F I N A L   R E P O R T

SCATTERGOOD GENERATING STATION

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

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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
lbs	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
mm/d	millimeters per day
MSL	mean sea level
mt	metric tons
MW	megawatts
NL	notochord length
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PacFIN	Pacific Fisheries Information Network

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 performed for the Los Angeles Department of Water and Power's Scattergood Generating Station (SGS) Impingement Mortality and Entrainment (IM&E) Characterization Study. This study was designed and performed to comply with EPA's 2004 316(b) Phase II regulations. Originally, results from the study were to be used in determining impingement mortality and entrainment from once-through cooling, evaluating potential fish protection technologies and operational measures at the facility, scaling potential restoration projects, and/or evaluating the benefits achieved in reducing IM&E at the facility. However, in March 2007, EPA suspended the Phase II regulations and directed administrators to determine compliance with 316(b) on a best professional judgment (BPJ) basis.

Prior to the Phase II Rule, 316(b) decisions were based on precedents from case law and on USEPA's (1977) draft "Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500." As Section 316(b) requires that an intake technology employs the 'best technology available' (BTA) for minimizing 'adverse environmental impacts' (AEI) there are two steps in determining compliance:

1. Whether or not an AEI is caused by the intake 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 SGS cooling water intake system (CWIS). The two primary impacts of a once-through power plant CWIS are impingement of juvenile and adult life stages of fishes, shellfishes, and other organisms on screens at the openings to the CWIS, and entrainment of smaller organisms, usually larval forms of fishes and shellfishes, and other forms of plankton, into the CWIS. The information in this report will also be used to assist in the renewal of the National Pollutant Discharge Elimination System (NPDES) permit for the SGS. This report provides a characterization of the fish and invertebrate species subject to entrainment and impingement at the SGS, information on the current levels of IM&E at the SGS, and a discussion on the level of significance of the IM&E losses.

1.1 ENTRAINMENT

Composition and abundance of ichthyoplankton and shellfish larvae entrained by SGS were determined by sampling in the immediate proximity of the cooling water intake every two weeks from January 2006 to January 2007. A total of 6,969 entrainable fish larvae from 73 separate taxonomic categories was collected from the 25 entrainment surveys. The most abundant larval fish taxon in the samples was unidentified yolk sac larvae (larvae too small and indistinct to be identified to even the family level), which comprised 19.7% of the total larvae collected, followed by unidentified anchovies (13.9%). A total of 82,375 fish eggs from 17 separate taxonomic categories was also collected during the entrainment surveys. The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 63.4% of the total eggs collected, followed by sand flounder eggs (12.4%). The peak in abundance of all the larval fish combined occurred in August, while the highest concentrations of eggs occurred during May. There were generally more larval fish and eggs collected during each survey at night than during the day. The estimated total annual entrainment of all fish eggs and larvae based on actual cooling water flow during the study was estimated to be 4.92 billion eggs and 365 million larvae, respectively. If the pumps were run at the maximum capacity an estimated 7.69 billion eggs and 524 million larvae could potentially be entrained at SGS.

A total of 502 larval invertebrates representing 22 taxa was also collected from the SGS entrainment station bi-weekly surveys in 2006-7. The most abundant target invertebrate larvae in the samples were kelp crab megalops (*Pugettia* spp.) followed by pea crab megalops (*Pinnixa* spp.), which made up 28.3% and 19.7%, respectively, of the total target invertebrate larvae collected. A total of 63 market squid (*Loligo opalescens*) paralarvae (hatchlings) was also collected. Total annual entrainment was estimated to be 27.3 million target invertebrate larvae based on actual cooling water flow, and 40.6 million target invertebrate larvae based on maximum (design) cooling water flow.

1.2 Source Water

To determine composition and abundance of the early life stages of fish and shellfish in the source waters of the SGS, sampling at ten stations in the coastal waters around the SGS was conducted once monthly on the same day that the entrainment station was sampled. 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 (Engraulidae; 23.4%) followed by white croaker (*Genyonemus lineatus*; 17.8%). The greatest concentrations of larval fishes occurred during March to July 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 invertebrates (shellfishes) representing 20 taxa was collected from the SGS source water stations during 12 monthly surveys in 2006–2007. The most abundant target invertebrate larvae in the samples were pea crab megalops, followed by kelp crab megalops, which made up 33.4% and 53.1%, respectively, of the total target invertebrate larvae collected. These were the same two most abundant taxa collected during entrainment sampling. A total of 93 market squid paralarvae were also collected.

1.3 Impingement

Weekly impingement surveys were performed during all 52 weeks at the SGS between January 2006 and January 2007. An additional 24 impingement surveys were conducted during a special study of the effectiveness of the SGS velocity cap in reducing impingement from October 2006 to January 2007, and seven heat treatment surveys in the normal flow configuration were performed in 2006-7.

During the one-year impingement study, a total of 78,635 fish weighing 3,166 kg (6,980 lbs) from at least 82 species were collected in impingement samples. Of this total, 7,551 fish weighing 663 kg (1,461 lbs) from at least 66 separate taxa were collected during weekly IM&E Characterization Study and Velocity Cap Study impingement samples, and the remaining 71,084 fish weighing 2,503 kg (5,519 lbs) from at least 65 separate taxa were collected during heat treatment impingement samples.

The most abundant fish species in the weekly impingement samples were Pacific sardine (*Sardinops sagax*), jacksmelt (*Atherinopsis californiensis*), and topsmelt (*Atherinops affinis*), which combined accounted for 62% of the sampled abundance. The species contributing most to biomass during the weekly IM&E Characterization Study and Velocity Cap Study impingement samples were Pacific electric ray (*Torpedo californica*), jacksmelt, and bat ray (*Myliobatis californica*), which combined accounted for 74% of the total abundance. The most abundant species in heat treatment impingement samples were queenfish (*Seriphus politus*), Pacific sardine, and northern anchovy (*Engraulis mordax*), which combined accounted for 84% of heat treatment abundance. Pacific sardine, queenfish, and bat ray, contributed most (67%) to heat treatment biomass.

Fish impingement abundance during the weekly normal operation surveys peaked in May 2006, while biomass was highest in August and December 2006. Annual fish impingement estimates at the SGS were 95,241 individuals weighing 4,274 kg (9,423 lbs) based on actual cooling water flow, and 108,843 individuals weighing 5,270 kg (11,621 lbs) based on design cooling water flow.

During the one-year impingement study, 24,298 macroinvertebrates weighing 317 kg (700 lbs) from at least 73 species were collected in impingement samples. Of this total, 20,449 macroinvertebrates weighing 170 kg (375 lbs) from at least 70 separate taxa were collected during weekly IM&E Characterization Study and Velocity Cap Study impingement samples, and the remaining 3,849 individuals weighing 148 kg (325 lbs) from at least 25 separate taxa were collected during heat treatment impingement samples.

The most abundant macroinvertebrate species in the weekly impingement samples were intertidal coastal shrimp (*Heptacarpus palpator*), the nudibranch hermissenda (*Hermissenda crassicornis*), and red rock shrimp (*Lysmata californica*), which combined accounted for 74% of invertebrate abundance. The species contributing most to biomass during the weekly IM&E Characterization Study and Velocity Cap Study impingement samples were yellow crab (*Cancer anthonyi*), California spiny lobster (*Panulirus interruptus*), and sheep crab (*Loxorhynchus grandis*), which combined accounted for 68% of invertebrate biomass.

The most abundant macroinvertebrate species in heat treatment impingement samples were red rock shrimp, intertidal coastal shrimp, and Pacific rock crab (*Cancer antennarius*), which accounted for 81% of heat treatment abundance. The species contributing most to biomass during the heat treatment samples were California spiny lobster, California two-spot octopus (*Octopus bimaculatus/bimaculoides*), and Pacific rock crab (94% of heat treatment biomass).

Macroinvertebrate impingement was substantially higher during spring and summer 2006, and greatly reduced during the fall and winter. Annual macroinvertebrate impingement estimates at the SGS were 145,640 individuals weighing 1,418 kg (3,127 lbs) based on actual cooling water flow, and 225,449 individuals weighing 2,134 kg (4,705 lbs) based on design cooling water flow.

1.4 IMPACT ASSESSMENT

The data collected from the entrainment, source water, and impingement sampling were used to assess the potential for AEI to fish and shellfish populations. The assessment was limited to the taxa that were sufficiently abundant to provide reasonable assessment of impacts. The list of species included in the assessment was reviewed and approved by the LARWQCB and other stakeholders. 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 SGS 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 modeling was not available for most species so combined assessments were only done for northern anchovy.

The assessment included 16 taxonomic groups or species of fishes and five taxonomic groups or species of shellfishes (Table 1.4-1 and 1.4-2). 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 1.4-3). 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 SGS CWIS. These would include taxa associated with offshore pelagic habitats (no species included) 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 highest estimated entrainment mortality (Tables 1.4-1 and 1.4-2). 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, they all need to be considered relative to the magnitude of the effects. At SGS 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). Several of the fishes included in the assessment are not targeted by commercial or recreational fishing. The assessment focused on fishes such as queenfish, sand and kelp basses, Pacific barracuda, and California halibut which are targeted by sport or commercial fishing because of the greater potential for AEI when CWIS and fishing mortality are combined. 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.

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 by two EPA scientists (Newbold and Iovanna 2007). They modeled the potential effects of entrainment and impingement on populations of fifteen fish stocks that are targeted by either commercial or recreational fisheries using empirical data on entrainment and impingement, life history, and stock size. For twelve of the fifteen species, the result of eliminating the use of once-through cooling to remove the effects of power plant entrainment and impingement potentially affecting the species had very little effect on the populations (less than 2.5% change). For the other three species, the effects ranged from 22.3% for striped bass on the Atlantic coast to 79.4% for Atlantic croaker. Their overall conclusions were that population level effects were negligible for most fish stocks but could be severe for a fishes with impacts similar to their three examples. Unlike the harvested fishes analyzed by Newbold and Iovanna (2007), the largest effects of entrainment at SGS were for two non-harvested fishes that also occur in sheltered waters and these were still at low levels that would not represent a risk of AEI to the populations.

Table 1.4-1. Summary of SGS entrainment and impingement sampling results and model output for fishes and shellfishes based on actual CWIS flows 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)	*AEM* [1]
Fishes									
Seriphus politus [2]	queenfish	52.92	–	0.06			34,085	649.25	36,199
Engraulis mordax	northern anchovy	44.58	236.04	0.19	36,444[C]	79,220[L]	10,214	55.57	18,465
Genyonemus lineatus	white croaker	32.10	34.30	0.37	38[E]		2,309	170.05	
Paralabrax spp.	sea basses	29.68	–	0.17			288	72.36	
Gobiidae unid.	CIQ gobies	16.19	–	5.07	30,904[L]	13,272[L]			
Sphyraena argentea	Pacific barracuda	11.43	2.92	0.36			5	0.38	
Paralichthys californicus	California halibut	9.90	1.24	0.26	22[E]		81	8.49	
Hypsoblennius spp.	combtooth blennies	8.32	–	0.39	9,514[L]	20,302[L]	273	2.94	
Citharichthys spp.	sanddabs	6.75	264.26	0.08	3,210[E]		269	2.21	
Parophrys vetulus	English sole	5.32	–	–			3	0.14	
Pleuronichthys guttulatus	diamond turbot	3.85	0.58	1.35			22	3.46	
Pleuronichthys ritteri	spotted turbot	3.82	–	0.24			254	9.35	
Oxyjulis californica	senorita	3.56	–	0.56			21	0.50	
Atherinopsidae unid. [3]	silversides	3.26	–	3.04			11,404	840.45	
Sardinops sagax	Pacific sardine	0.34	–				25,582	964.30	31,126
Hyperprosopon argenteum	walleye surfperch	–	–				2,937	139.70	
Shellfishes									
Cancer spp. [4]	cancer crabs	1.63	–				17,500	606.35	
Panulirus interruptus	spiny lobster	0.45	–				450	276.77	
Loxorhynchus grandis	sheep crab	–	–				306	182.27	
Octopus spp.	two-spot octopus	–	–				375	75.29	
Loligo opalescens	market squid	3.37	–	–			300	7.51	

1 standardized impingement adult equivalent mortality
2 larval entrainment estimate includes queenfish and unidentified croakers combined
3 topsmelt and jacksmelt combined for impingement
4 megalops larvae for entrainment

*(*ETM* – Empirical Transport Model [P_M –proportional mortality], *FH* – Fecundity Hindcasting, *AEL* – Adult Equivalent Loss, *EAM* – Adult Equivalent Model) Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

Table 1.4-2. Summary of SGS entrainment and impingement sampling results and model output for fishes and shellfishes based on design CWIS flows 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)	*AEM* [1]
Fishes									
Seriphus politus 2	queenfish	75.67	–	0.10			36,683	682.10	38,335
Engraulis mordax	northern anchovy	70.73	382.78	0.30	57,974[C]	125,680[L]	11,379	62.32	24,922
Genyonemus lineatus	white croaker	46.64	68.60	0.53	76[E]		2,822	174.66	
Paralabrax spp.	sea basses	40.35.	–	0.24			330	89.51	
Gobiidae unid.	CIQ gobies	24.43	–	7.41	46,642[L]	20,031[L]			
Sphyraena argentea	Pacific barracuda	15.45	3.93	0.52			5	0.38	
Paralichthys californicus	California halibut	14.12	2.65	0.37	38[E]		123	12.68	
Hypsoblennius spp.	combtooth blennies	14.23	–	0.63	16,264[L]	34,704[L]	390	4.17	
Citharichthys spp.	sanddabs	9.70	407.68	0.13	4,954[E]		420	3.43	
Parophrys vetulus	English sole	7.68	–	–			5	0.22	
Pleuronichthys guttulatus	diamond turbot	5.72	94.70	2.03			33	4.94	
Pleuronichthys ritteri	spotted turbot	5.15	–	0.33			372	11.99	
Oxyjulis californica	senorita	4.81	–	0.85			22	0.53	
Atherinopsidae unid.[3]	silversides	5.12	–	4.75			15,966	1,179.39	
Sardinops sagax	Pacific sardine	0.44	–				27,483	1,006.56	32,331
Hyperprosopon argenteum	walleye surfperch	–	–				2,956	140.20	
Shellfishes									
Cancer spp.[4]	cancer crabs	2.38	–				27,024	937.00	
Panulirus interruptus	spiny lobster	0.67	–				613	377.76	
Loxorhynchus grandis	sheep crab	–	–				477	284.39	
Octopus spp.	two-spot octopus	–	–				542	102.97	
Loligo opalescens	market squid	4.93	–	–			469	11.73	

[1] standardized impingement adult equivalent mortality
[2] larval entrainment estimate includes queenfish and unidentified croakers combined
[3] topsmelt and jacksmelt combined for impingement
[4] megalops larvae for entrainment
*(ETM – Empirical Transport Model [PM –proportional mortality], FH – Fecundity Hindcasting, AEL – Adult Equivalent Loss, EAM – Adult Equivalent Model) Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

Table 1.4-3. Habitat associations for taxa included in assessment of CWIS effects at the SGS.

		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**
Engraulidae unid.	anchovies	C			**X**	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Gobiidae unid.	CIQ goby complex		**X**			
Hyperprosopon ellipticum	walleye surfperch		x		**X**	
Hypsoblennius spp.	combtooth blennies		**X**	x		
Oxyjulis californica	señorita			**X**		
Paralabrax spp.	sand and kelp bass	S	x	**X**		
Paralichthys californicus	California halibut	S	x			**X**
Parophrys vetulus	English sole	C				**X**
Pleuronichthys guttulatus	diamond turbot	S	x			**X**
Pleuronichthys ritteri	spotted turbot	S	x			**X**
Sardinops sagax	Pacific sardine	C			**X**	
Sciaenidae unid.	croakers	S, C			**X**	x
Seriphus politus	queenfish	S			**X**	x
Sphyraena argentea	Pacific barracuda	S			**X**	
Cancer spp	cancer crabs	S	x	x		**X**
Loligo opalescens	market squid	S			**X**	
Panulirus interruptus	California spiny lobster	S		**X**		

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.

