F I N A L   R E P O R T

ALAMITOS GENERATING STATION

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

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December 20, 2007

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LIST OF ABBREVIATIONS AND ACRONYMS

ADCP	acoustic Doppler current profiler
AGS	Alamitos Generating Station
AEL	adult equivalent loss
BMPs	best management practices
BTA	best technology available
ca.	circa
CDFG	California Department of Fish and Game
CDS	Comprehensive Demonstration Study
cm	centimeter(s)
cm/s	centimeters per second
CPFV	commercial passenger fishing vessels
CWA	Clean Water Act
CWIS	cooling water intake system
dph	days post hatch
EAM	equivalent adult model
EFH	Essential Fish Habitat
El.	Elevation (relative to mean sea level)
ENSO	El Niño-Southern Oscillation
EPA	United States Environmental Protection Agency
ETM	Empirical Transport Model
FH	fecundity hindcasting
FMP	Fishery Management Plan
ft	feet
ft/s	feet per second
g	grams
gal	gallons
gpm	gallons per minute
HnGS	Haynes Generating Station
HTP	Hyperion Treatment Plant
in	inches
km	kilometers
LADWP	Los Angeles Department of Water and Power
LARWQCB	Los Angeles Regional Water Quality Control Board
lbs	pounds
m	meters
m/s	meters per second
m^3	cubic meters
mgd	million gallons per day
mi	miles
min	minute(s)
ml	milliliters
MLLW	mean lower low water
mm	millimeters
mm/d	millimeters per day
MSL	mean sea level
mt	metric tons
MW	megawatts
NL	notochord length

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PacFIN	Pacific Fisheries Information Network
PDO	Pacific Decadal Oscillation
PE	proportional entrainment
PFMC	Pacific Fisheries Management Council
PIC	Proposal for Information Collection
P_m	probability of mortality
ppt	parts per thousand
QA	Quality Assurance
QC	Quality Control
RecFIN	Recreational Fisheries Information Network
RWQCB	Regional Water Quality Control Board
SCB	Southern California Bight
SL	standard length
SWRCB	State Water Resources Control Board
TL	total length
USFWS	United States Fish and Wildlife Services
VRG	Vantuna Research Group – Occidental College
YOY	young-of-the-year

1.0 EXECUTIVE SUMMARY

This report presents data from in-plant and offshore field surveys performed for the AES Alamitos 316(b) Impingement Mortality and Entrainment Characterization Study. This study was designed and performed to comply with the EPA's Section 316(b) Phase II Final Regulations, which became effective in 2004. Originally the results from the study were to be used in determining impingement mortality and entrainment estimates, evaluating potential fish protection technologies and operational measures, scaling potential restoration projects, and/or evaluation of the benefits achieved in reducing IM&E at the AES Alamitos Generating Station (AGS). However, in March 2007, EPA suspended the Phase II regulations and directed administrators to determine compliance with Section 316(b) on a best professional judgment (BPJ) basis.

This report is being submitted to the Los Angeles Regional Water Quality Control Board (LARWQCB) with information that it can use in its determination with respect to 316(b) issues for the AGS. Prior to the Phase II regulations, 316(b) decisions were based on precedents from case law and on EPA's draft "Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500" (EPA 1977). 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 operation of the intakes, and if so,
2. What intake structure represents BTA to minimize that impact?

The usual approach for a 316(b) demonstration would include consideration of BTA only if a determination was 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 AGS cooling water intake systems (CWISs). The two primary impacts of a once-through CWIS are impingement of juvenile/adult life stages of fishes, shellfishes, and other organisms on screens, and entrainment of smaller organisms, usually larval forms of fishes and shellfishes, and other forms of plankton, into the CWIS. The information in this report will also be used to assist in the renewal of the National Pollutant Discharge Elimination System (NPDES) permit for the AGS. This report provides a characterization of the fish and invertebrate species subject to entrainment and impingement at the AGS, information on the current level of IM&E at the AGS, and a discussion of the level of significance of the IM&E losses.

1.1 ENTRAINMENT

Composition and abundance of ichthyoplankton and shellfish larvae entrained by Units 1 through 6 at the AGS were determined by biweekly sampling with plankton nets in the two intake canals from January 2006 to January 2007.

At the Units 1–4 intake canal, a total of 9,852 fish larvae from 29 separate taxonomic categories was collected during the 26 entrainment surveys. The most abundant larval fish taxon in entrainment samples was unidentified gobies, which comprised 66.7% of the total larvae collected, followed by combtooth blennies (21.7%). A total of 2,163 fish eggs from 11 separate taxonomic categories was also collected during the entrainment surveys. The most abundant taxonomic group of fish eggs was unidentifiable eggs, which made up 85.6% of the total eggs collected, followed by anchovy eggs (6.3%). The most abundant target shellfish larvae in the samples was shore crab megalops, which made up 36.7% of the total target invertebrate larvae collected.

At the Units 5&6 intake canal, a total of 10,084 fish larvae from 24 separate taxonomic categories was collected during the 26 entrainment surveys. The most abundant larval fish taxon in entrainment samples was unidentified gobies, which comprised 64.3% of the total larvae collected, followed by combtooth blennies (25.0%). A total of 2,641 fish eggs from 10 separate taxonomic categories was also collected during the entrainment surveys. The most abundant taxonomic group of fish eggs was unidentifiable eggs, which made up 93.2% of the total eggs collected, followed by anchovy eggs (2.3%). The most abundant target shellfish larvae in the samples was shore crab megalops, which made up 33.5% of the total target invertebrate larvae collected.

Two-thirds of the species entrained and 95% of the individuals had no direct sport or commercial fishery value. Concentrations of larval fishes were highest in May and June and lowest in November and December. Highest concentrations of fish eggs were recorded in July, while lowest concentrations were recorded in January, October, and November. There were generally more larval fish and eggs collected during at night than during the day. Using actual flow volumes during the study year (January 2006 – January 2007), total annual entrainment from Units 1&2 was estimated to be 51 million fish eggs and 122 million fish larvae. At Units 3&4, estimated annual entrainment was 226 million eggs and 729 million larvae, and at Units 5&6, estimated annual entrainment was 329 million eggs and 836 million larvae. During the study year, cooling water pumps were usually operating at Units 3&4, while Units 1&2 and 5&6 operated intermittently throughout the year.

A total of 39 target shellfish (invertebrate) larvae representing seven taxa was collected from the AGS entrainment stations during biweekly sampling in 2006. The most abundant target invertebrate larvae in the samples were shore crab megalops, kelp crab megalops, and pear crab megalops, which together comprised approximately 80% of the larval target taxa collected. No spiny lobster, rock crab, or market squid larvae were collected. Total annual entrainment based on actual cooling water flows was estimated to be 457,000 larvae at Units 1&2, 1.8 million larvae at Units 3&4, and 2.1 million larvae at Units 5&6.

1.2 SOURCE WATER

To determine composition and abundance of the early life stages of fish and shellfish in the Alamitos Bay and San Pedro Bay source waters for the AGS cooling water systems, sampling was conducted once monthly on the same day that the entrainment station was sampled. The AGS source water biological sampling boundaries consisted of the waters within Los Cerritos Channel and Alamitos Bay, and extending offshore, upcoast, and downcoast from the Alamitos Bay entrance Channel in San Pedro Bay.

A total of 46,687 fish larvae from 68 separate taxonomic categories was collected from the source water stations during the 12 monthly surveys in 2006. The most abundant fish larvae in the samples were unidentified gobies, combtooth blennies, white croaker, and anchovies, which comprised over 90% of all specimens collected. The greatest concentrations of larval fishes occurred during April and the lowest occurred in October. There were generally more larval fish collected during night sampling than during day sampling.

A total of 2,342 larval invertebrates representing 20 taxa was collected from the AGS source water stations during 12 monthly surveys in 2006. The most abundant target invertebrate larvae in the samples were megalops of kelp crabs, pea crabs, shore crabs, spider crabs, and unidentified crabs, which together comprised more than 90% of the total target invertebrate larvae collected.

1.3 IMPINGEMENT

Impingement surveys were conducted during all 52 weeks from January 6 to December 26, 2006 at the AGS. Sampling frequency varied by intake due to non-operation of many units during most of the year. During the study year, cooling water pumps were usually operating at Units 3&4, while Units 1&2 and 5&6 operated intermittently throughout the year. Results from the weekly normal operation surveys were extrapolated based on cooling water flow volumes to estimate total annual impingement. No heat treatments were conducted at the AGS during the study year. During the study year, an estimated 399,097 fish from 57 taxa weighing 6,467 kg (14,261 lbs) was estimated to be impinged during the study year based on actual cooling water flow volumes. The most abundant species were topsmelt, unidentified silversides, shiner perch, and Pacific staghorn sculpin. When the estimates were calculated using design (maximum) cooling water flow volumes for Units 3&4, which operated most of the study year, estimated annual impingement increased to 458,013 individuals weighing 7,685 kg (16,944 lbs). Abundance was highest at Units 3&4 (93% of sampled fish abundance), followed by Units 5&6 (5%) and Units 1&2 (2%). Impingement abundance was highest during/following periods of rainfall, and was significantly correlated to precipitation amount. Nearly 87% of the fish collected in impingement surveys occurred during two surveys with rainfall.

A total of 93,011 macroinvertebrates from 39 taxa weighing 3,601 kg (7,940 lbs) was estimated to be impinged during the study year based on actual cooling water flow volumes. The most abundant invertebrates were moon jelly, yellow shore crab, red jellyfish, and California seahare. When the estimates were calculated using design (maximum) cooling water flow volumes for Units 3&4, estimated annual impingement increased to 131,227 macroinvertebrates weighing 4,458 kg (9,829 lbs). Abundance was highest at Units 3&4 (61% of sampled macroinvertebrate abundance), followed by Units 1&2 (23%) and Units 5&6 (16%). Invertebrate abundance was generally higher in spring and summer, and there was no apparent increase in impingement following storm events.

1.4 IMPACT ASSESSMENT

The data collected from the entrainment, source water, and impingement sampling were used to assess the potential for AEI to fish and shellfish populations. The assessment was limited to the taxa that were sufficiently abundant to provide reasonable assessment of impacts. The list of taxa was reviewed and approved by all stakeholders, including the LARWQCB. The most abundant taxa had the greatest frequency of occurrence among surveys and stations. Since the most abundant organisms may not necessarily be those that experience the greatest effects at the population level, the data were also examined to determine if additional taxa should be included in the assessment, such as threatened or endangered taxa. The National Marine Fisheries Service requested that all species managed under the Magnuson-Stevens Fishery Conservation and Management Act be assessed in the impingement section. None of these species were included in the entrainment assessment (beyond those which comprised the most abundant taxa) since they occurred in very low number in entrainment samples. No species listed as threatened or endangered by the state or federal governments were entrained or impinged at the AGS during the study, consistent with past results.

The assessment was primarily done by calculating impingement and entrainment estimates based on both actual cooling water flow volumes at the AGS for individual taxa. Estimated entrainment and impingement using design (maximum) flow volumes at Units 3&4 were presented in the report, as well. The entrainment and impingement estimates were then used to model losses to adult and larval source populations using two general modeling approaches and three different models. One approach uses species-specific life history parameters in two different demographic models to estimate the equivalent number of adults lost due to entrainment and impingement: adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*). The number of adult equivalents was calculated for some taxa both entrained and impinged, while fecundity hindcasting was used to estimate the number of adult females whose reproductive output was lost to entrainment.

The other modeling approach was only used with the entrainment and source water data. This model (the empirical transport model [*ETM*]) estimates the conditional mortality on a population resulting from entrainment. The demographic estimates from entrainment and impingement were added together to evaluate combined effects of the cooling water systems. The life history information necessary for the modeling was not available for most species so a combined assessment was only performed with gobies and combtooth blennies.

The assessment included 10 taxonomic groups or species of fishes and three taxonomic groups of shellfishes (Table 1.4-1). These taxa were categorized into five habitat types that were simplified from a more detailed categorization of habitats by Allen and Pondella (2006b). Taxa that occurred in more than one habitat were assigned to the habitat group that best reflected the primary distribution for that taxon. This approach was used because it focused the assessment on the taxa and habitats that were most at risk for potential effects from the AGS cooling water systems.

Taxa that were associated with habitats that are only affected by the transport of larvae out of their native habitat into nearshore areas where they are susceptible to entrainment are at very low risk of being impacted by the AGS cooling water systems. These include taxa associated with offshore pelagic habitats and those whose primary distribution is on the continental shelf. Most of the taxa included in the assessment did not have limited habitat associations that would place them at greater potential risk to cooling water system effects. Although a taxon may be limited to a single habitat type, the entire distribution of the population is also important. For example, while market squid were assigned to the coastal pelagic habitats, they are distributed across large oceanic areas.

Table 1.4-1. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual flows at AGS Units 1- 6 in 2006.

Species	Common Name	Est. Annual Larval Ent. (millions)	Est. Annual Egg Ent. (millions)	*ETM* P_M (%)	2**FH*	*AEL*	Annual Imping. Estimate	Imping. Weight (kg)	*EAM*[1]
Fishes									
Gobiidae	gobies	1,065.6	–	13.32	2,292,044	974,076	–	–	
Hypsoblennius spp.	combtooth blennies	463.9	–	8.99	529,752	1,130,436	235	4.08	
Atherinopsidae unid.	silversides	56.0	13.2	8.39	–	–	293,792	4,851.14	
Engraulis mordax[2]	northern anchovy	21.4	552.5	–			8,044	2.75	
Seriphus politus	queenfish	0.6	–	–			2,167	15.82	3,146
Cymatogaster aggregata	shiner perch						64,166	339.30	
Leptocottus armatus	Pac. staghorn sculpin	0.2	–				17,973	216.85	
Sardinops sagax	Pacific sardine	0.3	–				389	6.76	343
Trachurus symmetricus	jack mackerel	–	–				69	5.24	91
Scomber japonicus	Pac. chub mackerel	–	–				17	4.17	33
Invertebrates									
Aplysia californica	California seahare						1,379	499.80	
Loligo opalescens	market squid	–	–				600	20.28	
Octopus spp.	two-spot octopus						140	29.40	

[1]*standardized impingement adult equivalent mortality*
[2]Engraulis mordax *larvae collected from impingement sampling are combined with adults*

Although habitat and geographic distribution are important considerations, they all need to be considered relative to the magnitude of effects. At the AGS the largest entrainment and impingement effects occurred to fish whose primary habitat is the abundant bay/harbor habitat of Alamitos Bay. It is important to note that many of the taxa entrained and/or impinged are not targeted by commercial or recreational fishing that would compound any effects of the operation of the cooling water systems on the populations. For taxa which are also targeted by sport and/or commercial fishing, such as anchovies, Pacific sardine, and market squid, the magnitude of impacts to these and other taxa were relatively low and not at levels that would represent risk of AEI to the populations.

Although EPA acknowledges it is difficult to determine the magnitude of impact that would result in an AEI, the conclusions of this study were consistent with a recent review on population-level effects on harvested fish stocks (Newbold and Iovanna 2007). The authors modeled the potential effects of entrainment and impingement on populations of 15 fish stocks that are targeted by either commercial and/or recreational fisheries by using empirical data on entrainment and impingement, life history, and stock size. For 12 of the 15 species modeled, the effects on the adult populations of theoretically removing all of the sources of power plant entrainment and impingement were 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 some species with population and harvest characteristics similar to their three examples. Unlike the harvested fishes analyzed by Newbold and Iovanna (2007), the largest effects of entrainment at the AGS occurred for non-harvested species (such as gobies and combtooth blennies) that occur mostly within the bay habitat that surrounds the cooling water intake structures, and these were still at low levels that would not represent a risk of AEI to the populations.

2.0 INTRODUCTION

The Alamitos Generating Station (AGS) is a fossil-fueled steam electric power generating station that is owned and operated by AES Alamitos, L.L.C. (AES) and is located along the Los Cerritos Channel in Long Beach, California. The AGS currently operates six oil/natural gas units. Cooling water for all six units is withdrawn through two intake canals that are hydraulically connected to the Los Cerritos Channel. Cooling water for all of the units is discharged through three submerged discharge structures into the lower San Gabriel River flood control channel.

Cooling water intake systems are regulated under §316(b) of the federal Clean Water Act (CWA). The U.S. Environmental Protection Agency (USEPA) recently established new regulations for §316(b) applicable to large existing power plants with daily cooling water volumes in excess of 50 mgd. Due to the design, location, and operating characteristics of the cooling water systems for AGS, which withdraws a maximum of 1,273.0 mgd, it was subject to these new regulations that required submittal of a comprehensive plan for compliance by January 2008. 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.

2.1 BACKGROUND AND OVERVIEW

On July 9, 2004, the U.S. Environmental Protection Agency published the second phase of new regulations under §316(b) of the CWA. The final Phase II regulations went into effect in September 2004, and applied to existing generating stations (Phase II facilities) with cooling water intake structures that withdraw at least 50 mgd from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. Pursuant to the Phase II regulations, AES submitted the Proposal for Information Collection (PIC) for AGS to the Los Angeles Regional Water Quality Control Board (LARWQCB) in September 2005. The PIC included the study plan for the AGS IM&E Characterization Study.

2.1.1 Section 316(b) of the Clean Water Act

Section 316(b) of the CWA requires that the location, design, construction, and capacity of CWISs reflect BTA to minimize adverse environmental impacts due to the impingement mortality of aquatic organisms (i.e., fish, shellfish, and other forms of aquatic life) on intake structures and the entrainment of eggs and larvae through cooling water systems. The new §316(b) Phase II regulations established performance standards for CWISs of existing power plants that withdraw more than 50 mgd of surface waters and use more than 25% of the withdrawn water for cooling purposes. The regulations required all large existing power plants to reduce impingement mortality by 80–95% and to reduce entrainment 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 were to be used to determine whether a facility was required to meet the performance standards for only impingement or both impingement and entrainment.

The Phase II regulations provided power plants with five options for meeting the performance standards, but unless a facility could show that it met the standards using the existing intake design or was installing one of the approved EPA technologies for IM&E reduction, it was required to submit information documenting its existing levels of IM&E. These data could be derived from existing data that may have previously been collected at the facility or a similar facility nearby. The data were then required to be submitted in an Impingement Mortality and Entrainment (IM&E) Characterization Study that was one component of the §316(b) Comprehensive Demonstration Study required under the Phase II regulations. The impingement mortality component of the studies was not required if the through-screen intake velocity was less than or equal to 0.5 feet per second (ft/s) (or 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.

Southern California Edison (SCE), as required by the Clean Water Act of 1972, completed the first 316(b) study at the AGS in 1979. Goals of this study were to determine the technologies best suited for minimizing the environmental impact of entrainment and impingement on the fishes in Alamitos Bay. Due to the proximity of AGS and Haynes Generating Station (HnGS), the latter was used as a representative site for entrainment analysis of AGS. Entrainment values were adjusted for relative flow values between the two generating stations. Impingement samples were collected from the screening facilities at the AGS.

In conjunction with the LARWQCB and the California Department of Fish and Game (CDFG), SCE selected target species based upon potential risks to their abundance and distribution. Criteria for determining target species included: 1) trophic importance (i.e. planktivorous, piscivorous, or benthic feeders, and their importance as a food source); 2) presence of the species in the source body during most periods of the year; 3) species vulnerable to impingement and entrainment; 4) species whose loss would evoke community-wide effects; and 5) commercial or recreational value. The final list, evaluated by Wintersteen and Dorn (1979) included 15 target species:

northern anchovy	*Engraulis mordax*
queenfish	*Seriphus politus*
white croaker	*Genyonemus lineatus*
white surfperch	*Phanerodon furcatus*
shiner perch	*Cymatogaster aggregata*
walleye surfperch	*Hyperprosopon argentum*
Pacific butterfish	*Peprilus simillimus*
kelp bass	*Paralabrax clathratus*
barred sand bass	*Paralabrax nebulifer*
sargo	*Anisotremus davidsonii*
spotfin croaker	*Roncador stearnsii*

bocaccio	*Sebastes paucispinis*
black surfperch	*Embiotoca jacksoni*
yellowfin croaker	*Umbrina roncador*
black croaker	*Cheilotrema saturnum*

Mean daily entrainment values were determined with approximately biweekly surveys from October 1979 to September 1980. Samples were collected near the HnGS intake structure in Alamitos Bay. Day samples were collected using a midwater pump while night samples were collected with nets to sample discrete levels in the water column. Manta nets, standard Bongo nets, and epibenthic Bongo nets were all used to collect far-field (source water) surface samples, midwater samples, and near-bottom samples, respectively.

Combtooth blennies (*Hypsoblennius* spp.) were collected in highest concentrations in entrainment samples, and represented 43.7% of entrainment abundance. Gobiid sp. complex comprised 38.1% of total entrainment abundance. Of the 15 target species, the anchovy species complex (including *E. mordax* as well as other anchovy species) constituted 8.6% of total entrained species. White croaker (*Genyonemus lineatus*) constituted 5.7% of total entrainment.

Mean daily impingement values were determined during two modes of operation at the power plant. Normal operation fish were impinged on protective screens. Impingement was also determined during heat treatments to reduce biofouling. Pacific butterfish, *Peprilus simillimus*, and shiner perch, *Cymatogaster aggregata*, dominated total impingement at all units.

2.1.2 Development of the Study Plan

The Phase II §316(b) regulations require that the plan for the IM&E Characterization Study include sufficient data to develop a scientifically valid estimate of IM&E including all methods and quality assurance/quality control (QA/QC) procedures for sampling and data analysis. The sampling and data analysis methods must be appropriate for a quantitative survey and include consideration of the methods used in other studies performed in the source water body. The sampling plan must also include a description of the study area (including the area of influence of the CWIS), and provide for taxonomic identifications of the sampled or evaluated biological assemblages (including all life stages of fish and shellfish) that are known to be relevant to the development of the plan.

The regulations also required that the PIC include summaries of any historical studies characterizing IM&E, and/or the physical and biological conditions in the vicinity of the cooling water intake structures and their relevance to the proposed studies. These are required to assist the LARWQCB in reviewing and commenting on the IM&E study plan. If the data from previous studies will be used in characterizing the existing levels of IM&E then the PIC must demonstrate that the data are representative of current conditions and were collected using appropriate QA/QC procedures.

The AGS IM&E Characterization Study Plan was developed in 2005 by MBC Applied Environmental Sciences and Tenera Environmental. The Study Plan was designed to provide the biological information necessary to fulfill all pertinent 316(b) Phase II requirements, and was based on entrainment and impingement studies performed in California in recent years for California Energy Commission relicensing studies (such as those at the AES Huntington Beach, Duke Morro Bay, Duke Moss Landing, and Duke South Bay Power Plants), and 316(b) Demonstrations (such as at the PG&E Diablo Canyon and NRG Encina Power Plants). All of these studies were performed with input from technical working groups, comprised of representatives from the project applicants, the California Regional Water Quality Control Board (RWQCB), CDFG, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and consultants.

The Study Plan was submitted to the LARWQCB in September 2005. AES and its consultants subsequently met with the LARWQCB to review the Study Plan and address comments. Pursuant to comments during the meeting that were included in a letter from the LARWQCB in January 2006, the following changes were made to the Study Plan:

- Fish eggs will be identified (to the extent practicable) and counted from entrainment samples; and
- Crab megalopae larvae will be identified (to the extent practicable) and counted from entrainment samples.

The revisions to the study plan only affected sample processing and did not affect the sampling that started in January 2006. The AES Alamitos sampling plan is provided as an attachment to this report.

2.1.3 Study Plan Objectives

Under the new §316(b) regulations, the IM&E Characterization Study must include the following elements (for all applicable components):

1. Taxonomic identifications of all life stages of fish, shellfish, and any species protected under federal, state, or tribal law (including threatened or endangered species) that are in the vicinity of the CWIS and are susceptible to impingement and entrainment;
2. A characterization of all life stages of fish, shellfish, and any species protected under federal, state, or tribal law (including threatened or endangered species) identified in the taxonomic identification noted previously, including a description of the abundance and temporal and spatial characteristics in the vicinity of the CWIS, based on sufficient data to characterize the annual, seasonal, and diel variations in the IM&E; and
3. Documentation of current IM&E of all life stages of fish, shellfish, and any protected species identified previously and an estimate of IM&E to be used as the calculation baseline.

The Phase II §316(b) regulations provided the LARWQCB with considerable latitude in determining the level of detail necessary in meeting these objectives and states that "while the taxonomic identification in item 1 will need to be fairly comprehensive, the quantitative data required in elements 2 and 3 may be more focused on species of concern, and/or species for which data are available." If the Comprehensive Demonstration Study (CDS) is based on a given technology, restoration or site-specific standards, the level of detail in terms of the quantification of the baseline can be tailored to the compliance alternative selected and does not have to address all species and life stages. Logically it can be based on dominant species and/or commercially or recreationally important species. Therefore, there was agreement with the

LARWQCB that the impingement sampling would identify, count, weigh, and measure all collected fishes, crabs, lobsters, shrimp, squid and octopus. This approach was taken to include all of the impingeable 'shellfish' that are recreationally or commercially important and a large number of species that are not fishery species. It was also agreed that the entrainment sampling would identify and count all fish eggs and larvae, megalops stage larvae for all species of crabs, California spiny lobster phyllosoma larvae, and market squid hatchlings.

The data collected from the study will be used in developing a characterization of baseline levels of IM&E for AGS required under the Phase II regulations. The calculation baseline is defined in the Phase II §316(b) regulations as follows:

> *"Calculation baseline means an estimate of impingement mortality and entrainment that would occur at your site assuming that: the cooling water system has been designed as a once-through system; the opening of the cooling water intake structure is located at, and the face of the standard 3/8 in mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody; and the baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls, including flow or velocity reductions, implemented in whole or in part for the purposes of reducing impingement mortality and entrainment. You may also choose to use the current level of impingement mortality and entrainment as the calculation baseline. The calculation baseline may be estimated using: historical impingement mortality and entrainment data from your facility or another facility with comparable design, operational, and environmental conditions; current biological data collected in the waterbody in the vicinity of your cooling water intake structure; or current impingement mortality and entrainment data collected at your facility. You may request that the calculation baseline be modified to be based on a location of the opening of the cooling water intake structure at a depth other than at or near the surface if you can demonstrate to the Director that the other depth would correspond to a higher baseline level of impingement mortality and/or entrainment."*

As presented in the PIC, the AGS CWIS does not conform to the calculation baseline. Significant deviations from the calculation baseline are:

- The cooling water intake systems include two intake canals; and
- The screen meshes differs from standard 3/8 in mesh.

The Phase II regulations allowed facilities to take credit for deviations from the calculation baseline if it can be demonstrated that these deviations provide reduced levels of IM&E. With the suspension of the Phase II regulations the same arguments regarding deviations from the calculation baseline would apply to determining if the current design represents the BTA for minimizing AEI. Neither of the differences from the calculation baseline is believed to provide a benefit in terms of fish protection.

Another objective of the study is to provide data that can be used in meeting different alternatives for compliance that might be used by AES. One approach that was the subject of the Court Decision was the use of restoration to meet the performance standards for IM&E reduction. To this end, source water data were collected to estimate the sizes of the populations potentially subject to entrainment. The Court decision rejected the use of restoration, but the source water data will still be important in assessing the impacts of entrainment at a population level that would otherwise be limited to a few species with adequate life history information. The study provides data that could be used to evaluate and estimate the economic value of the environmental benefit of meeting the performance standards. While the Court decision has limited the use of the data in cost-benefit analysis this aspect is still important in evaluating the potential AEI of IM&E and is one of the approaches used in the assessment presented in Section 6.0.

2.1.4 Study Plan Approach

The IM&E studies at AGS were designed to examine losses resulting from both impingement of juvenile and adult fish and shellfishes on traveling screens at the intake during normal operations and from entrainment of larval fishes and shellfishes into the cooling water intake system. The sampling methodologies and analysis techniques were designed to collect the data necessary for compliance with the §316(b) Phase II Final Rule and were similar to recent impingement and entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera 2007). The studies at Huntington Beach were performed as part of the California Energy Commission California Environmental Quality Act (CEQA) process for permitting power plant modernization projects, while the South Bay and Encina projects were for §316(b) compliance. The study plans for these projects were subject to review by state and federal resource agency staff and independent scientists from various environmental organizations.

Impingement sampling was conducted regularly from July 1992 to July 1993, and has been conducted regularly at the AGS since 2001. The impingement sampling methods used in this study are similar to the National Pollutant Discharge Elimination System (NPDES) monitoring program, but the sampling frequency has been increased to weekly to capture any seasonal variation and to collect additional data on diel variation.

The entrainment sampling was designed to reflect the uncertainties surrounding the use of restoration for compliance with the new §316(b) regulations. If the use of restoration was not allowed as a result of the court decision, the entrainment data would be used in baseline calculations of losses that would be required to estimate the commercial and recreational values of adult fish losses in a cost benefit analysis of various technology and operational alternatives being considered to comply with required reductions in entrainment mortality. Larval fish and shellfish abundances can vary greatly through the year and therefore biweekly sampling was used for characterizing entrainment. If the restoration option is upheld in the court decision, models of the conditional mortality due to entrainment could be used in designing appropriate restoration projects for offsetting entrainment losses. These models are based on proportional comparisons of entrainment and source water abundances and are theoretically insensitive to seasonal or annual changes in the abundance of entrained species. Therefore, source water sampling occurred monthly, which is consistent with the sampling frequency for recently completed studies in southern California.

2.2 REPORT ORGANIZATION

Section 3.0 of this report includes a detailed description of the AGS and its cooling water intake systems. Cooling water flow volumes withdrawn during the course of the 2006 studies are presented and discussed, and these flows were used in calculating estimates of IM&E presented in other sections of the report. Section 3.0 also includes a description of the habitats and marine biological communities in the vicinity of the AGS. The methods and results from the entrainment and source water sampling programs are presented in Section 4.0, and the methods and results for impingement are presented in Section 5.0. The results from the IM&E sampling are integrated into an impact assessment for the AGS in Section 6.0. References used in the report are presented in Section 7.0. Appendices to this report include study procedures and detailed summaries of entrainment, source water data, and impingement data.

2.3 CONTRACTORS AND RESPONSIBILITIES

The IM&E Study was designed and performed by EPRI Solutions (now EPRI, Palo Alto, CA), MBC Applied Environmental Sciences (Costa Mesa, California) and Tenera Environmental (San Luis Obispo, California). The roles of each of the respective firms were as follows:

- EPRI Solutions
    - Input on sampling design
- MBC Applied Environmental Sciences
    - Study design
    - Field sampling
    - Impingement Mortality data entry and analysis
    - Reporting
- Tenera Environmental
    - Study design
    - Physical oceanographic data collection and analysis
    - Field sampling Quality Assurance/Quality Control (QA/QC)
    - Laboratory processing of entrainment and source water plankton samples
    - Entrainment data entry and analysis
    - Reporting

Each contractor was responsible for ensuring that all data were verified prior to being entered, and that appropriate QA/QC measures were employed during data collection, entry, and analysis.

3.0 DESCRIPTION OF THE GENERATING STATION AND CHARACTERISTICS OF THE SOURCE WATER BODY

The following section describes the AGS and the surrounding aquatic environment. A description of the generating station and its cooling water intake systems is presented in Sections 3.1 and 3.2. A description of the physical and biological environments in the vicinity of the AGS is presented in Section 3.3.

3.1 DESCRIPTION OF THE GENERATING STATION

The AGS is located in the city of Long Beach in Los Angeles County, CA, along the shoreline of the lower San Gabriel River flood control channel (Figure 3.1-1). The AGS currently operates six natural gas units (Units 1–6). Units 1&2 and Units 3&4 each utilize a single CWIS; however, they share a common intake canal that withdraws water from the Los Cerritos Channel and Alamitos Bay. Units 5&6 also share a common intake canal that withdraws water from the Los Cerritos Channel and Alamitos Bay. The orientation of the intakes relative to AGS and Alamitos Bay is shown in Figure 3.2-1. Units 1–6 produce a combined output of 1,950 MW. However, over the past five years the annual capacity utilization for each unit has ranged between 6.0% (Unit 1 in 2000) and 66.9% (Unit 5 in 2001). The total annual energy generated is approximately 5,800,896 MWh. From 2000 through 2004, capacity factors at the AGS were as follows:

- Unit 1 – 7.9%
- Unit 2 – 12.2%
- Unit 3 – 34.0%
- Unit 4 – 30.0%
- Unit 5 – 38.9%
- Unit 6 – 30.2%

Figure 3.1-1. Location of the AES Alamitos Generating Station (AGS).

3.2 DESCRIPTION OF THE COOLING WATER INTAKE SYSTEMS

Cooling water for Units 1–6 is withdrawn through two intake canals: one canal serves Units 1–4, and the other serves Units 5&6 (Figure 3.2-1). Both canals are hydraulically connected to the Los Cerritos Channel, which is connected to Alamitos Bay. Trash racks are installed across the onshore intake structures to prevent large debris from entering the intake bays at Units 1&2 and Units 5&6. Traveling water screens are installed behind the trash racks to strain out smaller debris. Circulating water pumps are located downstream of the traveling water screens to convey screened flow to the condensers. Cooling water from all units is discharged through three discharge structures (one each for Units 1&2, Units 3&4, and Units 5&6) in the lower San Gabriel River flood control channel.

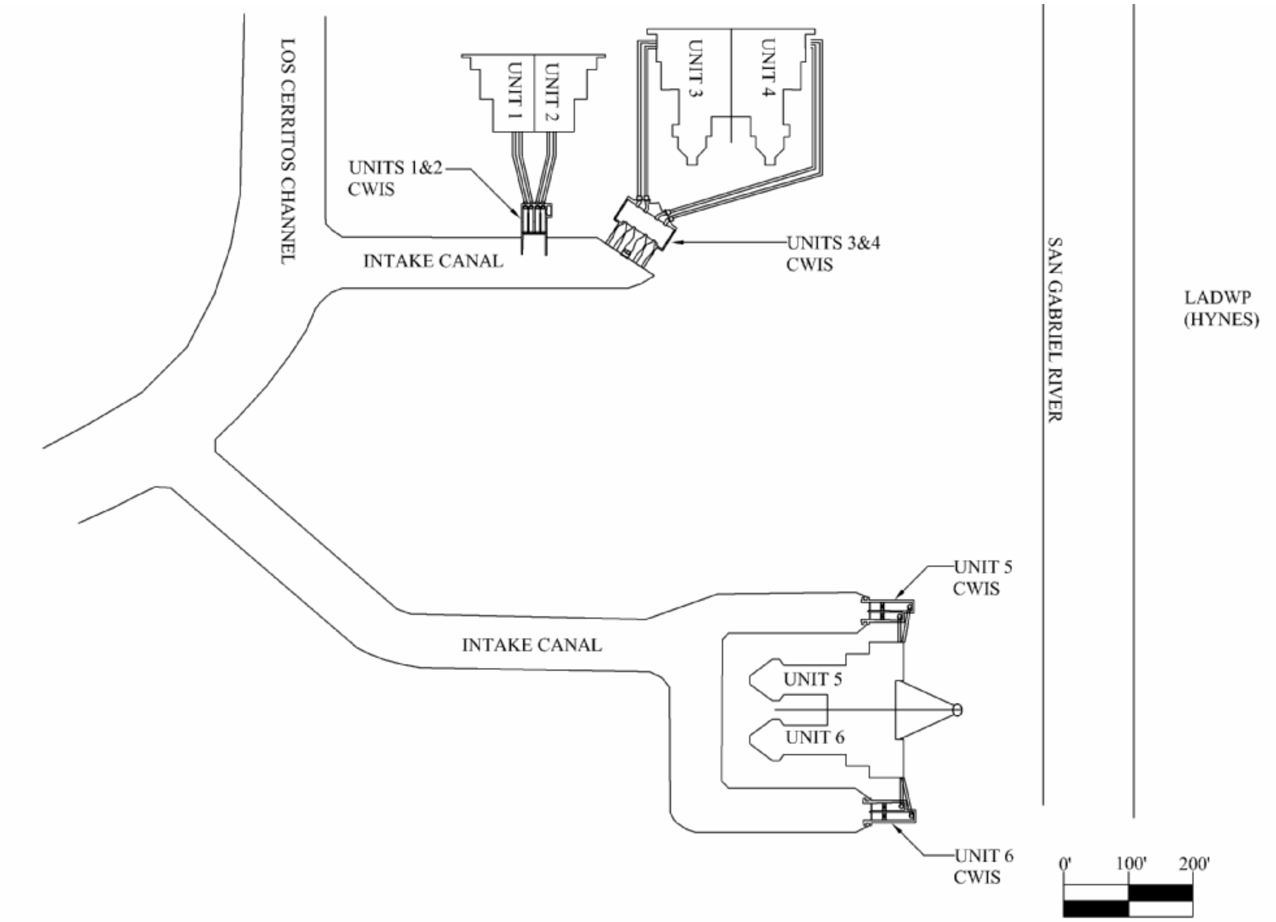


Figure 3.2-1. Location of the AGS intake structures. (Metric measurement units not included.)

3.2.1 Units 1&2 CWIS

The CWIS for Units 1&2 is located in the north intake canal, as depicted in Figure 3.2-1. This canal also supplies water to the Units 3&4 CWIS. The Units 1&2 CWIS has four intake bays—-two for each unit—and each bay is 2.5 m (8.2 ft) wide. (Figure 3.2-2). The invert of these bays ranges from El. -1.8 m (-6.0 ft) at the entrance to El. -2.7 m (-9.0 ft) at the traveling water screens (re: Mean Sea Level [MSL]) (Figure 3.2-2). To prevent debris from passing through the intake bays and damaging the circulating water pumps, each bay has a curtain wall and a traveling water screen.

The Units 1&2 curtain wall extends down to El. 0.6 m (2.0 ft; 2 feet above the mean low water level). The traveling water screens are located just downstream from the curtain wall.

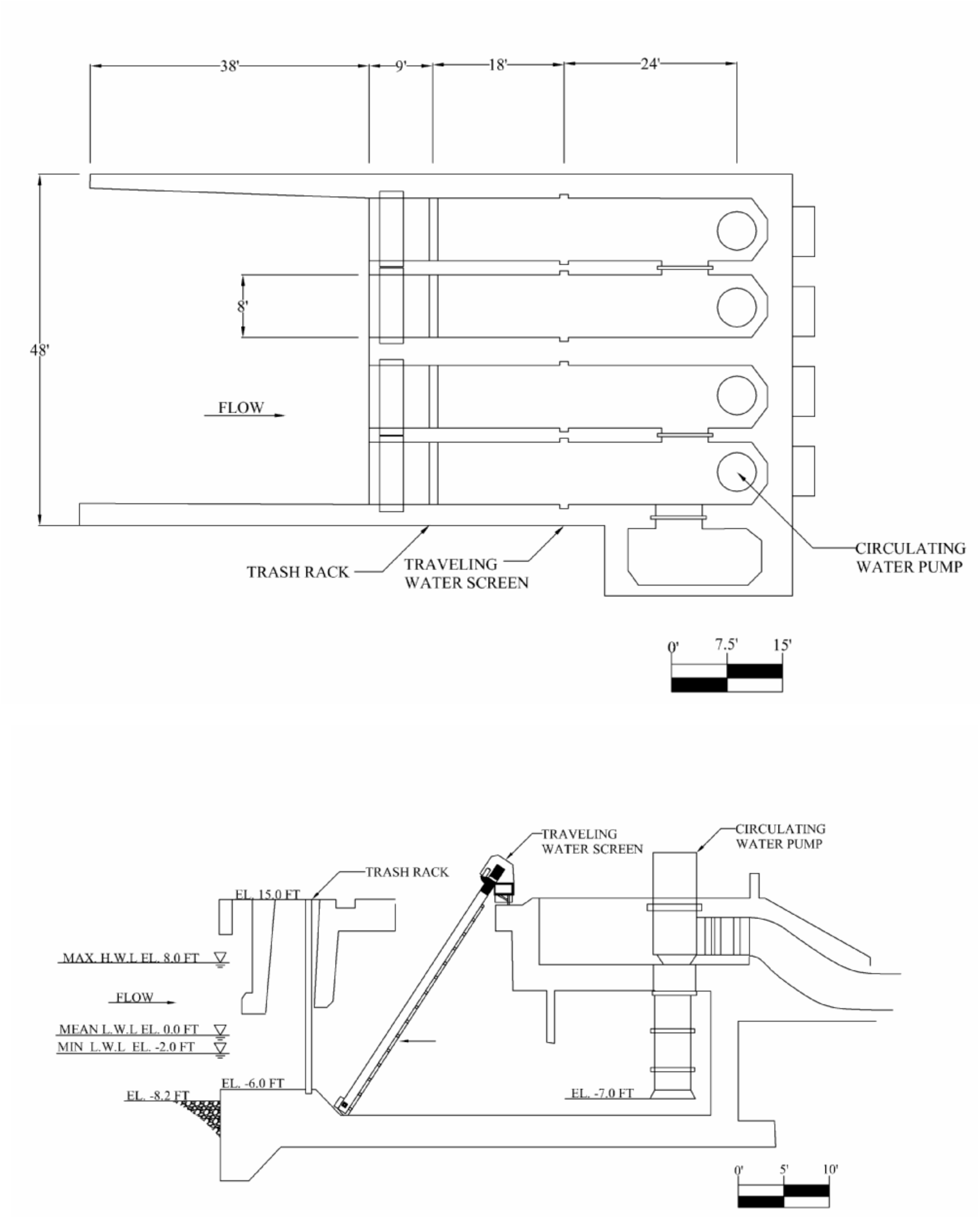


Figure 3.2-2. Units 1&2 intake structure: plan view and typical cross section. (Metric measurement units not included.)

The traveling water screens for Units 1&2 were designed by Farm Pump and Irrigation (F.P.I). These screens are angled at 33.3° from vertical and there are no individual screen baskets (Figure 3.2-3). The wire screen belt material is a continuous mesh loop that allows for the new screens to have a slimmer profile than standard traveling water screens while providing a greater screening area. The F.P.I. screens are 2.47 m (8.1 ft) wide and fit into a 2.50 m (8.2 ft) wide screen bay. The screen mesh is a multi-layer balanced wire mesh belt made out of 12 gage wire with 24 wire loops per foot wide and 20 cross rods per foot length (24-20-12). This results in a 68% open area through the mesh with a 12.7 mm (0.5 in) long and 19.1 mm (0.75 in) wide (maximum) openings. The screens can be operated either manually or in automatic mode. In automatic mode, the screens are rotated at 2.3 m/min (7.6 ft/min) when there is a 20.3 cm (8 in) differential across the screens. When the pressure differential reaches 15.2 cm (6 in), the screens stop. Screens are cleaned with a backwash system that uses 85–90 pounds per square inch gage (psig) of water. Fish and debris removed from the screens are deposited in a dumpster, hauled from the site, and disposed.

Figure 3.2-3. F.P.I. traveling water screens at the AGS.

Downstream of each traveling water screen is a circulating water pump; the pumps are Allis-Chalmers, vertical-stage, propeller type pumps. Each pump has a capacity of 136.3 m^3 per minute (36,000 gpm), providing a total unit flow of 272.5 m^3 per minute (72,000 gpm), and a total maximum flow through the Units 1&2 CWIS of 545.1 m^3 per minute (144,000 gpm). All water directed through the Units 1&2

cooling water system is subsequently discharged through a common 2.4-m (8-ft) diameter discharge conduit that terminates on the side slope of the lower San Gabriel River flood control channel.

The cooling water system was previously heat treated as needed to prevent condenser biofouling; however, this has not been performed in several years. Each cooling water pipeline is usually injected with liquid chlorine for 10 minutes per day per shift. Chlorine levels in the discharge water are kept within the limits of the NPDES permit.

3.2.2 Units 3&4 CWIS

The CWIS for Units 3&4 is located in the north intake canal, as depicted in Figure 3.2-1. This canal also supplies water to the Units 1&2 CWIS. The Units 3&4 CWIS has four intake bays—-two for each unit—and each bay is 2.7 m (9.0 ft) wide. (Figure 3.2-4). The invert of these bays ranges from El. -4.3 m (-14.0 ft) to El. 3.7 m (12.0 ft) at the top deck elevation (re: MSL) (Figure 3.2-4). To prevent debris from passing through the intake bays and damaging the circulating water pumps, each bay has a curtain wall and a traveling water screen; trash racks are not utilized at Units 3&4. The Units 3&4 curtain wall extends down to El. -1.2 m (-4.0 ft).

The traveling water screens for Units 3&4 were designed by F.P.I. These screens are angled at 34° from vertical and there are no individual screen baskets. The mesh has the same characteristics as that used at Units 1&2. The F.P.I. screens at Units 3&4 are 2.4 m (8 ft) wide, and can be operated either manually or in automatic mode. In automatic mode, the screens are rotated at 2.1 m/min (7.0 ft/min) when there is a 20.3 cm (8 in) differential across the screens. When the pressure differential reaches 15.2 cm (6 in), the screens stop. Screens are cleaned with a backwash system that uses 85–90 psig of water. Fish and debris removed from the screens are deposited in a dumpster, hauled from the site, and disposed.

Downstream of each traveling water screen is a circulating water pump; the pumps are horizontal, dry-pit pumps. Each pump has a capacity of 257.4 m^3 per minute (68,000 gpm), providing a total unit flow of 514.8 m^3 per minute (136,000 gpm), and a total maximum flow through the Units 3&4 CWIS of 1,029.6 m^3 per minute (272,000 gpm). All water directed through the Units 3&4 cooling water system is subsequently discharged through a common 3.4-m (11-ft) diameter discharge conduit that terminates on the side slope of the lower San Gabriel River flood control channel.

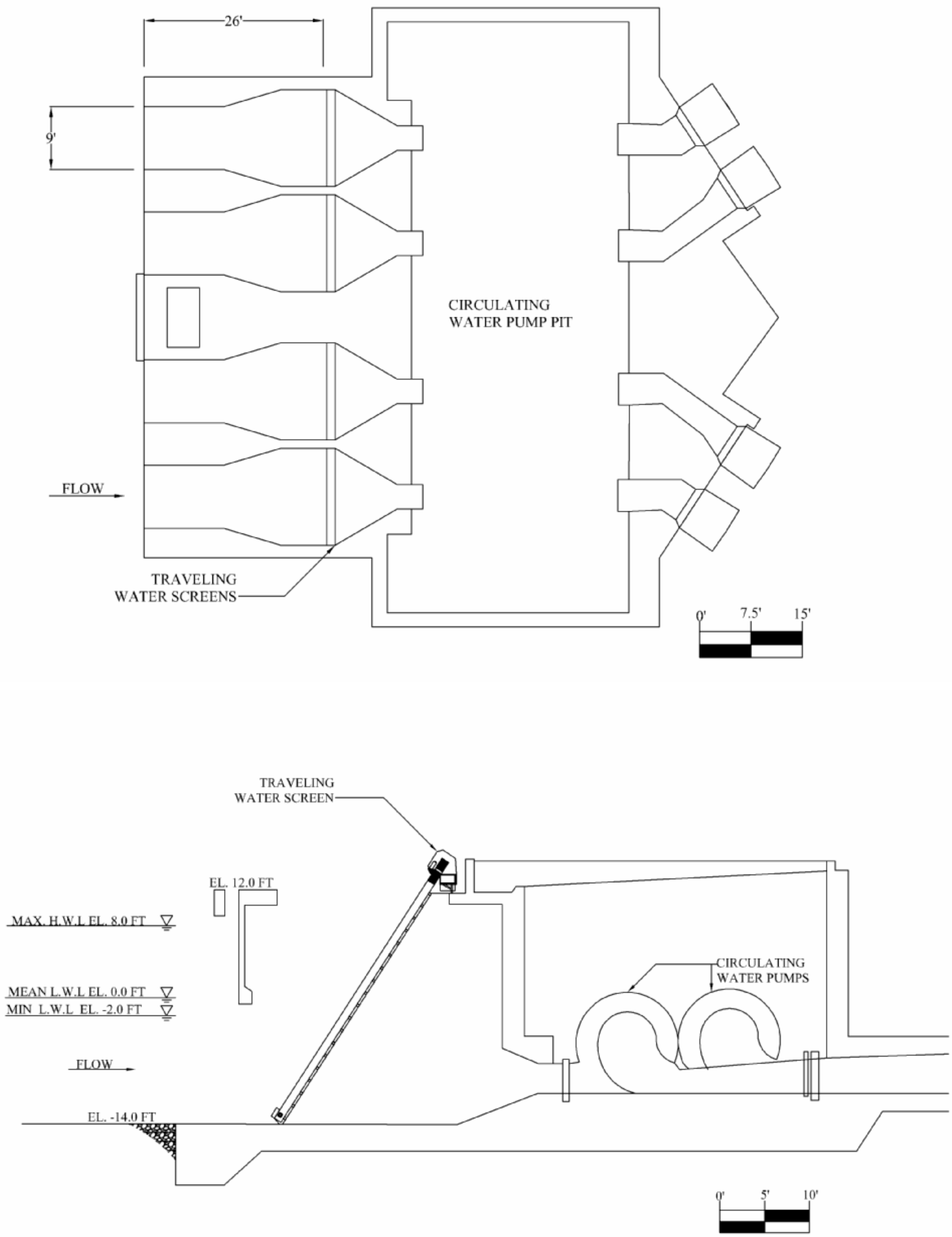


Figure 3.2-4. Units 3&4 intake structure: plan view and typical cross section. (Metric measurement units not included.)

The cooling water system used to be heat treated as needed to prevent condenser biofouling; however, this has not been performed in several years. Each cooling water pipeline is usually injected with liquid chlorine for 10 minutes per day per shift. Chlorine levels in the discharge water are kept within the limits of the NPDES permit.

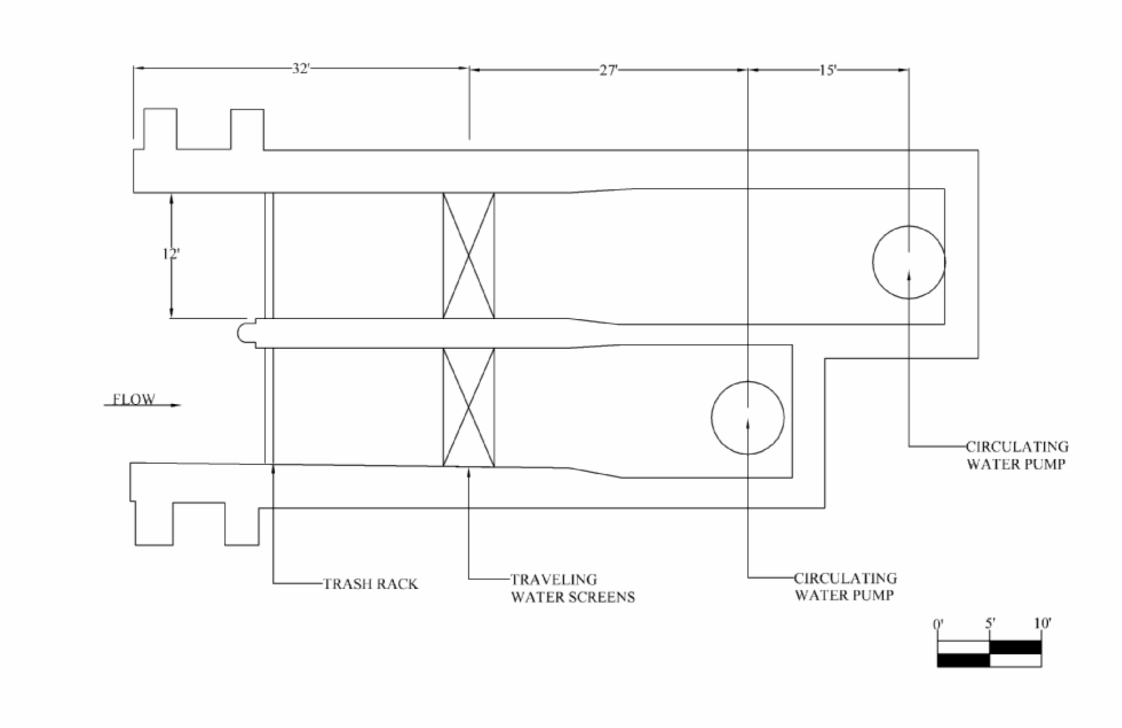
3.2.3 Units 5&6 CWIS

Units 5&6 each have a separate CWIS; however, the structures are mirror images of each other. The cooling water structures for Units 5&6 are located in the south intake canal, as depicted in Figure 3.2-1. Each of the CWISs has two intake bays equipped with a trash rack, a vertical traveling water screen, and a circulating water pump (Figure 3.2-5). The invert of these bays ranges from El. -6.1 m (-20.0 ft) to El. 3.4 m (11.0 ft) at the top deck elevation (Figure 3.2-5). To prevent debris from passing through the intake bays and damaging the circulating water pumps, each bay has a trash rack and a traveling water screen; curtain walls are not utilized at Units 5&6. The trash rack bars have 7.6-cm (3-in) spacing. The traveling water screens are located 6.2 m (20.5 ft) downstream from the bottom of the trash racks.

The traveling screens are standard, vertical, traveling water screens with 0.6 m (2 ft) high and 3.1 m (10 ft) wide screen panels. The screen mesh is constructed out of 15.9-mm (5/8-in) woven wire mesh. The screens rotate automatically when there is a 22.9 cm (9 in) differential pressure on the screens, or they can also be rotated manually. The screens are designed to handle a 2.7 m (9 ft) differential. The screens are cleaned by a frontal wash system, which provides 5.7 m^3 per minute (1,500 gpm) of wash water at 100 psi. There are two screenwash pumps per CWIS, but only one is needed to provide the wash water. The screenwash water is withdrawn from the circulating water pump discharges and therefore does not add to the flow of the CWIS. Fish and debris removed from the screens are disposed of in dumpsters.

Downstream of each traveling water screen is a circulating water pump; the pumps are centrifugal, mixed-flow pumps. Each pump has a capacity of 442.9 m^3 per minute (117,000 gpm), providing a total unit flow of 885.7 m^3 per minute (234,000 gpm), and a total maximum flow through Units 5&6 combined of 1,771.4 m^3 per minute (468,000 gpm). All water directed through the Units 5 and 6 cooling water systems is subsequently discharged through a common 2.4 m (8 ft) diameter discharge conduit that terminates on the side slope of the lower San Gabriel River flood control channel.

The cooling water system used to be heat treated as needed to prevent condenser biofouling; however, this has not been performed in several years. Each cooling water pipeline is usually injected with liquid chlorine for 10 minutes per day per shift. Chlorine levels in the discharge water are kept within the limits of the NPDES permit.



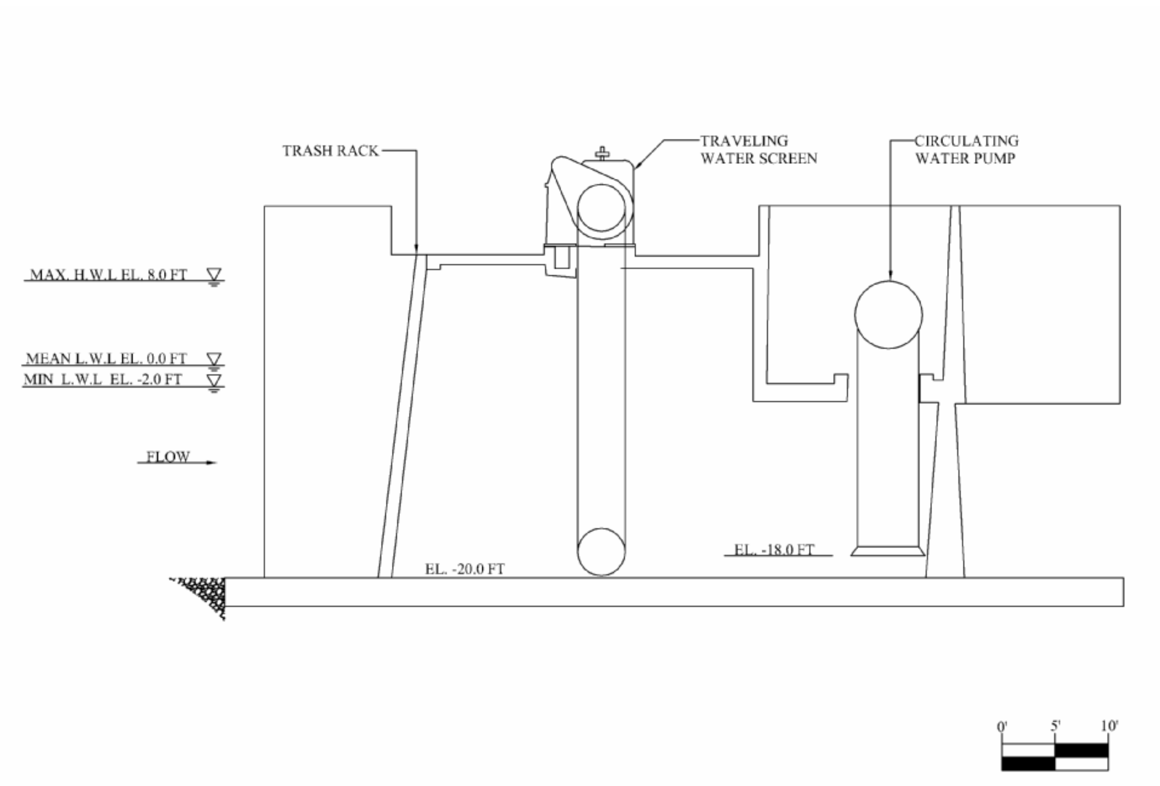


Figure 3.2-5. Unit 5 intake structure: plan view and typical cross section. (Unit 6 is a mirror image of Unit 5. Metric measurement units not included.)

3.2.4 Circulating Water Pump Flows

The AGS CWISs withdraw a maximum of 4,818,678 m^3 per day (1,272.96 mgd) of cooling water from the Los Cerritos Channel. The channel is about 27 m (87 ft) wide at the base and 32.6 m (107 ft) wide at the top, with an average depth of about 3 m (10 ft). The channel watershed is about 65 km^2 (25 mi^2) and highly urbanized.

Daily cooling water flow volumes at the AGS during 2006-7 are depicted in Figures 3.2-6 and 3.2-7. At Units 3&4, the cooling water system operated for most of the study year, with peak operations in spring and summer 2006. At Units 1&2, cooling water flows were intermittent throughout the year, with the main periods of operation between March and July 2006. At Units 5&6 the cooling water systems operated primarily between April and October 2006, with intermittent flows during other times of the year. From January 1, 2006 to January 31, 2007, daily cooling water flow averaged 17.6% of maximum at Units 1&2, 56.1% at Units 3&4, and 26.0% at Units 5&6. Overall, the AGS withdrew 33.8% of the maximum permitted cooling water flow at all units between January 1, 2006 and January 31, 2007.

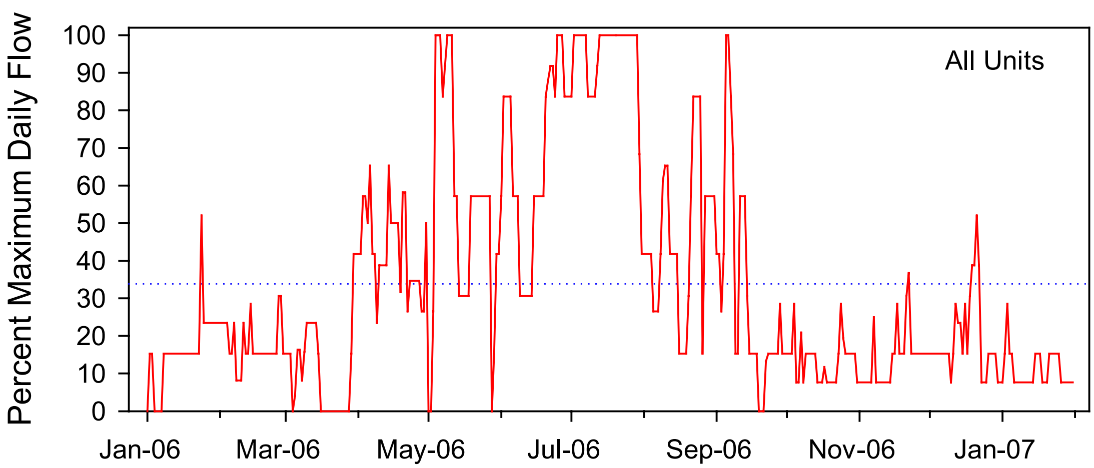


Figure 3.2-6. Daily cooling water flow volumes at the AGS (all units combined) from January 2006 to February 2007. Dotted line is the average daily flow during the analysis period (33.8%).

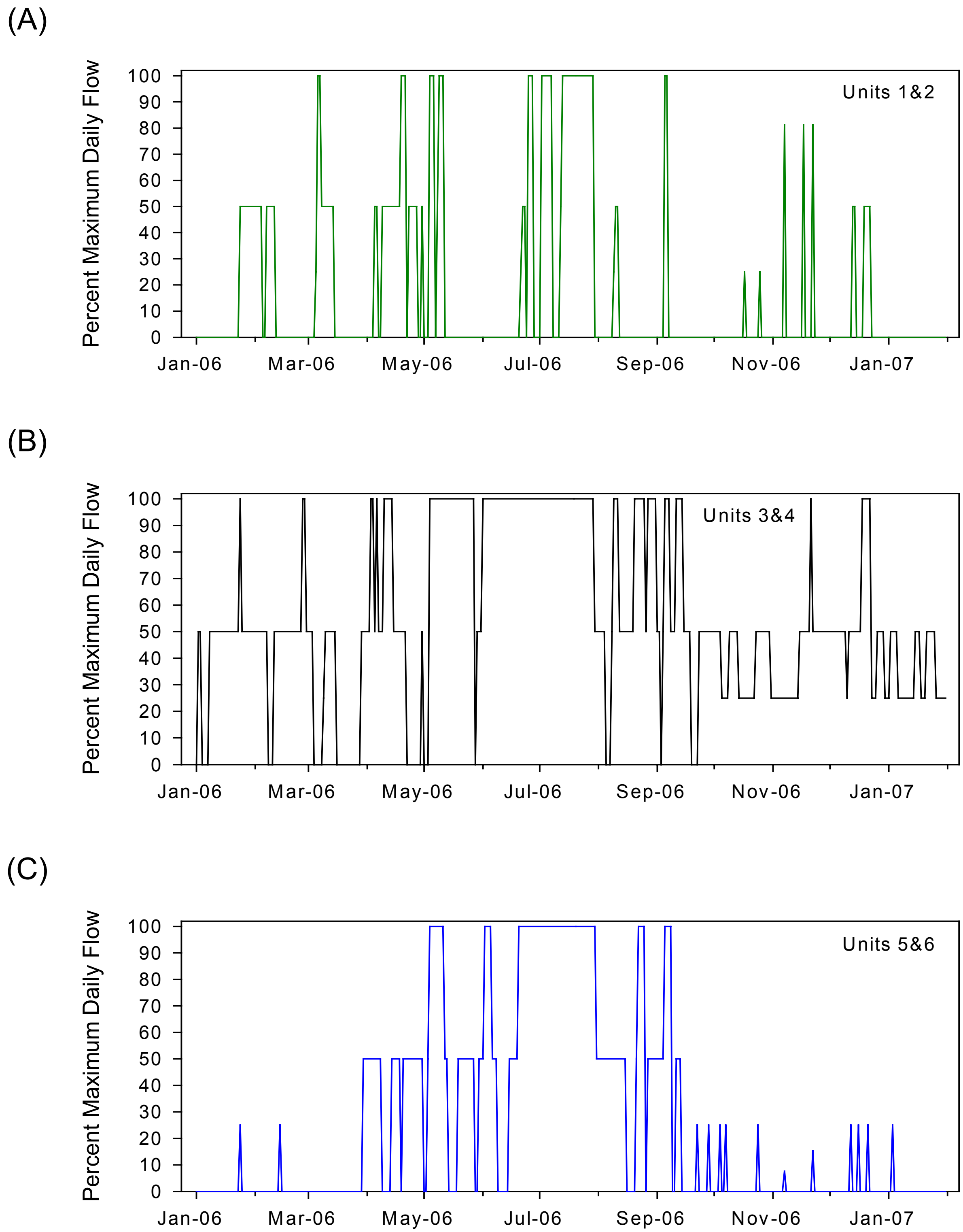


Figure 3.2-7. Daily cooling water flow volumes at the AGS from January 2006 to February 2007. (A) Units 1&2, (B) Units 3&4, and (C) Unit 5&6.

3.3 ENVIRONMENTAL SETTING

The following section describes the physical and biological environments in the vicinity of the AGS. The AGS withdraws cooling water from Los Cerritos Channel and Alamitos Bay, which is hydraulically connected to San Pedro Bay. Cooling water is discharged into the lower San Gabriel River flood control channel at points adjacent to the generating station.

3.3.1 Physical Description

Alamitos Bay is a man-made, small-vessel harbor that was constructed at the mouth of the San Gabriel River (Figure 3.3-1). It was once an estuary with tidal marshes and mud flats. It is relatively shallow with water depths throughout most of the Bay between 3.6 and 5.5 m (12 and 18 ft). The bay is exposed to semidiurnal tides with a mean range of 1.1 m (3.6 ft). Sediments within the Bay consist of sand, silt, and clay. Eelgrass (*Zostera marina*) is present at locations near the entrance channel, near the west end of Naples Island, and in the Marine Stadium arm of the Bay (Valle et al. 1999).

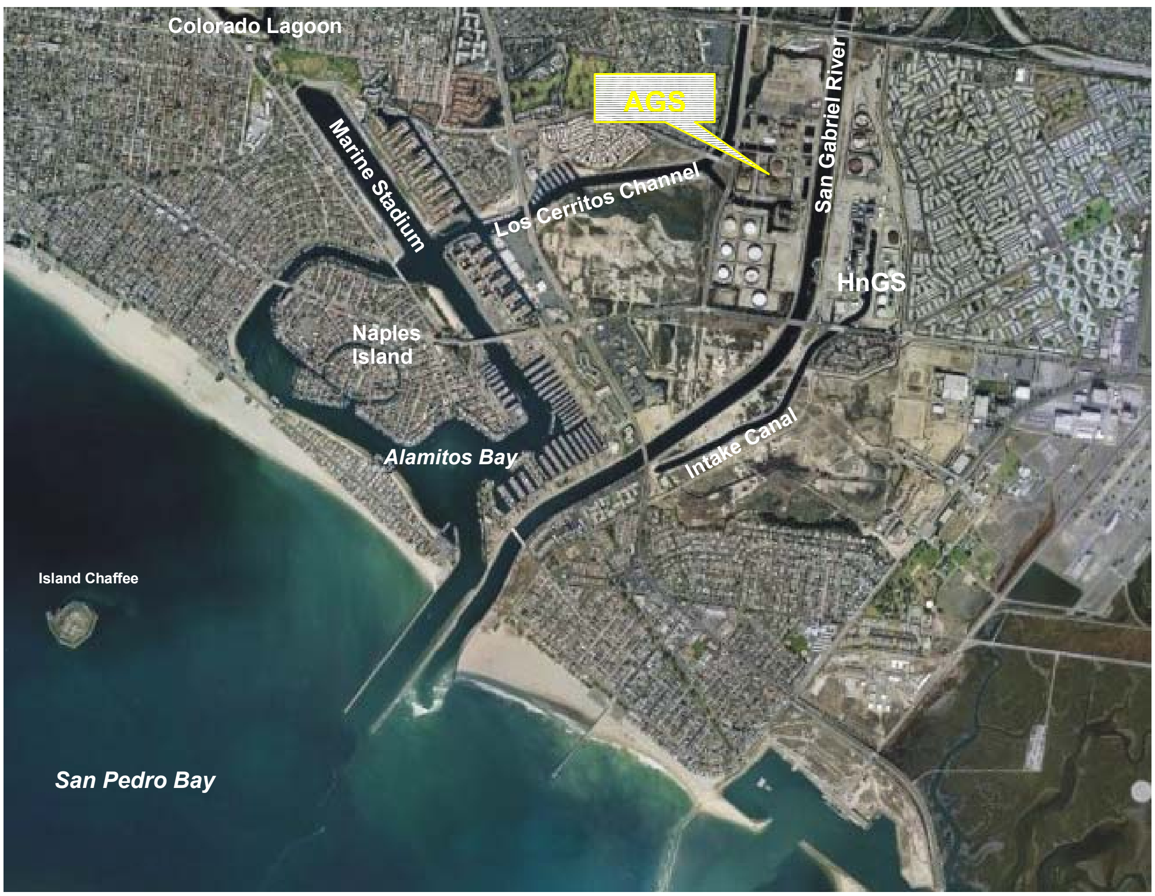


Figure 3.3-1. Aerial view of Alamitos Bay and San Gabriel River outlet vicinity.

The lower San Gabriel River empties into San Pedro Bay just downcoast, and adjacent to, the Alamitos Bay entrance jetty. The River originates in the San Gabriel Mountains, and historically flowed through to the Los Angeles River. In 1867, flooding altered the River's course, causing it to empty into Alamitos Bay. Catastrophic flooding in 1914 prompted flood protection measures on a basin-wide scale. During the 1920s, 1930s, and 1940s, several rivers, including the San Gabriel, were substantially dammed and channelized to prevent flooding and allow basin recharging. After this, most of the flow in the San Gabriel reduced the freshwater flow to the point that significant amounts of fresh water occurred in the lower reaches only during periods of rainfall.

3.3.1.1 Physical Features

Alamitos Bay has a surface area of approximately 1.2 km^2 (285 acres) (CSWRCB et al. 1998). Prominent features within Alamitos Bay include Naples Island, which is a marshland constructed of material dredged from the bay in 1908 and 1909 (Reish and Winter 1954), and Colorado Lagoon, which is a manmade tidal lagoon that receives sea water from an inlet that is connected to Marine Stadium and Alamitos Bay. Marine Stadium originally consisted of tidal flats and marshlands, and was dredged for rowing events for the 1932 U.S. Olympics (Reish and Winter 1954). Marinas within Alamitos Bay provide approximately 4,000 slips for boats.

Los Cerritos Channel is a flood control channel that connects with Alamitos Bay through the Marine Stadium. The tidal prism extends from Alamitos Bay to Anaheim Road. The channel is listed on the U.S. EPA 303(d) list of impaired water bodies by the LARWQCB due to elevated ammonia, phthalate, chlordane, several metals, coliform bacteria, and trash, all originating as non-point source pollution or from unknown sources (LARWQCB 2007). The AGS withdraws cooling water from Los Cerritos Channel via two rock-lined canals. The Los Cerritos Wetlands are located at the point where Los Cerritos Channel joins Alamitos Bay. The wetlands currently consist of about 0.5 wetland km^2 (130 wetland acres), with nearly 3.2 wetland km^2 (800 acres) of degraded habitat proposed for restoration. Historically the wetlands consisted of about 9.7 km^2 (2,400 acres) and included what is now Alamitos Bay. Since much of the site was modified due to former oil development activities, most of the land was privately held. In 2006, the California Coastal Conservancy was one of several agencies that purchased 0.3 km^2 (66 acres) of the wetlands, and hopes to acquire more.

Four oil production islands (Islands Grissom, Chaffee, Freeman, and White)—each 0.04 to 0.05 km^2 (10 to 12 acres) in size—are located just upcoast from the entrance to Alamitos Bay. The islands are constructed of large boulders and sand, and the drilling rigs are camouflaged and soundproofed. More than 1,200 wells have been drilled on the four islands. Platform Esther, an oil drilling platform, is located approximately 2 km (1.2 mi) southeast from the entrance of Alamitos Bay in approximately 12 m (39 ft) of water. Another drilling platform, Belmont Island, was formerly located off the entrance to Alamitos Bay in 14 m (46 ft) of water. It was decommissioned and removed between 2000 and 2002.

3.3.1.1.1 Climate and Weather

Southern California lies in a climatic regime defined as Mediterranean, characterized by mild winters and warm, dry summers. In Long Beach, coolest temperatures generally occur from December through February, with warmest temperatures in August and September (Weather Underground 2007). Average temperatures range from 8 to 28°C (46 to 83°F) (City of Long Beach 2007). Average annual precipitation in the coastal regions ranges between 25 and 38 cm (10 and 15 inches), with most precipitation occurring from October through April.

A subtropical high-pressure system offshore the Southern California Bight (SCB) produces a net weak southerly/onshore flow in the area (Dailey et al. 1993). Wind speeds are usually moderate, and are on the order of 10 km/hr (6.2 mph). Wind speeds diminish with proximity to the coast, averaging about one-half the speeds offshore. Coastal winds in southern California are about one-half those found off central and northern California. However, strong winds occasionally accompany the passage of a storm. A diurnal land breeze is typical, particularly during summer, when a thermal low forms over the deserts to the east of the Los Angeles area. On occasion, a high-pressure area develops over the Great Basin, reversing the surface pressure gradient and resulting in strong, dry, gusty offshore winds in the coastal areas. These Santa Ana winds are most common in late summer, but can occur any time of year.

3.3.1.2 Temperature and Salinity

Waters within Alamitos Bay are primarily marine (30–35 practical salinity units [PSU]) with water temperatures ranging from about 13°C (55°F) in winter to 25°C (77°F) in summer (Allen and Horn 1975; IRC 1981). The bay has undergone extensive changes in the last 100 years. Originally an estuary and wetland system, it is now highly developed.

The temperature and salinity of the waters offshore Alamitos Bay have been measured semiannually or annually for many years as part of the AGS NPDES monitoring program (Table 3.3-1). The monitoring program consists of 9 stations in the nearshore waters off Alamitos Bay and the mouth of the San Gabriel River flood control channel, from depths of 3.6 to 12.2 m (12 to 40 ft). Three additional stations are monitored within the San Gabriel River. From 2000 through 2004, all stations were sampled during both ebb and flood tides during five winter surveys and five summer surveys. Salinity is not a required monitoring component but results have been measured and reported since 2001.

Table 3.3-1. Temperature and salinity of surface and bottom waters off Alamitos Bay, 2001–2004.

Season	Parameter	Surface	Bottom
Winter	Minimum temperature °C (°F)	14.5 (58.2)	13.5 (56.3)
	Average temperature °C (°F)	16.7 (62.1)	14.6 (58.3)
	Maximum temperature °C (°F)	23.5 (74.2)	16.6 (61.9)
Summer	Minimum temperature °C (°F)	18.5 (65.3)	13.9 (57.1)
	Average temperature °C (°F)	21.3 (70.4)	18.1 (64.6)
	Maximum temperature °C (°F)	27.4 (81.3)	21.8 (71.2)
Winter	Minimum salinity (PSU)	28.8	32.4
	Average salinity (PSU)	32.1	33.2
	Maximum salinity (PSU)	33.4	33.6
Summer	Minimum salinity (PSU)	32.3	33.2
	Average salinity (PSU)	33.2	33.5
	Maximum salinity (PSU)	33.6	33.9

In general, temperatures in the study area are usually several degrees warmer in summer than in winter, with bottom waters consistently colder than surface waters. Temperatures throughout the water column in the study area are usually warmest in the afternoon due to solar heating, and the formation of a thermocline is especially common during summer, though thermoclines may also develop in winter. Salinity in the study area is relatively uniform, ranging from 28.8 to 33.9 practical salinity units (PSU), typical for nearshore waters of southern California. Salinity is usually slightly higher near bottom than at the surface. Lowest salinity typically occurs directly offshore the mouth of the San Gabriel River.

Additional water quality monitoring was performed at the AGS intake canals during spring and summer (April–June) 2004 (MBC 2005). Water temperatures at the surface and a depth of one meter ranged from about 19.5°C (67.1°F) to 22.0°C (71.6°F) during sampling, with little or no difference between the two depths. Salinity consistently ranged between 33.2 and 34.8 PSU.

3.3.1.3 Tides and Currents

Astronomical tides in southern California are classified as mixed, semi-diurnal, with two unequal high tides (high water and higher high water) and two unequal low tides (low water and lower low water) each lunar day (approximately 24.5 hr). Between 1997 and 2002, water level extremes in Outer Los Angeles Harbor ranged from –0.6 m to +2.35 m (–1.97 ft to + 7.71 ft) above Mean Lower Low Water (MLLW). The tidal prism of Alamitos Bay (defined as the body of water contained within the mean tidal range) is approximately 1.96 x 10^6 m^3 (517.8 million gallons) (IRC 1981).

