FINAL REPORT

EL SEGUNDO GENERATING STATION

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

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for

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LIST OF ABBREVIATIONS AND ACRONYMS

ADCP	acoustic Doppler current profilers
AEL	adult equivalent loss
BMPs	best management practices
BTA	best technology available
CDFG	California Department of Fish and Game
CDS	Comprehensive Demonstration Study
CFS	cubic feet per second
cm	centimeters
cm/s	centimeters per second
CPFV	commercial passenger fishing vessels
CWA	Clean Water Act
CWIS	cooling water intake systems
dph	days post hatch
EAM	equivalent adult model
EFH	Essential Fish Habitat
El.	Elevation (relative to mean sea level)
EPA	United States Environmental Protection Agency
ESGS	El Segundo Generating Station
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
HTP	Hyperion Treatment Plant
in	inches
km	kilometers
LADWP	Los Angeles Department of Water and Power
LARWQCB	Los Angeles Regional Water Quality Control Board
lb	pounds
m	meters
m/s	meters per second
m^3	cubic meters
mgd	million gallons per day
mi	miles
ml	milliliters
MLLW	mean lower low water
mm	millimeters
MSL	mean sea level
mt	metric tons
MWe	megawatts electric
NL	notochord length
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PacFIN	Pacific Fisheries Information Network
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
SGS	Scattergood Generating Station
SL	standard length
SWRCB	State Water Resources Control Board
TL	total length
USFWS	United States Fish and Wildlife Services
YOY	young-of-the-year

1.0 EXECUTIVE SUMMARY

This report presents data from in-plant and offshore field surveys conducted for the El Segundo Power, LLC El Segundo Generating Station (ESGS) Impingement Mortality and Entrainment (IM&E) Characterization Study. This study was designed and conducted to comply with EPA’s 2004 316(b) Phase II regulations. Originally, results from the study were to be used in determining IM&E from once-through cooling, evaluating potential fish protection technologies and operational measures at the facility, scaling potential restoration projects, and/or evaluating the benefits achieved in reducing IM&E at the facility. However, in March 2007, EPA suspended the Phase II regulations and directed administrators to determine compliance with 316(b) on a best professional judgment (BPJ) basis.

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

1. Whether or not an AEI is caused by operaion 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 be to consider the question of BTA only if a determination has been made that a facility is causing an AEI. The purpose of this report is to assess the potential for AEI from the operation of the ESGS cooling water intake system (CWIS). The two primary impacts of a once-through power plant’s CWIS are impingement of juvenile and adult life stages of fishes, shellfishes, and other organisms on screens at the openings to the CWIS, and entrainment of smaller organisms, usually larval forms of fishes and shellfishes, and other forms of plankton, into the CWIS. The information in this report will also be used in the renewal of the National Pollutant Discharge Elimination System (NPDES) permit for the ESGS. This report provides a characterization of the fish and invertebrate species subject to entrainment and impingement at the ESGS, information on the current levels of IM&E at the ESGS, and a discussion on the level of significance of the IM&E losses.

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

- The preliminary results from the IM&E sampling were used to identify 25 taxonomic groups or species of fishes and five taxonomic groups or species of shellfishes that were analyzed in greater detail in this report based on their abundances in the samples or their importance to commercial or recreational fisheries. The process of identifying the group of fishes and shellfishes that were analyzed was done collaboratively with staff from the LARWQCB, California Department of Fish and Game, National Marine Fisheries Service, and local environmental groups.

- The biological data and the actual cooling water flows measured during 2006 from Units 1–4 were used to estimate that 4.2 billion fish eggs, 222 million fish larvae, and 23.7 million target invertebrate larvae were entrained during the year. The majority of entrainment occurred at Units 3 & 4 (82.1% of the total fish eggs, 83.9% of the total fish larvae, and 85.1% of the total invertebrates).
- Data from sampling in the source waters of Santa Monica Bay around ESGS were used to determine the potential effects on larval populations using a model that estimates the additional mortality on a population caused by entrainment. The estimated effects were all very low, generally less than one percent, with the highest estimates occurring for two fishes that are either exclusively, or primarily associated, with bay and harbor habitats not affected by ESGS entrainment.
- The levels of entrainment mortality are far below the levels that might be expected to result in any AEI to the populations, especially since the largest values were estimated for fishes that are not targeted by commercial or recreational fishing which would represent an additional source of mortality that, unlike entrainment, affects reproductively active adult fishes.
- Impingement at ESGS was very low relative to other coastal power plants with similar capacities. At Units 1 & 2 only six fish weighing approximately 1 kg (2 lb) were collected during the 12 surveys, while at Units 3 & 4 a total of 938 fishes representing 47 species and weighing 172 kg (379 lb) was collected over the same period. The estimated annual total impingement based on cooling water flow volumes for Units 1 & 2 was 186 individuals weighing 29 kg (64 lb), while an estimated 1,527 individuals weighing 215 kg (473 lb) was impinged at Units 3 & 4. Four heat treatments at Units 3 & 4 contributed an additional 916 individuals from 45 species weighing 172 kg (378 lb).
- The low level of impingement at ESGS does not represent an AEI to fish or shellfish populations and is directly attributable to the design of the offshore intakes that are fitted with velocity caps that at other similar facilities have been proven to reduce impingement to the range of IM reductions (80-95 %) established in the Phase II Rule.
- No threatened or endangered fish or shellfish were collected during this or previous IM&E sampling at ESGS.

1.1 ENTRAINMENT

Composition and abundance of ichthyoplankton and shellfish larvae entrained by ESGS were determined by monthly sampling with plankton nets in the immediate proximity of the Unit 1 & 2 and Units 3 & 4 cooling water intakes from January 2006 through December 2006.

A total of 4,227 entrainable fish larvae from 66 separate taxonomic categories was collected from the 12 entrainment surveys. The most abundant larval fish taxon in the samples was white croaker, which comprised 23.7% of the total larvae collected, followed by unidentified anchovies (16.5%). A total of 57,248 fish eggs from 19 separate taxonomic categories was also collected from the entrainment surveys.

The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 55.4% of the total eggs collected, followed by sand flounder eggs (17.5%). Approximately half of the species entrained and 80% of the individuals had either sport or commercial fishery value. The greatest concentrations of larval fishes occurred in April and the least in January. Fish eggs also peaked in abundance in April with lows occurring in December. Larvae and eggs were generally more abundant in samples collected at night than those collected during the day. Total annual entrainment from Units 1–4 was estimated to be 4.2 billion fish eggs and 222 million fish larvae using the actual cooling water flows from 2006. Entrainment from Units 3 & 4 accounted for 82.1% of the total fish eggs and 83.9% of the total fish larvae. If Units 3 & 4 had been operated at the design flow volumes (maximum capacity), an estimated 5.8 billion eggs and 277 million larvae could have potentially been entrained at ESGS.

A total of 431 larval target shellfishes (invertebrates) representing 18 taxa was collected from the ESGS entrainment stations during 12 monthly surveys in 2006. The most abundant target invertebrate larvae in the samples was pea crab megalops, followed by kelp crab megalops which made up 30.9% and 25.3%, respectively, of the total target invertebrate larvae collected. Neither taxon has direct fishery value. Of the shellfish with fishery value, only 34 rock crab megalops and a single market squid paralarva (hatchling) were collected. Total annual entrainment was estimated to be 23.7 million target invertebrate larvae for all units combined. Entrainment from Units 3 & 4 accounted for 85.1% of the total target invertebrate larvae entrained annually. If Units 3 & 4 were operated at the design flow volumes (maximum capacity) entrainment estimates increased to 27.4 million larvae.

1.2 SOURCE WATER

To determine composition and abundance of the early life stages of fish and shellfish in the Santa Monica Bay source waters for the ESGS CWIS, sampling was conducted once a month on the same day that the entrainment stations were sampled. The ESGS source water biological sampling boundaries consisted of the waters that parallel the beach approximately 5,000 m (16,400 ft) up coast and 5,000 m downcoast from the generating station and offshore approximately 3,950 m (12,960 ft). The total source water surface area was calculated as 3,696 hectares (14.27 square miles) with a volume of 735,176,993 cubic meters (194,213 million gallons).

A total of 18,941 fish larvae from 87 separate taxonomic categories was collected from the source water stations during the 12 surveys. The most abundant fish larvae in the samples were unidentified anchovies (mostly northern anchovy) (23.4%) followed by white croaker (17.8%). The greatest concentrations of larval fishes occurred from March through June and the lowest were observed in January and February. As was seen at the entrainment station, there were generally more larval fish collected during night sampling than during day sampling.

A total of 3,500 larval target shellfishes (invertebrates) representing 20 taxa was collected from the ESGS source water stations during 12 monthly surveys in 2006–2007. The most abundant target invertebrate larvae in the samples was pea crab megalops followed by kelp crab megalops, which made up 33.4% and 53.1%, respectively of the total target invertebrate larvae collected.

1.3 IMPINGEMENT

Monthly IM&E Characterization impingement surveys were conducted during all 12 months at the ESGS between January 2006 through December 2006. Normal operation impingement surveys (as opposed to surveys done during heat treatment operations) were conducted every month at the ESGS at each of the two screening facilities between January 12 and December 22, 2006. No heat treatments occurred at Units 1 & 2 during the study period, while four heat treatments occurred at Units 3 & 4. Impingment monitoring was conducted during the heat treatments, which occurred on January 12, April 7, June 2, and July 27, 2006.

At Units 1 & 2, a total of only six fish representing two species weighing approximately 1 kg (2 lb) was collected during the twelve surveys, while at Units 3 & 4 a total of 938 fishes representing 47 species and weighing 172 kg (379 lb) was collected over the same period. The estimated annual total impingement based on cooling water flow volumes for Units 1 & 2 was 186 individuals weighing 29 kg (64 lb), while an estimated 1,527 individuals weighing 215 kg (473 lb) were impinged at Units 3 & 4. A total of 22 individuals from nine species weighing one kg (2.2 lb) was recorded during normal operation surveys at Units 3 & 4, which, based on cooling water flows, extrapolated to 611 individuals weighing 43 kg (95 lb) for the year. Four heat treatments at Units 3 & 4 contributed an additional 916 individuals from 45 species weighing 172 kg (378 lb). Approximately 75% of the species and biomass had either sport or commercial fishery value.

A total of 88 shellfish representing 12 species weighing 17 kg (37 lb) was collected during normal operation surveys at Units 1 & 2. Based on cooling water flows these observations extrapolated to an estimated annual impingement of 2,562 shellfish weighing 525 kg (1,157 lb). Pacific rock crab was the most abundant shellfish impinged at Units 1 & 2 (and also contributed most to biomass) with an estimated 1,041 individuals weighing 251 kg (553 lb). Of the 11 remaining species, only intertidal coastal shrimp contributed greater than 10% of the overall abundance with an estimated 605 individuals (23.6%), but only 0.1% of the total biomass with 0.5 kg (1 lb). Three additional shellfish species contributed greater than 10% of the total biomass, or 52 kg (115 lb). These included California spiny lobster with 207 individuals at 126 kg (278 lb), yellow crab with 246 individuals at 66 kg (145 lb), and sheep crab with 68 individuals at 64 kg (142 lb). The remaining eight shellfish taxa contributed less than 11 kg (24 lb) to total biomass.

At Units 3 & 4, 762 individuals representing 21 shellfish species weighing 22 kg (49 lb) were collected during normal operation surveys, which extrapolated to an annual impingement estimate of 14,534 individuals weighing 410 kg (904 lb). An additional 960 shellfish from 17 species weighing 42 kg (93 lb) were collected during the four heat treatments. In total, an estimated 15,494 shellfish weighing 451 kg (994 lb) was impinged during 2006 at Units 3 & 4 based on actual cooling water flows. When the estimates were calculated using the design (maximum) flows for Units 3 & 4, total projected numbers increased to 102,113 individuals with a weight of 2,969 kg (6,545 lb).

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 a reasonable assessment of impacts. The list of taxa was reviewed and approved by all stakeholders and the LARWQCB. The most abundant taxa had the greatest frequency of occurrence among surveys and among stations. 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. The National Marine Fisheries Service requested that all species managed under the Magnuson-Stevens Fishery Conservation and Management Act be included in the impingement results. None of these species were included in the entrainment assessment since they were scarce in entrainment and source water samples. No species listed as threatened or endangered by the state or federal governments were entrained or impinged at the ESGS during the study.

The assessment was primarily done by calculating impingement and entrainment estimates based on CWIS actual and design flow volumes for individual taxa, and then using these results to model the losses to adult and larval source populations using two general modeling approaches and three different models. One approach uses species life history information in two different demographic models to estimate the equivalent number of adults (adult equivalent loss [*AEL*]) or adult females (fecundity hindcasting [*FH*]) lost due to entrainment or impingement.

The other modeling approach was only used with the entrainment data. This model (empirical transport model [*ETM*]) estimates the conditional mortality on a population resulting from entrainment. The demographic model estimates from entrainment and impingement were added together to evaluate the combined effects of the CWIS. The life history information necessary for the demographic modeling was not available for most species so a combined assessment could only be done for northern anchovy.

The assessment included 25 taxonomic groups or species of fishes and five taxonomic groups or species of shellfishes (Tables 1.4-1 through 1.4-3). These taxa were categorized into five habitat types that were simplified from a more detailed categorization of habitats used by Allen and Pondella (2006) (Table 1.4-4). Taxa that occur in more than one habitat were included in the habitat group that best reflected the primary distribution for the taxa. This approach was used because it focused the assessment on the taxa and habitats that were most at risk to CWIS effects.

Taxa that are associated with habitats that are only affected by the transport of larvae out of their native habitat into nearshore areas where they are subject to entrainment are at very low risk of being impacted by the ESGS CWIS. These would include taxa associated with offshore deep-water pelagic habitats (no species included in this analysis) but also protected bay and harbor habitats that occur in Santa Monica Bay. Gobies and blennies both primarily occur in bays and harbors and as a result are at low risk to any CWIS effects even though gobies had the second highest estimated entrainment mortality (Tables 1.4-1 through 1.4-3). Most of the taxa included in the assessment did not have limited habitat associations that would place them at greater risk to CWIS effects. Although a taxon may be limited to a single habitat type, the entire distribution of the population is also important. Therefore, while Pacific sardine and northern anchovy primarily only occur in coastal pelagic habitats they are distributed across large coastal areas. Similarly, sanddabs and English sole that are distributed across broad areas of the shelf are at less risk than shelf species with more limited nearshore distributions.

Although habitat and geographic distribution are important considerations, these factors need to be considered relative to the magnitude of the effects. At ESGS the largest entrainment effects occurred to fish larvae that were transported into the nearshore from other habitats, and the largest impingement effects occurred to fishes with wide geographic distributions (Pacific sardine and northern anchovy) or fishes that occur in several different habitats (queenfish and silversides). It is also important that several of these fishes are not targeted by commercial or recreational fishing that would compound any effects of the CWIS on the population. Based on these criteria the assessment focused on fishes such as queenfish, sand and kelp basses, and California halibut, which are also targeted by sport or commercial fishing. The magnitude of the impacts to these and the other taxa were all relatively low and not at levels that would represent risk of AEI to the populations.

Although it is difficult to determine the magnitude of impact that would result in an AEI, the conclusions from this study were consistent with a recent review on population-level effects on harvested fish stocks (Newbold and Iovanna 2007). They modeled the potential effects of entrainment and impingement on populations of 15 fish stocks that are targeted by either commercial or recreational fisheries by using empirical data on entrainment and impingement, life history, and stock size. For 12 of the 15 species that were modeled, the effects 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 conclusion was 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 ESGS were for two non-harvested fishes (gobies and silversides) that mostly occur in sheltered waters, and these effects were still at low levels that would not represent a risk of AEI to the populations.

Table 1.4-1. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual cooling water flows for all four units (Units 1-4) at ESGS in 2006. Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

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									
Genyonemus lineatus	white croaker	44.37	4.50	0.29	6^{E}		0	–	
Engraulis mordax	northern anchovy	36.59	432.21	0.18	$33{,}850^{C}$	$65{,}013^{L}$	78	1.14	127
Seriphus politus[2]	queenfish	20.90	39.40	0.05			103	2.20	116
Paralabrax spp[3]	sea basses	10.75	4.94	0.33			171	37.14	2,022
Gobiidae unid.	CIQ gobies	8.55	0	1.50	$16{,}328^{L}$	$7{,}012^{L}$	0	–	
Hypsoblennius spp.	combtooth blennies	7.45	0	0.28	$8{,}516^{L}$	$18{,}173^{L}$	81	0.99	
Paralichthys californicus	California halibut	6.87	0.60	0.17	$<1^{E}$		1	0.04	
Citharichthys spp.[4]	sanddabs	4.48	165.39	0.10	$2{,}010^{E}$		15	0.04	
Atherinopsidae unid.[5]	silversides	2.36	0.14	1.78			19	3.06	
Pleuronichthys guttulatus	diamond turbot	2.15	0.14	0.94			0	–	
Parophrys vetulus	English sole	1.69	0	0.08			3	0.01	
Myliobatis californica	bat ray	–	–				96	47.26	
Rhacochilus toxotes	rubberlip seaperch	–	–				130	8.24	
Chromis punctipinnis	blacksmith	0	0				223	7.48	
Cheilotrema saturnum	black croaker	2.89	0				20	5.20	83
Rhacochilus vacca	pile perch	–	–				30	4.98	
Phanerodon furcatus	white seaperch	–	–				65	4.07	
Sebastes auriculatus	brown rockfish	0	0				7	2.40	
Hyperprosopon argenteum	walleye surfperch	–	–				34	2.04	
Trachurus symmetricus	jack mackerel	0	0				11	1.40	
Scomber japonicus	pacific chub mackerel	0	0				5	1.04	
Scorpaena guttata	California scorpionfish	0	0				170	30.82	
Cymatogaster aggregata	shiner perch	–	–				98	0.40	
Sardinops sagax	pacific sardine	0.07	0				10	0.14	
Sebastes miniatus	vermilion rockfish	0	0				3	0.02	

(table continued)

Table 1.4-1 (continued). Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual cooling water flows for all units at ESGS 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]
Invertebrates									
Cancer spp.[6]	cancer crabs	1.86	–				12,584	717.90	
Panulirus interruptus	spiny lobster	0.27	–				332	164.70	
Loxorhynchus grandis	sheep crab	–	–				68	64.41	
Octopus spp.	two-spot octopus	–	–				70	10.63	
Loligo opalescens	market squid	0.05	–				63	1.17	

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[1] standardized impingement adult equivalent mortality

[2] larval entrainment estimate includes queenfish and unidentified croakers combined120

[3] only kelp bass collected in abundance in impingement samples

[4] only speckled sanddab identified in impingement samples

[5] only jacksmelt collected in abundance in impingement samples

[6] megalops larvae for entrainment; only yellow and Pacific rock crabs collected in abundance in impingement samples

Table 1.4-2. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual cooling water flows for Units 3 & 4 only at ESGS in 2006. Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

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									
Genyonemus lineatus	white croaker	36.87	3.32	0.24	4^{E}		0	–	
Engraulis mordax	northern anchovy	30.81	363.48	0.15	$25{,}490^{C}$	$54{,}737^{L}$	78	1.14	127
Seriphus politus[2]	queenfish	18.10	31.60	0.04			103	2.20	116
Paralabrax spp[3]	sea basses	8.93	4.11	0.27			171	37.14	2,022
Gobiidae unid.	CIQ gobies	7.0	0	1.22	$13{,}360^{L}$	$5{,}737^{L}$	0	–	
Hypsoblennius spp.	combtooth blennies	6.18	0	0.23	$7{,}064^{L}$	$15{,}074^{L}$	81	0.99	
Paralichthys californicus	California halibut	5.87	0.45	0.14	$<1^{E}$		1	0.04	
Citharichthys spp.[4]	sanddabs	3.74	131.27	0.08	$1{,}594^{E}$		15	0.04	
Atherinopsidae unid.[5]	silversides	1.84	0.12	1.38			19	3.06	
Pleuronichthys guttulatus	diamond turbot	1.29	0	0.54			0	–	
Parophrys vetulus	English sole	1.37	0	0.06			3	0.01	
Myliobatis californica	bat ray	–	–				96	47.26	
Rhacochilus toxotes	rubberlip seaperch	–	–				130	8.24	
Chromis punctipinnis	blacksmith	0	0				189	5.23	
Cheilotrema saturnum	black croaker	2.53	0				20	5.20	83
Rhacochilus vacca	pile perch	–	–				30	4.98	
Phanerodon furcatus	white seaperch	–	–				65	4.07	
Sebastes auriculatus	brown rockfish	0	0				7	2.40	
Hyperprosopon argenteum	walleye surfperch	–	–				34	2.04	
Trachurus symmetricus	jack mackerel	0	0				11	1.40	
Scomber japonicus	pacific chub mackerel	0	0				5	1.04	
Scorpaena guttata	California scorpionfish	0	0				18	4.34	
Cymatogaster aggregata	shiner perch	–	–				98	0.40	
Sardinops sagax	pacific sardine	0.06	0				10	0.14	
Sebastes miniatus	vermilion rockfish	0	0				3	0.02	

(table continued)

Table 1.4-2 (continued). Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual cooling water flows for Units 3 & 4 only at ESGS 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]
Invertebrates									
Cancer spp. [6]	cancer crabs	1.58	–				11,297	401.89	
Panulirus interruptus	spiny lobster	0.23	–				125	39.00	
Loxorhynchus grandis	sheep crab	0	–				0	–	
Octopus spp.	two-spot octopus	–	–				6	0.08	
Loligo opalescens	market squid	0.04	–				29	0.73	

[1] standardized impingement adult equivalent mortality

[2] larval entrainment estimate includes queenfish and unidentified croakers combined

[3] only kelp bass collected in abundance in impingement samples

[4] only speckled sanddab identified in impingement samples

[5] only jacksmelt collected in abundance in impingement samples.

[6] megalops larvae for entrainment; only yellow and Pacific rock crabs collected in abundance in impingement samples

Table 1.4-3. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on design (maximum) cooling water flows for Units 3 & 4 only at ESGS in 2006. Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

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									
Genyonemus lineatus	white croaker	57.67	9.07	0.42	10^E		0	–	
Engraulis mordax	northern anchovy	44.57	529.01	0.22	41,270^C	79,188^L	78	1.14	127
Seriphus politus[2]	queenfish	21.60	60.90	0.05			103	2.20	116
Paralabrax spp[3]	sea basses	14.39	6.57	0.50			348	39.62	2,022
Gobiidae unid.	CIQ gobies	12.04	0	2.21	22,992^L	9,874^L			
Hypsoblennius spp.	combtooth blennies	9.93	0	0.40	11,346^L	24,211^L	666	7.39	
Paralichthys californicus	California halibut	7.79	1.18	0.24	2^E		1	0.04	
Citharichthys spp.[4]	sanddabs	5.70	264.88	0.15	3,218^E		15	0.04	
Atherinopsidae unid.[5]	silversides	4.15	0.16	3.19			19	3.06	
Pleuronichthys guttulatus	diamond turbot	6.77	0	3.09					
Parophrys vetulus	English sole	2.42	0	0.11			3	0.01	
Myliobatis californica	bat ray	–	–				123	58.02	
Rhacochilus toxotes	rubberlip seaperch	–	–				134	8.28	
Chromis punctipinnis	blacksmith	0	0				282	5.54	
Cheilotrema saturnum	black croaker	2.77	0				20	5.20	83
Rhacochilus vacca	pile perch	–	–				30	4.98	
Phanerodon furcatus	white seaperch	–	–				69	4.09	
Sebastes auriculatus	brown rockfish	0	0				7	2.40	
Hyperprosopon argenteum	walleye surfperch	–	–				34	2.04	
Trachurus symmetricus	jack mackerel	0	0				11	1.40	
Scomber japonicus	pacific chub mackerel	0	0				5	1.04	
Scorpaena guttata	California scorpionfish	0	0				18	4.34	
Cymatogaster aggregata	shiner perch	–	–				98	0.40	
Sardinops sagax	pacific sardine	0.77	0				10	0.14	
Sebastes miniatus	vermilion rockfish	0	0				3	0.02	

(table continued)

Table 1.4-3 (continued). Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on design (maximum) cooling water flows for Units 3 & 4 only at ESGS 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]
Invertebrates									
Cancer spp. [6]	cancer crabs	2.21	–				81,594	2,867.52	
Panulirus interruptus	spiny lobster	0.26	–				149	43.57	
Loxorhynchus grandis	sheep crab	0	–				0	–	
Octopus spp.	two-spot octopus	–	–				6	0.08	
Loligo opalescens	market squid	0.06	–				68	1.70	

[1] standardized impingement adult equivalent mortality

[2] larval entrainment estimate includes queenfish and unidentified croakers combined

[3] only kelp bass collected in abundance in impingement samples; EAM not extrapolated for design flows due to small sample size

[4] only speckled sanddab identified in impingement samples

[5] only jacksmelt collected in abundance in impingement samples.

[6] megalops larvae for entrainment; only yellow and Pacific rock crabs collected in abundance in impingement samples

Table 1.4-4. Habitat associations for taxa included in assessment of CWIS effects at the ESGS. Primary habitat in bold, upper case and secondary habitat in lower case. Taxa also designated as to whether they are targeted by a sport (S) or commercial (C) fishery.

		Fishery	**Habitats**			
Scientific name	**Common name**	**S-Sport C-Comm.**	**bays, harbors**	**reefs, kelp beds**	**coastal pelagic**	**shelf**
Atherinopsidae unid.	silversides	S, C	x		**X**	
Citharichthys spp.	sanddabs	S, C	x			**X**
Cheilotrema saturnum	black croaker	S		**X**	x	
Chromis punctipinnis	blacksmith	S		**X**		
Cymatogaster aggregata	shiner perch	S	**X**	x		
Engraulidae unid.	anchovies	C			**X**	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Gobiidae unid.	CIQ goby complex		**X**			
Hyperprosopon argenteum	walleye surfperch		x		**X**	
Hypsoblennius spp.	combtooth blennies		**X**	x		
Myliobatis californica	bat ray		**X**	x		
Paralabrax spp.	sand and kelp bass	S	x	**X**		
Paralichthys californicus	California halibut	S	x			**X**
Parophrys vetulus	English sole	C				**X**
Phanerodon furcatus	white seaperch	S	**X**	x		x
Pleuronichthys guttulatus	diamond turbot	S	x			**X**
Rhacochilus toxotes	rubberlip seaperch	S		**X**		x
Rhacochilus vacca	pile perch	S		**X**		
Sciaenidae unid.	croakers	S, C			**X**	x
Scorpaena guttulata	California scorpionfish	S		**X**		x
Seriphus politus	queenfish	S			**X**	x
Cancer spp	cancer crabs	S	x	x		**X**
Loligo opalescens	market squid	S			**X**	
Loxorhynchus grandis	sheep crab	C		**X**		x
Octopus spp.	two-spot octopus	C	x	**X**		
Panulirus interruptus	California spiny lobster	S		**X**		

2.0 INTRODUCTION

The El Segundo Generating Station (ESGS) is a fossil-fueled steam electric power generating station that is owned and operated by El Segundo Power, LLC (ESP) and is located in the in the City of Los Angeles on the shore of Santa Monica Bay. ESGS uses a once-through cooling water system for all four of its generating units with a maximum cooling water flow of 207.4 million gallons per day (mgd) for Units 1 & 2, and 398.6 mgd for Units 3 & 4. Two intake risers draw cooling water from approximately 700 meters (m) (2,600 feet [ft]) offshore. After passing through the plant, the cooling water is discharged back into Santa Monica Bay through separate discharge pipes that are approximately 600 m (2,000 ft) offshore and parallel to the intakes.

Cooling water intake systems (CWIS) are regulated under §316(b) of the federal Clean Water Act (CWA). In July 2004, the U.S. Environmental Protection Agency (EPA) published 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 system for ESGS, it was subject to these new regulations that required submittal of a comprehensive plan for compliance by January 2008. The new regulations were challenged by a coalition of environmental groups and the case was heard by the Second U.S. Circuit Court of Appeals. The court rendered a decision in January 2007 that remanded several key components of the regulations back to the EPA. In March 2007 the EPA issued a memorandum suspending the rule and directing that all permits for Phase II facilities implement 316(b) on a case-by-case basis using “best professional judgment” (BPJ). The language of the memorandum was expanded and published in the Federal Register in July 2007 (Volume 72, 130:37107-37109).

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

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 Clean Water Act (CWA) for cooling water intake structures (CWIS) that apply to existing facilities (Phase II facilities). The Phase II Final Rule went into effect in September 2004, and applies to existing generating stations with CWIS that withdraw at least 50 mgd from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. The cooling water system for the existing ESGS in Los Angeles, California withdraws a combined maximum of 207.4 million gallons of seawater per day (mgd) for Units 1 & 2, and 398.6 mgd for Units 3 & 4.

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

1. Has a capacity utilization rate of less than 15%;
2. Withdraws cooling water from a lake or reservoir, excluding the Great Lakes; or
3. Withdraws less than 5% of the mean annual flow of a freshwater river or stream.

Based on previously collected intake velocity measurements and plant operating characteristics, both of the IM&E components of the study were required at the ESGS. Previous §316(b) studies were done for ESGS in 1980 (SCE 1982b) using a study plan that focused on representative important species that were identified in cooperation with staff from the LARWQCB and the California Department of Fish and Game. A detailed summary of the historical IM&E studies is provided in Section 4.4. Due to the time period since the original data were collected, a Study Plan for new IM&E studies was submitted as part of the §316(b) Proposal for Information Collection (PIC) to the LARWQCB in October 2005.

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

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

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

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

For entrained and juvenile species the analysis will provide estimates of adult losses for a representative set of commercial and recreational species. For forage species, estimates of the reductions to commercial and recreational species will be made due to the reduction in biomass as a result of impingement and entrainment. Demonstrating no significant risk of AEI would be a technically sound basis to defer requirements for reducing impingement and/or entrainment until issues with the Phase II Rule are resolved. The rationale and approach for the AEI assessment in this report and the results and conclusions from our analysis are provided in Section 6.0.

2.1.2 Development of the Study Plan

The ESGS IM&E Characterization Study Plan was developed in 2005 by Tenera Environmental and MBC Applied Environmental Sciences. The Study Plan was designed to provide the biological information necessary to fulfill all pertinent 316(b) Phase II requirements, and was based on recent entrainment and impingement studies performed in California in recent years for California Energy Commission relicensing studies (such as those at the Huntington Beach, Morro Bay, Moss Landing, and South Bay Power Plants), and 316(b) demonstrations (such as at the Diablo Canyon Power Plant and Encina Power Station). 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), California Department of Fish and Game (CDFG), National Marine Fisheries Service, U.S. Fish and Wildlife Service (USFWS), and consultants.

The Study Plan was submitted to the LARWQCB in October 2005 as part of the PIC. El Segundo Power, LLC and its consultants subsequently met with the LARWQCB to review the Study Plan and address comments in December 2005. Changes that were made to the Study Plan included:

- An agreement to identify and enumerate all fish eggs (to the extent practicable) from entrainment sampling; and
- An agreement to identify and enumerate all crab megalopae (to the extent practicable) from entrainment sampling.

2.1.3 Study Plan Objectives

Under the Phase II §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 LARWQCB with considerable latitude in determining the level of detail necessary in meeting these objectives and stated 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 CDS is based on a specific technology or site-specific standard, 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.

The data collected from the study will be used in developing a characterization of baseline levels of IM&E for ESGS 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 ESGS CWIS does not conform to the calculation baseline. Significant deviations from the calculation baseline are:

- The intakes are located approximately (792 m) 2,600 ft offshore from the power plant rather than on the shoreline;
- The intakes are submerged rather than at or near the surface; and
- The intakes have velocity caps that result in the cooling water being drawn horizontally from depth rather than vertically through the water column.

The Phase II regulations allowed facilities to take credit for deviations from the calculation baseline if it can be demonstrated that these deviations provided 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.

Another objective of the study was to provide data that could be used in meeting different alternatives for Phase II compliance that might be used by ESP. 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 ESGS were designed to examine losses resulting from both impingement of juvenile and adult fishes and shellfishes on traveling screens at the intake during normal operations and heat treatments and from entrainment of larval fishes and shellfishes into the CWIS. 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, in preparation). 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 academic institutions and environmental organizations.

Impingement sampling during heat treatment operations at the ESGS has been conducted since the 1970s. The existing National Pollutant Discharge Elimination System (NPDES) permit for the plant requires sampling during all heat treatment procedures. The impingement methods used in the current study include continued sampling during heat treatments, but bi-weekly sampling over a 24-hour period is also done 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 Phase II §316(b) regulations. Since the use of restoration will not be allowed under the Court decision, the entrainment data will be used in baseline calculations of losses that would be required to estimate the commercial and recreational values of adult fish losses. Larval fish and shellfish abundances vary throughout the year and, therefore, monthly sampling was used for characterizing entrainment. If the restoration option is still available as a result of State action or further changes to the Phase II rule, 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, concurrent source water sampling was also done monthly, which is consistent with the sampling frequency for other recently completed studies in southern California.

2.2 REPORT ORGANIZATION

The remainder of this report is organized as follows. Section 3.0 includes a detailed description of the ESGS and CWIS. Data on circulating water pump flows from the study period are presented and discussed as these are the data used in calculating estimates of IM&E presented in other sections of the report. Section 3.0 also includes a description of the environmental setting for the plant including the physical oceanographic data used to support the boundaries of the source water potentially affected by the plant's CWIS. The methods and results for the entrainment and source water sampling are presented in Section 4.0 and the methods and results for the impingement sampling are presented in Section 5.0. The results from the entrainment and impingement sampling are integrated into an overall impact assessment for the ESGS CWIS in Section 6.0. The references used in the report are presented in Section 7.0. Appendices include study procedures and detailed summaries of the entrainment, source water, and impingement data.

2.3 CONTRACTORS AND RESPONSIBILITIES

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

- Tenera Environmental
    - Study design
    - Physical oceanographic data collection and analysis
    - Field sampling QA/QC
    - Entrainment/source water laboratory processing
    - Entrainment data entry and analysis
    - Reporting
- MBC *Applied Environmental Sciences*
    - Study design
    - Field sampling
    - Impingement Mortality data entry and analysis
    - Reporting

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

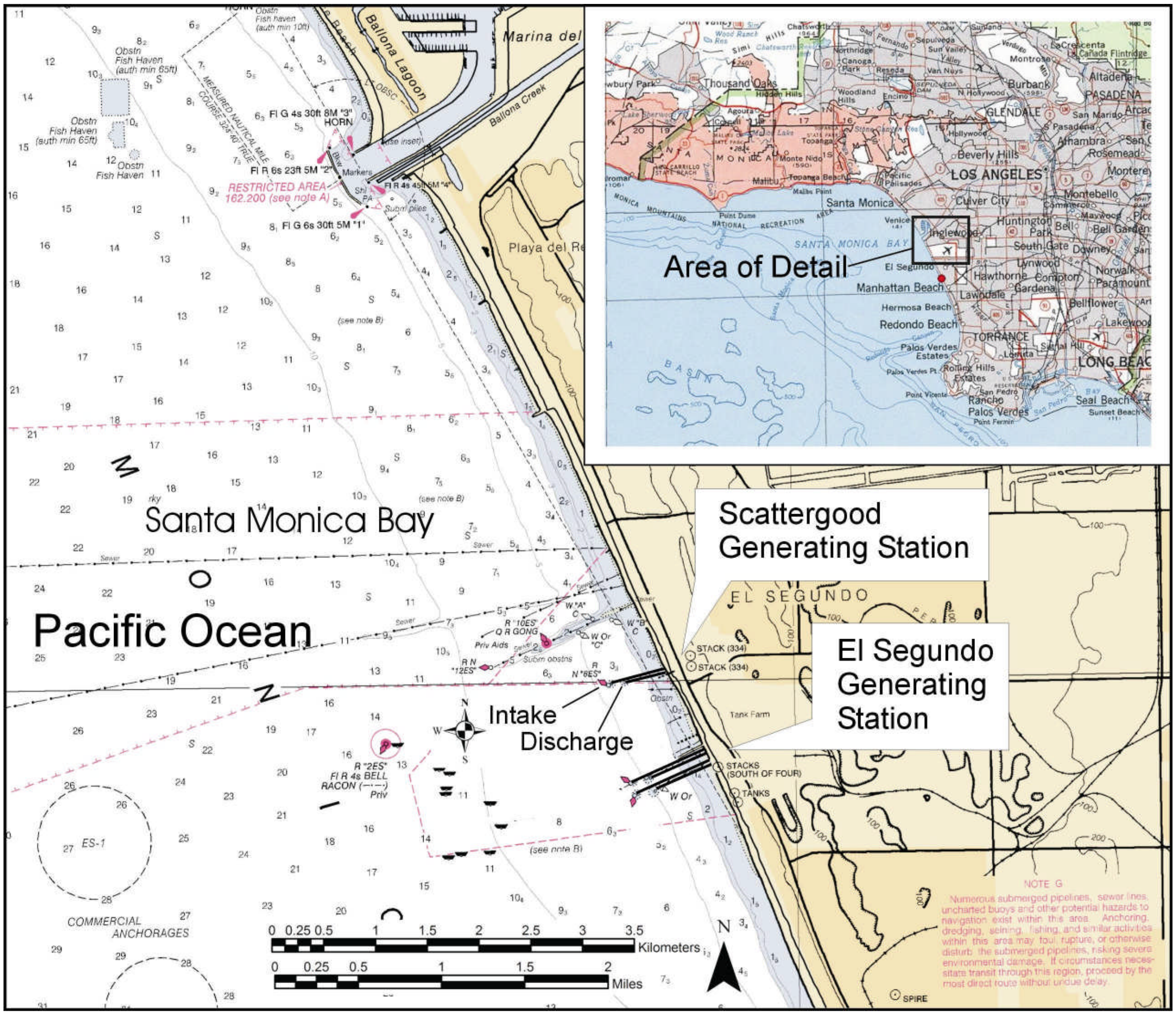
3.0 DESCRIPTION OF THE GENERATING STATION AND CHARACTERISTICS OF THE SOURCE WATER BODY

3.1 DESCRIPTION OF THE GENERATING STATION

The ESGS is located in the city of El Segundo, California, on the Santa Monica Bay on the Pacific Ocean (Figures 3.1-1 and 3.1-2). The facility is owned by El Segundo Power, LLC (ESP) and consists of four steam electric generating units. Units 1 & 2 are each rated at 175 megawatts (MWe) and Units 3 & 4 are each rated at 335 MWe for a total design capacity of 1,020 MWe. A repowering project, El Segundo Power Redevelopment (ESPR), will replace Units 1 & 2 with a new combined-cycle power facility (Units 5, 6, 7, and 8) that will not use ocean water for cooling. The following is a description of the facility and the Santa Monica Bay, from which the ESGS withdraws water for cooling purposes. A description of the design and operation of the CWIS and the rate of withdrawal of cooling water relative to the source waterbody is also included.

Photo credit: California Coastal Records Project

Figure 3.1-1. El Segundo Power Plant aerial view looking east. Units 1 & 2 are on the left side of the image (north) and Units 3 & 4 are on the right (south).



NOTE G
Numerous submerged pipelines, sewer lines, uncharted buoys and other potential hazards to navigation exist within this area. Anchoring, dredging, seining, fishing, and similar activities within this area may foul, rupture, or otherwise disturb the submerged pipelines, risking severe environmental damage. If circumstances necessitate transit through this region, proceed by the most direct route without undue delay.

Figure 3.1-2. Location of the ESGS, with the location of nearby Scattergood Generating Station also shown.

3.2 DESCRIPTION OF THE COOLING WATER INTAKE SYSTEM

Each of the four ESGS generating units utilizes a once-through cooling water system. Cooling water is supplied from the Santa Monica Bay through two separate submerged offshore intake systems equipped with velocity caps. One intake services Units 1 & 2, with a second intake servicing Units 3 & 4. Each CWIS includes onshore pump and screen structures. Characteristics and specifications of the two CWIS are presented in Table 3.2-1. A narrative description of each of the CWIS follows.

Table 3.2-1. Characteristics and design of the ESGS cooling water intake structure

	Units 1 & 2	Units 3 & 4
Design flow	144,000 gpm; (207.4 mgd)	276,800 gpm; (398.6 mgd)
Distance from sea wall	2,600 ft	2,600 ft
Depth of withdrawal (MLLW)	- 17.2 ft	- 15 ft
Velocity cap – height above bottom	12 ft	12 ft
Intake conduit (internal diameter)	10 ft	12 ft
Number of circulating water pumps	4	4
Pump capacity (per pump)	36,000 gpm	69,200 gpm
Trash bar opening	4 ½ inch	3 5/8 inch
Number of traveling water screens	4	4
Screen type	Conventional	Conventional
Screen opening	3/8 inch	5/8 inch
Screen height (in water, high tide)	14 ft	14 ft
Approach velocity (calculated)	0.8 ft/s	0.8 ft/s
Through-screen velocity (calculated)	1.8 ft/s	2.0 ft/s
Screen rotation	Manual – 8 min/12 hrs Auto – based on ΔDP	Manual – 8 min/12 hrs Auto – based on ΔDP
Screenwash pressure	70 psig	70 psig

3.2.1 Units 1 & 2 CWIS

Cooling water for Units 1 & 2 is withdrawn from the Santa Monica Bay via a single CWIS serving both units. Cooling water is withdrawn through a velocity cap inlet located approximately 698 m (2,289 ft) from the shoreline (Figure 3.2-1). The bottom of cooling water inlet is located at a depth of –3.7 m (12 ft) MLLW above the bottom of the Santa Monica Bay and is equipped with a velocity cap that withdraws cooling water through a 0.6 m (2 ft) deep opening (Figure 3.2-2). The top of the velocity cap is at a depth of approximately 5.2 m (17 ft) below the water surface at mean lower low water (MLLW). The circulating water flow is conveyed to the onshore screen well structure via a concrete pipe with an internal diameter of 3.1 m (10 ft).

Water entering the screen well structure passes through a trash rack that removes larger debris from the cooling water before it enters the traveling screens. The trash rack removes larger debris from the cooling water before it enters the traveling screens. There are four conventional traveling screens (two per unit), each with 1.0 cm (3/8 inch) mesh (Figure 3.2-3). There are no fish handling or return systems. Cooling water is discharged approximately 580 m (1,900 ft) offshore via a 3.1 m (10 ft) diameter discharge pipe (Figure 3.2-1).

3.2.2 Units 3 & 4 CWIS

The cooling water intake for Units 3 & 4 is very similar to that for Units 1 & 2. Cooling water for Units 3 & 4 is withdrawn from the Santa Monica Bay via a single CWIS serving both units. Cooling water is withdrawn through a velocity cap inlet located approximately (701 m) 2,300 ft from the shoreline

(Figure 3.2-1). The bottom of the cooling water inlet is located at a depth of approximately 3.1 m (10 ft) above the bottom of the Santa Monica Bay (Figure 3.2-2). The top of the velocity cap is located at a depth of approximately 4.9 m (16 ft) below MLLW. Water is drawn through an approximately 0.9 m (3 ft) deep opening. The circulating water flow is conveyed to the onshore screen well structure via a concrete pipe with an internal diameter of 3.7 m (12 ft).

Water entering the screen well structure passes through a trash rack that removes larger debris from the cooling water before it enters the traveling screens. There are four conventional traveling screens (two per unit) with 1.6 cm (5/8 inch) mesh (Figure 3.2-3). There are no fish handling or return systems. Cooling water is discharged approximately 640 m (2,100 ft) offshore via a 3.7 m (12 ft) diameter discharge pipe.

3.2.3 Intake Velocity Caps

The intakes for both sets of units are fitted with velocity caps that direct the intake flow horizontally rather than vertically through the water column (Figure3.2-2). Velocity caps reduce impingement by drawing in cooling water horizontally rather than vertically through the water column. Fishes are better able to detect and respond to horizontal flows than vertical flows. The velocity caps were installed after tests at ESGS showed a reduction in impingement of 95% between July 1956 through June 1957 prior to velocity cap installation when 272.2 tons were impinged to July 1957 to June 1958 after the velocity cap was installed when to 14.95 tons were impinged (Weight 1958). Model studies for the design of the Huntington Beach Generating Station (HBGS) intake and extensive field studies at HBGS and Ormond Beach Generating Station by the University of Washington verified the effectiveness of the velocity cap design (Thomas et al. 1980). More recent studies in 2006 at the Scattergood Generating Station also showed the effectiveness of this intake design for reducing impingement (MBC and Tenera unpubl. data).

3.3 COOLING WATER INTAKE STRUCTURE OPERATION

3.3.1 Units 1 & 2 CWIS

Units 1 & 2 ceased commercial operation on January 1, 2003. The CWIS remains in service and circulating water pumps operate to support other facility requirements. The four circulating water pumps at the Units 1 & 2 CWIS have a total capacity of 785,094 m^3 per day (207.4 mgd). Currently, one to two pumps typically remain in operation, for a total intake flow of 196,084–392,547 m^3/day (51.8–103.7 mgd).

Traveling screens are rotated at least twice per day to remove impinged debris, which may include aquatic organisms. A screen-wash is generally initiated by operations personnel once per 12-hour shift. Screens are rotated for 8 minutes, and are washed with water at a pressure of 70 pounds per square inch gauge (psig). Screens are also rotated automatically if there is a substantial increase in the differential pressure across the screens. Fish and debris removed from the screens are washed into a collection basket in the screenwash sluiceway. The baskets are emptied into the trash by plant staff.

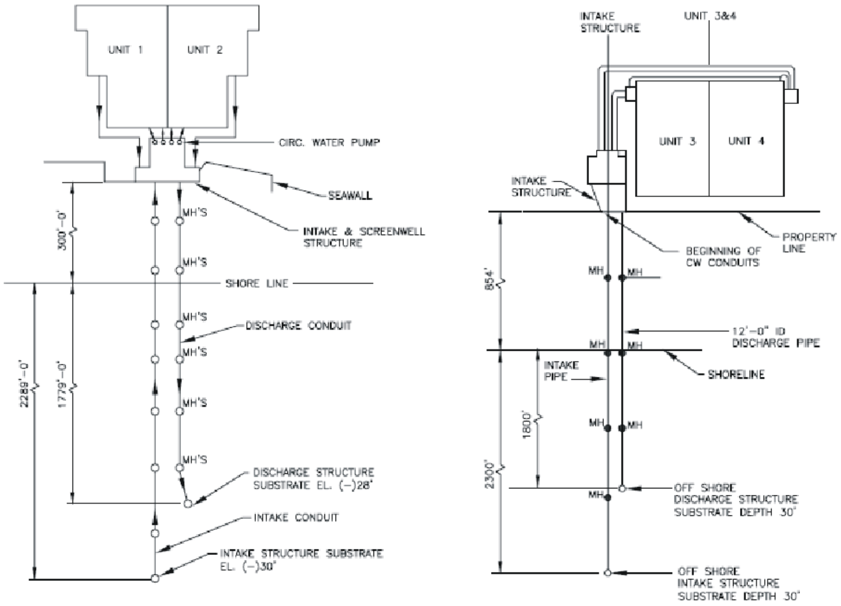
The ESPR Project will replace Units 1 & 2 with a new combined-cycle power facility made up of four generating units (Units 5, 6, 7, and 8). Units 5 & 7 will be gas turbine generators, while Units 6 & 8 will be steam turbines. The units will use a closed-loop fin-fan type cooling system that will not use ocean water.

3.3.2 Units 3 & 4 CWIS

The Units 3 & 4 generating units are fully operational and utilize a separate CWIS. The four circulating water pumps (two per unit) at the Units 3 & 4 CWIS have a total capacity of 1.51 million m^3 per day (398.6 mgd). When both units are operated at full loads, both circulating water pumps are operated for each unit.

Traveling screens are rotated at least twice per day to remove impinged debris, which may include aquatic organisms. A screen-wash is initiated by operations personnel once per 12-hour shift. Screens are rotated for 8 minutes, and are washed with water at a pressure of 70 psig. Screens are also rotated automatically if there is a substantial increase in the differential pressure across the screens. Fish and debris removed from the screens are washed into a collection basket, which is emptied into the trash by plant staff.

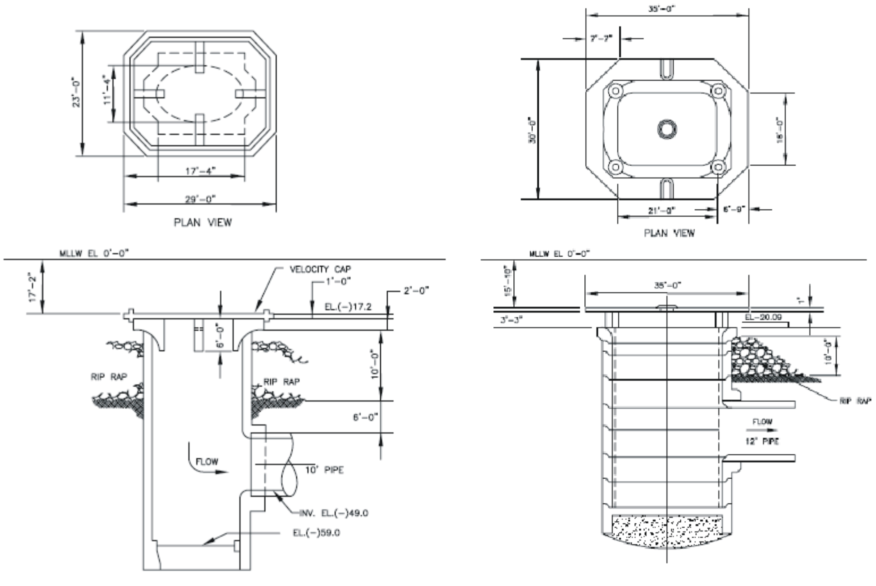
Marine growth in the cooling water system conduits for Units 3 & 4 is periodically controlled by conducting heat treatment procedures to remove mussels, barnacles, and other organisms that gradually encrust the conduit walls. The intake and discharge flows are reversed to discharge the warmer condenser effluent through the cooling water intake conduit to thermally shock and dislodge fouling organisms.



ESGS Units 1 & 2

ESGS Units 3 & 4

Figure 3.2-1. Cooling water intake and discharge piping layout.



ESGS Units 1 & 2

ESGS Units 3 & 4

Figure 3.2-2. Velocity cap inlet detail.

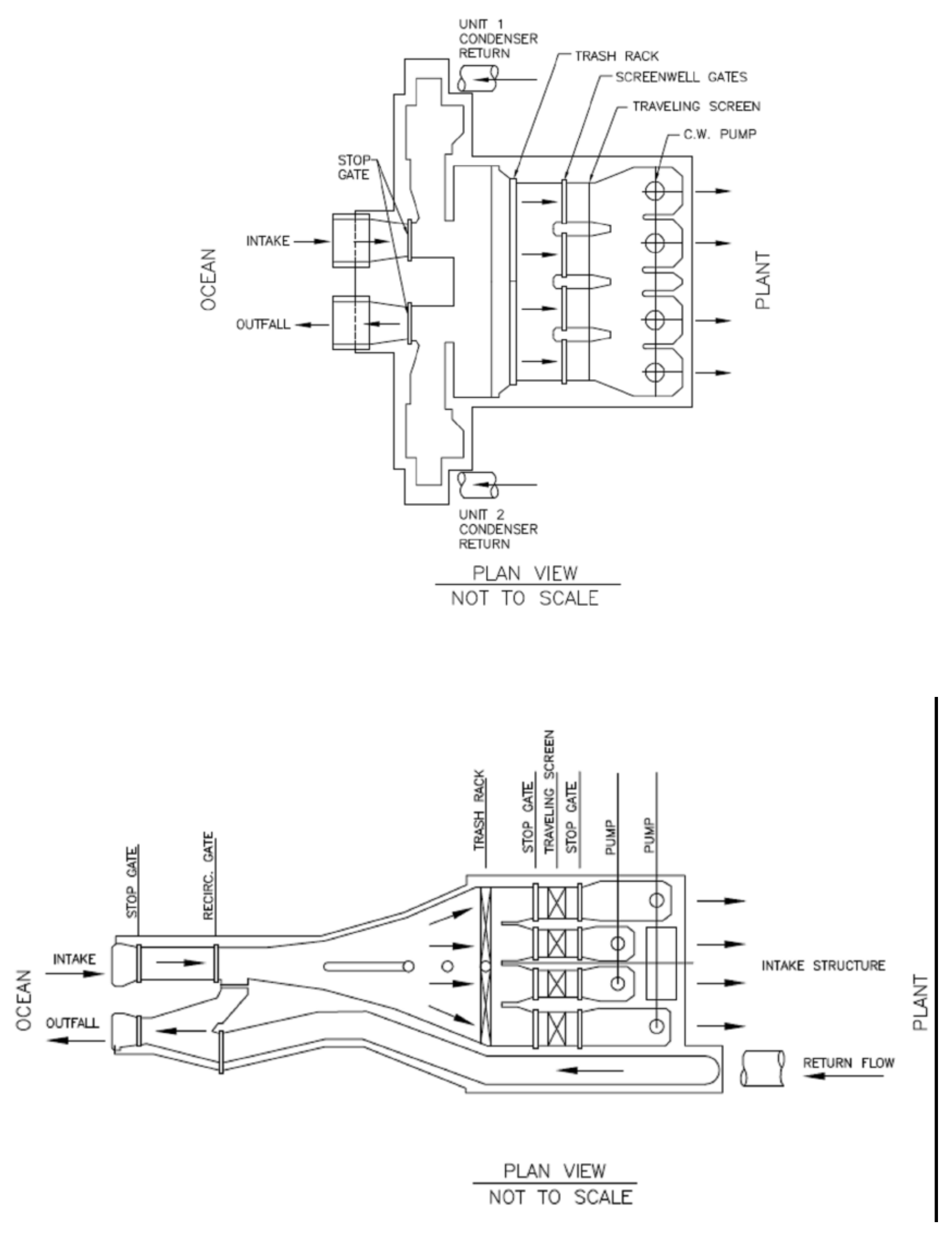


Figure 3.2-3. Screenwell structure diagram for ESGS Units 1 & 2 (top) and Units 3 & 4 (bottom).

3.3.3 Circulating Water Pump Flows

The ESGS CWISs withdraw a maximum of 2,293,528 m^3 per day (605.952 mgd) of cooling water from Santa Monica Bay. This total is comprised of up to 784,858 m^3 per day (207.360 mgd) for Units 1 & 2, and 1,508,670 m^3 per day (398.592 mgd) for Units 3 & 4. Units 1 & 2 ceased commercial operation on January 1, 2003; however, at least one circulating water pump is usually operational to support other facility requirements. At Units 1 & 2, the approach velocity was calculated at 0.2 m/s (0.8 ft/s), and the through screen velocity was calculated at 0.5 m/s (1.8 ft/s). At Units 3 & 4, the approach velocity was calculated at 0.2 m/s (0.8 ft/s), and the through screen velocity was calculated at 0.6 m/s (2.0 ft/s).

Daily cooling water flow volumes at the ESGS during 2006 and early 2007 are depicted in Figure 3.3-1. Only one of four circulating water pumps was usually in operation at Units 1 & 2, although there were periods when no pumps were operational (including two days in September 2006 and multiple days in January 2007). Flows at Units 3 & 4 were much more variable, which was attributable to the operation of the units. The highest flows (90 to 100% of maximum) were recorded during the first two weeks of January, and then intermittently from April through September 2006. From October 2006 through January 2007, daily cooling water flow at Units 3 & 4 was less than 50% of maximum except for two days in January. From January 1, 2006 to January 31, 2007, daily cooling water flow averaged 187,483 m^3 per day (49.533 mgd) at Units 1 & 2 and 717,808 m^3 per day (189.645 mgd) at Units 3 & 4. This was equivalent to approximately 24% of maximum flow at Units 1 & 2, 48% of maximum flow at Units 3 & 4, and 39% of maximum flow for both cooling water intake systems combined.

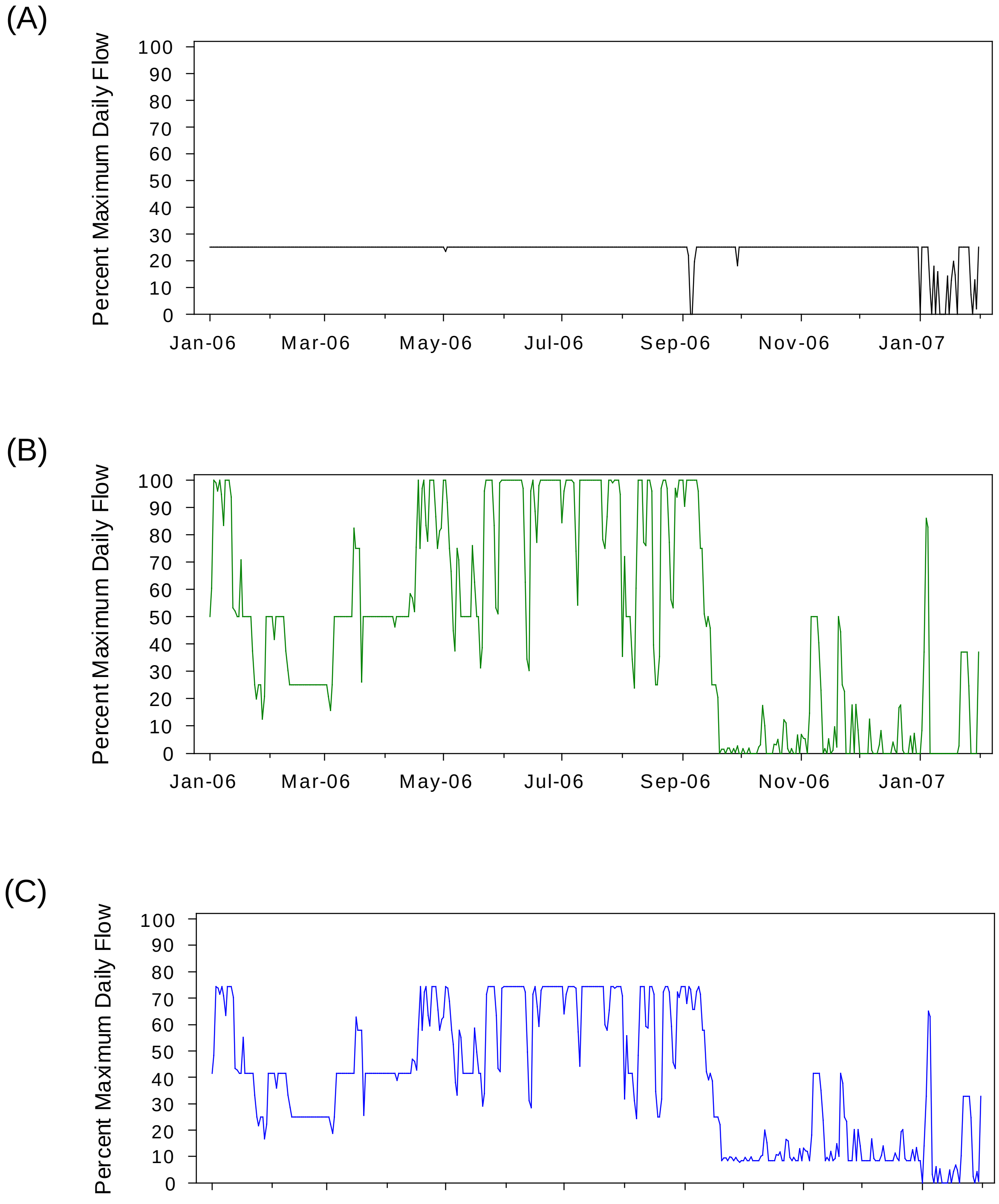


Figure 3.3-1. Daily cooling water flow volumes (percent of maximum) at the ESGS from January 2006 through January 2007. (A) Units 1 & 2, (B) Units 3 & 4, and (C) Units 1–4 combined.

3.4 ENVIRONMENTAL SETTING

3.4.1 Physical Description

Santa Monica Bay is an open embayment approximately 43 km (27 mi) across and bounded by Point Dume, which is located approximately 37 km (23 mi) to the northwest of the ESGS and Palos Verdes Point, which is located approximately 15 km (9 mi) to the south (Figure 3.4-1). The surface area of Santa Monica Bay is approximately 428 km^2 (266 square miles) (MBC 1988). It is characterized by a gently sloping continental shelf that extends seaward to the shelf break at water depths of approximately 80 m (265 ft) (Terry et al. 1956). Natural rocky outcrops are confined to the northern and southern portions of the bay from Point Dume to the Malibu coast area to the north, and the Palos Verdes point area to the south, respectively. Sediments off the ESGS are primarily composed of sand, with lesser amounts of silt and clay (MBC 2007).

The metropolitan area adjacent to the Santa Monica Bay is one of the world's most populous urban areas (SMBRC 2004). Marina del Rey, located just upcoast from the ESGS, is a large man-made small craft marina. Anthropogenic effects to the Santa Monica Bay include the discharge of treated wastewater, urban and storm water runoff, atmospheric deposition, and introduction of trash and litter to the Santa Monica Bay.

3.4.1.1 Physical Features

There are two submarine canyons in central and southern Santa Monica Bay: Redondo Canyon (off King Harbor, Redondo Beach, California) and Santa Monica Canyon, which is just upcoast and offshore the ESGS (Figure 3.4-1). Santa Monica Canyon heads at a depth of about 55 m (180 ft) at a location about 5.6 km (3.5 mi) offshore, and the average gradient along the canyon axis is 3% (Terry et al. 1956). The head of Redondo Canyon is much closer to shore, and the gradient is much steeper at the head (8%). However, the average gradient throughout the rest of the canyon (4%) is similar to that of Santa Monica Canyon.

Wastewater from the City of Los Angeles is discharged into Santa Monica Bay from an ocean discharge that extends 8 km (5 mi) offshore from the Hyperion Treatment Plant (HTP), which is 1.5 km (0.9 mi) upcoast from ESGS. The HTP has a design capacity of 1,703,250 m^3 per day (450 mgd) of secondary-treated effluent. Up until the 1980s, the HTP discharged sludge through another discharge that extends 11 km (7 mi) from shore. That outfall is still in place but not used. A third sewage outfall extends 2 km (1 mile) from shore immediately upcoast from the ESGS, but is only used for emergency purposes.

Two other coastal generating stations utilize Santa Monica Bay for cooling water purposes. The Scattergood Generating Station (SGS), located 1.0 km (0.6 mi) upcoast from the ESGS, operates a cooling water system with a maximum permitted volume of 1.875 million m^3 per day (495.4 mgd). The Redondo Beach Generating Station, 8 km (downcoast of ESGS withdraws up to 3.397 million m^3 per day (898 mgd) of cooling water from King Harbor and Santa Monica Bay. A Chevron refinery also discharges about 22,710–26,495 m^3 (6–7 mgd) of treated effluent to Santa Monica Bay downcoast from the ESGS.

Two small-vessel harbors serve Santa Monica Bay: Marina del Rey and King Harbor. Fourteen artificial reefs designed to enhance marine life and provide sport fishing opportunities were installed off Malibu, Paradise Cove, Santa Monica, Marina del Rey, Manhattan Beach, Hermosa Beach, and Redondo Beach beginning in 1958; at least nine of these reefs remain (MBC 1993). Public piers are located at Malibu, Santa Monica, Venice, Manhattan Beach, Hermosa Beach, and Redondo Beach.

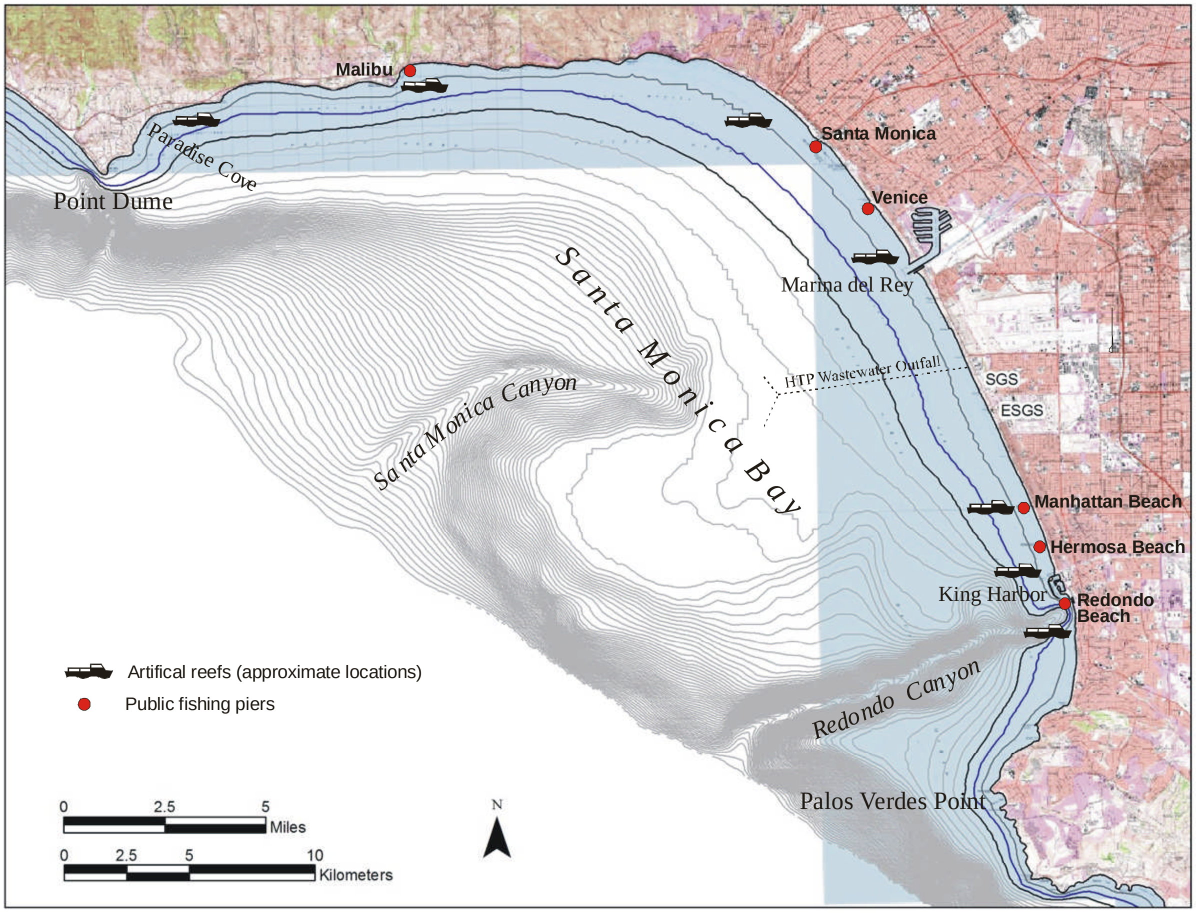


Figure 3.4-1. Santa Monica Bay geographical features.

3.4.1.1.1 Climate and Weather

Southern California has a Mediterranean climate, characterized by mild winters and warm, dry summers. In Santa Monica Bay, coolest temperatures generally occur from December through March, with warmest temperatures in August and September (NDBC 2007). In 2006, monthly average temperatures ranged from 12.6–22.7°C (54.6–72.8°F), while annual minimum and maximum temperatures of 5.0°C (41.0°F) and 39.9°C (93.0°F) occurred in March and June (National Climatic Data Center Station KLAX). 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 from 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.

3.4.1.2 Temperature and Salinity

The salinity in the surface waters of the SCB are relatively constant (isohaline). According to Dailey et al. (1993) salinities in the nearshore peak in July at around 33.6 ppt and decrease in late winter and early spring to 33.4–33.5 ppt. Tides and temperatures are recorded at the NOAA station (Station ID: 9410840) located on the Santa Monica Pier 12.8 km (8.0 mi) northwest of ESGS. In 2006, the sea temperatures ranged from a March low of 11.4°C (52.5°F) to 24.3°C (75.7°F) in July and averaged 17.0°C (62.6°F) (Figure 3.4-2).

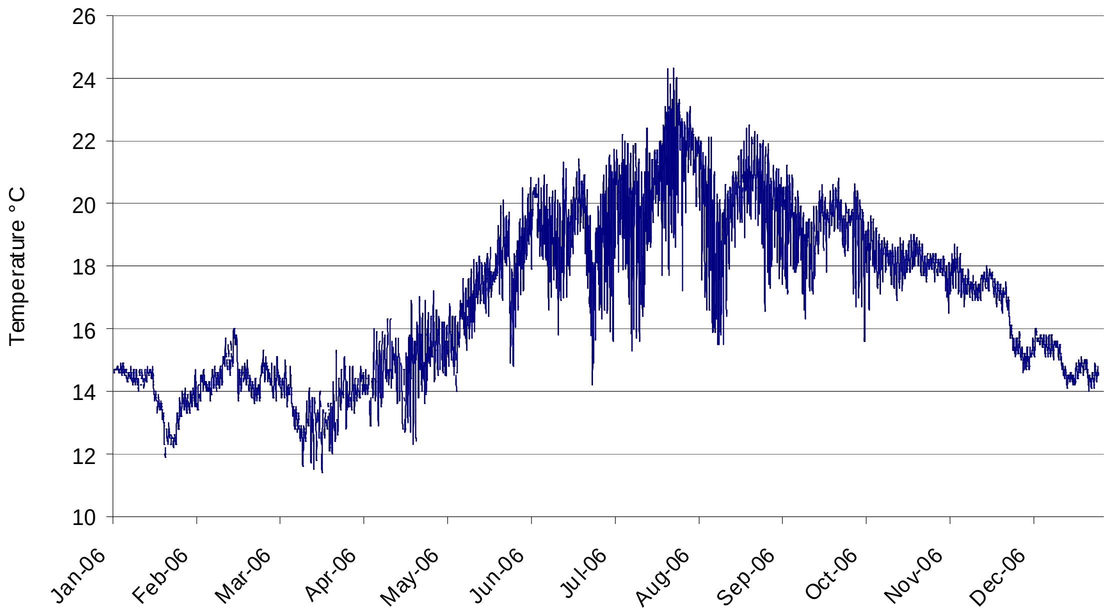


Figure 3.4-2. Hourly surface water temperatures at NOAA Station 9410840 at Santa Monica Pier, California from January through December, 2006.

3.4.1.3 Tides and Currents

3.4.1.3.1 Overview

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). From January 2006 through January 2007, water level extremes in Santa Monica Bay ranged from –0.622 m to +2.192 m (-2.040 ft to +7.192 ft) above Mean Lower Low Water (MLLW) (NOS 2007).

The prevailing current direction in the shallow, nearshore areas of Santa Monica Bay (SMB) is downcoast (equatorward) suggesting an eddy-type circulation pattern resulting from the upcoast (poleward) currents outside of the bay (Hendricks 1980). This description is supported by more extensive studies by Hickey (1992) that also showed downcoast currents on the shelf within the bay and prevailing upcoast (poleward) currents at the edge of the shelf at the outer boundary of SMB. The circulation pattern within the bay results from the presence of the Southern California Countercurrent in the outer coastal waters of the Southern California Bight. Hickey et al. (2003) found that subtidal currents in SMB are dominated by relatively long time scales (10–25 days), large alongshore scales, and significant offshore propagation. Large scale remote forcing initially pushes water into the bay as part of a throughflow, later becoming an eddy that produces counterflow in a typically southeastern direction along the SMB shoreline. However, currents shift in relation to upwelling events and other large scale hydrographic processes along the coast (Figure 3.4-3) resulting in flow regimes that differ seasonally (Figure 3.4-4). Current velocities that were measured offshore from the generating station in 2006 are presented in Section 3.4.2—*Source Water Definition*.

Hickey (1992) described the residence time of water within the Santa Monica and San Pedro basins using drifters. She found that the residence time is both spatially and temporally variable as some drifters barely moved at all whereas others nearby moved large distances in the same period. Drifters deployed in January 1990 escaped westward in about a week. In the July, residence times were only 3–5 days for drifters deployed anywhere over Santa Monica Basin. She found that drifters caught up by the Santa Monica canyon eddy escaped the basin in less than one week, and that most of the other drifters that were not cast ashore escaped the Bight in the ~2 week deployment period, roughly half passing north into the Santa Barbara Channel and half passing south of the Channel Islands.

The CROSS oceanographic study deployed current meters in the Santa Monica Basin over bottoms as shallow as 30 m (100 ft) in Santa Monica Bay from October 1985 to February 1986 (Hickey 1992). Monthly mean velocities from three depths at the station closest to ESGS are presented in Table 3.4-1.

Table 3.4-1. Mean velocities (cm/s) in the vicinity of ESGS from Hickey (1992) from October 1985 to February 1986 at Station C1 located at 30 m (100 ft) bottom depth.

Depth	OCT		NOV		DEC		JAN		ALL	
(m)	u*	v	u	v	u	v	u	v	u	v
5	-1.2	-8.8	-1.1	-7.9	-0.3	-1.7	-0.4	-1.3	-0.7	-4.5
10	1.3	-6.4	1.2	-5.2	1.0	-0.9	0.7	-0.5	1.0	-2.9
20	-0.4	-3.2	-0.5	-2.1	0.3	1.9	-0.1	0.6	-0.1	-0.3

*Note: u=across basin, v=along basin.

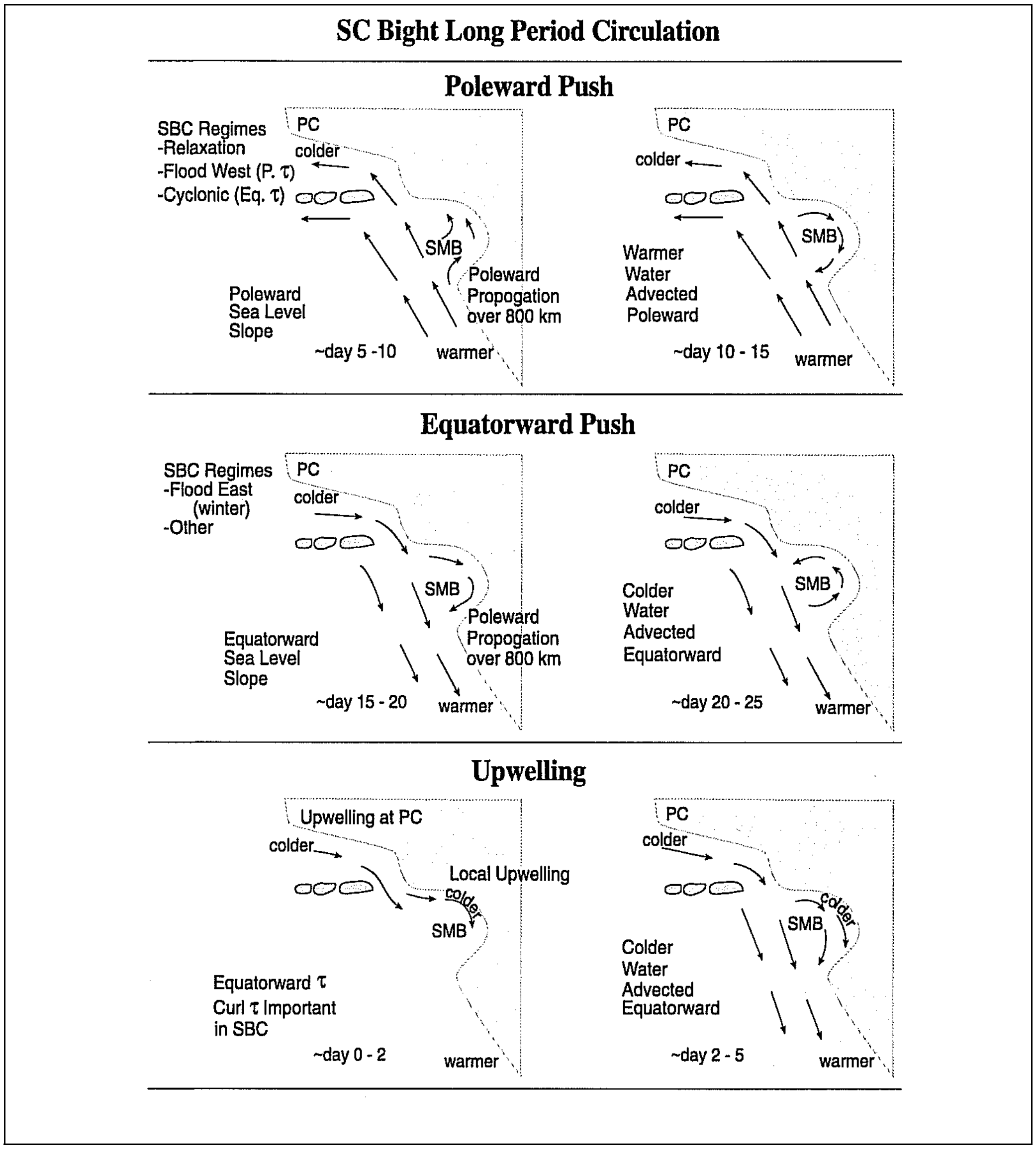


Figure 3.4-3. Schematic showing processes affecting long-period circulation and water properties in the Southern California Bight (from Hickey et al. 2003).

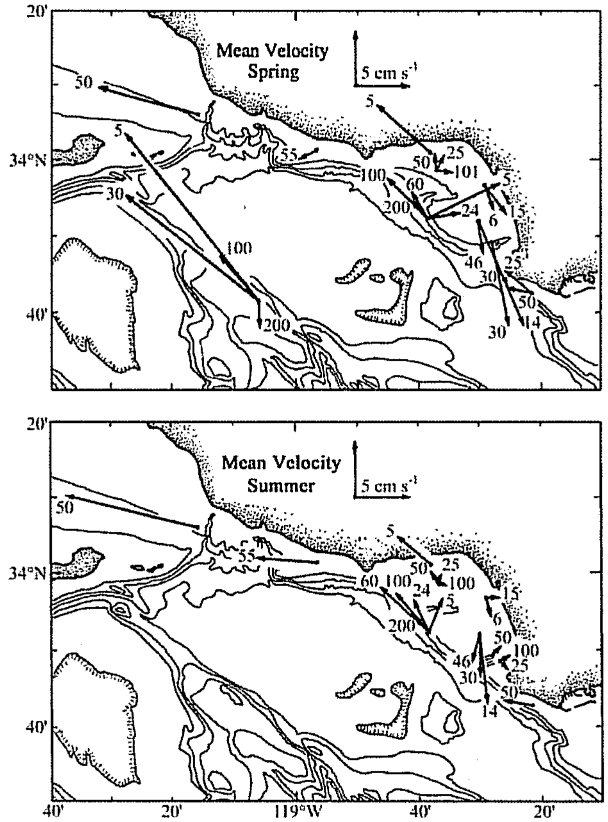


Figure 3.4-4. Selected mean currents in the central Southern California Bight for spring and summer. Measurement depth in meters is given near the tip of each arrow (from Hickey et al. 2003).

3.4.1.3.2 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 ESGS. Two Nortek Aquadopp® acoustic Doppler current profilers (ADCPs) were positioned in separate locations, one (CM 3) approximately 2.3 km (1.4 mi) from shore at a depth of –24.4 m (–80.0 ft) MLLW, and a second unit (CM 4) approximately 1.1 km (2.0 mi) from shore at a depth of –12.8 m (–41.9 ft) MLLW (Figure 3.4-5). The latitudes and longitudes of the two stations were 33.89020ºN, –118.44324ºW and 33.89442ºN, –118.43126ºW. Both stations were commissioned on January 10, 2006. Station CM 3 was decommissioned on January 12, 2007 and Station CM 4 was decommissioned on January 22, 2007. Data were downloaded on February 3, 2006, May 3, 2006, July 18, 2006, and September 1, 2006. The unit at CM 4 had an operating frequency of 1 MHz, while the unit at CM 3 had an operating frequency of 600 kHz (Table 3.4-2). 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 units. Other measurement specifications are listed in Table 3.4-2. Water temperature and water depth (pressure) were also measured by the units. Water temperatures were calibrated over an approximately 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 3.4-2. ADCP deployment parameters for current meters in the vicinity of ESGS (Stations CM 3 and CM 4).

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 3	600 kHz	24.4	15	1.0	15	1.4	100%	280	1.0
CM 4	1 MHZ	12.8	26	1.0	26	0.8	87%	180	1.0

The velocities recorded from near bottom to the near surface were averaged at hourly intervals to estimate water column average east and north velocity vectors. Hourly east and north displacements, calculated as the product of velocity and time, were used to estimate net displacement over the year. Figure 3.4-5 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 CM 3 was to the south and east. A strong eastward movement occurred from late spring through summer. At Station CM 4, net displacement was consistently southwest alongshore. The sum of the hourly alongshore components of each current measurement was maximized by applying a rotation of 29.8º at Station CM 3 and 17.6º at Station CM 4, averaging 23.7º. However, the coastline near the current meter stations is oriented to 338ºT, and therefore a rotation of 22º was applied to present current vectors in onshore and alongshore components. After rotating current velocities and averaging over the water column, plots of cumulative current vectors showed that currents at Station CM 3, located in twice as deep water than the inshore station, displayed downcoast-upcoast reversals from March to May (Figure 3.4-6). A strong onshore movement occurred from May through August. Currents at the inshore station (CM 4) moved predominantly downcoast during 2006 with few seasonal reversals, such as in March and April when currents reversed to upcoast (Figure 3.4-7). Shorter-term reversals occurred at both stations at other times of the year.

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 CM 3 varied from 23.8 m (78.1 ft) to 26.5 m (87.0 ft) and averaged 25.2 m (82.8 ft). Temperature varied from 10.1ºC (50.2ºF) to 18.6ºC (65.5ºF) and averaged 13.2ºC (55.8ºF). At the shallower CM 4, water depths varied from 12.1 m (39.8 ft) to 15.0 m (49.1 ft) and averaged 13.6 m (44.7 ft). Temperatures were somewhat warmer and varied from 10.4ºC (50.7ºF) to 20.7ºC (69.2ºF) and averaged 14.7ºC (58.4ºF). Current meter stations were cooler than Santa Monica Pier temperatures, reflecting the cooler near-bottom environments.

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. Data for December 2006 and January 2007 were used in place of data that were missing in December 2005 and early January 2006. A combined plot of data from the two locations using the upcoast-downcoast vector from CM 4 and the onshore-offshore vector from CM 3, showed net downcoast transport with a strong onshore component from late spring through summer (Figure 3.4-8). During fall through early spring there was little onshore-offshore movement. 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.

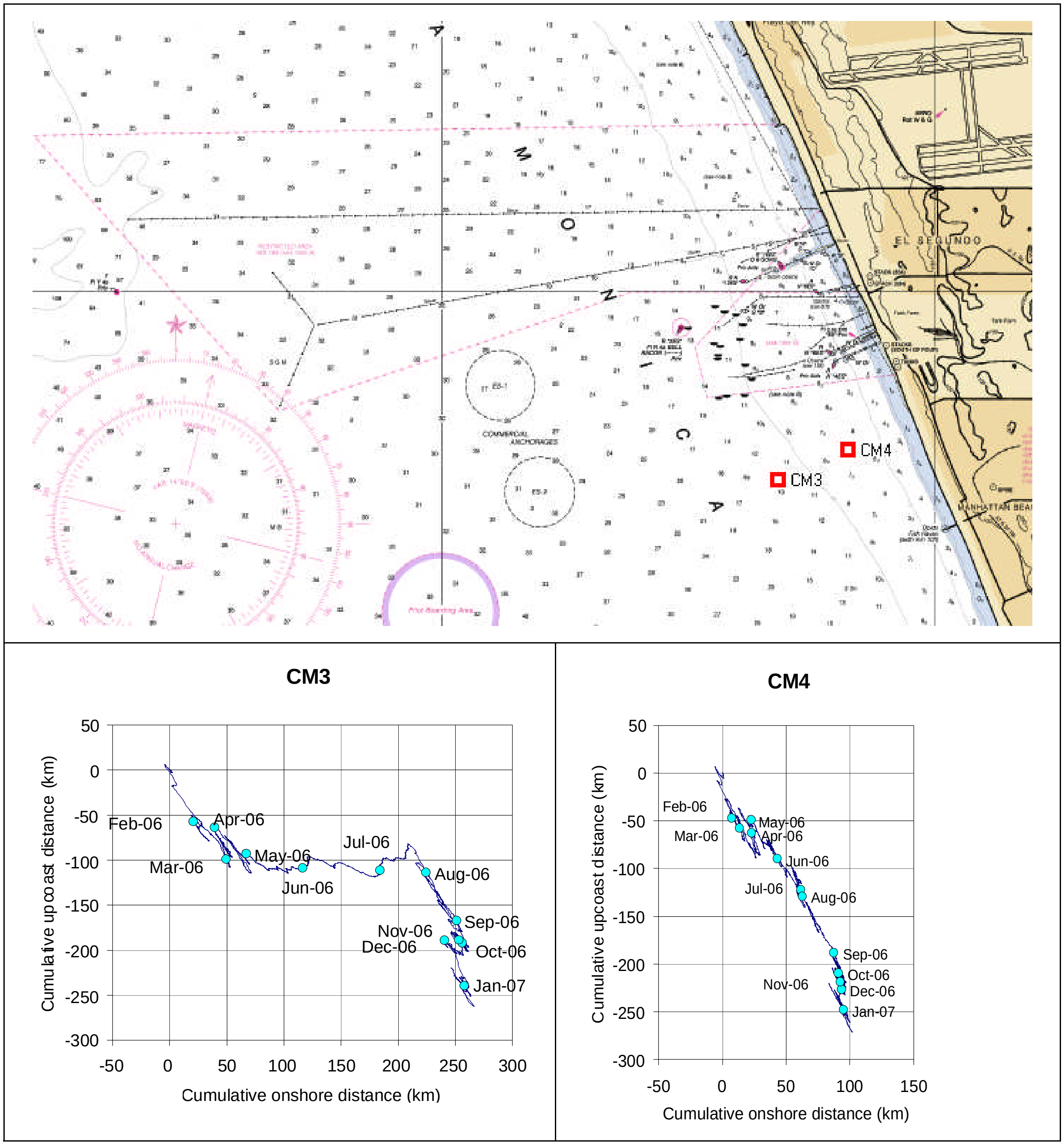


Figure 3.4-5. Net displacement at current meter stations CM 3 and CM 4 from January 2006 through January 2007.

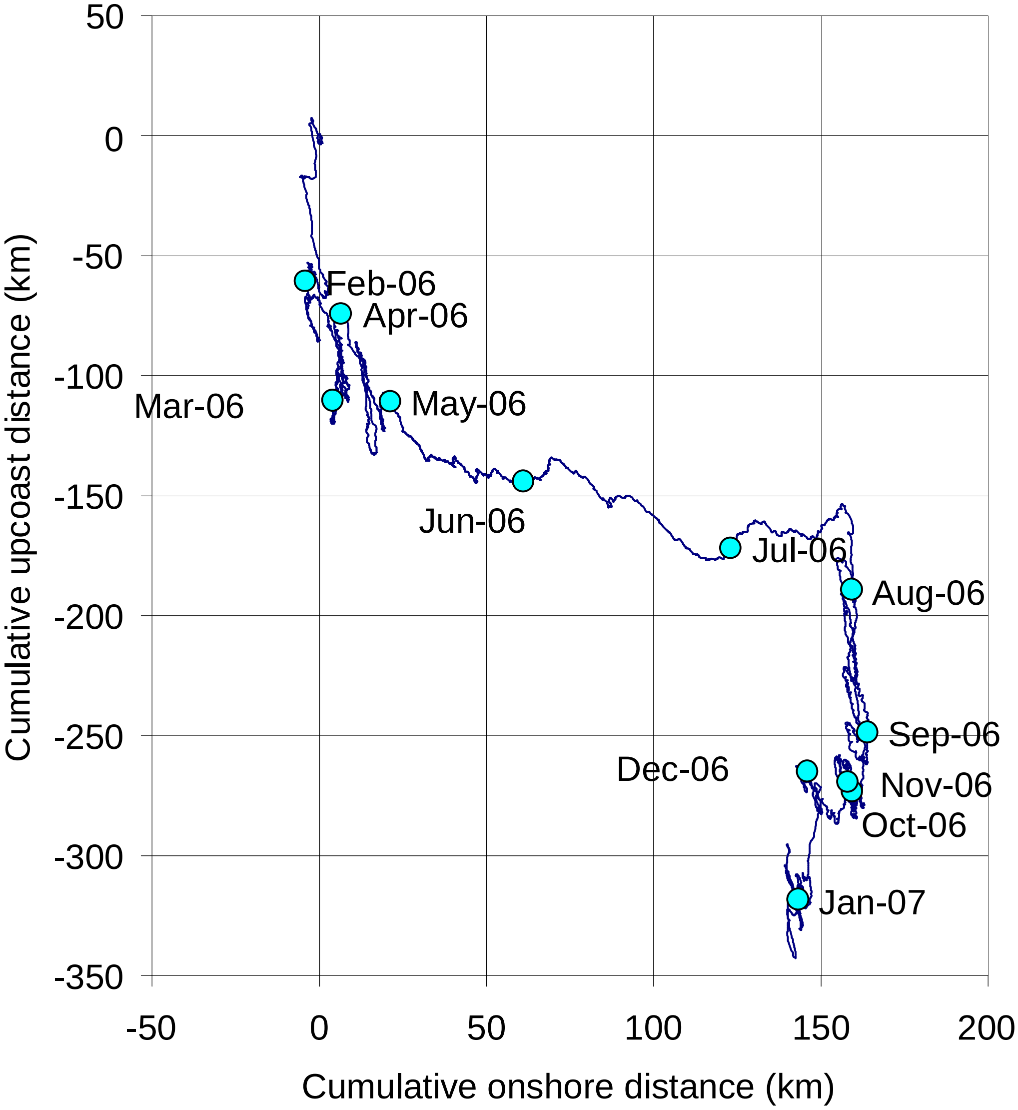


Figure 3.4-6. Cumulative current vectors from Station CM 3 in Santa Monica Bay, January 2006–January 2007.

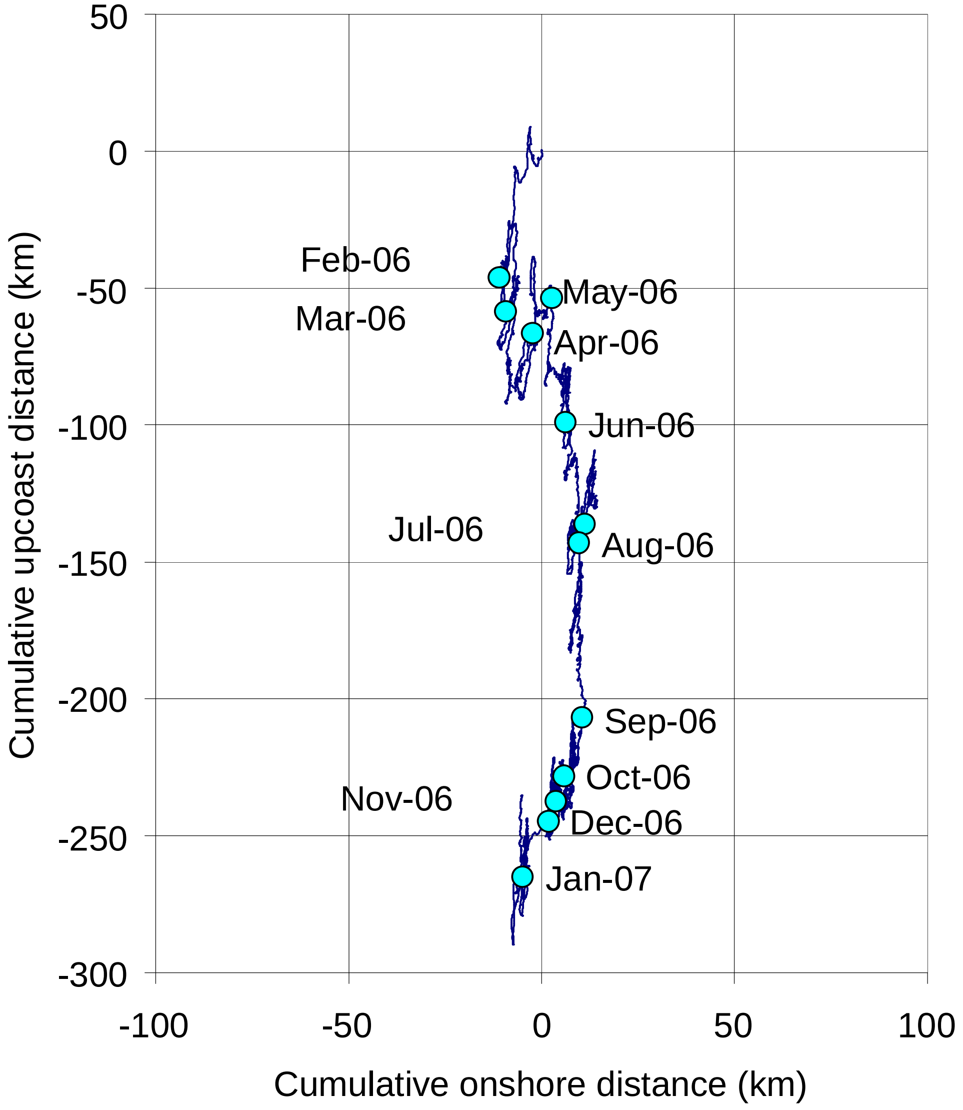


Figure 3.4-7. Cumulative current vectors from Station CM 4 in Santa Monica Bay, January 2006–January 2007.

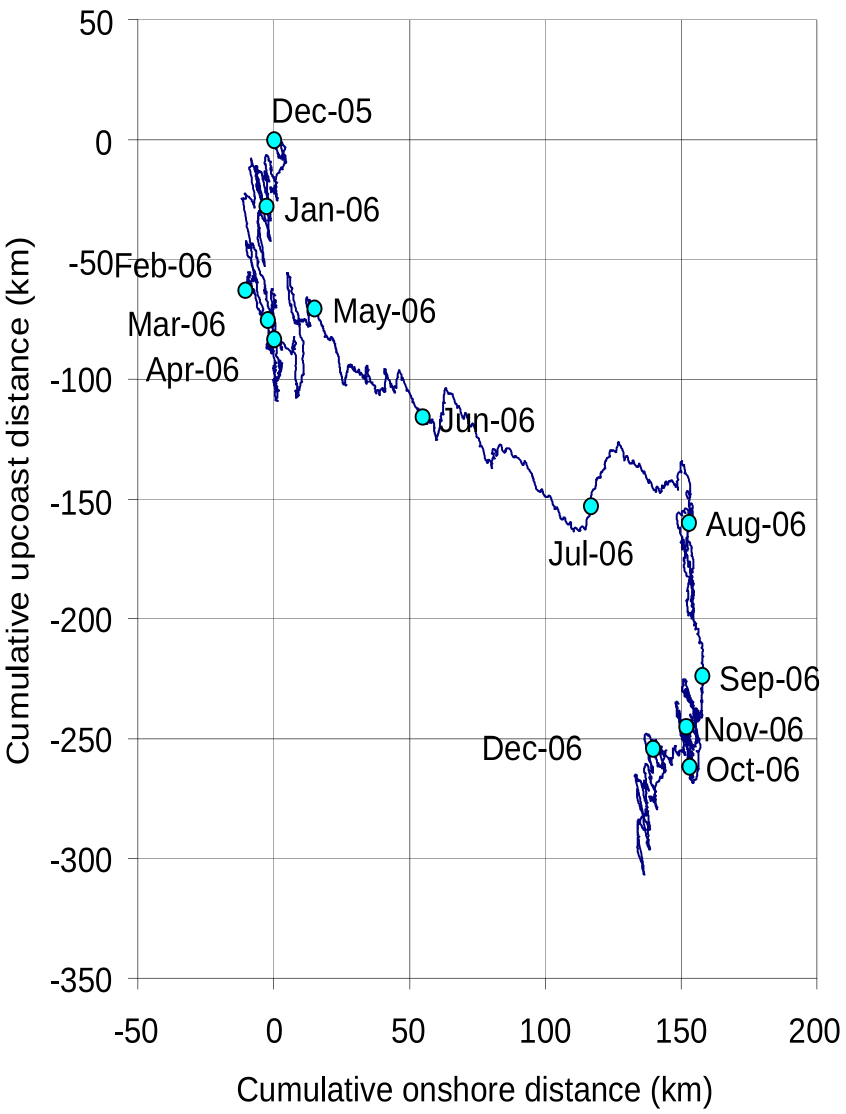


Figure 3.4-8. Composite cumulative current vectors from Stations CM 4 (upcoast) and CM 3 (onshore) in Santa Monica Bay, January 2006–January 2007.

3.4.2 Source Water Definition

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

3.4.2.1 Study Requirements and Rationale

The primary approach for assessing the effects of entrainment by the ESGS requires 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 current movement. Information on larval duration is estimated from data on the length of the larvae collected from the entrainment samples. The volume of the source water in the nearshore area, which is potentially subject to entrainment, is affected by currents, which change seasonally and due to weather and sea conditions. The rationale and methods for defining the source water for the ESGS are described in the following sections.

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. The source water sampling design was proposed because of the need to extrapolate densities offshore to determine the appropriate source water area during each survey. Besides the entrainment stations, source water sampling occurred at ten additional source water stations upcoast, downcoast, and offshore from the ESGS intake structure (Figure 3.4-9). Two stations were located 2 km and 4 km (1.2 and 2.4 mi) upcoast (Stations N1 and N2) and downcoast (Stations N3 and N4) from the midpoint between the ESGS and Scattergood Generating Station intake structures along the 10 m (33 ft) isobath.

The spacing of the samples upcoast and downcoast was based on a review of water current data available from the area. Data from Hickey (1992) showed that nearshore along-shelf water currents in Santa Monica Bay averaged 0.15 ft/s (4.5 cm/s) with a monthly maximum average speed of 0.29 ft/s (8.8 cm/s). Based on these water current speeds, the distances that larvae could be transported alongshore during a day ranged from 2.4 to 4.7 mi (3.9 to 7.6 km). The average value was used to determine the alongshore extent of the source water sampling stations upcoast and downcoast since the proportional entrainment estimate used in the *ETM* is an estimate of the daily entrainment mortality on the available source water population. The length of the sampling area alongshore was also designed to approximately equal the daily distance larvae could travel based on the maximum monthly average water current speed thus ensuring that even at higher water current speeds an adequate source water area was sampled.

Six additional stations were sampled offshore from the inshore line of stations, with three stations located along the 66 ft (20 m) isobath (Stations M1–M3) and three stations along the 98 ft (30 m) isobath (Stations O1–O3) (Figure 3.4-9). This sampling grid was similar in design to the study of cooling water system effects at the AES Huntington Beach Generating Station (MBC and Tenera 2005), but was modified to allow for a more complete characterization of the distribution of organisms alongshore and offshore. This was necessary because the distribution of organisms within the sampling area is used to extrapolate densities alongshore using water current displacement and offshore using a regression model of density and distance offshore. These extrapolations are used to estimate the plankton populations in the source water. The prevailing alongshore water currents in Santa Monica Bay (Hickey 1992) indicate that there may be less mixing of waters across the shelf close to shore compared with waters well offshore. As a result the data from the stations closest to shore may be poor predictors of the abundance and composition further offshore. The proposed sampling grid includes at least three stations at each depth contour alongshore that can be used in extrapolating the sampled source water data over a larger area.

3.4.2.2 Methods for Calculating ESGS Source Water

All depths (elevations) for determining source water volumes and planimetric surface areas for Santa Monica Bay were relative to MSL as measured at the tide gauge at Station 9410840, Santa Monica, CA. All themes were re-projected to the Albers Equal Area Projection (tn83m). A coastline theme was created from USGS topographic maps at 1:24,000 in the tn83m projection. All Coastal Maps were georeferenced to the California Digital Raster Graphics (DRGs), 7.5 Minute (O) Series, Albers NAD83.

The depth data points were identified and selected from all the source datasets that fell within the water portions of the source water regions for the respective harbors and selected offshore source water sampling zones. MLLW depths were adjusted to MSL (shallower by 0.85 m (2.79 ft) per the tide gauge at Station 9410400 Santa Monica, CA). The corrected depth data were then merged and exported to a new depth point theme relative to MSL. Surface grids representing the bathymetry relative to MSL were constructed from these selected points using Inverse Distance Weighting (IDW) with the default settings (ArcGIS 8.2). A 50 m (164 ft) cell surface grid was created for all offshore source water areas. Contours were made at 1 m (3.3 ft) intervals referenced from mean sea level and the new grid was converted into a polygon shapefile for area and volume calculations.

The ESGS source water region consists of the waters that parallel the beach approximately 5,000 m (16,400 ft) up coast and 5,000 meters downcoast from the generating station and offshore approximately 3,950 m (12,960 ft). The depths of the 50 m (164 ft) square grid cells used for offshore source water volume calculations were interpolated from 10 m (32.8 ft) contour lines from the California Department of Fish and Game GIS 2000 data set (2007a). These contours were derived from grid files made from 75 original digital elevation model (DEM) data files that were compiled into a single grid and re-sampled to 200 m (656 ft). The total source water surface area was calculated as 3,696 hectares (14.27 square miles) with a volume of 735,176,993 cubic meters (194,213 million gallons).