2.0 INTRODUCTION

The Scattergood Generating Station (SGS) is a fossil-fueled steam electric power generating station that is owned and operated by the Los Angeles Department of Water and Power (LADWP) and is located in the in the City of Los Angeles on the shore of Santa Monica Bay. SGS uses a once-through cooling water system for all three of its generating units with a maximum cooling water flow of 495.3 million gallons per day (mgd). All three units share a common intake structure located approximately 1,600 feet (ft) (500 meters [m]) offshore. After passing through the plant, the cooling water is discharged into Santa Monica Bay through a pipe that runs 1,200 ft offshore parallel to the intake.

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 SGS, which withdraws a maximum of 495.4 mgd, it was subject to these new regulations that required submittal of comprehensive plan for compliance by January 2008. The new regulations were challenged by a coalition of environmental groups that 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 judgement" (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. 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 EPA published the second phase of new regulations under §316(b) of the CWA. The final Phase II regulations went into effect in September 2004, and apply to existing generating stations (Phase II facilities) with CWIS that withdraw at least 50 mgd from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. Pursuant to the Phase II regulations, the LADWP submitted a Proposal for Information Collection (PIC) for SGS to the Los Angeles Regional Water Quality Control Board (LARWQCB) in October 2005 (LADWP 2005). The PIC included the Study Plan for the SGS Impingement Mortality and Entrainment (IM&E) Characterization Study.

2.1.1 Section 316(b) of the Clean Water Act

Section 316(b) of the CWA requires that the location, design, construction, and capacity of CWISs reflect 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 SGS. Previous §316(b) CDSs were done at SGS from 1978 through 1979 (IRC 1981). Entrainment sampling was performed biweekly for one year, and most sampling events consisted of both day and night sampling. No routine impingement sampling was done during the study. Impingement data presented in the 316(b) report included heat treatments and a 10-day special study under variable flow conditions. 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 with the 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 multiple aspects of EPA's final Phase II rule. The decision supported the petitioners contention that EPA exceeded its authority in rejecting closed-cycle cooling, and selecting instead a range of technologies as BTA that were based on the agency's use of improper cost-benefit analysis. Nevertheless, the Court found that EPA may consider costs to determine what technologies are reasonably available. The Court also criticized the EPA's selection of the suite of technologies as BTA, remanding to the EPA the provision establishing BTA and requiring more explanation on the basis for the agency's decision or a new determination of BTA based on appropriate considerations. The Court also remanded to EPA certain provisions in the Phase II rule that set performance standards to be achieved through compliance measures, and provisions that allowed compliance through the use of restoration measured in lieu of BTA.

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

The information in this report is being submitted to assist in the evaluation of fish protection technologies and operational measures described in the PIC so that when the issues with the Phase II Rule are resolved, LADWP 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 Phase II §316(b) regulations required that the plan for the IM&E Characterization Study include sufficient data to develop a scientifically valid estimate of IM&E, including all methods and Quality Assurance/Quality Control (QA/QC) procedures for sampling and data analysis. The sampling and data analysis methods must be appropriate for a quantitative survey and include consideration of the methods used in other studies performed in the source waterbody. The sampling plan must also include a description of the study area (including the area of influence of the CWIS, and provide for taxonomic identifications of the sampled or evaluated biological assemblages (including all life stages of fish and shellfish) that are known to be relevant to the development of the plan.

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

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

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

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

The revisions to the Study Plan only affected sample processing and did not affect the sampling that started in January 2006. 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), CDFG, and NMFS to review preliminary data from the SGS IM&E Characterization Study, and determine the fish and shellfish species that would be assessed in the IM&E Final Report. The

USFWS was invited to the meeting but did not attend. The meeting was also attended by a representative from Tetra Tech, a consultant to the EPA and Regional Board, and representatives from the following environmental groups: Heal the Bay and Santa Monica Baykeeper.

An initial draft of the IM&E results with the species identified at the January meeting was sent to the attendees in early May for review. Another meeting with the group was held on May 7, 2007 to finalize the list of species that would be included in the assessment presented in this report.

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

At the January 30 meeting, NMFS requested that all species managed under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) be assessed in the SGS IM&E report. Off southern California, these species are listed in the Coastal Pelagics Fishery Management Plan (FMP) and the Pacific Groundfish FMP. 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.

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 SGS 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 SGS CWIS does not conform to the calculation baseline. Significant deviations from the calculation baseline are:

- The intake is located 1,600 ft offshore from the power plant rather than on the shoreline;
- The intake is submerged rather than at or near the surface; and
- The intake has a velocity cap that results 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 LADWP. 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 SGS 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 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 SGS 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 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 can vary greatly through the year and, therefore, biweekly 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, source water sampling occurred monthly, which is consistent with the sampling frequency for 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 SGS 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 SGS CWIS in Section 6.0. The references used in the report are presented in Section 7.0. Appendices include detailed summaries of the physical studies, and the entrainment, source water, and impingement data.

2.3 CONTRACTORS AND RESPONSIBILITIES

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

- EPRI Solutions
  - Input on sampling design

- MBC Applied Environmental Sciences
  - Study design
  - Field sampling
  - Impingement mortality data entry and analysis
  - Reporting

- Tenera Environmental
  - Study design
  - Physical oceanographic data collection and analysis
  - Field sampling QA/QC
  - Laboratory processing of entrainment and source water plankton samples
  - Entrainment data entry and analysis
  - Reporting.

- URS Corporation
  - Project management

Each of the two biological contractors (i.e., MBC and Tenera) was responsible for ensuring that all data were verified prior to being entered, and that appropriate QA/QC measures were employed during data collection, entry and analysis.

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

3.1 DESCRIPTION OF THE GENERATING STATION

SGS is located on the shore of Santa Monica Bay (33°54'59" N, 118°26'08" W) in the city of Los Angeles, California (Figure 3.1-1). Santa Monica Bay is an open embayment 43 kilometers (km) (27 miles [mi]) across and delineated by Point Dume, which is located 37 km (23 mi) to the northwest of SGS, and Palos Verdes Point, which is located 15 km (9 mi) to the south (Figure 3.1-1). The surface area of the Bay is approximately 428 square km (266 square mi) (MBC 1988). The Bay 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.

SGS has two oil/gas boilers (Units 1 and 2) rated at a capacity of 179 megawatts (MW) each, and one gas boiler (Unit 3) rated at a capacity of 460 MW, for a total generating capacity of 818 MW. All three units draw cooling water from a common submerged offshore intake equipped with a velocity cap located approximately 1,600 ft (500 m) offshore.

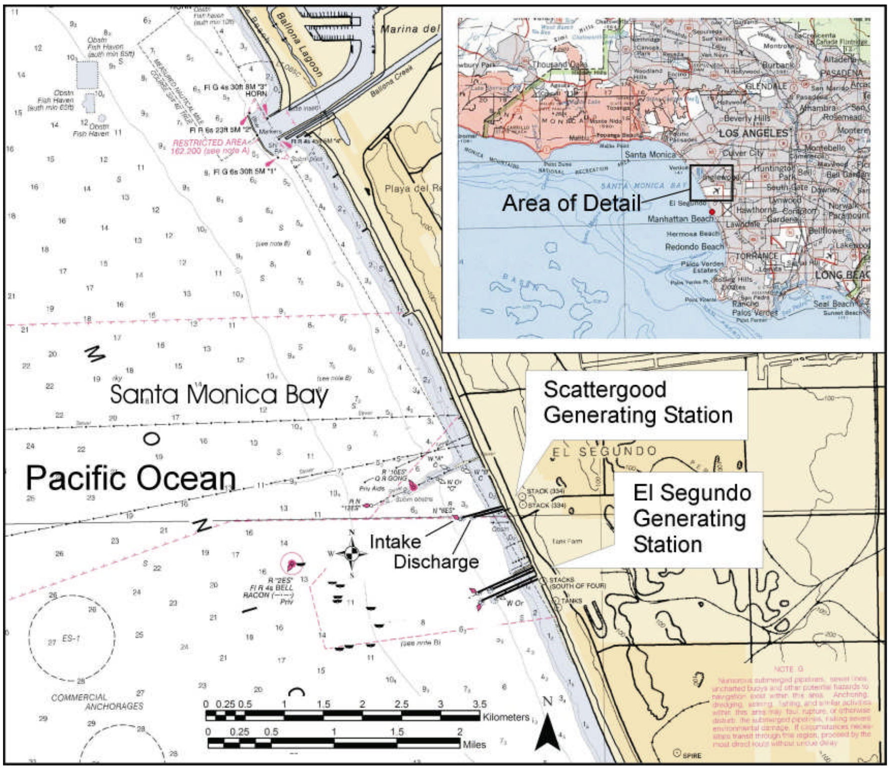


Figure 3.1-1. Location of the SGS, with the location of nearby El Segundo Generating Station also shown.

3.2 DESCRIPTION OF THE COOLING WATER INTAKE SYSTEM

3.2.1 System Configuration and Operation

One CWIS at the SGS serves all three units. The CWIS includes a single offshore intake pipe with velocity cap located approximately 488 m (1,600 ft) offshore (Table 3.2-1 and Figure 3.2-1). The ocean bottom surrounding the intake is at elevation[1] (El.) –8.8 m (-29.0 ft) (Figure 3.2-2). The top lip of the intake riser is at a depth of El. –3.4 m (-11.0 ft). The concrete pipe extends 4.0 m (13.0 ft) above the sea floor. A circular velocity cap was installed in 1974 to replace the cap from the original 1958 construction, which was severely damaged in a large storm. The velocity cap has a radius of 5.0 m (16.3 ft) with a 1.5-m (5 ft) opening between the bottom of the cap and the top of the intake riser. The velocity cap redirects the intake flow from a vertical direction to a horizontal direction. Water flows through the velocity cap, down a 5.3 m (17.5 ft) internal diameter vertical riser pipe, and into a 3.7 m (12.0 ft) internal diameter intake pipe that conveys the water to the onshore screen structure.

Table 3.2-1. Specifications of the SGS cooling water intake and discharge structures.

	Intake	**Discharge**
Distance from shore (m) [ft]	488 [1,601]	366 [1,200]
Riser height from bottom (m) [ft]	3.2 [10.5]	3.4 [11.2]
Riser inside diameter (m) [ft]	5.3 [17.4]	5.3 [17.4]
Approx. water depth (m MLLW*) [ft]	9 [29.5]	8 [26.2]
Depth below sea surface (m) [ft]	5.3 [17.4]	4.6 [15.1]

*Mean Level Low Water
Data Source: Pender (1975), IRC (1981)

The cooling water intake pipe is connected to an inlet chamber configured in a 21 m (68.8 ft) long, 60° wide arc (Figures 3.2-3 and 3.2-4). The length of the intake pipe from the velocity cap to the inlet chamber is 640 m (2,100 ft). Water entering the inlet chamber is redirected by guide vanes into the eight trash rack bays. These trash racks prevent large debris from reaching the traveling screens. Each trash rack bay is 1.8 m (6 ft) wide, with a bottom located at El. -7.2 m (-23.5 ft), and extends to El. 3.7 m (12.0 ft). The trash racks are vertical 3/8-in by 4-in steel bars centered 5 in apart.

Traveling water screens are positioned 9.1 m (30 ft) downstream of the trash rack. The screens are 1.8 m (6.0 ft) wide and have a bottom elevation of El. –7.2 m (-23.5 ft). The traveling screens have a rectangular 3/8-in by 3/4-in mesh pattern and are rotated and washed every eight hours. Each screen is washed by internal and external spray nozzles that spray debris from the descending screen panels into two troughs that lead to debris basket pits located on either side of the structure.

[1] All elevations refer to mean sea level.

The circulating water pumps are located 7.6 m (25 ft) downstream of the traveling screens. Units 1 and 2 each have two circulating water pumps, while Unit 3 has four pumps. The Unit 1 and 2 pumps are each rated at 86.9 cubic feet per second (cfs) [39,000 gallons per minute (gpm)], while the four pumps for Unit 3 are each rated at 104.7 cfs (47,000 gpm). The total circulating water flow for SGS is 766.5 cfs (344,000 gpm).

After passing through the condensers, warmed water is discharged into a 12 ft internal diameter pipe that runs 1,200 ft offshore parallel to the intake pipe. The discharged water exits through a 7.5 ft diameter vertical riser located 400 ft away from the intake velocity cap.

The cooling water is heat treated approximately once every eight weeks to prevent condenser biofouling. This is done by recirculation of the cooling water through the system. The circulated water is maintained at a temperature of 46.1 °C (115°F) for 1 hour and 40 minutes. Each cooling water pipeline is also injected with liquid chlorine for 40 minutes per day per shift. Chlorine levels in the discharge water are kept within the limits of the NPDES permit.

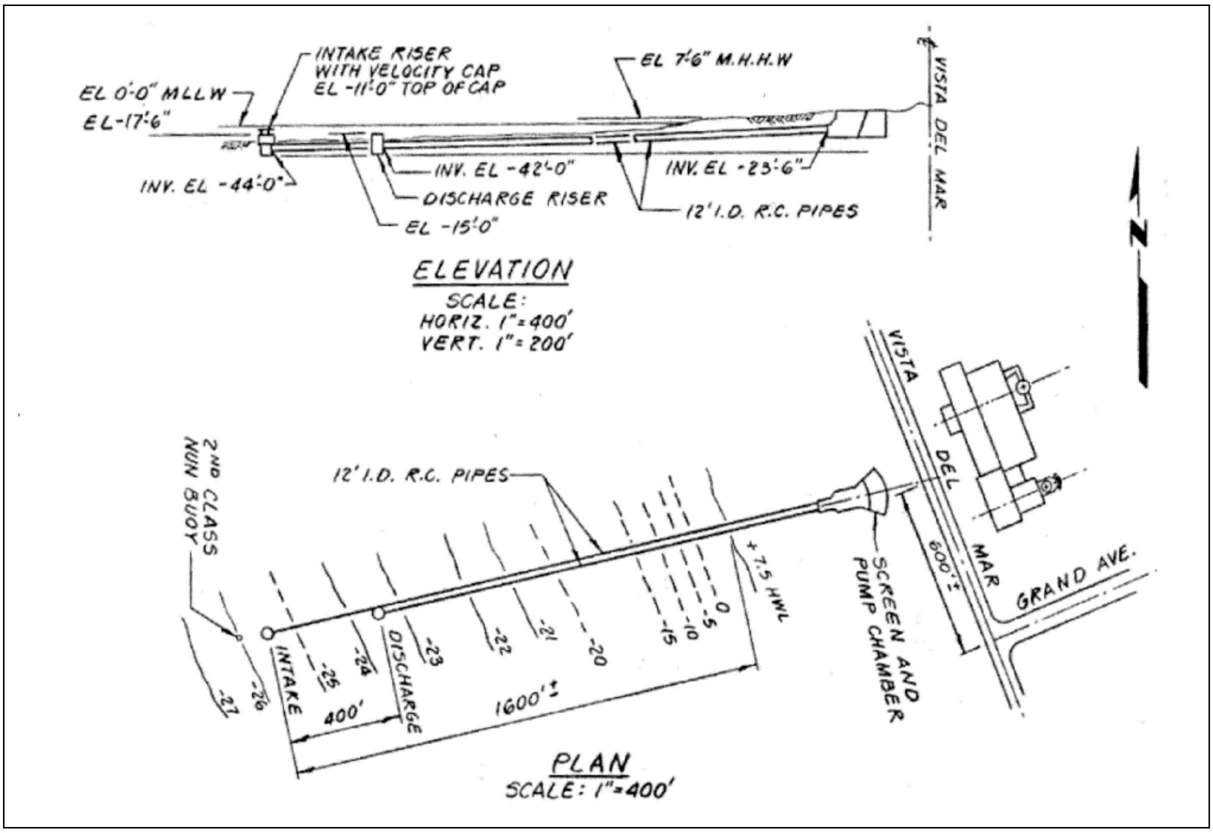


Figure 3.2-1. Plan view and elevation of the SGS offshore intake system.