3.3.1.3.1 Historical Overview

Detailed circulation studies were performed within Alamitos Bay and the nearshore areas of San Pedro Bay during the original 316(b) study conducted at the Haynes Generating Station (HnGS) (IRC 1981). Waters drawn into the Bay become progressively better mixed as they are drawn toward the inner reaches where the cooling water intakes are located. This is the opposite of what would normally occur in back bay areas, which normally have the poorest flushing and longest retention times. IRC (1981) determined that cooling water withdrawals due to HnGS and AGS induce a net transport into the bay, with the mean residence time of water estimated at about one day.

At the entrance to Alamitos Bay, currents are bi-directional, with a strong bias toward in-flowing over out-flowing currents, and speeds ranging to about 40 centimeters per second (cm/s) (1.4 feet per second [ft/s]) (IRC 1981). Current speeds diminish in mid-bay, with most current speeds less than 20 cm/s (0.7 ft/s).

Recirculation of discharged cooling water at HnGS (from the San Gabriel River back to the intake structure in Alamitos Bay) was estimated to be about 4%. This relatively low value was attributed to predominant downcoast currents which transport discharged waters away from Alamitos Bay. It was concluded that *"…very little of the water entrained into the Haynes Generating Station resided within Alamitos Bay more than five days.*" Due to the predominant downcoast water movement outside Alamitos Bay, the immediate oceanic source waters for Alamitos Bay were determined to lie in the northern lees of the Long Beach and Middle Breakwaters (Outer Long Beach Harbor), with minor amounts derived from downcoast between Alamitos and Anaheim Bays. Downcoast flow off Alamitos Bay averaged about 1.6 cm/s (0.05 ft/s), or about 1.5 km/day (0.9 miles/day) (IRC 1981).

Circulation patterns in the Ports of Los Angeles and Long Beach, which are part of the greater source water area for AGS, were described in a study of suspended sediment transport in the Harbor region (LARCSTF 2005). The ports are protected from incoming waves by the Federal Breakwater, which consists of three individual rock jetty structures. In addition to protecting the ports from waves, the Federal Breakwater reduces the exchange of the water between the harbor and the rest of San Pedro Bay, hence creating unique tidal circulation patterns.

Maximum flood and ebb current patterns in the Ports of Los Angeles and Long Beach under typical tidal conditions are shown in Figure 3.3-2. The tidal currents shown in the figures were predicted by a depth-averaged two- dimensional hydrodynamic model RMA2 developed by the US Army Corps of Engineers. The model was calibrated against field data collected by NOAA at the Port of Long Beach, as well as against a more sophisticated three-dimensional model. On the Long Beach side nearest Alamitos Bay and AGS, flood currents enter the harbor through the Queen's Gate as well as the opening near the eastern tip of the Federal Breakwater. Flood currents passing through Queen's Gate flow to either side of Pier J.

During ebb tide the flow in the harbor is drawn from all directions as a potential flow toward the exits. Ebb currents leaving the Los Angeles Harbor flow mainly through the Angel's Gate. On the Long Beach side, ebb currents exit either through the Queen's Gate or the eastern opening passing the tip of the Federal Breakwater. Tidal currents within the Ports of Los Angeles and Long Beach are generally very small. Typical maximum tidal currents within the harbor are in general less than 0.15 m/s (0.5 ft/s). Tidal currents entering and exiting Angel's Gate and Queen's Gate are higher, but are still in general less than 0.24 m/s (0.8 ft/s). Significant offshore flows from flood control channels such as the San Gabriel River can also occur during winter storms.

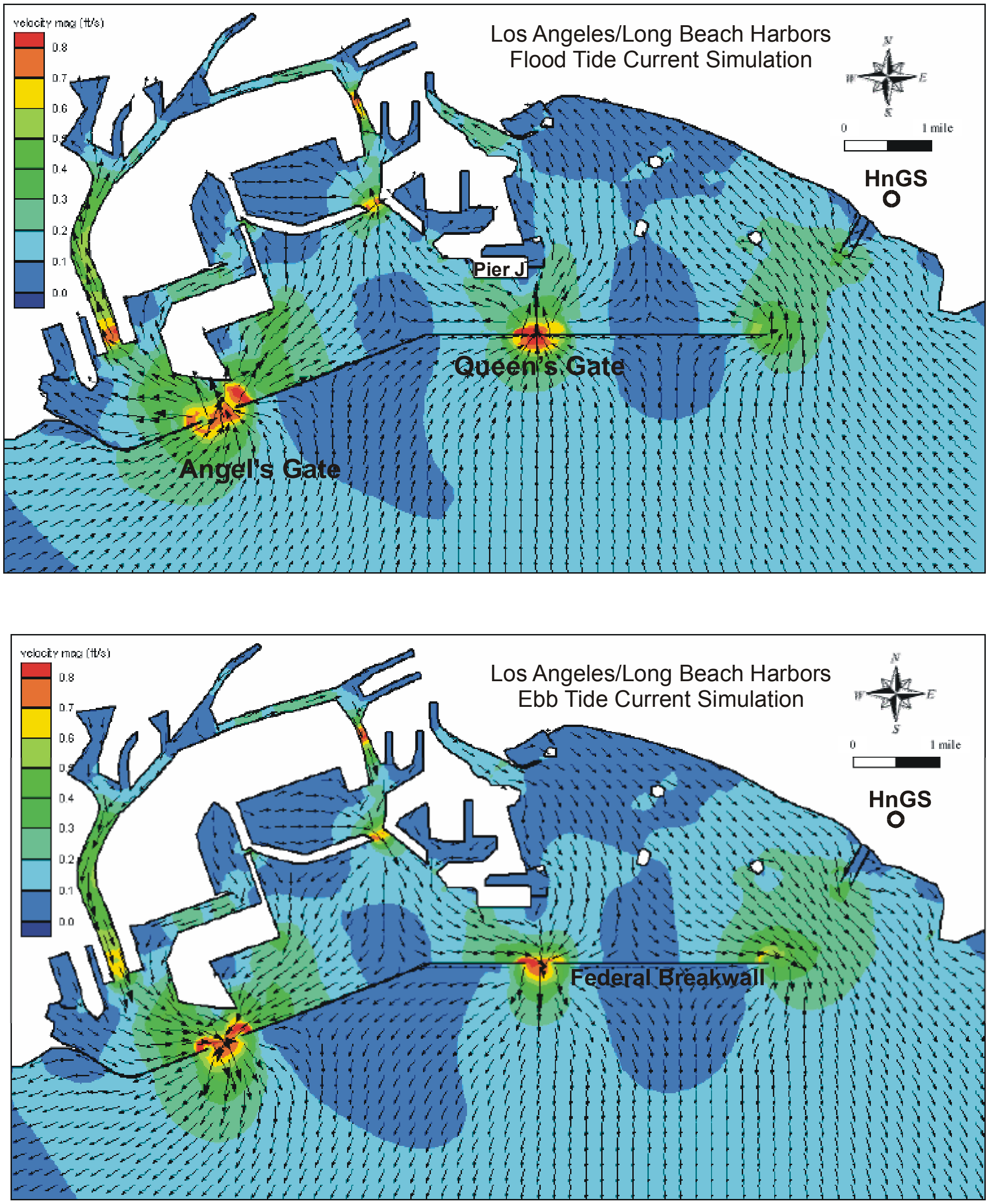


Figure 3.3-2. Current patterns in Los Angeles and Long Beach Harbors predicted by a depth-averaged two-dimensional hydrodynamic model developed by the US Army Corps of Engineers (Figures from Los Angeles RCSTF [2005]).

During ebb tide the flow in the harbor is drawn from all directions as a potential flow toward the exits. Ebb currents leaving the Los Angeles Harbor flow mainly through the Angel's Gate. On the Long Beach side, ebb currents exit either through the Queen's Gate or the eastern opening passing the tip of the

Federal Breakwall. Tidal currents within the Ports of Los Angeles and Long Beach are generally very small. Typical maximum tidal currents within the harbor are in general less than 0.5 ft/s. Tidal currents entering and exiting Angel's Gate and Queen's Gate are higher, but are still in general less than 0.8 ft/s. Significant offshore flows from flood control channels such as the San Gabriel River can also occur during winter storms.

A recently completed study quantified circulation throughout Alamitos Bay (Moffatt & Nichol 2007). The study was prompted by continuously poor water quality (high bacteria counts) at a popular swimming beach and other locations within Alamitos Bay. The study concluded that the cooling water flow rate at the AGS has the most significant effect on circulation within Alamitos Bay since it removes some of the "aging and poor quality water from upstream areas of the Bay and discharges it into the San Gabriel River. Otherwise, the poor-quality water would all circulate downstream past Mother's Beach toward the Haynes intake and the ocean during ebbing tides. This circulation pattern appears to be a possible trigger causing bacteria exceedances at Mother's Beach."

3.3.1.3.2 2006 ADCP Deployments

Physical oceanographic data were collected from the source water body to describe current regimes that can affect larval transport in the vicinity of the AGS. Two Nortek Aquadopp® acoustic Doppler current profilers (ADCPs) were positioned in separate locations, one (CM1) approximately 2.1 km (1.3 mi) from shore off the entrance to Alamitos Bay at a depth of −12.4 m (−40.7 ft) MLLW, and a second unit (CM2) approximately 3.2 km (2.0 mi) from shore off the San Gabriel River mouth at a depth of -16.2 m (−53.1 ft) MLLW (Figure 3.3-3). Both stations were commissioned on January 10, 2006. Station CM2 was decommissioned on January 8, 2007 and Station CM1 was decommissioned on January 11, 2007. Data were downloaded on May 2, 2006 and August 31, 2006. From May 2–5, 2006 Station CM1 did not collect current data due to operational error after the data download. The unit at CM1 had an operating frequency of 1 MHz, while the unit at CM2 had an operating frequency of 600 kHz (Table 3.3-2). Both units collected data at hourly intervals in a usable range that extended from 0.5 m (1.6 ft) from the ADCP to somewhat less than 90% of the distance to the surface. The half-power full beam-width was 2.4 degrees for both types of units. Other measurement specifications are listed in Table 3.3-2. Water temperature and water depth (pressure) were also measured concurrently by the units. Water temperatures were calibrated over an approximate four-month period from September 2006 to January 2007 using two calibrated Starr-Oddi thermistors. Pressure measurements were adjusted using barometric pressure data measured at the Los Angeles International Airport and corrected for sea level.

Table 3.3-2. ADCP deployment parameters for current meters in the vicinity of AGS (Stations CM1 and CM2).

Unit	Oper. Freq.	Deploy depth (m)	Cells (#)	Cell size (m)	Max. range (m)	Cell precision (cm/s)	Ping rate	Averaging Interval (s)	Repetition rate (hr)
CM 1	1 MHZ	12.4	15	1.0	15	0.8	87%	180	1.0
CM 2	600 kHz	16.2	20	1.0	20	1.4	100%	300	1.0

Figure 3.3-3 shows the net displacements at the current meter stations from January 2006 to January 2007 relative to the current meter locations. The net displacement of water at Station CM1 was to the north and to a lesser extent to the east. At Station CM2 net displacement varied east to west and slightly south. The sum of the hourly upcoast components of each current measurement was maximized to estimate a rotation of 39º at Station CM1. This rotation oriented alongshore currents to 321º true. After rotating current velocities and averaging over the water column, plots of cumulative current vectors showed that currents at the inshore station (CM1) moved predominantly in an upcoast and onshore direction during 2006 with few seasonal reversals (Figure 3.3-4). Small-scale changes in net direction may be attributed to tidally induced currents flowing into and out of the Los Angeles-Long Beach Harbor complex. In contrast, currents at Station CM2 located outside of the Long Beach Breakwater and in slightly deeper water than the inshore station displayed frequent upcoast-downcoast reversals (Figure 3.3-5). Net downcoast currents prevailed in January–April 2006 and in October 2006–January 2007, whereas net upcoast transport occurred from May–September 2006 but with frequent reversals during summer months. Over the year net transport was downcoast at CM2. Current vector frequencies, water temperatures and tidal elevation data from the ADCP units are presented in Appendix A as monthly plots for each station. Over the year water depths at CM1 varied from 11.75 m (38.6 ft) to 14.59 m (47.9 ft) with an average of 13.27 m (43.6 ft). At CM2 water depths varied from 15.64 m (51.2 ft) to 18.41 m (60.4 ft) and averaged 17.09 m (56.1 ft).

The extent of source populations of larval organisms was estimated from December 2005 to January 2007 using a combination of cross-shelf and alongshore components from the two stations, and with reproduction of December 2006 and January 2007 data for that missing in December 2005 and early January 2006. A combined plot of data from the two locations using the upcoast-downcoast vector from CM1 and the onshore-offshore vector from CM2 showed a net upcoast transport direction with a slight onshore component (Figure 3.3-6). Estimates of source populations were therefore based on a combination of currents measured at the two stations and also subject to the rotations that were used to estimate alongshore and onshore water excursions.

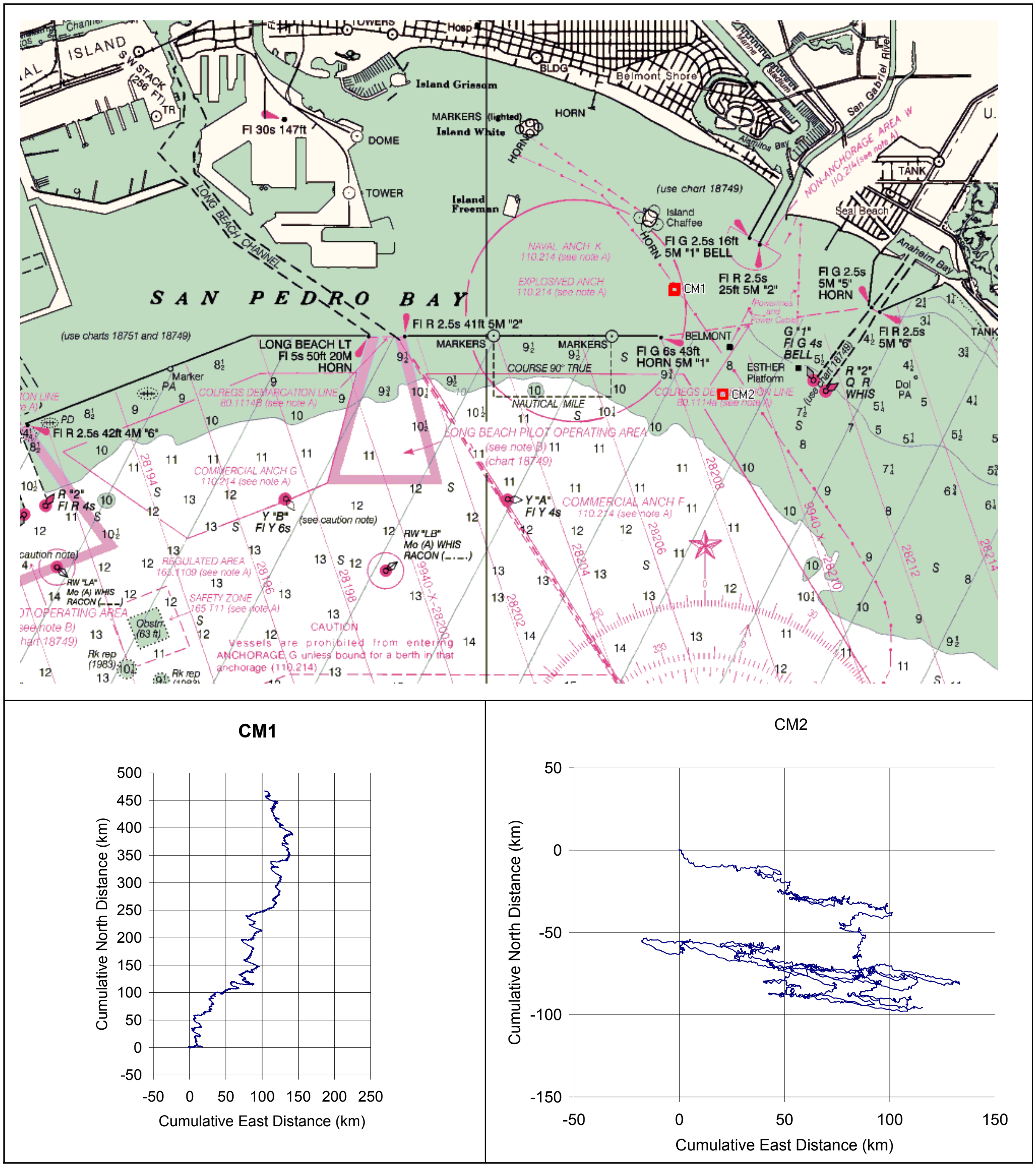


Figure 3.3-3. Net displacement at current meter stations CM1 and CM2 from January 2006 to January 2007.

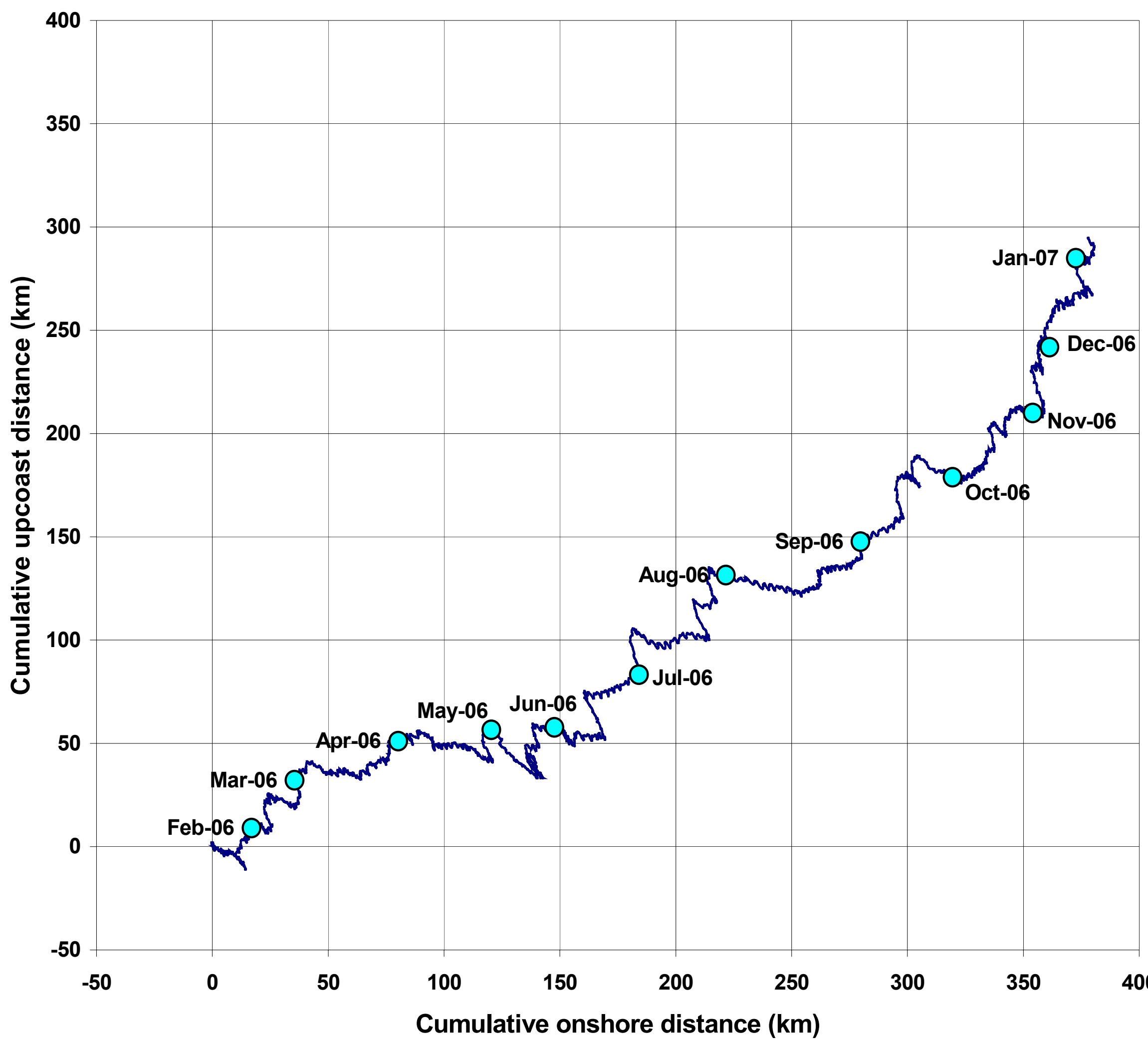


Figure 3.3-4. Cumulative current vectors from Station CM1 in San Pedro Bay from January 2006 to January 2007.

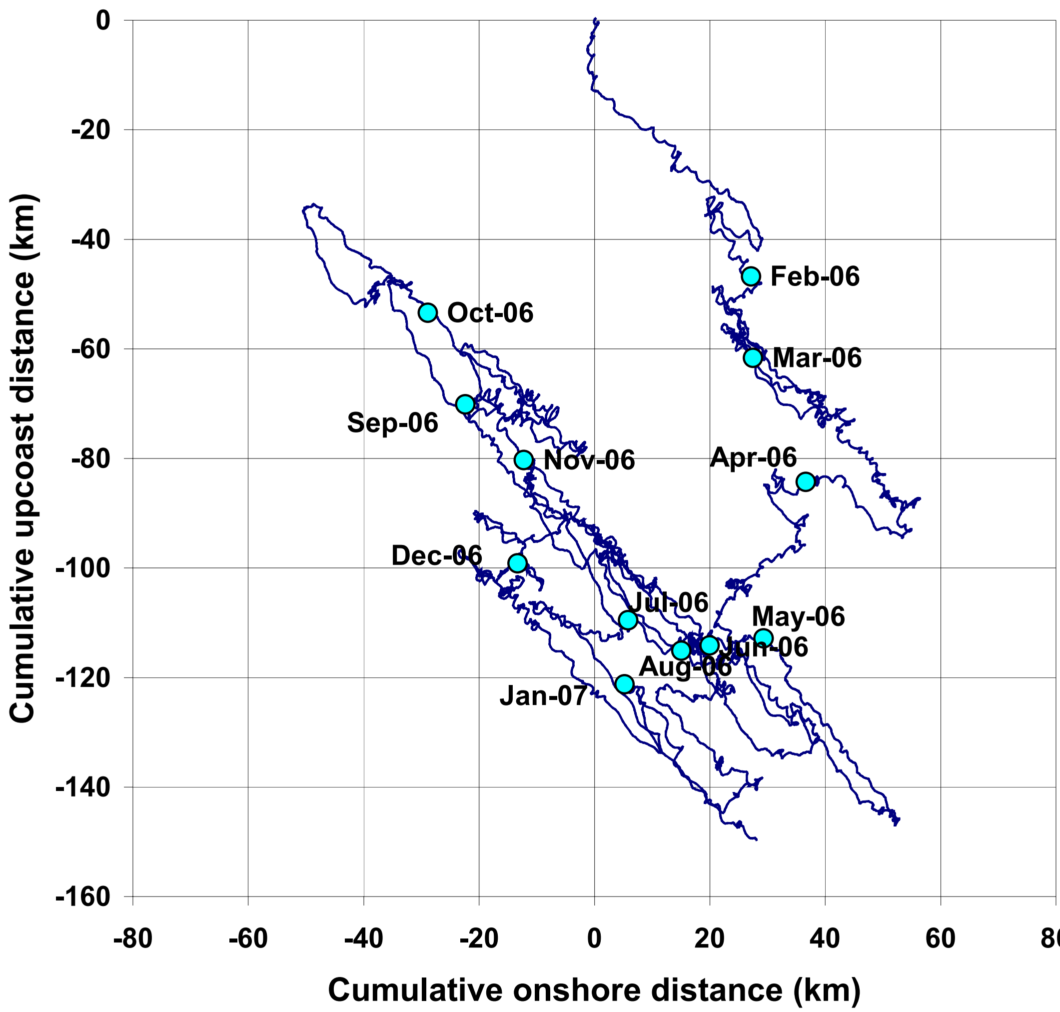
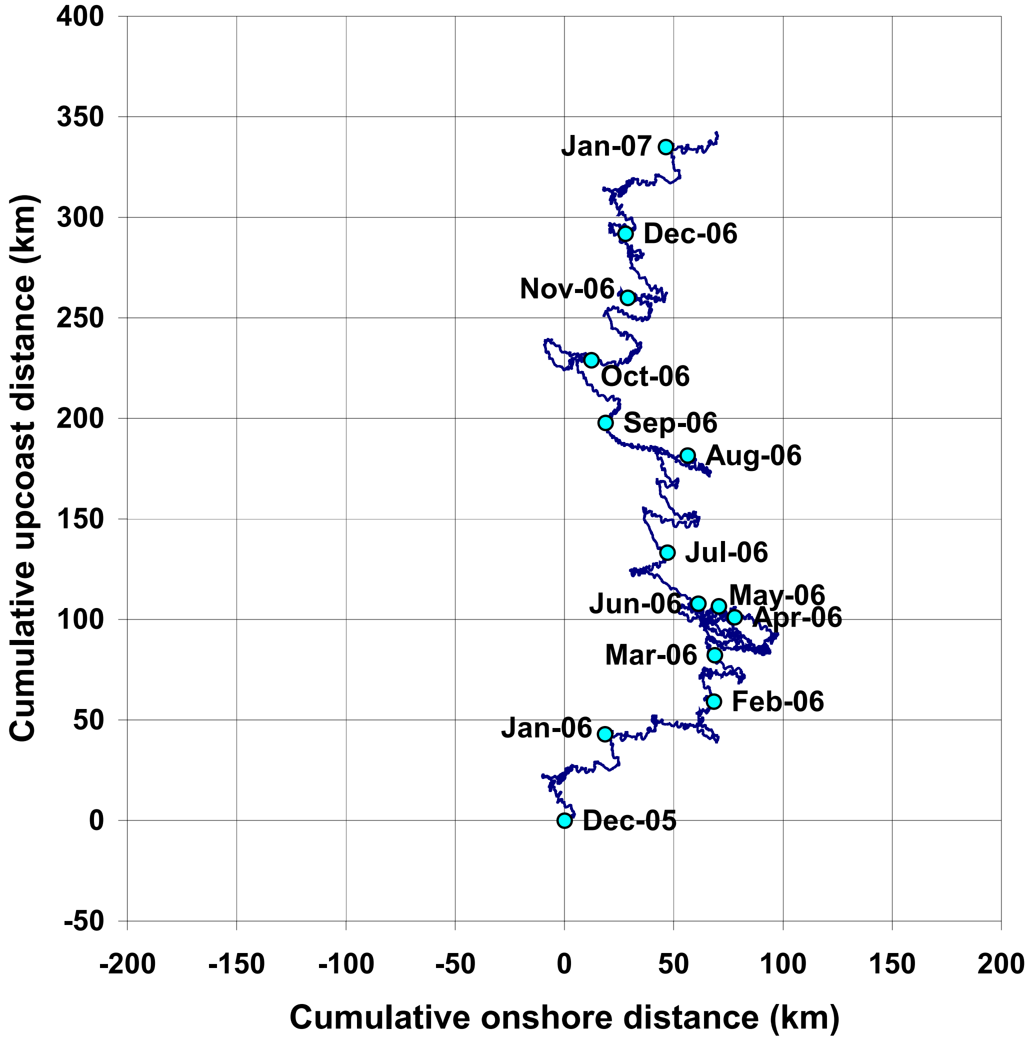


Figure 3.3-5. Cumulative current vectors from Station CM2 in San Pedro Bay from January 2006 to January 2007.



Note: For modeling purposes, data from December 2006 and January 2007 were substituted for the data missing in December 2005 and early January 2006

Figure 3.3-6. Composite cumulative current vectors from Stations CM1 (upcoast) and CM2 (onshore) in San Pedro Bay from January 2006 to January 2007.

3.3.2 Source Water Definition

The source water study area is designed to 1) characterize the larvae of ichthyoplankton and shellfish larvae potentially entrained by the AGS cooling water intakes, and 2) be representative of the nearshore habitats in the vicinity of the AGS intakes.

3.3.2.1 Study Requirements and Rationale

The primary approach used for assessing the effects of entrainment by the AGS required an estimate of the source water population for each species entrained. The spatial extent of the source water population subject to entrainment is a function of larval duration and circulation. Information on larval duration was estimated from data on the length of the larvae collected from the entrainment samples. The spatial extent of the source population for AGS is complicated since three components of the source water can be identified that operate on different time scales relative to the time scale of the period of time that larvae are subject to entrainment. The three source water components are: 1) Los Cerritos Channel and Alamitos Bay where the AGS intakes are located, 2) nearshore coastal water that is transported into Alamitos Bay on incoming tides, and 3) water that is transported out of Alamitos Bay into nearshore coastal waters on outgoing tides. The water volume within Alamitos Bay changes with tidal elevation, which also affects the outflow from Alamitos Bay into nearshore waters and flow into the bay from the nearshore waters. The volume of the source water in the nearshore area, which is potentially subject to entrainment, is affected by weather and sea conditions as well as currents that change seasonally. The rationale and methods for defining the source water for the AGS are described in the following sections.

The estimates of the source water population used in assessing the effects of entrainment were based on sampling that occurred in Alamitos Bay and nearshore areas outside the bay. The volume of the source water within Alamitos Bay is continually changing due to tidal flow. The volume is also affected by flow through the Haynes and Alamitos generating stations from the bay and back out to the ocean through the San Gabriel River. Oceanographic studies associated with the previous 316(b) study showed that the flows from the two plants reduce the residence time of the water in Alamitos Bay to approximately one day (IRC 1981). One of the benefits of this increased flow through the bay is improved water quality. The IRC studies estimated that the cooling water flows annually supply the bay with 45,000 kg (50 tons) additional tons of oxygen relative to the supply provided by natural exchange processes. The sampling inside Alamitos Bay provides an estimate of the larval concentrations subject to entrainment. The larval concentrations of different species were used with an estimate of the volume of the bay at mean sea level (MSL) to calculate the population of larvae potentially subject to entrainment. The same approach was used to estimate the larval populations from the nearshore source water stations (S1-S3 and O1-O3 [Figure 3.3-7]).

3.3.2.2 Methods for Calculating AGS Source Water

Two sources were used in gathering the data necessary for estimating the volume of Alamitos Bay and the nearshore source water stations. The inshore and nearshore bathymetry data were taken from Moffatt & Nichol (2007) and from NOAA electronic navigation chart (ENC) data. Some editing of these data was done to more closely match the depth and elevations derived from NOAA navigation data that included coverage for the entire harbor and associated NOAA charts. NOAA used a number of sources in compiling the ENC data including U.S. Army Corps of Engineers surveys, drawings, and permits, U.S. Coast Guard Local Notices to Mariner, National Imagery and Mapping Agency Notices to Mariners, NOAA hydrographic surveys, and the largest scale paper chart of an area.

To quantify the source water area sampled during the study, depth data points were identified and selected from the source datasets that fell within the water portions of the source water area. This area was identified using a coastline GIS layer created from a USGS topographic quad map at 1:24,000 scale and manually edited in ArcGIS to approximate the available NOAA GIS coastline themes and latest aerial images from Google Earth (March 2004). MLLW depths were adjusted to MSL (shallower by 0.86 m (2.8 ft) per the tide gauge at Station 9410660 Los Angeles, CA). The corrected depth data were merged and exported to a new depth point GIS layer relative to MSL. A 20 m (65.6 ft) surface grid representing the bathymetry relative to MSL was constructed from this new set of combined points resulting in contours at 1 m intervals. The resulting bathymetry surface grids were then converted into a polygon shapefile, clipped to the coastline, boundary of the source water, and used for area and volume calculations.

The Alamitos Bay source water region consisted of an inshore area including the Alamitos Bay waters inshore, northeast of the coastline, and portions of Colorado Lagoon, and Los Cerritos Channel. Another component of the source water is outflow from Alamitos Bay. This is used to account for larvae from Alamitos Bay that are transported into nearshore areas by ebbing tidal currents where they are still subject to entrainment due to subsequent flows back into the bay. This transport occurs on a daily basis and was estimated using hourly changes in bathymetric volumes of the bay as a function of tidal heights, together with estimated power plant flows of both AGS and the HnGS. The tidal heights in Alamitos Bay were estimated using records of the pressure sensor at Station CM1. Changes in atmospheric pressure were corrected using sea level pressure measurements made at the Los Angeles International Airport. Port of Los Angeles Outer Harbor tides were used for the time period between January 1 and January 10, 2006 before deployment of the current meter. Tidal data from Station CM2 were substituted when CM1 was not operating between May 2 and May 5, 2006 and when data were periodically downloaded. Moffatt & Nichol (2004) showed that tidal levels and tide phase at the Marine Stadium part of Alamitos Bay were very similar to those predicted at Los Angeles Outer Harbor. As an example, Figure 3.3-8 shows the correspondence between tidal heights estimated at Station CM1 and Los Angeles Outer Harbor (POLA) for the August 2006 time period. Figure 3.3-9 shows estimates of the daily Alamitos Bay outflows from January through December 2006.

The total volume of Alamitos Bay was calculated as 7,738,746 m^3, and the volume of the nearshore sampling area was calculated as 140,698,222 m^3. The components of the source water were used with the estimates of larval entrainment and AGS CWIS flows to calculate impacts on larval fish populations due to entrainment, as described in Section 4.2.4.2.2—*Data Analysis*: *Empirical Transport Model*.

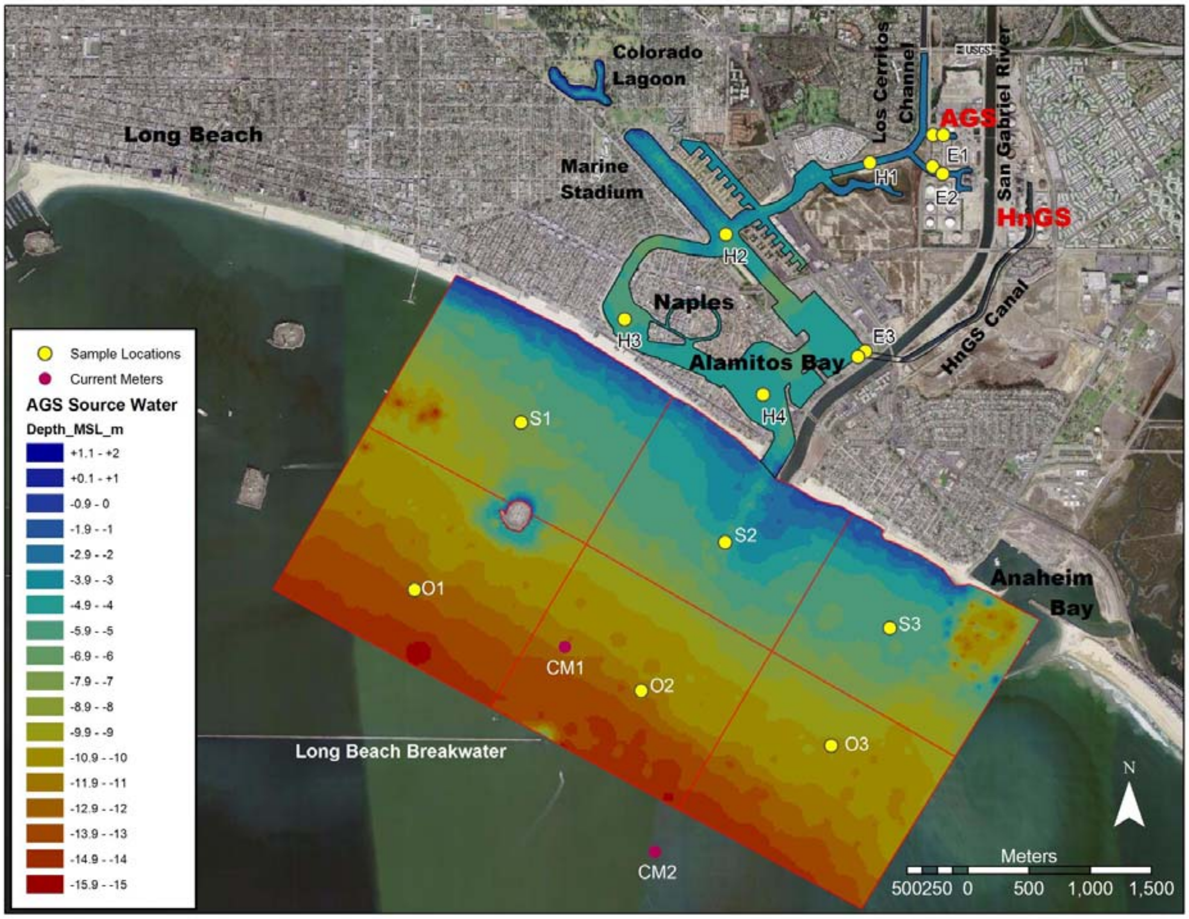


Figure 3.3-7. Source water boundaries and bathymetry defined for ETM modeling effects of AGS.

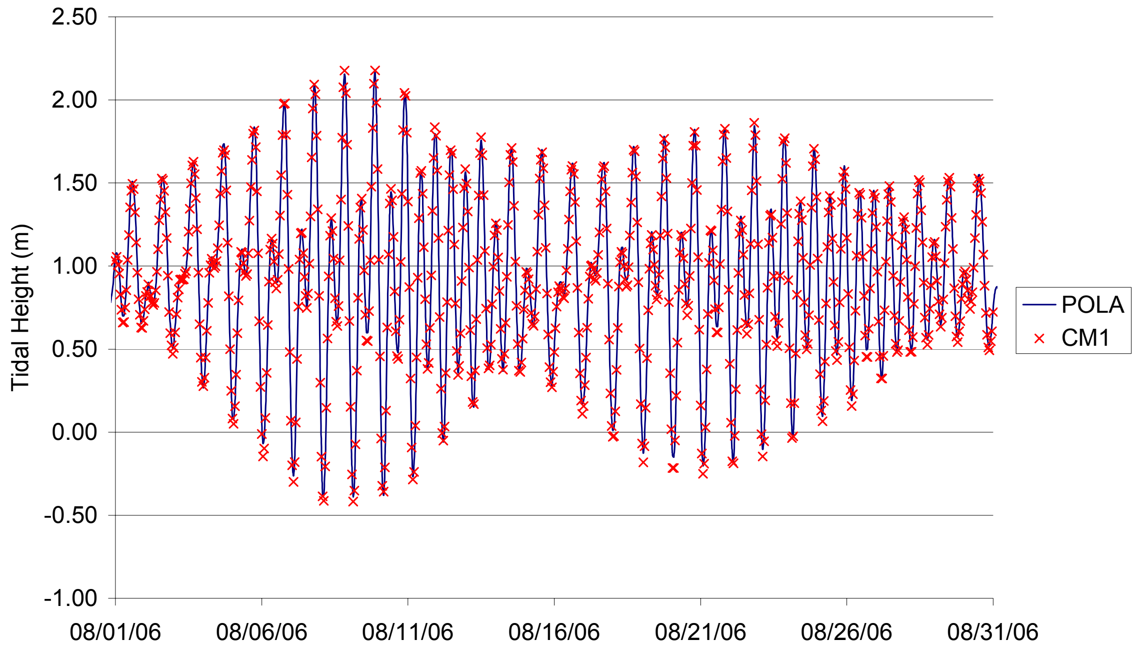


Figure 3.3-8. Correspondence of tidal heights estimated at Station CM1 and at Port of Los Angeles Outer Harbor (POLA), August 2006.

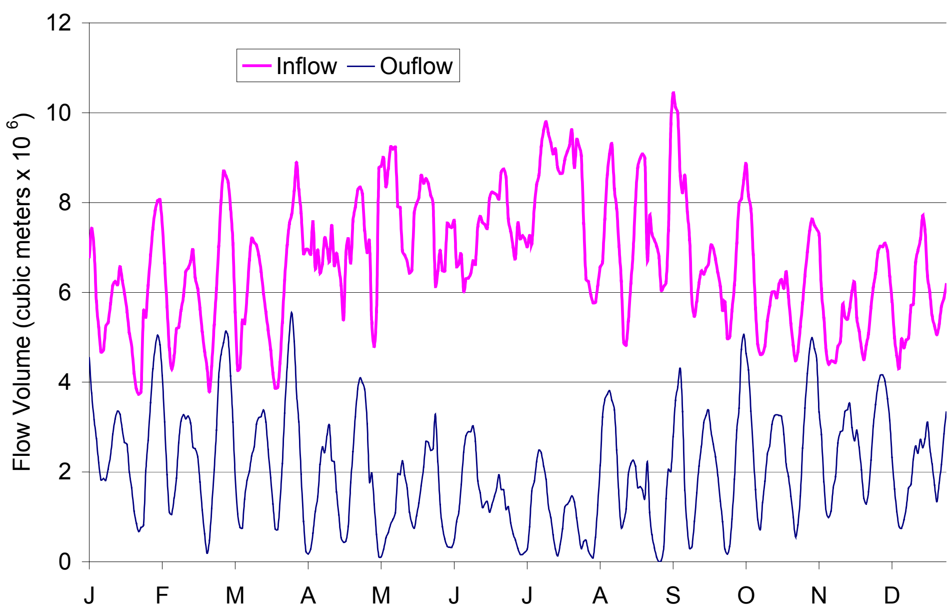


Figure 3.3-9. Estimates of Alamitos Bay daily inflow and outflow volumes, January–December 2006.

3.3.3 Biological Resources

The following sections describe the aquatic biological habitats and communities in the vicinity of the AGS, including both invertebrate and fish communities.

3.3.3.1 Habitat Variation

Subtidal sediments in Alamitos Bay consist primarily of sand and mud, and waters are primarily saline (Allen and Horn 1975). Subtidal vegetation (eelgrass [*Zostera marina*]) is present at locations near the entrance channel, near the west end of Naples Island, and in the Marine Stadium arm of the Bay (Valle et al. 1999). Depths throughout most of the bay are shallow, ranging from 3.6 to 5.5 m (12 to 18 ft). Most of the shoreline is developed, and consists of hard intertidal and subtidal substrates, such as concrete bulkheads and piers. The AGS intake canals are lined with rocks, which provides hard substrate habitat for fishes and invertebrates (Figure 3.3-10).

Figure 3.3-10. View of the AGS Units 1-4 intake canal looking at the Units 3&4 intake structure.

3.3.3.2 Nursery Grounds

The role as a nursery grounds for juveniles of coastal fish species is probably the most widely recognized and accepted function of bays and estuaries in their status as important fish habitats (Allen et al. 2006). Valle et al. (1999) sampled the juvenile fishes of Alamitos Bay from 1992 through 1995 with a 1.6-m (5.2-ft) beam trawl fitted with 3-mm (0.1-in) mesh. Of the 46 taxa collected, the most abundant were unidentified gobies (Gobiidae), cheekspot goby (*Ilypnus gilberti*), bay pipefish (*Syngnathus leptorhynchus*), shiner perch (*Cymatogaster aggregata*), and topsmelt (*Atherinops affinis*). The study concluded that shallow, unvegetated sand and mudflat, and eelgrass habitats were important for many fishes, especially juveniles. Juvenile California halibut (*Paralichthys californicus*) inhabited unvegetated areas, while barred sand bass (*Paralabrax nebulifer*) inhabited eelgrass beds. The habitats nearest the bay mouth are particularly important for juveniles of these two species, whereas habitats further inside the bay are more important for most other fishes.

Several features of bays and estuaries may be important to settling species, such as California halibut, including warmer water temperatures, decreased turbulence, finer sediments, and different biological communities compared with those on the open coast. MBC (1991) determined densities of recently settled California halibut in southern California increased with decreasing depth. The semi-protected waters of Queensway Bay and Outer Long Beach Harbor, just upcoast from Alamitos Bay, are also important habitats for juvenile fishes and invertebrates. Recently transformed cheekspot goby, California tonguefish (*Symphurus atricaudus*), white croaker (*Genyonemus lineatus*), and queenfish (*Seriphus politus*) were the most abundant juvenile fishes collected in seasonal surveys of Queensway Bay in 1990-1991 and 1994 (MBC 1994).

3.3.3.3 Fish Diversity (all Life Stages)

Bay and estuarine fish assemblages in California tend to be dominated in abundance by few (usually five or less) species and have low diversity even though many other species are typically encountered (Allen et al. 2006). A total of 44 fish species were documented from Alamitos Bay by Allen (1976), and 46 taxa were collected by Valle et al. (1999). Abundance is largely dominated by few species (Allen 1976). In Colorado Lagoon, four species comprised 99 percent of the total abundance: northern anchovy (*Engraulis mordax*), topsmelt, slough anchovy (*Anchoa delicatissima*), and shiner perch (Allen and Horn 1975). Species diversity and abundance at Colorado Lagoon were highest during summer (May–September) and both were highly correlated with water temperature, which ranged between 12.8 and 25.0°C.

IRC (1981) conducted bimonthly demersal fish surveys near the HnGS intake and just off Alamitos Bay in 1978-1979. The number of taxa collected outside the bay (41) was higher than the number from within the bay (31), and abundance outside the bay was about twice that from inside Alamitos Bay. Within Alamitos Bay, the most abundant species were white croaker, queenfish, and shiner perch, while white croaker, queenfish, and northern anchovy were most abundant offshore.

Long-term demersal fish and invertebrate surveys have been conducted just offshore Alamitos Bay and the mouth of the lower San Gabriel River (MBC 2007). At least 66 species of fish have been collected since 1972, although about 30 species are collected annually. Abundance has been dominated by northern anchovy, white croaker, queenfish, and California tonguefish, which combined account for 90 percent of the long-term trawl caught abundance. In 2006, abundance in summer was about twice that in winter, though species richness was the same between surveys. The warm waters emanating from the mouth of the San Gabriel River flood control channel leads to increased productivity and diversity in that area, especially in winter when both productivity and diversity would normally decrease (EQA/MBC 1973).

Between 2001 and 2006, at least 52 fish species were impinged at both the AGS and the HnGS (MBC 2007). Topsmelt, silversides (Atherinopsidae), shiner perch, and Pacific staghorn sculpin (*Leptocottus armatus*) were most abundant at AGS, while queenfish, topsmelt, pipefishes (Syngnathidae), and northern anchovy were most abundant at the HnGS. The assemblage impinged at HnGS was almost entirely comprised of marine and estuarine species, while freshwater species were occasionally impinged at AGS due to the proximity of the intakes to Los Cerritos Channel.

Between April and July 2004, at least 10 larval fish taxa from nine families were collected from the AGS intake canals, and at least 13 larval fish taxa from 11 families were collected from the HnGS intake structure (MBC 2004, 2005). At the AGS intake canals, gobies and combtooth blennies (*Hypsoblennius* spp.) accounted for 97 percent of the density, while gobies and silversides accounted for 93 percent of the larval densities at the HnGS intake structure.

3.3.3.4 Shellfish Diversity (all Life Stages)

Over 100 demersal macroinvertebrate taxa have been collected just offshore Alamitos Bay since 1978, although about 25 species are collected annually (MBC 2007). Blackspotted bay shrimp (*Crangon nigromaculata*), tuberculate pear crab (*Pyromaia tuberculata*), and spiny sand star (*Astropecten armatus*) are the most abundant species in the area, comprising 84 percent of the long-term abundance. In 2006, diversity and abundance were substantially higher in winter compared to summer. Diver surveys offshore Alamitos Bay in the early 1970s identified 116 definable taxa, with species richness lowest in winter and highest in summer (EQA/MBC 1973). The tubiculous polychaete *Diopatra splendidissima* was the most abundant invertebrate recorded during the study.

In 2006, the most abundant macroinvertebrates impinged at the AGS were: the yellow shore crab (*Hemigrapsus oregonensis*), moon jelly (*Aurelia aurita*), Kellet's whelk (*Kelletia kelletii*), red jellyfish (*Polyorchis penicillatus*), and the tuberculate pear crab (MBC 2007). The most abundant species at Haynes were red jellyfish, the nudibranch *Hermissenda crassicornis*, tuberculate pear crab, California aglaja (*Navanax inermis*), and the yellow shore crab.

3.3.3.5 Protected Species

Some fish and invertebrate species (abalone) in southern California are protected under CDFG regulations although few marine species are listed as either threatened or endangered. Special status fish species that could occur in the vicinity of AGS and that have planktonic larvae potentially at risk of entrainment include garibaldi (*Hypsypops rubicundus*), tidewater goby (*Eucyclogobius newberryi*), and California grunion (*Leuresthes tenuis*).

Garibaldi, designated as the California state marine fish, is a bright orange shallow-water species that is relatively common around natural and artificial rock reefs in southern California. Because of its territorial behavior it is an easy target for fishers and could be significantly depleted if not protected. Garibaldi spawn from March through October, and the female deposits demersal adhesive eggs in a nest that may contain up to 190,000 eggs deposited by several females (Fitch and Lavenberg 1975). 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). The larvae are susceptible to entrainment, particularly in summer months when spawning is at its peak.

The tidewater goby is a fish species endemic to California and is listed as federally endangered. The tidewater goby is threatened by modification and loss of habitat resulting primarily from coastal development. It appears to spend all life stages in lagoons, estuaries, and river mouths (Swift et al. 1989) but may enter marine environments when flushed out of these preferred habitats during storm events. Adults or larvae may not survive for long periods in the marine environment but larval transport over short distances may be a natural mechanism for local dispersal.

California grunion is a species with special status not because the population is threatened or endangered, but because their spring-summer spawning activities on southern California beaches puts them at risk of over harvesting, and CDFG actively manages the fishery to ensure sustainability. 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 (Love 1996). The female swims onto the beach, digs tail-first into the wet sand, and deposits her eggs, which are then fertilized by the male. After the eggs hatch, the larvae are carried offshore and can be susceptible to entrainment for approximately 30 days as they develop in the plankton.

Off southern California, the species with EFH designated are listed in the Coastal Pelagics Fishery Management Plan (FMP) and the Pacific Groundfish FMP. The goals of the management plans include, but are not limited to: the promotion of an efficient and profitable fishery, achievement of optimal yield, provision of adequate forage for dependent species, prevention of overfishing, and development of long-term research plans (PFMC 1998, 2006). There are four fish and one invertebrate species covered under the Coastal Pelagics FMP: northern anchovy, Pacific sardine (*Sardinops sagax*), jack mackerel (*Trachurus symmetricus*), Pacific (chub) mackerel (*Scomber japonicus*), and market squid (*Loligo opalescens*). There are 89 fish species covered under the Pacific Groundfish FMP, including ratfish (*Hydrolagus colliei*), finescale codling (*Antimora microlepis*), Pacific rattail (*Coryphaenoides acrolepis*), three species of sharks, three skates, six species of groundfish, 62 species of scorpionfishes and thornyheads, and 12 species of flatfishes. For both the Coastal Pelagics and Pacific Groundfish, EFH includes all waters off southern California offshore to the Exclusive Economic Zone. A list of species covered under the two FMPs that occurred during entrainment and impingement sampling at the AGS is provided in Table 3.3-3. More information on these species is provided in Sections 4.0 and 5.0.

Table 3.3-3. Fish and shellfish species with designated EFH or CDFG special status species entrained and/or impinged at the AGS in 2006.

Species	Common Name	Management Group
Engraulis mordax	northern anchovy	Coastal Pelagics
Loligo opalescens	market squid	Coastal Pelagics
Sardinops sagax	Pacific sardine	Coastal Pelagics
Scomber japonicus	Pacific chub mackerel	Coastal Pelagics
Trachurus symmetricus	jack mackerel	Coastal Pelagics
Hypsypops rubicundus	garibaldi	CDFG
Leuresthes tenuis	California grunion	CDFG

4.0 Cooling Water Intake Structure Entrainment and Source Water Study

4.1 Introduction

The entrainment study incorporated two design elements: 1) CWIS sampling, and 2) source water sampling. Sampling at the intakes provided estimates of the total numbers of each larval species entrained through the CWIS on a biweekly basis depending on pumping capacity. The source water populations of fish and shellfish larvae were sampled to estimate proportional entrainment losses for selected species. Abundances of larval fishes and shellfishes vary throughout the year due to changes in composition and the oceanographic environment. Because it is desirable from an impact modeling standpoint to have a higher resolution of temporal changes in the composition of entrained taxa than source water taxa, entrainment sampling was conducted biweekly while source water sampling was conducted monthly. The monthly sampling frequency is consistent with other recently completed entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera 2007).

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

- What are the species composition and abundance of the larval fishes, fish eggs, crab megalops, and spiny lobster larvae entrained by AGS?
- What are the local species composition and abundance of the entrainable larval fishes, fish eggs, crab megalops, and spiny lobster larvae in Alamitos Bay and adjacent nearshore areas?
- What are the potential impacts of entrainment losses on these populations due to operation of the CWIS?

The following sections explain the entrainment study methods, quality assurance procedures, and study results analyzed on a temporal and spatial basis in relation to power plant operation in 2006.

4.1.1 Discussion of Species to be Analyzed

Planktonic organisms in the source water body that are smaller than the CWIS screening system mesh (3/8 in) are susceptible to entrainment. These include species that complete their entire life cycle as planktonic forms (holoplankton) and those with only a portion of their life cycle in the plankton as eggs or larvae (meroplankton). This study estimated entrainment effects on meroplanktonic species including all fish eggs and larvae, and the advanced larval stages of several invertebrate species including all crabs, market squid (*Loligo opalescens*), and California spiny lobster (*Panulirus interruptus*). None of the holoplanktonic forms (such as copepods) were enumerated because these populations are typically widespread, the species have short generation times, and any population-level impacts would be very small. All target taxa in the samples were identified to the lowest practical taxonomic level, but some specimens were combined into broader taxonomic groups because the morphological characteristics of some species are not distinct at smaller stages, descriptions are lacking for some of the larvae (particularly for many of the crab megalops), or specimens were damaged and could not be positively identified. Although all target taxa specimens were enumerated in the samples, including uncommon species and those with no direct fishery value, detailed impact analysis was only applied to a few of the more abundant species or species-groups, in addition to the specific shellfish taxa (spiny lobsters, market squid) regardless of abundance.

4.1.1.1 Fish

Many of the marine fishes in the vicinity of the AGS produce free-floating larvae as an early life stage, a notable exception being the surfperches which bear well-developed live young. Planktonic larval development promotes dispersal of the population but also puts larvae at risk of entrainment. Some groups (e.g., croakers, flatfishes, anchovies) broadcast eggs directly into the water column where they develop in a free-floating state until hatching into the larval form. In this case both eggs and larvae are potentially susceptible to entrainment. For groups that deposit adhesive eggs onto the substrate (e.g., gobies, cottids) or brood eggs internally until larvae are extruded (e.g., rockfishes, pipefishes), only the larvae and not the eggs are potentially at risk of entrainment.

4.1.1.2 Shellfish

"Shellfish" is a general term to describe crabs, shrimps, lobsters, clams, squids and other invertebrates that are consumed by humans, and it is used to differentiate this group of fishery species from "finfish" which includes bony fishes, sharks and rays. In the present study, crabs, spiny lobster, and market squid were selected as representative of the shellfish species at potential risk of entrainment, some of which have direct fishery value and others that are primarily important only as forage species for higher trophic levels. The inclusion of certain shellfish larvae as target species, and the enumeration of only the later stages such as megalops and phyllosomes, was a compromise between attempting to characterize the abundance of all planktonic organisms entrained into the CWISs (a nearly impossible task) and only a few species with commercial fishery value. In addition, only a few species have complete larval descriptions, which makes accurate identifications problematical, increasing the level of uncertainty associated with the impact analyses based on these broad taxonomic groups. Nevertheless, by including the megalops stage of all crabs in the sample identifications (e.g. hermit crabs, porcelain crabs, shore crabs) there is some measure of the relative effects of entrainment on source populations of some of the more abundant but lesser-known species that have planktonic larvae.

4.1.1.3 Protected Species

Some fish and invertebrate species (abalone) in California are protected under California Department of Fish and Game regulations although few marine species are listed as either threatened or endangered. Special status fish species that could occur in the vicinity of the power plant and that have planktonic larvae potentially at risk of entrainment include garibaldi (*Hypsypops rubicundus*), tidewater goby (*Eucyclogobius newberryi*), and California grunion (*Leuresthes tenuis*).

4.2 HISTORICAL DATA

4.2.1 Summary of Historical Data

Daily entrainment rates for AGS Units 1-6 in 1979–1980 (SCE 1982a) were based on density data of plankton collected from the intakes at Haynes Generating Station (HnGS), both of which are located within the same vicinity between Los Cerritos Channel and the San Gabriel River. The densities were then applied to the daily cooling water volumes at AGS to calculate estimated annual entrainment for certain target species. The criteria given for using HnGS as a surrogate site for AGS were that both sites draw approximately the same volume of cooling water from within Anaheim Bay, and the biological communities affected by both facilities were relatively similar (Schlotterbeck et al. 1979). Cooling water for HnGS is supplied through a single CWIS, located in the Long Beach Marina, about 2.4 kilometers (km) (1.5 miles) southeast of the AGS. The normal depth of the marina at the site of the intake openings is 3 meters (m) (10 feet [ft]). There are seven intake openings in the marina's northwest facing bulkhead wall, below the gangways. Each opening is 2.3 m (7.5 ft) tall and 15.2 m (50 ft) wide and the velocity of incoming water is 704,000 gpm for all units combined.

Sampling efforts at HnGS focused on obtaining entrainment values of certain 'target species'. The list of 'target species' was determined by the CRWQCB as representative species of the Southern California Bight. The following criteria were used to identify potential 'target species':

- Importance in community trophic structure (planktivorous, piscivorous, benthic feeders, or as a prey food source),
- Present in the source water body during most of the year, allowing statistical comparisons of the data,
- Potentially subject to entrainment and/or impingement during some or all of their life stages,
- Economic value as a sport or commercial fishery species.

Mean daily entrainment values were determined through sampling near the entrance of the intake channel at HnGS (SCE 1982a). Samples were collected (approximately) biweekly using day and night tows from October 1979 through September 1980. Two replicates of approximately 60 m^3 were filtered through either 335 μm or 202 μm mesh nets and then preserved in 4% formalin.

Although survival rates of target species as a result of entrainment and passage through the cooling water system were calculated at 10 to 70%, a 100% mortality rate was used in order to give a conservative estimate of entrainment effects. Entrainment rates were then extrapolated from entrainment values at AGS by multiplying HnGS values by the ratio of the flow rates between the two stations.

Table 4.2-1 summarizes entrainment values of target species and other common fish taxa recorded over the 12-month study. Although daily fluctuations in flow rates were reported for HnGS (IRC 1981) they were not reported for AGS (SCE 1982a). So, in order to be consistent with the methodology described in the 316(b) assessment for AGS a value of 704,000 gpm or 44.4 m^3/sec from HnGS was applied to calculate daily larval entrainment rates for AGS. Northern anchovy and white croaker larvae were abundant target species in HnGS entrainment samples with densities averaging 425 and 279 larvae per 1,000 m^3 (264,000 gal), respectively. This translated to annual entrainment estimates of 595 million northern anchovy and 391 million white croaker larvae at AGS. Entrainment estimates were also high for other non-target taxa including gobies and blennies at 2,629 and 3,015 million larvae annually, respectively.

Table 4.2-1. Summary of larval fish densities and annual entrainment estimates for target and other taxa for Alamitos Generating Station in 1979−1980 (from SCE 1982a).

	Mean Daily Larval Density (#/1,000 m^3)	% of Total	Calculated Annual Entrainment at AGS (millions)
316 (b) Target Taxa			
anchovy complex	424.90	8.6	594.95
white croaker	279.19	5.7	390.92
queenfish	95.67	1.9	133.96
Other Taxa			
silverside complex	22.94	0.5	32.12
goby complex	1,877.40	38.1	2,628.73
combtooth blennies	2,153.19	43.7	3,014.90
diamond turbot	4.43	0.1	6.21
other taxa	72.21	1.4	101.11

Data were obtained from Haynes Generating Station as a representative site.
Note: A volume of 1,000 m^3 is equal to 264,000 gallons.

4.3 METHODS

4.3.1 Field Sampling

4.3.1.1 Cooling-Water Intake System Entrainment Sampling

To determine composition and abundance of ichthyoplankton and target invertebrates entrained by the AGS CWISs, sampling in the Units 1–4 and Units 5&6 intake canals was conducted every two weeks from January through December 2006. Entrainment samples were collected using an oblique tow through the water column. Two replicate tows were performed with a target volume of approximately 20 m^3 (5,200 gal) per tow. Sampling was conducted four times per 24-hr period--once every six hours.

Entrainment samples were collected with a single 0.5 m (1.6 ft) diameter 333-µm mesh plankton net fitted with a Dacron sleeve and a cod-end container to retain the organisms. A calibrated General Oceanics 2030 flowmeter was mounted in the net opening to allow the calculation of the amount of water filtered. At the end of each tow, the contents of the net were gently rinsed into the cod-end with seawater.

Contents were washed down from the outside of the net to avoid the introduction of plankton from the wash-down water. Samples were then carefully transferred to prelabeled jars with preprinted internal labels. One of the samples was preserved in 4 to 10% buffered formalin-seawater, while the contents from the other sample was preserved in 70 to 80% ethanol. Larvae preserved in ethanol were archived for genetic and/or otolith analysis, if required. Genetic analyses have been performed in recent studies in attempts to validate the identity of certain species.

4.3.1.2 Source Water Sampling

The configuration of the source water study area was selected to 1) characterize the larvae of ichthyoplankton and shellfish potentially entrained by the AGS cooling water intakes, and 2) represent larval forms present in the nearshore habitats in Alamitos Bay and the nearshore waters just outside Alamitos Bay.

To determine composition and abundance of ichthyoplankton in the source water, sampling was done monthly on the same day that the entrainment station was sampled. Source water was sampled at ten stations located in Los Cerritos Channel, Alamitos Bay, and San Pedro Bay (Figure 4.3-1). All stations were sampled using a wheeled bongo plankton frame with two paired nets using an oblique tow that sampled the entire water column. A calibrated General Oceanics 2030 flowmeter was mounted in the openings of both nets to allow the calculation of the amount of water filtered. At the end of each tow, the contents of the nets were gently rinsed into the cod-end and with seawater, transferred to labeled containers, and preserved using the same procedures used for entrainment samples. The samples from the two nets were processed separately but the volumes and counts combined for analysis. During each source water survey, the additional nine source water stations were sampled four times per 24-hr period at 6-hr intervals. This interval allowed adequate time for one vessel and crew to conduct all source water and entrainment sampling while also partitioning samples into day-night blocks for analysis of diel trends. During each sampling cycle the order in which the stations were sampled was varied to avoid introducing a systematic bias into the data. Detailed sampling procedures are presented in Appendix C.

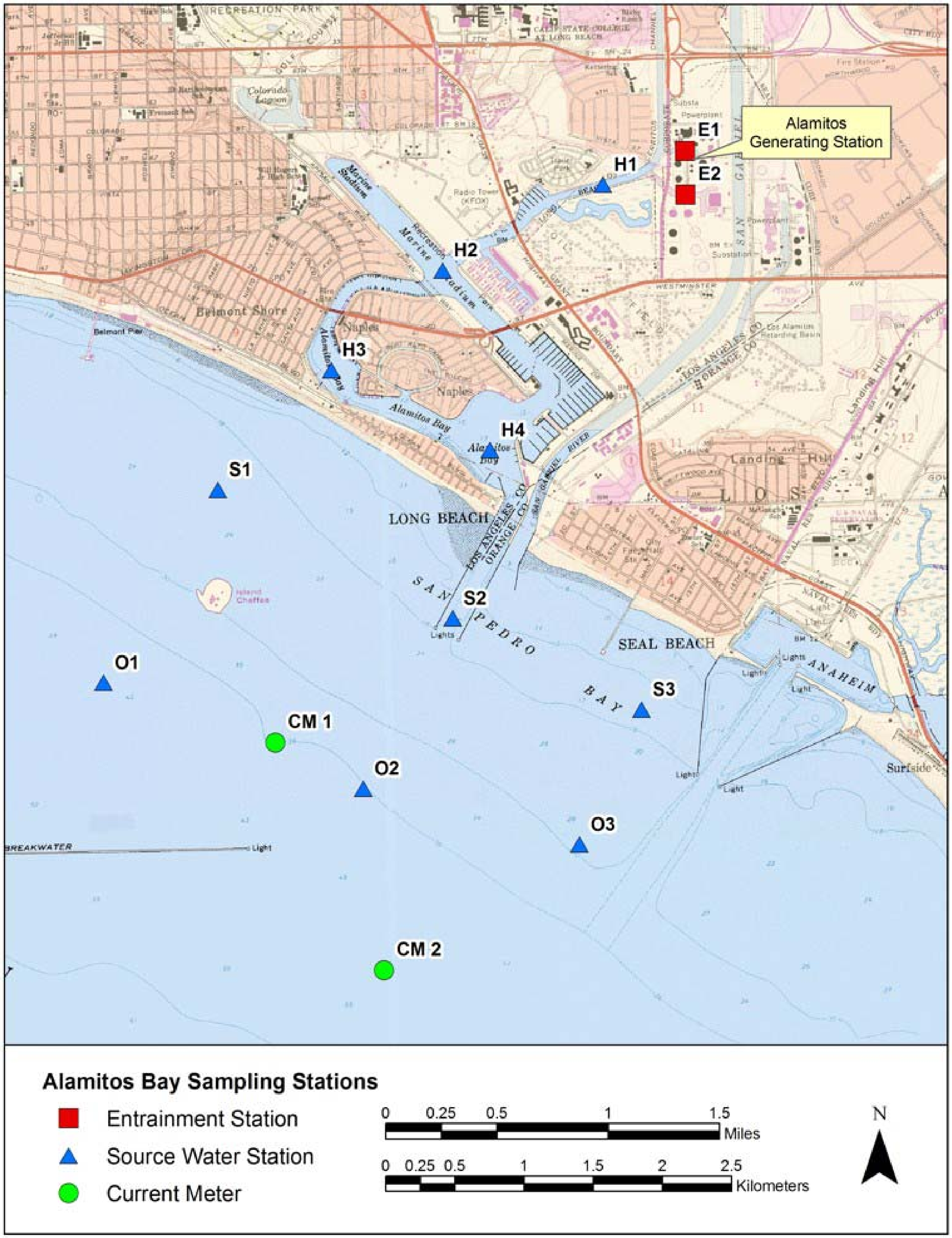


Figure 4.3-1. Map of AGS entrainment and source water sampling stations.

4.3.2 Laboratory Analysis

Samples were returned to the laboratory and transferred from formalin to 70% ethanol after approximately 72 hours. Samples were examined under a dissecting microscope and all fish eggs (entrainment samples only) and larvae were removed and placed in labeled vials, in addition, the following shellfish larvae were also removed:

- crab megalopae
- California spiny lobster phyllosoma
- market squid paralarvae

Specimens were enumerated and identified to the lowest practical taxon. A maximum of 50 representative fish larvae from each taxon from each survey were measured using a dissecting microscope and image analysis system. Total length was measured to an accuracy of at least 0.004 inch (0.1 millimeter). Fish eggs were only identified and enumerated from the entrainment samples.

4.3.3 QA/QC Procedures & Data Validation

A quality control (QC) program was implemented for the field and laboratory components of the study. Quality control surveys were completed on a quarterly basis to ensure that the field sampling was conducted properly. Prior to the start of the study the field survey procedures were reviewed with all personnel, and all personnel were given printed copies of the procedures.

A more detailed QC program was applied to all laboratory processing. The first ten samples sorted by an individual were resorted by a designated quality control (QC) sorter. A sorter was allowed to miss one target organism if the total number of target organisms in the sample was less than 20. For samples with 20 or more target organisms the sorter was required to maintain a sorting accuracy of 90%. After a sorter completed ten consecutive samples with greater than 90% accuracy, the sorter had one of their next ten samples randomly selected for a QC check. If the sorter failed to achieve an accuracy level of 90% then their next ten samples were resorted by the QC sorter until they met the required level of accuracy. If the sorter maintained the required level of accuracy random QC checks resumed at the level of one sample check per ten sorted.

A similar QC program was conducted for the taxonomists identifying the samples. The first ten samples of fish or invertebrates identified by an individual taxonomist were completely re-identified by a designated QC taxonomist. A total of at least 50 individual fish or invertebrate larvae from at least five taxa must have been present in these first ten samples; if not, additional samples were re-identified until this criterion was met. Taxonomists were required to maintain a 95% identification accuracy level in these first ten samples. After the taxonomist identified ten consecutive samples with greater than 95% accuracy, they had one of their next ten samples checked by a QC taxonomist. If the taxonomist maintained an accuracy level of 95% then they continued to have one of each ten samples checked by a QC taxonomist. If one of the checked samples fell below the minimum accuracy level then ten more consecutive samples were identified by the QC taxonomist until ten consecutive samples met the 95% criterion. Identifications were cross-checked against taxonomic voucher collections maintained by MBC and Tenera Environmental, and specialists were consulted for specimens whose identities could not be confirmed in-house.

4.3.4 Data Analysis

4.3.4.1 Entrainment Estimates

Estimates of daily larval entrainment for the sampling period from January 2006 through December 2006 at the AGS were calculated from data collected at the entrainment stations and data on daily cooling water flows from each circulating water pump at the power plant. Estimates of average larval concentration for the day when entrainment samples were collected were extrapolated across the days between surveys to calculate total entrainment during the days when no samples were collected. The total estimated daily entrainment for the survey periods and across the entire year where then summed to obtain estimates of total survey and annual entrainment, respectively. Separate estimates were calculated for each set of intakes: Units 1&2, Units 3&4, and Units 5&6. The estimates were calculated using actual cooling water flows during the year. The annual entrainment estimates, in conjunction with demographic data collected from the fisheries literature, were used in modeling CWIS effects 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 were used to calculate estimates of proportional entrainment (*PE*) that were used to estimate the probability of mortality (P_M) due to entrainment using the *ETM*. Each approach (e.g., *AEL*, *FH*, and *ETM*), as appropriate for each target taxon, was used to assess effects of power plant losses. The model estimates were calculated using the total entrainment from all three sets of units. The results from the models were used in determining the magnitude of the CWIS losses relative to source water data from other sources and evaluating the potential for adverse environmental impacts. Parameters of the models used in the analyses are detailed in Appendix C.

All of the modeling approaches require an estimate of the age of the larvae being entrained. The demographic approaches extrapolate estimates from the average age at entrainment, while the *ETM* requires an estimate of the period that the larvae are exposed to 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. Although a large number of larvae may have been collected and measured from entrainment samples a random sample of 200 from the total measurements was used to calculate the average age at entrainment and total larval duration. The average age at entrainment was calculated by dividing the difference between the estimated size at hatching and the average size of the larvae from entrainment by a larval growth rate obtained from the literature. The period of time that the larvae were exposed to entrainment was calculated by dividing the difference between the size at hatching and the size at the 95th percentile by a larval growth rate obtained from the literature. The duration of the egg stage was added to this value for species with planktonic eggs. The 95th percentile value was used to eliminate outliers from the calculations. The size at hatching was estimated as follows:

$$Hatch\ Length = Median\ Length - ((Median\ Length - 1^{st}\ Percentile\ Length)/2).$$

This calculated value was used because of the large variation in size among larvae smaller than the average length and approximates the value of the 25th percentile used in other studies as the hatch length. This calculation assumes that the length frequency distribution is skewed towards smaller sized larvae and usually resulted in a value close to the hatch size reported in the literature.

4.3.4.2 Entrainment Impact Assessment

4.3.4.3 Demographic Approaches

AEL 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 the AGS: *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.

Age-specific survival and fecundity rates are required for *AEL* and *FH*. *AEL* 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 collected during the study. 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 *FH* and *AEL* 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 *FH* and *AEL* calculations is an estimate of total annual larval entrainment. Estimates of larval entrainment at AGS were calculated using entrainment estimates based on the average daily larval concentration from both entrainment stations. The average concentration was multiplied by the total actual flow from all three sets of units (Units 1&2, Units 3&4, and Units 5&6) to calculate entrainment estimates for individual survey periods which were added together to calculate the total entrainment for the one-year study period. Estimates of entrainment for the study period were based on two-stage sampling designs, with days within surveys, 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.

*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 (age at which 50% of the females are mature) 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:

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

where

E_T = total entrainment estimate;

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

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 1 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 not be available 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 fecundity data used in calculating *TLF* is described below for each taxon.

*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, which is the life-stage most dealt with by resource managers. 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:

$$AEL = \sum_{j=1}^{n} E_j S_j \ , \qquad (2)$$

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 jth class to adulthood (Goodyear 1978).

Age-specific survival rates from the average age at entrainment to the age at first maturity must be included in this assessment method. The age at first maturity, when 50% of the females are mature, was used in the *AEL* extrapolations so the *FH* and *AEL* models are extrapolated to the same age and can be compared using the equivalency that $2FH \approx AEL$. We used a modified form of Equation 2 where the total entrainment was used having an average age a:

$$AEL = E_T \prod_{j=a}^{n} S_j \ , \qquad (3)$$

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 as described above. 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.

4.3.4.4 Empirical Transport Model

As an alternative to the demographic models described above, the *ETM* was proposed by the USFWS to estimate mortality rates resulting from circulating water withdrawals by power plants (Boreman et al. 1978, and subsequently in Boreman et al. 1981). The *ETM* model provides an estimate of incremental mortality (a conditional estimate in absence of other mortality, Ricker 1975) caused by the AGS on larval populations by using empirical data (plankton samples) rather than relying solely on hydrodynamic and demographic calculations. Consequently, *ETM* requires an additional level of field sampling to characterize the abundance and composition of source water larval populations. The fractional loss to the source water population represented by entrainment is provided by estimates of proportional entrainment (*PE*) for each survey that can then be expanded to predict regional effects on appropriate adult populations using *ETM*, as described below. *ETM* estimates were calculated using actual and design (maximum capacity) cooling water flows and a sampling volume in the nearshore of 140,698,222 m^3.

Variations of this model have been discussed in MacCall et al. (1983) and have been used to assess impacts at a southern California power plant (Parker and DeMartini 1989). The *ETM* has also been used to assess impacts at the Salem Nuclear Generating Station in Delaware Bay, New Jersey (PSE&G 1993) as well as other power stations along the East Coast. Empirical transport modeling permits the estimation of conditional mortality due to entrainment while accounting for the spatial and temporal variability in distribution and vulnerability of each life stage to power plant withdrawals. The modeling approach described below uses a *PE* approach that is similar to the method described by MacCall et al. (1983) and used by Parker and DeMartini (1989) in their final report to the California Coastal Commission (Murdoch et al. 1989a) for the San Onofre Nuclear Generating Station.

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

$$PE_i = \frac{N_{Ei}}{N_{Si}}, \tag{4}$$

where

N_{Ei} = estimated average number of larvae entrained during the day in survey i (calculated as estimated average daily concentration of larvae from entrainment stations E1 and E2 $\times$ average daily cooling flow water flow from Units 1-6 during the survey period), and

N_{Si} = estimated number of larvae in the source water that day in survey i (calculated as concentration of larvae in the souce water that day $\times$ source water volume).

The PE_i value represents the effects of a number of processes operating over a day and is estimated for each survey using the average larval concentrations from both entrainment stations and the actual cooling water flow from all six units. Since actual cooling water flow was used in calculating entrainment estimates, the PE_i estimate was calculated using the average daily cooling water flow over each entrainment survey period, an approximate period of one month.

The values used in calculating *PE* are population estimates based on the respective larval concentrations and volumes of both the cooling water system 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 AGS: 1) Los Cerritos Channel and Alamitos Bay where the AGS intakes are located, 2) nearshore coastal water that is transported into Alamitos Bay on incoming tides, and 3) water that is transported out of Alamitos Bay into nearshore coastal waters on outgoing tides. Each of these source water components operates on the time scale of the period of time 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* for the three source water components is incorporated into the *ETM* calculation for estimating the total annual proportional mortality due to entrainment, P_M as follows:

$$P_M = 1 - \sum_{i=1}^{N} f_i \left(1 - \left[\frac{N_{E_i}}{\frac{N_{NS_i} - N_{NSOut_i}}{P_{S_i}} + N_{AB_i} + (N_{ABOut_i} \cdot q)} \right] \right)^q, \tag{6}$$

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 average number of larvae entrained per day during the i^{th} survey;

N_{NS_i} = the estimated number of larvae in the nearshore per day 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 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 Alamitos Bay calculated using the average concentration from the nearshore sampling during the i^{th} survey and the outflow volume;

N_{AB_i} = the estimated number of larvae in Alamitos Bay during the i^{th} survey; and

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

The sizes of N_{NS}, N_{AB}, 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 six areas (Figure 4.3-1) with component densities and volumes. 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 current displacement measured using current meters deployed offshore from Alamitos Bay (Figure 4.3-1). 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 or offshore that larvae could have been transported into the nearshore areas around Alamitos Bay 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, measured using data from the current meter at Station CM1 was used to adjust the nearshore population estimate, N_{NS}, for the size of the total source water population for taxa that are primarily distributed in nearshore areas and embayments such as gobies and blennies. The data from the current meter at CM1 included both alongshore and onshore-offshore component vectors, but its location inside the Los Angeles-Long Beach Harbor breakwaters primarily provided data on alongshore movement in, and out of, the harbor complex.