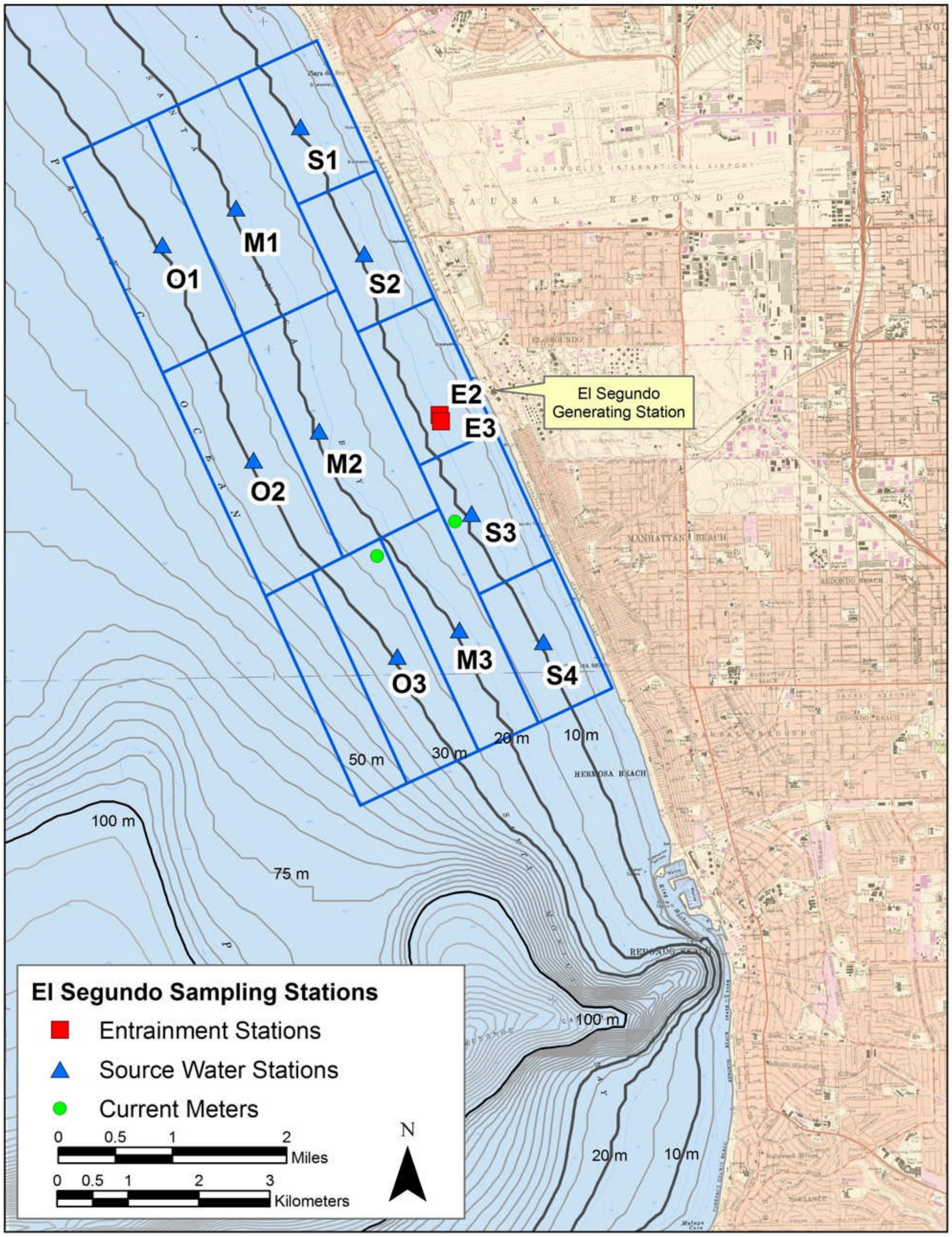


Figure 3.4-9. Locations of the ESGS entrainment and source water sampling stations, and current meter stations within the nearshore study grid.

3.4.3 Biological Resources

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

3.4.3.1 Habitat Variation

The pelagic habitat of Santa Monica Bay includes the entire water column within the bay, a volume of approximately 25,889 million m^3 (6,840 billion gallons) (MBC 1993). Organisms found in this habitat include a myriad of planktonic organisms (phytoplankton, zooplankton, and ichthyoplankton) that have little or no swimming ability to resist ocean currents, and nektonic organisms, such as fishes and sharks that are freely mobile in local and oceanic currents. The pelagic habitat also supports large numbers of pinnipeds (including Pacific harbor seal [*Phoca vitulina richardsi*] and California sea lion [*Zalophus californianus californianus*]), cetaceans (such as gray whale [*Eschrichtius robustus*], bottlenose dolphin [*Tursiops truncatus*], and common dolphin [*Delphinus delphis*]), and birds, including California brown pelican (*Pelecanus occidentalis californicus*), terns, and gulls (MBC 1988).

Intertidal habitat within the Santa Monica Bay is comprised of both sandy and rocky habitats (MBC 1988). The rocky intertidal habitat is comprised of both natural and artificial rocky substrate, such as the breakwaters at Marina del Rey and King Harbor. Natural rocky intertidal substrate occurs along the Malibu coast from Point Dume to Paradise Cove, along occasional patches from Paradise Cove to Big Rock Beach, and south along the Palos Verdes Peninsula.

Giant kelp (*Macrocystis pyrifera*) beds occur on submerged rocky reefs in depths of 6–21 m (20–70 ft). At present, kelp beds are limited to locations on the Palos Verdes Shelf and along Leo Carillo beach and the Malibu coast (SMBRC 2004). Current canopy coverage is relatively low compared to historic coverage, but the extent of kelp is considered stable at Palos Verdes. The kelp beds in the Malibu area have increased in recent years, due in part to recent restoration efforts, improved water quality, and favorable oceanic conditions.

Most of the seafloor in the Santa Monica Bay consists of unconsolidated (soft) sediments comprised of sand, silt, and clay. Most of the energy entering this habitat is in the form of detrital fallout and phytoplankton from the pelagic habitat, although detritus from surface runoff and discharged sewage may also be important (MBC 1988). A high proportion of soft-bottom benthos live most of their lives permanently in the sediments and are termed ‘infauna’; those which live on the surface of the seafloor are called ‘epifauna’. The soft-bottom habitat also supports several species of algae, macrofauna/megafauna (including crabs, snails, sea stars, urchins, and sea cucumbers), and fishes, including California halibut (*Paralichthys californicus*).

Ten brackish wetlands of various sizes and conditions located along Santa Monica Bay contribute larval and adult forms of marsh fish and invertebrates and vegetative organic production. The marshes range from small, seasonally-inundated river mouths (Zuma Beach west of Point Dume) to the larger Ballona Wetlands Complex at Marina del Rey. Historically, the Los Angeles River occasionally emptied into Santa Monica Bay at Ballona Creek instead of at its present-day mouth at Long Beach. The course of the River changed during unusually heavy storms from 1815–1825 and again in 1862 and 1884. The area between Ballona Creek and present-day Beverly Hills was often a vast swamp. In 1868, the Ballona Wetlands comprised 8.5 km^2 (2,100 acres). Development of Marina del Rey, the Venice Canal system, residential and commercial properties, and the channelization of Ballona Creek reduced this area to less than 0.6 km^2 (160 acres) of wetland habitat.

The wetlands at Ballona Creek support a number of transient fish species but only nine residents (Swift and Frantz 1981). Dominant species include arrow goby (*Clevelandia ios*), mosquitofish (*Gambusia affinis*; a freshwater species), and topsmelt (*Atherinops affinis*). Numerous shorebirds, water fowl, and terrestrial birds are known to occur at Ballona Wetlands, Marina del Rey, and Malibu Lagoon (MBC 1988). Diversity of birds is highest at Malibu Lagoon because it is adjacent to riparian woodland and chaparral habitats.

There are no major freshwater rivers that empty into the Santa Monica Bay, though there are some smaller streams. Small freshwater marshes occur at Malibu Lagoon and at Ballona Creek (MBC 1988). These marshes are home to numerous insects, amphibians, reptiles, and birds that live among the tules, cattails, and pond weeds (Jaeger and Smith 1966). Fresh water introduced by storm water and urban runoff has attracted increased attention in recent years. Control of pollutants from runoff has proven difficult due to the ubiquitous nature of the sources, and storm water regulations have relied on compliance with Best Management Practices (BMPs) instead of clearly defined effluent limits (SMBRC 2004). However, Total Maximum Daily Loads (TMDLs) are replacing BMPs, and are being developed for specific watersheds.

3.4.3.2 Nursery Grounds

It is unknown to what extent Santa Monica Bay serves as a nursery for fish and invertebrate species; however, it can be assumed that the variety of habitat types within the bay are likely used by numerous species for such purposes. On the open coast, recruitment to the mainland shelf occurs year-round, but is greatest from winter to spring (Cross and Allen 1993). The rocky intertidal zone is a turbulent and dynamic environment, and in southern California there are only a handful of fish species considered residents of this habitat, including some sculpins and pricklebacks. Most resident intertidal fishes lay demersal rather than planktonic eggs, and parental care is relatively high (Horn and Martin 2006). The larvae of most intertidal fishes spend about one to two months in the plankton, but disperse only short distances and tend to stay within the area they were hatched.

Reefs and kelp beds provide habitat for a wide variety of fishes and invertebrates. Most commonly, passive drift carries late larval stages to the vicinity of these habitats where settlement takes place (Cowen 1985). In other species (possibly including chubs and giant kelpfish [*Heterostichus rostratus*]), actively swimming late larval stages may follow gradients in perceptual cues or internal waves to reefs. In still other species, larvae produced on a reef may have behavioral mechanisms to retard drift processes, keeping them in the local area for settlement (Stephens et al. 2006).

On the soft-bottom substrata of the southern California mainland shelf, Allen (1982) found that 45% of the 40 major fish community members had pelagic eggs and larvae, 18% (all rockfishes) were ovoviviparous with pelagic larvae, 15% had demersal eggs and pelagic larvae (such as combfishes, sculpins, and poachers), 12% were viviparous (bearing live young – all surfperches), and 10% had demersal eggs and larvae (including midshipman and eelpouts). Southern California is located at the edge of the geographic range of many cool- and warm-water fish species, and recruitment of juveniles is episodic and species dependent (Allen 2006). Coastal settlement is more variable than in bays, and interannual variation is probably primarily due to oceanic conditions that affect transport and survival of larvae, along with spawning success and availability of suitable benthic habitat for settling juveniles. In 1989, Allen and Herbinson (1991) surveyed bay, open coast, and protected coastal habitats in southern California with fine-mesh beam trawls. In general, fish densities were higher in bays than on the open coast, densities decreased with increasing depth, and highest densities were recorded in spring (May). On the inner shelf (6–15 m [20-49 ft]), speckled sanddab (*Citharichthys stigmaeus*) was the most frequent juvenile fish taxa encountered, but queenfish (*Seriphus politus*) was most abundant.

3.4.3.3 Fish Diversity

In 2003, 23 species of fish were collected by otter trawl near the ESGS along the 6-m and 12-m (20-ft and 40-ft) isobaths (MBC 2004). The most abundant species were flatfishes, including speckled sanddab, English sole (*Parophrys vetulus*), hornyhead turbot (*Pleuronichthys verticalis*), and California halibut. Since 1990, at least 85 fish species have been impinged at the ESGS, and at least 107 distinct fish species have been impinged during heat treatment procedures at the nearby SGS, with an annual average of 57 species (MBC 2007). The most abundant species included queenfish (27% of abundance), topsmelt (24%), Pacific sardine (*Sardinops sagax*; 20%), jack mackerel (*Trachurus symmetricus*; 6%), and jacksmelt (*Atherinopsis californiensis*; 6%). The most abundant species included queenfish, jacksmelt, Pacific sardine, salema (*Xenistius californiensis*), and northern anchovy (*Engraulis mordax*), which accounted for 73% of impingement abundance.

3.4.3.4 Shellfish Diversity

In 2003, 16 species of macroinvertebrates were collected by otter trawl off the ESGS (MBC 2004). The most abundant species were spiny sand star (*Astropecten armatus*), the giant bell jelly (*Scrippsia pacifica*), California sand star (*Astropecten verrilli*), and tuberculate pear crab (*Pyromaia tuberculata*). From October 2005 through September 2006, the most abundant invertebrates impinged were Pacific rock crab (*Cancer antennarius*), the nudibranch *Hermissenda crassicornis*, and red rock shrimp (*Lysmata californica*), which together comprised 86% of the abundance and 46% of the biomass (MBC 2007). Other abundant taxa in impingement samples were intertidal coastal shrimp (*Heptacarpus palpator*), yellow crab (*Cancer anthonyi*), and the jelly *Polyorchis penicillatus.* Abundance of the crabs and shrimps was highest from May through August.

3.4.3.5 Protected Species

The §316(b) Phase II regulations require that "…*taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened and endangered species) identified pursuant to paragraph (b)(3)(i) of this section, including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize annual, seasonal, and diel variations in impingement mortality and entrainment (e.g. related to climate and weather differences, spawning, feeding, and water column migration). These may include historical data that are representative of the current operation of your facility and of biological conditions at the site.*"

3.4.3.5.1 Agencies consulted for identification of species

On January 30, 2007, representatives from ESP, Tenera Environmental, and MBC Applied Environmental Sciences met with representatives from the LARWQCB, EPA Region IX, State Water Resources Control Board (SWRCB), California Department of Fish and Game (CDFG), and National Marine Fisheries Service (NMFS) to review preliminary data from the ESGS IM&E Characterization Study, and determine the fish and shellfish species that would be assessed in the IM&E Report. The meeting was also attended by two environmental groups, Santa Monica BayKeeper and Heal the Bay.

3.4.3.5.2 Identification of species

No Federal/State threatened or endangered fish/shellfish species were identified in entrainment and impingement samples collected from ESGS (see Sections 4.0 and 5.0). This is consistent with past entrainment and impingement sampling conducted at ESGS (SCE 1982b; 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 assessed in the ESGS 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 would need additional assessment since impingement estimates are calculated for all species, and no additional modeling was proposed.

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; 2006b). There are four fish and one invertebrate species covered under the Coastal Pelagics Fishery Management Plan (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 collie*i), finescale codling (*Antimora microlepis*), Pacific rattail (*Coryphaenoides acrolepis*), three species of sharks, three skates, 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. A list of species covered under the two FMPs that occurred in entrainment and/or impingement samples at the ESGS is provided in Table 3.4-3. More information on some of these species is presented in Sections 4.0 and 5.0.

Some fish and invertebrate species (abalone) in southern California are protected under California Department of Fish and Game (CDFG) regulations although few marine species are listed as either threatened or endangered. Special-status fish species that could occur in the vicinity of ESGS and that have planktonic larvae potentially at risk of entrainment include garibaldi (*Hypsypops rubicundus*), giant sea bass (*Stereolepis gigas*), 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 giant sea bass is a long-lived species that can grow to over 2.1 m (7 ft) in length and weigh over 227 kg (500 lb) (Love 1996). Giant sea bass were once a relatively common inhabitant of Southern California waters, yet in the 1980s it was facing the threat of local extinction off the California coast due to overfishing. Actions were taken by CDF&G, resulting in protection from commercial and sport fishing that went into effect in 1982. Although the larvae are potentially susceptible to entrainment from coastally-sited power plants in southern California, no giant sea bass larvae have been identified from entrainment samples.

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 overharvesting, 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.

Table 3.4-3. Fish and shellfish species with designated EFH or CDFG special status entrained and/or impinged during normal operations at ESGS in 2006.

Species	Common Name	Management Group
Engraulis mordax	northern anchovy	Coastal Pelagics
Parophrys vetulus	English sole	Pacific Groundfish
Loligo opalescens	market squid	Coastal Pelagics
Hypsypops rubicundus	garibaldi	CDFG
Sardinops sagax	Pacific sardine	Coastal Pelagics
Merluccius productus	Pacific hake	Pacific Groundfish
Citharichthys sordidus	Pacific sanddab	Pacific Groundfish
Sebastes spp.	rockfishes	Pacific Groundfish
Scorpaena guttata	California scorpionfish	Pacific Groundfish
Leuresthes tenuis	California grunion	CDFG
Sebastes auriculatus	brown rockfish	Pacific Groundfish
Sebastes miniatus	vermilion rockfish	Pacific Groundfish

4.0 COOLING WATER INTAKE STRUCTURE ENTRAINMENT AND SOURCE WATER STUDY

4.1 INTRODUCTION

The entrainment study incorporates two design elements: 1) CWIS sampling, and 2) source water sampling. Sampling at the intake provides estimates of the total numbers of each larval species entrained through the CWIS depending on pumping capacity. The source water populations of fish and shellfish larvae are 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 and therefore entrainment and source water sampling was done monthly which is consistent with other recently completed entrainment studies conducted for the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera, in preparation).

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

- What are the species composition and abundance of the larval fishes, fish eggs, and advanced larval stages of crabs, market squid, and spiny lobster entrained by ESGS?
- What are the local species composition and abundance of the entrainable larval fishes, fish eggs, crab megalops, market squid, and spiny lobster larvae in Santa Monica Bay?
- 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 the small population-level impacts cannot be accurately estimated. 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 done for 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 Fishes

Many of the marine fishes in the vicinity of the CWIS 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 Shellfishes

“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 CWIS (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, and impact analyses based on broad taxonomic groups are subject to a great deal of uncertainty. 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

Larvae and eggs of some species protected under Federal, State, or Tribal Law (discussed in Section 3.4.3.5) were enumerated in entrainment samples. Most of these were represented by only a few specimens out of the nearly 4,300 fish larvae collected during the entrainment surveys. At the January 30th meeting, NMFS agreed that demographic or ETM calculations would only be done for 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. Of the taxa on the list, only northern anchovy (Engraulidae, *Engraulis mordax*) and English sole (*Parophrys vetulus*) were in sufficient abundance at ESGS to justify a more detailed analysis of potential IM&E impacts.

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*), giant sea bass (*Stereolepis gigas*), and California grunion (*Leuresthes tenuis*).

4.2 HISTORICAL DATA

4.2.1 Summary of Historical Data

Daily entrainment rates for ESGS Units 1-4 in 1979–1980 (SCE 1982a) were based on density estimates from data collected from the intakes at Ormond Beach Generating Station (OBGS), which is located 60 miles northwest of ESGS. The densities were then applied to the daily cooling water volumes at ESGS to calculate annual entrainment estimates for certain target species. Results from a physical and biological categorization study indicated that OBGS and ESGS shared similar habitat types and designs of the offshore velocity cap intake structures (Schlotterbeck et al. 1979). The rationale was that information collected at one location could be reasonably applied at another location provided each CWIS was in a similar habitat. The criteria given for using OBGS as a surrogate site for ESGS were that the velocity cap intake structures for both OBGS and ESGS had similar physical dimensions, were located in similar depths (ca. –10 m [–33 ft]), and were situated along similar sand-bottom coastal habitats. Cooling water for OBGS is supplied through a 4.3 m (14 ft) diameter flush cap vertical intake structure located 631 m (2,070 ft) offshore. ESGS has two separate intake structures, each of which uses an overhang cap vertical intake structure. Seawater for Units 1 & 2 enters a 3.0 m (10 ft) diameter intake located 698 m (2,289 ft) offshore and water for Units 3 & 4 enters a 3.7 m (12 ft) diameter intake (701 m) 2,300 ft offshore at a depth of 9.7 m (32 ft).

The sampling program at OBGS focused on obtaining entrainment levels for ‘target species’, which provided representative information regarding the effects of the generating station on the marine community, based upon criteria selected in consultation with the LARWQCB and the California Department of Fish and Game. These ‘key species’ were defined as those with some or all of the following characteristics:

- 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; or
- Economic value as a sport or commercial fishery species.

As explained in SCE (1982a), the entrainment study design measured entrainment of larval fishes based on the flow intake and volume (from representative site data) at OBGS to quantify losses to the fishery resource by means of an Impact Assessment Model. Water at the intake station at OBGS was sampled over a 10-day period during the middle of each month throughout the year. Within the 10-day period there were four 24-hour sampling periods (also referred to as replicate samples) during each monthly sampling survey, with six periods (two day, two night, and two crepuscular) sampled throughout a 24-hour period at the offshore intake riser. For each month, mean daily larval entrainment was estimated by multiplying larval concentrations by flow volumes specific to each station.

Through-plant mortality of entrained larvae for this study was assumed to be 100%, giving a conservative or higher than actual estimate of entrainment effects than suggested from previous studies that indicated through-plant survival rates of 30 to 90 % depending on the target species (SCE 1982b). Fish pump nets were used to sample entrained ichthyoplankton at OBGS within the intake risers using a centrifugal whorl Nielsen Model NCH Fish Pump (SCE 1982b). Samples were filtered through a 333 micron mesh net and preserved in 4% buffered formalin.

Table 4.2-1 summarizes the entrainment densities of target species and other common fish taxa recorded over the 12-month study. Annual variation in water flows at OBGS throughout the year were not reported, so daily and annual entrainment levels were calculated using the volume of 476,000 gpm or a flow rate of 30 m^3/sec. Northern anchovy larvae had the greatest concentrations in OBGS entrainment samples with densities averaging 851 larvae per 1,000 m^3 (264,000 gal). This translated to an estimated annual entrainment mortality of 806 million northern anchovy larvae at ESGS. Entrainment estimates for all other target species combined was 815 million larvae annually.

4.2.2 Relevance to Current Conditions

Although the study approach of using data from one power plant and applying it to another was accepted based on similarities in habitat and intake design, it is unlikely that the calculated annual entrainment estimates for ESGS were very accurate due to spatial variation between the two locations. Certainly the areas share many of the same dominant larval species (northern anchovy, white croaker, queenfish) but even in the present study it can be demonstrated that significant variation in densities may occur due to the patchy distribution of larvae and local differences in current patterns.

Also, it is not known how differences in sampling methods (pumping vs. towed net sampling) may affect density comparisons between studies although both studies used a 333-micron mesh size to collect larvae. Both studies also collected samples throughout day and nighttime periods, so general trends in larval abundance between time periods may be assessed, but definitive conclusions regarding changes in densities should be qualified based on study differences.

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

	Mean Daily Larval Density* (#/1,000 m^3)	**Overall Rank**	**% of Total**	**Calculated Annual Entrainment at ESGS (millions)**
316 (b) Target Species				
northern anchovy	851.47	1	41.8	805.56
white croaker	688.27	2	33.8	651.16
queenfish	167.05	3	8.2	158.05
Pacific butterfish	1.16	22	0.1	1.10
kelp bass	2.31	19	0.1	2.19
barred sand bass	1.93	20	0.1	1.83
sargo	<0.39	47	<0.1	0.37
black croaker	0.39	37	<0.1	0.37
yellowfin croaker	<0.39	42	<0.1	0.37
Other Species				
Pisces larvae, unid.	111.50	4	5.5	105.49
bay goby	62.89	5	3.1	59.50
Pisces, yolk sac larvae	43.21	6	2.1	40.88
cheekspot goby	39.74	7	2.0	37.60
goby type D	13.50	8	0.7	12.78
goby, unid	10.42	9	0.5	9.86
California halibut/ fantail sole	5.79	10	0.3	5.48
Other miscellaneous	35.49		0.7	33.58

* Data were obtained from Ormond Beach area as a representative site. 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

Composition and abundance of ichthyoplankton and shellfish larvae entrained by ESGS was determined by sampling in the immediate proximity of the cooling water intakes (Stations E2 and E3) monthly from January through December 2006. The locations of the sampling stations during each survey were determined using a differential global positioning system. Sampling was done within 164–328 ft (50–100 m) of the intake structures using an oblique tow that sampled the water column from the surface down to approximately 0.5 ft (0.15 m) off the bottom, and back to the surface. A wheeled bongo frame was used with 2 ft (60 cm) diameter net rings and plankton nets constructed of 333-µm Nitex® nylon mesh, similar to the standard nets used by the CalCOFI program. Each net was fitted with a Dacron sleeve, a plastic cod-end container to retain the organisms, and a calibrated General Oceanics flowmeter

(Model 2030R) to measure of the amount of water filtered. Sampling was conducted four times per 24-hour period—once every six hours.

Two replicate tows were taken with a target sample volume for each net of approximately 20–30 m^3 (5,300–8,000 gal). The nets were redeployed if the target volume was not collected during the initial tow. At the end of each tow, nets were retrieved and the contents of the net gently rinsed with seawater into the cod-end. 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 pre-labeled jars with pre-printed internal labels and the two samples preserved separately in 4% buffered formalin-seawater.

4.3.1.2 Source Water Sampling

The configuration of the source water study area was designed to 1) characterize the larvae of ichthyoplankton and shellfish potentially entrained by the ESGS cooling water intakes, and 2) represent larval forms present in the nearshore habitats in the vicinity of the ESGS intakes.

Source water was sampled at 10 stations located upcoast, downcoast, and offshore from the ESGS intake structures (refer to Figure 3.4-9). All stations were sampled using a wheeled bongo plankton net using the same oblique towing method as the entrainment sampling. Sampling was conducted once monthly on the same day that the entrainment station was sampled. Samples were processed using the same procedures described for entrainment sampling. During each monthly source water survey, the 10 source water stations were sampled four times per 24-hour period—once every six hours. 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 stepwise procedures are presented in Appendix B.

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 megalopa
- California spiny lobster phyllosoma
- market squid paralarvae

The samples from the two nets were preserved in separate 400 ml jars and processed separately, but the data from the two nets were combined for analysis. If the quantity of material exceeded 200 ml, then the sample was split into multiple jars to ensure that the material was properly preserved. In some cases the collection of ctenophores, salps, and other larger planktonic organisms resulted in samples with large volumes of material, but these could be separated from other plankton with little difficulty and were generally not split, depending upon the final volume of the material.

Specimens were enumerated and identified to the lowest practical taxon. If the quantity of material in the two samples was very large then only one of the two samples was processed and analyzed. In addition, in cases where samples contained a large number of eggs, an aliquot (sub-sample) was taken from the total sample and only the sub-sample was processed for eggs. A representative sample of up to 50 larvae from each species for each survey (100 during the first two surveys) was measured from the entrainment samples using a dissecting microscope and image analysis system. If fewer than 50 individuals from a species were collected during the survey then all of the larvae from the survey were measured. Total length was measured to an accuracy of at least 0.004 inch (0.1 millimeter).

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 problem specimens.

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 ESGS were calculated from larval densities averaged from the two entrainment stations (E2 and E3; total of 8 replicate measurements per survey), and data on daily cooling water flow from 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. In addition to the entrainment estimates using actual operating flows for all four units and separately for Units 3 & 4, estimates were also calculated using design (maximum) capacity flows for Units 3 & 4.

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 Empirical Transport Model (*ETM*). In the ESGS entrainment study each approach (e.g., *AEL*, *FH*, and *ETM*), as appropriate for each target taxon, was used to assess effects of power plant losses.

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 of time 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 size at hatching and the average size of the larvae from entrainment by a larval growth rate obtained from the literature. While 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:

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

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. The length frequency distributions for several of the fishes did not follow this pattern and the length of the 10th percentile of the distribution was used as the hatch length for these taxa to eliminate outlier values. Parameters of the models used in the analyses are detailed in Appendix C.

4.3.4.2 Demographic Approaches

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

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. We used two different but related demographic approaches in assessing entrainment effects at ESGS: *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*. Adult-equivalent loss estimates require survivorship estimates from the age at entrainment to adult recruitment; *FH* requires egg and larval survivorship up to the age of entrainment plus estimates of fecundity. Furthermore, to make estimation practical, the affected population is assumed to be stable and stationary, and age-specific survival and fecundity rates are assumed to be constant over time. Each of these approaches provides estimates of adult fish losses, which ideally need to be compared to standing stock estimates of adult fishes.

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa collected during the study. These rates, when available, were inferred from the literature. The uncertainty associated with published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported. Because the accuracy of the estimated entrainment effects from *AEL* and *FH* will depend on the accuracy of age-specific mortality and fecundity estimates, lack of demographic information may limit the utility of these approaches.

The precursor to the *AEL* and *FH* calculations is an estimate of total annual larval entrainment. Estimates of larval entrainment at ESGS were based on monthly sampling where E_T is the estimate of total entrainment for the yearlong study period and E_i is the entrainment estimate for the individual survey periods. 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 (estimated using the 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:

$$FH = \frac{E_T}{TLF \bullet \prod_{j=1}^{n} S_i} \tag{1}$$

where

E_T = total entrainment estimate;

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

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

The two key input parameters in Equation 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 that are familiar units to resource managers. Adult equivalent loss does not require source water estimates of larval abundance in assessing effects. This latter advantage may be offset by the need to gather age-specific mortality rates to predict adult losses and the need for information on the adult population of interest for estimating population-level effects (i.e., fractional losses).

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

$$AEL = \sum_{j=1}^{n} E_j S_j \tag{2}$$

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 j th 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:

$$AEL = E_T \prod_{j=a}^{n} S_j \tag{3}$$

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.

4.3.4.3 Empirical Transport Model

As an alternative to the demographic models described above, the empirical transport model (*ETM*) was proposed by the U.S. Fish and Wildlife Service 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 ESGS entrainment on local Santa Monica Bay 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* calculations were based on actual cooling water flow and a sampling volume in the nearshore of 735,176,994 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 (SONGS).

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 concentration of larvae in the water entrained that day) × (average daily cooling flow volume during the survey period),

$N_{Si} =$ estimated number of larvae in the source water that day in survey i (estimated concentration of larvae in the souce water that day) × (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. 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 two weeks.

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

$$(1-PE)^d$$

Larval duration from hatching to entrainment was calculated as described above.

The surveys in each study period were used to estimate larval mortality (P_M) due to entrainment using the following equation

$$P_M = 1 - \sum_{i=1}^{12} f_i (1 - PE_i \cdot P_S)^d \qquad (5)$$

where

$PE_i =$ estimate of proportional entrainment for the *i*th survey,
$P_S =$ estimate of the proportion of the total source water population represented by the sampled population,
$f_i =$ proportion of the total annual source water population present during the *i*th survey, and
$d =$ the estimated number of days of larval life.

To establish independent survey estimates, it is assumed that during each survey a new and distinct cohort of larvae is 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 i^{th} survey period. For the entire yearlong 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. As shown in Equations 4 and 5 estimates of *PE* are based on larval population estimates within specific volumes of water. While a reasonably accurate estimate of the volume of the cooling water intake flow can be obtained, estimating the volume of the source water is more difficult and will vary depending upon oceanographic conditions and taxa group. *ETM* estimates of P_M were calculated using two estimates for P_S, the proportion of the sampled source water population to the total source population. One estimate was based on alongshore and onshore current displacement while the other used only alongshore current displacement. The current displacement was calculated over the period of time that the larvae were estimated to be exposed to entrainment. This period of time was estimated using length data from a representative number of larvae (100-200) from the entrainment samples for each taxon. The maximum age was calculated as the upper 95th percentile value of the lengths measured from the samples. The maximum age at entrainment was calculated by dividing the difference between the upper 95th percentile values of the lengths and the estimated hatch length or 10th percentile value of the lengths, depending on the taxa, by an estimated larval growth rate.

The incorporation of P_S into the ETM model is typically defined by the ratio of the area or volume of the sampled population to a larger area or volume containing the population of inference (Parker and DeMartini 1989). If an estimate of the larval (or adult) population in the larger area is available, it can also be computed using the estimate of the larval or adult population in the study grid, defined by Ricker (1975) as the proportion of the parental stock. If the distribution in the larger area is assumed to be uniform, then the value of P_S for the proportion of the population will be the same as the proportion computed using area or volume. For taxa whose larval distribution extends to the offshore edge of the study grid, P_S will be calculated as the ratio:

$$P_S = N_S / N_P \ , \tag{6}$$

where N_S is the number of larvae in the sampled population, and N_P is the number of larvae in the population of inference. The numerator N_S is the same as estimate, N_{Si} (Equation 4), used in the calculation of *PE*, i.e.

$$N_{S_i} = \sum_{k=1}^{10} A_{G_k} \cdot \bar{D}_k \cdot \rho_{\mathrm{i,k}} \ , \tag{7}$$

where

A_{Gk} = area of source water sampling area station k,

$\bar{D}_{\mathrm{k}}$ = average depth of the k^{th} station, and

$\rho_{\mathrm{i,k}}$ = density (per m^3) of larvae in k^{th} station during survey *i.*

N_P in Equation 6 was estimated by offshore and alongshore extrapolation of the study grid densities, using water current measurements. First, a conceptual model was formulated to extrapolate larval densities (per m^3) offshore of the grid:

$$P_S = \frac{N_S}{N_P} = \frac{\sum_{k=1}^{10} L_{G_k} \cdot W_k \cdot \bar{D}_k \cdot \bar{\rho}_k}{\sum_{k=1}^{K\max} L_{Pk} \cdot W_k \cdot \bar{D}_k \cdot \bar{\rho}_k} , \tag{8}$$

where

L_{G_k} = alongshore length of source water sampling area station *k*,

W_{k} = average width of the k^{th} station,

$\bar{D}_{\mathrm{k}}$ = average depth of the k^{th} station,

$\bar{\rho}_k$ = estimated average density (per m^3) of larvae in k^{th} station,

Kmax = index of offshore extent, based on current data, and

L_{P_k} = alongshore length of the population based on current data.

The denominator in Equation 8 includes an extrapolation offshore that is a discrete version of a conceptually continuous function. Therefore, to ease implementation, an essentially equivalent formulation that incorporates the use of the average densities for the stations in the sampled area during each survey and integrates a linear extrapolation of density (per m^2) calculated by multiplying the density by the station depth as a function of offshore distance:

$$P_{S_i} = \frac{N_{G_i}}{N_{P_i}} = \frac{N_{G_i}}{\sum_{k=1}^{10} \frac{L_{P_i} \cdot N_{G_{ik}}}{L_{G_{ik}}} + L_{P_i} \cdot \int_{W_O}^{W_{max}} \rho\left(w\right) dw}, \tag{9}$$

where

L_{P_i} = alongshore length of the population in the i^{th} study period based on current data,

$\rho\left(w\right)$ = density of larvae (per m^2) as a linear function of w, distance offshore, and

W_{max}, W_O = limits of integration for extrapolation outside study grid.

The limits of the integration are from the offshore margin of the stations to a point estimated by the onshore movement of currents, where the extrapolated density is zero, or to the edge of the Santa Monica Bay shelf at a depth of 80 m (~45 fathoms) where a line drawn between Point Dume and Palos Verdes intersects a line drawn 90 degree to coastline at a point between the Scattergood and El Segundo generating stations, a distance of 15.2 km (9.4 mile). Note that the population number, N_P, is composed of two components that represent the alongshore extrapolation of the sampled source population and the offshore extrapolation of the sampled source population.

Parameter values needed in performing the extrapolation were obtained through a regression analysis using the data from all of the surveys. This resulted in the calculation of a common slope and intercept for all of the surveys for each of the taxa. The differences in onshore currents changed the limit of the extrapolation used for each survey.

For a P_S using only alongshore current, displacement was calculated without using the offshore extrapolation based on onshore or offshore current movement to predict a coastwise fraction of the population of inference. The total alongshore displacement in the i^{th} survey, included both upcoast and downcoast movement calculated during a period equal to the larval duration before each survey. For taxa with long larval durations the total alongshore displacement was limited to the shoreline length of Santa Monica Bay, estimated as 60 km (37 mile). This approach was taken since offshore currents appear to set up countercurrents within Santa Monica Bay forming a coastal eddy that may limit transport from coastal areas directly north and south of the bay (Hickey 1992). The P_S using only alongshore current was calculated as:

$$P_{S_i} = \frac{N_{S_i}}{N_{P_i}} = \frac{N_{S_i}}{\sum_{k=1}^{10} \frac{L_{P_i} \cdot N_{G_{ik}}}{L_{G_{ik}}}}. \tag{10}$$

The current data for both estimates were from data collected from the current meters (CM 3 and CM 4) located in the source water sampling area (Figure 3.4-9). The alongshore currents were taken from the inshore station (CM 4) while the onshore currents were taken from the current meter located further offshore (CM 3).

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; and
- 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*) from the estimates of PE_i as follows:

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

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 SAMPLING SUMMARY

Twelve entrainment surveys were completed between January 25, 2006 and December 13, 2006 at the entrainment and source water stations (Table 4.4-1). A total of 374 and 960 samples were collected from the entrainment and source water stations respectively. All but one of the entrainment samples and forty of the source water samples were processed for the target organisms.

Table 4.4-1. Entrainment/source water surveys and number of samples collected from January 2006 through January 2007.

		Entrainment Samples		**Source Water Samples**	
Survey Number	**Date**	**Number Collected**	**Number Processed**	**Number Collected**	**Number Processed**
SMBEA02	1/25/06	32	32	80	80
SMBEA04	2/23/06	32	32	80	80
SMBEA06	3/22/06	32	32	80	79
SMBEA08	4/19/06	32	32	80	80
SMBEA10	5/17/06	32	32	80	79
SMBEA12	6/14/06	24[a]	23	80	43[b]
SMBEA14	07/12/06	32	30	80	79
SMBEA16	08/09/06	32	32	80	80
SMBEA19	09/20/06	32	32	80	80
SMBEA21	10/18/06	32	32	80	80
SMBEA23	11/15/06	32	32	80	80
SMBEA25	12/13/06	32	32	80	80
		374	**373**	**960**	**920**

[a] samples could not be collected due to hazardous sea conditions

[b] samples voided due to improper preservation.

4.5 RESULTS

4.5.1 Cooling Water Intake Structure Entrainment Summary

4.5.1.1 Fishes

A total of 4,227 entrainable fish larvae from 66 separate taxonomic categories was collected from the twelve entrainment surveys (Table 4.5-1). The most abundant larval fish taxon in the samples was white croaker, which comprised 23.7% of the total larvae collected, followed by unidentified anchovies (16.5%). A total of 57,248 fish eggs from 19 separate taxonomic categories was collected from the entrainment surveys. The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 55.4% of the total eggs collected, followed by sand flounder eggs (17.5%). Greatest densities of larval fishes occurred in April and the least in January (Figure 4.5-1). Fish eggs also peaked in abundance in April with lows occurring in December (Figure 4.5-2). Larvae and eggs were generally more abundant in samples collected at night than those collected during the day in most surveys (Figures 4.5-3 and 4.5-4). Total annual entrainment from Units 1–4 of all fish eggs and larvae was estimated to be 4,192,081,093 and 222,275,332, respectively using the actual cooling water flows (Table 4.5-2). Entrainment from Units 3 & 4 accounted for 82.1% of the total fish eggs and 83.9% of the total fish larvae, with 3,442,879,223 eggs and 186,532,003 larvae entrained. If Units 3 & 4 were run at the design (maximum) capacity flow volumes, an estimated 5.8 billion eggs and 277.3 million larvae could potentially be entrained. Standard error data for total annual entrainment calculations is presented in Appendix D.

Table 4.5-1. Average abundances of larval fishes and fish eggs from samples collected at ESGS Entrainment Stations E2 and E3, from January 2006 to December 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Genyonemus lineatus	white croaker	114.79	1,001	23.68	23.68
Engraulidae unid.	anchovies	87.73	699	16.54	40.22
unidentified larvae, yolksac	unidentified yolksac larvae	65.66	530	12.54	52.76
Sciaenidae unid.	croakers	29.09	216	5.11	57.87
Gobiidae unid.	gobies	23.30	186	4.40	62.27
Paralabrax spp.	sea basses	23.04	198	4.68	66.95
Hypsoblennius spp.	combtooth blennies	18.07	141	3.34	70.29
unidentified larvae, damaged	unidentified damaged larvae	15.48	125	2.96	73.24
Paralichthys californicus	California halibut	14.46	113	2.67	75.92
Pleuronichthys guttulatus	diamond turbot	12.28	108	2.56	78.47
Stenobrachius leucopsarus	northern lampfish	11.60	106	2.51	80.98
Seriphus politus	queenfish	10.72	69	1.63	82.61
Citharichthys spp.	sanddabs	10.47	83	1.96	84.58
Atherinopsidae unid.	silversides	7.39	68	1.61	86.18
Pleuronichthys spp.	turbots	6.43	44	1.04	87.22
Sphyraena argentea	Pacific barracuda	5.41	40	0.95	88.17
Cheilotrema saturnum	black croaker	5.41	33	0.78	88.95
Haemulidae unid.	grunts	5.14	44	1.04	89.99
Parophrys vetulus	English sole	4.91	49	1.16	91.15
Oxyjulis californica	senorita	4.87	40	0.95	92.10
Pleuronectidae unid.	righteye flounders	4.23	41	0.97	93.07
Ophidiidae unid.	cusk-eels	3.69	30	0.71	93.78
larval/post-larval fish unid.	larval fishes	3.47	26	0.62	94.39
Lepidogobius lepidus	bay goby	2.88	25	0.59	94.98
Menticirrhus undulatus	California corbina	2.67	22	0.52	95.51
Pleuronichthys verticalis	hornyhead turbot	2.58	22	0.52	96.03
Xystreurys liolepis	fantail sole	2.16	17	0.40	96.43
Merluccius productus	Pacific hake	2.01	18	0.43	96.85
Semicossyphus pulcher	California sheephead	1.77	15	0.35	97.21
Pleuronichthys ritteri	spotted turbot	1.65	14	0.33	97.54
Symphurus atricaudus	California tonguefish	1.36	11	0.26	97.80
Labridae unid.	wrasses	1.35	12	0.28	98.08
Paralichthyidae unid.	sand flounders	0.98	9	0.21	98.30
Ophidion scrippsae	basketweave cusk-eel	0.98	8	0.19	98.49
Pleuronectiformes unid.	flatfishes	0.91	8	0.19	98.68
Halichoeres semicinctus	rock wrasse	0.64	5	0.12	98.79
Zaniolepis spp.	combfishes	0.58	5	0.12	98.91
Syngnathus spp.	pipefishes	0.51	4	0.09	99.01
Gibbonsia spp.	clinid kelpfishes	0.49	3	0.07	99.08
Hippoglossina stomata	bigmouth sole	0.37	3	0.07	99.15
Microstomus pacificus	Dover sole	0.36	4	0.09	99.24
Icelinus spp.	sculpins	0.36	3	0.07	99.31

(table continued)

Table 4.5-1. (continued). Average abundances of larval fishes and fish eggs from samples collected at ESGS Entrainment Stations E2 and E3, from January 2006 to December 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Labrisomidae unid.	labrisomid blennies	0.27	2	0.05	99.36
Gillichthys mirabilis	longjaw mudsucker	0.27	2	0.05	99.41
Bathymasteridae unid.	ronquils	0.26	2	0.05	99.46
Leptocottus armatus	Pacific staghorn sculpin	0.24	2	0.05	99.50
Peprilus simillimus	Pacific butterfish	0.24	2	0.05	99.55
Cottidae unid.	sculpins	0.23	2	0.05	99.60
Umbrina roncador	yellowfin croaker	0.21	1	0.02	99.62
Typhlogobius californiensis	blind goby	0.21	2	0.05	99.67
Sebastes spp.	rockfishes	0.19	2	0.05	99.72
Diaphus theta	California headlight fish	0.18	1	0.02	99.74
Cottus asper	prickly sculpin	0.16	1	0.02	99.76
Chaenopsidae unid.	tube blennies	0.15	1	0.02	99.79
Psettichthys melanostictus	sand sole	0.14	1	0.02	99.81
Clupeiformes unid.	herrings and anchovies	0.14	1	0.02	99.83
Myctophidae unid.	lanternfishes	0.14	1	0.02	99.86
Triphoturus mexicanus	Mexican lampfish	0.13	1	0.02	99.88
Acanthogobius flavimanus	yellowfin goby	0.12	1	0.02	99.91
Sardinops sagax	Pacific sardine	0.12	1	0.02	99.93
Anisotremus davidsonii	sargo	0.12	1	0.02	99.95
Ruscarius creaseri	roughcheek sculpin	0.12	1	0.02	99.98
Hypsypops rubicundus	garibaldi	0.10	1	0.02	100.00
		516.00	**4,227**		
Fish Eggs					
fish eggs unid.	unidentified fish eggs	6,444.66	31,718	55.40	55.40
Paralichthyidae unid.	sand flounder eggs	1,415.49	10,032	17.52	72.93
Sciaenidae / Paralichthyidae /	fish eggs	1,077.09	4,497	7.86	80.78
Engraulidae unid.	anchovy eggs	1,044.14	4,409	7.70	88.49
Citharichthys spp.	sanddab eggs	507.14	3,050	5.33	93.81
Pleuronichthys spp.	turbot eggs	379.23	2,291	4.00	97.81
Sciaenidae unid.	croaker eggs	118.71	992	1.73	99.55
Genyonemus lineatus	white croaker eggs	17.41	127	0.22	99.77
Paralabrax spp.	sea bass eggs	10.58	44	0.08	99.85
Sphyraena argentea	Pacific barracuda eggs	10.40	42	0.07	99.92
Paralichthys californicus	California halibut eggs	2.25	17	0.03	99.95
Labridae unid.	wrasse eggs	2.24	10	0.02	99.97
Pleuronectidae unid.	righteye flounder eggs	1.29	13	0.02	99.99
Atherinopsidae unid.	silverside eggs	0.26	1	<0.01	99.99
Pleuronichthys guttulatus	diamond turbot eggs	0.25	1	<0.01	99.99
Pleuronichthys coenosus	c-o turbot eggs	0.23	1	<0.01	99.99
Bathylagidae	blacksmelt eggs	0.10	1	<0.01	99.99
Lyopsetta exilis	slender sole eggs	0.09	1	<0.01	99.99
Merluccius spp.	hake eggs	0.09	1	<0.01	100.00
		11,031.64	**57,248**		

Table 4.5-2. Calculated total annual entrainment of larval fishes and fish eggs at ESGS in 2006 based on actual and design[1] cooling water intake pump flows for Units 1 & 2 and Units 3 & 4.

Taxon	Common Name	Actual Flows (All Units)	Actual Flows (Units 3 & 4)	Actual Flows (Units 1 & 2)	Design Flows (Units 3 & 4)
Larval Fish					
Genyonemus lineatus	white croaker	44,365,993	36,886,189	7,479,804	57,674,813
Engraulidae unid.	anchovies	36,589,361	30,806,088	5,783,273	44,566,730
unidentified larvae, yolksac	unidentified yolksac larvae	32,877,925	27,954,526	4,923,399	38,410,225
Sciaenidae unid.	croakers	15,122,724	13,080,938	2,041,786	15,708,573
Paralabrax spp.	sea basses	10,753,540	8,932,843	1,820,697	14,393,420
Gobiidae unid.	gobies	8,553,040	6,997,707	1,555,333	12,043,151
Hypsoblennius spp.	combtooth blennies	7,451,656	6,180,886	1,270,770	9,927,668
unidentified larvae, damaged	unidentified damaged larvae	7,095,438	6,018,166	1,077,272	8,381,958
Paralichthys californicus	California halibut	6,869,726	5,863,484	1,006,242	7,790,992
Seriphus politus	queenfish	5,807,906	5,038,592	769,314	5,915,819
Citharichthys spp.	sanddabs	4,476,374	3,738,404	737,970	5,698,399
Stenobrachius leucopsarus	northern lampfish	4,240,824	3,493,114	747,710	5,754,218
Pleuronichthys spp.	turbots	3,390,551	2,960,303	430,248	3,319,412
Sphyraena argentea	Pacific barracuda	2,923,078	2,516,814	406,264	3,130,058
Cheilotrema saturnum	black croaker	2,889,237	2,528,784	360,453	2,771,788
Haemulidae unid.	grunts	2,788,973	2,389,078	399,895	3,087,266
Oxyjulis californica	senorita	2,628,016	2,229,112	398,904	3,076,665
Atherinopsidae unid.	silversides	2,361,934	1,839,312	522,622	4,145,527
Pleuronichthys guttulatus	diamond turbot	2,148,380	1,288,095	860,285	6,768,632
Ophidiidae unid.	cusk-eels	2,051,192	1,747,031	304,161	2,338,910
Parophrys vetulus	English sole	1,685,987	1,371,804	314,183	2,416,978
larval/post-larval fish unid.	larval fishes	1,638,736	1,396,081	242,655	1,867,946
Pleuronectidae unid.	righteye flounders	1,477,214	1,205,683	271,531	2,089,182
Menticirrhus undulatus	California corbina	1,475,529	1,262,690	212,839	1,636,675
Xystreurys liolepis	fantail sole	1,039,682	882,753	156,929	1,232,319
Lepidogobius lepidus	bay goby	1,036,482	850,455	186,027	1,431,791
Pleuronichthys verticalis	hornyhead turbot	1,011,497	843,859	167,638	1,294,165
Semicossyphus pulcher	California sheephead	812,007	673,980	138,027	1,065,730
Symphurus atricaudus	California tonguefish	755,046	646,635	108,411	833,654
Merluccius productus	Pacific hake	667,807	539,453	128,354	987,186
Labridae unid.	wrasses	598,847	493,382	105,465	831,640
Pleuronichthys ritteri	spotted turbot	578,822	464,029	114,793	902,867
Ophidion scrippsae	basketweave cusk-eel	544,846	464,053	80,793	621,270
Halichoeres semicinctus	rock wrasse	353,013	300,667	52,346	402,530
Pleuronectiformes unid.	flatfishes	305,428	246,518	58,910	453,174
Paralichthyidae unid.	sand flounders	267,300	195,727	71,573	581,524
Zaniolepis spp.	combfishes	247,526	207,136	40,390	317,203
Syngnathus spp.	pipefishes	235,368	201,654	33,714	259,251
Gibbonsia spp.	clinid kelpfishes	203,962	171,922	32,040	246,524
Icelinus spp.	sculpins	171,061	147,123	23,938	184,341

(table continued)

Table 4.5-2 (continued). Calculated total annual entrainment of larval fishes and fish eggs at ESGS in 2006 based on actual and design[1] cooling water intake pump flows for Units 1 & 2 and Units 3 & 4.

Taxon	**Common Name**	**Actual Flows (All Units)**	**Actual Flows (Units 3 & 4)**	**Actual Flows (Units 1 & 2)**	**Design Flows (Units 3 & 4)**
Hippoglossina stomata	bigmouth sole	149,817	125,618	24,199	186,083
Microstomus pacificus	Dover sole	117,828	94,641	23,187	178,298
Umbrina roncador	yellowfin croaker	111,057	97,336	13,721	105,511
Gillichthys mirabilis	longjaw mudsucker	102,243	85,040	17,203	132,449
Bathymasteridae unid.	ronquils	100,741	84,161	16,580	127,681
Diaphus theta	California headlight fish	95,116	83,364	11,752	90,366
Peprilus simillimus	Pacific butterfish	83,690	65,697	17,993	149,529
Typhlogobius californiensis	blind goby	81,022	67,564	13,458	103,625
Psettichthys melanostictus	sand sole	77,669	68,275	9,394	72,233
Clupeiformes unid.	herrings and anchovies	77,535	66,037	11,498	88,410
Labrisomidae unid.	labrisomid blennies	76,054	58,169	17,885	137,706
Myctophidae unid.	lanternfishes	73,538	64,453	9,085	69,866
Triphoturus mexicanus	Mexican lampfish	70,944	60,424	10,520	80,895
Cottus asper	prickly sculpin	70,510	59,878	10,632	81,936
Sardinops sagax	Pacific sardine	67,493	57,484	10,009	76,960
Anisotremus davidsonii	sargo	67,298	57,318	9,980	76,737
Chaenopsidae unid.	tube blennies	63,406	53,845	9,561	73,680
Sebastes spp.	rockfishes	62,674	50,341	12,333	94,838
Hypsypops rubicundus	garibaldi	54,943	46,796	8,147	62,650
Acanthogobius flavimanus	yellowfin goby	54,042	45,894	8,148	62,800
Leptocottus armatus	Pacific staghorn sculpin	44,295	28,359	15,936	122,543
Cottidae unid.	sculpins	42,550	25,044	17,506	141,174
Ruscarius creaseri	roughcheek sculpin	38,838	31,195	7,643	58,769
		222,275,332	186,532,003	35,743,328	276,934,913
	Percent of Total	100.00	83.92	16.08	–
Fish Eggs					
fish eggs unid.	unidentified fish eggs	2,565,757,29	2,126,699,674	439,057,624	3,405,009,564
Sciaenidae / Paralichthyidae / Labridae	SPL fish eggs	483,931,072	407,914,231	76,016,841	592,934,824
Engraulidae unid.	anchovy eggs	432,212,026	363,479,754	68,732,272	529,013,191
Paralichthyidae unid.	sand flounder eggs	347,101,345	252,841,920	94,259,425	726,152,480
Citharichthys spp.	sanddab eggs	165,393,976	131,272,426	34,121,550	264,875,098
Pleuronichthys spp.	turbot eggs	140,959,171	115,111,117	25,848,054	200,392,640
Sciaenidae unid.	croaker eggs	39,447,603	31,614,098	7,833,505	60,894,283
Sphyraena argentea	Pacific barracuda eggs	5,777,626	4,924,839	852,787	6,557,694
Paralabrax spp.	sea bass eggs	4,935,308	4,109,380	825,928	6,568,642
Genyonemus lineatus	white croaker eggs	4,498,770	3,319,629	1,179,141	9,067,268
Paralichthys californicus	California halibut eggs	602,696	449,338	153,358	1,179,277
Labridae unid.	wrasse eggs	549,366	388,228	161,138	1,283,731
Pleuronectidae unid.	righteye flounder eggs	417,594	335,419	82,175	631,905
Atherinopsidae unid.	silverside eggs	144,521	123,091	21,430	164,793
Pleuronichthys guttulatus	diamond turbot eggs	136,981	116,669	20,312	156,195

(table continued)

Table 4.5-2 (continued). Calculated total annual entrainment of larval fishes and fish eggs at ESGS in 2006 based on actual cooling water intake pump flows for Units 1 & 2 and Units 3 & 4.

Taxon	**Common Name**	**Actual Flows (All Units)**	**Actual Flows (Units 3 & 4)**	**Actual Flows (Units 1 & 2)**	**Design Flows (Units 3 & 4)**
Pleuronichthys coenosus	c-o turbot eggs	126,221	107,505	18,716	143,926
Bathylagidae	blacksmelt eggs	31,583	25,368	6,215	47,791
Lyopsetta exilis	slender sole eggs	29,430	23,639	5,791	44,534
Merluccius spp.	hake eggs	28,506	22,897	5,609	43,136
		4,192,081,093	**3,442,879,223**	**749,201,870**	**5,805,160,975**
	Percent of Total	100.00	82.13	17.87	–

[1] Annual entrainment estimates using design (maximum) flow volumes were only calculated for Units 3 & 4 due to the minimal operation of Units 1 & 2 during the study.

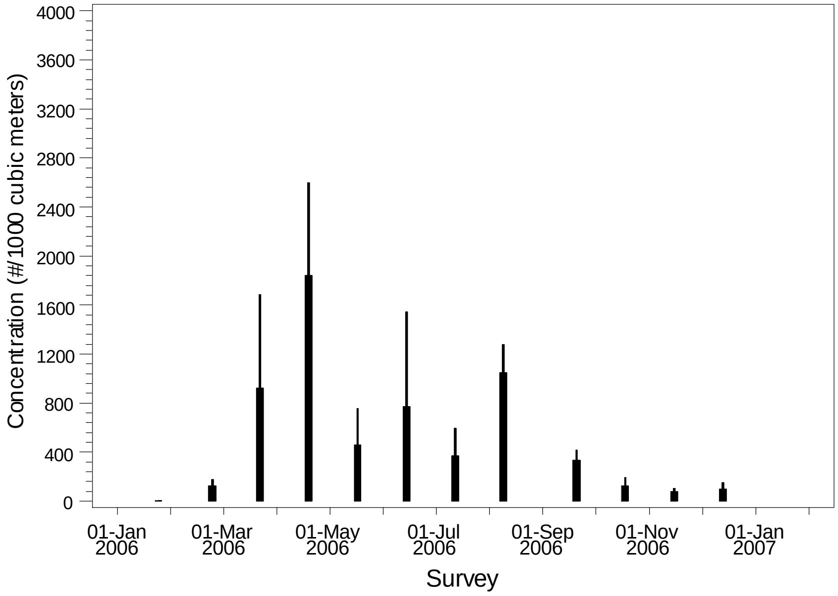


Figure 4.5-1. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of all larval fishes collected at the ESGS Entrainment Stations E2 and E3 during 2006.

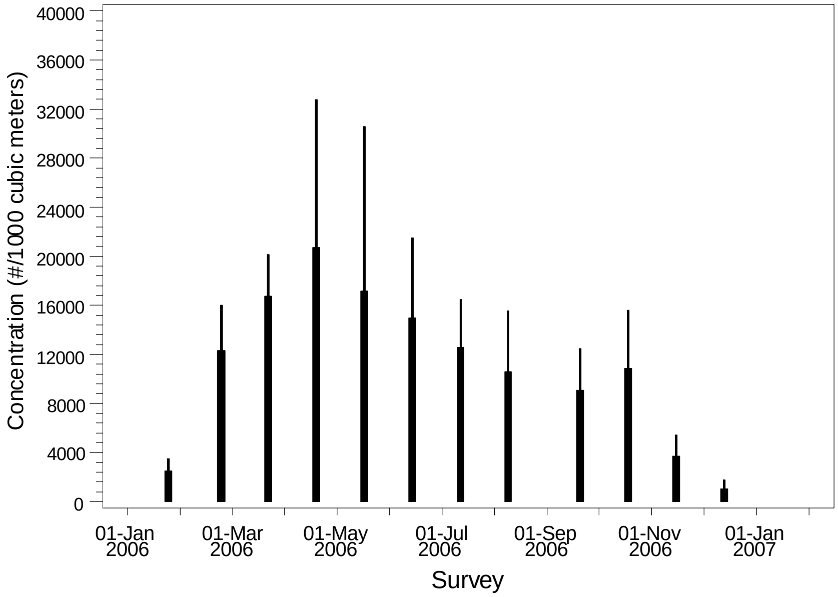


Figure 4.5-2. Mean concentration (# per 1,000 m^3 [264, 264,000 gal]) and standard deviation of fish eggs collected at the ESGS Entrainment Stations E2 and E3 during 2006.

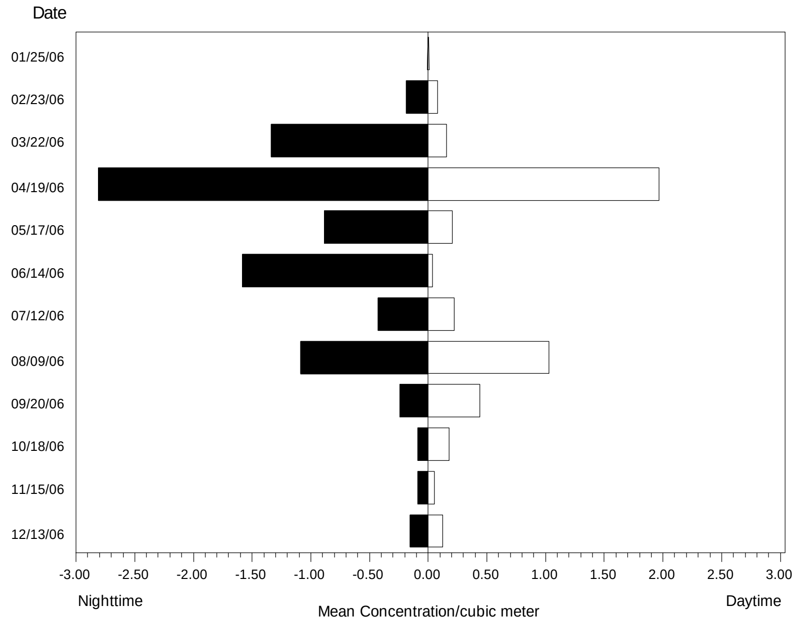


Figure 4.5-3. Mean concentration (# per 1.0 m^3 [264 gal]) of all fish larvae at the ESGS Entrainment Stations E2 and E3 during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are an artifact of the plotting routine.

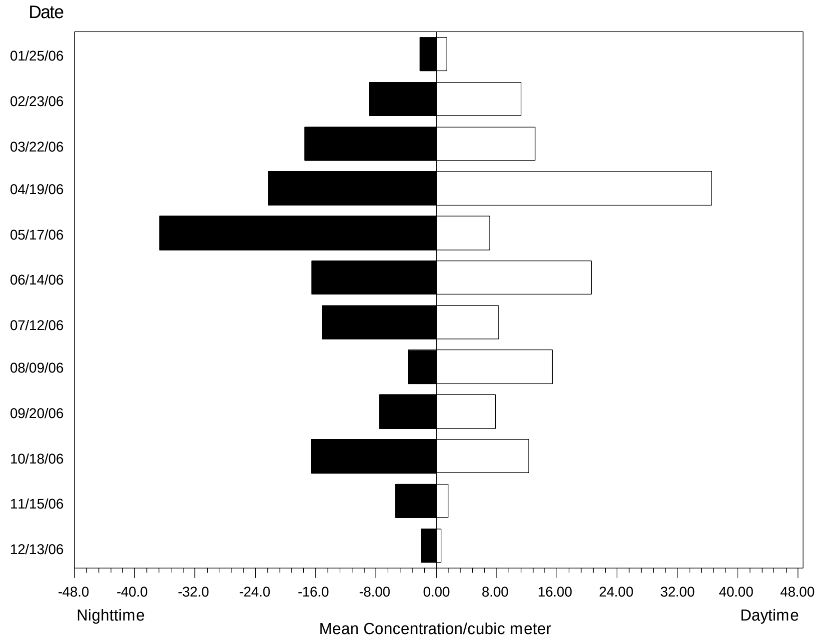


Figure 4.5-4. Mean concentration (# per 1.0 m^3 [264 gal]) of all fish eggs at the ESGS Entrainment Stations E2 and E3 during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are an artifact of the plotting routine.

4.5.1.2 Shellfishes

A total of 431 larval target shellfishes (invertebrates) representing 18 taxa was collected from the ESGS entrainment stations during 12 monthly surveys in 2006 (Table 4.5-3 and Appendix D). The most abundant target invertebrate larvae in the samples were pea crab megalops (*Pinnixa* spp.) followed by kelp crab megalops (*Pugettia* spp.), which made up 30.9% and 25.3%, respectively, of the total target invertebrate larvae collected. Only a single market squid paralarva (hatchling) was collected. Total annual entrainment was estimated to be 23.7 million target invertebrate larvae for all units combined (Table 4.5-4). Entrainment from Units 3 & 4 accounted for 85.1% of the total target invertebrate larvae entrained annually. If Units 3 & 4 were run at the design, or maximum capacity, flow volumes, entrainment estimates increased to 27.4 million larvae. Standard error data for total annual entrainment calculations is presented in Appendix D.

Table 4.5-3. Average abundances of target invertebrate larvae from samples collected at ESGS Entrainment Stations E2 and E3 from January 2006 and January 2007.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Pinnixa spp.	pea crabs megalops	15.98	133	30.86	30.86
Pugettia spp.	kelp crabs megalops	13.24	109	25.29	56.15
Cancer spp.	cancer crabs megalops	4.16	34	7.89	64.04
Pachycheles spp.	porcelain crabs megalops	4.15	30	6.96	71.00
Majidae unid.	spider crab megalops	2.23	19	4.41	75.41
Pinnotheres spp.	pea crab megalops	2.19	18	4.18	79.58
Paguridae unid.	hermit crab megalops	1.85	11	2.55	82.13
Porcellanidae unid.	porcelain crab megalops	1.59	13	3.02	85.15
Lophopanopeus spp.	black-clawed crab	1.55	12	2.78	87.94
Emerita analoga	mole crabs megalops	1.52	13	3.02	90.95
unidentified crab	unidentified crab megalops	1.14	11	2.55	93.50
Grapsidae unid.	shore crab megalops	1.09	10	2.32	95.82
Petrolisthes spp.	porcelain crab megalops	1.02	8	1.86	97.68
P. interruptus (phyllosome)	Calif. spiny lobster	0.49	3	0.70	98.38
Brachyura unid.	unidentified crab megalops	0.32	3	0.70	99.07
Portunus xantusii	Xantus' swimming crab	0.22	2	0.46	99.54
Loligo opalescens	market squid	0.12	1	0.23	99.77
Pachycheles rudis	thickclaw porcelain crab	0.09	1	0.23	100.00
		52.95	**431**		

Table 4.5-4. Calculated total annual entrainment of target invertebrates larvae at ESGS based on actual and design[1] cooling water intake pump flows from January 2006 to January 2007.

Taxon	Common Name	Actual Flows (All Units)	Actual Flows (Units 3 & 4)	Actual Flows (Units 1 & 2)	Design Flows (Units 3 & 4)
Pinnixa spp.	pea crabs megalops	7,681,714	6,622,400	1,059,314	8,170,052
Pugettia spp.	kelp crabs megalops	5,156,073	4,263,545	892,528	6,923,911
Pachycheles spp.	porcelain crabs megalops	2,209,439	1,935,713	273,726	2,104,880
Cancer spp.	cancer crabs megalops	1,860,530	1,577,364	283,166	2,205,141
Majidae unid.	spider crab megalops	982,451	832,284	150,167	1,156,103
Pinnotheres spp.	pea crab megalops	957,020	812,721	144,299	1,112,100
Paguridae unid.	hermit crab megalops	916,469	794,334	122,135	940,030
Lophopanopeus spp.	black-clawed crab megalops	830,481	726,419	104,062	800,333
Porcellanidae unid.	porcelain crab megalops	795,187	690,551	104,636	805,329
Emerita analoga	mole crabs megalops	582,933	482,451	100,482	778,761
Petrolisthes spp.	porcelain crab megalops	471,903	404,955	66,948	515,655
unidentified crab	unidentified crab megalops	405,052	331,004	74,048	569,827
Grapsidae unid.	shore crab megalops	350,720	274,199	76,521	605,635
P. interruptus (phyllosome)	California spiny lobster (larval)	265,951	231,901	34,050	261,835
Brachyura unid.	unidentified crab megalops	105,928	82,542	23,386	187,850
Loligo opalescens	market squid	51,473	43,712	7,761	59,814
Portunus xantusii	Xantus' swimming crab	33,941	19,221	14,720	113,193
Pachycheles rudis	thickclaw porcelain crab	28,506	22,897	5,609	43,136
		23,685,773	**20,148,213**	**3,537,558**	**27,353,585**
	Percent of Total	100.00	85.06	14.94	–

[1] Annual entrainment estimates using design (maximum) flow volumes were only calculated for Units 3 & 4 due to the minimal operation of Units 1 & 2 during the study.

4.5.2 Source Water Summary

4.5.2.1 Fishes

A total of 18,941 fish larvae from 87 separate taxonomic categories was collected from the source water stations during the twelve surveys (Table 4.5-5). The most abundant fish larvae in the samples were unidentified anchovies (23.4%) followed by white croaker (17.8%). The greatest concentrations of larval fishes occurred during March to July and the lowest were observed in January and February (Figure 4.5-5). As was seen at the entrainment station, there were generally more larval fish collected during night sampling than during day sampling (Figure 4.5-6). Data from the entrainment and source water surveys including standardized concentrations of larvae per water volume are presented in Appendix D.

Table 4.5-5. Average abundances of larval fishes from samples collected at the ESGS source water stations in Santa Monica Bay (Stations S1–S4, M1-M3, and O1–O3) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Engraulidae unid.	anchovies	167.95	4,427	23.37	23.37
Genyonemus lineatus	white croaker	132.23	3,373	17.81	41.18
larvae, unid. yolksac	unid. yolksac larvae	67.70	1,567	8.27	49.45
Paralabrax spp.	sea basses	38.17	919	4.85	54.31
Parophrys vetulus	English sole	37.64	1,316	6.95	61.25
Sciaenidae unid.	croakers	36.15	757	4.00	65.25
Paralichthys californicus	California halibut	30.93	759	4.01	69.26
Citharichthys spp.	sanddabs	27.84	680	3.59	72.85
Hypsoblennius spp.	combtooth blennies	24.05	554	2.92	75.77
Seriphus politus	queenfish	23.69	554	2.92	78.70
unidentified fish, damaged	unidentified damaged fish	21.55	566	2.99	81.69
Gobiidae unid.	gobies	13.88	303	1.60	83.28
Pleuronichthys verticalis	hornyhead turbot	11.28	305	1.61	84.90
Haemulidae unid.	grunts	9.69	258	1.36	86.26
Stenobrachius leucopsarus	northern lampfish	9.26	268	1.41	87.67
Icelinus spp.	sculpins	8.23	216	1.14	88.81
Pleuronectidae unid.	righteye flounders	7.45	232	1.22	90.04
Pleuronichthys ritteri	spotted turbot	7.02	182	0.96	91.00
Pleuronichthys guttulatus	diamond turbot	6.36	152	0.80	91.80
Pleuronichthys spp.	turbots	6.09	153	0.81	92.61
Sphyraena argentea	Pacific barracuda	4.73	93	0.49	93.10
Symphurus atricaudus	California tonguefish	4.20	100	0.53	93.63
Atherinopsidae unid.	silversides	3.99	80	0.42	94.05
Merluccius productus	Pacific hake	3.31	118	0.62	94.67
Lepidogobius lepidus	bay goby	2.84	70	0.37	95.04
Ophidiidae unid.	cusk-eels	2.65	61	0.32	95.36
Oxyjulis californica	senorita	2.59	57	0.30	95.67
Xystreurys liolepis	fantail sole	2.54	70	0.37	96.04
Cheilotrema saturnum	black croaker	2.12	45	0.24	96.27
Pleuronectiformes unid.	flatfishes	1.93	59	0.31	96.58
Umbrina roncador	yellowfin croaker	1.88	44	0.23	96.82
Chitonotus / Icelinus	sculpins	1.77	43	0.23	97.04
Hypsypops rubicundus	garibaldi	1.48	30	0.16	97.20
Menticirrhus undulatus	California corbina	1.40	27	0.14	97.34
larval/post-larval fish unid.	larval fishes	1.35	33	0.17	97.52
Chromis punctipinnis	blacksmith	1.20	29	0.15	97.67
Semicossyphus pulcher	California sheephead	1.11	25	0.13	97.80
Halichoeres semicinctus	rock wrasse	1.07	22	0.12	97.92
Zaniolepis spp.	combfishes	1.06	29	0.15	98.07
Paralichthyidae unid.	sand flounders	1.05	26	0.14	98.21
Sebastes spp.	rockfishes	1.03	34	0.18	98.39
Bathylagidae unid.	blacksmelt	0.93	28	0.15	98.54

(table continued)

Table 4.5-5 (continued). Average abundances of larval fishes from samples collected at the ESGS source water stations in Santa Monica Bay (Stations S1–S4, M1-M3, and O1–O3) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Bathymasteridae unid.	ronquils	0.89	30	0.16	98.70
Typhlogobius californiensis	blind goby	0.69	18	0.10	98.79
Labridae unid.	wrasses	0.63	13	0.07	98.86
Peprilus simillimus	Pacific butterfish	0.60	16	0.08	98.94
Leuroglossus stilbius	California smoothtongue	0.58	19	0.10	99.04
Xenistius californiensis	salema	0.57	12	0.06	99.11
Triphoturus mexicanus	Mexican lampfish	0.42	10	0.05	99.16
Lyopsetta exilis	slender sole	0.39	11	0.06	99.22
Labrisomidae unid.	labrisomid blennies	0.37	9	0.05	99.27
Myctophidae unid.	lanternfishes	0.37	9	0.05	99.31
Atractoscion nobilis	white seabass	0.34	9	0.05	99.36
Gillichthys mirabilis	longjaw mudsucker	0.31	8	0.04	99.40
Odontopyxis trispinosa	pygmy poacher	0.31	10	0.05	99.46
Hippoglossina stomata	bigmouth sole	0.28	7	0.04	99.49
Cottidae unid.	sculpins	0.26	7	0.04	99.53
Diaphus theta	California headlight fish	0.23	7	0.04	99.57
Girella nigricans	opaleye	0.22	5	0.03	99.59
Isopsetta isolepis	butter sole	0.22	7	0.04	99.63
Sardinops sagax	Pacific sardine	0.18	4	0.02	99.65
Chitonotus pugetensis	roughback sculpin	0.16	4	0.02	99.67
Chilara taylori	spotted cusk-eel	0.15	3	0.02	99.69
Ruscarius creaseri	roughcheek sculpin	0.14	5	0.03	99.71
Syngnathus spp.	pipefishes	0.13	4	0.02	99.74
Rhinogobiops nicholsii	blackeye goby	0.12	3	0.02	99.75
Artedius spp.	sculpins	0.11	3	0.02	99.77
Clinocottus spp.	sculpins	0.11	3	0.02	99.78
Ophidion scrippsae	basketweave cusk-eel	0.11	2	0.01	99.79
Roncador stearnsii	spotfin croaker	0.11	3	0.02	99.81
Platichthys stellatus	starry flounder	0.10	3	0.02	99.83
Hexagrammidae unid.	greenlings	0.09	3	0.02	99.84
Lythrypnus zebra	zebra goby	0.09	2	0.01	99.85
Argentina sialis	Pacific argentine	0.08	2	0.01	99.86
Chaenopsidae unid.	tube blennies	0.08	2	0.01	99.87
Gibbonsia spp.	clinid kelpfishes	0.08	3	0.02	99.89
Liparis spp.	snailfishes	0.08	2	0.01	99.90
Microstomus pacificus	Dover sole	0.08	4	0.02	99.92
Anisotremus davidsonii	sargo	0.07	2	0.01	99.93
Lepidopsetta bilineata	rock sole	0.07	2	0.01	99.94
Leptocottus armatus	Pacific staghorn sculpin	0.07	2	0.01	99.95
Scorpaenichthys marmoratus	cabezon	0.06	1	0.01	99.96

(table continued)

Table 4.5-5 (continued). Average abundances of larval fishes from samples collected at the ESGS source water stations in Santa Monica Bay (Stations S1–S4, M1-M3, and O1–O3) in 2006.

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Gobiesocidae unid.	clingfishes	0.05	1	0.01	99.96
Oligocottus spp.	sculpins	0.05	1	0.01	99.97
Pomacentridae unid.	damselfishes	0.05	1	0.01	99.97
Scorpaenidae unid.	scorpionfishes	0.05	1	0.01	99.98
Brosmophycis marginata	red brotula	0.04	1	0.01	99.98
Cyclothone signata	showy bristlemouth	0.04	1	0.01	99.99
Nannobrachium spp.	lanternfishes	0.04	1	0.01	99.99
Pleuronectes spp.	righteye flounders	0.04	1	0.01	100.00
		743.68	**18,941**		

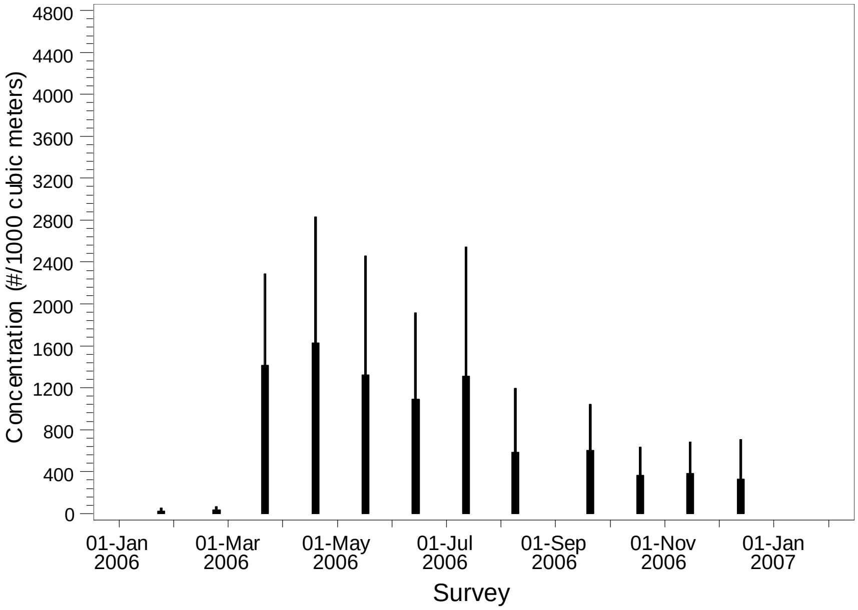


Figure 4.5-5. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of all larval fishes collected at the ESGS source water stations during 2006.

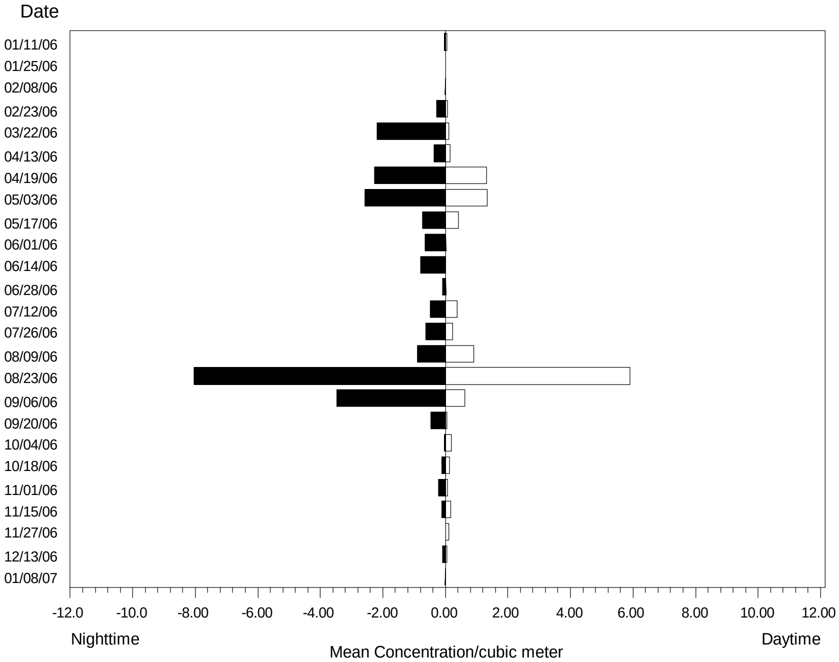


Figure 4.5-6. Mean concentration (# per 1.0 m^3 [264 gal]) of all fish larvae at the ESGS source water Stations during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are an artifact of the plotting routine.

4.5.2.2 Shellfishes

A total of 3,500 larval target shellfishes (invertebrates) representing 20 taxa was collected from the ESGS source water stations during 12 monthly surveys in 2006–2007 (Table 4.5-6 and Appendix D). The most abundant target invertebrate larvae in the samples were pea crab megalops (*Pugettia* spp.) followed by kelp crab megalops (*Pinnixa* spp.), which made up 33.4% and 53.1%, respectively of the total target invertebrate larvae collected. A total of 93 market squid paralarvae were collected.

Table 4.5-6. Average abundances of target invertebrate larvae from samples collected at the ESGS source water stations in Santa Monica Bay (Stations S1–S4, M1-M3, and O1–O3) in 2006.

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Pinnixa spp.	pea crabs megalops	45.45	1,170	33.43	33.43
Pugettia spp.	kelp crabs megalops	27.22	687	19.63	53.06
Cancer spp.	cancer crabs megalops	16.54	449	12.83	65.89
Panulirus interruptus	California spiny lobster (larval)	11.71	340	9.71	75.60
Majidae unid.	spider crab megalops	8.53	226	6.46	82.06
Lophopanopeus spp.	black-clawed crab megalops	4.49	114	3.26	85.31
Loligo opalescens	market squid paralarvae	2.96	93	2.66	87.97
Paguridae unid.	hermit crab megalops	2.59	68	1.94	89.91
Pinnotheres spp.	pea crab megalops	2.37	57	1.63	91.54
Pachycheles spp.	porcelain crabs megalops	2.17	47	1.34	92.89
Grapsidae unid.	shore crab megalops	1.78	43	1.23	94.11
Petrolisthes spp.	porcelain crab megalops	1.65	40	1.14	95.26
Brachyura unid.	unidentified crab megalops	1.64	39	1.11	96.37
Emerita analoga	mole crabs megalops	1.55	40	1.14	97.51
Porcellanidae unid.	porcelain crab megalops	1.36	31	0.89	98.40
unidentified crab	unidentified crab megalops	1.13	34	0.97	99.37
Diogenidae	left-handed hermit crabs meg.	0.58	15	0.43	99.80
Portunus xantusii	Xantus' swimming crab meg.	0.19	5	0.14	99.94
Pinnotheridae	pea crab megalops	0.06	1	0.03	99.97
Anomura unid.	unid. crab megalops	0.04	1	0.03	100.00
		134.02	**3,500**		

4.5.3 Results by Species for Cooling Water Intake Structure Entrainment

The following fish taxa were selected for detailed evaluation of entrainment effects based on their abundance in entrainment samples or status as a PFMC managed species. Unidentified yolk-sac larvae comprised almost 20% all specimens collected and were probably a mix of recently hatched croakers and flatfishes, both of which have very small larvae that cannot be reliably identified even to the family level. Including these unidentified fishes, the list of species analyzed comprised over 85% of the larvae entrained at ESGS in 2006 (Table 4.5-1). In taxonomic order these are:

- anchovies (*Engraulis mordax* and Engraulidae) + eggs
- silversides (Atherinopsidae)
- sea basses (*Paralabrax* spp.)
- white croaker (*Genyonemus lineatus*)
- queenfish (*Seriphus politus*)
- unidentified croakers (Sciaenidae)
- combtooth blennies (*Hypsoblennius* spp.)
- unidentified gobies (Gobiidae)
- sanddabs (*Citharichthys* spp.)
- California halibut (*Paralichthys californicus*)
- English sole (*Parophrys vetulus*)
- diamond turbot (*Pleuronichthys guttulatus*)

4.5.3.1 Anchovies (Engraulidae)

Mark Conlin

Three species of anchovies (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. Over half of the specimens classified 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.

Northern anchovy range 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 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).

4.5.3.1.1 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 anchovy spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978) although this may vary annually and 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.

The northern anchovy egg hatches in two to four days, has a larval phase lasting approximately 70 days, and undergoes transformation into a juvenile at about 35–40 mm (Hart 1973; MBC 1987; Moser 1996). Larvae begin schooling at 11–12 mm (0.4–0.5 in) SL (Hunter and Coyne 1982). Northern anchovy on average reach 102 mm (4 in) in their first year, and 119 mm (4.7 in) in their second (Sakagawa and Kimura 1976). Larval survival is strongly influenced by the availability and density of phytoplankton species (Emmett et al. 1991). Storms and strong upwelling reduce larval food availability, and strong upwelling may transport larvae out of the Southern California Bight (Power 1986). However, strong upwelling may benefit juveniles and adults by increasing 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 in) in length, in their first or second year (Frey 1971; Hunter and Macewicz 1980). Maximum size is reported at 230 mm (9.1 in) 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 are 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). Temperatures above 25°C are avoided by juveniles and adults (Brewer 1974).

4.5.3.1.2 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. The northern anchovy population 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 a 3) 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 (Durrand 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).

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 144,242 kg (318,000 lb) were landed (PacFIN 2007). In 2004 there were 147,417 kg (325,000 lb) landed in the Los Angeles area as compared to 2.75 million kg (6.07 million lb) in the Santa Barbara area, and

3.89 million kg (8.58 million lb) 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 3.9 million kg (8.6 million lb) in 2001, to a low of 0.14 million kg (0.3 million lb) in 2004, with an average of 1.4 million kg (3 million lb) annually (Table 4.5-7).

Table 4.5-7. Annual landings and revenue for northern anchovy in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lb)	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

4.5.3.1.3 Sampling Results

Engraulid larvae (predominantly northern anchovy) were the second most abundant taxon at the entrainment station with a mean concentration of 88 larvae per 1,000 m^3 over all surveys while engraulid eggs had an average concentration of 1,044 per 1,000 m^3 (Table 4.5-1). Almost all larvae occurred in April–May (Figure 4.5-7). During periods of maximum abundance in early May 2006 anchovies were present in the entrainment samples at average concentrations of approximately 600 larvae per 1,000 m^3. They were absent or present in only very low concentrations in all other months. Monthly source water concentrations followed a similar seasonal pattern with maximum concentrations exceeding 1,100 per 1,000 m^3 in May 2006 (Figure 4.5-8). There was no consistent trend in abundance between daytime and nighttime samples (Figure 4.5-9). The length frequency distribution of measured northern anchovy larvae showed a bi-modal distribution with the predominant peak consisting of recently hatched larvae, and a smaller peak in the range of 7–10 mm (0.27–0.39 in) (Figure 4.5-10), reflecting growth of the initial strong cohort from the April spawning event (Figure 4.5-6). The lengths of the larvae from the entrainment station samples ranged from 1.1–25.1 mm (0.04–0.99 in) with a mean of 5.2 mm (0.20 in) NL.

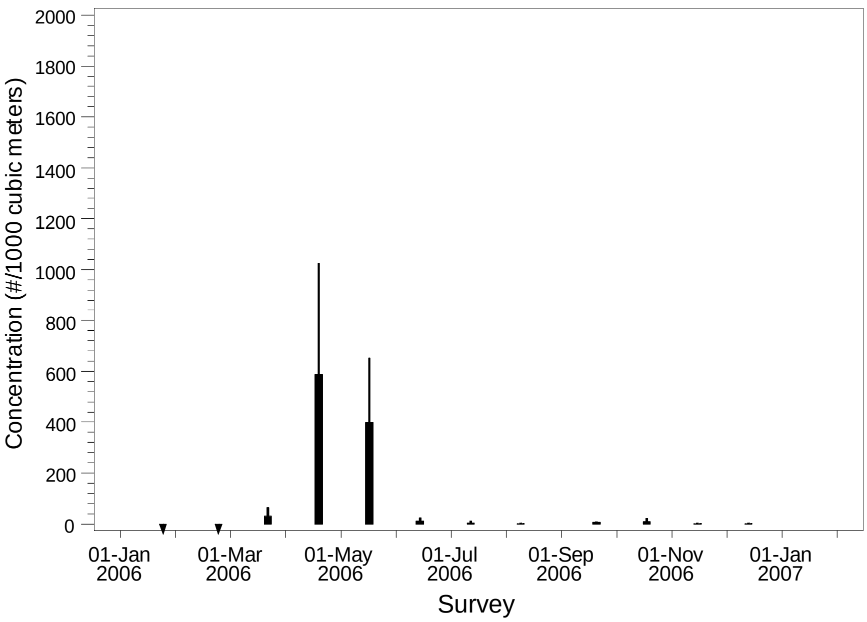


Figure 4.5-7. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of anchovy larvae collected at ESGS entrainment stations during 2006.

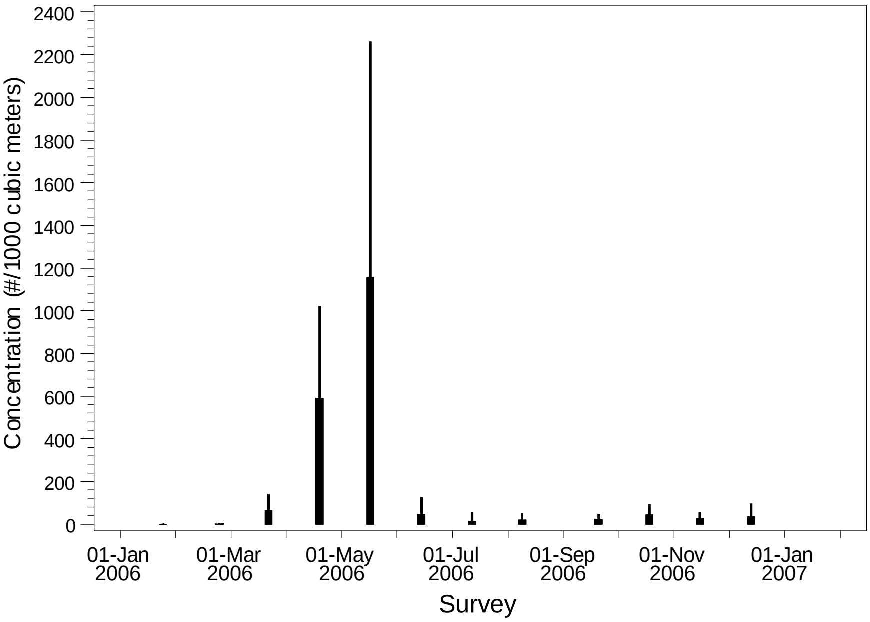


Figure 4.5-8. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of anchovy larvae collected at ESGS source water stations during 2006.

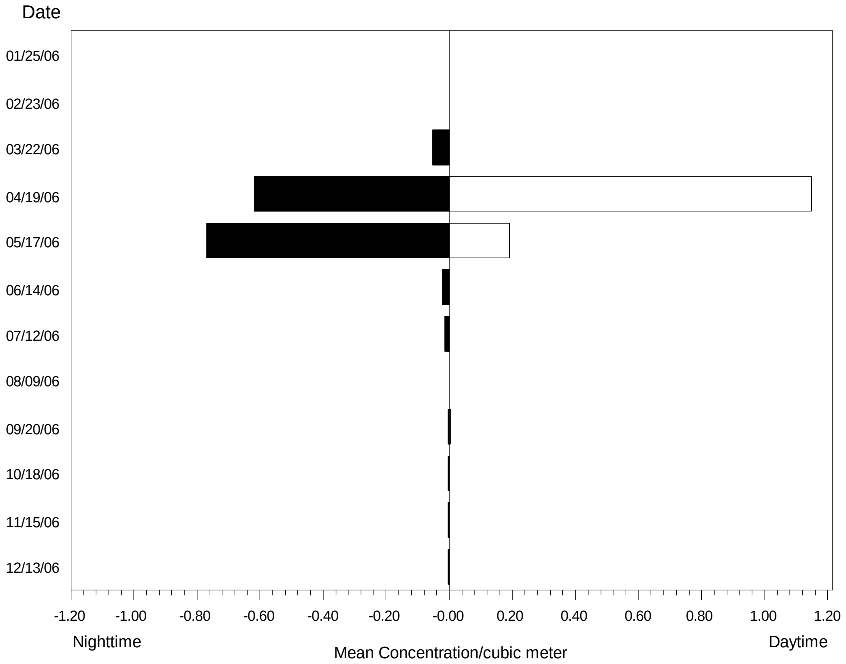


Figure 4.5-9. Mean concentration (# per 1.0 m^3 [264 gal]) of anchovy larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through December 2006.

Note: Negative nighttime values are an artifact of the plotting routine.

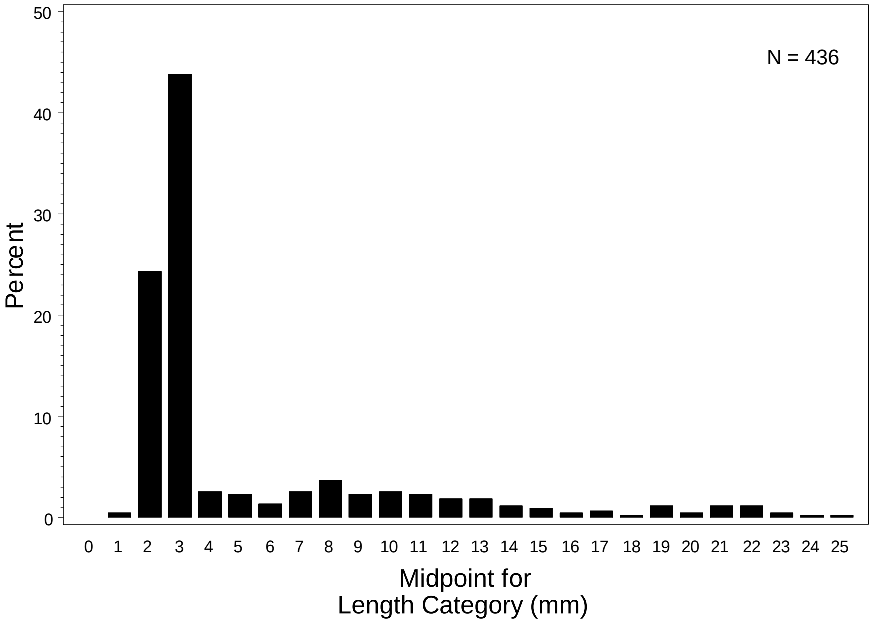


Figure 4.5-10. Length (mm) frequency distribution for larval anchovy collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.1.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of entrainment effects on Engraulidae (northern anchovy) larvae. Adult female equivalents were also estimated using *FH* for Engraulidae (northern anchovy) egg entrainment. Total annual entrainment at ESGS was estimated at 432,212,026 eggs (standard error of 23,593,521) and 36,589,361 larvae (standard error of 1,759,118) using measured cooling water flows during 2006 (Table 4.5-2). An estimated 363,479,754 eggs and 30,806,088 larvae were entrained at Units 3 & 4 based on measured cooling water flows during 2006. If Units 3 & 4 had been operated at the design (maximum capacity) cooling water flows during the period, the estimates increased to 529,013,191 eggs and 44,566,730 larvae. Standard errors for total annual entrainment calculations are presented in Appendix D. The total duration used in the *ETM* calculations included both the estimated egg duration from the literature and the estimated larval duration to provide an integrated estimate of entrainment effects on northern anchovy.

Fecundity Hindcasting (*FH*)

The entrainment estimates for northern anchovy eggs and larvae for the 2006 sampling period were used to estimate the number of breeding females at the age of maturity (age at which 50% of the females are mature) 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 4.5-8). The average age of the eggs in the entrainment samples was calculated to be 1.29 days, the mean of an exponential distribution based on the *Z* for the egg stage from Butler et al. (1993). Survival to the average age was calculated as 0.74 using the stage survival over 2.9 days. 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 0.005 up to the mean age at entrainment (7.3 days). The mean age at entrainment was calculated by dividing a larval growth rate of 0.41 mm/day (0.02 in/day) into the difference between the mean length (5.1 mm [0.20 in]) and the estimated hatch length of 2.1 mm (0.08 in).

Table 4.5-8. 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 value of one year. 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 4.5-9 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 4.5-9. 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 (year)	**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**

Note: The total lifetime fecundity (TLF) was calculated as the sum of L_xM_x divided by 1,000.

The estimated numbers of reproductive age adult female northern anchovies whose lifetime reproductive output was entrained through the ESGS CWS for 2006 were 3,570 based on egg entrainment and 13,355 based on larval entrainment using actual cooling water flows during the period (Table 4.5-10). The estimated adult female numbers attributable to the operation of Units 3 & 4 were 3,002 based on egg entrainment and 11,244 based on larval entrainment, or 84% of the total estimate. Using the design flows for Units 3 & 4, egg entrainment equated to 4,369 adult females and larval entrainment equated to 16,266 adult females if the pumps were run at maximum flow volumes. The sensitivity analysis based on the 90% confidence intervals show that the variation in our estimates of entrainment had much less of an effect on the variation of the *FH* estimates than the life history parameters used in the model.

Table 4.5-10. Results of *FH* modeling for anchovy eggs and larvae based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate[2]	*FH* Upper Estimate	*FH* Range
Actual Flows					
Eggs (All units)					
FH Estimate	**3,570**	2,532	1,112	11,463	10,351
Total Entrainment	432,212,026	23,593,521	3,249	3,890	641
Eggs (Units 3 & 4)					
FH Estimate	**3,002**	2,129	935	9,641	8,706
Total Entrainment	363,479,754	20,110,051	2,729	3,275	546
Larvae (All units)					
FH Estimate	**13,355**	11,583	3,206	55,627	52,421
Total Entrainment	36,589,361	1,759,118	12,298	14,411	2,112
Larvae (Units 3 & 4)					
FH Estimate	**11,244**	9,753	2,699	46,838	44,139
Total Entrainment	30,806,088	1,505,760	10,340	12,148	1,808
Design Flows					
Eggs (Units 3 & 4)					
FH Estimate	4,369	3,098	1,361	14,027	12,666
Total Entrainment	529,013,191	27,930,305	3,990	4,748	759
Larvae (Units 3 & 4)					
FH Estimate	16,266	14,106	3,906	67,739	63,833
Total Entrainment	44,566,730	2,025,423	15,050	17,482	2,432

[1] Results using the design CWS flows only calculated for Units 3 & 4.

[2] 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. 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 4.5-9). The early larval stage survival was adjusted to the mean age at entrainment (7.3 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 estimated from the number of larvae entrained through the ESGS CWS for the sampling period was 65,013 based on actual flows during the period (Table 4.5-11). The estimated equivalent number of adult northern anchovies attributable to the operation of Units 3 & 4 was 54,737, or 84.2% of the total. Based on the design flows for Units 3 & 4 during the period, the equivalent number of adult anchovy estimate increases to 79,188.

Table 4.5-11. Results of *AEL* modeling for northern anchovy larvae based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate[2]	*AEL* Upper Estimate	*AEL* Range
Actual Flows					
All Units Combined					
AEL Estimate	**65,013**	75,266	9,681	436,602	426,921
Total Entrainment	36,589,361	1,759,118	59,872	70,155	10,283
Units 3 & 4					
AEL Estimate	**54,737**	63,372	8,150	367,613	359,463
Total Entrainment	30,806,088	1,505,760	50,336	59,139	8,802
Design Flows					
Units 3 & 4					
AEL Estimate	79,188	91,668	11,794	531,698	519,905
Total Entrainment	44,566,730	2,025,423	73,268	85,108	11,840

[1] Results using the design CWS flow only calculated for Units 3 & 4.
[2] 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 in/day) for northern anchovies was estimated from Methot and Kramer (1979) and used with the difference in the lengths between the estimated hatch length and the 95th percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of approximately 33.4 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 36.3 days.

The monthly estimates of proportional entrainment (*PE*) for northern anchovies for 2006 ranged from 0 to 0.00214 using the actual cooling water flows during the period (Table 4.5-12). The largest estimate was calculated for the April survey, but the largest proportion of the source population was present during the May survey (f_i = 0.644 or 64.4%). The values in the table were used to calculate a P_M estimate of 0.0018 with a standard error of 0.0008 using the offshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.00182 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0015 with a standard error of 0.0007 was calculated from these values. Based on the design flows for Units 3 & 4, estimates of *PE* ranged from 0 to 0.00249 during the period. A P_M estimate of 0.0022 (standard error of 0.0009) was calculated based on these values. The long larval duration allows entrainable larvae to be transported into the nearshore sampling area from far offshore, an average distance over the 12 surveys of 21.7 km (13.5 mi). The average alongshore displacement (limited by the shoreline distance of the bay) over the same time period was 50.8 km (31.6 mi) indicating that larvae from throughout the 60 km (37 mi) coastline of Santa Monica Bay may be subject to entrainment. Total average displacement not limited to the shoreline length of Santa Monica Bay was 54.6 km (33.9 mi). The small estimate of P_M is a direct result of the large source population potentially subject to entrainment.

Table 4.5-12. *ETM* data for northern anchovy larvae. P_M calculated using **offshore** extrapolation of population and P_S of 0.0667.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0.00032
23-Feb-06	0	0	0	0	0	0	0.00007
22-Mar-06	0.00048	0.00028	0.00039	0.00023	0.00073	0.00042	0.03241
19-Apr-06	0.00214	0.00084	0.00182	0.00072	0.00249	0.00095	0.19081
17-May-06	0.00040	0.00014	0.00033	0.00012	0.00050	0.00017	0.64480
14-Jun-06	0.00030	0.00019	0.00026	0.00017	0.00028	0.00018	0.03540
12-Jul-06	0.00037	0.00041	0.00032	0.00036	0.00034	0.00038	0.00900
9-Aug-06	0.00012	0.00013	0.00010	0.00011	0.00014	0.00014	0.01211
20-Sep-06	0.00025	0.00009	0.00020	0.00008	0.00045	0.00014	0.01437
18-Oct-06	0.00006	0.00005	0.00001	0.00002	0.00036	0.00030	0.01919
15-Nov-06	0.00002	0.00003	0.00001	0.00002	0.00008	0.00008	0.01444
13-Dec-06	0.00002	0.00002	0.00001	0.00001	0.00011	0.00007	0.02709
P_M	**0.0018**		**0.0015**		**0.0022**		
Std. Error	0.0008		0.0007		0.0009		

4.5.3.2 Silversides (Atherinopsidae)

Jamie Siler

Three species of silversides (family Atherinopsidae) occur in California ocean waters: 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). Jacksmelt are found in estuaries and coastal marine environments from Yaquina Bay, Oregon to Magdalena Bay, Baja California (Miller and Lea 1972), with a disjunct distribution in the northern Gulf of California (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).

4.5.3.2.1 Life History and Ecology

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

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

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). These fish reach maturity after two years at a size range of 18–20 cm (7.0–7.8 in) SL, and can live to a maximum age of nine or ten years (Clark 1929). Grunion reach 19 cm (7.5 in) in length, with a life span of up to four years. They mature at one year old at a length of approximately 12–13 cm (5 in).

The spawning activity of topsmelt corresponds to changes in water temperature (Middaugh et al. 1990). In Newport Bay, topsmelt spawn from February to June peaking in May and June (Love 1996). Females deposit the eggs on marine plants and other floating objects where fertilization occurs (Love 1996).

Fecundity is a function of female body size with individuals in the 110–120 mm range spawning approximately 200 eggs per season, and fish 160 mm or greater spawning 1,000 eggs per season (Fronk 1969). The spawning season for jacksmelt is from October through March (Clark 1929), with peak activity from January through March (Allen et al. 1983). Individuals may spawn multiple times during the reproductive season and reproductive females have eggs of various sizes and maturities present in the ovary (Clark 1929). Fecundity has not been well documented but is possibly over 2,000 eggs per female (Emmett et al. 1991). Females lay eggs on marine plants and other floating objects where fertilization by males occurs (Love 1996). Hatch length for topsmelt ranges from 4.3–5.4 mm (0.17–0.21 in), and 6–9 mm (0.24–0.35 in) (typically 7.5–8.5 mm [0.29–0.33 in]) for jacksmelt (Moser 1996). Larval growth rate averages approximately 0.37 mm/day (0.01 in/day) for both species based on data from Middaugh et al. (1990).

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 (0.23–0.27 in) (Moser 1996).

4.5.3.2.2 Population Trends and Fishery

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 2006). 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 0.9 million kg (2 million lb) in 1945 to 1,148 kg (2,530 lb) 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 harvested by hand by recreational fishers 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.

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 jacksmelt 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 topsmelt 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 45 kg (100 lb) of jacksmelt with a revenue of $75 were landed in the Santa Monica Bay area in 2006, while 0.9 kg (2 lb) of topsmelt with a revenue of $20 were landed according to specific CDF&G catch block data from the area.