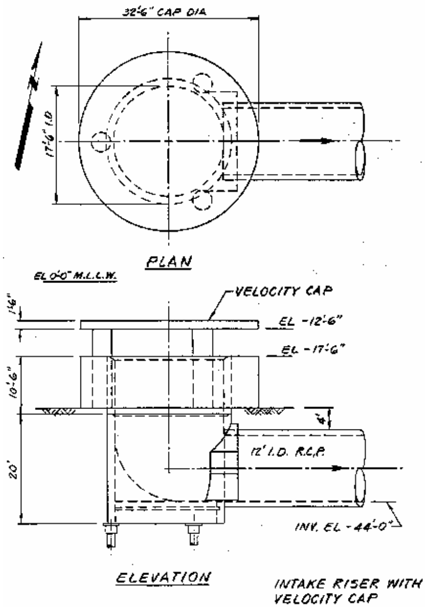


Figure 3.2-2. Detail of the SGS offshore intake riser and velocity cap.

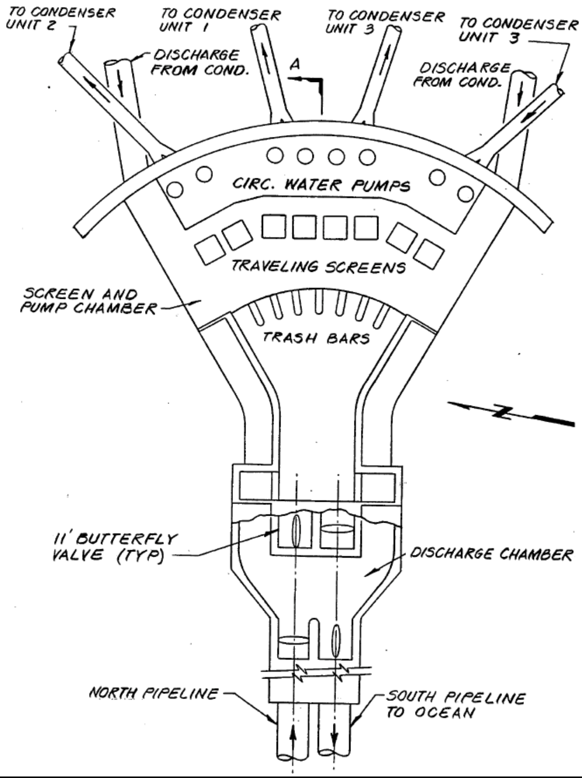


Figure 3.2-3. Plan view of the SGS onshore intake structure.

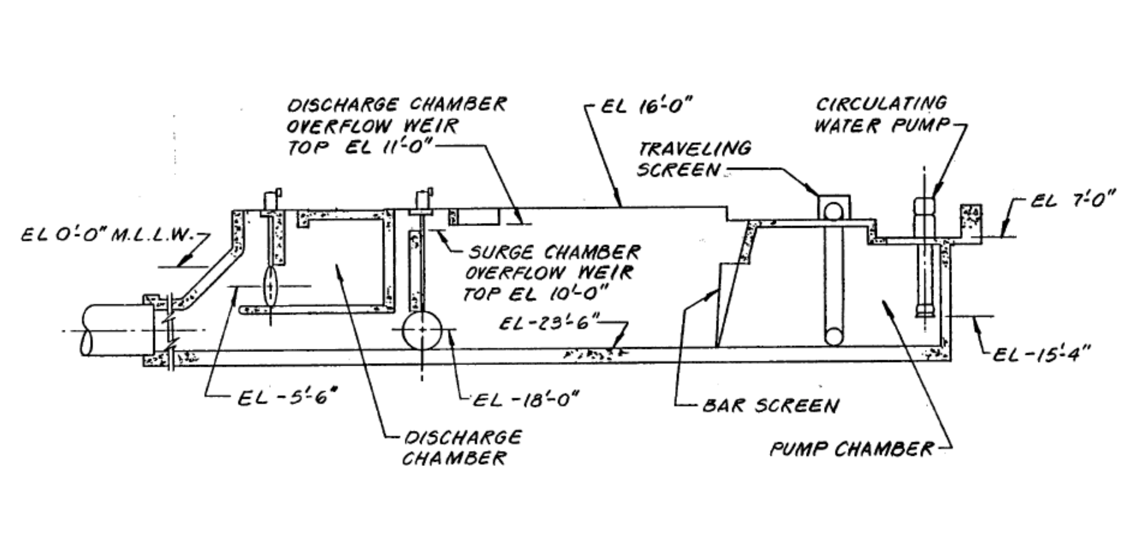


Figure 3.2-4. Section view of the SGS onshore intake structure.

3.2.2 Circulating Water Pump Flows

The SGS CWIS withdraws a maximum of 1,874,938 cubic meters (m^3) per day (495.4 mgd) of cooling water from Santa Monica Bay. Velocities inside the circulating water system were calculated using design flow of the facility and the water level at MLLW, El. 0.0 m. The horizontal water velocity at the velocity cap opening was calculated to be 0.5 meters per second (m/s), or 1.5 ft/s, in the intake pipe to be 2.1 m/s (6.8 ft/s), and the approach velocity prior to the traveling screens to be 0.18 m/s (0.6 ft/s) at Units 1 and 2 and 0.21 m/s (0.7 ft/s) at Unit 3. Intake structure characteristics, formulas, and velocity calculations for the SGS are provided in Appendix A of the SGS PIC.

Daily cooling water flow volumes at the SGS during 2006 are depicted on Figure 3.2-5. Lowest flows generally occurred in May and June 2006, when there was no cooling water flow at Unit 3, and during January and February 2006, when there was no cooling water flow at Unit 2. Highest flows generally occurred in July and August 2006; however, there was substantial variation. Daily cooling flow from January 1, 2006 to January 2, 2007 averaged 1,199,687 m^3 per day (317.0 mgd), or about 64% of maximum design flow. The combined Unit 1 & 2 flows were 72% of maximum from January 2006 to February 2007, while Unit 3 operated at an average of 59% of maximum (Table 3.2-2).

Table 3.2-2. Daily average cooling water flow volumes by Unit at SGS in 2006.

	U1 & U2	U3
Daily average flow (m^3)	612,471	600,027
Daily average flow (gallons)	161,797,705	158,510,424
Percent of maximum	71.97	58.55

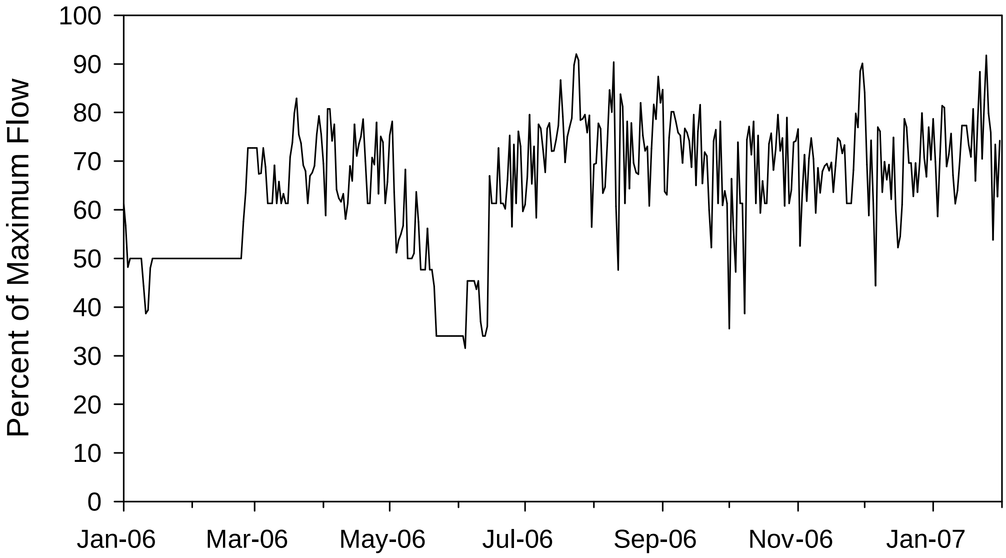


Figure 3.2-5. Daily cooling water flow volumes at the SGS from January 2006 to February 2007. (Maximum = 1,874,938 m^3 per day, or 495.360 mgd)

3.3 ENVIRONMENTAL SETTING

3.3.1 Physical Description

Santa Monica Bay is an open embayment approximately 43 km (27 mi) across and delineated by Point Dume, which is located approximately 37 km (23 mi) to the northwest of the SGS and Palos Verdes Point, which is located approximately 15 km (9 mi) to the south (Figure 3.3-1). The surface area of Santa Monica Bay is approximately 428 km^2 (266 mi^2) (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 SGS 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 El Segundo Generating Station (ESGS), is a large man-made small craft marinas. 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.

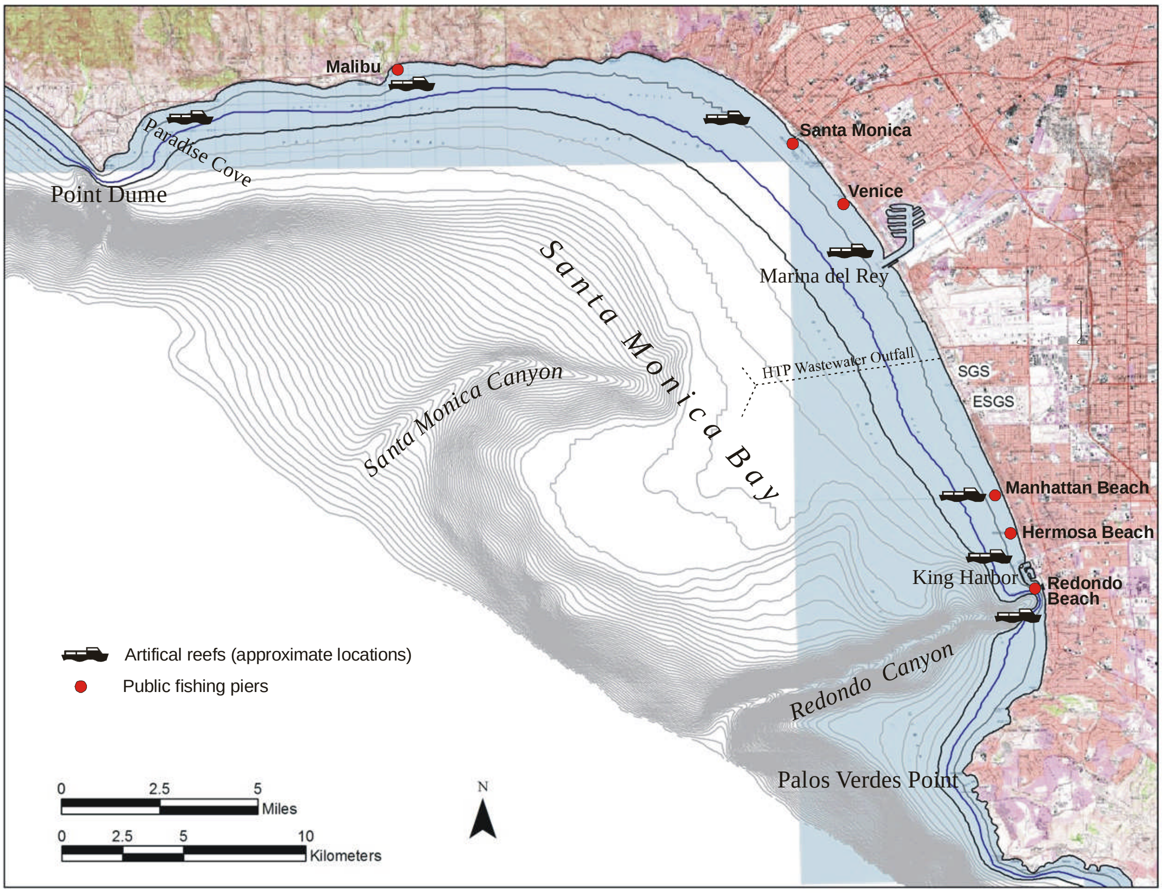


Figure 3.3-1. Santa Monica Bay geographical features.

3.3.1.1 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 SGS. 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 adjacent to the SGS. 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 mi) from shore immediately upcoast from the SGS, but is only used for emergency purposes.

Two other coastal generating stations utilize the bay for cooling water purposes. The ESGS, located just downcoast from the SGS, operates two cooling water systems with a maximum permitted volume of 2,295,981 m^3 per day (607 mgd). The AES Redondo Beach Generating Station withdraws up to 3,397,302 m^3 per day (898 mgd) of cooling water from King Harbor and Santa Monica Bay. A Chevron refinery also discharges about 22,710 to 26,495 m^3 (6 to 7 mgd) of treated effluent to Santa Monica Bay downcoast from the SGS.

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.

3.3.1.1.1 Climate and Weather

Southern California lies in a climatic regime defined as Mediterranean, characterized by mild winters and warm, dry summers. In 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 in), with most precipitation occurring from October through April.

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

3.3.1.2 Temperature and Salinity

The salinity in the surface waters of the SCB is relatively constant (isohaline). According to Dailey et al. (1993), salinities in the nearshore peak in July at around 33.6 parts per thousand (ppt) and decrease in late winter and early spring to 33.4–33.5 ppt. Tides and temperatures are recorded at the National Oceanic and Atmospheric Administration (NOAA) station (Station ID: 9410840) located on the Santa Monica Pier 11.8 km (7.4 mi) northwest of SGS (34° 0.5' N, 118° 30.0' W). 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 3.3-2.)

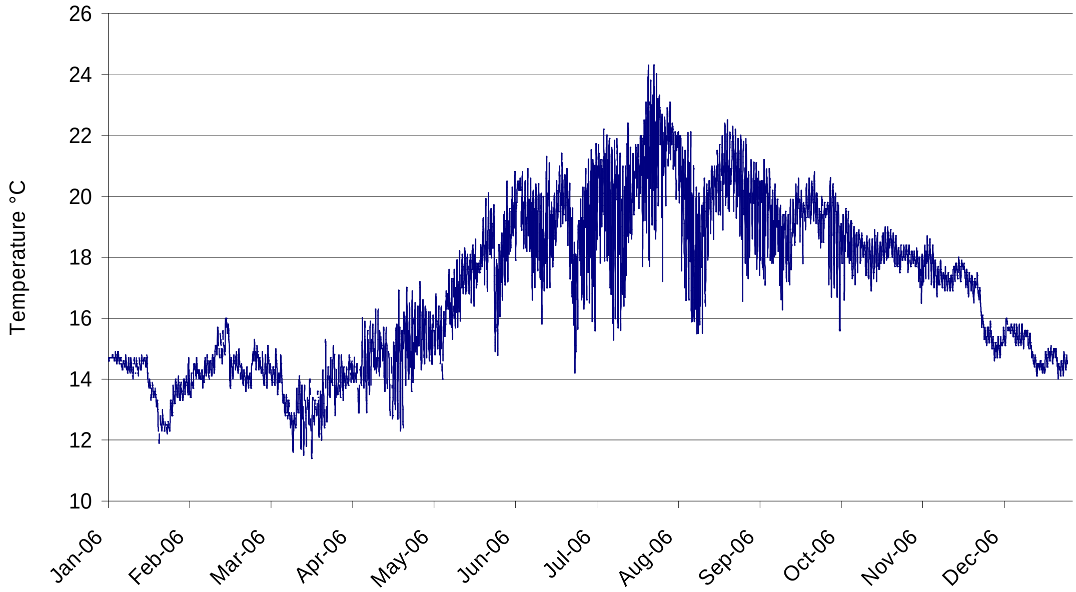


Figure 3.3-2. Hourly surface water temperatures at NOAA Station 9410840 at Santa Monica Pier, California from January through December, 2006.

3.3.1.3 Tides and Currents

3.3.1.3.1 Overview

Tides in southern California are classified as mixed, semi-diurnal, with two unequal high tides (i.e., high water and higher high water) and two unequal low tides (i.e., low water and lower low water) each lunar day (approximately 24.5 hours). 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 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 Santa Monica Bay. The circulation pattern within the bay results from the presence of the southern California Countercurrent in the outer coastal waters of the SCB. Hickey et al. (2003) found that subtidal currents in Santa Monica Bay 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 Santa Monica Bay shoreline. However, currents shift in relation to upwelling events and other large scale hydrographic processes along the coast (Figure 3.3-3) resulting in flow regimes that differ seasonally (Figure 3.3-4). Current velocities that were measured offshore from the generating station in 2006 are presented in Section 3.3.2—*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 and 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 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 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 SGS are presented in Table 3.3-1.