The estimate of P_S, the proportion of the sampled source water population to the total source population, was adjusted for taxa with more offshore distributions using data from the current meter at Station CM2 which was located outside of the harbor breakwaters. Data from this station provided more accurate data on onshore currents that could transport larvae from offshore into nearshore areas where they could be subject to entrainment. Unlike the data from Station CM1 that included upcoast and downcoast displacement, only onshore displacement was used in calculating the offshore distance for the source population. Rather than extrapolating the entire coastal length of the potential source water population offshore a much more conservative approach was used that based the estimate of P_S on the ratio of the width of the nearshore sampling area to the offshore displacement indicated by the current meter data.

To establish independent survey estimates, it was assumed that during each survey a new and distinct cohort of larvae was subject to entrainment. Each of the surveys was weighted by f_i and estimated as the proportion of the total annual source water population present during each ith survey period. For each study period, the sum of the proportions equals one:

$$f_i = \frac{N_S}{\sum_{i=1}^{n} N_{Si}} \text{ and } \sum_{i=1}^{n} f_i = 1.$$

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

Assumptions associated with the estimation of P_M include the following:

- The samples at each survey period represent a new and independent cohort of larvae.
- The estimates of larval abundance for each survey represent a proportion of total annual larval production during that survey.
- The conditional probability of entrainment PE_i is constant within survey periods.
- Lengths and applied growth rates of larvae accurately estimate larval duration.

The variance calculations associated with P_M only include the error directly associated with the sampling in the PE_i and was calculated using the average coefficient of variation (*CV*), the ratio of the standard deviation to the mean, from the estimates of PE_i as follows:

$$Var(P_M) = \sqrt{(\overline{CV}_{PE} / 100)\hat{P}_M} .$$

This estimate does not include the error associated with the estimates of P_S, the larval duration, and source water, entrainment, and outflow volumes. It also does not account for the variance across the days within a survey period. The sources of variation included in the estimate represent the sampling error and natural variation of the entrainment and source water populations.

4.4 DATA SUMMARY

4.4.1 Data Summary of Processed Samples

Twenty-six entrainment surveys and twelve source water surveys were completed between January 5 and December 19, 2006 (Table 4.3-1). Sampling efforts alternated between surveys where only entrainment samples were collected and surveys where both entrainment and source water samples were collected. Totals of 416 entrainment samples and 863 source water samples were processed for data analysis.

Table 4.3-1. Entrainment/source water surveys and number of samples collected from January through December 2006.

		Entrainment Samples		Source Water Samples	
Survey Number	**Date**	**Number Collected**	**Number Processed**	**Number Collected**	**Number Processed**
ABEA01	1/5/06	16	16	–	–
ABEA02	1/17/06	16	16	72	72
ABEA03	1/31/06	16	16	–	–
ABEA04	2/14/06	16	16	72	72
ABEA05	2/27/06	16	16		
ABEA06	3/13/06	16	16	72 [a]	71
ABEA07	3/26/06	16	16	–	–
ABEA08	4/10/06	16	16	72	72
ABEA09	4/24/06	16	16	–	–
ABEA10	5/8/06	16	16	72	72
ABEA11	5/22/06	16	16	–	–
ABEA12	6/5/06	16	16	72	72
ABEA13	6/19/06	16	16	–	–
ABEA14	7/05/06	16	16	72	72
ABEA15	7/17/06	16	16	–	–
ABEA16	7/31/06	16	16	–	–
ABEA17	8/14/06	16	16	72	72
ABEA18	8/28/06	16	16		
ABEA19	9/11/06	16	16	72	72
ABEA20	9/25/06	16	16	–	–
ABEA21	10/09/06	16	16	72	72
ABEA22	10/23/06	16	16	–	–
ABEA23	11/06/06	16	16	72	72
ABEA24	11/20/06	16	16	–	–
ABEA25	12/04/06	16	16	72	72
ABEA26	12/18/06	16	16	–	–
	Total	**416**	**416**	**864**	**863**

[a] One sample from Station O2 was not preserved properly and was voided.

4.5 RESULTS

4.5.1 Cooling Water Intake Structure Entrainment Summary

4.5.1.1 Fishes

Results for the entrainment sampling are divided into two parts: 1) larval fish, fish egg, and target invertebrate concentrations measured at Station E1 (in the intake canal for Units 1–4), and concentrations measured at Station E2 (in the intake canal for Units 5&6). In addition, the calculation of annual total entrainment by species is presented separately for Units 1&2, 3&4, and 5&6 using the flow-weighted averages for each unit pair multiplied by the larval concentrations from the associated entrainment station (either E1 or E2). Finally, the estimated annual entrainment for all AGS units combined is presented.

For AGS Units 1–4 entrainment sampling a total of 9,852 entrainable fish larvae from 29 separate taxonomic categories was collected from the 26 entrainment surveys (Table 4.5-1). The most abundant larval fish taxon in the samples was unidentified gobies, which comprised 66.7% of the total larvae collected, followed by combtooth blennies (21.7%). A total of 2,163 fish eggs from 11 separate taxonomic categories was collected from the 26 entrainment surveys. The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 85.6% of the total eggs collected, followed by anchovy eggs (6.3%).

For AGS Units 5&6 entrainment sampling a total of 10,084 entrainable fish larvae from 24 separate taxonomic categories was collected from the 26 entrainment surveys (Table 4.5-2). The most abundant larval fish taxon in the samples was unidentified gobies, which comprised 64.3% of the total larvae collected, followed by combtooth blennies (25.0%). A total of 2,641 fish eggs from 10 separate taxonomic categories was collected from the 26 entrainment surveys. The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 93.2% of the total eggs collected, followed by anchovy eggs (2.3%). The most abundant target invertebrate larvae in the samples was shore crab megalops, which made up 33.5% of the total target invertebrate larvae collected.

Total annual entrainment for Units 1&2 was 121,970,937 larval fish and 51,067,976 fish eggs (Table 4.5-3). Because of higher pump flows during the same period, the calculated annual entrainment of larval fishes and fish eggs for Units 3&4 using actual flows was 728,944,910 and 226,484,317, respectively (Table 4.5-4). When design (maximum) flows of 389 mgd were used to calculate annual entrainment, these values increased to 1,109,972,44 and 288,466,063 for larvae and eggs, respectively. Units 5&6 had the greatest estimated annual entrainment of the three AGS unit pairs at 835,841,962 larval fishes and 329,055,083 fish eggs (Table 4.5-5).

The peak in abundance of all the larval fish combined was seen in May and June (Figure 4.5 1) while the highest concentrations of eggs seen during July (Figure 4.5-2). There were generally more larval fish and eggs collected during each survey at night than during the day (Figures 4.5-3 and 4.5-4).

Table 4.5-1. Average concentration of larval fishes and fish eggs for AGS Units 1–4 based on entrainment data from Station E1.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Gobiidae unid.	gobies	1,383.41	5,182	66.69	66.69
Hypsoblennius spp.	combtooth blennies	449.80	1,680	21.68	88.37
Atherinopsidae unid.	silversides	115.94	392	5.59	93.96
Gobiesocidae unid.	clingfishes	24.28	93	1.17	95.13
unidentified fish, damaged	unidentified damaged fish	17.41	65	0.84	95.97
Gillichthys mirabilis	longjaw mudsucker	16.11	57	0.78	96.74
Engraulidae unid.	anchovies	15.33	56	0.74	97.48
Labrisomidae unid.	labrisomid blennies	14.78	54	0.71	98.20
Acanthogobius flavimanus	yellowfin goby	5.79	21	0.28	98.47
Gibbonsia spp.	clinid kelpfishes	5.49	20	0.26	98.74
Genyonemus lineatus	white croaker	5.23	20	0.25	98.99
Syngnathus spp.	pipefishes	3.23	11	0.16	99.15
larvae, unidentified yolksac	unidentified yolksac larvae	3.19	14	0.15	99.30
larval/post-larval fish unid.	larval fishes	2.51	10	0.12	99.42
Typhlogobius californiensis	blind goby	1.89	7	0.09	99.51
Pleuronichthys guttulatus	diamond turbot	1.85	7	0.09	99.60
Sciaenidae unid.	croakers	1.26	5	0.06	99.66
Tridentiger trigonocephalus	chameleon goby	0.93	3	0.04	99.71
Clinidae unid.	kelp blennies	0.84	3	0.04	99.75
Heterostichus rostratus	giant kelpfish	0.82	3	0.04	99.79
Cottidae unid.	sculpins	0.81	3	0.04	99.83
Chaenopsidae unid.	tube blennies	0.73	3	0.04	99.86
Leptocottus armatus	Pacific staghorn sculpin	0.58	2	0.03	99.89
Paralichthys californicus	California halibut	0.53	2	0.03	99.92
Roncador stearnsii	spotfin croaker	0.29	1	0.01	99.93
Seriphus politus	queenfish	0.26	1	0.01	99.94
Clinocottus spp.	sculpins	0.26	1	0.01	99.95
Ruscarius creaseri	roughcheek sculpin	0.26	1	0.01	99.97
Lepidogobius lepidus	bay goby	0.25	1	0.01	99.98
Triphoturus mexicanus	Mexican lampfish	0.22	1	0.01	99.99
Cheilotrema saturnum	black croaker	0.22	1	0.01	100.00
		2,609.57	**9,852**		
Fish Eggs					
fish eggs unid.	unidentified fish eggs	464.91	1,869	85.61	85.61
Engraulidae unid.	anchovy eggs	34.09	122	6.28	91.89
Paralichthyidae unid.	sand flounder eggs	13.96	54	2.57	94.46
Atherinops affinis	topsmelt eggs	8.09	34	1.49	95.95
Sciaen. / Paralich / Labr.	SPL fish eggs	6.43	25	1.18	97.13
Genyonemus lineatus	white croaker eggs	5.45	20	1.00	98.14

(table continued)

Table 4.5-1 (continued). Average concentration of larval fishes and fish eggs for AGS Units 1–4 based on entrainment data from Station E1.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Atherinopsidae unid.	silverside eggs	4.03	16	0.74	98.88
Paralichthys californicus	California halibut eggs	1.68	6	0.31	99.19
Citharichthys spp.	sanddab eggs	1.61	6	0.30	99.49
Pleuronichthys spp.	turbot eggs	1.55	6	0.28	99.77
Sciaenidae unid.	croaker eggs	1.24	5	0.23	100.00
		543.04	**2,163**		

Table 4.5-2. Average concentration of larval fishes and fish eggs for AGS Units 5&6 based on entrainment data from Station E2.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Gobiidae unid.	gobies	1,694.23	6,474	64.33	64.33
Hypsoblennius spp.	combtooth blennies	658.30	2,527	24.99	89.32
Labrisomidae unid.	labrisomid blennies	92.56	366	3.51	92.83
Atherinopsidae unid.	silversides	54.44	213	2.07	94.90
Engraulidae unid.	anchovies	25.49	88	0.97	95.87
Gobiesocidae unid.	clingfishes	24.40	94	0.93	96.80
Acanthogobius flavimanus	yellowfin goby	14.60	56	0.55	97.35
Gillichthys mirabilis	longjaw mudsucker	14.55	54	0.55	97.90
unidentified fish, damaged	unidentified damaged fish	14.10	54	0.54	98.44
Gibbonsia spp.	clinid kelpfishes	10.72	41	0.41	98.84
larval/post-larval fish unid.	larval fishes	7.77	30	0.30	99.14
Syngnathus spp.	pipefishes	6.11	24	0.23	99.37
Genyonemus lineatus	white croaker	5.50	20	0.21	99.58
Pleuronichthys guttulatus	diamond turbot	1.98	8	0.08	99.66
larvae, unidentified yolksac	unidentified yolksac larvae	1.62	7	0.06	99.72
Sciaenidae unid.	croakers	1.58	6	0.06	99.78
Seriphus politus	queenfish	1.41	5	0.05	99.83
Typhlogobius californiensis	blind goby	1.24	5	0.05	99.88
Clinocottus spp.	sculpins	1.11	4	0.04	99.92
Oxyjulis californica	senorita	0.56	2	0.02	99.94
Cottidae unid.	sculpins	0.30	1	0.01	99.95
Paralichthys californicus	California halibut	0.29	1	0.01	99.96
Pleuronectiformes unid.	flatfishes	0.26	1	0.01	99.97
Blennioidei unid.	blennies	0.25	1	0.01	99.98
Menticirrhus undulatus	California corbina	0.24	1	0.01	99.99
Hypsypops rubicundus	garibaldi	0.22	1	0.01	100.00
		2,633.83	**10,084**		
Fish Eggs					
fish eggs unid.	unidentified fish eggs	590.81	2,474	93.23	93.23
Engraulidae unid.	anchovy eggs	14.31	56	2.26	95.49
Paralichthyidae unid.	sand flounder eggs	9.75	37	1.54	97.03
Sciaen. / Paralich / Labr.	SPL fish eggs	6.09	25	0.96	97.99
Genyonemus lineatus	white croaker eggs	4.40	17	0.69	98.68
Atherinops affinis	topsmelt eggs	2.93	11	0.46	99.15
Citharichthys spp.	sanddab eggs	1.82	7	0.29	99.43
Sciaenidae unid.	croaker eggs	1.69	6	0.27	99.70
Atherinopsidae unid.	silverside eggs	1.13	5	0.18	99.88
fish egg unid., damaged	damaged fish eggs unid.	0.56	2	0.09	99.97
Pleuronichthys spp.	turbot eggs	0.21	1	0.03	100.00
		633.68	**2,641**		

Table 4.5-3. Calculated total annual entrainment of larval fishes and fish eggs at AGS Units 1&2 in 2006 based on actual cooling water intake pump flows.

Taxon	**Common Name**	**Annual Entrainment (Actual Flow)**	**Standard Error**
Gobiidae unid.	gobies	84,867,910	6,576,841
Hypsoblennius spp.	combtooth blennies	27,250,185	2,502,290
Engraulidae unid.	anchovies	1,806,944	407,718
Gobiesocidae unid.	clingfishes	1,576,207	244,279
Atherinopsidae unid.	silversides	1,483,620	425,698
unidentified fish, damaged	unidentified damaged fish	1,066,935	249,472
Gillichthys mirabilis	longjaw mudsucker	984,887	277,598
Genyonemus lineatus	white croaker	553,686	127,528
Labrisomidae unid.	labrisomid blennies	406,722	133,636
Acanthogobius flavimanus	yellowfin goby	406,168	122,806
larval/post-larval fish unid.	larval fishes	338,332	97,443
Syngnathus spp.	pipefishes	221,589	76,803
Gibbonsia spp.	clinid kelpfishes	187,479	64,116
Typhlogobius californiensis	blind goby	159,729	67,985
larvae, unidentified yolksac	unidentified yolksac larvae	94,055	51,833
Pleuronichthys guttulatus	diamond turbot	93,824	31,672
Sciaenidae unid.	croakers	90,682	38,924
Cottidae unid.	sculpins	71,353	36,517
Leptocottus armatus	Pacific staghorn sculpin	70,481	40,692
Paralichthys californicus	California halibut	68,384	34,034
Heterostichus rostratus	giant kelpfish	43,848	26,774
Clinocottus spp.	sculpins	26,336	16,656
Clinidae unid.	kelp blennies	18,758	22,704
Ruscarius creaseri	roughcheek sculpin	15,666	12,791
Lepidogobius lepidus	bay goby	15,003	12,250
Triphoturus mexicanus	Mexican lampfish	14,556	14,339
Cheilotrema saturnum	black croaker	14,373	14,158
Chaenopsidae unid.	tube blennies	12,568	11,242
		121,970,937	
Fish Eggs			
fish eggs unid.	unidentified fish eggs	47,178,602	12,560,138
Engraulidae unid. (eggs)	anchovy eggs	1,032,489	302,913
Paralichthyidae unid. (eggs)	sand flounder eggs	732,391	222,183
Sciaenidae / Paralichthyidae / Labr	SPL fish eggs	586,476	215,540
Atherinopsidae unid. (eggs)	silverside eggs	522,818	331,344
Genyonemus lineatus (eggs)	white croaker eggs	425,277	74,805
Atherinops affinis (eggs)	topsmelt eggs	151,655	43,007
Citharichthys spp. (eggs)	sanddab eggs	125,999	52,007
Paralichthys californicus (eggs)	California halibut eggs	125,850	53,450
Pleuronichthys spp. (eggs)	turbot eggs	109,344	55,046
Sciaenidae unid. (eggs)	croaker eggs	77,074	31,722
		51,067,976	

Table 4.5-4. Calculated total annual entrainment of larval fishes and fish eggs at AGS Units 3&4 in 2006 based on actual cooling water intake pump flows.

		Actual Flow		Design Flow	
Taxon	**Common Name**	**Annual Entrainment**	**Standard Error**	**Annual Entrainment**	**Standard Error**
Gobiidae unid.	gobies	475,626,819	21,554,412	739,308,636	16,822,723
Hypsoblennius spp.	combtooth blennies	165,381,770	7,985,281	242,418,145	5,462,071
Atherinopsidae unid.	silversides	45,904,119	14,219,473	60,835,501	7,857,048
Gobiesocidae unid.	clingfishes	8,763,357	835,496	13,051,216	642,361
Engraulidae unid.	anchovies	6,089,461	1,031,023	8,216,907	604,555
unidentified fish, damaged	unidentified damaged fish	5,778,489	657,185	9,279,701	485,277
Labrisomidae unid.	labrisomid blennies	5,371,113	702,323	7,951,777	432,943
Gillichthys mirabilis	longjaw mudsucker	4,144,532	753,345	8,482,286	567,472
Genyonemus lineatus	white croaker	1,830,810	381,245	2,874,813	249,824
Acanthogobius flavimanus	yellowfin goby	1,527,833	371,027	3,045,452	291,040
Syngnathus spp.	pipefishes	1,498,990	400,191	1,722,271	212,270
larvae, unidentified yolksac	unidentified yolksac larvae	1,342,999	404,207	1,805,881	230,435
Gibbonsia spp.	clinid kelpfishes	840,728	226,694	2,783,445	294,758
Typhlogobius californiensis	blind goby	749,558	216,995	1,086,650	131,583
larval/post-larval fish unid.	larval fishes	588,675	149,151	1,345,401	150,012
Pleuronichthys guttulatus	diamond turbot	522,156	118,506	990,196	89,947
Sciaenidae unid.	croakers	495,288	126,871	741,991	84,850
Tridentiger trigonocephalus	chameleon goby	463,027	256,841	498,645	133,268
Chaenopsidae unid.	tube blennies	282,492	79,481	390,331	53,250
Cottidae unid.	sculpins	276,807	121,649	582,268	103,310
Paralichthys californicus	California halibut	191,758	82,454	286,593	54,283
Leptocottus armatus	Pacific staghorn sculpin	165,274	90,859	308,512	82,453
Clinidae unid.	kelp blennies	156,798	61,663	449,138	88,616
Heterostichus rostratus	giant kelpfish	135,324	48,420	430,265	67,522
Roncador stearnsi	spotfin croaker	127,278	72,575	154,947	41,411
Triphoturus mexicanus	Mexican lampfish	126,027	65,080	126,027	32,540
Cheilotrema saturnum	black croaker	124,441	64,261	124,441	32,131
Ruscarius creaseri	roughcheek sculpin	115,104	55,631	205,718	44,891
Lepidogobius lepidus	bay goby	110,233	53,277	197,012	42,991
Clinocottus spp.	sculpins	108,691	60,911	138,334	36,971
Seriphus politus	queenfish	104,956	59,136	139,941	37,401
		728,944,910		**1,109,972,442**	
Fish Eggs					
fish eggs unid.	unidentified fish eggs	194,290,951	30,736,883	246,388,198	15,922,084
Engraulidae unid. (eggs)	anchovy eggs	16,285,304	2,859,941	18,504,331	1,545,077
Paralichthyidae unid. (eggs)	sand flounder eggs	4,323,994	927,936	7,514,568	641,702
Atherinops affinis (eggs)	topsmelt eggs	3,753,870	1,125,865	4,335,020	586,998
Sciaenidae / Paralichthyidae (eegs)	fish eggs	3,236,553	653,222	3,434,052	335,838
Atherinopsidae unid. (eggs)	silverside eggs	1,656,860	824,878	2,169,608	466,120
Genyonemus lineatus (eggs)	white croaker eggs	1,324,312	185,627	2,889,391	175,639
Sciaenidae unid. (eggs)	croaker eggs	494,598	135,378	666,619	86,328
Paralichthys californicus (eggs)	California halibut eggs	397,002	133,359	901,235	138,254
Citharichthys spp. (eggs)	sanddab eggs	388,076	131,380	853,824	135,439
Pleuronichthys spp. (eggs)	turbot eggs	332,795	99,636	809,218	106,379
		226,484,317		**288,466,063**	

Table 4.5-5. Calculated total annual entrainment of larval fishes and fish eggs at AGS Units 5&6 in 2006 based on actual cooling water intake pump flows.

Taxon	**Common Name**	**Annual Entrainment (Actual Flow)**	**Standard Error**
Gobiidae unid.	gobies	505,144,012	32,051,840
Hypsoblennius spp.	combtooth blennies	271,230,400	16,143,344
Engraulidae unid.	anchovies	13,513,837	2,734,965
Labrisomidae unid.	labrisomid blennies	10,302,441	1,255,729
Atherinopsidae unid.	silversides	8,645,177	1,434,710
Gobiesocidae unid.	clingfishes	6,802,379	741,743
Syngnathus spp.	pipefishes	3,271,880	439,631
Gillichthys mirabilis	longjaw mudsucker	2,950,493	1,174,633
unidentified fish, damaged	unidentified damaged fish	2,528,352	428,265
Genyonemus lineatus	white croaker	2,099,329	230,974
Acanthogobius flavimanus	yellowfin goby	1,984,740	772,839
larval/post-larval fish unid.	larval fishes	1,733,346	417,549
Gibbonsia spp.	clinid kelpfishes	1,411,361	291,055
Sciaenidae unid.	croakers	803,738	260,611
Seriphus politus	queenfish	486,888	289,251
Typhlogobius californiensis	blind goby	475,521	232,881
Clinocottus spp.	sculpins	474,751	146,741
Pleuronichthys guttulatus	diamond turbot	462,522	117,482
larvae, unidentified yolksac	unidentified yolksac larvae	443,713	279,902
Oxyjulis californica	senorita	387,570	126,436
Menticirrhus undulatus	California corbina	219,350	117,248
Paralichthys californicus	California halibut	185,343	115,422
Hypsypops rubicundus	garibaldi	103,960	69,660
Cottidae unid.	sculpins	89,903	59,935
Pleuronectiformes unid.	flatfishes	78,487	52,325
Blennioidei unid.	blennies	12,470	14,400
		835,841,962	
Fish Eggs			
fish eggs unid.	unidentified fish eggs	311,084,282	48,922,721
Engraulidae unid. (eggs)	anchovy eggs	7,783,972	1,808,598
Sciaenidae / Paralichthyidae / Labr	fish eggs	4,598,497	1,085,979
Paralichthyidae unid. (eggs)	sand flounder eggs	2,963,007	487,810
Atherinops affinis (eggs)	topsmelt eggs	875,007	301,444
Atherinopsidae unid. (eggs)	silverside eggs	645,019	215,714
Sciaenidae unid. (eggs)	croaker eggs	583,025	141,333
Citharichthys spp. (eggs)	sanddab eggs	455,159	153,456
Genyonemus lineatus (eggs)	white croaker eggs	29,895	20,531
Pleuronichthys spp. (eggs)	turbot eggs	28,002	28,002
fish egg unid., damaged	damaged fish eggs unid.	9,220	18,440
		329,055,083	

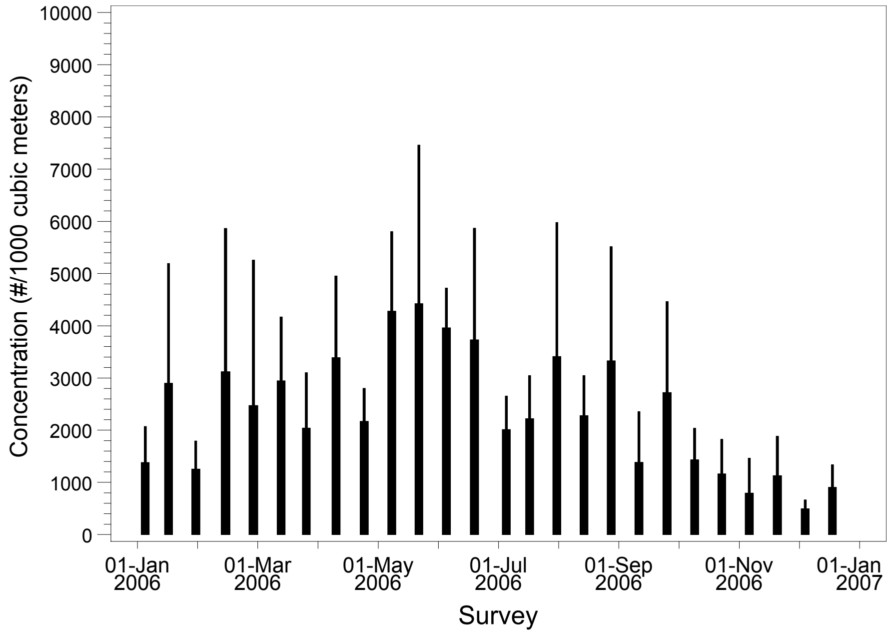


Figure 4.5-1. Mean concentration (# / 1,000 m^3) and standard deviation of all larval fishes collected at entrainment Stations E1 and E2 combined during 2006.

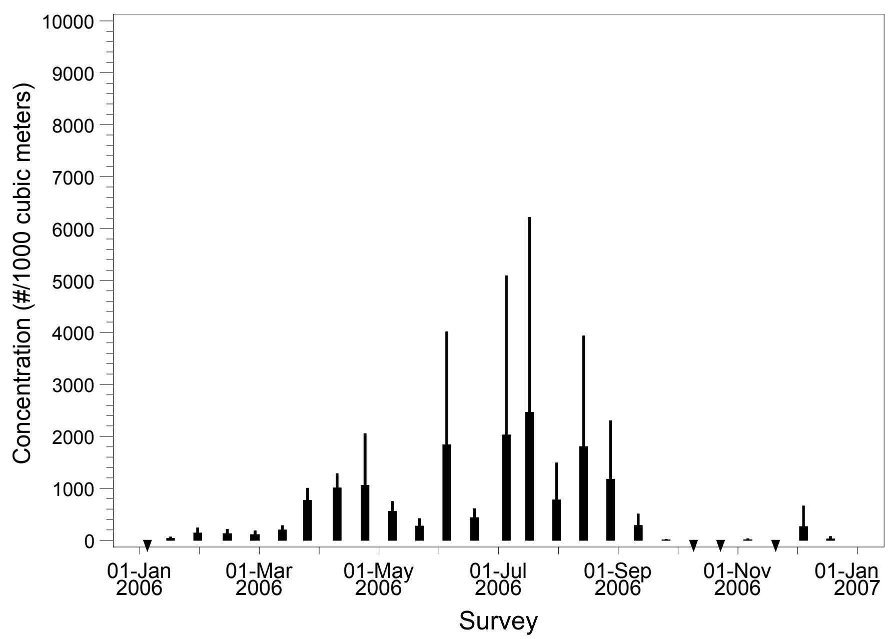


Figure 4.5-2. Mean concentration (# / 1,000 m^3) and standard deviation of fish eggs collected at entrainment Stations E1 and E2 combined during 2006.

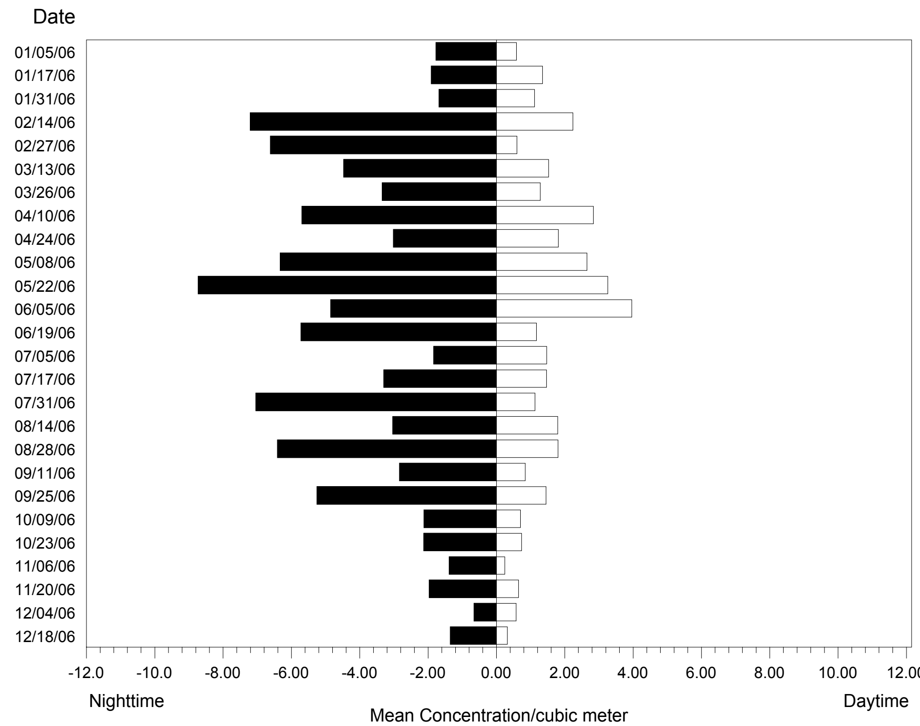


Figure 4.5-3. Mean concentration (#/1.0 m^3) of all fish larvae at entrainment Stations E1 and E2 combined during night (Cycle 3) and day (Cycle 1) sampling.

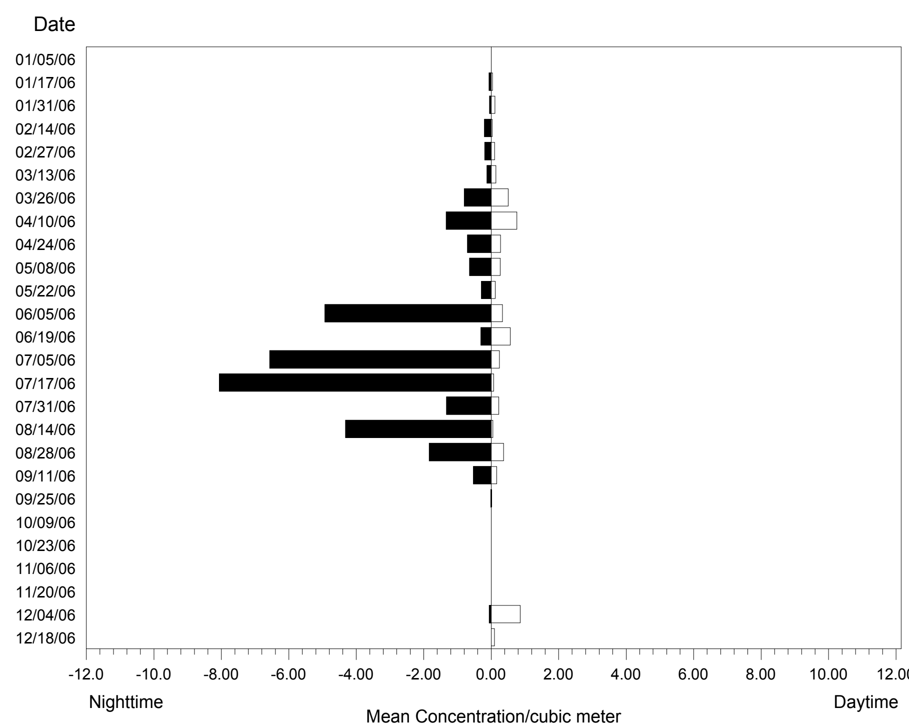


Figure 4.5-4. Mean concentration (#/1.0 m^3) of all fish eggs at entrainment Stations E1 and E2 combined during night (Cycle 3) and day (Cycle 1) sampling.

4.5.1.2 Shellfishes

A total of 39 larval target shellfishes (developmentally advanced larvae of crabs, spiny lobsters, and market squid) representing 8 taxa was collected from the AGS entrainment stations (E1 and E2 combined) during 26 bi-weekly surveys in 2006 (Tables 4.5-6, 4.5-7 and Appendix D). The most abundant target shellfish larvae in the samples were shore crab megalops (Grapsidae unid.), kelp crab megalops (*Pugettia* spp.) and pea crab megalops (*Pinnixa* spp.) which together comprised approximately 80% of the entrained target shellfish larvae for Units 1–4 and Units 5&6. Unidentified crab megalops included species for which there were no descriptions as well as specimens that had some type of damage that prevented identification to a lower taxonomic category. There was no seasonality apparent in the abundance of the larvae due to the low numbers collected and there were no target larvae that had any direct commercial fishery value. Total annual entrainment was estimated to be 4.33 million target invertebrate larvae using the actual cooling water flows, with 10% of the individuals from Units 1&2, 42% from Units 3&4, and 48% from Units 5&6 (Tables 4.5-8, -9, and -10). When design (maximum) flows of 389 mgd were used to calculate annual entrainment for Units 3 & 4, the total number of target invertebrate larvae increased from 1,800,943 to 3,154,318 (Table 4.5-9).

Table 4.5-6. Average concentration of target invertebrate larvae for AGS Units 1–4 based on entrainment data from Station E1.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Target Invertebrates					
Grapsidae unid.	shore crab megalops	2.11	8	36.72	36.72
Pugettia spp.	kelp crabs megalops	1.66	6	28.80	65.53
Hemigrapsus oregonensis	yellow shore crab megalops	0.74	3	12.91	78.44
Pinnixa spp.	pea crabs megalops	0.45	2	7.78	86.22
Petrolisthes spp.	porcelain crab megalops	0.29	1	5.09	91.32
Pachygrapsus crassipes	striped shore crab meg.	0.25	1	4.43	95.75
unidentified crab	unidentified crab megalops	0.24	1	4.25	100.00
		5.75	**22**		

Table 4.5-7. Average concentration of target invertebrate larvae for AGS Units 5&6 based on entrainment data from Station E2.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Target Invertebrates					
Grapsidae unid.	shore crab megalops	1.50	6	33.46	33.46
Pinnixa spp	pea crabs megalops	1.08	4	24.19	57.65
Pugettia spp.	kelp crabs megalops	1.07	4	23.97	81.62
Pachygrapsus crassipes	striped shore crab megalops	0.28	1	6.36	87.98
unidentified crab	unidentified crab megalops	0.28	1	6.19	94.17
Hemigrapsus oregonensis	yellow shore crab megalops	0.26	1	5.83	100.00
		4.47	**17**		

Table 4.5-8. Calculated total annual entrainment of target invertebrate larvae at AGS Units 1&2 in 2006 based on actual cooling water intake pump flows.

Taxon	Common Name	Annual Entrainment (Actual Flow)	Standard Error
Pugettia spp. (megalops)	kelp crabs megalops	217,105	91,655
Grapsidae unid. (megalops)	shore crab megalops	89,473	41,400
Pinnixa spp. (megalops)	pea crabs megalops	45,659	28,878
Petrolisthes spp. (megalops)	porcelain crab megalops	35,858	29,278
unidentified crab (megalops)	unidentified crab megalops	34,906	22,301
Pachygrapsus crassipes (post-larval)	striped shore crab	33,805	26,004
		456,807	

Table 4.5-9. Calculated total annual entrainment of target invertebrate larvae at AGS Units 3&4 in 2006 based on actual cooling water intake pump flows.

		Actual Flow		Design Flow	
Taxon	Common Name	Annual Entrainment	Standard Error	Annual Entrainment	Standard Error
Grapsidae unid. (megalops)	shore crab megalops	723,170	152,145	1,204,863	110,883
Hemigrapsus oregonensis	yellow shore crab	369,313	121,420	397,721	63,002
Pugettia spp. (megalops)	kelp crabs megalops	283,729	118,620	887,382	147,482
Pinnixa spp. (megalops)	pea crabs megalops	188,442	105,603	239,835	64,099
Pachygrapsus crassipes (post-larval)	striped shore crab	107,322	64,718	136,592	36,506
Petrolisthes spp. (megalops)	porcelain crab megalops	100,902	61,407	156,959	41,949
unidentified crab (megalops)	unidentified crab megalops	28,064	22,914	130,966	35,002
		1,800,943		**3,154,318**	

Table 4.5-10. Calculated total annual entrainment of target invertebrate larvae at AGS Units 5&6 in 2006 based on actual cooling water intake pump flows.

Taxon	Common Name	Annual Entrainment (Actual Flow)	Standard Error
Grapsidae unid. (megalops)	shore crab megalops	745,747	261,484
Pinnixa spp. (megalops)	pea crabs megalops	493,346	179,949
Pugettia spp. (megalops)	kelp crabs megalops	401,928	166,149
Pachygrapsus crassipes (megalops)	striped shore crab megalops	179,096	111,531
unidentified crab (megalops)	unidentified crab megalops	174,314	108,553
Hemigrapsus oregonensis (post-larval)	yellow shore crab	77,773	51,849
		2,072,205	

4.5.2 Source Water Summary

4.5.2.1 Fishes

A total of 46,687 larval fishes representing 68 taxa was collected from AGS source water stations in and near Alamitos Bay (Stations H1–H4, S1–S3 and O1–O3) during 12 monthly surveys in 2006 (Table 4.5-11 and Appendix D). Unidentified gobies (CIQ goby complex), combtooth blennies, white croaker, and anchovies were the most abundant taxa and comprised over 90% of all specimens collected. Damaged fishes that could not be positively identified comprised less than 1.0% of the total catch. The greatest concentrations of larval fishes occurred during April 2006 (ca. 5,800 per 1,000 m^3) and the fewest in October 2006 (ca. 600 per 1,000 m^3) (Figure 4.5.5). Mean concentrations were slightly higher overall in nighttime tows as compared with daytime tows (Figure 4.5-6).

4.5.2.2 Target Shellfishes

A total of 2,312 larval target invertebrates representing 20 taxa (combined species designations) was collected from AGS source water stations in and near Alamitos Bay (Stations H1–H4, S1–S3 and O1–O3) during 12 monthly surveys in 2006 (Table 4.5-12 and Appendix D). Megalops of kelp crabs, pea crabs, shore crabs, spider crabs, and unidentified megalops were the most abundant taxa and comprised over 90% of all specimens collected. Data presented in Appendix D include abundances for the uncombined species designations by survey.

Table 4.5-11. Average concentration of larval fishes in samples collected at AGS source water stations in and near Alamitos Bay (Stations H1–H4, S1–S3 and O1–O3) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Gobiidae unid.	gobies	1,158.44	23,508	50.35	50.35
Hypsoblennius spp.	combtooth blennies	407.17	8,179	17.52	67.87
Genyonemus lineatus	white croaker	406.54	7,891	16.90	84.77
Engraulidae unid.	anchovies	159.03	3,137	6.72	91.49
larvae, unidentified yolksac	unidentified yolksac larvae	35.87	698	1.50	92.99
Sciaenidae unid.	croakers	27.80	566	1.21	94.20
unidentified fish, damaged	unidentified damaged fish	21.92	443	0.95	95.15
Atherinopsidae unid.	silversides	19.15	389	0.83	95.98
Acanthogobius flavimanus	yellowfin goby	13.74	256	0.55	96.53
Gobiesocidae unid.	clingfishes	9.75	199	0.43	96.96
Paralichthys californicus	California halibut	9.25	188	0.40	97.36
Labrisomidae unid.	labrisomid blennies	8.42	169	0.36	97.72
Seriphus politus	queenfish	6.97	139	0.30	98.02
Pleuronichthys guttulatus	diamond turbot	5.08	98	0.21	98.23
Gillichthys mirabilis	longjaw mudsucker	4.91	103	0.22	98.45
Hypsypops rubicundus	garibaldi	4.30	91	0.19	98.64
Paralabrax spp.	sand bass	3.11	56	0.12	98.76
Typhlogobius californiensis	blind goby	2.98	57	0.12	98.89
Pleuronichthys verticalis	hornyhead turbot	2.05	38	0.08	98.97
Syngnathus spp.	pipefishes	1.92	39	0.08	99.05
Gibbonsia spp.	clinid kelpfishes	1.92	37	0.08	99.13
Citharichthys spp.	sanddabs	1.65	33	0.07	99.20
Parophrys vetulus	English sole	1.65	34	0.07	99.27
Lepidogobius lepidus	bay goby	1.55	33	0.07	99.34
Leptocottus armatus	Pacific staghorn sculpin	1.41	31	0.07	99.41
Pleuronichthys ritteri	spotted turbot	1.41	27	0.06	99.47
Cheilotrema saturnum	black croaker	1.16	23	0.05	99.52
Pleuronichthys spp.	turbots	1.14	23	0.05	99.57
Stenobrachius leucopsarus	northern lampfish	1.10	20	0.04	99.61
larval/post-larval fish unid.	larval fishes	1.01	20	0.04	99.65
Roncador stearnsii	spotfin croaker	0.80	17	0.04	99.69
Merluccius productus	Pacific hake	0.73	14	0.03	99.72
Clinocottus spp.	sculpins	0.60	11	0.02	99.74
Sebastes spp.	rockfishes	0.58	13	0.03	99.77
Pleuronectidae unid.	righteye flounders	0.49	10	0.02	99.79
Heterostichus rostratus	giant kelpfish	0.38	8	0.02	99.81
Menticirrhus undulatus	California corbina	0.33	7	0.01	99.82
Ruscarius creaseri	roughcheek sculpin	0.32	6	0.01	99.84
Peprilus simillimus	Pacific butterfish	0.31	6	0.01	99.85
Symphurus atricaudus	California tonguefish	0.27	5	0.01	99.86
Pleuronectiformes unid.	flatfishes	0.25	5	0.01	99.87

(table continued)

Table 4.5-11 (continued). Average concentration of larval fishes in samples collected at AGS source water stations in and near Alamitos Bay (Stations H1–H4, S1–S3 and O1–O3) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Oxyjulis californica	senorita	0.24	5	0.01	99.88
Triphoturus mexicanus	Mexican lampfish	0.22	4	0.01	99.89
Oxylebius pictus	painted greenling	0.19	4	0.01	99.90
Blennioidei unid.	blennies	0.18	3	0.01	99.91
Paralichthyidae unid.	sand flounders	0.17	4	0.01	99.91
Ophidiidae unid.	cusk-eels	0.17	3	0.01	99.92
Umbrina roncador	yellowfin croaker	0.16	3	0.01	99.93
Scorpaenidae unid.	scorpionfishes	0.16	3	0.01	99.93
Ophidion scrippsae	basketweave cusk-eel	0.16	3	0.01	99.94
Rhinogobiops nicholsii	blackeye goby	0.15	3	0.01	99.95
Sphyraena argentea	Pacific barracuda	0.15	3	0.01	99.95
Semicossyphus pulcher	California sheephead	0.11	2	<0.01	99.96
Girella nigricans	opaleye	0.11	2	<0.01	99.96
Sardinops sagax	Pacific sardine	0.11	2	<0.01	99.97
Chaenopsidae unid.	tube blennies	0.09	2	<0.01	99.97
Zaniolepis spp.	combfishes	0.09	2	<0.01	99.97
Cottidae unid.	sculpins	0.08	2	<0.01	99.98
Icelinus spp.	sculpins	0.06	1	<0.01	99.98
Halichoeres semicinctus	rock wrasse	0.06	1	<0.01	99.98
Pomacentridae unid.	damselfishes	0.06	1	<0.01	99.99
Bathylagidae unid.	blacksmelt	0.06	1	<0.01	99.99
Neoclinus spp.	fringeheads	0.06	1	<0.01	99.99
Myctophidae unid.	lanternfishes	0.05	1	<0.01	99.99
Haemulidae unid.	grunts	0.05	1	<0.01	99.99
Artedius spp.	sculpins	0.04	1	<0.01	100.00
Hexagrammidae unid.	greenlings	0.04	1	<0.01	100.00
Scorpaenichthys marmoratus	cabezon	0.04	1	<0.01	100.00
		2,330.48	**46,687**		

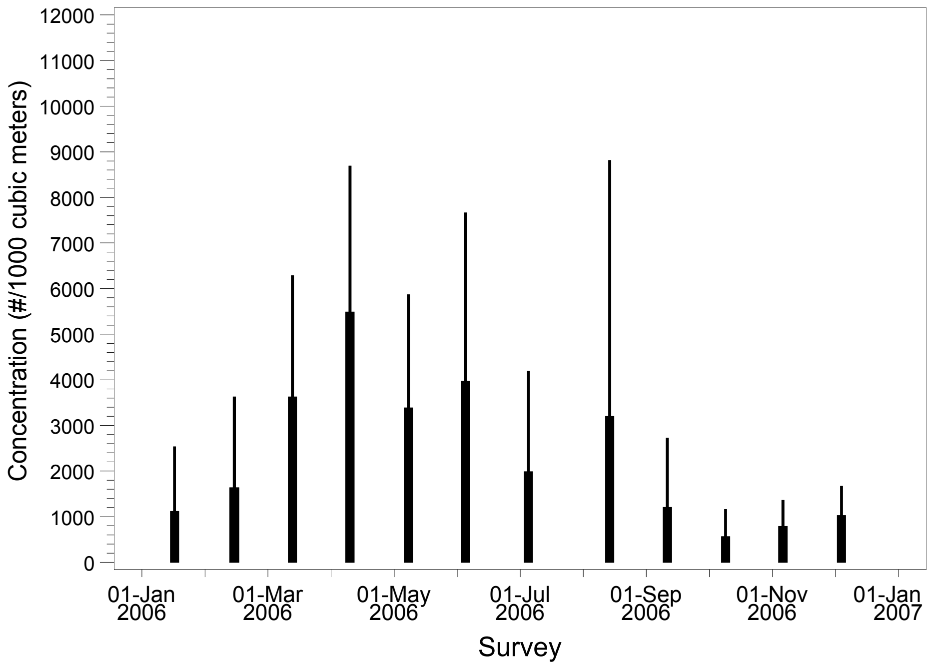


Figure 4.5-5. Mean concentration (# / 1,000 m^3) and standard deviation of all larval fishes collected at AGS source water stations during 2006.

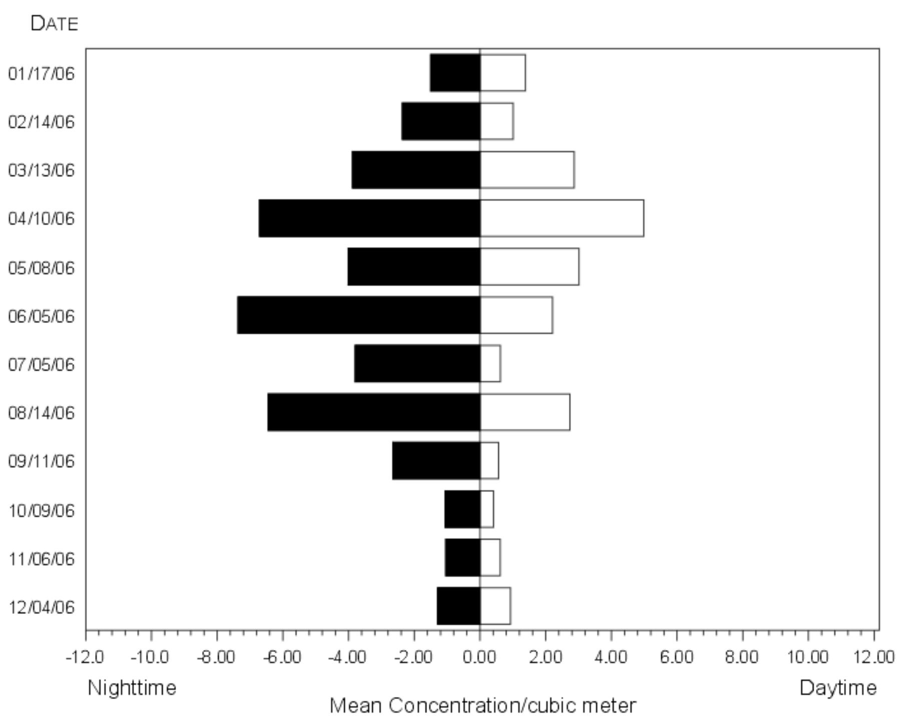


Figure 4.5-6. Mean concentration (# / 1,000 m^3) of all larval fishes collected at AGS source water stations during 2006 during night and day tows.

Table 4.5-12. Average concentration of larval target invertebrates in samples collected at AGS source water stations in and near Alamitos Bay (Stations H1–H4, S1–S3 and O1–O3) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Pugettia spp	kelp crabs megalops	63.75	1,272	54.31	54.31
Pinnixa spp.	pea crabs megalops	14.73	311	13.28	67.59
Grapsidae unid.	shore crab megalops	11.33	230	9.82	77.41
unidentified crab	unidentified crab megalops	7.34	147	6.28	83.69
Majidae unid.	spider crab megalops	4.10	81	3.46	87.15
Brachyura unid.	unidentified crab megalops	3.21	67	2.86	90.01
Paguridae unid.	hermit crab megalops	2.61	51	2.18	92.19
Pinnotheres spp.	pea crab megalops	2.15	45	1.92	94.11
Cancer spp.	cancer crabs megalops	1.62	32	1.37	95.47
Porcellanidae unid. (megalops)	porcelain crab megalops	1.08	23	0.98	96.46
Petrolisthes spp.	porcelain crab megalops	1.04	20	0.85	97.31
Pachycheles spp.	porcelain crabs megalops	0.99	19	0.81	98.12
Lophopanopeus spp. (megalops)	black-clawed crab megalops	0.96	22	0.94	99.06
Diogenidae	left-handed hermit crabs	0.32	7	0.30	99.36
Pachycheles rudis	thickclaw porcelain crab	0.32	7	0.30	99.66
Panulirus interruptus (phyllosome)	California spiny lobster (larval)	0.15	3	0.13	99.79
Loligo opalescens	market squid	0.11	2	0.09	99.87
Pachygrapsus crassipes	striped shore crab megalops	0.06	1	0.04	99.91
Hippoidea (megalops)	mole crab megalops	0.06	1	0.04	99.96
Panulirus interruptus	California spiny lobster	0.04	1	0.04	100.00
		126.03	**2,342**		

4.5.3 Results by Species for Cooling Water Intake Structure Entrainment

The following three fish taxa were selected for detailed evaluation of entrainment effects based on their abundance in entrainment samples. Together they comprised over 90% of the larvae sampled at the AGS entrainment station in 2006 (Tables 4.5-1 through 4.5-3). In taxonomic order these are:

- silversides (Atherinopsidae)
- combtooth blennies (*Hypsoblennius* spp.)
- unidentified gobies (Gobiidae)
- anchovies (Engraulidae)

4.5.3.1 Silversides (Atherinopsidae)

Jamie Siler

Three species of silversides (family Atherinopsidae) occur in California ocean waters and in the vicinity of the AGS: 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).

4.5.3.1.1 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 percent of the individuals and 9 percent 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.

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).

Summary of silverside distribution and life history attributes.

***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.

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). Hatch length for topsmelt ranges from 4.3–5.4 mm, and 6–9 mm (typically 7.5–8.5 mm) for jacksmelt (Moser 1996). Larval growth rate averages approximately 0.37 mm/d for both species based on data from Middaugh et al. (1990). Plankton sampling conducted in Alamitos Bay during an earlier 316(b) study (IRC 1981) found that nearly all silverside larvae were collected in surface samples indicating a strong behavioral tendency for these larvae to actively maintain their position in surface strata, possibly through a phototatic response.

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. Hatch length for grunion ranges from 6.5−7.0 mm (Moser 1996).

4.5.3.1.2 Fishery and Population Trends

Bays, estuaries, and soft bottom sediments in the surf zone are the primary habitats where silversides (jacksmelt, topsmelt, and grunion) are typically most abundant within southern California (Allen et al. 2006; Allen and Pondella 2006a). Topsmelt numbers are much greater in bays compared to semi-protected or exposed coastlines (Allen and Herbinson 1991), whereas jacksmelt form larger and denser schools than topsmelt in nearshore areas (Gregory 2001a). Differential habitat use within bays and estuaries indicate that topsmelt occupy much of the water column both along the shoreline and main channels (Allen et al. 2002; Valle et al. 1999).

A limited fishery exists for silversides in which they are marketed fresh for human consumption or for bait (Gregory 2001a). The commercial fishery for silversides has been conducted with a variety of gears including gillnets, lampara nets, and round haul nets. Historically, set-lines were used in San Francisco Bay for jacksmelt, and during the 1920s beach nets were used at Newport Beach (Gregory 2001a). 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. Silversides, in general, are an incidental fishery and the large fluctuations in the catch records reflect demand rather than relative abundances.

Grunion are primarily harvested by recreational fishers by hand when these fish spawn on wet sandy beaches during spring and summer. They are also taken incidentally in bait nets and other round haul nets in limited quantities and are used as live bait, although no commercial landings have been reported (Gregory 2001b). 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.

Table 4.5-13. Annual landings for jacksmelt and topsmelt in the Southern California region based on RecFIN data (values are estimated numbers of fish).

Year	Jacksmelt	Topsmelt
2000	124,000	30,000
2001	128,000	41,000
2002	90,000	152,000
2003	115,000	29,000
2004	173,000	87,000
2005	140,000	70,000
2006	181,000	66,000

Both topsmelt and jacksmelt make up a significant portion of the catch from piers and along shores. Jacksmelt shore landings declined by over 75% in the 1990s compared to the 1980s (Jarvis et al. 2004) Recent catch estimates of topsmelt by recreational anglers in southern California from 2000 to 2006 ranged from 29,000 to 152,000 fish, with an average of 67,900 fish caught annually (Table 4.5-13). Sport fishery catch estimates for jacksmelt in southern California from 2000 to 2006 ranged from 90,000 to 181,000 fish, with an average of 135,900 fish caught annually. A total of 62 lbs of jacksmelt with a revenue of $35 were landed in the Los Angeles-Long Beach area in 2006, while 10 lbs of topsmelt with a revenue of $50 were landed according to specific CDF&G catch block data from the area.

4.5.3.1.3 Sampling Results

Silverside larval complex (combined for community analysis) was the third most abundant taxon at entrainment Station E1 with a mean concentration of 116 per 1,000 m^3, and fourth in abundance at entrainment Station E2 with 54 larvae per 1,000 m^3 (Tables 4.5-1 and 4.5-2). Silverside eggs were present but infrequent at both stations. Approximately 70% of the silverside larvae in the entrainment samples were positively identified as topsmelt, followed by unidentified silversides, California grunion, and jacksmelt (Table 4.5-14). The larvae mostly occurred at the entrainment stations in late February and late May, with maximum abundances of approximately 1,000 per 1,000 m^3 (Figure 4.5-7). They were absent or very low in abundance in samples collected from June through January. Monthly source water concentrations peaked in April and were lowest in August and September (Figure 4.5-8) but overall were much lower (ca. average of 20–80 per 1,000 m^3) than concurrent entrainment concentrations. The larvae tended to be much more abundant in nighttime samples than daytime samples (Figure 4.5-9). The length frequency distribution of measured silverside larvae showed a unimodal distribution with most larvae in the range of 8–10 mm (Figure 4.5-10). The lengths of the larvae from the entrainment station samples ranged from 2.5 to 24.4 mm with a mean of 9.5 mm NL.

Table 4.5-14. Average concentrations and annual entrainment mortality of silverside taxa at AGS. Note: average concentrations calculated from data at both Stations E1 and E2, while entrainment calculated as the sum of the individual unit pairs.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	% of Total	Annual Entrainment (Actual Flow)	Standard Error
Larval Fishes						
Atherinops affinis	topsmelt	58.75	413	68.26	40,625,341	13,901,836
Atherinopsidae unid.	unid. silversides	13.45	101	16.69	9,830,643	1,238,368
Leuresthes tenuis	California grunion	5.32	38	6.28	3,999,804	1,114,923
Atherinopsis californiensis	jacksmelt	7.10	53	8.76	1,577,128	384,027
		84.60	**605**		**56,032,917**	
Fish Eggs						
Atherinops affinis (eggs)	topsmelt eggs	5.51	45	68.18	4,780,532	1,169,476
Atherinopsidae unid. (eggs)	silverside eggs	2.58	21	31.82	2,824,698	1,124,373
		8.09	**66**		**7,605,230**	

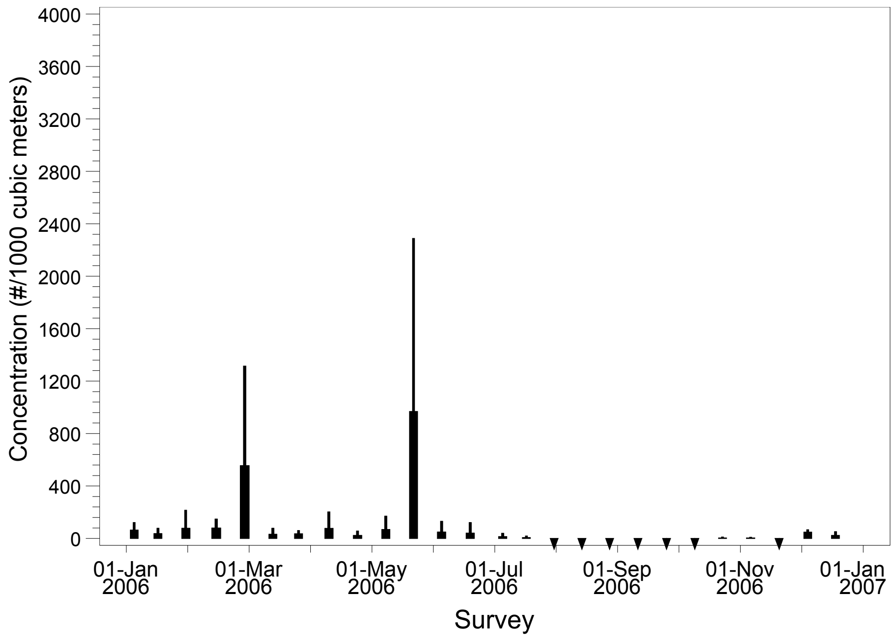


Figure 4.5-7. Mean concentration (# / 1,000 m^3) and standard deviation of silverside larvae collected at AGS entrainment Stations E1 and E2 combined during 2006.

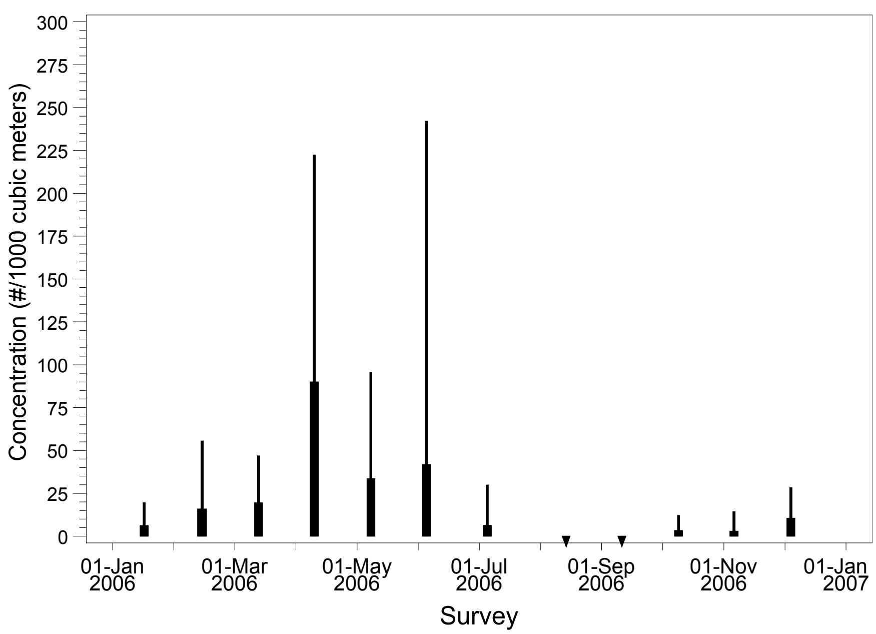


Figure 4.5-8. Mean concentration (# / 1,000 m^3) and standard deviation of silverside larvae collected at AGS source water stations during 2006.

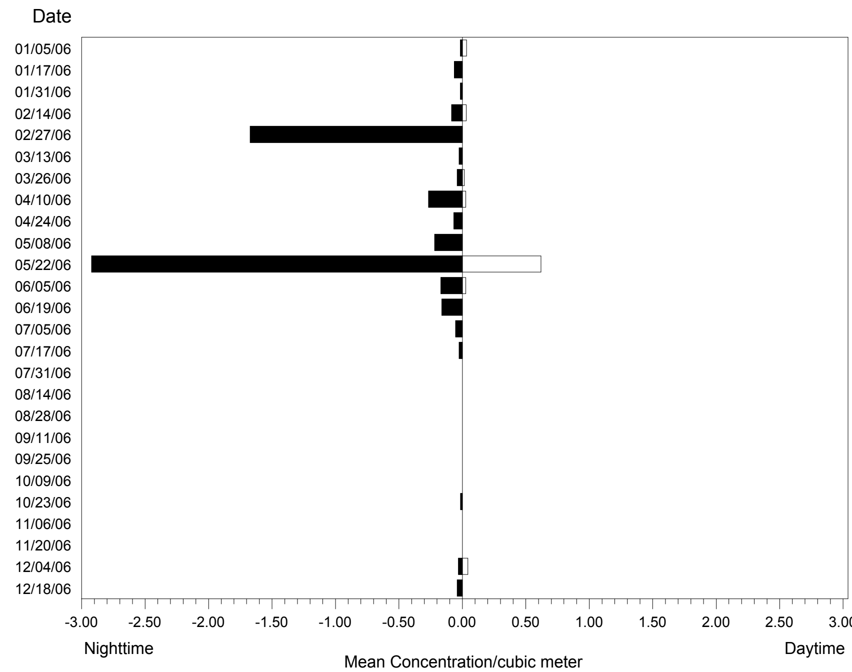


Figure 4.5-9. Mean concentration (#/1.0 m^3) of silverside larvae at entrainment Stations E1 and E2 combined during night (Cycle 3) and day (Cycle 1) sampling.

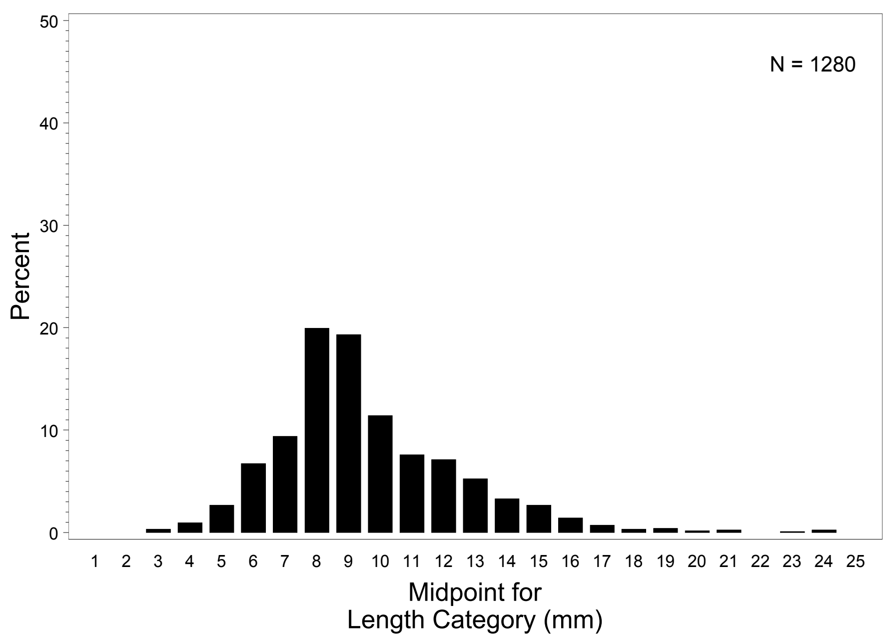


Figure 4.5-10. Length (mm) frequency distribution for larval silversides collected at entrainment stations in Alamitos Bay.

4.5.3.1.4 Modeling Results

The following sections present the results for empirical transport modeling of entrainment effects on Atherinopsidae complex (silverside) eggs and larvae. Although there was information on the early life history for California grunion, there was very little species-specific information available for the other two species, topsmelt and jacksmelt, that were collected in greater abundances during the study. Therefore, circulating water system effects were estimated using only the *ETM* and not the demographic models. Total annual entrainment of silversides at AGS was estimated at 56,032,916 during 2006 for all six units combined, with over 80% attributed to the operation of Units 3 & 4 (Tables 4.5-3 through 4.5-5).

Empirical Transport Model (ETM)

A larval growth rate of 0.44 mm/d (0.02 mm/d) for silversides was estimated from laboratory studies by Middaugh et al. (1990) and used with the difference in the lengths of the 10th and 95th percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of approximately 17.1 days (d).

The monthly estimates of proportional entrainment (*PE*) for silversides for 2006 ranged from 0 to 0.01948 (Table 4.5-15). 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 = 0.355 or 35.5%). The values in the table were used to calculate a P_M estimate of 0.0839 (8.4%) with a standard error of 0.1453.

Table 4.5-15. *ETM* data for silverside larvae. *ETM* calculations based on actual cooling water flow.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Jan-06	0.01182	0.04828	0.02158	0.01038
14-Feb-06	0.0044	0.02209	0.08485	0.0436
13-Mar-06	0.00211	0.01735	0.05876	0.02328
10-Apr-06	0.00442	0.02381	0.3555	0.11228
8-May-06	0.01948	0.14566	0.07427	0.02963
5-Jun-06	0.00322	0.02706	0.28109	0.15834
5-Jul-06	0.00618	0.10985	0.04056	0.03066
14-Aug-06	0	0	0	0
11-Sep-06	0	0	0	0
9-Oct-06	0	0	0.01684	0.00869
6-Nov-06	0.00124	0.00848	0.01071	0.01027
4-Dec-06	0.00549	0.01553	0.05584	0.02513

4.5.3.2 Combtooth blennies (*Hypsoblennius* spp.)

Gerald Allen

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 AGS: bay blenny (*H. gentilis)*, rockpool blenny (*H. gilberti*), and mussel blenny (*H. jenkinsi*). These species co-occur throughout much of their range although they occupy different habitats. The bay blenny is found along both coasts of Baja California and up the California coast to as far north as Monterey Bay, (Miller and Lea 1972; Robertson and Allen 2002). The rockpool blenny occurs from Magdalena Bay, Baja California to Point Conception, California (Miller and Lea 1972; Stephens et al. 1970). The range of the mussel blenny extends from Morro Bay to Magdalena Bay, Baja California and in the northern Gulf of California (Love et al. 2005).

4.5.3.2.1 Life History and Ecology

Combtooth blennies are all relatively small fishes that typically grow to a total length of less than 200 mm (7.9 in) (Moser 1996). Most have blunt heads that are topped with some arrangement of cirri (Moyle and Cech 1988; 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 (Ninos 1984; Moser 1996). For this reason most *Hypsoblennius* in the AGS 316(b) plankton collections were identified only to the generic level. Certain morphological features (e.g., preopercular spines) become distinctive at larger larval sizes and allow identification to the species level.

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 appear to have general habitat requirements and may inhabit a variety of intertidal and subtidal areas (Stephens et al. 1970). They are commonly found in mussel beds and on encrusted floats, buoys, docks, and even fouled boat hulls (Stephens 1969; Stephens et al. 1970). Bay 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.

Summary of combtooth blenny distribution and life history attributes.

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 Baja California

Life History:
- Size: bay blenny to 14.7 cm (5.8 in) TL, 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

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). Total lifetime fecundity may be up to 7,700 eggs (Stephens 1969).

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 mm and 45 mm (1.6 in 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, cabezon, and other benthic predatory fishes (Stephens et al. 1970).

4.5.3.2.2 Population Trends and Fishery

Combtooth blennies were common in the eelgrass habitat sampled within Alamitos Bay in a series of trawls conducted from 1992–1995. The bay blenny was more common in the outer part of the bay (Valle et al. 1999). Long-term data on abundances of combtooth blennies from King Harbor in Redondo Beach were collected from surveys of quarry rock boulders from 1984–2006 (Pondella, unpubl. data). An average of 1.62 blennies was collected per boulder each year. At the beginning of the study, they were found in the highest densities (9.57 individuals/boulder) and then declined until 1995 when the density recorded was 0.143/boulder (Figure 4.5-11). Since 1995, the density increased to 1.57 individuals/boulder in 2005. Annual average densities of combtooth blennies in King Harbor were correlated with average annual sea surface temperatures. This is shown in the decline in densities following major El Niño periods in 1983, 1987, 1992–1993, and 1997. The period of warm seawater temperatures resulted in declines in combtooth blenny larvae in King Harbor in the 1990s (Stephens and Pondella 2002). The correlation between adult density and sea surface temperature suggests that the abundance of this short-lived species was dependent on successful recruitment in response to optimal oceanographic conditions.

Daily entrainment rates for AGS Units 1-6 during the earlier 316(b) study in 1978–1979 (SCE 1982a) were based on representative density data of plankton collected from the nearby HnGS intake structure. Mean density values of *Hypsoblennius* species complex larvae were lowest from mid-January through the end of March and relatively high for the remainder of the year. Survey means for the near-field varied from 0 to 20,493 larvae per 1,000 m^3 (average 2,725 per 1,000 m^3) and from 1 to 1,800 larvae per 1,000 m^3 (average 120 per 1,000 m^3) for the far-field. These near-field densities were approximately four times greater than the 2006 densities measured at the entrainment station while the far field station densities were about one-third of the 2006 source water densities.

Stephens and Pondella (2002) measured annual larval densities at King Harbor in Redondo Beach from 1974–1997 and found an overall decline in combtooth blennies from highest densities in the mid 1970s to lowest densities in the mid 1990s. Part of the decline was attributed to a period of warmer water temperatures throughout the region beginning in the late 1970s, but other localized disturbances to nesting habitat from storm damage, breakwater renovation, and channel dredging may have had an effect on larval production.

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

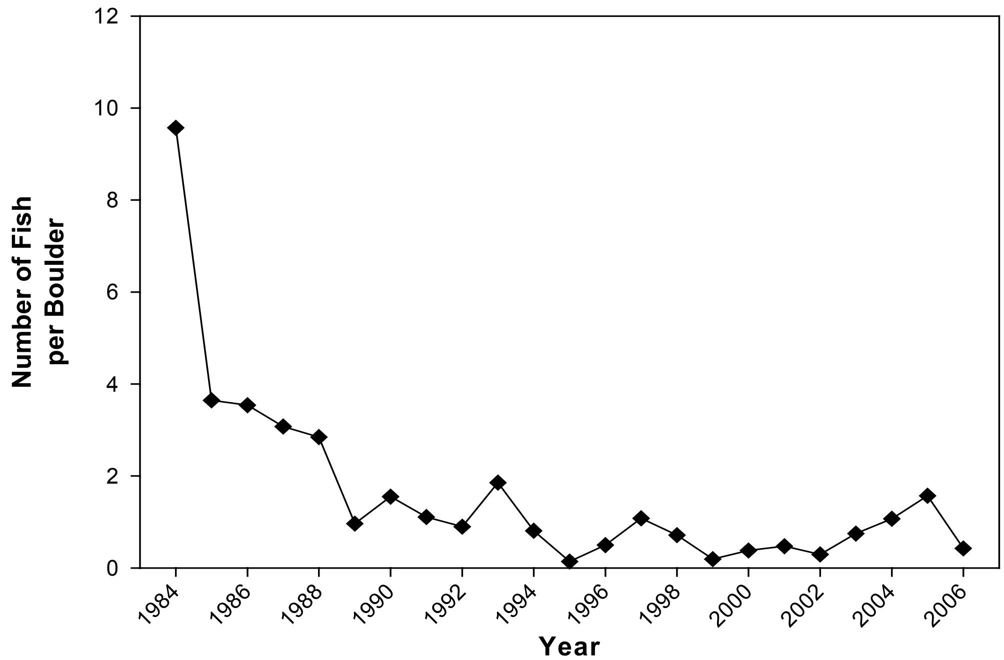


Figure 4.5-11. Abundance of combtooth blennies collected per boulder at King Harbor, Redondo Beach, California from 1984–2006 (from Pondella, unpubl. data).

4.5.3.2.3 Sampling Results

Combtooth blenny was the second most abundant taxon at entrainment Stations E1 and E2 with a mean concentration of 450 larvae per 1,000 m^3 and 658 larvae per 1,000 m^3, respectively, over all surveys (Tables 4.5-1 and 4.5-2). They were most abundant in late spring and summer, with peaks in May and June, and a smaller peak in early fall (Figure 4.5-12). They were relatively low in abundance in winter samples. During periods of maximum abundance in early May 2006 combtooth blennies were present in the entrainment samples at average concentrations of 1,600 per 1,000 m^3. Source water abundances followed a similar seasonal pattern with peak average concentrations in June of approximately 1,200 per 1,000 m^3 (Figure 4.5-13). There were substantially more larvae in most nighttime samples than paired daytime samples (Figure 4.5-14). The length frequency range for larvae was small with almost all measured specimens within the 2.0–3.0 mm size classes (Figure 4.5-15). The mean length of specimens from the entrainment station samples was 2.38 mm NL with a size range from 1.7 mm to 11.1 mm.

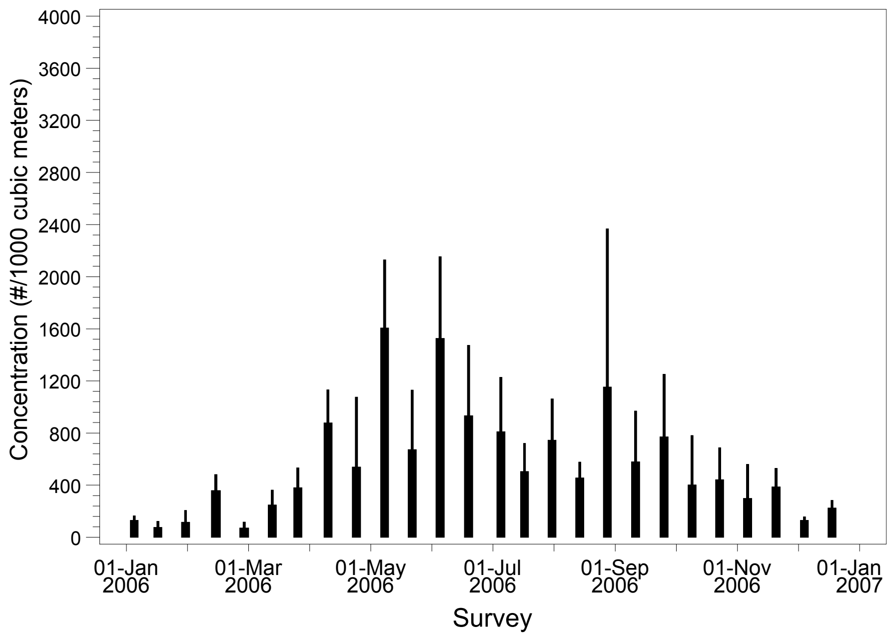


Figure 4.5-12. Mean concentration (# / 1,000 m^3) and standard deviation of combtooth blenny larvae collected at AGS entrainment Stations E1 and E2 combined during 2006.

