fishes potentially affected by entrainment are typically distributed across hundreds of miles of coastline that are connected by coastal currents that help distribute larvae into areas that may have reduced abundances. At EPS, the largest entrainment and impingement effects occurred to fishes that were resident in AHL, but the two resident fishes whose larvae were most affected by entrainment, gobies and blennies, were not greatly affected by impingement since they occupy bottom or cryptic habitats as adults. It is also important that the fishes with the greatest potential impacts are not targeted by commercial or recreational fishing that would compound any effects of the CWIS on the population. Since the magnitude of the impacts to some of these taxa, especially due to entrainment, were relatively high, special studies were initiated in AHL to examine the adult populations of some of these fishes. These studies and comparisons with the previous 316(b) study and other studies in AHL all indicate that healthy populations of these species are present in AHL and that the CWIS is not resulting in any AEI to these species.

The conclusion that the levels of entrainment and impingement at EPS are not resulting in any AEI to fish or shellfish populations is consistent with a recent review on population-level effects on harvested fish stocks (Newbold and Iovanna 2007). They modeled the potential effects of entrainment and impingement on populations of fifteen fish stocks that are targeted by either commercial or recreational fisheries using empirical data on entrainment and impingement, life history, and stock size. For twelve of the fifteen species, the effects of theoretically removing all of the sources of power plant entrainment and impingement were very low (less than 2.5%). For the other three species, the effects ranged from 22.3% for striped bass on the Atlantic coast to 79.4% for Atlantic croaker. Their overall conclusions were that population-level effects were negligible for most fish stocks but could be severe for a few.

Newbold and Iovanna (2007) attributed the absence of large effects for most species to compensatory mechanisms that are probably acting on the populations at some level. If there is strong density dependence acting on these populations during the life stages from the period when they are vulnerable to entrainment as larvae through the age of maturity, then they concluded that there should be very little potential for population-level effects due to entrainment and impingement. The results for gobies from the studies conducted in AHL provide evidence of strong density dependence at recruitment which helps explain the apparent absence of any effects on local populations of this group despite the high levels of entrainment mortality.

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