Table 3.3-1. Mean velocities (cm s^{-1}) of across basin (u) and along basin (v) currents at Station C1 in Santa Monica Bay. Positive values indicate onshore (u) and upcoast (v) vectors. Data from Hickey (1992).

Depth	Oct 1985		Nov 1985		Dec 1985		Jan 1985		**Average**	
(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

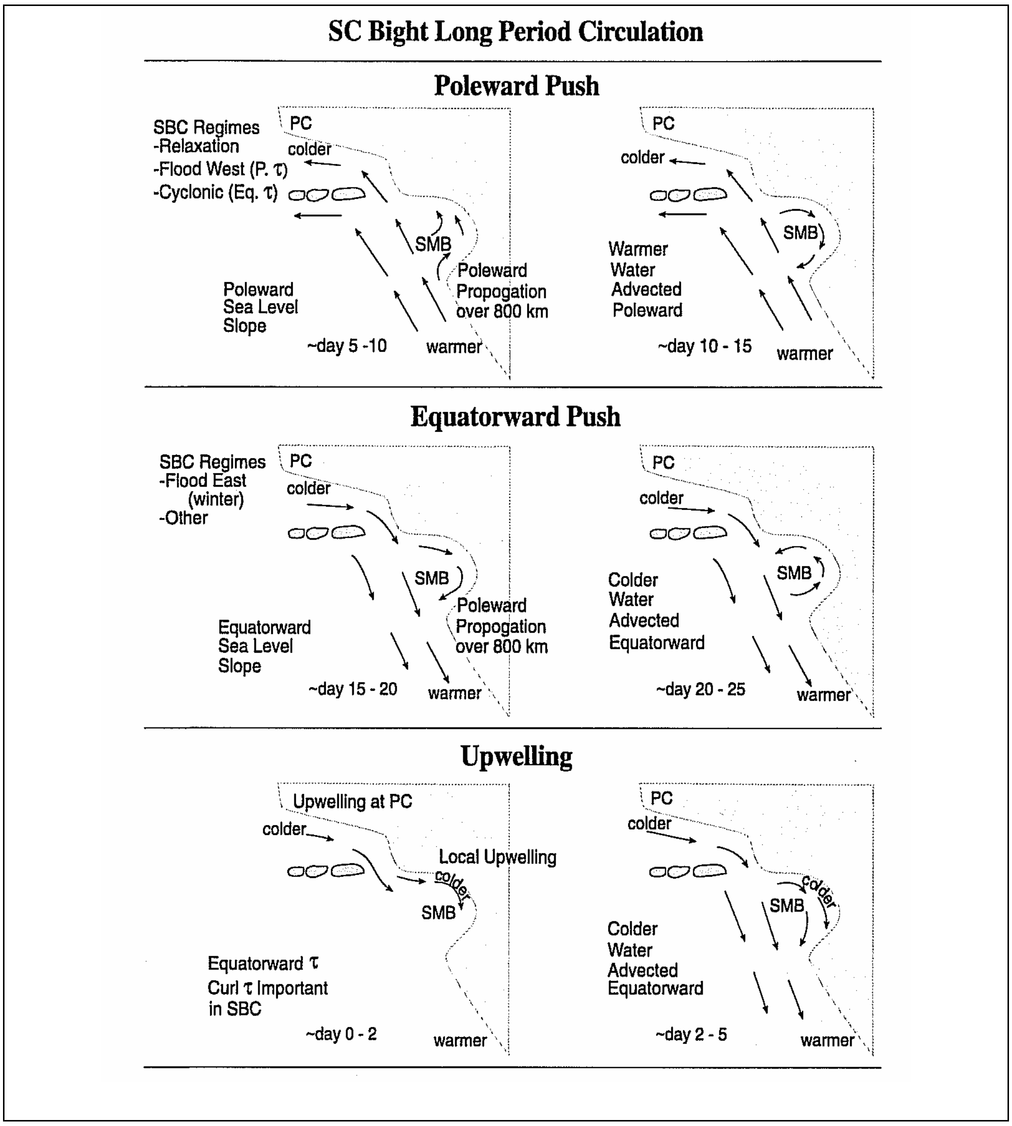


Figure 3.3-3. Schematic showing processes affecting long-period circulation and water properties in the southern California Bight (from Hickey et al. 2003).

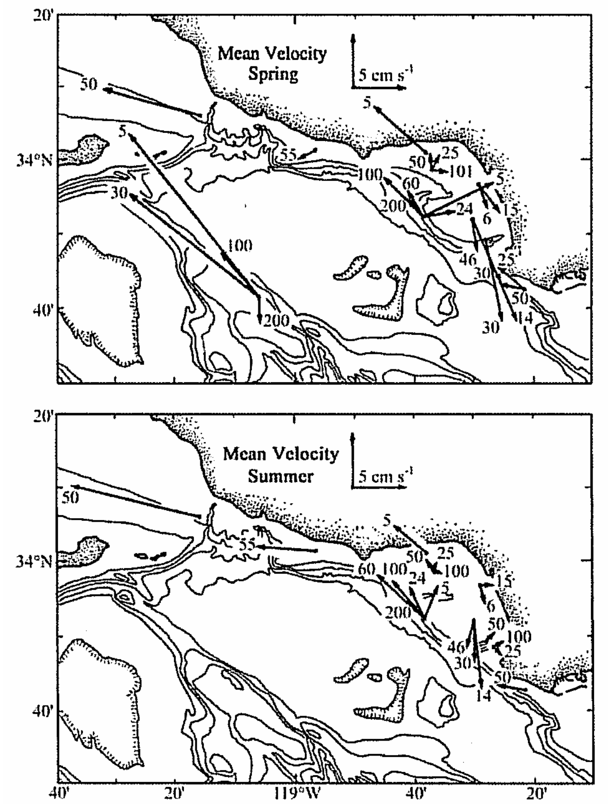


Figure 3.3-4. Selected mean currents in the central southern California Bight for spring and summer. Measurement depth in meters is given near the tip of each arrow (from Hickey et al. 2003).

3.3.1.3.2 2006 ADCP Deployments

Physical oceanographic data were collected from the source water body to describe current regimes that can affect larval transport in the vicinity of the SGS. 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 at a depth of –12.8 m (–41.9 ft) MLLW (Figure 3.3-2). 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, and 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 3.3-2). Both units collected data at hourly intervals in a usable range that extended from 0.5 m (1.6 ft) from the ADCP to somewhat less than 90% of the distance to the surface. The half-power full beam-width was 2.4 degrees for both units. Other measurement specifications are listed in Table 3.3-2. Water temperature and water depth (pressure) were also measured concurrently by the units. Water temperatures were calibrated over an 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 3.3-2. ADCP deployment parameters for current meters in the vicinity of SGS (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 by the product of velocity and time, were used to estimate net displacement over the year. Figure 3.3-5 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 3.3-6). 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 3.3-7). 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 and with reproduction of December 2006 and January 2007 data for data 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 3.3-8). 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.

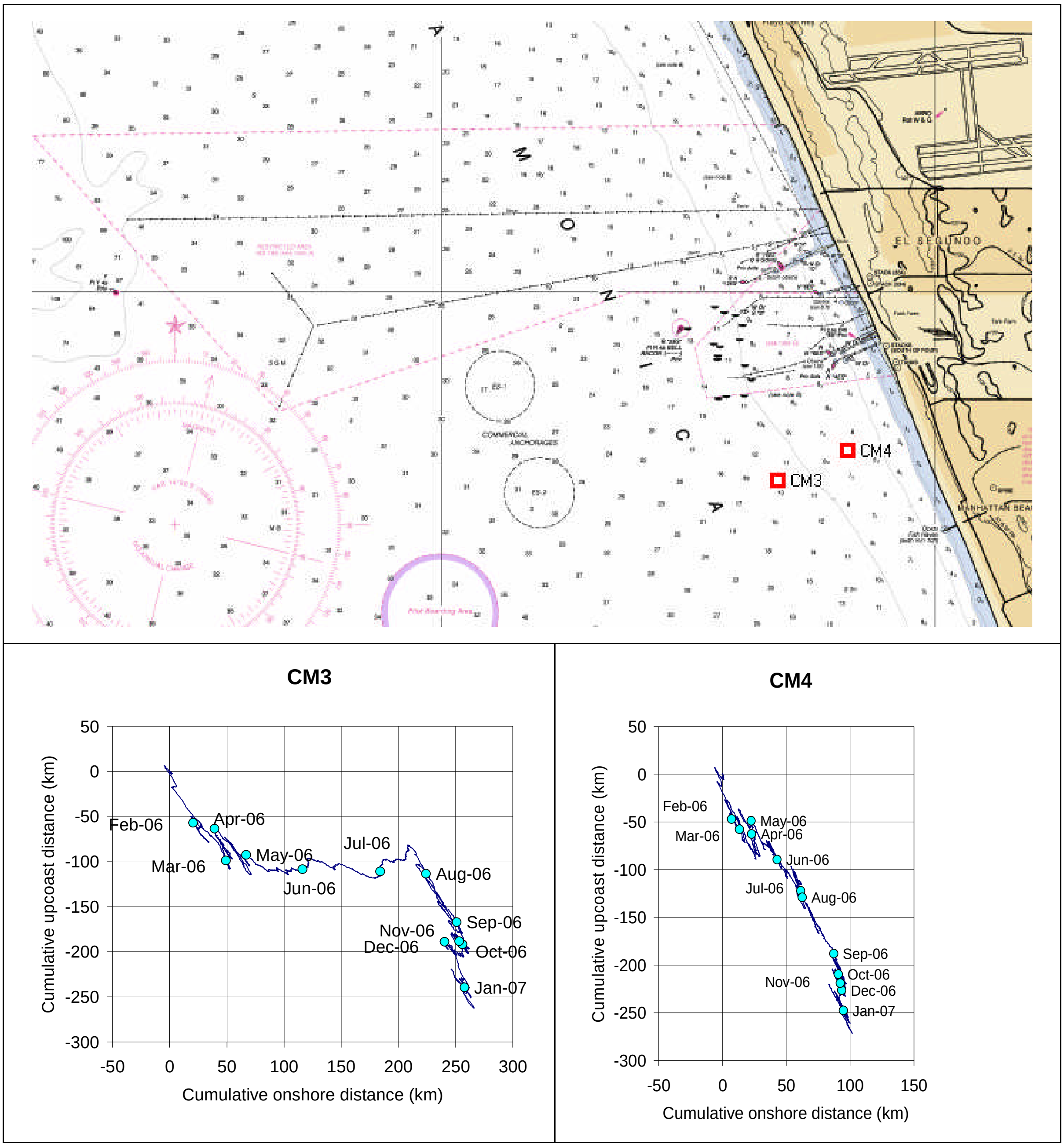


Figure 3.3-5. Net displacement at current meter stations CM 3 and CM 4 from January 2006 to January 2007.

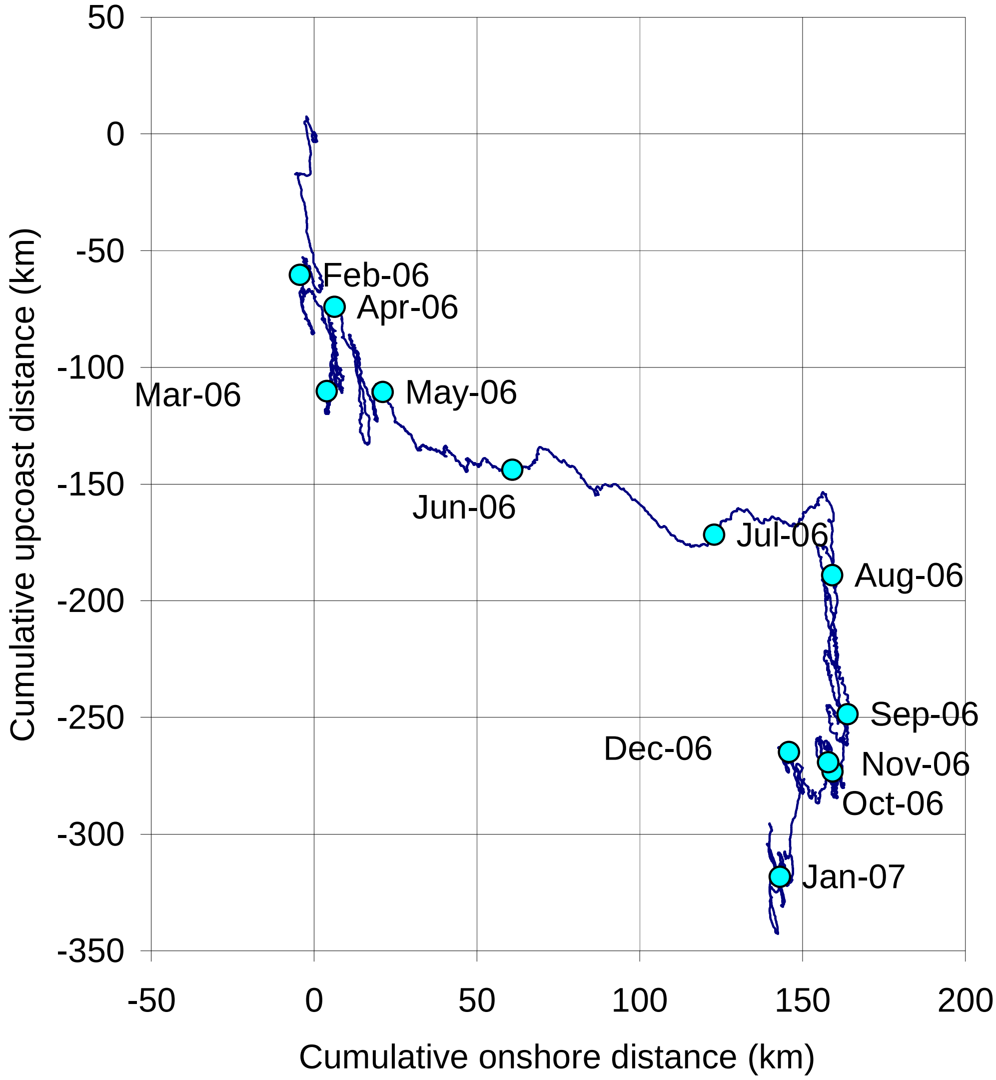


Figure 3.3-6. Cumulative current vectors from Station CM 3 in Santa Monica Bay, January 2006–January 2007.

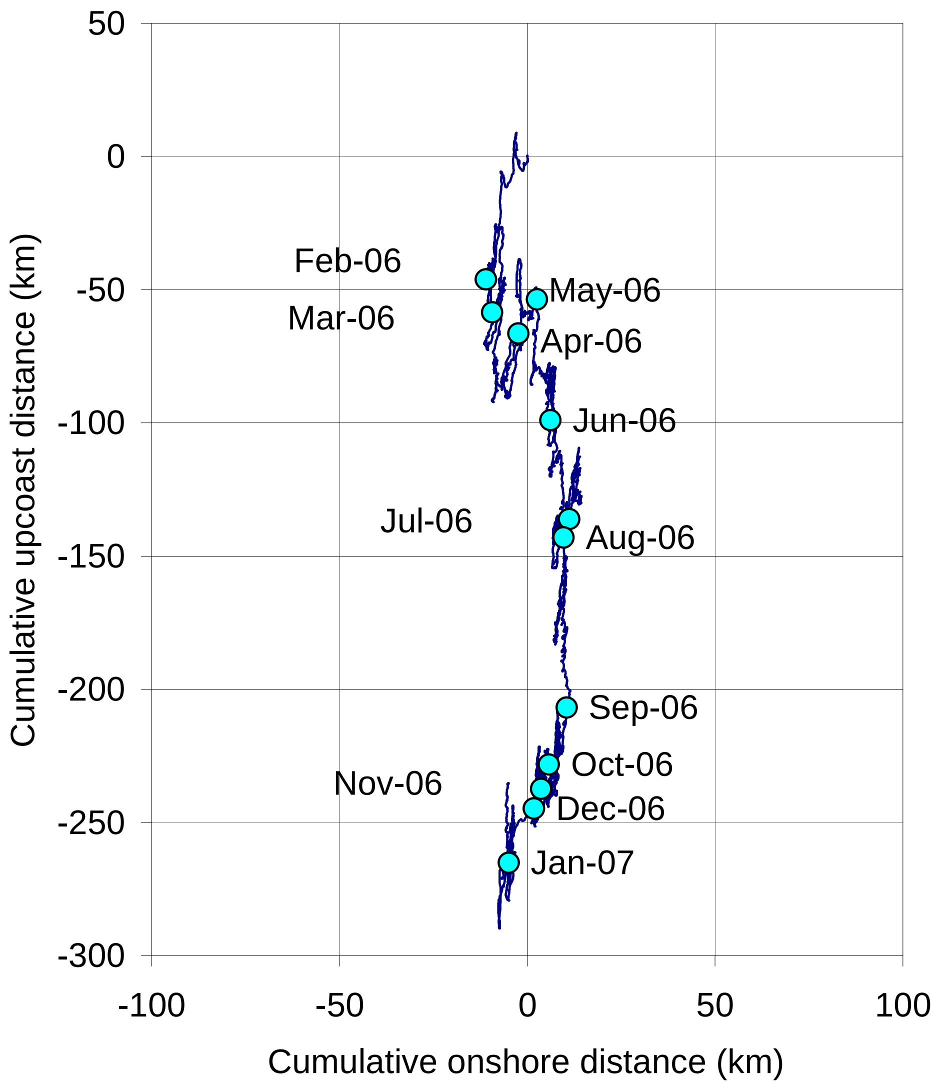


Figure 3.3-7. Cumulative current vectors from Station CM 4 in Santa Monica Bay, January 2006–January 2007.