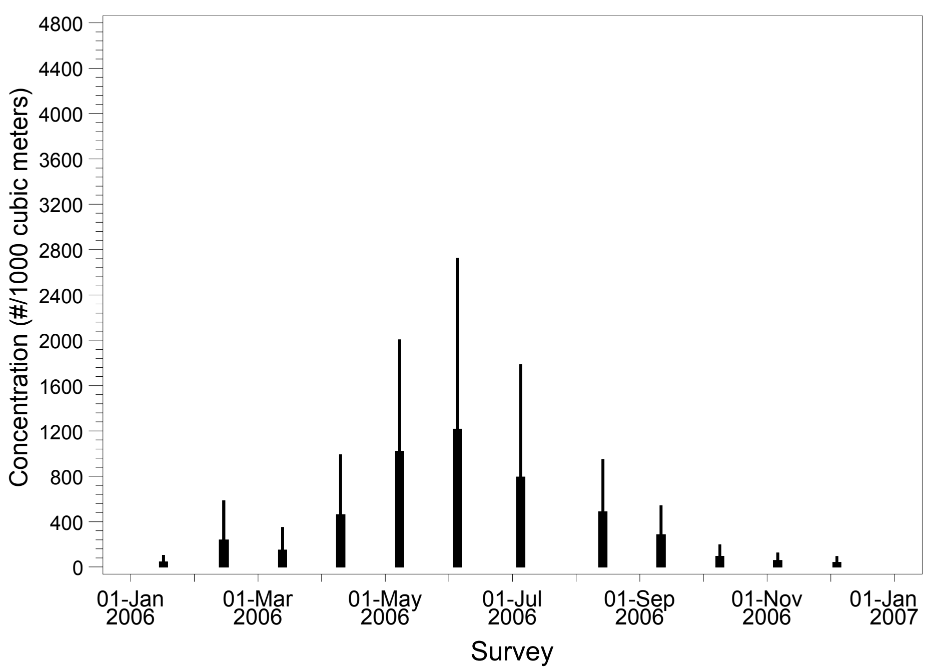


Figure 4.5-13. Mean concentration (# / 1,000 m^3) and standard deviation of combtooth blenny larvae collected at AGS source water stations during 2006.

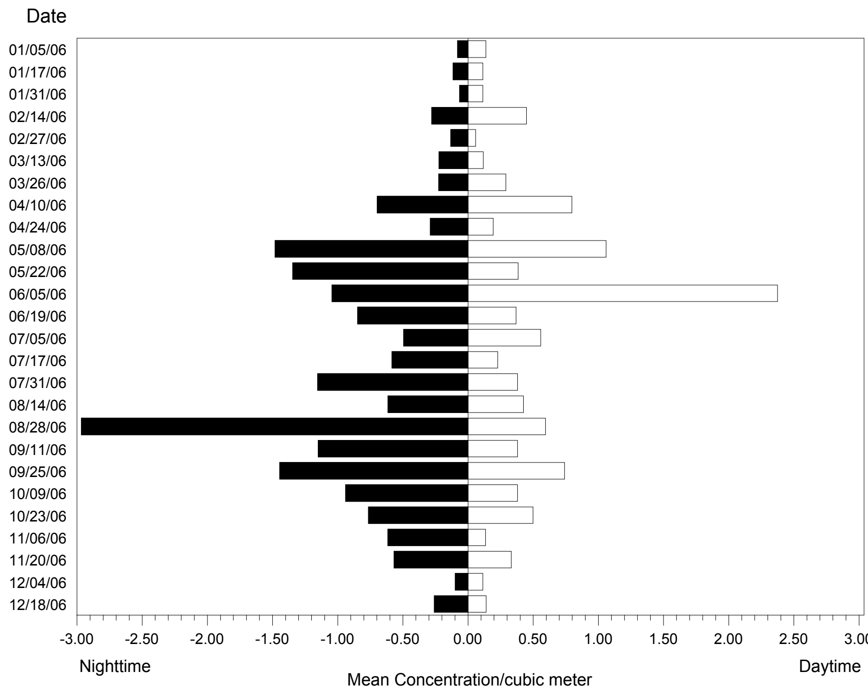


Figure 4.5-14. Mean concentration (#/1.0 m^3) of combtooth blenny larvae at entrainment Stations E1 and E2 combined during night (Cycle 3) and day (Cycle 1) sampling.

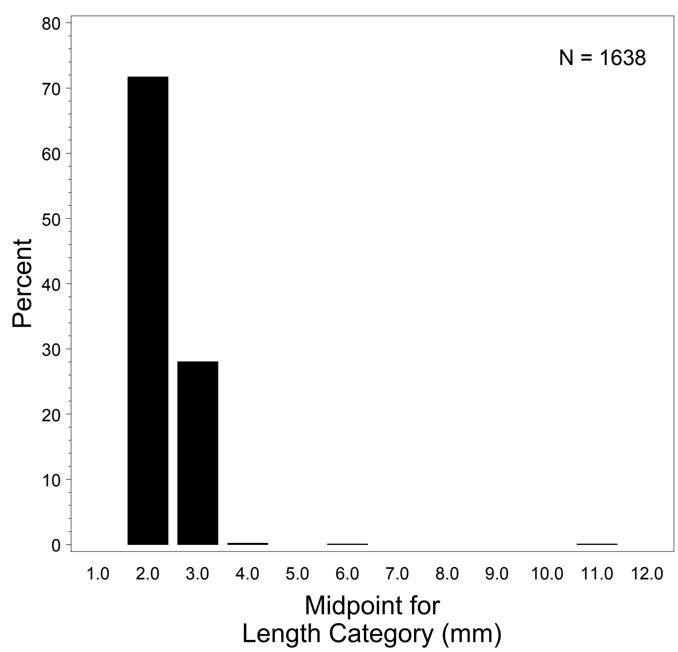


Figure 4.5-15. Length (mm) frequency distribution for larval combtooth blennies collected at entrainment stations in Alamitos Bay.

4.5.3.2.4 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 both *FH* and *AEL* estimates. Total annual entrainment of combtooth blennies at AGS was estimated at 463,862,355 during 2006 for all six units combined, with 58% attributed to the operation of Units 5 & 6, 35% to Units 3 & 4, and the remainder to Units 1 & 2 (Tables 4.5-3 through 4.5-5).

Fecundity Hindcasting (*FH*)

The annual entrainment estimate for combtooth blenny larvae was 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%. A larval growth rate of 0.20 mm/day (0.008 inches/d) was derived from data in Stevens and Moser (1982). The mean length of 2.4 mm (0.09 inches) from 200 randomly selected lengths from the 1,489 larvae measured and calculated hatch length of 2.1 mm (0.08 inches) were used with the growth rate to estimate that the mean age at entrainment was 1.5 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 $0.89^{1.5} = 0.84$. A quadratic equation was used to estimate adult survival *S* at age in days *x* using Figure 17 in Stephens (1969):

$$S = 8.528 \times 10^{-8} x^2 - 3.918 \times 10^{-4} x + 0.4602 \tag{5}$$

An adult survivorship table (Table 4.5-16) was constructed using the survival equation based on Stephens (1969) and information about eggs from Stephens (1969; Table 3) on *H. gentilis*, *H. gilberti* and *H. jenkinsi* to estimate a lifetime fecundity of 2,094 eggs.

Table 4.5-16. 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).

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 total lifetime fecundity was calculated as the sum of L_xM_x divided by 1,000.

The estimated numbers of female combtooth blennies at the age of maturity (0.5 years) whose lifetime reproductive output was entrained through the AGS CWS during 2006 was 264,876 based on entrainment estimates calculated using actual cooling water flow during the period (Table 4.5-17). 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 than the life history parameters used in the model.

Table 4.5-17. Results of *FH* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual CWS flow.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH Estimate	**264,876**	229,638	63,631	1,102,593	1,038,962
Total Entrainment	463,862,356	18,725,481	247,286	282,465	35,179

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.

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 $0.89^{(50-1.5)} = 0.004$ 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 AGS CWS for the sampling period was 1,130,436 based on actual cooling water flows during 2006. (Table 4.5-18). The results of the sensitivity analysis show that the model estimate was much more sensitive to the error associated with the life history estimates than the entrainment estimates used in the model.

Table 4.5-18. Results of *AEL* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual CWS flow.

Parameter	Estimate	Std. Error	AEL Lower Estimate	AEL Upper Estimate	AEL Range
AEL Estimate	**1,130,436**	1,385,248	150,590	8,485,877	8,335,287
Total Entrainment	463,862,356	18,725,481	1,055,368	1,205,505	150,136

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.

Empirical Transport Model (*ETM*)

A sample of 200 lengths from the measured larvae was used to calculate the difference between the estimated hatch length and the 95^{th} percentile (3.0 mm [0.12 inches]) of the measurements and a growth rate of 0.20 mm/day (0.008 inches/d) to estimate that blennies were exposed to entrainment for a period of approximately 4.4 d.

The monthly estimates of proportional entrainment (*PE*) for combtooth blennies for the 2006 period varied among surveys and ranged from 0.01089 to 0.06491 and were collected during all of the paired entrainment-source water surveys (Table 4.5-19). The largest estimate was calculated for the April survey, but the largest proportion of the source population was present during the June survey (f_i = 0.305 or 30.5%). The values in the table were used to calculate a P_M estimate of 0.090 (9.0%) with a standard error of 0.051.

Table 4.5-19. *ETM* data for combtooth blenny larvae. *ETM* calculations based on actual cooling water flow.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Jan-06	0.01817	0.02096	0.00437	0.00109
14-Feb-06	0.01718	0.01475	0.01907	0.00383
13-Mar-06	0.01711	0.01202	0.01776	0.00386
10-Apr-06	0.06491	0.03014	0.05711	0.01191
8-May-06	0.03529	0.03167	0.14613	0.02245
5-Jun-06	0.01834	0.01678	0.30460	0.06697
5-Jul-06	0.01089	0.02766	0.22711	0.05786
14-Aug-06	0.01834	0.00695	0.11668	0.02231
11-Sep-06	0.01296	0.03643	0.06578	0.01228
9-Oct-06	0.01663	0.03066	0.02002	0.00322
6-Nov-06	0.02215	0.02841	0.01085	0.00267
4-Dec-06	0.01401	0.01363	0.01053	0.00348

4.5.3.3 CIQ Goby complex (*Clevelandia, Ilypnus, Quietula*)

Gobies are small, demersal fishes that are found worldwide in shallow tropical to temperate marine environments. Many members of the family are euryhaline and are able to tolerate very low salinities and even freshwater. 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 (arrow goby *Clevelandia ios* [pictured above], cheekspot goby

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Ilypnus gilberti, and shadow goby *Quietula y-cauda*), there are at least six other common species in southern California: blackeye goby (*Rhinogobiops nicholsii*), yellowfin goby (*Acanthogobius flavimanus*), longjaw mudsucker (*Gillichthys mirabilis*), blind goby (*Typhlogobius californiensis*), bay goby (*Lepidogobius lepidus*), and bluebanded goby (*Lythrypnus dalli*).

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 (*Clevelandia*, *Ilypnus* and *Quietula*), or the family level 'Gobiidae' if specimens were damaged but could still be recognized as gobies. Some larger larval specimens with well-preserved pigmentation 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 following section presents an overview of the family and life history characteristics of each of the three species.

4.5.3.3.1 Life History and Ecology

All three species have overlapping ranges in southern California 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). Arrow and cheekspot gobies were reported as abundant from the Cabrillo Beach area in outer Los Angeles Harbor based on beach seine sampling (Allen et al. 1983). 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

Arrow goby have the most northerly range of the three species, occurring from Vancouver Island, British Columbia to southern 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 sub-tropical southern ranges that extend well into the Gulf of California (Robertson and Allen 2002). Their physiological tolerances reflect their geographic distributions with arrow goby less tolerant of warmer temperatures compared to cheekspot goby. When exposed to temperatures of 32.1°C for three days in a laboratory experiment, no arrow gobies survived but 95% of cheekspot goby did survive (Brothers 1975). The species inhabits burrows of ghost shrimps (*Neotrypaea* spp.) and other burrowing invertebrates such as the fat innkeeper worm (*Urechis caupo*), and gobies exposed to warm temperatures on mudflats can seek refuge in their burrows where temperatures can be several degrees cooler than surface temperatures.

Summary of CIQ goby distribution and life history attributes.

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 and multiple spawning of 2–5 times per yr
- Juveniles from 14.0–29.0 mm are < 1 yr old

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

Fishery: None.

The reproductive biology is similar among the three species in the CIQ complex. 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 (Brothers 1975). Mature females for all three of these species are oviparous and produce demersal eggs that are elliptical in shape, adhesive, and attached to a nest substratum at one end (Matarese et al. 1989; Moser 1996). Hatched larvae are planktonic with the duration of the planktonic stage estimated at 60 days for populations in Mission Bay (Brothers 1975) which is approximately 135 km (84 mi) south of Alamitos Bay. Arrow goby 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 (Moser 1996). Data from Brothers (1975) were used to estimate an average growth rate of 0.16 mm/d for the approximately 60-day period from hatching to settlement. Brothers (1975) estimated a 60-day larval mortality of 98.3% 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, 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 exceeded 3 yr of age based on otolith records, whereas cheekspot and shadow gobies commonly lived for 4 yr (Brothers 1975).

Gobies eat a variety of larval, juvenile, and adult crustaceans, mollusks, and insects. Many will also eat small fishes, fish eggs, and fish larvae.

4.5.3.3.2 Population Trends and Fishery

The earlier 316(b) study of the AGS in 1978–1979 (IRC 1981), based on sampling conducted at the nearby HnGS intake, found that gobiid larvae were comparatively abundant throughout the year except during a late August survey. The range of mean density values was 2 to 20,640 larvae per 1,000 m^3 for the day surveys and 7 to 24,890 larvae per 1,000 m^3 for the night surveys. These were substantially greater than the average densities of 1,661 larvae per 1,000 m^3 measured during the present study in 2006 indicating a potential decline in population abundances over time.

Gobiidae juveniles and adults, primarily cheekspot goby, were the most common species group collected in a series of trawls conducted in Alamitos Bay from 1992-1995, comprising about 55% of the total number of species collected (Valle et al. 1999). There are no published multi-year studies of post-settlement goby populations in the Los Angeles-Long Beach Harbor complex area, but in a 5-year study of fishes in San Diego Bay from 1994–1999, approximately 75% of the estimated 4.5 million (standing stock) gobies were juveniles (Allen et al. 2002). Seasonal peaks in population abundance generally occurred in summer and fall and were associated with settlement of young-of-the-year although high abundances were also recorded in January and April of some years. Population abundances vary among years and may be correlated to the severity of winter rainfall events and urban runoff that may impact the water quality of seasonal estuaries in southern California. There is no fishery for gobies because of their small size.

4.5.3.3.3 Sampling Results

CIQ goby larval complex was the most abundant taxon at both entrainment Stations E1 and E2 with mean concentrations for all surveys of 1,383 per 1,000 m^3 and 1,694 per 1,000 m^3, respectively (Tables 4.5-1 and 4.5-2). They were present during all surveys but tended to be least abundant in November and December (Figure 4.5-16). Over a period of several months from January through September CIQ gobies were present in the entrainment samples at average concentrations exceeding 2,500 per 1,000 m^3. They were also present at the source water stations during all months of the year with a peak average concentration in August 2006 of over 2,500 larvae per 1,000 m^3 (Figure 4.5-17). The larvae were more abundant in nighttime samples during all surveys (Figure 4.5-18). 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 (Moser et al. 2001). The size classes of most larvae were in the 2.0–5.0 mm range with a very small proportion greater than 6.0 mm (Figure 4.5-19). The mean length of 1,741 specimens from the entrainment stations was 3.4 mm NL with a size range from 1.8 mm to 21.3 mm.

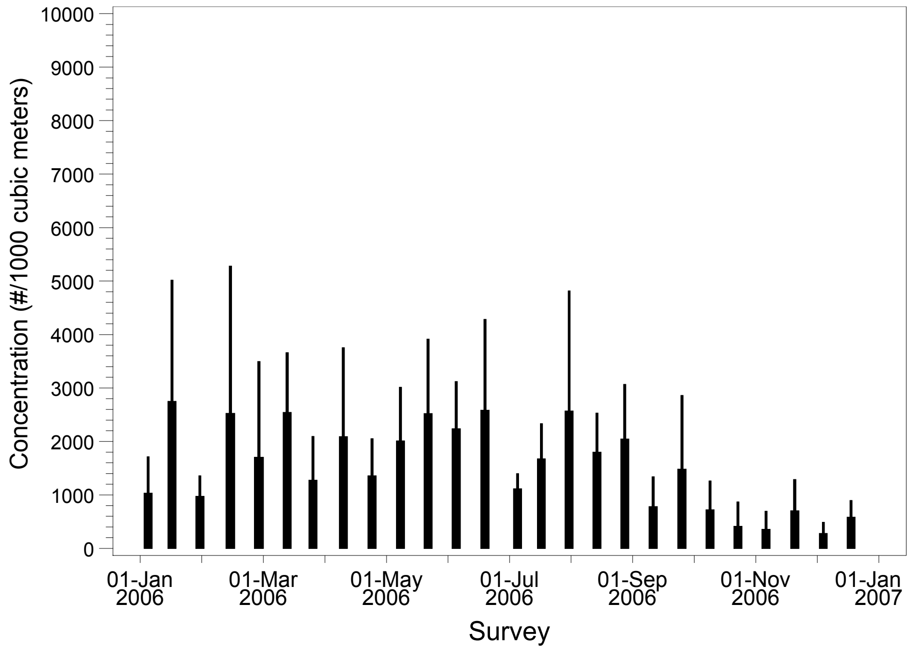

Figure 4.5-16. Mean concentration (# / 1,000 m^3) and standard deviation of unidentified goby larvae (CIQ gobies) collected at AGS entrainment Stations E1 and E2 during 2006.

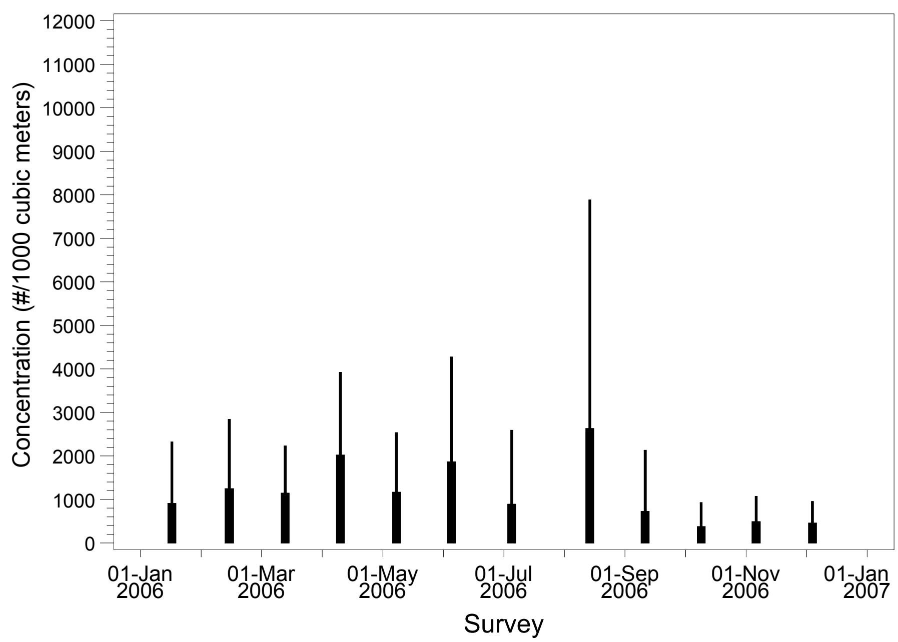

Figure 4.5-17. Mean concentration (# / 1,000 m^3) and standard deviation of unidentified goby larvae (CIQ gobies) collected at AGS source water stations during 2006.

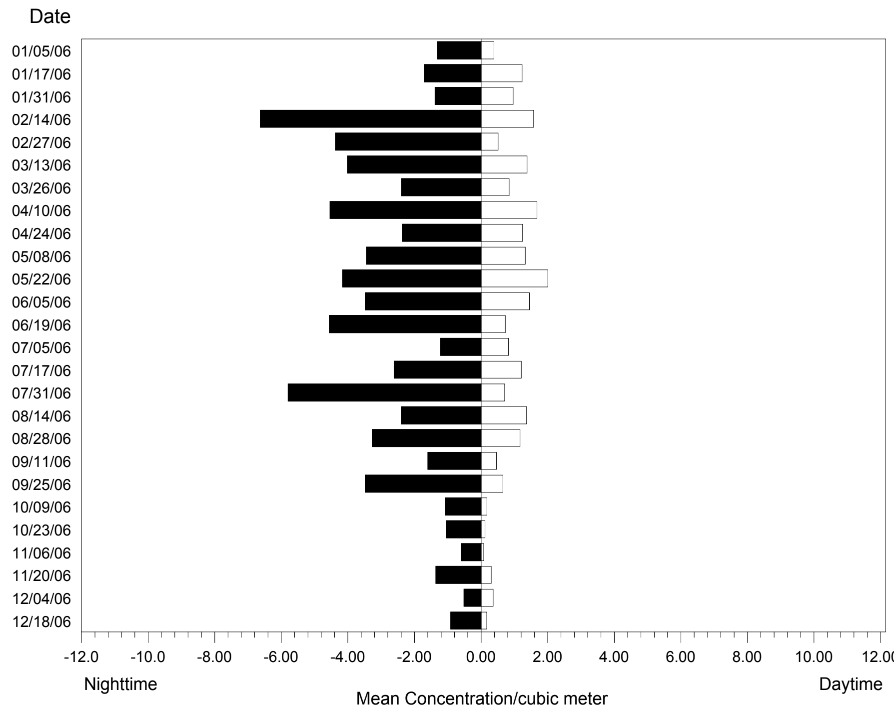

Figure 4.5-18. Mean concentration (#/1.0 m^3) of unidentified goby larvae at entrainment Stations E1 and E2 during night (Cycle 3) and day (Cycle 1) sampling.

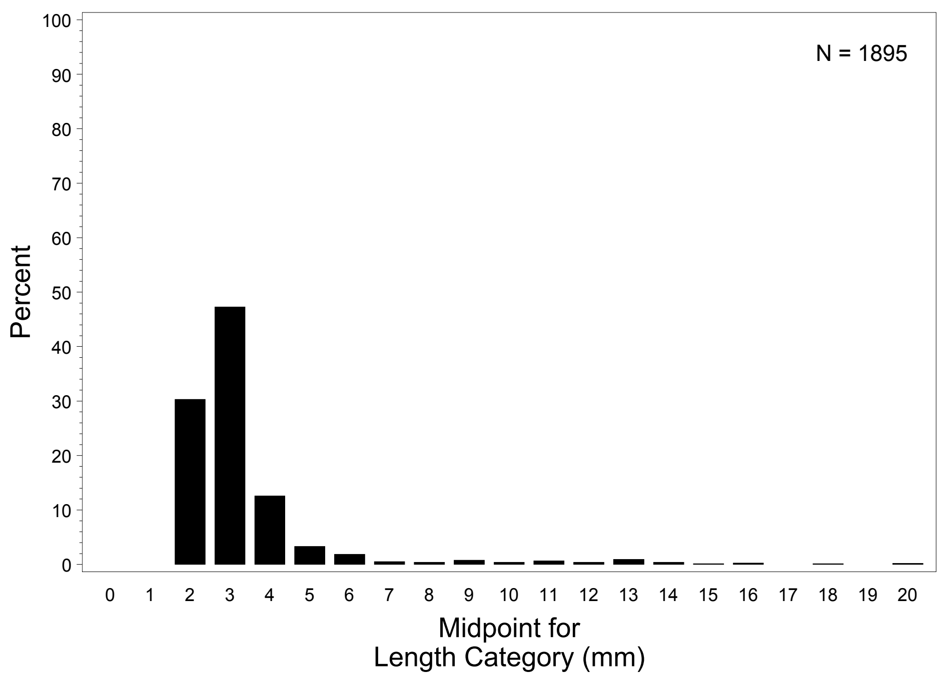

Figure 4.5-19. Length (mm) frequency distribution for unidentified goby larvae collected at entrainment stations in Alamitos Bay.

4.5.3.3.4 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CWS entrainment effects on CIQ 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 AGS was estimated to be 1,065,638,741 using actual measured cooling water flow during 2006 (Tables 4.5-3 through 4.5-5).

Fecundity Hindcasting (FH)

The annual entrainment estimate for CIQ gobies was 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 (3.3 mm [0.16 in]) and the estimated hatch length of 2.84 mm (0.11 in) from a random sample of 200 of the measured larvae were used with the calculated growth rate to estimate that the mean age at entrainment was 5.7 d. Survival to the average age at entrainment was then estimated as $0.93^{5.7} = 0.66$. A survivorship table was constructed using data from Brothers (1975) and was used to estimate a total lifetime fecundity of 1,400 eggs (Table 4.5-20). The age when at 50% of the female population was reproductive averaged 1.67 years.

The estimated numbers of female gobies at the age of maturity whose lifetime reproductive output was entrained through the AGS circulating water system for the 2006 period ranged was estimated as 1,146,022 (Table 4.5-21). The results of the sensitivity analysis show that the greatest uncertainty associated with the estimate is related to the life history parameters in the model and not the entrainment estimate.

Table 4.5-20. 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	0					
	1	100	81	450	1.5	54,675	547	
	2	4	100	700	2.0	5,600	56	**603**
Ilypnus gilberti	0	500	0					
	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	0					
	1	74	23	410	0	0		
	2	50	87	620	1.5	4,0455	809	
	3	26	99	840	2.5	54,054	1081	
	4	7	100	1,200	3.0	25,200	504	**2,394**
							Mean	**1,400**

Table 4.5-21. Results of *FH* modeling for CIQ goby complex larvae based on entrainment estimates calculated using actual CWS flow.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH Estimate	**1,146,022**	993,457	275,350	4,769,804	4,494,454
Total Entrainment	1,065,638,741	40,878,680	1,073,704	1,218,339	144,636

Note: 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.

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 $0.93^{60-5.3} = 0.02$ 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 yr from life table data for the three species was estimated as 0.994 and was used to calculate a finite survival over the period of 0.21.

The estimated number of adult CIQ gobies equivalent to the number of larvae entrained through the AGS circulating water system for the 2006 sampling period was 974,076 based on an entrainment estimate calculated using actual CWS flows (Table 4.5-22). The results of the sensitivity analysis show that the greatest uncertainty associated with the estimate is related to the life history parameters in the model and not the entrainment estimate.

Table 4.5-22. Results of *AEL* modeling for CIQ goby complex larvae based on entrainment estimates calculated using actual CWS flow.

Parameter	Estimate	Std. Error	AEL Lower Estimate	AEL Upper Estimate	AEL Range
AEL Estimate	**974,076**	1,094,504	153,410	6,184,902	6,031,492
Total Entrainment	1,065,638,741	40,878,680	912,608	1,035,543	122,935

Note: 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.

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 95th percentile (5.9 mm [0.23 in]) and the estimated hatch length of 2.8 mm (0.11 in) 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 21.8 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 2006 period ranged from 0.00090 to 0.01965 (Table 4.5-23). The largest estimates occurred during the May survey with the largest proportion of the source population occurring in the April survey (f_i = 0.211 or 21.1%). The values in the table were used to calculate a P_M estimate of 0.133 (13.3%) with a standard error of 0.103.

Table 4.5-23. *ETM* data for CIQ goby complex larvae. *ETM* calculations based on actual cooling water flow.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Jan-06	0.00771	0.04365	0.04221	0.00845
14-Feb-06	0.00455	0.03868	0.05926	0.01845
13-Mar-06	0.00310	0.00853	0.10456	0.01912
10-Apr-06	0.00517	0.01795	0.21064	0.03165
8-May-06	0.01965	0.05980	0.06880	0.01732
5-Jun-06	0.01053	0.02649	0.12190	0.03088
5-Jul-06	0.00866	0.04157	0.07617	0.02386
14-Aug-06	0.00700	0.01797	0.13885	0.03824
11-Sep-06	0.00559	0.04106	0.03909	0.00926
9-Oct-06	0.00531	0.01813	0.02185	0.00463
6-Nov-06	0.00099	0.00345	0.04847	0.00818
4-Dec-06	0.00090	0.00331	0.06821	0.01549

4.5.3.4 Anchovies (Engraulidae)

Three species of anchovy (Family Engraulidae) inhabit nearshore areas of southern California: 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. Ninety-five percent of the specimens identified in the entrainment samples as Engraulidae were northern anchovy. The remainder were very small specimens still in their recently-hatched yolk-sac stage and some that were damaged to an extent that they could not be positively identified to the species level.


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Northern anchovy ranges from Cabo San Lucas, Baja California to Queen Charlotte Island, British Columbia (Miller and Lea 1972), and the Gulf of California (Hammann and Cisneros-Mata 1989). They are most common from Magdalena Bay, Baja California to San Francisco Bay and within 157 km (98 mi) of shore (Hart 1973; MBC 1987). Three genetically distinct subpopulations are recognized for northern anchovy; (1) Northern subpopulation, from northern California to British Columbia; (2) Central subpopulation, from central California to northern Baja California; and (3) Southern subpopulation, off southern Baja California (Emmett et al. 1991).

4.5.3.4.1 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 depths of about 50 m (164 ft), while larvae are found from the surface to about 75 m (246 m) in epipelagic and nearshore waters (Garrison and Miller 1982). Northern anchovy larvae feed on dinoflagellates, rotifers, and copepods (MBC 1987).

Northern anchovies spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978) although this may vary annually and also geographically. Most spawning takes place within 100 km (62 mi) of shore (MBC 1987). On average, female anchovies off Los Angeles 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.

Northern anchovy eggs hatch in two to four days, undergo a larval phase lasting approximately 70 days, and transform into the juvenile stage at about 35–40 mm (Hart 1973; MBC 1987; Moser 1996). Larvae begin schooling at 11−12 mm (0.4–0.5 inches) SL (Hunter and Coyne 1982). Northern anchovy reach 102 mm (4 inches) on average in their first year, and 119 mm (4.7 inches) in their second (Sakagawa and Kimura 1976). Larval survival is strongly influenced by the availability and density of phytoplankton (Emmett et al. 1991). Strong upwelling may transport some larvae out of the Southern California Bight (Power 1986), however, it may also benefit juveniles and adults by increasing certain food resources. 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 78−140 mm (3.1–5.5 inches) in length, in their first or second year (Frey 1971; Hunter and Macewicz 1980). Maximum recorded size is about 230 mm (9.1 inches) and 60 g (2.1 oz) (Fitch and Lavenberg 1971; Eschmeyer and Herald 1983). Maximum age is about seven years (Hart 1973), though most live less than four years (Fitch and Lavenberg 1971).

Northern anchovy is very important in the trophic ecology of marine food webs. They are random planktonic feeders, filtering plankton as they swim (Fitch and Lavenberg 1971). 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). 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). Juveniles and adults avoid temperatures above 25°C (Brewer 1974).

4.5.3.4.2 Population Trends and Fishery

Northern anchovy (*Engraulis mordax*) is one of four coastal pelagic species managed by the Pacific Fisheries Management Council (PFMC)—the other species include Pacific sardine, Pacific mackerel, and jack mackerel. Northern anchovy in the northeastern Pacific is divided into three subpopulations, or stocks: northern, central, and southern. Since 1978 the PFMC has managed northern anchovy from the central and northern subpopulations. The central subpopulation includes landings from San Francisco to Punta Baja, Baja California.

Three separate commercial fisheries target northern anchovy in California and Mexico waters: 1) the reduction fishery, 2) the live bait fishery, and 3) the non-reduction fishery (Bergen and Jacobson 2001). In the reduction fishery anchovies are converted to meal, oil, and protein supplements while the non-reduction fishery includes fish that are processed for human consumption, for animal food, or frozen for use as fishing bait.

Northern anchovy populations began to increase following the collapse of the Pacific sardine (*Sardinops sagax*) fishery in 1952. Landings remained fairly low throughout the 1950s but increased rapidly in the mid-1960s when reduction of anchovy without associated canning was permitted (Bergen and Jacobson

2001). The demand for this fishery was highly linked to the production and price of fish meal worldwide (Mason 2004). A drastic decline of 40% in fish meal prices worldwide during the early 1980s (Durand 1998) and the decline in anchovy abundance nearly ended anchovy reduction by 1983.

Estimates of the central subpopulation averaged about 359,000 tons from 1963 through 1972, increased to over 1.7 million tons in 1974, and then declined to 359,000 tons in 1978 (Bergen and Jacobsen 2001). Anchovy biomass in 1994 was estimated at 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 temperatures related to a cold regime in the Pacific Decadal Oscillation (Chavez et al. 2003).

In the Los Angeles-Long Beach Harbor complex, northern anchovy was one of the most abundant species, along with topsmelt (*Atherinopsis affinis*), in purse seine and beach seine sampling in the early 1980s (Allen et al. 2006). Seasonally the greatest population abundances typically occur in summer and early fall as a result of large numbers of young-of-the-year. The earlier 316(b) sampling at the HnGS in 1978–1979 (IRC 1981) measured mean densities of anchovy larvae that were lowest from July through September and greatest from January through June. Survey means for the near-field varied from 0 to 880 larvae per 1,000 m^3 for day surveys and from 0 to 4,250 larvae per 1,000 m^3 for night surveys. During the period of peak abundance for January–June, the average survey density was 13,650 per 1,000 m^3. These densities are over fifty times greater than the highest 2006 densities recorded in April (see Section 4.5.3.1.3–*Sampling Results*).

The California commercial fishery for northern anchovy varies substantially by region and year. There have not been any landings of northern anchovy recorded from San Diego County since 1996 when 318,000 lbs were landed (PacFIN 2007). In 2004 there were 325,000 lbs landed in the Los Angeles area as compared to 6.07 million lbs. in the Santa Barbara area, and 8.58 million lbs. in the Monterey area for a total value of $750,000. Annual landings in the Los Angeles region since 2000 have varied from a high of 8.6 million lbs in 2001 to a low of 0.3 million lbs in 2004, with an average of 3 million lbs annually (Table 4.5-24).

Table 4.5-24. Annual landings and revenue for northern anchovy in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	Revenue
2000	1,279,437	2,820,677	$145,579
2001	3,656,509	8,061,223	$319,628
2002	1,205,307	2,657,247	$100,716
2003	327,468	721,944	$37,750
2004	147,003	324,087	$35,699
2005	1,979,989	4,365,130	$185,579
2006	865,971	1,909,139	$75,104

4.5.3.4.3 Sampling Results

Engraulid larvae (predominantly northern anchovy) were the sixth most abundant taxon at entrainment Station E1 and the fifth most abundant at Station E2, with mean concentrations of 15 and 25 larvae per 1,000 m^3, respectively, over all surveys (Table 4.5-1). Engraulid eggs had average concentrations of 34 and 14 per 1,000 m^3 at Stations E1 and E2, respectively. Almost all larvae occurred in April–May (Figure 4.5-20). During periods of maximum abundance in early May 2006 anchovies were present in the entrainment samples at average concentrations of 330 per 1,000 m^3. They were absent from samples in almost all other months except June and July. Monthly source water concentrations had a similar seasonal occurrence with maximum concentrations exceeding 900 per 1,000 m^3 in April 2006 (Figure 4.5-21). There was no consistent trend in abundance between daytime and nighttime samples (Figure 4.5-22). The length frequency distribution of measured northern anchovy larvae showed a bi-modal distribution with the predominant peak consisting of recently-hatched larvae, ranging from 3-5 mm notochord length (NL), and a smaller peak in the range of 10–14 mm (Figure 4.5-23), reflecting growth of the initial strong cohort from the early April spawning event (Figure 4.5-20). The lengths of the larvae from the entrainment station samples ranged from 2.3–28.7 mm with a mean of 5.3 mm NL.

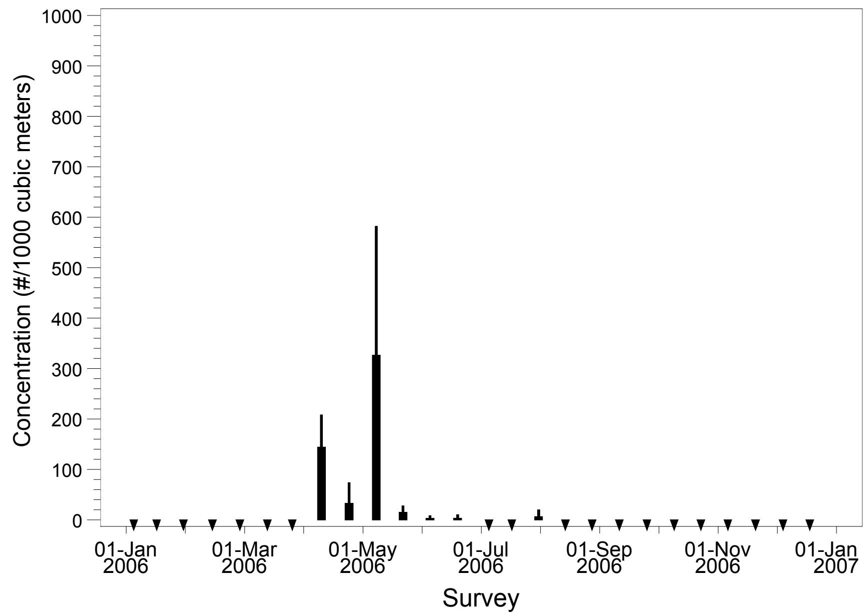


Figure 4.5-20. Mean concentration (# / 1,000 m^3) and standard deviation of anchovy larvae collected at AGS entrainment Stations E1 and E2 during 2006.

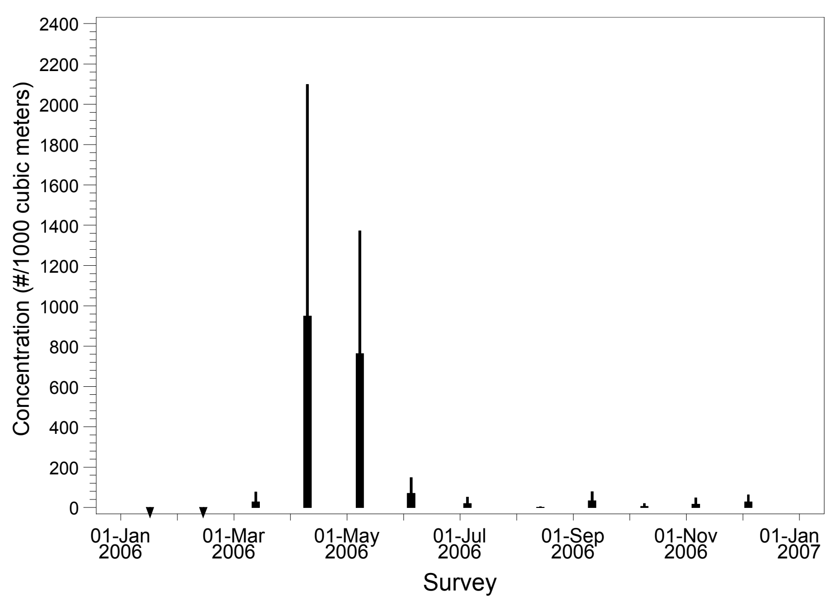


Figure 4.5-21. Mean concentration (# / 1,000 m^3) and standard deviation of anchovy larvae collected at AGS source water stations during 2006.

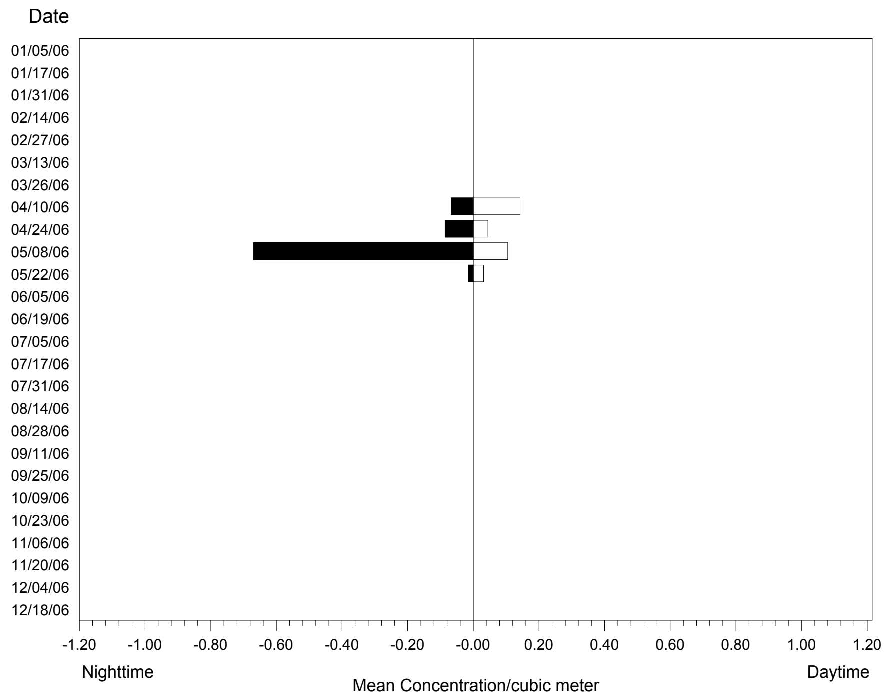


Figure 4.5-22. Mean concentration (#/1.0 m^3) of anchovy larvae at entrainment Stations E1 and E2 during night (Cycle 3) and day (Cycle 1) sampling.

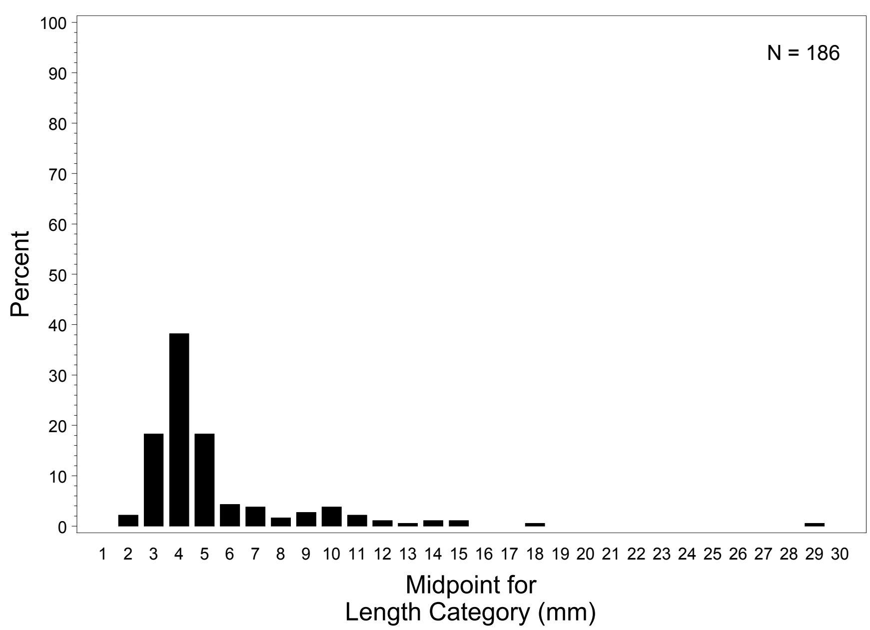


Figure 4.5-23. Length (mm) frequency distribution for larval anchovy collected at entrainment stations in Alamitos Bay.

4.5.3.4.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of entrainment effects on Engraulidae (northern anchovy) larvae. Total annual entrainment at AGS for all six units combined was estimated at 21,410,242 larvae and 25,101,765 eggs using measured cooling water flows during 2006 with 63% of the larvae attributed to the operation of Units 5 & 6, 28% to Units 3 & 4, and the remainder to Units 1 & 2 (Tables 4.5-3 through 4.5-5). For anchovy eggs the proportions among unit pairs were 31%, 65% and 4% for Units 5 & 6, Units 3 & 4, and Units 1 & 2, respectively.

Fecundity Hindcasting (*FH*)

The entrainment estimate for northern anchovy for the 2006 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 4.5-25). Fish at the mean age of entrainment include yolk sac, early stage and late stage larvae. Therefore, survival estimates for all three stages were combined to obtain a finite survival value of 0.002 up to the mean age at entrainment (5.0 days). This was calculated by dividing a larval growth rate of 0.41 mm/day (0.02 inches/day) into the difference between the mean length (5.29 mm [0.21 inches]) and the calculated hatch length of 3.28 mm [0.13 inches]).

Table 4.5-25. 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 (days)**	**Age (days)**	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) reported age at sexual maturity as 1–2 years. Similarly, Leet et al. (2001) reported 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) reported a value of seven years, but Leet et al. (2001) stated that northern anchovy in the fished population rarely exceed four years of age. The survivorship values in Table 4.5-26 were used to estimate an average annual fecundity of 163,090 eggs produced over a seven-year period using the data presented in Butler et al. (1993).

Table 4.5-26. 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).

Age (years)	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 total lifetime fecundity (TLF) was calculated as the sum of L_xM_x divided by 1,000.

The estimated number of reproductive age adult female northern anchovies whose lifetime reproductive output was entrained through the AGS CWIS for 2006 was 4,180 based on egg and larval abundances in actual cooling water flows during the period (Table 4.5-27). The sensitivity analysis, based on the 90% confidence intervals, shows that the variation in estimates of entrainment had much less of an effect on the variation of the *FH* estimate than the life history parameters used in the model.

Table 4.5-27. Results of *FH* modeling for anchovy larvae based on entrainment estimates calculated using actual CWIS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
Eggs					
FH Estimate	**207**	149	63	678	615
Total Entrainment	25,101,765	3,457,030	160	254	94
Larvae					
FH Estimate	**3,973**	3,487	938	16,834	15,897
Total Entrainment	21,410,242	3,059,013	3,039	4,907	1,868

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.

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 age of maturity. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage (Table 4.5-25). The early larval stage survival was adjusted to the mean age at entrainment (5.0 days) and used to calculate a finite survival through age 63.5 days of 0.174 using the daily survival rates for late stage larvae. The other finite survival rates from Butler et al. (1993) were used to estimate the number of adults of age one year, the age of first maturity when 50% of the females are sexually mature. The equivalent number of adult northern anchovies calculated from the number of larvae entrained through the AGS CWIS for 2006 was 19,484 based on actual flows during the period (Table 4.5-28).

Table 4.5-28. Results of *AEL* modeling for northern anchovy larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
AEL Estimate	**19,484**	22,709	2,864	132,536	129,672
Total Entrainment	21,410,242	3,059,013	14,905	24,064	9,159

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.

Empirical Transport Model (*ETM*)

A larval growth rate of 0.41 mm/day (0.02 inches/day) for northern anchovies was estimated from Methot and Kramer (1979) and used with the difference in the lengths of the calculated hatch length (3.28 mm [0.13 inches]) and 95th percentile value (11.19 mm [0.47 inches]) for the measurements to estimate that the larvae were exposed to entrainment for a period of approximately 19.5 days. The average duration of the planktonic egg stage, 2.9 days, was added to the period for the larvae to estimate a total period of exposure of 22.5 days.

The monthly estimates of proportional entrainment (*PE)* for northern anchovies for 2006 ranged from 0 to 0.0007 and could only be calculated for three of the paired entrainment-source water surveys (Table 4.5-29). The largest estimate was calculated for the May survey, but the results also show that anchovy larvae were collected during almost all of the source water surveys with the largest proportion present during the April survey (f_i = 0.551 or 55.1%). The values in the table were used to calculate a P_M estimate of 0.0071 (0.07%) with a standard error of 0.0048. Estimates were calculated using the alongshore extrapolated estimate of the total source population. The average alongshore displacement over the period of exposure was 27.02 km (16.8 mi) and the average onshore transport was 24.43 km (15.2 mi).

Table 4.5-29. *ETM* data for northern anchovy larvae. *ETM* calculations based on actual cooling water flow.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Jan-06	0	0	0	0
14-Feb-06	0	0	0	0
13-Mar-06	0	0	0.01715	0.00522
10-Apr-06	0.00016	0.00089	0.55068	0.04595
8-May-06	0.00073	0.00912	0.31722	0.03981
5-Jun-06	0.00004	0.00106	0.04641	0.00666
5-Jul-06	0	0	0.01339	0.00447
14-Aug-06	0	0	0.00036	0.00036
11-Sep-06	0	0	0.0211	0.00444
9-Oct-06	0	0	0.00259	0.00138
6-Nov-06	0	0	0.00892	0.00333
4-Dec-06	0	0	0.02218	0.00424

5.0 IMPINGEMENT STUDY

5.1 INTRODUCTION

The purpose of the impingement study is to determine the extent of potential impacts from the operation of the cooling water systems of the AGS on fishes and selected invertebrates. Impingement occurs when organisms larger than the traveling screen mesh size become trapped against the screens, either because they are too fatigued to swim against the intake flow at the screens or they are dead.

Samples collected during normal operations were used to characterize fish loss from the day-to-day operation of the generating station. As mentioned previously, heat treatments have not been conducted at the AGS for many years. Normal operation samples were collected over a 24-hr period to determine the daily loss from operation of the cooling water system. Normal operation samples were used to estimate the annual loss of juvenile and adult fishes and shellfishes due to the operation of the cooling water intake systems at the AGS.

5.1.1 Discussion of Species to be Analyzed

Several types of organisms are susceptible to impingement by the generating station. All fishes and macroinvertebrates were processed (identified, enumerated, and where appropriate, measured) in impingement samples. However, assessment of impingement effects was limited to the most abundant fish taxa that together comprised more than 90% of all juveniles and adults collected in impingement samples at the generating station. Assessment of impingement effects on invertebrates was limited to those that were considered commercially or recreationally important, and were collected in sufficient numbers to warrant analysis.

On January 30, 2007, representatives from AES Alamitos, MBC, and Tenera met with representatives from the LARWQCB, EPA Region IX, State Water Resources Control Board (SWRCB), CDFG, and NMFS to review preliminary data from the AGS IM&E Characterization Study, and determine the fish and shellfish species that would be assessed in the IM&E Report.

No Federal/State threatened or endangered fish/shellfish species were identified in entrainment and impingement samples collected from the AGS (see Sections 4.0 and 5.0). This is consistent with past entrainment and impingement sampling conducted at the AGS (SCE 1982a; MBC 2007).

At the January 30 meeting, NMFS requested that all species impinged or entrained that have Essential Fish Habitat (EFH) designated under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) be considered for assessment in the AGS IM&E report. It was agreed that for entrainment, additional demographic or *ETM* calculations would only be performed on these species if they were collected in sufficient abundance in entrainment and source water samples, and if sufficient life history information was available to permit those calculations. For impingement, it was agreed that only market squid (*Loligo opalescens*) would need additional assessment since impingement estimates are calculated for all species, and no additional modeling was proposed. At a subsequent meeting on May 7, 2007, it was agreed that all species with designated EFH that were impinged would be assessed in the impingement mortality assessments.

Off southern California, the species with designated EFH are listed in the Coastal Pelagics FMP and the Pacific Groundfish FMP. The goals of the management plans include, but are not limited to: the promotion of an efficient and profitable fishery, achievement of optimal yield, provision of adequate forage for dependent species, prevention of overfishing, and development of long-term research plans (PFMC 1998, 2006). There are four fish and one invertebrate species covered under the Coastal Pelagics FMP: northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), jack mackerel (*Trachurus symmetricus*), Pacific (chub) mackerel (*Scomber japonicus*), and market squid. There are 89 fish species covered under the Pacific Groundfish FMP, including ratfish (*Hydrolagus colliei*), finescale codling (*Antimora microlepis*), Pacific rattail (*Coryphaenoides acrolepis*), three species of sharks, three skate species, six species of roundfish, 62 species of scorpionfishes and thornyheads, and 12 species of flatfishes. For both the Coastal Pelagics and Pacific Groundfish, EFH includes all waters off southern California offshore to the Exclusive Economic Zone.

5.2 METHODS

The following sections provide information on the impingement sample collection and data analysis methods. The impingement sampling provided current estimates of the taxonomic composition, abundance, biomass, seasonality, and diel periodicity of organisms impinged at the AGS. The sampling program also documented the size, sex, and physical condition of selected fish and shellfish. The abundance and biomass of organisms impinged was used to calculate impingement rates (e.g., the number of organisms impinged per 1,000,000 m^3 [264,172,052 gallons] cooling water flowing into each CWIS).

The AGS consists of four separate screening facilities: one each for Units 1&2, Units 3&4, Unit 5, and Unit 6. Each screening facility consists of traveling screens and the circulating water pumps; bar racks are also installed at Units 5&6. Seawater drawn into each AGS unit first enters the in-plant forebay, passes through the bar racks (Units 5&6 only), followed by the traveling screens, and is then pumped to the condensers. All material that was impinged on the traveling screens during the surveys was subsequently rinsed from the screens by a high-pressure wash system into a collection basket. A more complete description of the cooling water systems is presented in Section 3.2.

5.2.1 Field Sampling

Impingement sampling was conducted approximately weekly during normal operations, between January 6 and December 27, 2006. Normal operation impingement sampling at the AGS was conducted over one 24-hour period each week at units that had operating circulating water pumps during the day of sampling. Before each sampling effort, the traveling screens were rotated and washed clean of all impinged debris and organisms. The sluiceways and collection baskets were also cleaned before the start of each sampling effort. The operating status of the circulating water pumps was recorded on an hourly basis during the study year. During each survey, the 24-hour sampling period was divided into four 6-hour cycles. Initiation of sample collection occurred as follows: Cycle 1 (approx. 0700-1300 hr), Cycle 2 (approx.

1300-1900 hr), Cycle 3 (approx. 1900-0100 hr), and Cycle 4 (approx. 0100-0700 hr). During this time, the traveling screens were stationary for a period of approximately 5.75 hours and then rotated and washed for 15 minutes. This rinse period allowed the entire screen to be rinsed of all material impinged since the last screen wash cycle. The impinged material was rinsed from the screens into the collection baskets associated with each set of screens.

On some occasions, the screen wash systems were operated (automatically or manually) prior to end of each cycle. The material that was rinsed on these occasions was combined with the material collected at the end of each cycle. All debris and organisms rinsed from each unit was processed separately from other units.

All fishes and macroinvertebrates collected at the end of each cycle were removed from any other impinged debris, identified, enumerated, and weighed. Depending on the number of individuals of a given species present in the sample, one of two specific procedures was used, as described below. Each of these procedures involved the following measurements and observations:

- The appropriate linear measurement for individual fish and shellfish was determined and recorded. These measurements were recorded to the nearest 1 mm (0.04 in). The following standard linear measurements were used for the animal groups indicated:

  Fishes - Total body length (TL) for sharks and rays and standard length (SL) for bony fishes.

  Crabs - Maximum carapace width (CW).

  Shrimps & Lobsters - Carapace length (CL), measured from the anterior margin of carapace between the eyes to the posterior margin of the carapace.

  Octopus - Maximum "tentacle" spread (arm span), measured from the tip of one tentacle to the tip of the opposite tentacle.

  Squid - Dorsal mantle length (DML), measured from the edge of the mantle to the posterior end of the body.

- The wet body weight of individual fish and shellfish was determined after shaking loose water from the body. Total weight of all individuals combined was determined in the same manner. All weights were recorded to the nearest 1 g (0.035 ounce).
- The qualitative body condition of individual fish and shellfish was determined and recorded, using codes for decomposition and physical damage.
- Determination of sex was made for fishes where such determination could be made by external morphology (such as surfperches, sharks, and rays).
- Shellfishes and other macroinvertebrates were identified to species and their abundance recorded, but they were not measured.
- The amount and type of debris (e.g., *Mytilus* shell fragments, wood fragments, etc.) and any unusual operating conditions in the screen well system were recorded in the "Notes" section of the data sheet. Information on weather was also recorded during each collection.

The following specific procedures were used for processing fishes and shellfishes when the number of individuals per species in the sample or subsample was less than 30:

- For each individual of a given species, the linear measurement, weight, and body condition codes were determined and recorded.

The following specific subsampling procedures were used for fishes and shellfishes when the number of individuals per species was greater than 30:

- The linear measurement, individual weight, and body condition codes for a subsample of 30 individuals were recorded individually on the data sheet. The individuals selected for measurement were selected after spreading out all of the individuals in a sorting container, making sure that they were well mixed and not segregated into size groups. Individuals with missing heads or other major body parts were not measured.
- The linear measurements of up to 200 individuals of each taxon were recorded.
- The total number and total weight of all the remaining individuals combined was determined and recorded separately.

Heat treatment impingement sampling occurred during all heat treatments. Sampling procedures for heat treatment sampling involved rotating and rinsing the traveling screens prior to the start of the procedure. During the heat treatment, the traveling screens were rotated until normal cooling water system operation was resumed and no more dead fish or shellfish were washed off the screens. Sample processing procedures were the same as those for normal operation impingement sampling.

5.2.2 QA/QC Procedures and Data Validation

A QA/QC program was implemented to ensure that all of the organisms were removed from the debris and that the correct identification, enumeration, length, and weight measurements of the organisms were recorded on the data sheets. Random cycles were chosen for QA/QC re-sorting to verify that all the collected organisms were removed from the impinged material. Quality control surveys were done on a quarterly basis during the study. If the count of any individual taxon made during the QA/QC survey varied by more than 5% (or one individual if the total number of individuals was less than 20) from the count recorded by the observer, then the next three sampling cycles for that biologist were checked. The survey procedures were reviewed with all personnel prior to the start of the study and all personnel were given printed copies of the procedures.

5.2.3 Data Analysis

5.2.3.1 Impingement Estimates

Daily observations of each of the circulating water pumps for the entire study period were recorded by AES Alamitos. Impingement rates were calculated using the circulating water flow during each of the cycles of each 24-hour survey. The total time for each cycle was multiplied by the known flow rate of each of the circulating water pumps in operation during each cycle.

The estimated daily impingement rate was used to calculate the weekly 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 designating the days before and after the collection date to the closest sampling day to create a monthly survey period. The total calculated flow for each survey period was multiplied by the taxon-specific impingement rates for both abundance and biomass. The estimated impingement rate for each weekly survey period was summed to determine the annual normal operation impingement estimates for each taxon based on actual cooling water flow volumes. Similar calculations were made based on the design (maximum) flow volumes at Units 3&4 (which operated consistently) and the actual flow volumes at Units 1&2 and Units 5&6 (which operated intermittently).

During impingement sampling, all fishes and invertebrates that were retained on the traveling screens were rinsed from the screens, flowed along a water-filled sluiceway, and were deposited into the impingement collection baskets for processing. Data are presented for all impinged taxa, but a subset of species was selected for more detailed analysis. This included fish that together comprised the top 90% or more of the total abundance in impingement samples. In addition, commercially or recreationally important invertebrates that were also impinged were selected for additional analysis. Lastly, NMFS requested all species impinged that have EFH designated under the Magnuson-Stevens Fishery Conservation and Management Act be assessed in the AGS IM&E Characterization Study Report. This methodology was approved by the LARWQCB, SWRCB, EPA Region IX, NMFS, and CDFG during our May 7, 2007 meeting.

To put the impingement results in context, losses were compared with (1) known population estimates where available, (2) commercial fishing landings for those species harvested commercially, and (3) sport fishing landings for those species targeted by recreational anglers. Commercial landing data were derived from three potential sources: (1) the Pacific Fishery Information Network (PacFIN), which summarized all commercial landings in the Los Angeles Area for the last seven years, (2) CDFG landing reports originating from Los Angeles area ports from 2005, and (3) CDFG catch block data from Long Beach area catch blocks in 2006. The five catch blocks included in this analysis included: 718, 719, 738, 739, and 740. Sport fishing landings were derived from the Recreational Fishery Information Network (RecFIN), which included all marine areas in southern California.

5.2.3.2 Impingement Impact Assessment

For an assessment of the potential impacts on fish stocks from species impinged at the AGS, annual impingement estimates were used to estimate the number of equivalent adults lost to impingement. These individuals would have lived and been subject to mortality sources other than impingement at the AGS. The method of computing equivalent adults is similar to demographic modeling of entrainment mortality estimates. Conversion of impingement totals was limited to few species with sufficient life history information. Such a conversion of numbers of juveniles and adults in impingement samples to number equivalent adults has not been performed in recent impingement studies in California. However, the methods described below are similar to those used by the EPA in developing the §316(b) Phase I and

Phase II regulations. Results and discussion of the assessments for both impingement and entrainment are presented in Section 6.0—Impact Assessment.

5.2.3.2.1 Equivalent Adult Model

Ages were assigned to individual recorded lengths for impinged Pacific sardine, queenfish, northern anchovy, and jack mackerel using growth curves. Species-specific von Bertalanffy growth parameters, annual (daily) total instantaneous mortality (Z), and female length at 50% maturity were collected from available age and growth studies, both published and unpublished, and online databases (such as FishBase [www.fishbase.org] and the CDFG web life history database [www.dfg.ca.gov/mrd/lifehistories/index.html]). For each individual fish the age was estimated using the von Bertalanffy growth model with the appropriate parameters (L_∞, k, t_0).

$$L_t = L_\infty \left(1 - e^{-k(t-t_0)}\right)$$

Annual (daily) age was calculated as

$$t = t_0 + \ln\left(1 - \frac{L_t}{L_\infty}\right) \Big/ -k \quad .$$

An interval of time *t* was calculated using the difference between the estimated age of impingement *t* and the age at 50% maturity $L_{50\%}$:

$$\Delta t = \frac{\ln\left(1 - \frac{L_{50\%}}{L_\infty}\right) - \ln\left(1 - \frac{L_t}{L_\infty}\right)}{-k} \, .$$

Instantaneous mortality (Z) for each species was taken from these same age and growth studies (see species-specific analysis for citation), where available, or calculated based on published daily mortality rates. Total annual instantaneous survival was calculated as $S = e^{-Z}$. The species-specific age at 50% female maturity was derived using the von Bertalanffy equation using the reported size at 50% maturity. Equivalent adult abundances of the species-specific age at 50% maturity were calculated using a modification of the Equivalent Adult Model (EAM; USEPA 2002):

$$AE = \sum_{i=1}^{N} S^{(t_{50\%} - t_{est})} \; ,$$

where:

AE = number of target age equivalents killed,

N = number of individuals impinged,

S = total annual instantaneous survival,

$t_{50\%}$ = age at female 50% maturity, and

t_{est} = estimated age of impinged fish.

Equivalent adults were summed across all surveys. All calculations were based on measured individuals. The proportion of the total measured to the total impinged was calculated. Total survey-specific equivalent adult estimates were divided by the proportion measured to derive the total adult equivalents taken based on total impinged abundance by survey type. Adult equivalents attributed to normal operation impingement characterization surveys were extrapolated based on cooling water flows as described previously for normal operation estimated abundance. In the instances that not all impinged individuals were measured, the equivalent adult estimate was adjusted based on the ratio of measured individuals to total impinged individuals prior to extrapolation over flow.

5.3 DATA SUMMARY

The following sections summarize historical and recent impingement data from the AGS. A summary of historical impingement data is presented in Section 5.4, while data from the 2006-7 316(b) Impingement Mortality Study is presented in Section 5.5.

5.4 HISTORICAL DATA

Impingement sampling was conducted during the 1978–1980 316(b) demonstration (SCE 1982a) and since 2000 as required by the AGS NPDES permit (MBC 2007). These data are summarized to provide information on historical impingement at the AGS.

5.4.1 Summary of Historical Data

During the first 316(b) demonstration at the AGS, impingement samples were collected from October 1978 through September 1980 (SCE 1982a). Twenty-four-hour normal operation sampling was done at all cooling water intakes. Samples were collected approximately weekly at all intakes, though samples were collected twice per week from August 1979 through July 1980. During normal operation surveys, traveling/slide screens and collection baskets were initially cleared, and impinged organisms were allowed to collect for a 24-hr period. Estimated annual normal operations totals were calculated by multiplying the mean daily impingement loss by the number of operational days during each study period. The study periods were stratified by month for purposes of analysis. Heat treatments were not performed during the study.

The most abundant target species collected during the 1978–1980 316(b) demonstration impingement study were Pacific pompano (*Peprilus simillimus*), shiner perch (*Cymatogaster aggregata*), and queenfish (*Seriphus politus*), which comprised 74%, 11%, and 8%, respectively, of impingement abundance at AGS Units 1–6. The next most abundant taxa were white seaperch (*Phanerodon furcatus*), white croaker (*Genyonemus lineatus*), and northern anchovy, which contributed an additional 5% to the impingement abundance (Table 5.4-1).

Table 5.4-1. Daily average impingement estimates for target taxa at the AGS from October 1978 through September 1980.

		Average Daily Impingement (Fish impinged per day)			
Taxon	**Common Name**	**Units 1&2**	**Units 3&4**	**Units 5&6**	**Percent of Total**
Peprilus simillimus	Pacific pompano	2.63	27.96	118.84	73.75
Cymatogaster aggregata	shiner perch	1.25	4.30	16.16	10.71
Seriphus politus	queenfish	0.61	2.60	13.17	8.08
Phanerodon furcatus	white seaperch	0.35	0.67	3.62	2.29
Genyonemus lineatus	white croaker	0.11	0.51	2.94	1.76
Engraulis mordax	northern anchovy	0.09	0.81	1.77	1.32
Hyperprosopon argenteum	walleye surfperch	0.05	0.18	1.62	0.91
Embiotoca jacksoni	black perch	0.11	0.28	1.28	0.82
Umbrina roncador	yellowfin croaker	-	0.01	0.27	0.14
Paralabrax nebulifer	barred sand bass	0.01	0.01	0.24	0.13
Cheilotrema saturnum	black croaker	0.02	0.02	0.04	0.04
Anisotremus davidsonii	sargo	0.01	0.01	0.03	0.02
Paralabrax clathratus	kelp bass	-	0.01	0.03	0.02
Sebastes paucispinis	bocaccio	-	-	-	-
Roncador stearnsii	spotfin croaker	-	-	-	-
Total		**5.24**	**37.37**	**160.01**	**100.00**

Though not a target species, tilapia (*Oreochromis* spp.) comprised 24% of the abundance at Units 1&2, 12% at Units 3&4, and 6% at Units 5&6 (Herbinson 1981). The California Fish and Game Commission introduced tilapia to California in 1971 as part of an experiment on insect and weed control (Dill and Cordone 1997). At least five species are established, and there appears to be hybridization among the five. In 1976 there was a breeding population of Mozambique tilapia (*Oreochromis mossambicus*) in Los Cerritos Channel, the source waters for the AGS. The two-year study at Alamitos coincided with two winters of heavy rainfall, and several brackish or freshwater fish taxa were impinged, including catfish (*Ictalurus platycephalus*), striped bass (*Morone saxitalis*), bluegill (*Lepomis macrochirus*), carp (*Cyprinus carpio*), threadfin shad (*Dorosoma petenense*), and goldfish (*Carassius auratus*) (Herbinson 1981). In downtown Los Angeles, annual (water-year) rainfall totaled 33.4 inches in 1977-78, 19.7 inches in 1978-79, and 27.0 inches in 1979-80 (NWS 2007). Through 2005, annual average rainfall at that station was 15.1 inches.

At all units, highest impingement of Pacific pompano occurred during the first five months of monitoring (October 1978 through February 1979), during which time over 13 in of rain fell in the area (NWS 2007). Shiner perch were recorded throughout the study, but highest abundances were recorded during summer 1979 and March 1980. Largest numbers of queenfish were recorded in June 1979, January 1980, and June 1980.

Composition, abundance, and biomass of juvenile and adult fish and macroinvertebrates entrapped and impinged on traveling screens at the AGS have been studied for many years as part of a continuing NPDES monitoring program. From July 1992 to July 1993, fish and macroinvertebrate impingement sampling was conducted biweekly during representative periods of normal operation. From 2000 to the present, normal operation and heat treatment impingement surveys occurred periodically as required by the AGS NPDES permit.

A total of 76 surveys was performed during the one-year study in 1992-3. The number of fishes impinged at the AGS was substantially lower than in 1978–1980, but impingement was still highest at Units 5&6. However, invertebrate impingement was highest at Units 3&4. Impingement abundance was largely influenced by the January 13, 1993 survey, where fish impingement was equivalent to 42% of the study total at Units 1&2, 25% at Units 3&4, and 56% at Units 5&6. During that survey, impingement was comprised of primarily topsmelt (*Atherinops affinis*) at Units 1–4 and Pacific sardine (*Sardinops sagax*) and topsmelt at Units 5&6. Approximately 6.8 in of rain fell in the seven days leading up to the January 13, 1993 impingement survey (NWS 2007).

From 2001 through 2005, a total of 933 fish weighing 12.1 kg (26.7 lbs) was collected in impingement samples at the AGS (MBC 2006). The most abundant fish species impinged were topsmelt (44% of total abundance), queenfish (22%), shiner perch (11%), and northern anchovy (8%). Specklefin midshipman (*Porichthys myriaster*) contributed most to biomass (23%). A total of 426 macroinvertebrates weighing 9.6 kg (21.1 lbs) was also impinged during surveys from 2001 through 2005. The most abundant species were yellow shore crab (*Hemigrapsus oregonensis*; 34% of total abundance), tuberculate pear crab (*Pyromaia tuberculata*; 25%), striped shore crab (*Pachygrapsus crassipes*; 12%), moon jelly (*Aurelia aurita*; 8%), and California two-spot octopus (*Octopus bimaculatus/bimaculoides*; 5%). During the five-year period, moon jelly contributed most to biomass (60%).

5.4.2 Relevance to Current Conditions

The historical impingement data presented in Section 5.4 is relevant for historical comparisons. During the 1978–1980 study, all six units were operational, and design cooling water flows were the same as in 2006. However, the units were operated as baseload units, and cooling water flows were likely much higher than during the present study. The same may be true of the 1992-3 study.

5.4.3 QA/QC Procedures & Data Validation

The sampling program during the 1978–1980 study was conducted with the approval of the LARWQCB, and detailed procedures and methodologies can be found in SCE (1982a-c).

During the NPDES impingement surveys (2001 to present), sampling was done in accordance with specifications set forth by the LARWQCB in the NPDES permit for the plant. Specimens of uncertain identity were crosschecked against taxonomic voucher collections maintained by MBC, as well as available taxonomic literature. Occasionally, outside experts were consulted to assist in the identification of species whose identification was difficult. Scales used to measure biomass (spring and electronic) were calibrated every three months.

The following measures were employed to ensure accuracy of all data entered into computer databases and spreadsheets:

- Upon returning from the field, all field data sheets were checked by the Project Manager for completeness and any obvious errors;
- Data were entered into pre-formatted spreadsheets;
- After data were entered, copies of the spreadsheets were checked against the field data sheets;
- Data were submitted annually to the LARWQCB, EPA Region IX, and the CDFG.

5.5 RESULTS

The following sections summarize results from the 2006 impingement sampling at the AGS. The study was designed to provide information necessary to characterize annual, seasonal, and diel variations in impingement mortality as required by the §316(b) Phase II regulations. Annual variation was characterized by comparison to previous impingement studies. Seasonal variation was characterized by analysis of impingement rates during the yearlong study, and diel variation was characterized by analysis of daytime and nighttime impingement collections during 2006-7.

5.5.1 Impingement Summary

During 2006, normal operation impingement surveys were performed during 52 weeks at the AGS between January 6 and December 26, 2006. Samples were collected at Units 1&2 during 11 of 52 weeks, at Units 3&4 during 50 weeks, at Unit 5 during 15 weeks, and at Unit 6 during 16 weeks. Sample collection was highly variable due to the non-operation of each cooling water system at various times of the year. The cooling water system at Units 3&4 operated most consistently, with a minimum of one pump on nearly continuously to support in-plant waste requirements. No heat treatments were conducted in 2006 at the AGS.

In total, 28,082 individual fish from 57 taxa weighing 502.803 kg (1,108.681 lbs) was collected across all surveys at all three intake areas (Table 5.5-1). The majority of the collected samples were recorded at Units 3&4, with 26,048 individuals weighing 459.678 kg (1,013.590 lbs) followed by the combined screenwells for Units 5&6 with 1,514 individuals weighing 33.255 kg (73.327 lbs) and Units 1&2 with 520 individuals weighing 9.870 kg (21.763 lbs) (Table 5.5-2). The total estimated annual impingement at the AGS, adjusted for actual cooling water flow, was 399,097 individuals weighing 6,467.383 kg (14,260.579 lbs). Using design (maximum) cooling water flow volumes at Units 3&4, total AGS impingement increased to an estimated 458,013 individuals weighing 7,684.524 kg (16,944.375 lbs).

Observed fish abundance was significantly correlated with local precipitation ($R = 0.61$, $p < 0.001$). Two impingement surveys, performed on February 27 and May 22, occurred immediately after or during periods of rain, and cumulatively recorded nearly 87% of the total annual impingement (Figure 5.5-1). Similar instances of high impingement associated with precipitation have been recorded previously at the AGS. Herbinson (1981) noted the occurrence of typically freshwater fish species, such as tilapia (*Tilapia* spp), bullhead catfish (*Ameiurus* spp), and goldfish (*Carassius auratus*) as well as high impingement abundances coinciding with period of high storm water runoff. A similar instance was observed on January 12-13, 1993 when the highest recorded normal operation impingement prior to 2006 (351 individuals) was observed following 0.8 inches of rainfall reported in Long Beach, California (Weather Underground 2007).

Table 5.5-1. Summary of AGS fish impingement from January 2006 through December 2006 based on actual and design (maximum) cooling water flow volumes.

		Total Collected in Samples		Estimated Annual Impingement			
				Actual Flow		Design Flow	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Atherinops affinis	topsmelt	11,694	186.324	221,960	3,550.255	226,259	3,602.827
Atherinopsidae	silverside, unid.	9,118	162.615	71,658	1,282.169	118,355	2,095.305
Cymatogaster aggregata	shiner perch	3,660	22.486	64,166	339.300	67,681	373.125
Leptocottus armatus	Pacific staghorn sculpin	1,279	16.636	17,973	216.853	18,277	221.115
Engraulis mordax larvae	northern anchovy larvae	628	0.026	6,582	0.197	6,791	0.215
Seriphus politus	queenfish	301	1.337	2,167	15.824	2,772	16.795
Gillichthys mirabilis	longjaw mudsucker	238	0.986	2,007	8.469	3,100	12.516
Syngnathus leptorhynchus	bay pipefish	169	0.247	2,777	3.879	2,884	4.015
Pleuronichthys guttulatus	diamond turbot	143	30.221	1,600	304.373	2,077	419.227
Engraulis mordax	northern anchovy	174	0.275	1,462	2.551	1,517	2.732
Anchoa delicatissima	slough anchovy	94	0.358	1,300	4.849	1,406	5.338
Acanthogobius flavimanus	yellowfin goby	63	2.246	666	23.223	777	27.903
Anchoa compressa	deepbody anchovy	38	0.472	576	7.450	584	7.522
Porichthys myriaster	specklefin midshipman	52	14.691	426	121.433	480	133.838
Sardinops sagax	Pacific sardine	50	0.881	389	6.760	587	9.440
Paralichthys californicus	California halibut	37	20.524	481	220.390	581	296.731
Syngnathus sp	pipefish, unid.	44	0.065	303	0.454	570	0.911
Urobatis halleri	round stingray	30	10.176	245	83.334	266	91.870
Embiotoca jacksoni	black perch	11	0.949	152	7.575	170	13.753
Fundulus parvipinnis	California killifish	31	0.125	221	0.919	387	1.520
Umbrina roncador	yellowfin croaker	19	2.709	189	25.850	200	27.436
Atherinopsis californiensis	jacksmelt	12	1.972	99	17.898	119	19.871
Leuresthes tenuis	California grunion	11	0.115	75	0.822	114	1.320
Genyonemus lineatus	white croaker	12	0.423	90	3.380	106	4.344
Menticirrhus undulatus	California corbina	20	13.832	205	131.482	278	186.682
Hypsoblennius gentilis	bay blenny	21	0.334	163	2.621	260	4.198
Myliobatis californica	bat ray	20	5.900	146	41.938	168	50.205
Syngnathus californiensis	kelp pipefish	10	0.030	198	0.593	199	0.597
Heterostichus rostratus	giant kelpfish	19	0.220	149	1.670	163	2.095
Porichthys notatus	plainfin midshipman	2	0.460	21	4.673	21	4.673
Strongylura exilis	California needlefish	9	0.279	66	2.391	73	2.450
Pleuronichthys ritteri	spotted turbot	7	0.009	47	0.057	77	0.090
Xenistius californiensis	salema	7	0.090	46	0.704	77	0.762
Trachurus symmetricus	jack mackerel	10	0.838	69	5.244	69	5.244
Hypsoblennius gilberti	rockpool blenny	4	0.084	65	1.414	72	1.533
Sphyraena argentea	Pacific barracuda	5	0.012	35	0.085	41	0.097
Paraclinus integripinnis	reef finspot	3	0.009	59	0.178	60	0.179
Cichlidae	tilapia, unid.	3	0.061	19	0.408	27	0.480
Gibbonsia elegans	spotted kelpfish	2	0.052	20	0.500	20	0.500
Atractoscion nobilis	white seabass	4	0.032	23	0.159	30	0.261
Scomber japonicus	Pacific chub mackerel	3	0.791	17	4.174	38	10.853
Cheilotrema saturnum	black croaker	2	0.014	14	0.097	21	0.153
Lepidogobius lepidus	bay goby	1	0.002	4	0.008	28	0.055
Pleuronichthys sp	righteyed flounder, unid.	1	0.046	4	0.181	28	1.275

(table continued)

Table 5.5-1. (Continued). Summary of AGS fish impingement from January 2006 through December 2006 based on actual and design (maximum) cooling water flow volumes.