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

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

4.5.3.2.3 Sampling Results

Silverside larvae were the fourteenth most abundant taxon at the entrainment station with a mean concentration of 7 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). The larvae occurred sporadically in December–June (Figure 4.5-11), but during periods of maximum abundance in late April 2006 silversides were present in the entrainment samples at average concentrations of 30 per 1,000 m^3 (264,172 gal). They were absent from samples from July through November. Monthly source water concentrations followed a similar seasonal pattern (Figure 4.5-12) but were lower (ca. average of less than 10 per 1,000 m^3 [264,172 gal]) during spring than the entrainment concentrations. They were found almost exclusively in nighttime samples, comparing Cycle 1 and Cycle 3 abundances (Figure 4.5-13). The length frequency distribution of 217 measured silverside larvae was skewed toward the smaller size classes with a peak in the range of 7–9 mm (0.28–0.35 in) (Figure 4.5-14). The lengths of the larvae from the entrainment station samples ranged from 4.5–16.0 mm (0.18–0.63 in) with a mean of 8.0 mm (0.31 in) NL.

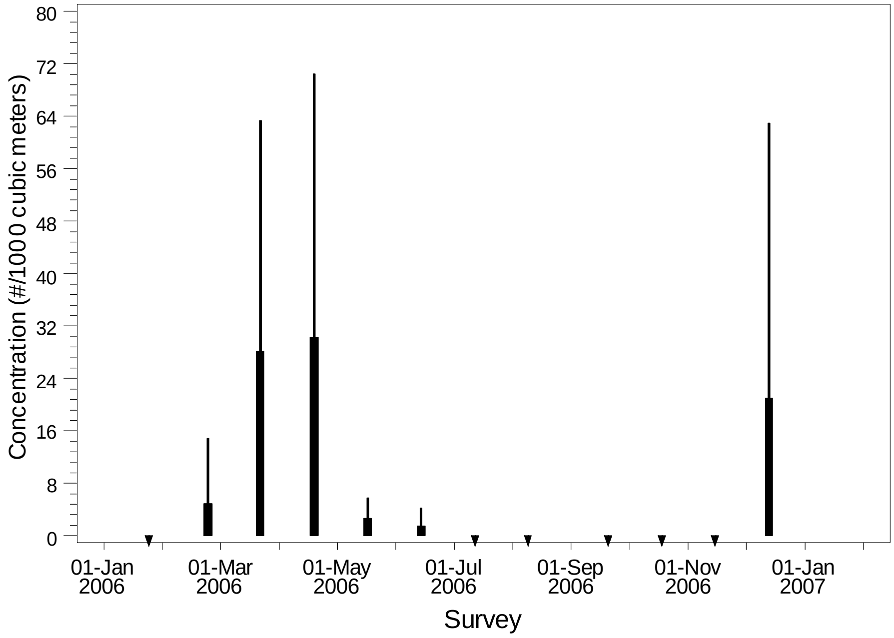


Figure 4.5-11. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of silverside larvae collected at ESGS entrainment stations during 2006.

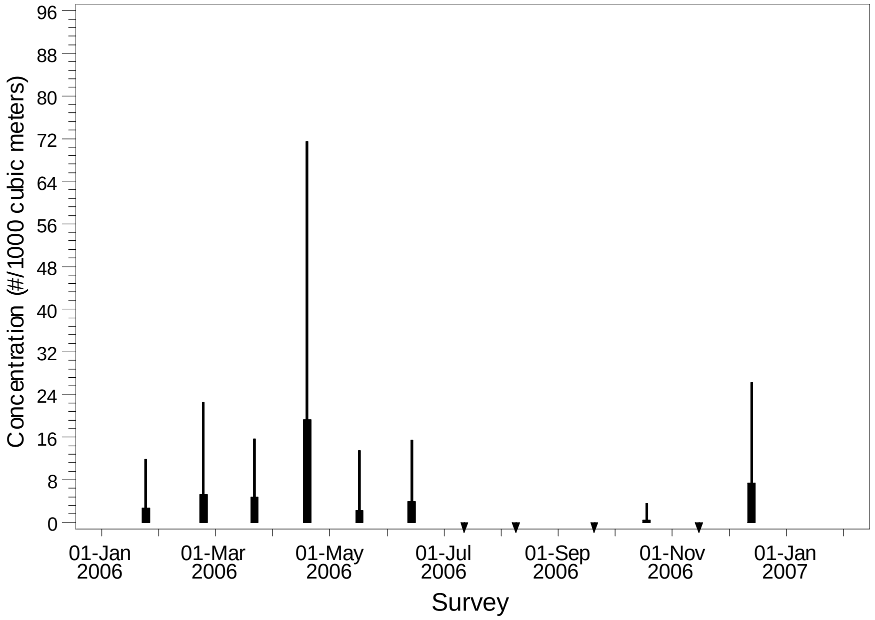


Figure 4.5-12. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of silverside larvae collected at ESGS source water stations during 2006.

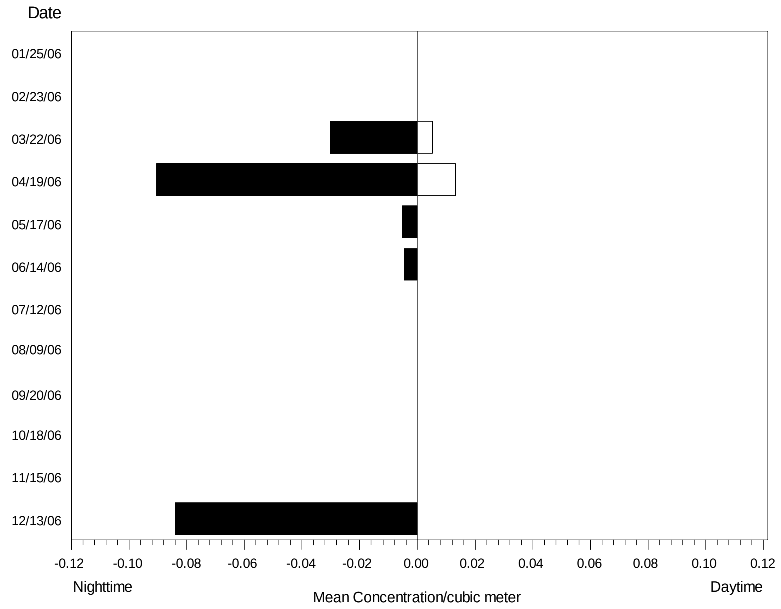


Figure 4.5-13. Mean concentration (# per 1.0 m^3 [264 gal]) of silverside larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.

Note: Negative nighttime values are an artifact of the plotting routine.

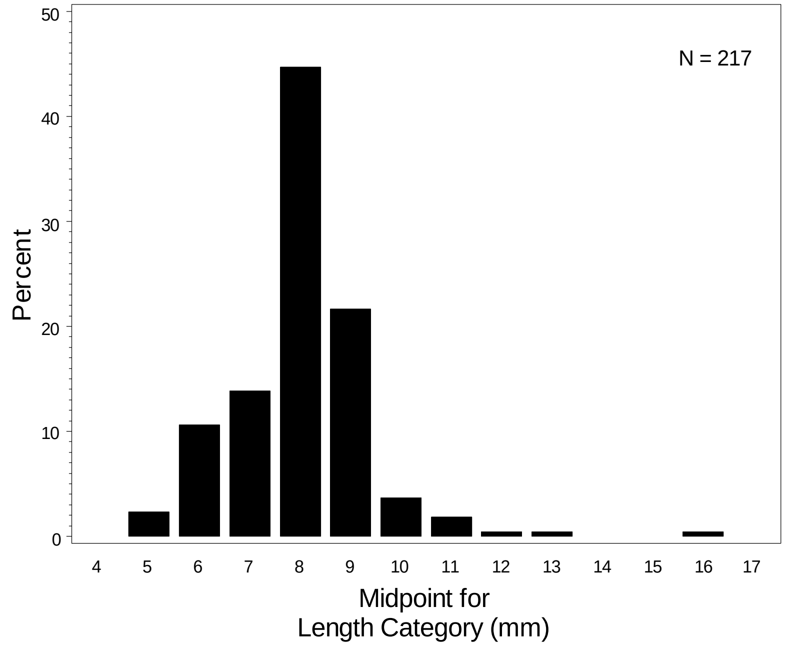


Figure 4.5-14. Length (mm) frequency distribution for silverside larvae collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.2.4 Modeling Results

The following section presents the results of the *ETM* for Atherinopsidae complex (silverside) 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, CWIS effects were estimated using only the *ETM*. Annual entrainment of silverside eggs was estimated at 144,521 (standard error of 25,609) using measured cooling water flows during 2006 (Table 4.5-2). Total annual larval silverside entrainment at ESGS was estimated at 2,361,934 (standard error of 180,016). A total of 123,091 eggs and 1,839,312 larvae were estimated to be entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flow volumes, estimates increased to 164,793 eggs and 4,145,527 larvae. Standard errors for total annual entrainment calculations are presented in Appendix D.

Empirical Transport Model (ETM)

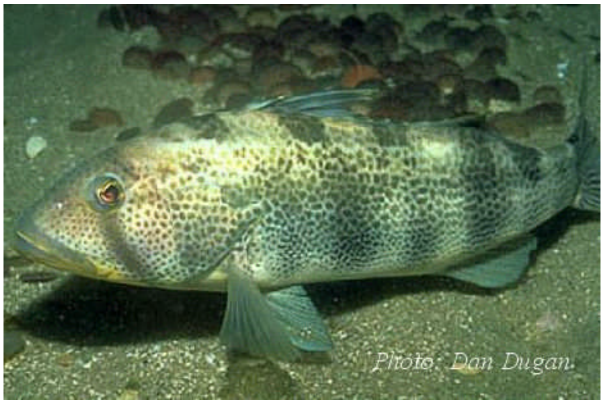
A larval growth rate of 0.44 mm/day (0.02 in/day) for silversides was estimated from laboratory studies by Middaugh et al. (1990) and used with the difference between the calculated hatch length (6.5 mm [0.25 in]) and the length of the 95th percentile of the measurements (10.0 mm [0.39 in]) to estimate that the larvae were exposed to entrainment for a period of approximately 7.9 days.

The monthly estimates of proportional entrainment (*PE*) for silversides for 2006 ranged from 0 to 0.01153 using the actual cooling water flows during the period (Table 4.5-14). The largest estimate was calculated for the March survey, but the largest proportion of the source population was present during the April survey (f_i = 0.333 or 33.3%). The values in the table were used to calculate a P_M estimate of 0.0178 with a standard error of 0.0154 using the alongshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.00926 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0138 with a standard error of 0.0152 was calculated from these values. Using the flows based on the design (or maximum) capacity CWS flows for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.01744 and a P_M estimate of 0.0319 was calculated (standard error of 0.0248). Silversides are primarily distributed close to shore as shown by the results of the offshore density extrapolation that estimated a density of zero at 3.5 km (2.2 mi) offshore within the offshore boundaries of the nearshore sampling area. The alongshore current data were used to estimate that the total larval source population extended along an average distance of 26.1 km (16.2 mi) along the coast within the Santa Monica Bay based on the number of days that the larvae are potentially exposed to entrainment.

Table 4.5-14. *ETM* data for silverside larvae. P_M calculated using **alongshore** extrapolation of population and P_S of 0.3810.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0.11204
23-Feb-06	0.00131	0.00144	0.00089	0.00100	0.00320	0.00345	0.13339
22-Mar-06	0.01153	0.00843	0.00926	0.00681	0.01744	0.01263	0.13453
19-Apr-06	0.00678	0.00505	0.00575	0.00432	0.00787	0.00573	0.33288
17-May-06	0.00372	0.00333	0.00311	0.00281	0.00470	0.00414	0.04956
14-Jun-06	0.00336	0.00394	0.00294	0.00346	0.00319	0.00370	0.04149
12-Jul-06	0	0	0	0	0	0	0
9-Aug-06	0	0	0	0	0	0	0
20-Sep-06	0	0	0	0	0	0	0
18-Oct-06	0	0	0	0	0	0	0.00593
15-Nov-06	0	0	0	0	0	0	0
13-Dec-06	0.00278	0.00405	0.00109	0.00291	0.01431	0.01519	0.19017
P_M	**0.0178**		**0.0138**		**0.0319**		
Std. Error	0.0154		0.0152		0.0248		

4.5.3.3 Sea Basses (*Paralabrax* spp.)



Three species of sea basses, family Serranidae, genus *Paralabrax*, occur in California ocean waters: spotted sand bass (*P. maculatofasciatus)*, barred sand bass (*P. nebulifer)* [pictured at right], and kelp bass (*P. clathratus)*. Spotted sand bass are found from Monterey, California to Mazatlan, Mexico, including the Gulf of California (Robertson and Allen 2002); barred san bass are found from Santa Cruz to Magdalena Bay; and kelp bass are found from the mouth of the Columbia River in Washington to Magdalena Bay, Baja California (Miller and Lea 1972). However, Love (1996) reported that spotted sand bass are uncommon north of Newport Bay in southern California, and Allen and Hovey (2001a,b) reported that barred and kelp bass are uncommon north of Point Conception.

4.5.3.3.1 Life History and Ecology

The life history of the spotted sand bass is described in Allen et al. (1995). Adults can reach 56 cm (22 in) in length and live to at least 14 years of age. Females mature within the first year and approximately half are mature when they reach 15.5 cm (6 in) long. Males mature are all mature at 3 yrs with about half of the males reaching maturity at 18 cm (7 in). Some individuals within populations are protogynous, changing sex from female to male as they grow. Spawning in California occurs from June through August. Love et al. (1996) analyzed life history parameters for barred sand bass and kelp bass. Adult barred sand bass can reach 65 cm (25.5 in) and live to 24 years of age. Adult kelp bass reach 72 cm (28.5 in) and live to at least 34 years of age. Kelp and barred sand bass reach sexual maturity between 18–27 cm (7.0–10.5 in), at about 3–5 years of age. Kelp and barred sand bass form large breeding aggregations in deeper waters and spawn from April through November, peaking in summer months. All three species are multiple spawners (Oda et al. 1993).

In a study of *Paralabrax* fecundity by DeMartini (1987), the number of eggs ranged over a factor of 15 from about 12,000 eggs in a 447 g (0.99 lb) fish to >185,000 eggs in a 2,625 g (5.8 lb) fish. The smallest fish, a 148 g (0.3 lb) sand bass, contained 16,500 eggs. Sample females contained a mean of 760 eggs per gram of ovary and 70 eggs per gram of ovary-free body weight. All three species –*P. clathratus*, *P. maculatofasciatus*, and *P. nebulifer* – are capable of daily spawning (Oda et al. 1993). However, not all fish captured in the Oda et al. (1993) study demonstrated evidence of daily spawning: 32% of the *P. clathratus* females (n = 84), 20% of the *P. maculatofasciatus* females (n = 79), and 31% of the *P. nebulifer* females (n = 81) showed evidence of spawning on two consecutive days. There was no statistically significant difference in the average size of specimens that exhibited evidence of daily spawning, compared to those that had spawned the day before collection. A standard weight female (ca. 700 g [1.5 lb; ovary-free weight] and 300 mm [11.8 in] SL) was calculated to average 81,000 eggs per batch. This estimate of batch fecundity for *Paralabrax* is higher than that reported by DeMartini (1987) and may indicate the variation possible in these species of *Paralabrax*.

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

4.5.3.3.2 Population Trends and Fishery

Kelp bass (*Paralabrax clathratus*) and barred sand bass (*P. nebulifer*) are two of the most important nearshore recreational species caught within southern California waters (Allen and Hovey 2001a, b). The fishery for these species occurs throughout most of southern California from Ensenada, Baja California to Gaviota in Santa Barbara County, including the Channel Islands.

These species have been an important component of both recreational and commercial catches since the early 1900s. The earliest management attempt to conserve these species occurred in 1939 when a limit of 15 fish/day was placed on sport fish catches in California. Since then a number of other regulation changes have been added including a ban on commercial fishing for these species in California waters and a size limit of 10.5 in on the recreational fishery in 1953, a 12 in size limit in 1959, and a limit of 10 fish in 1979 (Young 1963; Stull et al. 1987).

Records prior to 1975 did not differentiate catches of kelp bass and barred sand bass from other related categories including “rock bass” (*Paralabrax spp.*, which also includes the spotted sand bass, *P. maculatofasciatus*). Catches of both kelp and barred sand bass have fluctuated greatly since the early 1960s and may be influenced by the density of kelp forests (*Macrocystis*) which vary inter-annually (Dotson and Charter 2003). Catch rates for these species were higher during the late 1980s compared to the 1970s while mean lengths were essentially unchanged between those periods (Love et al. 1996). Specific habitat requirements indicate that highest adult densities of kelp bass occur within kelp/rock habitat whereas barred sand bass prefer rocky, hard-bottom or sand areas (Stull et al. 1987).

Recent population trends indicate that landings aboard CPFVs declined during the 1990s compared to the 1980s (Allen and Hovey 2001a, b). Specific habitat requirements and a high degree of site fidelity with limited movements (Lowe et al. 2003) suggest that these species can be subject to changes in abundance depending on the availability and amount of suitable habitat. Sport fishery catch estimates of spotted sand bass in the southern California region from 2000 to 2006 ranged from 14,000 to 74,000 fish, with an average of 44,000 fish caught annually (Table 4.5-15). Catch estimates of kelp bass in southern California ranged from 157,000 to 587,000 fish from 2000 to 2006, with an average of 351,300 fish caught annually. Barred sand bass catch estimates ranged from 139,000 to 1,130,000 fish caught annually between 2000-2006, with an average of 720,000 fish caught annually (RecFin 2007).

Table 4.5-15. Annual landings for barred sandbass, kelp bass, and spotted sandbass in the Southern California region based on RecFIN data.

Year	Barred Sandbass	Kelp Bass	Spotted Sandbass	Total
2000	1,130,000	587,000	74,000	1,791,000
2001	806,000	385,000	49,000	1,240,000
2002	1,062,000	291,000	52,000	1,405,000
2003	892,000	434,000	62,000	1,388,000
2004	704,000	446,000	14,000	1,164,000
2005	307,000	157,000	38,000	502,000
2006	139,000	159,000	19,000	317,000

4.5.3.3.3 Sampling Results

The 3 species of sea basses were grouped together for analysis purposes. The sea bass larvae complex was the fifth most abundant taxon at the entrainment station with a mean concentration of 23 per 1,000 m^3 over all surveys (Table 4.5-1). Sea bass larvae occurred from July through October at the entrainment station (Figure 4.5-15). Average sea bass larvae concentrations peaked in July at approximately 150 per 1,000 m^3 at the entrainment station. Monthly average source water concentrations followed a similar seasonal pattern (Figure 4.5-16) with measured concentrations peaking in September at about 230 per 1,000 m^3 in the source water samples. There was no consistent trend in abundance between daytime and nighttime samples (Figure 4.5-17). The length frequency distribution of measured sea bass larvae was normally distributed with a peak in the range of 1.5–2.0 mm (0.06–0.08 in) (Figure 4.5-18). The lengths of the larvae from the entrainment station samples ranged from 0.9–2.8 mm (0.03–0.11 in) with a mean of 1.7 mm (0.67 in) NL.

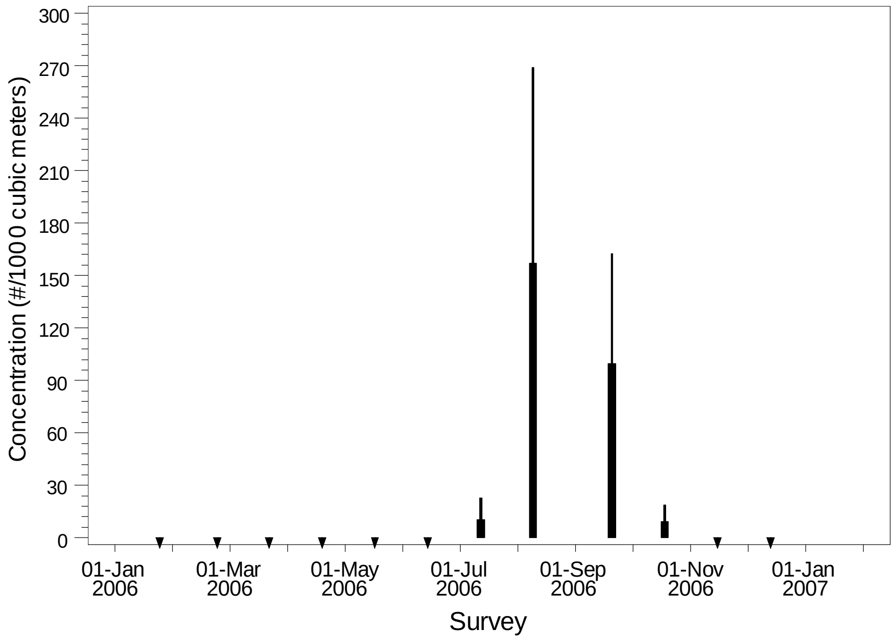


Figure 4.5-15. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of sea bass larvae collected at ESGS entrainment stations during 2006.

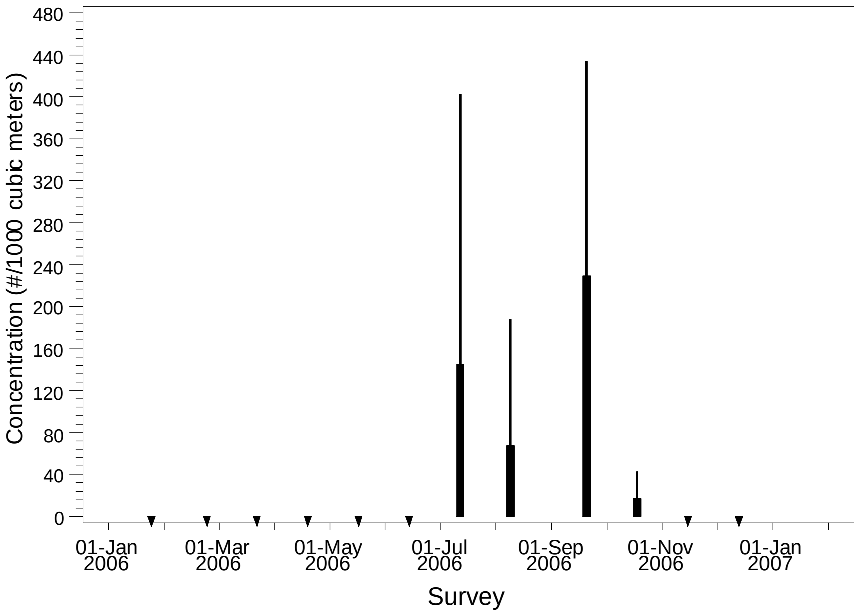


Figure 4.5-16. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of sea bass larvae collected at ESGS source water stations during 2006.

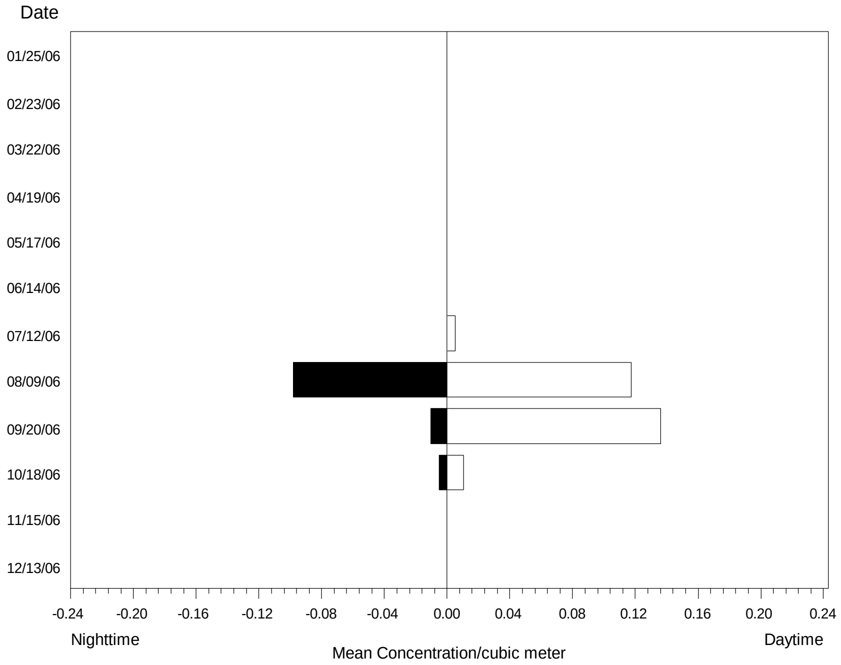


Figure 4.5-17. Mean concentration (# per 1.0 m^3 [264 gal]) of sea bass larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.

Note: Negative nighttime values are an artifact of the plotting routine.

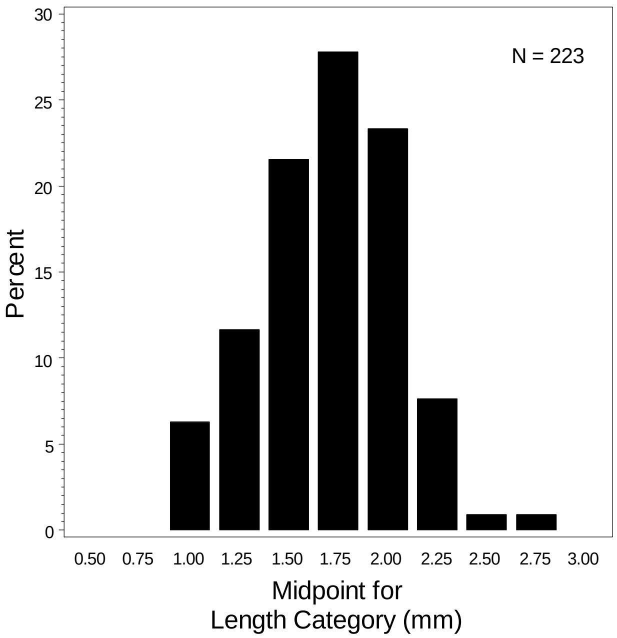


Figure 4.5-18. Length (mm) frequency distribution for sea bass larvae collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.3.4 Modeling Results

There was very little species-specific information available on the early life history of sea basses. Therefore, circulating water system effects were estimated using only the *ETM* and neither of the demographic models. The planktonic egg stage duration is estimated at 3 days (Cordes and Allen 1997). The total duration used in the *ETM* calculations included both the estimated egg duration from the literature and the estimated larval duration to provide an integrated estimate of entrainment effects on sea basses. Total annual sea bass entrainment at ESGS was estimated at 4,935,308 eggs (standard error of 450,414) and 10,753,540 larvae (standard error of 502,321) using measured cooling water flows during 2006 (Table 4.5-2). An estimated 4,109,380 eggs and 8,932,843 larvae were entrained at Units 3 & 4 based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, an estimated 6,568,642 eggs and 14,393,420 larvae could have been entrained at these units. Standard errors for total annual entrainment calculations are presented in Appendix D.

Empirical Transport Model (ETM)

A larval growth rate of 0.27 mm/day (0.01 in/day) for sea bass larvae was calculated from data available in Cailliet et al. (2000) and Moser (1996) and used with the difference between the calculated hatch length (1.3 mm [0.05 in]) and the length of the 95th percentile of the measurements (2.2 mm [0.09 in]) to estimate that the larvae were exposed to entrainment for a period of approximately 3.2 days. The egg duration of 3 days was added to this value for a total period of exposure of 6.2 days.

The monthly estimates of proportional entrainment (*PE*) for sea basses for 2006 ranged from 0–0.00968 using the actual cooling water flows during the period (Table 4.5-16). Larvae were only collected for four months from July through October. The largest *PE* estimate was calculated for the August survey, but the largest proportion of the source population was present during the September survey (f_i = 0.568 or 56.8%). The values in the table were used to calculate a P_M estimate of 0.0033 with a standard error of 0.0017 using the alongshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.00824 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0027 with a standard error of 0.0015 was calculated from these values. Using the flows based on the design (or maximum) capacity CWS flows for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.01104 and a P_M estimate of 0.005 (standard error of 0.0023) was calculated. The model calculations only used four estimates of *PE* increasing the uncertainty associated with the estimate for this taxa group. Sea basses are primarily distributed close to shore as shown by the results of the offshore density extrapolation that only showed a very small increase in density with distance offshore. The alongshore current data were used to estimate that the total larval source population extended along an average coastal distance of 21.9 km (13.6 mi) within the Santa Monica Bay based on the number of days that the larvae are potentially exposed to entrainment. An onshore transport of 5.6 km was also used in the calculations.

Table 4.5-16. *ETM* data for sea bass larvae. P_M calculated using **alongshore** extrapolation of population and P_S = 0.8225.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0
23-Feb-06	0	0	0	0	0	0	0
22-Mar-06	0	0	0	0	0	0	0
19-Apr-06	0	0	0	0	0	0	0
17-May-06	0	0	0	0	0	0	0
14-Jun-06	0	0	0	0	0	0	0
12-Jul-06	0.00013	0.00009	0.00011	0.00007	0.00012	0.00008	0.33606
9-Aug-06	0.00968	0.00396	0.00824	0.00342	0.01104	0.00435	0.06929
20-Sep-06	0.00048	0.00020	0.00037	0.00017	0.00085	0.00029	0.56823
18-Oct-06	0.00022	0.00013	0.00004	0.00004	0.00139	0.00080	0.02642
15-Nov-06	0	0	0	0	0	0	0
13-Dec-06	0	0	0	0	0	0	0
P_M	**0.0033**		**0.0027**		**0.0050**		
Std. Error	0.0017		0.0015		0.0023		

4.5.3.4 White croaker (*Genyonemus lineatus*)

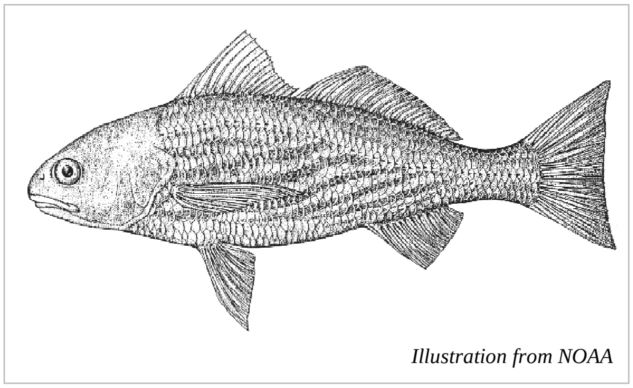


Illustration from NOAA

White croaker (*Genyonemus lineatus*) range from Magdalena Bay, Baja California (Miller and Lea 1972), north to Barkley Sound, British Columbia (Eschmeyer and Herald 1983). They are one of eight species of croakers (Family Sciaenidae) found off California. The other croakers include: white seabass (*Atractoscion nobilis*), black croaker (*Cheilotrema saturnum*), queenfish (*Seriphus politus*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), and shortfin corvina (*Cynoscion parvipinnis*).

4.5.3.4.1 Life History and Ecology

The reported depth range of white croaker is from near the surface to depths of 238 m (781 ft) (Love et al. 2005); however, in southern California, Allen (1982) found white croaker over soft bottoms between 10 and 130 m (426 ft), and it was collected most frequently at 10 m (33 ft). It is nocturnally active, and is considered a benthic searcher that feeds on a wide variety of benthic invertebrate prey. Adults feed on polychaetes and crustaceans, while juveniles feed during the day in midwater on zooplankton (Allen 1982).

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

Newly hatched white croaker larvae are 1–2 mm (0.04–0.08 in) SL and not well developed (Watson 1982). Larvae are principally located within 4 km (2.5 mile) from shore, and as they develop tend to move shoreward and into the epibenthos (Schlotterbeck and Connally 1982). Maximum reported size is

414 mm (16.2 in) (Miller and Lea 1972), with a life span of 12–15 years (Frey 1971; Love et al. 1984). White croakers grow at a fairly constant rate throughout their lives, though females increase in size more rapidly than males from age 1 (Moore 2001). No mortality estimates are available for any of the life stages of this species.

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

4.5.3.4.2 Population Trends and Fishery

White croaker is an important constituent of commercial and recreational fisheries in California. Prior to 1980, most commercial catches of white croaker were taken by otter trawl, round haul net (lampara), gill net, and hook and line in southern California, but after 1980 most commercial catches were taken primarily by trawl and hook and line (Love et al. 1984). Also, since then the majority of the commercial fishery shifted to central California near Monterey mainly due to the increased demand for this species from the developing fishery by Southeast Asian refugees (Moore and Wild 2001). Most of the recreational catch still occurs in southern California from piers, breakwaters, and private and sport boats.

Before 1980, state-wide white croaker landings averaged 310,710 kg (685,000 lb) annually, exceeding 0.45 million kg (1 million lb) for several years (Moore and Wild 2001). High landings in 1952 probably occurred due to the collapse of the Pacific sardine fishery. Since 1991, landings averaged 209,106 kg (461,000 lb) and steadily declined to an all-time low of 64,637 kg (142,500 lb) in 1998. Landings by recreational fishermen aboard commercial passenger fishing vessels (CPFVs) averaged about 12,000 fish per year from 1990 to 1998, with most of the catch coming from southern California.

Annual relative abundance of white croaker in impingement samples at southern California power plants showed decreases during the strong El Niño events of 1982–83, 1986–87, and 1997-98 as compared with non-El Niño years (Herbinson et al. 2001). Additionally, the relative abundance of local populations have been influenced by contamination from PCBs and other chlorinated hydrocarbons within bays and has lead to early ovulation, lower batch fecundities, and lower fertilization rates when compared to non-contaminated areas (Cross and Hose 1988).

Annual commercial landings in the Los Angeles region since 2000 have been variable with an average biomass of 19,686 kg (43,400 lb) and an average net worth of $29,385 annually (Table 4.5-17). Sport fishery catch estimates of white croaker in the southern California region from 2000–2006 ranged from 64,000–253,000 fish, with an average of 189,400 fish caught annually (RecFIN 2007).

Table 4.5-17. Annual landings and revenue for white croaker in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lb)	Revenue
2000	40,025	88,240	$50,688
2001	23,387	51,560	$36,086
2002	25,880	57,056	$41,816
2003	21,772	48,000	$33,837
2004	8,894	19,608	$14,653
2005	11,182	24,652	$17,531
2006	6,809	15,011	$11,079

4.5.3.4.3 Sampling Results

White croaker larvae was the most abundant taxon at the entrainment station with a mean concentration of 115 per 1,000 m^3 (264,000 gal) over all surveys (Table 4.5-1). White croaker larvae were mainly present at the entrainment station in March and April, and only occurred sporadically in other months (Figure 4.5 19). Average concentrations of white croaker peaked at approximately 800 larvae per 1,000 m^3 (264,000 gal) in April. Source water larval abundances peaked in spring but also occurred in October-December (Figure 4.5-20). Substantially more larvae were entrained at night than during the day (Figure 4.5-21). The length frequency plot for entrained white croaker larvae was skewed toward the lower size classes with about 75% of sampled larvae in the 2–3 mm (0.08–0.12 in) size classes and a decline in frequency of occurrence at larger size classes to 9.0 mm 0.35 in), with a few sampled larvae in the 12.0 and 14.0 mm (0.47 and 0.55 in) size classes (Figure 4.5-22).

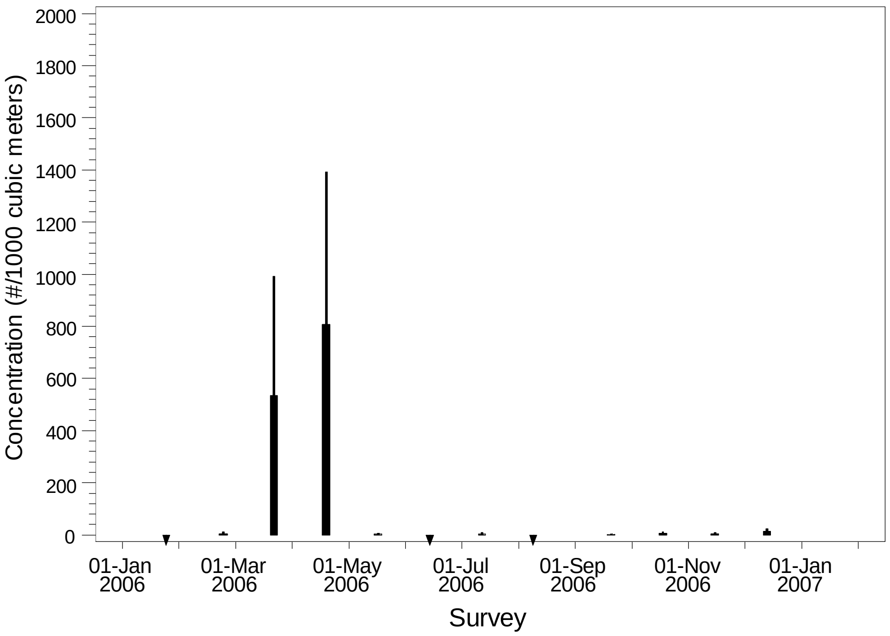


Figure 4.5-19. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of white croaker larvae collected at ESGS entrainment stations during 2006.

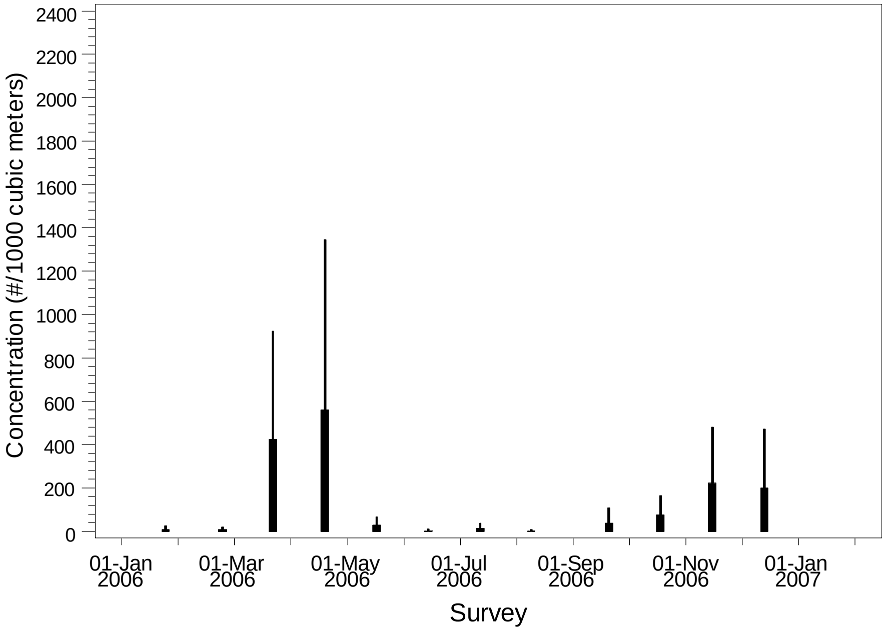


Figure 4.5-20. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of white croaker larvae collected at ESGS source water stations during 2006.

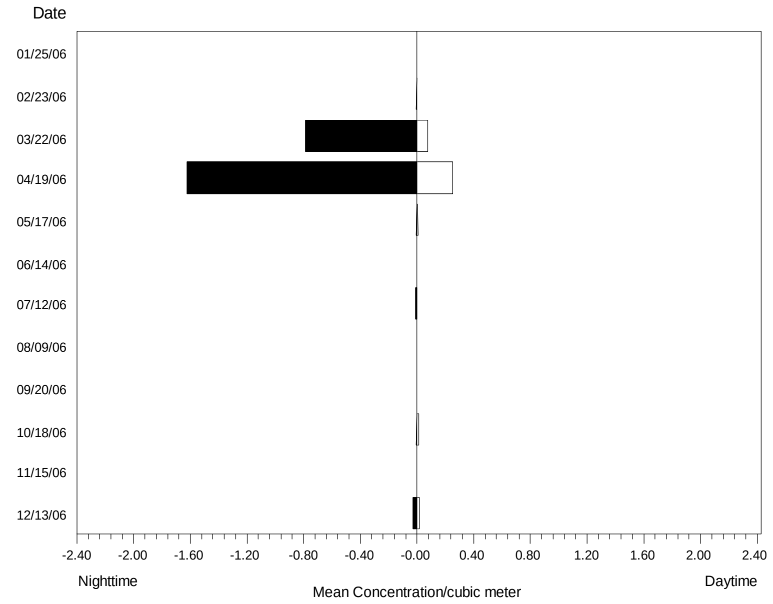


Figure 4.5-21. Mean concentration (# per 1.0 m^3 [264 gal]) of white croaker larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.
Note: Negative nighttime values are an artifact of the plotting routine.

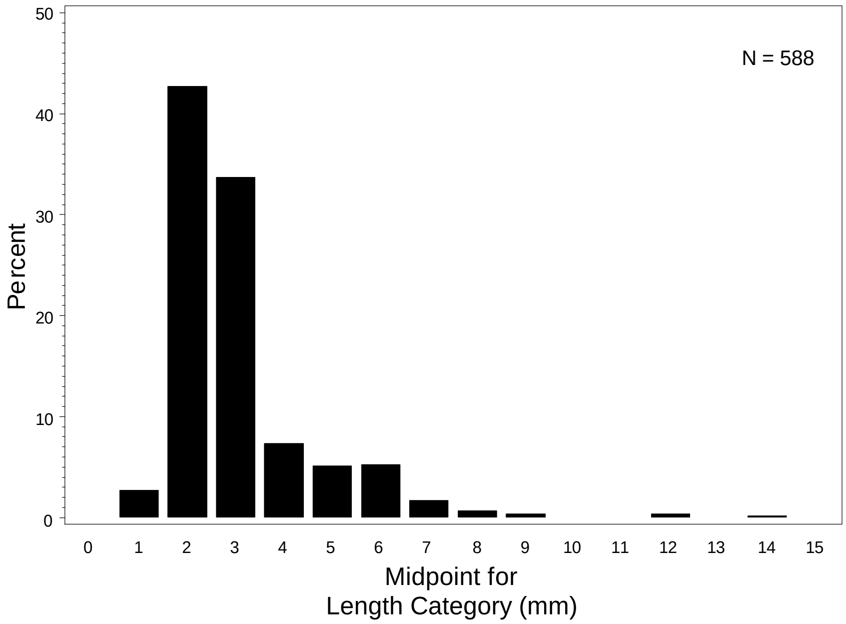


Figure 4.5-22. Length (mm) frequency distribution for white croaker larvae collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.4.4 Modeling Results

The following section present the results for the empirical transport modeling of entrainment effects on white croaker. No age-specific estimates of survival for larval and later stages of development were available from the literature for white croaker, therefore no estimates of *FH* or *AEL* were calculated, but enough information was available to estimate *FH* based on numbers of eggs entrained. Total annual entrainment at ESGS was estimated at 44,365,993 larvae (standard error of 2,385,477) and 4,498,770 eggs (standard error of 208,476) using measured cooling water flows during 2006 (Table 4.5-2). A total of 36,886,189 larvae and 3,319,629 eggs was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows during the period, estimates increased to 57,674,813 larvae and 9,067,268 eggs. Standard errors for total annual entrainment calculations are presented in Appendix D. The total duration used in the *ETM* calculations included both the estimated egg duration from the literature and the estimated larval duration to provide an integrated estimate of entrainment effects on white croaker.

Fecundity Hindcasting (FH)

The annual entrainment estimate for white croaker eggs was used to calculate the number of females of average age and fecundity that would produce in their lifetime the number of eggs entrained. An estimate of egg survival of 0.781 was based on an egg stage duration of 2.17 days and an average age at entrainment of 0.97 days. A total lifetime fecundity of 2,294,250 eggs per female was calculated based on an average number of eggs per batch of 19,000, an average number of 21 batches per year, and a average age in the population of 5.75 years. Life history information presented in Love et al. (1984) is summarized in Section 4.5.3.4.1 *Life History and Ecology*.

The estimated number of female white croakers at the age of first maturity whose lifetime reproductive output was entrained through the ESGS CWIS for the 2006 period was three for all units combined, or two if only the entrainment estimates from Units 3 & 4 were used in the calculations (Table 4.5-18). Using the design flows for Units 3 & 4, the number of reproductive age female white croaker was five based on egg entrainment if the pumps were run at maximum flows. 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 4.5-18. Results of *FH* modeling for white croaker eggs based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate[2]	*FH* Upper Estimate	*FH* Range
Actual Flows					
Eggs (All units)					
FH Estimate	**3**	2	1	8	7
Total Entrainment	4,498,770	208,476	2	3	0
Eggs (Units 3 & 4)					
FH Estimate	**2**	1	1	6	5
Total Entrainment	3,319,629	164,120	2	2	0
Design Flows					
Eggs (Units 3 & 4)					
FH Estimate	5	4	2	16	15
Total Entrainment	9,067,268	370,437	5	5	1

[1] Results using the design CWS flows only calculated for Units 3 & 4.
[2] 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.

Empirical Transport Model (ETM)

A larval growth rate was derived from data on five species of Sciaenidae (croakers) that were raised in the laboratory by Southwest Fisheries Science Center staff (Moser 1996). These were the black croaker (*Cheilotrema saturnum*), corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), queenfish (*Seriphus politus*), and yellowfin croaker (*Umbrina roncador*). Hatch lengths and larval length at various number of days after birth presented in Moser (1996) were used to calculate an average daily growth rate from hatching through the flexion stage for Sciaenidae. The growth rate calculated from these data was 0.2480 mm/day (0.01 in/day). Although the species did not include white croaker this estimate was used for both white croaker and unidentified croakers since the species that were measured all have larvae that are nearly indistinguishable at small sizes (Moser 1996). A random sample of 200 lengths from the 588 measured white croaker larvae were used to calculate a difference between the estimated hatch length (2.0 mm [0.08 in]) and the 95th percentiles of the measurements (6.3 mm [0.25 in]) to estimate that white croaker were exposed to entrainment for periods of approximately 17.3 days. The duration of the planktonic egg stage, 2.2 days, was added to the periods for the larvae to estimate a total periods of exposure of 19.5 days.

The monthly estimates of proportional entrainment (*PE*) for white croaker for 2006 ranged from 0 to 0.00346 using the actual cooling water flows during the period (Table 4.5-19). The largest estimate was calculated for the April survey, and the largest proportion of the source population was also present during the April survey (f_i = 0.247 or 24.7%). The values in the table were used to calculate a P_M estimate of 0.0029 with a standard error of 0.0017 using the offshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.00249 using only larval entrainment from Units 3 & 4 and a

P_M estimate of 0.0024 with a standard error of 0.0018 was calculated from these values. Based on the design flow for Units 3 & 4 during the period, *PE* values ranged from 0 to 0.00402 and a P_M estimate of 0.0042 with a standard error of 0.0021 was calculated. The period of larval exposure to entrainment allows larvae to be transported into the nearshore sampling area from an average offshore distance over the 12 surveys of 13.5 km (8.4 mi). The average alongshore displacement (limited by the shoreline distance of the bay) over the same time period was 38.7 km (24.0 mi) indicating that larvae from more than half of the 60 km (37 mi) coastline of Santa Monica Bay may be subject to entrainment. Total average displacement was 39.4 km (24.5 mi). The small estimate of P_M (less than half of one percent) is a direct result of the large source population potentially subject to entrainment.

Table 4.5-19. *ETM* data for white croaker larvae. P_M calculated using **offshore** extrapolation of population and P_S of 0.1990.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0.00834
23-Feb-06	0.00055	0.00039	0.00038	0.00027	0.00135	0.00094	0.00435
22-Mar-06	0.00219	0.00100	0.00176	0.00081	0.00331	0.00149	0.19125
19-Apr-06	0.00346	0.00137	0.00294	0.00118	0.00402	0.00156	0.24665
17-May-06	0.00015	0.00009	0.00012	0.00008	0.00019	0.00011	0.01879
14-Jun-06	0	0	0	0	0	0	0.00287
12-Jul-06	0.00033	0.00034	0.00029	0.0003	0.00031	0.00031	0.01124
9-Aug-06	0	0	0	0	0	0	0.00211
20-Sep-06	0.00002	0.00003	0.00002	0.00003	0.00004	0.00005	0.04397
18-Oct-06	0.00002	0.00001	0	0	0.00013	0.00005	0.05843
15-Nov-06	0.00001	0.00001	0	0	0.00003	0.00002	0.19244
13-Dec-06	0.00002	0.00001	0.00001	0.00001	0.00011	0.00005	0.21956
P_M	**0.0029**		**0.0024**		**0.0042**		
Std. Error	0.0017		0.0018		0.0021		

4.5.3.5 Queenfish (*Seriphus politus*) and Unidentified Croakers (Sciaenidae)

Milton Love

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 (*Cheilotrema saturnum*), white croaker (*Genyonemus lineatus*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), white seabass (*Atractoscion nobilis*), and shortfin corvina (*Cynoscion parvipinnis*). This section also includes results on unidentified croakers because queenfish and several other croakers spawn during the summer and their larvae cannot be reliably separated into species at very small sizes. White croaker is not included in this group because they generally spawn earlier in the year and their larvae can be distinguished from other croakers at small sizes. This section only includes life history and other information on queenfish.

4.5.3.5.1 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 (4.1–5.0 in) TL (DeMartini and Fountain 1981; Love 1996), during their first spring or second summer. Maximum reported size is 30.5 cm (12.0 in) TL (Miller and Lea 1972). Immature individuals grow at a rate of about 2.5 mm/day (0.10 in/day), while early adults grow about 1.8 mm/day (0.07 in/day) (Murdoch et al. 1989b). Mortality rate estimates are unavailable for this species.

Queenfish are summer spawners. Goldberg (1976) found queenfish enter spawning condition in April and spawning 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 [5.3 in] 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 (5.8 in) 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 (3.9–4.1 in) 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 (4.1 in) female to about 90,000 eggs in a 25 cm (9.8 in) fish. The average-sized female (14 cm [5.5 in], 42 g [0.09 lb]) had a potential batch fecundity of 12,000–13,000 eggs. Parker and DeMartini (1989) estimated the average batch fecundity to be 12,700 for queenfish collected over a five-year period. Based on a female spawning frequency of 7.4 days, a 10.5 cm (4.1 in) female that spawns for three months (April–June) can produce about 60,000 eggs per year, while a 25 cm (9.8 in) female that spawns for six months (March through August) can produce nearly 2.3 million eggs per year (DeMartini and Fountain 1981).

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

4.5.3.5.2 Population Trends and Fishery

Queenfish (*Seriphus politus*) 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 2006). 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 6–12 m (20–40 ft). 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.

Although queenfish are not considered a highly desired species compared to other sciaenids, they are caught in fairly substantial numbers from both recreational and commercial fisheries. No specific landings were reported in commercial landings in southern California from 2000-2006 (PacFIN 2007), although they may be 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 to 2006 ranged from 66,000 to 942,000 fish, with an average of 270,000 fish caught annually (Table 4.5-20).

Table 4.5-20. Annual landings for queenfish in the Southern California region based on RecFIN data.

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

4.5.3.5.3 Sampling Results

Queenfish larvae was the twelfth most abundant taxon at the entrainment station with a mean concentration of 11 per 1,000 m^3 (264,172 gal) over all the surveys (Table 4.5-1). Unidentified croaker (Sciaenidae), which consisted of a combination of newly-hatched queenfish, and several other croaker species including white croaker, was the fourth most abundant taxon with a mean concentration of 29 per 1,000 m^3 (264,172 gal). Queenfish larvae were present only in the summer entrainment surveys from June to August (Figure 4.5-23). Average larval queenfish concentrations peaked at approximately 80 larvae per 1,000 m^3 (264,172 gal) in June. Larvae in the source water occurred mainly in June and July but were present through September (Figure 4.5-24). Unidentified croaker larvae were abundant in summer samples at both the entrainment and source water stations (Figures 4.5-25 and 4.5-26). Queenfish and unidentified croaker larvae were generally more common in the night samples than in the daytime samples (Figures 4.5-27 and 4.5-28). The length frequency plot for queenfish showed the majority of sampled larvae were smaller than 2.5 mm (0.10 in) with a low frequency of occurrence at larger size classes to 6.0 mm (0.24 in) (Figure 4.5-29). Lengths ranged from 1.3 mm (0.05 in) NL to 6.1 mm (0.24 in) NL with a mean length of 2.3 mm (0.09 in) NL. Over 93% of the measured unidentified croakers in entrainment samples were smaller than 2.5 mm (0.10 in) (Figure 4.5-30) indicating that they were recently hatched and had not developed the pigmentation and other characteristics necessary for positive identification to the species level. The mean length of specimens from the entrainment station samples was 1.6 mm (0.06 in) NL for unidentified croakers.

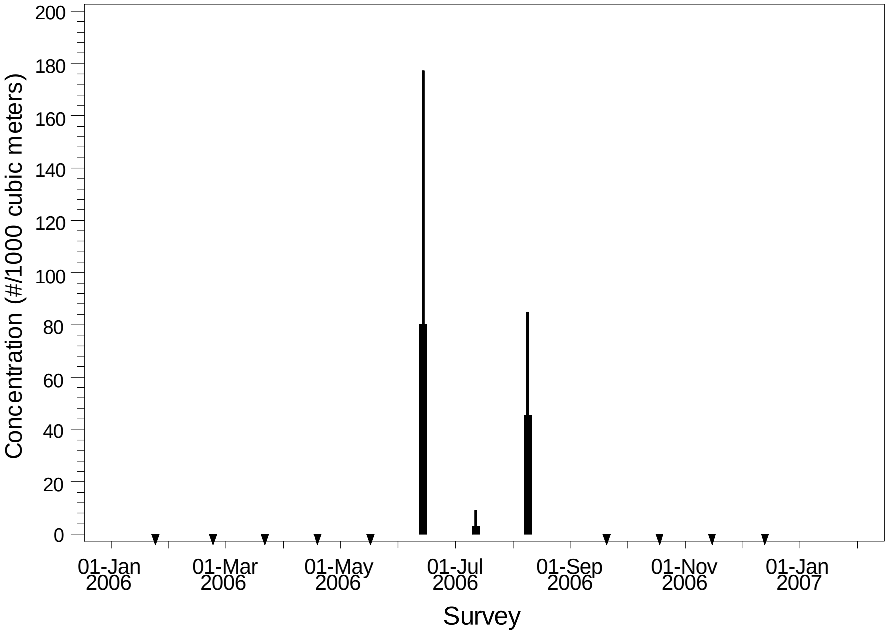


Figure 4.5-23. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of queenfish larvae collected at ESGS entrainment stations during 2006.

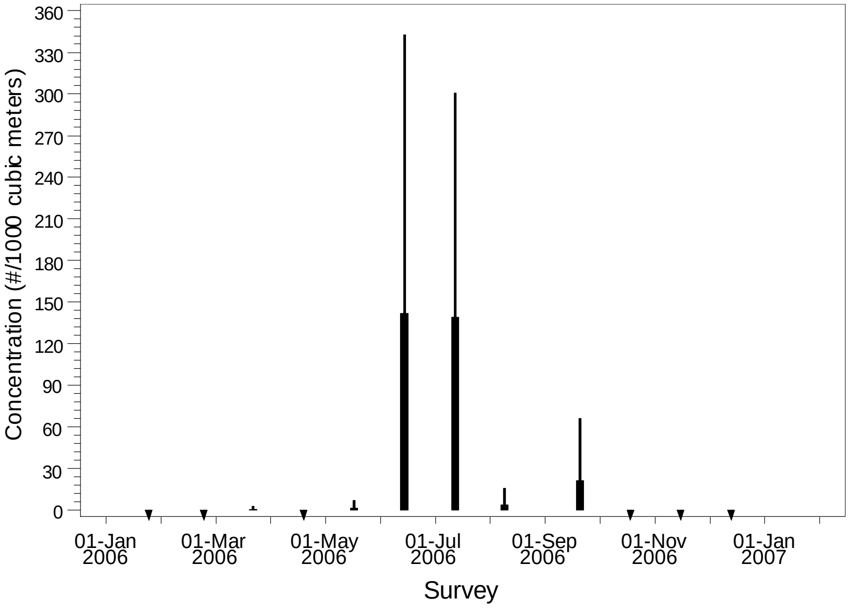


Figure 4.5-24. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of queenfish larvae collected at ESGS source water stations during 2006.

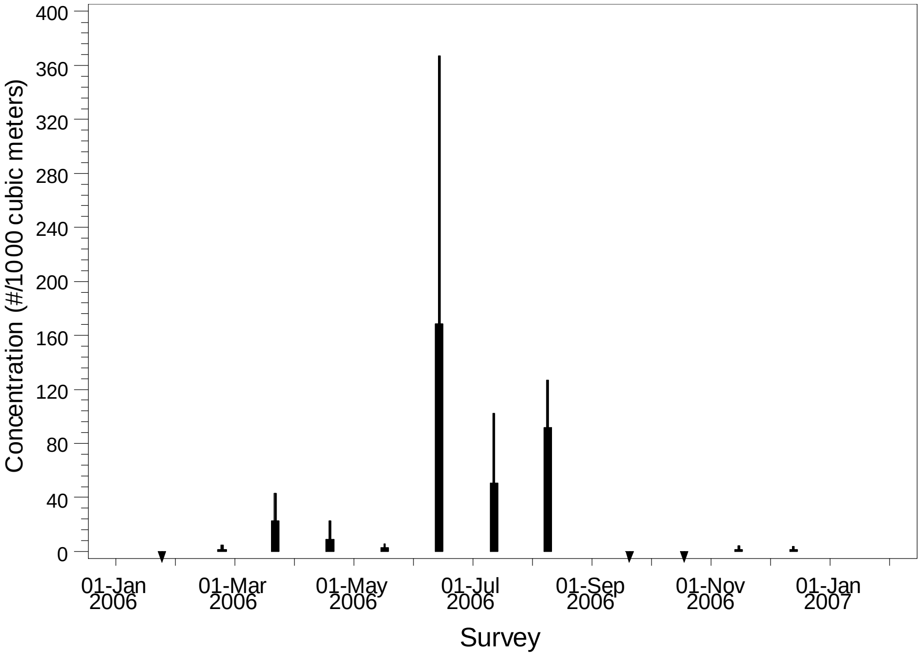


Figure 4.5-25. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of unidentified croaker larvae collected at ESGS entrainment stations during 2006.

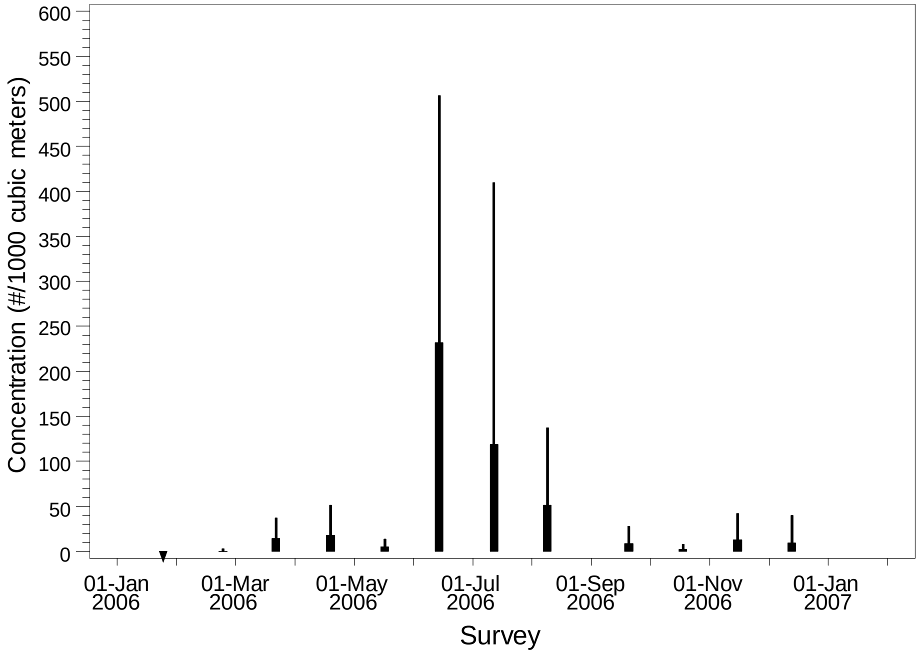


Figure 4.5-26. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of unidentified croaker larvae collected at ESGS source water stations during 2006.

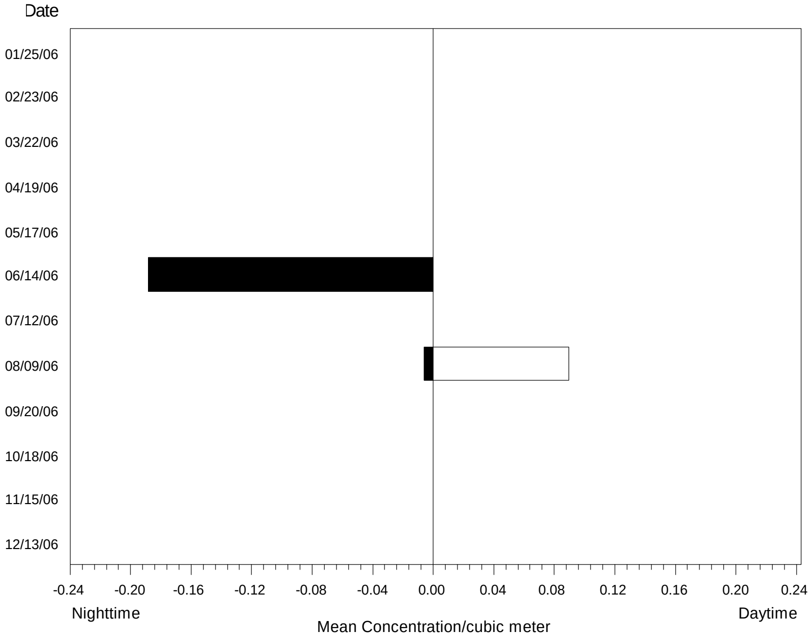


Figure 4.5-27. Mean concentration (# per 1.0 m^3 [264 gal]) of queenfish larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006. *Note: Negative nighttime values are an artifact of the plotting routine.*

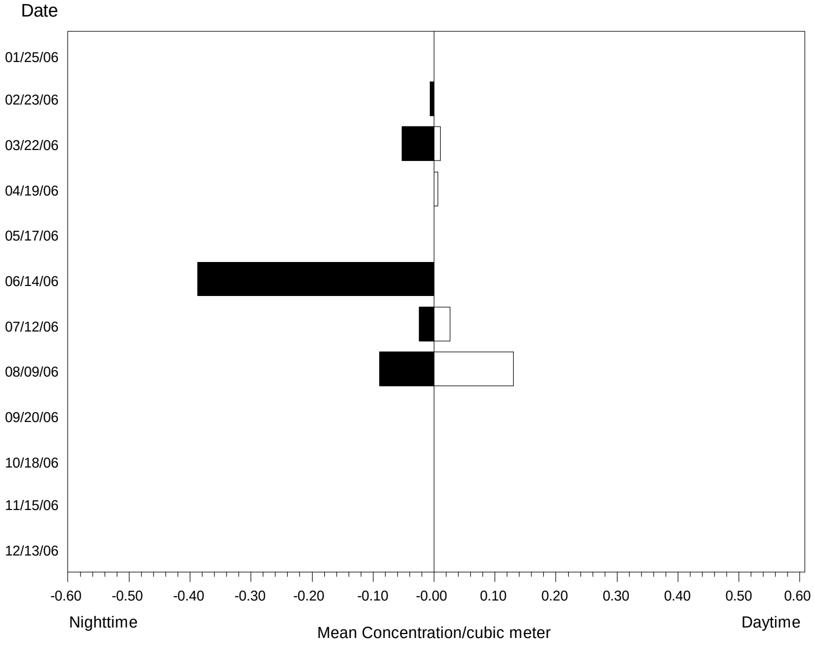


Figure 4.5-28. Mean concentration (# per 1.0 m^3 [264 gal]) of unidentified croaker at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006. *Note: Negative nighttime values are an artifact of the plotting routine.*

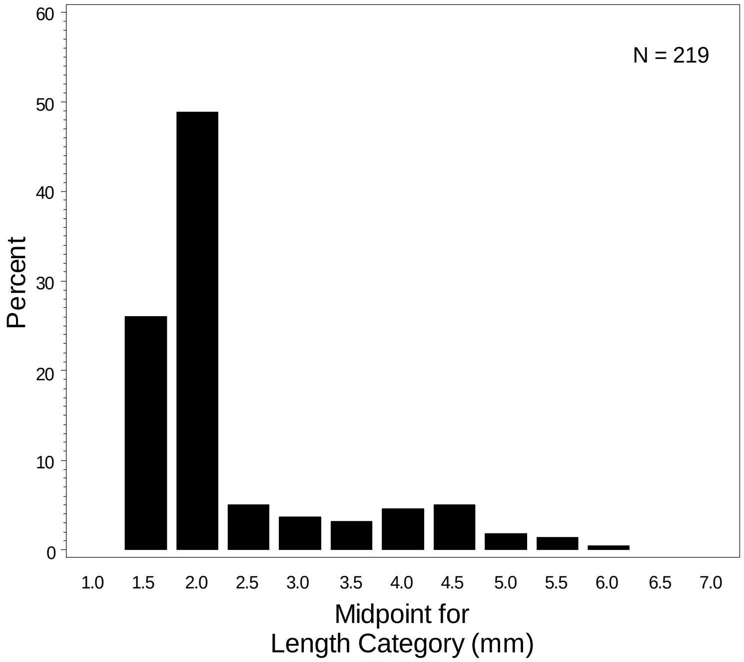


Figure 4.5-29. Length (mm) frequency distribution for larval queenfish collected at entrainment stations in Santa Monica Bay during 2006.

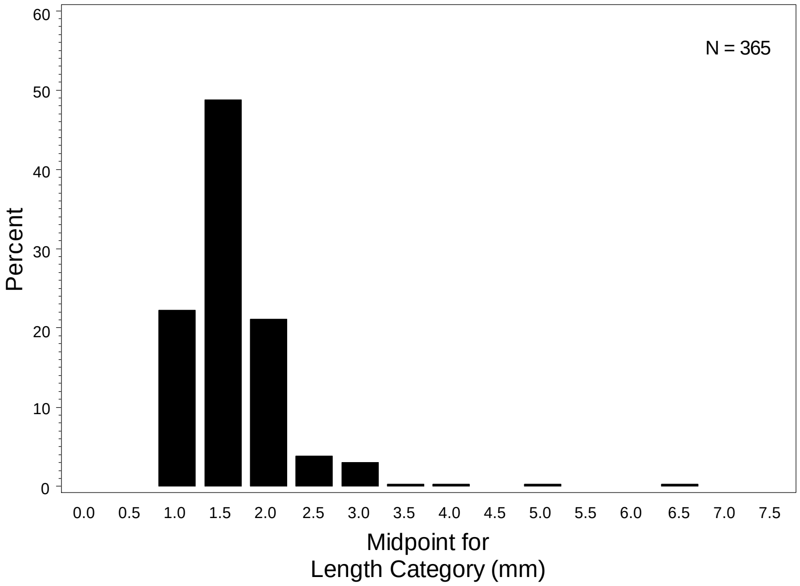


Figure 4.5-30. Length (mm) frequency distribution for larval unidentified croakers collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.5.4 Modeling Results

The following section presents the results for empirical transport modeling of entrainment effects on queenfish and unidentified croaker larvae. No age-specific estimates of survival for larval and later stages of development were available from the literature for queenfish, and therefore no estimates of *FH* or *AEL* were calculated. Total annual entrainment at ESGS was estimated at 5,807,906 (standard error of 506,192) for queenfish larvae and 15,122,724 (standard error of 1,016,195) for unidentified croaker larvae using measured cooling water flows during 2006 (Table 4.5-2). An estimated total of 5,038,592 queenfish larvae and 13,080,938 unidentified croaker larvae was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 5,915,819 queenfish larvae and 15,708,573 unidentified croaker larvae. Standard errors for total annual entrainment calculations are presented in Appendix D. The total duration used in the *ETM* calculations included both the estimated egg duration and the estimated larval duration from the literature to provide an integrated estimate of entrainment effects.

Empirical Transport Model (ETM)

A larval growth rate was derived from data on five species of Sciaenidae (croakers) that were raised in the laboratory by Southwest Fisheries Science Center staff (Moser 1996). These were the black croaker (*Cheilotrema saturnum*), corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), queenfish (*Seriphus politus*), and yellowfin croaker (*Umbrina roncador*). Hatch lengths and larval length at various number of days after birth presented in Moser (1996) were used to calculate an average daily growth rate from hatching through the flexion stage for Sciaenidae. The growth rate calculated from these data was 0.2480 mm/day (0.01 in/day). A random sample of 200 lengths from the 219 measured queenfish and 365 measured unidentified croaker larvae were used to calculate a difference between the estimated hatch lengths (the 10th percentile length for unidentified croakers) and the 95th percentiles of the measurements to estimate that white croaker and unidentified croakers were exposed to entrainment for periods of approximately 12.3 and 7.5 days, respectively. The duration of the planktonic egg stage, 2.2 days, was added to the periods for the larvae to estimate a total periods of exposure of 14.5 and 9.7 days, respectively.

The monthly estimates of proportional entrainment (*PE*) for queenfish for 2006 ranged from 0 to 0.02533 using the actual cooling water flows during the period (Table 4.5-21). Queenfish larvae were only collected from the entrainment station during three of the paired entrainment-source water surveys, whereas they were collected at the source water stations at six surveys between March and September with the largest proportion of the source population present during the June and July surveys (f_i = 0.459 and 0.443 or 45.9 and 44.3%, respectively). The values in the table were used to calculate a P_M estimate of 0.0005 with a standard error of 0.0004 using the offshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.002157 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0004 with a standard error of 0.0003 was calculated from these values. Using the flow volumes based on the design (or maximum) capacity CWS flow for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.02888, and a P_M estimate of 0.0005 with a standard error of 0.0004 was calculated. The model calculations are based on only three estimates of *PE* increasing the uncertainty associated with the estimate for this taxa group. The period of larval exposure to entrainment allows larvae to be transported into the nearshore sampling area from an average offshore distance over the 12 surveys of 9.7 km (6.0 mi). The average alongshore displacement (limited by the shoreline distance of the bay) over the same time period was 35.2 km (21.9 mi) indicating that larvae from more than half of the 60 km (37 mi) coastline of Santa Monica Bay may be subject to entrainment. Total average displacement (not limited by the shoreline length of Santa Monica Bay) was 35.9 km (22.3 mi). The small estimate of P_M (less than half of one percent) is a direct result of the large source population potentially subject to entrainment.

Table 4.5-21. *ETM* data for queenfish larvae. P_M calculated using **offshore** extrapolation of population and P_S of 0.0557.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0
23-Feb-06	0	0	0	0	0	0	0
22-Mar-06	0	0	0	0	0	0	0.00117
19-Apr-06	0	0	0	0	0	0	0
17-May-06	0	0	0	0	0	0	0.00270
14-Jun-06	0.00092	0.00068	0.00081	0.00059	0.00088	0.00063	0.45915
12-Jul-06	0.00004	0.00004	0.00003	0.00003	0.00003	0.00003	0.44289
9-Aug-06	0.02533	0.01449	0.02157	0.01247	0.02888	0.01604	0.00991
20-Sep-06	0	0	0	0	0	0	0.08418
18-Oct-06	0	0	0	0	0	0	0
15-Nov-06	0	0	0	0	0	0	0
13-Dec-06	0	0	0	0	0	0	0
P_M	**0.0005**		**0.0004**		**0.0005**		
Std. Error	0.0004		0.0003		0.0004		

The monthly estimates of proportional entrainment (*PE*) for unidentified croakers for 2006 ranged from 0 to 0.0070 (Table 4.5-22). The largest estimate was calculated for the August 2006 survey, but the largest proportion of the source population was present during the June survey (f_i = 0.368 or 36.8%). The values in the table were used to calculate a P_M estimate of 0.0066 with a standard error of 0.0046 using the alongshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.00596 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0057 with a standard error of 0.0044 was calculated from these values. Using the flow volumes based on the design (or maximum) capacity CWS flow for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.00798, and a P_M estimate of 0.0068 with a standard error of 0.0045 was calculated. The period of larval exposure to entrainment allows larvae to be transported into the nearshore sampling area from an average offshore distance over the 12 surveys of 7.4 km (4.6 mi). The average alongshore displacement over the same time period was 28.5 km (17.7 mi) indicating that larvae from almost half of the 60 km (37 mi) coastline of

Santa Monica Bay may be subject to entrainment. The small estimate of P_M (less than one-half percent) is a direct result of the large source population potentially subject to entrainment.

Table 4.5-22. *ETM* data for unidentified croaker larvae. P_M calculated using **alongshore** extrapolation of population P_S of 0.3904.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0
23-Feb-06	0.00217	0.00300	0.00148	0.00207	0.00532	0.00727	0.00160
22-Mar-06	0.00160	0.00085	0.00129	0.00069	0.00242	0.00128	0.04913
19-Apr-06	0.00092	0.00077	0.00078	0.00066	0.00107	0.00087	0.04580
17-May-06	0.00113	0.00080	0.00095	0.00067	0.00143	0.00098	0.01019
14-Jun-06	0.00263	0.00188	0.00231	0.00166	0.00250	0.00176	0.36882
12-Jul-06	0.00098	0.00060	0.00086	0.00053	0.00091	0.00056	0.30586
9-Aug-06	0.00700	0.00204	0.00596	0.00175	0.00798	0.00227	0.07863
20-Sep-06	0	0	0	0	0	0	0.03088
18-Oct-06	0	0	0	0	0	0	0.00347
15-Nov-06	0.00004	0.00005	0.00002	0.00004	0.00013	0.00014	0.05443
13-Dec-06	0.00004	0.00006	0.00001	0.00004	0.00019	0.00022	0.05119
P_M	**0.0066**		**0.0057**		**0.0068**		
Std. Error	0.0046		0.0044		0.0045		

4.5.3.6 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 southern California: 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).

4.5.3.6.1 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 (Moser 1996; Ninos 1984). For this reason most *Hypsoblennius* identified in the EPS 316(b) plankton collections were identified as *Hypsoblennius* spp. Certain morphological features (e.g., preopercular spines) develop at larger sizes and allow taxonomists to identify some larvae 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 (3.3 ft) of their chosen refuge (Stephens et al. 1970). Bay blennies are 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.

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 and 45 mm (1.6 and 1.8 in) total length, respectively (Stephens et al. 1970). Bay blenny grow to a slightly larger size and live longer than mussel blenny, reaching a size of 15 cm (5.9 in) and living for 6–7 years (Stephens 1969; Stephens et al. 1970; Miller and Lea 1972). Mussel blennies grow to 13 cm (5.1 in) and have a life span of 3–6 years (Stephens et al. 1970; Miller and Lea 1972). Male and female growth rates are similar.

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

4.5.3.6.2 Population Trends and Fishery

There is no fishery for combtooth blennies and therefore no records on adult population trends in Santa Monica Bay based on landings data. However, Stephens and Pondella (2002) measured annual larval densities at King Harbor 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.

4.5.3.6.3 Sampling Results

Combtooth blenny was the seventh most abundant taxon at the entrainment station with a mean concentration of 18 larvae per 1,000 m^3 (264,172 gal) for all the surveys (Table 4.5-1). They were present in the entrainment samples from March through December, with a peak in June (Figure 4.5-31). During periods of maximum abundance in June 2006, combtooth blennies were present at average concentrations of approximately 75 per 1,000 m^3 (264,172 gal). Source water abundances followed the same seasonal trend, with a peak in average concentration in June at approximately 80 per 1,000 m^3 (264,172 gal) (Figure 4.5-32). There were more larvae in the nighttime samples than daytime samples during spring and early summer surveys (Figure 4.5-33). The length frequency range for larvae was unimodal, with 99% of measured specimens in the 2–3 mm (0.08–0.12 in) NL size classes and a few in the 4–6 mm (0.16–0.24 in) NL and 13 mm (0.51 in) NL size classes (Figure 4.5-34). The mean length of specimens from the entrainment station samples was 2.3 mm (0.90 in) NL with a size range from 1.7–13.1 mm (0.07–0.52 in) NL.

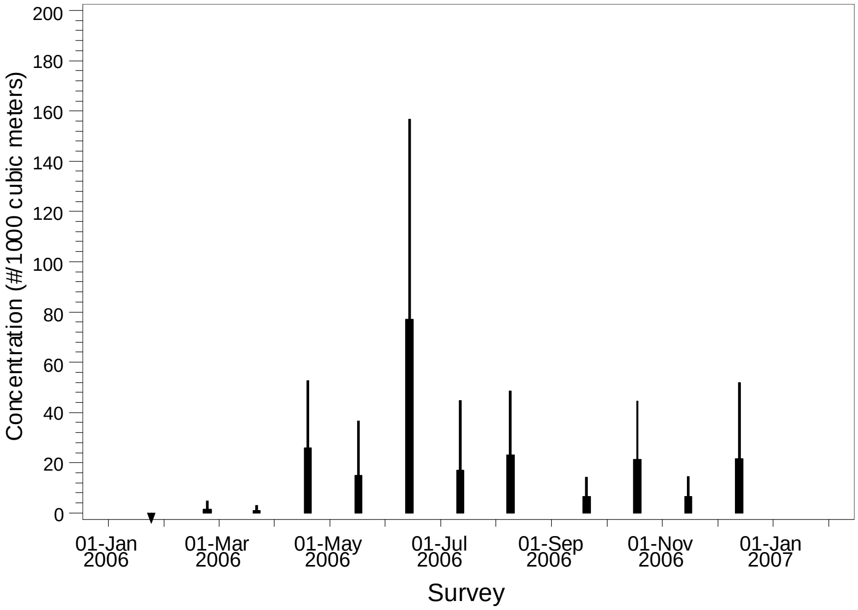


Figure 4.5-31. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of combtooth blenny larvae collected at ESGS entrainment stations during 2006.

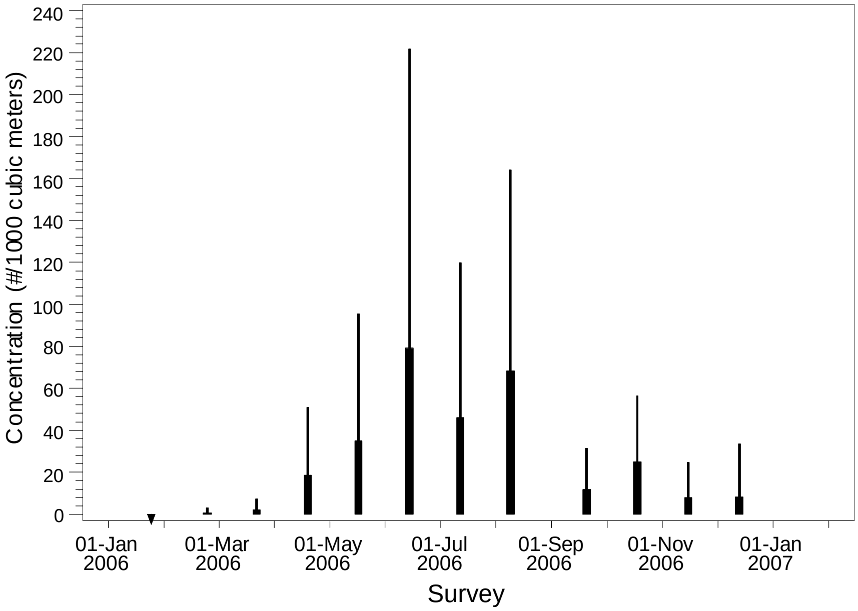


Figure 4.5-32. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of combtooth blenny larvae collected at ESGS source water stations during 2006.

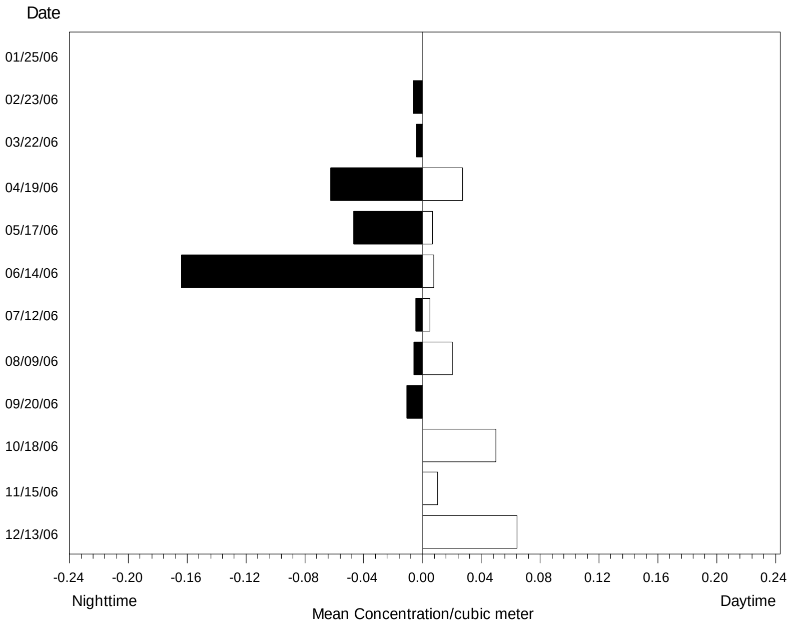


Figure 4.5-33. Mean concentration (# per 1.0 m^3 [264 gal]) of combtooth blenny larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.
Note: Negative nighttime values are an artifact of the plotting routine.

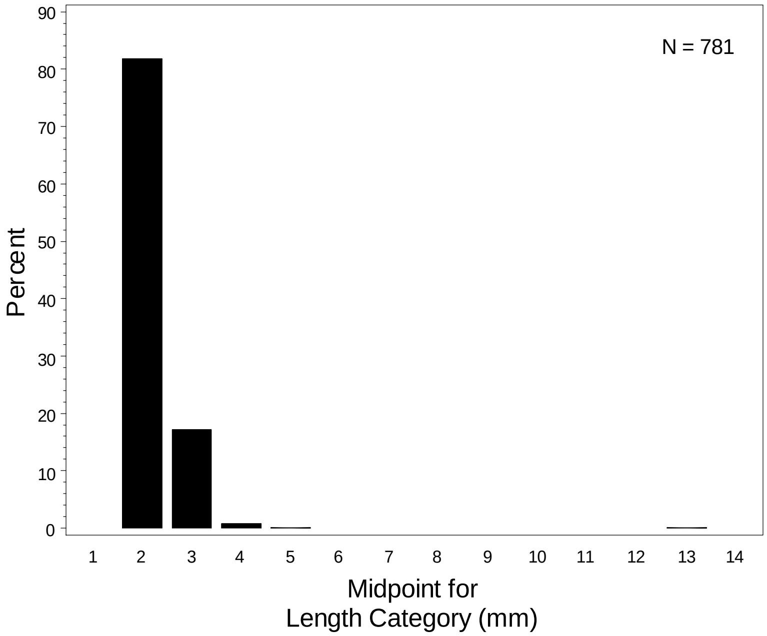


Figure 4.5-34. Length (mm) frequency distribution for combtooth blenny larvae collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.6.4 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CWS effects on combtooth blennies. There was enough information on the life history of blennies to calculate both *FH* and *AEL* estimates. Larval survival was estimated using data from Stephens (1969) and Stevens and Moser (1982), and larval growth was estimated using information from Stevens and Moser (1982). Total annual entrainment of combtooth blenny larvae at ESGS was estimated at 7,451,656 (standard error of 442,735) using actual cooling water flows during 2006 (Table 4.5-2). A total of 6,180,886 combtooth blenny larvae was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 9,927,668 larvae. Standard errors for total annual entrainment calculations are presented in Appendix D.

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%. The mean length from a random sample of 200 combtooth blenny larvae was 2.4 mm (0.09 in). A larval growth rate of 0.20 mm/day (0.008 in/day) was derived from data in Stevens and Moser (1982). The mean length of 2.3 mm (0.09 in) and estimated hatch length of 2.1 mm (0.08 in) 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) as follows:

$$S = 8.528\times10^{-8}x^2 - 3.918\times10^{-4}x + 0.4602\,.$$

An adult survivorship table (Table 4.5-23) 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 4.5-23. Survivorship table for adult combtooth blenny from data in Stephens (1969) showing spawners (L_x) surviving to the age interval and numbers of eggs spawned annually (M_x). The total lifetime fecundity was calculated as the sum of L_xM_x divided by 1,000.

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

The estimated number of female combtooth blennies at the age of maturity (0.5 years) whose lifetime reproductive output was entrained through the ESGS CWS during 2006 was 4,258 based on entrainment estimates calculated using actual cooling water flows during the period (Table 4.5-24). The estimated number attributable to the operation of Units 3 & 4 was 3,532, or 83% of the total with all units. Based on the design flow volumes for Units 3 & 4, the estimated number of reproductive female combtooth blennies was 5,673 based on larval entrainment if the pumps are run at maximum capacity. The sensitivity analysis 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 4.5-24. Results of *FH* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	**Estimate**	**Std. Error**	***FH* Lower Estimate[2]**	***FH* Upper Estimate**	***FH* Range**
Actual Flows					
Larvae (All units)					
FH Estimate	**4,258**	3,696	1,021	17,757	16,736
Total Entrainment	7,451,656	442,735	3,842	4,674	832
Larvae (Units 3 & 4)					
FH Estimate	**3,532**	3,067	847	14,735	13,888
Total Entrainment	6,180,886	387,875	3,167	3,897	729
Design Flows					
Larvae (Units 3 & 4)					
FH Estimate	5,673	4,920	1,362	23,627	22,264
Total Entrainment	9,927,668	460,269	5,240	6,106	865

[1] Results using the design CWS flows only calculated for Units 3 & 4.

[2] 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 $0.89^{(50-1.5)} = 0.003$ using the same daily survival rate used in formulating *FH.* Juvenile and adult survival was calculated from observed age group abundances in Stephens (1969). Daily survival through the average female age of 2.7 years for the three species was estimated as 0.99 and was used to calculate a finite survival of 0.79.

The estimated number of equivalent number of adult combtooth blennies estimated from the number of larvae entrained through the ESGS CWS for the sampling period was 18,173 based on actual cooling water flows during 2006 (Table 4.5-25). The estimated number attributable to the operation of Units 3 & 4 was 15,074, or 83% of the total estimate. Using the design flows of Units 3 & 4, the estimated number of equivalent adults was 24,211 based on the larval entrainment. 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 4.5-25. Results of *AEL* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	***AEL*** **Lower Estimate**[2]	***AEL*** **Upper Estimate**	***AEL*** **Range**
Actual Flows					
All Units Combined					
AEL Estimate	**18,173**	22,283	2,418	136,591	134,173
Total Entrainment	7,451,656	442,735	16,396	19,949	3,552
Units 3 & 4					
AEL Estimate	**15,074**	18,485	2,005	113,328	111,323
Total Entrainment	6,180,886	387,875	13,518	16,630	3,112
Design Flows					
Units 3 & 4					
AEL Estimate	24,211	29,673	3,224	181,808	178,584
Total Entrainment	9,927,668	460,269	22,364	26,057	3,693

[1] Results using the design CWS flows only calculated for Units 3 & 4.

[2] 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 were used to calculate the difference between the estimated hatch length and the 95th percentiles (2.8 mm [0.11 in]) of the measurements and a growth rate of 0.20 mm/day (0.008 in/day) was used to estimate that blennies were exposed to entrainment for a period of approximately 3.8 days.

The monthly estimates of proportional entrainment (*PE*) for combtooth blennies using the actual cooling water flows during the period for the 2006 period varied among surveys and ranged from 0 to 0.0047

(Table 4.5-26). 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 = 0.393 or 39.3%). The values in the table were used to calculate a P_M estimate of 0.0028 with a standard error of 0.002 using only the alongshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.00399 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0023 with a standard error of 0.0018 was calculated from these values. Using the design flow volumes for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.00961 and a P_M estimate of 0.004 with a standard error of 0.0028 was calculated. The relatively short period of larval exposure to entrainment was used to estimate that larvae were transported an average distance alongshore over the 12 surveys of 13.0 km (8.1 mi) within the Santa Monica Bay. An average onshore transport of 3.5 km was also used in the calculations. The small estimate of P_M (less than half of one percent) is a direct result of the large source population potentially subject to entrainment.

Table 4.5-26. *ETM* data for combtooth blenny larvae. P_M calculated using **alongshore** extrapolation of population and P_S of 0.7404.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0
23-Feb-06	0.00199	0.00276	0.00136	0.00190	0.00487	0.00668	0.00201
22-Mar-06	0.00080	0.00091	0.00064	0.00073	0.00121	0.00136	0.00481
19-Apr-06	0.00470	0.00263	0.00399	0.00226	0.00547	0.00299	0.02891
17-May-06	0.00090	0.00069	0.00075	0.00058	0.00113	0.00084	0.08022
14-Jun-06	0.00125	0.00089	0.00110	0.00078	0.00119	0.00084	0.39277
12-Jul-06	0.00093	0.00079	0.00082	0.00069	0.00087	0.00073	0.11884
9-Aug-06	0.00067	0.00041	0.00057	0.00035	0.00076	0.00045	0.22985
20-Sep-06	0.00071	0.00055	0.00056	0.00048	0.00127	0.00082	0.03887
18-Oct-06	0.00035	0.00020	0.00006	0.00006	0.00218	0.00123	0.05963
15-Nov-06	0.00051	0.00040	0.00029	0.00028	0.00169	0.00116	0.02359
13-Dec-06	0.00186	0.00199	0.00073	0.00138	0.00961	0.00771	0.02050
P_M	**0.0028**		**0.0023**		**0.0040**		
Std. Error	0.0020		0.0018		0.0028		

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

Greg Goldsmith, USFWS

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 *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 (for *Clevelandia*, *Ilypnus* and *Quietula*), or the family level 'Gobiidae' if specimens were damaged but could still be recognized as gobiids. Some larger larval specimens with well-preserved pigmentation patterns could be identified to the species level (W. Watson, Southwest Fisheries Science Center, pers. comm.) but those that were speciated in this study were subsequently combined into the CIQ complex for analysis. The following section presents an overview of the family and life history characteristics of each of the three species.

4.5.3.7.1 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 and Herald 1983). The reported northern range limits of both shadow goby (*Quietula y-cauda*) and cheekspot goby (*Ilypnus gilberti*) are in central California with 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 (89.8°F) 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.

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). 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 (0.08–0.12 in) (Moser 1996). Data from Brothers (1975) were used to estimate an average growth rate of 0.16 mm/day (0.01 in/day) 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 (0.39–0.59 in) 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 yrs of age based on otolith records, whereas cheekspot and shadow gobies commonly lived for 4 yrs (Brothers 1975).

4.5.3.7.2 Population Trends and Fishery

There are no published multi-year studies of post-settlement goby populations in the Santa Monica Bay 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. Ballona Wetlands, approximately 8 km (5 mi) north of ESGS, provides habitat for both arrow goby and shadow goby and may be a source of larvae entrained at ESGS. There is no fishery for CIQ goby species because of their small size.

4.5.3.7.3 Sampling Results

CIQ complex goby larvae were the fifth abundant taxon at the entrainment stations with a mean concentration of 23 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were present in all but two surveys with peaks in concentrations in February and April (Figure 4.5-35). During periods of maximum abundance in April 2006 CIQ complex gobies were present in the entrainment samples at average concentrations of approximately 160 per 1,000 m^3 (264,172 gal). Gobies were present at the source water stations during all months of the year with a peak average concentration in April 2006 of approximately 45 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-36). The larvae were more abundant in nighttime samples during almost all surveys (Figure 4.5-37). The length-frequency distribution for a representative sample of CIQ goby larvae showed that the majority of the sampled larvae were recently hatched based on the reported hatch size of 2–3 mm (0.08–0.12 in) (Moser 1996). A small proportion of the measured larvae were in the 4–13 mm (0.16–0.47 in) size classes (Figure 4.5-38) with a mean length of 3.0 mm (0.12 in) NL.

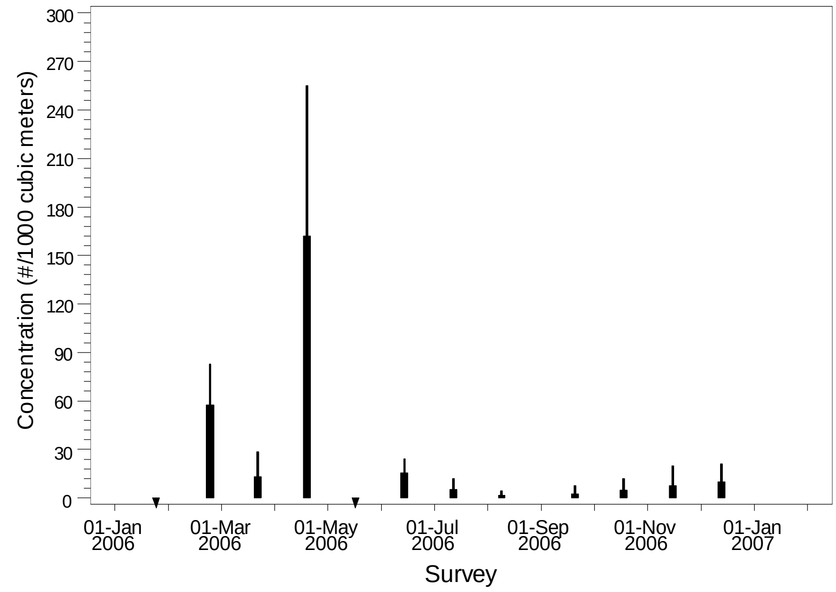


Figure 4.5-35. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of unidentified goby larvae (CIQ gobies) collected at ESGS entrainment stations during 2006.

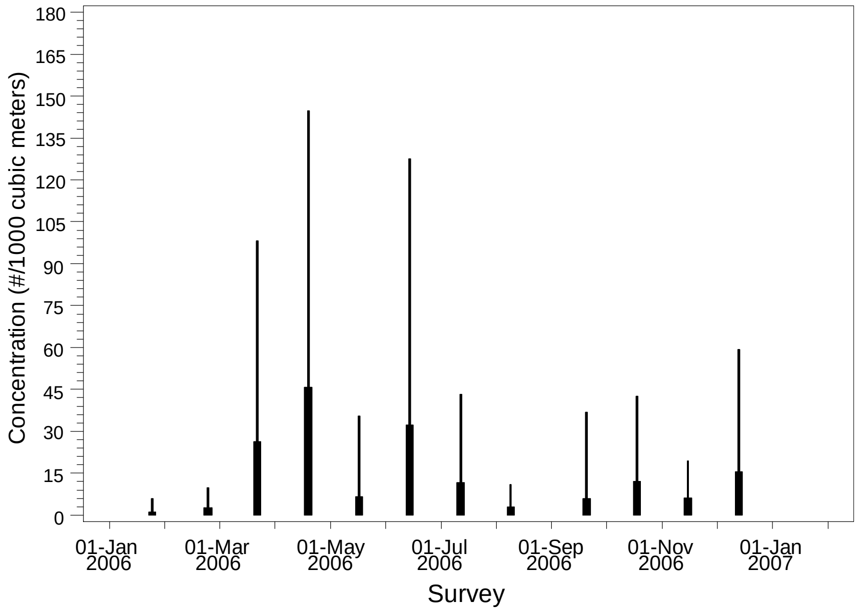


Figure 4.5-36. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of unidentified goby larvae (CIQ gobies) collected at ESGS source water stations during 2006.

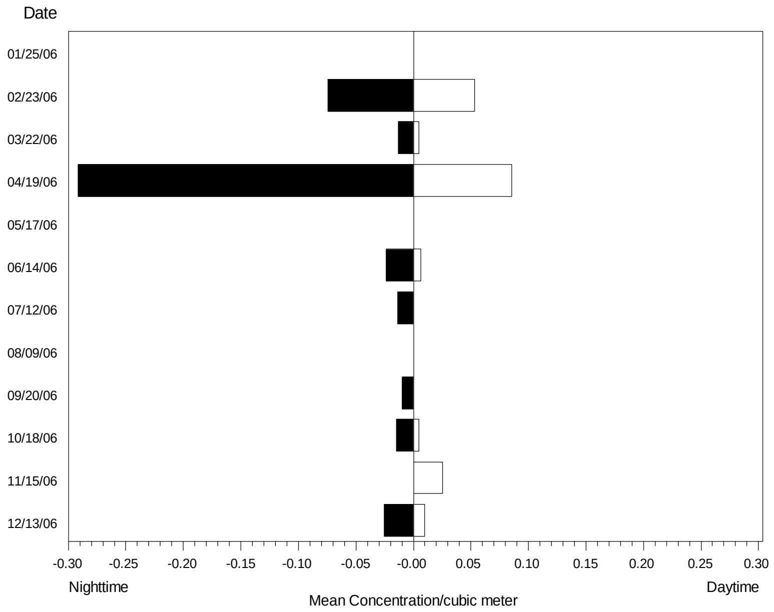


Figure 4.5-37. Mean concentration (#/1.0 m^3 [264 gal]) of unidentified goby larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.

Note: Negative nighttime values are an artifact of the plotting routine.

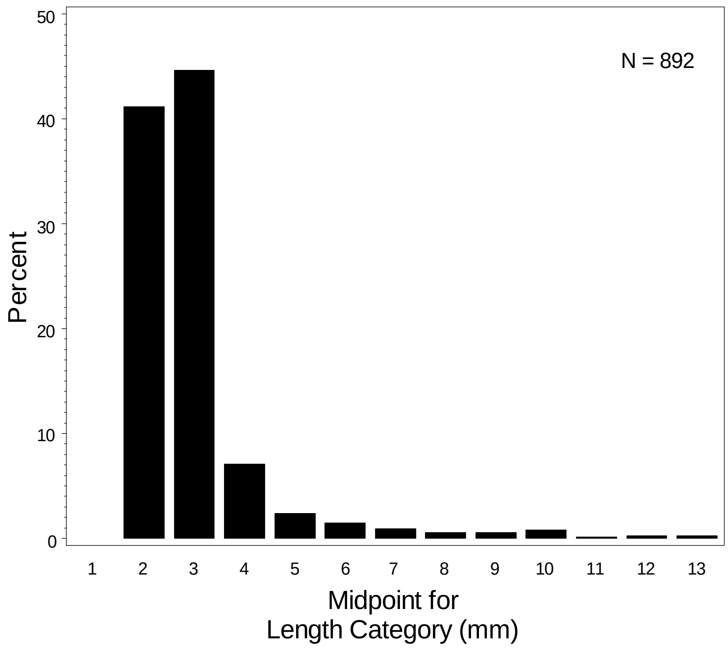


Figure 4.5-38. Length (mm) frequency distribution for unidentified goby larvae collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.7.4 Modeling Results

The following section presents 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) from Mission Bay in San Diego County provided the necessary life history information for both the *FH* and *AEL* demographic models. Total annual entrainment of CIQ goby larvae at ESGS was estimated to be 8,553,040 (standard error of 339,939) using actual measured cooling water flows during 2006 (Table 4.5-2). A total of 6,997,707 CIQ goby larvae was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 12,043,151 goby larvae. Standard errors for total annual entrainment calculations are presented in Appendix D.

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/day (0.006 in/day) was estimated from transformation lengths reported by Brothers (1975) for the three species and an estimated transformation age of 60 days. The mean length (2.8 mm [0.11 in]) and the estimated hatch length of 2.2 mm (0.09 in) based on the length of the 10th percentile 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 4.1 days. Survival to the average age at entrainment was then estimated as $0.93^{4.1} = 0.75$. A survivorship table was constructed using data from Brothers (1975) and was used to estimate a total lifetime fecundity of 1,400 eggs (Table 4.5-27). The age when at 50% of the female population was reproductive averaged 1.67 years.

The estimated number of female gobies at the age of maturity whose lifetime reproductive output was entrained through the ESGS circulating water system for the 2006 period was estimated at 8,164 (Table 4.5-28). The estimated number attributable to the operation of Units 3 & 4 was 6,680 or 82% of the total with all units. Based on the design flows for Units 3 & 4, the estimated number of reproductive CIQ female gobies was 11,496 based on larval entrainment if the pumps are run at maximum capacity. 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 4.5-27. 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 4.5-28. Results of *FH* modeling for CIQ goby complex larvae based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate[2]	*FH* Upper Estimate	*FH* Range
Actual Flows					
Larvae (All units)					
FH Estimate	**8,164**	7,078	1,961	33,983	32,022
Total Entrainment	8,553,040	339,939	7,630	8,698	1,068
Larvae (Units 3 & 4)					
FH Estimate	**6,680**	5,791	1,604	27,807	26,203
Total Entrainment	6,997,707	290,743	6,223	7,136	913
Design Flows					
Larvae (Units 3 & 4)					
FH Estimate	11,496	9,963	2,763	47,829	45,066
Total Entrainment	12,043,151	401,817	10,865	12,126	1,262

[1] Results using the design CWS flows only calculated for Units 3 & 4.
[2] 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 $0.93^{60-4.1} = 0.02$ 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 yrs 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 ESGS circulating water system for the 2006 sampling period was 7,012 based on an entrainment estimate calculated using actual CWS flows (Table 4.5-29). The estimated number attributable to the operation of Units 3 & 4 was 5,737 or 82% of the total with all units. Using the design flows of Units 3 & 4, the estimated number of equivalent adults was 9,874 based on the larval entrainment. 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 4.5-29. Results of *AEL* modeling for CIQ goby complex larvae based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate[2]	*AEL* Upper Estimate	*AEL* Range
Actual Flows					
All Units Combined					
AEL Estimate	**7,012**	7,880	1,104	44,528	43,423
Total Entrainment	8,553,040	339,939	6,554	7,471	917
Units 3 & 4					
AEL Estimate	**5,737**	6,447	903	36,434	35,531
Total Entrainment	6,997,707	290,743	5,345	6,129	784
Design Flows					
Units 3 & 4					
AEL Estimate	9,874	11,093	1,555	62,676	61,121
Total Entrainment	12,043,151	401,817	9,332	10,416	1,084

[1] Results using the design CWS flows only calculated for Units 3 & 4.
[2] 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 (4.7 mm [0.32 in]) and the estimated hatch length of the estimated hatch length of 2.2 mm (0.09 in) based on the length of the 10th percentile was used with a growth rate of 0.16 mm/day (0.006 in/day) to estimate that CIQ goby larvae were vulnerable to entrainment for a period of 15.7 days.