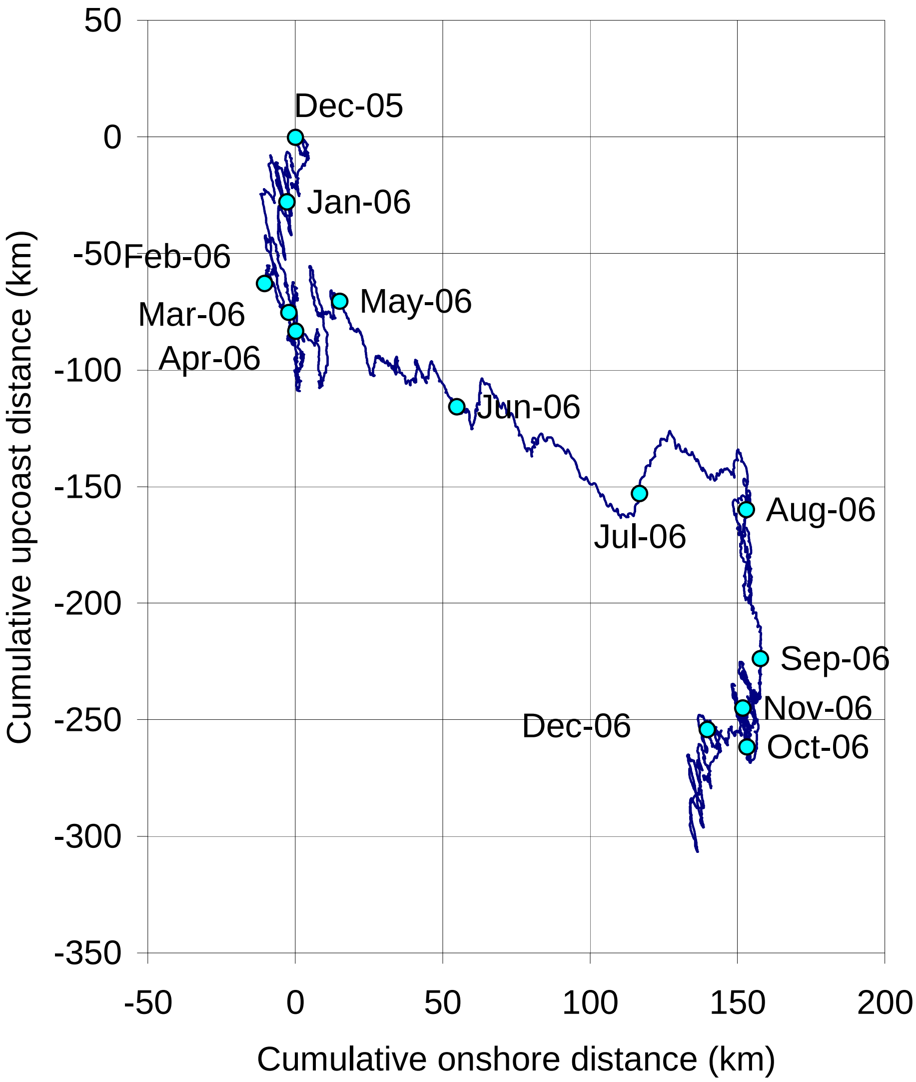


Figure 3.3-8. Composite cumulative current vectors from Stations CM 4 (upcoast) and CM 3 (onshore) in Santa Monica Bay, January 2006–January 2007.

3.3.2 Source Water Definition

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

3.3.2.1 Study Requirements and Rationale

The primary approach for assessing the effects of entrainment by the SGS 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 circulation. 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 that change seasonally and by weather and sea conditions. The rationale and methods for defining the source water for the SGS 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 SGS intake structure (Figure 3.3-9). Two stations were located, respectively, 2 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 SGS and ESGS 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 alongshelf water currents in Santa Monica Bay averaged 0.15 ft/s (4.5 centimeters per second [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 (*PE*) estimate used in the Empirical Transport Model (*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 located along the 98 ft (30 m) isobath (Stations O1-O3) (Figure 3.3-8). 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.

3.3.2.2 Methods for Calculating SGS Source Water

All depths (elevations) for determining source water volumes and planimetric surface areas for the Santa Monica Bay were relative to mean sea level (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 U.S. Geological Survey 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 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 SGS source water region consists of the waters that parallel the beach approximately 5,000 m (16,400 ft) upcoast and 5,000 m downcoast from the generating station and offshore approximately 3,950 m (12,960 ft). The 50 m (164 ft) grid cells used for offshore source water area and volume calculations were created from 10 m (32.8 ft) contour lines from the CDFG Geographic Information System data from 2000 (CDFG 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).

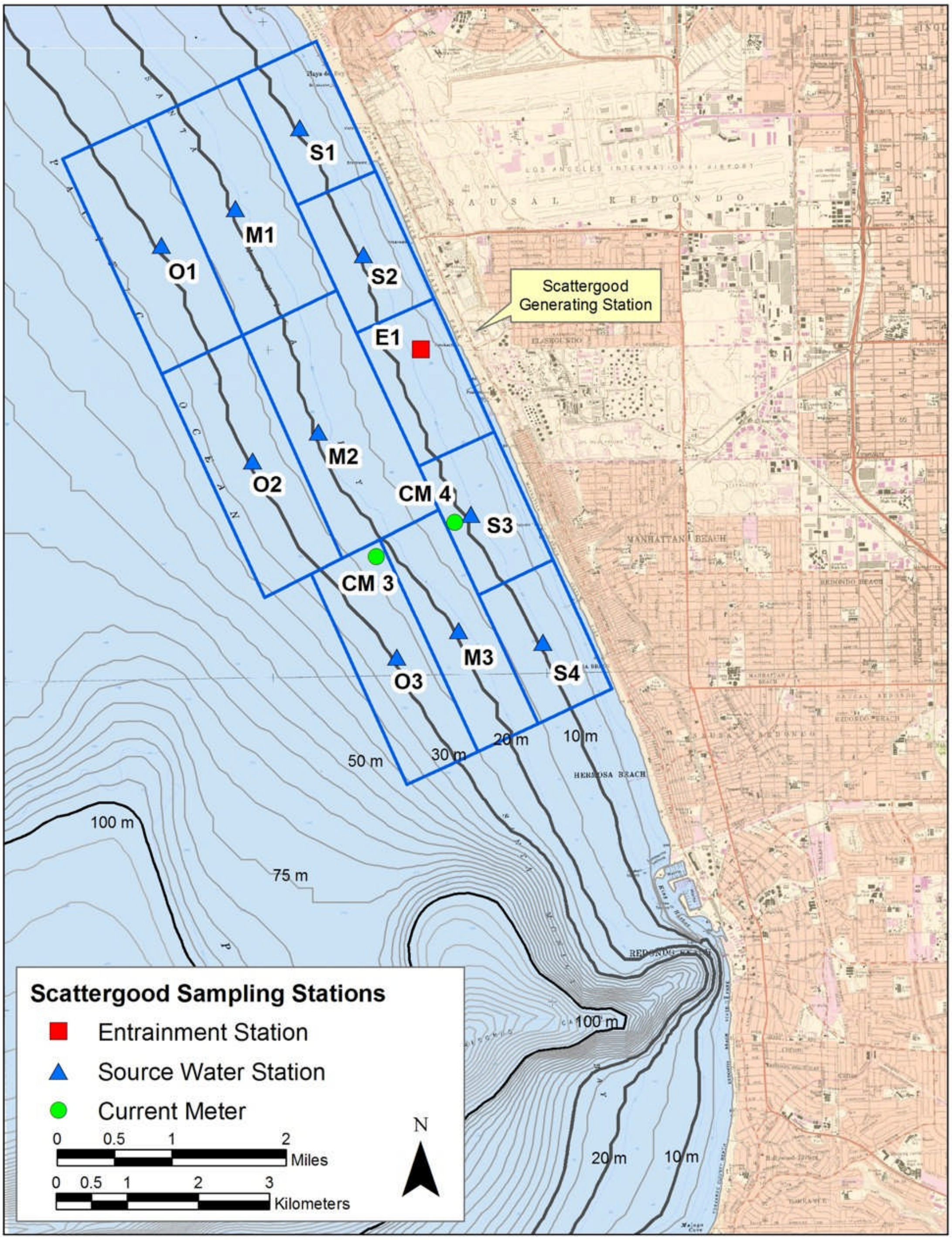


Figure 3.3-9. Locations of the SGS entrainment and source water sampling stations, and current meter stations within the study grid.

3.3.3 Biological Resources

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

3.3.3.1 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 (i.e., 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 about 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, although 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 are replacing BMPs, and are being developed for specific watersheds.

3.3.3.2 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, M. (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 to 15 m, or 20 to 49 ft), speckled sanddab (*Citharichthys stigmaeus*) was the most frequent juvenile fish taxa encountered, but queenfish (*Seriphus politus*) was most abundant.

3.3.3.3 Fish Diversity

In 2003, 23 species of fish were collected by otter trawl off the SGS 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 107 distinct fish species have been impinged during heat treatment procedures at the 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%). At least 85 fish species have been impinged since 1990 at the ESGS, just downcoast from the SGS. The most abundant species included queenfish, jacksmelt, Pacific sardine, salema (*Xenistius californiensis*), and northern anchovy (*Engraulis mordax*), which accounted for 73% of impingement abundance.

As reported in the annual NPDES monitoring report, from October 2005 through September 2006, at least 53 distinct fish species were impinged during normal operations at the SGS (MBC 2007). The most abundant taxa were queenfish, jacksmelt, northern anchovy, topsmelt, and white croaker (*Genyonemus lineatus*). These five species combined accounted for 67% of annual impingement abundance. Abundance was highest in April (when the most dominant species were jacksmelt, queenfish, California lizardfish (*Synodus lucioceps*), and northern anchovy) and August, when topsmelt and jacksmelt were dominant. At the ESGS, located just downcoast from the SGS, six fish species were impinged during normal operations, including California scorpionfish (*Scorpaena guttata*), spotted turbot (*Pleuronichthys ritteri*), kelp bass (*Paralabrax clathratus*), blacksmith (*Chromis punctipinnis*), grass rockfish (*Sebastes rastrelliger*), and giant kelpfish.

From May to July 2004, at least 37 larval fish species from 21 families were collected during day/night ichthyoplankton sampling off the SGS (MBC 2005). The most abundant taxa were unidentified gobies (Gobiidae; 57% of mean density), northern anchovy (12%), combtooth blennies (*Hypsoblennius* spp.; 11%), queenfish (5%), and white croaker (2%). Higher densities of anchovies at the 21-m (69-ft) isobath compared with the 10-m (33-ft) isobath, and higher densities of queenfish inshore compared to offshore, agreed with results of the previous 316(b) demonstration (IRC 1981).

3.3.3.4 Shellfish Diversity

In 2003, 16 species of macroinvertebrates were collected by otter trawl off the SGS (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*). As reported in the annual NPDES monitoring report, from October 2005 through September 2006, at least 67 distinct macroinvertebrate taxa were impinged during normal operations at the SGS (MBC 2007). The most abundant taxa were intertidal coastal shrimp (*Heptacarpus palpator*), the nudibranch (*Hermissenda crassicornis)*, red rock shrimp (*Lysmata californica*), yellow crab (*Cancer anthonyi*), and the jelly (*Polyorchis penicillatus)*. These five species combined accounted for 86% of annual impingement abundance. Abundance of the crabs and shrimps was highest from May through August.

3.3.3.5 Protected Species

Some fish and invertebrate species (abalone) in southern California are protected under CDFG regulations, although few marine species are listed as either threatened or endangered. Special-status fish species that could occur in the vicinity of SGS 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 7 ft in length and weigh over 500 pounds (lbs) (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 CDFG, 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.

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. The goals of the management plans include, but are not limited to: the promotion of an efficient and profitable fishery, achievement of optimal yield, provision of adequate forage for dependent species, prevention of overfishing, and development of long-term research plans (PFMC 1998, 2006). There are four fish and one invertebrate species covered under the Coastal Pelagics FMP: northern anchovy, Pacific sardine (*Sardinops sagax*), jack mackerel (*Trachurus symmetricus*), Pacific (chub) mackerel (*Scomber japonicus*), and market squid (*Loligo opalescens*). There are 89 fish species covered under the Pacific Groundfish FMP, including ratfish (*Hydrolagus colliei*), finescale codling (*Antimora microlepis*), Pacific rattail (*Coryphaenoides acrolepis*); three species of sharks, three skates; six species of 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.

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 on a biweekly basis depending on pumping capacity. The source water populations of fish and shellfish larvae are sampled to estimate *PE* losses for selected species. Abundances of larval fishes and shellfishes vary throughout the year due to changes in composition and the oceanographic environment. Because it is desirable from an impact modeling standpoint to have a higher resolution of temporal changes in the composition of entrained taxa than source water taxa, entrainment sampling is conducted biweekly, while source water sampling is conducted monthly. The monthly sampling frequency is consistent with other recently completed entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera, 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, crab megalops, and spiny lobster larvae entrained by SGS?
- What are the local species composition and abundance of the entrainable larval fishes, fish eggs, crab megalops, 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 (i.e., 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 population-level impacts, although small, 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 applied to a few of the more abundant species or species-groups, in addition to the specific shellfish taxa (spiny lobsters, market squid) regardless of abundance.

4.1.1.1 Fishes

Many of the marine fishes in the vicinity of the CWIS produce free-floating larvae at 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 3.3.3.5) were enumerated in entrainment samples. Most of these were represented by only a few specimens out of the nearly 7,000 larvae collected during the entrainment surveys. At the January 30 meeting, NMFS agreed that 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. Although calculations of these models can be done provided the appropriate life history data exist, the level of uncertainty associated with the estimates is very high unless a species is collected in adequate numbers during several surveys. Of the taxa on the list, only northern anchovy (Engraulidae, *Engraulis mordax*) and English sole (*Parophrys vetulus*) were in sufficient abundance at SGS to justify a more detailed analysis of potential IM&E impacts.

Some fish and invertebrate species (abalone) in California are protected under CDFG regulations, although few marine species are listed as either threatened or endangered. Special status fish species that could occur in the vicinity of 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*).

The 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 7 ft in length and weigh over 500 lbs (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 CDFG, 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.

Grunion are a special status species 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 lays 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.

4.2 HISTORICAL DATA

4.2.1 Summary of Historical Data

The entrainment sampling program at SGS in 1978–1979 (IRC 1981) focused on sampling ‘critical taxa’ which provided representative information regarding the effects of the generating station on the marine community, based upon criteria described in federal and state 316(b) Guidelines at the time (USEPA 1977). These taxa were defined as those that can or do support fisheries, provide significant habitat to aquatic communities, or constitute significant trophic links. Within this framework, critical taxa were selected using information obtained from literature reviews, prior field experience in the region, and data collected during sampling efforts conducted for a preliminary report. The critical taxa list for larval fishes was reviewed by the CDFG and submitted to the LARWQCB for approval.