				Estimated Annual Impingement			
		Total Collected in Samples		Actual Flow		Design Flow	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Phanerodon furcatus	white seaperch	3	0.096	21	0.812	24	0.815
Xystreurys liolepis	fantail sole	2	0.400	16	3.139	16	3.139
Ameiurus sp	bullhead catfish, unid.	2	0.117	16	0.945	23	1.331
Gobiesox rhessodon	California clingfish	2	0.005	11	0.026	23	0.054
Porichthys sp	midshipman, unid.	2	0.099	16	0.799	23	1.127
Mustelus californicus	grey smoothhound	1	0.064	20	1.265	20	1.274
Anisotremus davidsonii	sargo	2	0.011	13	0.074	17	0.091
Pleuronichthys verticalis	hornyhead turbot	1	0.070	7	0.521	7	0.521
Symphurus atricaudus	California tonguefish	2	0.036	15	0.294	15	0.294
Hypsoblennius jenkinsi	mussel blenny	1	0.006	7	0.042	14	0.084
Anchoa sp	anchovy, unid.	1	0.014	7	0.103	7	0.103
Peprilus simillimus	Pacific pompano	1	0.031	7	0.202	7	0.219
Sciaenidae	croaker, unid.	1	1.900	7	12.377	7	13.421
Totals:		28,082	502.803	399,097	6,467.383	458,013	7,684.524

Table 5.5-2. Annual fish abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	**Units 3&4**	**Units 5&6**	**Total**
Fish Abundance	520	26,048	1,514	28,082
Fish Biomass (kg)	9.870	459.678	33.255	502.803

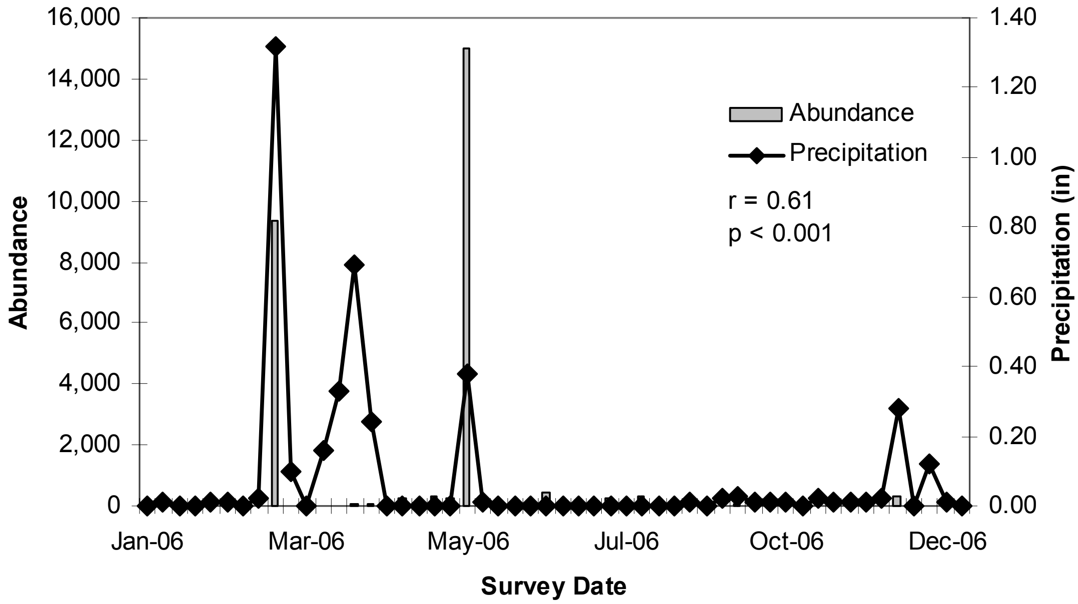


Figure 5.5-1. Fish impingement abundance at AGS by survey and recorded precipitation in Long Beach for the 48-hr period preceding the end of each survey.

Two silverside taxa, topsmelt (*Atherinops affinis*) and unidentified silversides, combined to contribute more than 74% of all impinged fish, or 11,694 and 9,118 observed individuals, respectively (Table 5.5-1). These same two taxa cumulatively contributed greater than 69% of the overall recorded fish biomass with 186.324 kg (410.844 lbs) and 162.615 kg (358.566 lbs), respectively. The next most abundant species recorded were shiner perch (*Cymatogaster aggregata*) and Pacific staghorn sculpin (*Leptocottus armatus*) with 3,660 and 1,279 individuals each, respectively. Cumulatively, these four taxa contributed nearly 92% of the overall observed abundance and 77% of the recorded biomass.

During the 52 weekly surveys, a total of 11,169 macroinvertebrates weighing 458.016 kg (1,009.925 lbs) representing 39 taxa were impinged (Table 5.5-3). As was seen with fish, the majority of impinged macroinvertebrates were recorded at Units 3&4, with 6,849 individuals weighing 227.944 kg (502.617 lbs) followed by Units 1&2 with 2,547 individuals weighing 125.876 kg (277.557 lbs) and Units 5&6 combined with 1,773 individuals weighing 104.196 kg (229.752 lbs) (Table 5.5-4). No relationship between precipitation and impingement abundance was detected for macroinvertebrates as was seen in fish.

Yellow shore crab (*Hemigrapsus oregonensis*) and moon jelly (*Aurelia aurita*) cumulatively contributed better than 91% of the overall impinged abundance, with no other single taxa accounting for greater than 3% (Table 5.5-3). Impinged moon jelly and California seahare (*Aplysia californica*) cumulatively represented nearly 94% of the total impinged macroinvertebrate biomass recorded at the AGS in 2006. No other species contributed greater than 3% of the total impinged macroinvertebrate biomass.

Table 5.5-3. Summary of AGS invertebrate impingement from January 2006 through December 2006 based on actual and design (maximum) cooling water flow volumes.

		Total Collected in Samples		Estimated Annual Impingement			
				Actual Flow		Design Flow	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Aurelia aurita	moon jelly	5,069	332.791	46,048	2,893.027	56,577	3,593.780
Hemigrapsus oregonensis	yellow shore crab	5,104	11.678	40,793	96.982	65,031	152.354
Polyorchis penicillatus	red jellyfish	142	0.621	1,070	4.525	1,463	6.525
Aplysia californica	California seahare	293	96.796	1,379	499.801	1,410	520.037
Aurelia sp	moon jelly, unid.	54	1.623	214	6.391	1,480	44.890
Pyromaia tuberculata	tuberculate pear crab	110	0.125	727	0.891	947	1.144
Loligo opalescens	Calif. market squid	93	3.126	600	20.283	977	34.974
Leptopecten sp	scallop, unid.	58	0.150	485	0.814	669	1.074
Navanax inermis	California aglaja	87	0.961	610	6.653	707	8.372
Bulla gouldiana	California bubble	28	0.496	167	2.996	357	5.774
Argopecten ventricosus	Pacific calico scallop	18	0.110	168	0.976	267	1.622
Portunus xantusii	Xantus swimming crab	11	0.141	76	1.016	93	1.120
Farfantepenaeus calif.	yellowleg shrimp	10	0.449	66	3.168	87	3.589
Oct. bimac./bimaculoides	Cal. two-spot octopus	21	4.343	140	29.401	229	40.206
Haminoea vesicula	blister glassy bubble	12	0.020	47	0.076	248	0.406
Pycnogonida	sea spider, unid.	9	0.002	70	0.015	111	0.021
Dendronotus frondosus	leafy dendronotid	3	0.001	33	0.011	33	0.011
Gastropoda	gastropod, unid.	6	0.005	48	0.040	77	0.064
Pachygrapsus crassipes	striped shore crab	6	0.079	36	0.479	61	0.782
Pugettia producta	northern kelp crab	5	0.011	38	0.083	61	0.113
Neotrypaea gigas	giant ghost shrimp	3	0.014	18	0.084	49	0.245
Diaulula sandiegensis	ring-spotted dorid	4	0.025	29	0.181	29	0.181
Aplysia sp	seahare, unid.	2	3.550	15	27.907	15	27.907
Crepipatella dorsata	Pacific half-slippersnail	1	0.001	4	0.004	28	0.028
Heptacarpus palpator	intertidal coastal	1	0.001	9	0.009	28	0.028
Protothaca staminea	Pacific littleneck	2	0.023	13	0.155	25	0.307
Hermissenda crassicornis	hermissenda	2	0.002	9	0.009	9	0.009
Haminoea sp	glassy bubble, unid.	2	0.002	6	0.006	15	0.015
Upogebia pugettensis	blue mud shrimp	2	0.004	13	0.028	18	0.033
Archidoris montereyensis	Monterey sea-lemon	1	0.059	6	0.352	17	0.980
Cancer anthonyi	yellow crab	2	0.002	13	0.013	17	0.017
Hemigrapsus nudus	purple shore crab	1	0.009	7	0.063	7	0.063
Strongylo. purpuratus	purple sea urchin	1	0.008	6	0.050	16	0.127
Alpheus californiensis	mudflat snapping	1	0.001	7	0.007	14	0.014
Cancer antennarius	Pacific rock crab	1	0.712	5	3.897	14	9.989
Crangon nigromaculata	blackspotted bay	1	0.001	14	0.014	14	0.014
Pisaster sp	sea star, unid.	1	0.002	7	0.014	7	0.014
Pandalus tridens	yellowleg pandalid	1	0.068	9	0.629	9	0.629
Kelletia kelletii	Kellet's whelk	1	0.004	6	0.024	11	0.042
Totals:		11,169	458.016	93,011	3,601.074	131,227	4,457.500

Table 5.5-4. Annual macroinvertebrate abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	**Units 3&4**	**Units 5&6**	**Total**
Macroinvertebrate Abundance	2,547	6,849	1,773	11,169
Macroinvertebrate Biomass (kg)	125.876	227.944	104.196	458.016

Figures 5.5-2 and 5.5-3 present the fish impingement density (based on abundance and biomass) during the 52 weekly surveys conducted from January through December 2006. Due to limited operation of the CWS at all screenwells other than Units 3&4, fish impingement was recorded principally during the spring through summer months. At Units 1&2, fish impingement was recorded during only 11 weeks of the year, with peak abundance occurring in late July. Fish impingement was observed nearly every week of the year at Units 3&4, where peaks generally coincided with seasonal precipitation, most notably in March and May (Figure 5.5-1). Weather-independent fish impingement generally increased during the spring through summer months at Units 3&4. Samples of the independent screenwells for Unit 5 and Unit 6 recorded individual seasonal trends in abundance, although the seasonal operation of the CWS was relatively consistent between the two units. At Unit 6, peak abundances were recorded in spring, which were substantially higher than abundances at Unit 5. Fish impingement was highest at Unit 5 in the summer months, but again failed to reach levels commensurate with Unit 6 in spring. Seasonal trends in impinged fish biomass were generally consistent with those for abundance, except at Unit 5, where spring values were similar to peak summer values (Figure 5.5-3). Overall, consistently higher abundance and biomass was recorded during night surveys than during day surveys at all screenwells (Figures 5.5-4 and 5.5-5).

Macroinvertebrate impingement density (based on abundance and biomass) is presented in Figures 5.5-6 and 5.5-7 for the 52 weekly surveys conducted from January through December 2006. As was seen in the fish, recorded macroinvertebrate impingement was limited to the periods of CWS operation at each screenwell. Impinged abundance was consistently highest at all screenwells in July and August, while biomass was more variable with relatively high values recorded during both spring and summer surveys. Unlike the diel patterns observed in fish, no overriding pattern was observed in macroinvertebrate impingement (Figure 5.5-8). At Units 1&2, nighttime impingement was generally more consistent, but individual, survey-specific abundance was highest during daytime surveys. Impingement abundances at Units 3&4 were generally consistent between the two diel periods, although the most abundant period was at nighttime in June 2006, while several individual surveys were notably higher during the day. At both Units 5 and 6, slightly higher average abundances were recorded at night, but overall survey-specific peaks were recorded during the day. Unlike abundance, macroinvertebrate biomass exhibited strong trends towards daylight surveys (Figure 5.5-9). At all four screenwells, impinged biomass was more likely to be greatest during the day than at night.

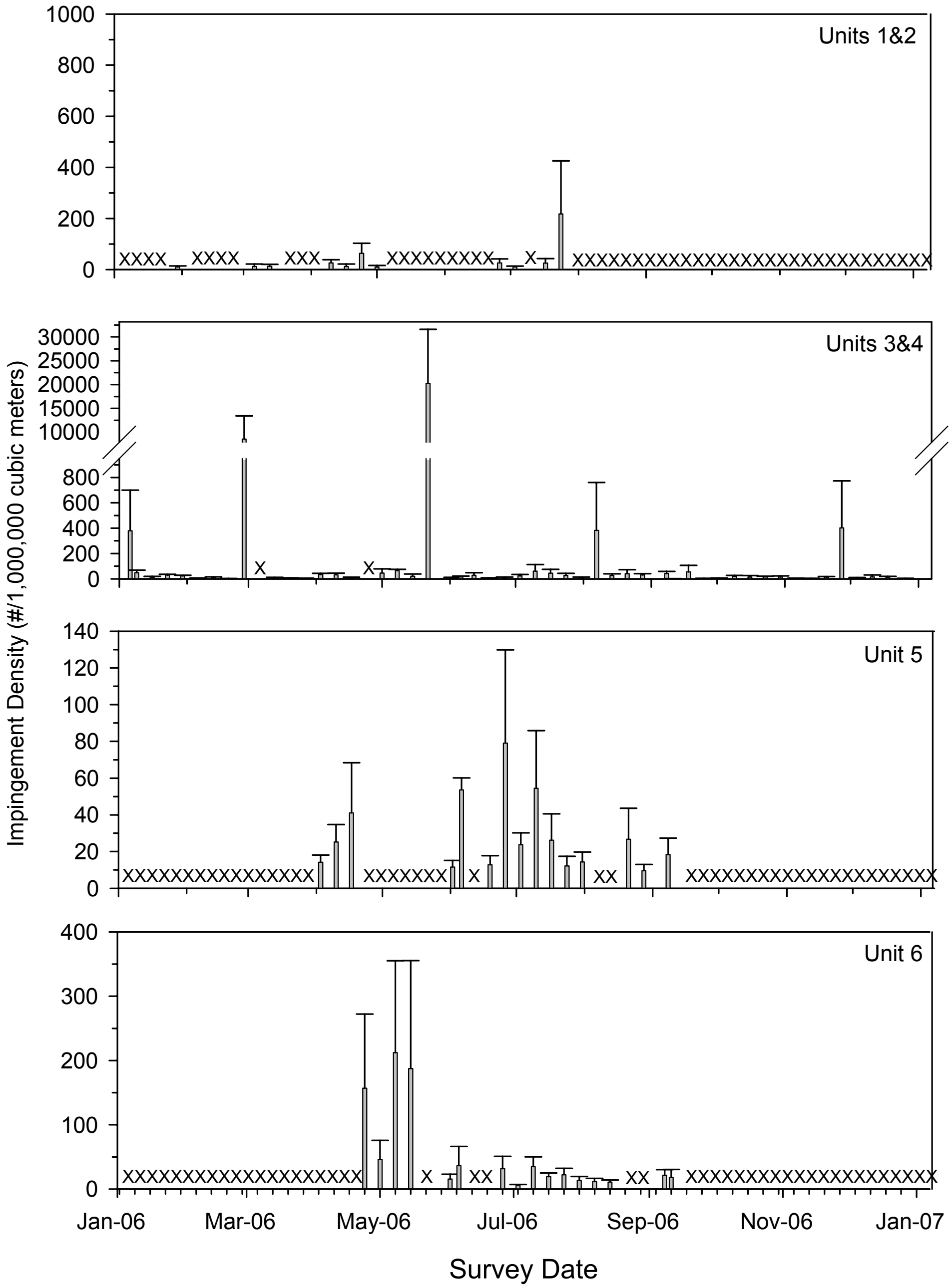


Figure 5.5-2. Mean concentration (# / 1,000,000 m^3) and standard error of fishes collected in AGS impingement samples in 2006. “X” denotes weeks with no sample collection.

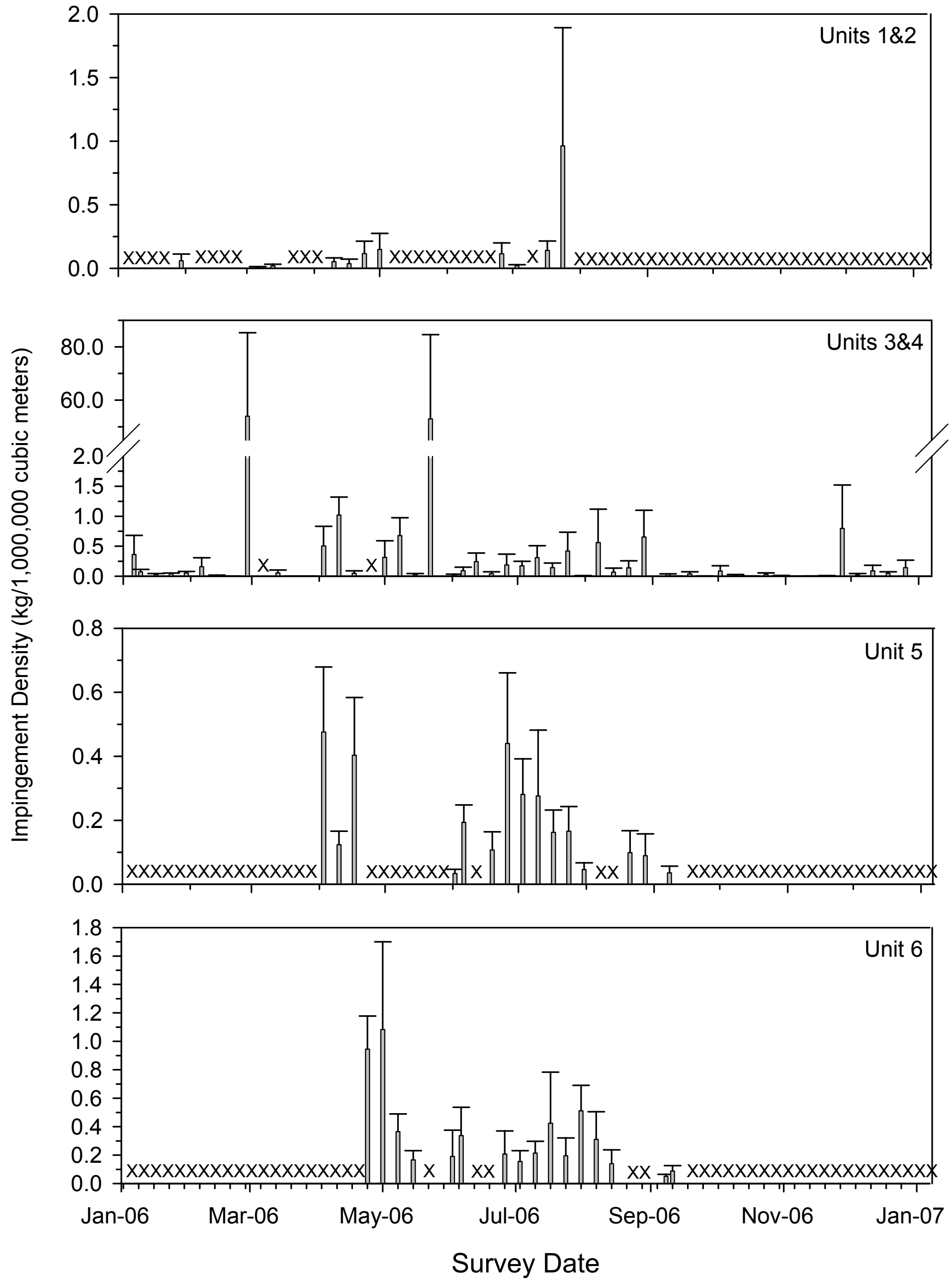


Figure 5.5-3. Mean biomass (kg / 1,000,000 m^3) and standard error of fishes collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

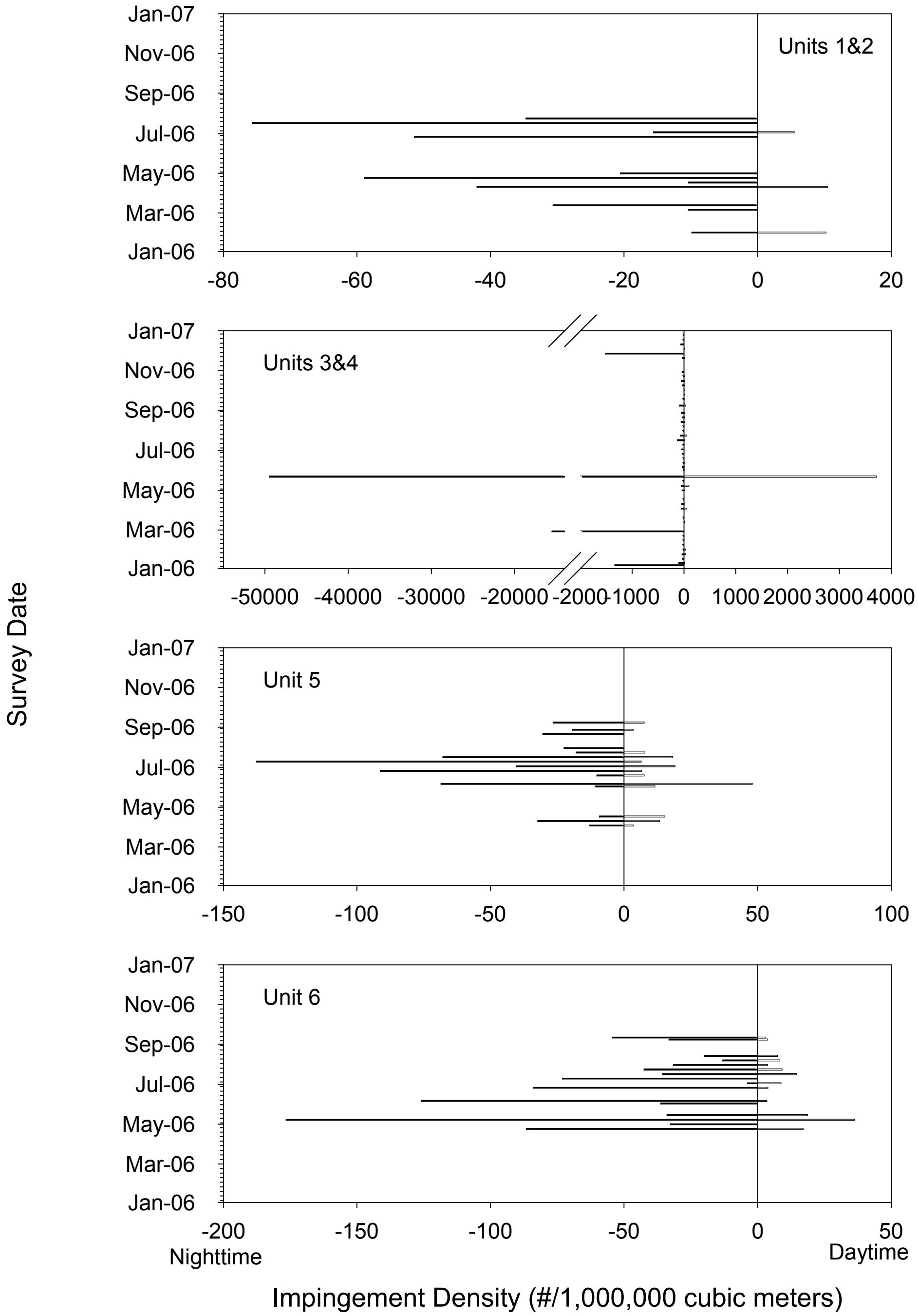


Figure 5.5-4. Mean concentration (# / 1,000,000 m^3) of fishes in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006. "X" denotes weeks with no sample collection.

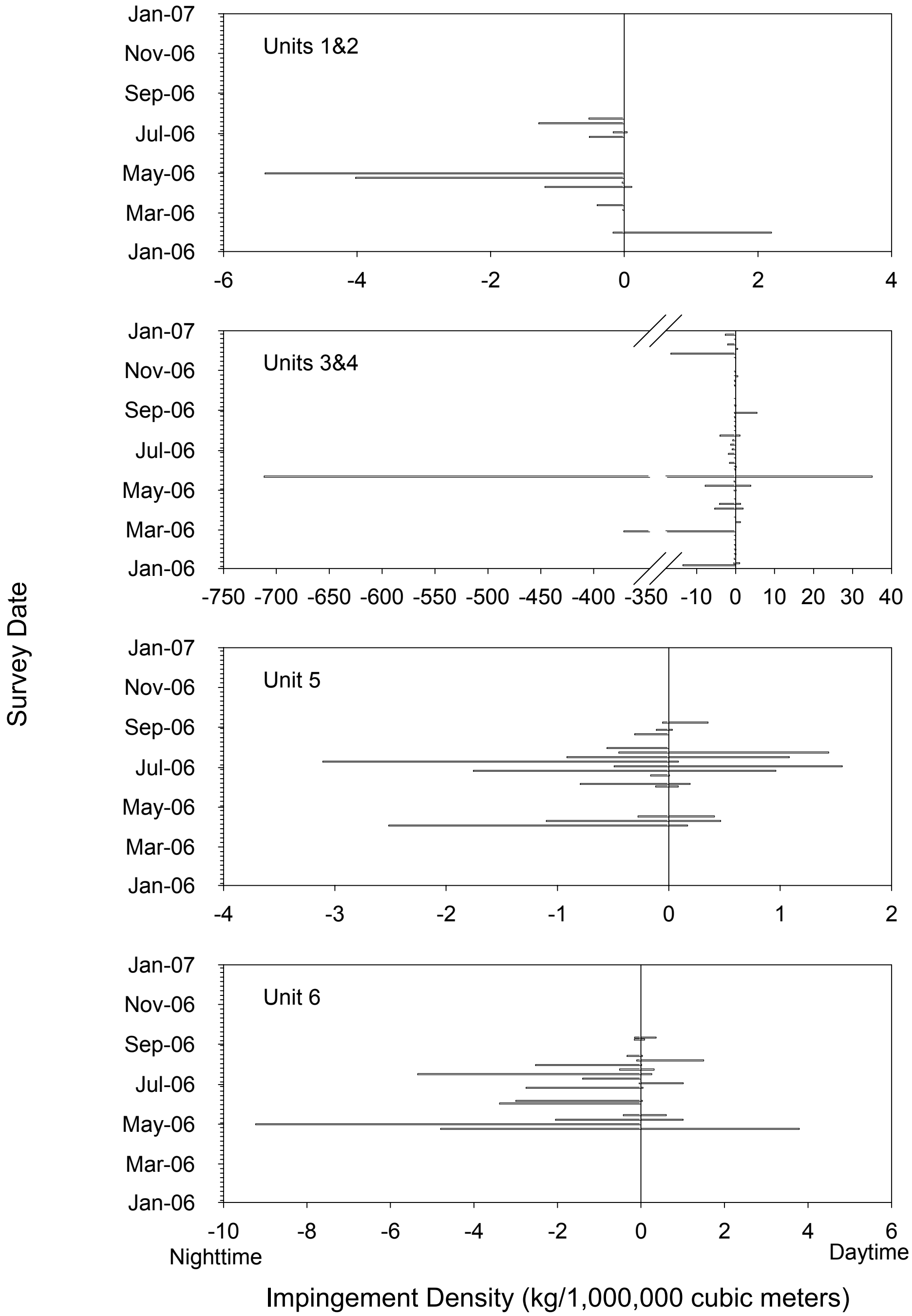


Figure 5.5-5. Mean biomass (kg / 1,000,000 m^3) of fishes in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006. "X" denotes weeks with no sample collection.

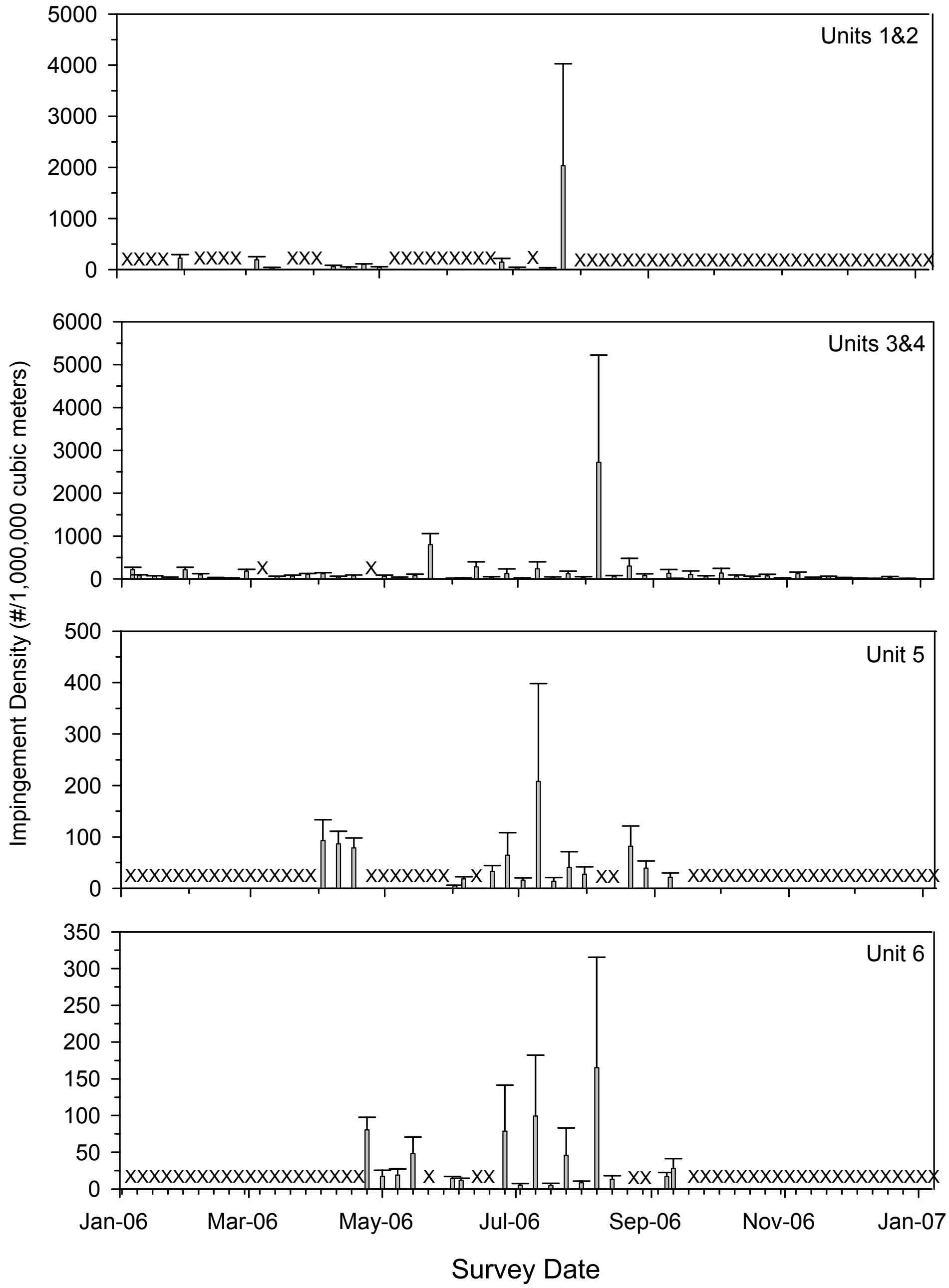


Figure 5.5-6. Mean concentration (# / 1,000,000 m^3) and standard error of invertebrates collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

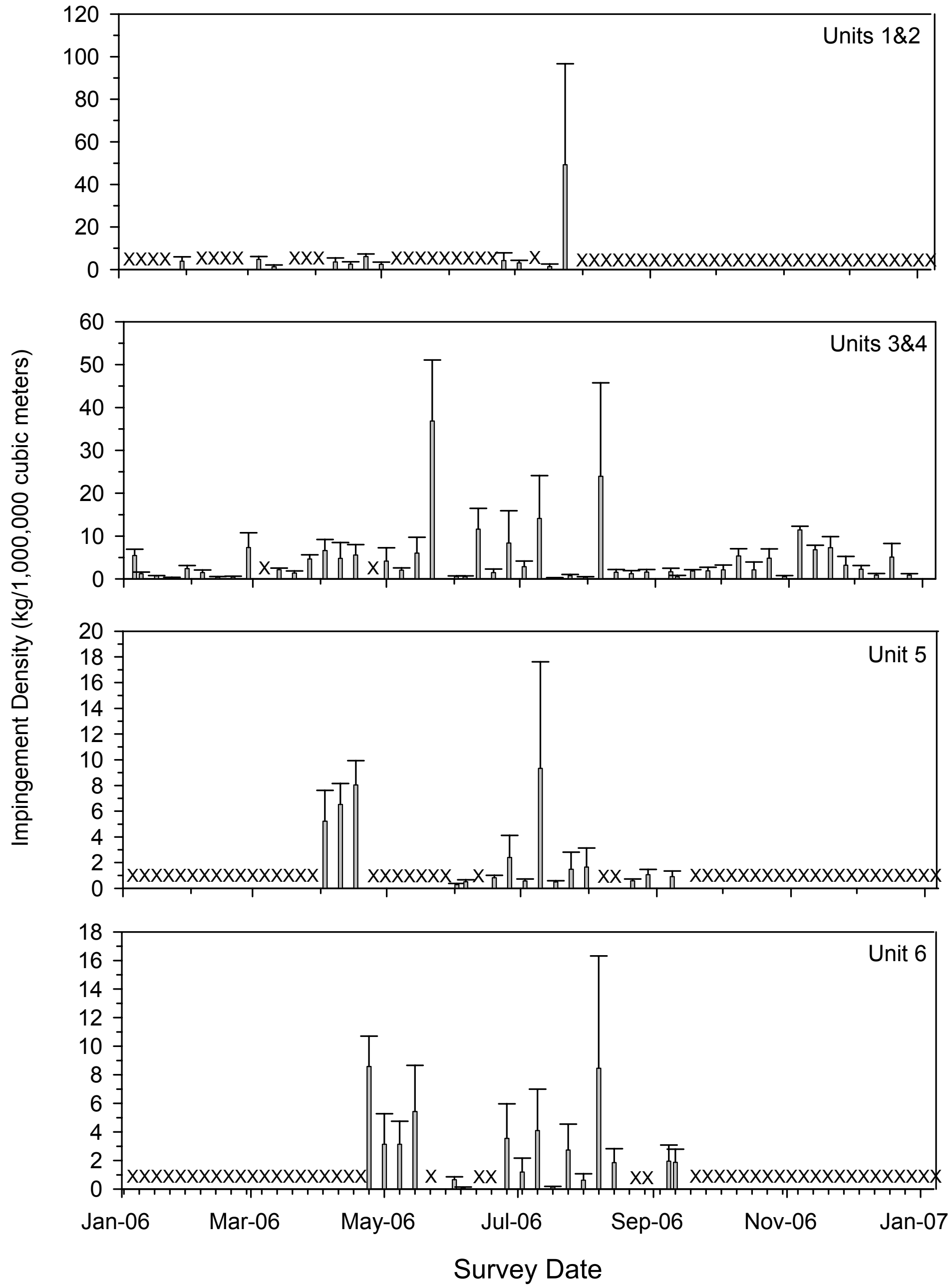


Figure 5.5-7. Mean biomass (kg / 1,000,000 m^3) and standard error of invertebrates collected in AGS impingement samples in 2006. “X” denotes weeks with no sample collection.

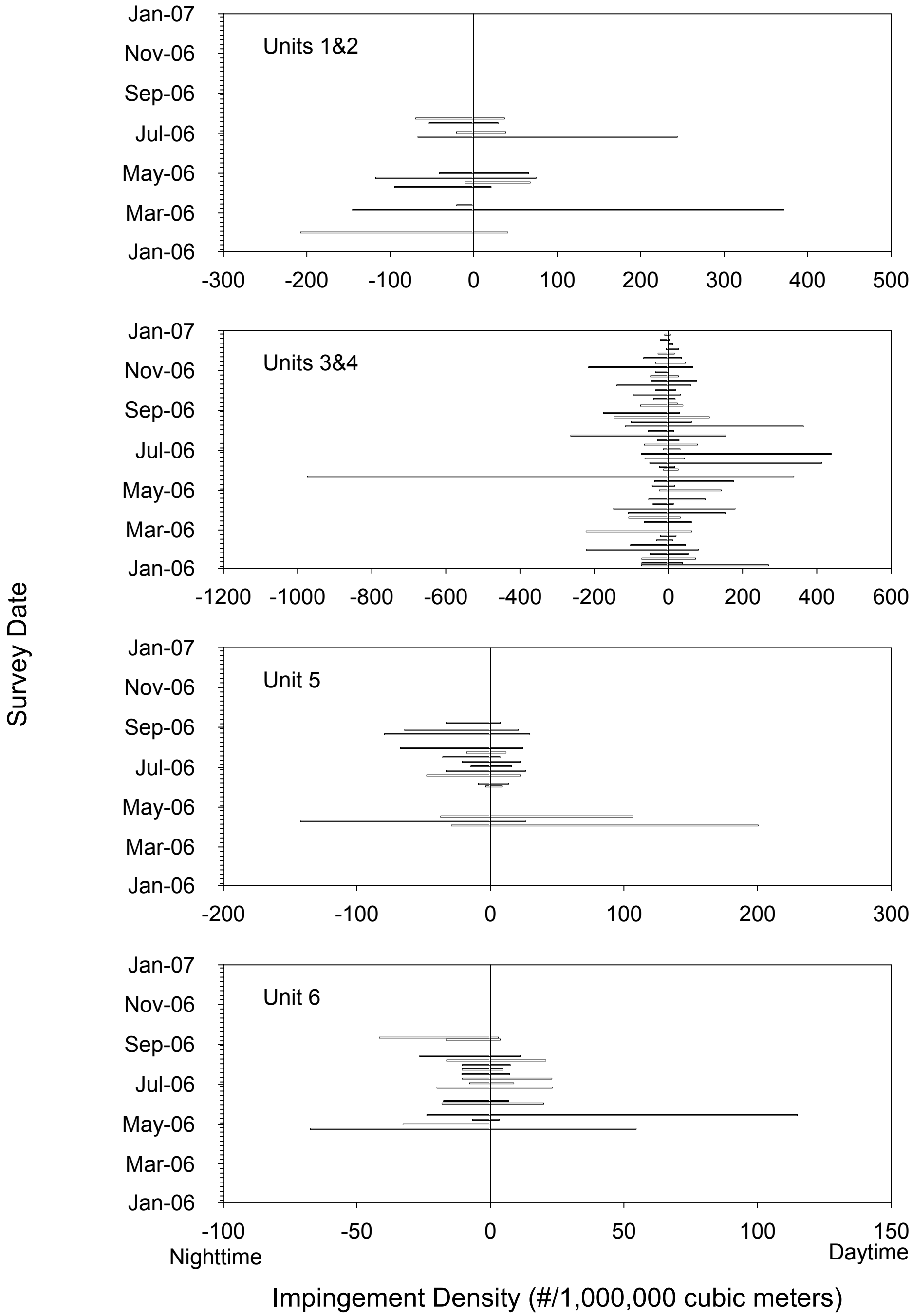


Figure 5.5-8. Mean concentration (# / 1,000,000 m^3) of invertebrates in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

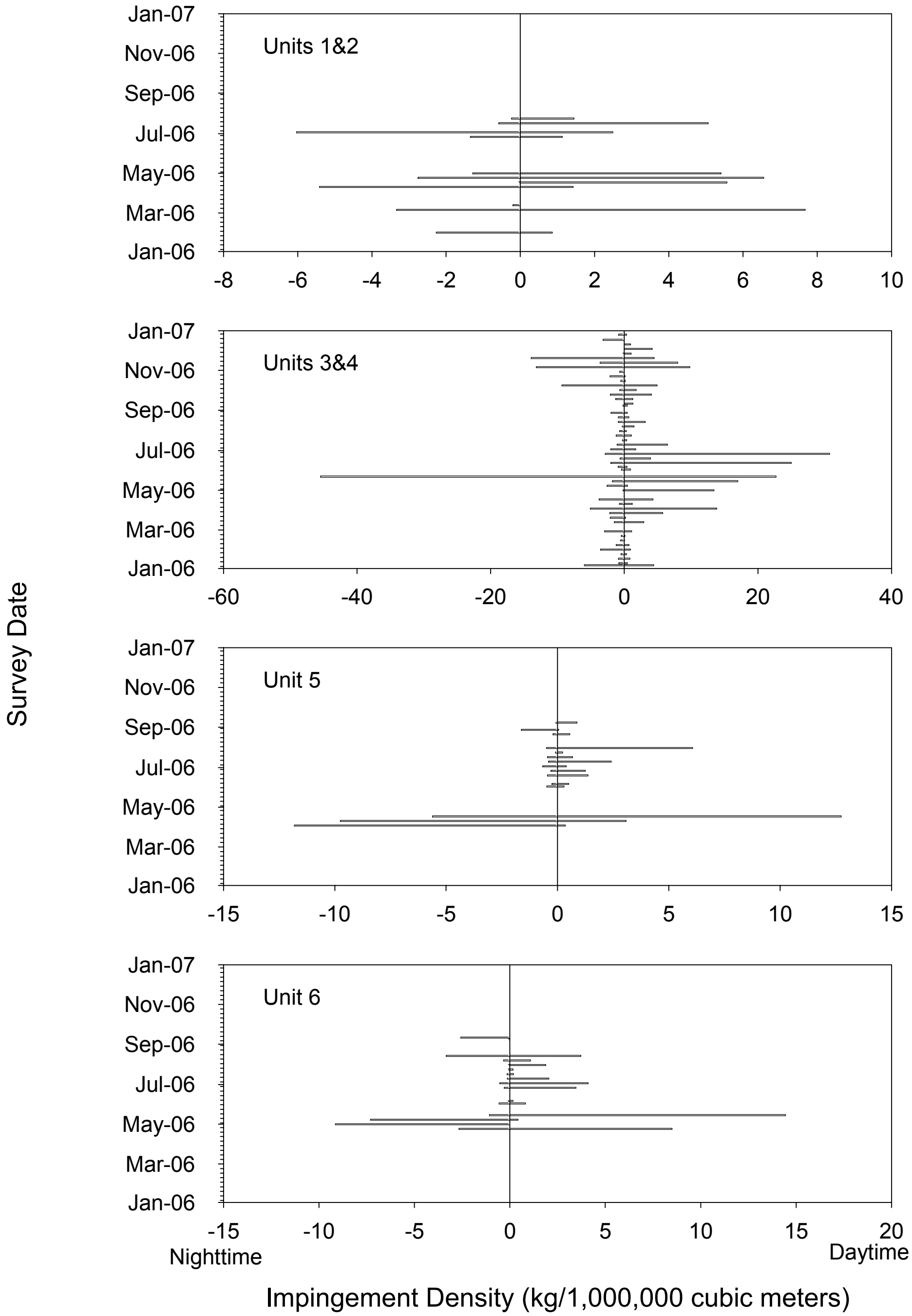


Figure 5.5-9. Mean biomass (kg / 1,000,000 m^3) of invertebrates in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

Los Cerritos Channel, from which the AGS directly withdraws cooling water, functions as a stormwater channel, thereby collecting substantial quantities of fouling material, or material that can clog the traveling screen mesh, such as trash (plastic cups, bags, etc.) and vegetation (terrestrial and marine). Both intake canals at the AGS have booms that span from shore to shore, and these effectively capture much of the floating anthropogenic trash. Most material that was observed in impingement surveys was suspended in the water column and thereby able to flow under the booms. The most prevalent fouling material observed at the AGS was vegetation, most often either green algae (*Ulva* spp) or filamentous green algae (*Enteromorpha* spp) that may have been dislodged from the hard substrate that lines the Los Cerritos Channel (Figure 5.5-10). Shell debris (or shell hash), namely empty *Mytilus* spp shells, comprised a small portion of the overall fouling material observed during impingement surveys. Impingement of organisms/size classes typically entrained through the CWS can be directly related to the impingement of fouling material, especially the marine vegetation. Impingement of late stage northern anchovy larvae (*Engraulis mordax*) was frequently observed to coincide with marine vegetation, as the individual anchovies were trapped within the algal mat which was subsequently impinged. The exact weight of anthropogenic trash removed from the marine system was not recorded during the current survey, as much of it was sequestered by the skimming booms, where it was regularly removed and hauled off to a landfill.

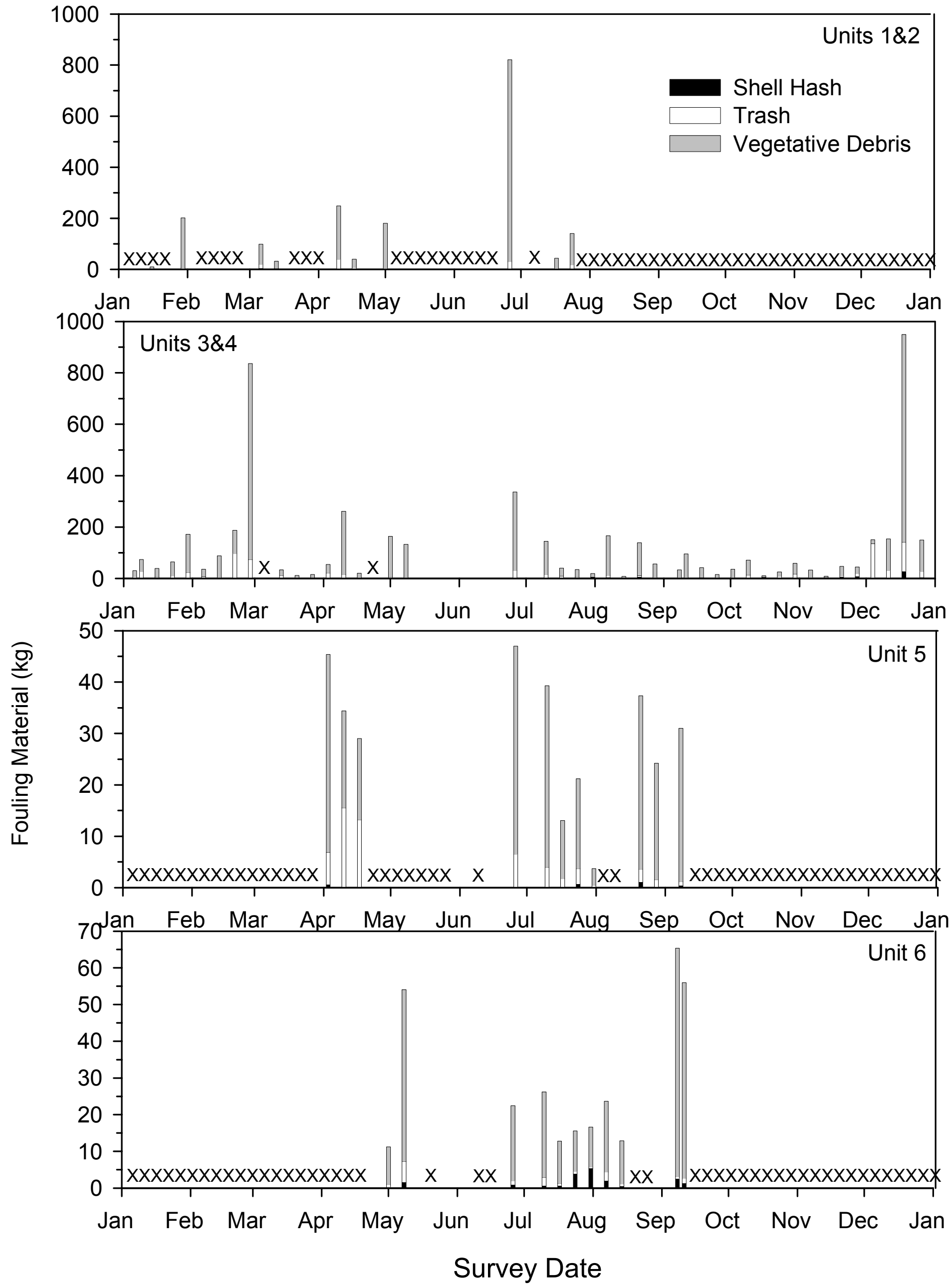


Figure 5.5-10. Biomass (kg) of debris impinged by screenwell and survey at the AGS in 2006.

5.5.1.1 Comparison with Previous Studies

The annual fish impingement estimate for 2006 based on actual cooling water flow volumes was 399,097 fish weighing 6,467 kg (14,261 lbs), the equivalent of 1,093 fish per day. This is substantially higher than the impingement estimate from 1978-1980 (203 fish per day) (SCE 1982a). Nearly 87% of the fish recorded in impingement samples occurred on two surveys during or immediately following rain events. As discussed in Section 5.5.1, this has been documented in past impingement studies at the AGS. Herbinson (1981) noted the occurrence of typically freshwater fish species, such as tilapia, bullhead catfish, and goldfish as well as high impingement abundances coinciding with period of high storm water runoff. At all units, highest impingement of Pacific pompano, the most abundant target taxa, occurred during the first five months of monitoring (October 1978 through February 1979), during which time over 13 inches of rain fell in the area. Only one Pacific pompano was recorded in 2006. This species has declined in trawl and impingement samples in the Bight since the 1970s, coinciding with increased water temperatures and a decrease in zooplankton abundance in the California Current (Beck and Herbinson 2003).

Since 2001, the average number of fish recorded per impingement survey at the AGS at all screenwells combined was 24 fish (MBC 2007). Similarly, the average number of fish recorded per survey during the 1992-3 study was 30 fish. Therefore, results from the present study are also inconsistent with those from these other studies. As mentioned previously, this is primarily driven by the high impingement during rain events in 2006.

5.5.2 All Life Stages of Fishes by Species

Six fish taxa were impinged in sufficient numbers to warrant further analysis. These taxa included (with sampled abundance in parentheses):

- topsmelt (11,694 individuals)
- silversides (9,118 individuals)
- shiner perch (3,660 individuals)
- Pacific staghorn sculpin (1,279 individuals)
- queenfish (301 individuals)
- northern anchovy (174 individuals)

Three additional species were requested to be analyzed in further detail due their inclusion in the Coastal Pelagics Fishery Management Plan: Pacific sardine (50 individuals), jack mackerel (10 individuals), and Pacific chub mackerel (3 individuals). Combined, these nine taxa represented 93.6% of the sampled impingement abundance.

5.5.2.1 Topsmelt (*Atherinops affinis*) and Silversides (Atherinopsidae)

Information on the life history and ecology of silversides (Atherinopsidae), including topsmelt, is summarized in Section 4.5.3.1.

5.5.2.1.1 Population Trends and Fishery

Silversides, including topsmelt, were not analyzed in detail during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). During the two-year study however, topsmelt ranked second in impingement abundance at Units 1&2 (1,760 individuals), fifth in abundance at Units 3&4 (1,571 individuals), and second in abundance at Units 5&6 (85,106 individuals) (Herbinson 1981). During that same study, lower numbers of jacksmelt (404 individuals) and California grunion (2,868 individuals) were collected in impingement samples, with highest impingement at Units 5&6 and lowest at Units 1&2. From 2001 through 2005, annual abundance of topsmelt in impingement samples ranged from one individual (2002) to 298 individuals (2003) (MBC 2006). It was the most abundant species collected during the five-year study period. A total of nine California grunion and seven jacksmelt were collected in impingement samples during the same time period.

5.5.2.1.2 Sampling Results

Topsmelt was the most abundant fish species impinged (based on actual cooling water flows) with an estimated 221,960 individuals, or 56% of the annual total, weighing 3,550.255 kg (7,828.312 lbs) (Table 5.5-1). Highest normal operation impingement (abundance and biomass) was recorded at Units 3&4, which accounted for 98% of the total abundance, with 1% at each of the remaining unit pairs (Table 5.5-5).

Table 5.5-5. Annual topsmelt abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	Units 3&4	Units 5&6	Total
Fish Abundance	110	11,440	144	11,694
Fish Biomass (kg)	2.033	181.694	2.597	186.324

Topsmelt were impinged throughout the year, though peak impingement densities were recorded from May through September (Figure 5.5-11). Impinged biomass was generally highest from June through August (Figure 5.5-12). Both impinged abundance and biomass was highest overall in May, coinciding with a rainstorm (Figure 5.5-1). Substantial diel periodicity was observed in the impingement of topsmelt (Figures 5.5-13 and 5.5-14). Both abundance and biomass was notably higher during night surveys.

Length frequency analysis of 1,178 measured individuals indicated a mean standard length of 110 mm (4.3 in). There was a wide distribution of size classes, although most of the measured fishes were centered around the 100 mm (3.9 in) with a second small grouping centered at 150 mm SL (5.9 in) size classes (Figure 5.5-15). Considering topsmelt mature at two years and 100 mm (3.9 in) or greater (Love 1996), most of the individuals impinged were in their second to third year. Of the 474 individuals that were evaluated for condition factor, 97% were dead, 2.5% mutilated, and the remaining 0.5% alive.

A total of 9,118 unidentified members of the same taxonomic family as topsmelt (Atherinopsidae) were collected on three surveys (January 6 & 9, February 27) at the Units 3&4 screenwell. These individuals weighed 162.615 kg (358.566 lbs). Better than 99% were observed at night, with the largest impingement event occurring during the evening/night surveys of the February 27 survey, which was marked by substantial rainfall (0.68 inches). Based on actual cooling water flow, an estimated 71,658 individuals weighing 1,282.169 kg (2,827.183 lbs) were impinged. Recalculation based on design (maximum) cooling water flow indicates an estimated 118,355 individuals weighing 2,095.305 kg (4,620.148 lbs) were impinged during the year. Eighty individuals were assessed for their condition upon collection. Of these, 95% were dead while the remaining 5% were alive. The mean length of these 80 individuals was 110 mm SL, with a unimodal distribution with peaks in the 110-120 mm SL size classes (Figure 5.5-16).

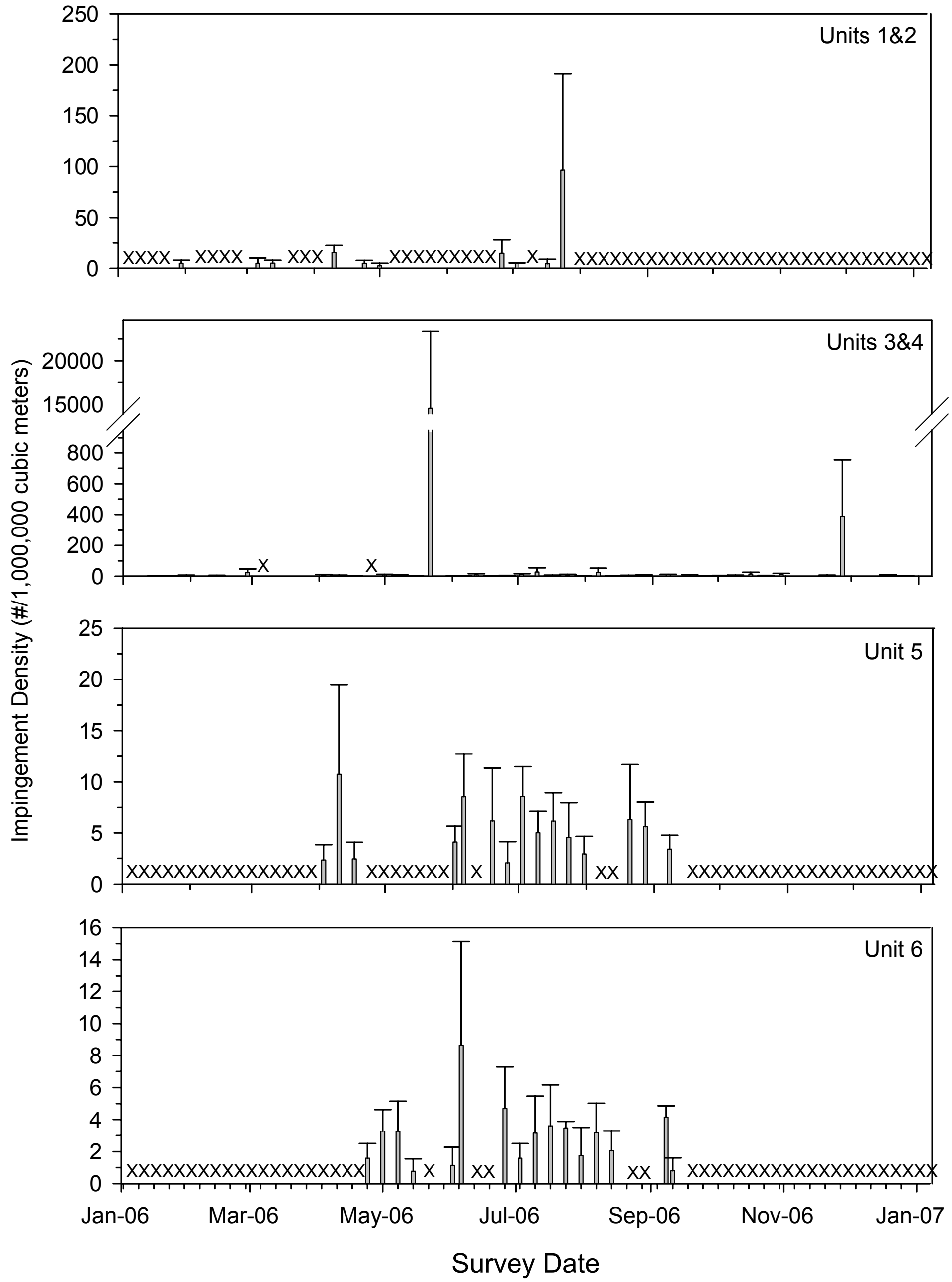


Figure 5.5-11. Mean concentration (# / 1,000,000 m^3) and standard error of topsmelt collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

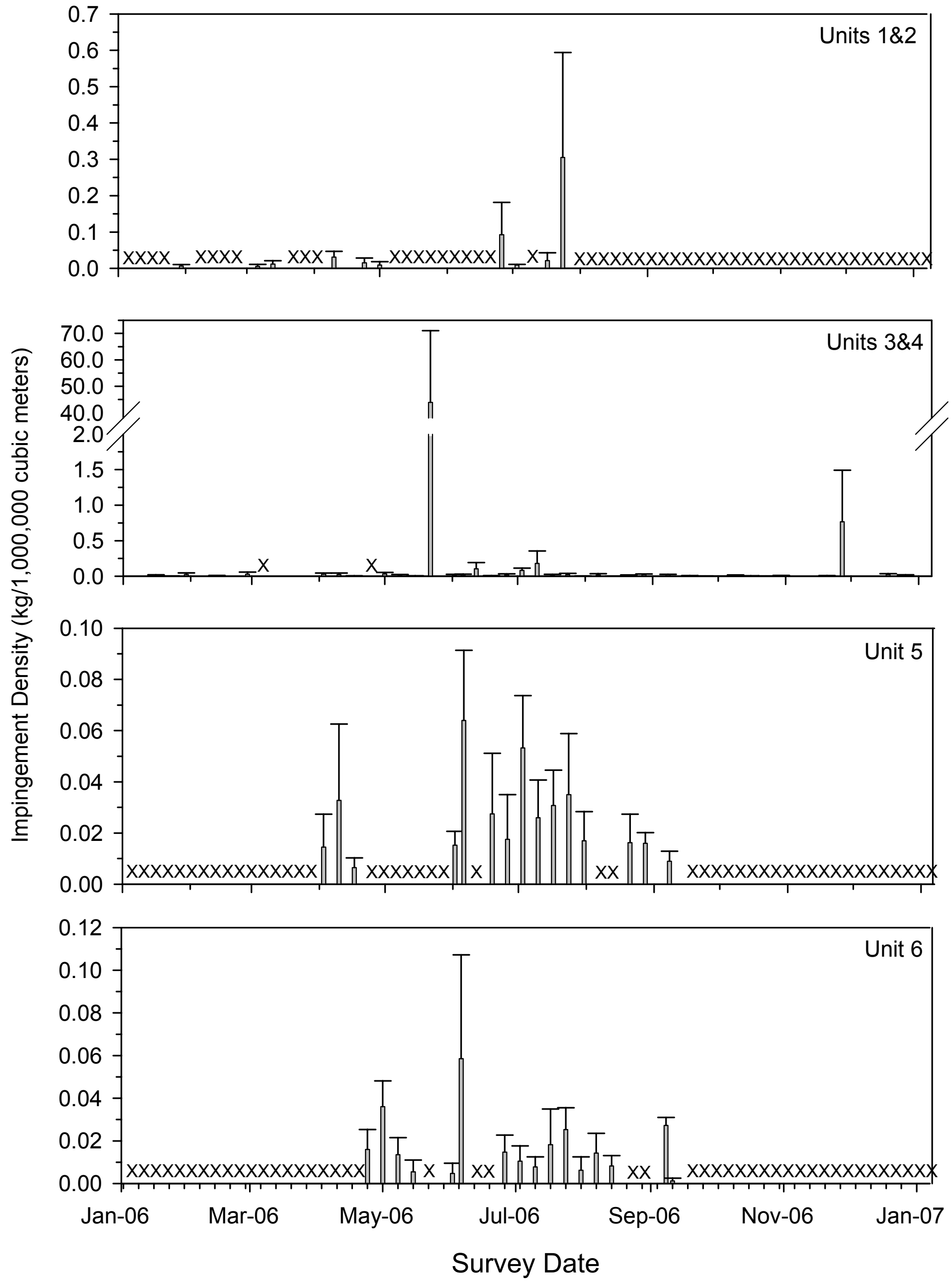


Figure 5.5-12. Mean biomass (kg / 1,000,000 m^3) and standard error of topsmelt collected in AGS impingement samples in 2006. “X” denotes weeks with no sample collection.

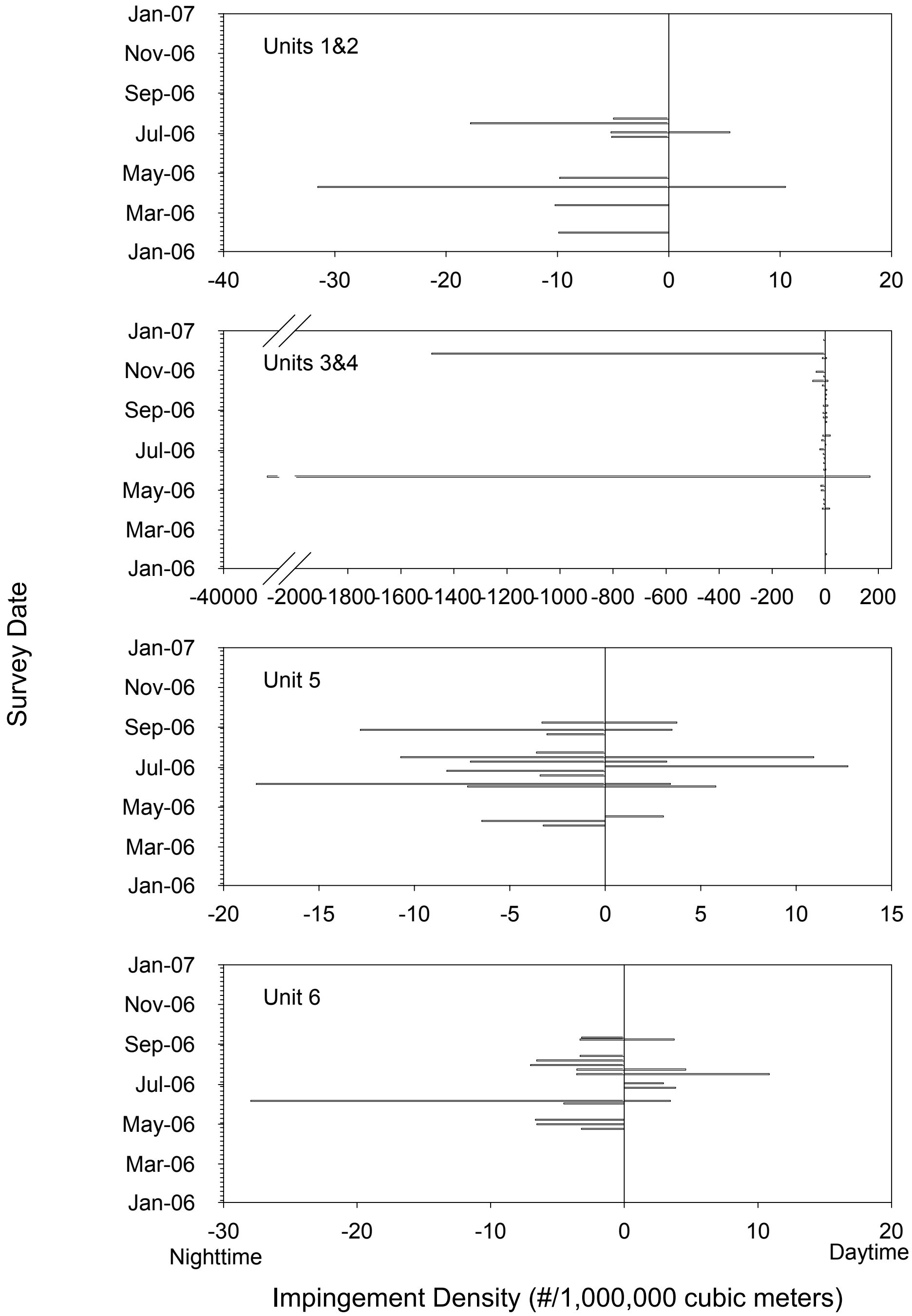


Figure 5.5-13. Mean concentration (# / 1,000,000 m^3) of topsmelt in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

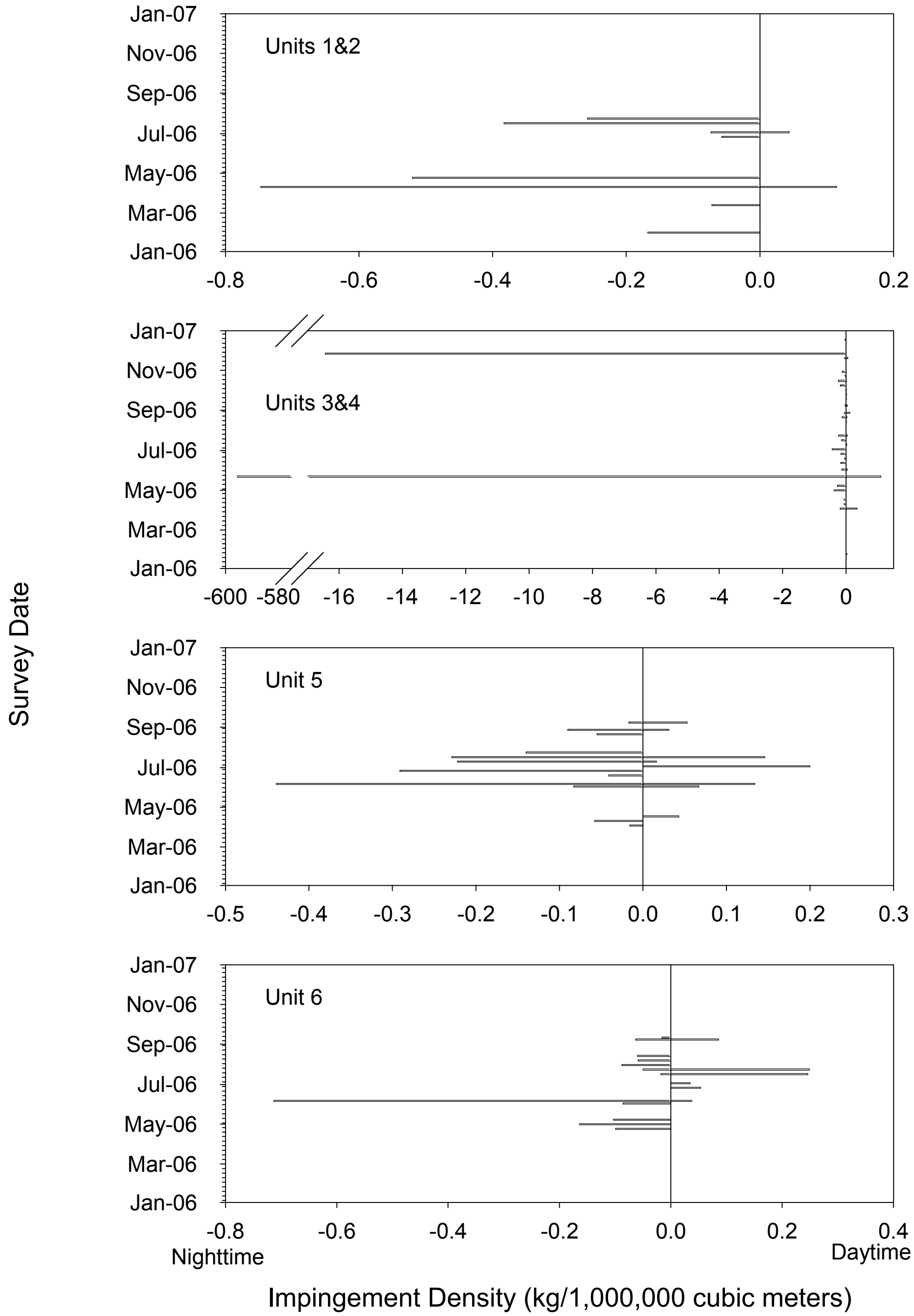


Figure 5.5-14. Mean biomass (kg / 1,000,000 m^3) of topsmelt in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

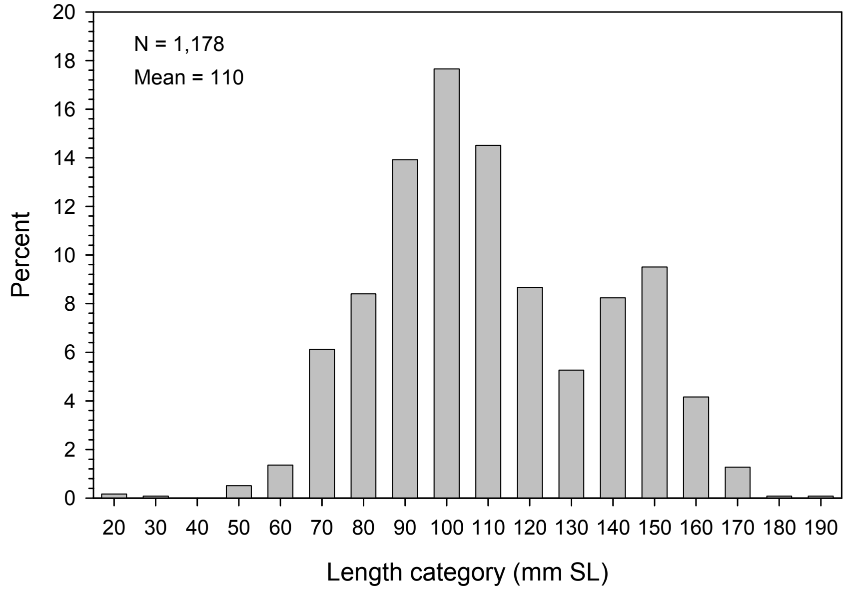


Figure 5.5-15. Length (mm) frequency distribution for topsmelt collected in impingement samples.

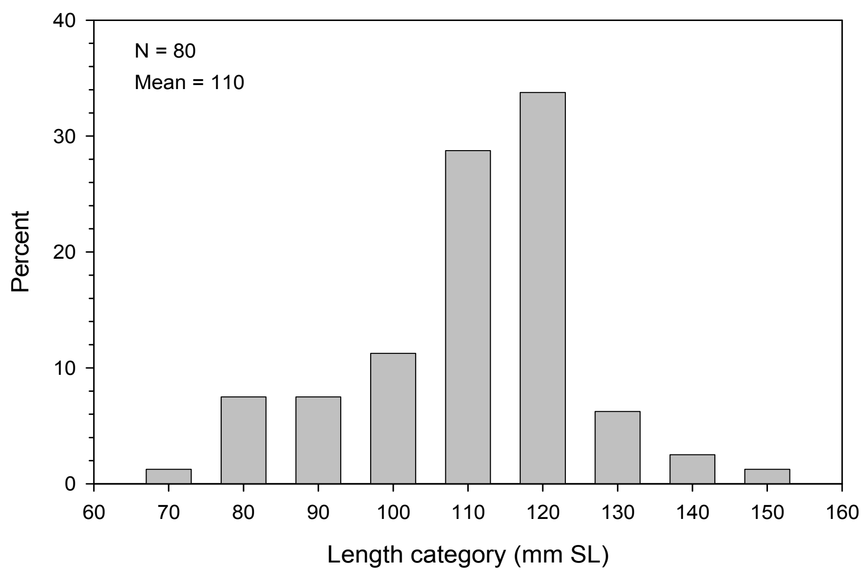


Figure 5.5-16. Length (mm) frequency distribution for unidentified silversides collected in impingement samples.

5.5.2.2 Shiner perch (*Cymatogaster aggregata*)

Shiner perch (*Cymatogaster aggregata*) ranges from San Quintin Bay, Baja California, to Port Wrangell, Alaska (Miller and Lea 1972). There are 19 species of Pacific nearshore surfperches (Family Embiotocidae) that occur off southern California (Miller and Lea 1972). Most inhabit nearshore waters, bays, and estuaries, though some are found further offshore.

5.5.2.2.1 Life History and Ecology

Shiner perch occurs primarily in shallow-water marine, bay, and estuarine habitats (Emmett et al. 1991), and is demersal on sandy and muddy bottoms. On the southern California shelf, shiner perch are found at depths to 90 m (295 ft), and Allen (1982) reported most occur at about 70 m (230 ft). It has been reported to depths of 146 m (480 ft) (Miller and Lea 1972). Juveniles and adults occur in oligohaline to euryhaline waters, and even occasionally in fresh water. This species forms schools or aggregations during the day (Fitch and Lavenberg 1975), but solitary individuals are found on the bottom at night. Important prey items for this species off southern California include calanoid copepods and chaetognaths (Allen 1982). It is a predominantly diurnal visual plankton picker, but larger individuals may engage in nocturnal epibenthic searching (Allen 1982). Shiner perch, along with white croaker, formed Allen’s (1982) “nearshore schoolers” recurrent group; the two species occur commonly off southern California even though shiner perch is considered a cold-temperate, outer-shelf species, while white croaker is a temperate, inner-shelf species.

Eggs of the shiner perch are fertilized internally, and females give birth to live young. Mating occurs primarily in the spring and summer in California (Bane and Robinson 1970). The reproductive capacity of this species is directly related to female size; smaller females produce as few as 5 young, while larger females can produce over 20 young (Wilson and Millemann 1969). Shiner perch have no larval stage. At birth, fully developed young are about 34 to 78 mm (1.3 to 3.1 in) in length (Wilson and Millemann 1969; Hart 1973). Shiner perch live for about eight years and reach about 180 mm (7.1 in) in length (Miller and Lea 1972; Hart 1973).

5.5.2.2.2 Population Trends and Fishery

This species is not commercially important, but some shiner perch are landed for bait and human consumption (Emmett et al. 1991). Shiner perch are fished recreationally, especially from piers and in bays and estuaries. Total statewide recreational landings of “surfperches” were 489,000 fish in 1999, with most of the catch in central and northern California (Fritzsche and Collier 2001). Commercial landings in the Los Angeles area have fluctuated between about 161 and 1,278 kg (roughly 300 and 3,000 lbs) per year since 2000 (Table 5.5-6). In 2005, “surfperch” landings in the Los Angeles area totaled 21.3 kg (47 lbs) at a value of $86 (CDFG 2006). Commercial landings of “surfperches” reported from catch blocks in the Santa Monica Bay area totaled 117.0 kg (258 lbs) in 2006, at an estimated value of $1,092 (CDFG 2007b). Numbers of shiner perch in southern California waters declined after the mid-1970s, and this is likely related to warming ocean temperature, decreased zooplankton biomass, and reduced upwelling (Stull and Tang 1996; Beck and Herbinson 2003; Allen et al. 2003).