CIQ gobies larvae were present in the source water samples throughout the year, but were not collected from the entrainment station during two of the surveys (Table 4.5-30). The monthly estimates of proportional entrainment (*PE*) for the 2006 period ranged from 0 to 0.01486 using the actual cooling water flows during the period. The largest estimate occurred during the February survey with the largest proportion of the source population occurring in April (f_i = 0.205 or 20.5%). The values in the table were used to calculate a P_M estimate of 0.0150 with a standard error of 0.0217 using only the alongshore extrapolated estimate of the total source population. *PE* estimates ranged from 0 to 0.01257 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0122 with a standard error of 0.0218 was calculated from these values. Based on the design flows for Units 3 & 4 during the period, PE estimates ranged from 0 to 0.03639 and a P_M estimate of 0.0221 was calculated. The period of larval exposure to entrainment was used to estimate that larvae could have been transported an average distance alongshore over the 12 surveys of 36.5 km (22.7 mi) limited by the boundaries of the Santa Monica Bay, although the source of most of the goby larvae are probably the enclosed bay and wetland habitats in nearby Marina del Rey and Ballona Wetlands approximately 7 km (4.3 mi) north of the power plant. Total average displacement (not limited by the boundaries of Santa Monica Bay) was 37.2 km (23.1 mi). An average onshore transport of 10.5 km was also used in the calculations.

Table 4.5-30. *ETM* data for CIQ goby larvae. P_M calculated using **alongshore** extrapolation of population and P_S of 0.3301.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0.00364
23-Feb-06	0.01486	0.00490	0.01012	0.00337	0.03639	0.01188	0.03432
22-Mar-06	0.00199	0.00136	0.00160	0.00110	0.00302	0.00203	0.09167
19-Apr-06	0.01480	0.00514	0.01257	0.00440	0.01720	0.00586	0.20468
17-May-06	0	0	0	0	0	0	0.05168
14-Jun-06	0.00361	0.00197	0.00317	0.00173	0.00343	0.00187	0.09740
12-Jul-06	0.00140	0.00101	0.00123	0.00088	0.00130	0.00093	0.08847
9-Aug-06	0.00115	0.00133	0.00098	0.00115	0.00132	0.00146	0.03164
20-Sep-06	0.00030	0.00045	0.00023	0.00038	0.00053	0.00071	0.12798
18-Oct-06	0.00020	0.00016	0.00004	0.00005	0.00128	0.00098	0.08254
15-Nov-06	0.00137	0.00136	0.00078	0.00096	0.00458	0.00389	0.03619
13-Dec-06	0.00042	0.00037	0.00016	0.00025	0.00214	0.00144	0.14977
P_M	**0.0150**		**0.0122**		**0.0221**		
Std. Error	0.0110		0.0110		0.0146		

4.5.3.8 California halibut (*Paralichthys californicus*)

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

4.5.3.8.1 Life History and Ecology

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

California halibut is a broadcast spawner with eggs being fertilized externally. The spawning season is generally thought to extend from February to August with most spawning occurring in May (Frey 1971) although some fall spawning may also occur. The average number of eggs per spawn is 313,000–589,000 with an average reproductive output of approximately 5.5 million eggs per spawning season (Caddell et al. 1990). During spawning season females may release eggs every 7 days and the largest individuals may produce in excess of 50 million eggs per year (Caddell et al. 1990). Captive specimens were observed to spawn at least 13 times per season. Halibut eggs are 0.7–0.8 mm (0.03 in) diameter (Ahlstrom et al. 1984) and are most abundant in the water column in less than 75 m (246 ft) depths and within 6.5 km (4.0 mi) from shore (Kramer et al. 2001).

Upon hatching, the larvae (1.6–2.1 mm [0.06–0.08 in] NL [Moser 1996]) are pelagic (Frey 1971) and tend to be most abundant between Santa Barbara, California, and Punta Eugenia, Baja California Sur (Ahlstrom and Moser 1975) from January through August (Moser 1996). California halibut have a pelagic larval stage of 20–29 days (Gadomski et al. 1990). Larval transformation occurs at a length of ca. 7.5–9.4 mm (0.30–0.37 in) SL (Moser 1996) at which time the young fish settle to the bottom, generally in bays but also occasionally in shallow substrates along the open coast (Haugen 1990). Kramer (1991a) found that 6–10 mm (0.24–0.39 in) California halibut larvae grew <0.3 mm/day (0.01 in/day), while larger 70-120 mm (2.8–4.7 in) halibut grew about 1.0 mm/day (0.04 in/day). In a laboratory study, California halibut held at 16°C (60.8°F) grew to a length of 11.1 mm ± 2.61 (0.48 in ± 0.10 in) in 2 mo. from an initial hatch length of 1.9 mm (0.07 in) (Gadomski et al. 1990). After settling in bays, the juveniles may remain there for about 2 years until they emigrate to the outer coast. There is a large discrepancy in size and age of maturity between males and females (Love and Brooks 1990). Males mature at sizes ranging between 19–32 cm (7.5–12.6 in) with 50% maturity at 22.5 cm (8.9 in), while females mature between 36–59 cm (14.2–23.2 in) with 50% maturity occurring at 47 cm (18.5 in). Most males are mature by the first year and all are mature at 3 years, whereas a few females spawn during their second year, half at about 4.5 years, and all are mature by age 7. Males emigrate out of the bays when they mature (ca. 20 cm [7.9 in]) but females migrate out as subadults at a length of about 25 cm (9.8 in) (Haugen 1990). Subadults remain nearshore at depths of 6–20 m (20–66 ft) (Clark 1930; Haaker 1975). California halibut may reach 152 cm (59.8 in) and 33 kg (72.8 lb) (Eschmeyer and Herald. 1983). Individuals may live as long as 30 years (Frey 1971).

California halibut feed during both day and night, but show a preference for daytime feeding (Haaker 1975). This species is an ambush feeder, typically lying partially buried in the sand until prey approaches. They prey on Pacific sardine, anchovies, squid, and other nektonic nearshore fish species (Kramer et al. 2001). Small halibut in bays eat small crustaceans and shift to feeding on other fishes as they increase in size. Other similar species of flatfishes such as sand sole and bigmouth sole may compete with California halibut for food resources (Haugen 1990).

4.5.3.8.2 Population Trends and Fishery

California halibut is an important species to both commercial and recreational fisheries in southern and central California. Halibut are harvested commercially through the use of otter trawls, set gill and trammel nets, and hook and line (Kramer et al. 2001). Trawl or drag nets were first used in the San Francisco area dating back to 1876. Two vessels towed the original trawl nets, known as paranzella. This method remained fairly standard for the trawl fishery for nearly 50 years until the late 1930s and early 1940s when the otter trawl replaced paranzellas and reduced the need for a second boat (Clark 1935, Scofield 1948). Entangling nets such as trammel nets have been used to catch halibut since the 1880s (Ueber 1988). Historically, most halibut were primarily taken by trammel nets or trawl, although more recently the use of set gill nets in southern California have replaced trawling as the dominant gear type used (Barsky 1990).

Barsky (1990) described the many shifts that have occurred in the geographic center of the commercial California halibut fishery. Most shifts occurred due to shifting abundances in different localities and also because of regulation changes, although environmental influences may have played a role as well. During the earliest years the fishery was centered off southern and Baja California in areas such as San Pedro near Los Angeles and Mexico. Trammel nets were the choice of preference for fleets in these areas since trawl nets were prohibited in the early 1900s of Los Angeles and San Diego counties. Gradually the fishery shifted northwards to Ventura and Santa Barbara counties during the 1970s. Prior to 1969 the trawl fishery caught most halibut for these counties, but tighter regulations on the trawl fishery in the early 1970s along with the ease, efficiency, and cost effectiveness of entangling nets paved the way for this method. Exceptions have occurred during El Nino years such as 1983 when halibut landings were greatest in the San Francisco area.

A number of regulation changes have been implemented throughout the history of this fishery in order to assist with restoration efforts for this species. Trawl fishing has been prohibited in state waters (0–3 nautical miles from shore) since 1915, with a few seasonal and area closures since then. Today trawling is permitted in federal waters (3-200 nautical miles from shore) with a minimum mesh size of 4.5 inches but is prohibited in state waters with the exception of designated “California halibut trawl grounds” between Point Arguello and Point Mugu with certain mesh size requirements and seasonal closures to protect spawning adults. Similarly, trammel nets were originally prohibited in state waters in 1911, but since then have been subject to various area, depth, mesh size requirements, and seasonal closures throughout the state. A sharp decline in recreational landings during the 1960s lead to regulation changes in 1971 that set a minimum size limit of 56 cm (22 in) for sport caught halibut. A 13-fold decrease in recreational landings from 1948–1958 was attributed to the expanding CPFV fleet and no size restrictions, and it appears that a ban on gillnetting in 1994 or any other regulations have had little effect on halibut as recreational catches have remained consistently low since the 1960s (Dotson and Charter 2003). Commercial fishing laws prohibit sale of California halibut less than 56 cm (22 in) although four halibut less than legal size may be retained for personal consumption. For recreational anglers the same 56 cm (22 in) size limit also applies with a daily bag limit of 5 fish south of Point Sur and 3 fish north of Point Sur.

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 5.9 fish per station for California halibut at bay and harbor stations during 5–10 minute trawls. This species was not as abundant at inner shelf stations where the abundance was 1.3 fish per station.

It appears that the size of the California halibut population may be limited by the availability of shallow-water nursery habitat, and a long-term decline in landings corresponds to a decline in these habitats in southern California associated with dredging and filling of bays and wetlands (Kramer et al. 2001). Also, larval abundance has shown strong correlations with commercial landings, suggesting a cycle of abundance with peaks approximately every 20 years (Moser and Watson 1990). A fishery-independent trawl survey for halibut conducted in the early 1990s estimated that the southern California biomass was 3.1 million kg (6.9 million lb) [3.9 million adult fish] and the central California biomass was 1.0 million kg (2.3 million lb) [0.7 million fish].

California halibut have a high commercial and recreational fishery value. The fishery for this species was reviewed in Kramer et al. (2001) and since 1980 the commercial catch has remained relatively constant averaging approximately 1.0 million lb (0.54 million kg) per year statewide. In southern California the commercial landings for halibut averaged 165 697 kg (365,330 lb) between 2000 and 2006 landed for an average annual revenue of $1,370,368 (PacFIN 2007) (Table 4.5-31). In Los Angeles County commercial catches have varied from a high of 86,393 kg (190,464 lb) in 2000 to a low of 25,310 kg (55,800 lb) in 2006. Recreational catch of halibut in the southern California region has varied annually from an estimated 104,000 fish in 2002 to 25,000 in 2004.

Table 4.5-31. Annual landings for California halibut in the Southern California region based on RecFIN and PacFIN data from 2000–2006.

	Southern California (All Counties Combined)				Los Angeles County		
Year	**Estimated Recreational Catch**	**Commercial Landings (lb)**	**Commercial Landings (kg)**	**Value**	**Commercial Landings (lb)**	**Commercial Landings (kg)**	**Value**
2000	103,000	461,216	209,204	$1,447,476	190,464	86,393	$632,251
2001	85,000	505,417	229,253	$1,662,777	124,679	56,553	$433,402
2002	104,000	483,400	219,267	$1,695,468	145,065	65,800	$538,929
2003	87,000	332,273	150,716	$1,237,440	92,366	41,897	$383,049
2004	25,000	340,600	154,494	$1,459,720	112,383	50,976	$487,091
2005	31,000	214,989	97,517	$977,340	62,080	28,159	$296,200
2006	27,000	219,413	99,524	$1,112,354	55,800	25,310	$270,768
Average	66,000	365,330	165,711	$1,370,368	111,834	50,727	$434,527

4.5.3.8.3 Sampling Results

California halibut was the eighth most abundant larval fish species at the entrainment station with a mean concentration of 14 per 1,000 m^3 (264,172 gal) from all the surveys (Table 4.5-1). They were collected at the entrainment station from February through September (Figure 4.5-39). Peak abundance of halibut larvae occurred in summer with a high of 48 larvae per 1,000 m^3 (264,172 gal) collected in July 2006. California halibut larvae were present in all source water surveys with peak average abundance also occurring in July at approximately 105 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-40). There was no substantial difference in abundance between daytime and nighttime samples (Figure 4.5-41). The length-frequency distribution for measured halibut larvae showed that the majority of the sampled larvae were recently hatched based on the reported hatch size of ca. 1.8 mm (0.07 in) (Figure 4.5-42) (Moser1996). The mean length of measured specimens from the entrainment station samples was 2.1 mm (0.08 in) NL with a size range from 1.1–7.8 mm (0.04–0.31 in) NL.

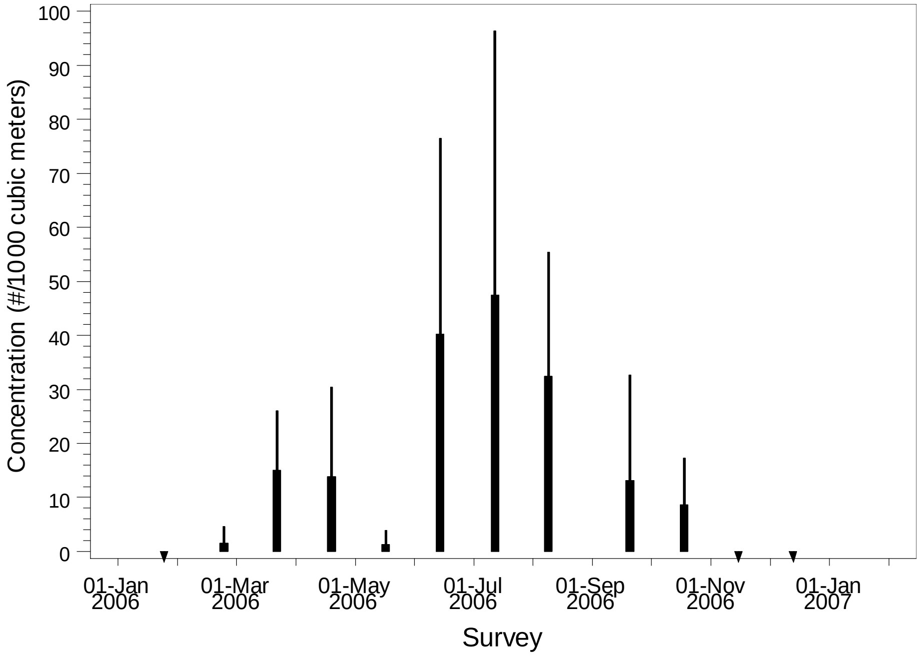


Figure 4.5-39. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of California halibut larvae collected at ESGS entrainment stations during 2006.

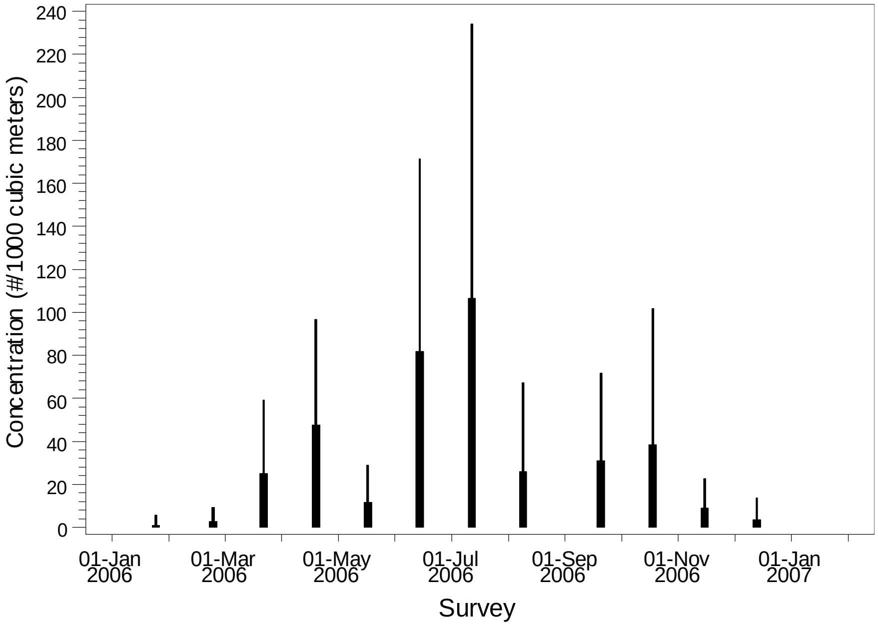


Figure 4.5-40. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of California halibut larvae collected at ESGS source water stations during 2006.

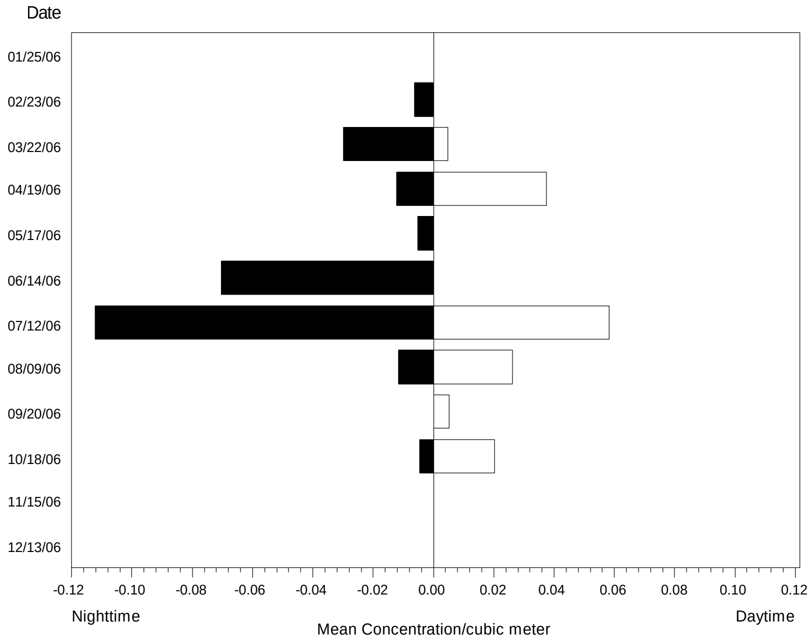


Figure 4.5-41. Mean concentration (# per 1.0 m^3 [264 gal]) of California halibut larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.

Note: Negative nighttime values are an artifact of the plotting routine.

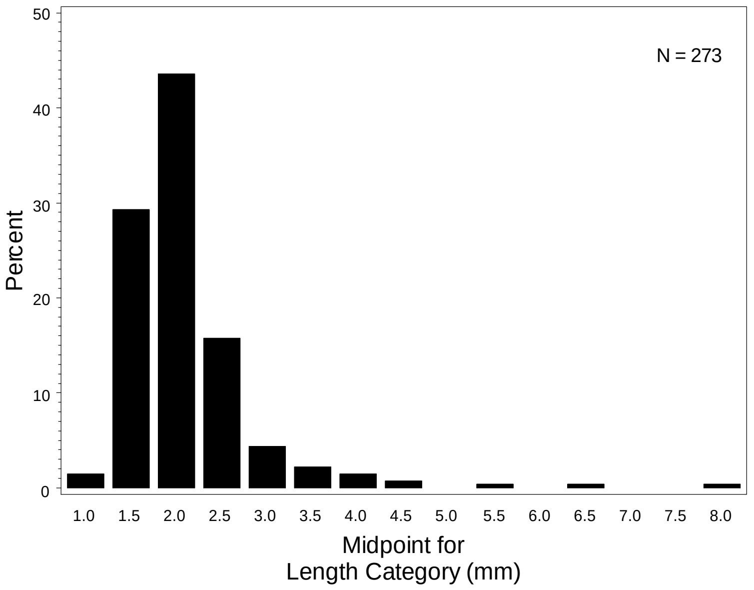


Figure 4.5-42. Length (mm) frequency distribution for larval California halibut collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.8.4 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CWS effects on California halibut eggs and larvae. There was information on California halibut life history that allowed for calculation of an *FH* estimate, but not enough information on late larval and juvenile survival necessary for calculating an estimate of *AEL*. Total annual entrainment of California halibut eggs and larvae at ESGS was estimated to be 602,696 eggs (standard error of 59,364) and 6,869,726 larvae (standard error of 305,706) using actual measured cooling water flows during 2006 (Table 4.5-2). A total of 449,338 halibut eggs and 5,863,484 larvae was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006 (Table 4.5-2). If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 1,179,277 eggs and 7,790,992 larvae. Standard errors for total annual entrainment calculations are presented in Appendix D. The total duration used in the *ETM* calculations included both the estimated egg duration from the literature and the estimated larval duration to provide an integrated estimate of entrainment effects.

Fecundity Hindcasting (*FH*)

The annual entrainment estimates for California halibut eggs and larvae were used to estimate the number of females at the age of maturity needed to produce the numbers of eggs and larvae over their lifetimes. An estimate of total egg survival of 0.5 was calculated from laboratory studies by Caddell et al. (1990) for an estimated planktonic duration of 2.19 days (Gadomski et al. 1990; Emmett et al. 1991; Gadomski and Cadell 1995). Daily larval survival for early stage larvae up to age 43.3 days was estimated at 0.95 from data in Kramer (1991a). The mean length (2.1 mm [0.08 in]) and estimated hatch length of 1.6 mm (0.06 in) were used with a growth rate of 0.19 mm/day (0.01 in/day) calculated from data in (Gadomski and Peterson 1988) to estimate that the larvae were exposed to entrainment for an average period of 2.7 days. The survival to the average age at entrainment was then calculated as $0.95^{2.7} = 0.89$. Total lifetime fecundity was estimated at 1,973,371 eggs using data in MacNair et al. (1991). This life history information was used to estimate that the numbers of entrained eggs and larvae were equivalent to the loss of a total of eight female California halibut (Table 4.5-32). Using only the annual entrainment estimates from Units 3 & 4 resulted in a calculated loss of seven adult females. Based on the design flows of Units 3 & 4 during the period, an estimated 10 adult females were lost. The results of the sensitivity analysis show that the greatest uncertainty associated with the estimates is associated with the life history parameters and not the entrainment estimate.

Table 4.5-32. Results of *FH* modeling for California halibut eggs and larvae based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate[2]	*FH* Upper Estimate	*FH* Range
Actual Flows					
Eggs (All units)					
FH Estimate	**<1**	<1	0	1	1
Total Entrainment	602,696	59,364	0	0	0
Eggs (Units 3 & 4)					
FH Estimate	**<1**	<1	0	1	1
Total Entrainment	449,338	47,685	0	0	0
Larvae (All units)					
FH Estimate	**8**	7	2	33	31
Total Entrainment	6,869,726	305,706	7	8	1
Larvae (Units 3 & 4)					
FH Estimate	**7**	6	2	28	26
Total Entrainment	5,863,484	268,193	6	7	1
Design Flows					
Eggs (Units 3 & 4)					
FH Estimate	1	1	0	3	2
Total Entrainment	1,179,277	96,866	1	1	0
Larvae (Units 3 & 4)					
FH Estimate	9	8	2	37	35
Total Entrainment	7,790,992	303,092	8	9	1

[1] Results using the design CWS flows only calculated for Units 3 & 4.
[2] 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.

Empirical Transport Model (ETM)

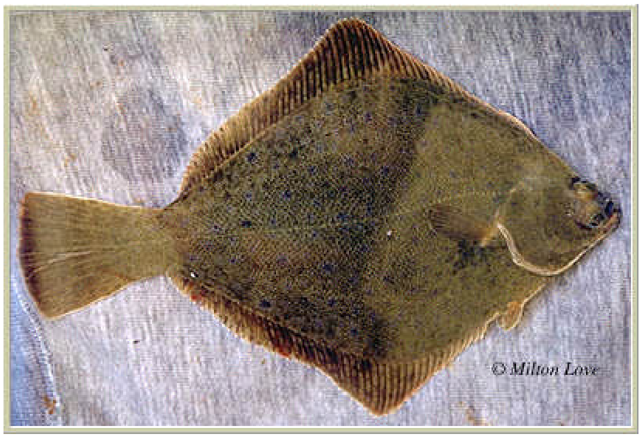
The same growth rate used in the FH modeling, 0.19 mm/day (0.01 in/day), was used with the estimated length at hatching (1.6 mm [0.06 in]) and length of the 95th percentile length (3.5 mm [0.14 in]) of a random sample of 200 of the measured larvae to estimate that the larvae were exposed to entrainment for a maximum period of 10.0 days. The total period of exposure is increased to 12.1 days when the duration of the egg stage is added to the estimate.

The monthly estimates of proportional entrainment (*PE*) for California halibut for 2006 ranged from 0 to 0.00312 using the actual cooling water flows during the period (Table 4.5-33). California halibut larvae were collected from the entrainment station during nine of the paired entrainment/source water surveys but were present at the source water stations during all of the surveys, reflecting the capacity of individual females to spawn multiple times throughout the year (Caddell et al 1990). The largest proportion of the source water population was present during the July survey (f_i = 0.295 or 29.5%). The values in the table were used to calculate a P_M estimate of 0.0017 with a standard error of 0.0010 using the extrapolated offshore estimate of the total source population. *PE* estimates ranged from 0 to 0.00266 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0014 with a standard error of 0.0009 was calculated from these values. Based on the design flows for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.00356 and a P_M estimate of 0.0024 with a standard error of 0.0014 was calculated. The period of larval exposure to entrainment allows larvae to be transported an average distance from offshore over the 12 surveys of 8.2 km (5.1 mi) and alongshore an average of 32.2 km (20.0 mi) within the Santa Monica Bay indicating that larvae from more than half of the 60 km (37 mi) coastline of the bay may be subject to entrainment.

Table 4.5-33. *ETM* data for California halibut larvae. P_M calculated using offshore extrapolation of population and P_S of 0.2371.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0.00264
23-Feb-06	0.00039	0.00043	0.00027	0.00030	0.00097	0.00104	0.00724
22-Mar-06	0.00080	0.00037	0.00064	0.00030	0.00121	0.00055	0.05401
19-Apr-06	0.00047	0.00029	0.00040	0.00025	0.00054	0.00033	0.11533
17-May-06	0.00012	0.00013	0.00010	0.00011	0.00015	0.00015	0.03832
14-Jun-06	0.00101	0.00059	0.00089	0.00052	0.00096	0.00055	0.18896
12-Jul-06	0.00078	0.00043	0.00069	0.00038	0.00073	0.00039	0.29486
9-Aug-06	0.00312	0.00137	0.00266	0.00118	0.00356	0.00152	0.05138
20-Sep-06	0.00040	0.00037	0.00031	0.00032	0.00071	0.00054	0.10507
18-Oct-06	0.00006	0.00003	0.00001	0.00001	0.00036	0.00020	0.10744
15-Nov-06	0	0	0	0	0	0	0.02322
13-Dec-06	0	0	0	0	0	0	0.01153
P_M	**0.0017**		**0.0014**		**0.0024**		
Std. Error	0.0010		0.0009		0.0014		

4.5.3.9 Diamond turbot (*Pleuronichthys guttulatus*)



Diamond turbot *Pleuronichthys guttulatus* is classified in the family of right-eyed flatfishes (Pleuronectidae). It is one of twenty pleuronectid species that occur off California, and ranges from Cape San Lucas, Baja California to Cape Mendocino, California (Eldridge 1975). An isolated population has also been reported from the upper Gulf of California (Miller and Lea 1972). The scientific name of this species was recently changed from *Hypsopsetta guttulata* to *Pleuronichthys guttulatus* (Nelson et al. 2004).

4.5.3.9.1 Life History and Ecology

Diamond turbot are found in bays and shallow coastal waters with sandy or muddy bottoms. The diamond turbot occurs in water depths between less than 1 m (3.3 ft) and 50 m (164 ft), but is most common in shallow water less than 10 m (33 ft) (Lane 1975). They feed primarily on invertebrates that live on top of, or in the upper layers of the substrate. Gut contents of diamond turbot collected in Anaheim Bay, California included polychaete worms, crustaceans, and mollusks (Lane 1975). This species feeds primarily during daylight hours. Predators include angel shark, Pacific electric ray, and other piscivorous fish.

Little is known of the reproductive habits of the diamond turbot. Females become sexually mature at two to three years (Fitch and Lavenberg 1975), but no equivalent information is available concerning the males. Both sexes are sexually mature at a total length of 16.5 cm (6.5 in) (Love 1996). Spawning occurs year-round and appears to peak during the winter months (Eldridge 1975). Eggs collected in San Francisco Bay averaged 0.8 mm in diameter (Eldridge 1975).

The largest diamond turbot reported in literature was 46 cm (18 in) in total length (Lane 1975). The maximum age for this species, based on otoliths and scales, is about eight years (Love 1996; Fitch and Lavenberg 1975). Newly hatched larvae collected in San Francisco Bay averaged 1.6 mm (0.06 in) NL (Eldridge 1975). Larvae are planktonic and settle to the bottom in shallow water after about 5–6 weeks. Standard length at the time of settlement is about 1.1–1.2 cm (0.43–0.47 in) (Eldridge 1975). Early growth rates appear to be similar to other flatfish including the California halibut (*Paralichthys californicus*). Total length of diamond turbot at one year is about 14 cm (5.5 in) (Lane 1975).

4.5.3.9.2 Population Trends and Fishery

Diamond turbot makes up a minor portion of the California marine sport fishery (Leos 2001). They are taken by anglers fishing from the shore, piers, or boats in shallow bays and estuaries. This species has little commercial importance but is taken occasionally as part of the incidental catch. It is usually reported under the grouping of 'unspecified turbot' along with several other flatfish species. California Department of Fish and Game reported annual landings of ‘turbot’ in California of about 5,900 kg (13,000 lb) and 3,000 kg (6,600 lb) for the years 2001 and 2002, respectively. The proportion of this total contributed by diamond turbot is not known.

4.5.3.9.3 Sampling Results

Diamond turbot larvae was the ninth most abundant taxon at the entrainment station with a mean concentration of 12 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They primarily occurred in fall and winter (Figure 4.5-43). Peak abundance in the entrainment samples occurred in February at 43 larvae per 1,000 m^3 (264,172 gal). Source water sample concentrations had peak abundances in October at approximately 20 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-44). There was no significant trend in abundance between daytime and nighttime samples (Figure 4.5-45). The length frequency plot for larvae was skewed toward the smaller size classes with over 25% of sampled larvae in the 2.0 mm (0.08 in) size class and a general decline in frequency of occurrence at larger size classes to 5.5 mm (0.22 in) (Figure 4.5-46). The mean length of measured specimens from the entrainment station samples was 2.7 mm (0.11 in) NL with a size range from 1.4–5.6 mm (0.06–0.22 in) NL.

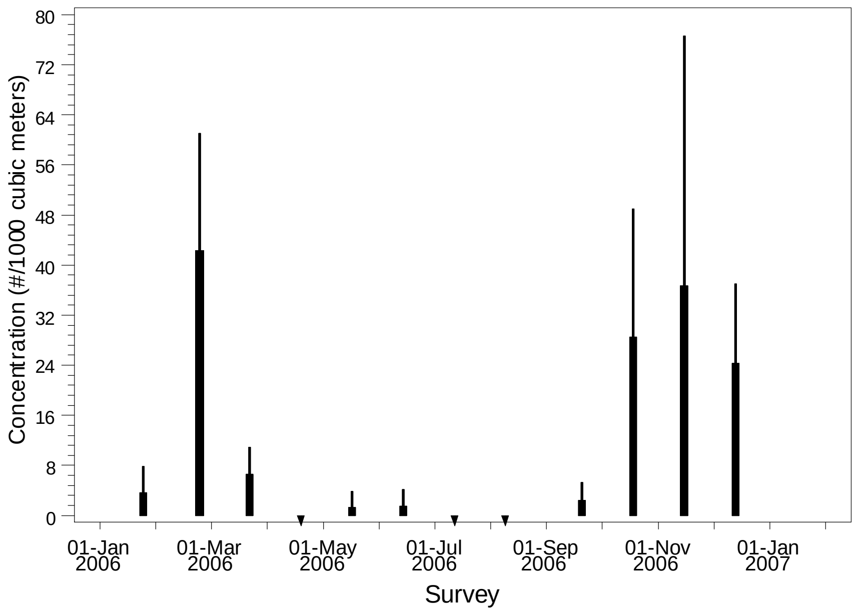


Figure 4.5-43. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of diamond turbot larvae collected at ESGS entrainment stations during 2006.

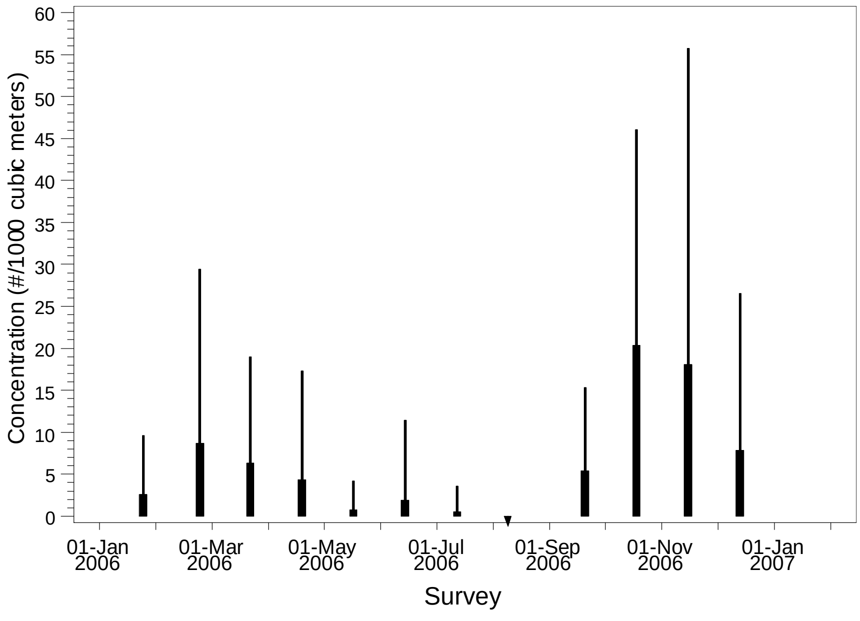


Figure 4.5-44. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of diamond turbot larvae collected at ESGS source water stations during 2006.

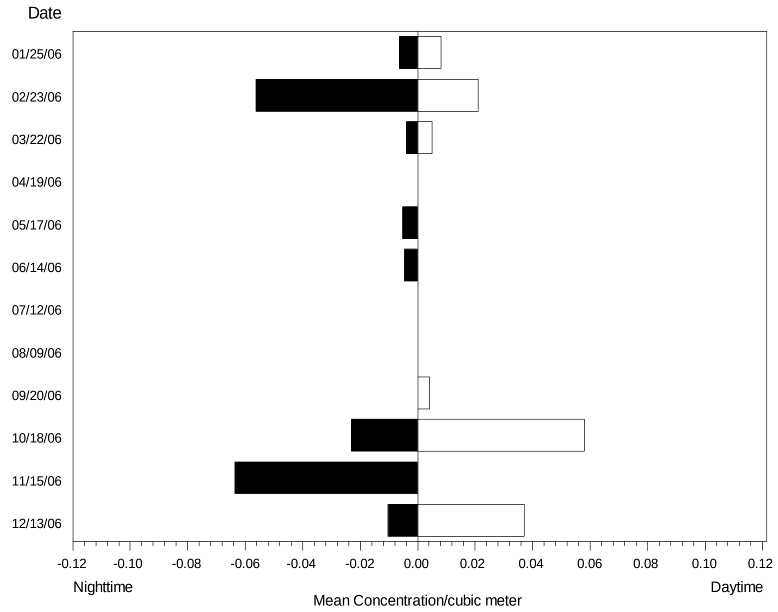


Figure 4.5-45. Mean concentration (#/1.0 m^3 [264 gal]) of diamond turbot larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006. *Note: Negative nighttime values are an artifact of the plotting routine.*

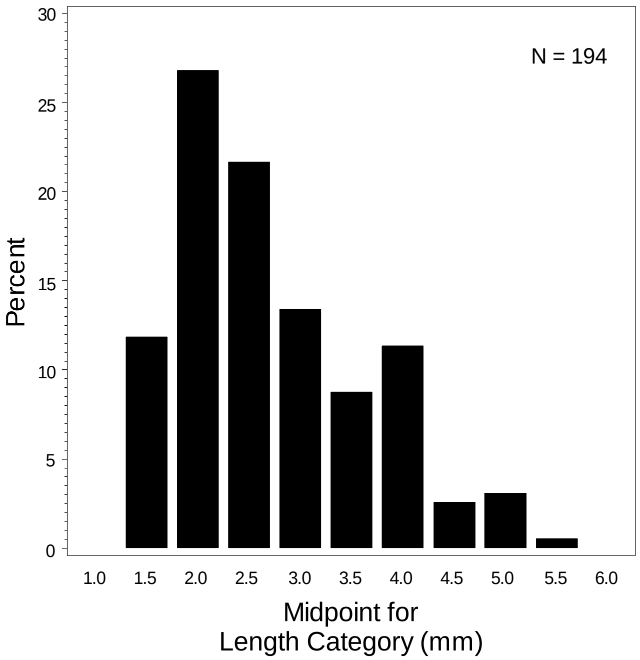


Figure 4.5-46. Length (mm) frequency distribution for larval diamond turbot collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.9.4 Modeling Results

The following sections present the results for empirical transport modeling of entrainment effects on diamond turbot. No age-specific estimates of survival for larval and later stages of development were available from the literature for this species, and therefore no estimates of *FH* or *AEL* were calculated. Total annual entrainment of eggs and larvae at ESGS was estimated at 136,981 and 2,148,380 (standard errors of 24,272 and 72,431), respectively for diamond turbot using actual measured cooling water flows during 2006 (Table 4.5-2). An estimated total of 116,669 turbot eggs and 1,288,095 larvae was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 156,195 eggs and 6,768,632 diamond turbot larvae. Standard errors for total annual entrainment calculations are presented in Appendix D. The total duration used in the *ETM* calculations included both the estimated egg duration from the literature and the estimated larval duration to provide an integrated estimate of entrainment effects.

Empirical Transport Model (ETM)

No data were available on planktonic duration or larval growth for diamond turbot so a value 0.19 mm/day (0.01 in/day) from California halibut was used in calculating the larval duration used in the *ETM* modeling. A sample of 194 lengths from the collected diamond turbot larvae was used to calculate a difference between the estimated hatch length of 1.9 mm (0.07 in) and the 95th percentile value of the measurements (4.4 mm [0.17 in]) to estimate that the larvae were exposed to entrainment for a period of approximately 13.2 days. The 2.2 day duration of the planktonic egg stage from California halibut was added to the period for the larvae to estimate a total period of exposure of 15.4 days.

The monthly estimates of proportional entrainment (*PE*) for diamond turbot for 2006 ranged from 0 to 0.00654 using the actual cooling water flows during the period (Table 4.5-34). Diamond turbot larvae were collected during nine of the paired entrainment/source water surveys and from the source water stations during all of the surveys expect August 2006 with the largest proportion of the source population present during the October survey (f_i = 0.268 or 26.8%). The values in the table were used to calculate a P_M estimate of 0.0094 with a standard error of 0.005 using the alongshore extrapolation of the total source population. *PE* estimates ranged from 0 to 0.00573 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0054 with a standard error of 0.0036 was calculated from these values. Using the flow volumes based on the design (or maximum) capacity CWS flows for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.01112, and a P_M estimate of 0.0309 with a standard error of 0.015 was calculated. The period of larval exposure to entrainment allows larvae to be transported an average distance alongshore (limited by the shoreline distance of the bay) of 37.0 km (23.0 mi) indicating that larvae over a large portion of the total 60 km (37 mi) coastline of Santa Monica Bay may be subject to entrainment. Total average displacement (not limited by the shoreline distance of the bay) was 36.9 km (22.9 mi). An average onshore transport of 10.5 km was also used in the calculations.

Table 4.5-34. *ETM* data for diamond turbot larvae. P_M calculated using **alongshore** extrapolation of population and P_S of 0.3490.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0.00169	0.00135	0.00134	0.00108	0.00272	0.00210	0.05324
23-Feb-06	0.00642	0.00224	0.00438	0.00154	0.01573	0.00543	0.10061
22-Mar-06	0.00154	0.00077	0.00123	0.00062	0.00233	0.00115	0.10202
19-Apr-06	0	0	0	0	0	0	0.06562
17-May-06	0.00146	0.00173	0.00122	0.00146	0.00185	0.00212	0.02603
14-Jun-06	0.00654	0.00896	0.00573	0.00787	0.00621	0.00844	0.00925
12-Jul-06	0	0	0	0	0	0	0.01135
9-Aug-06	0	0	0	0	0	0	0
20-Sep-06	0.00058	0.00049	0.00045	0.00042	0.00103	0.00075	0.10918
18-Oct-06	0.00063	0.00026	0.00011	0.00008	0.00397	0.00161	0.26843
15-Nov-06	0.00313	0.00211	0.00177	0.00150	0.01042	0.00601	0.13154
13-Dec-06	0.00216	0.00109	0.00085	0.00065	0.01112	0.00480	0.12273
$\boldsymbol{P_M}$	**0.0094**		**0.0054**		**0.0309**		
Std. Error	0.0050		0.0036		0.0150		

4.5.3.10 Sanddabs (*Citharichthys* spp.)

Dan Dugan

There are three common species of sanddabs in California waters: the pacific sanddab (*Citharichthys sordidus*), speckled sanddab (*Citharichthys stigmaeus*), and the longfin sanddab (*Citharichthys xanthostigma*). Pacific sanddabs range from Kodiak Island, Western Gulf of Alaska to Cabo San Lucas, Southern Baja California (Miller and Lea 1972), speckled sanddabs range from Prince William Sound, northern Gulf of Alaska to Magdalena Bay, southern Baja California (Miller and Lea 1972) and in Bahia Conception, Gulf of California (Galvan-Magana et al. 2000), and longfin sanddabs occur from Monterey Bay (Eschmeyer and Herald 1983) to Costa Rica (Miller and Lea 1972). They are benthic animals found from intertidal depths to 549 m (1,200 ft) (Love et al. 2005).

4.5.3.10.1 Life History and Ecology

Sanddabs are primarily soft bottom dwellers, living over sand or occasionally mud, but they have also been reported from hard, flat substrate (Love 1996). Speckled sanddabs prefer sand bottoms, rather than mud (Helly 1974). They swim well above the bottom in search of food, particularly at night, and have been observed hovering 1–2 m (3–6 ft) above the bottom (Love 1996)

Sanddabs are broadcast spawners with externally fertilized eggs. The spawning season is generally thought to extend year-round with most spawning occurring from June–October (Love 1996). The average number of eggs per spawn is 4,300–30,800, depending on the size of the female. Sanddab eggs are 0.55-0.77 mm (0.02–0.03 in) in diameter and are spawned on the open coast. The eggs are pelagic and occur in coastal and polyhaline waters (Cailliet et al. 2000).

The larvae are 1.3–2.6 mm [0.05–0.10 in] NL upon hatching and can occur from the Bering Sea to Southern Baja California (Moser 1996). Speckled sanddab larvae are common from August to December, with a peak in October, and Pacific sanddab larvae are common from January to February, and August to October (Moser 1996). Sanddabs have a lengthy larval duration of 271–324 days (Cailliet et al. 2000). Larval transformation occurs at a length of ca. 24–40 mm (0.94–1.57 in) SL (Moser 1996) at which time the young fish settle to the bottom. Females mature at 2–3 years and 19–22.5 cm (7.5–8.9 in) SL (Love 1996). Sanddabs may reach 40 cm (15.7 in) (Miller and Lea 1972), and may live 11 years or more (Love 1996).

Sanddabs feed during both day and night, both on and above the bottom (Love 1996). They prey on copepods, polychaetes, amphipods, cumaceans, mysids, shrimp, squid, small fish, worms, crabs, octopus, anchovies, and echiurids. Small sanddabs eat small crustaceans, copepods, and amphipods and gradually switch to larger prey items with size. Other similar species of flatfishes such as California tonguefish, English sole, California halibut, and other sanddab species may compete with sanddabs for food within their range (Cailliet et al. 2000).

In southern California, Pacific sanddabs can occur in association with contaminated bottom sediments that contain chemicals such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), as well as heavy metals (Houge and Paris 2002). The occurrence of endoparasites in Pacific Sanddabs in Santa Monica Bay can be an indicator of exposure to pollutant sources such as wastewater outfalls (Houge and Swig 2007).

4.5.3.10.2 Population Trends and Fishery

Sanddabs make up a large portion of demersal fish assemblages over soft bottom substrates within most of California. Pacific sanddabs (*Citharichthys sordidus*) have a high frequency of occurrence along the middle to outer shelf in southern California and co-occur with other key species such as Dover sole, plainfin midshipman, and stripetail rockfish (Allen et al. 2007). It appears that the population of speckled sanddabs is continuous throughout the geographical range of the species, with individuals moving due to temperature fluctuations and other physical factors. Fish found in warmer temperatures tend to have a much higher occurrence of the parasitic isopod *Lironeca vulgaris*, suggesting that these fish are stressed (Helly 1974). Speckled sanddabs (*Citharichthys stigmaeus*) are widespread along the inner shelf (5–30 m [16–98 ft]) and are an important species in beam trawl surveys of the surf zone areas near drift algal beds, and in semi-protected and exposed areas of coastline (Allen and Pondella 2006; Allen and Herbinson 1991).

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 averaged 109 fish per station for speckled sanddab and 6.6 fish per station for Pacific sanddab at inner shelf stations during 5–10 minute trawls. These species were not as abundant in bay and harbor stations as the abundance averaged 0.25 fish per station for speckled sanddab and Pacific sanddab was absent.

Although sanddabs are not as important to California fisheries as some other species of flatfishes, they are caught in fairly substantial numbers in both commercial and recreational fisheries. Most landings of sanddabs are taken commercially by otter trawls and some by hook and line, particularly off San Francisco and Eureka. Early landings during the 1920s were fairly high, while annual landings from 1930 to 1974 were below 454,000 kg (1 million lb) (Allen and Leos 2001). Since 1975, landings have gradually risen and increased rapidly during the mid to late 1990s. Notable drops in commercial catches have occurred during strong El Nino events, and have also been affected by a shift in effort towards more desirable flatfish species.

Sanddabs are targeted in recreational fisheries aboard private boats and in the commercial passenger fishing vessel (CPFV) fishery. The recreational fishery in southern California developed during the early 1990s and annual catches averaged below 2,000 until 1998 when recreational catches soared to 80,000 fish annually and peaked at 244,000 in 2001 (Dotson and Charter 2003). While the cause for the upsurge in sanddab catches remains uncertain, a combination of factors such as tight restrictions on the rockfish fishery during winter months, a large increase in sanddab numbers, or a more recent discovery of the fishery may have contributed to this increase.

Annual commercial landings in the Los Angeles region since 2000 have varied from a high of 40,000 kg (88,200 lb) in 2000 to a low of 6,800 kg (15,000 lb) in 2006, with an average of 19,700 kg (43,400 lb) and average net worth of $29,385 annually. Sport fishery catch estimates of Pacific sanddabs in the southern California region from 2000 to 2006 ranged from 32,000 to 373,000 fish, with an average of 196,000 fish caught annually (RecFIN 2007). Catch estimates for speckled sanddab were much lower and averaged 1,300 fish annually between 2000 and 2006. In the Santa Monica Bay area in 2006, only 16.6 kg (36.5 lb) of sanddabs were landed with a total value of $62.50 according to specific CDF&G catch block data from the area.

4.5.3.10.3 Sampling Results

Sanddabs were the twelfth most abundant taxon at the entrainment station with a mean concentration of 10 per 1,000 m^3 (264,172 gal) from all of the surveys (Table 4.5-1). They were present at the entrainment station from February to November in most surveys with peak average abundance in September at 33 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-47). Sanddab larvae were present in all source water surveys throughout the year with peak average abundance occurring in late June at approximately 120 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-48). Sanddab larvae were generally more common in the nighttime samples than in daytime samples (Figure 4.5-49). The length frequency plot for 177 larvae measured from Santa Monica Bay showed a unimodal curve with about 95% of sampled larvae in the 1–2 mm (0.04–0.08 in) size classes, indicating that the majority of the sampled larvae were recently hatched based on the reported hatch size of 1–2 mm (0.04–0.08 in) (Figure 4.5-50; Moser 1996). Few larvae were collected in the 22 mm (0.89 in) and 24 mm (0.94 in) NL size classes, which is the size at which transformation typically occurs. The mean length of measured specimens from the entrainment station samples was 1.7 mm (0.07 in) NL with a size range from 0.9–24.1 mm (0.04-0.95 in) NL.

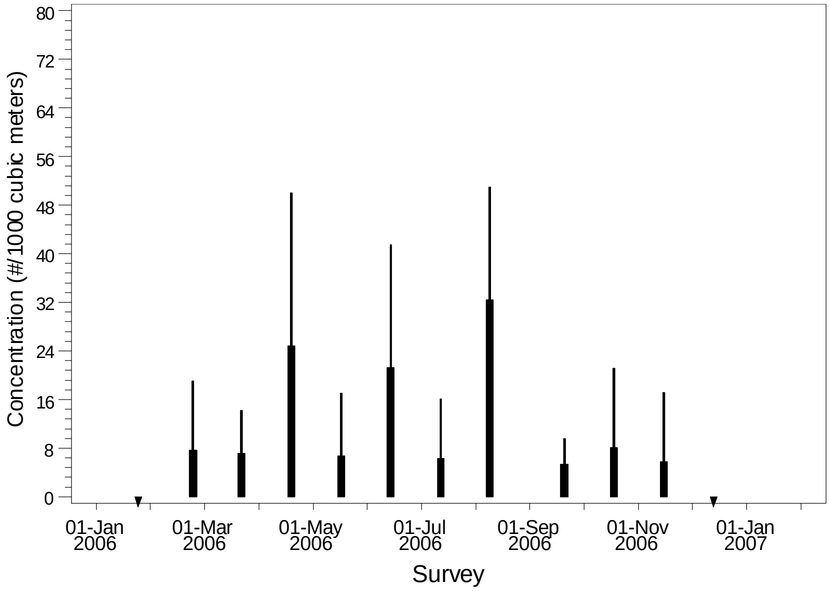


Figure 4.5-47. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of sanddab larvae collected at ESGS entrainment stations during 2006.

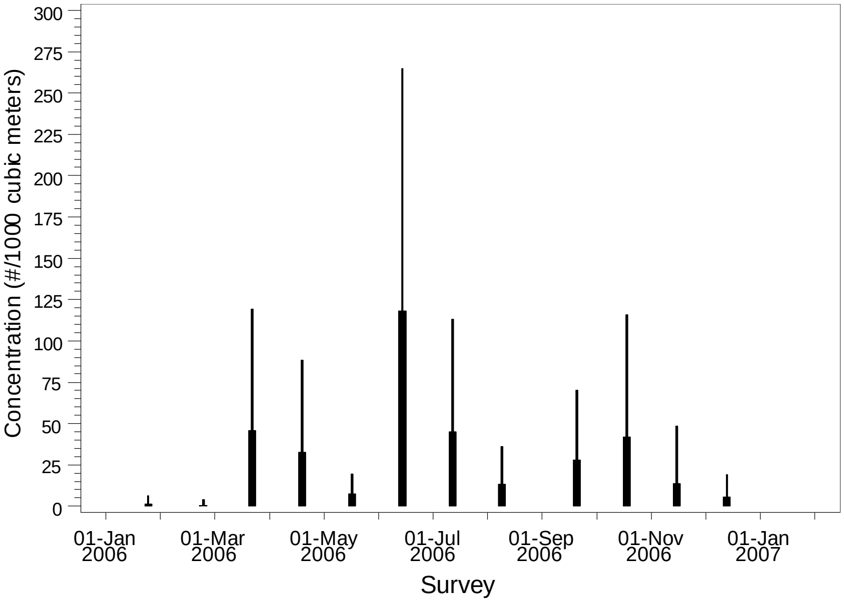


Figure 4.5-48. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of sanddab larvae collected at ESGS source water stations during 2006.

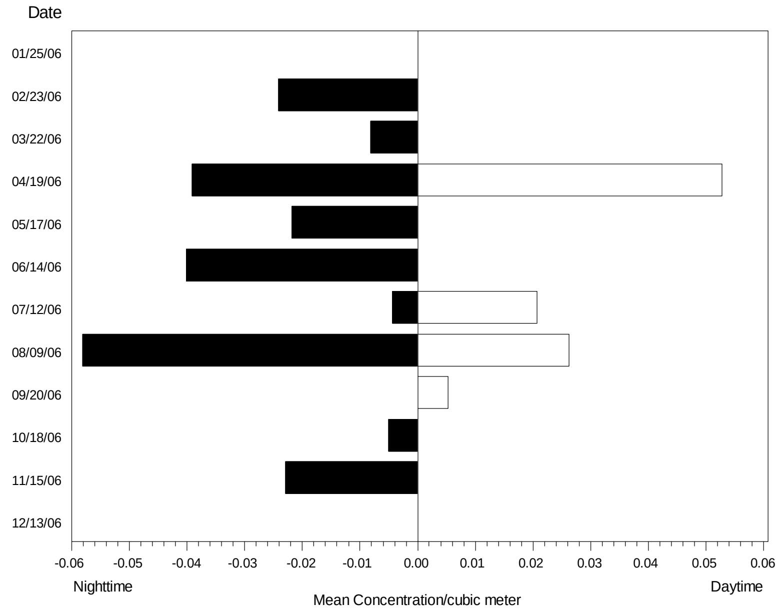


Figure 4.5-49. Mean concentration (#/1.0 m^3 [264 gal]) of sanddab larvae at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.
Note: Negative nighttime values are an artifact of the plotting routine.

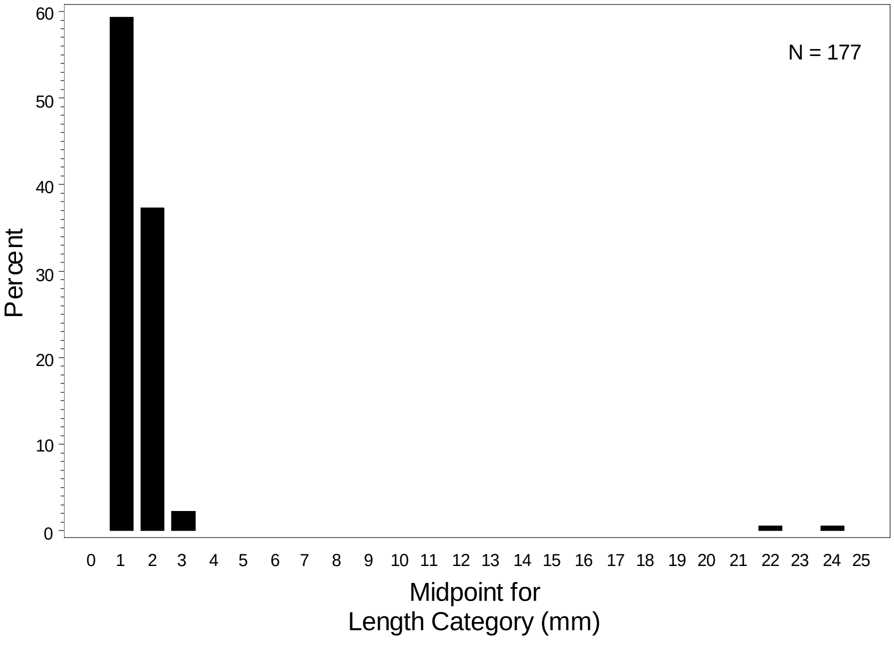


Figure 4.5-50. Length (mm) frequency distribution for larval sanddabs collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.10.4 Modeling Results

The following sections present the results for empirical transport modeling of entrainment effects on sanddabs. No age-specific estimates of survival for larval and later stages of development were available from the literature for this species, therefore no estimates of *FH* or *AEL* were calculated. Total annual entrainment of eggs and larvae at ESGS was estimated at 165,393,976 and 4,476,374 (standard errors of 4,814,971 and 166,388), respectively using actual measured cooling water flows during 2006 (Table 4.5-2). A total of 131,272,426 eggs and 3,738,404 sanddab larvae was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 264,875,098 eggs and 5,698,399 sanddab larvae. Standard errors for total annual entrainment calculations are presented in Appendix D. The total duration used in the *ETM* calculations included both the estimated egg duration from the literature and the estimated larval duration to provide an integrated estimate of entrainment effects.

Fecundity Hindcasting (FH)

The annual entrainment estimate for sanddab eggs was used to calculate the number of females at the age of first maturity that would produce in their lifetime the number of eggs entrained. There were no data on sanddab egg survival and duration so the same estimates used for California halibut were substituted for sanddab. These values were 2.27 days for the egg stage, 0.5 for survival, and an average age of 0.96 days. A total lifetime fecundity of 223,763 eggs per female was calculated based on an average number of eggs per batch of 17,550, an average number of 3 batches per year, and a average age in the population of 4.25 years (Ford 1965, Love 1996).

The estimated numbers of female sanddabs at the age of maturity whose lifetime reproductive output was entrained through the ESGS CWS for the 2006 period was calculated as 1,005 (Table 4.5-35). Using only the annual entrainment estimates from Units 3 & 4 resulted in a calculated loss of 797 adult females. Based on the design CWS flows of Units 3 & 4, the estimated number of reproductive sanddabs was 1,609 based on the egg entrainment if the pumps were run at maximum capacity. 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 4.5-35. Results of *FH* modeling for sanddab eggs based on entrainment estimates calculated using actual and design[1] CWS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate[2]	*FH* Upper Estimate	*FH* Range
Actual Flows					
Eggs (All units)					
FH Estimate	**1,005**	711	314	3,218	2,905
Total Entrainment	165,393,976	4,814,971	957	1,053	96
Eggs (Units 3 & 4)					
FH Estimate	**797**	564	249	2,555	2,306
Total Entrainment	131,272,426	4,078,409	757	838	82
Design Flows					
Eggs (Units 3 & 4)					
FH Estimate	1,609	1,139	502	5,153	4,651
Total Entrainment	264,875,098	6,919,299	1,540	1,678	138

[1] Results using the design CWS flows only calculated for Units 3 & 4.
[2] 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.

Empirical Transport Model (ETM)

No data were available on the planktonic duration of the egg stage for either species of sanddabs so the value of 2.2 days for California halibut was substituted. Growth for zero age sanddabs from Rogers (1985) was used to estimate a daily larval growth rate of 0.25 mm/day (0.01 in/day). A sample of 177 lengths from the sanddab larvae collected from the entrainment stations in Santa Monica Bay was used to calculate a difference between the estimated hatch length of 1.2 mm (0.09 in) and the 95th percentile value of the measurements (2.3 mm [0.05 in]) to estimate that the larvae were exposed to entrainment for a period of approximately 4.6 days. The 2.2 day duration of the planktonic egg stage was added to the period for the larvae to estimate a total period of exposure of 6.8 days.

The monthly estimates of proportional entrainment (*PE*) for sanddabs for 2006 ranged from 0 to 0.00693 using the actual cooling water flows during the period (Table 4.5-36). Sanddab larvae were collected during all paired entrainment/source water surveys except January and December with the largest proportion of the source population present during the June survey ($f_i = 0.327$ or 32.7%). The values in the table were used to calculate a P_M estimate of 0.0010 with a standard error of 0.0006 using the offshore extrapolation value for the estimate of the total source population. *PE* estimates ranged from 0 to 0.00591 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0008 with a standard error of 0.0006 was calculated from these values. Based on the design flows of Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.01786 and a P_M estimate of 0.0015 with a standard error of 0.0009 was calculated. The period of larval exposure to entrainment allows larvae to be transported an average distance onshore of 6.2 km (3.9 mi) and alongshore of 23.9 km (14.9 mi) indicating that larvae over almost half of the total 60 km (37 mi) coastline of Santa Monica Bay may be subject to entrainment.

Table 4.5-36. *ETM* data for sanddab larvae. P_M calculated using **offshore** extrapolation of population and P_S of 0.3816.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0.00552
23-Feb-06	0.00729	0.00795	0.00497	0.00548	0.01786	0.01928	0.00225
22-Mar-06	0.00015	0.00009	0.00012	0.00007	0.00022	0.00013	0.16150
19-Apr-06	0.00153	0.00089	0.00130	0.00077	0.00178	0.00102	0.07368
17-May-06	0.00098	0.00082	0.00082	0.00069	0.00124	0.00100	0.02839
14-Jun-06	0.00036	0.00022	0.00032	0.00019	0.00034	0.00020	0.32701
12-Jul-06	0.00026	0.00021	0.00022	0.00018	0.00024	0.00019	0.13886
9-Aug-06	0.00693	0.00263	0.00591	0.00227	0.00791	0.00292	0.02698
20-Sep-06	0.00019	0.00010	0.00015	0.00009	0.00034	0.00015	0.10323
18-Oct-06	0.00008	0.00007	0.00002	0.00002	0.00053	0.00044	0.08033
15-Nov-06	0.00034	0.00041	0.00019	0.00030	0.00113	0.00117	0.02656
13-Dec-06	0	0	0	0	0	0	0.02569
P_M	**0.0010**		**0.0008**		**0.0015**		
Std. Error	0.0006		0.0006		0.0009		

4.5.3.11 English Sole (*Parophrys vetulus*)

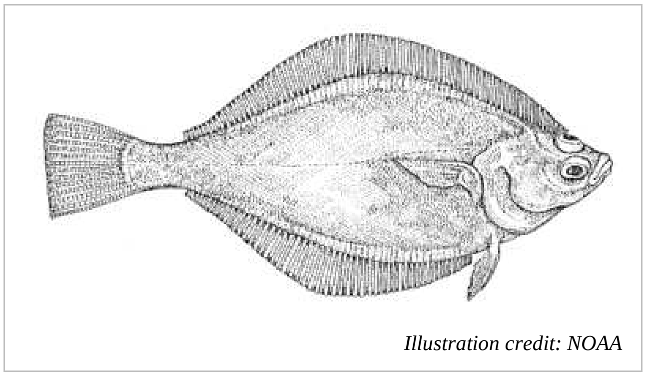


Illustration credit: NOAA

English sole (*Parophrys vetulus*) ranges from the Aleutian Islands in the Bering Sea to Bahia San Cristobal in southern Baja California (Pearson et al. 2001). They are one of 20 species of flatfish that occur off the coast of California. English sole can hybridize with starry flounder *Platichthys stellatus*, producing a hybrid sole (Love 1996).

4.5.3.11.1 Life History and Ecology

English sole occurs over soft bottom or rocky bottoms with algal cover, from the intertidal zone to depths of 550 m (1,800 ft). Juveniles primarily recruit into shallow areas of estuaries and bays and migrate to deeper water after 1–2 years (Kramer 1991b). Adults are typically found at depths of 46–274 m (150–900 ft.) over soft bottom (Pearson et al. 2001). They are reported to attain a maximum length of 57.2 cm TL (22.5 in). Females grow larger and mature later, typically maturing at 35 cm (14 in, 3–5 yrs) while males mature at 29 cm (11.5 in, 2–3 yrs).

English sole spawn year-round in California, with a peak from January through April (Pearson et al. 2001). Spawning typically occurs over sand or mud-bottoms at depths of 61–110 m (200–360 ft). Females are oviparous and may spawn more than once per season, producing from 150,000–2,100,000 eggs. Eggs are buoyant upon release, but sink to the bottom where hatching occurs after 4–12 days. Eggs are about 1.0 mm (0.04 in) in diameter. Larvae are initially ca. 2.5 mm (0.1 in) in length and begin flexion at ca. 7.6 mm (0.3 in) (Moser 1996). Larvae are found in the mid-water column and settle at the bottom in about 6-10 weeks, when they undergo transformation. Larvae are typically ca. 17 mm (0.7 in) when they begin to transform into the adult flatfish body shape.

Larval English sole feed upon copepods and other planktonic organisms (Emmett et al. 1991) and as juveniles, feed upon small invertebrates such as bivalves, polychaetes, copepods, brittlestars and amphipods (Becker 1984; Emmett et al. 1991; Houge and Carey 1982). As adults they are typically opportunistic, feeding upon worms, small crustaceans, clams, shrimp or fish. Larger fishes, such as rockfish and lingcod, prey upon juveniles. Adults are preyed upon by larger fish, sharks, marine mammals, or birds (Allen 1982; Emmett et al. 1991; Love 1996).

4.5.3.11.2 Population Trends and Fishery

The majority of English sole landed in California are taken by trawlers fishing off the Eureka and San Francisco areas, and very few are taken commercially south of Point Conception (Pearson et al. 2001). Within the southern California Bight this species made up a very small portion of the trawl fishery (0.5%) during the past 30 years. Their catch rates have not been shown to be strongly influenced by regional oceanographic factors such as PDO, water temperatures, El Nino events, or upwelling, although the relatively small numbers sampled in the fishery could mask any apparent trends (Allen et al. 2003).

Populations of juvenile English sole are more abundant in bays and estuaries, whereas adults are more evenly distributed along portions of the continental shelf. English sole are absent or occur in very low numbers in most bays and estuaries within southern California, but they are fairly common in bays in central and northern California (Moyle and Cech 2000). Most fish in southern California were collected in open coastal areas (Kramer 1991b; Allen and Herbinson 1991). NMFS trawl surveys on the continental shelf (55–183 m [180–600 ft]) off central and northern California found that English sole were particularly abundant in the region off Eureka (Wilkens 1998).

English sole have been a commercially important species since trawl nets were first introduced in 1876. Most English sole are harvested primarily through trawling, with very few taken by gill net or hook and line. The fishery peaked in 1929 in the southern portion of its range (Point Conception to Monterey) at 3,976 metric tons (mt) (8.76 million pounds) and in 1948 in the northern area (Eureka to Vancouver) at 4,008 mt (8.84 million pounds) (Stewart 2006). English sole catches have decreased since the mid 1960s and were at historical lows in the 1990s.

English sole are managed by the Pacific Fishery Management Council and assessed as a single stock from Pt. Conception to the Canadian border. The boundary at the Eureka/Monterey INPFC regions splits the stock into two areas, with most of the catch coming from the north. Recent trends in English sole landings from 2000–2004 ranged from 64 metric tons (mt) (141,000 lb) in 2003) to 199 mt (438,700 lb) in 2001 in the southern area, and ranged from 569 mt (1.25 million pounds) in 2000 to 1,067 mt (2.35 million pounds) in 2002 in the northern areas (Stewart 2006). Current assessments show that the stock is growing and that spawning biomass is increasing for English sole (Stewart 2006).

4.5.3.11.3 Sampling Results

English sole larvae was the eighteenth most abundant taxon at the entrainment station with a mean concentration of 5 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were collected in entrainment samples during only two surveys in March and April (Figure 4.5-51), and at the source water stations from February through June (Figure 4.5-52). All of the larvae counted for a comparison of day and night concentrations (Cycles 1 and 3) occurred at night (Figure 4.5-53). The length frequency plot for 97 larvae measured from all of the Santa Monica Bay entrainment samples was skewed toward the lower size classes of 2–3 mm NL, indicating that most sampled larvae were newly hatched based on the reported hatch size of 2.4 mm (Figure 4.5-54; Moser 1996). The mean length of measured specimens from the entrainment station samples was 3.1 mm NL with a size range from 1.9–13.8 mm NL.

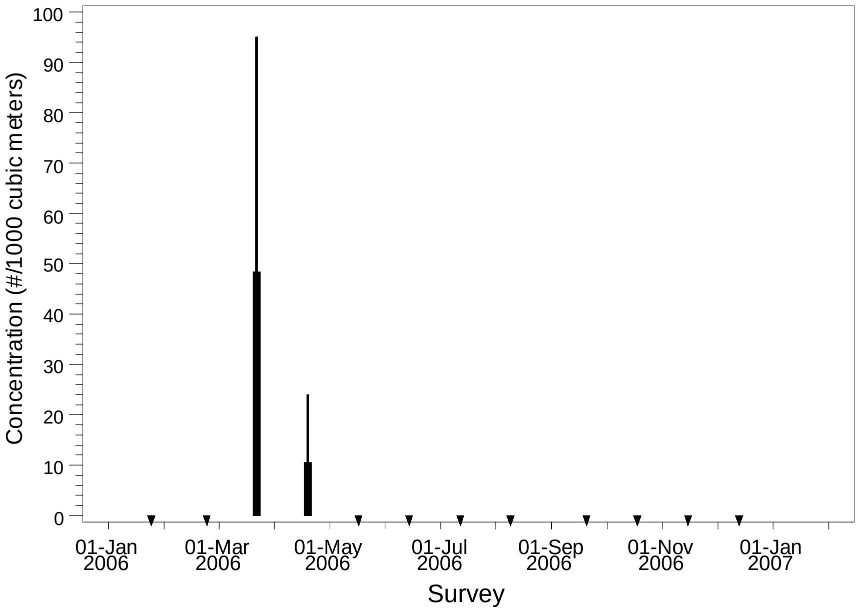


Figure 4.5-51. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of English sole larvae collected at ESGS entrainment stations during 2006.

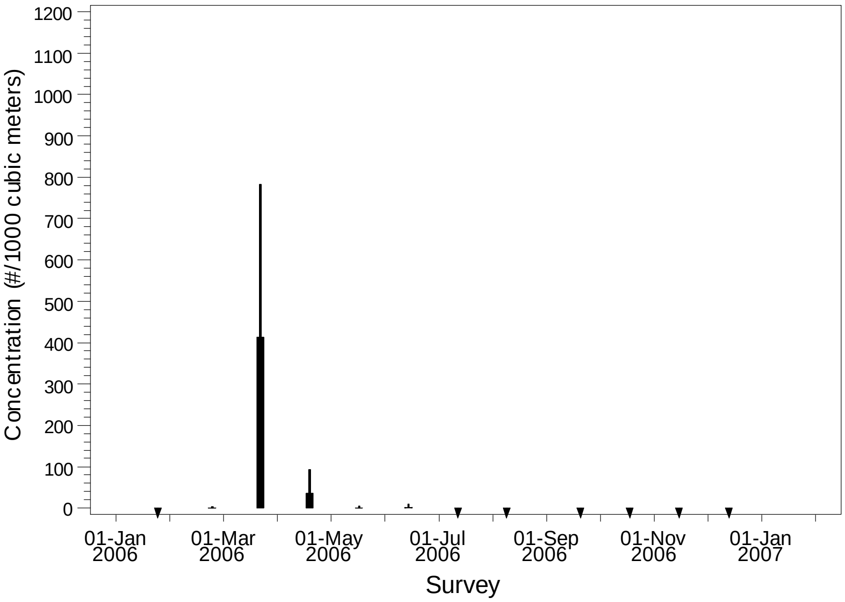


Figure 4.5-52. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of English sole larvae collected at ESGS source water stations during 2006.

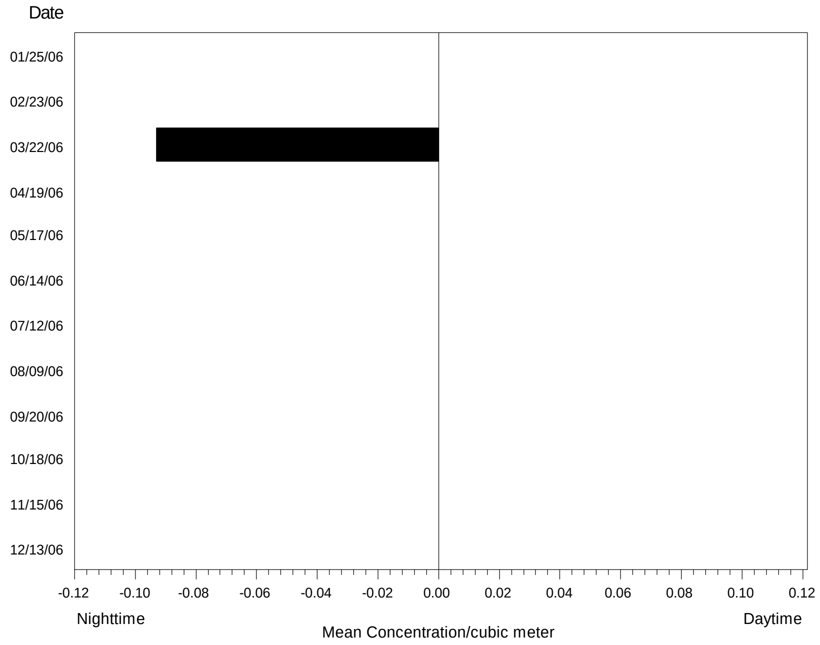


Figure 4.5-53. Mean concentration (#/1.0 m^3 [264 gal]) of larval English sole at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.

Note: Negative nighttime values are an artifact of the plotting routine.

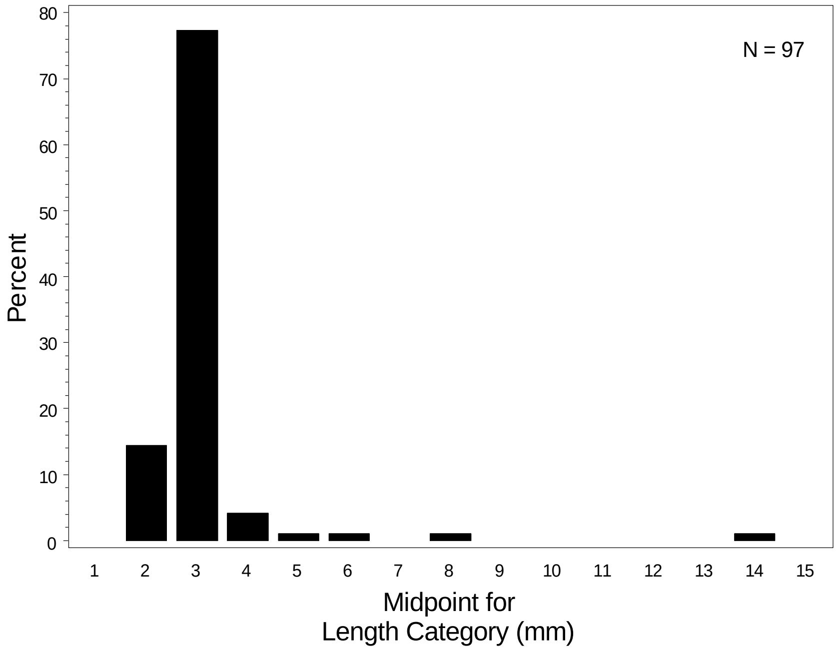


Figure 4.5-54. Length (mm) frequency distribution for larval English sole collected at entrainment stations in Santa Monica Bay during 2006.

4.5.3.11.4 Modeling Results

Total annual entrainment of English sole larvae at ESGS was estimated at 1,685,987 (standard error of 131,436) (Table 4.5-2). A total of 1,371,804 English sole larvae was entrained at Units 3 & 4 alone based on measured cooling water flows during 2006. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 2,416,978 larvae. Standard errors for total annual entrainment calculations are presented in Appendix D.

The two monthly estimates of proportional entrainment (*PE*) for English sole for 2006 were 0.0001 and 0.0004 in March and April, the only two survey months that they were present at the entrainment station (Table 4.5-37). The confidence in the accuracy of the *ETM* estimates for English sole are low because they were only collected during two entrainment surveys. They were more common in the source water samples with the largest proportion of the source population present during March (f_i = 0.9046 or 90.5%). The values in the table were used to calculate a P_M estimate of 0.0008 with a standard error of 0.0004 based on the actual cooling water flows during the period using the offshore extrapolation value for the estimate of the total source population. *PE* estimates ranged from 0 to 0.00033 using only larval entrainment from Units 3 & 4 and a P_M estimate of 0.0006 with a standard error of 0.0003 was calculated from these values. Using the flow volumes based on the design (or maximum) capacity CWS flow for Units 3 & 4 during the period, *PE* estimates ranged from 0 to 0.00059, and a P_M estimate of 0.0011 with a standard error of 0.0006 was calculated. The period of larval exposure to entrainment allows larvae to be transported an average distance onshore of 7.6 km (4.7 mi) and alongshore of 29.3 km (18.3 mi) (limited by the shoreline distance of the bay) indicating that larvae over almost half of the total 60 km (37 mi) coastline of Santa Monica Bay may be subject to entrainment. Total average displacement (not limited by the shoreline distance of the bay) was 29.8 km (18.5 mi).

Table 4.5-37. *ETM* data for English sole larvae. P_M calculated using **offshore** extrapolation of population and P_S of 0.5607.

	Total Actual Flows		**Units 3 & 4 Actual Flows**		**Units 3 & 4 Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0
23-Feb-06	0	0	0	0	0	0	0.00117
22-Mar-06	0.00012	0.00006	0.00010	0.00005	0.00019	0.00009	0.90456
19-Apr-06	0.00038	0.00026	0.00033	0.00022	0.00045	0.00029	0.08486
17-May-06	0	0	0	0	0	0	0.00244
14-Jun-06	0	0	0	0	0	0	0.00698
12-Jul-06	0	0	0	0	0	0	0
9-Aug-06	0	0	0	0	0	0	0
20-Sep-06	0	0	0	0	0	0	0
18-Oct-06	0	0	0	0	0	0	0
15-Nov-06	0	0	0	0	0	0	0
13-Dec-06	0	0	0	0	0	0	0
P_M	**0.0008**		**0.0006**		**0.0011**		
Std. Error	0.0004		0.0003		0.0006		

4.5.3.12 Rock crabs (*Cancer* spp.)

Dan Dugan

Crabs of the genus *Cancer* are widely distributed in the coastal waters of the West Coast of North America. They occur in intertidal and shallow subtidal habitats on both rock and sand substrate. Of the nine species known to occur in the northeast Pacific, four species contribute to economically significant fisheries. Dungeness crab (*Cancer magister*) has the highest economic value among these, and three species of rock crabs (i.e., yellow crab, Pacific [brown] rock crab, and red rock crab) comprise the remainder of the catches. These three species of rock crab, including hairy rock crab, the smaller slender crab (*C. gracilis*), and bigtooth rock crab (*C. amphioetus*), may all be found in the vicinity of ESGS.

4.5.3.12.1 Life History and Ecology

All species of *Cancer* crabs share certain fundamental life history traits. Eggs are extruded from the ovaries through an oviduct and are carried in a sponge-like mass beneath the abdominal flap of the adult female. After a development period of several weeks, the eggs hatch and a pre-zoea larva emerges, beginning the planktonic life history phase. As in all crustaceans, growth progresses through a series of molts. The planktonic larvae advance through six stages of successive increases in size: five zoea (not including the brief pre-zoea stage), and one megalopal. After several weeks as planktonic larvae, the crabs metamorphose into the first crab stage (first instar) and settle out to begin their benthic life history phase. Maturity is generally attained within one to two years. Mature females mate while in the soft shell molt condition and extrude fertilized eggs onto the abdominal pleopods. Females generally produce one or two batches per year, typically in winter.

The main determinant of brood size and reproductive output in brachyuran crabs is body size, and the range of egg production in *Cancer* crabs generally reflects this relationship (Hines 1991). Yellow crab produce on average 2.21 million eggs per brood. Red rock crab females produce 877,000 eggs per brood. Brown rock crab females seem to be an exception to this relationship because they are, on average, smaller than the red rock crab, yet produce an average of 1.2 million eggs per batch. Slender crab is one of the smallest of the five species living near ESGS and their average egg production per brood is 454,000. Female *Cancer* crabs typically produce a single batch per year, generally in the winter; however, due to occasional multiple spawnings, the average number of batches per year may be greater than one (Carroll 1982; Hines 1991).

Cancrid crabs function as both scavengers and predators in the marine environment. Prey varies as a function of age and size of the individual but benthic invertebrates such as clams, worms, and snails comprise the majority of prey species. Claw morphology of each species is adapted to the types of preferred prey. For example, the heavier crusher claws of the brown rock crab and yellow crab facilitate the breaking of gastropod shells whereas the tapered dactyls of the slender crab are used to probe in soft sediments for worms and other soft-bodied prey. Winn (1985) documented the occurrence of cannibalism among rock crabs, particularly adults on juveniles. However, since juveniles generally inhabited shallower areas than adults, effects on the younger cohorts were diminished.

During their planktonic existence, crab larvae can become widely distributed in nearshore waters. In a study in Monterey Bay, Graham (1989) found that slender crab stage 1 zoeae were very abundant close to shore (within 6 km or 3.7 mi) during March and August. Later stage larvae, including megalopae, were found further from shore during all times of the year. This off shore larval distribution, compared to the nearshore distribution of Pacific (brown) rock crab larvae found off Diablo Canyon Power Plant, probably reflects the fact that adult slender crabs are widely distributed in coastal shelf areas, further off shore than brown rock crabs. The megalops larvae and juvenile crabs are frequently found crawling unharmed on and under the bells, and even in the stomachs, of larger jellyfishes, especially purple-striped jelly *Chrysaora colorata* (Morris et al. 1980).

Juvenile rock crabs are an important prey item for a variety of fishes and invertebrates. In southern California, this includes barred sand bass (*Paralabrax nebulifer*), shovelnose guitarfish (*Rhinobatos productus*), and the sand star (*Astropecten verrilli*) (Roberts et al. 1984; VanBlaricom 1979).

Each species in the genus has characteristic differences in distribution, preferred habitat, growth rates, and demographic parameters. For example, brown rock crab is a relatively large species (carapace width >200 mm) that lives primarily on sand and mud substrates in estuarine and coastal shelf areas. Slender crab is a smaller species (carapace width >130 mm) associated with mixed rock-sand substrates in shallow outer coast habitats. These types of differences imply that specific information on life history parameters cannot readily be generalized among *Cancer* species. The following sections describe the life history and ecology of the three most abundant rock crabs collected in entrainment samples in 2006: yellow cancer crab, Pacific cancer crab, and slender crab.

Yellow crab

Yellow crab ranges from Humboldt Bay, California to Bahia Magdalena, Baja California. It occurs in rocky areas of bays and estuaries, the low intertidal zone, and subtidally to depths of 132 m (291 ft), but is most commonly found in depths between 18 to 55 m (59 to 180 ft) (Morris et al. 1980; Carroll and Winn 1989; Jensen 1995). Within this range their distribution is almost exclusively associated with sand substrata (Winn 1985; Carroll and Winn 1989). The species is most abundant on the expanses of open, sandy substrata that characterize much of the SCB. It is, however, also commonly encountered near the rock-sand interface of natural and artificial reefs in the region (Morris et al. 1980; Carroll and Winn 1989). In the northern parts of their range, where rocky benthic substrata predominate, their distribution appears to be confined more to bays, sloughs, and estuaries (Jensen 1995). They are the most abundant rock crab species harvested in southern California, often composing 70 to 95% of the total crab catch in the region (Carroll and Winn 1989). During diver surveys of yellow rock crab populations in Santa Monica Bay, it was noted that the species was never seen during daylight hours in the vicinity of traps, but were often abundant in the traps the next morning (R. Hardy, CDFG, pers. comm.). These observations suggest that yellow rock crab are nocturnally active in shallow water and remain buried and inactive during daylight hours.

Anderson and Ford (1976) described the growth of yellow crab under laboratory conditions. Total larval development times from hatching through the megalops stage were 33 days and 45 days at 22°C and 18°C, respectively. The total time spent in the megalops stage averaged 8 days at 22°C and 12 days at 18°C. Yellow crab can live at least 5 years and attain a carapace width of 170 mm (6.7 in) after 16 crab instars (molts).

Pacific (brown) rock crab

Pacific rock crab (or brown rock crab) ranges between Queen Charlotte Sound, British Columbia, and Isla de Todos Santos, Baja California (Jensen 1995), although the range of peak abundance extends from San Francisco Bay to coastal areas south of the U.S.-Mexico border (Carroll and Winn 1989). They occur from the lower intertidal zone to depths exceeding 100 m (328 ft), but are typically found near the rock-sand interface in depths of less than 55 m (180 ft) (Carroll and Winn 1989). Juvenile brown rock crabs inhabiting the intertidal zone survive exposure to the air during low tide by sheltering themselves under rocks and algae (Ricketts et al. 1985). This species is a scavenger and active predator.

Mating occurs after females molt and are still soft-shelled, and ovigerous females are most common from November to January, but may be found year-round (Morris et al. 1980; Carroll 1982). Adult crabs are sexually dimorphic, with males attaining a larger size and growing larger more robust chelae (claws). Male crabs grow to a size (maximum CW) of 178 mm (7 in) while females reach 148 mm (5.8 in) (Jensen 1995). The life span of brown rock crab is estimated to be five to six years (Carroll 1982). The size of a female's egg mass is variable and can contain from 410,000 to 2.79 million eggs (Carroll and Winn 1989). Development of the eggs and subsequent hatching takes seven to eight weeks at temperatures of 10° to 18° C (50° to 64° F) (Anderson and Ford 1976; Carroll 1982). Size (CW) increases in the brown rock crab range from 7 to 26% per molt, while increases in body weight of 50 to 70% have been measured (Carroll 1982). The sexes undergo a molt to maturity (50% maturity value of population using Somerton [1980] method) from between 60 mm and 80 mm CW (2.4 in and 3.1 in) (Carroll 1982). Brown rock crabs are estimated to go through 10 to 12 molts before reaching sexual maturity (Parker 2001).

Brown rock crab eggs require a development time of approximately seven to eight weeks from extrusion to hatching (Carroll 1982). Larval development in the brown rock crab was described by Roesijadi (1976). Eggs hatch into pre-zoea larvae that molt to first stage zoea in less than 1 hour. Average larval development time (from hatching through completion of the fifth stage) was 36 days at 13.8°C. Although some crabs molted to the megalops stage, none molted to the first crab instar stage, so the actual duration of the megalops stage is unknown. Based on predicted megalops duration of approximately 12 days measured for the closely related yellow crab, the estimated length of time from hatching to settling for brown rock crab is approximately 48 days. Brown rock crabs mature at an age of about 18 months post-settlement with a size of approximately 60 mm CW (2.4 in) and a weight of 73 g (0.161 lb) (Carroll 1982). Faster growth rates may occur in highly productive environments such as on the supporting members of off shore oil platforms and females may become reproductive in less than one year post-settlement (D. Dugan, pers. comm.). Brown rock crabs can probably live to a maximum age of about six years. Size at recruitment to the fishery is approximately 125 mm CW (4.9 in), at an age of four years for males and four and one-half years for females.

Graceful (slender) crab

Graceful crab (or slender crab) ranges between Prince William Sound, Alaska, and Bahia Playa Maria, Baja California. It is found in the lower intertidal zone in bays, on mud flats, in eelgrass beds, and subtidally to 174 m (571 ft). While found in bays, this species cannot tolerate brackish conditions. It feeds primarily on animal remains and barnacles. In Elkhorn Slough (Monterey County, California), mating occurs in November, with ovigerous females appearing in July and August. Males remain with the females after mating, and are thought to protect them (Morris et al. 1980).

Females produce one batch per year, although in a laboratory setting, some females produced a small second batch. The number of eggs extruded per female can range from 143,000 to one million. Females are able to spawn for at least two, and possibly three seasons, over their lifetime (Orensanz and Gallucci 1988). Their carapace width measures up to 115 mm (4.5 in) in males and up to 87 mm (3.4 in) in females (Jensen 1995). It is estimated that slender crabs mature at a size of about 60 mm CW (2.4 in) and at approximately 10 months of age (post-settlement) (Orensanz and Gallucci 1988). Slender crab molt approximately 11 to 12 times and live for about four years.

Slender crab larval development was described by Ally (1975). Eggs hatch into pre-zoea larvae, which quickly molt to first stage zoea. Average larval development time (from hatching through completion of the megalops stage) was 48.9 days at 17°C, with most zoeal stages lasting approximately one week. Ally (1975) found an average duration of the megalops stage of 14.6 days. Growth occurs through 11–12 instars, with crabs attaining an estimated maximum age of four years post-settlement.

4.5.3.12.2 Population Trends and Fishery

Rock crabs are fished along the entire California coast using traps (crab pots), although some landings are reported from set gill nets and trawls as well (CDFG 2004). Three species are harvested commercially in southern California: brown rock crab, red rock crab, and yellow crab. There is no commercial fishery for the slender crab or hairy rock crab. The rock crab fishery is most important in southern California (from Morro Bay south), which produces a majority of the landings, and of lesser importance in northern areas of California where a fishery for the more desirable Dungeness crab takes place. Most rock crabs are landed alive for retail sale by fresh fish markets. The commercial harvest has been difficult to assess on a species-by-species basis because the fishery statistics are combined into the general “rock crab” category. From 1991 through 1999, state-wide rock crab landings (including claws) averaged 544,311 kg (1.2 million lb) per year (Parker 2001).

Regulations currently specify a minimum harvest size of 4.25-in CW. A small recreational fishery for rock crabs also exists, with a 4.00-in minimum carapace width and a personal bag limit of 35 crabs per day. Crabs are collected by divers or shore pickers with hoop nets and crab traps. Los Angeles area landings based on the PacFIN database have remained steady at an annual total of about 33,000 kg (72,765 lb) and $110,000 (Table 4.5-38). Commercial landings of rock crabs in 2006 in Santa Monica Bay catch blocks totaled 21,328 kg (47,020 lb) at a value of $75,574 (CDFG 2007b). In 2005, Los Angeles area landings (between Dana Point and Santa Monica) for unspecified rock crabs totaled 45,100 kg (99,446 lb) at a value of $134,622, while landings for red rock crab totaled 325 kg (716 lb) at a value of $1,184 (CDFG 2006).

Table 4.5-38. Annual landings and revenue for red rock crab in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lb)	Revenue
2000	24,444	53,900	$79,273
2001	34,306	75,645	$115,603
2002	33,572	74,026	$113,128
2003	32,417	71,480	$109,409
2004	34,303	75,638	$109,554
2005	32,152	70,896	$105,542
2006	33,923	74,800	$112,529

4.5.3.12.3 Sampling Results

Cancer crab larvae was the third most abundant invertebrate taxon at the entrainment stations with a mean concentration of 4 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-3). They were collected in entrainment samples from March through December, with increased average abundance from May to July (Figure 4.5-55). The peak average abundance occurred in July at approximately 22 larvae per 1,000 m^3. Cancer crab larvae were collected in source water samples from March through December (Figure 4.5-56) with increased abundances from late April to July. Average concentrations peaked in July at about 125 larvae per 1,000 m^3, over 2 times greater in magnitude than average concentrations in other source water surveys. All of the larvae counted for a comparison of day and night concentrations (Cycles 1 and 3) occurred at night (Figure 4.5-57). Of the five species of *Cancer* crab larvae identified in the samples, yellow, brown, and slender crab were the most abundant (Table 4.5-39).

Table 4.5-39. Mean concentration (#/1,000 m^3 [264,172 gal]) of *Cancer* crab species in entrainment and source water samples.

Common Name	Entrainment Mean Concentration	%	Source Water Mean Concentration	%
Yellow crab megalops	2.866	78.82	1.382	68.10
Brown rock crab megalops	0.411	11.30	0.549	27.07
Slender crab megalops	0.124	3.41	0.078	3.83
Unidentified *Cancer* megalops	0.144	3.95	0.012	0.58
Red rock crab megalops	0.092	2.52	0.004	0.21
Pygmy rock crab megalops	–	–	0.004	0.23

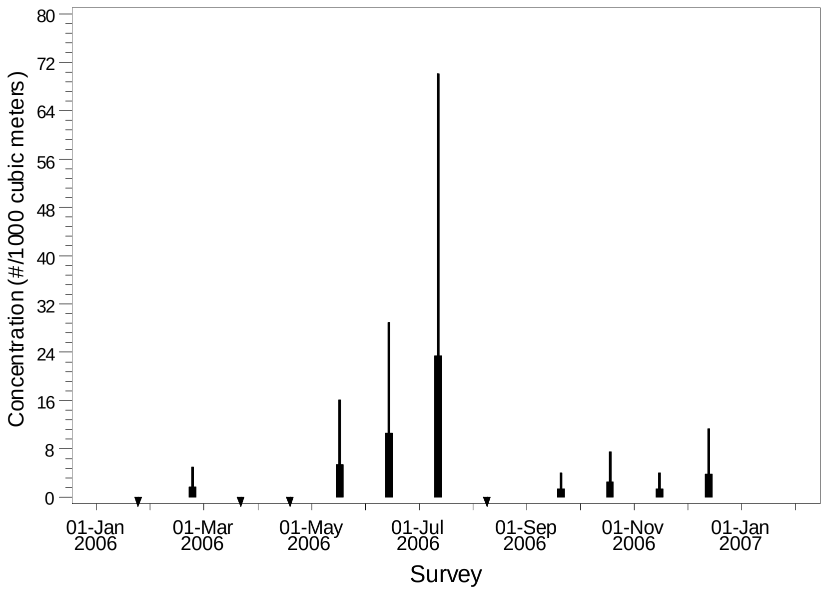


Figure 4.5-55. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of *Cancer* spp. megalops collected at ESGS entrainment stations during 2006.

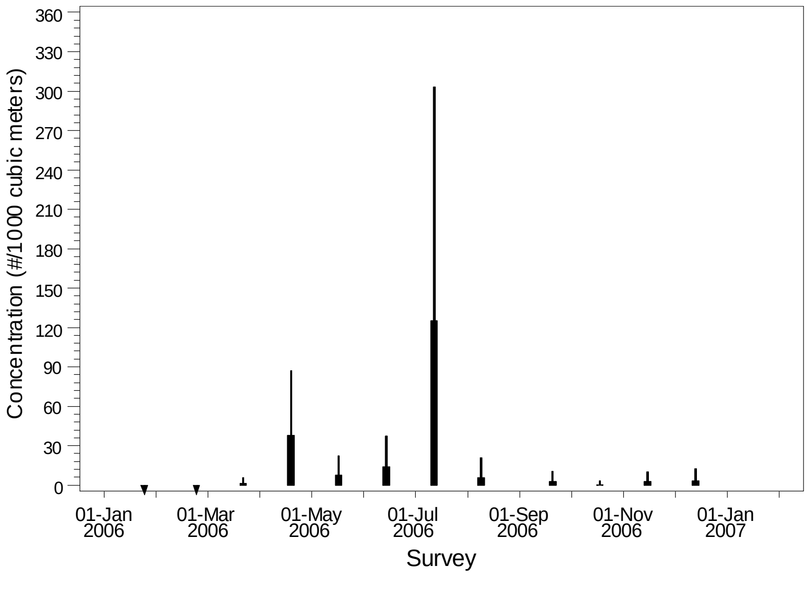


Figure 4.5-56. Mean concentration (# per 1,000 m^3 [264,000 gal]) and standard deviation of *Cancer* spp. megalops collected at ESGS source water stations during 2006.

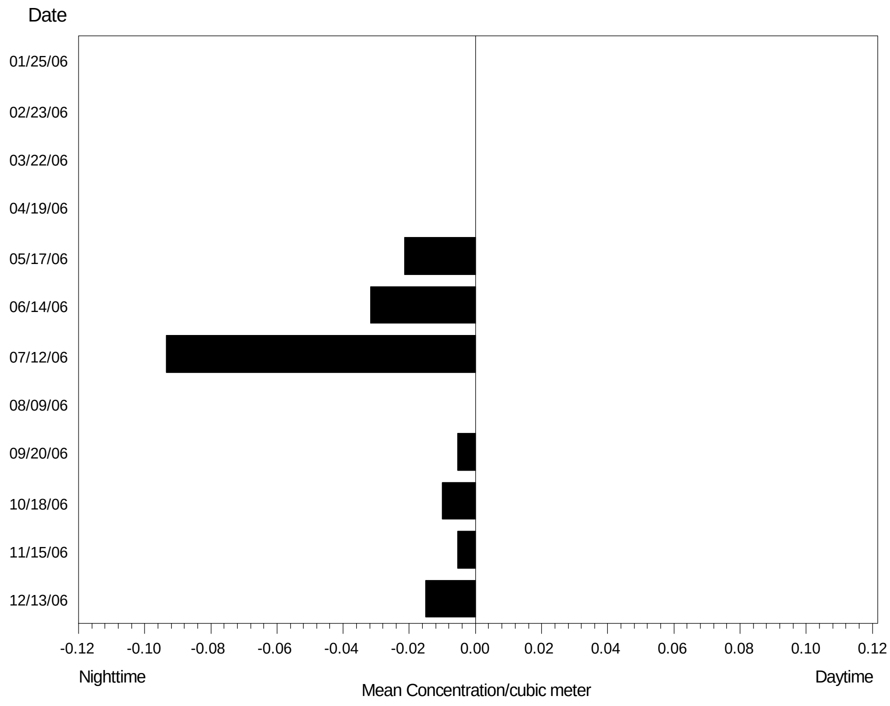


Figure 4.5-57. Mean concentration (# per 1.0 m^3 [264 gal]) of *Cancer* spp. megalops at entrainment stations during night (Cycle 3) and day (Cycle 1) sampling during 2006.
Note: Negative nighttime values are an artifact of the plotting routine.

4.5.3.12.4 Modeling Results

Modeling of entrainment effects on Cancer crab megalops was not done since the larvae were present at both the entrainment and source water stations during only one survey allowing only a single estimate of *PE* to be computed (Table 4.5-40). Therefore, no estimate of P_M was calculated. Total annual entrainment of *Cancer spp*. megalops at ESGS was estimated at 1,860,530 (standard error of 224,302) using the actual cooling water flows in 2006 (Table 4.5-4). A total of 1,577,364 Cancer crab megalops was entrained at Units 3 & 4 alone during the period. If Units 3 & 4 were run according to the design (maximum capacity) cooling water flows, estimates increased to 2,205,141 megalops. Standard errors for total annual entrainment calculations are presented in Appendix D.

Table 4.5-40. *ETM* data for *Cancer* crab megalops.

	Total Actual Flows		Units 3 & 4 Actual Flows		Units 3 & 4 Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0	0	0
23-Feb-06	0	0	0	0	0	0	0
22-Mar-06	0	0	0	0	0	0	0
19-Apr-06	0	0	0	0	0	0	0
17-May-06	0	0	0	0	0	0	0.29760
14-Jun-06	0.06805	0.08419	0.06805	0.08419	0.07377	0.09035	0.04407
12-Jul-06	0	0	0	0	0	0	0.65833
9-Aug-06	0	0	0	0	0	0	0
20-Sep-06	0	0	0	0	0	0	0
18-Oct-06	0	0	0	0	0	0	0
15-Nov-06	0	0	0	0	0	0	0
13-Dec-06	0	0	0	0	0	0	0
P_M	–		–		–		
Std. Error	–		–		–		

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 ESGS on fishes and selected invertebrates. Impingement occurs when organisms larger than the traveling screen mesh size (9.5 mm or 3/8 inch at Units 1 & 2 and 15.9 mm or 5/8 inch at Units 3 & 4) become trapped against the screens, either because they are too fatigued to swim against the intake flow at the screens or they are dead.

There are two facets to the impingement study: *normal operation* sampling and *heat treatment* sampling. Samples collected during normal operations were used to characterize fish loss from the day-to-day operation of the generating station. These samples were collected over a 24-hr period to determine the daily loss from operation of the cooling water system. Samples were also collected during heat treatments, when waters within the Units 3 & 4 CWIS were heated and fishes and invertebrates succumbed to the higher temperatures. (Heat treatments have not been performed at Units 1 & 2 since 2002). Combined, normal operation and heat treatment samples were used to estimate the annual loss of juvenile and adult fishes and shellfishes due to operation of the cooling water intake systems at the ESGS.

5.1.1 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 approximately 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 the LADWP, URS, MBC, and Tenera met with representatives from the LARWQCB, EPA Region IX, State Water Resources Control Board (SWRCB), California Department of Fish and Game (CDFG), and National Marine Fisheries Service (NMFS) to review preliminary data from the ESGS 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 ESGS (see Sections 4.0 and 5.0). This is consistent with past entrainment and impingement sampling conducted at the ESGS (SCE 1982b; 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 assessed in the ESGS 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 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 morality assessments.

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, 2006a). There are four fish and one invertebrate species covered under the Coastal Pelagics Fishery Management Plan (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 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 ESGS. 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 [264,200,793 gallons] cooling water flowing into each CWIS).

The ESGS consists of two separate screening facilities: one for Units 1 & 2 and one for Units 3 & 4. Each screening facility consists of bar racks, traveling screens, and the circulating water pumps. Seawater drawn into each ESGS unit first enters the in-plant forebay, passes through the bar racks, 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 monthly during normal operations, as well as during all scheduled heat treatments, between January 12 and December 22, 2006. Normal operation impingement sampling at the ESGS was conducted over one 24-hour period each month at each screening facility. 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, each 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. The collection baskets were fitted with plastic liners of 6.4 mm (1/4-inch) mesh.

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 inch). The following standard linear measurements were used for the animal groups indicated:
    - Fishes - Total body length (TL) for sharks and rays and standard lengths for bony fishes.
    - Crabs - Maximum carapace width (CW).
    - Shrimps & Lobsters - Carapace length, measured from the anterior margin of carapace between the eyes to the posterior margin of the carapace.
    - Octopus - Maximum “tentacle” spread, 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 presence 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 was 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 was determined and recorded.

The following specific subsampling procedures was 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 treatment procedures. 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 of 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 observer 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

A log with hourly observations of each of the circulating water pumps for the entire study period was obtained from plant operations personnel. 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 monthly and annual impingement. The days between the impingement collections were assigned to a monthly 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 monthly survey period was summed to determine the annual normal operation impingement estimates for each taxon. These were added to impingement totals from heat treatments to estimate total annual impingement.

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 approximately the top 84% 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 Essential Fish Habitat (EFH) designated under the Magnuson-Stevens Fishery Conservation and Management Act be assessed in the ESGS IM&E Characterization Study Report. This methodology was approved by the LARWQCB, CSWRCB, EPA Region IX, NMFS, and CDFG during our January 30, 2006 and May 7, 2007 meetings.