As explained in IRC (1981), the entrainment study design was closely associated with the entrainment mortality (attributable to conduit grazing) sampling program. The combined study design called for day and night samples obtained bi-weekly at the velocity cap and in the forebay. Velocity cap data were collected beginning with Survey 8 and continuing through Survey 24. These data were synoptic with forebay collections to determine conduit grazing losses. Forebay data collections included Survey 1 through Survey 26. Concurrent forebay and velocity cap data were necessary to evaluate the loss, if any, of planktonic organisms passing through the SGS intake conduit. Only if planktonic losses within the conduit system could not be detected would forebay data produce representative entrainment samples. Conversely, if a significant plankton loss within the conduit was detected, then velocity cap data are necessary as a control to quantify planktonic losses with respect to days after heat treatments. Forebay data could then be adjusted according to derived conduit loss coefficients to estimate entrainment of organisms from source waters.

Analysis of field data indicated that velocity cap counts were often significantly less than forebay densities, suggesting a sampling bias at the velocity cap. In addition, a significant loss within the conduit was indicated 20 or more days after a heat treatment. Consequently, a new approach was developed to estimate entrainment and involved the determination of a sampling bias coefficient that could be applied to the velocity cap data. Based on adjusted velocity cap mean densities, the proportion of plankton lost within the conduit/forebay system was ascertained for selected intervals of time after a heat treatment. Based upon these proportions, forebay data were used to predict the magnitude of plankton entrained on each scheduled survey and throughout the year.

Zooplankton densities, including fish eggs and larvae, were measured bi-weekly at an entrainment station, and three source water stations: one near-field station and two far-field stations (Figure 4.2-1). Plankton nets were used to sample the source water stations and a high volume pump was used to sample in front of the intake structure. The near-field station was located within a 50m radius of the intake riser and the far-field stations were located in Santa Monica Bay (3,800 m up coast on the same isobath and 2,400 m directly offshore from the intake). These served as control areas. Two replicate entrainment samples were obtained from the forebay bi-weekly samples during both the day and night for Surveys 1 through 26. Samples were collected with a high-volume pump and filtered through a 202µ mesh net. During Surveys 8 through 24, when concurrent velocity cap samples were taken for the conduit grazing study, two of the four conduit grazing replicates were also designated for analysis as entrainment samples.

Table 4.2-1 summarizes the entrainment densities of critical taxa recorded over the 12-month study. The mean daily cooling water flow rate at the generating station varied from a low of 1,078,842 m^3 per day (285 mgd) during the month of February 1979 to a high of 1,839,710 m^3 per day (486 mgd) during October 1978. Anchovy larvae had the greatest concentrations in the entrainment samples with densities averaging 835 larvae per 1,000 m^3 (264,172 gal). This translated to an annual entrainment mortality of 382 million larvae for anchovies (Table 4.2-1). Entrainment estimates for all of the critical taxa combined was 865 million larvae annually. Croaker egg entrainment was estimated at 11 billion annually, while entrainment of northern anchovy and turbot eggs together was estimated at approximately 7% of this number.

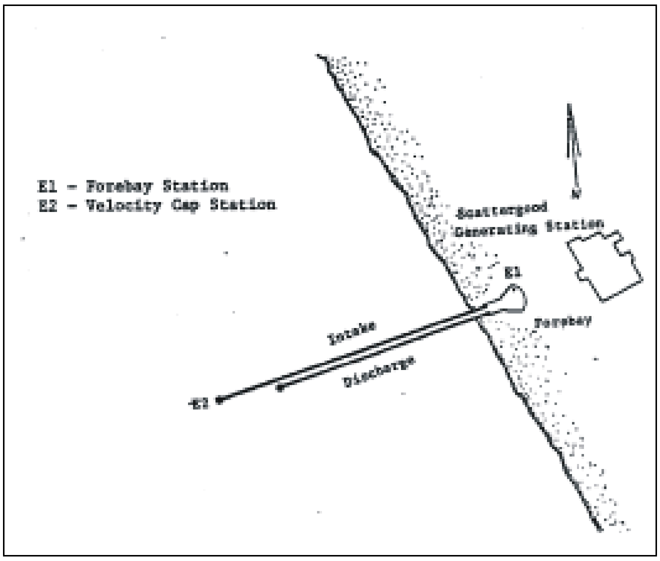
Non-critical fish larvae were identified and enumerated to provide additional information about the ichthyoplankton community, but these data were not statistically analyzed. These taxa included the Gobiid species complex, *Hypsoblennius* spp., *Hypsopsetta guttulata*, and unidentified teleosts. Unidentified teleost larvae occurred in at least one sample from all surveys and stations. In general, density values were highest from February to July and lowest from late September to November. Mean density values varied from 0 to 108 larvae/100 m^3 at Station 1, 0 to 95 larvae/100 m^3 at Station 2, and 0 to 44 larvae/100 m^3 at Station 3. Mean night density values exceeded day values at all stations.

Table 4.2-1. Summary of larval fish and fish egg densities, and annual entrainment mortality estimates for critical taxa for SGS in 1978–1979 (from IRC 1981).

Taxon	Common Name	Mean Day Density (#/1,000m^3)	Mean Night Density (#/1,000m^3)	% Freq. (Day)	% Freq. (Night)	Annual Entrainment Estimate (millions)
Larval Fishes						
Atherinopsidae	silversides	<10	150	4	4	47
Engraulidae	anchovies	930	740	46	96	382
Genyonemus lineatus	white croaker	680	580	50	58	228
Seriphus politus	queenfish	400	260	19	42	179
Sciaenid complex	croakers	–	130	–	15	27
Pleuronichthys spp.	turbots	10	–	8	–	<1
Fish Eggs						
Engraulis mordax	northern anchovy	730	920	15	15	508
Sciaenid complex	croakers	10,140	37,090	88	96	11,000
Pleuronichthys spp.	turbots	320	710	81	85	250

Note: A volume of 1,000 m^3 is equal to 264,172 gallons (gal).

Density estimates were also calculated for several ‘critical’ planktonic invertebrate taxa (Table 4.2-2), including three species of mysid shrimps, larval rock crab, larval sand crab, and the adults and larvae of one taxon of copepod. *Acartia* spp. copepods (adult stage) were the most abundant of the critical taxon and were present year-round. These seven taxa accounted for estimated annual losses of 1.62 trillion organisms from the SGS CWIS, assuming 100% through-plant mortality.



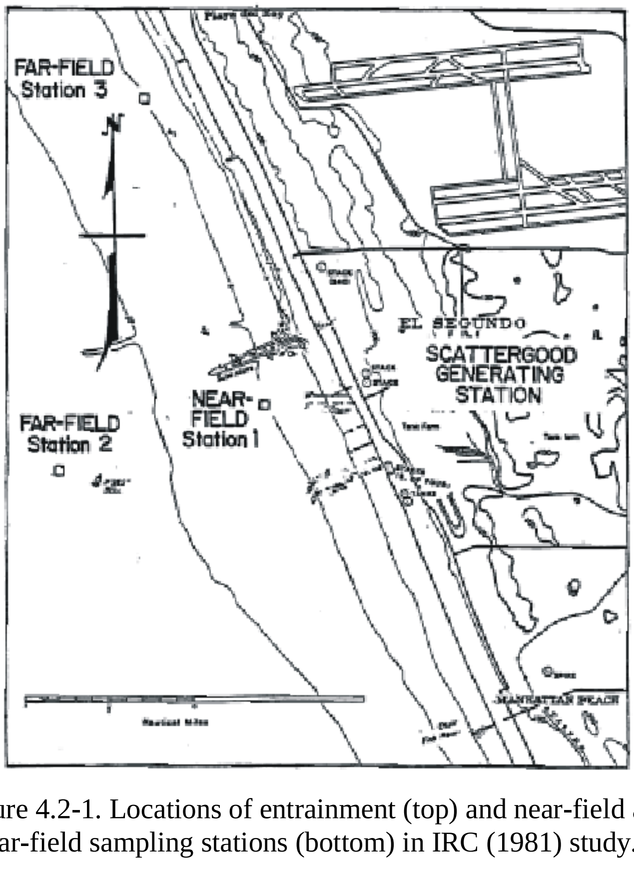


Figure 4.2-1. Locations of entrainment (top) and near-field and far-field sampling stations (bottom) in IRC (1981) study.

Table 4.2-2. Summary of planktonic invertebrate densities and annual entrainment mortality estimates for critical taxa for SGS in 1979–1980 (from IRC 1981).

Taxon	Common Name	Mean Day Density (#/1,000 m^3)	Mean Night Density (#/1,000 m^3)	% Freq. (Day)	% Freq. (Night)	Entrainment Estimate (# /year)
Acartia spp. (adults) [a]	copepods	1,664,970	2,390,190	100	100	9.7×10^{11}
Acartia spp. (larvae) [a]	copepods	1,032,300	2,137,130	100	100	5.9×10^{11}
Cancer spp. (zoeae)	rock crabs	1,150	920	42	42	3.2×10^{8}
Emerita analoga. (zoeae)	sand crab	210	640	8	23	2.0×10^{8}
Acanthomysis macropsis	mysid shrimp	2,100	32,800	50	100	7.9×10^{9}
Neomysis kadiakensis	mysid shrimp	1,280	26,660	46	92	6.0×10^{9}
Metamysidopsis elongata	mysid shrimp	1,540	195,800	62	100	4.1×10^{10}

Note: A volume of 1,000 m^3 is equal to 264,172 gallons (gal).

The following conclusions were noted for the plankton entrainment portion of the study (IRC 1981):

- The seasonal period of highest overall entrainment occurred from February through July. Exceptions to this included *Engraulis mordax* eggs, *Genyonemus lineatus* larvae, and *Seriphus politus* larvae, which exhibited seasonal peaks before or after this period.

- The diel differences in entrainment were significant for the following: mysids, Engraulidae eggs, and *Seriphus politus* larvae, all which were entrained to a greater extent at night. The dispersal of mysids and *S. politus* larvae throughout the water column at night lead to an increased susceptibility to entrainment. The increase in Engraulidae egg entrainment at night may be associated with spawning cycles.

4.2.2 Relevance to Current Conditions

Some differences in study methods may affect direct comparability of the entrainment data between the earlier and present study. One is the use of a pump to collect samples in the earlier study in contrast to the towed plankton net used in the present study. There are benefits and drawbacks to each collection method but overall the densities of collected larvae should be equivalent between the two methods. However, samples were collected at the forebay of the intake, and a correction factor applied to the estimated entrainment numbers in order to adjust for losses attributed to conduit biofouling. This affected the precision of the sampled densities and introduced more uncertainty into the annual entrainment estimates. Therefore, the density estimates for entrainment between the studies should only be compared in relative terms even though abundances and seasonality patterns of the planktonic larvae were adequately sampled by both methods. During the 1978–1979 study, the average flow during the study year was 1,460,201 m^3 per day (385.786 mgd), or 78% of maximum. Flow during the 2006 study averaged about 1,199,687 m^3 per day (316.958 mgd), or 64% of design flow.

4.2.3 QA/QC Procedures and Data Validation

The sampling program during the 1978–1979 study was conducted with the approval of the LARWQCB, and detailed procedures and methodologies, as well as QA/QC methods, can be found in Appendices G (Biological Field Procedures), H (Laboratory Procedures), and I (Statistical and Analytical Procedures) of IRC (1981). The procedures ensured that the collected data were accurately recorded and reported.

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 SGS were determined by sampling in the immediate proximity of the cooling water intake (Station E1, Figure 3.3-9) every two weeks from January through December 2006. The location of the sampling station was determined using a differential global positioning system. Sampling was done within 164–328 ft (50–100 m) of the intake structure 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 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 5,300–8,000 gallons (20–30 m^3). 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 4–10% 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 SGS cooling water intake, and 2) be representative of the nearshore habitats in the vicinity of the SGS intake.

Source water was sampled at 10 stations located upcoast, downcoast, and offshore from the SGS intake structure (refer to Figure 3.3-9). 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 alongshelf 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 miles (3.9 to 7.6 km). The average value was used to determine the alongshore extent of the source water sampling locations 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 approximately equal to the daily distance larvae 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.

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; and
- market squid paralarvae (hatchlings).

The samples from the two nets were preserved in separate 400 milliliters (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.

If the quantity of material in the two samples was very large, then only one of the two paired samples was processed and analyzed. In addition, in cases where samples contained a large quantity of eggs, an aliquot (sub sample) was taken from the total sample and only the sub sample was processed for eggs. Specimens were enumerated and identified to the lowest practical taxon. 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 in (0.1 millimeter [mm]).

4.3.3 QA/QC Procedures & Data Validation

A quality control (QC) program was implemented for the field and laboratory components of the study. QC 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 10 samples sorted by an individual were resorted by a designated 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 10 consecutive samples with greater than 90% accuracy, the sorter had one of their next 10 samples randomly selected for a QC check. If the sorter failed to achieve an accuracy level of 90% then their next 10 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 10 sorted.

A similar QC program was conducted for the taxonomists identifying the samples. The first 10 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 10 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 10 samples. After the taxonomist identified 10 consecutive samples with greater than 95% accuracy, they had one of their next 10 samples checked by a QC taxonomist. If the taxonomist maintained an accuracy level of 95% then they continued to have one of each 10 samples checked by a QC taxonomist. If one of the checked samples fell below the minimum accuracy level then 10 more consecutive samples were identified by the QC taxonomist until 10 consecutive samples met the 95% criterion. Identifications were cross-checked against taxonomic voucher collections maintained by MBC and Tenera, and specialists were consulted for problem specimens.

Occasionally, outside experts were consulted to assist in the identification of the fish eggs. Due to the large overlap in diagnostic characteristics of several species of fishes in the egg and early embryo stages, egg identification is highly subjective and therefore no QC program was conducted to verify the egg identification.

4.3.4 Data Analysis

4.3.4.1 Entrainment Estimates

Estimates of daily larval entrainment for the sampling period from January 2006 through January 2007 at SGS were calculated from data collected at the entrainment station 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 were then summed to obtain estimates of total survey and annual entrainment, respectively. 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 *PE* that were used to estimate the probability of mortality (P_m) due to entrainment using the *ETM*. In the SGS 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. Parameters of the models used in the analyses are detailed in Appendix C.

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

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

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

4.3.4.2 Demographic Approaches

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

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. We used two different but related demographic approaches in assessing entrainment effects at SGS: *AEL*, which expresses effects as absolute losses of numbers of adults, and *FH*, which estimates the number of adult females at the age of maturity whose reproductive output has been eliminated by entrainment of larvae.

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

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa collected during the study. These rates, when available, were inferred from the literature. 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 SGS were based on bi-weekly 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.

<u>Fecundity Hindcasting (*FH*)</u>

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 females at the age of maturity (age at which 50% of 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:

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

Where:

E_T = total entrainment estimate;

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

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

The two key input parameters in Equation 1 are total lifetime fecundity *TLF* and survival rates S_j from spawning to the average age at entrainment. The average age at entrainment was estimated from lengths of a representative sample of larvae measured from the entrainment samples. Descriptions of these parameters may not be available for many species and are a possible limitation of the method. *TLF* was estimated in these studies using survivorship and fecundity tables that account for changes in fecundity with age. The fecundity data used in calculating *TLF* are described below for each taxon.

<u>Adult Equivalent Loss (AEL)</u>

The *AEL* approach uses estimates of the abundance of the entrained or impinged organisms to project the loss of equivalent numbers of adults based on mortality schedules and age-at-recruitment. The primary advantage of this approach is that it translates power plant-induced early life-stage mortality into numbers of adult fishes, which is the life-stage most relevant to resource managers. *AEL* 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 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 *ETM* was proposed by the USFWS to estimate mortality rates resulting from circulating water withdrawals by power plants (Boreman et al. 1978, and subsequently in Boreman et al. 1981). The *ETM* provides an estimate of incremental mortality (a conditional estimate in absence of other mortality, Ricker 1975) caused by SGS 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 *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 and design (maximum) cooling water flows 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.

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

$$PE_i = \frac{N_{Ei}}{N_{Si}} \qquad (4)$$

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) $\times$ (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) $\times$ (source water volume).