Table 5.5-6. Annual landings and revenue for surfperches in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**kilograms**	**pounds**	**Revenue**
2000	1,278	2,817	$3,085
2001	239	526	$1,315
2002	972	2,143	$6,455
2003	414	913	$1,743
2004	164	362	$689
2005	161	354	$403
2006	497	1,095	$2,624

Shiner perch was the second most abundant target species analyzed during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). An average of 21.7 shiner perch was impinged daily at the AGS, with most occurring at Units 5&6 (Table 5.4-1). Shiner perch were taken throughout the two-year study. From 2001 through 2005, shiner perch was the third most abundant species in impingement samples, with annual abundance in impingement samples ranging from six individuals (2002) to 61 individuals (2003) (MBC 2006).

5.5.2.2.3 Sampling Results

Shiner perch was the third most abundant fish taxa impinged (based on actual cooling water flow volumes) with an estimated 64,166 individuals, or 16% of the annual total, weighing 339.300 kg (748.157 lbs) (Table 5.5-1). The majority of individuals, 93%, were recorded at Units 3&4, followed by the combined screenwell observations for Units 5&6 with 7% (Table 5.5-7). Relatively few individuals were recorded at Units 1&2. Impinged biomass was similar to abundance with Units 3&4 contributing the largest proportion (84%), followed by Units 5&6 (15%) and Units 1&2 (1%).

Table 5.5-7. Annual shiner perch abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	Units 3&4	Units 5&6	Total
Fish Abundance	9	3,386	265	3,660
Fish Biomass (kg)	0.212	18.893	3.381	22.486

Shiner perch were most abundant in impingement samples during spring surveys, with impinged biomass following the same trend (Figures 5.5-17 and 5.5-18). During periods of highest abundance, impingement abundance and biomass were usually higher during nighttime surveys (Figures 5.5-19 and 5.5-20).

Length frequency analysis of 970 measured individuals indicated a mean standard length of 57 mm (2.2 in). Size distribution was dominated by individuals in the 40 and 50 mm SL (1.6–2.0 in) size classes (Figure 5.5-21). A second, smaller peak was observed, centered at the 110 mm SL (4.3 in) size class. Of the 479 individuals that were evaluated for condition factor, nearly 99% were dead, approximately 1% was mutilated and one individual was collected alive. Sixty-seven percent of the 542 individuals analyzed were juveniles, 16% were female, and the 7% were male. Ten percent of those analyzed could not be accurately assigned to either class.

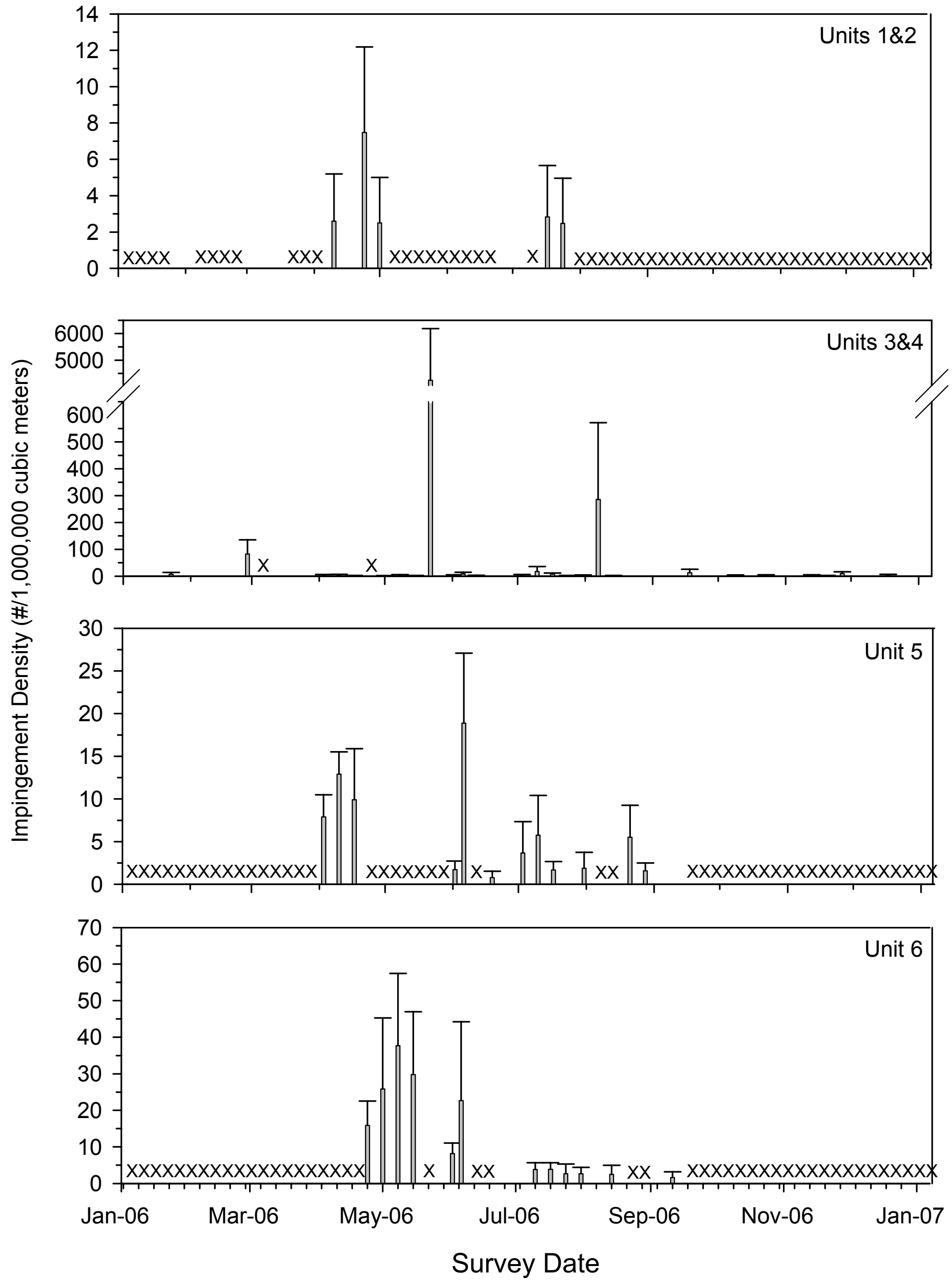


Figure 5.5-17. Mean concentration (# / 1,000,000 m^3) and standard error of shiner perch collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

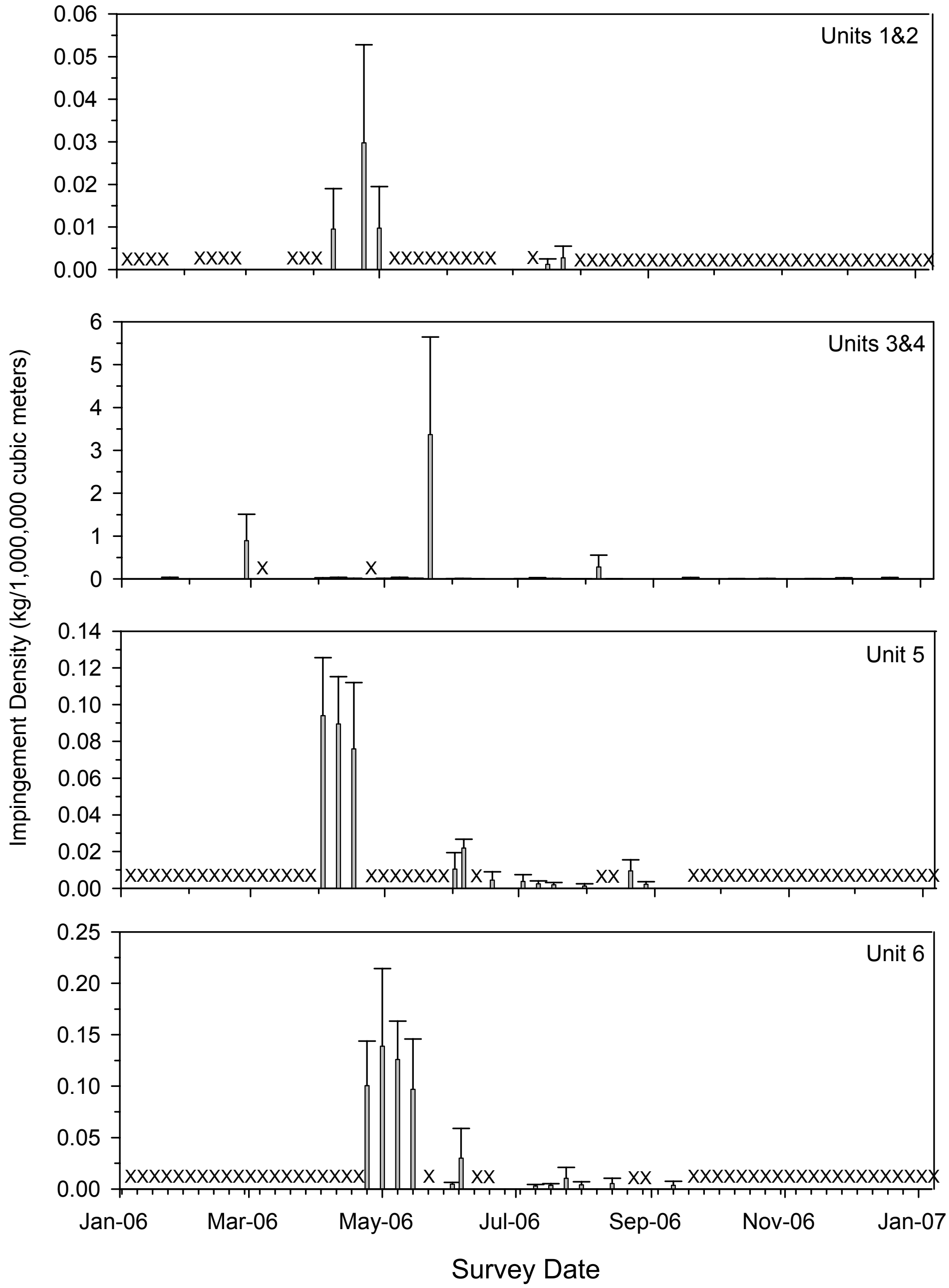


Figure 5.5-18. Mean biomass (kg / 1,000,000 m^3) and standard error of shiner perch collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

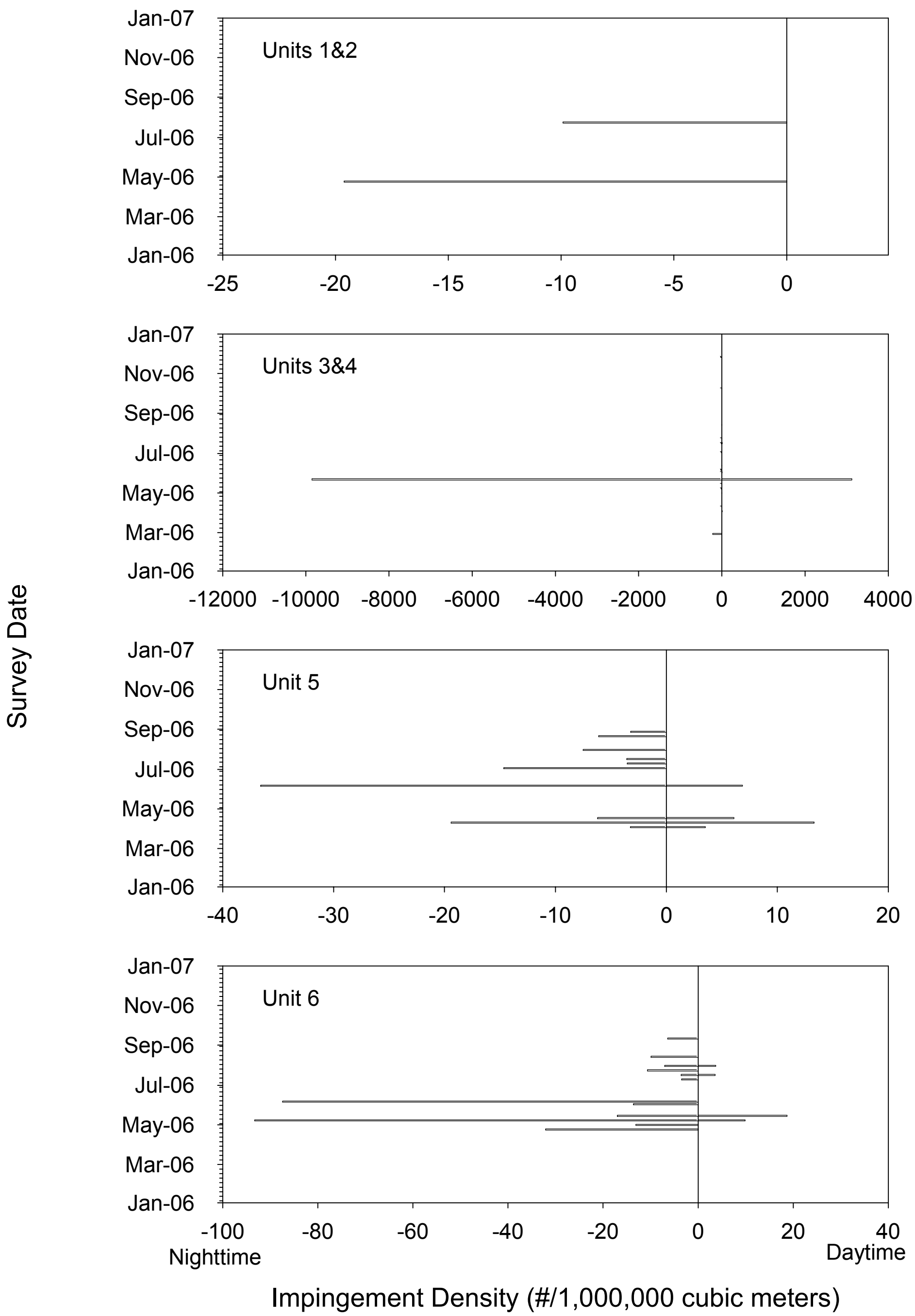


Figure 5.5-19. Mean concentration (# / 1,000,000 m^3) of shiner perch in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

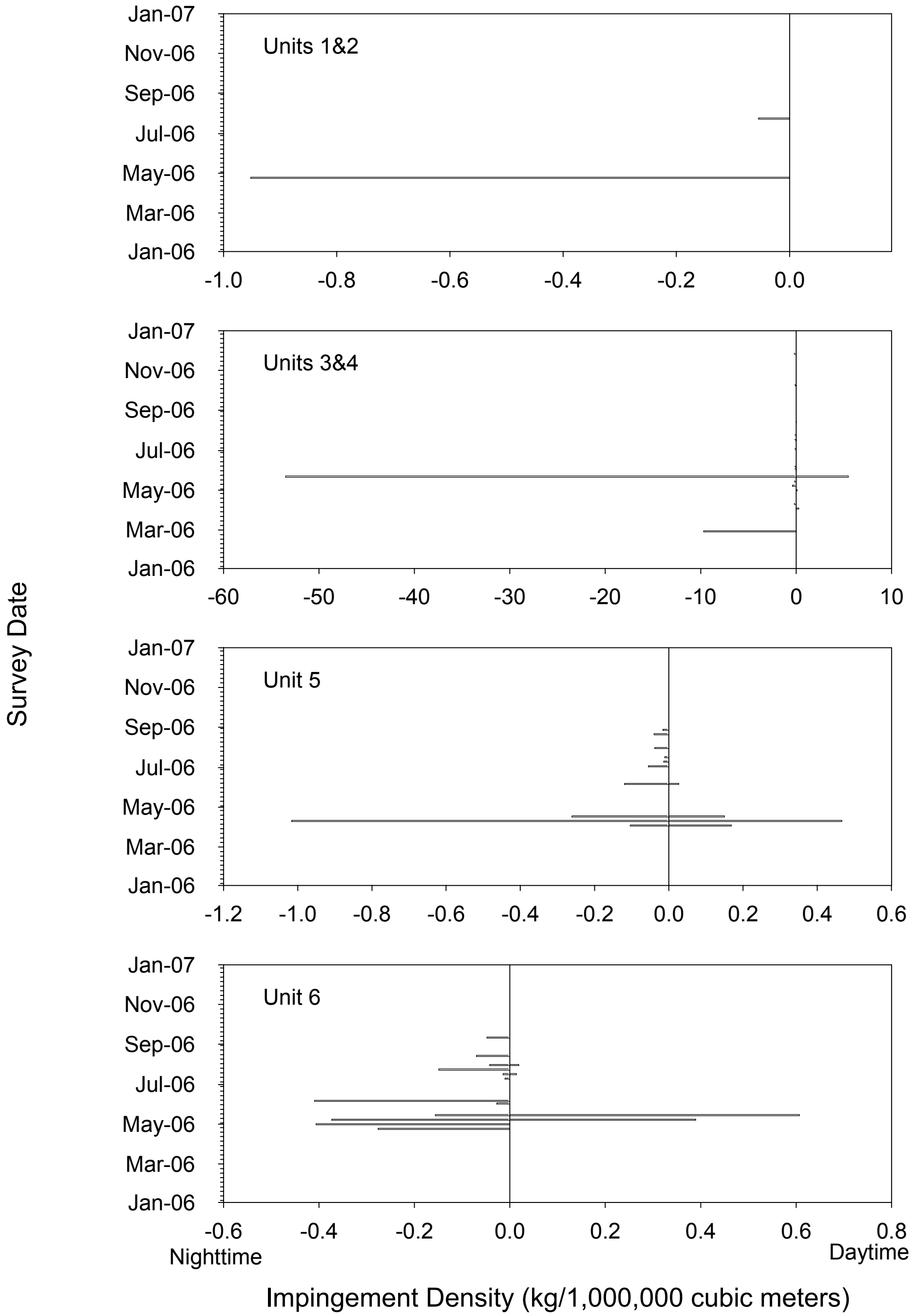


Figure 5.5-20. Mean biomass (kg / 1,000,000 m^3) of shiner perch in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

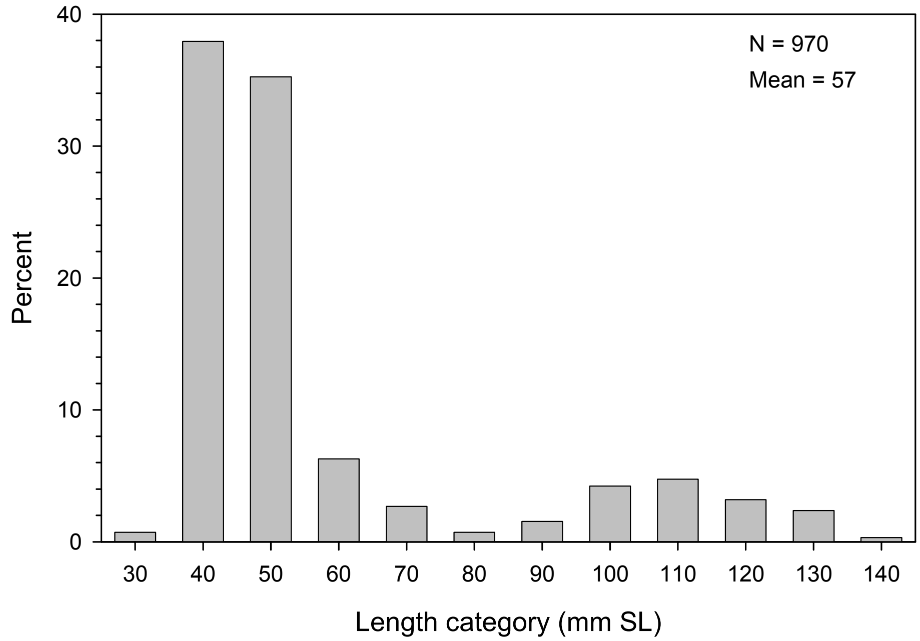


Figure 5.5-21. Length (mm) frequency distribution for shiner perch collected in impingement samples.

5.5.2.3 Pacific staghorn sculpin (*Leptocottus armatus*)

Pacific staghorn sculpin ranges from San Quintin, Baja California, Mexico to Port Moeller on the Bering Sea in depths from tidepools to 91 m (Miller and Lea 1972; Love et al. 2005). Allen and Pondella (2006b) included Pacific staghorn sculpin in their northern bay and estuary species group. Pacific staghorn sculpin have been commonly observed during impingement sampling at stations withdrawing seawater from bays and harbors (MBC unpubl. data).

5.5.2.3.1 Life History and Ecology

Common to bays and estuaries throughout its range, Pacific staghorn sculpin has been recorded in 13 bays or estuaries in California and Baja California, ranging from the Kalamath River mouth to Bahia de San Quintin (Allen et al. 2006). Moyle (2002) reported that Pacific staghorn sculpins move freely between salinity regimes, with juveniles most abundant in coastal streams. Tasto (1975) reported results from a tagging study in Anaheim Bay, noting high site fidelity, although this was based on a small percentage of tag recaptures (5.5%).

Pacific staghorn sculpins mature at 120 to 150 mm SL (4.7 to 5.9 in), or one year old (Moyle 2002). Tasto (1975) indicated that spawning takes place between mid-December and min-March with peaks in January and February. This author further noted that females were generally more abundant than males within Anaheim Bay, California, although seasonal variation in the sex ratio was observed, with females increasing to 4:1 over males during spawning season. Moyle (2002) reported that this species attaches the fertilized eggs to the substrate, where the males protect the developing embryos. The author further describes their larvae as planktonic, usually swimming near the surface waters before settling out at approximately 10 – 15 mm (0.4 to 0.6 in) total length.

Limited age and growth information is available for Pacific staghorn sculpin, although Tasto (1975) reported data based on sampling within Anaheim Bay. The predominance of specimens collected was one year old or less, limiting the analysis. Age at length analysis of these individuals indicated a near straight line when plotted. A single older fish was collected during the study, a 172-mm (6.8 in) SL female that was approximately 2 years old (Tasto 1975).

5.5.2.3.2 Population Trends and Fishery

Pacific staghorn sculpin have been taken as bycatch by recreational anglers in bays and estuaries throughout their range, with no targeted commercial or recreational fishery. Moyle (2002) suggests this species has been very common throughout the San Francisco Bay, California, he notes that fishermen seldom eat it. No further recent information regarding population trends is readily available in the relevant literature.

Pacific staghorn sculpin was not analyzed in detail during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). During the two-year study however, staghorn sculpin ranked seventh in impingement abundance at Units 1&2 (146 individuals), thirteenth in abundance at Units 3&4 (196 individuals), and ninth in abundance at Units 5&6 (2,271 individuals) (Herbinson 1981). From 2001 through 2005, Pacific staghorn sculpin was the seventh most abundant species in impingement samples, with annual abundance in impingement samples ranging from no individuals (2001 and 2004) to six individuals (2003 and 2005) (MBC 2006).

5.5.2.3.3 Sampling Results

Pacific staghorn sculpin was the fourth most abundant fish taxa impinged (based on actual cooling water flow volumes) with an estimated 17,973 individuals, or 5% of the annual total, weighing 216.853 kg (478.161 lbs) (Table 5.5-2). The majority of individuals, 64%, were recorded at Units 3&4, followed by Units 1&2 with 22% and the combined Units 5&6 with 13% (Table 5.5-8). Impinged biomass was similar to abundance with Units 3&4 contributing the largest proportion (58%), followed by Units 1&2 (23%) and Units 5&6 (19%).

Table 5.5-8. Annual Pacific staghorn sculpin abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	Units 3&4	Units 5&6	Total
Fish Abundance	285	824	170	1,279
Fish Biomass (kg)	3.877	9.642	3.117	16.636

Pacific staghorn sculpin were most abundant in impingement samples during late-spring through summer, with impinged biomass following the same trend (Figures 5.5-22 and 5.5-23). During periods of highest abundance, impingement abundance and biomass were consistently higher during nighttime (Figures 5.5-24 and 5.5-25).

Length frequency analysis of 442 measured individuals indicated a mean standard length of 87 mm (2.2 in). Size distribution was dominated by individuals greater than 80 mm SL (3.1 in) with peak abundance in the 80 mm SL size class. (Figure 5.5-26). Of the 265 individuals that were evaluated for condition factor, 64% were dead, 36% alive, and one individual collected that was mutilated.

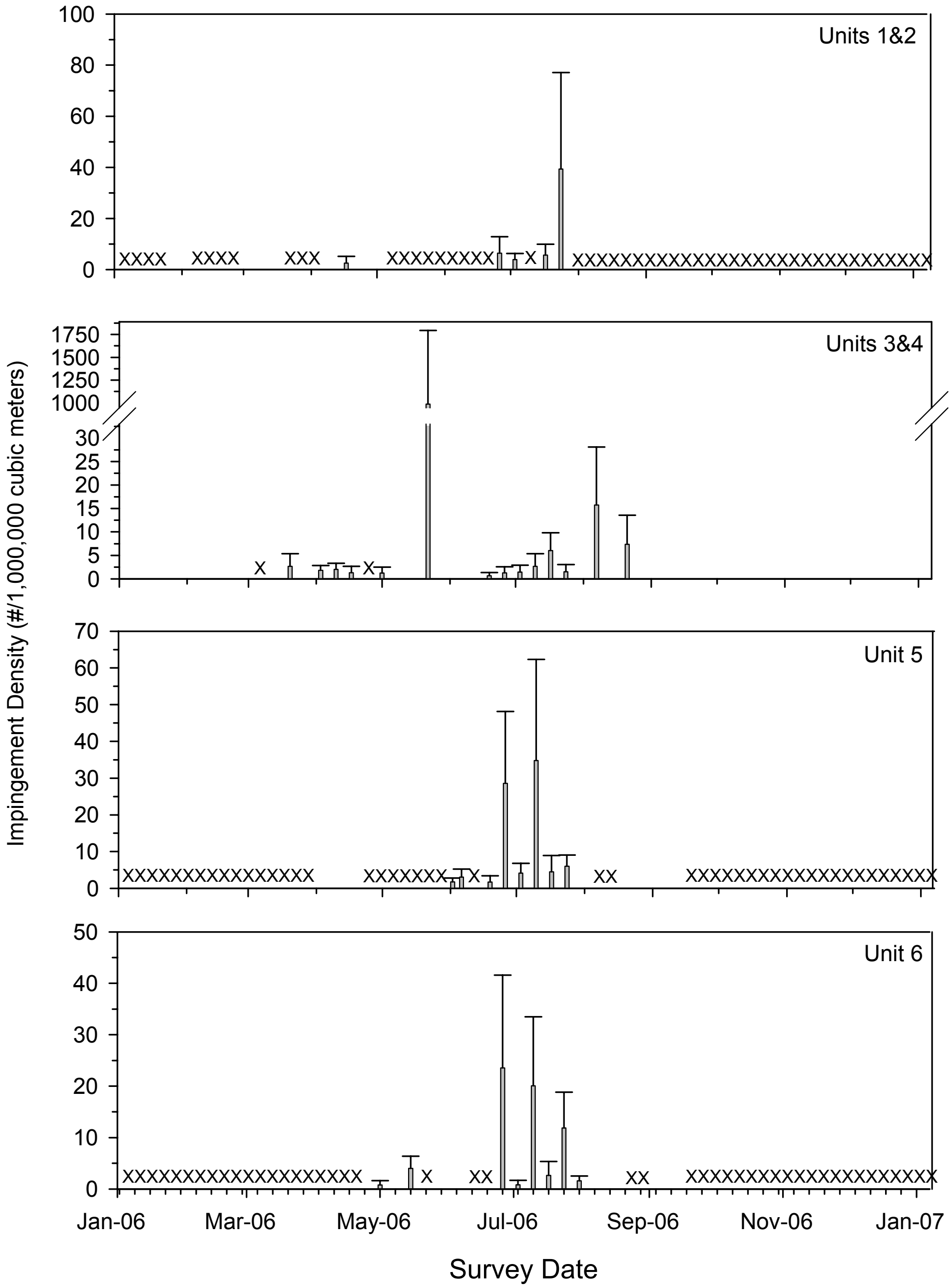


Figure 5.5-22. Mean concentration (# / 1,000,000 m^3) and standard error of staghorn sculpin collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

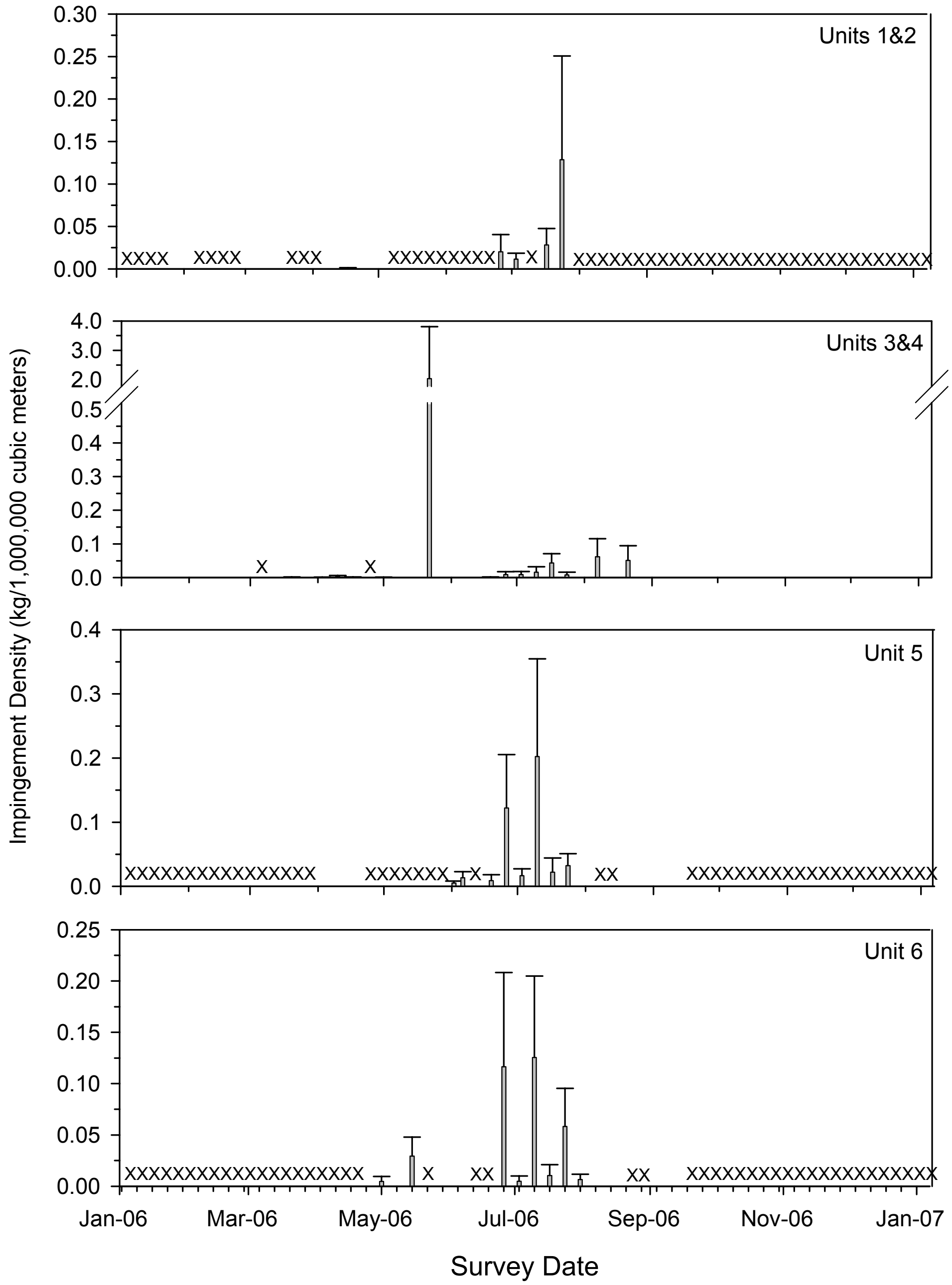


Figure 5.5-23. Mean biomass (kg / 1,000,000 m^3) and standard error of staghorn sculpin collected in AGS impingement samples in 2006. “X” denotes weeks with no sample collection.

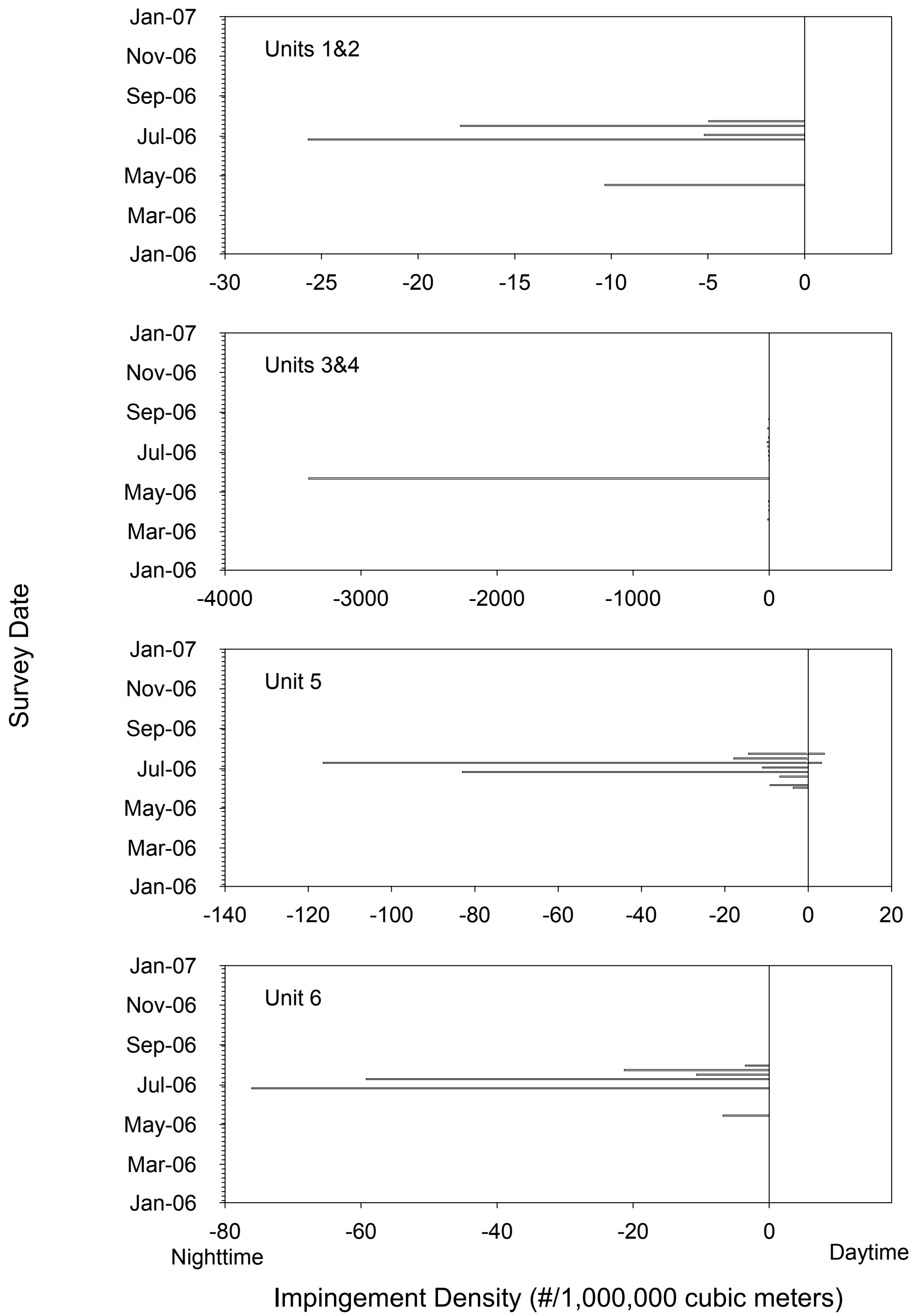


Figure 5.5-24. Mean concentration (# / 1,000,000 m^3) of staghorn sculpin in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

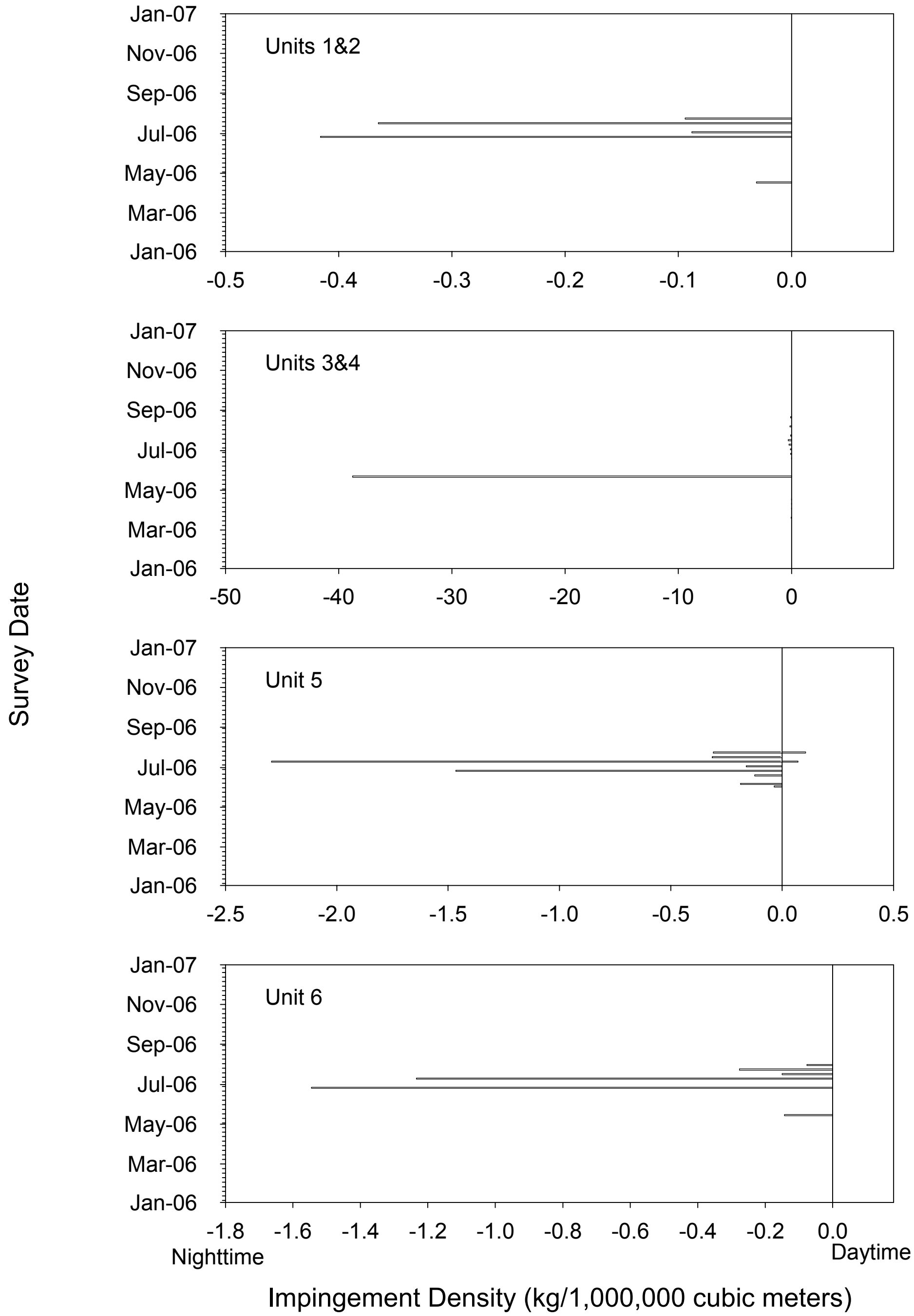


Figure 5.5-25. Mean biomass (kg / 1,000,000 m^3) of staghorn sculpin in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

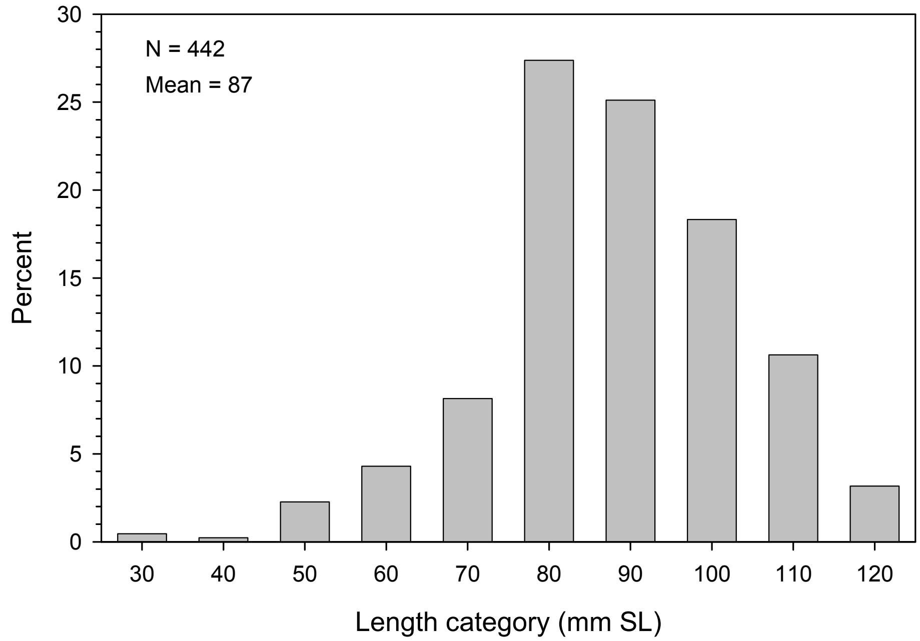


Figure 5.5-26. Length (mm) frequency distribution for staghorn sculpin collected in impingement samples.

5.5.2.4 Northern anchovy (*Engraulis mordax*)

Information on the life history and ecology of northern anchovy is summarized in Section 4.5.3.4.

5.5.2.4.1 Population Trends and Fishery

Northern anchovy was the sixth most abundant target species analyzed during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). An average of 2.7 anchovies was impinged daily at the AGS, with most occurring at Units 5&6 (Table 5.4-1). At all units it was collected in highest numbers at the onset of the study from October-December 1978. From 2001 through 2005, northern anchovy was the fourth most abundant species in impingement samples, with annual abundance in impingement samples ranging from no individuals (2002) to 50 individuals (2004) (MBC 2006).

5.5.2.4.2 Sampling Results

Northern anchovy was the ninth most abundant fish post-recruitment taxa impinged (based on actual cooling water flows) with an estimated 1,462 individuals, or 0.4% of the annual total, weighing 2.551 kg (5.625 lbs) (Table 5.5-2). Additionally, an estimated 6,582 late stage larvae weighing 0.197 kg (0.434 lbs) were impinged when trapped in algal mats. Observed normal operation impinged abundance was nearly identical between the screenwells at Units 3&4 and Units 5&6 (samples combined), with approximately 1% recorded at Units 1&2 (Table 5.5-9). Although impingement was nearly evenly spread among two screenwells, Units 3&4 impinged substantially greater biomass, due to a higher mean individual biomass, than the combined records at Units 5&6, with minimal values recorded at Units 1&2.

Table 5.5-9. Annual northern anchovy abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	Units 3&4	Units 5&6	Total
Fish Abundance	1	86	87	174
Fish Biomass (kg)	0.018	0.207	0.050	0.275

Northern anchovy were impinged throughout the first three quarters of the year, with peak impingement densities recorded in May and July (Figure 5.5-27). Impingement biomass followed a similar pattern to abundance (Figure 5.5-28). During periods of highest abundance, impingement abundance was usually higher during daytime at all screenwells except Units 1&2 (Figure 5.5-29). Diel patterns in impinged biomass, however, suggest larger individuals were impinged during nighttime surveys at Units 3&4 and Unit 6 (Figure 5.5-30). The remaining screenwells recorded impinged biomass trends consistent with impinged abundance. The late stage larvae that were impinged were predominantly recorded during April and May surveys during the night.

Length frequency analysis of 96 measured post-settlement individuals indicated a mean standard length of 47 mm (1.9 in). There was a wide distribution of size classes, although most of the measured fishes were between the 20 and 40 mm (0.8 and 1.6 in) size classes with a peak at 30 mm (1.2 in) (Figure 5.5-31), indicating most were in their first year. Of the 89 individuals that were evaluated for condition factor, 98% were dead and the remaining 2% were mutilated.

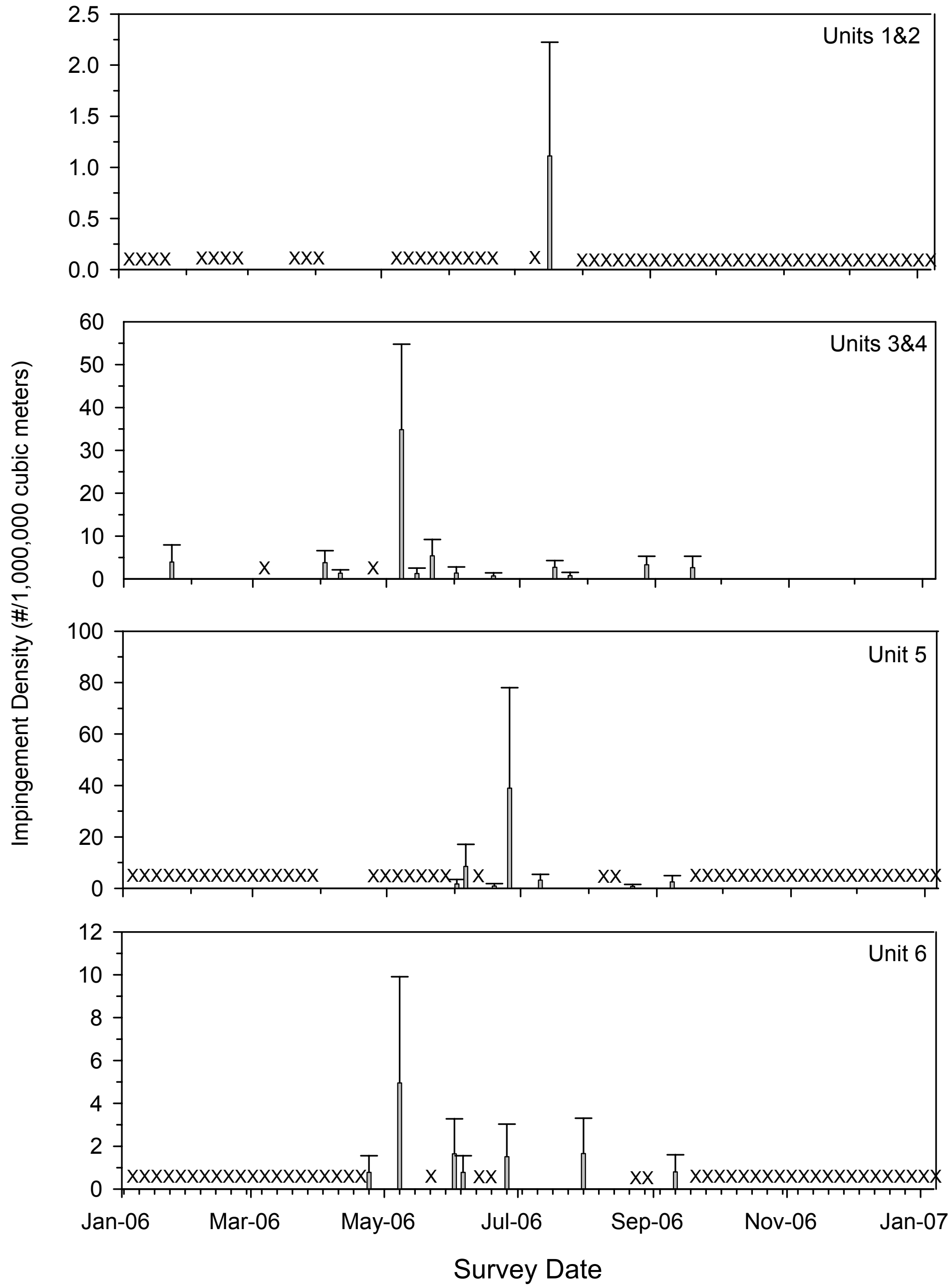


Figure 5.5-27. Mean concentration (# / 1,000,000 m^3) and standard error of northern anchovy collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

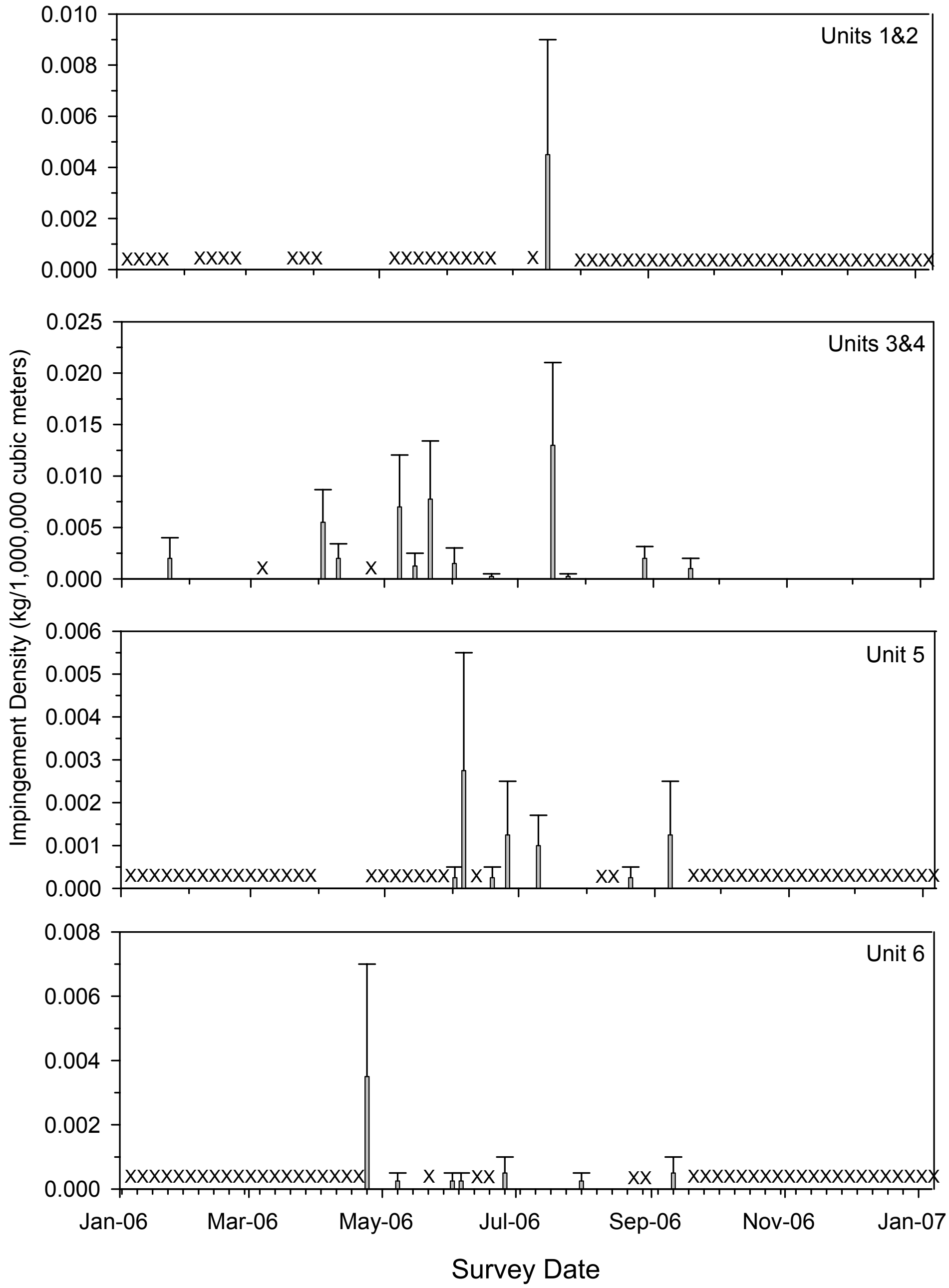


Figure 5.5-28. Mean biomass (kg / 1,000,000 m^3) and standard error of northern anchovy collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

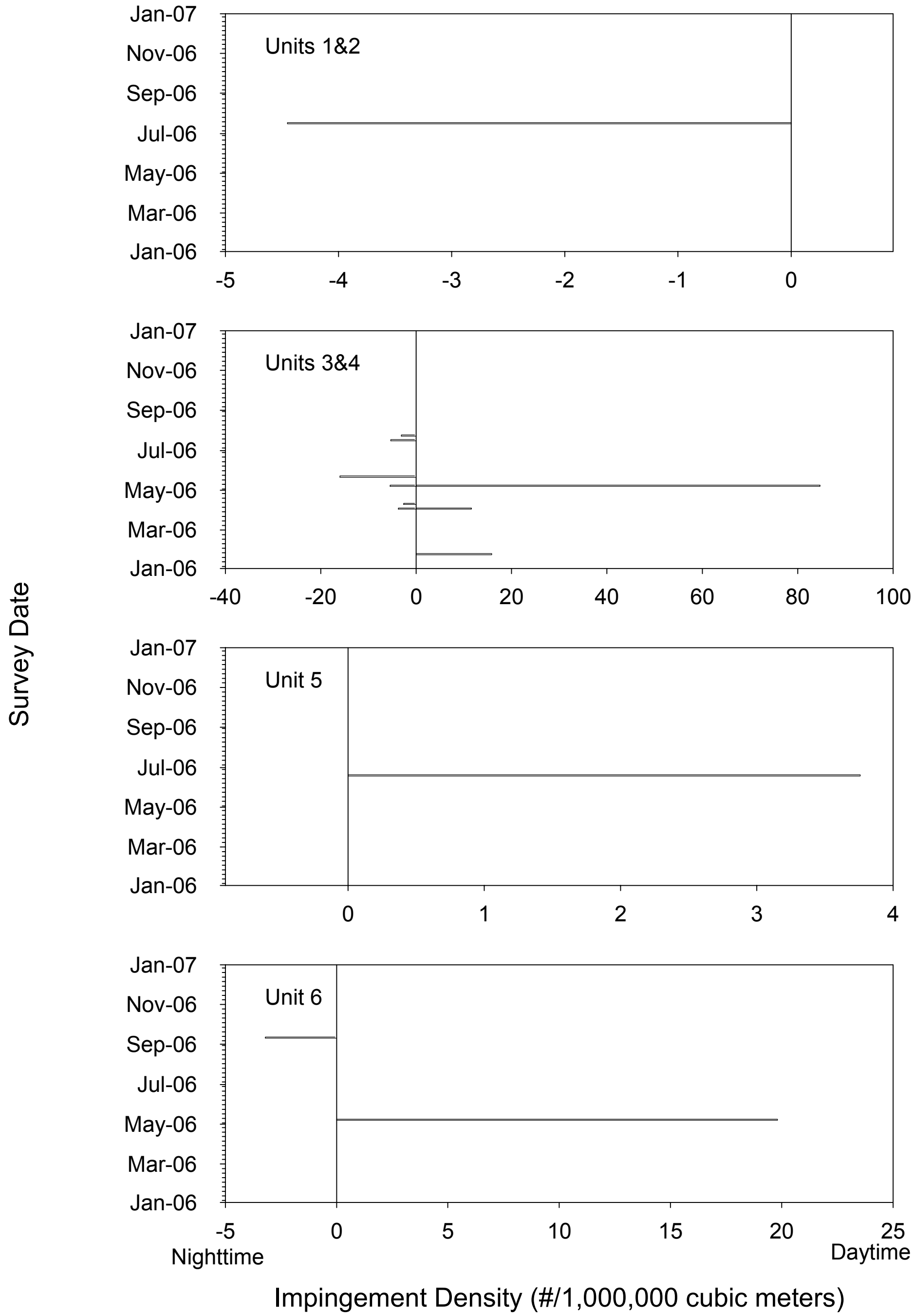


Figure 5.5-29. Mean concentration (# / 1,000,000 m^3) of northern anchovy in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

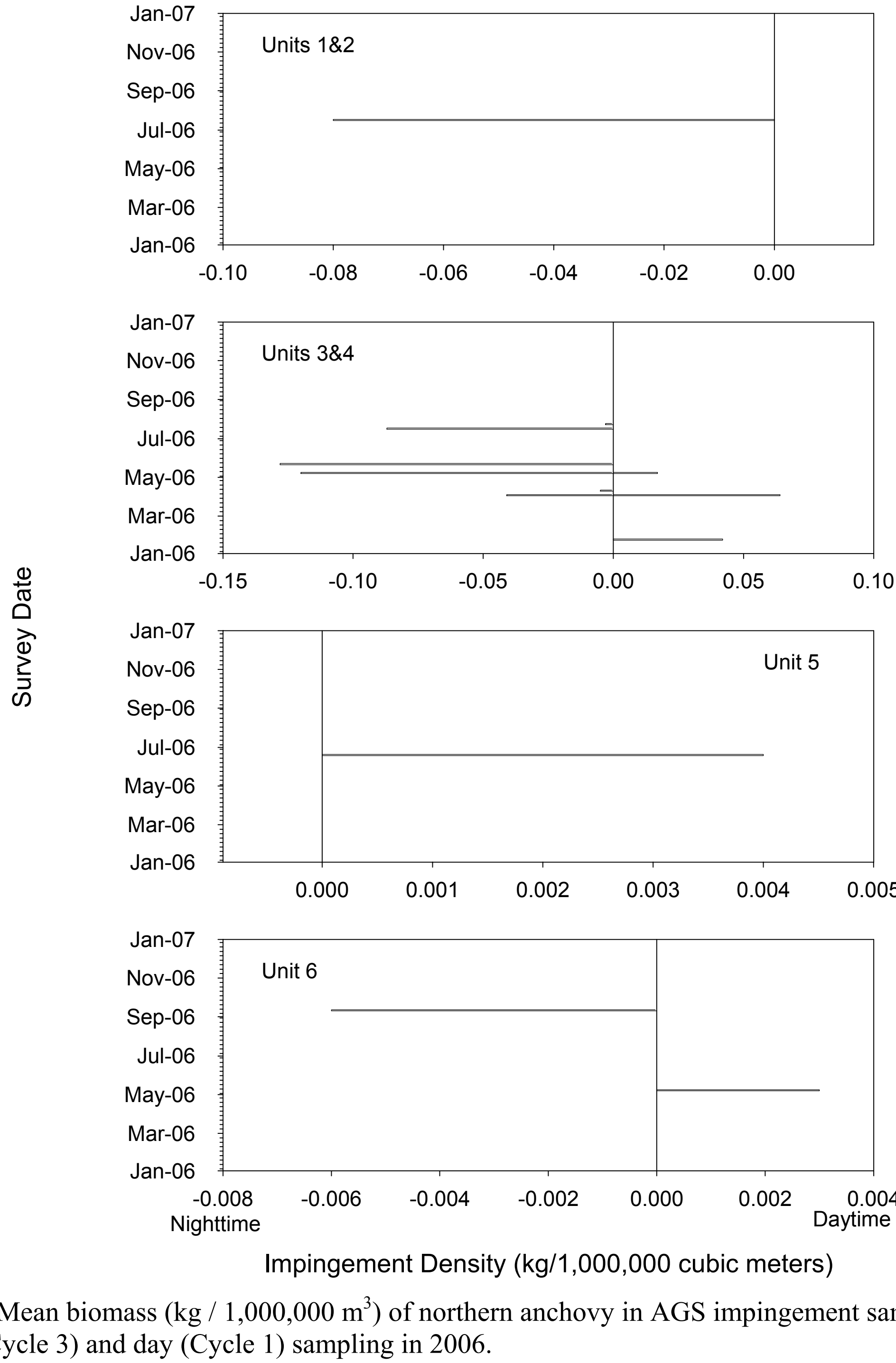


Figure 5.5-30. Mean biomass (kg / 1,000,000 m^3) of northern anchovy in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

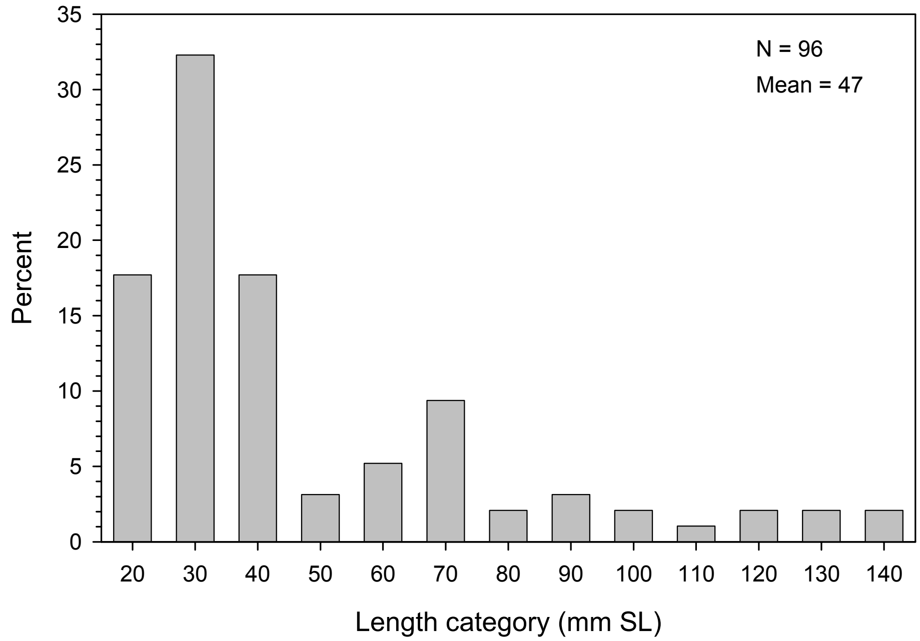


Figure 5.5-31. Length (mm) frequency distribution for northern anchovy collected in impingement samples.

5.5.2.5 Queenfish (*Seriphus politus*)

Queenfish (*Seriphus politus*) ranges from Vancouver Island, British Columbia to southern Gulf of California (Love et al. 2005). Queenfish is common in southern California, but rare north of Monterey. It is one of eight species of croakers or 'drums' (Family Sciaenidae) found off California. The other croakers include: black croaker, white croaker, California corbina, spotfin croaker, yellowfin croaker, white seabass, and shortfin corvina.

Milton Love

5.5.2.5.1 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 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 (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 (Murdoch et al. 1989a). Mortality rate estimates are unavailable for this species.

Queenfish are summer spawners. Goldberg (1976) found queenfish 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 state 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). 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 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 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 female to about 90,000 eggs in a 25 cm fish. The average-sized female (14 cm, 42 g) had a potential batch fecundity of 12,000–13,000 eggs. Murdoch et al. (1989a) 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 female that spawns for three months (April–June) can produce about 60,000 eggs per year, while a 25cm 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 1968b; Feder et al. 1974; Hobson and Chess 1976; Hobson et al. 1981). 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.

5.5.2.5.2 Population Trends and Fishery

Queenfish are numerically one of the most abundant species along sandy or muddy bottom habitats in southern California. They dominate much of the surf zone along with other species such as silversides (topsmelt and jacksmelt) and northern anchovy (Allen and Pondella 2006a). Large numbers of juveniles typically aggregate near drift algal beds within the surf zone (Allen and DeMartini 1983)

Queenfish are one of the most abundant species sampled in beam trawls, otter trawls, and lampara nets. They were 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 study using otter trawls (Love et al. 1986). They were more abundant in shallower water depth strata making up about 47% of the fish sampled from 6.1-12.2 m. Queenfish were also major constituents in beam trawl surveys and made up 50% of catches in exposed coastal sites and 72% of the catch in semi-protected coastal along with white croaker (Allen and Herbinson 1991).

Long term trends from coastal generating power plants indicate that queenfish was the most abundant species impinged at five southern California generating stations from 1977 to 1998, and that they accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). Their abundance was stable during this period, with notable declines occurring during strong El Niño events. Abundance remained relatively high throughout the 20-year study period.

Queenfish was the third most abundant target species analyzed during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). An average of 16.4 queenfish was impinged daily at the AGS, with most occurring at Units 5&6 (Table 5.4-1). At all units it was generally collected in highest numbers in summer and fall. From 2001 through 2005, queenfish was the second most abundant species in impingement samples, with annual abundance in impingement samples ranging from three individuals (2002) to 78 individuals (2003) (MBC 2006).

A total of 30 inner shelf and 16 bay and harbor stations were sampled during 2003 within the southern California Bight by the Southern California Coastal Water Research Project (SCCWRP) (Allen et al. 2007). Species abundance was 11.6 fish/ station for queenfish at bay and harbor stations during 5-10 minute trawls. This species was scarce at inner shelf stations with a mean abundance of 0.03 fish/station.

Various time-series analyses conducted by the Vantuna Research Group (Pondella, unpubl. data) showed that catches of queenfish fluctuated over time. In the recreational fishery, no visible trend was apparent, with catches fluctuating between 38,000 and 292,000 fish per year and an aberrant peak in 2002 (Figure 5.5-32a). The catch data did not reflect any significant response to oceanographic variables (PDO, SST, and ENSO). In the OREHP data set, catch fluctuated appreciably in both Santa Monica Bay and the remainder of the bight (Figure 5.5-32b). These two time series were not correlated with each other. Catch in the bight showed an increasing trend from 1995–2006 while catch in Santa Monica Bay was largely unchanged. April 2002 (67.1 fish/station) was the second highest catch in the OREHP study with the greatest catch in June 2000 (71.6 fish/station). The increasing trend in the NPDES trawl data set since the late 1990s peaked in 2002; however, catch was higher in several previous years (Figure 5.5-32c). Trawl data did not suggest a positive or negative trend in queenfish population. Queenfish catches were correlated with sea surface temperature and the ENSO index. Queenfish populations appear to respond positively during warm water periods, and as such, catches were consistent over the last two decades and may be increasing.

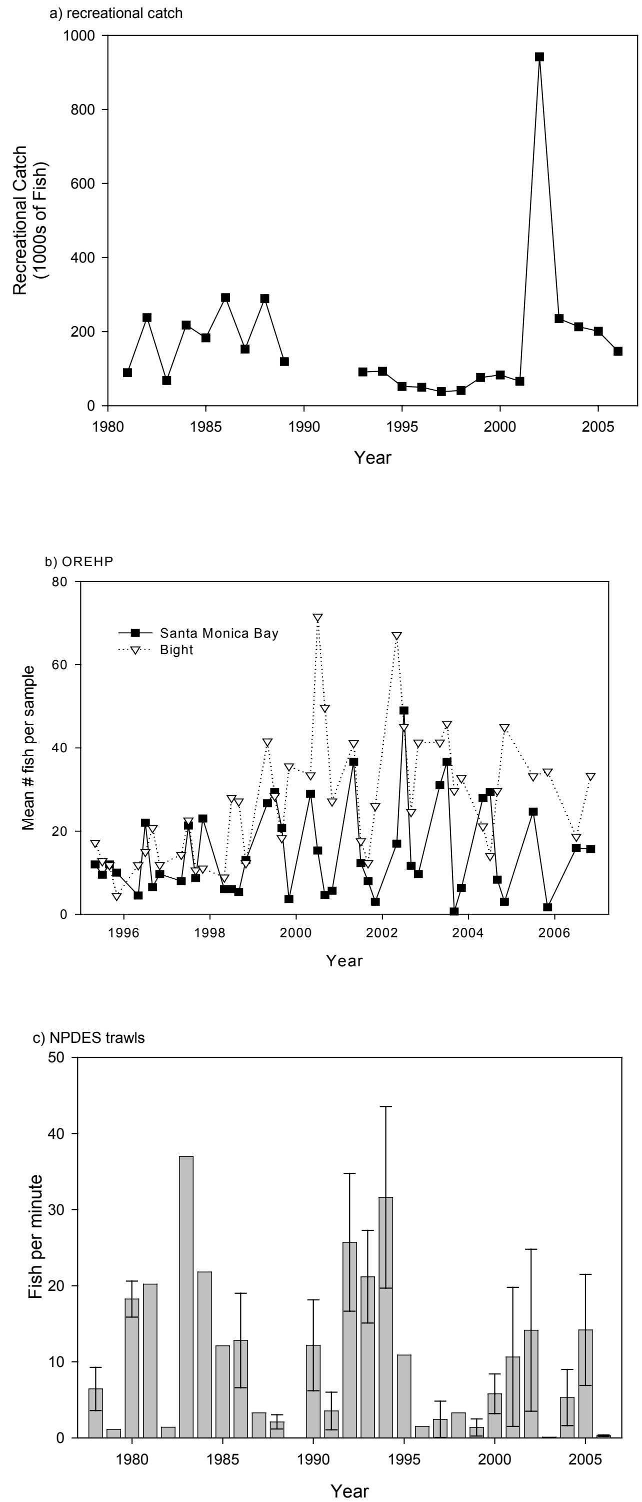


Figure 5.5-32. Queenfish fishery and population trends: a) recreational and commercial landings, b) Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring data, and c) NPDES trawl programs.

Concentrations of queenfish larvae, as measured in King Harbor as part of the Occidental College – Vantuna Research Group's long-term studies, were collected in highest numbers prior to the 1983-4 El Niño event (Figure 5.5-33). Larval sciaenid concentrations peaked in 1976, 1988, and 2001.

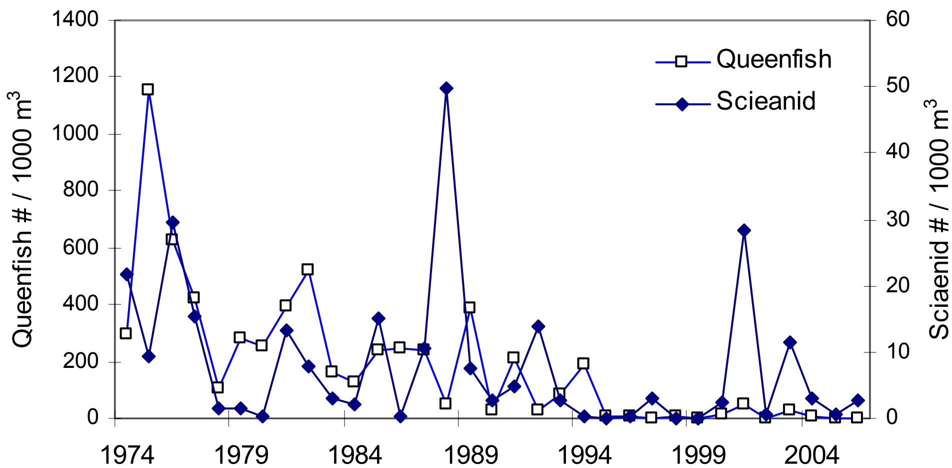


Figure 5.5-33. Mean concentration (# / 1,000 m^3) of queenfish and unidentified sciaenid larvae collected from King Harbor, 1974-2006. Source: Vantuna Research Group.

Although queenfish is not considered a highly desired species compared to other sciaenids, it is caught in fairly substantial numbers by both recreational and commercial fisheries. No specific landings were reported in commercial landing statistics for southern California from 2000–2006 (PacFIN 2007), although they may have been grouped as 'unspecified croakers'. Recent population trends indicate a decline in shore landings by over 75% in the 1990s compared to the 1980s (Jarvis et al. 2004). Sport fishery catch estimates of queenfish in the southern California region from 2000–2006 ranged from 66,000 to 942,000 fish, with an average of 270,000 fish caught annually (Table 5.5-10).

Table 5.5-10. Annual landings for queenfish in the Southern California region based on RecFIN data.

Year	Estimated Catch
2000	83,000
2001	66,000
2002	942,000
2003	235,000
2004	213,000
2005	201,000
2006	147,000

5.5.2.5.3 Sampling Results

Queenfish was the seventh most abundant fish species impinged (based on actual cooling water flows) with an estimated 2,167 individuals, or 0.5% of the annual total, weighing 15.824 kg (34.892 lbs) (Table 5.5-1). Highest normal operation impingement was recorded at Units 3&4 (186), followed by the combined impingement at Units 5&6 (95), and lastly Units 1&2 (20) (Table 5.5-11). Recorded impinged biomass by screenwell followed the same ranked pattern as abundance with observed impingement at all three less than 1.000 kg (2.205 lbs) each.

Table 5.5-11. Annual queenfish abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	**Units 3&4**	**Units 5&6**	**Total**
Fish Abundance	20	186	95	301
Fish Biomass (kg)	0.020	0.767	0.550	1.337

Queenfish impingement density peaked in late-July through September at all screenwells (Figure 5.5-34). Few queenfish were impinged during the first six months of the year, and after September occurrences were low and restricted to Units 3&4 due to the non-operation at the other screenwells. Biomass followed a pattern similar to abundance, although the sporadic instances during the first six months were more pronounced compared to abundance, principally due to the impingement of larger individuals (Figure 5.5-35).

Substantial diel periodicity was observed in the impingement of queenfish (Figures 5.5-36 and 5.5-37). When impinged, queenfish were most likely observed during nighttime surveys. Impinged biomass mostly followed the same trend as abundance, although surveys at Unit 5 occasionally recorded substantially larger individuals during the day.

Length frequency analysis of 253 measured individuals indicates a mean standard length of 53 mm (2.1 in) (Figure 5.5-38). The distribution of length classes confirmed this with greater than 45% of all individuals represented in the 50-mm (2.0-in) size class, followed by the 40-mm and 60-mm (1.6-in and 2.4-in) size classes. The majority of these measured individuals were young of the year, with queenfish reaching age one at approximately 100 mm SL (3.9 inches) (MBC and VRG unpubl. data[1]). Of the 252 individuals that were evaluated for condition factor, over 99% were dead and the remaining individuals were mutilated, with no queenfish collected alive.

5.5.2.5.4 Modeling Results

Queenfish life history parameters are presented in Table 5.5-12. Unpublished research by MBC and the Occidental College Vantuna Research Group (VRG) provided all of the applicable adult life history parameters that indicate the age at 50% maturity is 1.77 years. Nearly 80% of all individuals were less

[1] MBC Applied Environmental Sciences and Vantuna Research Group. Analysis of the age and growth of juvenile and adult queenfish (*Seriphus politus*) from southern California. Project in progress.

than 60 mm SL (2.4 in), or less than six months old. A total of 3,146 adult equivalents were taken over the year based on actual cooling water flow. Recalculating the actual flow estimates to design (maximum) flow equated to a total loss of 5,284 adult equivalents.

Table 5.5-12. Queenfish life history parameters used in equivalent adult modeling.