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 Santa Monica Bay area catch blocks in 2006. The seven catch blocks included in this analysis included: 680, 701, 702, 703, 720, 721, and 722. 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 ESGS impact on fish stocks impinged in the CWS, annual impingement numbers and sizes were used to estimate the number of equivalent adults lost to impingement. These individuals would have lived and been subject to mortality from sources other than impingement. The method of computing equivalent adults is similar to demographic modeling of entrainment mortality estimates. Conversion of impingement totals was limited to species with sufficient life history information. Such a conversion of numbers of juveniles and adults collected in impingement sampling to numbers of equivalent adults has not been performed in recent impingement studies in California. However, the methods described below are similar to those used by EPA in developing the Phase I and Phase II 316(b) regulations. Results and discussion of the assessments for both the impingement and entrainment are presented in Section 6.0–Impact Assessment.

Equivalent Adult Model

Ages were assigned to individual recorded lengths for impinged kelp bass, queenfish, northern anchovy, and black croaker 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:

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

The time difference between the estimated age of impingement t and the age at 50% maturity L50% was calculated as:

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

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,

$t50\%$ = age at female 50% maturity, and

t_{est} = estimated age of impinged fish.

Equivalent adults were summed across all surveys. Of the species analyzed, only kelp bass was collected during normal operation surveys at the ESGS; all others were collected solely during heat treatments. Equivalent adults of those individuals collected during normal operations were subjected to flow adjustment calculations to estimate the annual normal operation impingement.

5.3 SAMPLING SUMMARY

The following sections summarize historical and recent impingement data from the ESGS. A summary of historical impingement data is presented in Section 5.4, while data from the 2006 Impingement Mortality Study is presented in Section 5.5.

5.4 HISTORICAL DATA

Impingement sampling was conducted during the 1978–1979 316(b) demonstration (SCE 1982b) and from the 1970s through 2005 as required by the ESGS NPDES permit (MBC 2007). These data are summarized to provide information on historical impingement at the ESGS.

5.4.1 Summary of Historical Data

The most abundant species collected during the 1978–1980 316(b) demonstration impingement study were queenfish (*Seriphus politus*) and walleye surfperch (*Hyperprosopon argenteum*), which together comprised 75% of impingement abundance at Units 1–4. The next most abundant taxa were white croaker (*Genyonemus lineatus*), white seaperch (*Phanerodon furcatus*), and shiner perch (*Cymatogaster aggreagata*), which contributed an additional 20% to the impingement abundance.

At Units 1 & 2, impingement was dominated by queenfish (50%) and walleye surfperch (22%) (Table 5.4-1). Queenfish was collected throughout the two-year study period, though highest abundances were recorded in December 1979 and February 1980. Walleye surfperch were not common during the first year of the two-year study, but were taken in highest abundance in December 1979. More than 76% of the impingement abundance at Units 1 & 2 occurred during heat treatments.

Table 5.4-1. Daily average impingement estimates at the ESGS, October 1978 through September 1980.

Species	Common Name	Units 1 & 2 Normal Ops.	Units 1 & 2 Heat Treatment	Units 3 & 4 Normal Ops.	Units 3 & 4 Heat Treatment	Percent of Total
Seriphus politus	queenfish	12.70	45.51	14.07	157.30	63.9
Hyperprosopon argenteum	walleye surfperch	8.66	17.37	1.56	10.53	10.6
Genyonemus lineatus	white croaker	2.36	2.25	1.85	19.96	7.4
Phanerodon furcatus	white seaperch	0.78	11.56	4.96	8.41	7.2
Cymatogaster aggregata	shiner perch	1.02	1.82	2.02	15.65	5.7
Paralabrax clathratus	kelp bass	0.38	3.12	0.05	4.03	2.1
Engraulis mordax	northern anchovy	0.42	0.12	0.42	2.47	1.0
Paralabrax nebulifer	barred sand bass	0.07	0.81	0.07	1.02	0.5
Anisotremus davidsonii	sargo	0.02	0.57	-	1.17	0.5
Peprilus simillimus	Pacific pompano	0.37	0.42	0.21	0.44	0.4
Embiotoca jacksoni	black perch	0.10	0.93	0.11	0.42	0.4
Cheilotrema saturnum	black croaker	0.01	0.27	0.01	0.59	0.2
Roncador stearnsii	spotfin croaker	-	-	-	-	<0.1
Sebastes paucispinis	bocaccio	-	0.01	-	0.04	<0.1
Umbrina roncador	yellowfin croaker	-	-	0.01	0.02	<0.1
		26.89	**84.76**	**25.34**	**222.05**	**100.0**

At Units 3 & 4, queenfish comprised the major portion of impingement abundance during the two-year study period (Table 5.4-1). Queenfish comprised 68% of total impingement at Units 3 & 4, and was taken regularly during most months of normal operation collections. Adult queenfish were most abundant at Units 3 & 4 during December 1979 and March 1980. The same species that were common at Units 1 & 2 also occurred at Units 3 & 4, including white croaker (9%), shiner perch (7%), white seaperch (5%), walleye surfperch (5%), and kelp bass (*Paralabrax clathratus*; 2%). White croaker collected during normal operations occurred primarily in November 1978 and March 1980. Most impinged individuals of the other four most abundant species were taken during December 1979 and March 1980. Nearly 62% of the normal operation impingement total was collected during these two months. More than 89% of the impingement abundance at Units 3 & 4 occurred during heat treatments.

During the last sixteen years of normal operation and heat treatment impingement monitoring at the ESGS (1990–2005), a total of 113,574 fish was estimated to be impinged (MBC 2006). The most abundant fish species impinged were queenfish (41% of total abundance), jacksmelt (*Atherinopsis californiensis*; 11%), Pacific sardine (*Sardinops sagax*; 9%), salema (*Xenistius californiensis*; 7%), and northern anchovy (*Engraulis mordax*; 6%). Since 2002, annual impingement abundance has ranged between 1,189 individuals (2004) and 2,088 individuals (2005). In 2005, the most abundant species were queenfish (788 individuals), blacksmith (*Chromis punctipinnis*; 333 individuals), kelp bass (182 individuals), northern anchovy (113 individuals), and California scorpionfish (*Scorpaena guttata*; 98 individuals). Of the 2,088 fish estimated to be impinged, 95% were recorded at Units 3 & 4 (815 during heat treatments and 1,175 estimated during normal operations). At Units 1 & 2, the annual impingement estimate was 98 fish (all California scorpionfish). A total of 17,027 macroinvertebrates weighing 1,403.337 kg (3,094.358 lb) was also impinged in 2005. The most abundant invertebrates impinged were Pacific rock crab (*Cancer antennarius*), the nudibranch *Hermissenda crassicornis*, and red rock shrimp (*Lysmata californica*), which together comprised 86% of the abundance and 46% of the biomass. Nearly all of the Pacific rock crab and *Hermissenda* were collected during normal operations, while most of the red rock shrimp were collected during heat treatments.

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, the generating station operated more frequently and at higher capacity; therefore, impingement was noticeably higher than recent levels. Units 1 & 2 were also capable of performing heat treatments during that study, which accounted for more than 76% of impingement abundance.

5.4.3 QA/QC Procedures

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,b).

During the NPDES impingement surveys (1990–2005), 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; and
- Data were submitted annually to the LARWQCB, U.S. EPA Region IX, and the CDFG.

5.5 RESULTS

The following sections summarize results from the 2006 impingement sampling at the ESGS. 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.

5.5.1 Impingement Summary

During 2006, normal operation impingement surveys were done monthly at the ESGS between January 12 and December 22, 2006, with 12 surveys being completed at each of the two screening facilities. No heat treatments occurred at Units 1 & 2 during the study period, while four heat treatments were monitored at Units 3 & 4. Those heat treatments occurred on January 12, April 7, June 2, and July 27, 2006.

At Units 1 & 2, a total of six fish representing two species weighing 0.859 kg (1.894 lb) was collected during the twelve surveys, while at the Units 3 & 4 screenwell a total of 938 fishes representing 47 species and weighing 171.597 kg (378.371 lb) was collected over the same period (Tables 5.5-1 and 5.5-2). The estimated annual total impingement based on cooling water flow volumes for Units 1 & 2 was 186 individuals weighing 28.733 kg (63.356 lb), while an estimated 1,527 individuals weighing 214.634 kg (473.268 lb) was impinged at Units 3 & 4. A total of 22 individuals from 9 species weighing 1.391 kg (3.067 lb) was recorded during normal operation surveys at Units 3 & 4, which, based on cooling water flows, extrapolated to 611 individuals weighing 43.037 kg (94.897 lb) for the year. Four heat treatments at Units 3 & 4 contributed an additional 916 individuals from 45 species weighing 171.597 kg (378.371 lb).

Table 5.5-1. Summary of ESGS Units 1 & 2 fish impingement from January through December 2006.

		Recorded in Normal Op. Samples		Estimated Annual Impingement		Percent of Total	
Species	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Scorpaena guttata	California scorpionfish	5	0.792	152	26.481	81.7	92.2
Chromis punctipinnis	blacksmith	1	0.067	34	2.252	18.3	7.8
		6	**0.859**	**186**	**28.733**	**100.0**	**100.0**

California scorpionfish was the most abundant fish species impinged at Units 1 & 2 with an estimated 152 individuals (81.7% of the total) weighing 26.481 kg (58.391 lb) (92.2% of the total), followed by 34 blacksmith weighing 2.252 kg (4.966 lb) (Table 5.5-1). Based on actual flows for 2006 at Units 3 & 4, blacksmith was the most abundant species impinged with an estimated 189 individuals (12.4%) weighing 5.229 kg (11.530 lb) (2.4%) followed by 171 kelp bass weighing 37.143 kg (81.900 lb), 142 black perch weighing 43.825 kg (96.634 lb), 130 rubberlip seaperch (*Rhacochilus toxotes*) weighing 8.238 kg (18.165 lb), and 103 queenfish weighing 2.198 kg (4.847 lb) (Table 5.5-2). The remaining 42 species were each represented by less than 100 individuals, with seven species represented by a single individual impinged during one of the heat treatments. Bat ray (*Myliobatis californica*) contributed the most to annual biomass with 47.260 kg (104.208 lb) for 96 individuals. Total numbers and biomass at Units 3 & 4 were 1,527 individuals weighing 214.634 kg, respectively. When the estimates were calculated using the design (maximum) flows for Units 3 & 4, total projected numbers increased to 2,521 individuals with a weight of 245.739 kg (Table 5.5-3).

Eighty-eight shellfish representing 12 species weighing 17.004 kg (37.494 lb) were collected during normal operation surveys at Units 1 & 2 (Table 5.5-4). Based on cooling water flows these observations extrapolated to an estimated 2,562 shellfish weighing 525.129 kg (1,157.909 lb) impinged. Pacific rock crab (*Cancer antennarius*) was the most abundant shellfish impinged at Units 1 & 2 (and contributed most to biomass) with an estimated 1,041 individuals weighing 250.582 kg (552.533 lb) (Table 5.5-4). Of the 11 remaining species, only intertidal coastal shrimp (*Heptacarpus palpator*) contributed greater than 10% of the overall abundance with an estimated 605 individuals (23.6%), but only 0.1% of the total biomass with 0.501 kg (1.105 lb). Three additional shellfish species contributed greater than 10% of the total biomass, or 52 kg (115 lb). These included California spiny lobster (*Panulirus interruptus*) with 207 individuals at 125.856 kg (277.512 lb), yellow crab (*Cancer anthonyi*) with 246 individuals at 65.524 kg (144.480 lb), and sheep crab (*Loxorhynchus grandis*) with 68 individuals at 64.413 kg (142.031 lb). The remaining eight shellfish taxa contributed less than 11 kg (24.255 lb) to total biomass.

At Units 3 & 4, 762 individuals representing 21 shellfish species weighing 21.602 kg (47.632 lb) were recorded during normal operation surveys, which equates to an annual estimate of 14,534 individuals weighing 409.836 kg (903.688 lb) impinged during normal operations (Table 5.5-5). An additional 960 shellfish from 17 species weighing 41.584 kg (91.693 lb) were observed during the four heat treatments. In total, an estimated 15,494 shellfish weighing 451.420 kg (995.381 lb) were impinged during the year at Units 3 & 4 based on actual cooling water flows. When the estimates were calculated using the design (maximum) flows for Units 3 & 4, total projected numbers increased to 102,113 individuals with a weight of 2,969.141 kg (6,545.835 lb) (Table 5.5-6).

At Units 3 & 4, two *Cancer* species cumulatively contributed 72.9% of the abundance and 89.1% of the biomass (Table 5.5-5). Pacific rock crab contributed the greatest abundance and biomass of all shellfish with an estimated 7,839 individuals weighing 273.449 kg (602.955 lb). Almost all of the individuals were recorded during normal operations. Yellow crab accounted for the second highest value in both categories with 3,458 individuals weighing 128.451 kg (283.234 lb). The remaining 23 shellfish taxa each represented less than 7% of the total abundance.

Table 5.5-2. Summary of ESGS Units 3 & 4 fish impingement from January through December 2006 based on **actual** cooling water flow volumes.

		Recorded in Normal Op. Samples		**Estimated Normal Op. Impingement**		**Recorded in Heat Treatments**		**Estimated Annual Impingement**	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Chromis punctipinnis	blacksmith	3	0.010	126	0.419	63	4.810	189	5.229
Paralabrax clathratus	kelp bass	3	0.023	95	0.323	76	36.820	171	37.143
Embiotoca jacksoni	black perch	-	-	-	-	142	43.825	142	43.825
Rhacochilus toxotes	rubberlip seaperch	4	0.048	107	1.284	23	6.954	130	8.238
Seriphus politus	queenfish	-	-	-	-	103	2.198	103	2.198
Cymatogaster aggregata	shiner perch	-	-	-	-	98	0.404	98	0.404
Myliobatis californica	bat ray	2	0.736	61	22.985	35	24.275	96	47.260
Engraulis mordax	northern anchovy	-	-	-	-	78	1.137	78	1.137
Hypsoblennius gilberti	rockpool blenny	4	0.051	63	0.898	7	0.053	70	0.951
Phanerodon furcatus	white seaperch	1	0.008	28	0.227	37	3.840	65	4.067
Pleuronichthys verticalis	hornyhead turbot	2	0.507	61	16.721	2	0.194	63	16.915
Syngnathus sp.	pipefish, unid.	2	0.005	59	0.146	-	-	59	0.146
Hyperprosopon argenteum	walleye surfperch	-	-	-	-	34	2.043	34	2.043
Rhacochilus vacca	pile perch	-	-	-	-	30	4.976	30	4.976
Cheilotrema saturnum	black croaker	-	-	-	-	20	5.200	20	5.200
Atherinopsis calif.	jacksmelt	-	-	-	-	19	3.056	19	3.056
Scorpaena guttata	Calif. scorpionfish	-	-	-	-	18	4.339	18	4.339
Peprilus simillimus	Pacific pompano	-	-	-	-	15	0.501	15	0.501
Citharichthys stigmaeus	speckled sanddab	-	-	-	-	15	0.039	15	0.039
Trachurus symmetricus	jack mackerel	-	-	-	-	11	1.395	11	1.395
Hypsoblennius gentilis	bay blenny	1	0.003	11	0.034	-	-	11	0.034
Sardinops sagax	Pacific sardine	-	-	-	-	10	0.144	10	0.144
Girella nigricans	opaleye	-	-	-	-	7	7.337	7	7.337
Sebastes auriculatus	brown rockfish	-	-	-	-	7	2.396	7	2.396
Oxyjulis californica	senorita	-	-	-	-	6	0.271	6	0.271
Paralabrax nebulifer	barred sand bass	-	-	-	-	5	2.578	5	2.578
Medialuna californiensis	halfmoon	-	-	-	-	5	1.583	5	1.583
Scomber japonicus	Pacific chub mackerel	-	-	-	-	5	1.044	5	1.044
Atherinops affinis	topsmelt	-	-	-	-	5	0.174	5	0.174
Urobatis halleri	round stingray	-	-	-	-	4	2.636	4	2.636
Menticirrhus undulatus	California corbina	-	-	-	-	4	1.507	4	1.507
Synodus lucioceps	California lizardfish	-	-	-	-	4	0.039	4	0.039
Platyrhinoidis triseriata	thornback	-	-	-	-	3	1.183	3	1.183
Xenistius californiensis	salema	-	-	-	-	3	0.179	3	0.179
Brachyistius frenatus	kelp perch	-	-	-	-	3	0.056	3	0.056
Sebastes miniatus	vermilion rockfish	-	-	-	-	3	0.022	3	0.022
Parophrys vetulus	English sole	-	-	-	-	3	0.013	3	0.013
Semicossyphus pulcher	California sheephead	-	-	-	-	2	1.332	2	1.332
Anisotremus davidsonii	sargo	-	-	-	-	2	0.591	2	0.591
Roncador stearnsii	spotfin croaker	-	-	-	-	2	0.288	2	0.288
Balistes polylepis	finescale triggerfish	-	-	-	-	1	1.626	1	1.626
Umbrina roncador	yellowfin croaker	-	-	-	-	1	0.400	1	0.400
Amphistichus argenteus	barred surfperch	-	-	-	-	1	0.065	1	0.065
Paralichthys californicus	California halibut	-	-	-	-	1	0.042	1	0.042
Leuresthes tenuis	California grunion	-	-	-	-	1	0.017	1	0.017
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	1	0.014	1	0.014
Clinocottus analis	woolly sculpin	-	-	-	-	1	0.001	1	0.001
		22	**1.391**	**611**	**43.037**	**916**	**171.597**	**1,527**	**214.634**

Table 5.5-3. Summary of ESGS Units 3 & 4 fish impingement from January through December 2006 based on **design** (maximum) cooling water flow volumes.

		Recorded in Normal Op. Samples		**Estimated Normal Op. Impingement**		**Recorded in Heat Treatments**		**Estimated Annual Impingement**	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Hypsoblennius gilberti	rockpool blenny	4	0.051	533	6.962	7	0.053	540	7.015
Paralabrax clathratus	kelp bass	3	0.023	272	2.796	76	36.820	348	39.616
Chromis punctipinnis	blacksmith	3	0.010	219	0.730	63	4.810	282	5.540
Embiotoca jacksoni	black perch	-	-	-	-	142	43.825	142	43.825
Syngnathus sp	pipefish, unid.	2	0.005	136	0.340	-	-	136	0.340
Rhacochilus toxotes	rubberlip seaperch	4	0.048	111	1.328	23	6.954	134	8.282
Hypsoblennius gentilis	bay blenny	1	0.003	126	0.379	-	-	126	0.379
Myliobatis californica	bat ray	2	0.736	88	33.742	35	24.275	123	58.017
Seriphus politus	queenfish	-	-	-	-	103	2.198	103	2.198
Cymatogaster aggregata	shiner perch	-	-	-	-	98	0.404	98	0.404
Pleuronichthys verticalis	hornyhead turbot	2	0.507	88	27.613	2	0.194	90	27.807
Engraulis mordax	northern anchovy	-	-	-	-	78	1.137	78	1.137
Phanerodon furcatus	white seaperch	1	0.008	32	0.252	37	3.840	69	4.092
Hyperprosopon argenteum	walleye surfperch	-	-	-	-	34	2.043	34	2.043
Rhacochilus vacca	pile perch	-	-	-	-	30	4.976	30	4.976
Cheilotrema saturnum	black croaker	-	-	-	-	20	5.200	20	5.200
Atherinopsis californiensis	jacksmelt	-	-	-	-	19	3.056	19	3.056
Scorpaena guttata	California scorpionfish	-	-	-	-	18	4.339	18	4.339
Peprilus simillimus	Pacific pompano	-	-	-	-	15	0.501	15	0.501
Citharichthys stigmaeus	speckled sanddab	-	-	-	-	15	0.039	15	0.039
Trachurus symmetricus	jack mackerel	-	-	-	-	11	1.395	11	1.395
Sardinops sagax	Pacific sardine	-	-	-	-	10	0.144	10	0.144
Girella nigricans	opaleye	-	-	-	-	7	7.337	7	7.337
Sebastes auriculatus	brown rockfish	-	-	-	-	7	2.396	7	2.396
Oxyjulis californica	senorita	-	-	-	-	6	0.271	6	0.271
Paralabrax nebulifer	barred sand bass	-	-	-	-	5	2.578	5	2.578
Medialuna californiensis	halfmoon	-	-	-	-	5	1.583	5	1.583
Scomber japonicus	Pacific chub mackerel	-	-	-	-	5	1.044	5	1.044
Atherinops affinis	topsmelt	-	-	-	-	5	0.174	5	0.174
Urobatis halleri	round stingray	-	-	-	-	4	2.636	4	2.636
Menticirrhus undulatus	California corbina	-	-	-	-	4	1.507	4	1.507
Synodus lucioceps	California lizardfish	-	-	-	-	4	0.039	4	0.039
Platyrhinoidis triseriata	thornback	-	-	-	-	3	1.183	3	1.183
Xenistius californiensis	salema	-	-	-	-	3	0.179	3	0.179
Brachyistius frenatus	kelp perch	-	-	-	-	3	0.056	3	0.056
Sebastes miniatus	vermilion rockfish	-	-	-	-	3	0.022	3	0.022
Parophrys vetulus	English sole	-	-	-	-	3	0.013	3	0.013
Semicossyphus pulcher	California sheephead	-	-	-	-	2	1.332	2	1.332
Anisotremus davidsonii	sargo	-	-	-	-	2	0.591	2	0.591
Roncador stearnsii	spotfin croaker	-	-	-	-	2	0.288	2	0.288
Balistes polylepis	finescale triggerfish	-	-	-	-	1	1.626	1	1.626
Umbrina roncador	yellowfin croaker	-	-	-	-	1	0.400	1	0.400
Amphistichus argenteus	barred surfperch	-	-	-	-	1	0.065	1	0.065
Paralichthys californicus	California halibut	-	-	-	-	1	0.042	1	0.042
Leuresthes tenuis	California grunion	-	-	-	-	1	0.017	1	0.017
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	1	0.014	1	0.014
Clinocottus analis	woolly sculpin	-	-	-	-	1	0.001	1	0.001
		22	**1.391**	**1,605**	**74.142**	**916**	**171.597**	**2,521**	**245.739**

Table 5.5-4. Summary of ESGS Units 1 & 2 shellfish impingement from January through December 2006.

		Recorded in Normal Op. Samples		Estimated Annual Impingement		Percent of Total	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Cancer antennarius	Pacific rock crab	34	8.194	1,041	250.582	40.6	48.6
Heptacarpus palpator	intertidal coastal shrimp	24	0.020	605	0.501	23.6	0.1
Cancer anthonyi	yellow crab	8	2.163	246	65.524	9.6	12.3
Panulirus interruptus	California spiny lobster	7	4.139	207	125.856	8.1	23.5
Lysmata californica	red rock shrimp	4	0.006	124	0.181	4.8	<0.1
Cancer gracilis	graceful crab	3	0.233	83	6.461	3.2	1.2
Loxorhynchus grandis	sheep crab	2	1.910	68	64.413	2.7	12.0
O .bimaculatus/bimaculoides	California two-spot octopus	2	0.304	64	10.555	2.5	2.0
Loligo opalescens	California market squid	1	0.013	34	0.437	1.3	0.1
Crangon nigromaculata	blackspotted bay shrimp	1	0.001	34	0.034	1.3	<0.1
Pachygrapsus crassipes	striped shore crab	1	0.020	28	0.557	1.1	0.1
Pagurus sp.	hermit crab, unid.	1	0.001	28	0.028	1.1	<0.1
		88	**17.004**	**2,562**	**525.129**	**100.0**	**100.0**

Table 5.5-5. Summary of ESGS Units 3 & 4 shellfish impingement from January through December 2006 based on **actual** cooling water flow volumes.

		Recorded in Normal Op. Samples		**Estimated Normal Op. Impingement**		**Recorded in Heat Treatments**		**Estimated Annual Impingement**	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Cancer antennarius	Pacific rock crab	395	13.778	7,832	273.372	7	0.077	7,839	273.449
Cancer anthonyi	yellow crab	187	6.701	3,083	110.419	375	18.032	3,458	128.451
Lysmata californica	red rock shrimp	53	0.090	854	1.260	153	0.165	1,007	1.425
Pyromaia tuberculata	tuberculate pear crab	22	0.014	571	0.258	122	0.231	693	0.489
Podochela hemphilli	Hemphill kelp crab	13	0.009	545	0.377	-	-	545	0.377
Heptacarpus palpator	intertidal coastal shrimp	6	0.003	199	0.073	145	0.088	344	0.161
Portunus xantusii	Xantus swimming crab	11	0.124	267	2.209	4	0.063	271	2.272
Pachygrapsus crassipes	striped shore crab	15	0.098	251	1.969	17	0.203	268	2.172
Betaeus longidactylus	visored shrimp	18	0.010	223	0.160	-	-	223	0.160
Crangon nigromaculata	blackspotted bay shrimp	6	0.014	176	0.410	7	0.022	183	0.432
Lophopanopeus bellus	blackclaw crestleg crab	18	0.010	139	0.077	-	-	139	0.077
Panulirus interruptus	California spiny lobster	3	0.576	87	16.628	38	22.371	125	38.999
Cancer jordani	hairy rock crab	3	0.014	88	0.284	1	0.002	89	0.286
Cancer gracilis	graceful crab	-	-	-	-	75	0.163	75	0.163
Cancer amphioetus	bigtooth rock crab	4	0.118	46	1.343	1	0.002	47	1.345
Pugettia producta	northern kelp crab	1	0.001	42	0.042	1	0.077	43	0.119
Heterocrypta occidentalis	sandflat elbow crab	1	0.001	42	0.042	-	-	42	0.042
Loligo opalescens	California market squid	1	0.025	29	0.732	-	-	29	0.732
Blepharipoda occidentalis	spiny mole crab	1	0.004	29	0.117	-	-	29	0.117
Lophop. leucomanus	knobkneed crestleg crab	2	0.002	23	0.023	-	-	23	0.023
O. bimac./bimaculoides	Calif. two-spot octopus	-	-	-	-	6	0.078	6	0.078
Cancer productus	red rock crab	-	-	-	-	6	0.008	6	0.008
Hemigrapsus oregonensis	yellow shore crab	1	0.009	4	0.037	1	0.001	5	0.038
Alpheus californiensis	mudflat snapping shrimp	1	0.001	4	0.004	-	-	4	0.004
Heptacarpus sp	coastal shrimp, unid.	-	-	-	-	1	0.001	1	0.001
		762	**21.602**	**14,534**	**409.836**	**960**	**41.584**	**15,494**	**451.420**

Table 5.5-6. Summary of ESGS Units 3 & 4 shellfish impingement from January through December 2006 based on **design** (maximum) cooling water flow volumes.

		Recorded in Normal Op. Samples		Estimated Normal Op. Impingement		Recorded in Heat Treatments		Estimated Annual Impingement	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Cancer antennarius	Pacific rock crab	395	13.778	55,225	1,930.910	7	0.077	55,232	1,930.987
Cancer anthonyi	yellow crab	187	6.701	25,987	918.501	375	18.032	26,362	936.533
Lysmata californica	red rock shrimp	53	0.090	6,628	11.485	153	0.165	6,781	11.650
Lophopanopeus bellus	blackclaw crestleg crab	18	0.010	2,512	1.395	-	-	2,512	1.395
Betaeus longidactylus	visored shrimp	18	0.010	2,325	1.209	-	-	2,325	1.209
Pyromaia tuberculata	tuberculate pear crab	22	0.014	2,090	1.391	122	0.231	2,212	1.622
Pachygrapsus crassipes	striped shore crab	15	0.098	1,854	10.462	17	0.203	1,871	10.665
Portunus xantusii	Xantus swimming crab	11	0.124	946	8.689	4	0.063	950	8.752
Podochela hemphilli	hemphill kelp crab	13	0.009	950	0.657	-	-	950	0.657
Heptacarpus palpator	intertidal coastal shrimp	6	0.003	473	0.254	145	0.088	618	0.342
Cancer amphioetus	bigtooth rock crab	4	0.118	505	14.891	1	0.002	506	14.893
Crangon nigromaculata	blackspotted bay shrimp	6	0.014	408	0.952	7	0.022	415	0.974
Cancer jordani	hairy rock crab	3	0.014	299	1.661	1	0.002	300	1.663
Lophopanopeus leucomanus	knobkneed crestleg crab	2	0.002	252	0.252	-	-	252	0.252
Hemigrapsus oregonensis	yellow shore crab	1	0.009	153	1.376	1	0.001	154	1.377
Alpheus californiensis	mudflat snapping shrimp	1	0.001	153	0.153	-	-	153	0.153
Panulirus interruptus	California spiny lobster	3	0.576	111	21.200	38	22.371	149	43.571
Cancer gracilis	graceful crab	-	-	-	-	75	0.163	75	0.163
Pugettia producta	northern kelp crab	1	0.001	73	0.073	1	0.077	74	0.150
Heterocrypta occidentalis	sandflat elbow crab	1	0.001	73	0.073	-	-	73	0.073
Loligo opalescens	California market squid	1	0.025	68	1.701	-	-	68	1.701
Blepharipoda occidentalis	spiny mole crab	1	0.004	68	0.272	-	-	68	0.272
O.bimaculatus/bimaculoides	Calif. two-spot octopus	-	-	-	-	6	0.078	6	0.078
Cancer productus	red rock crab	-	-	-	-	6	0.008	6	0.008
Heptacarpus sp	coastal shrimp unid	-	-	-	-	1	0.001	1	0.001
		22	**1.391**	**101,153**	**2,927.557**	**916**	**171.597**	**102,113**	**2,969.141**

5.5.1.1 Seasonal Variation

Figures 5.5-1 through 5.5-8 present the impingement rates (based on abundance and biomass) for fish and shellfish impinged during the twelve monthly samples taken at each screenwell during 2006. At Units 1 & 2, fish were only impinged in January, March, April, and September 2006, with the peak abundance in March (Figure 5.5-1). Impingement rates based on biomass were similarly high in March and September, while biomass in January and April was comparatively depressed (Figure 5.5-2). Fish abundance rates at Units 3 & 4 were variable, but peaked from September to December (Figure 5.5-3). Fish biomass at Units 3 & 4 peaked in April with the impingement of two relatively larger fish: bat ray (*Myliobatis californica*) and hornyhead turbot (*Pleuronichthys verticalis*) (Figure 5.5-4). Abundance of shellfish at Units 1 & 2 was seasonally higher from late spring to mid-summer, but the highest impingement rate was recorded in January 2006 (Figures 5.5-5). Shellfish biomass at Units 1 & 2 was highest from June through August (Figure 5.5-6). At Units 3 & 4, shellfish abundance and biomass were substantially higher from September through December, with peak rates recorded in November (Figures 5.5-7 and 5.5-8).

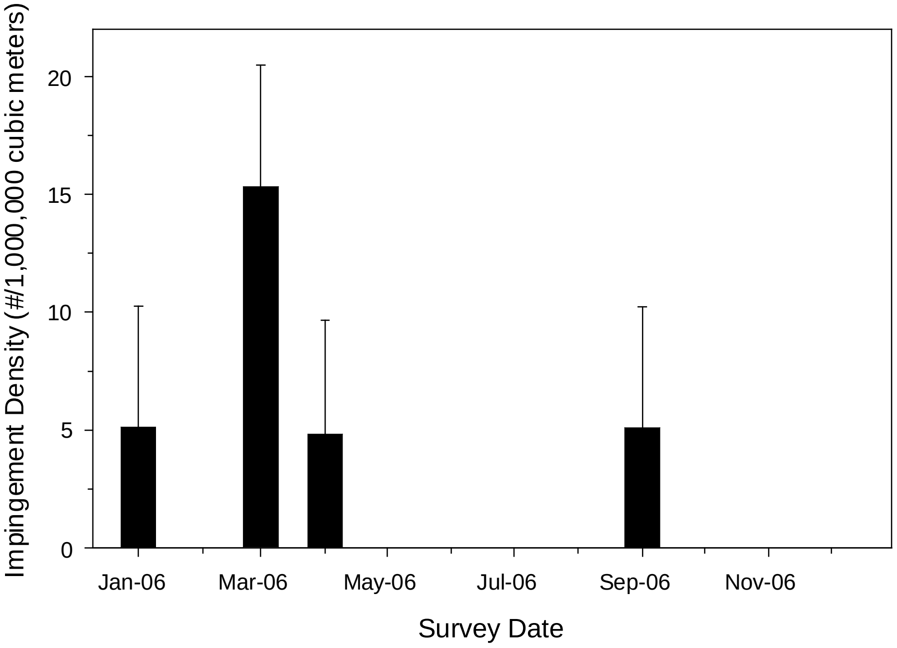


Figure 5.5-1. Mean concentration (# per 1,000,000 m^3 [264 million gal]) and standard error of fishes collected in ESGS Units 1 & 2 impingement samples during 2006.

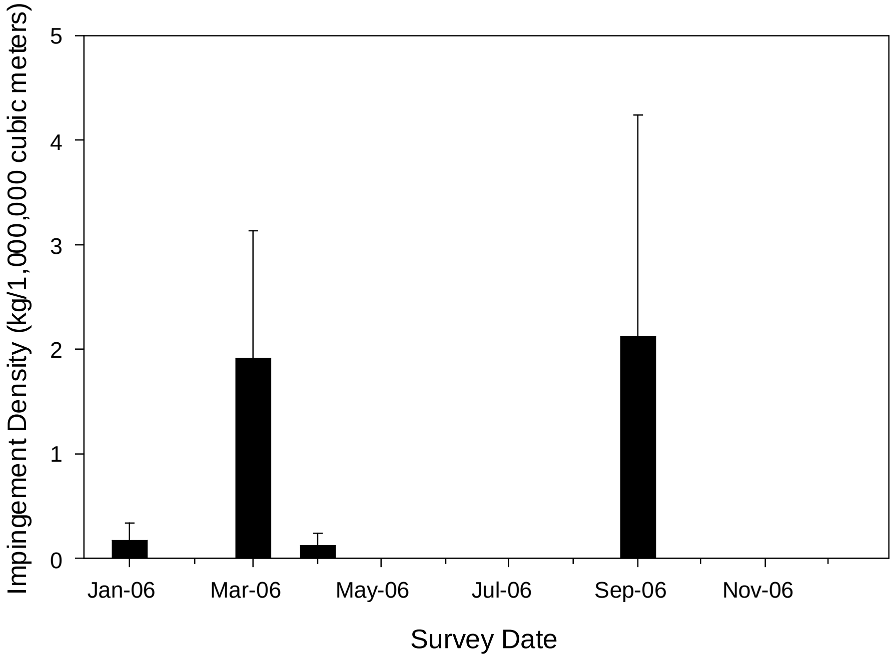


Figure 5.5-2. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) and standard error of fishes collected in ESGS Units 1 & 2 impingement samples during 2006.

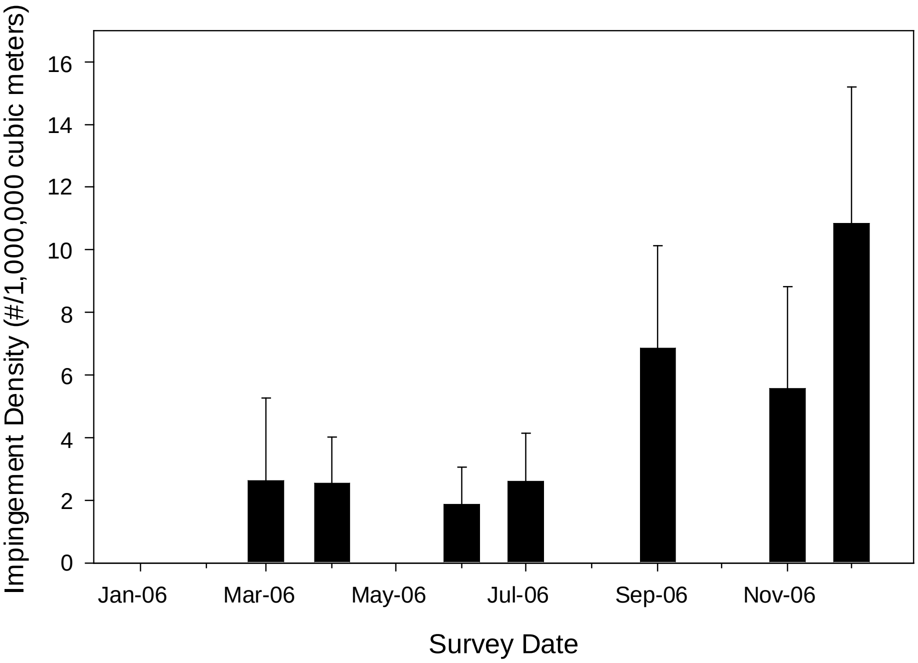


Figure 5.5-3. Mean concentration (# per 1,000,000 m^3 [264 million gal]) and standard error of fishes collected in ESGS Units 3 & 4 impingement samples during 2006.

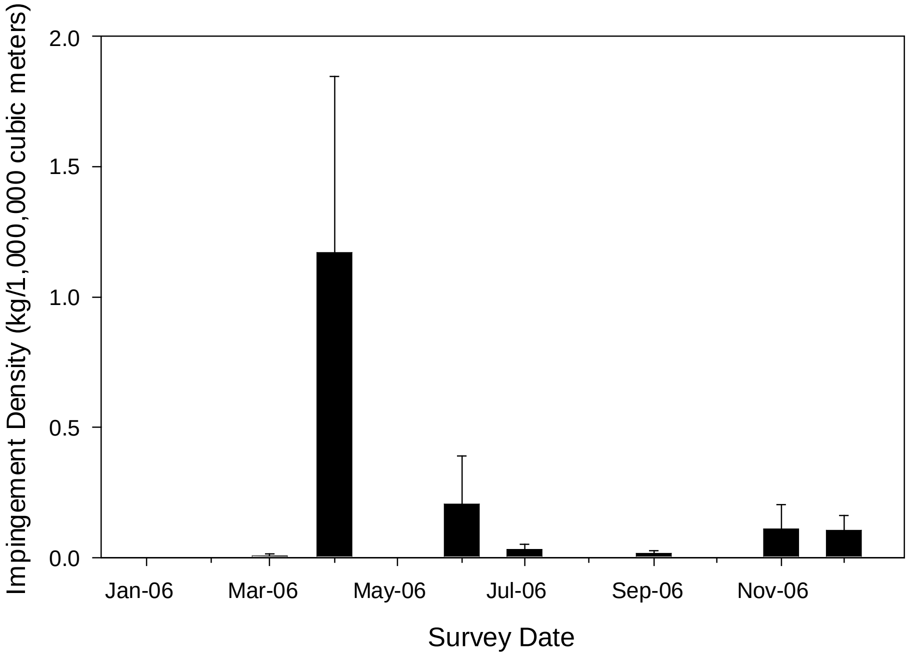


Figure 5.5-4. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) and standard error of fishes collected in ESGS Units 3 & 4 impingement samples during 2006.

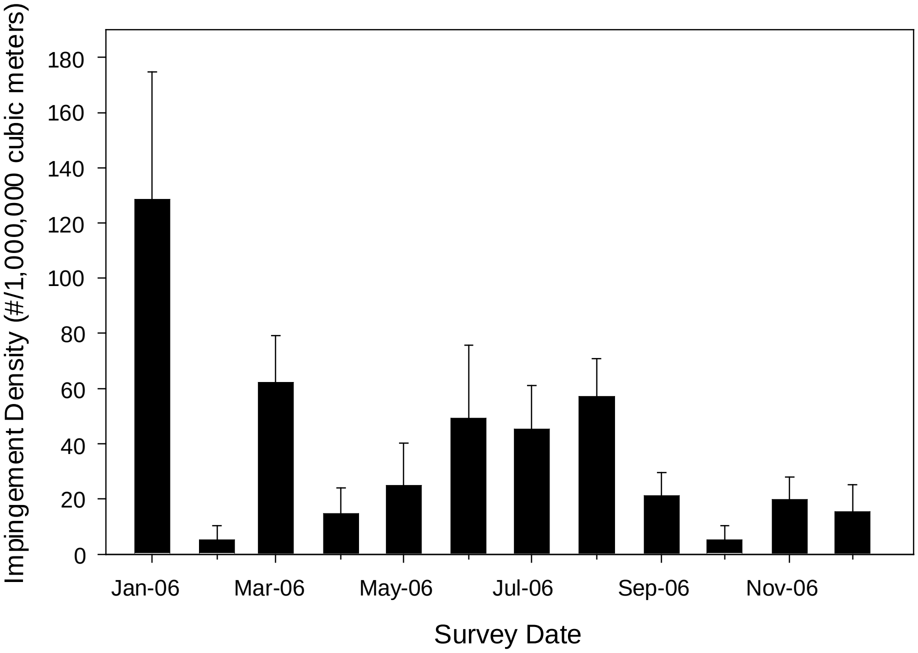


Figure 5.5-5. Mean concentration (# per 1,000,000 m^3 [264 million gal]) and standard error of shellfish collected in ESGS Units 1 & 2 impingement samples during 2006.

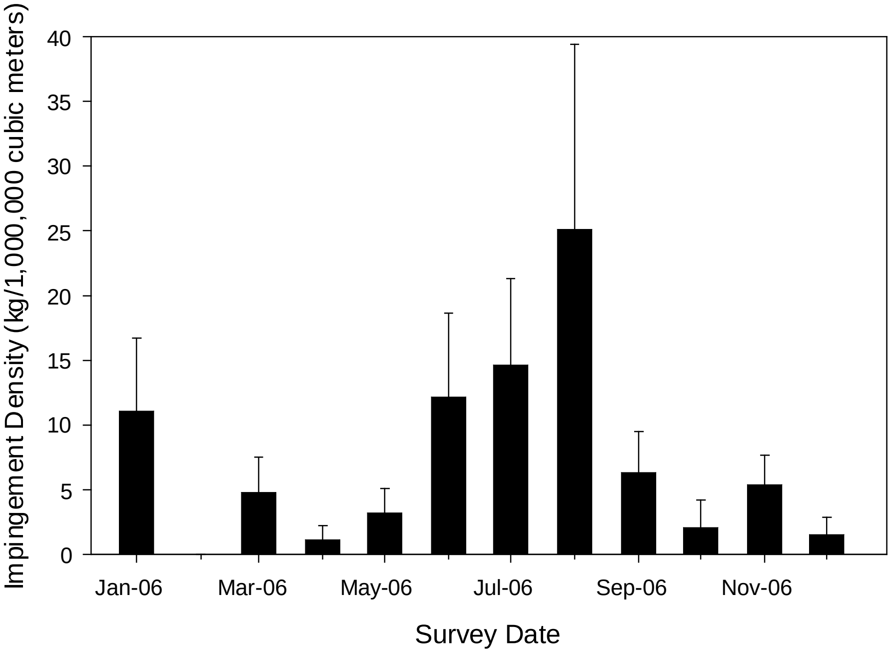


Figure 5.5-6. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) and standard error of shellfish collected in ESGS Units 1 & 2 impingement samples during 2006.

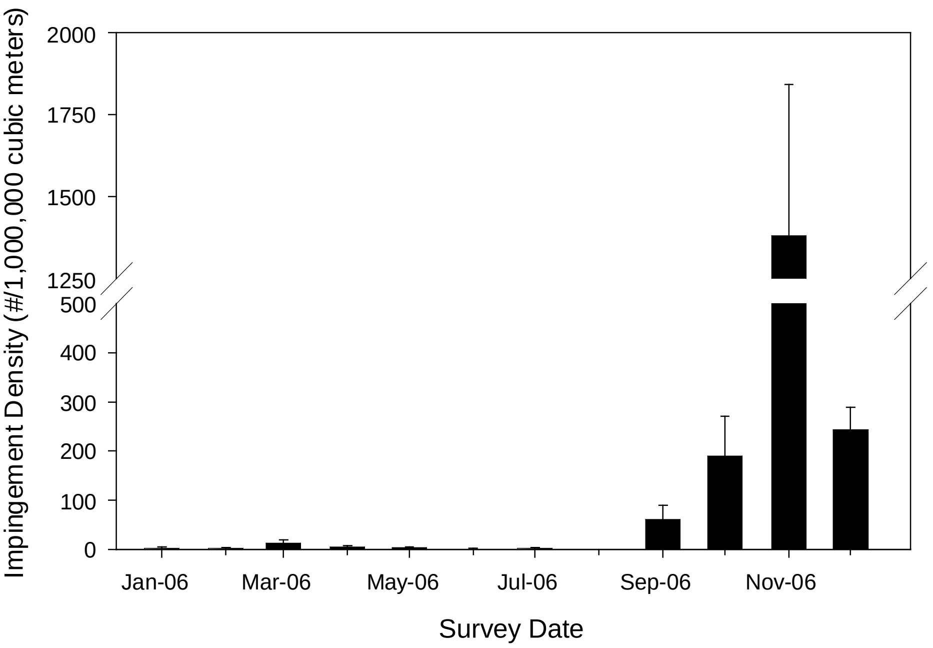


Figure 5.5-7. Mean concentration (# per 1,000,000 m^3 [264 million gal]) and standard error of shellfish collected in ESGS Units 3 & 4 impingement samples during 2006.

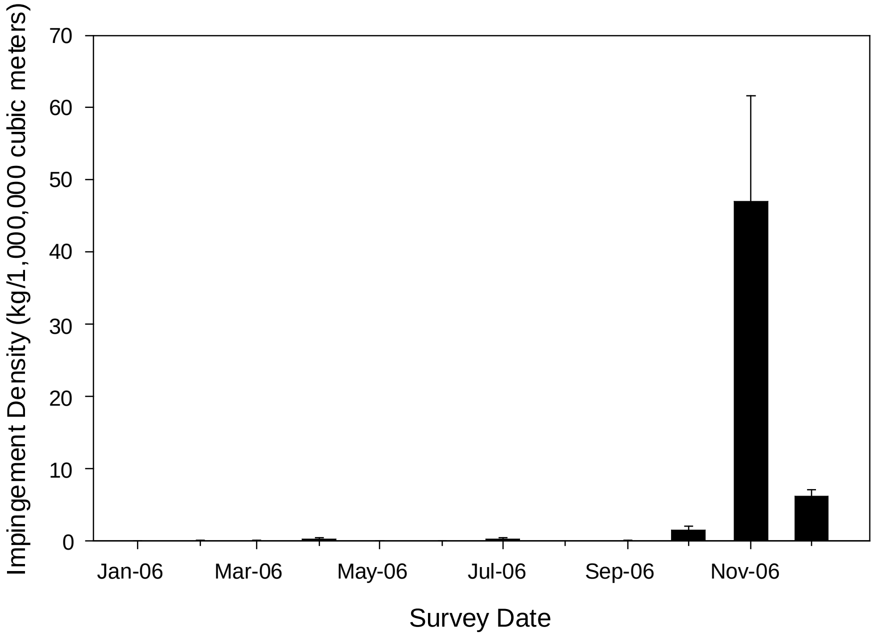


Figure 5.5-8. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) and standard error of shellfish collected in ESGS Units 3 & 4 impingement samples during 2006.

5.5.1.2 Diel Variation

Most of the six fish collected at Units 1 & 2 were recorded after dusk (Figures 5.5-9 and 5.5-10; *Note: Negative nighttime values in all diel comparison figures are an artifact of the plotting routine*). At Units 3 & 4, impingement occurred during both diel periods with peak impingement abundance observed during the day (Figure 5.5-11). Fish biomass at Units 3 & 4 exhibited similar patterns except the nighttime impingement rate in April was more than four times than the other impingement rates (Figure 5.5-12). Shellfish abundance and biomass at Units 1 & 2 was generally higher during nighttime surveys (Figures 5.5-13 and 5.5-14). At Units 3 & 4, abundance and biomass were similar between daytime and nighttime surveys, although daytime rates were higher for both measurements (Figures 5.5-15 and 5.5-16).

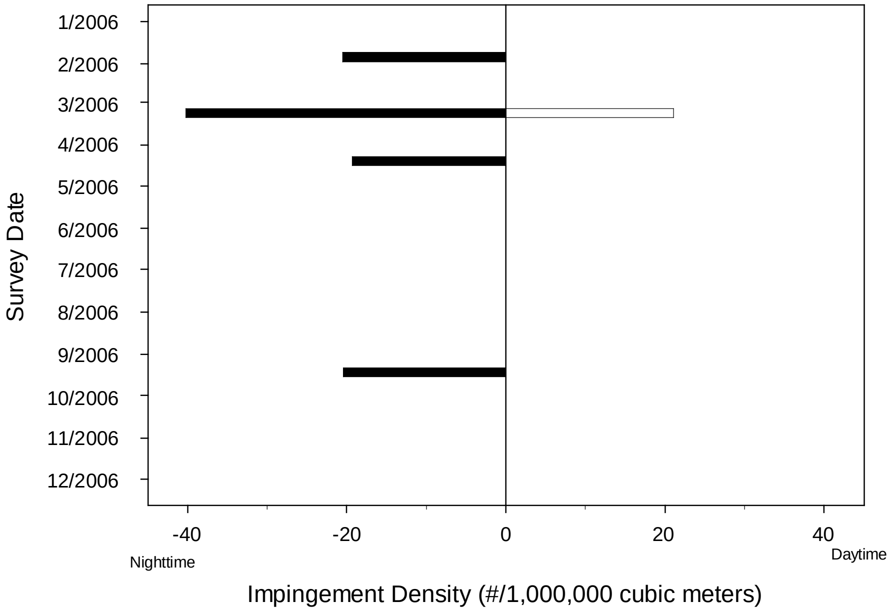


Figure 5.5-9. Mean concentration (# per 1,000,000 m^3 [264 million gal]) of fishes in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 1 & 2.

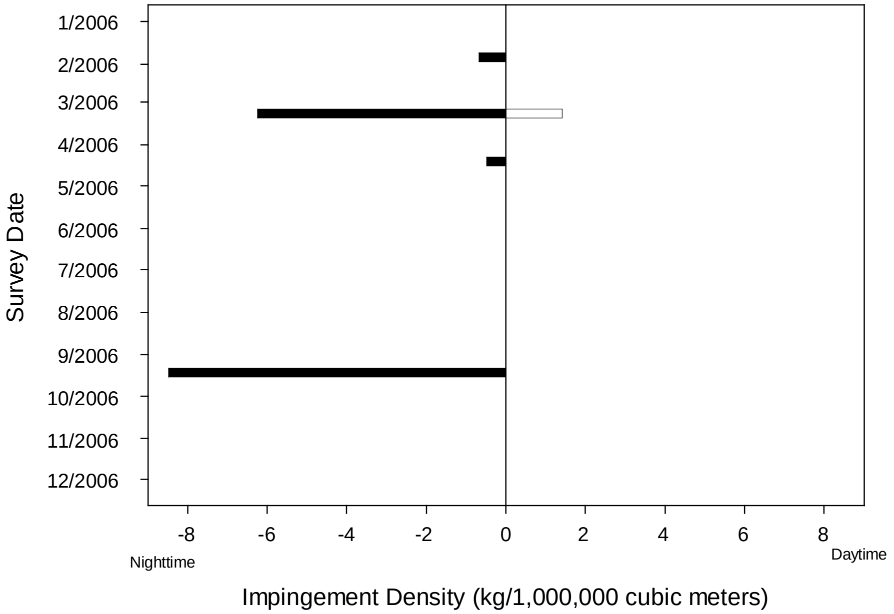


Figure 5.5-10. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) of fishes in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 1 & 2.

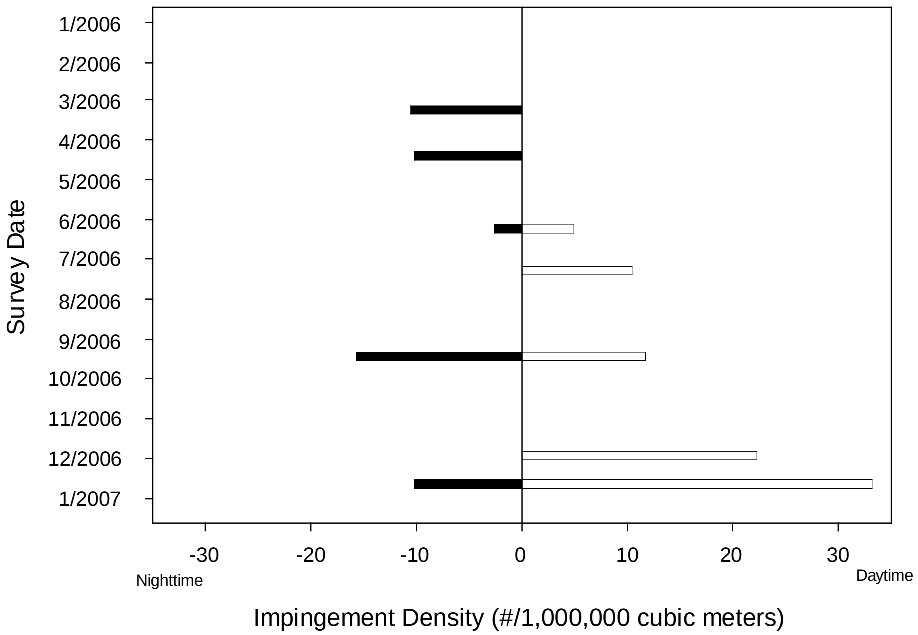


Figure 5.5-11. Mean concentration (#per 1,000,000 m^3 [264 million gal]) of fishes in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 3 & 4.

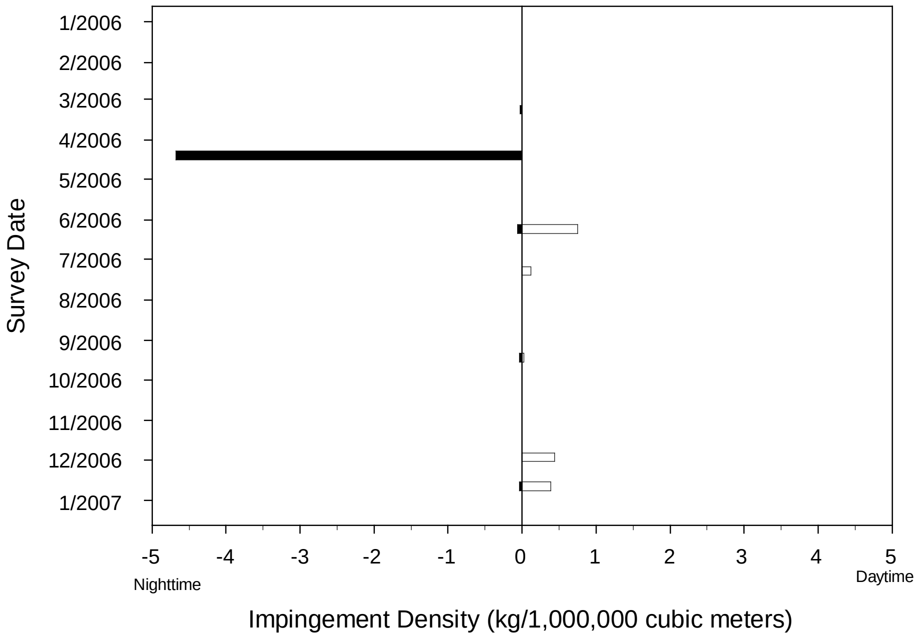


Figure 5.5-12. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) of fishes in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 3 & 4.

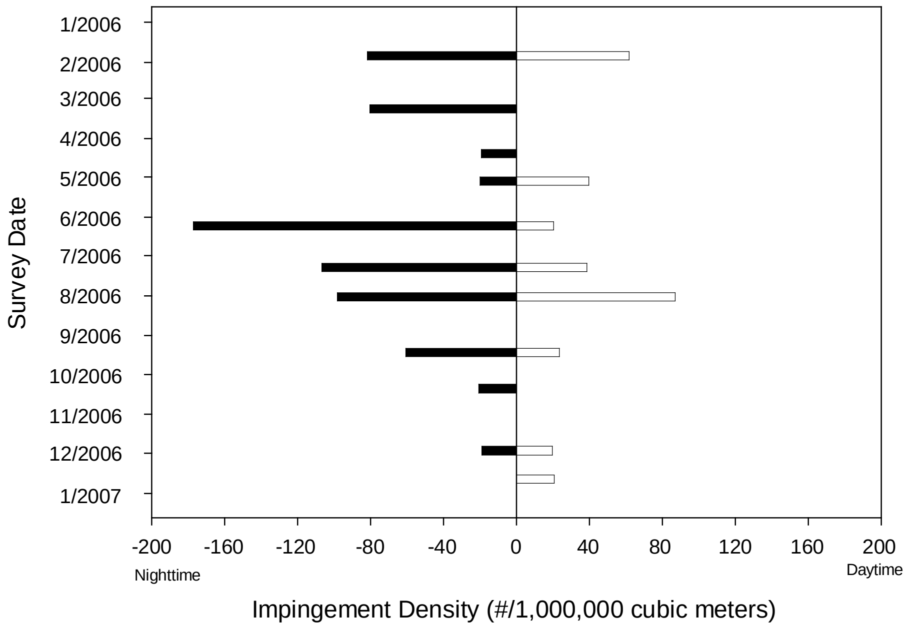


Figure 5.5-13. Mean concentration (#per 1,000,000 m^3 [264 million gal]) of shellfish in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 1 & 2.

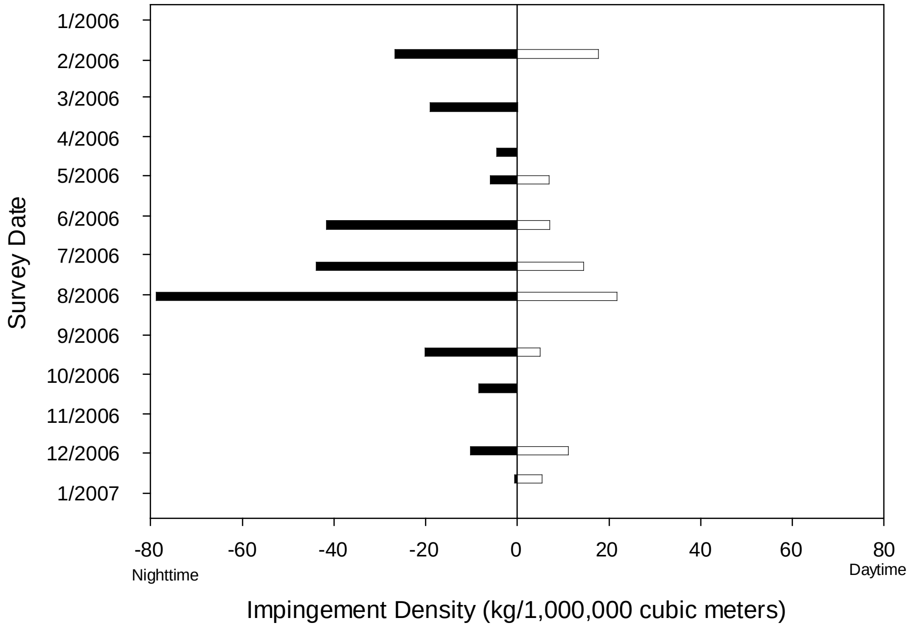


Figure 5.5-14. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) of shellfish in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 1 & 2.

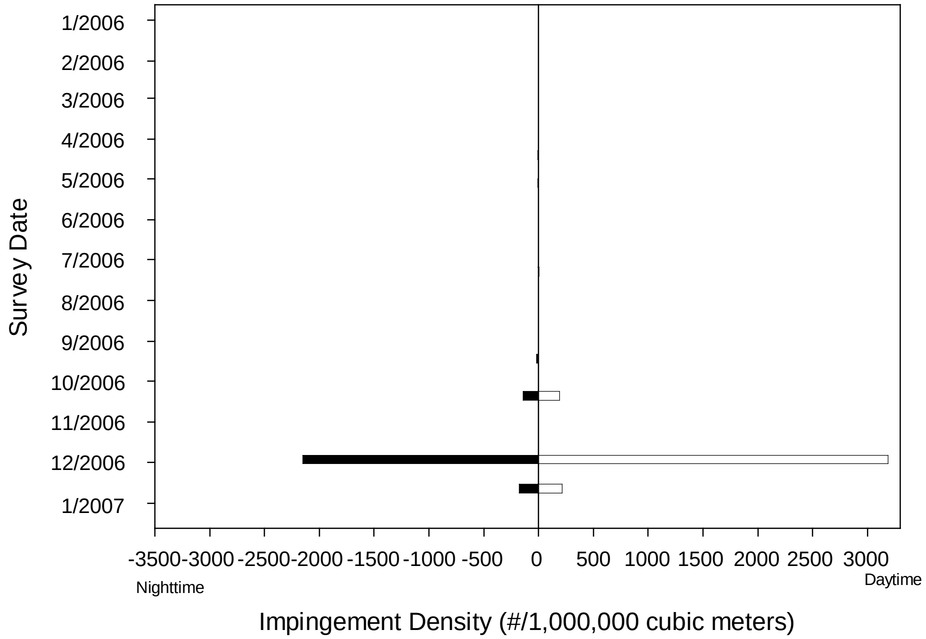


Figure 5.5-15 Mean concentration (#per 1,000,000 m^3 [264 million gal]) of shellfish in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 3 & 4.

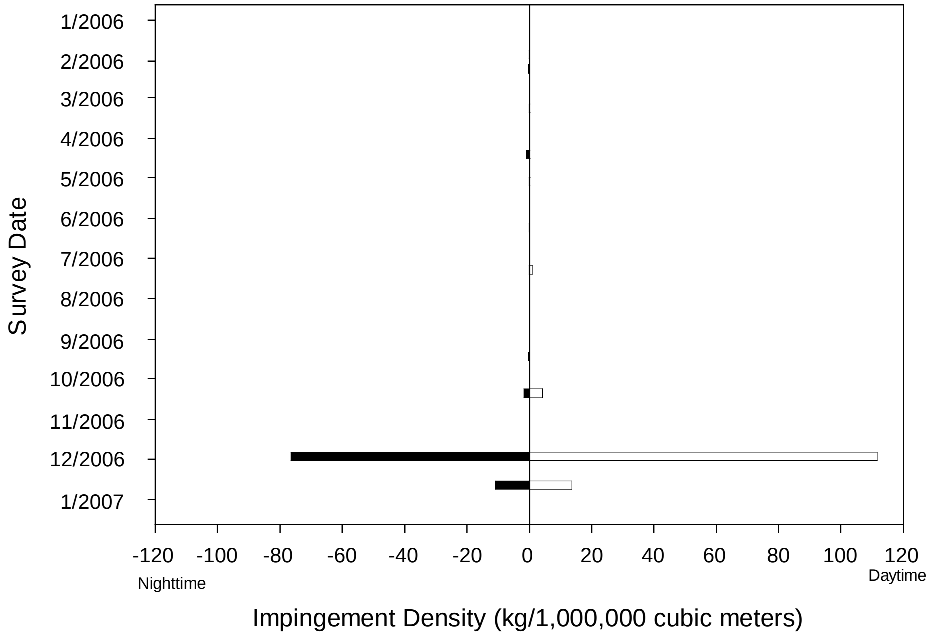


Figure 5.5-16 Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) of shellfish in impingement samples during night (Cycles 3 & 4) and day (Cycles 1 & 2) sampling at Units 3 & 4.

5.5.1.3 Comparison with Previous Studies

The annual fish impingement estimate for 2006 (186 fish at Units 1 & 2 and 1,527 fish at Units 3 & 4) is substantially lower than the impingement estimates recorded from 1978-80 (111 fish per day at Units 1 & 2 and 247 fish per day at Units 3 & 4) (SCE 1982b). This is likely due in part to substantial changes in plant operations, especially reduced operations of Units 1 & 2, where only one circulating water pump typically operates and heat treatments are no longer performed.

During the last 16 years of normal operation and heat treatment impingement monitoring at the ESGS (1990–2005), a total of 113,574 fish was estimated to be impinged (MBC 2006). However, since 2002, annual impingement abundance has ranged between 1,189 individuals (2004) and 2,088 individuals (2005). Therefore, results from 2006 are consistent with recent trends. In 2005, the most abundant species were queenfish (788 individuals), blacksmith (333 individuals), kelp bass (182 individuals), northern anchovy (113 individuals), and California scorpionfish (98 individuals). In the current study, the most abundant species were blacksmith, kelp bass, black perch, rubberlip seaperch (*Rhacochilus toxotes*), and queenfish. All of these species have been consistently impinged at the ESGS in the last 16 years.

Of the 2,088 fish estimated to be impinged in 2005, 95% were recorded at Units 3 & 4 (815 during heat treatments and 1,175 estimated during normal operations). At Units 1 & 2, the annual impingement estimate was 98 fish (all California scorpionfish). In 2006, 89% of the impingement abundance was recorded at Units 3 & 4, and 81% of the abundance at Units 1 & 2 (186 individuals) was comprised of California scorpionfish.

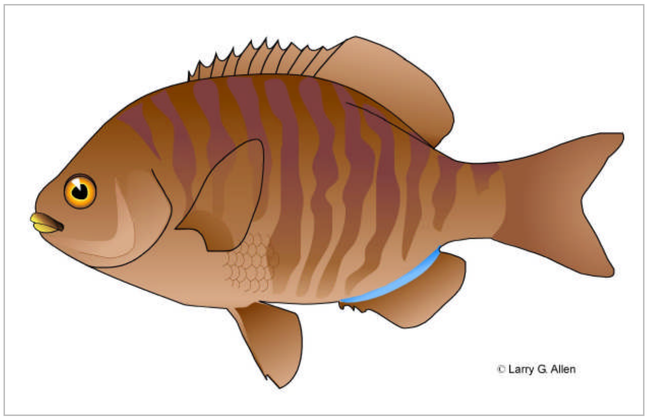
5.5.2 All Life Stages of Fishes by Species

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

- black perch (142 individuals)
- queenfish (103 individuals)
- shiner perch (98 individuals)
- kelp bass (79 individuals)
- northern anchovy (78 individuals)
- blacksmith (67 individuals)
- white seaperch (38 individuals)
- bat ray (37 individuals)
- walleye surfperch (34 individuals)
- pile perch (30 individuals)
- rubberlip seaperch (27 individuals)
- California scorpionfish (23 individuals)
- black croaker (20 individuals)
- jacksmelt (19 individuals)

Combined, these 14 species represented approximately 84% of the sampled impingement abundance. Three additional species were analyzed in further detail due to their inclusion in the Coastal Pelagics Fishery Management Plan: jack mackerel (11 individuals), Pacific sardine (10 individuals), and Pacific chub mackerel (5 individuals). Three other fish species were analyzed in further detail due to their inclusion in the Pacific Groundfish Fishery Management Plan: brown rockfish (7 individuals), vermilion rockfish (3 individuals), and English sole (3 individuals).

5.5.2.1 Black perch (*Embiotoca jacksoni*)



Black perch (*Embiotoca jacksoni*) range from Pt. Abreojos, Baja California, Mexico to Fort Bragg, California in depths from 0 to 50 m (0 to 164 ft) (Miller and Lea 1972; Allen 1982). Nineteen species of perch are common to the nearshore waters of southern California, with 10 of these species commonly observed in central and southern California (Miller and Lea 1972; Allen and Pondella 2006). Allen and Pondella (2006) included black perch in their southern California shallow rock sand group. Black perch have been frequently observed in impingement sampling throughout southern California since 1990, albeit in greatly reduced abundances in comparison to more abundant perch species, such as walleye surfperch (*Hyperprosopon argenteum*) (MBC unpubl. data).

5.5.2.1.1 Life History and Ecology

Quast (1968a) included black perch in his Zone II classification as a bottom microcarnivore, typically patrolling the areas of coralline red algae. Stephens et al. (2006) further confirmed this habitat affinity, noting a stronger presence in the southern portion of the Southern California Bight. Within this zone, Quast (1968b) reported their primary prey items reflect this habitat preference, with the principle composition including polychaete worms, amphipods, spider crabs, etc. Allen (1982) determined that amphipods and shrimps comprised the majority of prey items, though polychaetes were also important. Black perch ranked higher in abundance along the mainland (14th) than at Santa Catalina Island (30th) in fish assemblages sampled by gillnet from 1996 to 1998, indicating preference for the mainland, which may be attributed to the greater overall frequency of the rocky-reef, sandy-bottom ecotone they prefer (Pondella and Allen 2000; Allen and Pondella 2006). Along the Los Angeles Federal Breakwater, black perch represented nearly 12% of all fishes, or the second most abundant species observed (Froeschke et al. 2005).

Like all surfperch, black perch are viviparous, producing free-swimming, fully developed young. Young surfperches are often larger than the typical 9.5-mm (3/8-inch) screen mesh at most generating stations, preventing their entrainment and transport throughout the cooling water system. Froeschke et al. (in press) reported that black perch exhibit a general 1:1 sex ratio, with a peak spawning period in southern California from July through October. These authors noted that gestating females were capable of carrying between 4 and 17 embryos, with larger females carrying more embryos.

Froeschke et al. (in press) reported black perch to reach a maximum age of seven years old, with the predominance of individuals less than five years old. The authors noted that, as with most fish, growth was fastest during the early part of their life, with maximum growth between ages 0 and 2 before slowing.

5.5.2.1.2 Population Trends and Fishery

Surfperch commercial landings, overall, steadily declined from the peak in 1982, with some research indicating the decline may partially be attributable to increased water temperature that dominated the northeast Pacific Ocean throughout much of the 1980s and 1990s (Fritzsche and Collier 2001). The NMFS Los Angeles Times recreational fishing database recorded an annual mean landing of 50 black perch from all landings ranging from Paradise Cove on the northwestern edge of the Santa Monica Bay south to San Diego, California over the period 1991–2003 (NMFS 2007). Due to the random nature of the recreational fishing data, no real population trends can be determined for black perch. 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 136 and 1,361 kg (300 and 3,000 lb) per year since 2000 (Table 5.5-7). In 2005, "surfperch" landings in the Los Angeles area totaled 21.3 kg (47 lb) 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 lb) in 2006, at an estimated value of $1,092 (CDFG 2007b).

Table 5.5-7. Annual landings and revenue for surfperches in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**(kg)**	**(lb)**	**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

During 1978–80, an estimated average of 1.0 black perch were impinged daily at Units 1 & 2, and 0.5 black perch were impinged daily at Units 3 & 4 (SCE 1982b). From 2003 through 2005, estimated annual impingement of black perch ranged from 9 individuals (2004) to 36 individuals (2003) (MBC 2007). Since 1990, 431 black perch were estimated to have been impinged at the ESGS, an average of about 27 individuals per year.

5.5.2.1.3 Sampling Results

A total of 142 black perch weighing 43.825 kg (96.634 lb) were collected exclusively during heat treatments at Units 3 & 4 (Table 5.5-2). Standard lengths of 141 individuals was recorded ranging from 54 to 256 mm with a mean length of 176 mm SL. Length frequency analysis indicated a bimodal distribution with peaks at 70 and 190 mm SL (Figure 5.5-17), corresponding to young of the year and Age Class V individuals. The sex of 122 individuals was determined with 45.1% male, 38.5% female, and

16.4% juvenile. Of the 93 individuals that were assessed for their relative condition, 94.6% were dead and 5.4% were mutilated.

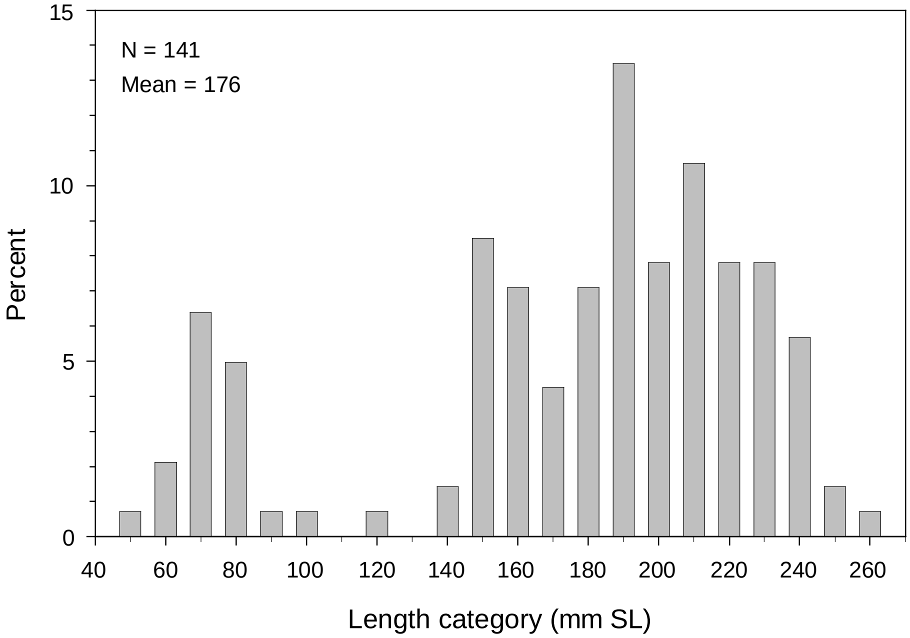


Figure 5.5-17 Length (mm) frequency distribution for black perch collected in impingement samples.

5.5.2.2 Queenfish *(Seriphus politus)*

Milton Love

Queenfish (*Seriphus politus* Ayres 1860) range from west of Uncle Sam Bank, Baja California, north to Yaquina Bay, Oregon (Miller and Lea 1972). Queenfish are common in southern California, but rare north of Monterey. They are one of eight species of croaker or ‘drums’ (Family Sciaenidae) found off California. The other croakers include: white seabass (*Atractoscion nobilis*), black croaker (*Cheilotrema saturnum*), white croaker, California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), and shortfin corvina (*Cynoscion parvipinnis*). Shortfin corvina was common off the California coast as far north as San Pedro in the late 1800s (Jordan and Evermann 1896), but has not been common off the California coast since the 1930s (Miller and Lea 1972). In recent years it has been documented as far north as San Diego Bay (Tenera 2004).

5.5.2.2.1 Life History and Ecology

The reported depth range of queenfish is from the surface to depths of about 37 m (120 ft) (Miller and Lea 1972); however, in southern California, Allen (1982) found queenfish over soft bottoms between 10 and 70 m (33 and 230 ft), with highest abundance occurring at 10 m. During the day, queenfish hover in dense, somewhat inactive schools close to shore, but disperse to feed in midwater after sunset (Hobson and Chess 1976). It is active throughout the night, and feeds several meters off the seafloor in small schools or as lone individuals.

Queenfish is a summer spawner. Goldberg (1976) found queenfish to enter spawning condition in April and spawn into August, while DeMartini and Fountain (1981) recorded spawning in queenfish between March and August. Spawning is asynchronous among females, but there are monthly peaks in intensity during the waxing (first quarter) of the moon (DeMartini and Fountain 1981). They also stated that mature queenfish spawn every 7.4 days on average, regardless of size. Duration of the spawning season is a function of female body size, ranging from three months (April–June) in recruit spawners to six months (March–August) in repeat spawners (>13.5 cm standard length [SL], or 5.3 inches). 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).

Goldberg (1976) found no sexually mature females less than 14.8 cm SL (5.8 inches) in Santa Monica Bay. This differs from the findings of DeMartini and Fountain (1981) off San Onofre. They found females sexually mature at 10.0–10.5 cm SL (3.9–4.1 inches) at slightly greater than age-1. Batch fecundities in queenfish off San Onofre ranged from 5,000 eggs in a 10.5-cm (4.1-inch) female to about 90,000 eggs in a 25-cm (9.8-inch) fish. The average-sized female in that study (14 cm [5.5 inches], 42 g [0.09 lb]) had a potential batch fecundity of 12,000–13,000 eggs. Parker and DeMartini (1989) estimated the average batch fecundity to be 12,700 for queenfish collected over a five-year period. Based on a female spawning frequency of 7.4 days, a 10.5-cm (4.1-inch) female that spawns for three months (April–June) can produce about 60,000 eggs/year, while a 25-cm (9.8-inch) female that spawns for six months (March through August) can produce nearly 2.3 million eggs/year (DeMartini and Fountain 1981).

Queenfish mature at 10.5 to 12.7 cm (4.1 to 5.0 inches) (DeMartini and Fountain 1981; Love 1996), during their first spring or second summer. Maximum reported size is 30.5 cm (12 inches) (Miller and Lea 1972). Immature individuals grow at a rate of about 2.5 mm/day (0.1 inch/day), while early adults grow about 1.8 mm/day (0.07 inch/day) (Murdoch et al. 1989b). Mortality estimates are unavailable for this species. Queenfish feed mainly on crustaceans, including amphipods, copepods, and mysids, along with polychaetes and fishes (Quast 1968b; Hobson and Chess 1976; Hobson et al. 1981; Feder et al. 1974).

5.5.2.2.2 Population Trends and Fishery

Queenfish was the most abundant sciaenid impinged at five generating stations in southern California from 1977 to 1998, and accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). Annual abundance fluctuated from year to year, with notable declines during the strong El Niño events of 1982-83, 1986-87, and 1997-98. However, abundance remained relatively high throughout the over

20-year study period. There were no reported commercial landings of queenfish in the commercial CDFG or PacFIN records (CDFG 2006, 2007; PacFIN 2007). Annual recreational landings (RecFIN 2007) have averaged about 270,000 fish per year since 2000, with a notable increase in 2002 (Table 5.5-8).

Table 5.5-8. Annual recreational landings for queenfish in the Los Angeles region based on RecFIN data.

Year	**Total Landed**
2000	83,000
2001	66,000
2002	942,000
2003	235,000
2004	213,000
2005	201,000
2006	147,000

Queenfish was the most abundant fish species in the 1978-1980 316(b) demonstration, with impingement averaging about 58 individuals per day at Units 1 & 2 and 171 individuals per day at Units 3 & 4 (SCE 1982b). From 2003 through 2005, estimated annual impingement of queenfish ranged from 486 individuals (2003) to 788 individuals (2005) (MBC 2007). Since 1990, 46,226 queenfish were estimated to have been impinged at the ESGS, an average of 2,889 individuals per year.

5.5.2.2.3 Sampling Results

During the yearlong study, 103 queenfish weighing 2.198 kg (2.847 lb) were impinged at ESGS Units 3 & 4 exclusively during heat treatments (Table 5.5-2). Length frequency analysis of the 103 individuals measured indicates a mean length of 102 mm SL, with lengths ranging from 66 to 160 mm SL in a bimodal distribution with peaks at 80 and 110 mm SL (Figure 5.5-18), corresponding to young of the year and Age Class II individuals (MBC and VRG unpubl. data). Nearly all individuals collected (98%) were dead with 1% alive and 1% mutilated.

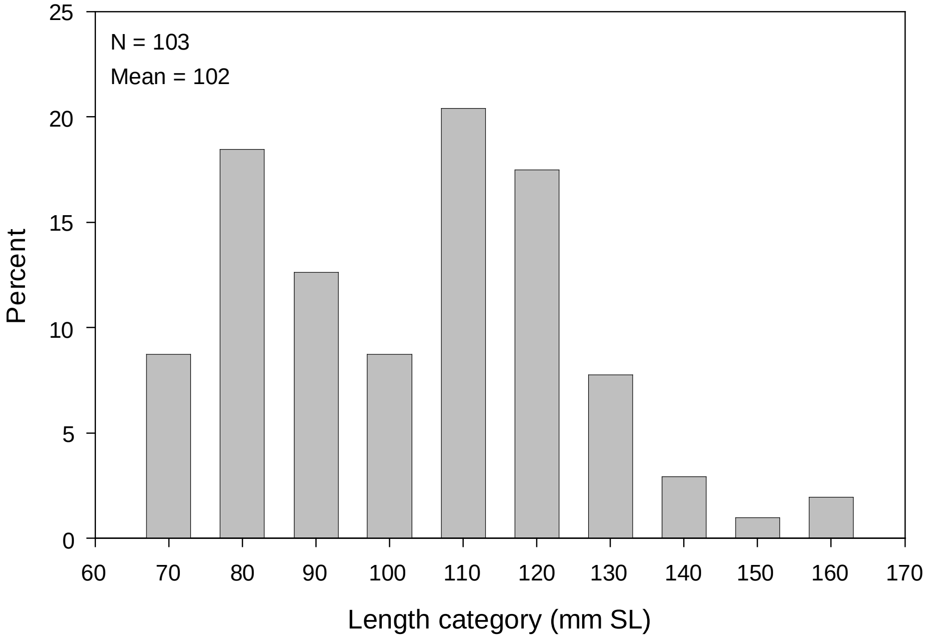


Figure 5.5-18 Length (mm) frequency distribution for queenfish collected in impingement samples.

5.5.2.2.4 Modeling Results

Queenfish life history parameters are presented in Table 5.5-9. Unpublished research by MBC and the Occidental College Vantuna Research Group (VRG) provided all of the applicable adult life history parameters, which indicates the age at 50% maturity is 1.76642 years. All 103 queenfish impinged were impinged during heat treatments. Based on these and the associated life history parameters, an estimated 116 equivalent adults were taken, using either actual cooling water intake or design (maximum capacity) flow volumes. The distribution of queenfish age classes of the 103 measured individuals is presented in Figure 5.5-19.

Table 5.5-9. Queenfish life history parameters used in equivalent adult modeling.

		von Bertalanffy growth parameters				
Adult Annual Instantaneous Mortality (Z)	**Survival (S)**	**L_{inf}**	**k**	**t_0**	**Age at 50% Maturity**	**Length at 50% Maturity**
0.3512	0.703843	176.2 mm SL	0.302	-1.234	1.766	105 mm SL

Data from MBC and VRG, unpubl. data

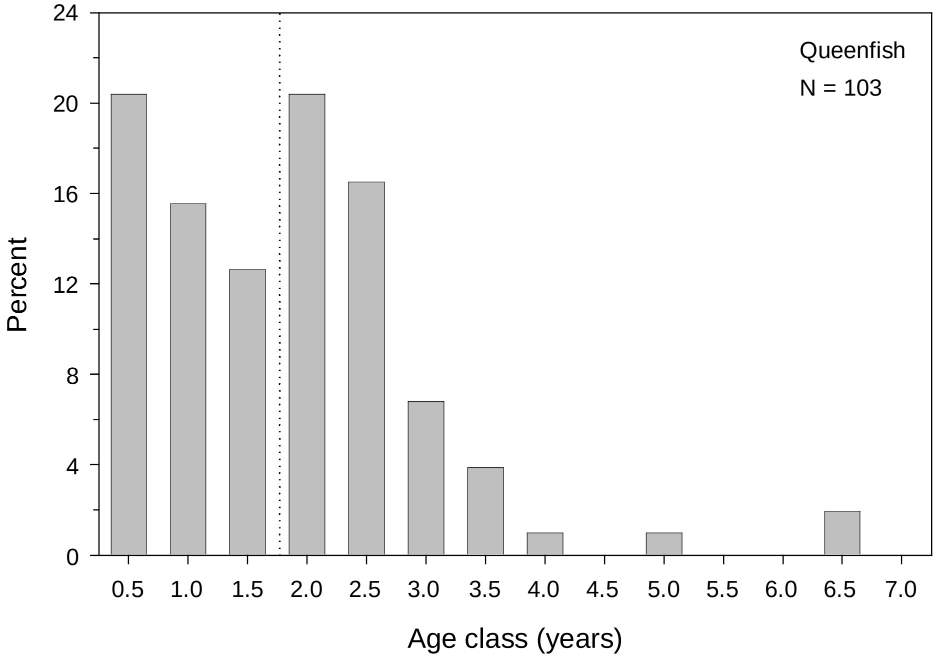


Figure 5.5-19. Distribution of queenfish age classes in ESGS impingement samples. Vertical dotted line denotes age at 50% maturity.

5.5.2.3 Shiner perch (*Cymatogaster aggregata*)

Shiner perch 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.

5.5.2.3.1 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 waters with a range of salinities, and may even occasionally be found 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 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 five young, while larger females can produce over twenty young (Wilson and Millemann 1969). Shiner perch have no larval stage. At birth, fully developed young are about 34 to 78 mm in length (Wilson and Millemann 1969; Hart 1973). Shiner perch live for about eight years and reach about 180 mm in length (Miller and Lea 1972; Hart 1973).

5.5.2.3.2 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 (Fritzche and Collier 2001). Commercial landings in the Los Angeles area have fluctuated between about 136 and 1,361 kg (300 and 3,000 lb) per year since 2000 (Table 5.5-7). In 2005, "surfperch" landings in the Los Angeles area totaled 21.3 kg (47 lb) 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 lb) 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). Shiner perch was the sixth most abundant species analyzed during the 1978-1980 316(b) demonstration at Units 1 & 2, and the third most abundant species at Units 3 & 4, with an estimated daily impingement of about 3 individuals at Units 1 & 2 and about 18 individuals at Units 3 & 4 (SCE 1982b). From 2003 through 2005, estimated annual impingement of shiner perch ranged from 3 individuals (2005) to 44 individuals (2004) (MBC 2007). Since 1990, 420 shiner perch were estimated to have been impinged at the ESGS, an average of about 26 individuals per year.

5.5.2.3.3 Sampling Results

Shiner perch were exclusively impinged during heat treatments at ESGS Units 3 & 4 in 2006 (Table 5.5-2). A total of 98 individuals weighing 0.404 kg (0.891 lb) was recorded during surveys. All of these were measured to the nearest millimeter standard length, with lengths ranging from 34 to 65 mm and a mean of 50 mm (Figure 5.5-20). The sex of 60 individuals was determined with all classified as juveniles, while 100% of 31 individuals examined for body condition were dead.

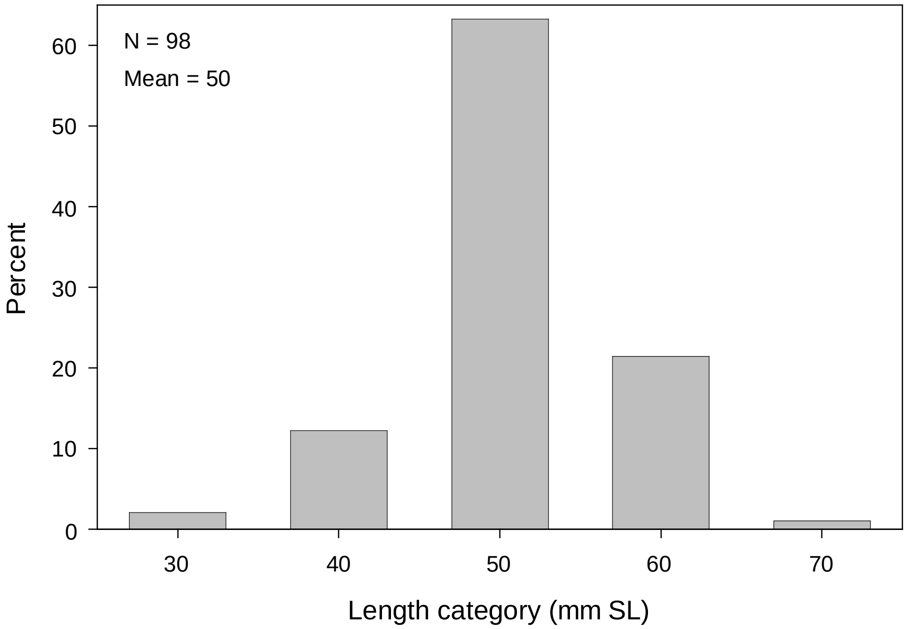
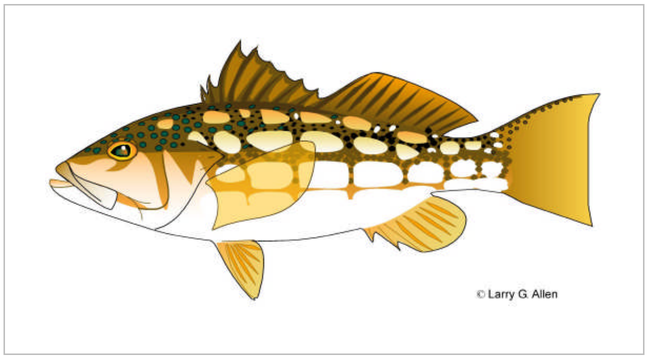


Figure 5.5-20. Length (mm) frequency distribution for shiner perch collected in impingement samples.

5.5.2.4 Kelp bass *(Paralabrax clathratus)*



Kelp bass (*Paralabrax clathratus*) is a member of the Family Serranidae, which is comprised of sea basses. Most fish of this family exhibit robust body forms with large mouths. They occur in both temperate and tropical oceans, though most commonly in tropical waters.

Kelp bass are olive or brown with pale square blotches along the dorsal area with yellow-tinted fins (Miller and Lea 1972; Eschmeyer and Herald 1983). The range of the kelp bass extends from Columbia River, Washington, to southern Baja California; yet they are rarely found north of southern California.

5.5.2.4.1 Life History and Ecology

True to their name, kelp bass are usually found amongst the kelp beds, from the shallow water to 46 m (150 ft) (Love et al. 2005); however, these fish generally occur between 2.4 m and 21 m (8 ft and 70 ft). Kelp bass lead mostly solitary lives, with periods of assembly during spawning and feeding on schools of fish (Allen and Hovey 2001b; Erisman and Allen 2005). Several studies revealed that, once settled, kelp bass rarely migrate from their home range, making them perceptible to overfishing (Quast 1968d; Eschmeyer and Herald 1983).

The largest kelp bass recorded had a length of 72 cm (28.5 in), and weighed 6.6 kg (14.5 lb) (Eschmeyer and Herald 1983). Kelp bass have rapid growth rates with some first-year bass reaching lengths of 20 cm (8 in) (Love et al. 1996). Cordes and Allen (1997) suggest that kelp bass grow at a rate of 0.59 mm per day in the first 90 days after hatching. At five years, however, kelp bass slow their growth rates (Love et al. 1996). Male and female kelp bass are found to reach sexual maturity at similar ages. Starting at a length of 18 cm (7 in), a few individuals mature and all bass are mature by 26 cm (10 in). Studies shows that kelp bass spawn in the late spring (April or May) to early fall (October), with peaks in the summer months (Cordes and Allen 1997; Allen and Hovey 2001b; Erisman and Allen 2005). After fertilization, larvae emerge in about 36 hours and remain planktonic for a period of 28 to 30 days. Kelp bass recruits have been shown to begin settlement into shallow water among algae between April and December, reaching a peak in May and December (Love et al. 1996).

These serranids are classified as “generalized carnivores,” covering a broad variety of prey items, beginning with larval kelp bass feeding on copepods and other plankton (Quast 1968d; Allen and Hovey 2001b). Juvenile diets consist mostly of crabs, shrimps, isopods and amphipods while diets of adults are mostly comprised of fishes, squids, and octopuses. Kelp bass also have a seasonal pattern of feeding, where feeding increases May through September after the light winter-feeding period.

5.5.2.4.2 Population Trends and Fishery

The kelp bass has been an important species to the southern California fisheries since the 1900s (Allen and Hovey 2001b). Between the 1920s and 1930s, commercial landings of ‘rock bass’ (kelp bass, barred and spotted sand bass) averaged 226,796 kg (500,000 lb), which recent data would assume kelp bass as a majority of the catch. However during World War II and thereafter, a decline in fishing activity lowered annual landings to 68,039 kg (150,000 lb) and below. This rapid drop was alarming and resulted in the closure of the kelp bass commercial fishery in 1953.

Recreational fishing for kelp bass remained after the commercial fishery closed and continued to be successful (Allen and Hovey 2001b). Although catch records date back to 1935, reliable data begins in 1975, when kelp bass were recorded separately from the other ‘rock bass’ species. The end of World War II was followed by an increase in fishing pressure that probably contributed to the decline in kelp bass populations reflected in the commercial fishery catches. In 1950, the California Department of Fish and Game began life history studies of this species in order to establish bag limits, which would hopefully reduce the rate of depletion. Legal size limits were set at a length of 27 cm (10.5 in) but extended to 31 cm (12 in) by 1959.

Since 1980, recreational catches have varied greatly, with the annual catch averaging at around one million kelp bass per year (Allen and Hovey 2001b). The mid-1980s contained catches which equaled over one million fish annually. Love et al. (1996) attributed the population spike, which resulted in high catches, to the rising temperature of southern California waters during the 1970s and 1980s. Beginning in

1993, the kelp bass recreational landings have begun to decline (Allen and Hovey 2001b). A recent record of catches showed 129,475 fish landed in 1999, an 80% decrease from the previous year's landings.

There were no commercial landings of kelp bass reported in the Los Angeles area in 2005 (CDFG 2006) or from catch blocks in the Santa Monica Bay area in 2006 (CDFG 2007b). Recreational landings in the Los Angeles area have fluctuated between about 150,000 and 450,000 individuals per year since 2000 (Table 5.5-10).

Table 5.5-10. Annual recreational landings for kelp bass in the Los Angeles region based on RecFIN data.

Year	Total Landed
2000	587,000
2001	385,000
2002	291,000
2003	434,000
2004	446,000
2005	157,000
2006	159,000

Kelp bass was the fifth most abundant fish species in the 1978-1980 316(b) demonstration at Units 1 & 2, and the sixth most abundant fish species at Units 3 & 4 (SCE 1982b). During that study, impingement averaged about four individuals per day at both Units 1 & 2 and Units 3 & 4. From 2003 through 2005, estimated annual impingement of kelp bass ranged from 41 individuals (2004) to 182 individuals (2005) (MBC 2007). Since 1990, 3,521 kelp bass were estimated to have been impinged at the ESGS, an average of about 220 individuals per year. Highest annual impingement (563 individuals) was recorded in 1990.

5.5.2.4.3 Sampling Results

At Units 3 & 4, a total of 171 kelp bass weighing 37.143 kg (81.900 lb) were impinged during normal operation and heat treatments (Table 5.5-2). Of these, an estimated 95 individuals weighing 0.323 kg (0.712 lb) were impinged during normal operations while the remaining 76 individuals weighing 36.820 kg (81.188 lb) were impinged during heat treatments. Normal operation abundance was similar between the two months kelp bass were impinged (September and December) (Figure 5.5-21); however, there was a large disparity between biomass rates due to the larger size of the individual collected in December (Figure 5.5-22). Two of the three individuals collected during normal operation surveys were collected during daylight hours while the remaining individual was collected at night. Length frequency analysis of 78 individuals noted individuals ranging from 26 to 390 mm SL with a mean standard length of 228 mm. The distribution among size classes indicated at bimodal distribution with peaks at 180 and 260 mm SL (Figure 5.5-23), which correspond to Age Class II and VI (Love et al. 1996). The sex of 50 kelp bass was recorded with 44% female, 34% male, and 22% juvenile. Of the 45 individuals whose condition was recorded, 93.3% were dead, 4.4% mutilated, and 2.2% alive.

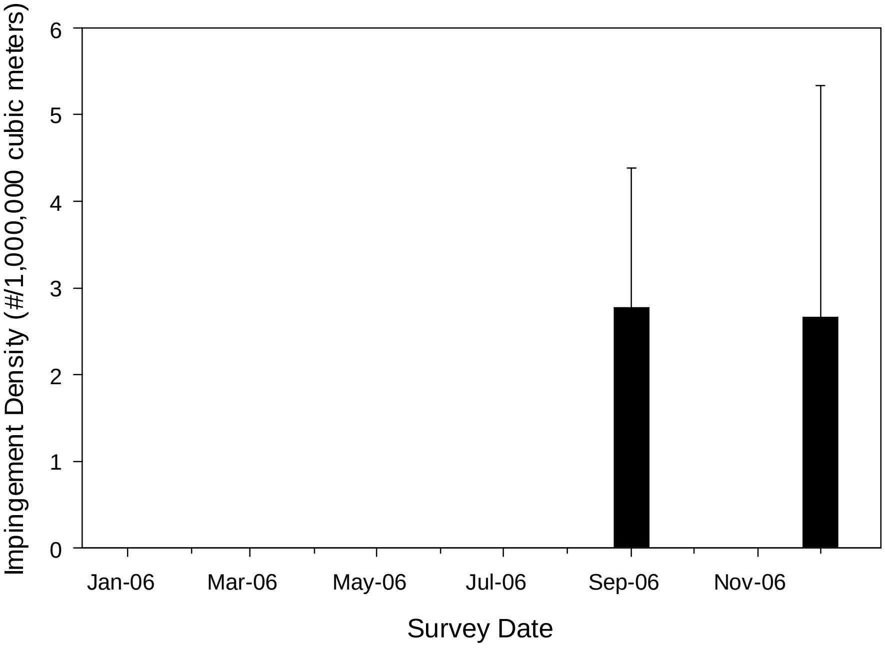


Figure 5.5-21. Mean concentration (#per 1,000,000 m^3 [264 million gal]) and standard error of kelp bass collected in ESGS Units 3 & 4 impingement samples during 2006.

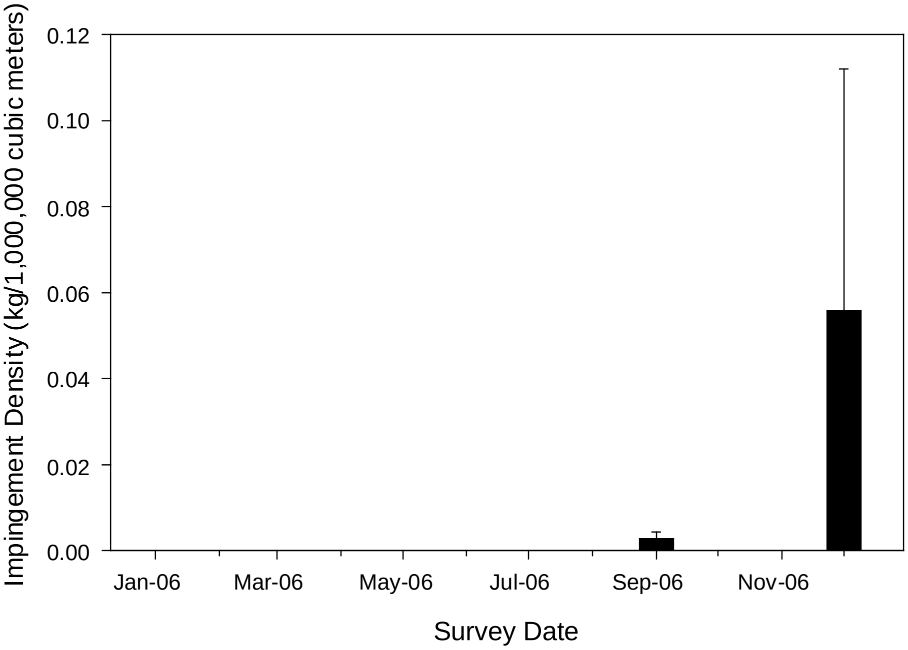


Figure 5.5-22. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) and standard error of kelp bass collected in ESGS Units 3 & 4 impingement samples during 2006.

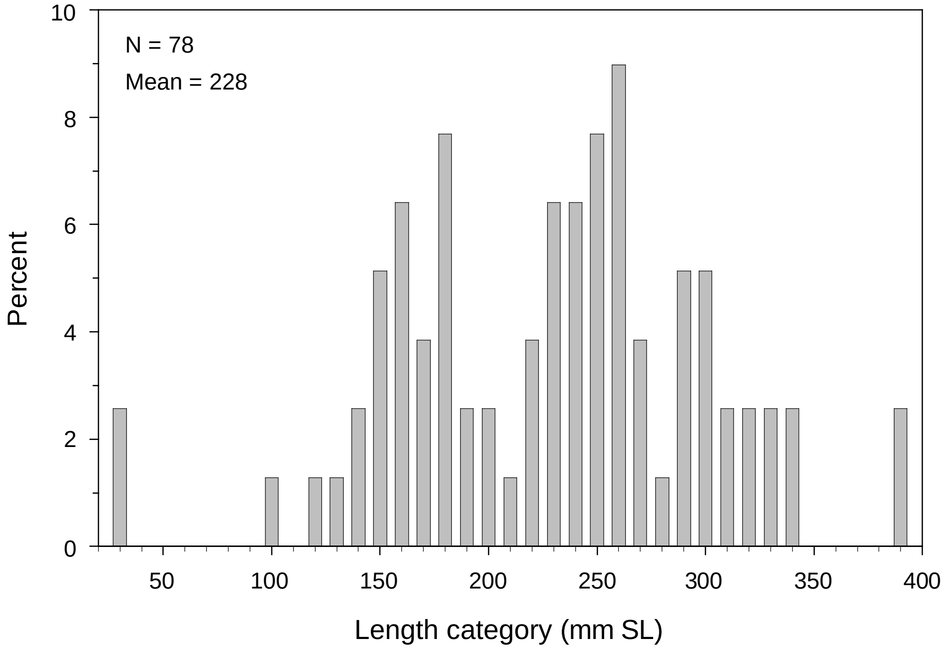


Figure 5.5-23. Length (mm) frequency distribution for kelp bass collected in impingement samples.

5.5.2.4.4 Modeling Results

Kelp bass life history parameters are presented in Table 5.5-11. Love et al. (1996) described the length at age relationship and the length at 50% female maturity (226 mm TL), equivalent to 3.02067 years. Lengths of impinged kelp bass were converted from standard length to total length by the equation TL = 1.41 + 1.2SL prior to inclusion of any further calculations (Love et al. 1996). The instantaneous annual mortality (Z = 0.544) was used as kelp bass are a principle target species for southern California sportfishers (www.dfg.ca.gov/mrd/lifehistories/index.html). Based on these parameters an estimated 2,022 adults equivalent to the age at 50% maturity were taken over the year, using the actual cooling water intake flow volumes. This is much higher than the impingement estimate of 279 individuals, but 15 of these individuals ranged in age from 8 years to more than 15 years, which equates to a range of 15 to 716 adult equivalents per observed individual. Since the equivalent adult model is calculated for individuals collected in normal operations, and only 3 individuals were collected in normal operation sampling, an estimate of equivalent adults for design flow was not calculated. The distribution of kelp bass age classes of the 78 measured individuals is presented in Figure 5.5-24.

Table 5.5-11. Kelp bass life history parameters used in equivalent adult modeling.