The PE_i value represents the effects of a number of processes operating over a day and is estimated for each survey. 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

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

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 year-long 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 *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:

$$P_S = N_S / N_P \ , \qquad (6)$$

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*, as follows:

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

Where:

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

$\bar{D}_k$ = 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:

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

Where:

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

W_k = average width of the k^{th} station;

$\bar{D}_k$ = average depth of the k^{th} station;

$\widehat{\rho_k}$ = estimated average density (per m^3) of larvae in k^{th} station;

K_{max} = 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:

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

Where:

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

$\rho(w)$ = 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 (~270 feet) where a line drawn between Point Dume and Palos Verdes intersects a line drawn 90 degrees to the coastline at a point between the SGS and ESGS, a distance of 15.2 km (9.4 mi). 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, including both upcoast and downcoast movement, was 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 mi). 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:

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

The estimates of P_S using alongshore currents or offshore extrapolation of the alongshore population were integrated into the calculation of P_M (Equation 5) as appropriate for each species.

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. 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, the ratio of the standard variation to the mean) from the estimates of PE_i as follows:

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

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

4.4 Sampling Summary

Twenty-five entrainment surveys were completed between January 11, 2006 and January 8, 2007 at the entrainment station and 12 surveys at the source water stations (Table 4.4-1). Sampling efforts alternated between surveys were only entrainment samples were collected and surveys where both entrainment and source water samples were collected. A total of 388 and 960 samples were collected from the entrainment and source water stations, respectively. All 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**
SMBEA01	1/11/06	16	16	–	–
SMBEA02	1/25/06	16	16	80	80
SMBEA03	2/8/06	16	15	–	–
SMBEA04	2/23/06	16	16	80	80
SMBEA05	no survey[a]	–	–	–	–
SMBEA06	3/22/06	16	16	80	79
SMBEA07	4/13/06	16	16	–	–
SMBEA08	4/19/06	16	16	80	80
SMBEA09	5/3/06	16	16	–	–
SMBEA10	5/17/06	16	16	80	79
SMBEA11	6/1/06	16	16	–	–
SMBEA12	6/14/06	12 [b]	12	80	43 [c]
SMBEA13	6/28/06	16	16	–	–
SMBEA14	07/12/06	16	16	80	79
SMBEA15	07/26/06	16	16	–	–
SMBEA16	08/09/06	16	16	80	80
SMBEA17	08/23/06	16	16	–	–
SMBEA18	09/06/06	16	16	–	–
SMBEA19	09/20/06	16	16	80	80
SMBEA20	10/04/06	16	16	–	–
SMBEA21	10/18/06	16	16	80	80
SMBEA22	11/01/06	16	16	–	–
SMBEA23	11/15/06	16	16	80	80
SMBEA24	11/27/06	4 [b]	4	–	–
SMBEA25	12/13/06	16	16	80	80
SMBEA26	01/08/07	16	16	–	–
		384	**383**	**960**	**920**

[a] Survey cancelled due to hazardous sea conditions.
[c] 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 6,969 entrainable fish larvae from 73 separate taxonomic categories was collected from the 25 entrainment surveys (Table 4.5-1 and Appendix D). A list of the species collected during the study are presented in Appendix F. The most abundant larval fish taxon in the samples was unidentified yolk sac larvae (larvae too small and indistinct to be identified to even the family level), which comprised 19.7% of the total larvae collected, followed by unidentified anchovies (13.9%). A total of 82,375 fish eggs from 18 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 63.4% of the total eggs collected, followed by sand flounder eggs (12.4%). The peak in abundance of all the larval fish combined occurred in August (Figure 4.5-1), while the highest concentrations of eggs occurred during May (Figure 4.5-2). There were generally more larval fish and eggs collected during each survey at night than during the day (Figures 4.5-3 and 4.5-4). Total annual entrainment of all fish eggs and larvae was estimated to be 4,919,422,026 and 365,258,133, respectively (Table 4.5-2). If the pumps were run at the design, or maximum capacity, CWIS flow volume, an estimated 7,691,177,343 eggs and 524,202,652 larvae could potentially be entrained at SGS.

Table 4.5-1. Average concentration of fish larvae and fish eggs sampled at SGS Entrainment Station E1 from January 2006 to January 2007.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
larvae, unid. yolksac	unid. yolksac larvae	147.84	1,375	19.73	19.73
Engraulidae unid.	anchovies	114.17	969	13.90	33.63
Sciaenidae unid.	croakers	91.87	793	11.38	45.01
Genyonemus lineatus	white croaker	64.40	554	7.95	52.96
Paralabrax spp.	sand bass	61.48	573	8.22	61.19
unidentified fish, damaged	unidentified damaged fish	35.97	330	4.74	65.92
Gobiidae unid.	gobies	35.38	291	4.18	70.10
Seriphus politus	queenfish	24.33	199	2.86	72.95
Sphyraena argentea	Pacific barracuda	23.59	224	3.21	76.17
Hypsoblennius spp.	combtooth blennies	22.03	182	2.61	78.78
Paralichthys californicus	California halibut	21.42	186	2.67	81.45
Citharichthys spp.	sanddabs	14.90	135	1.94	83.38
larval/post-larval fish unid.	larval fishes	13.54	127	1.82	85.21
Stenobrachius leucopsarus	northern lampfish	10.28	95	1.36	86.57
Pleuronichthys guttulatus	diamond turbot	8.57	64	0.92	87.49
Atherinopsidae unid.	silversides	7.88	63	0.90	88.39
Pleuronichthys ritteri	spotted turbot	7.76	71	1.02	89.41
Oxyjulis californica	senorita	7.35	72	1.03	90.44
Parophrys vetulus	English sole	6.86	61	0.88	91.32
Menticirrhus undulatus	California corbina	6.02	55	0.79	92.11
Ophidiidae unid.	cusk-eels	5.71	56	0.80	92.91
Haemulidae unid.	grunts	5.40	51	0.73	93.64
Symphurus atricaudus	California tonguefish	4.46	44	0.63	94.27
Ophidion scrippsae	basketweave cusk-eel	4.06	41	0.59	94.86
Xenistius californiensis	salema	3.65	37	0.53	95.39
Lepidogobius lepidus	bay goby	3.32	32	0.46	95.85
Pleuronichthys spp.	turbots	3.17	28	0.40	96.25
Halichoeres semicinctus	rock wrasse	3.03	29	0.42	96.67
Pleuronectidae unid.	righteye flounders	2.99	29	0.42	97.09
Anisotremus davidsonii	sargo	2.87	30	0.43	97.52
Cheilotrema saturnum	black croaker	2.52	20	0.29	97.80
Semicossyphus pulcher	California sheephead	2.15	19	0.27	98.08
Xystreurys liolepis	fantail sole	2.03	19	0.27	98.35
Hippoglossina stomata	bigmouth sole	1.10	10	0.14	98.49
Icelinus spp.	sculpins	1.00	8	0.11	98.61
Pleuronichthys verticalis	hornyhead turbot	0.90	8	0.11	98.72
Sardinops sagax	Pacific sardine	0.67	7	0.10	98.82
Hypsypops rubicundus	garibaldi	0.67	7	0.10	98.92
Gibbonsia spp.	clinid kelpfishes	0.56	5	0.07	99.00
Leptocottus armatus	Pacific staghorn sculpin	0.54	5	0.07	99.07
Chilara taylori	spotted cusk-eel	0.49	5	0.07	99.14
Labrisomidae unid.	labrisomid blennies	0.44	4	0.06	99.20
Merluccius productus	Pacific hake	0.41	4	0.06	99.25
Ruscarius meanyi	Puget Sound sculpin	0.40	1	0.01	99.27
Paralichthyidae unid.	sand flounders	0.35	3	0.04	99.31
Triphoturus mexicanus	Mexican lampfish	0.32	3	0.04	99.35
Kyphosidae unid.	sea chubs	0.32	3	0.04	99.40
Pleuronectiformes unid.	flatfishes	0.32	3	0.04	99.44

Table 4.5-1. (continued) Average concentration of fish larvae and fish eggs sampled at SGS Entrainment Station E1 from January 2006 to January 2007.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Syngnathus spp.	pipefishes	0.31	3	0.04	99.48
Gillichthys mirabilis	longjaw mudsucker	0.28	3	0.04	99.53
Gobiesocidae unid.	clingfishes	0.27	2	0.03	99.56
Oxylebius pictus	painted greenling	0.27	2	0.03	99.58
Myctophidae unid.	lanternfishes	0.25	2	0.03	99.61
Pomacentridae unid.	damselfishes	0.21	2	0.03	99.64
Sebastolobus spp.	thornyheads	0.21	2	0.03	99.67
Labridae unid.	wrasses	0.20	2	0.03	99.70
Atractoscion nobilis	white seabass	0.20	2	0.03	99.73
Typhlogobius californiensis	blind goby	0.20	2	0.03	99.76
Roncador stearnsii	spotfin croaker	0.19	2	0.03	99.78
Lyopsetta exilis	slender sole	0.18	2	0.03	99.81
Acanthogobius flavimanus	yellowfin goby	0.14	1	0.01	99.83
Rhinogobiops nicholsii	blackeye goby	0.14	1	0.01	99.84
Bathylagidae unid.	blacksmelt	0.14	1	0.01	99.86
Artedius spp.	sculpins	0.12	1	0.01	99.87
Clupea pallasii	Pacific herring	0.12	1	0.01	99.89
Ruscarius creaseri	roughcheek sculpin	0.11	1	0.01	99.90
Chromis punctipinnis	blacksmith	0.10	1	0.01	99.91
Sebastes spp.	rockfishes	0.10	1	0.01	99.93
Etrumeus teres	round herring	0.10	1	0.01	99.94
Girella nigricans	opaleye	0.09	1	0.01	99.96
Isopsetta isolepis	butter sole	0.09	1	0.01	99.97
Zaniolepis spp.	combfishes	0.09	1	0.01	99.99
Hexagrammidae unid.	greenlings	0.09	1	0.01	100.00
		783.73	**6,969**		
Fish Eggs					
fish eggs unid.	unidentified fish eggs	7,580.55	52,321	63.39	63.39
Paralichthyidae unid.	sand flounder eggs	1,309.79	10,254	12.42	75.81
Sciaenidae/Paralich./Labridae	SPL fish eggs	864.80	4,937	5.98	81.80
Engraulidae unid.	anchovy eggs	633.30	5,174	6.27	88.06
Citharichthys spp.	sanddab eggs	574.02	4,194	5.08	93.15
Pleuronichthys spp	turbot eggs	438.22	3,224	3.91	97.05
Genyonemus lineatus	white croaker eggs	154.83	1,491	1.81	98.86
Sciaenidae unid.	croaker eggs	94.05	784	0.95	99.81
Paralichthys californicus	California halibut eggs	6.67	76	0.09	99.90
Pleuronectidae unid.	righteye flounder eggs	6.09	40	0.05	99.95
Sphyraena argentea	Pacific barracuda eggs	5.98	27	0.03	99.98
Roncador stearnsii	spotfin croaker eggs	0.95	6	0.01	99.99
Paralabrax spp.	sand bass eggs	0.56	2	<0.01	99.99
Labridae unid.	wrasse eggs	0.45	2	<0.01	99.99
Microstomus pacificus	Dover sole eggs	0.22	2	<0.01	99.99
Oxyjulis californica	senorita eggs	0.16	1	<0.01	99.99
Pleuronichthys guttulatus	diamond turbot eggs	0.14	1	<0.01	99.99
Scomber japonicus	Pacific mackerel eggs	0.09	1	<0.01	100.00
		11,670.88	**82,537**		

Table 4.5-2. Calculated total annual entrainment of fish larvae and fish eggs at SGS in 2006 based on actual and design (maximum) cooling water intake pump flows.

Taxon	Common Name	Calculated Annual Entrainment (Actual Flows)	Calculated Annual Entrainment (Design Flows)
Larval Fish			
larvae, unidentified yolksac	unidentified yolksac larvae	71,105,628	97,034,455
Engraulidae unid.	anchovies	44,584,991	70,732,578
Sciaenidae unid.	croakers	42,076,568	59,935,823
Genyonemus lineatus	white croaker	32,104,891	46,634,188
Paralabrax spp.	sand bass	29,681,768	40,350,936
unidentified fish, damaged	unidentified damaged fish	16,873,865	23,667,890
Gobiidae unid.	gobies	16,188,141	24,432,450
Sphyraena argentea	Pacific barracuda	11,426,718	15,454,497
Seriphus politus	queenfish	10,845,071	15,732,743
Paralichthys californicus	California halibut	9,901,902	14,119,061
Hypsoblennius spp.	combtooth blennies	8,324,912	14,230,416
Stenobrachius leucopsarus	northern lampfish	6,802,760	9,850,466
Citharichthys spp.	sanddabs	6,752,119	9,704,922
larval/post-larval fish unid.	larval fishes	6,518,392	8,886,496
Parophrys vetulus	English sole	5,321,852	7,679,874
Pleuronichthys guttulatus	diamond turbot	3,849,543	5,715,338
Pleuronichthys ritteri	spotted turbot	3,819,479	5,149,021
Oxyjulis californica	senorita	3,557,915	4,808,587
Atherinopsidae unid.	silversides	3,262,545	5,118,106
Menticirrhus undulatus	California corbina	2,923,692	3,949,712
Ophidiidae unid.	cusk-eels	2,736,151	3,748,116
Haemulidae unid.	grunts	2,639,783	3,544,185
Lepidogobius lepidus	bay goby	2,486,739	3,585,709
Symphurus atricaudus	California tonguefish	2,223,026	2,960,941
Ophidion scrippsae	basketweave cusk-eel	2,020,099	2,666,075
Xenistius californiensis	salema	1,802,466	2,398,412
Pleuronectidae unid.	righteye flounders	1,705,131	2,479,133
Halichoeres semicinctus	rock wrasse	1,485,009	1,987,553
Anisotremus davidsonii	sargo	1,429,808	1,885,888
Pleuronichthys spp.	turbots	1,371,357	2,015,258
Cheilotrema saturnum	black croaker	1,057,263	1,612,817
Semicossyphus pulcher	California sheephead	996,476	1,410,524
Xystreurys liolepis	fantail sole	947,250	1,321,097
Hippoglossina stomata	bigmouth sole	504,168	692,795
Pleuronichthys verticalis	hornyhead turbot	458,506	695,163
Leptocottus armatus	Pacific staghorn sculpin	396,988	587,603
Hypsypops rubicundus	garibaldi	342,045	439,007
Sardinops sagax	Pacific sardine	336,514	440,204
Icelinus spp.	sculpins	332,245	673,518
Gibbonsia spp.	clinid kelpfishes	323,127	483,606
Merluccius productus	Pacific hake	320,228	462,059
Chilara taylori	spotted cusk-eel	240,042	323,484
Gobiesocidae unid.	clingfishes	213,464	308,008
Labrisomidae unid.	labrisomid blennies	206,915	285,812
Ruscarius meanyi	Puget Sound sculpin	192,282	264,225
Paralichthyidae unid.	sand flounders	164,761	226,429
Gillichthys mirabilis	longjaw mudsucker	162,636	227,901
Triphoturus mexicanus	Mexican lampfish	153,952	211,113

Table 4.5-2. (continued). Calculated total annual entrainment of fish larvae and fish eggs at SGS in 2006 based on actual and design (maximum) cooling water intake pump flows.