Total Adult Mortality (Z)	Survival (S)	von Bertalanffy growth parameters* L_{inf}	k	t_0	Age at 50% Maturity	Length at 50% Maturity
0.3512	0.703843	176 mm TL	0.302	-1.234	1.76642	105 mm TL

**Data from MBC and VRG unpublished data*

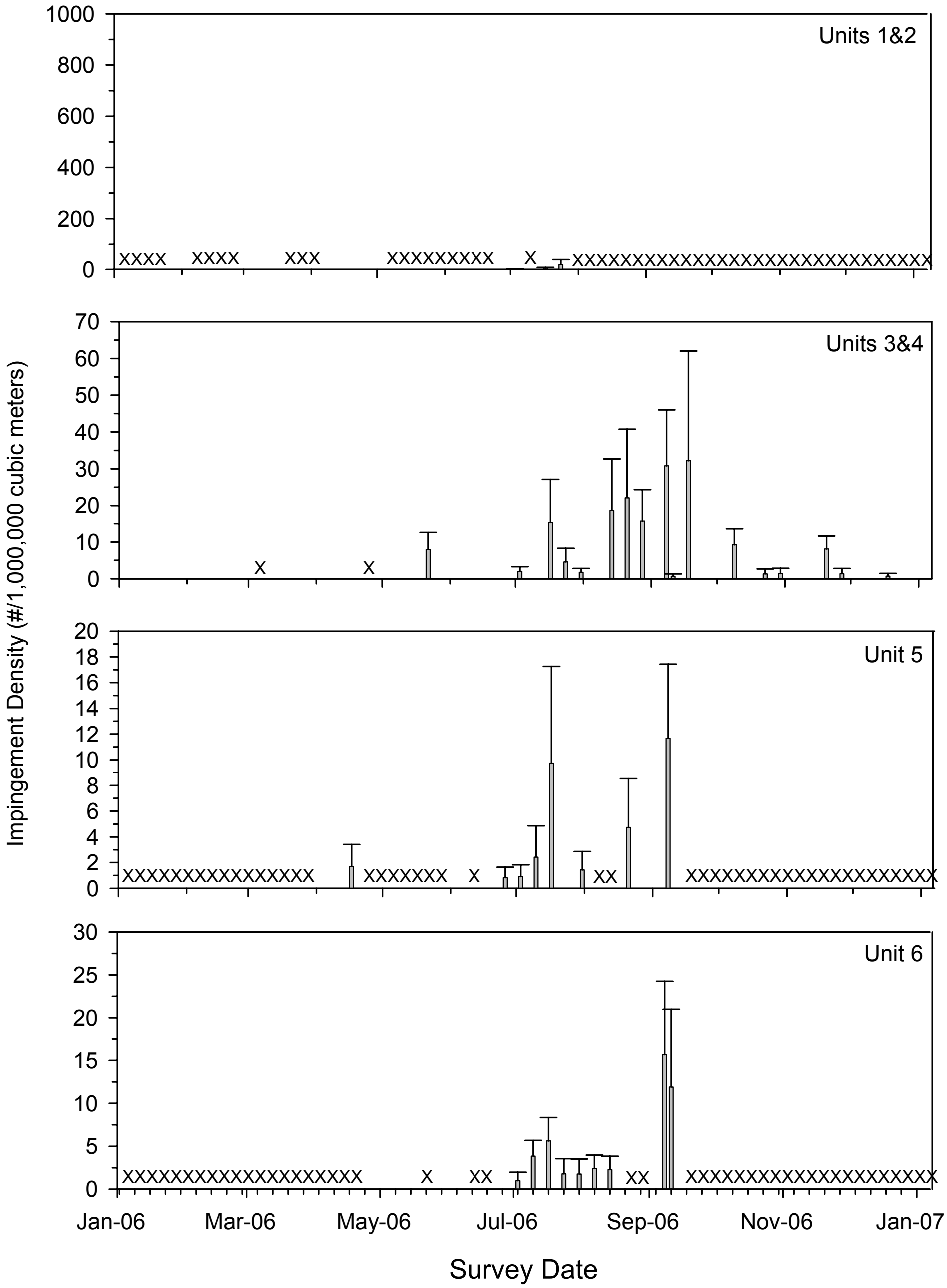


Figure 5.5-34. Mean concentration (# / 1,000,000 m^3) and standard error of queenfish collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

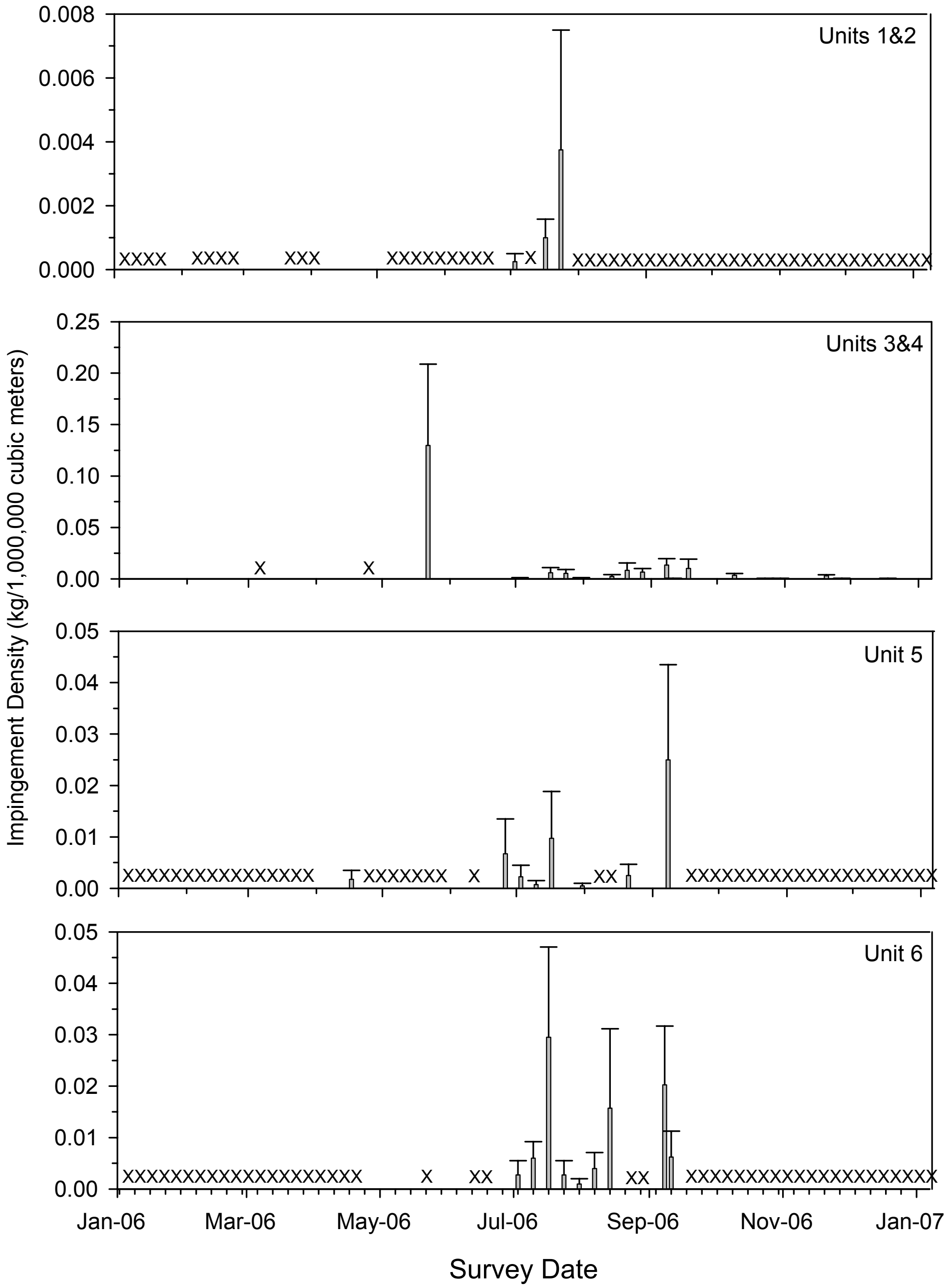


Figure 5.5-35. Mean biomass (kg / 1,000,000 m^3) and standard error of queenfish collected in AGS impingement samples in 2006. “X” denotes weeks with no sample collection.

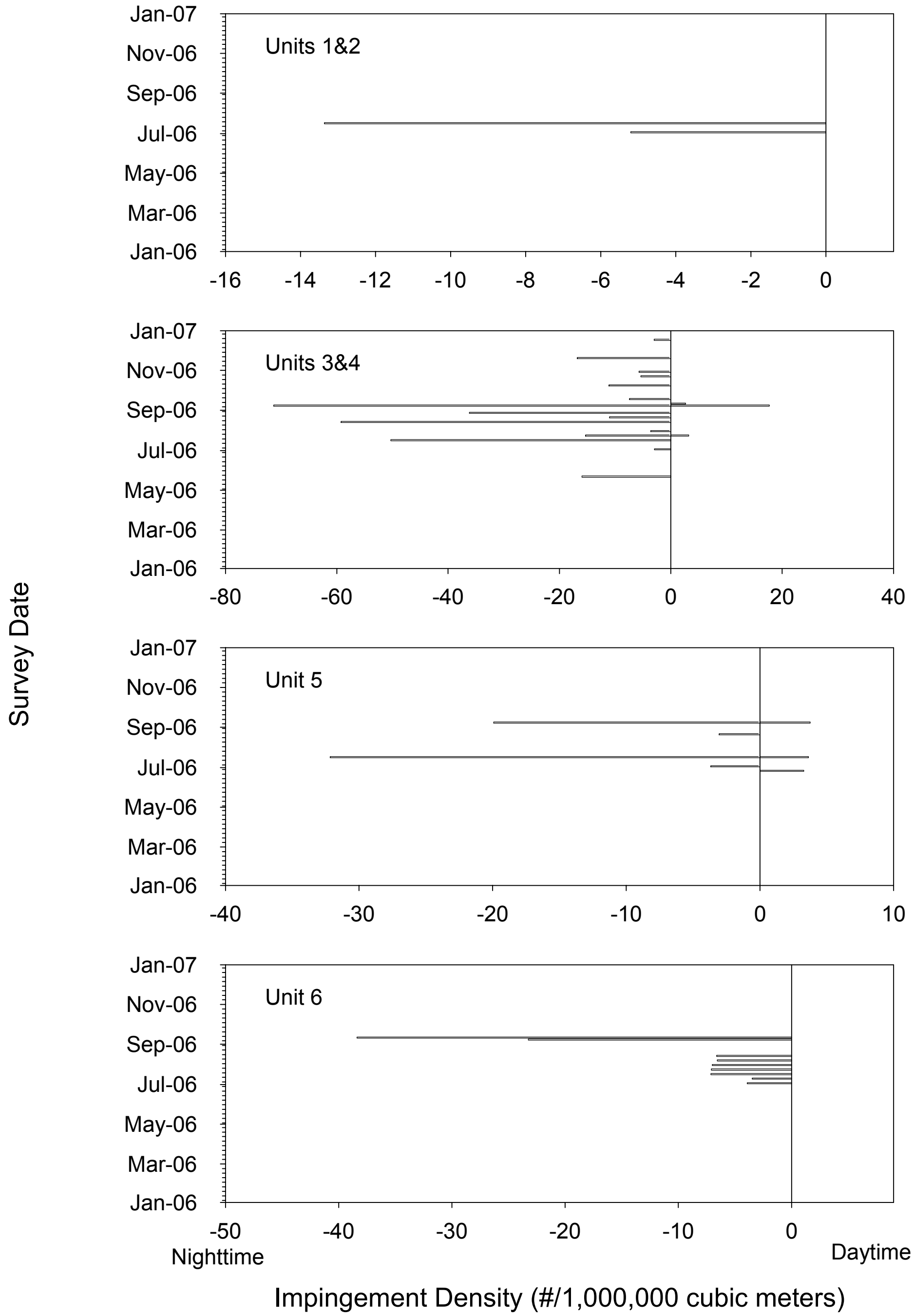


Figure 5.5-36. Mean concentration (# / 1,000,000 m^3) of queenfish in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

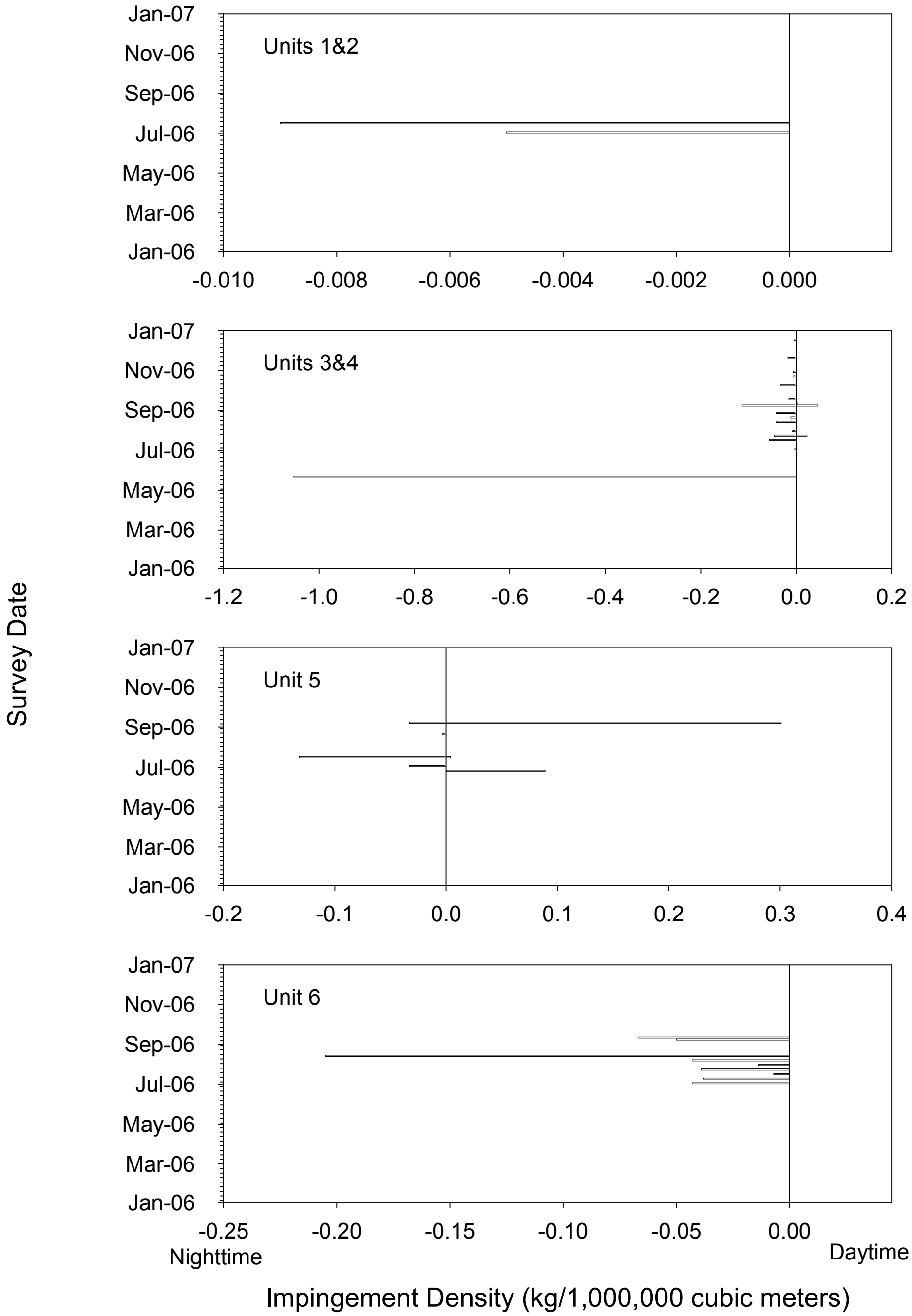


Figure 5.5-37. Mean biomass (kg / 1,000,000 m^3) of queenfish in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

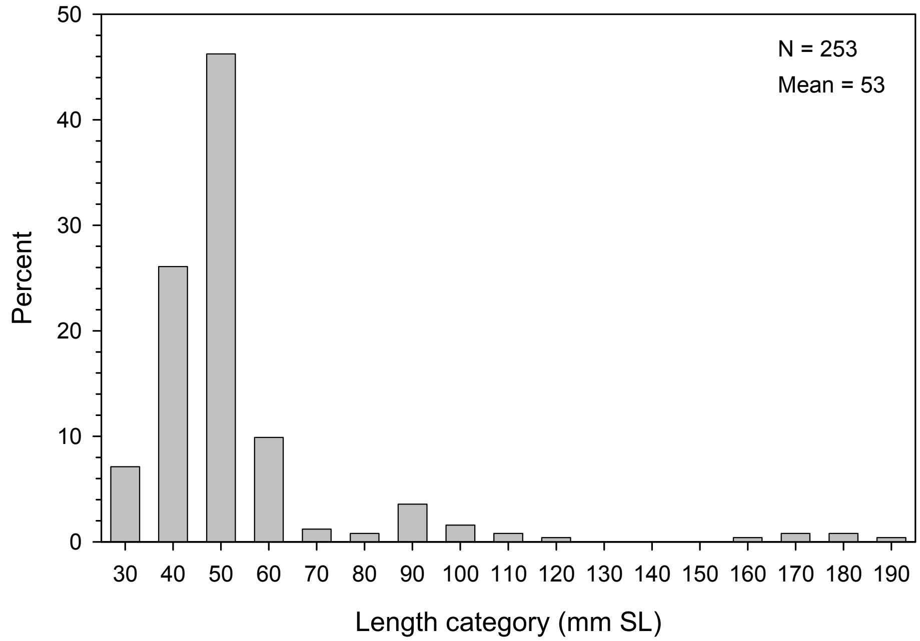
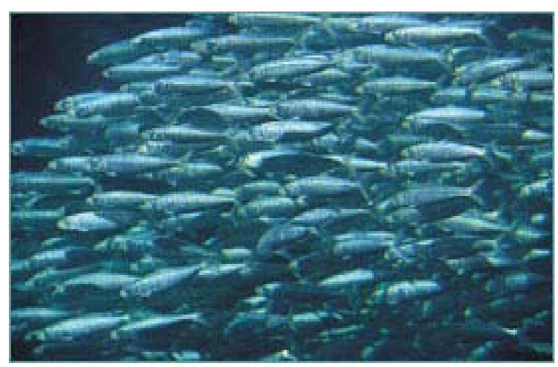


Figure 5.5-38. Length (mm) frequency distribution for queenfish collected in impingement samples.

5.5.2.6 Pacific sardine (*Sardinops sagax*)



The genus *Sardinops* occurs in coastal areas of warm temperature zones of nearly all ocean basins. Pacific sardine range from Kamchatka, Russia to Guaymas, Mexico, Peru, and Chile (Miller and Lea 1972; Eschmeyer et al. 1983). Similar lineages occur off Africa, Australia, and Japan. Pacific sardine is one of five species of herrings (Family Clupeidae) that could occur in the waters off the AGS.

5.5.2.6.1 Life History and Ecology

Pacific sardine is epipelagic, occurring in loosely aggregated schools (Wolf et al. 2001). Spawning occurs year-round in the upper 50 m (164 ft) of the water column, with seasonal peaks occurring from April to August between Point Conception, California and Magdalena Bay, Baja California. Adults are believed to spawn two to three times per season (Fitch and Lavenberg 1971). The primary spawning area for the principal northern subpopulation (ranging from northern Baja to Alaska) is between San Francisco and

San Diego, California, and out to about 241 km (150 miles) offshore, though they are known to spawn as far offshore as 563 km (350 miles) offshore. Butler et al. (1993) estimated fecundity at 146,754 eggs to 2,156,600 eggs per two- and ten-year-old females, respectively, with longevity estimated at 13 years. Eggs and larvae occur near the sea surface, and eggs require about three days to hatch at 15°C (59°F).

Sardines are filter feeders and prey on planktonic crustaceans, fish larvae, and phytoplankton (Wolf et al. 2001). The average non-feeding swim speed of Pacific sardine is about 0.78 body lengths per second (BL/sec), while particulate feeding sardines exhibit swim speeds of 1.0 to 2.0 BL/sec; this equaled maximum speeds of 26 to 51 cm/sec (10.2 to 20.1 in/sec) (van der Lingen 1995). Pacific sardines are about 115 mm (4.5 in) after one year, 173 mm (6.8 in) after two years, 200 mm (7.9 in) after three years, and 215 mm (8.5 in) after four years (Hart 1973). They make northward migrations early in summer and return southward again in fall, with migrations becoming further with each year of life. Natural adult mortality (M) has been estimated as 0.4/year (MacCall 1979).

5.5.2.6.2 Population Trends and Fishery

Pacific sardine supported the largest fishery in the Western Hemisphere during the 1930s and 1940s. However, the fishery collapsed in the 1940s and 1950s, leading to the establishment of the CalCOFI program in 1947, originally named the Cooperative Sardine Research Program. Extreme natural variability and susceptibility to recruitment overfishing are characteristic of clupeoid stocks, including Pacific sardine (Hill et al. 2006). Regimes of high abundance of sardines (*S. sagax* and *S. pilchardus*) have alternated with regimes of high abundance of anchovy (*Engraulis* spp) in each of the five regions of the world where these taxa co-occur (Lluch-Belda et al. 1992). Both sardine and anchovy populations tend to vary over periods of roughly 60 years, although sardine have varied more than anchovy. Sardine population recoveries lasted an average of 30 years (Baumgartner et al. 1992). The Pacific sardine population began increasing at an average rate of 27% per year in the early 1980s, and recent estimates indicate the total biomass of Age-1 and older sardines is greater than one million metric tons (Hill et al. 2006; NMFS-SWFSC 2007).

Sardine landed in the U.S. fishery are mostly frozen and sold overseas as bait and aquaculture feed, with smaller amounts canned or sold for human consumption and animal food (Hill et al. 2006). Commercial landings of Pacific sardine in 2006 in Santa Monica Bay catch blocks totaled 3,591,016 kg (9,134,600 lbs.) at a value of $426,626 (CDFG 2007b). Los Angeles area landings (between Dana Point and Santa Monica) for 2005 totaled 24,143,616 kg (53,236,674 lbs.) at a value of $2,344,817 (CDFG 2006). Based on PacFIN (2007), annual commercial landings in the Los Angeles region since 2000 have varied from a high of 41 million kg (90 million lbs) in 2001, to a low of 24 million kg (52 million lbs) in 2004 (Table 5.5-13). In the CDFG catch blocks off Long Beach, the 2006 catch totaled 14,106,375 kg (31,098,710 lbs) at an estimated value of $1,629,681 (CDFG 2007b).

Table 5.5-13. Annual landings and revenue for Pacific sardine in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**kilograms**	**pounds**	**Revenue**
2000	39,121,935	86,263,867	$4,187,391
2001	40,755,801	89,866,542	$4,476,752
2002	39,299,341	86,655,046	$3,826,155
2003	24,422,289	53,851,147	$1,961,269
2004	23,672,717	52,198,341	$2,255,501
2005	24,143,507	53,236,434	$2,348,577
2006	26,651,664	58,766,919	$3,240,006

Pacific sardine was not analyzed in detail during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). During the two-year study no sardines were collected in impingement samples (Herbinson 1981). That study was conducted during an anchovy regime when Pacific sardines were virtually absent from the nearshore waters of the Southern California Bight (Horn and Stephens 2006). Statewide sardine landings were less than 10,000 kg in the mid- to late-1970s. From 2001 through 2005, Pacific sardine was the eighth most abundant species in impingement samples, with annual abundance in impingement samples ranging from no individuals (2002 and 2004) to nine individuals (2003) (MBC 2006).

5.5.2.6.3 Sampling Results

A total of 50 Pacific sardine were collected at the AGS, resulting in an estimated annual impingement (calculated using actual cooling water flow volumes) of 389 Pacific sardine weighing 6.760 kg (14.906 lbs) (Table 5.5-1). Eighty percent of all impinged individuals were collected at one nighttime survey on February 28, 2007 at Units 3&4. The remaining ten individuals were randomly collected during surveys from June through August. Twelve measured individuals ranged from 62 to 175 mm SL (2.4 – 6.9 in) or 139 mm SL on average (5.5 in). Fifty-percent of all individuals were recorded in the 150-160 mm (5.9-6.3 in) size class. All of the individuals assessed for condition factor were dead.

5.5.2.6.4 Modeling Results

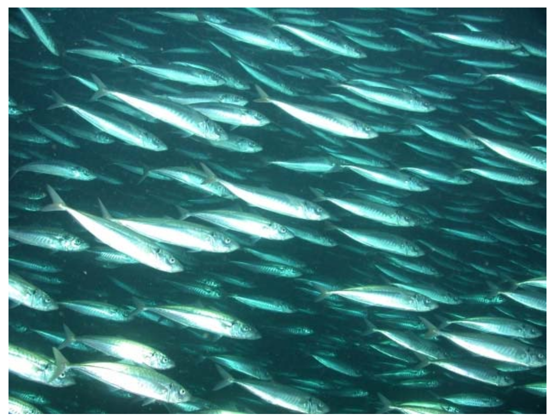
Pacific sardine life history parameters are presented in Table 5.5-14. von Bertalanffy parameters were taken as reported by Hill et al. (2006). Annual survival estimates were calculated based on daily mortality rates (0.998901) summarized in Butler et al. (1993). Age at 50% maturity was -0.25208 based on the length at 50% maturity (125 mm or 4.9 in SL) first published by Ahlstrom (1960 cited in Butler et al. 1996). Nine of the twelve measured individuals were between one and two years of age, while the remaining three individuals were between 0.5-0.9 years old. Adult equivalents taken during actual operation of the cooling water system totaled 393 individuals, and design flow-based estimates totaled 621.

Table 5.5-14. Pacific sardine life history parameters used in equivalent adult modeling.

Daily Mortality (Z)*	Survival (S)*	von Bertalanffy growth parameters**			Age at 50% Maturity***	Length at 50% Maturity***
		L_{inf}	k	t_0		
0.998901	0.669315	244 mm SL	0.319	-2.503	-0.25208	125 mm SL

**Calculated from Butler et al. 1993*
***Hill et al. 2006*
****Ahlstrom 1960 cited in Butler et al. 1996*

5.5.2.7 Jack Mackerel (*Trachurus symmetricus*)



Courtesy of NOAA

Jack mackerel (*Trachurus symmetricus*) are not true mackerels, but a member of the jack family Carangidae, one of about twelve jack species that occur locally, including yellowtail (*Seriola lalandi*) and Mexican scad (*Decapterus scombrinus*), although most are more common offshore of Baja California (Eschmeyer et al. 1983). Most jacks are streamlined, fast-swimming fish with deeply forked tails and narrow caudal peduncles. About 200 species in the jack family occur worldwide, mostly in warm seas. Most species school, and many are important sport or food fishes.

Jack mackerel are torpedo-shaped, blue or green above and silver below, with a yellow to reddish caudal fin (Eschmeyer et al. 1983, Love 1996). Jack mackerel commonly occur from southeast Alaska to at least the end of the Baja Peninsula, out to about 1,900 km (1,200 mi). Young fish, less than six years old, and about 30 cm (12 in), often form dense, nearshore schools over reefs and near kelp and piers, but generally school in water less than 60 m (200 ft) deep (Eschmeyer et al. 1983; Love 1996; Mason and Bishop 2001). Larger fish, those over about 15 years and 50 cm (20 in), are found offshore as solitary fish or in loose aggregations. These large fish are known to move north and nearshore into the Gulf of Alaska seasonally with warm water, but large fish are also caught year-round off southern and Baja California. The distribution of fish between 6 and 15 years is not well known.

5.5.2.7.1 Life History and Ecology

Jack mackerel have a lifespan of about 35 years, reaching a length of 81 cm (32 in.) (Eschmeyer et al. 1983; Love 1996). They grow fast to about 20 cm (8 in) in their first year, then growth slows, with a 36-cm (14 in.) fish about four-years old (Love 1996). Most (70 percent) individuals mature at one year, with 90 percent mature by their second year (Mason and Bishop 2001). Jack mackerel spawn about 100 to 500 km (60 to 300 mi) offshore of California from January through November, with spawning between Punta Eugenia and Point Conception from March through July (Love 1996; Mason and Bishop 2001). Spawning in the species begins with larger, offshore individuals in southern California and Mexico and proceeds northward as the season progresses. Nearshore spawning by younger individuals occurs later in the summer. Most spawning occurs in water between about 14-16°C (57-61°F). Jack mackerel are multiple spawners, with females on average spawning every five days and 25 times per year. Egg count is variable through the season, with each female releasing about 104,000 eggs during the first spawning of the year and then about 73,000 eggs during each subsequent spawning event (Mason and Bishop 2001). Eggs are about 1 mm (0.04 in.) in diameter and float between 2 and 5 days before hatching, depending on temperature (Love 1996; Mason and Bishop 2001).

Jack mackerel larvae feed on copepods, while juveniles take copepods and larger plankton species such as euphausiids, and juvenile squid and anchovy (Love 1996, Mason and Bishop 2001). The food preference of the older, offshore individuals is not known. Jack mackerel are fed on by large fish species including tuna, billfish, giant seabass and sharks and several marine mammals such as Pacific white-sided dolphin and California sea lion. Because of their relatively large size as adults, only smaller and young-of-the-year individuals are likely to be taken by sea birds such as cormorants.

5.5.2.7.2 Population Trends and Fishery

Jack mackerel, originally known as horse mackerel, was taken commercially in California as early as 1888, but principally as incidental take of the coastal pelagic species (CPS) seine net fishery for market squid, Pacific sardine, Pacific mackerel and northern anchovy (Mason and Bishop 2001). Between 1926 and 1946, jack mackerel accounted for less than 3% of the CPS fishery with annual landings of 181,437 to 13,607,771 kg (4 million to 30 million lbs). During the 1940s and 1950s, the sardine fishery collapsed and Pacific mackerel landings were in decline. Consequentially, the jack mackerel fishery boomed and, in order to increase consumer appeal, the U.S. Food and Drug Administration changed the name “horse mackerel” to “jack mackerel”. Between 725,748 to 6,622,449 kg (1.6 million to 14.6 million lbs) of jack mackerel were landed from 1947 through 1979, equaling 6 to 65% of the annual CPS landings. During the late 1970s, the Pacific mackerel fishery showed an increase in population, thus drawing fishing efforts away from the jack mackerel.

Awareness of overfishing, beginning with the collapse of the sardine and anchovy fishery, prompted the implementation of national programs to avoid future collapses (Mason and Bishop 2001). Jack mackerel were first categorized in the Pacific Coast Groundfish Fishery Management Plan in 1982 due to incidental landings of jack mackerel with Pacific whiting (hake) trawls, a species categorized as “groundfish”; yet fishery total catches were only restrained north of the 39° latitude. Concern for the jack mackerel population rose and pressure from southern California fishermen resulted in the inclusion of jack mackerel to the Coastal Pelagic Species Fisheries Management Plan (CPS FMP) in 1999. Currently, jack mackerel is a “monitored” species in the CPS FMP, meaning that stocks are monitored but federal fishery controls are not implemented (PFMC 2006). From the early 1990s on, jack mackerel landings have occurred from December to April at an average of two percent of CPS landings, less than 1,814,370 kg (4 million lbs) per year.

Jack mackerel from the U.S. Fishery are generally canned; however, fresh jack mackerel are occasionally found in markets (Love 1996). The recreational fishery for jack mackerel is small when compared to the commercial fishery. Most of the landings derive from commercial passenger fishing vessel, with additional catches from anglers on fishing piers (Mason and Bishop 2001). This fishery remains a small contributor to the total catch of jack mackerel and high variability in the number of catches since 1980, numbering from 5,000 to over 350,000 fish. Landings reported in the Los Angeles region in the PacFIN (2007) database have fluctuated between about 100,000 and 3.6 million kg (220,000 and 7.9 million lbs) annually (Table 5.5-15). Commercial landings of jack mackerel in 2005 in southern California totaled 115,719 kg (255,117 lbs) at a value of $16,367 (CDFG 2006). Landings from Long Beach area catch blocks in 2006 totaled 106,093 kg (233,890 lbs) at a value of $11,443 (CDFG 2007b).

Table 5.5-15. Annual landings and revenue for jack mackerel in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**kilograms**	**pounds**	**Revenue**
2000	1,209,240	2,666,375	$225,723
2001	3,623,138	7,989,020	$561,444
2002	1,003,217	2,212,094	$201,797
2003	133,373	294,087	$51,142
2004	1,026,873	2,264,254	$248,547
2005	166,590	367,330	$49,078
2006	1,025,614	2,261,479	$168,442

Jack mackerel was not analyzed in detail during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). During the two-year study 71 jack mackerel were collected in impingement samples, all at Units 5&6 (Herbinson 1981). From 2001 through 2005, one jack mackerel was collected at Units 5&6; the individual was collected in August 2005 (MBC 2006).

5.5.2.7.3 Sampling Results

Ten jack mackerel were collected at the AGS, resulting in an estimated annual impingement (calculated using actual cooling water flow volumes) of 69 individuals weighing 5.244 kg (11.563 lbs) (Table 5.5-1). All but two individuals were collected at Unit 5, with the remaining collections occurring at Unit 6. Recorded impingement of jack mackerel was unique to June and July, with all but two individuals collected at night. All jack mackerel were dead upon collection.

5.5.2.7.4 Modeling Results

Jack mackerel life history parameters are presented in Table 5.5-16. All life history parameters were gathered from MacCall (1980), including age specific mortality estimates. Six jack mackerel were measured with lengths ranging from 175 to 241 mm (6.9 to 9.5 in) SL, with estimated ages ranging from 1.0 to 2.9 years. All measured standard lengths were converted to fork length (FL) prior to any analysis using the equation for the morphologically similar Pacific chub mackerel: (SL-2.33)/0.86 (Hill and Crone

2005). No direct (SL-FL) conversion factors for jack mackerel were available, with intermediaries providing questionable results, e.g. FL<SL (www.fishbase.org). Adult equivalents taken during actual operation of the cooling water system totaled 91 individuals. Recalculation of these estimations based on design (maximum) flow of the cooling water pumps indicates 103 adult equivalent jack mackerel would have been taken at continuous full flow operation for the year.

Table 5.5-16. Jack mackerel life history parameters used in equivalent adult modeling.

		von Bertalanffy growth parameters*				
Annual Mortality (Z)*	**Survival (S)***	**L_{inf}**	**k**	**t_0**	**Age at 50% Maturity***	**Length at 50% Maturity***
0.46 – 0.54	0.58 – 0.63	602.8 mm FL	0.0935	-3.252	1	198 mm FL

**MacCall 1980*

5.5.2.8 Pacific Chub Mackerel (*Scomber japonicus*)

Pacific chub mackerel (*Scomber japonicus*) are a member of the Family Scombridae, which is comprised of mackerels and tunas (Eschmeyer et al. 1983). Most fish belonging to this family are streamlined, fast-swimming fish with pointed snouts. They occur in both temperate and tropical oceans, along the coast and in the open pelagic realm, with many species being known to migrate long distances. Some species are major commercial fishery species.

Courtesy of NOAA

Pacific mackerel exhibit blue or green coloration above and silver below, with dark, wavy vertical bars along the back (Eschmeyer et al. 1983; Love 1996). The northeastern Pacific range of the Pacific mackerel extends from Alaska to the Gulf of Mexico; yet they are most common between Monterey Bay and southern Baja California, and most abundant south of Point Conception, California.

5.5.2.8.1 Life History and Ecology

Pacific mackerel tend to form schools within 32 km (20 mi) of shore near the upper water column, but have been found 402 km (250 mi) offshore at depths of about 302 m (990 ft) (Love 1996; Bergen 2001). Adult Pacific mackerel tolerate temperatures ranging from 10 to 21°C (50° to 70°F) and generally occupy the surface waters near shallow banks and migrate north in the summer. Juveniles are found off sandy beaches, kelp beds, and in open bays. Inshore schools of Pacific mackerel tend to occur from July to November and move offshore from March to May. Pacific mackerel tagging studies have shown that schools travel between California and Baja California.

Pacific mackerel reach lengths of 64 cm (25 in), but average between 41 and 46 cm (16 and 18 in) (Eschmeyer et al. 1983; Love 1996). Records from otolith readings provided a twelve-year-old fish but catches of Pacific mackerel are most commonly comprised of fish at Age-4 or less (Bergen 2001). Male Pacific mackerel mature quickly, with most reaching sexual maturity at Age-1 (Love 1996). Females, however, mature more slowly and at varying ages, where twenty-five percent are mature by the first year and all females are mature by the second or third year (Bergen 2001). Pacific mackerel have three spawning stocks in the northeastern Pacific. Along the California coast, females spawn about eight or more times a year, and have a fecundity of at least 68,000 eggs at each release. In California, spawning occurs from 3 to 322 km (2 to 200 mi) offshore in late April through July, while spawning off Baja California takes place from June through October. Pacific mackerel eggs hatch four to five days after spawning, wherein the larvae remain in the surface waters as plankton (Love 1996). Growth appears to be density-dependent, with fish weight-at-age being higher in smaller populations, and populations seem to have three- to seven-year cycles of reproductive success (Bergen 2001).

Larval Pacific mackerel feed on copepods and fish larvae, including other Pacific mackerel larvae. Adult Pacific mackerel diets are comprised of small fish, squid and krill. Predators of Pacific mackerel include bald eagles, brown pelicans, the least tern, larger fish (i.e. marlins and sailfish), and marine mammals such as California sea lions and porpoises (Love 1996; Bergen 2001).

5.5.2.8.2 Population Trends and Fishery

The Pacific mackerel fishery includes three fisheries. In California, the commercial fishery as well as the southern California sport fishery collects Pacific mackerel. Mexico also harvests this species commercially (Bergen 2001). Historically, Pacific mackerel have been canned since the late 1920s, and new developments in canning techniques increased the demand for mackerel. Catches were brought in incidentally by boats also focusing on other coastal pelagic species such as jack mackerel, Pacific sardines, and market squid, using lamparas which were succeeded by purse seines and other types of gear (Love 1996; Bergen 2001). The mackerel market became a major California fishery in the 1930s, 1940s, and 1980s. The 1930s reflected a year of great fluctuation with the low being in the early 1930s, as a result of economic depression, compared to catches in 1935 peaking at 66,418,624 kg (146,428,000 lbs). Thereafter, the fishery began to decline as the steady demand for canned mackerel exceeded the supply until the stock collapsed in 1970.

Following a moratorium, legislation imposed landing quotas based on age one-plus biomass in 1972 (Bergen 2001). The population showed signs of increase in the late 1970s and, in 1977, the fishery reopened. A quota system was implemented and the stock remained relatively stable. Thus the state imposed a moratorium in 1985 on directed fishing whenever total biomass reached a low of 18,143,695 kg (40 million lbs) or less. Incidental catches were set at 18 percent during the moratorium as well. Biomasses between 18,143,695 and 136,077,711 kg (40 million and 300 million lbs) within the season of July 1 through June 30 of the following year allowed a seasonal quota of 30 percent of the total biomass, and no quota would be set at a total biomass over 136,077,711 kg (300 million lbs). Between 1985 and 1991, no quotas were set due to biomasses exceeding the upper biomass limitations. An average of 22,176,131 kg (48,890,000 lbs) was set as the quota between 1992 and 2000. As a result, the 1990 through 1999 fishery was comprised of 87% Pacific mackerel landings of the total California mackerel landings; and in California finfish landings, it was third in volume.

In 1999, the management of the Pacific mackerel fishery was taken over by the Pacific Fishery Management Council, whereas previously it had been overseen by the state. The Coastal Pelagic Species Fishery Management Plan (CPS FMP) required an annual stock assessment in order to establish harvest guidelines for the following year as well as a number of additional research to continue rebuilding the Pacific mackerel population (PFMC 2006). As of 25 May 2005, the fishing season for 2005-2006 set the harvest guideline at 17,419,000 kg (38,402,322 lbs), which was 32% greater than the previous year's harvest guideline (Hill and Crone 2005).

Pacific mackerel from the U.S. Fishery have been sold frozen, fresh, or canned for human consumption while also being sold for pet food and as live and dead bait (Bergen 2001). In 2006, commercial landings in Long Beach area catch blocks totaled 197,128 kg (434,586 lbs) at an estimated value of $23,530 (CDFG 2007b).

The Pacific mackerel has ranked within the top 11 important southern California sportfish; however, this was result of the high abundance rather than appeal. Prior to 1977, recreational landings of this mackerel averaged 60,000 kg (132,276 lbs) (Bergen 2001). Thereafter, the recreational fishery increased to an average of 1,360,777 kg (3,000,000 lbs) between 1977 and 1991. After a peak in 1980 when commercial passenger fishing vessels caught over 1.31 million Pacific mackerel, total landings began a steady decline and, in the California recreational fishery, the 2004-2005 season, landings totaled 56,000 kg (123,459 lbs) (Bergen 2001; Hill and Crone 2005).

Pacific chub mackerel was not analyzed in detail during the 1978-1980 316(b) demonstration at the AGS (SCE 1982a). During the two-year study 53 Pacific chub mackerel were collected in impingement samples: seven at Units 3&4 and 46 at Units 5&6 (Herbinson 1981). From 2001 through 2005, two Pacific chub mackerel were collected at the AGS; both individuals were collected in August 2005 at Units 5&6 (MBC 2006).

5.5.2.8.3 Sampling Results

Three Pacific chub mackerel were collected at the AGS, resulting in an estimated annual impingement (calculated using actual cooling water flow volumes) of 17 individuals weighing 4.174 kg (9.204 lbs) (Table 5.5-2). All three individuals were collected at Units 3&4 during daylight surveys on January 9 (two individuals) and February 6 (one individual). No live or mutilated individuals were collected.

5.5.2.8.4 Modeling Results

Pacific chub mackerel life history parameters are presented in Table 5.5-17. All life history parameters were gathered from Hill and Crone (2005). The lengths of all three individuals were recorded as 215, 230, and 363 mm SL (8.5, 9.1, 14.3 in, respectively) with estimated ages of 0.9, 1.3, and 7 years, respectively. All measured standard lengths were converted to fork length (FL) prior to any analysis using the equation: (SL-2.33)/0.86 (Hill and Crone 2005). Adult equivalents taken during actual operation of the cooling water system totaled 33 individuals. Recalculation of these estimations based on design (maximum) flow of the cooling water pumps indicates 90 adult equivalent individuals would have been taken at continuous full flow operation for the year.

Table 5.5-17. Pacific chub mackerel life history parameters used in equivalent adult modeling.

Annual Mortality (Z)*	Survival (S)*	von Bertalanffy growth parameters* L_{inf}	k	t_0	Age at 50% Maturity*	Length at 50% Maturity*
0.5	0.606531	400 mm FL	0.3124	-2.14	3.48534	331 mm FL

**Hill and Crone 2005*

5.5.3 All Life Stages of Shellfish by Species

Three shellfish taxa were impinged in sufficient numbers to warrant further analysis: California seahare (293 individuals collected), California market squid (93 individuals), and California two-spot octopus (21 individuals).

5.5.3.1 California seahare (*Aplysia californica*)

Seahares are opisthobranchs, gastropod mollusks with reduced shells or with no shells at all, as in the nudibranchs. Seahares, in the family Aplysiidae, are a very distinct group with an internal shell, deriving their common name from their humped shape and extended rhinophores (paired sensory projections from the head) that resemble a sitting hare's body and ears (Beeman 1968). Four species in this group are known to occur in California, with the California seahare (*Aplysia californica*) the most conspicuous. California seahares are found in the Eastern Pacific along the California coast from Humboldt Bay to Gulf of California.

5.5.3.1.1 Life History and Ecology

California seahares are often very abundant on sheltered and rocky shores and in kelp beds from the low intertidal to 18 m (59 ft) depth, and on mud flats and bottoms of shallow bays, estuaries and harbors. They are among the largest of the local nearshore invertebrate species, with large individuals exceeding 400 mm (15.7 inches) in length and weighing several kilograms (Morris et al. 1980). Young specimens are usually reddish, while older individuals can be reddish, brownish and/or greenish with a network of dark lines and spots.

Adult individuals are simultaneous hermaphrodites, but are unable to self-fertilize and must mate with other individuals (Morris et al. 1980). During mating, individuals may act as only male or female, or both sexes simultaneously, and chains or circles of mating individuals are occasionally observed. Eggs are deposited among rocks and seaweed, inter-and subtidally, in long, tangled, greenish-yellow strings containing up to a million eggs. Eggs hatch in about 12 days. Hatched veliger larvae stay in the plankton at least 34 days, after which they settle on red algae and undergo metamorphosis. After metamorphosis, individuals can double their weight every 10 days for three month before growth slows down. Individuals may attain sexual maturity within 120 days of hatching, although not yet fully grown. The life span of individuals is usually a year or less, and population numbers can vary greatly among years.

The California seahare is herbivorous, feeding mainly during the day on a variety algae and eelgrass (Morris et al. 1980). Food is scented from a distance by receptor organs and the animal moves inchworm-like towards the food. When feeding, the animal tears off large pieces of plant material with its toothed radula, which is then swallowed and temporarily held in the esophagus, then passed to a muscular gizzard where the plant material is ground up and mixed with enzymes for digestion. Seahares show avoidance to some sea star and predaceous opisthobranch species, but the digestive gland of the sea hare contains toxic chemicals and few animals are known to prey on seahares following metamorphosis of the larvae (Morris et al. 1980; Silverstein and Campbell 1989). When irritated, California seahares exude a dark-purple ink to discourage harassment. The purple ink gets its color from pigments in red algae. Individuals milked of their ink then fed on only brown and green algae do not produce the purple dye.

5.5.3.1.2 Population Trends and Fishery

Seahares possess very large nerve cells, some up to 1 mm (0.04 inches) in diameter (Morris et al. 1980; Silverstein and Campbell 1989). Not only are the neurons large, many are consistently placed and distinctly colored, making it possible to identify corresponding cells in different individuals. The simple behavior of these animals along with the ease of study of the nerve cells make seahares ideal for research relating animal behavior to the structure and function of the nervous system.

As a result, researchers provide a steady market for California seahares, supporting both seahare mariculture and a wild-caught sea hare fishery (Silverstein and Campbell 1989; CDFG 2007b). In 2005, Los Angeles area landing of seahares totaled 4,783 kg (10,547 lbs) at an estimated value of $35,352 (CDFG 2006). Commercial landings of seahares in 2006 in Long Beach area catch blocks totaled 1,947 kg (4,293 lbs) at a value of $33,523 (CDFG 2007b). Herbinson (1981) did not report macroinvertebrate impingement. No seahares were recorded from 2001 through 2005 during annual impingement monitoring at the AGS (MBC 2006).

5.5.3.1.3 Sampling Results

A total of 293 California seahares was collected in impingement samples, with an estimated annual impingement of 1,379 individuals weighing 499.801 kg (1,102.061 lbs) based on actual cooling water flow rates (Table 5.5-1). Highest impingement abundance was recorded at Units 1&2, which accounted for 86% of the total abundance, followed by Units 5&6 (9%) and Units 3&4 (5%) (Table 5.5-18). Impinged biomass was similarly distributed among the screenwells.

Table 5.5-18. Annual California seahare abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	**Units 3&4**	**Units 5&6**	**Total**
Invertebrate Abundance	252	16	25	293
Invertebrate Biomass (kg)	74.3	8.407	14.089	96.796

California seahare was most abundant during summer months, with peak impingement density recorded from July through September (Figure 5.5-39). Impinged biomass did not exhibit any distinct seasonal trend, as the impingement of large individuals during low abundance periods potentially distorted the trends (Figure 5.5-40). Seahares were more frequently impinged during daytime than during nighttime (Figures 5.5-41 and 5.5-42).

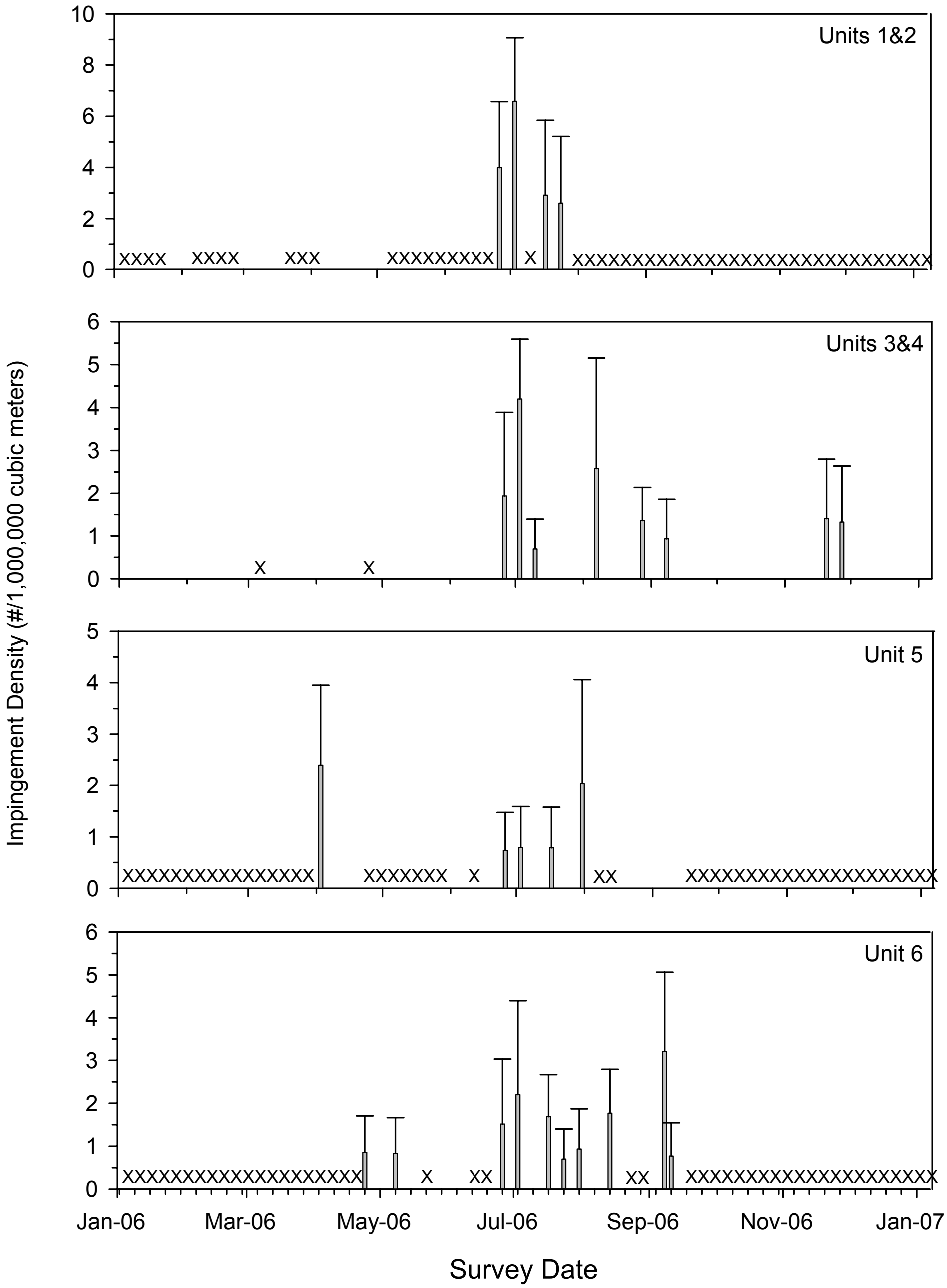


Figure 5.5-39. Mean concentration (# / 1,000,000 m^3) and standard error of California seahare collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

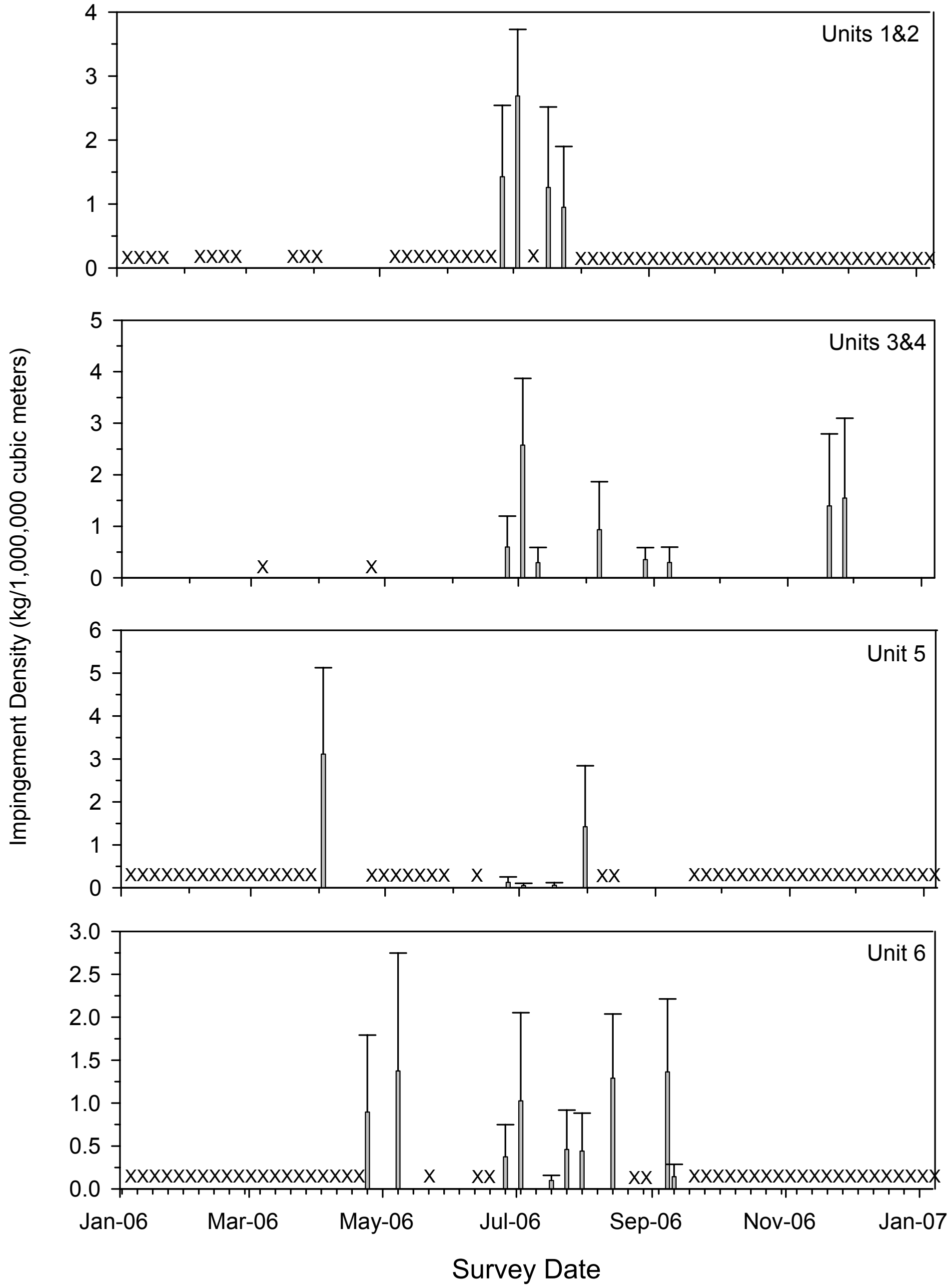


Figure 5.5-40. Mean biomass (kg / 1,000,000 m^3) and standard error of California seahare collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

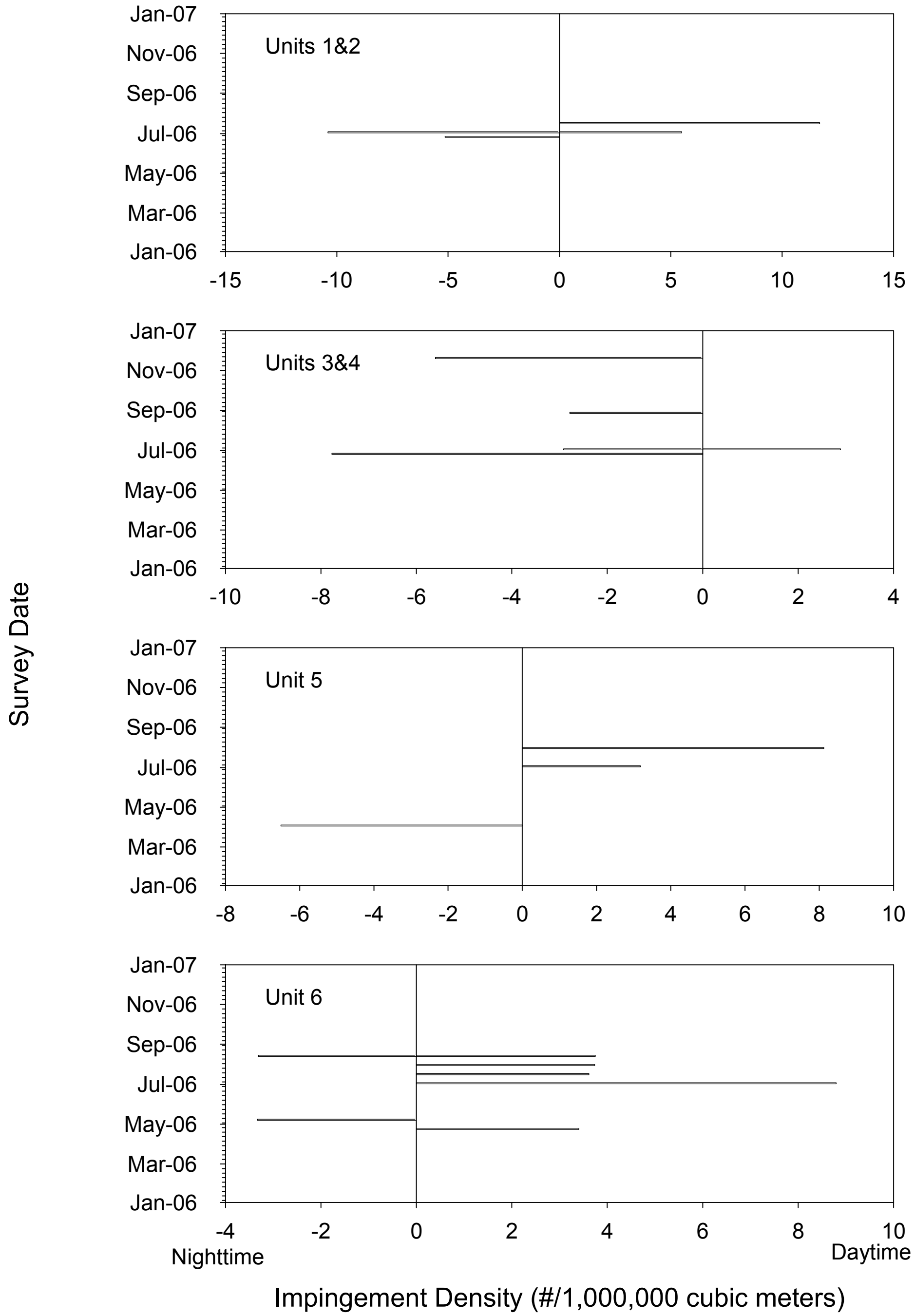


Figure 5.5-41. Mean concentration (# / 1,000,000 m^3) of California seahare in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

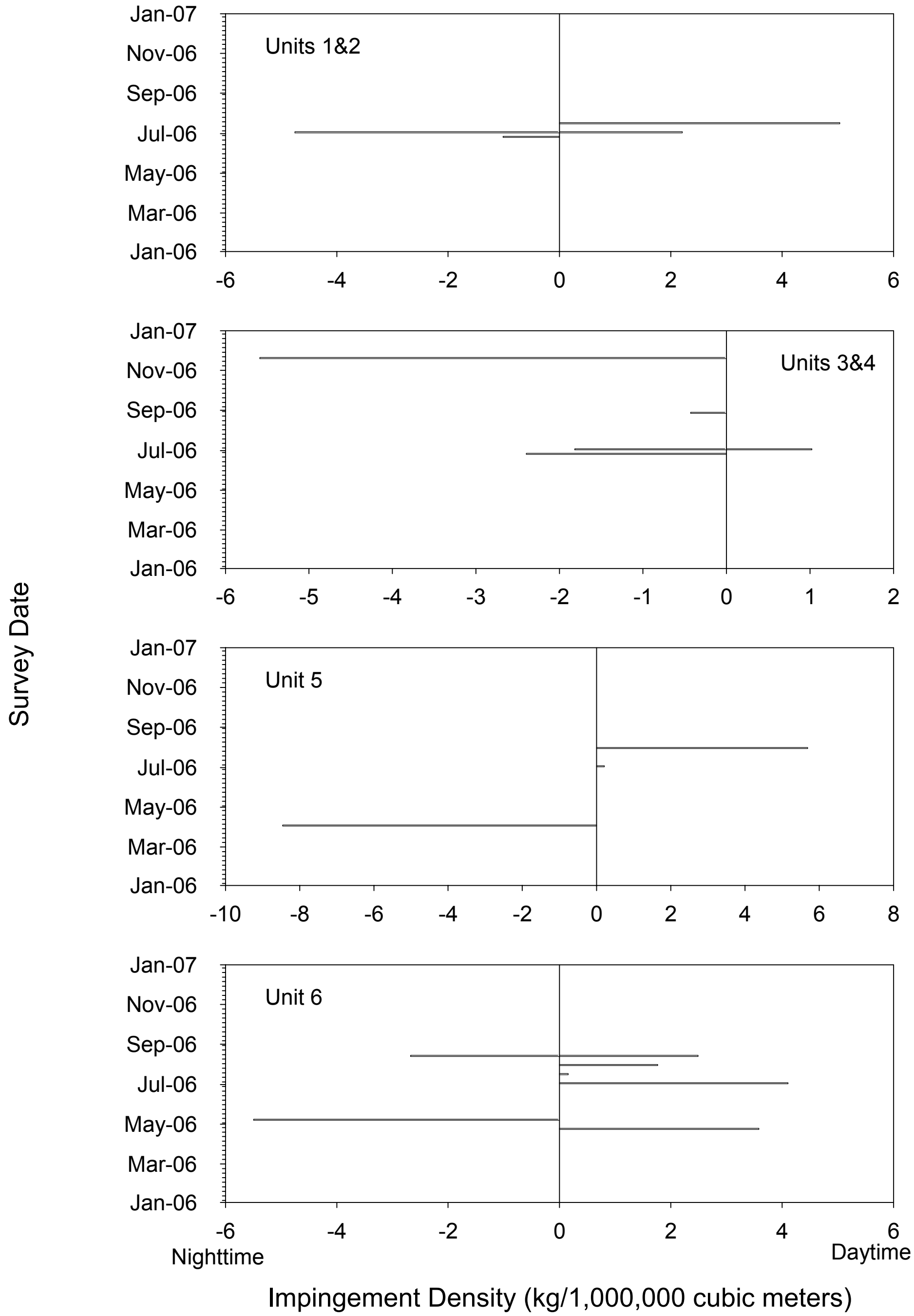


Figure 5.5-42. Mean biomass (kg / 1,000,000 m^3) of California seahare in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

5.5.3.2 Market squid (*Loligo opalescens*)

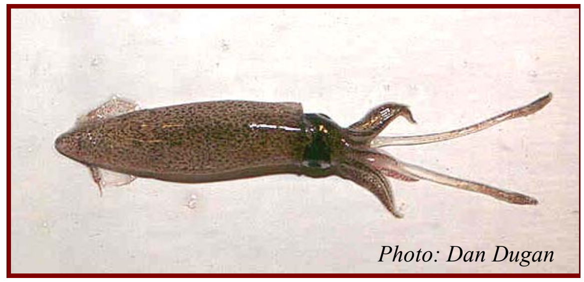


Photo: Dan Dugan

Market squid (*Loligo opalescens*) range from offshore British Columbia to Bahia Asuncion, Baja California, including Guadalupe Island off Baja California (Morris et al. 1980; MBC 1987). However, they are found in highest numbers between Monterey and San Diego, California, and are found north of Puget Sound only during or following El Niño events. The distribution of this species is classified as 'Transitional Endemic' since market squid are limited to the California Current and the eastern portion of the Northeast Pacific Transition Zone. Market squid are managed under the Coastal Pelagic Species Fishery Management Plan (PFMC 1998).

5.5.3.2.1 Life History and Ecology

Eggs of the market squid are benthic, while juveniles and adults are considered pelagic (Fields 1965). They are actually found over the continental shelf from the surface to depths of at least 800 m (2,625 ft) (PFMC 1998). Recksiek and Kashiwada (1979) found larvae in much higher concentrations near bottom than in the water column. Mature squid form large spawning aggregations in nearshore waters, and in southern California, these usually occur from November through August (Fields 1965).

During copulation, a male holds the female from below, and a bundle of spermatophores is subsequently transferred from the mantle cavity of the male to a position near the female's oviduct (Hurley 1977). In southern California, squid spawn primarily in winter (November through August), though spawning has also been recorded in July (Morris et al. 1980). Fields (1965) suggested nighttime spawning in market squid; however, recent observations suggest this species spawns exclusively during daytime (Forsythe et al. 2004). Market squid are terminal spawners, spawning once then dying.

Age at first reproduction is 24–28 weeks (Yang et al. 1986). Egg capsules are usually deposited on sandy substrate, often at the edges of canyons or rocky outcroppings (McGowan 1954). Egg deposition occurs between depths of 5 and 55 m (16 and 180 ft), and is most common between 20 and 35 m (66 and 115 ft) (PFMC 1998). Each egg capsule contains 180 to 300 eggs (Morris et al. 1980). Egg development is dependent on water temperature; eggs hatch at 19–25 days at 17°C (63°F), 27–30 days at 15°C (59°F), and 30–35 days at 14°C (57°F) (Yang et al. 1986). Females produce 20–30 egg capsules, and each capsule is individually attached to the substrate (PFMC 1998). Fields (1965) reported four females depositing 17,000 eggs in 85 capsules in one evening, equivalent to about 21 capsules and 4,250 eggs per squid. Recksiek and Frey (1978) reported a fecundity of 4,000 to 9,000 eggs per female (MBC 1987). Macewicz et al. (2004) report an average fecundity of 3,844 oocytes based on an average female length of 129 mm (5.1 in) dorsal mantle length (DML).

Young squid hatch within three to five weeks after the capsule is deposited (McGowan 1954; Fields 1965). Newly hatched squid (paralarvae) resemble miniature adults and are about 2.5–3.0 mm (0.1 in) in length. After hatching, young *Loligo* swim upward toward the light, bringing them to the sea surface (Fields 1965).

Butler et al. (1999) determined growth averages about 0.6 mm (0.02 in) DML per day, and maximum ages in 1998 were 238 days for females and 243 days for males. Yang et al. (1986) recorded a maximum life span of 235 and 248 days for two laboratory-reared populations. Yang et al. (1986), Butler et al. (1999), and Jackson (1998) determined that Fields (1965) and Spratt (1979) underestimated growth and overestimated longevity—squid were initially reported to live as long as three years. Growth increases exponentially during the first two months, and then slows to logarithmically thereafter (Yang et al. 1986). Schooling behavior has been observed in squid as small as 15 mm (0.6 in) DML (Yang et al. 1986).

Squid spawned in early summer (August -May) will grow rapidly during the summer growing season when nutrients from increased upwelling cause plankton blooms. As spawning continues from June through September, newly hatched squid have less time available in the growing season, which can slow the growth rate (Spratt 1979). Adults measure up to 305 mm (12 in) total length and weigh between 56 and 84 g (0.12 and 0.19 lbs) (Vojkovich 1998), with spawning males normally being larger than females. Males reach 19 cm DML (7.5 in), a maximum weight of about 130 g (0.29 lbs), and have larger heads and thicker arms than females (PFMC 1998). Females reach about 17 cm DML (6.7 in) and a maximum weight of 90 g (0.20 lbs).

Planktonic invertebrates are the primary food source of young squid (Spratt 1979). Squid feed mostly on crustaceans, and to a lesser degree fishes, cephalopods, gastropods, and polychaetes (Karpov and Cailliet 1979). The diet of market squid changes with water depth and location, but does not differ much among size classes or between sexes (Karpov and Cailliet 1979). Squid captured in deeper water feed more frequently on euphausiids and copepods, whereas squid captured near the surface feed predominantly on euphausiids, as well as cephalopods, fish, mysids, and megalops larvae. In spawning schools, 75% of stomachs examined had remains of market squid (Fields 1965).

Cailliet et al. (1979) determined affinities of multiple species with market squid. In Monterey Bay, the species with the highest affinities with market squid were northern anchovy, Pacific electric ray (*Torpedo californica*), Scyphomedusae (sea jellies), plainfin midshipman (*Porichthys notatus*), Pacific sanddab (*Citharichthys stigmaeus*), and white croaker.

5.5.3.2.2 Population Trends and Fishery

Large-scale fluctuations are characteristic of the squid stock, due primarily to its short life span and from the influence of wide variations in oceanographic conditions (NMFS 1999). However, the short life history of this species allows for squid to recover after natural population declines as soon as ocean conditions improve. The best information indicates squid have a high natural mortality rate (approaching 100% per year) and that the adult population is composed almost entirely of new recruits (PFMC 1998). In 1997, California passed Assembly Bill AB 364, which not only initiated closures and established a fishery permit fee, but designated funds from the permits to be used for squid research and management.

The California fishery for market squid began in Monterey Bay in the late-1800s (Vojkovich 1998). It expanded into southern California only after the 1950s, and prior to 1987, catches in southern California rarely exceeded 20,000,000 kg (44,100,000 lbs). After that, landings increased four-fold until the fishery collapsed in 1998, and California squid fishers sought federal disaster assistance (Zeidberg et al. 2004). In California, most squid marketed for human consumption is frozen, but smaller amounts are canned or sold fresh (PFMC 1998). Squid are also sold live and frozen for bait. Los Angeles area commercial landings have varied substantially since 2000, ranging between 7.7 and 44.8 million kg (16.9 and 98.8 million pounds) annually (PacFIN 2007), with both the total catch and market value increasing substantially the last four years (Table 5.5-19). Los Angeles area landings in 2005 totaled 31,552,713 kg (69,573,734 lbs) at an estimated value of $18,511,585 (CDFG 2006). Landings in Long Beach area catch blocks in 2006 totaled 4,896,450 kg (10,794,643 lbs) at an estimated value of $2,647,959 (CDFG 2007b). Herbinson (1981) did not report macroinvertebrate impingement. Three market squid were recorded from 2001 through 2005 during annual impingement monitoring at the AGS, all in September 2003 at Units 1&2, Unit 5, and Unit 6 (MBC 2006).

Table 5.5-19. Annual landings and revenue for market squid in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**kilograms**	**pounds**	**Revenue**
2000	44,831,189	98,854,319	$11,360,252
2001	39,163,504	86,355,527	$8,491,578
2002	28,155,199	62,082,214	$6,430,766
2003	7,703,122	16,985,383	$4,424,230
2004	10,501,964	23,156,830	$4,845,324
2005	31,808,088	70,136,834	$18,664,223
2006	37,053,145	81,702,193	$20,370,612

5.5.3.2.3 Sampling Results

A total of 93 market squid was collected in impingement samples, with an estimated annual impingement of 600 individuals weighing 20.283 kg (44.724 lbs), based on actual cooling water flow rates (Table 5.5-1). Most of the impingement occurred at Units 3&4 with 60% of abundance and 64% of biomass, followed by Units 5&6 with 38% of abundance and 34% of biomass (Table 5.5-20). Units 1&2 contributed 2% of each impingement metric.

Table 5.5-20. Annual California market squid abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	**Units 3&4**	**Units 5&6**	**Total**
Shellfish Abundance	2	56	35	93
Shellfish Biomass (kg)	0.063	2.01	1.053	3.126

Impingement of squid occurred between February and September, with peak impingement density (abundance and biomass) recorded in mid-March and June (Figures 5.5-43 and 5.5-44). Surveys indicated that impinged abundance and biomass increased at night (Figures 5.5-45 and 5.5-46).

Length frequency analysis of 60 measured individuals indicated a mean mantle length (ML) of 117 mm (4.6 in), which roughly corresponds to squid five to six months old (Figure 5.5-47). Of the 60 individuals that were evaluated for condition factor, 80% were dead and the remaining 20% were alive.

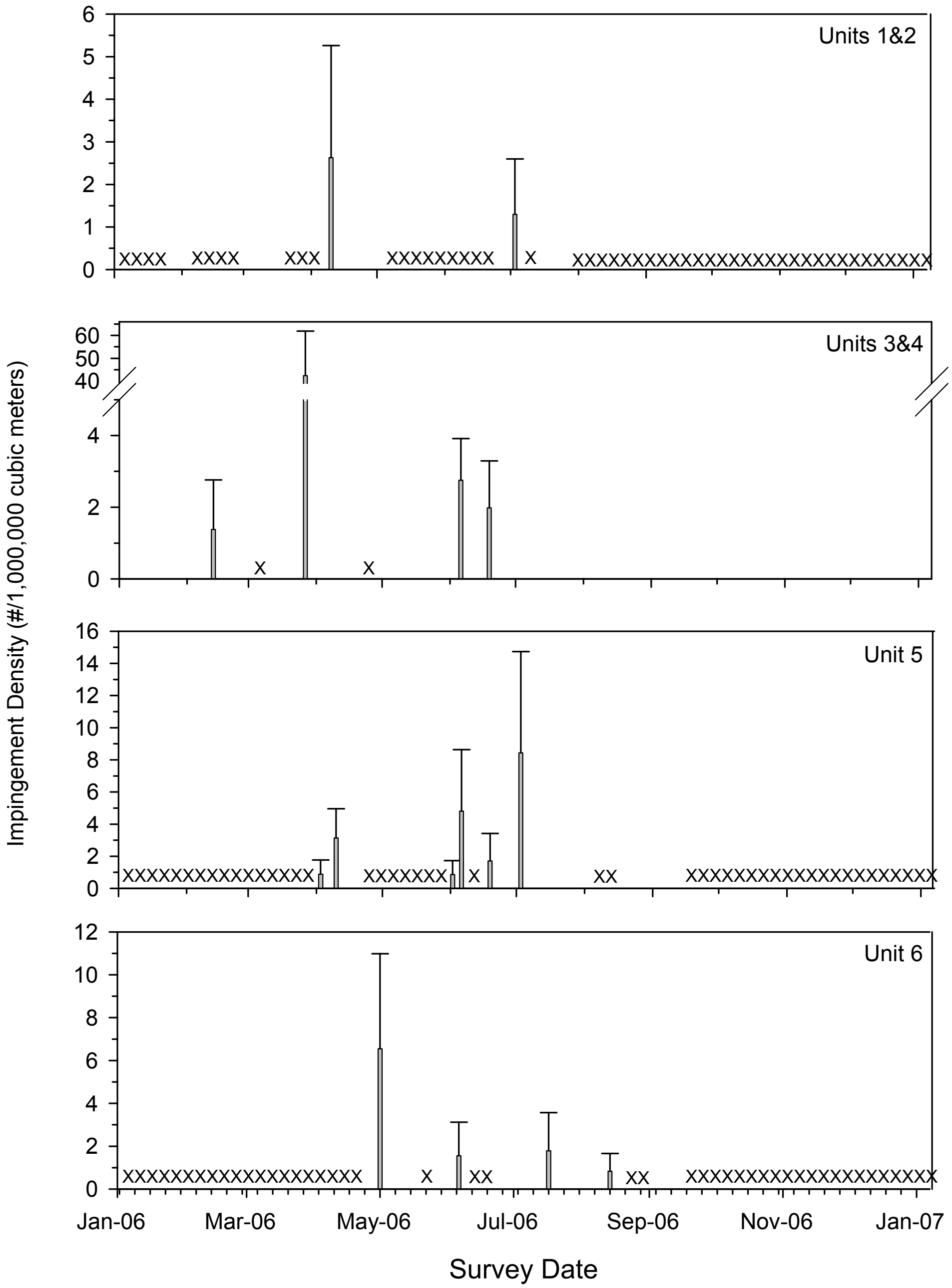


Figure 5.5-43. Mean concentration (# / 1,000,000 m^3) and standard error of market squid collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

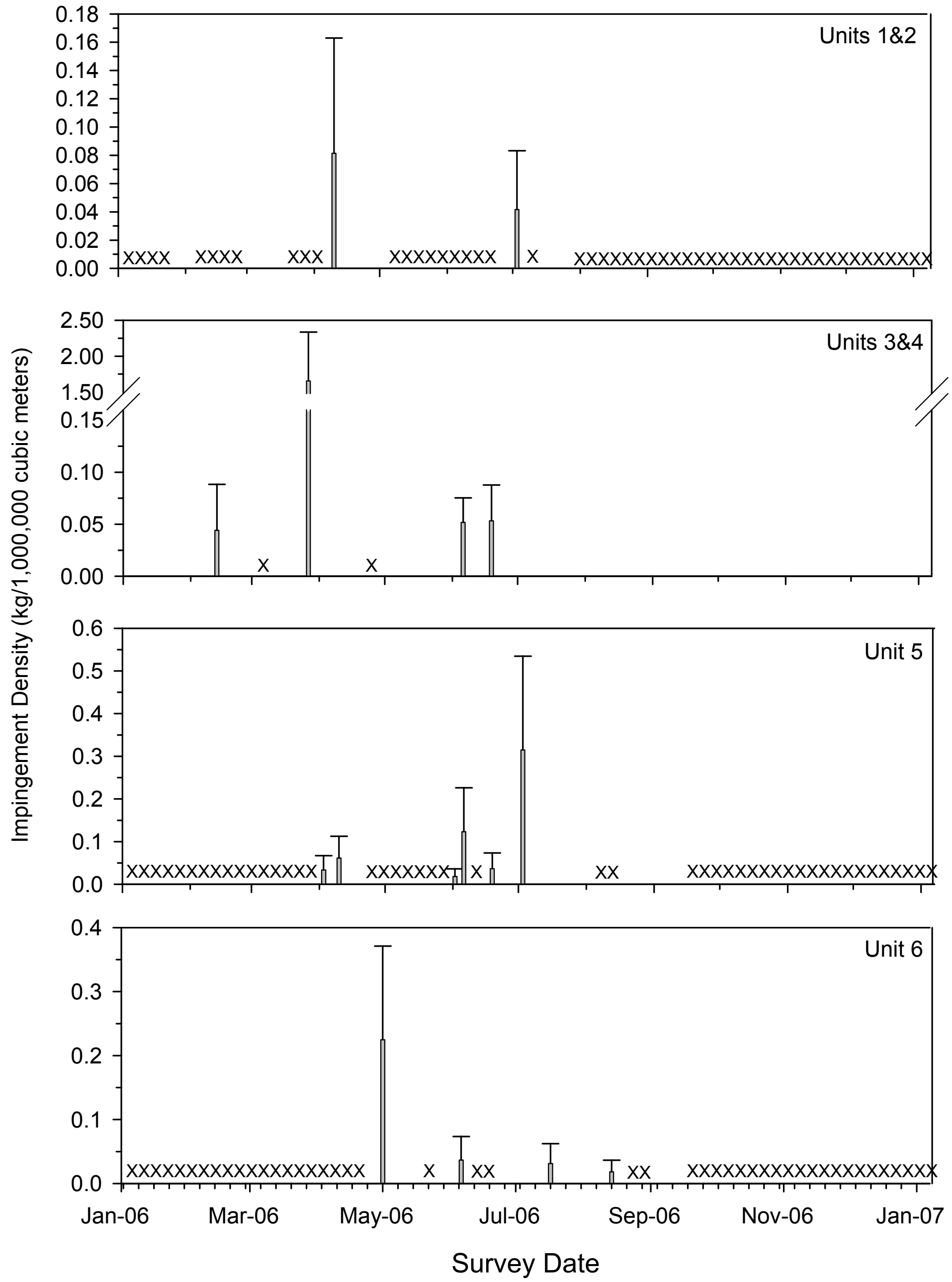


Figure 5.5-44. Mean biomass (kg / 1,000,000 m^3) and standard error of market squid collected in AGS impingement samples in 2006. "X" denotes weeks with no sample collection.