Adult Annual Instantaneous Mortality (Z)*	Annual Survival (S)	von Bertalanffy growth parameters** L_{inf}	k	t_0	Age at 50% Maturity (yr)	Length at 50% Maturity
0.544	0.580422	698 mm TL	0.06	-3.5	3.021	226 mm TL

* From CDFG web-site (www.dfg.ca.gov/mrd/lifehistories/index.html)

** Love et al. 1996

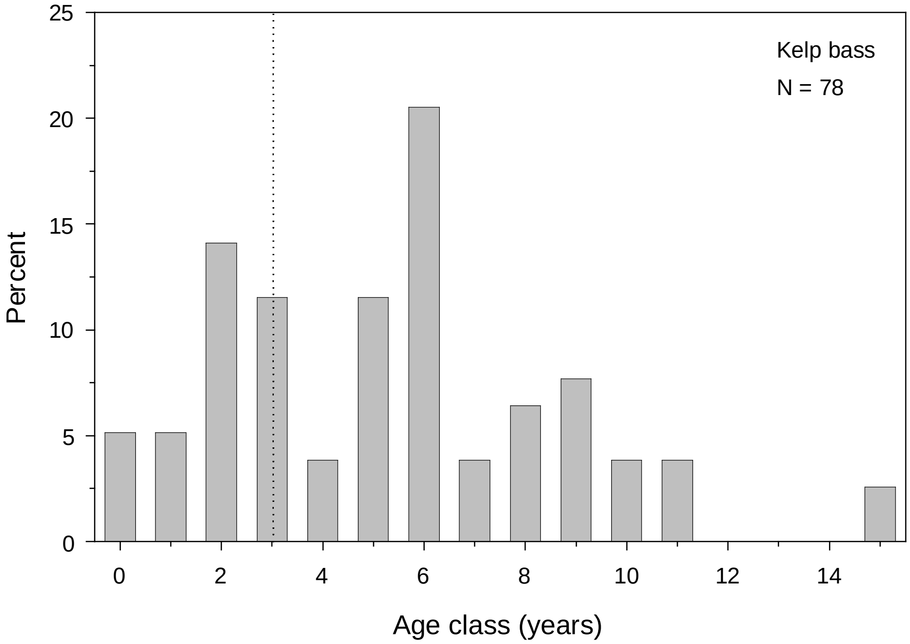


Figure 5.5-24. Distribution of kelp bass age classes in ESGS impingement samples. Vertical dotted line denotes age at 50% maturity.

5.5.2.5 Northern anchovy *(Engraulis mordax)*


Mark Conlin

Northern anchovy (*Engraulis mordax* Girard 1854) range from Cape San Lucas, Baja California to Queen Charlotte Island, British Columbia, and offshore to 480 km (Hart 1973). They are most common from Magdalena Bay, Baja California to San Francisco Bay and within 157 km of shore (Hart 1973; MBC 1987). Northern anchovy is one of four species of anchovies (Family Engraulidae) that occurs off California (Miller and Lea 1972). Deepbody anchovy (*Anchoa compressa*) and slough anchovy (*Anchoa delicatissima*) are found in the vicinity of the ESGS, while the anchoveta (*Cetengraulis mysticetus*) is considered rare north of Magdalena Bay, Baja California.

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

5.5.2.5.1 Life History and Ecology

The reported depth range of northern anchovy is from the surface to depths of 300 m (984 ft) (PFMC 1983). Juveniles are generally more common inshore and in estuaries. Eggs are found from the surface to 50 m, and larvae are found from the surface to 75 m in epipelagic and nearshore waters (Garrison and Miller 1982). Northern anchovy larvae feed on dinoflagellates, rotifers, and copepods (MBC 1987). Juveniles and adults feed on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971; Frey 1971; Hart 1973; PFMC 1983). Northern anchovy feed largely during the night, though they were previously thought to feed during the day (Allen and DeMartini 1983).

Northern anchovy spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978). Most spawning takes place within 100 km from shore (MBC 1987). On average, female anchovies off Los Angeles spawn every 7 to 10 days during peak spawning periods, approximately 20 times per year (Hunter and Macewicz 1980; MBC 1987). In 1979, it was determined that most spawning occurs at night (2100 to 0200 hr), with spawning complete by 0600 hr (Hunter and Macewicz 1980). Northern anchovies off southern and central California can reach sexual maturity by the end of their first year of life, with all individuals being mature by four years of age (Clark and Phillips 1952; Daugherty et al. 1955; Hart 1973). Bergen and Jacobsen (2001) stated that they are mature by two years of age, and that maturation of younger individuals is dependent on water temperature. 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 produce up to 320,000 eggs per year.

Northern anchovies hatch from the egg stage in two to four days and have a larval phase lasting approximately 70 days at which time they transform into juveniles at a length of about 35–40 mm (Hart 1973; MBC 1987; Moser 1996). Larvae begin schooling at 11–12 mm SL (Hunter and Coyne 1982). Northern anchovy reach 102 mm in their first year, and 119 in their second (Sakagawa and Kimura 1976). Growth in length occurs rapidly during the first four months, while weight increases more gradually during the first year (Hunter and Macewicz 1980; PFMC 1983). They mature at 78–140 mm in length, in their first or second year (Frey 1971; Hunter and Macewicz 1980). Maximum size is about 230 mm and 60 g (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 are random planktonic feeders, filtering plankton as they swim (Fitch and Lavenberg 1971). They feed mostly on larval crustaceans, but also on fish eggs and larvae (Fitch and Lavenberg 1971). Temperatures above 25°C are avoided by juveniles and adults (Brewer 1974). Numerous fishes and marine mammals feed on northern anchovy. Elegant tern and California brown pelican production is strongly correlated with abundance of northern anchovy (Emmett et al. 1991).

Larval survival is strongly influenced by the availability and density of appropriate phytoplankton species (Emmett et al. 1991). Storms and strong upwelling reduce larval food availability, and strong upwelling may transport larvae out of the Southern California Bight (Power 1986). However, strong upwelling may benefit juveniles and adults.

5.5.2.5.2 Population Trends and Fishery

Northern anchovy are fished commercially for reduction (e.g., fish meal, oil, and paste) and live bait (Bergen and Jacobsen 2001). This species is the most important bait fish in southern California, and is also used in Oregon and Washington as bait for sturgeon (*Acipenser* spp.), salmonids (*Oncorhynchus* spp.), and other species (Emmett et al. 1991). Northern anchovy populations increased dramatically during the collapse of the Pacific sardine fishery, suggesting competition between these two species (Smith 1972).

Estimates of the central subpopulation averaged about 359,000 tons from 1963 through 1972, then increased to over 1.7 million tons in 1974, 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 temperature.

Annual landings in the Los Angeles region since 2000 have varied from a high of 3.7 million kg (8.1 million lb) in 2001 to a low of 136,000 kg (0.3 million lb) in 2004, with an average of about 1.36 million kg (3 million lb) annually (Table 5.5-12). In 2005, northern anchovy landings in the Los Angeles area totaled 1,992,064 kg (4,392,501 lb) at a value of $191,664 (CDFG 2006). Commercial landings of northern anchovy reported from catch blocks in the Santa Monica Bay area totaled 11,356 kg (25,040 lb) in 2006, at an estimated value of $663 (CDFG 2007b).

Table 5.5-12. Annual landings and revenue for northern anchovy in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**(kg)**	**(lb)**	**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

Northern anchovy was the eleventh most abundant species analyzed during the 1978-1980 316(b) demonstration at Units 1 & 2, and the seventh most abundant species at Units 3 & 4 (SCE 1982b). During that study, impingement averaged less than one fish per day at Units 1 & 2 and about three fish per day at Units 3 & 4. From 2003 through 2005, estimated annual impingement of northern anchovy ranged from 43 individuals (2003) to 142 individuals (2004) (MBC 2007). Since 1990, 6,923 northern anchovy were estimated to have been impinged at the ESGS, an average of about 433 individuals per year. Highest impingement occurred in 1996 (3,855 individuals) and 1997 (959 individuals).

5.5.2.5.3 Sampling Results

Northern anchovy was observed exclusively during heat treatment surveys at Units 3 & 4 in 2006 (Table 5.5-2). A total of 78 individuals weighing 1.137 kg (2.507 lb) was impinged during the four heat treatments, including one in January and 77 in April. All of these were measured to the nearest millimeter standard length with a range of 87–134 mm and a mean length of 103 mm (Figure 5.5-25). Frequency distribution among the size classes indicated a modal distribution peaking at the 100 mm SL size class, or Age Class I individuals (Parrish et al. 1986). Thirty-one individuals were assessed for their relative condition, with 96.8% dead and 3.2% alive upon inspection.

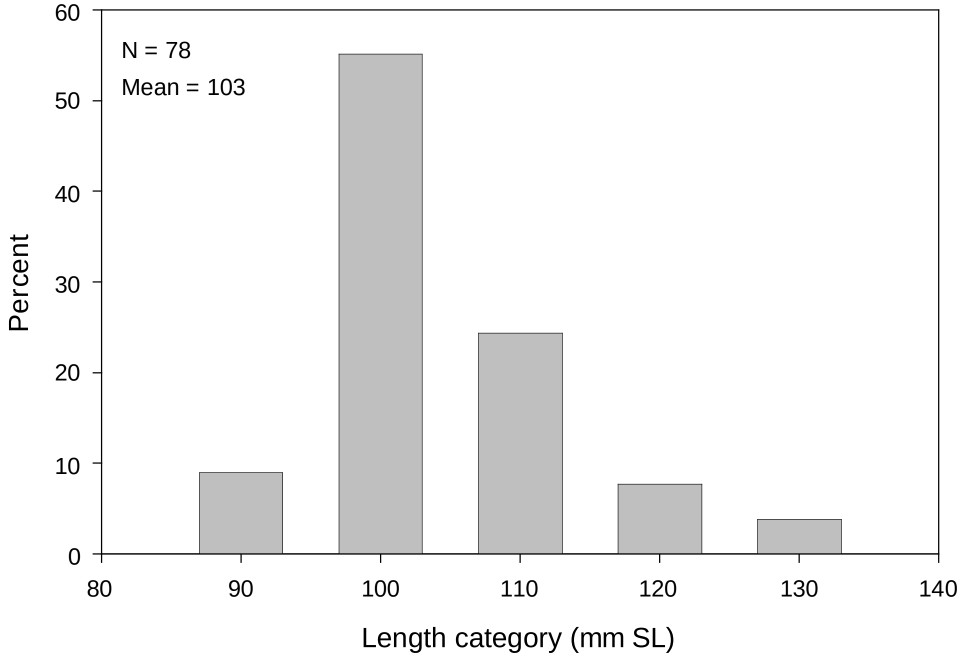


Figure 5.5-25. Length (mm) frequency distribution for northern anchovy collected in impingement samples.

5.5.2.5.4 Modeling Results

Northern anchovy life history parameters are presented in Table 5.5-13. von Bertalanffy parameters were derived from data presented for San Pedro Channel, California in Parrish et al. (1985). Annual survival estimates were calculated based on the daily mortality rate (0.997902) summarized in Butler et al. (1993). Age and size at 50% maturity, 0.986614 years and 96 mm SL, respectively, were taken from Hunter and Macewicz (1980). Northern anchovies were unique to heat treatment impingement, with a total of 78 individuals impinged. Lengths of these individuals, in association with the appropriate life history parameters, equated to 127 50% maturity equivalents, using either actual cooling water intake or design (maximum capacity) flow volumes. The distribution of northern anchovy age classes of the 78 measured individuals is presented in Figure 5.5-26.

Table 5.5-13. Northern anchovy life history parameters used in equivalent adult modeling.

		von Bertalanffy growth parameters**				
Adult Annual Instantaneous Mortality (Z)*	**Survival (S)**	**L_{inf}**	**k**	**t_0**	**Age at 50% Maturity*** **	**Length at 50% Maturity*** **
0.997902	0.464636	135.7 mm SL	0.784	-0.58	0.987	96 mm SL

* Calculated from Butler et al. (1993)
** Calculated from Parrish et al. (1985)
*** Hunter and Macewicz (1980)

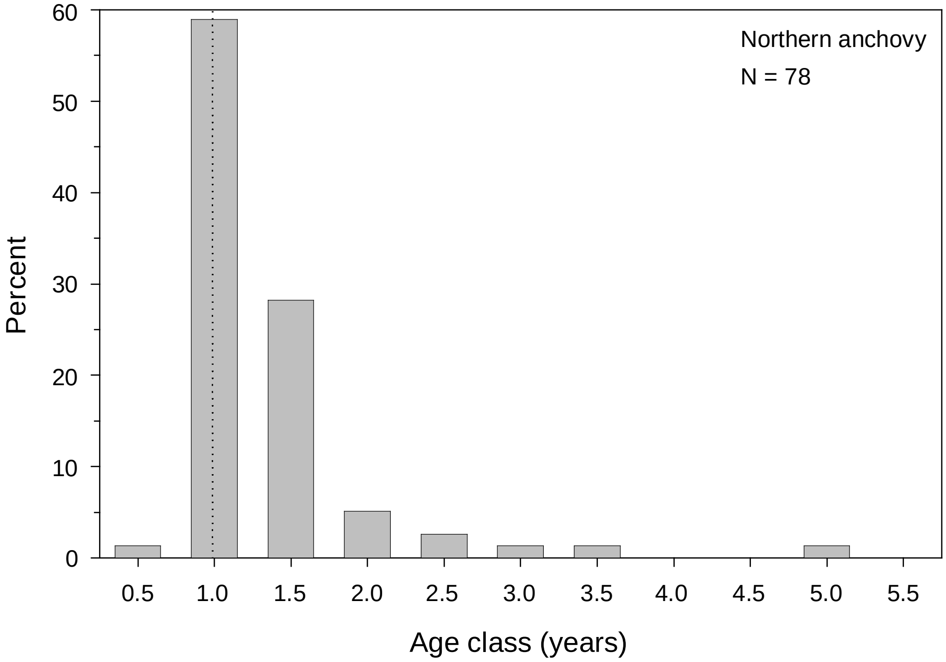
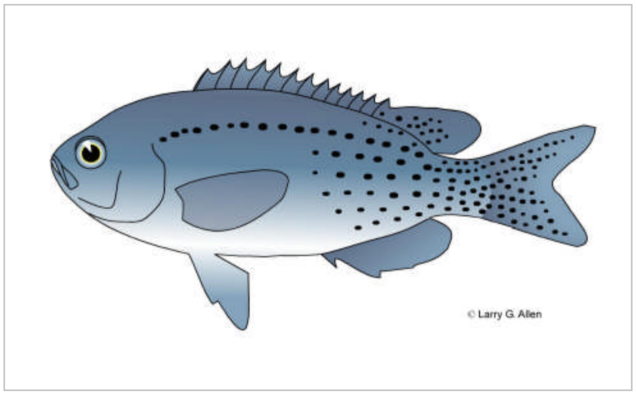


Figure 5.5-26. Distribution of northern anchovy age classes in ESGS impingement samples. Vertical dotted line denotes age at 50% maturity.

5.5.2.6 Blacksmith *(Chromis punctipinnis)*



Blacksmith ranges from Pt. San Pablo, Baja California, Mexico to Monterey, California in depths from the surface to 46 m (Miller and Lea 1972). It is one of only two species of the family Pomacentridae common to southern California, the other being garibaldi (*Hypsypops rubicundus*). Both species were included in the 'southern kelp reef species' assemblage described by Allen and Pondella (2006). Blacksmith have been frequently observed in impingement sampling throughout southern California since 1990 (MBC unpubl. data).

5.5.2.6.1 Life History and Ecology

Limbaugh (1964) reported blacksmith to frequently occur over high-relief rocky reefs, with or without kelp. Quast (1968c) reported similar findings, with densities increasing among more southward stations in San Diego, California and into Mexican waters as compared with more northerly stations, such as Gaviota, California, with densities increasing seasonally with the onset of reproductive activities. Quast (1968a) included blacksmith in his Zone III classification for their common occurrence within the open water areas of the kelp bed, typically below the area occupied by topsmelt (*Atherinops affinis*). Within this zone, blacksmith commonly prey on small "microscopic" prey items such as various planktonic organisms, such as copepods, mysids, and crustacean eggs (Limbaugh 1964; Quast 1968b). Hobson and Chess (1976) reported blacksmith primarily hunt during daylight hours, before retreating to the caves and crevices of the reef at night. Blacksmith ranked higher in abundance at Santa Catalina Island (20th) than along the mainland (35th) in fish assemblages sampled by gillnet from 1996 to 1998, indicating slight preference for the island, which may be attributed to the greater overall frequency of rocky reef habitat (Pondella and Allen 2000). Along the Los Angeles Federal Breakwall, blacksmith numerically dominated the overall assemblage, accounting for nearly 57% of all fishes, many of which were recently recruited juveniles (Froeschke et al. 2005).

Blacksmith lay eggs in closely guarded nests created by the males, often in holes or caves throughout the reef (Limbaugh 1964). This author described the courtship has aggressive, with the male frequently biting and harassing the female as he led her to his nest. Once the eggs are laid, the female is chased off while the male continues to guard the nest; otherwise the eggs are subject to predation from nearby reef fishes. Pelagic larvae are typically observed from midsummer to early fall. Juvenile blacksmith were frequently observed in large schools, typically from August through October (Limbaugh 1964; Froeschke and Allen 2006). Little information is available in the primary literature regarding age and growth of blacksmith (Cailliet et al. 2000). Limbaugh (1964) suggested blacksmith mature at 140 mm, or approximately two years old.

5.5.2.6.2 Population Trends and Fishery

Blacksmith is not the subject of any targeted fishery, commercial or recreational, although they do occur as bycatch in both. They are commonly taken by pier fishermen as well as recreational anglers fishing adjacent to rocky reefs. The NMFS Los Angeles Times recreational fishing database recorded an annual mean landing of 2,182 blacksmith from all landings ranging from Paradise Cove on the northwestern edge of the Santa Monica Bay south to San Diego, California over the period 1991-2003 (NMFS 2007). Due to the random nature of the recreational fishing data, no real population trends can be determined for blacksmith. In 2005, blacksmith landings in the Los Angeles area totaled 25.8 kg (57 lb) at a value of $32 (CDFG 2006). There were no commercial landings of blacksmith reported from catch blocks in the Santa Monica Bay area in 2006 (CDFG 2007b).

Blacksmith was not analyzed in detail in the 1978–1980 316(b) demonstration (SCE 1982b). During that two-year study, only 16 individuals were impinged at Units 1 & 2 and 55 individuals were impinged at Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of blacksmith ranged from 2 individuals (2004) to 333 individuals (2005) (MBC 2007). Since 1990, 4,458 blacksmith were estimated to have been impinged at the ESGS—an average of about 279 individuals per year. However, nearly 63% of the individuals impinged were recorded from 1990 through 1992.

5.5.2.6.3 Sampling Results

At Units 1 & 2, 34 blacksmith (*Chromis punctipinnis*) weighing 2.252 kg (4.966 lb) were impinged during normal operations (Table 5.5-1). At Units 3 & 4, 189 blacksmith weighing 5.229 kg (11.530 lb) were impinged overall, with 63 individuals weighing 4.810 kg (10.606 lb) collected during heat treatments and an additional 126 individuals weighing 0.419 kg (0.924 lb) collected during normal operations (Table 5.5-2). The three individuals collected at Units 3 & 4 were observed in September, with two of the three individuals collected at night. The one individual collected at Units 1 & 2 was observed during daytime in March. Of the 63 individuals recorded during heat treatments, 51 occurred in January. A total of 67 individuals were measured with a mean length of 162 mm SL ranging from 50 to 229 mm SL and a bimodal distribution with peaks at 90 – 100 mm SL and 140 mm SL (Figure 5.5-27), which equates to approximately young-of-the-year and 2-year-old individuals (Limbaugh 1964). Of these 67 individuals only one (1.5%) was still alive when collected.

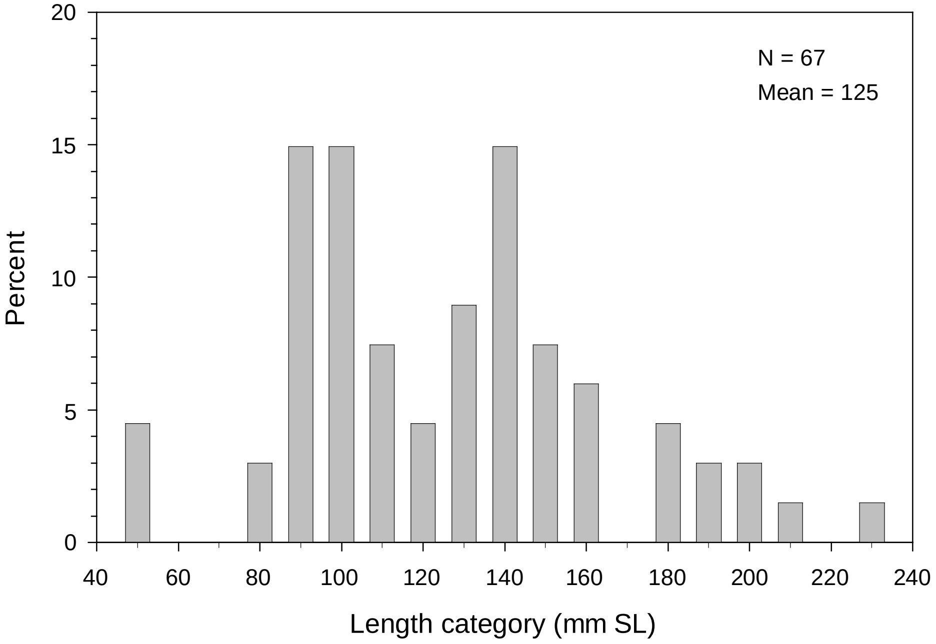
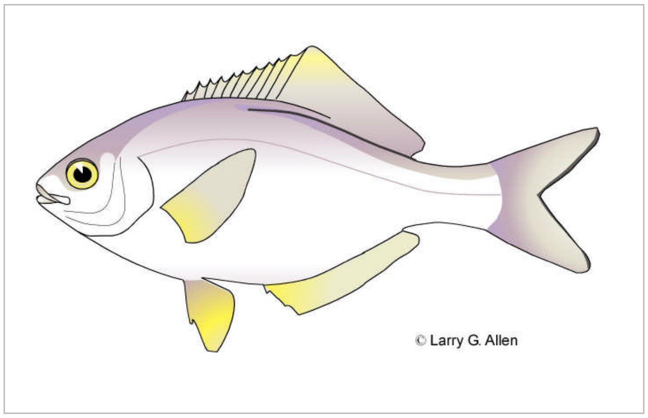


Figure 5.5-27. Length (mm) frequency distribution for blacksmith collected in impingement samples.

5.5.2.7 White seaperch (*Phanerodon furcatus*)



White seaperch (*Phanerodon furcatus*) ranges from Bahia San Carlos, Baja California, Mexico to Vancouver Island, British Columbia, Canada ranging in depths from the surfzone to 70 m (Miller and Lea 1972; Love et al. 2005). Allen and Pondella (2006) included white seaperch in their 'southern shallow rock-sand' species group. White seaperch have been commonly observed in low abundances during impingement sampling at southern California coastal generating stations (MBC unpubl. data).

5.5.2.7.1 Life History and Ecology

Feder et al. (1974) noted that white seaperch tend to form loose schools in open water around the reef along the rock-sand interface. Helvey and Dorn (1981) reported white seaperch to be common around offshore cooling water structures in southern California, especially in fall and summer.

Like all surfperch, kelp perch are viviparous, producing free-swimming, fully developed young. The young are often larger than the typical 9.5-mm (3/8-in) screen mesh at most coastal generating stations, preventing their entrainment and transport throughout the cooling water system. Feder et al. (1974) reported that young were observed in September.

Age and growth in white seaperch have been studied in two disjoint populations, one in Humboldt Bay, California and one in Anaheim Bay, California (Anderson and Bryan 1970; Eckmayer 1979). Both studies recorded individuals up to seven years old, with the northern population attaining a greater size (214 mm SL) than the southern individuals (195 mm SL), based on growth model estimations. Both populations exhibited the greatest growth over the first two years before markedly slowing.

5.5.2.7.2 Population Trends and Fishery

Surfperch commercial landings, overall, steadily declined from a peak in 1982, with some research indicating the decline may partially be attributable to increased water temperature that dominated the northeast Pacific Ocean throughout much of the 1980s and 1990s (Fritzsche and Collier 2001). Fishery dependent data on white seaperch, specifically, is limited as they are of minimal importance as a commercial or recreational fishery and are generally taken only as bycatch. The lack of interest may be due to their preference for small prey items. The bulk of recorded surfperch landings can be attributed to other species of surfperch. Total statewide recreational landings of surfperches were 489,000 fish in 1999, with most of the catch in central and northern California (Fritzche and Collier 2001). Commercial landings in the Los Angeles area have fluctuated between about 136 and 1,361 kg (300 and 3,000 lb) per year since 2000 (Table 5.5-7). In 2005, surfperch landings in the Los Angeles area totaled 21.3 kg (47 lb) 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 lb) in 2006, at an estimated value of $1,092 (CDFG 2007b).

White seaperch was the third most abundant species analyzed during the 1978-1980 316(b) demonstration at Units 1 & 2, and the fourth most abundant species at Units 3 & 4 (SCE 1982b). Average daily impingement during that study was about 12 individuals at Units 1 & 2 and 13 individuals at Units 3 & 4, with the majority of impingement occurring during heat treatments. From 2003 through 2005, estimated annual impingement of white seaperch ranged from 13 individuals (2004) to 40 individuals (2003) (MBC 2007). Since 1990, 757 white seaperch were estimated to have been impinged at the ESGS, an average of about 47 individuals per year. Highest impingement occurred in 1993 (226 individuals).

5.5.2.7.3 Sampling Results

White seaperch were only impinged at Units 3 & 4 in 2006 (Table 5.5-2). In total, an estimated 65 individuals weighing 4.067 kg (8.967 lb) were impinged during the year. Of these, 37 individuals weighing 3.840 kg (8.467 lb) were observed during heat treatments while the remaining 28 individuals at 0.227 kg (0.501 lb) were estimated to be impinged during normal operations. The one individual observed during normal operation surveys was collected during the day in June. All observed individuals were measured to the nearest millimeter standard length, and ranged from 54 to 192 mm with a mean of 151 mm (Figure 5.5-28). Length frequency distribution indicated a trimodal distribution with peaks in the 60, 120, and 170 mm SL size classes corresponding to young of the year, Age Class I, and Age Class IV (Eckmayer 1979). The sex of 20 individuals was determined with 55% female and 45% male. Additionally, the condition of 38 individuals was determined with 92.1% dead and 7.9% mutilated.

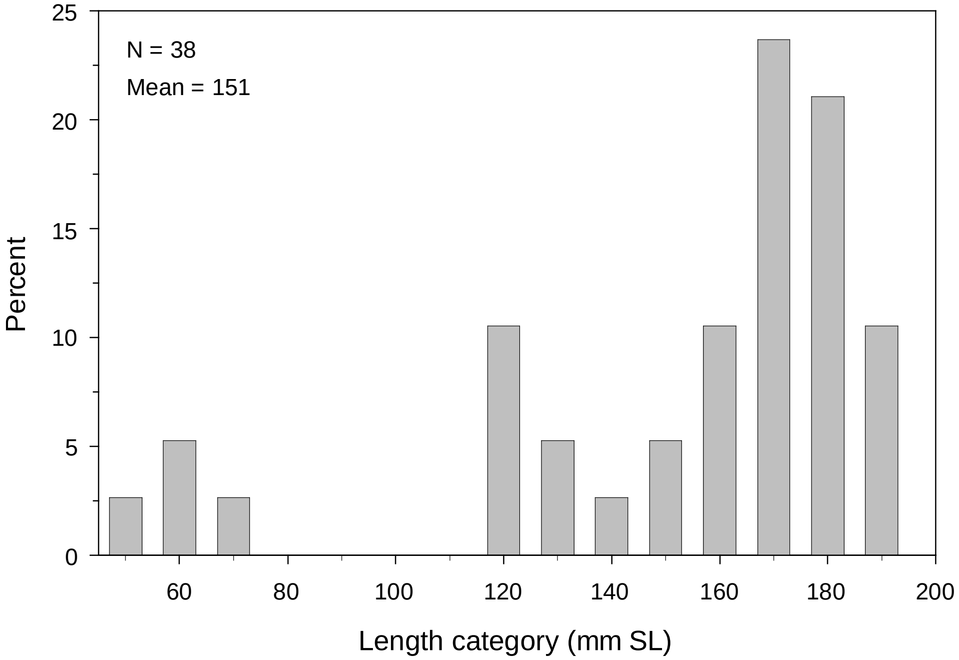
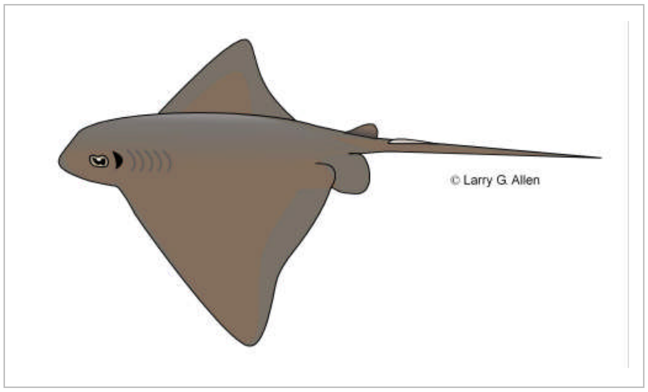


Figure 5.5-28. Length (mm) frequency distribution for white seaperch collected in impingement samples.

5.5.2.8 Bat Ray (*Myliobatis californica*)



The bat ray, *Myliobatis californica*, is found in a wide variety of habitats ranging from Oregon to the Gulf of California. They are most commonly found in shallow inshore water bodies from northern California southward (Love 1996; Zorzi et al. 2001). Bat rays are one of two species belonging to the family Myliobatidae, which is one of eight families in the order Myliobatiformes. Rays in this order are all warm water organisms found close to shore (Bond 1996). With the bat rays ability to adapt to varying bottom environments and their wide food source, they are commonly seen at most coastal and estuarine generating stations in southern California.

5.5.2.8.1 Life History and Ecology

The habitat distribution of the bat ray is widely ranged. They are commonly found in muddy or sandy bottoms in bays as well as rocky intertidal areas and kelp beds. They range from near surface waters and have been found as deep as 60 m (198 ft), although they are more commonly found to 46 m (150 ft) (Love 1996; Zorzi et al. 2001). Routinely found lying on or buried in the substrate, they are also found swimming in midwater and surface areas, typically at night (Love 1996).

Bat rays bear live young. The gestation period is estimated to last anywhere from nine to twelve months with spawning occurring during summer months. A female can produce anywhere from two to twelve young per litter with individuals 228 to 304 mm wide at birth (Love 1996; Zorzi et al. 2001).

Length being measured by disc width (wingtip to wingtip), females will reach a greater size than males, with a maximum disc width of 1.8 m and a weight of 95 kg. The growth rate for the bat ray is rather slow; males grow slower than females and have a shorter life span living to approximately six years. A ray 609 mm wide is two to four years old, with a 914 mm ray being approximately seven years, and a twelve year old being 1.219 m wide. A male bat ray matures at two to three years and a female at five to seven years (Love 1996; Zorzi et al. 2001).

Bat rays are one of three ray species that use hydraulic action through the movement of their large pectoral fins to dislodge prey with their blunt heads and thick snouts. They can also use their large wing-like fins to remove sand and mud from the bottom with a flapping motion to expose their prey. Feeding on such organisms as clams, marine snails, shrimps, crabs, and other invertebrates, bat rays break down their food with the use of broad grinding plates, which are used as teeth (Bond 1996; Love 1996; Zorzi et al. 2001). The sting of the bat ray contains a poison, which is used in defense by a striking motion of the tail. The sting as well as the tail can be broken off without causing mortality to the bat ray; this is one reason why rays are typically measured by disc width instead of total length.

5.5.2.8.2 Population Trends and Fishery

Bat rays are caught from pier and vessel anglers as well as from shore. They are most commonly targeted by nighttime shore anglers in southern California. Occasionally there is a small market for bat rays in southern California. These are incidental catches taken by gillnet and trawl fishermen who are otherwise targeting other species (Zorzi et al. 2001). The wings of rays and skates are marketed by the commercial fishery. Typically the bodies are discarded; however on occasion they may be sold as bait for the rock crab fishery (Zorzi et al. 2001). Retail markets and restaurants have been known to use circular cut-outs of ray wings and sell them as a substitute for scallops.

In 2005, bat ray landings in the Los Angeles area totaled 2,463.5 kg (5,432 lb) at a value of $1,850 (CDFG 2006). Landings were reported from the ports of San Pedro, Terminal Island, Huntington Beach, and Los Angeles. There were no reported commercial landings of bat ray from catch blocks in the Santa Monica Bay area in 2006 (CDFG 2007b).

Bat ray was not analyzed during the 1978-1980 316(b) demonstration at ESGS (SCE 1982b). During the two-year impingement study 18 individuals were impinged at Units 1 & 2 and 112 were impinged at

Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of bat ray ranged from no individuals (2004) to six individuals (2003) (MBC 2007). Since 1990, 289 bat rays were estimated to have been impinged at the ESGS, an average of about 18 individuals per year. Highest impingement occurred in 1997 (78 individuals).

5.5.2.8.3 Sampling Results

Bat ray was only observed at Units 3 & 4 during normal operations and heat treatments (Table 5.5-2). An estimated total of 96 individuals weighing 47.260 kg (104.208 lb) was impinged during the year with 35 individuals weighing 24.275 kg (53.526 lb) impinged during heat treatments and the remaining 61 individuals and 22.985 kg (50.682 lb) impinged during normal operations. Two individuals were collected during normal operation surveys, with one individual collected at night in April and the other during daytime in June. The disc width of 36 individuals was measured with a range of 169 to 579 mm and a mean of 323 mm (Figure 5.5-29). The distribution of size classes indicated a highly variable distribution with peaks in the 230 and 300 mm DW size classes, or young of the year. Of these 36 individuals, 63.9% were female and 36.1% were male. Additionally, 94.4% of these individuals were dead and 5.6% were alive when collected.

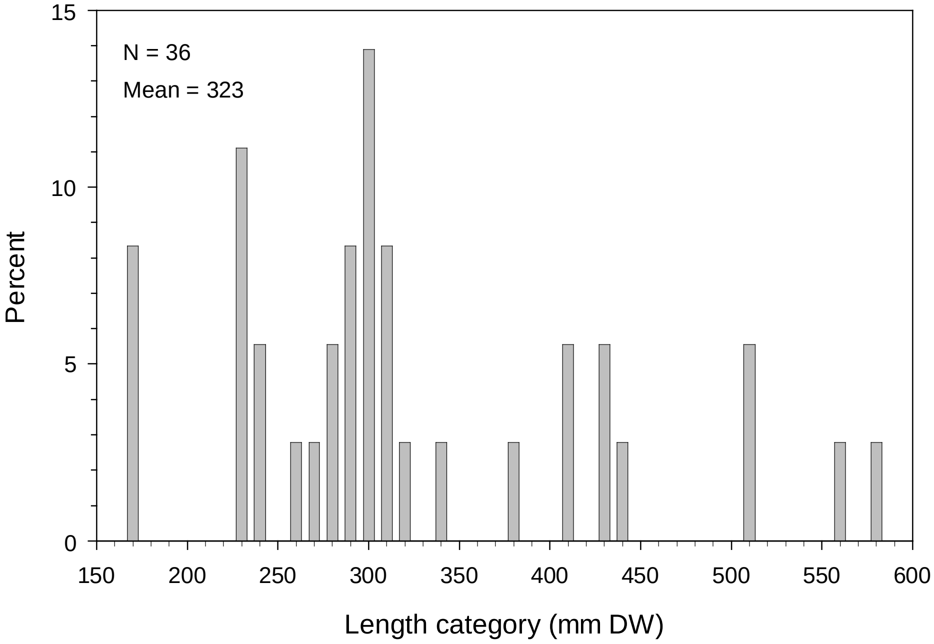
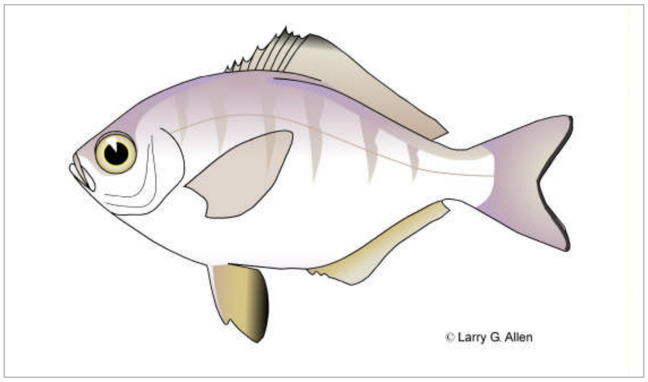


Figure 5.5-29. Disc width (mm) frequency distribution for bat ray collected in impingement samples.

5.5.2.9 Walleye surfperch *(Hyperprosopon argenteum)*



Walleye surfperch (*Hyperprosopon argenteum*) is a member of the Family Embiotocidae, the surfperches (Eschmeyer and Herald 1983; Fritzsche and Collier 2001). Fish of this family are perch-like, compressed laterally with an elliptical shape and forked tail. Most species occurring off California are found in beaches, rocky reefs, and kelp beds. Surfperches reproduce by internal fertilization and vivipary, bearing live young.

Defining characteristics of the walleye surfperch include silver to bluish coloration, black tipped pelvic fins, and large eyes (Miller and Lea 1972; Eschmeyer and Herald 1983; Fritzsche and Collier 2001). The range of the walleyes extends south of Vancouver Island, British Columbia to Punta San Rosarito, central Baja California, Mexico; though they are most abundant in southern California (Love et al. 2005).

5.5.2.9.1 Life History and Ecology

Walleye surfperches inhabit the shallow waters to depths of 18 m (60 ft), often along the surf zone of sandy beaches, among piers, and within kelp beds. This species is often encountered in schools. Walleye surfperches can grow up to 30 cm (12 in) (Miller and Lea 1972; Eschmeyer and Herald 1983). Their fastest growth rate occurs during the first year then decreases consistently over time following sexual maturity (Anderson and Bryan 1970; Eckmayer 1979; DeMartini et al. 1983). Female surfperches achieve sexual maturation at as small as 9.5 cm (3.7 in), within a year after birth, and begin mating in the fall or winter (DeMartini et al. 1983; Fritzsche and Collier 2001). Larger, older females generally become pregnant sooner than younger females and produce numerous fully developed young. After internal fertilization occurs, gestation lasts five to six months with young released in late spring to early summer (DeMartini et al. 1983). The peak of release is late April to early May (DeMartini et al. 1983). On average, females birth five to twelve young at about 3.8 cm (1.5 in) in length, with number of young dependent on the size of the female (Fritzsche and Collier 2001). These surfperches generally forage along the bottom feeding on polychaetes, mollusks, isopods, and small crustaceans such as sand crabs (Eschmeyer and Herald 1983; Fritzsche and Collier 2001).

5.5.2.9.2 Population Trends and Fishery

The commercial fishery for surfperches in general has been variable with a relatively low demand for fresh surfperch (Fritzsche and Collier 2001). Until 1987, the California Department of Fish and Game did not have a separate market for surfperches. In 1999, the total catch for all surfperches was 68,039 kg (49,000 lb) (Fritzsche and Collier 2001). The recreational fishery, on the other hand, brings in high landings of surfperch. Surfperches overall are popular sport fishery species. Walleyes, specifically, numbered 164,000 in the 1993 catch, with pier, shore, and jetty landings comprising 90% of the catch (Fritzsche and Collier 2001). Currently, sport take is calculated to average 112,000 fish annually, and no restriction on catches of walleye surfperch has been set (Fritzsche and Collier 2001). However, the total walleye population is unknown, thus the effects of fishing on the population is unknown (Fritzsche and Collier 2001).

Walleye surfperch was the second most abundant species analyzed during the 1978-1980 316(b) demonstration at Units 1 & 2, and the fifth most abundant species at Units 3 & 4 (SCE 1982b). The estimated daily impingement during the two-year study was about 26 individuals per day at Units 1 & 2 and 12 individuals at Units 3 & 4. From 2003 through 2005, estimated annual impingement of walleye surfperch ranged from 0 individuals (2005) to 248 individuals (2003) (MBC 2007). Since 1990, 4,048 walleye surfperch were estimated to have been impinged at the ESGS, an average of about 253 individuals per year. Highest impingement occurred in 1997 with 1,264 individuals.

5.5.2.9.3 Sampling Results

Walleye surfperch were only collected during heat treatments at Units 3 & 4 in 2006 (Table 5.5-2). During the four heat treatments a combined total of 34 individuals weighing 2.043 kg (4.505 lb) was impinged. Of these, 24 individuals (71%) occurred during the April heat treatment. All of the individuals were measured with lengths ranging from 42 to 155 mm SL with a mean length of 121 mm SL. Length frequency distribution indicates a modal distribution with a peak in the 120-mm SL, or near their second birthday, and a single young of the year individual in the 40-mm SL size class (Figure 5.5-30). The sex of 27 individuals was determined with 59.3% male, 37.0% female, and 3.7% juvenile. Of the 34 individuals that were assessed for their condition, 79.4% were dead and 20.6% were mutilated.

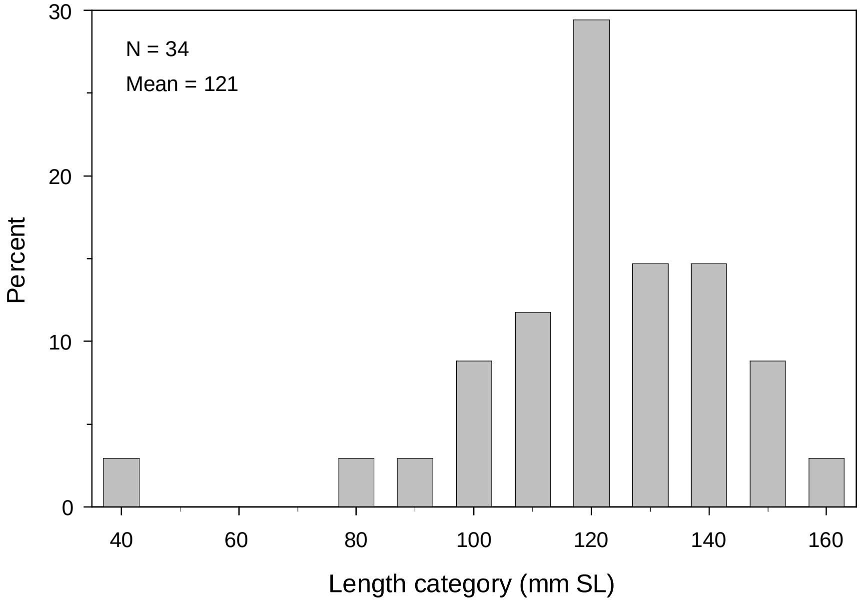
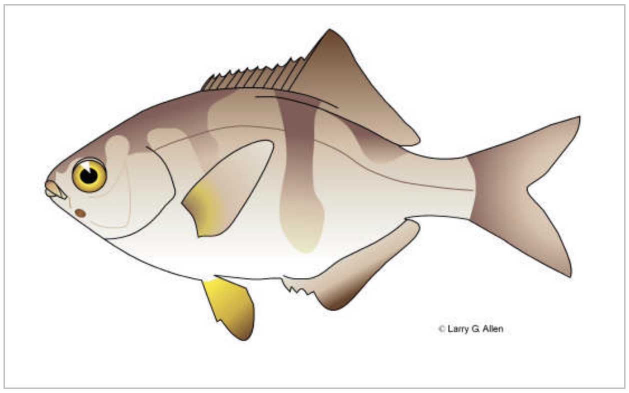


Figure 5.5-30. Length (mm) frequency distribution for walleye surfperch collected in impingement samples.

5.5.2.10 Pile perch *(Rhacochilus vacca)*



Pile perch (*Rhacochilus vacca*) is a relatively large (to 44 cm, 17.5 in) member of California's nearshore surfperch (Embiotocidae) community (Eschmeyer and Herald 1983; Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001). Pile perch is found from southeastern Alaska to north-central Baja California, including Guadalupe Island, but occurs more commonly south of British Columbia.

5.5.2.10.1 Life History and Ecology

Typically an inshore species, pile perch are common in rocky areas, in kelp beds, and around piers and underwater structures, from the shallow subtidal to about 46 m (150 ft) where they are active during the day. Pile perch are blackish, gray, or brownish above and silvery below with a dark bar mid-body and a distinctive dorsal fin with the first soft rays longer than the others, giving the fin a peaked shape. In the field, pile perch may be observed singly, in small schools or larger aggregations. They prefer cooler water and at Redondo Beach in southern California the species is known to move into shallow depths (4-5 m, 13-16 ft) in winter and spring and more offshore (8 m, 26 ft) when water temperatures rise in summer and fall (Fritzsche and Hassler 1989; Love 1996).

Individuals may live up to ten years, becoming sexually mature during their second year at about 18 cm (7 in) (Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001). In fall, breeding males become very dark, almost black, with black spots on their snouts (Eschmeyer and Herald 1983; Love 1996). Courtship involves males darkening and leaving the protection of their normal habitat to hang head down in the mid water column (Love 1996). Aggression among males during courtship has been observed and single males have been seen escorting multiple females. Mating occurs when a pair of pile perch swimming in the same direction turns on their sides or backs and briefly brings their urogenital openings into contact (Fritzsche and Hassler 1989). Spawning in southern California pile perch begins in April (Love 1996). Like all surfperches, pile perch are viviparous, with the young being highly developed at birth. Brood size in pile perch is correlated to size, weight and age of the female (Fritzsche and Hassler 1989). At the age of first reproduction females produce 11.7 offspring on average, while older individuals (7 to 10 years) may produce broods of up to 60 young. The birth of the perch in late spring and early summer coincides with maximum kelp and algae cover available to the small perch for protection.

Pile perch have strong, well-developed teeth that allow them to feed on hard-shelled animals (Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001). In the laboratory they have been observed to feed on whole mussels up to 2.5 cm (1 in) long, and even newborns are known to eat small clams and mussels. In the field, pile perch feed on a wide variety of hard-bodied animals such as brittle stars, crabs, snails, clams and mussels. Young pile perch are vulnerable to larger fish such as kelp bass, while adults are preyed on by larger predators including electric rays, sharks, large basses, pinnipeds and cormorants (Fritzsche and Hassler 1989; Love 1996).

5.5.2.10.2 Population Trends and Fishery

Pile perch are an important recreational species along the west coast of the United States (Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001). Pile perch may be caught year-round, and in California, an average of 16,000 perch were caught annually between 1993 and 1999 (Fritzsche and Collier 2001). Many are taken from piers, jetties, beaches, and boats or by spear by divers (Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001).

Pile perch have been reported to support some localized small commercial fisheries but otherwise do not contribute significantly to commercial landings in California (Fritzsche and Collier 2001). Because commercial landings do not differentiate most surfperch species, current size of the fishery and population estimates are difficult to determine, however it is estimated that the fishery averages about 90 kg (200 lb) per year (Love 1996). In 2005, pile perch landings in the Los Angeles Area totaled 12.7 kg (28 lb) at an estimated value of $28 (CDFG 2006). In 2006, the Santa Monica Bay catch blocks of unspecified surfperch (which may include pile perch) totaled 117 kg (258 lb) at a value of $1,092 (CDFG 2007b).

Pile perch was not analyzed during the 1978-1980 316(b) demonstration at the ESGS (SCE 1982b). During that two-year study, 228 individuals were recorded at Units 1 & 2 and 259 individuals from Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of pile perch ranged from 8 individuals (2004) to 27 individuals (2005) (MBC 2007). Since 1990, 399 pile perch were estimated to have been impinged at the ESGS, an average of about 25 individuals per year. Highest impingement occurred in 1991 (62 individuals).

5.5.2.10.3 Sampling Results

All of the observed pile perch were recorded during heat treatments at Units 3 & 4 (Table 5.5-2). A total of 30 individuals weighing 4.976 kg (10.972 lb) were impinged during the year, including 16 in April and 10 in June. Standard lengths were recorded for all of these individuals with lengths ranging from 54 to 269 mm with a mean length of 152 mm. Length frequency distribution was highly variable with equal peaks in the 150 and 170 mm SL size classes (Figure 5.5-31), corresponding to individuals near their second year. The sex was determined for 29 individuals with 44.8% male, 31.0% female, and 24.1% juvenile. All of the 30 individuals collected were dead at the time of examination.

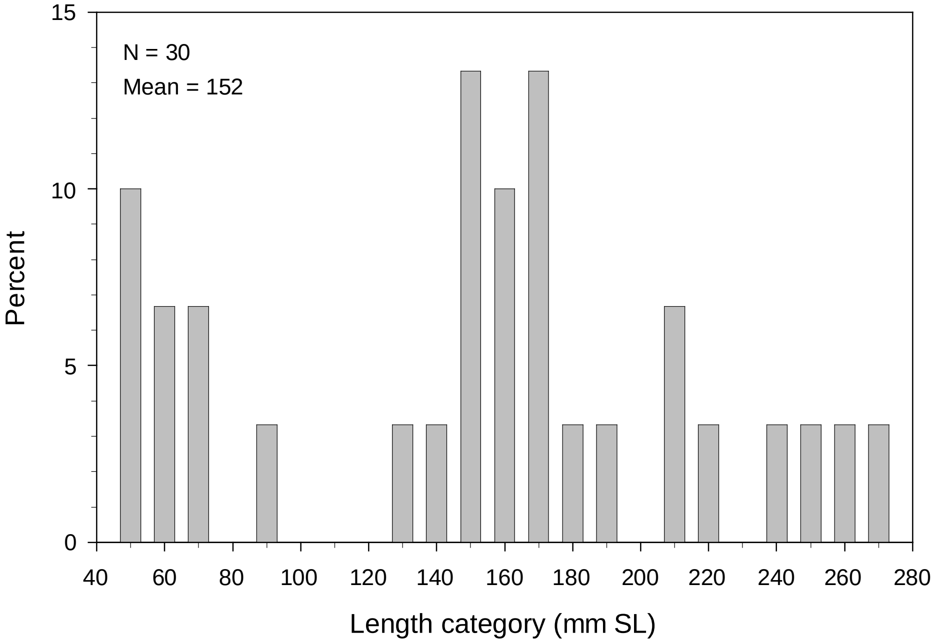
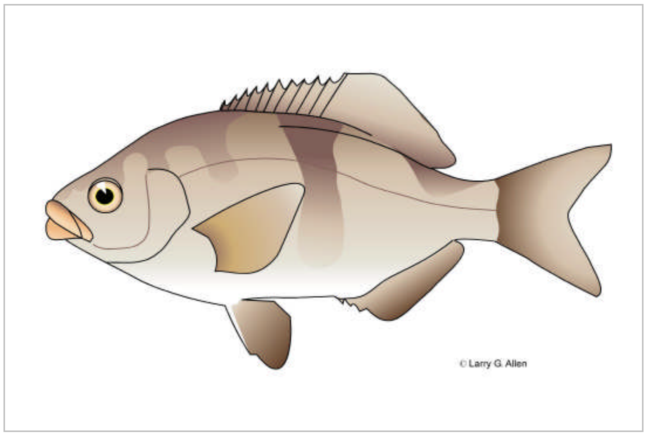


Figure 5.5-31. Length (mm) frequency distribution for pile perch collected in impingement samples.

5.5.2.11 Rubberlip seaperch *(Rhacochilus toxotes)*



Rubberlip seaperch (*Rhacochilus toxotes*) is the largest member of the surfperch family (Embiotocidae), with individuals reaching up to 47 cm (18.5 in) total length (Eschmeyer and Herald 1983; Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001). Rubberlips derive their name from their very thick white or pale pink lips that distinguish them from other surfperches. The body color ranges, with most individuals silvery-green fading to brassy below, while others show with black, blue or purplish tints on the dorsal surfaces and many are dark overall (Eschmeyer and Herald 1983; Fritzsche and Hassler 1989). Adults have one or two dusky bars along the sides, while young up to 15 cm (6 in) are pinkish with a dark bar mid-side. Rubberlip seaperch ranges from Mendocino County, northern California to central Baja California, including Guadalupe Island, but are most common south of central California (Eschmeyer and Herald 1983; Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001).

5.5.2.11.1 Life History and Ecology

Rubberlips are often found in schools of 50 to 100 individuals and are abundant near hard structures such as rocky reefs, in kelp beds, around piers and underwater structures, and occasionally in quiet backwaters. While known to occur at depths from the shallow subtidal to 46 m (150 ft), they more commonly are found at between 3 and 30 m (10 to 98 ft). Adults typically occur near bottom or mid-water near the lower kelp canopy, while the young utilize the kelp understory or areas with thick cover for concealment (Fritzsche and Hassler 1989; Love 1996). Rubberlip seaperch feed both diurnally and nocturnally, and may occur slightly more frequently at night (Fritzsche and Hassler 1989).

Rubberlip surfperch have a lifespan of seven to ten years (Fritzsche and Hassler 1989). Little is known about the life history of the species. Individuals appear to be at almost 9 cm (>3.5 in) when born, about 33 cm (13 in) at 4 years, 42 cm (16.5 in) at 8 years, and 43 cm (17 in) at 9 years (Fitch and Lavenberg 1971; Love 1996). Age of sexual maturity is not known (Fritzsche and Collier 2001). Mating probably occurs in late summer or fall with males darkening and leaving the protection of their normal habitat to hang head down in the mid water column away from the protection of the kelp canopy (Love 1996). During courtship single males have been observed escorting multiple females but breeding behavior has not been noted. Spawning in southern California occurs late spring to early summer (Fitch and Lavenberg 1971. Fritzsche and Collier 2001). Like all surfperches, rubberlip seaperch are viviparous, with the young being highly developed at birth. Brood size in rubberlips has not been studied, but an eight-year-old female collected at Redondo Beach was reported with 21 nearly mature embryos (Fitch and Lavenberg 1971).

Rubberlip seaperch are considered an ‘oral winnower’, using their flexible lips to suction thin-shelled invertebrates from rocks (Love 1996; Fritzsche and Hassler 1989). The fish are then able to sort the small invertebrates from debris in their mouths, expelling the debris and swallowing the prey. Diet of the perch is almost exclusively crustaceans such as shrimp, amphipods, and small crabs, but small mollusks and algae are also occasionally taken. Young pile perch are vulnerable to larger fish such as kelp bass, while adults are preyed on by larger predators including electric rays, sharks, large basses, pinnipeds and cormorants (Fritzsche and Hassler 1989; Love 1996).

5.5.2.11.2 Population Trends and Fishery

Rubberlip seaperch is an important recreational species in California (Fitch and Lavenberg 1971; Fritzsche and Hassler 1989; Love 1996; Fritzsche and Collier 2001). Many are taken from piers, jetties, and small skiffs near kelp beds or by spear by divers. In California, recreational anglers caught an average of 19,000 rubberlips between 1993 and 2000, ranging from 13,000 in 1993 to 44,000 in 1997 (Fritzsche and Collier 2001). Recreational "surfperch" landings for southern California for 2000-2006 are presented in Table 5.5-7.

No recent estimates of the rubberlip seaperch population size are available (Fritzsche and Collier 2001). Rubberlips support a small commercial fishery in California, caught by seine or hook and line (Love 1996; Fritzsche and Collier 2001). In 2005, “surfperch” landings in the Los Angeles area totaled 21.3 kg (47 lb) at a value of $86 (CDFG 2006). Commercial landings differentiate rubberlip seaperch from other surfperch species, but in 2006, the Santa Monica Bay catch blocks indicated that no rubberlip seaperch were taken commercially during the year (CDFG 2007b).

Rubberlip seaperch was not analyzed during the 1978-1980 316(b) demonstration at the ESGS (SCE 1982b). During the two-year study, however, 69 individuals were recorded from Units 1 & 2 and 58 individuals were recorded from Units 3 & 4. From 2003 through 2005, estimated annual impingement of rubberlip seaperch ranged from two to three individuals (MBC 2007). Since 1991, 214 rubberlip seaperch were estimated to have been impinged at the ESGS, an average of about 13 individuals per year.

5.5.2.11.3 Sampling Results

An estimated 130 rubberlip seaperch weighing 8.238 kg (18.165 lb) were impinged at ESGS exclusively at Units 3 & 4 during the yearlong study (Table 5.5-2). Of these, 23 individuals weighing 6.954 kg (15.334 lb) were observed during heat treatments, while an estimated 107 individuals weighing 1.284 kg (2.831 lb) were impinged during normal operation. All four individuals collected during normal operation surveys were observed during daytime surveys in July. Standard lengths were recorded for 26 individuals ranging from 68 to 265 mm with a mean of 174 mm. Length frequency distribution of these size classes indicated a bimodal distribution with a strong peak in the 70-mm SL size class (young of the year) as well as the 240- and 250-mm SL size classes (less than four years old) (Figure 5.5-32). Of the 26 measured individuals 96.2% were dead and 3.8% were alive. The sex was determined for 23 of the measured 26 individuals with 56.5% female, 8.7% male, and 34.8% juvenile.

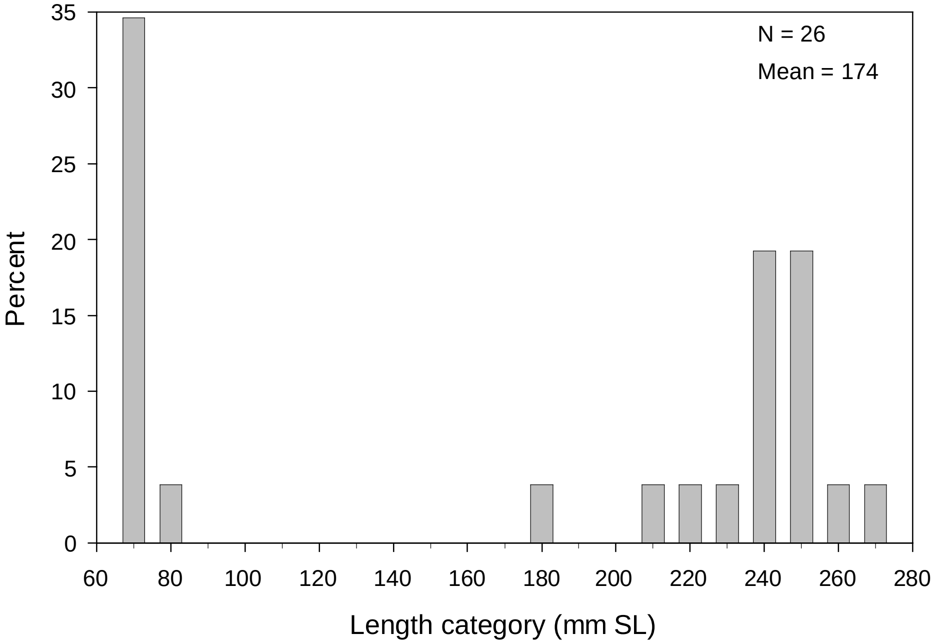
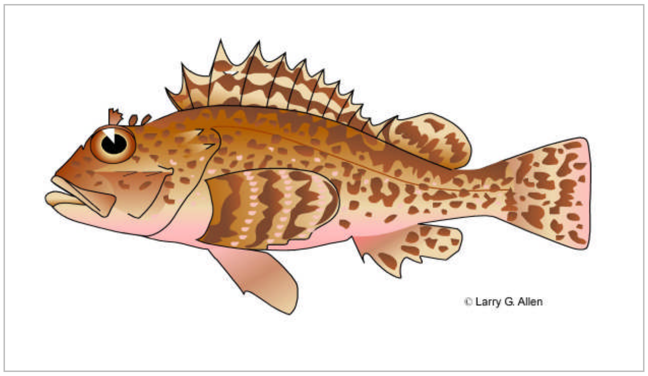


Figure 5.5-32. Length (mm) frequency distribution for rubberlip seaperch collected in impingement samples.

5.5.2.12 California scorpionfish *(Scorpaena guttata)*



California scorpionfish (*Scorpaena guttata*) ranges from Uncle Sam Bank, Baja California, Mexico to Santa Cruz, California in depths from the surf zone to 183 m (Miller and Lea 1972; Love et al. 2005). Allen and Pondella (2006) included California scorpionfish in their northern kelp and southern mid depth reef species group. California scorpionfish have been commonly observed during impingement sampling throughout southern California (MBC unpubl. data).

5.5.2.12.1 Life History and Ecology

Love et al. (1987) reported California scorpionfish was often found lodged in crevices of the reef, while they were noted to seasonally aggregate over sand and muddy bottoms. Within the reef community, California scorpionfish typically occur as a Zone I bottom mesocarnivore, primarily hunting fish and macroinvertebrates near the base of a kelp/rock reef (Quast 1968a). Exhibiting a generally southern distribution within the Southern California Bight, California scorpionfish catch rates were lowest near Santa Barbara, California before increasing with distance southward before peaking near San Diego, California as well around the Santa Catalina, San Clemente, and Coronado Islands, based on California Department of Fish and Game records (Love et al. 1987). Furthermore, these authors reported high spawning site fidelity for California scorpionfish, with all 17 of the 17 tag recoveries off Dago Bank (Horseshoe Kelp) being initially tagged and released there. They further note that few individuals were found on the bank year round, rather dense aggregations forming in late spring and summer.

California scorpionfish generally matures near 180 mm total length, or two years of age, with peak gonosomatic indices for both sexes from June through August (Love et al. 1987). The authors further hypothesized that California scorpionfish aggregate at ‘traditional’ spawning sites and engage in polygamous spawning. Characterization of the dispersal patterns of the planktonic stages has been difficult with few collected during long-term monitoring programs, namely offshore surveys by CalCOFI and within King Harbor, Redondo Beach, California (Love et al. 1987). The lack of larvae within King Harbor was further puzzling due to the relatively high abundance of young-of-the-year and 1-year-old individuals within the harbor.

Love et al. (1987) reported males and females to grow at significantly different rates, with females attaining greater size and age (443 mm TL, 21 years old). Females were observed to grow at a faster rate through their first seven years before leveling off, while males grew at a more consistent rate throughout their life, with a slight reduction in the last five years (Love et al. 1987).

5.5.2.12.2 Population Trends and Fishery

At the time, Love et al. (1987), reporting on data from April 1975 to December 1978, noted that California scorpionfish constituted at minor portion of the commercial passenger fishing vessel catch, ranking 15th, or comprising about 1.5% of all individuals taken. Analysis of long-term trends in the NMFS Los Angeles Times recreational fishing database recorded an annual mean landing of 36,767 individuals from all landings ranging from Paradise Cove on the northwestern edge of the Santa Monica Bay south to San Diego, California over the period 1959 – 2003 (NMFS 2007). Notably, the mean annual landings from 1987 to 2003 (93,890) increased nearly 45-fold over the annual average for 1959 to 1986 (2,085). Commercial landings indicate a slightly different trend, with relatively high landings recorded, albeit with high interannual variation, before 1979, followed by notably reduced landings overall from 1980 to 1999 (Love 2001). The author further noted that fishery-independent data suggested substantial short term fluctuations in the local populations. In 2005, California scorpionfish landings in the Los Angeles area totaled 4,439 kg (9,789 lb) at a value of $27,888 (CDFG 2006). Commercial landings of California scorpionfish reported from catch blocks in the Santa Monica Bay area totaled 33.6 kg (74 lb) in 2006, at an estimated value of $206 (CDFG 2007b).

Scorpionfish was not analyzed in detail in the 1978-1980 316(b) demonstration (SCE 1982b). During that two-year study, a total of 53 individuals were impinged at Units 1 & 2 and 130 individuals from Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of scorpionfish ranged from 1 individual (2004) to 98 individuals (2005) (MBC 2007). Since 1990, 524 California scorpionfish were estimated to have been impinged at the ESGS, an average of about 33 individuals per year.

5.5.2.12.3 Sampling Results

California scorpionfish was observed at both screening facilities at the ESGS in 2006, with an estimated 152 individuals weighing 26.481 kg (58.391 lb) impinged during normal operations at Units 1 & 2 and an additional 18 individuals weighing 4.339 kg (9.567 lb) impinged during heat treatments at Units 3 & 4 (Tables 5.5-1 and 5.5-2). Five individuals were observed during normal operation surveys at Units 1 & 2 (all at nighttime), with March the peak month for abundance with two individuals and the highest biomass recorded in September (one individual at 0.415 kg). Twenty-three individuals were measured, with lengths ranging from 65 to 290 mm SL and a mean of 162 mm SL. Length frequency distribution analysis indicated a bimodal distribution with equal peaks in the 80- and 200-mm SL size classes (Figure 5.5-33), corresponding to Age Class II fish (Love et al. 1987). Of the 23 measured individuals, 69.6% were dead, 21.7% were alive, and 8.7% were mutilated.

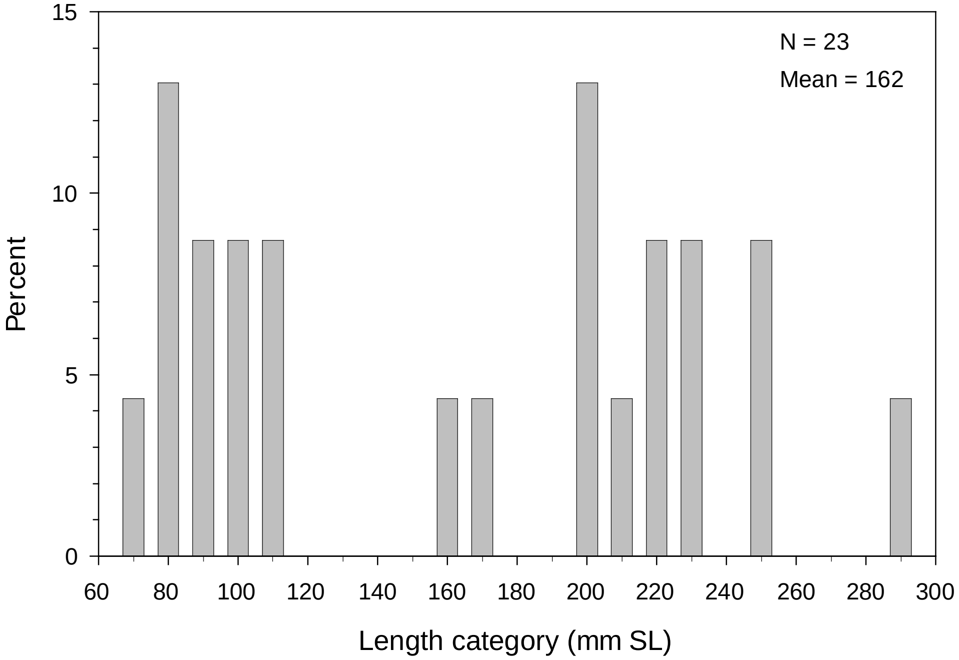
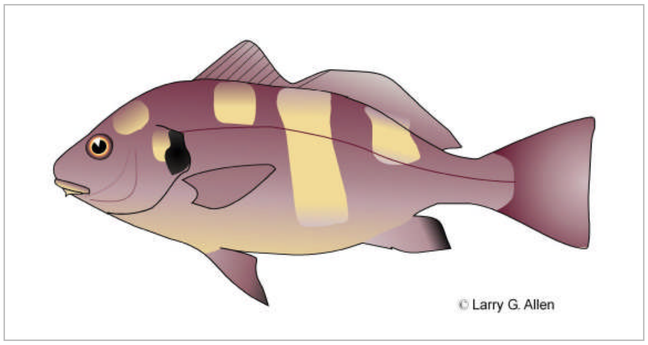


Figure 5.5-33. Length (mm) frequency distribution for California scorpionfish collected in impingement samples.

5.5.2.13 Black croaker *(Cheilotrema saturnum)*



Black croaker (*Cheilotrema saturnum*) is a member of the drums and croakers family (Sciaenidae) and ranges from Point Conception, California to central Baja California (including the Gulf of California) in depths from 3–50 m (Limbaugh 1961; Miller and Lea 1972). Seven species of croaker, in addition to black croaker, are common to the Southern California Bight (SCB), including white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), yellowfin croaker (*Umbrina roncador*), white seabass (*Atractoscion nobilis*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), and shortfin corvina (*Cynoscion parvipinnis*; Miller and Lea 1972). Two other species [orangemouth corvina (*Cynoscion xanthulus*) and bairdiella (*Bairdiella icistia*)] are currently believed to be restricted to the Salton Sea, California within the SCB.

5.5.2.13.1 Life History and Ecology

Black croaker is common to open-coast, shallow rocky reefs and kelp beds (Limbaugh 1961; Allen 1985) with large adults occupying shelters within the reef structure and smaller individuals typically occurring above the sand substrate in and around the reef (Limbaugh 1961). Nocturnal in nature, aggregations have been observed migrating away from the reef to feed and reproduce at night, while remaining relatively sessile within the reef area during the day (Limbaugh 1961). Limbaugh (1961) observed aggregations of adults concentrated near the 7-m (23-ft) isobath, but as deep as 50 m (164 ft). He noted that individuals were more abundant in the shallower portion of their depth distribution.

Black croaker is an oviparous broadcast spawner with pelagic eggs and larvae (Moser 1996). Greater than 50% of both males and females are reproductively mature by 150 mm (6 in) standard length (SL) or approximately one year of age (Miller et al., in prep). Spawning is most prevalent in the late spring to summer months, with a peak in June and July based on histological examination (Goldberg 1981) and seasonal gonosomatic index (GSI) analysis (Miller et al., in prep). Late-stage larvae have been collected as early as July (Miller et al., in prep), with regular collections from August through October (Limbaugh 1961, Moser 1996). Spawning populations were found to be statistically skewed towards males at a ratio of 1.22:1 (male:female), with each sex represented in all size and age classes (Miller et al., in prep).

Moser (1996) reported newly hatched black croaker larvae to be 1.5 mm NL (notochord length). Flexion occurs at approximately 5.6 mm NL and transformation occurs at standard lengths in excess of 11 mm (Moser 1996). Black croaker grows rapidly during the first six years, attaining an average length of 200 mm SL before growth rates slow (Miller et al., in prep). Black croaker reportedly grows to 380 mm SL (15 in) (Miller and Lea 1972) and 22 years old with no significant differences in the growth rates between males and females (Miller et al., in prep). The strongest recruitment year within the last decade occurred in 1997, which corresponded to the highest sea surface temperature in the same time period (Miller et al. in prep). The estimated annual survivorship rate for black croaker is 0.85 (0.15 mortality) (Miller et al., in prep).

Gut contents of adults indicate their diet consists primarily of demersal crustaceans such as crabs, shrimp, and amphipods (Limbaugh 1961). Recent anecdotal observations of one adult black croaker gut contents included two blackeye gobies (*Rhinogobiops nicholsii*) (Miller, personal observation). Nearshore gillnet sampling from Newport Beach to Santa Barbara, California, including Santa Catalina Island, indicated the largest sustaining population to occur near the Palos Verdes Peninsula, California (Miller et al. in prep). Pondella and Allen (2000) also noted higher population densities occurred at mainland sites compared to Santa Catalina Island sites. However, the individuals collected at the island sites were larger on average than those encountered along the mainland (Miller et al. in prep). Black croaker is commonly found in association with sargo (*Anisotremus davidsonii*) and salema, with the juveniles of both species displaying similar body coloration to those of young black croaker (Limbaugh 1961).

5.5.2.13.2 Population Trends and Fishery

Historically, black croaker has been the third most abundant croaker species among impingement samples at southern California coastal generating stations since 1976, surpassed only by white croaker and queenfish (Herbinson et al. 2001). Long-term trends in impingement observations indicate an overall declining abundance, with a minor upturn in 1997. Currently, no commercial fisheries target black croaker, and only incidental catches occur in the recreational fishery.

Black croaker was not very abundant during in the 1978-1980 316(b) demonstration, with impingement averaging 0.3 individuals per day at Units 1 & 2 and 0.6 individuals per day at Units 3 & 4, with almost all impingement occurring during heat treatments (SCE 1982b). From 2003 through 2005, estimated annual impingement of black croaker ranged from 34 individuals (2003) to 97 individuals (2005) (MBC 2007). Since 1990, 1,115 black croaker were estimated to have been impinged at the ESGS, an average of about 70 individuals per year.

5.5.2.13.3 Sampling Results

Black croaker was unique to heat treatments at Units 3 & 4 during the yearlong impingement survey at ESGS (Table 5.5-2). A total of 20 individuals weighing 5.200 kg (11.466 lb) were collected during heat treatments in 2006, including 1 in April, 9 in June, and 10 in July 2006. All of the individuals were measured with lengths ranging from 124 to 266 mm SL with a mean of 204 mm SL. Length frequency distribution was highly variable with a peak in the 220-mm SL size class (Figure 5.5-34), which corresponds to Age Class VIII or older (Miller unpubl. data). Nineteen individuals were assessed for their condition factor, with all of them dead upon collection.

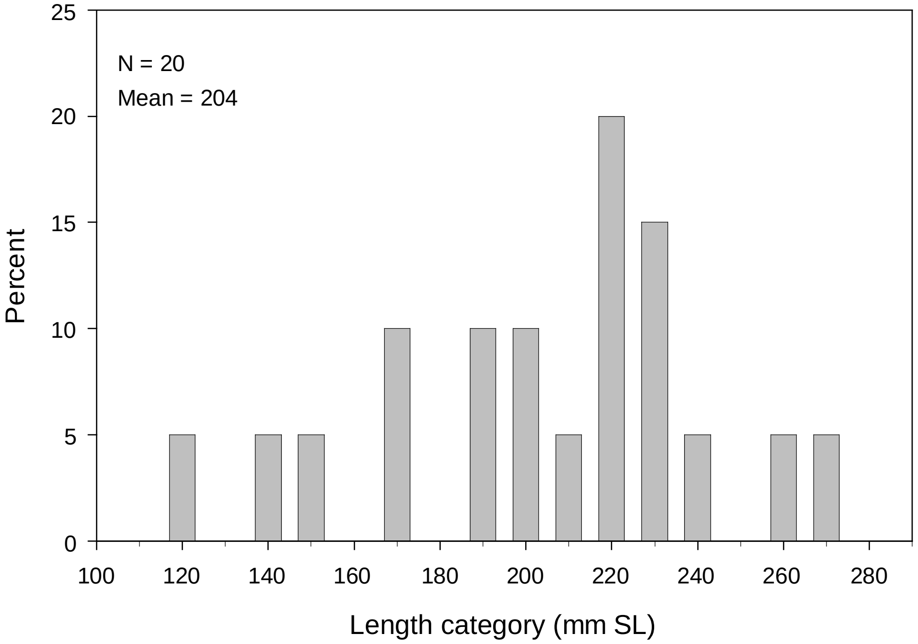


Figure 5.5-34. Length (mm) frequency distribution for black croaker collected in impingement samples.

5.5.2.13.4 Modeling Results

Black croaker life history parameters are presented in Table 5.5-14. All pertinent life history parameters were taken from Miller et al. (in prep). Total annual mortality (Z) was reported as 0.17 with age at 50% maturity at 1.429 years. All 20 observed black croaker were impinged during heat treatments. Based on recorded lengths of these individuals and the associated parameters, an estimated 83 adult equivalents were impinged in 2006, using either actual cooling water intake or design (maximum capacity) flow volumes. The distribution of black croaker age classes of the 20 measured individuals is presented in Figure 5.5-35.

Table 5.5-14. Black croaker life history parameters used in equivalent adult modeling.

Adult Annual Instantaneous Mortality (Z)*	Survival (S)	von Bertalanffy growth parameters*			Age at 50% Maturity*	Length at 50% Maturity*
		L_{inf}	k	t_0		
0.17	0.843664	237.7 mm SL	0.31	-1.78	1.429	150 mm SL

*Data from Miller et al. (in prep)

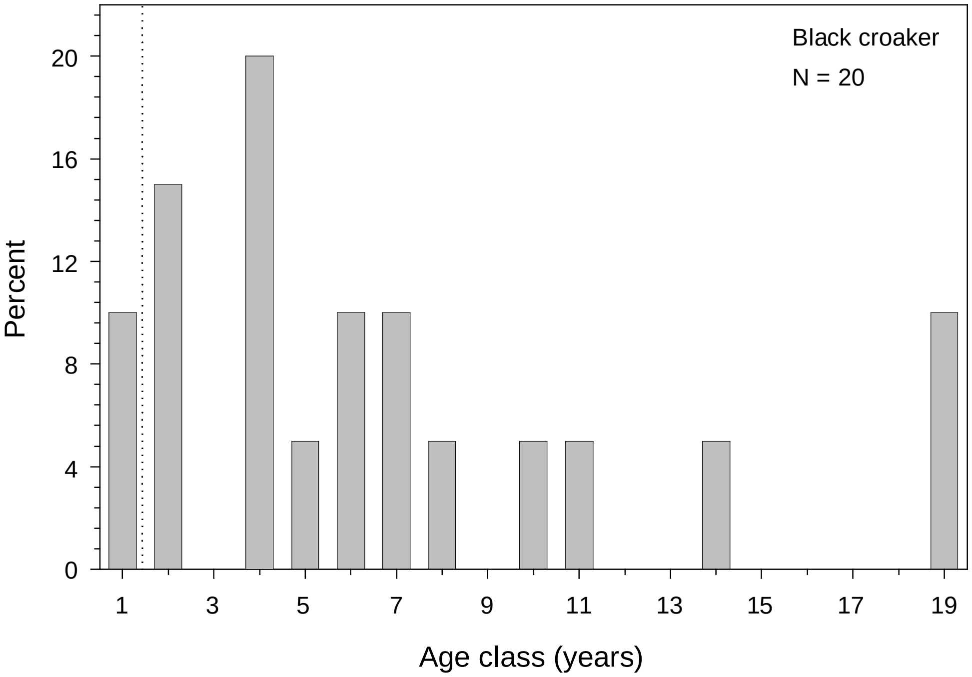


Figure 5-5.35. Distribution of black croaker age classes in ESGS impingement samples. Vertical dotted line denotes age at 50% maturity.

5.5.2.14 Jacksmelt (*Atherinopsis californiensis*)

Three species of silversides (Family Atherinopsidae) occur in the waters off southern California: topsmelt (*Atherinops affinis*), jacksmelt (*Atherinopsis californiensis*), and California grunion (*Leuresthes tenuis*). Jacksmelt ranges from Yaquina, Oregon to Santa Maria Bay, Baja California (Miller and Lea 1972). All three species commonly occur in Santa Monica Bay (MBC 2006).

5.5.2.14.1 Life History and Ecology

Jacksmelt occur over much of the nearshore areas of California, and are usually found in bays and within a few miles of shore (Gregory 2001a). Juveniles and adults are surface-oriented pelagic schooling fishes (Allen and DeMartini 1983). Jacksmelt form denser and larger schools than topsmelt, although the two species often school together.

Spawning occurs in winter (October to April), and egg masses are attached to aquatic plants (eelgrass and algae) and flotsam by long filaments. Fecundity has been estimated at over 2,000 eggs per female (Emmett et al. 1991). They reach 114 to 127 mm (4.5 to 5 in) during their first year, and up to 203 mm (8 in) during their second year (Gregory 2001a). Maximum size is about 560 mm (22 in). Jacksmelt mature at about two to three years. Adults feed on plankton and small fishes (Horn and Allen 1985).

5.5.2.14.2 Population Trends and Fishery

Jacksmelt are caught recreationally, but a parasitic nematode often infests the flesh, thus reducing their commercial and recreational value (Emmett et al. 1991). Commercial landings of jacksmelt in 2006 in Santa Monica Bay catch blocks totaled 45 kg (100 lb) at a value of $75 (CDFG 2007b). Los Angeles area landings (between Dana Point and Santa Monica) for 2005 totaled 1,541 kg (3,399 lb) at a value of $1,777 (CDFG 2006).

Jacksmelt was not analyzed during in the 1978-1980 316(b) demonstration at the ESGS (SCE 1982b). During that two-year study, 483 individuals were reported from Units 1 & 2 and 126 individuals were reported from Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of jacksmelt ranged from 0 individuals (2005) to 169 individuals (2003) (MBC 2007). Since 1990, 12,434 jacksmelt were estimated to have been impinged at the ESGS, an average of about 777 individuals per year. However, 54% of the long-term total was impinged in 1997.

5.5.2.14.3 Sampling Results

Jacksmelt were limited to heat treatment surveys at Units 3 & 4 during impingement monitoring at ESGS in 2006 (Table 5.5-2). A total of 19 individuals weighing 3.056 kg (6.738 lb) were impinged during heat treatments, including 9 in April and 10 in June. All of these individuals were measured with lengths ranging from 190 to 284 mm SL with a mean length of 229 mm SL. Length frequency analysis indicated a highly variable distribution with peak abundance in the 230-mm SL size class (Figure 5.5-36). All of the individuals collected were dead upon examination.

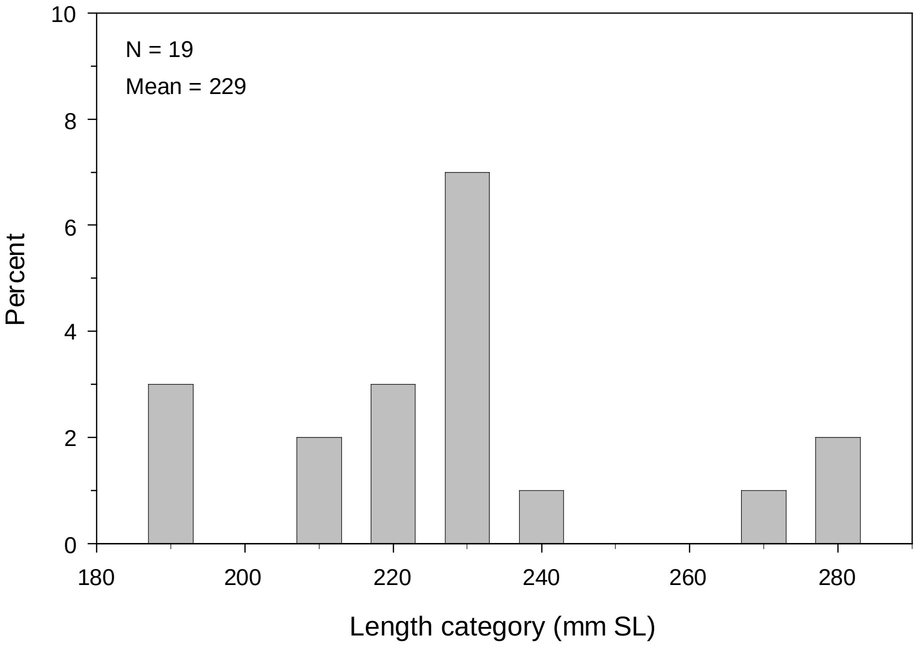
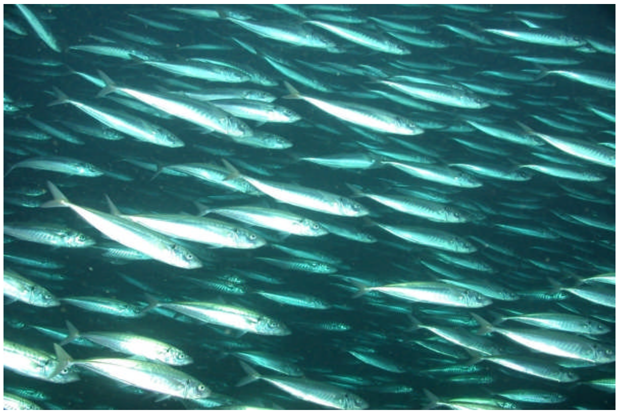


Figure 5.5-36. Length (mm) frequency distribution for jacksmelt collected in impingement samples.

5.5.2.15 Jack Mackerel (*Trachurus symmetricus*)

Jack mackerel 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 and Herald 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.


NOAA-NMFS

Jack mackerel are torpedo-shaped, blue or green above and silver below, with a yellow to reddish caudal fin (Eschmeyer and Herald 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 and Herald 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.

5.5.2.15.1 Life History and Ecology

Jack mackerel have a lifespan of about 35 years, reaching a length of 81 cm (32 in) (Eschmeyer and Herald 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%) individuals mature at one year, with 90% 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.

5.5.2.15.2 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 lb). 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 lb) 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 2006b). From the early 1990s on, jack mackerel landings have occurred from December to April at an average of 2% of CPS landings, less than 1,814,370 kg (4 million lb) 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 lb) annually (Table 5.5-15). Commercial landings of jack mackerel in 2005 in southern California totaled 115,719 kg (255,117 lb) at a value of $16,367 (CDFG 2006). Landings from Santa Monica Bay catch blocks in 2006 totaled 9,237.1 kg (20,364 lb) at a value of $4,924 (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	**(kg)**	**(lb)**	**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

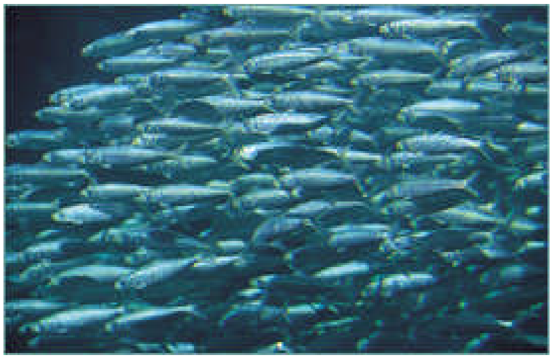
Jack mackerel was not analyzed during in the 1978-1980 316(b) demonstration at the ESGS (SCE 1982b). During that two-year study, 243 individuals were reported from Units 1 & 2 and 186 individuals were reported from Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of jack mackerel ranged from 0 to 2 individuals (MBC 2007). Since 1990, 612 jack mackerel were estimated to have been impinged at the ESGS, an average of about 38 individuals per year. However, 92% of the long-term total was impinged in 1993 and 1994.

5.5.2.15.3 Sampling Results

Eleven jack mackerel weighing 1.395 kg (3.076 lb) were impinged at the ESGS in 2006; all occurred during the June 2, 2006 heat treatment.

5.5.2.16 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 and Herald 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 ESGS.



5.5.2.16.1 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 mi.) offshore, though they are known to spawn as far offshore as 563 km (350 mi.). 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 feeding 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).

5.5.2.16.2 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 California Cooperative Oceanic Fisheries Investigations (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 lb) 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 lb) at a value of $2,344,817 (CDFG 2006). Los Angeles area landings based on the PacFIN database declined slightly after 2002, and annual landings since have ranged between 23 million and 27 million kg (50,715,000 and 59,535,000 lb) (Table 5.5 16).

Table 5.5-16. Annual landings and revenue for Pacific sardine in the Los Angeles region based on PacFIN data.

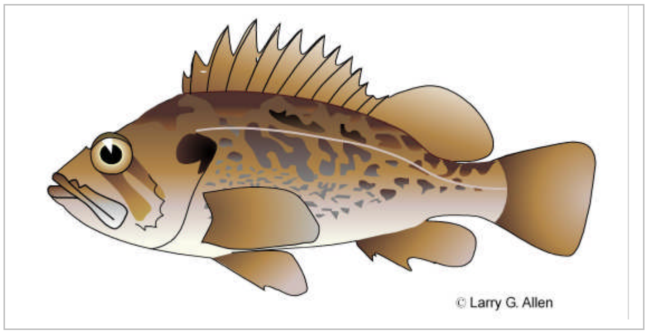
	Landed Weight		
Year	**(kg)**	**(lb)**	**Revenue**
2000	39,121,935	86,263,867	$4,187,391
2001	40,755,801	89,866,542	$4,476,752
2002	39,299,341	86,655,046	$3,826,155
2003	24,422,289	53,851,147	$1,961,269
2004	23,672,717	52,198,341	$2,255,501
2005	24,143,507	53,236,434	$2,348,577
2006	26,651,664	58,766,919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

Pacific sardine was not analyzed during in the 1978-1980 316(b) demonstration at the ESGS (SCE 1982b). During that two-year study, no individuals were impinged at the ESGS (Herbinson 1981). From 2003 through 2005, estimated annual impingement of Pacific sardine ranged from 11 individuals (2005) to 70 individuals (2003) (MBC 2007). Since 1990, 9,815 Pacific sardine were estimated to have been impinged at the ESGS, an average of about 613 individuals per year. However, highest impingement occurred between 1993 and 1995 (7,352 individuals).

5.5.2.16.3 Sampling Results

Ten Pacific sardine weighing 0.144 kg (0.318 lb) were impinged at the ESGS in 2006; all occurred during the June 2, 2006 heat treatment.

5.5.2.17 Brown rockfish (*Sebastes auriculatus*)



Brown rockfish (*Sebastes auriculatus*) ranges from Prince William Sound, Alaska to Bahia San Hipolito, Baja California, Mexico in depths ranging from shallow nearshore waters to 135 m (Love et al. 2002). Allen and Pondella (2006) included brown rockfish in their kelp reef species group. Brown rockfish have been commonly observed in low abundances during impingement sampling at southern California coastal generating stations (MBC unpubl. data).

5.5.2.17.1 Life History and Ecology

Brown rockfish exhibit age (developmental) stage specific habitat preferences. Love et al. (2002) report that pelagic juveniles maintain within the water column for 2.5 to 3 months before settling out in shallow water, where they will stay for the next several years, before gradually moving deeper with age. Rocky outcroppings, in both shallow and deeper waters, provide the most desirable habitat for brown rockfish (Love et al. 2002). These authors further noted that extensive subadult migrations from shallow bays to outer coastal waters have been recorded, some covering up to 50 km in distance.

Female rockfish undergo internal fertilization before producing pelagic larvae. Within southern California, Love et al. (2002) reported brown rockfish matured at a smaller size than their more northerly counterparts, with all groups reaching 50% maturity between 240 and 310 mm. They further reported that a female produces up to 339,000 eggs per season, with the principle spawning season from January through August in southern California.

Brown rockfish have been aged to 34 years, with a 190-mm individual averaging 3 years of age, a 240- to 310-mm individual being between 4 and 5 years old, and a 380-mm individual being approximately 10 years old (Love et al. 2002). Love et al. (2002) noted that female brown rockfish reached a greater maximum size than males, with both sexes maturing at about the same age and length.

5.5.2.17.2 Population Trends and Fishery

Historically, brown rockfish, along with all *Sebastes* species have been regularly targeted by both commercial and recreational anglers (Love et al. 2002). Commonly taken by the commercial live-fish fishery, the commercial and recreational landings of brown rockfish have declined in recent years (Ashcraft and Heisdorf 2001), due to reduced stocks, as with all Eastern Pacific rockfishes, as well as more recent fishery regulations implementing seasonal closures in addition to depth and gear restrictions.

There were no reported commercial landings of rockfish in the Los Angeles area in the PacFIN database since 2000. In 2005, brown rockfish landings in the Los Angeles area totaled 13.6 kg (30 lb) at a value of

$68 (CDFG 2006). Commercial landings of "nearshore rockfishes" reported from catch blocks in the Santa Monica Bay area totaled 105.5 kg (233 lb) in 2006, at an estimated value of $523 (CDFG 2007b).

Brown rockfish was not analyzed in detail during the 1978-1980 316(b) demonstration (SCE 1982b). However, during the two-year study 67 individuals were impinged at Units 1 & 2 and 89 individuals were impinged at Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of brown rockfish ranged from 0 individuals (2004) to 27 individuals (2003) (MBC 2007).

5.5.2.17.3 Sampling Results

Seven brown rockfish weighing 2.396 kg (5.283 lb) were impinged at the ESGS in 2006; four occurred during the January 12 heat treatment, one during the June 2 heat treatment, and two during the July 27 heat treatment.

5.5.2.18 Pacific Chub Mackerel (*Scomber japonicus*)


NOAA-NMFS

Pacific chub mackerel are a member of the Family Scombridae, which is comprised of mackerels and tunas (Eschmeyer and Herald 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.

Pacific mackerel exhibit blue or green coloration above and silver below, with dark, wavy vertical bars along the back (Eschmeyer and Herald 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 Pt. Conception, California.

5.5.2.18.1 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 can migrate 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 and Herald 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 25% 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).

5.5.2.18.2 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 lb). 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 lb) or less. Incidental catches were set at 18% during the moratorium as well. Biomasses between 18,143,695 and 136,077,711 kg (40 million and 300 million lb) within the season of July 1 through June 30 of the following year allowed a seasonal quota of 30% of the total biomass, and no quota would be set at a total biomass over 136,077,711 kg. 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 lb) 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 2006b). As of 25 May 2005, the fishing season for 2005–2006 set the harvest guideline at 17,419,000 kg (38,402,322 lb), 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 2005, commercial landings in Santa Monica Bay catch blocks totaled 110,174.9 kg (242,890 lb) at an estimated value of $30,317 (CDFG 2006). In southern California, total commercial landings from the 2006 season were 314,796 kg (694,006 lb) at a value of $54,372 (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 lb) (Bergen 2001). Thereafter, the recreational fishery increased to an average of 1,360,777 kg (3,000,000 lb) 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 lb) (Bergen 2001; Hill and Crone 2005).

Pacific chub mackerel was not analyzed in detail during the 1978–1980 316(b) demonstration (SCE 1982b). However, during the two-year study three individuals were impinged at Units 1 & 2 and six individuals were impinged at Units 3 & 4 (Herbinson 1981). From 2003 through 2005, estimated annual impingement of Pacific chub mackerel ranged from 0 individuals (2004) to 9 individuals (2003) (MBC 2007).

5.5.2.18.3 Sampling Results

Five Pacific chub mackerel weighing 1.044 kg (2.302 lb) were impinged at the ESGS in 2006; one occurred during the January 12 heat treatment, and four occurred during the June 2 heat treatment.

5.5.2.19 Vermilion rockfish (*Sebastes miniatus*)

Vermilion rockfish (*Sebastes miniatus*) belong to the family Scorpaenidae. True to its common name, the vermilion rockfish coloration varies from bright red to dark dusky red and mottled with gray along the sides (Eschmeyer and Herald 1983; Love et al. 2002). The species ranges from Prince William Sound, Alaska to central Baja California, Mexico, but are most abundant from northern California to northern Baja California.

5.5.2.19.1 Life History and Ecology

Vermilion rockfish inhabit depths from the subtidal zone to 436 m (1,440 ft). Most adults are found between 50 m to 100 m (165-495 ft), while juveniles tend to be more subtidal (Love 1996; Love et al. 2002; Miller and Lea 1972). Adult vermilion rockfish generally aggregate in high relief areas, and can occasionally be found along the bottom of oil platforms or live solitarily in shallow-water caves (Love et al. 2002). Juvenile rockfish, however, are solitary and tend to inhabit sand patches between structures or near rocky substrata (Love et al. 2002). The largest length recorded for vermilion rockfish is 76 cm (30 in) (Eschmeyer and Herald 1983; Love et al. 2002).

Vermilion rockfish differ in size and age at maturity (Love et al. 2002). Some females have been recoded as mature at the length of 31 cm (12 in) at four years. However, all females are mature by 47 cm (19 in) and nine years. Recorded fecundity shows a range of 63,000 eggs in a female of 32 cm (12.5 in) to 2,600,000 eggs in a female of 55 cm (21.5 in) (VenTresca 2001). Vermilion rockfish have been recorded displaying courtship behavior, wherein females undergo internal fertilization. Release of larvae with lengths of about 4.3 mm (0.2 in) occurs from July to March in southern California. When released, larvae are generally found in pelagic waters and settle in May near protective structures in shallower waters until they progressively move to deeper depths (VenTresca 2001; Love et al. 2002). Vermilion rockfish prey primarily on fish and benthic organisms including northern anchovies, lanternfish, squid, crabs, and octopi, but have been recorded feeding on salps, shrimp, copepods, and polychaetes.

5.5.2.19.2 Population Trends and Fishery

Historically, the commercial and recreational fishery has viewed vermilion rockfish as a highly prized market species. However due to its inclusion of a general market category of “rockfish, Group Red”, historical data on catch abundances are unreliable previous to 1994, when “Rockfish, vermilion” became a printed market category (VenTresca 2001). During the late 1990s, annual landings of vermilion rockfish declined when the NMFS implemented a Nearshore Fishery Management Plan in 1999 in an attempt to rebuild the nearshore fish population. As of 2004, recreational fishery landings (167,000 kg [368,172 lb]) remained higher than commercial landings (5,000 kg [11,024 lb]) (MacCall 2005). The current recreational fishery often takes vermilion rockfish by hook-and-line anglers along California and is composed mostly of juvenile fishes (VenTresca 2001; Love et al. 2002). Vermilion rockfish is covered under the Pacific Groundfish FMP.

Commercial landings in the Los Angeles area were only recorded in 2000 in the PacFIN database (Table 5.5-17). In 2005, vermilion rockfish landings in the Los Angeles area totaled 1,671.6 kg (3,686 lb) at a value of $3,686 (CDFG 2006). Commercial landings of vermilion rockfish reported from catch blocks in the Santa Monica Bay area totaled 191.2 kg (422 lb) in 2006, at an estimated value of $913 (CDFG 2007b).

Table 5.5-17. Annual landings and revenue for vermilion rockfish in the Los Angeles region based on PacFIN data.

Year	**Landed Weight in kg (lb)**	**Revenue**
2000	78 (172)	$367
2001	-	-
2002	-	-
2003	-	-
2004	-	-
2005	-	-
2006	-	-

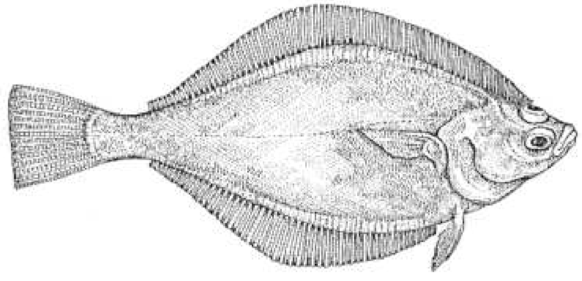
Vermilion rockfish was not analyzed in detail during the 1978-1980 316(b) demonstration (SCE 1982b), and it was not collected during the two-year study (Herbinson 1981). The only year it was impinged at the ESGS was 2000 (12 individuals) (MBC 2007).

5.5.2.19.3 Sampling Results

Three vermilion rockfish weighing 0.022 kg (0.049 lb) were impinged at the ESGS in 2006; all three occurred during the June 2 heat treatment.

5.5.2.20 English Sole (*Parophrys vetulus*)

English sole (*Parophrys vetulus*) ranges from the Aleutian Islands in the Bering Sea to Bahia San Cristobal in southern Baja California (Pearson et al. 2001). They are one of 20 species of flatfish that occur off the coast of California. English sole can hybridize with starry flounder (*Platichthys stellatus*) producing the hybrid sole (Love 1996).



NOAA-NMFS

5.5.2.20.1 Life History and Ecology

English sole occurs over soft bottom or rocky bottoms with algal cover, from the intertidal zone to depths of 550 m (1,800 ft). Juveniles primarily recruit into shallow areas of estuaries and bays and migrate to deeper water after 1–2 years (Kramer 1991b). Adults are typically found at depths of 46–274 m (150–900 ft) over soft bottom (Pearson et al. 2001). They are reported to attain a maximum length of 57.2 cm TL (22.5 in). Females grow larger and mature later, typically maturing at 35 cm (14 in, 3–5 yrs) while males mature at 29 cm (11.5 in, 2–3 yrs).

English sole spawn year-round in California, with a peak from January through April (Pearson et al. 2001). Spawning typically occurs over sand or mud-bottoms at depths of 61–110 m (200–360 ft). Females are oviparous and may spawn more than once per season, producing from 150,000–2,100,000 eggs. Eggs are buoyant upon release, but sink to the bottom where hatching occurs after 4–12 days. Eggs are about 1.0 mm (0.04 in) in diameter. Larvae are initially ca. 2.5 mm (0.1 in) in length and begin flexion at ca. 7.6 mm (0.3 in) (Moser 1996). Larvae are found in the mid-water column and settle at the bottom in about 6-10 weeks, when they undergo transformation. Larvae are typically ca. 17 mm (0.7 in) when they begin to transform into the adult flatfish body shape.

Larval English sole feed upon copepods and other planktonic organisms (Emmett et al. 1991) and as juveniles, feed upon small invertebrates such as bivalves, polychaetes, copepods, brittlestars and amphipods (Becker 1984, Emmett et al. 1991, Houge and Carey 1982). As adults they are typically opportunistic, feeding upon worms, small crustaceans, clams, shrimp or fish. Larger fishes, such as rockfish and lingcod, prey upon juveniles and adults are preyed upon by larger fish, sharks, marine mammals, or birds (Allen 1982, Emmett et al. 1991, Love 1996).

5.5.2.20.2 Population Trends and Fishery

The majority of English sole landed in California are taken by trawlers fishing off the Eureka and San Francisco areas, and very few are taken commercially south of Point Conception (Pearson et al. 2001). Within the SCB this species made up a very small portion of the trawl fishery (0.5%) during the past 30 years. Their catch rates have not been shown to be strongly influenced by regional oceanographic factors such as PDO, water temperatures, El Nino events, or upwelling, although the relatively small numbers sampled in the fishery could mask any apparent trends (Allen et al. 2003).

Populations of juvenile English sole are more abundant in bays and estuaries, whereas adults are more evenly distributed along portions of the continental shelf. English sole are absent or occur in very low numbers in most bays and estuaries within southern California, but they are fairly common in bays in central and northern California (Moyle and Cech 2000). Most fish in southern California were collected in open coastal areas (Kramer 1991b, Allen and Herbinson 1991). NMFS trawl surveys on the continental shelf (55–183 m [180–600 ft]) off central and northern California found that English sole were particularly abundant in the region off Eureka (Wilkens 1998).

English sole have been a commercially important species since trawl nets were first introduced in 1876. Most English sole are harvested primarily through trawling, with very few taken by gill net or hook and line. The fishery peaked in 1929 in the southern portion of its range (Point Conception to Monterey) at 3,976 mt (8.76 million lb) and in 1948 in the northern area (Eureka to Vancouver) at 4,008 mt (8.84 million lb) (Stewart 2006). English sole catches have decreased since the mid 1960s and were at historical lows in the 1990s.

English sole are managed by the PFMC and assessed as a single stock from Pt. Conception to the Canadian border. The boundary at the Eureka/Monterey INPFC regions splits the stock into two areas, with most of the catch coming from the north. Recent trends in English sole landings from 2000–2004 ranged from 64 mt (141,000 lb) in 2003) to 199 mt (438,700 lb) in 2001 in the southern area, and ranged from 569 mt (1.25 million lb) in 2000 to 1,067 mt (2.35 million lb) in 2002 in the northern areas (Stewart 2006). Current assessments show that the stock is growing and that spawning biomass is increasing for English sole (Stewart 2006).

English sole was not analyzed in detail during the 1978-1980 316(b) demonstration (SCE 1982b). During that two-year study, four individuals were collected at Units 3 & 4 (Herbinson 1981). This species was not previously recorded from impingement samples at the ESGS, and from 1990 through 2005, only one individual has been collected at the Scattergood Generating Station immediately upcoast from the ESGS (MBC 2007).

5.5.2.20.3 Sampling Results

Three English sole weighing 0.013 kg (0.029 lb) were impinged at the ESGS in 2006; all three occurred during the June 2 heat treatment.

5.5.3 All Life Stages of Shellfishes by Species

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

- yellow crab (570 individuals)
- Pacific rock crab (500 individuals)
- California spiny lobster (48 individuals)

One additional species was requested to be analyzed in further detail due its inclusion in the Coastal Pelagics Fishery Management Plan: market squid (two individuals).

5.5.3.1 Rock crabs (*Cancer spp.*)

Dan Dugan

Crabs of the genus *Cancer* are widely distributed in the coastal waters of the west coast of North America. They occur in intertidal and shallow subtidal habitats on both rock and sand substrate. Of the nine species known to occur in the northeast Pacific, four species contribute to economically significant fisheries. Dungeness crab (*Cancer magister*) has the highest economic value among these, and three species of rock crabs (yellow crab [*C. anthonyi*], Pacific (brown) rock crab [*C. antennarius*], and red rock crab [*C. productus*]) comprise the remainder of the catches. These three species of rock crab, including hairy rock crab, the smaller slender crab (*C. gracilis*), and bigtooth rock crab (*C. amphioetus*) may all be found in the vicinity of the ESGS. All but Dungeness crab and bigtooth rock crab occurred in impingement samples at the ESGS in 2006. Yellow crab and Pacific rock crab occurred in sufficient numbers to warrant analysis.

5.5.3.1.1 Life History and Ecology

All species of *Cancer* crabs share certain fundamental life history traits. Eggs are extruded from the ovaries through an oviduct and are carried in a sponge-like mass beneath the abdominal flap of the adult female. After a development period of several weeks, the eggs hatch and a pre-zoea larva emerges, beginning the planktonic life history phase. As in all crustaceans, growth progresses through a series of molts. The planktonic larvae advance through six stages of successive increases in size: five zoea (not including the brief pre-zoea stage) and one megalopal. After several weeks as planktonic larvae, the crabs metamorphose into the first crab stage (first instar) and settle out to begin their benthic life history phase. Maturity is generally attained within one to two years. Mature females mate while in the soft shell molt condition and extrude fertilized eggs onto the abdominal pleopods. Females generally produce one or two batches per year, typically in winter.

The main determinant of brood size and reproductive output in brachyuran crabs is body size, and the range of egg production in *Cancer* crabs generally reflects this relationship (Hines 1991). Yellow crab produce on average 2.21 million eggs per brood. The next largest species collected in impingement sampling, red rock crab, produces 877,000 eggs per brood. Brown rock crab females seem to be an exception to this relationship because they are, on average, smaller than the red rock crab, yet produce an average of 1.2 million eggs per batch. Slender crab is one of the smallest of the five species living near ESGS and their average egg production per brood is 454,000. Female *Cancer* crabs typically produce a single batch per year, generally in the winter; however, due to occasional multiple spawnings, the average number of batches per year may be greater than one (Carroll 1982; Hines 1991).

Cancrid crabs function as both scavengers and predators in the marine environment. Prey varies as a function of age and size of the individual but benthic invertebrates such as clams, worms, and snails comprise the majority of prey species. Claw morphology of each species is adapted to the types of preferred prey. For example, the heavier crusher claws of the brown rock crab and yellow crab facilitate the breaking of gastropod shells whereas the tapered dactyls of the slender crab are used to probe in soft sediments for worms and other soft-bodied prey. Winn (1985) documented the occurrence of cannibalism among rock crabs, particularly adults on juveniles. However, since juveniles generally inhabited shallower areas than adults, effects on the younger cohorts were diminished.

During their planktonic existence, crab larvae can become widely distributed in nearshore waters. In a study in Monterey Bay, Graham (1989) found that slender crab stage 1 zoeae were very abundant close to shore (within 6 km or 3.7 mi) during March and August. Later stage larvae, including megalopae, were found further from shore during all times of the year. This offshore larval distribution, compared to the nearshore distribution of Pacific (brown) rock crab larvae found off Diablo Canyon Power Plant, probably reflects the fact that adult slender crabs are widely distributed in coastal shelf areas, further offshore than brown rock crabs. The megalops larvae and juvenile crabs are frequently found crawling unharmed on and under the bells, and even in the stomachs, of larger jellyfishes, especially purple-striped jelly *Chrysaora colorata* (Morris et al. 1980).

Juvenile rock crabs are an important prey item for a variety of fishes and invertebrates. In southern California, this includes barred sand bass, shovelnose guitarfish (*Rhinobatos productus*) and the sand star (*Astropecten verrilli*) (VanBlaricom 1979; Roberts et al. 1984).

Each species in the genus has characteristic differences in distribution, preferred habitat, growth rates, and demographic parameters. For example, brown rock crab is a relatively large species (carapace width >200 mm) that lives primarily on sand and mud substrates in estuarine and coastal shelf areas. Slender crab is a smaller species (carapace width >130 mm) associated with mixed rock-sand substrates in shallow outer coast habitats. These types of differences imply that specific information on life history parameters cannot readily be generalized among *Cancer* species. The following sections describe the life history and ecology of the five most abundant rock crabs collected in impingement samples in 2006.

Yellow crab

Yellow crab ranges from Humboldt Bay, California to Bahia Magdalena, Baja California. It occurs in rocky areas of bays and estuaries, the low intertidal zone, and subtidally to depths of 132 m (291 ft), but are most commonly found in depths between 18 to 55 m (59 to 180 ft) (Morris et al. 1980; Carroll and Winn 1989; Jensen 1995). Within this range their distribution is almost exclusively associated with sand substrata (Winn 1985; Carroll and Winn 1989). The species is most abundant on the expanses of open, sandy substrata that characterize much of the Southern California Bight. It is, however, also commonly encountered near the rock-sand interface of natural and artificial reefs in the region (Morris et al. 1980; Carroll and Winn 1989). In the northern parts of their range, where rocky benthic substrata predominate, their distribution appears to be confined more to bays, sloughs, and estuaries (Jensen 1995). They are the most abundant rock crab species harvested in southern California, often composing 70 to 95% of the total crab catch in the region (Carroll and Winn 1989). During diver surveys of yellow rock crab populations in Santa Monica Bay it was noted that the species was never seen during daylight hours in the vicinity of traps, but were often abundant in the traps the next morning (R. Hardy, CDFG, pers. comm.). These observations suggest that yellow rock crab are nocturnally active in shallow water and remain buried and inactive during daylight hours.

Anderson and Ford (1976) described the growth of yellow crab under laboratory conditions. Total larval development times from hatching through the megalops stage were 33 days and 45 days at 22°C and 18°C, respectively. The total time spent in the megalops stage averaged 8 days at 22°C and 12 days at 18°C. Yellow crab can live at least 5 years and attain a carapace width of 170 mm (6.7 inches) after 16 crab instars (molts).

Pacific (brown) rock crab

Pacific rock crab (or brown rock crab) ranges between Queen Charlotte Sound, British Columbia, and Isla de Todos Santos, Baja California (Jensen 1995), although the range of peak abundance extends from San Francisco Bay to coastal areas south of the U.S.-Mexico border (Carroll and Winn 1989). They occur from the lower intertidal zone to depths exceeding 100 m (328 ft) but are typically found near the rock-sand interface in depths of less than 55 m (180 ft) (Carroll and Winn 1989). Juvenile brown rock crab inhabiting the intertidal zone survive exposure to the air during low tide by sheltering themselves under rocks and algae (Ricketts et al. 1985). This species is a scavenger and active predator.

Mating occurs after females molt and are still soft-shelled, and ovigerous females are most common from November to January, but may be found year-round (Morris et al. 1980; Carroll 1982). Adult crabs are sexually dimorphic, with males attaining a larger size and growing larger more robust chelae (claws). Male crabs grow to a size (maximum CW) of 178 mm (7 inches) while females reach 148 mm (5.8 inches) (Jensen 1995). The life span of brown rock crab is estimated to be five to six years (Carroll 1982). The size of a female’s egg mass is variable and can contain from 410,000 to 2.79 million eggs (Carroll and Winn 1989). Development of the eggs and subsequent hatching takes seven to eight weeks at temperatures of 10° to 18° C (50° to 64° F) (Anderson and Ford 1976; Carroll 1982). Size (CW) increases in the brown rock crab range from 7 to 26% per molt, while increases in body weight of 50 to 70% have been measured (Carroll 1982). The sexes undergo a molt to maturity (50% maturity value of population using Somerton [1980] method) from between 60 mm and 80 mm CW (2.4 inches and 3.1 inches) (Carroll 1982). Brown rock crabs are estimated to go through 10 to 12 molts before reaching sexual maturity (Parker 2001).

Brown rock crab eggs require a development time of approximately seven to eight weeks from extrusion to hatching (Carroll 1982). Larval development in the brown rock crab was described by Roesijadi (1976). Eggs hatch into pre-zoea larvae that molt to first stage zoea in less than 1 hour. Average larval development time (from hatching through completion of the fifth stage) was 36 days at 13.8°C. Although some crabs molted to the megalops stage, none molted to the first crab instar stage, so the actual duration of the megalops stage is unknown. Based on a predicted megalops duration of approximately 12 days measured for the closely related yellow crab, the estimated length of time from hatching to settling for brown rock crab is approximately 48 days. Brown rock crabs mature at an age of about 18 months post-settlement with a size of approximately 60 mm CW (2.4 inches) and a weight of 73 g (0.161 lb) (Carroll 1982). Faster growth rates may occur in highly productive environments such as on the supporting members of offshore oil platforms and females may become reproductive in less than one year post-settlement (D. Dugan, pers. comm.). Brown rock crabs can probably live to a maximum age of about six years. Size at recruitment to the fishery is approximately 125 mm CW (4.9 inches), at an age of four years for males and four and one-half years for females.

5.5.3.1.2 Population Trends and Fishery

Rock crabs are fished along the entire California coast with crab pots, though some landings are reported from set gill nets and trawls as well (CDFG 2004). Three species are harvested commercially in southern California: brown rock crab, red rock crab, and yellow crab. There is no commercial fishery for the slender crab or hairy rock crab. The rock crab fishery is most important in southern California (from Morro Bay south), which produces a majority of the landings, and of lesser importance in northern areas of California where a fishery for the more desirable Dungeness crab takes place. Most rock crabs are landed alive for retail sale by fresh fish markets. The commercial harvest has been difficult to assess on a species-by-species basis because the fishery statistics are combined into the general “rock crab” category. From 1991 through 1999 state-wide rock crab landings (including claws) averaged 1.2 million lb per year (Parker 2001).

Regulations currently specify a minimum harvest size of 4.25-in carapace width. A small recreational fishery for rock crabs also exists, with a 4.00-inch minimum carapace width and a personal bag limit of 35 crabs per day. Crabs are collected by divers or shore pickers with hoop nets and crab traps. Commercial landings of rock crabs in 2006 in Santa Monica Bay catch blocks totaled 21,328 kg (47,020 lb) at a value of $75,574 (CDFG 2007b). In 2005, Los Angeles area landings (between Dana Point and Santa Monica) for unspecified rock crabs totaled 45,100 kg (99,446 lb) at a value of $134,622, while landings for red rock crab totaled 325 kg (716 lb) at a value of $1,184 (CDFG 2006).

Invertebrates were not analyzed during the 1978-1980 316(b) demonstration (SCE 1982b). In 2005, a total of 11,765 rock crabs were impinged at the ESGS, including 10,860 Pacific rock crab, 490 yellow crab, 406 slender crab, and 9 red rock crab (MBC 2006). All but 130 Pacific rock crab were impinged at Units 3 & 4. In 2004, a total of 2,243 rock crabs were impinged at the ESGS, including 1,728 Pacific rock crab, 431 yellow crab, 58 slender crab, 25 hairy rock crab, and 1 red rock crab (MBC 2005). In 2003, 1,405 rock crabs were impinged at the ESGS, including 979 Pacific rock crab, 220 yellow crab, 179 slender crab, and 27 hairy rock crab (MBC 2004).

5.5.3.1.3 Sampling Results

In 2006, an estimated 246 yellow crab weighing 65.524 kg (144.480 lb) were impinged at Units 1 & 2, while it was estimated that an additional 3,458 individuals weighing 128.451 kg (283.234 lb) were impinged at Units 3 & 4 during heat treatments and normal operations (Tables 5.5-4 and 5.5-5). Abundance and biomass impingement rates at Units 1 & 2 were highly variable, though the most individuals collected in a single survey occurred in July (3 individuals). Both abundance and biomass peaked at the end of the year at Units 3 & 4, with 29 individuals recorded in October, 125 in November, and only one in December. Abundance and biomass impingement rates at both screenwells were markedly higher during nighttime surveys than during daytime surveys (Figures 5.5-37 through 5.5-40). The carapace width of 262 measured individuals, combined from both screenwells, ranged from 9 to 128 mm with a mean width of 57 mm. Width frequency analysis indicated peak abundance occurred in the 60-mm DW size class in a unimodal distribution (Figure 5.5-41). Sex was determined for 207 individuals, 64.3% of which were male, 39.1% female, and 0.5% juvenile. Approximately 57.2% of the 187 individuals examined for condition were alive, while the remaining 42.8% were dead.

An estimated 1,041 Pacific rock crabs weighing 250.582 kg (552.533 lb) were impinged at ESGS Units 1 & 2 during normal operations and an additional estimated 7,839 individuals weighing 273.449 kg (602.955 lb) were impinged during normal operations and heat treatments at Units 3 & 4 (Tables 5.5-4 and 5.5-5). All but seven of these individuals weighing 0.077 kg (0.170 lb) were attributed to normal operation. At Units 1 & 2, abundance and biomass impingement rates both peaked from late spring through mid-summer, with highest numbers collected in June (eight individuals) and August (seven individuals). Abundance and biomass impingement rates peaked late in 2006 at Units 3 & 4 with 385 individuals collected in November. There was no real diel pattern to impingement at Units 1 & 2 for either abundance or biomass, with impingement rates relatively evenly distributed between the day and night (Figures 5.5-42 and 5.5-43; *Note: negative nighttime values on the figures are a plotting artifact*). At Units 3 & 4, however, impingement rates for abundance and biomass were substantially higher during daytime surveys than nighttime (Figures 5.5-44 and 5.5-45). The carapace width of 394 individuals was recorded at both screenwells and combined for analysis. Measurements ranged from 17–120 mm CW with a mean of 62 mm CW. Width frequency analysis indicates a unimodal distribution with a peak in the 60 mm CW size class (Figure 5.5-46). The sex of 230 individuals was determined with 64.3% female and 35.7% male. Of the 170 individuals whose condition upon collection was recorded, 82.9% were alive, 15.9% were dead, and 1.2% was mutilated.

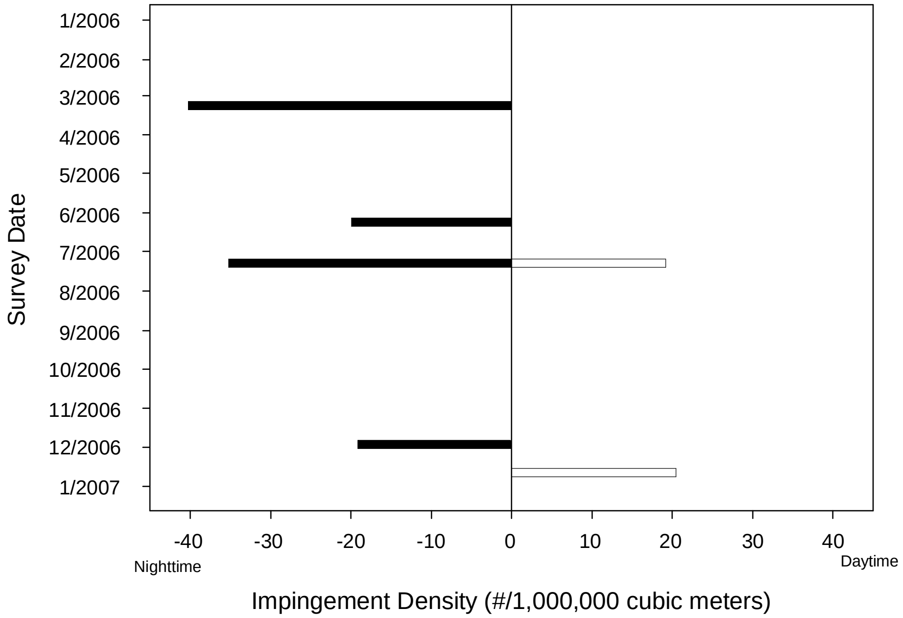


Figure 5.5-37. Mean concentration (# per 1,000,000 m^3 [264 million gal]) of yellow crab in impingement samples during night and day sampling at Units 1 & 2.

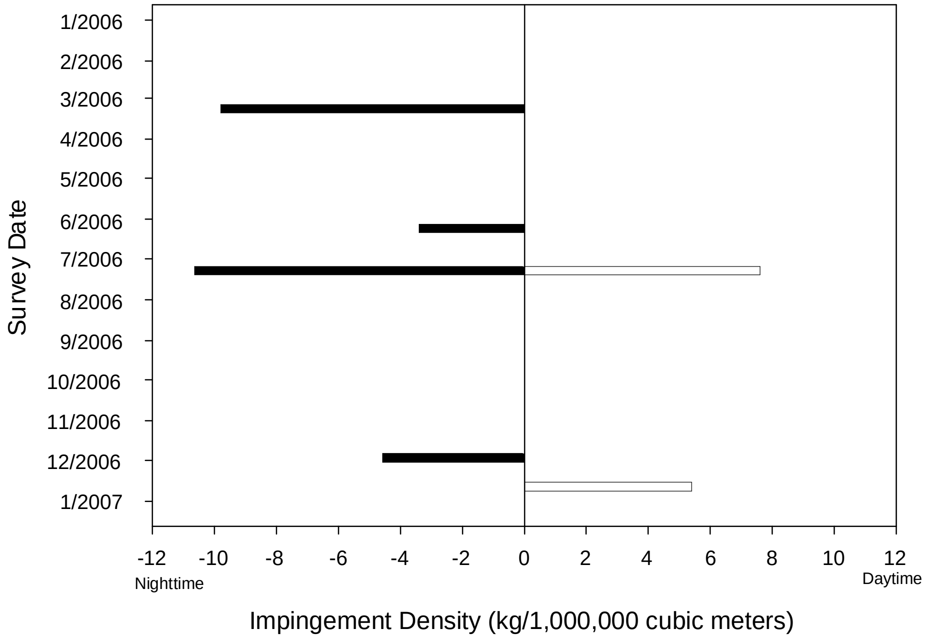


Figure 5.5-38. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) of yellow crab in impingement samples during night and day sampling at Units 1 & 2.

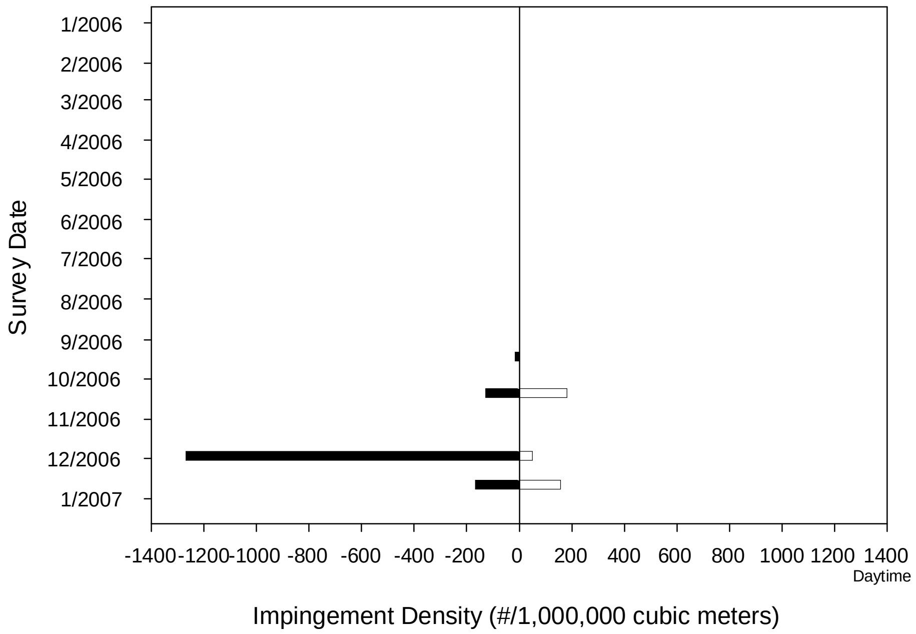


Figure 5.5-39. Mean concentration (#per 1,000,000 m^3 [264 million gal]) of yellow crab in impingement samples during night and day sampling at Units 3 & 4.

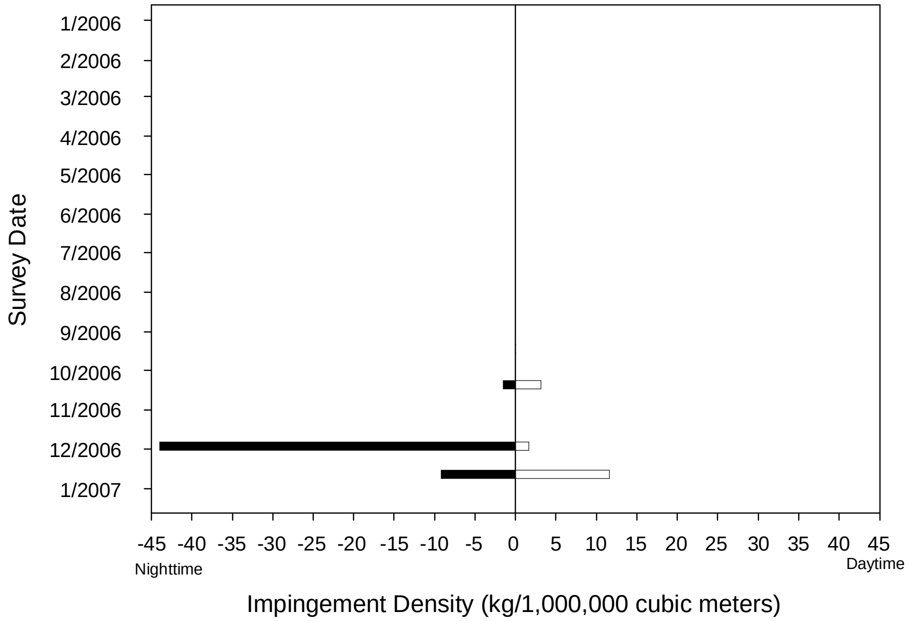


Figure 5.5-40. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) of yellow crab in impingement samples during night and day sampling at Units 3 & 4.

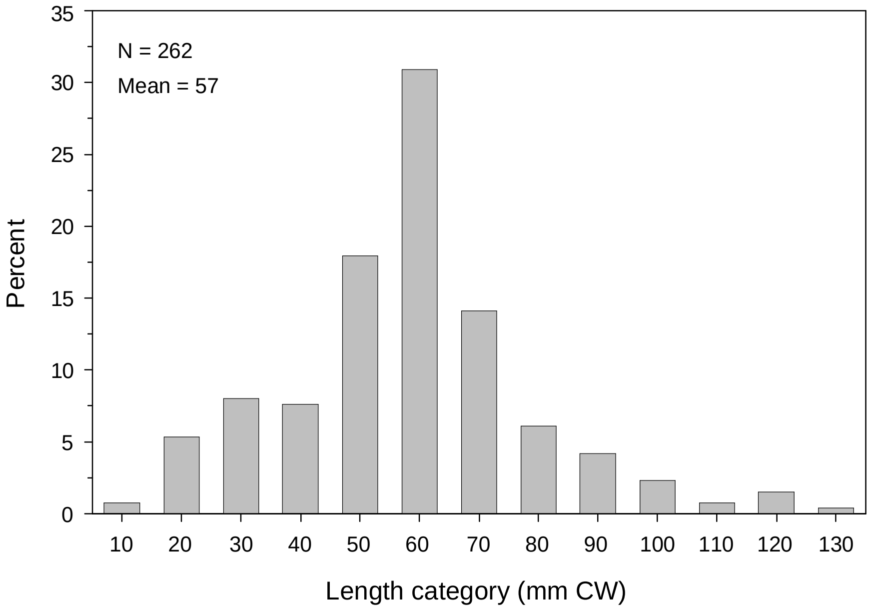


Figure 5.5-41. Carapace width (mm) frequency distribution for yellow crab collected in impingement samples.

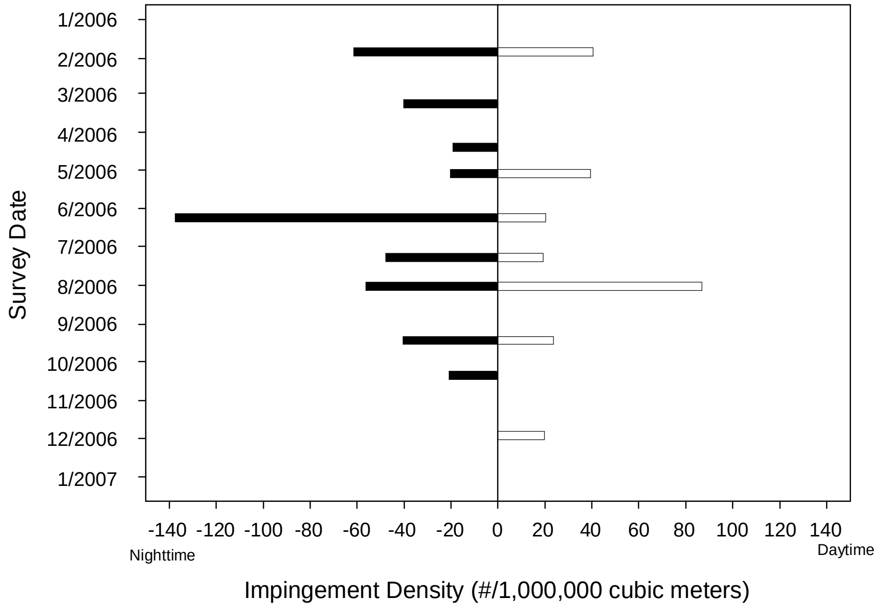


Figure 5.5-42. Mean concentration (#per 1,000,000 m^3 [264 million gal]) of Pacific rock crab in impingement samples during night and day sampling at Units 1 & 2.

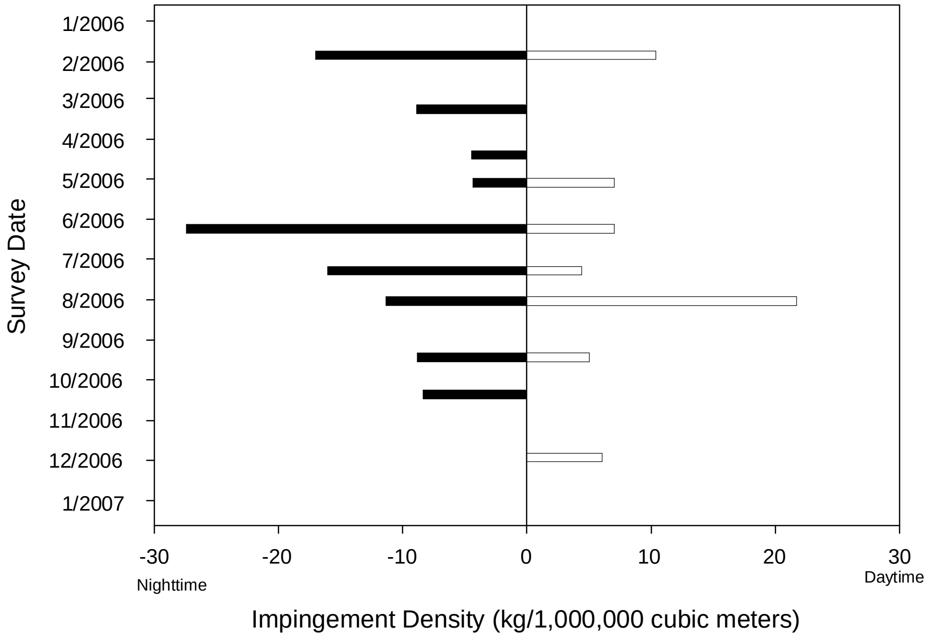


Figure 5.5-43. Mean concentration (kg per 1,000,000 m^3 [264 million gal]) of Pacific rock crab in impingement samples during night and day sampling at Units 1 & 2.

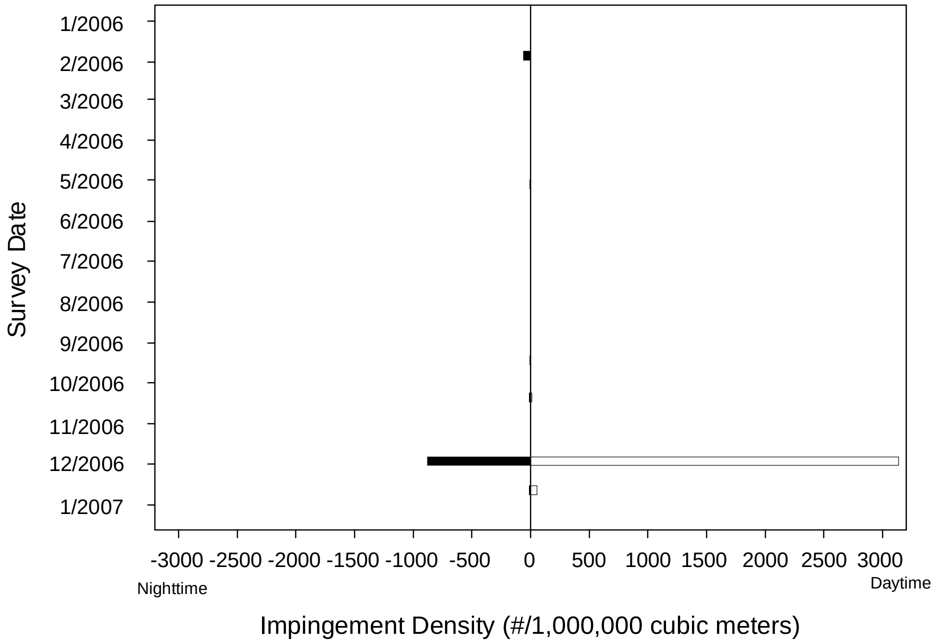


Figure 5.5-44. Mean concentration (#per 1,000,000 m^3 [264 million gal]) of Pacific rock crab in impingement samples during night and day sampling at Units 3 & 4.

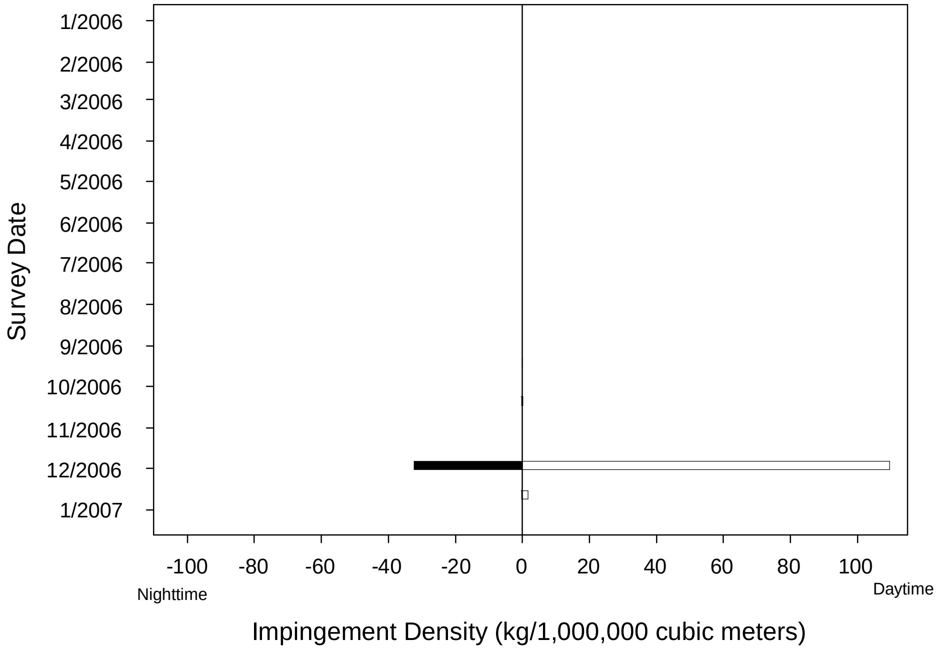


Figure 5.5-45. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) of Pacific rock crab in impingement samples during night and day sampling at Units 3 & 4.

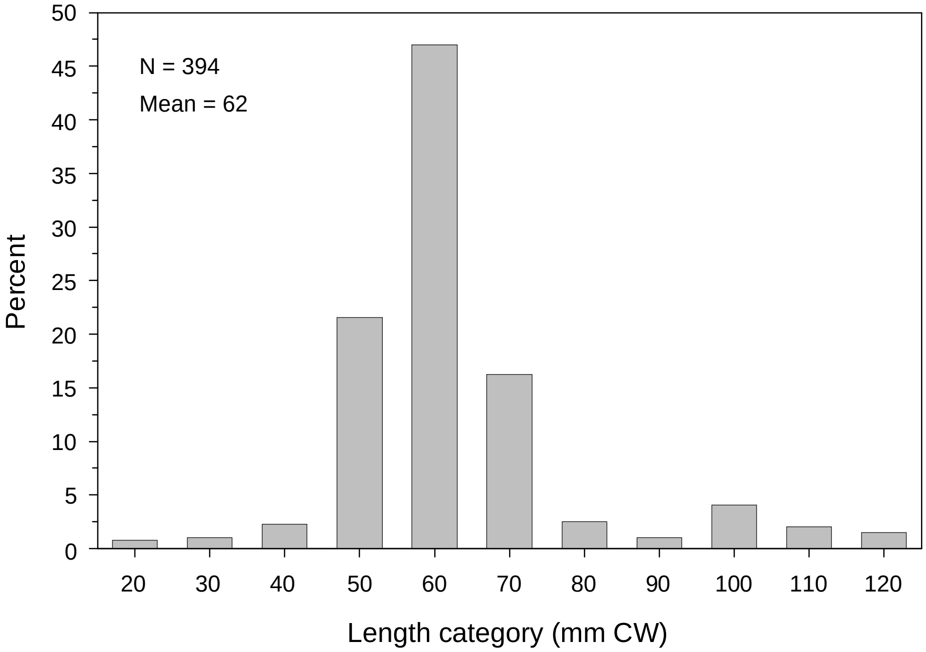


Figure 5.5-46. Carapace width (mm) frequency distribution for Pacific rock crab collected in impingement samples.

5.5.3.2 California spiny lobster (*Panulirus interruptus*)

NOAA-NMFS

California spiny lobster ranges from Monterey Bay, California, to Manzanillo, Mexico, and there is also a small population along the northwestern shore of the Gulf of California (MBC 1987). They are the only representative of the spiny lobster family (Palinuridae) in southern California.

5.5.3.2.1 Life History and Ecology

During their first two years, juveniles inhabit surfgrass beds from the lower intertidal to depths of about 5 m (16 ft). Juveniles and adults are considered benthic, though they have been observed swimming near the surface, and occur from the intertidal zone to about 80 m (262 ft). Preferred habitats include mussel beds, rocky areas, and in kelp beds (Morris et al. 1980, Barsky 2001).

California spiny lobster are oviparous, the sexes are separate, and fertilization is external. With few exceptions, adult females spawn every year. Barsky (2001) reported that mating occurs from November through May, and Wilson (1948) indicated the primary spawning season was from March to August. Mating takes place on rocky bottoms in water depths of 10 to 30 m (33 to 98 ft) (Mitchell et al. 1969). Spawning occurs from the Channel Islands off southern California to Magdalena Bay, Baja California, including other offshore islands and banks, such as Cortez and Tanner (MBC 1987). Females move inshore to depths less than 10 m (33 ft) to extrude and fertilize the eggs. At San Clemente Island, females carried between 120,000 eggs (66 mm [2.6 in] CL) and 680,000 eggs (91 mm [3.6 in] CL) (Barsky 2001).

Hatching occurs from March to December. Larvae are pelagic and are found from the surface to depths of 137 m (449 ft), and within 530 km (329 mi) of shore (MBC 1987). Upon hatching, transparent larvae (phyllosoma) go through 12 molts, increasing in size with each subsequent molt. Phyllosoma are infrequently collected in the Southern California Bight (Johnson 1956; MBC 1987). After five to ten months, the phyllosoma transforms into the puerulus larval stage, which resembles the adult form but is still transparent. The puerulus actively swims inshore where it settles in shallow water. At La Jolla, puerulus appeared in nearshore waters in late May and occurred there through mid-September (Serfling and Ford 1975). It is hypothesized that the puerulus stage of California spiny lobster lasts approximately two to three months (Serfling and Ford 1975).

A 6.1-mm (0.2 in) CL juvenile specimen goes through 20 molts to reach 45.7 mm (1.8 in) CL at the end of its first year (Barsky 2001). Spiny lobsters molt four times during the second year, and three times during the third year. Mitchell et al. (1969) found adult spiny lobsters (larger than 41 mm [1.6 in] CL) molt once yearly. Both sexes reach maturity at approximately 5 to 6 years at a mean size of 63.5 mm (2.5 in) CL (Barsky 2001). It takes a spiny lobster 7 to 11 years to reach the legal fishery size of 83 mm (3.3 in) CL. Females grow faster (4.4 mm/yr [0.2 in/yr]) than males (3.7 mm/yr [0.1 in/yr]) (Mitchell et al. 1969). Males may live up to 30 years, and reach a maximum length of 91 cm TL [35.8 in] and maximum weight of 15.8 kg (34.8 lb). Females may live up to 17 years, and reach a maximum size of 50 cm TL [19.7 in] and 5.5 kg (12.1 lb) (MBC 1987).

Lobsters are nocturnal, seeking crevices in which to hide during the day, and moving about the bottom at night (Wilson 1948). *Panulirus* is an omnivorous bottom forager, feeding on snails, mussels, urchins, clams, and fish (Tegner and Levin 1983; Barsky 2001). A large portion of the population makes seasonal migrations stimulated by changes in water temperature, with an offshore migration in winter and an inshore migration in late-spring and early summer (Mitchell et al. 1969; Barsky 2001). By the end of August, berried females and juveniles comprise the bulk of the shallow-water population. Warmer water temperatures shorten the development time of lobster eggs. By late September, the thermocline breaks down and lobsters move to deeper water (10–30 m) where they remain for the winter (MBC 1987).

5.5.3.2.2 Population Trends and Fishery

California spiny lobster have been fished commercially in southern California since the late 1800s (Barsky 2001). They are fished with traps, most of which are constructed of wire mesh. Most traps are fished in shallow rocky areas in waters shallower than 31 m (100 ft) deep. Commercial landings in the Los Angeles area have fluctuated, ranging between 43,084 kg and 62,585 kg (95,000 lb and 138,000 lb) per year since 2000 (Table 5.5-18). In 2005, commercial landings of spiny lobster in the Los Angeles area totaled 101,324 kg (223,420 lb) at a value of $1,771,864 (CDFG 2006). Commercial landings from Santa Monica Bay area catch blocks in 2006 totaled 18,213 kg (40,152 lb) at an estimated value of $372,220 (CDFG 2007b).

Table 5.5-18. Annual landings and revenue for California spiny lobster in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**(kg)**	**(lb)**	**Revenue**
2000	47,879	105,574	$715,355
2001	49,333	108,779	$707,831
2002	43,429	95,761	$653,172
2003	54,654	120,512	$858,713
2004	62,419	137,634	$997,151
2005	55,946	123,362	$977,519
2006	52,902	116,650	$1,086,553

Invertebrates were not analyzed during the 1978-1980 316(b) demonstration (SCE 1982b). In 2005, a total of 101 California spiny lobster were impinged at the ESGS; 65 were recorded at Units 1 & 2 and 36 at Units 3 & 4 (MBC 2006). In 2004, a total of 285 California spiny lobster were impinged at the ESGS; of these, 245 were recorded at Units 1 & 2 (MBC 2005). In 2003, a total of 78 California spiny lobster were impinged at the ESGS; all were recorded at Units 3 & 4 (MBC 2004).

5.5.3.2.3 Sampling Results

California spiny lobster was the fourth most abundant species impinged at Units 1 & 2 with an estimated 207 individuals, but contributed the second highest biomass with 125.856 kg (277.512 lb) (Table 5.5-4). At Units 3 & 4, however, this species ranked twelfth in abundance with an estimated 125 individuals impinged during heat treatments and normal operations, but ranked third in impinged biomass with an estimated 38.999 kg (85.993 lb) (Table 5.5-5). Of these, 38 individuals weighing 22.371 kg (49.328 lb) were impinged during heat treatments with the remaining abundance/biomass attributed to normal operations. One individual was collected in January at Units 1 & 2, with the rest of the individuals collected from June through September, with peaks in abundance and biomass occurring in August, with all but one individual collected at night (Figures 5.5-47 and 5.5-48). At Units 3 & 4, two individuals were collected in July, one day and one night, and one individual collected at night in April (Figure 5.5-49 and 5.5-50). Measurements of 46 individuals ranged from 8 to 136 mm CL with a mean length of 86 mm CL. Length frequency analysis indicated the predominance of individuals were in the 70- through 100-mm CL size classes (Figure 5.5-51). Approximately 65.2% of these measured individuals were male, 32.6% were female, and 2.2% were juveniles. The condition of 45 of these individuals was nearly evenly split between live and dead individuals: 51.1 to 48.9%, respectively.

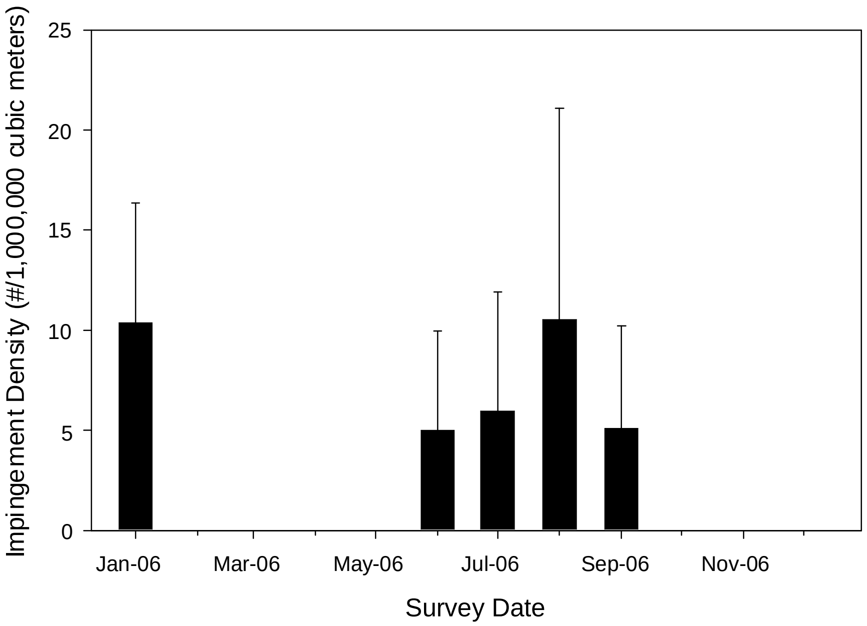


Figure 5.5-47. Mean concentration (#per 1,000,000 m^3 [264 million gal]) and standard error of spiny lobster collected in ESGS Units 1 & 2 impingement samples during 2006.

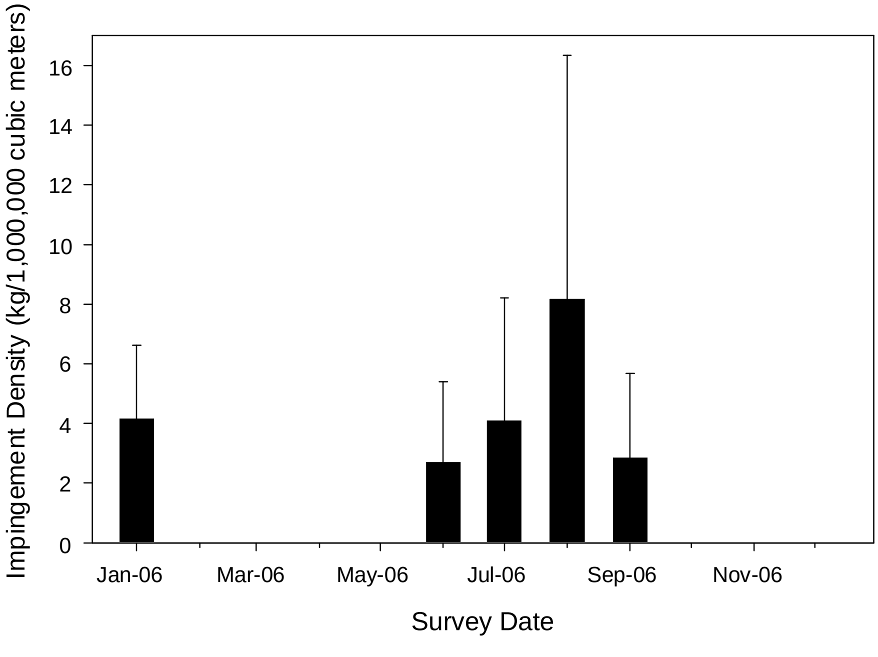


Figure 5.5-48. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) and standard error of spiny lobster collected in ESGS Units 1 & 2 impingement samples during 2006.

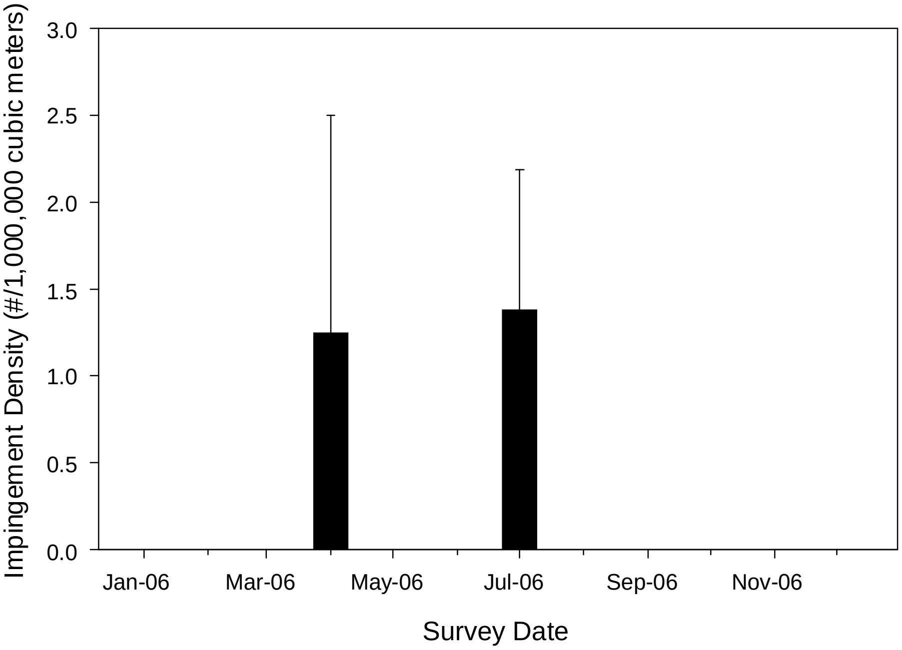


Figure 5.5-49. Mean concentration (#per 1,000,000 m^3 [264 million gal]) and standard error of spiny lobster collected in ESGS Units 3 & 4 impingement samples during 2006.

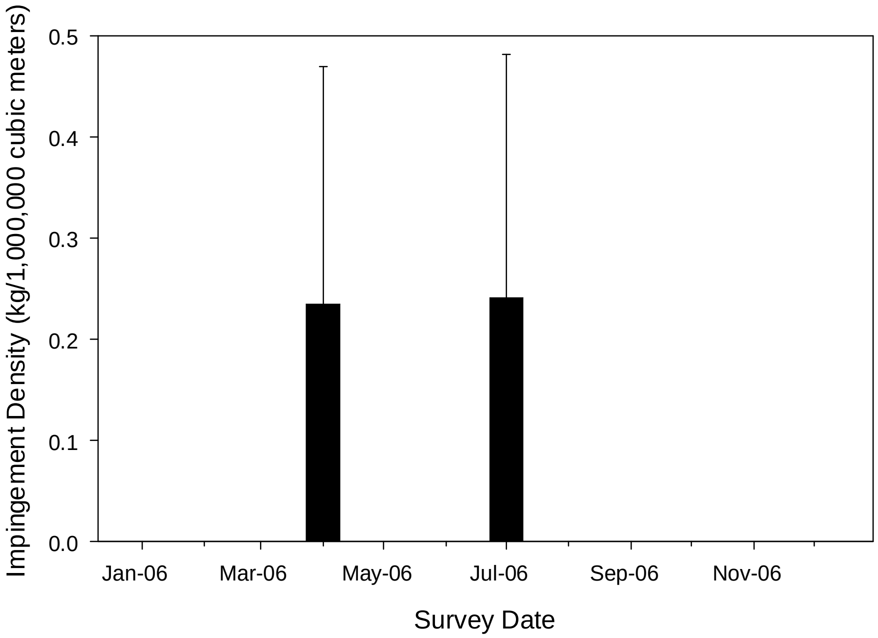


Figure 5.5-50. Mean biomass concentration (kg per 1,000,000 m^3 [264 million gal]) and standard error of spiny lobster collected in ESGS Units 3 & 4 impingement samples during 2006.

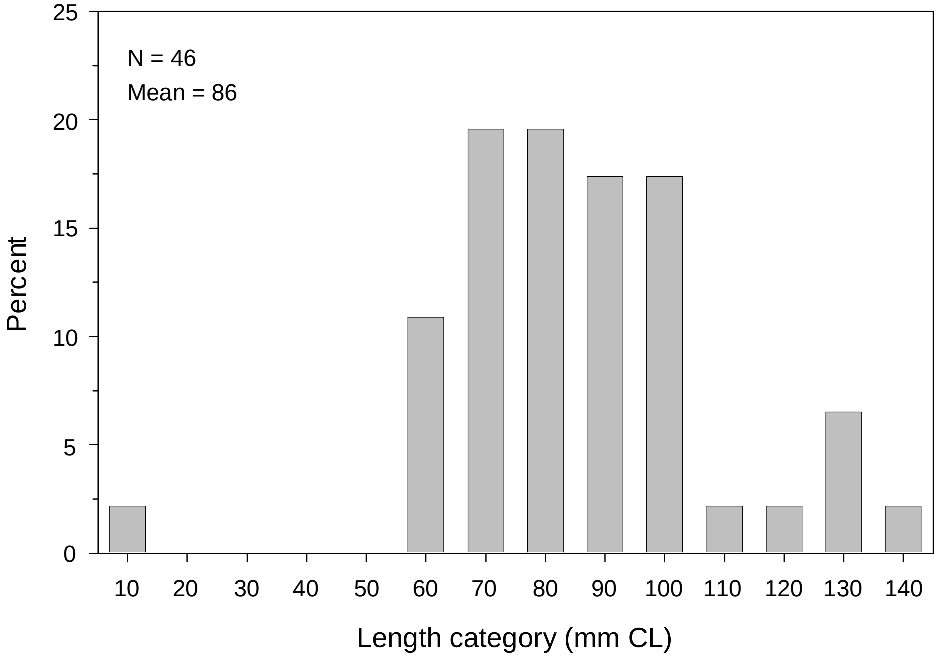


Figure 5.5-51. Carapace length (mm) frequency distribution for spiny lobster collected in impingement samples.

5.5.3.3 Market squid (*Loligo opalescens*)

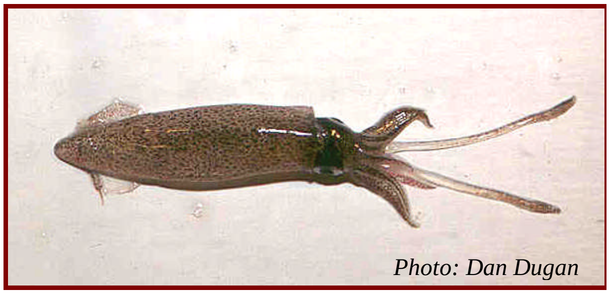


Photo: Dan Dugan

Market squid 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 only found north of Puget Sound 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).

5.5.3.3.1 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 (December to March), 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 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 to 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, then slows to a logarithmic progression 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 hatched 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 (0.123 and 0.185 lb) (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 (0.287 lb), 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 (0.198 lb).

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 (jellies), plainfin midshipman (*Porichthys notatus*), Pacific sanddab (*Citharichthys stigmaeus*), and white croaker.

5.5.3.3.2 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 lb). 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 31,59,678 kg (69,573,734 lb) at an estimated value of $18,511,585 (CDFG 2006). Landings in Santa Monica Bay area catch blocks in 2006 totaled 307,773 kg (678,512 lb) at an estimated value of $169,920 (CDFG 2007b).

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

	Landed Weight		
Year	**(kg)**	**(lb)**	**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

Invertebrates were not analyzed during the 1978-1980 316(b) demonstration at ESGS (SCE 1982b). In 2005, a total of 16 market squid were impinged during normal operations at Units 3 & 4 (MBC 2006). No market squid were impinged in 2003 or 2004 at the ESGS (MBC 2004, 2005).

5.5.3.3.3 Sampling Results

An estimated 34 California market squid weighing 0.437 kg (0.936 lb) were impinged at Units 1 & 2 (Table 5.5-4). At Units 3 & 4, an additional estimated 29 individuals weighing 0.732 kg (1.614 lb) were impinged in 2006 (Table 5.5-5). All individuals were attributed to normal operation at both screenwells. Observations were limited to one at each screenwell during normal operation surveys in March, during the nighttime at Units 1 & 2 and in the daytime at Units 3 & 4. Both individuals were dead when collected with one collected at Units 1 & 2 measuring 84 mm DML and the Units 3 & 4 individual measuring 132 mm DML.

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 impact (AEI). In 2004, EPA published 316(b) Phase II 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 rule was 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 CWIS technologies or methods by which EPA must make its determinations under Section 316(b).

Prior to the publication of the Phase II rule 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 the ESGS, the previous 316(b) demonstration evaluated entrainment and impingement impacts using several methods, including:

1. Evaluation of IM&E losses relative to known source populations;
2. Estimation of the probability of avoiding IM&E during a five-year period; and
3. Assigning a relative level of impact for each taxa analyzed.

The projected effect of switching to alternative intake technologies on the levels of impact was also assessed as part of the intake technology evaluation.

Under the previous 316(b) evaluation, impacts were classified as 'significant' or 'insignificant'. An insignificant impact was one in which the IM&E losses would have no effect on nearshore population dynamics, and long-term population observations would not reveal significant differences in abundance or distribution of the affected organisms. A significant impact was one in which the IM&E losses caused a discernible statistical effect on population abundance and/or distribution that could lead to ecological or economic impacts. The ultimate conclusion of the previous ESGS 316(b) demonstration was that there were no significant adverse impacts on nearshore fish populations in the Southern California Bight from the operation of the ESGS, and the velocity-capped configuration of the intakes represented BTA for minimizing AEI.

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 adverse environmental impacts.

In its 1977 draft guidance document, EPA indicated "*Adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact.*" EPA 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, entrainment and impingement losses were measured by collecting samples within the ESGS (IM) and in the vicinity of the offshore intakes (E). The purpose of this impact assessment is to put the measured losses into context, and to 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)*. The recent NPDES permit for the ESGS indicated that the generating station continues to operate in compliance with the Thermal Plan. Entrainment occurs when organisms are drawn into a cooling water intake structure and subsequently pass through the ESGS. Organisms large enough to become trapped on the traveling screens are impinged.

In discussing the potential effects of the ESGS CWIS on fish and shellfish populations, the life history of the species in the community needs to be considered. Several fish species in the nearshore coastal areas around ESGS 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 entrained. In addition, for fishes with entrainable life stages, the period of time that they are vulnerable to entrainment may be relatively short. As the results for ESGS show, many species are only vulnerable to entrainment for a few days when they are newly hatched since their swimming ability increases rapidly with age and development. Gobies, which were one of the most abundant taxa entrained, have demersal eggs, which are not subject to entrainment. Also, with increased age most fishes begin searching for adult habitat, usually on the bottom, where they are not 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 bottom-dwellers and also, generally, strong swimmers. 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 velocity 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 ESGS. 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 focuses on addressing impacts to fish and shellfish rather than lower tropic levels such as phyto- and zoo- plankton. EPA recognized the low vulnerability of phyto- and zoo- plankton in its 1977 draft 316(b) guidance (EPA 1977). There are several reasons why there is a low potential for impacts to phyto- and zoo- plankton and why it made sense for the EPA to focus on effects on fish and shellfish. The reasons include the following:

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

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

The impingement and entrainment sampling was therefore focused on fishes and shellfishes as required in the new 316(b) Phase II regulations. All of the fishes and shellfishes collected during the impingement sampling were counted and identified, while fish eggs and larvae, megalops stages of crabs, phyllosome larvae of spiny lobster, and squid larvae were identified and counted from the entrainment samples. The new 316(b) Phase II regulations provide latitude for focusing on the set of species that can be accurately quantified and that will provide the necessary detail to support development of other aspects of the CDS, and therefore, allows 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 agreed to at a January 12, 2006 LARWQCB meeting.

The specific taxa (species or group of species) that were included in the assessment are limited to the taxa that were sufficiently abundant to provide reasonable assessment of impacts. For the purposes of this assessment, the taxa analyzed 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 assessing the effects of the ESGS CWIS. Since the most abundant organisms may not necessarily be the organisms that experience the greatest effects on the population level, the data were also carefully examined to determine if additional taxa should be included in the assessment. For example, this might include commercially or recreationally important taxa, taxa with limited habitats, and any threatened or endangered fish or shellfish species would be included in the assessment. No listed species were entrained or impinged at the ESGS 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. The age used in the AEL and FH 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 will only be possible for a few fishes such as northern anchovy.

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 the ESGS, the permit applicant is obligated to provide the Los Angeles RWQCB with the “best information reasonably available” to assist it in fulfilling its decision-making responsibility. To make Section 316(b) decisions, permit writers have relied on precedent from other cases and on USEPA’s (1977) informal 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 'best technology available' (BTA) for minimizing 'adverse environmental impacts' (AEI):

1. Whether or not an AEI is caused by the intakes and, if so,
2. What intake technologies represent 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

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

The USEPA (1977) draft guidelines acknowledge that the determination of the extent of AEI when it is occurring is difficult to assess. They 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 ESGS 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:

- Characteristics of source water body – currents, potential larval sources
- Vulnerability based on distribution (sink/source), habitat preference, life history attributes of spawning populations
- Lack of entrainment impacts to species such as surfperches, elasmobranches with no planktonic phase
- Lack of impingement impacts to fishes and invertebrates with limited mobility
- Rates of decrease for non-IM&E fishes due to other causes and comparing to IM&E species

The criteria used to evaluate the potential for AEI need to be placed into a larger context using the characteristics of the source water and the biological community. This assessment focuses on a set of species that were collected during the study in adequate abundances to provide reasonable confidence in the estimates of entrainment and impingement effects. These species were also selected to be broad enough to include representatives from the different habitats and species groups present in the source water. As previously discussed (Section 6.1.1), not all of the fishes and shellfishes in the source water are subject to entrainment or impingement, and only a few species occur in high abundance in both entrainment and impingement samples. These differences in the vulnerability to entrainment and impingement occur due to different life histories of the species, and the differences in habitat preferences and behavior that may occur at different life stages. This assessment focuses on the distribution of the species and their habitats to determine which species are at greatest risk.

The extreme case of highest risk would occur for a rare or endangered species with a distribution that was limited to the shallow sandy shoreline areas of Santa Monica Bay. Conversely, a species such as northern lampfish that occurs to depths of 2,900 m (9,500 ft) was entrained at the ESGS, but the primary distribution for this species is the outer coastal waters from Baja California to the Bering Sea and Japan (Figure 6.1-1) (Miller and Lea 1972). The larvae for this species that are transported into Santa Monica Bay are not likely to contribute to an adult population that occurs further offshore. Therefore, entrainment losses represent very little if any risk to sustaining this population.

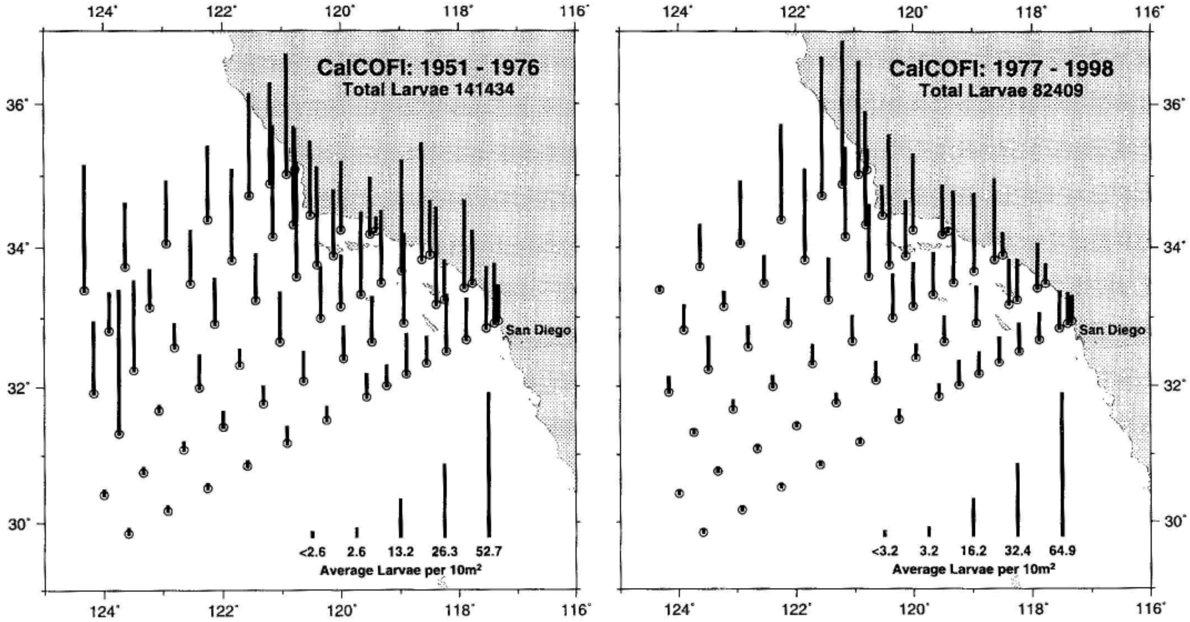


Figure 6.1-1. Distribution and abundance of northern lampfish larvae (*Stenobrachius leucopsarus*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

Data on water current flow and direction collected during the study and the size distributions of entrained larvae were used to estimate the spatial extent of the effective source populations of larvae for modeling entrainment effects. The larval durations for the species analyzed for this report, with the exception of northern anchovy, indicated that the source populations for the larvae were largely limited to the vicinity of Santa Monica Bay. The source population for northern anchovy for the modeling was limited to the bay, but the larval duration and corresponding current data indicated that the source population extended beyond the bay. These data were consistent with results from CalCOFI showing that northern anchovy larvae are distributed throughout the Southern California Bight (SCB) with peak abundances in the outer shelf areas (Figure 6.1-2) (Moser et al. 2001). In the outer shelf beyond the boundaries of Santa Monica Bay larvae are transported by the predominant upcoast (poleward) California Countercurrent (Hickey 1992). The presence of the southern California Countercurrent in the outer coastal waters of the SCB results in an eddy-type circulation pattern within Santa Monica Bay (Hickey et al. 2003). Hickey (1992) described the residence time of water within the Santa Monica and San Pedro basins using drifters. Drifters deployed in January 1990 in Santa Monica Bay escaped westward in about a week and most of the other drifters, which were not cast ashore, escaped the SCB in the ~2 week deployment period, roughly half passing north into the Santa Barbara Channel and half passing south of the Channel Islands. The estimates of larval duration and the prevailing oceanographic conditions indicate that Santa Monica Bay is a logical focus for examining the potential effects of entrainment and impingement.

The use of Santa Monica Bay as the source water for examining the potential effects of entrainment and impingement would not be appropriate for gobies, blennies, and other species that are generally restricted to bay and harbor habitats as adults. Fishes from these habitats are similar in some respects to northern lampfish, which are also transported out of their typical adult habitat into the nearshore areas around ESGS where they are subject to entrainment. Fishes that typically occupy bay and harbor habitats are also rarely impinged as adults by ESGS. The focus of the assessment should be on species with adult populations in the nearshore areas of Santa Monica Bay that are directly affected by entrainment and impingement at the ESGS CWIS. This would include fishes such as croakers, sand basses, and halibut that largely occur as adults in nearshore areas and CalCOFI data show their larvae have similar distributions (Figure 6.1-3). Therefore the following criteria listed above (distribution, range, density, dispersion of population, and population center) 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.

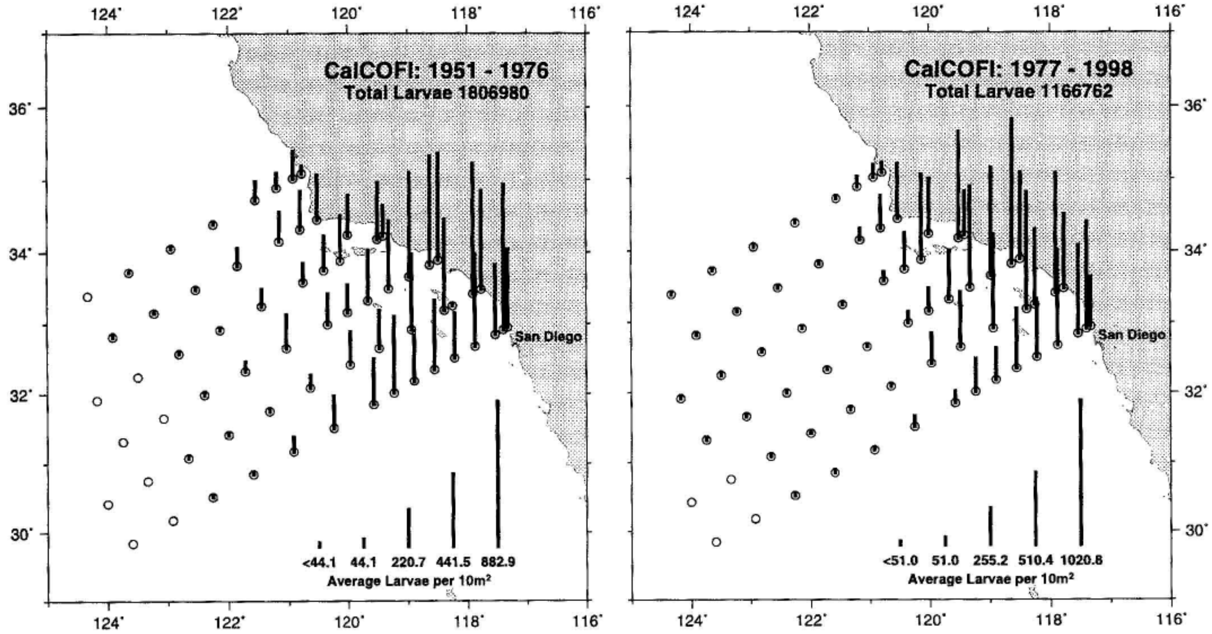
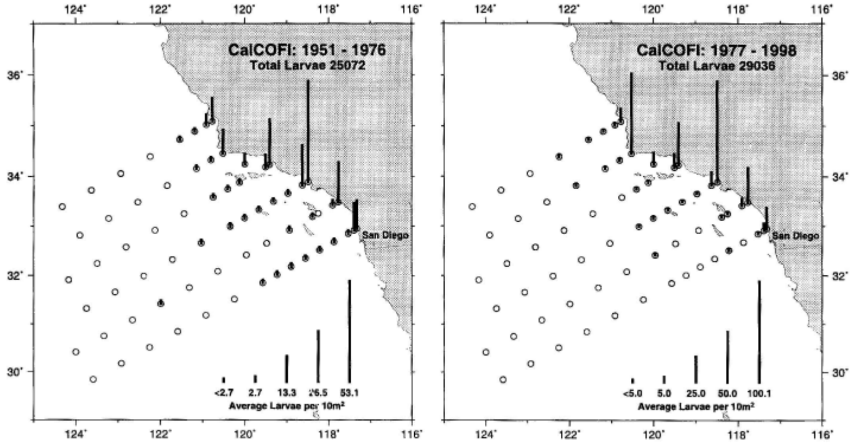
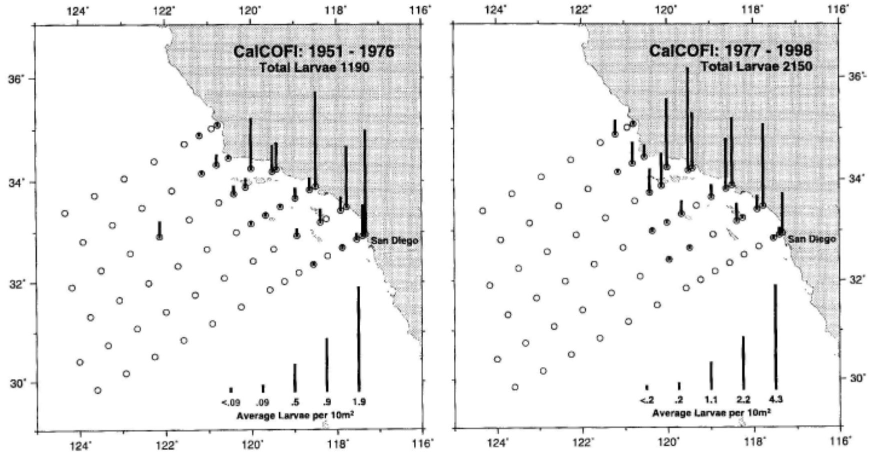


Figure 6.1-2. Distribution and abundance of northern anchovy larvae (*Engraulis mordax*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

a) croakers



b) kelp and sand basses



c) California halibut

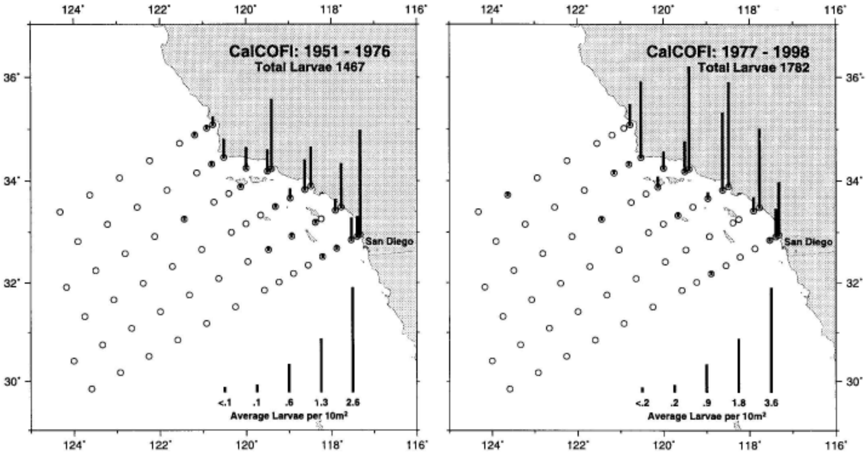


Figure 6.1-3. Distribution and abundance of larvae of a) croakers (Family Sciaenidae), b) kelp and sand basses (*Paralabrax* spp.), and c) California halibut (*Paralichthys californicus*) across permanent stations in the SCB from 1951 through 1998 (from Moser et al. 2001).

These criteria relate directly to the habitats associated with the fish and shellfish potentially affected by entrainment and impingement. This approach to classification has been taken in recent studies of marine fishes of California (Horn and Allen 1978, Allen 1985, Allen and Pondella 2006) and will be used to organize the discussion of taxa included in this assessment. We have simplified the more detailed categorization of habitats used by Allen and Pondella (2006) which included several habitats used to define deeper offshore areas (Figure 6.1-4). These deeper offshore habitat types can be combined for the purposes of our assessment since the taxa associated with those habitats are generally not at risk due to entrainment and impingement and were collected in very low numbers. The habitats defined by Allen and Pondella (2006) have been simplified for this assessment to the following habitat types:

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

The taxa included in this assessment were categorized into these habitat types (Table 6.1-1). Taxa that occur in more than one habitat will be included in the habitat group that best reflects the primary distribution for the taxa and if a primary habitat cannot be identified, the one that places them at greatest risk to the effects of entrainment and impingement. For example, kelp and sand basses occur in both bay and harbor, and rocky reef/kelp habitats but are more commonly associated with rocky reef/kelp habitats, the habitat that also places them at greater risk to power plant effects. This raises an important point in regards to impact assessment. Taxa that occupy several different habitats will be less at risk from power plant impacts especially if at least one of the habitats is not directly affected by entrainment and impingement. For example, white croakers occur in sandy shallow nearshore areas where they are directly at risk to entrainment and impingement but also in bays and harbors where they are not at risk. As previously discussed, the risk of impacts to a taxa group like the CIQ gobies is very low since their primary habitat is not directly affected by the power plant.

This approach to assessing AEI is consistent with recent trends in fisheries management to 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.

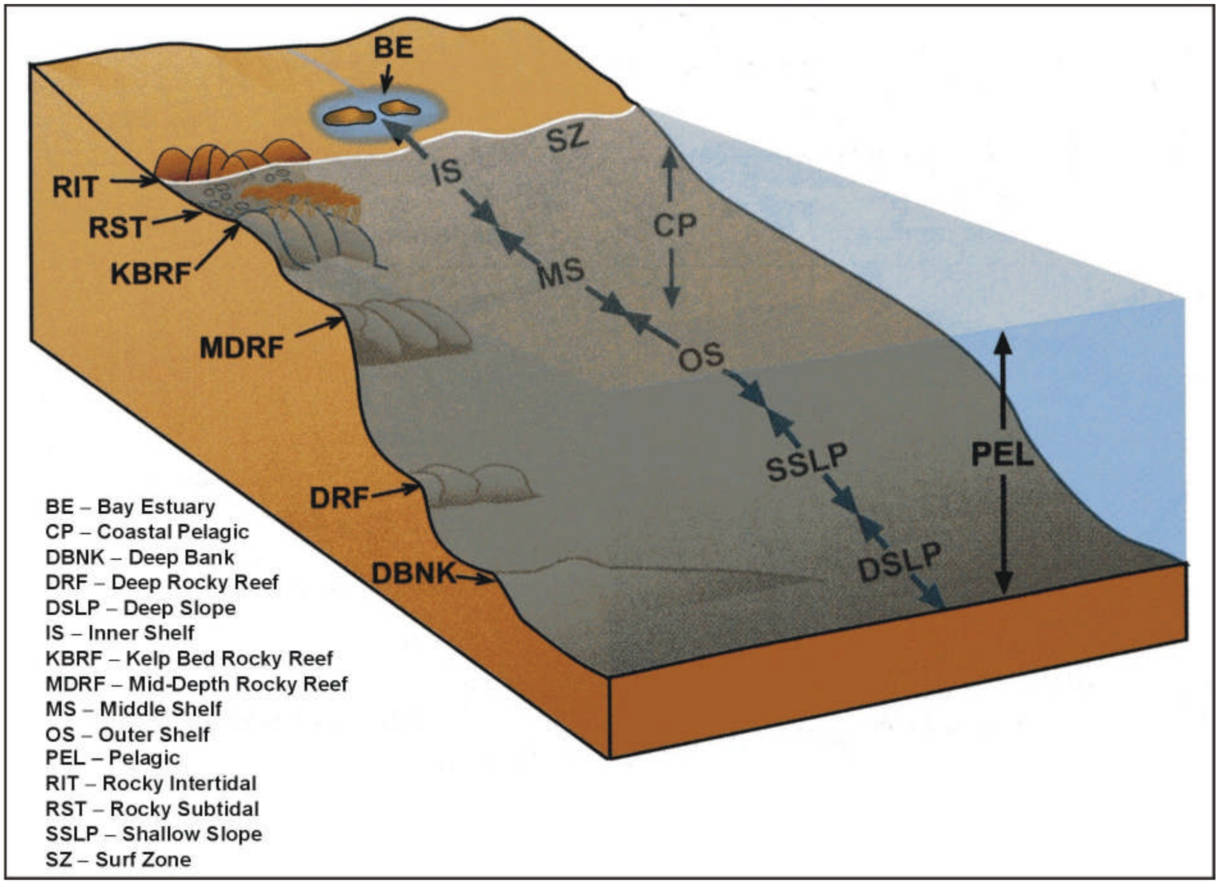


Figure 6.1-4. Marine habitat types in California (from Allen and Pondella [2006]).

Table 6.1-1. Habitat associations for taxa included in assessment of CWIS effects at the ESGS. Primary habitat in bold, upper case and secondary habitat in lower case. Taxa also designated as to whether they are targeted by a sport (S) or commercial (C) fishery.

		Fishery	**Habitats**			
Scientific name	**Common name**	**S-Sport C-Comm.**	**bays, harbors**	**reefs, kelp beds**	**coastal pelagic**	**shelf**
Atherinopsidae unid.	silversides	S, C	x		**X**	
Citharichthys spp.	sanddabs	S, C	x			**X**
Cheilotrema saturnum	black croaker	S		**X**	x	
Chromis punctipinnis	blacksmith	S		**X**		
Cymatogaster aggregata	shiner perch	S	**X**	x		
Engraulidae unid.	anchovies	C			**X**	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Gobiidae unid.	CIQ goby complex		**X**			
Hyperprosopon argenteum	walleye surfperch		x		**X**	
Hypsoblennius spp.	combtooth blennies		**X**	x		
Myliobatis californica	Bat ray		**X**	x		
Paralabrax spp.	sand and kelp bass	S	x	**X**		
Paralichthys californicus	California halibut	S	x			**X**
Parophrys vetulus	English sole	C				**X**
Phanerodon furcatus	white seaperch	S	**X**	x		x
Pleuronichthys guttulatus	diamond turbot	S	x			**X**
Rhacochilus toxotes	rubberlip seaperch	S		**X**		x
Rhacochilus vacca	pile perch	S		**X**		
Sciaenidae unid.	croakers	S, C			**X**	x
Scorpaena guttulata	California scorpionfish	S		**X**		x
Seriphus politus	queenfish	S			**X**	x
Cancer spp	cancer crabs	S	x	x		**X**
Loligo opalescens	market squid	S			**X**	
Loxorhynchus grandis	sheep crab	C		**X**		x
Octopus spp.	two-spot octopus	C	x	**X**		
Panulirus interruptus	California spiny lobster	S		**X**		

6.2 SUMMARY OF ENTRAINMENT AND IMPINGEMENT RESULTS

The following section summarizes the combined results of the entrainment and impingement studies at ESGS Units 1–4 to provide an overview of annual impacts to marine life that are directly attributable to operations at the generating station. Earlier sections of the report provide greater detail and explanation of the results on individual species, and the information in this section provides an overview of the major results. In addition, for those species such as queenfish 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 on such species, calculated losses are standardized to a common age-class that represents fishes at the age of maturity for that species. In later sections, the information on calculated losses is compared to long-term population trends and then discussed in terms of adverse environmental impacts to Santa Monica Bay.

6.2.1 All Life Stages of Fishes by Species

6.2.1.1 Taxa Composition

Data from monthly entrainment surveys conducted at ESGS in 2006 were used to estimate that 222.3 million fish larvae and 4.2 billion fish eggs were entrained through the combined CWIS using actual cooling water flow volumes (Table 6.2-1). Units 3 & 4 accounted for the majority of the entrained larvae with 186.5 million fish larvae and 3.4 billion fish eggs entrained at these units. Using the design flow volumes for Units 3 & 4, potential entrainment increases to 276.9 million fish larvae and 5.8 billion fish eggs. At least one-fourth of the total larvae entrained were white croaker, one-fifth were northern anchovies, and twelve other species each contributed from 1%–5% of the annual total (Table 6.2-2). Larvae of approximately 63 fish taxa were represented in the collections. Approximately 15% of the larvae and 60% of the 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 third most abundant larval category was unidentified yolksac larvae (12.5%) although a substantial fraction of these were thought to be queenfish and other croakers based on the late summer peak of occurrence. The most abundant taxonomic groups of fish eggs in the samples were unidentified eggs (61.2%), followed by the composite category of Sciaenidae, Paralichthyidae, and Labridae eggs (11.5%), and then anchovy eggs (10.3%). Eggs of approximately 19 taxa were represented in the collections. A complete listing of all of the taxonomic categories identified during the study is presented in Appendix F.

Impingement was the combined result of flows from normal operations and also from heat treatment procedures implemented periodically to remove fouling organisms from the conduits. An estimated total of 1,713 fishes (including sharks and rays) with a biomass of 243 kg (536 lb) was impinged at both ESGS intakes in 2006 (Tables 5.5-1 and 5.5-2). Almost all of the impingement of fishes in 2006 occurred as a result of the operation and maintenance of ESGS Units 3 & 4. Units 1 & 2 cooling water pumps were operational at 25% or less flow capacity during most of 2006 while Units 3 & 4 operated at nearly full capacity during May–September, and at variable capacity during other months. A total of 1,527 fishes with a biomass of 215 kg (474 lb) were impinged at Units 3 & 4 based on actual CWIS flows in 2006. Eighty percent of the impinged fish biomass was the result of the four heat treatment operations. The top three species (bat ray, black surfperch, and kelp bass) impinged by weight accounted for slightly over half of the annual impingement biomass (Table 6.2-3). Seventeen species comprised the top 90% of impingement by biomass and contributed greater than one percent individually, with an additional 30 species comprising the remaining 10%. In terms of numbers, blacksmith was the most abundantly impinged species at Units 3 & 4 (estimated at 189 per year), followed by kelp bass (171) and black perch (142). If the pumps were run at the design flow volumes, the projected impingement estimate increased to 2,521 fishes with a biomass of 246 kg (542 lb) impinged at ESGS (Table 6.2-4).

Table 6.2-1. Estimated annual entrainment of common fish larvae and eggs at ESGS in 2006 based on actual and design[1] CWS flow volumes.

Common Name	**All Units Actual Flows**	**Units 3 & 4 Actual Flows**	**Units 1 & 2 Actual Flows**	**Units 3 & 4 Design Flows**
Fish Larvae				
white croaker	44,365,993	36,886,189	7,479,804	57,674,813
northern anchovy	36,589,361	30,806,088	5,783,273	44,566,730
yolksac larvae, unid.	32,877,925	27,954,526	4,923,399	38,410,225
croakers, unid.	15,122,724	13,080,938	2,041,786	15,708,573
sea basses, unid.	10,753,540	8,932,843	1,820,697	14,393,420
gobies, unid.	8,553,040	6,997,707	1,555,333	12,043,151
combtooth blennies	7,451,656	6,180,886	1,270,770	9,927,668
damaged larvae, unid.	7,095,438	6,018,166	1,077,272	8,381,958
California halibut	6,869,726	5,863,484	1,006,242	7,790,992
diamond turbot	2,148,380	1,288,095	860,285	6,768,632
northern lampfish	4,240,824	3,493,114	747,710	5,754,218
sanddabs	4,476,374	3,738,404	737,970	5,698,399
queenfish	5,807,906	5,038,592	769,314	5,915,819
silversides	2,361,934	1,839,312	522,622	4,145,527
English sole	1,685,987	1,371,804	314,183	2,416,978
turbots, unid.	3,390,551	2,960,303	430,248	3,319,412
grunts, unid.	2,788,973	2,389,078	399,895	3,087,266
righteye flounders	1,477,214	1,205,683	271,531	2,089,182
45 other taxa	24,217,785	20,486,792	3,730,993	28,841,952
	222,275,332	**186,532,003**	**35,743,328**	**276,934,913**
Fish Eggs				
unidentified fish eggs	2,565,757,298	2,126,699,674	439,057,624	3,405,009,564
SPL fish eggs[2]	483,931,072	407,914,231	76,016,841	592,934,824
anchovy eggs	432,212,026	363,479,754	68,732,272	529,013,191
sand flounder eggs	347,101,345	252,841,920	94,259,425	726,152,480
15 other taxa	363,079,352	291,943,644	71,135,708	552,050,915
	4,192,081,093	**3,442,879,223**	**749,201,870**	**5,805,160,975**

[1]. Entrainment based on design CWS flow volumes only calculated for Units 3 & 4.

[2] Combined taxon including Sciaenidae, Paralichthyidae, and Labridae (croakers, sand flounders, and wrasses).

Table 6.2-2. Rank and percent composition of common fish larvae and eggs entrained at ESGS in 2006 for all units.

Rank	Common Name	% comp	Cumulative % Comp.
	Fish Larvae		
1	white croaker	23.68	23.68
2	northern anchovy	16.54	40.22
3	yolksac larvae, unid.	12.54	52.76
4	croakers, unid.	5.11	57.87
5	sea basses, unid.	4.68	62.55
6	gobies, unid.	4.40	66.95
7	combtooth blennies	3.34	70.29
8	damaged larvae,	2.96	73.24
9	California halibut	2.67	75.92
10	diamond turbot	2.56	78.47
11	northern lampfish	2.51	80.98
12	sanddabs	1.96	82.94
13	queenfish	1.63	84.58
14	silversides	1.61	86.18
15	English sole	1.16	87.34
16	turbots, unid.	1.04	88.38
17	grunts, unid.	1.04	89.43
18	righteye flounders	0.97	90.40
	45 other taxa	9.60	100.00
	Fish Eggs		
1	unidentified fish	61.20	61.20
2	SPL fish eggs[1]	11.54	72.75
3	anchovy eggs	10.31	83.06
4	sand flounder eggs	8.28	91.34
	15 other taxa	8.66	100.00

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[1] Combined taxon including Sciaenidae, Paralichthyidae, and Labridae (croakers, sand flounders, and wrasses).

Table 6.2-3. Estimated annual impingement (number and biomass) of common fishes at ESGS Units 3 & 4 in 2006 using actual flows.

Common Name	**Estimated Number**	**% Total Number**	**Estimated Biomass (kg)**	**% Total Biomass**
blacksmith	189	12.38	5.229	2.44
kelp bass	171	11.20	37.143	17.31
black perch	142	9.30	43.825	20.42
rubberlip seaperch	130	8.51	8.238	3.84
queenfish	103	6.75	2.198	1.02
shiner perch	98	6.42	0.404	0.19
bat ray	96	6.29	47.260	22.02
northern anchovy	78	5.11	1.137	0.53
rockpool blenny	70	4.58	0.951	0.44
white seaperch	65	4.26	4.067	1.89
hornyhead turbot	63	4.13	16.915	7.88
pipefish, unid.	59	3.86	0.146	0.07
walleye surfperch	34	2.23	2.043	0.95
pile perch	30	1.96	4.976	2.32
black croaker	20	1.31	5.200	2.42
jacksmelt	19	1.24	3.056	1.42
Calif. scorpionfish	18	1.18	4.339	2.02
30 other taxa	142	9.30	27.507	12.82
	1,527	100.00	**214.634**	100.00

Table 6.2-4. Estimated annual impingement (number and biomass) of common fishes at ESGS Units 3 & 4 in 2006 using design (maximum) flows.

Common Name	**Estimated Number**	**% Total Number**	**Estimated Biomass (kg)**	**% Total Biomass**
rockpool blenny	540	21.42	7.015	2.85
kelp bass	348	13.80	39.616	16.12
blacksmith	282	11.19	5.540	2.25
black perch	142	5.63	43.825	17.83
pipefish, unid.	136	5.39	0.340	0.14
rubberlip seaperch	134	5.32	8.282	3.37
bay blenny	126	5.00	0.379	0.15
bat ray	123	4.88	58.017	23.61
queenfish	103	4.09	2.198	0.89
shiner perch	98	3.89	0.404	0.16
hornyhead turbot	90	3.57	27.807	11.32
northern anchovy	78	3.09	1.137	0.46
white seaperch	69	2.74	4.092	1.67
walleye surfperch	34	1.35	2.043	0.83
pile perch	30	1.19	4.976	2.02
32 other taxa	188	7.46	40.068	16.31
	2,521	100.00	**245.739**	100.00

6.2.1.2 Temporal Occurrence

The greatest densities of larval fishes occurred in April and the least in January (Figure 4.5-1). Fish eggs also peaked in abundance in April with lows occurring in December (Figure 4.5-2). Although this is a typical pattern that is associated with spawning during spring upwelling periods in high productivity coastal waters, some species also had well-defined seasonal spawning peaks in either winter or summer months. For example, diamond turbot occurred mainly in October–March whereas California halibut peaked in June–July. Larvae and eggs were generally more abundant in samples collected at night than those collected during the day (Figures 4.5-3 and 4.5-4). For the larvae, some of the increased nighttime densities may have resulted from more efficient capture rates of the nets at night compared to daylight hours.

Fish impingement rates were a function of both plant operating capacity and abundance of fishes in the source water. Impingement abundance at Units 3 & 4 peaked from September to December while fish biomass at Units 3 & 4 peaked in April with the impingement of two relatively larger fish: bat ray (*Myliobatis californica*) and hornyhead turbot (*Pleuronichthys verticalis*) (Figure 5.5-4). At Units 1 & 2, fish were only impinged in January, March, April, and September 2006, with the peak mean abundance rate recorded in March (Figure 5.5-1). Impingement rates based on biomass were similarly high in March and September, while biomass in January and April was comparatively depressed (Figure 5.5-2).

6.2.2 All Life Stages of Shellfishes by Species

6.2.2.1 Taxa Composition

Entrainment of invertebrate larvae was focused only on "shellfish" which by definition were crabs, lobsters and squid. The vast majority of entrained invertebrate larvae and holoplanktonic species (all life stages are planktonic) were not enumerated because of the impracticality of sorting and identifying them—many have no published guides to their identification, as well as their typically high densities and widespread distribution. The target list of shellfish also included several species with some type of fishery value. A total of 431 larval invertebrates representing 18 taxa was collected from the ESGS entrainment stations during 12 monthly surveys in 2006 (Table 4.5-3). Total annual entrainment at ESGS was estimated to be 23.7 million target invertebrate larvae (Table 6.2-5) with pea crab megalops (*Pinnixa* spp.) and kelp crab megalops (*Pugettia* spp.) the most abundant target invertebrate larvae in the samples (Table 6.2-6). For species with commercial fishery importance, an estimated 1.86 million Cancer crab megalops and 51,000 market squid larvae were entrained. Units 3 & 4 accounted for the majority of the entrained shellfish with 20.1 million larvae entrained at these units. Using the design flow volumes for Units 3 & 4, entrainment estimates increased to 27.4 million larvae potentially entrained at ESGS (Table 6.2-5).

Pacific rock crab, yellow crab, and California spiny lobster comprised 90% of the impinged shellfish biomass. A total of 28 species of shellfishes comprised a total estimated annual impingement of 976 kg (2,152 lb) with over half contributed by Pacific rock crab (Tables 5.5-4 and 5.5-6). A total of 15,494 shellfishes with a biomass of 451 kg (994 lb) were impinged at Units 3 & 4, and accounted for 83% of the total abundance and 46% of the total biomass impinged (Table 6.2-7). If Units 3 & 4 were run at the design flow volumes, impingement biomass estimates would increase to 102,113 shellfishes with a biomass of 2,969 kg (6,546 lb) potentially entrained at ESGS (Table 6.2-8).

Table 6.2-5. Estimated annual entrainment of common target shellfish larvae at ESGS in 2006.

Common Name	**All Units Actual Flows**	**Units 3 & 4 Actual Flows**	**Units 1 & 2 Actual Flows**	**Units 3 & 4 Design Flows**
Target Shellfish Larvae				
Pinnixa spp. pea crabs megalops	7,681,714	6,622,400	1,059,314	8,170,052
kelp crabs megalops	5,156,073	4,263,545	892,528	6,923,911
porcelain crabs megalops	2,209,439	1,935,713	273,726	2,104,880
cancer crabs megalops	1,860,530	1,577,364	283,166	2,205,141
spider crab megalops	982,451	832,284	150,167	1,156,103
Pinnotheres spp. pea crab	957,020	812,721	144,299	1,112,100
hermit crab megalops	916,469	794,334	122,135	940,030
black-clawed crab megalops	830,481	726,419	104,062	800,333
porcelain crab megalops	795,187	690,551	104,636	805,329
9 other taxa	2,296,407	1,892,882	403,525	3,135,706
	23,685,771	**20,148,213**	**3,537,558**	**27,353,585**

Table 6.2-6. Rank and percent composition of common target shellfish larvae entrained at ESGS in 2006 for All Units.

Rank	**Common Name**	**% comp**	**Cumulative % Comp.**
	Target Shellfish Larvae		
1	*Pinnixa* spp. pea crabs megalops	32.43	32.43
2	kelp crabs megalops	21.77	54.20
3	porcelain crabs megalops	9.33	63.53
4	cancer crabs megalops	7.86	71.38
5	spider crab megalops	4.15	75.53
6	*Pinnotheres* spp. pea crab	4.04	79.57
7	hermit crab megalops	3.87	83.44
8	black-clawed crab megalops	3.51	86.95
9	porcelain crab megalops	3.36	90.30
	9 other taxa	9.70	100.00

Table 6.2-7. Estimated annual impingement (number and biomass) of common shellfishes at ESGS Units 3 & 4 in 2006 using actual flows.

Common Name	Estimated Number	% Total Number	Estimated Biomass (kg)	% Total Biomass
Shellfishes				
Pacific rock crab	7,839	50.59	273.449	60.58
yellow crab	3,458	22.32	128.451	28.45
red rock shrimp	1,007	6.50	1.425	0.32
tuberculate pear crab	693	4.47	0.489	0.11
Hemphill kelp crab	545	3.52	0.377	0.08
intertidal coastal shrimp	344	2.22	0.161	0.04
Xantus swimming crab	271	1.75	2.272	0.50
striped shore crab	268	1.73	2.172	0.48
visored shrimp	223	1.44	0.160	0.04
blackspotted bay shrimp	183	1.18	0.432	0.10
15 other taxa	663	4.28	42.032	9.31
	15,494	100.00	**451.420**	100.00

Table 6.2-8. Estimated annual impingement (number and biomass) of common shellfishes at ESGS Units 3 & 4 in 2006 using design (maximum) flows.

Common Name	Estimated Number	% Total Number	Estimated Biomass (kg)	% Total Biomass
Shellfishes				
Pacific rock crab	55,232	54.09	1,930.987	65.04
yellow crab	26,362	25.82	936.533	31.54
red rock shrimp	6,781	6.64	11.65	0.39
blackclaw crestleg crab	2,512	2.46	1.395	0.05
visored shrimp	2,325	2.28	1.209	0.04
tuberculate pear crab	2,212	2.17	1.622	0.05
striped shore crab	1,871	1.83	10.665	0.36
Xantus swimming crab	950	0.93	8.752	0.29
hemphill kelp crab	950	0.93	0.657	0.02
16 other taxa	2,918	2.86	65.671	2.21
	102,113	100.00	**2,969.141**	100.00

6.2.2.2 Temporal Occurrence

Cancer crab larvae were the most abundant group of target shellfish with any commercial significance, and these were most abundant during June and July. They were absent or in very low abundance in January through April and present during eight of the twelve surveys. Target shellfish larvae for all other taxa were highly variable among surveys, typically with one or two of the monthly surveys with high densities and few or none present during other surveys.

Abundance of shellfish at Units 1 & 2 was seasonally higher from late spring to mid-summer, but the highest impingement rate was recorded in January 2006 (Figures 5.5-5). Shellfish biomass at Units 1 & 2 was highest from June through August (Figure 5.5-6). At Units 3 & 4, shellfish abundance and biomass were substantially higher from September through December, with peak rates recorded in November (Figures 5.5-7 and 5.5-8).

6.2.3 Combined Analysis and Modeling Results for Selected Species

Annual impacts for all IM&E species that were subjected to detailed analysis are presented based on actual flow rates for all units (Table 6.2-9), and for Units 3 & 4 only based on actual flows (Table 6.2-10) and on design, or maximum capacity, flows (Table 6.2-11). The criteria for detailed treatment was either a species that ranked high in IM&E abundance, or one that was of significant fishery importance even if it did not have overall high abundances. Eleven fish species (or taxa groups of similar species) and one shellfish species were modeled for entrainment effects, and twenty fish species and three shellfish species were evaluated for impingement effects. Three modeling approaches (*AEL*, *FH*, and *ETM*) were potentially used to approximate population-level effects of entrainment, but the *FH* or *AEL* models were dependent on detailed life history information and could only be applied to six of the eleven species. Because the *ETM* approach was based on proportional entrainment between intake and source water larval densities, it could be applied to all eleven species. All of the species with modeled entrainment impacts had impingement data also, but seven of the impinged species (rays and surfperches) had no concurrent entrainment data because the species were live–bearers. Another modeling approach, *EAM*, which is equivalent to the *AEL* model used for entrainment, was used to approximate population-level effects of impingement. Modeling of impingement totals was limited to species with sufficient life history information, thus was only performed for four species.

In terms of estimated annual numbers of adult fishes impacted, northern anchovy was the species most affected, with approximately 34,000 to 65,000 adult equivalents lost annually due to the entrainment of eggs and larvae. Impingement losses were minor in comparison, with an estimated 127 equivalent adults lost due to the impingement of juveniles and adults. Approximately 84% of the Engraulidae larvae and 100% of the juveniles and adults were entrained at Units 3 & 4. Equivalent adult losses at Units 3 & 4 ranged from approximately 25,000 to 55,000 fish, depending upon the *FH* or *AEL* model. If Units 3 & 4 were run at the design flow volumes, the projected losses would increase to approximately 41,000 to 80,000 equivalent adults lost due to the entrainment at ESGS. The projected loss due to impingement would not change since all individuals were collected in the heat treatments and not during normal operation sampling. The *ETM* calculations provided an estimated larval mortality due to entrainment (P_M) of 0.15% for Units 3 & 4 only using actual flow volumes. If Units 3 & 4 were run at the design flow volumes, this estimate would increase to 0.22% of the larval anchovy population lost due to entrainment.

Enough life history information was available to calculate each demographic model from entrainment estimates for goby larvae. Equivalent adult losses ranged from approximately 7,000 to 16,000 fish, using the *AEL* and *FH* models. Approximately 82% of the goby larvae were entrained at Units 3 & 4, and no juveniles or adults were impinged. Equivalent adult losses at Units 3 & 4 ranged from approximately 6,000 to 13,000 fish, depending upon the *AEL* or *FH* model. If Units 3 & 4 were run at the design flow volumes, the projected losses would increase to approximately 10,000 to 23,000 equivalent adults lost due to the entrainment at ESGS. The *ETM* calculations provided an estimated larval mortality due to entrainment (P_M) of 1.22% for Units 3 & 4 only using actual flow volumes. If Units 3 & 4 were run at the design flow volumes, this estimate would increase to 2.21% of the goby population lost due to entrainment.

All demographic models for entrainment estimates were calculated for combtooth blenny larvae. Equivalent adult losses ranged from approximately 9,000 to 18,000 fish, using the *FH* and *AEL* models. Only 81 juveniles and adults were impinged, thus *EAM* was not calculated for this species group. Approximately 83% of the blenny larvae were entrained at Units 3 & 4. Equivalent adult losses at Units 3 & 4 ranged from approximately 7,000 to 15,000 fish, depending upon the *FH* or *AEL* model. If Units 3 & 4 were run at the design flow volumes, the projected losses would increase to approximately 11,000 to 24,000 equivalent adults lost due to the entrainment at ESGS. The *ETM* calculations provided an estimated larval mortality due to entrainment (P_M) of 0.23% for Units 3 & 4 only using actual flow volumes. If Units 3 & 4 were run at the design flow volumes, this estimate would increase to 0.40% of the blenny population lost due to entrainment.

Impingement was relatively low for all species but three species in particular, bat ray, black perch, and kelp bass, had the greatest impingement estimates. Of these three species, only enough life history information was available on kelp bass to calculate the equivalent adult mortality. *FH* and *AEL* were not calculated for this species since life history data is lacking for the larval stages of sea basses. Approximately 2,000 equivalent adult kelp bass were estimated to be lost due to impingement at ESGS using the actual flow volumes. Out of the 79 individuals collected in the impingement sampling, only 3 were collected in the normal operation sampling. Therefore, *EAM* calculations were not done using design flow volumes due to the small sample size. The number of equivalent adults lost should not increase substantially above the 2,000 estimated lost using actual flow volumes. The *ETM* calculations provided an estimated larval mortality due to entrainment (P_M) of 0.27% for Units 3 & 4 only using actual flow volumes. If Units 3 & 4 were run at the design flow volumes, this estimate would increase to 0.50% of the larval kelp bass lost due to entrainment.