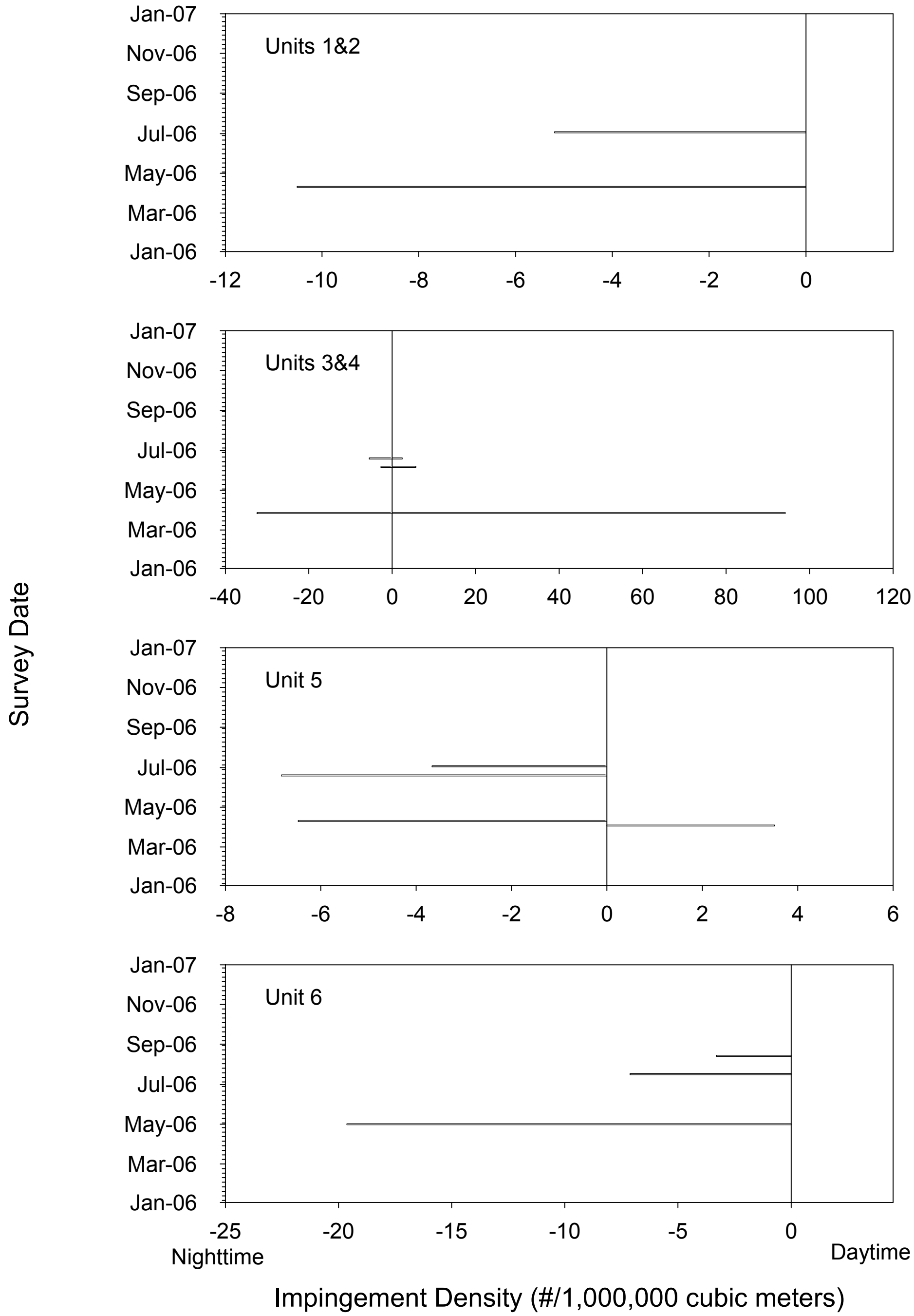


Figure 5.5-45. Mean concentration (# / 1,000,000 m^3) of market squid in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

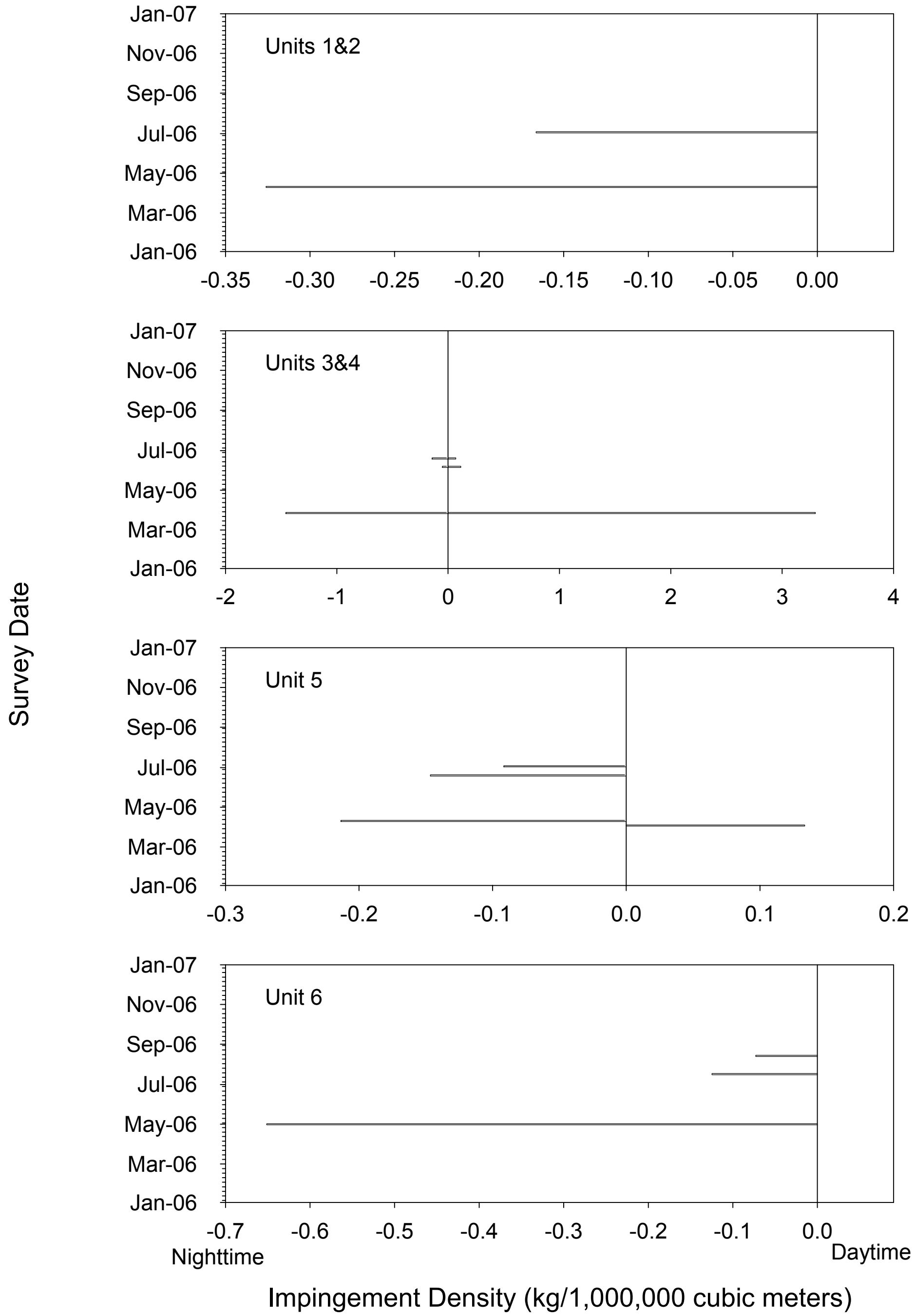


Figure 5.5-46. Mean biomass (kg / 1,000,000 m^3) of market squid in AGS impingement samples during night (Cycle 3) and day (Cycle 1) sampling in 2006.

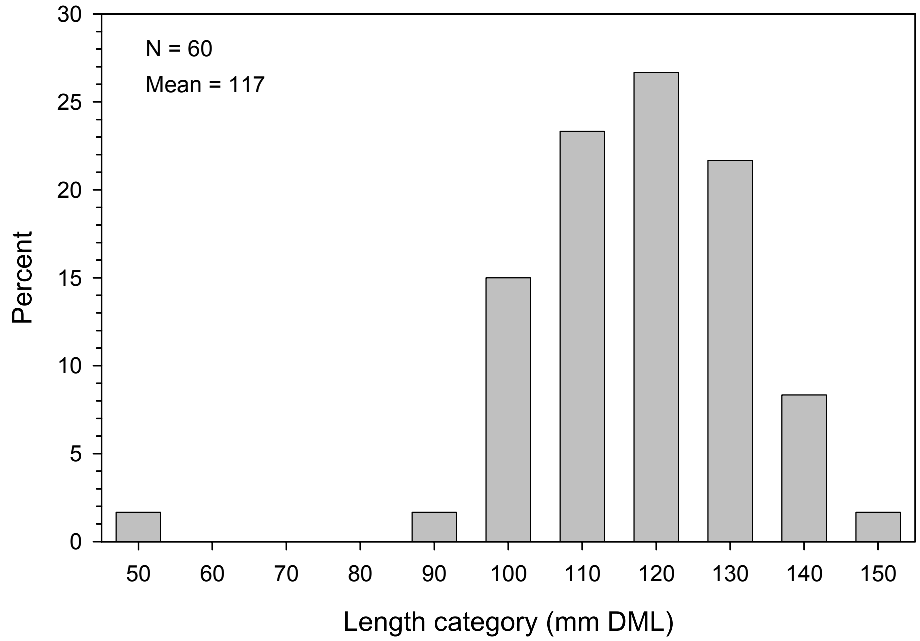


Figure 5.5-47. Length (mm) frequency distribution for market squid collected in impingement samples.

5.5.3.3 California two-spot octopus (*Octopus bimaculatus/bimaculoides*)

There are two similar octopus species that occur in southern California: *Octopus bimaculatus* and *O. bimaculoides*. Both are referred to as the California two-spot octopus since they are difficult to distinguish, and for more than 60 years were thought to represent a single species (Morris et al. 1980). *O. bimaculoides* ranges from San Simeon, California, to Bahia San Quintin, Baja California, and is found in a variety of habitats to depths of 20 m (66 ft) (Lang and Hochberg 1997). The sibling species *O. bimaculatus* has a similar geographic distribution, occurring from Santa Barbara, California, south to Punta Eugenia, Baja California, and in some locations within the Gulf of California. It also occurs in slightly deeper depths (to 50 m [164 ft]) (Morris et al. 1980; Lang and Hochberg 1997).

5.5.3.3.1 Life History and Ecology

Both octopus species occur in a variety of habitats, including mudflats, intertidal zones, reefs, crevices, and kelp beds. *O. bimaculoides* females lay their eggs under rocks from late winter to early summer, and brood them continuously for two to four months (Morris et al. 1980). Females lay between 200 and 800 eggs, depending on female size and condition (Lang and Hochberg 1997). The young remain on the bottom after hatching, and often move toward the intertidal. Adults feed on mollusks, crustaceans, and fishes. In the rocky intertidal zone, *O. bimaculoides* drills and feeds principally on limpets (*Collisella* and *Notoacmea*), snails (*Tegula* spp.), Pacific littleneck (*Protothaca staminea*), and hermit crabs (*Pagurus* spp.) (Morris et al. 1980). They also feed on mussels (*Mytilus* spp.) and the Pacific calico scallop (*Argopecten ventricosus*) (Lang and Hochberg 1997).

O. bimaculatus spawns throughout most of the year, though there is a distinct seasonal peak from April through July (Lang and Hochberg 1997). Hatching takes place in a relatively short time-frame since there is an inverse relationship between development time and water temperature (Ambrose 1981). Ambrose (1981) also reported an average clutch size of about 20,000 eggs for a female weighing about 260 g (0.573 lbs). After hatching, young octopuses are planktonic for several months, and then settle to the bottom (Lang and Hochberg 1997). Juvenile *O. bimaculatus* feed on small crustaceans, while adults consume a wide variety of motile benthic invertebrates.

5.5.3.3.2 Population Trends and Fishery

Most California landings of octopus result from incidental catches in other fisheries (Lang and Hochberg 1997). In 2005, commercial landings of octopus in the Los Angeles area totaled 183 kg (403 lbs) at a value of $558 (CDFG 2006). Commercial landings from Long Beach area catch blocks in 2006 totaled 18 kg (39 lbs) at an estimated value of $105 (2007b). Herbinson (1981) did not report macroinvertebrate impingement. Twenty-one octopus were recorded from 2001 through 2005 during annual impingement monitoring at the AGS, with 11 recorded at Units 3&4 in 2004 (MBC 2006).

5.5.3.3.3 Sampling Results

A total of 21 two-spot octopus was collected in impingement samples, with an estimated annual impingement of 140 individuals weighing 29.401 kg (64.829 lbs), based on actual cooling water flow rates (Table 5.5-1). Most of the impingement occurred at Units 3&4 with 52% of abundance and 49% of biomass, followed by Units 5&6 with 43% of abundance and 49% of biomass (Table 5.5-21). Only one octopus was collected at Units 1&2. They were impinged throughout the year, although nearly one-half of the individuals (10) occurred during August 2006. There was no consistent diel pattern of impingement.

Table 5.5-21. Annual California two-spot octopus abundance and biomass collected in impingement samples by screenwell. Units 5 and 6 combined for cooling water flow considerations.

	Units 1&2	Units 3&4	Units 5&6	Total
Invertebrate Abundance	1	11	9	21
Invertebrate Biomass (kg)	0.072	2.132	2.139	4.343

Length frequency analysis of measured individuals indicated an arm spread of 343 mm (13.5 in), with a range between 42 and 724 mm (1.7 and 28.5 in). Of the 20 individuals that were evaluated for condition factor, 60% were dead, 5% were mutilated, and the remaining 35% were alive. The sex could not be determined for most (70%) individuals, although the remaining 30% were females.

6.0 IMPACT ASSESSMENT

6.1 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 transmitted 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). At AGS, the previous 316(b) demonstration that was conducted in 1978–1980 had the following objectives:

- Evaluate IM&E losses relative to known source populations of adult and larval fishes
- Assign a level of impact to each intake for selected target taxa.

The previous 316(b) study used an impact assessment model to calculate the magnitude of losses for all life stages of a particular species or species-complex. Entrainment was dominated by gobies and combtooth blennies, although northern anchovy, white croaker and queenfish were also represented in the entrainment sampling. The most abundantly impinged target species included Pacific butterfish, shiner perch, queenfish, and white seaperch. The impact assessment determined that in no case was more than 1.1% of any species population affected. In most cases the probability was a small fraction of 1%, and the impact on all 15 target species was determined to be insignificant to nearshore fish populations in the Southern California Bight. Furthermore, the configuration of the intakes represented BTA for minimizing AEI. The intake technology evaluation in the previous report also included an assessment on the effects of switching to alternative intake technologies based on the levels of potential impact.

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 AEI, EPA determined 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 body 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 "*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.*" USEPA also clarified in the guidance document: "*Regulatory agencies should clearly recognize that some level of intake damage can be acceptable if that damage represents a minimization of environmental impact.*"

In the 2006 IM&E study, impingement losses were measured by collecting samples at the AGS screening facilities and entrainment losses were measured by collecting samples at two locations in the AGS intake canals. The purpose of this impact assessment is to put the measured losses into context, and to evaluate the potential for AEI due to the CWIS.

6.1.1 CWIS impacts

There are three general types of effects associated with cooling water intake structures: (1) thermal effects, (2) impingement effects, and (3) entrainment effects. Thermal effects 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 organisms are drawn into a cooling water intake structure and pass through the AGS cooling water system. Organisms large enough to become trapped on the traveling screens are impinged.

In discussing the potential effects of the AGS CWIS on fish and shellfish populations, the first thing that needs to be considered is the life history of the species in the community. First of all, several fish species in the nearshore coastal areas around AGS 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. Many species are only vulnerable to entrainment for a few days when they are newly hatched because their swimming ability increases rapidly with age and development. Gobies, which were one of the most abundantly entrained taxa, have demersal eggs, which are not subject to entrainment. Also, as their development progresses, post-larval fishes begin searching for adult habitat, and those species that settle on the bottom are no longer susceptible to entrainment. From the standpoint of impingement effects, one of the most abundant groups of species in protected bays and estuaries, 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 also bottom-dwellers. Even fish species that swim in the water column are generally not susceptible to impingement effects as they mature because they are able to swim against the slow approach velocities of the cooling water inflow.

6.1.2 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 interpreted as including 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 AGS. This definition does not include organisms such as clams, mussels, and other crustaceans and mollusks that may only be harvested occasionally for recreational purposes, although the entrainment processing was expanded, at the request of the LARWQCB staff, to include all crab megalops stage larvae, and the impingement sampling quantified all of the organisms. 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 focused on addressing impacts to fish and shellfish rather than lower tropic levels such as phytoplankton and zooplankton. EPA recognized the low vulnerability of phyto- and zooplankton in its 1977 draft 316(b) guidance (USEPA 1977). There were several reasons why there is a low potential for impacts to phytoplankton and zooplankton and why it made sense for the USEPA to focus on effects on fish and shellfish. The reasons included the following:

- Very short generation times and life spans, on the order of a few hours to a few days, for phytoplankton, and a few days to a few weeks for zooplankton;
- Both phytoplankton and zooplankton have the capability to reproduce continually depending on environmental conditions; and
- The most abundant phytoplankton 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 phytoplankton and zooplankton, larval fishes make up a minute 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 phytoplankton and zooplankton. In many species, spawning occurs only once during the year;
- Unlike phytoplankton 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 phytoplankton and zooplankton, there is a greater likelihood of mortality due to entrainment in larval fishes, since many lower trophic 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 indicated in the suspended 316(b) Phase II regulations. All of the fishes and shellfishes collected during impingement sampling were counted and identified, while fish eggs and larvae, megalops stages of crabs, phyllosome larvae of spiny lobster, and market squid larvae were identified and counted from the entrainment samples. The regulations provided latitude for focusing on the set of species that could be accurately quantified and that provided the necessary detail to support development of other aspects of the CDS, and therefore, allowed for negotiating an acceptable compromise between the regulating agency and the discharger. The target group of organisms that were included in the entrainment sample processing was finalized at a January 12, 2006 meeting with staff from the LARWQCB 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 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 AGS during the study and no additional taxa beyond the taxa selected based on sampling abundance were included in the assessment.

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 and in the equivalent adult model (*EAM*) for the impingement data. The age used in the *AEL*, *FH*, and *EAM* modeling was the age of first maturity where approximately 50% of the females in the population are reproductive. Unfortunately, the life history information necessary for the modeling is unavailable for most species so combined assessments were only possible for a few species, including northern anchovy and queenfish. Estimates using the *EAM* could only be calculated for queenfish, northern anchovy, Pacific sardine, and jack mackerel.

6.1.3 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 AGS, the permit applicant is obligated to provide the LARWQCB 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:

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.

6.1.3.1 Adverse Environmental Impact (AEI) Standard

Because there were no regulations defining AEI, permit decisions must be based on the EPA's AEI interpretations provided in guidance documents issued since the 1970s. In those documents, the EPA 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 EPA stated that *"…adverse 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 EPA 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."*

EPA (1977) draft guidelines acknowledge that the determination of the extent of AEI is difficult to assess. They state 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 AGS 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.

6.1.4 Relating Measured Impacts to Source Populations

The potential magnitude of the losses due to entrainment and impingement depend on many factors including the physical characteristics of the source water body, and the biological characteristics of the affected populations including the following:

- Reproductive biology that affects the vulnerability of certain life stages, such as surfperches and sharks and rays with no planktonic larval phase,
- Distribution and habitat preferences that affect vulnerability, and
- Duration of time that larval and juvenile stages are vulnerable due to behavior, mobility, and habitat preferences.

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 taxa that were collected during the study in adequate abundances to provide reasonable confidence in the estimates of entrainment and impingement effects. These taxa 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 6.1.1), not all of the fishes and shellfishes in the source water are subject to entrainment or impingement, and only a few taxa 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 differences in habitat preferences and behavior may occur at different life stages. While these factors contribute to the potential magnitude of the losses due to entrainment and impingement we will focus primarily on the distribution of the taxa and their habitats to organize the assessment and determine which ones are at greatest risk of AEI. Using this approach, an example of a species at high risk would be a rare or endangered species with a distribution that was limited to the area around the AGS intakes in Alamitos Bay. In contrast, a species at low risk of AEI would be one such as northern anchovy that is abundant over a large expanse of coastline. To determine the spatial extent of the effective source populations of larvae for modeling entrainment effects, data on water current flow and direction were collected during the study.

The focus of the assessment will be on species with adult populations in the nearshore areas of Alamitos Bay that are directly affected by entrainment and impingement at the AGS cooling water intakes. Therefore, 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 used in recent studies of marine fishes of California (Horn and Allen 1978; Allen 1985; Allen and Pondella 2006b) 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 (2006b) which included several habitats used to define deeper offshore areas (Figure 6.1-1). 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 (2006b) 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.

The taxa included in this assessment were categorized into these habitat types (Table 6.1-1). Taxa that occurred in more than one habitat were included in the habitat group that best reflects the primary distribution for the taxa and if a primary habitat could not be identified, the one that placed them at greatest risk to the effects of entrainment and impingement. For example, silversides occur in both bay and harbor, and coastal pelagic habitats, but since their occurrence in bay and harbor habitats places them at greater risk to power plant effects, they were treated along with other taxa specific to that habitat. 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, white croaker occurs in bays and harbors where they may be directly at risk to impingement and entrainment at AGS but also in sandy shallow nearshore areas where they are not at risk.

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.

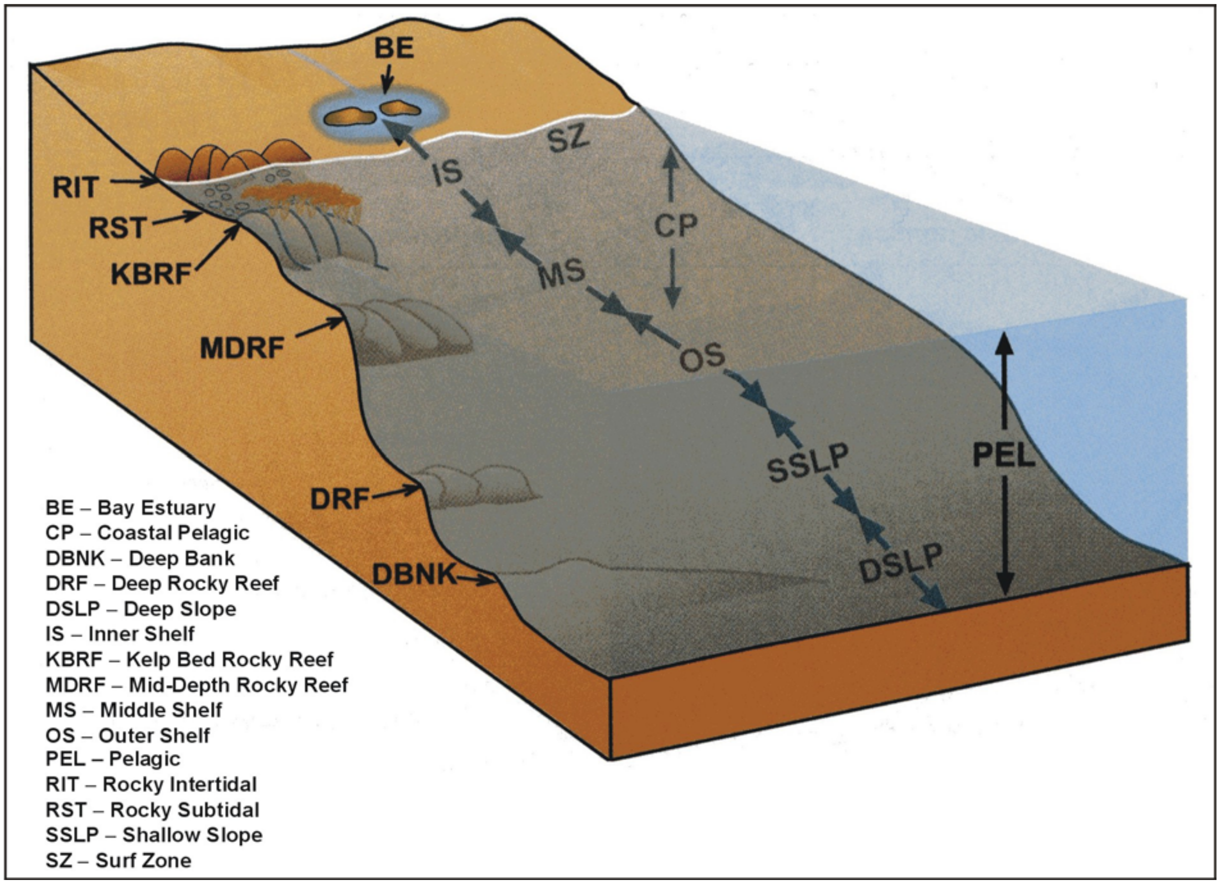


Figure 6.1-1. Marine habitat types in California (from Allen and Pondella [2006b]).

Table 6.1-1. Habitat associations for taxa included in assessment of CWIS effects at the AGS. Primary habitat in bold, upper case and secondary habitat in lower case.

		Fishery	**Habitats**			
Scientific name	**Common name**	**S-Sport, C-Comm.**	**bays, harbors**	**reefs, kelp beds**	**coastal pelagic**	**shelf**
Fishes						
Atherinopsidae	silversides	S, C	**X**		x	
Atherinops affinis	topsmelt	S. C	**X**		x	
Cymatogaster aggregata	shiner perch	S	**X**	x		
Engraulidae	anchovies	C			**X**	
Gobiidae	CIQ goby complex		**X**			
Hypsoblennius spp.	combtooth blennies		**X**	x		
Leptocottus armatus	Pacific staghorn sculpin		**X**			x
Sardinops sagax	Pacific sardine	C	x		**X**	
Seriphus politus	queenfish	S			**X**	x
Scomber japonicus	Pacific chub mackerel	S, C		x	**X**	
Trachurus symmetricus	jack mackerel	S,C		x	**X**	
Shellfishes/Invertebrates						
Aplysia californica	California seahare	C	x	**X**		
Loligo opalescens	market squid	S			**X**	
Octopus spp.	Calif. two-spot octopus	C	x	**X**		

6.2 SUMMARY OF ENTRAINMENT AND IMPINGEMENT RESULTS

The following section summarizes the combined results of the entrainment and impingement studies at AGS to provide an overview of annual impacts to marine life that are directly attributable to operations at the generating station. The information in this section provides an overview of the major results, while earlier sections of the report provide greater detail and explanation of the results on individual taxa. In addition, for those taxa such as silversides that were affected by both entrainment of eggs and larvae and impingement of juveniles and adults, the data are summarized together for all life stages. In order to compare predicted effects of IM&E, calculated losses were standardized to a common age-class that represents the age of first maturity where approximately 50% of the females in the population are reproductive. In later sections, the information on calculated losses is compared to long-term population trends and then discussed in terms of adverse environmental impacts.

6.2.1 Taxa Composition

Data from the bi-weekly entrainment surveys conducted at the AGS cooling water intakes were used to calculate that an estimated 1.69 billion fish larvae and 607 million fish eggs were entrained through the generating station CWIS in 2006 (Table 6.2-1). Approximately 63% of the larvae were gobies, 28% were combtooth blennies, 3% were silversides, and a total of thirty other taxa contributed about 6% of the annual total. Many of the larvae and eggs could not be positively identified to the species level, and this added some uncertainty to the estimates of annual entrainment for individual species. The most abundant taxonomic group of fish eggs in the samples were unidentified eggs (91%), followed by anchovy eggs (4%). Eggs of nine identified groups of fishes were represented in the collections. A complete listing of all of the taxonomic categories identified during the study is presented in Attachment F.

There were an estimated 4.3 million target shellfish larvae entrained represented by seven taxa (Table 6.2-1). Shore crab megalops comprised 36% of the annual entrainment of target invertebrate larvae. No shellfish species with direct commercial fishery value were identified from the samples.

Data from the weekly normal operations sampling were used to estimate that annual fish impingement at the AGS from was 399,097 individuals weighing 6,467 kg (14,260 lbs) based on actual cooling water flows, and 458,013 individuals weighing 7,685 kg (16,944 lbs) based on actual flows at Units 1&2 and 5&6 and design cooling water flow at Units 3&4 (Table 6.2-2). The most abundant fish taxa collected in impingement samples were topsmelt, unidentified silversides, shiner perch, and Pacific staghorn sculpin. The fish taxa contributing most to impingement biomass were topsmelt, unidentified silversides, diamond turbot, and shiner perch. A complete listing of all of the taxonomic categories identified during the study is presented in Attachment F. Nearly 87% of annual impingement abundance was recorded during two surveys affected by rainfall.

Annual macroinvertebrate impingement estimates at the AGS were 93,011 individuals weighing 3,601 kg (7,940 lbs) based on actual cooling water flows, and 131,227 individuals weighing 4,458 kg (9,829 lbs) based on actual flows at Units 1&2 and 5&6 and design cooling water flow at Units 3&4 (Table 6.2-3). Moon jelly was the most abundant species, followed by yellow shore crab, red jellyfish, and California seahare. Combined these species accounted for 95% of the sampled impingement abundance and 96% of the biomass.

Table 6.2-1. Rank and estimated annual entrainment of most common fish larvae, fish eggs, and target shellfishes at all AGS intake structures in 2006.

Rank	Taxa	Est. Annual Entrainment (actual flows)	% Comp (actual flows)	Cumulative % Comp.
	Fish Larvae			
1	gobies	1,065,638,741	63.18	63.18
2	combtooth blennies	463,862,355	27.50	90.68
3	silversides	56,032,916	3.32	94.00
4	anchovies	21,410,242	1.27	95.27
	29 Other taxa	79,813,555	4.73	100
		1,686,757,809		
	Fish Eggs			
1	unidentified fish eggs	552,553,835	91.09	91.09
2	anchovy eggs	25,101,765	4.14	95.23
3	sand flounder eggs	8,019,392	1.32	96.55
	8 Other taxa	101,508,151	3.45	100.00
		606,607,376		
	Target Shellfishes			
1	shore crab megalops	1,558,390	35.99	35.99
2	kelp crabs megalops	902,762	20.85	56.84
3	pea crabs megalops	727,447	16.80	73.64
4	yellow shore crab	447,086	10.33	83.97
5	striped shore crab megalops	320,223	7.40	91.36
6	unidentified crab megalops	237,284	5.48	96.84
7	porcelain crab megalops	136,760	3.16	100.00
		4,329,952		

Table 6.2-2. Rank and estimated annual impingement of the most common fish taxa at AGS in 2006 by estimated abundance and weight for actual and design flows.

Rank	Common Name	Total No. Actual Flows	Total No. Design Flows	% Total Actual Flows	Cumulative % Total Actual Flows
1	topsmelt	221,960	226,259	55.62	55.62
2	silversides	71,658	118,355	17.93	73.55
3	shiner perch	64,166	67,681	16.08	89.63
4	Pacific staghorn sculpin	17,973	18,277	4.50	94.13
5	bay pipefish	2,777	2,884	0.70	94.83
6	queenfish	2,167	2,772	0.54	95.37
7	longjaw mudsucker	2,007	3,100	0.50	95.87
8	diamond turbot	1,600	2,077	0.40	96.27
9	northern anchovy	1,462	1,517	0.37	96.64
10	slough anchovy	1,300	1,406	0.33	96.96
	46 Other taxa	12,117	13,685	3.04	100.00
		399,097	**458,013**		

Rank	Common Name	Total Wt. (kg) Actual Flows	Total Wt. (kg) Design Flows	% Total Actual Flows	Cumulative % Total Actual Flows
1	topsmelt	3,550.3	3,602.8	54.89	54.89
2	silversides	1,282.2	2,095.3	19.83	74.72
3	shiner perch	339.3	373.1	5.25	79.97
4	diamond turbot	304.4	419.2	4.71	84.67
5	California halibut	220.4	296.7	3.41	88.08
6	Pacific staghorn sculpin	216.9	221.1	3.35	91.43
7	California corbina	131.5	186.7	2.03	93.47
8	specklefin midshipman	121.4	133.8	1.88	95.34
	48 Other taxa	301.1	355.7	4.66	100.00
		6,467.4	**7,684.5**		

Table 6.2-3. Rank and estimated annual impingement of the most common invertebrates at AGS in 2006 by estimated abundance and weight for actual and design normal flows.

Rank	Common Name	Total No. Actual Flows	Total No. Design Flows	% Total Acutal Flows	Cumulative % Total Actual Flows
1	moon jelly	46,048	56,577	49.51	49.51
2	yellow shore crab	40,793	65,031	43.86	93.37
3	California seahare	1,379	1,410	1.48	94.52
4	red jellyfish	1,070	1,463	1.15	96.00
	39 Other Taxa	3,721	6,746	4.00	100.00
		93,011	**131,227**		
		Total Wt. (kg) Actual Flows	**Total Wt. (kg) Design Flows**	**% Total Actual Flows**	**Cumulative % Total Actual Flows**
1	moon jelly	2,893.0	3,593.8	80.34	80.34
2	California seahare	499.8	520.0	13.88	94.22
3	yellow shore crab	97.0	152.3	2.69	96.91
4	Calif. two-spot octopus	29.4	40.2	0.82	97.73
	39 Other Taxa	81.9	151.1	2.27	100.00
		3,601.1	**4,457.5**		

6.2.2 Temporal Occurrence

The highest concentrations of larval fishes occurred in May and June, and the lowest concentrations occurred in December (Figure 4.5-1). Fish eggs peaked in abundance in July with lows occurring from September through February (Figure 4.5-2). Larvae were generally more abundant in samples collected at night than those collected during the day and fish eggs were almost exclusively collected at night (when comparing Cycle 1 samples to Cycle 3 samples) (Figure 4.5-3 and 4.5-4).

The highest fish impingement abundance and biomass occurred during the surveys on February 27 and May 22, which occurred immediately after or during periods of rain (Figures 5.5-1 through 5.5-3). This was consistent with results from previous impingement investigations at the AGS. Fish impingement abundance and biomass were generally higher at night than during the day (Figures 5.5-4 and 5.5-5). Invertebrate impingement was highest in summer (July and August), while biomass was variable with peaks in spring and summer months (Figures 5.5-6 and 5.5-7). There was no consistent diel pattern of impingement for invertebrates (Figures 5.5-8 and 5.5-9).

6.2.3 Combined Analysis and Modeling Results for Selected Species

Several species of fishes and shellfishes that were abundant in either the entrainment or impingement samples, had recreational or commercial fishery value, or were federally managed species, were analyzed in detail in Sections 4 and 5. Some of the larval taxa had sufficient information available on their life history to estimate losses based on conversion to adult equivalents. In addition, some of the impinged taxa abundances could also be scaled to adult equivalents. The results of these analyses using actual flow rates at AGS in 2006 are presented in Table 6.2-4.

Table 6.2-4. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual flows at AGS in 2006.

Species	Common Name	Est. Annual Larval Ent. (millions)	Est. Annual Egg Ent. (millions)	*ETM* P_M (%)	2**FH*	*AEL*	Annual Imping. Estimate	Imping. Weight (kg)	*EAM*[1]
Fishes									
Gobiidae	gobies	1,065.6	–	13.32	2,292,044	974,076	–	–	
Hypsoblennius spp.	combtooth blennies	463.9	–	8.99	529,752	1,130,436	235	4.08	
Atherinopsidae unid.	silversides	56.0	13.2	8.39	–	–	293,792	4,851.14	
Engraulis mordax[2]	northern anchovy	21.4	552.5	0.07	8,360	19,484	8,044	2.75	
Seriphus politus	queenfish	0.6	–	–			2,167	15.82	3,146
Cymatogaster aggregata	shiner perch						64,166	339.30	
Leptocottus armatus	Pac. staghorn sculpin	0.2	–				17,973	216.85	
Sardinops sagax	Pacific sardine	0.3	–				389	6.76	343
Trachurus symmetricus	jack mackerel	–	–				69	5.24	91
Scomber japonicus	Pac. chub mackerel	–	–				17	4.17	33
Invertebrates									
Aplysia californica	California seahare						1,379	499.80	
Loligo opalescens	market squid	–	–				600	20.28	
Octopus spp.	two-spot octopus						140	29.40	

[1]*standardized impingement adult equivalent mortality*
[2]Engraulis mordax *larvae collected from impingement sampling are combined with adults*

6.3 ASSESSMENT OF TAXA BY HABITAT TYPE

The following sections present assessments for taxa from the five habitat types simplified from Allen and Pondella (2006b). A general discussion of the habitat and the potential risk to the habitat due to AGS operation will be followed by discussion of the specific impacts to the fishes and shellfishes included in the assessment for each habitat type (Table 6.1-1).

6.3.1 Background 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, defined as the nearshore coastal area from Point Conception south into Baja California, is a transition zone between the cool temperate Oregonian fauna, to the north and the warm temperate San Diegan fauna to 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 on the Southern California Bight (SCB) and the most pertinent debate concerns when it will switch back to a cold phase (Bograd 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 1970s 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 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 mobile warm-water fishes and invertebrates immigrate or recruit into the region (Lea and Rosenblatt 2000; Pondella and Allen 2001). Cold water fishes 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 mobile 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 6.3-1). 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.

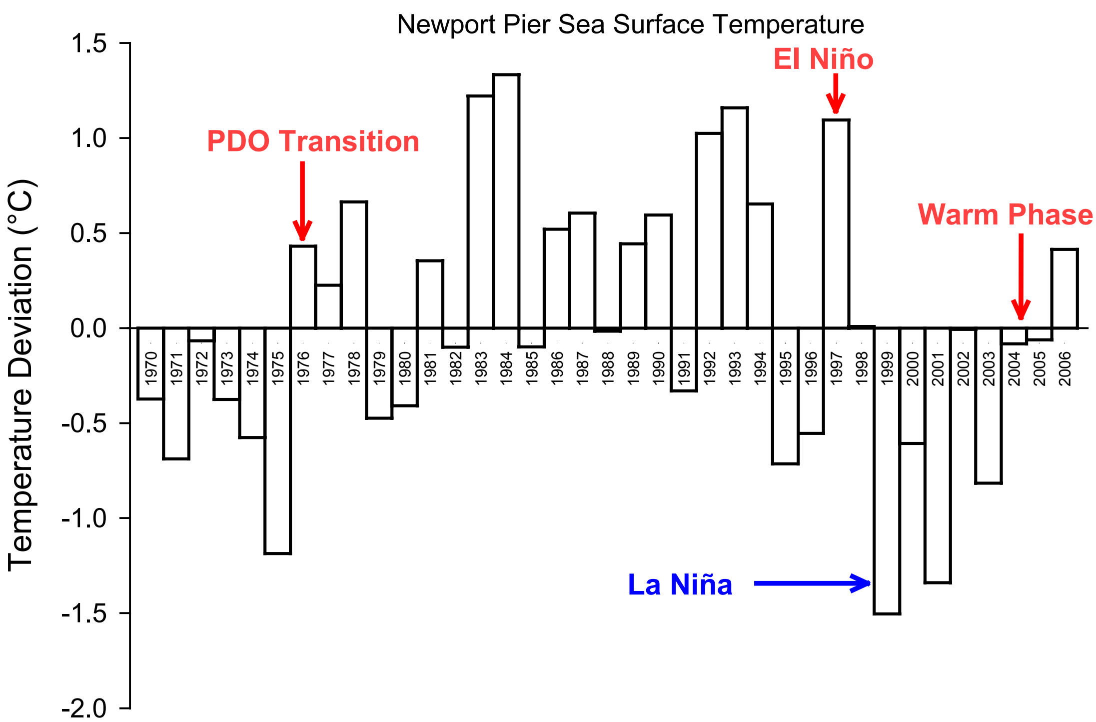


Figure 6.3-1. Sea surface temperature anomalies for Newport Pier, California. Values are ± the long-term average (1925-2006).

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 of 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) 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.

6.3.1.1 Habitat Associations and Fisheries

Entrained larvae were categorized in terms of the habitat types typically utilized by juveniles and adults, and the type of fishery, if any, that the species supports. Most larval taxa were from species typically found associated with the types of habitats in close proximity to the intakes: bay/harbor and rocky reef. Species primarily associated with the bays and harbor habitat (e.g., gobies, blennies) had the highest number of taxa and highest abundances entrained (Table 6.3-1). Most of the impinged fish taxa were also from the bay/harbor habitat group, as well as the nearshore shelf/slope group. However, the impingement biomass was dominated by taxa with some dependence on the bay/harbor habitat. Sport fishery species accounted for approximately 3.5% of the total number of larvae entrained and commercial fishery species accounted for 4.6%, while species with no direct fishery value comprised the majority (95.3%) of the larvae entrained. (Note that some species such as white croaker were classified as both a sport and commercial fishery species). Approximately 53% of the impinged species and 8% of the biomass were from fish and rays that have no direct fishery value.

Table 6.3-1. Percent of larvae entrained (abundance) or adults/juveniles impinged (biomass) associated with general habitat types and fisheries.

Attributes	Entrained % of taxa	Entrained % of abundance	Impinged % of taxa	Impinged % of biomass
Habitat Association				
Bays, harbors	54.55	97.28	66.66	97.37
Rocky reef, kelp	45.45	67.85	26.32	6.19
Coastal pelagic	24.24	29.23	29.82	75.79
Continental shelf / slope	21.21	0.86	35.09	12.52
Deep pelagic	3.03	0.02	0.00	0.00
Fishery				
Sport	30.30	3.48	36.84	91.49
Commercial	21.21	4.64	26.32	79.13
None	66.67	95.26	52.63	8.16

Note: Percentages do not total 100% because species may have more than one associated habitat and fishery.

The percentages of taxa associated with different habitats are somewhat similar for both entrainment and impingement with the largest percentage of the taxa being associated with the bay and harbor habitat where the intake canals are located (Table 6.3-1). As the percentages show, many of the entrained taxa are not targeted by sport or commercial fishing; however, the opposite was true for impingeable taxa. Although fishes and shellfishes from other habitats occur in bay and harbors, the taxa with the greatest potential for CWIS losses from AGS will be the taxa that only occur in that habitat such as gobies and blennies (Table 6.1-1).

6.3.2 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 seasonal freshwater input lowers salinities in some areas of the habitat. Much of the nearshore habitat in the vicinity of AGS is of the bay and harbor type including Alamitos Bay, Anaheim Bay and the much larger Los Angeles-Long Beach Harbor Complex. Although no undisturbed wetland areas still exist within the highly developed Harbor Complex, there is a small wetlands area, Los Cerritos Wetlands, inside Alamitos Bay, and extensive salt marsh areas within Anaheim Bay downcoast from Alamitos Bay. Characteristic fishes from these habitats in Alamitos Bay would include gobies (Gobiidae), bay pipefish (*Syngnathus leptorhynchus*), and bay blenny (*Hypsoblennius gentilis*) (Allen and Pondella 2006a). Approximately 50 to 70% of the fish taxa and almost all of the fishes collected during the IM&E sampling had some dependency on bay and harbor habitats during at least some stage of their life. It is considered the primary habitat for the six fish taxa included in this assessment: CIQ gobies, silversides (including topsmelt), combtooth blennies, shiner perch, and Pacific staghorn sculpin (Table 6.1-1). While CIQ gobies and staghorn sculpin occur almost exclusively in these habitats, two species of combtooth blennies, the rockpool blenny (*Hypsoblennius gilberti*) and mussel blenny (*Hypsoblennius jenkinsi*), also inhabit shallow intertidal and subtidal rocky reef habitats, while silversides and shiner perch also occur on the outer coast.

Annual entrainment of goby larvae was estimated to be 1.1 billion larvae based on actual flow volumes (Tables 6.2-1). No goby eggs were entrained because eggs are laid in nests and are not vulnerable to entrainment until they hatch as larvae. The entrainment and source water data on larval concentrations were used to estimate that 13% of the larval goby populations were potentially lost due to entrainment based on actual flows (Table 6.2-4). The entrainment losses were also used to estimate that the larvae entrained would have resulted in the production of 0.97-2.29 million adult gobies based on actual flow volumes. Gobies were not common in impingement sampling because they generally occur on the bottom and not in the water column where they would be subject to impingement. No arrow, cheekspot, or shadow gobies were collected in impingement samples in 2006.

Combtooth blennies had the second highest entrainment with an estimated annual entrainment of 463.9 million larvae based on actual flows. It was estimated that this level of entrainment resulted in the loss of approximately 9% of the larval combtooth blenny populations in the source water subject to entrainment. These estimates were used to estimate that the larvae represented the loss of 0.52-1.13 million adult equivalents. Combtooth blennies are similar to gobies in that they have adhesive demersal eggs that are not vulnerable to entrainment. Adult combtooth blennies, which could be identified to the species level, were impinged in low numbers (annual total of 235 blennies). Combtooth blennies, especially mussel blennies, can utilize submerged artificial substrates (pier pilings, dock floats, breakwater material) and their associated fouling communities for shelter and spawning habitat. The slips for approximately 4,000 boats in Alamitos Bay provide abundant habitat for a large local population of combtooth blennies and this explains why their larvae were entrained in large numbers. Most blenny larvae that were captured were recently hatched, based on size frequency distributions, and reached peak concentrations during summer months. The largest impingement occurred for the bay blenny (163 individuals).

Silversides, represented by topsmelt, jacksmelt and California grunion, were the third most abundant taxa group entrained at AGS in 2006. An estimated 56.0 million larvae and 13.2 million eggs were entrained at AGS in 2006 based on actual flows. It was estimated that this level of entrainment resulted in the loss of approximately 8% of the larval silverside population in the source water subject to entrainment. Topsmelt and jacksmelt deposit their eggs on submerged aquatic vegetation or shallow structures in bays and harbors, and the larvae were much more abundant on the east part of Alamitos Bay near the HnGS entrainment sampling location than in other parts of the bay. The greatest concentrations were entrained during nighttime surveys in May, and it is possible that the high concentrations of newly-hatched larvae are attracted to the brightly lighted areas around the power plant where they were subsequently entrained into the cooling water flows. Silversides were the most abundant taxon in the impingement samples, with an estimated 293,792 silversides weighing 4,851 kg (10,697 lbs) impinged at AGS in 2006 based on actual flows. Of this total, approximately 76% were topsmelt.

Other bay and harbor fishes included Pacific staghorn sculpin, which ranked third in impingement abundance, and was collected in relatively low numbers in entrainment samples (0.2 million larvae) (Table 6.2-4). Shiner perch was another bay and harbor species that was collected in the impingement sampling, but was not susceptible to entrainment because it bears free-swimming young. Shiner perch was the second most abundant species in impingement, with 64,166 individuals impinged using actual flows. Shiner perch are highly mobile species and are widespread among nearshore sandy habitats as well as rocky reef and kelp habitats.

If additional mortality rates from IM&E from both the AGS and nearby HnGS were causing long-term declines in fishes within Alamitos Bay, this should be reflected in overall changes to larval densities. Most of these organisms are affected through entrainment since the juveniles and adults of species such as gobies and blennies occupy benthic habitats within the bay where they are less susceptible to the effects of impingement. Determining the effects of the the power plant is complicated by uncertainty regarding the magnitude of the impacts to these and other species due to environmental variables and other stressors that can cause population changes. There are no long-term data from Alamitos Bay for any of these fishes, however, data collected from the earlier 316(b) study in 1978–1980 (IRC 1981) at the HnGS that were used to calculate entrainment estimates for AGS (SCE 1982a) documented average entrainment densities of silverside larvae at <10 per 1,000 m^3, but in 2006 the average densities had increased to 778 per 1,000 m^3. CIQ goby and combtooth blenny densities, on the other hand, were lower than recorded during the earlier study, so the historical data are ambiguous in this regard. In contrast, higher larval densities for blennies and gobies from the earlier study (ca. 4,000 per 1,000 m^3 for blennies and 3,000 per 1,000 m^3 for gobies) suggests a substantially greater spawning biomass in the late 1970s as compared to 2006 when larval densities were 16% and 55% of the 1978–1980 densities, respectively.

Even with a substantial fraction of the source larval production in Alamitos Bay cropped by power plant entrainment, the bay habitat continues to sustain a thriving population of gobies, blennies, and silversides as evidenced by the large numbers collected during the entrainment sampling. In a lagoon or bay such as Alamitos Bay that is significantly affected by tidal exchange, many of the larvae are inevitably lost to the system due to export by outgoing tidal currents despite 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 bay after a period of development in offshore waters. 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), but most of these exported larvae experience much higher mortality rates in the open ocean than those that are retained in their natal estuaries.

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 silversides, are generally not limited by habitat availability but by other factors such as food availability, oceanographic conditions, or predation. In Alamitos Bay where there is a limited amount of benthic habitat, density-dependent mortality may be a substantial factor affecting post-settlement recruitment, similar to the conclusions of Brothers (1975) on goby populations in Mission Bay, San Diego. Therefore, projections of adult equivalents based on larval entrainment likely overestimate actual adult losses. For example, similar levels of entrainment mortality were estimated for the South Bay Power Plant in south San Diego Bay (Tenera 2004). Data from a previous entrainment study and long-term data on adults indicated that the population in south San Diego Bay was stable and not affected by the additional larval mortality due to entrainment. Unfortunately, complementary data on adult abundances for 316(b) studies, including AGS, are usually not available.

In terms of potential economic losses resulting from entrainment and impingement of CIQ gobies, combtooth blenny, staghorn sculpin, silversides, and shiner surfperch, there are no direct impacts because they have no fishery value, except for the occasional use of larger specimens as fishing bait and a small recreational fishery for silversides. 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 be difficult to estimate due to the high natural variation in the system and the unknown compensatory response of other species present in the bay and nearshore environment.

6.3.3 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. Much of the shoreline of Alamitos Bay consists of hard intertidal and subtidal substrates, such as concrete bulkheads and piers. Common species in these assemblages include kelp bass (*Paralabrax clathratus*), barred sand bass (*P. nebulifer*), black perch (*Embiotoca jacksoni*), opaleye (*Girella nigricans*), halfmoon (*Medialuna californiensis*), California sheephead (*Semicossyphus pulcher*), señorita (*Oxyjulis californica*), garibaldi (*Hypsypops rubicundus*), salema (*Xenistius californiensis*) and zebraperch (*Hermosilla azurea*) (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 invertebrates that are primarily associated with rocky reef habitats that were impinged at the AGS included the California seahare and California two-spot octopus (Table 6.1-1). A small fishery exists for seahare (for educational/research purposes), while octopus are usually reported as bycatch. Taxa such as octopus, California seahare and others that occur across a number of habitats will be less susceptible to CWIS impacts than species with more specific associations with habitats directly affected by the CWIS.

Few fish taxa primarily associated with this habitat type were impinged, and the most abundant species was black perch (152 individuals impinged annually). No species primarily associated from this habitat were abundant enough to be included in this assessment, primarily because there are no significant patches of kelp bed and outer coastal reef habitat in Alamitos Bay. Impacts to representative species from this habitat are briefly discussed.

The intake structures (and canals) at the AGS are located in the sand and mud habitat in Los Cerritos Channel which is connected to Alamitos Bay. Species associated with rocky reef and kelp habitats migrate between areas and occasionally find suitable habitat in bays and harbors due to the presence of eelgrass, rock jetties, and other structures that provide shelter, especially for juveniles that may recruit into these habitats after being transported into Alamitos Bay as larvae. While some individuals may recruit and grow within small habitat patches it is more likely that adults take up temporary residence when they encounter such habitat patches during their movements.

6.3.4 Coastal Pelagic Habitats

Several species entrained or impinged at the AGS are characteristic of the coastal pelagic zone, which was expanded to include the surf zone for the purposes of this assessment. These included northern anchovy, queenfish, Pacific sardine, Pacific chub mackerel, jack mackerel, and market squid (Table 6.1-1). Some of these species, such as northern anchovy and queenfish, can be considered habitat generalists because they are also found in bays and a variety of other shallow water locations (Allen and Pondella 2006b). 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 during the impingement sampling.

The estimated annual loss of northern anchovy due to operation of the AGS CWIS included 21.4 million larvae and 552.5 million eggs (Table 6.2-4). No estimates of entrainment impacts were calculated due to the low numbers of larvae collected relative to the other species which are resident in the back areas of Alamitos Bay where AGS is located. Northern anchovy ranges widely throughout the Southern California Bight, and the proportion of larvae entrained from the source waters due to operation of the AGS would be very low. Annual impingement of juvenile/adult northern anchovy was estimated as 1,462 individuals with a combined weight of 2.6 kg (5.63 lbs) based on actual flows, and an additional 6,582 anchovy larvae weighing 0.2 kg (0.4 lbs) were also collected in impingement samples. An estimated 0.3 million Pacific sardine larvae were also entrained at AGS in 2006 (Table 6.2-4). Annual impingement of Pacific sardine was estimated at 389 individuals weighing 6.8 kg (14.9 lbs) based on actual flow volumes, which corresponded to 343 equivalent adults.

The evidence suggests that large-scale oceanographic phenomena, and not localized perturbations such as intake effects, are responsible for the population-wide changes seen in these two species. Northern anchovy and Pacific sardine are two indicator organisms for the PDO in the California Current System, (Chavez et al. 2003; Norton and Mason 2005; Horn and Stephens 2006). Northern anchovy dominates during the cold water phase and Pacific sardine during the warm water phase. Scale deposition of these two species in the anoxic Santa Barbara basin is one tool used for reconstructing the phases of the PDO over the past 2,000 years (Baumgartner et al. 1992; Finney et al. 2002). The commercial catch of northern anchovy follows this pattern, and by 1983 the catch of northern anchovy had basically disappeared in California (Mason 2004). The faunal switch associated with the PDO at the end of the 1970s was really completed in the Southern California Bight with the 1982–84 El Niño (Stephens et al. 1984; Holbrook et al. 1997), the largest El Niño recorded at that time. During the strong La Niña years (1999-2002) there was resurgence in catch of this stock. However, a return in catch of northern anchovy and a corresponding stock increase in Southern California will undoubtedly be delayed until the next cold phase of the PDO.

The difference in the entrainment estimates for northern anchovy between the 1979–1980 (IRC 1981) and the 2006 studies probably reflects changes in the oceanographic environment. The estimated annual entrainment during the previous study was 37 million compared with 21 million from the 2006 study. The recent entrainment estimate is approximately 57% of the estimate from the previous study. This reduction is much smaller than the decrease in the landings from Los Angeles area ports over the same period, which were 38,383,362 kg (84,620,828 lbs) in 1981 (data before 1981 not available from PacFIN) and averaged only 1,351,669 kg (2,979,921 lbs) from 2000–2006, or 2% of the 1981 landings. The total weight of the impingement losses amounted to approximately 0.0002% of the average landings at Los Angeles area ports from 2000–2006. These values do not represent significant AEI to northern anchovy, especially since this species has a broad distribution throughout the SCB. Annual landings of Pacific sardine ranged from 23 to 41 million kg from 2000–2006, whereas estimated annual impingent in 2006 was less than 7 kg.

Jack mackerel and Pacific chub mackerel were also collected in impingement samples, but not in entrainment samples. Estimated annual impingement was 69 jack mackerel (5.2 kg, or 11.6 lbs) and 17 Pacific chub mackerel (4.2 kg, or 9.2 lbs). This corresponded to an estimated 91 equivalent adult jack mackerel and 33 equivalent adult Pacific chub mackerel, respectively. As with anchovy and sardine, these annual totals represent only a small fraction of the commercial take in the Los Angeles area. Annual landings from 2000–2006 ranged from 133,000 to 3.6 million kg for jack mackerel. In 2006, landings of Pacific chub mackerel were 197,000 kg.

Queenfish is another common member of the croaker family found in Alamitos Bay, and also in the nearshore sand bottom habitat. Queenfish larvae were relatively uncommon in entrainment samples with an estimated 0.6 million larvae entrained in 2006 based on actual flow volumes (Table 6.2-4), but it was the fifth most abundant species impinged with approximately 2,200 individuals weighing 15.8 kg (34.9

lbs). This estimate was used to calculate that 3,146 equivalent adults were lost due to impingement at the AGS in 2006. The majority of the queenfish impinged were small young-of-the-year and likely use the habitat within Alamitos Bay as nursery grounds.

Catches of queenfish fluctuated over time in the various time-series analyses, but have shown increases in recent years that, similar to white croaker, may be in response to the prolonged cooler water temperatures since 1999 (Peterson et al. 2006). In the recreational fishery, catches were relatively consistent over time, fluctuating between 38,000 and 292,000 fish per year with the exception of one peak in 2002 (Figure 6.3-2a). Impingement of queenfish at the Huntington Beach Generating Station (HBGS) downcoast from Alamitos Bay shows a sharp drop through the 1980s with low fluctuating levels through the 1990s until after 2000 when levels began increasing (Figure 6.3-2b). Although this may be a response to the cooling trends in ocean temperatures, Herbinson et al. (2001) do not report a similar decline for queenfish in their analysis of impingement data from several southern California power plants. Both the catch data and impingement data are not adjusted for numbers of fishers and plant cooling water flow. This may explain why the data from trawls conducted off Huntington Beach and Alamitos Bay show much more variable results (Figure 6.3-2c). (See also Figure 5.5-32). All three data sets show increases in recent years that may be a response to ocean conditions.

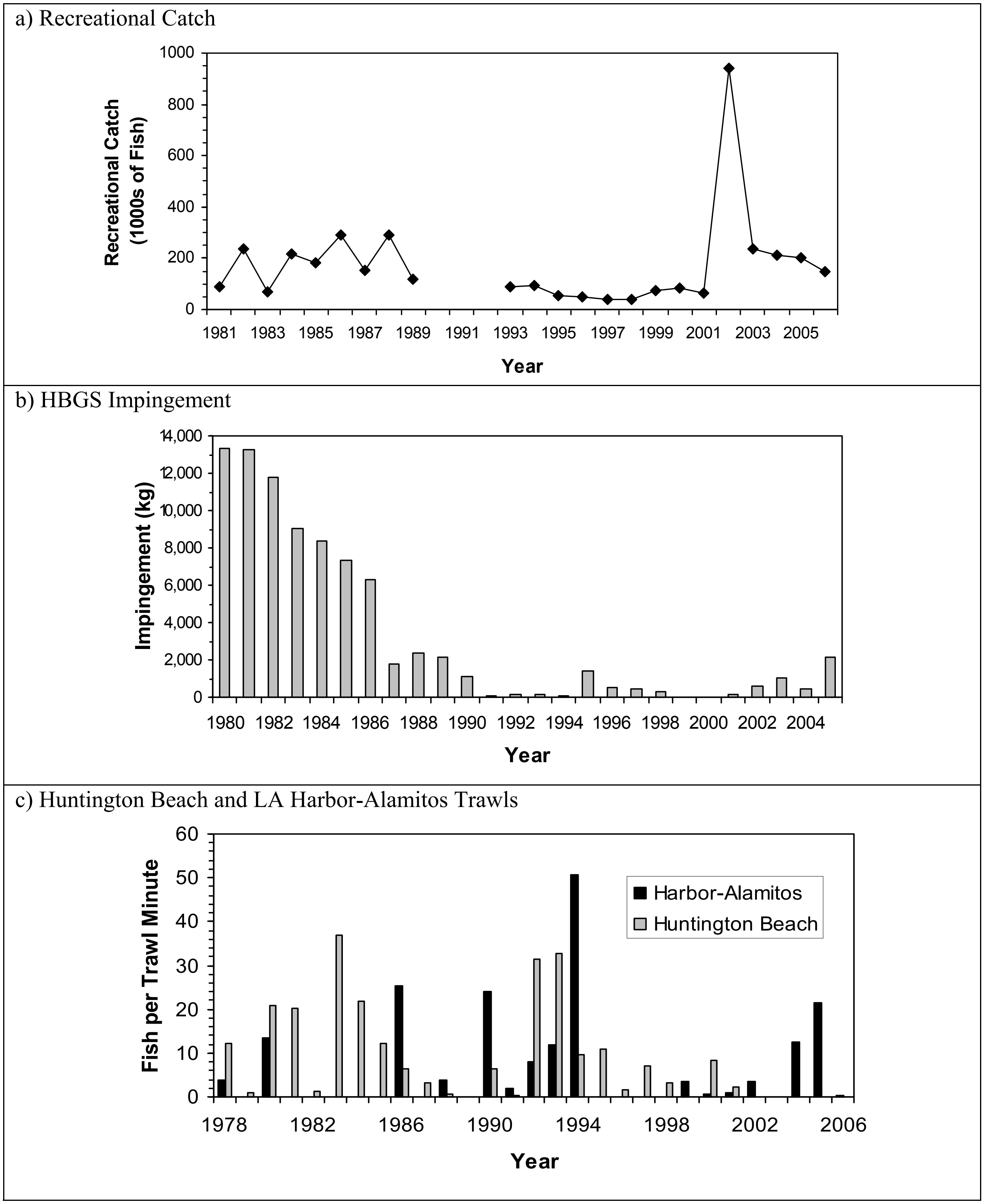


Figure 6.3-2. Queenfish fishery and population trends: a) recreational landings for Los Angeles area ports from RecFIN database; b) HBGS impingement average annual biomass; and c) average number of fish per trawl minute for HBGS and Harbor, Haynes and Alamitos Generating Stations, collected off Huntington Beach and inside the Los Angeles-Long Beach Harbor breakwaters, respectively.

One of the target invertebrates selected for analysis was the market squid, *Loligo opalescens,* because of its wide distribution and commercial fishery importance. Large-scale fluctuations are characteristic of the squid stock, due primarily to its short life span and the influence of variations in oceanographic conditions (NMFS 1999). Los Angeles area commercial landings ranged between 7.7 and 44.8 million kg (16.9 and 98.8 million pounds) annually from 2000–2006 with both the total catch and market value increasing substantially during the last two years (PacFIN 2007). No squid larvae were collected in entrainment samples, but an estimated 600 squid with a combined weight of 20.2 kg (44.7 lbs) were impinged at the AGS in 2006. This is very small compared to the annual take from the commercial fishery, which has grown over recent years to be the largest fishery in California.

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 are wide-ranging. Most have a directed commercial or sport fishery and their populations are generally sensitive to large-scale oceanographic influences. The changes in abundance that appear to fluctuate in response to ocean conditions indicate that the effects of impingement or entrainment are probably not significant since power plant impacts would occur as a long-term downward trend in abundance. Since the AGS is located in Alamitos Bay it does not affect this habitat directly and given the wide distributions of most of the component species, including distributions in other habitats where they are not as susceptible to CWIS effects, there is no indication that the facility adversely impacts these populations. Three coastal pelagic fishes (Pacific sardine, Pacific chub mackerel, and jack mackerel) and one invertebrate (market squid) were included in the assessment because they are under federal management. All were collected in very low numbers during the IM&E sampling, mainly because of their primarily offshore distribution.

6.3.5 Shelf Habitats

Shelf habitats include several different habitats from Allen and Pondella (2006b) 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 California halibut (*Paralichthys californicus*), bay goby (*Lepidogobius lepidus*), California tonguefish (*Symphurus atricaudus*), bigmouth sole (*Hippoglossina stomata*), hornyhead turbot (*Pleuronichthys verticalis*), and California skate (*Raja inornata*) (Allen and Pondella 2006b). Fishes characteristic of the outer shelf and slope include plainfin midshipman (*Porichthys notatus*), Pacific sanddab (*Citharichthys stigmaeus*), pink seaperch (*Zalembius roscaceus*), curlfin turbot (*Pleuronichthys decurrens*), Dover sole (*Microstomus pacificus*), longspine thornyhead (*Sebastolobus altivelis*), and California grenadier (*Nezumia stelgidolepis*) (Allen and Pondella 2006b).

While the shelf species are treated in this assessment as an assemblage, it is apparent that the only potential impacts from AGS entrainment and impingement would occur to fishes that inhabit the inner shelf close to shore. As pointed out by Allen (2006) the inner shelf is also more subject to highly variable ocean conditions caused by runoff, pollution, etc. Although this would increase the potential for impacts to these species, the location of the AGS intakes inside Alamitos Bay reduces the potential impacts to these species. As a result, the estimated effects of entrainment and impingement on the fishes from shelf habitats were low relative to species from other habitat types that occur in the vicinity of the intake. None of the species assessed from the IM&E sampling occurred primarily in the shelf habitats (Table 6.1-1).

6.3.6 Deep Pelagic Habitats

Deep pelagic habitats include several different habitats described by Allen and Pondella (2006b) 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 (*Merluccius productus*), splitnose rockfish (*Sebastes diploproa*), rex sole (*Glyptocephalus zachirus*), sablefish (*Anoplopoma fimbria*), blackgill rockfish (*S. melanostomus*), and shortspine thornyhead (*Sebastolobus alascanus*). Several different species of rockfishes dominate the fish assemblages on the deep reef, shelf and canyon habitats including bocaccio (*Sebastes paucispinis*), chilipepper (*S. goodei*), and greenspotted (*S. chlorostichus*), greenstriped (*S. elongatus*), rosethorn (*S. helvomaculatus*), and pinkrose (*S. simulator*) rockfishes. Fishes characteristic of open ocean pelagic habitats include swordfish (*Xiphias gladius*), striped marlin (*Tetrapturus audax*), several species of shark, albacore (*Thunnus alalunga*), and bluefin (*T. thynnus*), bigeye (*T. obesus*), and yellowfin tuna (*T. albacares*). 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. As a result, the estimated effects of entrainment and impingement on the fishes from deep pelagic habitats were low relative to species from other habitat types that occur in the vicinity of the intake. None of the species assessed from the IM&E sampling occurred primarily in the deep pelagic habitats (Table 6.1-1); therefore there is a very low probability that CWIS impacts from AGS would impact species from this habitat.

6.4 CONCLUSIONS AND DISCUSSION

Impacts to SCB fish and invertebrate populations caused by the entrainment of planktonic larvae through the AGS CWIS can only be assessed indirectly through modeling. The estimates from these models can be added to impingement estimates of juvenile and adult losses to estimate the total losses due to the operation of the AGS CWIS. Three taxa (CIQ goby complex, combtooth blennies, and silversides) comprised 94% of all entrained fish larvae. Of these three, only silversides have any direct commercial or recreational fishery value. All of the abundantly entrained species can be considered forage species for larger predatory fishes, sea birds, or marine mammals. Approximately one-third of the different fish taxa entrained belonged to species with some direct fishery value (e.g., anchovies, silversides, croakers, sand basses, and California halibut) even though most of those (except silversides and anchovies) were in very low abundance in the samples and as a result were not assessed for potential impacts.

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 13.3%. The next greatest probabilities of mortality were for combtooth blennies (9.0%) and silversides (8.4%). The spatial extent of the habitats 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 Alamitos Bay, and most larvae were entrained at sizes that indicated they were recently hatched. For example, the silverside mortality estimate resulted from two pulses of larvae entrained in February and May, probably from eggs that had been deposited on dock structures or other substrate in Alamitos Bay. Larvae of gobies and blennies were essentially present throughout the study year. No other fish or invertebrate taxa were modeled for entrainment impacts due to their relatively low abundance in entrainment samples.

The most abundant impinged target taxa in 1978–1980 were Pacific pompano (73.8%), shiner perch (10.7%), and queenfish (8.1%), while in the 2006 samples silversides, shiner perch, and Pacific staghorn sculpin were most abundant. The annual impingement abundance in 2006 was substantially higher than in the previous 316(b) demonstration (1,093 fish per day vs. 203 fish per day). The higher abundance in 2006 largely resulted from higher impingement during/after rain events. During these events, it is likely that fishes in Los Cerritos Channel either become stressed (or perish) due to the influx of fresh water, or the increase in turbidity and debris in the water which could limit visibility and/or interfere with normal physiological processes. The configuration of the AGS cooling water systems has remained largely unchanged since all units went into service, although the cooling water flow in 2006 was likely much less than during the prior study due to reduced operations. Still, changes in impingement and entrainment through time are most likely due to natural biological changes and not due to substantial changes in plant operations.

6.4.1 IM&E Losses Relative to 1977 USEPA AEI Criteria

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.

Fishes in the vicinity of the AGS intake structure in Alamitos Bay are characteristic of the fish assemblages found in other bays and harbors in southern California, as defined by Allen and Pondella (2006b). The structural complexity of Alamitos Bay contributes to the habitat value of the area as a spawning and nursery ground for numerous species. The area in which the AGS intake canals are located is the Los Cerritos Channel within Alamitos Bay, which is a highly modified, dredged embayment that was once part of a natural wetland system. Of the three taxa (CIQ gobies, combtooth blennies, and silversides) that comprised 94% of all entrained larvae, all use embayments as primary spawning and nursery areas. For example, gobies are abundant in quiet-water areas with soft substrates where they inhabit burrows and lay their eggs. Blennies utilize the complex fouling communities on pilings, floating docks, and boat moorings to seek shelter and spawn demersal eggs, while silversides deposit adhesive egg masses to eelgrass or man-made structures. For the abundantly impinged species, size-frequency distributions indicated that most of the topsmelt were small, young-of-the-year fishes, while the unidentified silversides were around one year old. Similar habitat complexity also occurs in the much larger Los Angeles-Long Beach Harbor complex west of Alamitos Bay, and so this type of habitat, although productive, is not unique to the area. Because these species have short life spans and their populations are likely limited by the availability of adult habitat (for gobies and blennies), the additional mortality due to entrainment would not be expected to substantially affect their local populations. Higher levels of entrainment mortality were estimated for gobies at the South Bay Power Plant in south San Diego Bay (Tenera 2004). Although, data from a previous entrainment data and long-term data on adults indicated that the population in south San Diego Bay was stable and not affected by the additional larval mortality due to entrainment, the populations in Alamitos Bay are affected by the operations of both the HnGS and the AGS.

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 AGS intakes are not located with such a corridor, this issue is not of concern for any of the species that were impinged.

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 AGS. This is consistent with past entrainment and impingement sampling conducted at the AGS. Off southern California, species managed under the Magnuson-Stevens Fishery Conservation and Management Act are listed in the Coastal Pelagic Fishery Management Plan (FMP) and the Pacific Groundfish FMP. EFH includes all waters off southern California offshore to the Exclusive Economic Zone. Seven species covered under the two FMPs that occurred in entrainment and/or impingement samples at the AGS are shown in Table 6.4-2.

Table 6.4-2. Fish and shellfish species under NMFS federal management or with CDFG special status entrained and/or impinged at AGS in 2006 based on actual flow volumes.

Species	Common Name	Management Group	Estimated No. Larvae Entrained (millions)	Juveniles/Adults Impinged
Engraulis mordax	northern anchovy	Coastal Pelagics	21.41	8,044
Loligo opalescens	market squid	Coastal Pelagics	-	600
Sardinops sagax	Pacific sardine	Coastal Pelagics	-	389
Scomber japonics	Pac. chub mackerel	Coastal Pelagics	-	17
Trachurus symmetricus	jack mackerel	Coastal Pelagics	-	69
Leuresthes tenuis	California grunion	CDFG	-	75
Hypsypops rubicundus	garibaldi	CDFG	0.10	-

6.4.2 IM&E Losses Relative to Other AEI Criteria

Additional criteria that were evaluated because they were specific to the marine environment around AGS 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).

The criteria of distribution, range, habitat, and population center all need to be considered relative to the magnitude of the effects.

The magnitude of the CWIS losses due to AGS were all relatively low for taxa that are primarily associated with other habitats. Not only were the estimated effects low for these taxa, the broad geographic distributions throughout the SCB for fishes such as northern anchovy, queenfish, Pacific sardine, Pacific chub mackerel, and jack mackerel further reduce the potential for any adverse environmental impacts (AEI). Alamitos Bay is not the source or primary habitat for many of the taxa and is not critical to these populations. Data on some of the fishes from other studies support the conclusion that there is very low risk of AEI due to the AGS CWIS.

This low risk of AEI to these taxa is supported by fish impingement data that has been routinely measured for decades at several coastal power plants in southern California. The same core group of fish species continues to be impinged at these power plants, and there is no measurable effect on fish populations from the operation of the cooling water systems. For species that are harvested commercially, such as northern anchovy, the biomass of fish impinged is orders of magnitude less than annual commercial landings.

These taxa seem to be responding to factors other than power plant impacts and several types of effects over time were found for the species in the detailed evaluation (Table 6.4-3). Anchovies disappeared from the commercial fishery after the regime shift and were essentially absent during the last two decades. Any time series data that extends to before or during this regime shift has evidence of this change. Other fisheries were declining (white croaker) while catch in the fishery independent monitoring programs found them to be either increasing or stable over time. Fisheries that were not declining (queenfish) had some type of positive correlation with ENSOs and/or SST, while the declining fisheries did not. This indicates that the fishing effects may be masking the natural variation for these taxa.

Table 6.4-3. Summary of positive time series findings for fish species in detail evaluation with respect to oceanographic variables (ENSO, SST, and PDO), fishing effects and the current population trends.

Taxon	ENSO	SST	PDO	Fishing Effects	Current Population Trend
Anchovies			Yes	Historic	stable
Silversides			Yes	none	increasing
White croaker				Yes, declining	increasing
Queenfish	Yes, positive	Yes, positive		Yes, stable	stable
Combtooth blennies		Yes, positive	Yes	none	stable

After the faunal shift (i.e., post 1982−1984 El Niño), fishes that would be negatively affected by warming conditions were essentially extirpated from the nearshore environment of the San Pedro Bay area. This period was marked by general low fish productivity (Brooks et al. 2002) until the La Niña of 1999 and the following four-year cool water period. At this point, the catch or density of these stocks appeared to either increase or remain stable through 2006.

Although it seems clear that there is very low risk of any AEI to taxa that are not primarily distributed in Alamitos Bay, the potential risk to the fishes included in the assessment that are primarily distributed in Alamitos Bay and associated with bay and harbor habitats is more difficult to assess. The estimated losses to gobies and blennies, primarily due to entrainment, are large but similar in magnitude to losses from other bays and harbors in southern California. Other data were available from these locations that showed the losses did not represent a significant risk to the populations. Similar data were not available for Alamitos Bay that could be used for assessing the potential for AEI. One factor that reduces the potential risk to these taxa is the abundance of bay and harbor habitat in the areas surrounding Alamitos Bay. Larvae potentially lost due to entrainment at small sizes may be replaced by larvae transported into Alamitos Bay that were spawned in similar habitats which are abundant in the Los Angeles-Long Beach Harbor area potentially reducing the potential for AEI.

The low potential for AEI for most of the taxa entrained and impinged at AGS is consistent with a recent review on population level effects of IM&E on harvested fish stocks (Newbold and Iovanna 2007). They modeled the potential effects of IM&E on populations of 15 East Coast fish stocks that are targeted by either commercial or recreational fisheries using empirical data on entrainment and impingement, life history, and stock size. For 12 of the 15 species, the effects of 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 22.8% 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. They attributed the absence of large effects for most species to compensatory effects 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 greatest potential for AEI at AGS was for gobies, combtooth blennies, and silversides, two of which are small, non-harvested species.

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