Table 6.2-9. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual cooling water flows for all four units (Units 1-4) at ESGS in 2006. Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

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									
Genyonemus lineatus	white croaker	44.37	4.50	0.29	6^E		0	–	
Engraulis mordax	northern anchovy	36.59	432.21	0.18	33,850^C	65,013^L	78	1.14	127
Seriphus politus[2]	queenfish	20.90	39.40	0.05			103	2.20	116
Paralabrax spp[3]	sea basses	10.75	4.94	0.33			171	37.14	2,022
Gobiidae unid.	CIQ gobies	8.55	0	1.50	16,328^L	7,012^L	0	–	
Hypsoblennius spp.	combtooth blennies	7.45	0	0.28	8,516^L	18,173^L	81	0.99	
Paralichthys californicus	California halibut	6.87	0.60	0.17	<1^E		1	0.04	
Citharichthys spp.[4]	sanddabs	4.48	165.39	0.10	2,010^E		15	0.04	
Atherinopsidae unid.[5]	silversides	2.36	0.14	1.78			19	3.06	
Pleuronichthys guttulatus	diamond turbot	2.15	0.14	0.94			0	–	
Parophrys vetulus	English sole	1.69	0	0.08			3	0.01	
Myliobatis californica	bat ray	–	–				96	47.26	
Rhacochilus toxotes	rubberlip seaperch	–	–				130	8.24	
Chromis punctipinnis	blacksmith	0	0				223	7.48	
Cheilotrema saturnum	black croaker	2.89	0				20	5.20	83
Rhacochilus vacca	pile perch	–	–				30	4.98	
Phanerodon furcatus	white seaperch	–	–				65	4.07	
Sebastes auriculatus	brown rockfish	0	0				7	2.40	
Hyperprosopon argenteum	walleye surfperch	–	–				34	2.04	
Trachurus symmetricus	jack mackerel	0	0				11	1.40	
Scomber japonicus	pacific chub mackerel	0	0				5	1.04	
Scorpaena guttata	California scorpionfish	0	0				170	30.82	
Cymatogaster aggregata	shiner perch	–	–				98	0.40	
Sardinops sagax	pacific sardine	0.07	0				10	0.14	
Sebastes miniatus	vermilion rockfish	0	0				3	0.02	

(table continued)

Table 6.2-9 (continued). Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual flows for all units at ESGS 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]
Invertebrates									
Cancer spp.[6]	cancer crabs	1.86	–				12,584	717.90	
Panulirus interruptus	spiny lobster	0.27	–				332	164.70	
Loxorhynchus grandis	sheep crab	–	–				68	64.41	
Octopus spp.	two-spot octopus	–	–				70	10.63	
Loligo opalescens	market squid	0.05	–				63	1.17	

[1] standardized impingement adult equivalent mortality

[2] larval entrainment estimate includes queenfish and unidentified croakers combined

[3] only kelp bass was collected in abundance in impingement samples

[4] only speckled sanddab identified in impingement samples

[5] only jacksmelt was collected in abundance in impingement samples.

[6] megalops larvae for entrainment; only yellow and Pacific rock crabs collected in abundance in impingement samples

Table 6.2-10. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual cooling water flows for Units 3 & 4 only at ESGS in 2006. Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

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									
Genyonemus lineatus	white croaker	36.87	3.32	0.24	4^E		0	–	
Engraulis mordax	northern anchovy	30.81	363.48	0.15	$25{,}490^C$	$54{,}737^L$	78	1.14	127
Seriphus politus[2]	queenfish	18.10	31.60	0.04			103	2.20	116
Paralabrax spp[3]	sea basses	8.93	4.11	0.27			171	37.14	2,022
Gobiidae unid.	CIQ gobies	7.0	0	1.22	$13{,}360^L$	$5{,}737^L$	0	–	
Hypsoblennius spp.	combtooth blennies	6.18	0	0.23	$7{,}064^L$	$15{,}074^L$	81	0.99	
Paralichthys californicus	California halibut	5.87	0.45	0.14	$<1^E$		1	0.04	
Citharichthys spp.[4]	sanddabs	3.74	131.27	0.08	$1{,}594^E$		15	0.04	
Atherinopsidae unid.[5]	silversides	1.84	0.12	1.38			19	3.06	
Pleuronichthys guttulatus	diamond turbot	1.29	0	0.54			0	–	
Parophrys vetulus	English sole	1.37	0	0.06			3	0.01	
Myliobatis californica	bat ray	–	–				96	47.26	
Rhacochilus toxotes	rubberlip seaperch	–	–				130	8.24	
Chromis punctipinnis	blacksmith	0	0				189	5.23	
Cheilotrema saturnum	black croaker	2.53	0				20	5.20	83
Rhacochilus vacca	pile perch	–	–				30	4.98	
Phanerodon furcatus	white seaperch	–	–				65	4.07	
Sebastes auriculatus	brown rockfish	0	0				7	2.40	
Hyperprosopon argenteum	walleye surfperch	–	–				34	2.04	
Trachurus symmetricus	jack mackerel	0	0				11	1.40	
Scomber japonicus	pacific chub mackerel	0	0				5	1.04	
Scorpaena guttata	California scorpionfish	0	0				18	4.34	
Cymatogaster aggregata	shiner perch	–	–				98	0.40	
Sardinops sagax	pacific sardine	0.06	0				10	0.14	
Sebastes miniatus	vermilion rockfish	0	0				3	0.02	

(table continued)

Table 6.2-10 (continued). Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual flows for Units 3 & 4 only at ESGS 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]
Invertebrates									
Cancer spp. [6]	cancer crabs	1.58	–				11,297	401.89	
Panulirus interruptus	spiny lobster	0.23	–				125	39.00	
Loxorhynchus grandis	sheep crab	0	–				0	–	
Octopus spp.	two-spot octopus	–	–				6	0.08	
Loligo opalescens	market squid	0.04	–				29	0.73	

[1] standardized impingement adult equivalent mortality

[2] larval entrainment estimate includes queenfish and unidentified croakers combined

[3] only kelp bass was collected in abundance in impingement samples

[4] only speckled sanddab identified in impingement samples

[5] only jacksmelt was collected in abundance in impingement samples.

[6] megalops larvae for entrainment; only yellow and Pacific rock crabs collected in abundance in impingement samples

Table 6.2-11. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on design (maximum) cooling water flows for Units 3 & 4 only at ESGS in 2006. Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

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									
Genyonemus lineatus	white croaker	57.67	9.07	0.42	10^{E}		0	–	
Engraulis mordax	northern anchovy	44.57	529.01	0.22	$41{,}270^{C}$	$79{,}188^{L}$	78	1.14	127
Seriphus politus[2]	queenfish	21.60	60.90	0.05			103	2.20	116
Paralabrax spp[3]	sea basses	14.39	6.57	0.50			348	39.62	2,022
Gobiidae unid.	CIQ gobies	12.04	0	2.21	$22{,}992^{L}$	$9{,}874^{L}$			
Hypsoblennius spp.	combtooth blennies	9.93	0	0.40	$11{,}346^{L}$	$24{,}211^{L}$	666	7.39	
Paralichthys californicus	California halibut	7.79	1.18	0.24	2^{E}		1	0.04	
Citharichthys spp.[4]	sanddabs	5.70	264.88	0.15	$3{,}218^{E}$		15	0.04	
Atherinopsidae unid.[5]	silversides	4.15	0.16	3.19			19	3.06	
Pleuronichthys guttulatus	diamond turbot	6.77	0	3.09					
Parophrys vetulus	English sole	2.42	0	0.11			3	0.01	
Myliobatis californica	bat ray	–	–				123	58.02	
Rhacochilus toxotes	rubberlip seaperch	–	–				134	8.28	
Chromis punctipinnis	blacksmith	0	0				282	5.54	
Cheilotrema saturnum	black croaker	2.77	0				20	5.20	83
Rhacochilus vacca	pile perch	–	–				30	4.98	
Phanerodon furcatus	white seaperch	–	–				69	4.09	
Sebastes auriculatus	brown rockfish	0	0				7	2.40	
Hyperprosopon argenteum	walleye surfperch	–	–				34	2.04	
Trachurus symmetricus	jack mackerel	0	0				11	1.40	
Scomber japonicus	pacific chub mackerel	0	0				5	1.04	
Scorpaena guttata	California scorpionfish	0	0				18	4.34	
Cymatogaster aggregata	shiner perch	–	–				98	0.40	
Sardinops sagax	pacific sardine	0.77	0				10	0.14	
Sebastes miniatus	vermilion rockfish	0	0				3	0.02	

(table continued)

Table 6.2-11 (continued). Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on design (maximum) flows for Units 3 & 4 only at ESGS 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]
Invertebrates									
Cancer spp. [6]	cancer crabs	2.21	–				81,594	2,867.52	
Panulirus interruptus	spiny lobster	0.26	–				149	43.57	
Loxorhynchus grandis	sheep crab	0	–				0	–	
Octopus spp.	two-spot octopus	–	–				6	0.08	
Loligo opalescens	market squid	0.06	–				68	1.70	

[1] standardized impingement adult equivalent mortality

[2] larval entrainment estimate includes queenfish and unidentified croakers combined

[3] only kelp bass was collected in abundance in impingement samples; EAM not extrapolated for design flows due to small sample size

[4] only speckled sanddab identified in impingement samples

[5] only jacksmelt was collected in abundance in impingement samples.

[6] megalops larvae for entrainment; only yellow and Pacific rock crabs collected in abundance in impingement samples

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 (2006). A general discussion of the habitat and the potential risk to the habitat due to ESGS 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 Information on Oceanographic Setting and Population Trends

Water temperatures and current patterns have a significant effect on marine faunal composition. Understanding the nature of the variability in these physical factors is essential for explaining long-term population trends for many marine species. The Southern California Bight is the transition zone between the cool temperate Oregonian fauna, 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 (Bogard et al. 2000; Durazo et al. 2001; Lluch-Belda et al. 2001). During the cold phase, the bight is colder than average and dominated by the Oregonian fauna. The opposite is the case for the warm phase; the bight is warmer than average and dominated by the San Diegan fauna. There have been three transitions in the PDO over the last century. The most recent oscillation of the PDO caused a regime shift starting in the late 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 1982–1984 El Niño effectively extirpated the Oregonian fauna from the nearshore environment of Santa Monica Bay.

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

In the decade prior to this study there were three major events that affected the California Current System that need to be explained in order to understand the oceanographic setting of this study period. The first was the 1997–98 El Niño, the strongest recorded event of its kind. This was followed by a series of four cold water years (1999–2002) including the strongest La Niña on record (Schwing et al. 2000, Goericke et al. 2005). The possible return to the cold water phase of the PDO did not occur since 2003–2004 was described as a 'normal' year (Goericke et al. 2004). 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.

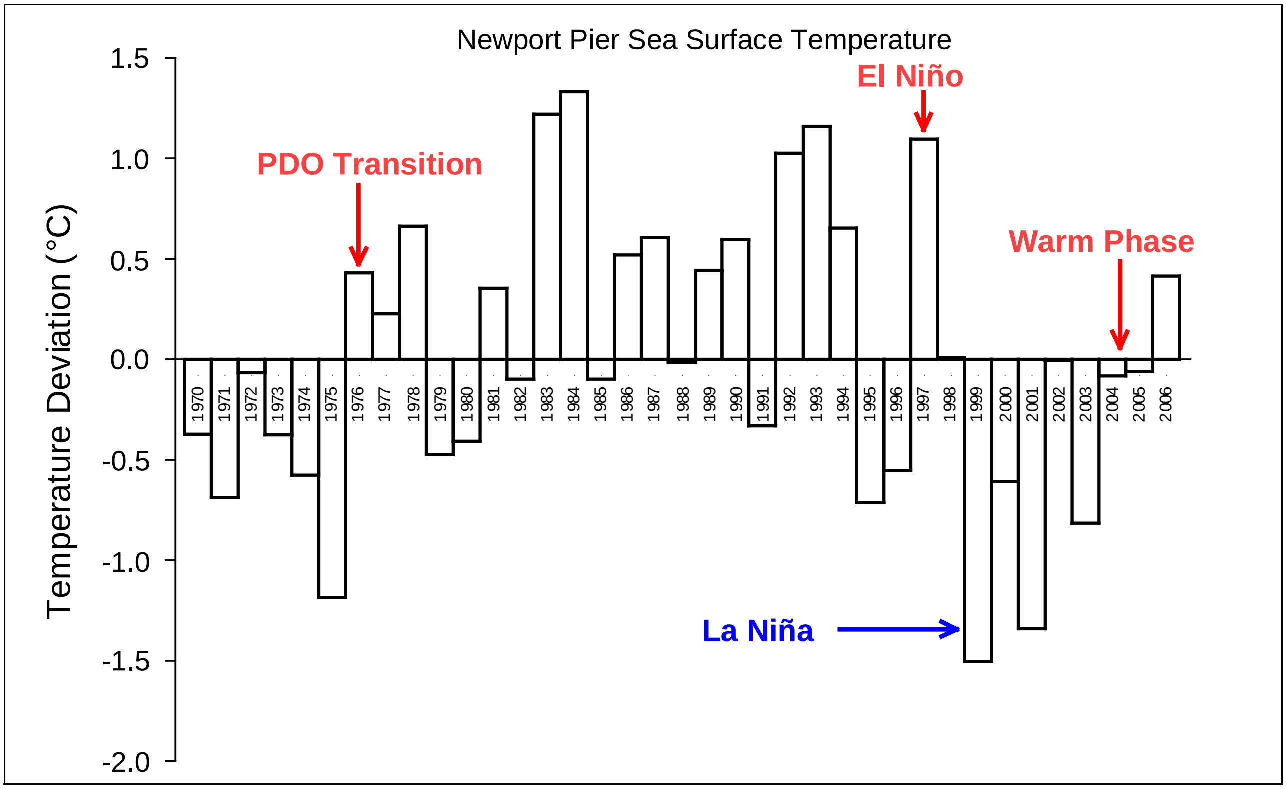


Figure 6.3-1. Sea surface temperature anomalies for Newport Pier, California. Values are ± the long-term average (1925-2006).

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 etc.) as they were historically over fished by commercial fishers (Young 1963); others were primarily commercial species (e.g. anchovies); while others are extracted by both fisheries (e.g. California halibut). Fishery data may or may not reflect actual population trends due to socioeconomic considerations such as market value, effort, management actions, etc. Fishery independent monitoring programs produce the best population time series metrics and also allow non-commercial species to be evaluated.

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, shelf sand bottom, and rocky reef. Species primarily associated with the coastal pelagic habitat (e.g., anchovies, queenfish, silversides) had the greatest number of individuals entrained (60.3%) even though there were few taxa (16.7%) compared to other habitat types (Table 6.3-1). Sport fishery species accounted for approximately 59% of the total number of larvae entrained while commercial fishery species accounted for 68%, and species with no direct fishery value comprised only 19% of the larvae entrained. (Note that some species such as white croaker were classified as both a sport and commercial fishery species). For impinged species the majority of the biomass was from species targeted by sport fisheries with very little contribution from commercial species. Approximately one-fourth of the impinged species and biomass were from fish and rays that have no direct fishery value.

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

Attributes	Entrained % abundance	Entrained % # taxa	Impinged % biomass	Impinged % # taxa
Habitat Association				
bays, harbors	9.91	20.00	44.46	31.25
coastal pelagic	60.26	16.67	5.35	18.75
continental shelf	15.54	36.67	8.15	14.58
rocky reef, kelp	11.81	20.00	42.04	35.42
deep pelagic	2.48	6.67	0	0
Fishery				
sport	58.87	35.00	76.21	66.67
commercial	67.93	30.00	5.35	27.08
none	19.35	53.33	23.25	27.08

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

Since impingement affects juvenile and adult stages of fishes and shellfishes, there are greater percentages of species associated with the types of habitats in close proximity to the intakes than found from the entrainment data (Table 6.3-1). For example, no species from deep pelagic habitats were collected and by far the greatest abundance of fishes were associated with the bays and harbors and the rocky reef and kelp habitats most at risk to impingement. The percentage is much greater than found among the fishes in the entrainment samples since the larvae from these other habitats can be transported into the vicinity of the ESGS intakes where they are subject to entrainment.

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 freshwater input results in lower salinity seawater in some areas of the habitat. Bays and harbors in Santa Monica Bay include areas like Marina del Rey and King Harbor. Characteristic fishes from these habitats include deepbody anchovy, bay pipefish, bay blenny, round stingray and diamond turbot (Allen and Pondella 2006). Estuarine areas in Santa Monica Bay include Malibu Lagoon and Ballona Wetlands. Characteristic fishes from this habitat include slough anchovy, barred pipefish, shadow and arrow goby, and longjaw mudsucker (Allen and Pondella 2006). A large percentage of the fishes collected during the entrainment and impingement sampling had some dependency on bay and harbor habitats during at least some stage of their life, but this habitat is the primary habitat for five fish taxa included in this assessment: shiner perch, CIQ gobies, combtooth blennies, bat rays, and white seaperch (Table 6.1-1). While CIQ gobies are almost totally confined to these habitats, one species of combtooth blenny, the rockpool blenny (*Hypsoblennius gilberti*), also inhabits shallow intertidal and subtidal rocky reef habitats. Shiner perch, white seaperch, and bat rays are highly mobile species that are also found in rocky reef and kelp bed habitat.

Annual entrainment of goby and blenny larvae at Units 3 & 4 was estimated to be 7.0 and 6.2 million larvae, respectively, based on actual flow volumes and 12.0 and 9.9 million larvae, respectively, based on design flow volumes (Table 6.2-1). No eggs from either group of fishes were entrained because both have nests or attached eggs that are tended by the adults and don't become vulnerable to entrainment until they hatch as larvae. The entrainment and source water data on larval concentrations were used to estimate that 1.5% of the larval gobies and 0.3% and larval blenny populations were potentially lost due to entrainment (Table 6.2-9). The percentage losses to gobies were second only to silversides. The entrainment losses were also used to estimate that the larvae entrained would have resulted in an additional 7,000 – 16,300 adult gobies and 8,500 – 18,200 adult blennies based on actual flow volumes (Table 6.2-9).

Since gobies generally only occur as adults in protected bays, harbors, and estuaries they were not collected during impingement sampling. Even other species of gobies that do occur in shallow nearshore areas, such as blackeye and bay goby, were not collected during impingement sampling because they occur on the bottom and not in the water column where they would be subject to impingement. Blennies were impinged in low numbers. The largest impingement occurred for the rockpool blenny, which has a broader distribution than the other two species that includes nearshore rocky habitat. The total estimated impingement for all species of blenny ranged from 81 to 666 fishes depending on whether actual or design flows were used in the calculations.

The effects on gobies and blennies and other inhabitants of bays, harbors, and estuaries would be expected to be low since a large percentage of the adult population resides in these habitats where they are not vulnerable to the effects of the power plant. Although CIQ complex gobies (arrow, cheekspot and shadow goby) were the sixth most abundant larvae entrained and had the highest estimated entrainment effects based on one modeling approach there is very little risk to these populations. The larvae entrained by the plant likely originated in areas such as Marina del Rey and the Ballona Wetlands upcoast (north) of the plant. Once the larvae from these areas are transported out into the coastal waters of the bay they are effectively lost to the population since there is only a small likelihood that they would be transported back into their native adult habitat where they could undergo transformation and settlement. As a result, the estimated proportional mortality (P_M) due to entrainment tends to overestimate the impacts to the population because it was calculated using a larval source water population extrapolated along the coast north and south of the plant but did not include the shallow marsh or embayment areas where they are typically spawned and where their larval densities would be substantially higher as compared to the outer coast densities.

There were no independent data on goby population abundances from any of the areas within Santa Monica Bay located for this assessment. Long-term data on abundances of combtooth blennies from King Harbor in Redondo Beach south of the ESGS 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 was 0.143/boulder (Figure 6.3-2). Since 1995, the density increased to 1.57 individuals/boulder in 2005. Annual average densities of combtooth blennies in King Harbor was found to be correlated with average annual sea surface temperatures (R = 0.492, P = 0.017). 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 in adult density with sea surface temperature suggests that the abundance of this short-lived species was dependent on successful recruitment in response to optimal oceanographic conditions.

The intake for the Redondo Beach Generating Station (RBGS) is located in King Harbor where these data were collected. While this makes it difficult to use these data to determine the effects of ESGS on blenny populations, the results of the King Harbor studies demonstrate the importance of oceanographic conditions and other factors on fish abundances. The effects of these and other factors, such as cooling water intake system effects, are easier to assess for combtooth blennies and other fishes that are not subject to recreational or commercial fishing mortality. The RBGS was operating throughout the entire period of these studies including the period from 1999–2005 when cooler ocean temperatures contributed to higher level of productivity resulting in the recovery of several fisheries (Zeidberg et al. 2006). These fluctuations in response to ocean conditions do not indicate any effects from entrainment by RBGS. The additional mortality due to ESGS on blennies of less than one percent does not represent any risk of adverse environmental impacts since the intake structures are not located in King Harbor or Marina del Rey where the source population of adults is located.

Fishes that are primarily associated with bay, harbor, and estuarine habitats should not be the focus of this assessment because the primary CWIS effect on these populations is entrainment of larvae that have been transported out of their native adult habitat into the nearshore areas around ESGS where they are subject to entrainment. This is identical to the effects on a fish such as the northern lampfish, which are transported from offshore deep water habitats into nearshore areas where they are subject to entrainment.

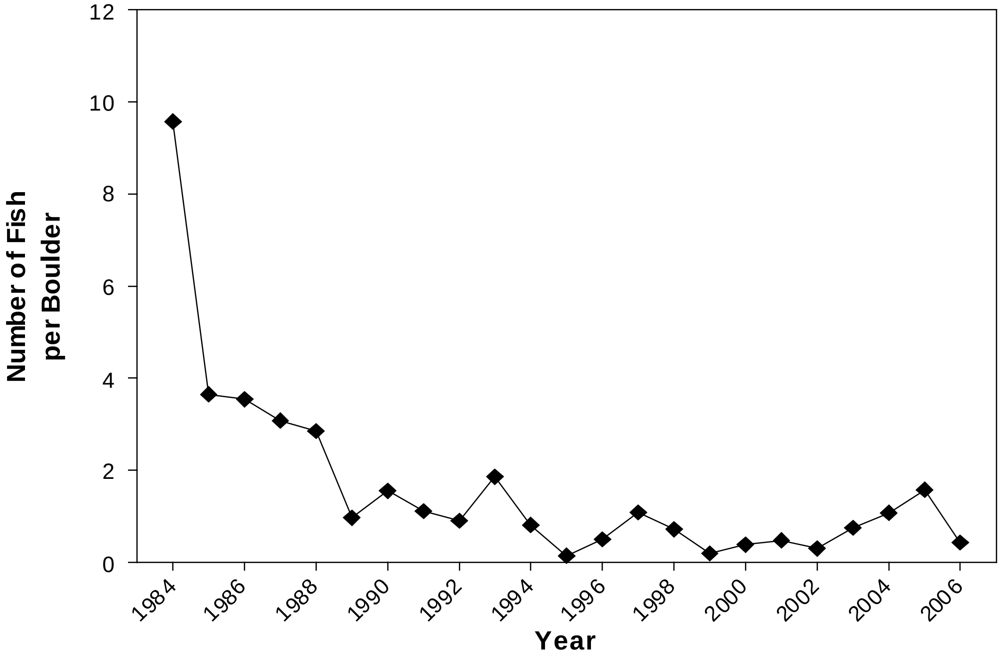


Figure 6.3-2. Abundance of combtooth blennies collected per boulder at King Harbor, Redondo Beach, California from 1984–2006 (from Pondella, unpubl. data).

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. In the Santa Monica Bay region, the greatest area of these habitats occurs near headlands in the vicinity of Palos Verdes Point and the coastline of Malibu and Point Dume. Artificial structures such as harbor breakwaters at King Harbor and Marina del Rey, and emplaced artificial fishing reefs within Santa Monica Bay are also significant resources for fishes associated with these habitats. Common species in these assemblages include kelp bass, barred sand bass, black perch, opaleye, halfmoon, California sheephead, senorita, garibaldi, salema and zebraperch (Stephens et al. 2006). Although the presence and extent of giant kelp affects the abundance of some reef fishes, many other factors can also affect their distributions, and it is not unusual to find many of the species characteristic of kelp bed habitats in other shallow water locations. Common species of fishes and target invertebrates that are typically associated with rocky reef habitats and were entrained or impinged at ESGS included the black croaker (*Cheilotrema saturnum*), blacksmith (*Chromis punctipinnis*), sea basses (*Paralabrax* spp. [includes kelp bass, *P. clathratus*, spotted sand bass, *P. maculatofasciatus*, and barred sand bass, *P. nebulifer*]), seaperches (rubberlip sea perch, *Rhacochilus toxotes*; and pile perch, *Rhacochilus vacca*), California scorpionfish *Scorpaena guttulata*, and California spiny lobster (*Panulirus interruptus* (Table 6.1-1). Impacts to representative species from this habitat are briefly discussed.

Of the fish species impinged and entrained with kelp forest as their primary habitat, the sea basses (*Paralabrax* spp.) had the greatest estimated numbers. The estimated annual loss of sea basses due to operation of the ESGS Units 3 & 4 CWIS included 8.9 million larvae, based on actual flow volumes, and 14.4 million based on design flow volumes (Table 6.2-1). An estimated 4,109,380 eggs were entrained using the actual flow volumes, or 6,568,642 based on the design flow volumes. The entrainment and source water data on larval concentrations were used to estimate that 0.3% of the source water population of larval sea basses was entrained, based on actual flows (Table 6.2-10), and 0.5% based on design flows (Table 6.2-11). There was not enough life history information available on these species to model the number of adults that this number of larvae would represent, but all three species are capable of spawning on consecutive days, particularly in summer months, and a typical female may spawn 81,000 eggs per batch (see Section 4.5.3.3.1—*Sea Basses: Life History and Ecology*). Annual impingement of sea basses was estimated as 171 individuals with a combined weight of 37.1 kg (82 lb) based on actual flows (Table 6.2-10) and 348 individuals with a combined weight of 39.6 kg (87.3 lb) based on design flows (Table 6.2-11). The EAM was calculated as 2,022 individuals based on actual flows.

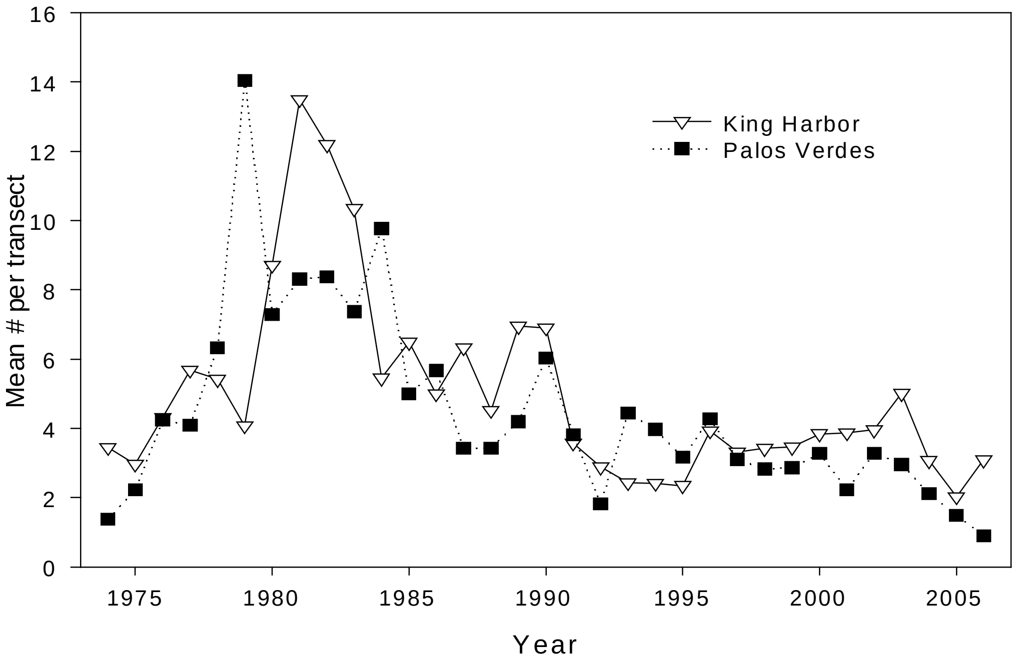
California spiny lobster was one of the target invertebrate larvae that was selected for analysis because of its importance in commercial and sport fisheries in southern California, and the fact that it is a common macroinvertebrate in the rocky reef and kelp bed habitats. Estimated annual entrainment based on actual flows and design flows was 230,000 and 260,000 phyllosome larvae, respectively. However, it comprised such a small fraction of the entrained larvae that no demographic or *ETM* modeling was done on the species. California spiny lobster was the twelfth most abundant invertebrate species impinged with an estimated 125 individuals weighing 39 kg (86 lb) based on actual flows and 149 individuals weighing 43.6 kg (96.1 lb) based on design flows (Tables 6.2-10 and 6.2-11). However, in terms of biomass it was the third most abundant species. It was impinged sporadically throughout the year, with peaks in abundance measured in April and July. The mean carapace length (CL) of 46 impinged lobsters was 86 mm (3.4 in) corresponding to the approximate legal minimum fishery size limit (83 mm) and an approximate age of 7–11 years old.

The offshore intake structures at ESGS provide a small area of moderate-relief habitat in the largely sand bottom and coastal pelagic habitat types that dominate the area around the intake and discharge risers. Species such as the ones listed above are more common along contiguous stretches of rock coastline, but can migrate between areas and occasionally find suitable habitat patches. 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. Spiny lobsters, for example, forage over sand bottoms at night and their activities could bring them in contact with the ESGS intake conduits where they would be attracted as a shelter during the day, thus explaining their impingement. It was found that approximately 20% of the entrained larval taxa and 35% of the impinged taxa had some association with rocky reefs or kelp bed habitats (Table 6.3-1). In terms of total abundance the reef-associated larvae comprised less than 12% of total entrainment, and the impingement biomass was largely comprised (42%) by reef-associated species, California spiny lobster in particular.

Fishery-independent data from underwater counts of sea basses at King Harbor and Palos Verdes Point showed that kelp bass populations peaked in the early 1980s and have steadily declined since then (Figure 6.3-3). When barred sand bass increased in the 1990s, apparently as a result of a long-term ocean warming trend, kelp bass did not show a similar response. Both species have declined following the increases through 2002. Ocean temperature regime changes and fishing pressure may have contributed to the declines.

The annual losses due to entrainment and impingement of species associated with rock reefs and kelp habitats was low in comparison to the fishery take for these species. Sport fishery catch estimates of kelp bass in southern California ranged from 157,000 to 587,000 fish from 2000 to 2006, with an average of 351,300 fish caught annually. Barred sand bass catch estimates ranged from 139,000 to 1,130,000 fish caught annually between 2000-2006, with an average of 720,000 fish (RecFin 2007). Assuming that entrainment losses translate directly to losses of recreational catch, the combined annual losses from both entrainment and impingement of both species at ESGS in 2006 was less than 0.6% of this take. This is a conservative estimate because, as previously stated, kelp and sand basses occur in other bay and harbor habitats that are not subject to CWIS effects. Although spiny lobster had the greatest biomass of any impinged macroinvertebrate, it too was low relative to the landings of this species in the Santa Monica Bay area. Commercial landings of California spiny lobster in the Los Angeles area totaled 101,324 kg (223,420 lb) in 2005 (CDFG 2006). Commercial landings from Santa Monica Bay area catch blocks in 2006 totaled 18,213 kg (40,152 lb) at an estimated value of $372,220 (CDFG 2007b). Because the intakes at ESGS are not in close proximity to extensive areas of rocky reef or kelp bed habitat, the effects of the intakes are minimal on such assemblages.

a) kelp bass



b) barred sand bass

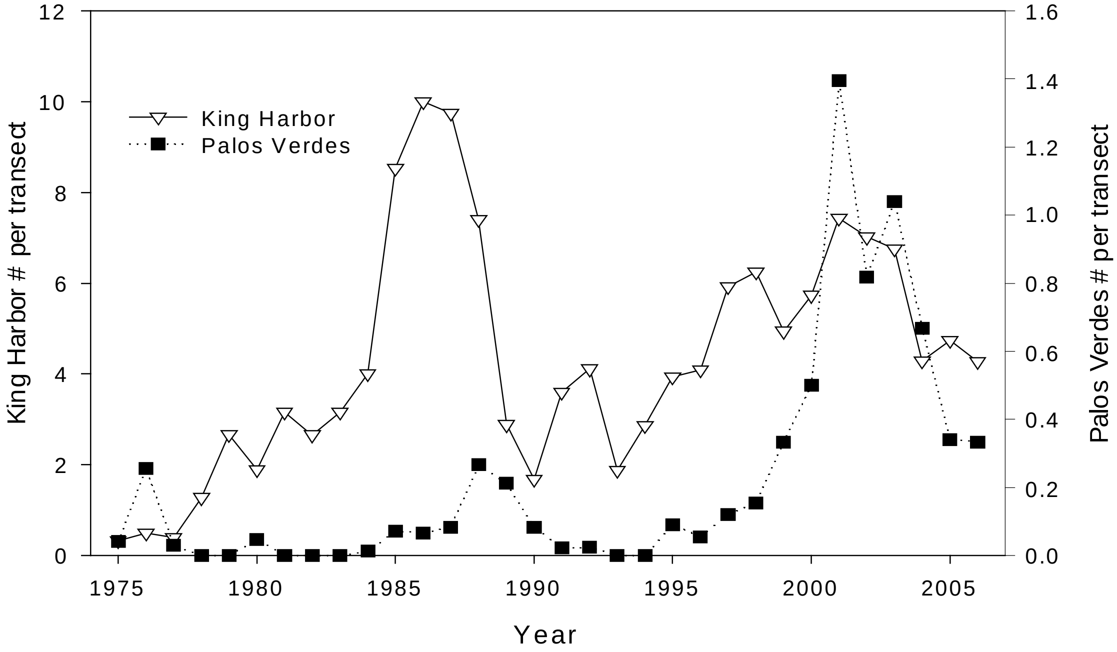


Figure 6.3-3. Abundance of kelp bass (*Paralabrax clathratus*) and barred sand bass (*P. nebulifer*) measured on diver transects at King Harbor and Palos Verdes from 1974–2006. Source: Vantuna Research Group.

6.3.4 Coastal Pelagic Habitats

The most extensive type of nearshore habitat in Santa Monica Bay is the coastal pelagic habitat, which in the expanded definition used for this assessment also includes the surfzone habitat. Most of the shallow water areas of Santa Monica Bay are over sand bottom with relatively few hard bottom relief features. This is the main habitat type in close proximity to the ESGS intakes and many of the species entrained or impinged are characteristic of the coastal pelagic zone. These included northern anchovy, white croaker, queenfish, silversides (primarily topsmelt and jacksmelt), walleye surfperch, and market squid (Table 6.1-1). Some of these species, such as northern anchovy and white croaker, can be considered habitat generalists because they are also be found in bays and a variety of other shallow water locations (Allen and Pondella 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 from impingement data.

The estimated annual loss of northern anchovy due to operation of the ESGS Units 3 & 4 CWIS included 30.8 million larvae, based on actual flow volumes, and 44.6 million based on design flow volumes (Table 6.2-1). An estimated 363 million eggs were entrained using the actual flow volumes, or 528 million based on the design flow volumes. Northern anchovy were only collected during heat treatments during the impingement sampling. Annual impingement of northern anchovy was estimated as 78 individuals with a combined weight of 1.1 kg (2.4 lb) based on actual flows and on design flows (Tables 6.2-10 and 6.2-11).

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 northern anchovy. Northern anchovy are an indicator organism for the PDO in the California Current System, (Chavez et al. 2003, Norton and Mason 2005, Horn and Stephens 2006). Scale deposition of this 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). Northern anchovy dominates during the cold water phase. 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.

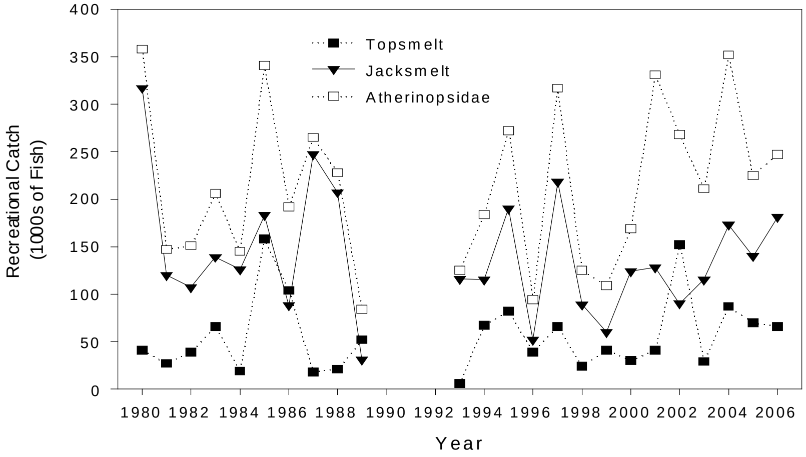
Another nearshore pelagic taxon characteristic of the coastal pelagic habitat is silversides, a family represented by topsmelt, jacksmelt and grunion. Relatively few larvae of this taxon were entrained or impinged with annual entrainment estimated at 1.8–4.1 million larvae per year, and a total of 19 with a biomass of 3.1 kg (6.8 lb) impinged. Topsmelt and jacksmelt deposit their eggs on submerged aquatic vegetation or shallow structures in bays and harbors, so larval entrainment would be expected to be low on the open coast in the vicinity of the ESGS intakes. Their widespread occurrence in the coastal pelagic habitat in southern California explains their presence in the impingement samples, and the numbers impinged annually are a small fraction of the population in Santa Monica Bay.

Population trends of silversides can be examined to evaluate variability over time. There were no consistent trends for the recreational catch in southern California from 1980-2006 (Figure 6.3-4a). In the King Harbor time series, silversides were combined into one category due to the difficulty of identifying species-level differences in the field. From 1974-2006, two trends emerge. First, the density of silversides was generally higher prior to the regime shift associated with the PDO (Figure 6.3-4b). Secondly, the density of silversides declined from the early 1970s to the early 1990s, then remained fairly constant through 2006. Overall, the density of silversides declined significantly from 1974-2006. In the OREHP time series (Figure 6.3-4c), catch per sampling period from 1995-2006 varied around an average of 10.7 fish/station in Santa Monica Bay and 15.3 fish/station in the rest of the Southern California Bight. The difference between the two time series were high catches of jacksmelt in the April samples at Seal Beach in 1995, 1999, 2001. Jacksmelt move into this area in the spring to lay their eggs. These two time series were significantly correlated and not significantly different from each other. Overall, since the mid-1990s silversides were increasing in catch throughout the southern California bight including Santa Monica Bay.

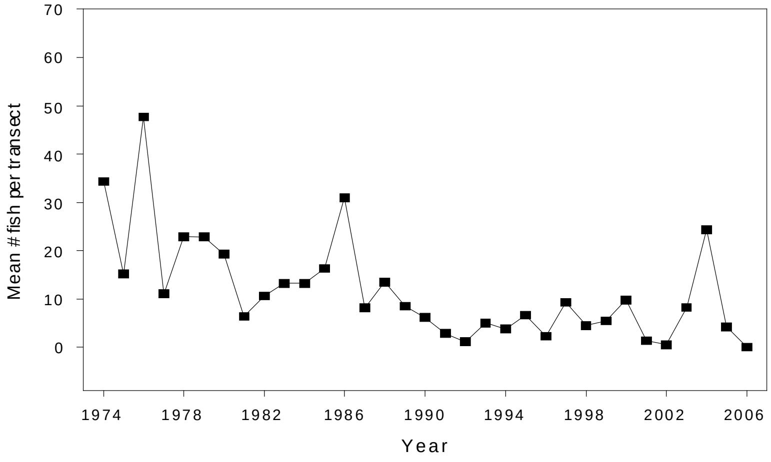
White croaker and queenfish are two common members of the croaker family that are found in Santa Monica Bay in the nearshore sand bottom habitat—queenfish as a pelagic species and white croaker as a bottom-associated species. White croaker were the most abundant larvae entrained at Units 3 & 4, but were not collected in the impingement samples. Queenfish larvae were the seventh most abundant larvae with 5-6 million larvae entrained using actual or design flow volumes (Table 6.2-1) and the fifth most abundant species impinged with 103 individuals collected during heat treatments at a biomass of 6.8 kg (15 lb). Other species of croaker such as yellowfin or spotfin croaker, was entrained or impinged in comparatively low numbers.

Recreational and commercial catch data for white croaker indicating a declining fishery were not consistent with the fishery independent data. Recreational and commercial catches both declined significantly from 1980-2006 (Figure 6.3-5a). These two data sets were positively correlated with each other, and the commercial catch was correlated with sea surface temperature ($R = 0.484$, $P = 0.019$). In the OREHP monitoring program, the catch per sampling period increased (not significantly) over the sample period (Figure 6.3-5b). The NPDES trawl data suggested a similar pattern (Figure 6.3-5c) with catches of white croaker from 1978–2006 oscillating without a significant trend over the study period ($p = 0.523$). This catch was not correlated with any oceanographic parameters (PDO, SST, or ENSO).

a) recreational catch



b) King Harbor



c) OREHP

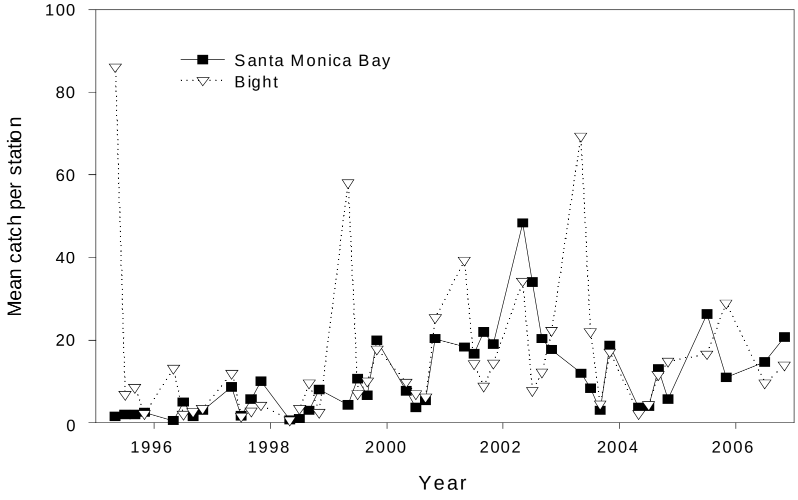


Figure 6.3-4. Silverside fishery and population trends: a) recreational landings, b) King Harbor observational data, and c) Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring data. Error bars are ± 1 S.E.

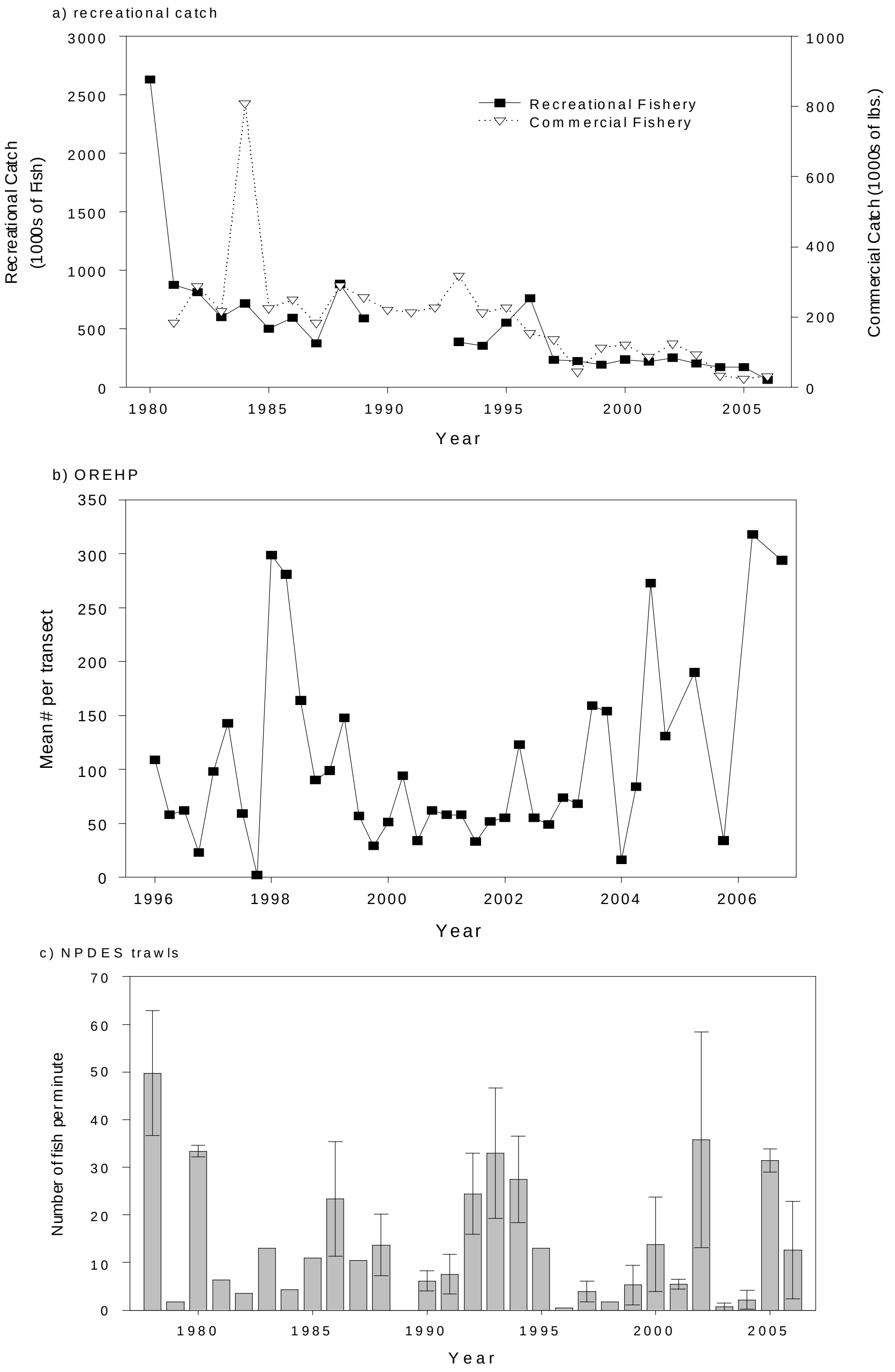


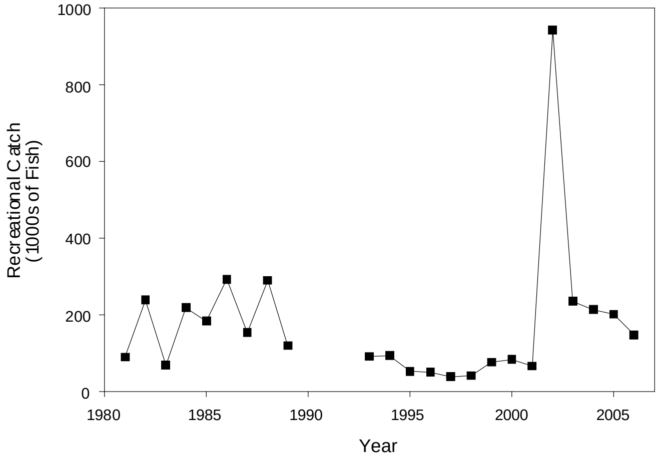
Figure 6.3-5. White croaker fishery and population trends: a) recreational and commercial landings, b) Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring data, and c) NPDES trawl programs. Error bars are ± 1 S.E.

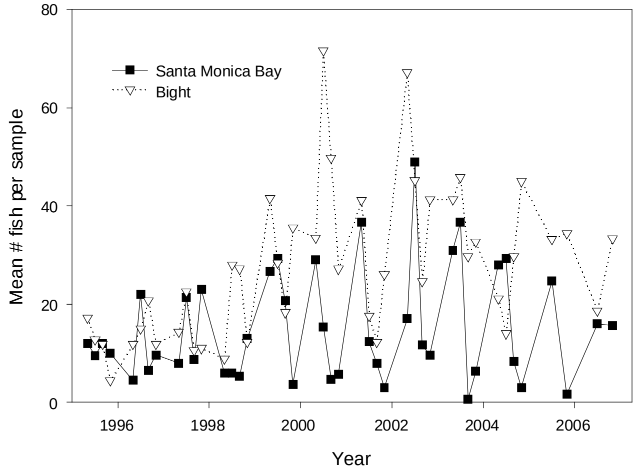
Catches of queenfish fluctuated over time in the various time-series analyses. In the recreational fishery, catches were relatively consistent over time, fluctuating between 38,000 and 292,000 fish per year with the exception of one aberrant peak in 2002 (Figure 6.3-6a). The catch data did not reflect any significant response to oceanographic variables (PDO, SST, ENSO). In the OREHP data set, catch fluctuated appreciably in both Santa Monica Bay and the remainder of the bight (Figure 6.3-6b). These two time series were not correlated with each other. Catch in the bight increased significantly 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 6.3-6c). There was not a significant positive or negative trend in queenfish catch for the trawl data set but catch was correlated with sea surface temperature and the ENSO index (R=0.503, p=0.005, R=0.408, p=0.028, respectively). 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.

Walleye surfperch is a member of the live-bearing surfperch family, and as such it is not susceptible to entrainment, only impingement. Walleye surfperch was only collected during heat treatment sampling, and was the thirteenth most abundant species with an estimated 34 individuals, weighing 2 kg (4.4 lb). Like most other members of the surfperch family, individuals are strong swimmers adapted to living in swift currents and wave-swept nearshore areas. While they are apparently capable of maintaining position in the intake conduits under normal operations, they are susceptible to the heat treatment operations that are conducted periodically to remove marine growth.

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). Landings in Santa Monica Bay area catch blocks in 2006 totaled 307,773 kg (678,512 lb). Squid paralarvae (hatchlings) were present during spring months in the entrainment samples and the projected annual losses of larvae due to entrainment was from 0.04–0.06 million larvae for actual and design flows, respectively. There was not enough information available on natural mortality rates to project adult equivalents from this number of larvae, but the total impingement was estimated as approximately 29–68 adults annually. 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 intake at ESGS affects species in this particular marine habitat type more than any of the habitats in the vicinity of the generating station, but 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 their populations.


a) recreational catch


b) OREHP

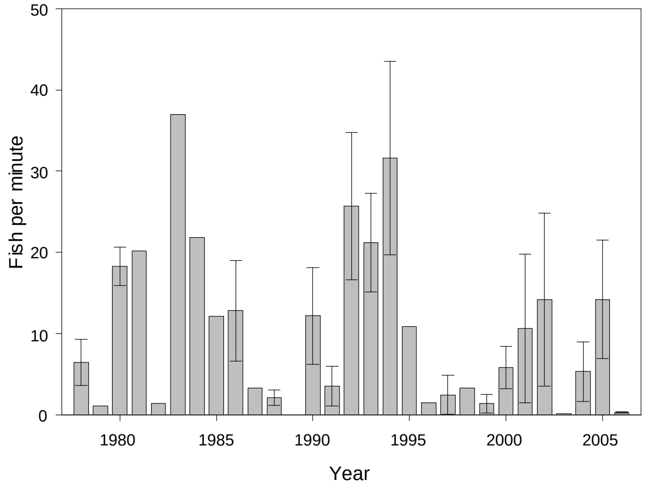

c) NPDES trawls

Figure 6.3-6. 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.

6.3.5 Shelf Habitats

Shelf habitats include several different habitats from Allen and Pondella (2006) including inner, middle, and outer shelf, and shallow slope habitats. The abundance, biomass, and other population attributes of the fish assemblages in these habitats increase from the inner to outer shelf (Allen 2006). Allen attributed this gradient to the increased variability in ocean conditions on the inner shelf due to runoff, pollution, and a variety of other factors. A variety of flatfishes and other species dominate the fish assemblages on the soft mud and sandy bottoms in these habitats. Fishes characteristic of the inner and middle shelf include California halibut, bay goby, California tonguefish, bigmouth sole, hornyhead turbot, and California skate (Allen and Pondella 2006). Fishes characteristic of the outer shelf and slope include plainfin midshipman, Pacific sanddab, pink seaperch, curlfin turbot, Dover sole, longspine thornyhead, and California rattail (Allen and Pondella 2006).

The fishes from these habitats support a variety of commercially and recreationally important fishery species including rock and Dungeness crab fisheries. The species caught by commercial fisheries in these habitats are broadly categorized as groundfish and are jointly managed by the California Department of Fish and Game (CDFG), and the Pacific Fishery Management Council (PFMC) and NOAA Fisheries. Two periods of rapid growth in groundfish landings have been identified (Mason 2004). The first period was during the early 1940s when demand due to World War II led to increased landings with Dover sole as the most abundant component of the catch. The second period of increase occurred in the 1970s leading to the largest groundfish landing on record in the late 1970s and early 1980s with rockfishes, Dover sole, and sablefish being the largest components of the catch. Through the 1990s there was a general decline in landings. Mason (2004) identified market demand, variability in ocean conditions, and effects of exploitation as the three primary factors contributing to the changes in groundfish landings.

Soft bottom habitats in southern California have been widely studied by several research organizations. Extensive sampling of the Southern California Bight (SCB) by the Southern California Coastal Water Research Project (SCCWRP) was conducted in 1994, 1998, and 2003 using a stratified random sampling design that primarily targeted the inner and middle shelf habitats (Allen et al. 1998, 2002, 2007). During the survey in 1994, 87 species of fish were collected with flatfish dominating the catch. Pacific sanddab, Dover sole (*Microstomus pacificus*), and hornyhead turbot (*Pleuronichthys verticalis*) had the highest percentage occurrence; Pacific sanddab, plainfin midshipman, and slender sole (*Eopsetta exilis*) were the most abundant; and California halibut, Pacific sanddab, and white croaker comprised the largest percentage of the total biomass in the survey. A more extensive survey in 1998 that included harbor areas collected 143 species with Pacific sanddab, and California lizardfish (*Synodus lucioceps*) having the highest percentage occurrence; white croaker, Pacific sanddab, California lizardfish, and queenfish had the greatest abundance; and white croaker, Pacific sanddab, California halibut, longfin sanddab, and queenfish comprised the largest percentage of the biomass. The 2003 survey was expanded to include the continental slope and collected 142 species with Dover sole and Pacific sanddab having the highest frequency of occurrence; Pacific sanddab, speckled sanddab, slender sole, and yellowchin sculpin (*Icelinus quadriseriatus*) had the greatest abundance; and Pacific sanddab, slender sole, California halibut, queenfish, Dover sole, English sole, and round stingray (*Urobatis halleri*) comprised the largest percentage of the total biomass.

Despite the similarities in the dominant species among the three surveys there were significant changes in response to the prevailing ocean climate during each of the surveys (1994-warm regime; 1998-El Niño; and 2003-cold regime) (Allen et al. 2007). These differences occurred as species shifted their depth distributions in response to changes in ocean temperatures. This was consistent with Allen's (2006) observation that shelf fish assemblages varied by depth more than by regions within southern California. Overall, mean fish abundance and species richness per haul increased with fish abundance in 2003 during the cold regime to levels about two times greater than in any of the previous surveys. The results showed the importance of considering oceanic regime in any assessment of demersal fish communities to avoid confusing natural changes with the effects of the CWIS or other human-induced impact. The overall conclusions from the SCWRRP surveys were that fish assemblages in southern California were healthy.

The results of the SCCWRP studies show the importance of considering the depth distribution in the assessment for a species. Sanddab were one of the most frequently collected fishes from the studies during all three of their surveys (Allen et al. 1998, 2002, 2007). The broad distribution of the adults is consistent with results on the distribution of sanddab larvae throughout the SCB (Moser et al. 2001) (Figure 6.3-7). This contrasts with other shelf fishes such as California halibut, and diamond and spotted turbot that are more limited to inner shelf nearshore areas (Allen 2006). The distribution of the larvae for these species appears to mirror the adult distribution (Figure 6.1-3c and Figure 6.3-8). The English sole has a distribution across the inner and middle shelf (Allen 2006). The SCCWRP surveys showed that adult English sole where in higher abundances in deeper water during the 1983 and 1998 surveys during warm water years and occurred in shallower water on the inner shelf during the 2003 survey when seawater temperatures were cooler (Allen et al. 2007). This is consistent with CalCOFI data showing a more widespread distribution of larvae during the period of cooler ocean temperatures prior to 1976 compared with the period following 1976 when the shift to warmer seawater appeared to have caused a shift in the distribution to the northern areas of the bight (Figure 6.3-9). Shifts in distribution on both multi-decadal and annual scales in response to changing ocean conditions make assessment of effects due to other factors such as power plants more difficult especially for a species like English sole.

While the shelf species are treated in this assessment as an assemblage, it is apparent that impacts from entrainment and impingement would have the greatest potential impacts on fishes that are less sensitive to ocean conditions and have more stable distributions on the inner shelf. In the assessment for shelf species this would include California halibut, and diamond turbot. As pointed out by Allen (2006) the fishes that occur on the inner shelf closer to the shoreline are more subject to highly variable ocean conditions caused by runoff, pollution, etc. This would also make them more susceptible to CWIS effects. Fishes, such as sanddabs and English sole that are more broadly distributed across the shelf would be less subject to these sources of variation.

The estimated effects of entrainment and impingement on the fishes from shelf habitats were all low relative to species from other habitat types that occur in the vicinity of the intakes. For example, California halibut had the highest estimated larval entrainment of the shelf habitat species at 5.9–7.8 million larvae based on actual and design flows, respectively (Tables 6.2-1). This was the ninth highest of all of the taxa entrained. These levels of entrainment are low relative to the estimate of total average lifetime fecundity of 1,973,371 eggs (estimated from data in MacNair et al. 1991) and estimates of maximum annual fecundity for large females of up to 6.5 million eggs (Caddell et al. 1990). The entrainment estimates for California halibut eggs and larvae represent the loss of up to only two adult halibut. The estimated mortality due to entrainment was lowest for English sole, and highest for diamond turbot, which similar to California halibut, are primarily distributed along the inner shelf.

Impingement was highest for speckled sanddabs, but these and the other shelf species totaled only 0.03% of the total fish biomass collected during impingement sampling (Table 5.5-1). Impingement of shelf species was probably low relative to other habitat types because these fishes are largely bottom dwellers and generally do not occur in the water column where the intakes are located. Entrainment of cancer crab megalops were too low to analyze, but impingement of cancer crabs of all species totaled 88% (402 kg [886 lb]) of the total biomass of invertebrates collected during impingement. The majority of the impinged cancer crabs were from two species, Pacific rock crab (*Cancer antennarius*) and yellow crab (*C. anthonyi*), which are both targets of commercially and recreational fishing.

The broad distribution of sanddabs and the low estimates of entrainment and impingement mortality indicate very little risk of AEI due to the ESGS intakes. The health of the sanddab population is documented by independent studies done by SCCWRP and CalCOFI which are supported by data on commercial and recreational catch. The patterns of fluctuation over time of the catch from both fisheries were similar (R = 0.665, P = 0.001). The recreational catch fluctuated from between 13,000 and 154,000 fish per year; yet this catch did not change significantly over time (Figure 6.3-10, R=0.238, p=0.261). The commercial take varied between 129 and 6,346 kg (284 and 13,991 lb) per year and increased significantly in recent years (R=0.468, P=0.018) (Figure 6.3-10). The increase in the sport and commercial catch in recent years indicates that the population of sanddabs in the SCB is healthy and there is no risk to the population from the low levels of entrainment and impingement losses from the ESGS.

The distribution of English sole across the inner and middle shelf and the low levels of entrainment indicate very little risk of AEI due to the ESGS intakes especially since the primary distribution for this species is north of Point Conception (Stewart 2006). The fishery peaked in 1929 in the southern portion of its range (Point Conception to Monterey) at 3,976 metric tons (mt) (8.76 million pounds) and in 1948 in the northern area (Eureka to Vancouver) at 4,008 mt (8.84 million pounds) (Stewart 2006). Recent trends in English sole landings from 2000–2004 ranged from 64 mt (141,000 lb) in 2003 to 199 mt (438,700 lb) in 2001 in the southern area, and ranged from 569 mt (1.25 million pounds) in 2000 to 1,067 mt (2.35 million pounds) in 2002 in the northern areas (Stewart 2006). Although English sole catches decreased following the mid 1960s and were at historical lows in the 1990s, current assessments show that the stock is growing and that spawning biomass is increasing with the estimate for 2005 over three times the estimate from 1995 (Stewart 2006). Since the primary distribution for English sole is north of Point Conception and the population appears to be recovering there is no risk to the population from the low levels of entrainment and impingement losses from the ESGS.

The most important component of the shelf habitat species included in this assessment is California halibut. Although the low levels of entrainment and estimated entrainment mortality of only 0.14–0.24% indicate very low potential for AEI due to ESGS intake effects (Tables 6.2-10 and 6.2-11), it is also the species most likely to be affected since it is the only species of this group that is primarily distributed on the inner shelf that is also targeted by commercial and recreational fisheries. Independent studies in the SCB by SCCWRP show that halibut were a dominant component of the biomass in their surveys done in 1993, 1998, and 2003. Since it is an inner shelf species, California halibut are exposed to numerous other impacts that might affect the population. From 1981-2006, commercial catch of California halibut fluctuated between 142,292 kg (315,090 lb) in 1985 and a low of 14,511 kg (31,991 lb) in 1994 (Figure 6.3-11) with the catch declining significantly between these years (R=0.521, p=0.006). Neither this decline nor the overall pattern of commercial catch was correlated with oceanographic variables (SST, PDO, or ENSO). The decline between 1985 and 1994 may best be explained by fishery practices during this period. The white seabass fishery crashed by 1981 (Allen et al., in press) resulting in increased landings of halibut, leopard shark and soupfin in the nearshore gill net fishery in southern California as fishers targeted the remaining stocks. This preempted a decline in all of these stocks until the gill net fishery was moved out of state waters in 1994 (Pondella and Allen, in review). Following the 1994 management action, these nearshore stocks rebounded, yet catch of halibut declined again from 1999–2006. The recreational catch has fluctuated over time but the range in recent years is not very different from levels in the early 1980s (Figure 6.3-11).

Commercial and recreational catch data are sometimes difficult to interpret without the backdrop of the effort and other socioeconomic information. From 1995-2006 sampling was done quarterly using gill nets at several locations in the SCB (Pondella unpubl. data). The mean catch in Santa Monica Bay for California halibut over the period was 1.28 fish/station and the mean catch in the remainder of the bight was 2.23 fish/station (Figure 6.3-12). This difference was statistically significant (ANOVA $F_{1,86}=10.52$, p=0.0017). Mean catch in Santa Monica Bay was correlated with mean catch in the remainder of the bight (R=0.349, p=0.02). Although this may indicate that the stock in Santa Monica Bay was under the same constraints as the remainder of the bight from 1995-2006, the increase in mean catch in Santa Monica Bay in 2006 resulted in the highest values recorded during the study. The data show an almost inverse relationship with the trends in recreational and commercial catch over the same period, most noticeably with the increase in catch from 2003 through 2004 that compares with declines in fishery catches.

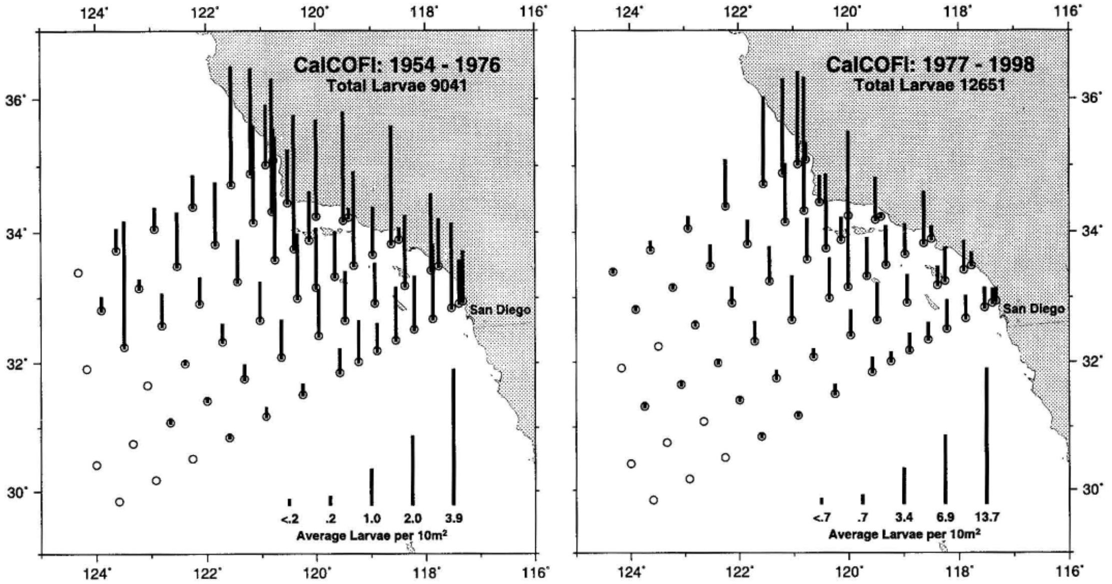
Although it is difficult to determine the status of California halibut populations in Santa Monica Bay the low levels of entrainment and impingement from the ESGS represent very little risk to the healthy population indicated by results from the SCCWRP and OHREP studies.

Diamond turbot has limited value to recreational or commercial fishers, but are taken as incidental catch in otter trawls. Diamond turbot are also taken by anglers fishing from the shore, piers, or boats in shallow bays and estuaries. Entrainment and impingement losses to both species were low with entrainment estimates of 3.8 to 5.7 million larvae per year based on actual and design flows, respectively. This level of entrainment is very low relative to the potential fecundity of these and other flatfishes even though the proportional mortality for diamond turbot was estimated as 0.5 to 3.1% of the source water larval population (Tables 6.2-10 and 6.2-11). Although this estimate is higher than other species it needs to be placed in context with the actual number of larvae entrained which is low relative to the fecundity of this species if it is similar to California halibut and other flatfishes. In trawling done for the NPDES monitoring programs spotted turbot was caught consistently beginning in 1986 (Figure 6.3-13a) with no trend to its catch from 1978-2006 ($F_{1,27}$ = 1.73, R=0.245, p=0.200). Diamond turbot was less abundant but continued to be present in low numbers in the nearshore open coast environment (Figure 6.3-13b). However, this is not their primary habitat, as they are found in higher densities in enclosed bays and estuaries.

In assessing the potential risk of AEI on diamond turbot two additional factors need to be considered. First, this species also occurs in bay and harbor habitats, which were not sampled by the study. This reduces any potential risk to the population because a portion is located in a habitat where they are not subject to CWIS impacts. Second, it is not targeted by commercial and recreational fishing reducing another source of potential impact to the population. Fishes that are heavily exploited by fishing and experiencing high levels of entrainment or impingement would be at much greater risk of AEI.

Rock crabs of the genus Cancer are widely distributed on shelf habitats, but are also common on rock reefs (*C. antennarius*) and bays (*C. anthonyi*). Although the Dungeness crab (*C. magister*) is a highly managed species and is the most desirable from a fishery standpoint, it occurs mostly north of Point Conception and does not contribute significantly to the crab fishery in southern California. Most of the commercial catches in the SCB are comprised of yellow crab, red rock crab, and Pacific rock crab. Long-term trends in the fishery for this species complex in the Los Angeles region showed a peak in the early 1980s followed by a decline to a stable, but low, catch rate (Figure 6.3-14). These species have a high fecundity and are widely distributed throughout the region. It is unlikely that the CWIS entrainment or impingement would have any significant effect on their local populations.

a) speckled sanddab



b) Pacific sanddab

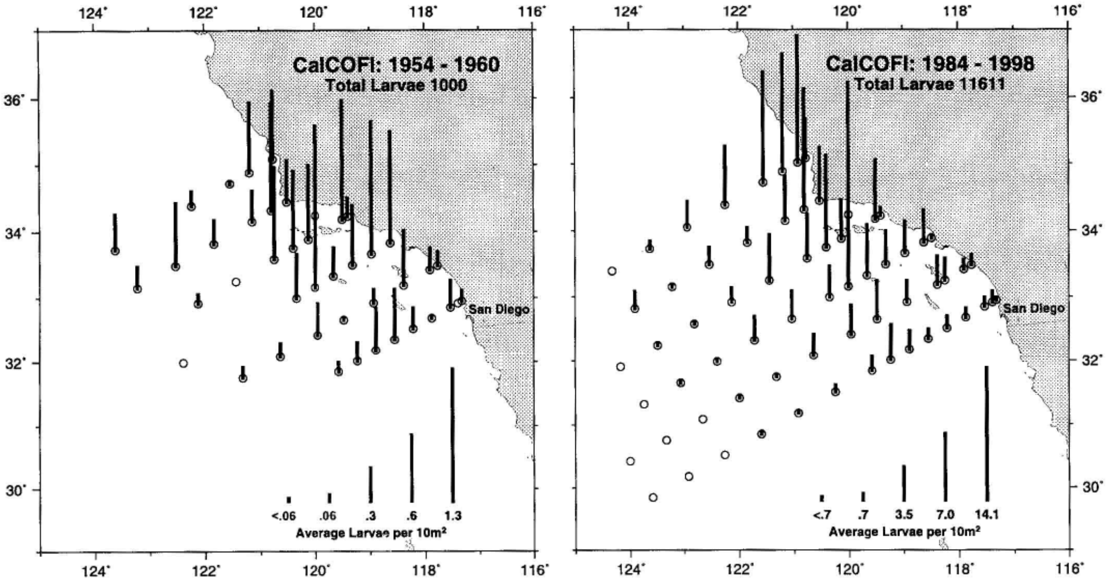
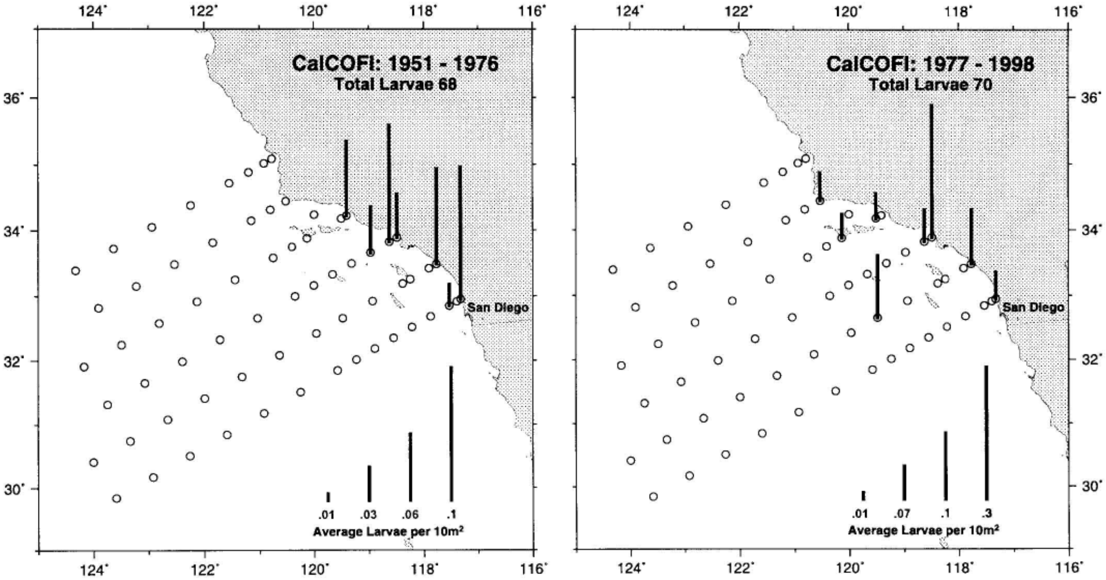


Figure 6.3-7. Distribution and abundance of two species of larval sanddabs a) speckled sanddab (*Citharichthys stigmaeus*), and b) Pacific sanddab (*Citharichthys sordidus*) across permanent stations in the SCB from 1951 through 1998 (from Moser et al. 2001).

a) diamond turbot



b) spotted turbot

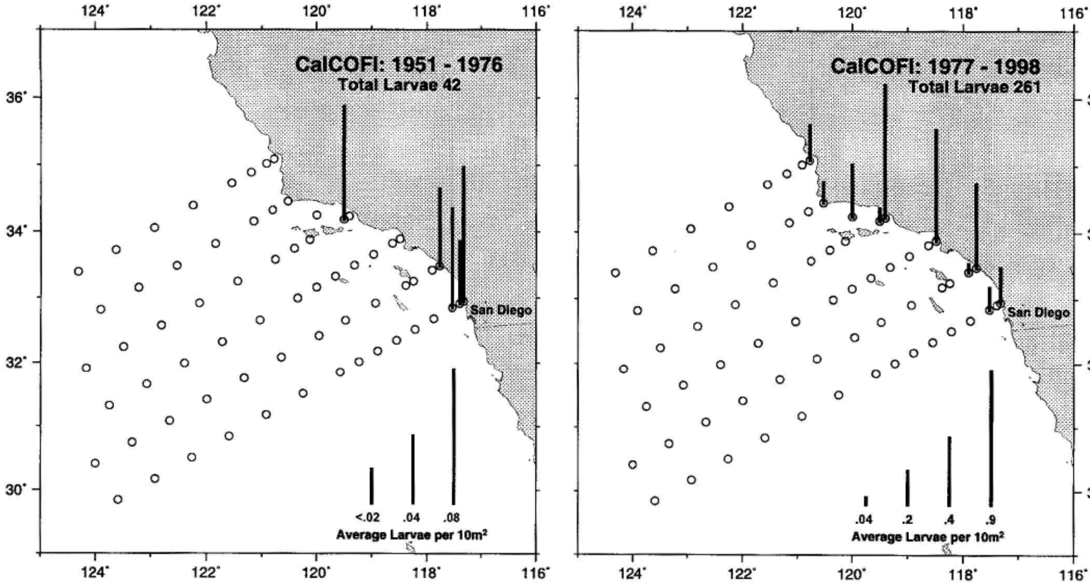


Figure 6.3-8. Distribution and abundance of larvae of a) diamond turbot (*Pleuronichthys guttulatus*), and b) spotted turbot (*Pleuronichthys ritteri*) across permanent stations in the SCB from 1951 through 1998 (from Moser et al. 2001).

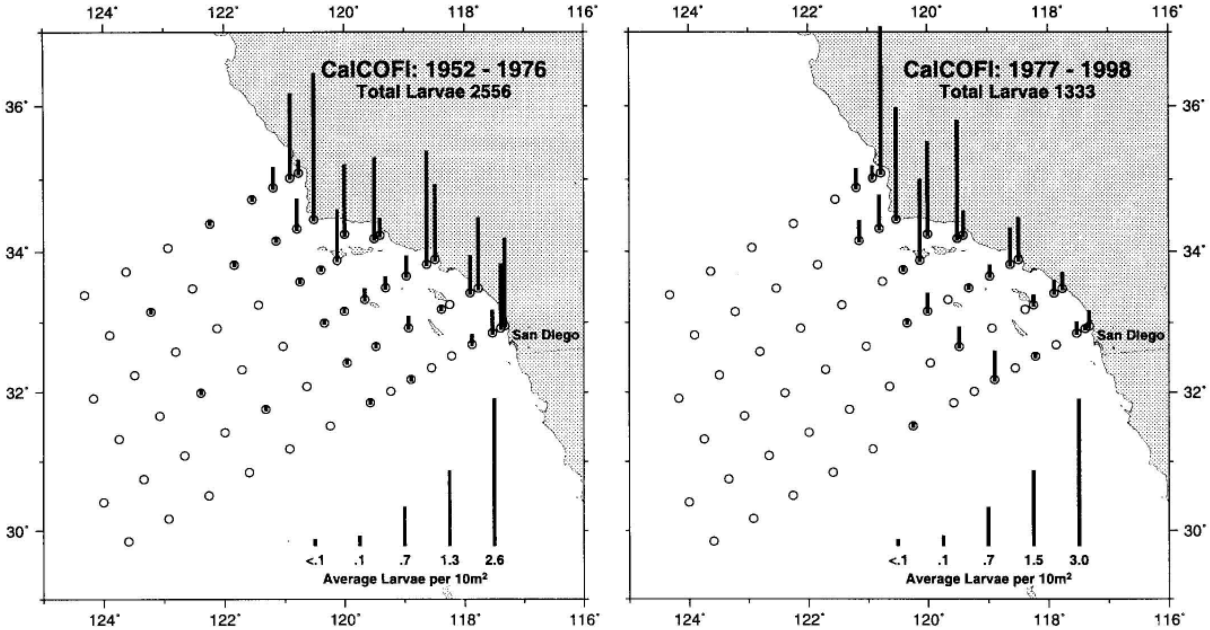


Figure 6.3-9. Distribution and abundance of larval English sole (*Parophrys vetulus*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

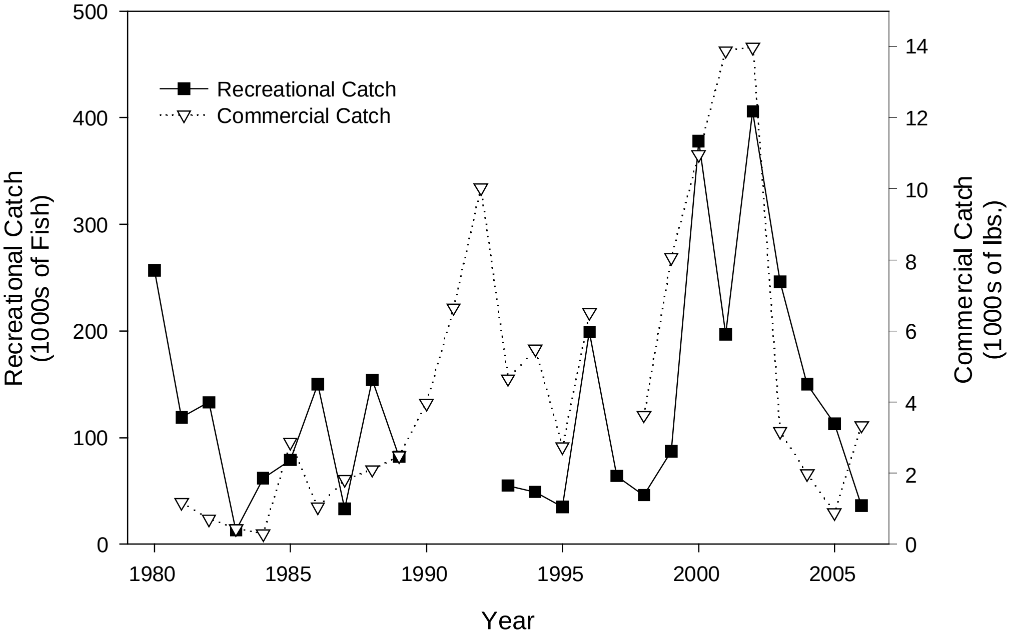


Figure 6.3-10. Recreational (1,000s of fish) and commercial (1,000s of lb) of sanddabs (*Citharichthys* spp.) from 1980-2006 (sources: PacFIN and RecFIN databases).

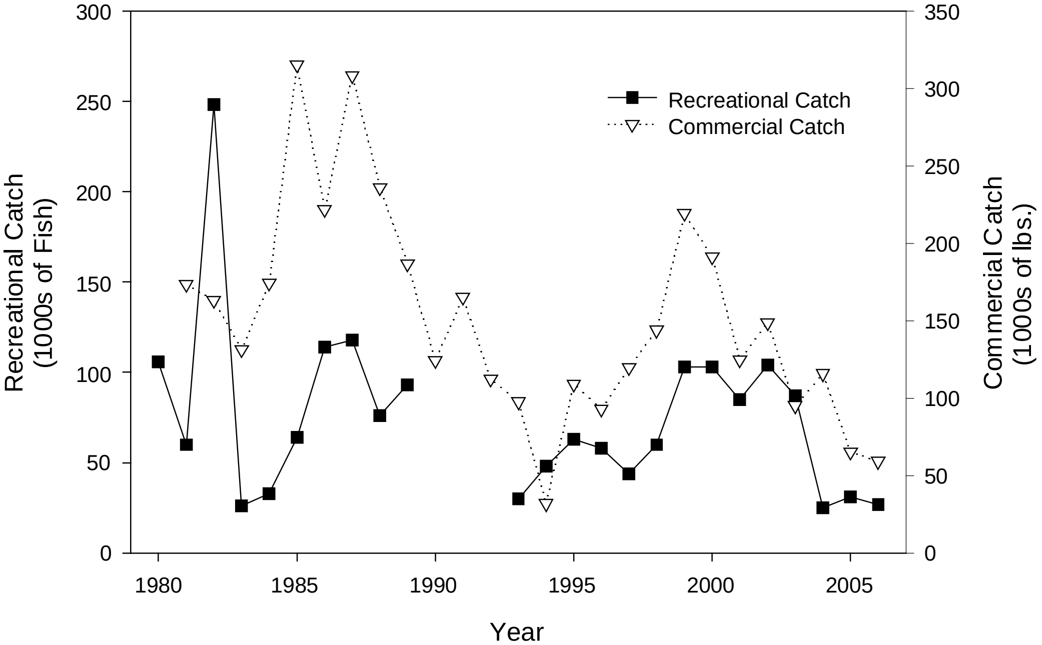


Figure 6.3-11. Recreational (1,000s of fish) and commercial (1,000s of lb) of California halibut (*Paralichthys californicus*) from 1980–2006 (sources: PacFIN and RecFIN databases).

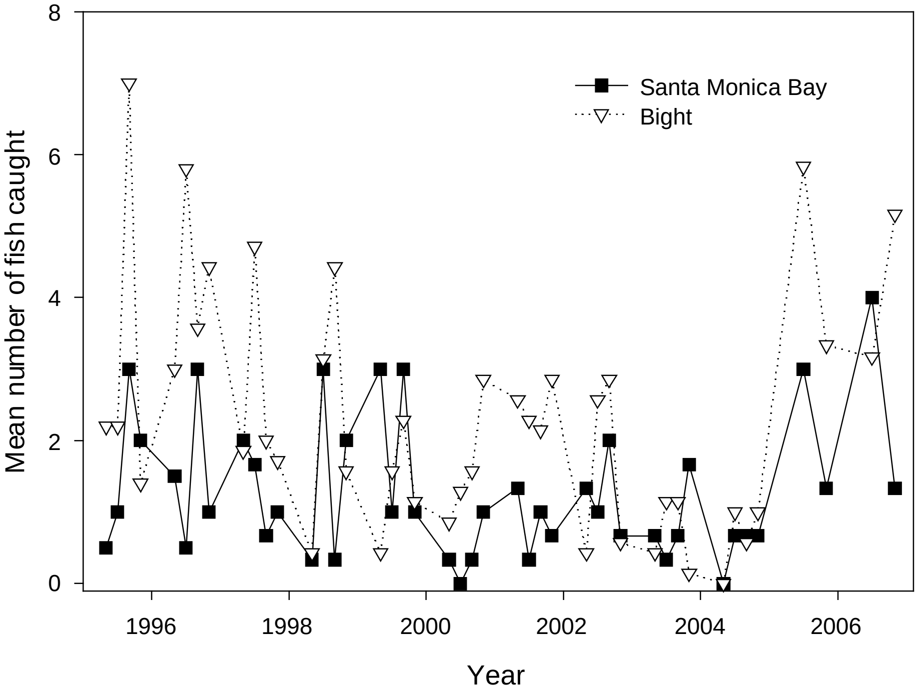
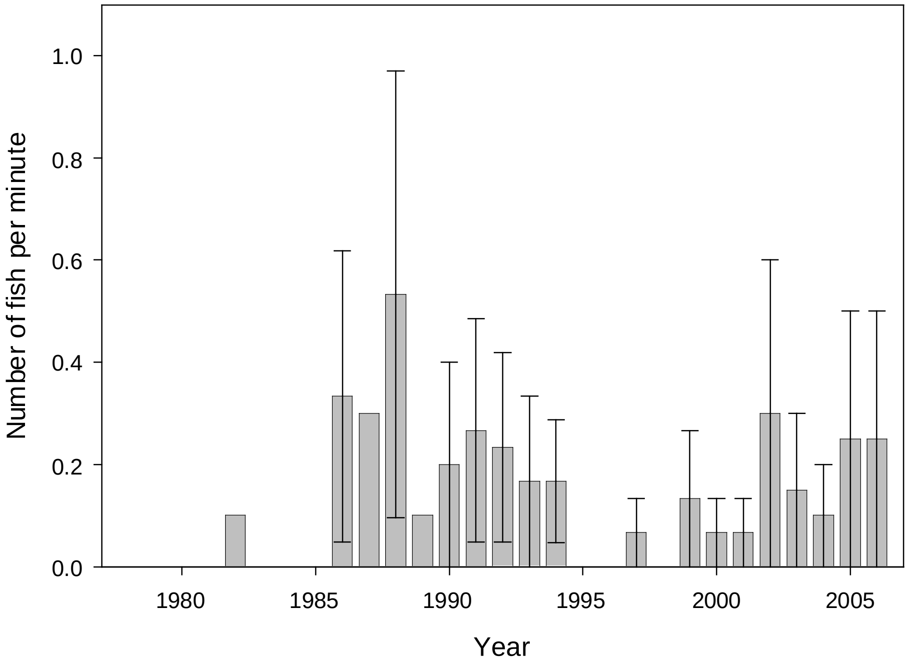


Figure 6.3-12. Mean catch (#fish/station) of California halibut in Santa Monica Bay and the remainder of the Southern California Bight from 1995–2006. Data are from the Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring program.

a) spotted turbot



b) diamond turbot

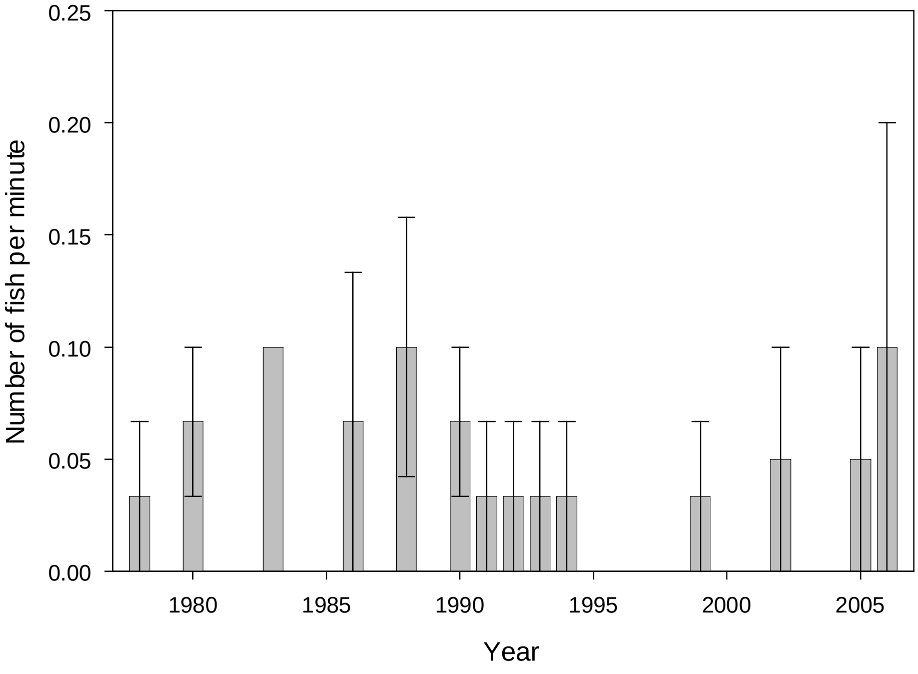


Figure 6.3-13. The mean catch per minute tow from NPDES trawl programs, 1978–2006 of a) spotted turbot (*Pleuronichthys ritteri*) and b) diamond turbot (*Pleuronichthys guttulatus*). Error bars are ± 1 S.E.

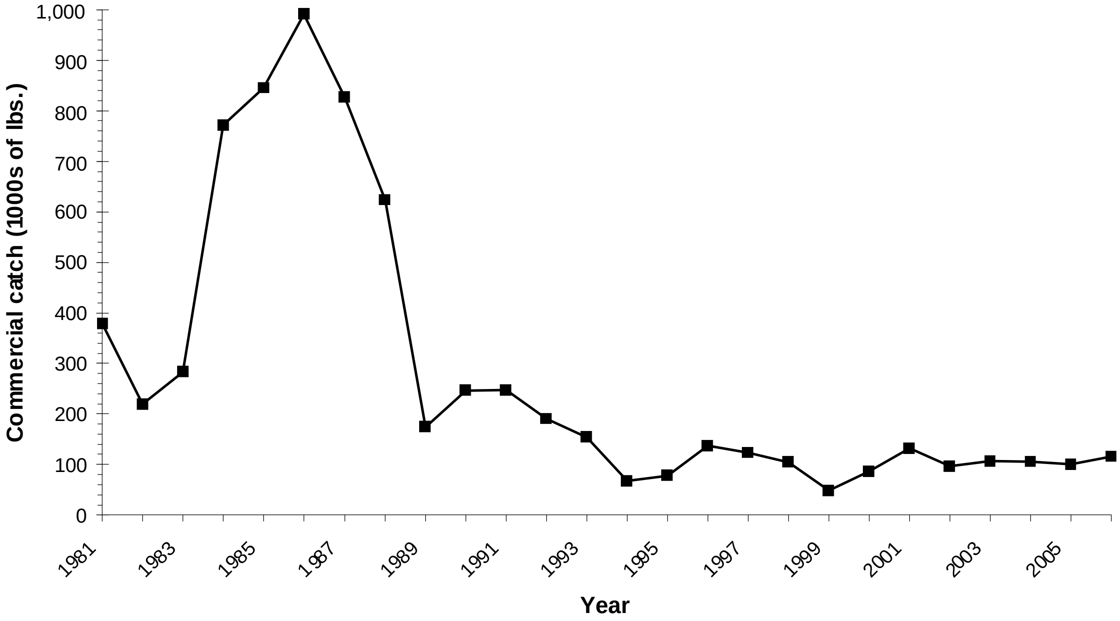


Figure 6.3-14. Commercial catches of rock crab (*Cancer* spp.) in the Los Angeles region, 1981–2006.

6.3.6 Deep Pelagic Habitats

Deep pelagic habitats include several different habitats described by Allen and Pondella (2006) including deep slope, deep bank, and deep rocky reef habitats. This category also includes open ocean pelagic habitats. Some of these habitats are extremely productive and the fishes inhabiting these areas are the basis of large commercial fisheries. The fisheries in the areas outside the three-mile limit of California state waters are federally managed by the PFMC. Fishes characteristic of the deep shelf, bank and slope habitats include Pacific hake, splitnose rockfish, rex sole, sablefish, blackgill rockfish, and shortspine thornyhead. Several different species of rockfishes dominate the fish assemblages on the deep reef, shelf and canyon habitats including bocaccio, chilipepper, and greenspotted, greenstripe, rosethorn, and pinkrose rockfishes. Fishes characteristic of open ocean pelagic habitats include swordfish, striped marlin, several species of shark, albacore, and bluefin bigeye, and yellowfin tuna. Although the fishes characteristic of these habitats occasionally occur closer to shore their primary habitats are offshore in open water or at deep ocean depths.

Fishes from these habitats are not at risk due to entrainment or impingement by the ESGS CWIS. No fishes or shellfishes characteristic of this habitat type were collected during impingement sampling. The larvae from these habitats are subject to entrainment, but once the larvae are transported into nearshore areas the likelihood of them maturing to adults is probably very low due to the unique adaptations many of these species have to life in deep water habitats that do not occur close to shore. One species from these habitats that was collected during entrainment samples was northern lampfish, which was the 12th most abundant taxa group in the samples. This species is characteristic of an offshore species that occurs to depths of 2,900 m (9,500 ft) but also occurs in midwater (Neighbors and Wilson 2006) where its larvae are subject to onshore currents that result in transport into Santa Monica Bay where the larvae are subject to entrainment. The primary distribution for this species is the outer coastal waters where its larvae are in higher abundances (Figure 6.1-1) and therefore it was not included in this assessment.

6.4 CONCLUSIONS AND DISCUSSION

6.4.1 IM&E Losses Relative to 1977 EPA AEI Criteria

The USEPA (1977) provided some general guidelines to determine the “relative biological value of the source water body zone of influence for selected species and the potential for damage by the intake structure” based on the following considerations of the value of a given area to a particular species:

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

The area in which the ESGS intake structures are located does not include any essential fish or invertebrate habitat such as kelp forest, rocky reef or eelgrass. It is located approximately 488 m (1,600 ft) offshore on a sand bottom environment. The sea floor surrounding the intake riser is at –8.8 m (-29.0 ft) relative to mean sea level and cooling water is drawn from the riser opening at a depth of –3.4 m (-11.0 ft) MSL. Currents in the area of the intakes typically flow downcoast in a southeastern direction along the Santa Monica Bay shoreline, although short-term flow reversals are not uncommon.

Fishes in the vicinity of the ESGS intake structures are part of the outer surf zone and coastal pelagic zone fish assemblages in Santa Monica Bay, as defined by Allen and Pondella (2006). These include northern anchovy, silversides, queenfish, spotfin croaker, yellowfin croaker, white seabass, salema, Pacific barracuda, walleye surfperch, and barred surfperch among others. In regards to the AEI criteria, the habitat is not unique as a spawning area for these particular fishes because they are widespread along sand bottom habitats in southern California. Examples of unique spawning areas for certain species would be embayments with submerged aquatic vegetation (e.g. silversides), vertical rock faces of shallow reefs or constructed breakwalls (e.g. garibaldi), intertidal sand beaches (e.g. California grunion), or intertidal boulder fields (e.g. plainfin midshipmen). Spotfin croaker are known to form spawning aggregations in the nearshore coastal pelagic zone in summer, but the lack of any high density pulses of larvae in the ESGS entrainment samples indicates that the vicinity of the ESGS intakes is not an important area for such aggregations.

Concerning specific nursery areas for young-of-the-year (YOY) fishes, these would mostly include bay habitats (e.g. California halibut, gobies) although nearshore areas with accumulations of drift algae or surfgrass on the bottom can also attract many species of juvenile fishes (Allen and Pondella 2006). In the present study, approximately 50% of the queenfish impinged were juveniles in the 50–70 mm size range, and over 70% of the northern anchovy were juveniles in the 60-80 mm size range. This indicates that the intake location in shallow water has a disproportionate effect on juveniles of these two coastal pelagic species due to the midwater intake opening and weaker swimming abilities of these YOY fishes compared with the adults.

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 ESGS intakes are located on the open coast, this issue is not of concern for any of the species that were impinged. In addition, most of the impinged species are year-round residents and not highly migratory although some, such as Pacific barracuda, have a tendency to migrate north into the southern California bight in spring and summer, and others such as California halibut may exhibit some seasonal onshore-offshore movements.

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 ESGS. This is consistent with past entrainment and impingement sampling conducted at ESGS. Off southern California, species managed under the Magnuson-Stevens Fishery Conservation and Management Act are listed in the Coastal Pelagics Fishery Management Plan (FMP) and the Pacific Groundfish FMP. EFH includes all waters off southern California offshore to the Exclusive Economic Zone. A list of species covered under the two FMPs that occurred in entrainment and/or impingement samples at the ESGS is provided in Table 6.4-1. More information on some of these species is presented in Sections 4.0 and 5.0.

Table 6.4-1. Fish and shellfish species under NMFS federal management or with CDFG special status entrained and/or impinged at ESGS in 2006 based on actual flow volumes.

Species	**Common Name**	**Management Group**	**Estimated No. Larvae (Entrainment)**	**Estimated No. Juveniles/Adults (Impingement)**
Engraulis mordax	northern anchovy	Coastal Pelagics	36,589,361	78
Parophrys vetulus	English sole	Pacific Groundfish	1,685,987	3
Loligo opalescens	market squid	Coastal Pelagics	51,473	–
Hypsypops rubicundus	garibaldi	CDFG	54,943	–
Sardinops sagax	Pacific sardine	Coastal Pelagics	67,493	10
Merluccius productus	Pacific hake	Pacific Groundfish	667,807	–
Citharichthys sordidus	Pacific sanddab	Pacific Groundfish	160,533	–
Sebastes spp.	rockfishes	Pacific Groundfish	62,674	–
Scorpaena guttata	California scorpionfish	Pacific Groundfish	–	170
Leuresthes tenuis	California grunion	CDFG	–	1
Sebastes auriculatus	brown rockfish	Pacific Groundfish	–	7
Sebastes miniatus	vermilion rockfish	Pacific Groundfish	–	3

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 ESGS included:

- distribution (pelagic, subtidal, nearshore subtidal & intertidal);
- range, density, and dispersion of population;
- population center (source or sink);
- magnitude of effects;
- long-term abundance trends (e.g., fishery catch data);
- long-term environmental trends (climatological or oceanographic); and
- life history strategies (e.g., longevity and fecundity).

These criteria were used in assessing the effects of individual taxa and to place the estimated effects into a larger context using the characteristics of the source water and the biological community. The separation of the taxa on the basis of habitat allowed us to focus on the groups most at risk due to entrainment and impingement. Taxa with larvae that are transported out of their native habitat into nearshore areas where they are subject to entrainment are less at risk than taxa that occur in the vicinity of the intake where all life stages are vulnerable to both entrainment and impingement. Gobies and blennies both primarily occur in protected bay and harbor habitats and as a result are at low risk to any CWIS effects even though gobies had the highest estimated entrainment mortality. Also, taxa that occur in several different habitats will be less at risk than taxa that only occur in habitats directly affected by the ESGS intake. Most of the taxa included in the assessment did not have limited habitat associations that would place them at greater risk to entrainment. Finally, the entire distribution of the population is also important, especially for species that may be more limited to shallow nearshore areas where they are not only subject to CWIS effects from ESGS and other facilities, but other impacts associated with nearshore coastal environments such as pollution. As a result, fishes such as Pacific sardine and northern anchovy that are distributed across large coastal areas, and sanddabs and English sole that are distributed across the shelf will be less at risk than species with more limited nearshore distributions.

The criteria of distribution, range, habitat, and population center all need to be considered relative to the magnitude of the effects. There would be reason for concern if the largest estimated impacts were occurring to fishes or shellfishes with limited distribution in a habitat directly affected by the intake. The potential for entrainment effects at power plants like ESGS with intakes on the open coast are much reduced from power plants that draw cooling water from more enclosed water bodies. The fish populations potentially affected by entrainment from these facilities are typically distributed across hundreds of miles of coastline that are connected by coastal currents that help distribute larvae into areas that may have reduced abundances. As a result, there should be very little potential for impacts due to once-through cooling on the open coast. At ESGS the largest entrainment effects occurred to fish larvae that were transported into the nearshore from other habitats, and the largest impingement effects occurred to fishes with wide geographic distributions (Pacific sardine and northern anchovy) or fishes that occur in several different habitats (queenfish and silversides). It is also important that several of these fishes are not targeted by commercial or recreational fishing that would compound any effects of the CWIS on the population. Based on these criteria the assessment focused on fishes such as queenfish, sand and kelp basses, and California halibut, which are also targeted by sport or commercial fishing. The magnitude of the impacts to these and the other taxa were all relatively low and not at levels that would represent a risk of AEI to the populations.

Fish impingement has been routinely measured for decades at several coastal power plants in southern California, and these data are reported annually as part of their NPDES receiving water monitoring studies. 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. One of the reasons for the low impingement, and low potential for population-level effects is the velocity caps used at ESGS and other coastal power plants with offshore intakes. Velocity caps have been shown to be effective at reducing impingement to the range required in the suspended §316(b) Phase II regulations.

The same is true for species that are targeted by recreational fishing. From the mid-1940s to the early 1970s, the sportfish catch per unit effort in Santa Monica Bay more than doubled despite the fact that three generating stations commenced operation during that time period (MBC 1985). Analysis of this trend revealed that fish abundance was highly correlated with water temperature and transparency. Similar correlations have been recorded in recent years by many researchers, suggesting regional climatic events play a much larger role in the fluctuations of fish populations that any effects due to impingement or entrainment.

Table 6.4-2. Summary of positive time series findings for fish species in detailed 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		increasing
kelp bass			Yes	Yes, declining	declining
barred sand bass		Yes, negative			increasing
spotted sand bass				Yes, declining	declining
white croaker				Yes, declining	increasing
queenfish	Yes, positive	Yes, positive		Yes, stable	stable
senorita					increasing
combtooth Blennies		Yes, positive	Yes		stable
Pacific barracuda				Yes, declining	stable
California halibut				Yes, declining	stable
diamond turbot					stable
sanddabs		Yes, negative		Yes, stable	stable
spotted turbot					stable

For the species in the detailed evaluation several types of effects over time were found (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. For example, kelp bass increased in density from the early 1970s to the early 1980s and then declined through 2006. Its fishery has undergone a similar decline. Spotted sand bass exhibited a similar trend. Considering that they are primarily found in bays and estuaries and this is a very popular sportfish and area to fish (Hovey and Allen 2001), the decline in catch most likely represents a decline in the stock. Other fisheries were declining (Pacific barracuda, California halibut, and 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, barred sand bass and sanddabs) 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.

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 Santa Monica Bay. Other than the taxa that appear to be affected by commercial and recreational fishing pressure, the remaining species are stable over time (Table 6.4-2). 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.

The conclusion that the levels of entrainment and impingement at ESGS are not resulting in any AEI to fish or shellfish populations in Santa Monica Bay is consistent with a recent review on population-level effects on harvested fish stocks (Newbold and Iovanna 2007). They modeled the potential effects of entrainment and impingement on populations of fifteen fish stocks that are targeted by either commercial or recreational fisheries. Variables included entrainment and impingement rates, life history parameters, harvest levels and stock size. For twelve of the fifteen species, the effects of theoretically removing all of the sources of power plant entrainment and impingement were 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. 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. Unlike the potentially large impacts to some of the harvested fishes analyzed by Newbold and Iovanna (2007), the largest effects of entrainment at ESGS (less than 2%) were on two non-harvested taxa (gobies and silversides), and these estimates were similar to the levels that Newbold and Iovanna (2007) concluded represented little risk to the populations.

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