Taxon	Common Name	Calculated Annual Entrainment (Actual Flows)	Calculated Annual Entrainment (Design Flows)
Larval Fish			
Kyphosidae unid.	sea chubs	153,952	211,113
Pleuronectiformes unid.	flatfishes	151,803	224,418
Lyopsetta exilis	slender sole	142,944	206,255
Syngnathus spp.	pipefishes	125,294	181,415
Rhinogobiops nicholsii	blackeye goby	106,732	154,004
Bathylagidae unid.	blacksmelt	106,732	154,004
Pomacentridae unid.	damselfishes	105,813	140,515
Sebastolobus spp.	thornyheads	100,556	135,379
Myctophidae unid.	lanternfishes	96,636	158,229
Roncador stearnsii	spotfin croaker	95,473	126,622
Labridae unid.	wrasses	93,572	132,172
Ruscarius creaseri	roughcheek sculpin	88,773	128,091
Atractoscion nobilis	white seabass	83,223	136,452
Oxylebius pictus	painted greenling	72,573	168,293
Isopsetta isolepis	butter sole	71,472	103,128
Typhlogobius californiensis	blind goby	66,577	140,052
Clupea pallasii	Pacific herring	57,162	78,803
Chromis punctipinnis	blacksmith	49,752	68,224
Etrumeus teres	round herring	48,516	63,639
Acanthogobius flavimanus	yellowfin goby	47,765	67,380
Sebastes spp.	rockfishes	47,244	64,785
Girella nigricans	opaleye	46,855	61,460
Zaniolepis spp.	combfishes	43,694	58,703
Hexagrammidae unid.	greenlings	43,694	58,703
Artedius spp.	sculpins	40,139	56,622
		365,258,133	**524,202,652**
Fish Eggs			
fish eggs unid.	unidentified fish eggs	3,186,607,290	4,957,177,075
Paralichthyidae unid.	sand flounder eggs	581,532,916	943,922,353
Sciaenidae/Paralichthyidae/Labridae	fish eggs	363,868,587	546,560,618
Citharichthys spp.	sanddab eggs	264,262,380	407,681,780
Engraulidae unid.	anchovy eggs	236,042,601	382,782,525
Pleuronichthys spp.	turbot eggs	196,522,432	300,553,243
Sciaenidae unid.	croaker eggs	48,599,063	71,832,520
Genyonemus lineatus	white croaker eggs	34,295,926	68,597,355
Sphyraena argentea	Pacific barracuda eggs	2,921,818	3,927,243
Pleuronectidae unid.	righteye flounder eggs	2,514,297	3,682,243
Paralichthys californicus	California halibut eggs	1,240,920	2,653,308
Paralabrax spp.	sand bass eggs	272,775	366,476
Roncador stearnsii	spotfin croaker eggs	226,555	624,741
Labridae unid.	wrasse eggs	201,832	303,034
Microstomus pacificus	Dover sole eggs	175,271	252,900
Pleuronichthys guttulatus	diamond turbot eggs	57,905	94,696
Scomber japonicus	Pacific mackerel eggs	41,699	61,110
Oxyjulis californica	senorita eggs	37,759	104,124
		4,919,422,026	**7,691,177,343**

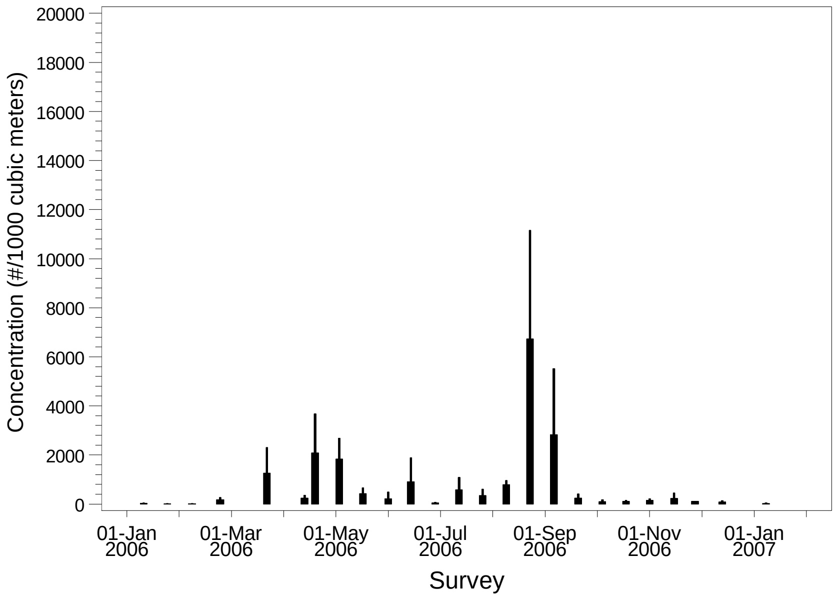


Figure 4.5-1. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of all larval fishes collected at the SGS Entrainment Station E1 from January 2006 through January 2007.

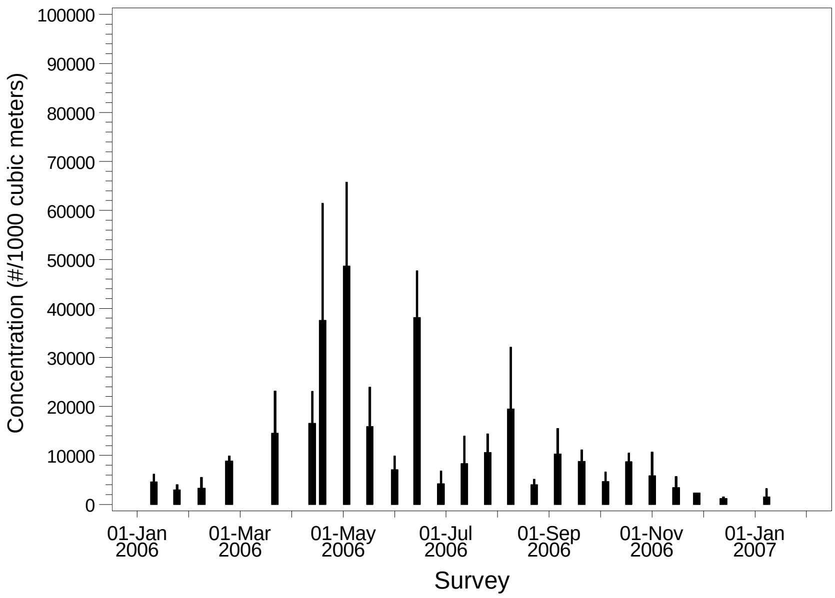


Figure 4.5-2. Mean concentration (# / 1,000 m3 [264,172 gal]] – wide bars) and standard deviation (narrow bars) of fish eggs collected at the SGS Entrainment Station E1 from January 2006 through January 2007.

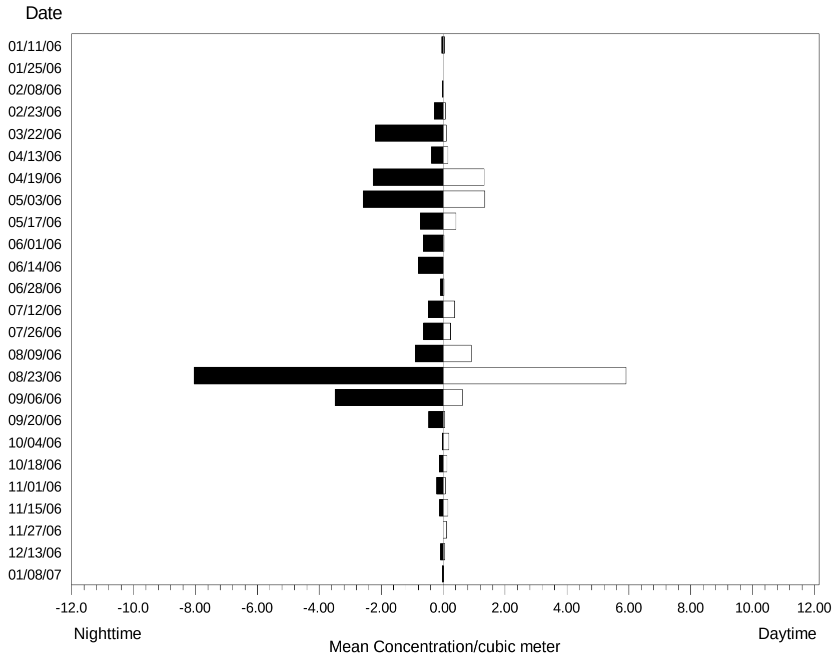


Figure 4.5-3. Mean concentration (#/1.0 m^3 [264 gal]) of all fish larvae at the SGS Entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

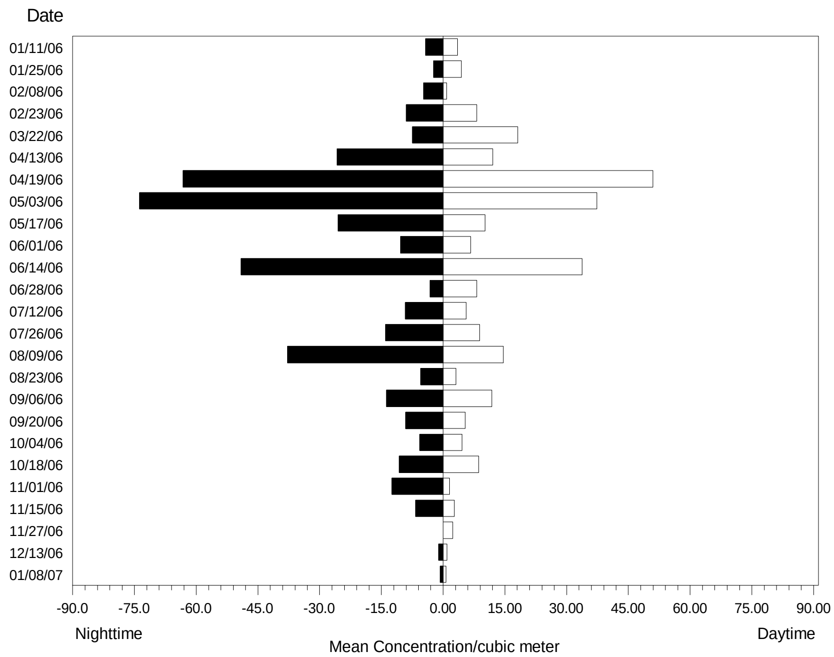


Figure 4.5-4. Mean concentration (#/1.0 m^3 [264 gal]) of all fish eggs at the SGS Entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

4.5.1.2 Shellfishes

A total of 502 larval invertebrates representing 22 taxa was collected from the SGS entrainment station (E1) during 26 bi-weekly surveys in 2006-2007 (Table 4.5-3 and Appendix D). The most abundant target invertebrate larvae in the samples were kelp crab megalops (*Pugettia* spp.) followed by pea crab megalops (*Pinnixa* spp.), which made up 28.3% and 19.7%, respectively, of the total target invertebrate larvae collected. A total of 63 market squid paralarvae (hatchlings) was collected. Total annual entrainment was estimated to be 27.3 million target invertebrate larvae (Table 4.5-4). Based on the design, or maximum capacity, flow volume, an estimated 40.6 million target invertebrate larvae could potentially be entrained.

Table 4.5-3. Average concentration of target shellfish larvae sampled at SGS Entrainment Station E1 from January 2006 and January 2007.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumul. %
Pugettia spp.	kelp crabs megalops	15.37	142	28.29	28.29
Pinnixa spp.	pea crabs megalops	11.64	99	19.72	48.01
Loligo opalescens	market squid paralarvae	7.67	63	12.55	60.56
Cancer spp.	cancer crabs megalops	3.64	34	6.77	67.33
Petrolisthes spp.	porcelain crab megalops	3.19	25	4.98	72.31
Grapsidae unid.	shore crab megalops	2.67	25	4.98	77.29
Lophopanopeus spp.	black-clawed crab meg.	2.38	23	4.58	81.87
Paguridae unid.	hermit crab megalops	1.86	16	3.19	85.06
Majidae unid.	spider crab megalops	1.72	16	3.19	88.25
Pachycheles spp.	porcelain crabs megalops	1.44	14	2.79	91.04
Brachyura unid.	unidentified crab megalops	1.24	10	1.99	93.03
Pachycheles rudis	thickclaw porcelain crab meg.	1.18	9	1.79	94.82
Emerita analoga	mole crabs megalops	0.95	8	1.59	96.41
Porcellanidae unid.	porcelain crab megalops	0.56	5	1.00	97.41
unidentified crab	unidentified crab megalops	0.42	4	0.80	98.21
Hippoidea unid.	mole crab megalops	0.22	2	0.40	98.61
Pinnotheres spp.	pea crab megalops	0.21	2	0.40	99.00
Fabia subquadrata	grooved mussel crab meg.	0.14	1	0.20	99.20
Petrolisthes cinctipes	flat porcelain crab meg.	0.14	1	0.20	99.40
Pachycheles	pubescent porcelain crab meg.	0.13	1	0.20	99.60
Diogenidae	left-handed hermit crabs meg.	0.12	1	0.20	99.80
Panulirus interruptus	California spiny lobster (larval)	0.10	1	0.20	100.00
		57.00	**502**		

Table 4.5-4. Calculated total annual entrainment of target shellfish larvae at SGS based on actual and design (maximum) cooling water intake pump flows from January 2006 to January 2007.

Taxon	Common Name	Calculated Annual Entrainment (Actual Flows)	Calculated Annual Entrainment (Design Flows)
Pugettia spp.	kelp crabs megalops	10,007,018	14,664,011
Pinnixa spp.	pea crabs megalops	4,328,231	6,809,148
Loligo opalescens	market squid	3,367,525	4,929,707
Cancer spp.	cancer crabs megalops	1,634,850	2,380,819
Petrolisthes spp.	porcelain crab megalops	1,113,720	1,577,486
Majidae unid.	spider crab megalops	1,092,243	1,573,624
Lophopanopeus spp.	black-clawed crab megalops	1,074,059	1,537,121
Grapsidae unid.	shore crab megalops	1,047,391	1,553,225
Paguridae unid.	hermit crab megalops	776,523	1,124,963
Pachycheles spp.	porcelain crabs megalops	719,490	992,034
Emerita analoga	mole crabs megalops	484,611	737,259
Brachyura unid.	unidentified crab megalops	409,418	591,144
Pachycheles rudis	thickclaw porcelain crab megalops	358,426	735,780
Porcellanidae unid.	porcelain crab megalops	260,586	405,689
unidentified crab	unidentified crab megalops	241,620	373,902
Hippoidea unid.	mole crab megalops	101,667	143,472
Pinnotheres spp.	pea crab megalops	83,454	120,369
Diogenidae	left-handed hermit crabs megalops	56,636	76,091
Fabia subquadrata	grooved mussel crab megalops	47,765	67,380
Panulirus interruptus	California spiny lobster (larval)	45,031	67,381
Pachycheles pubescens	pubescent porcelain crab megalops	40,343	79,418
Petrolisthes cinctipes	flat porcelain crab megalops	32,230	88,875
		27,322,839	**40,628,889**

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 12 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 concentration of fish larvae in samples collected at the SGS 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, unidentified yolksac	unidentified yolksac larvae	67.70	1,567	8.27	49.45
Paralabrax spp.	sand bass	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 concentration of fish larvae in samples collected at the SGS 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 concentration of fish larvae in samples collected at the SGS 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**		

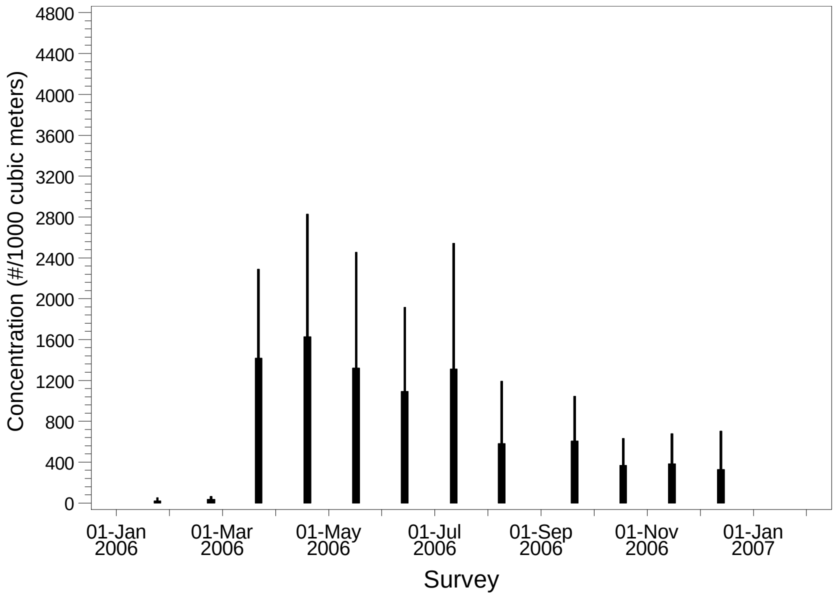


Figure 4.5-5. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of all larval fishes collected at the SGS source water stations during 2006.

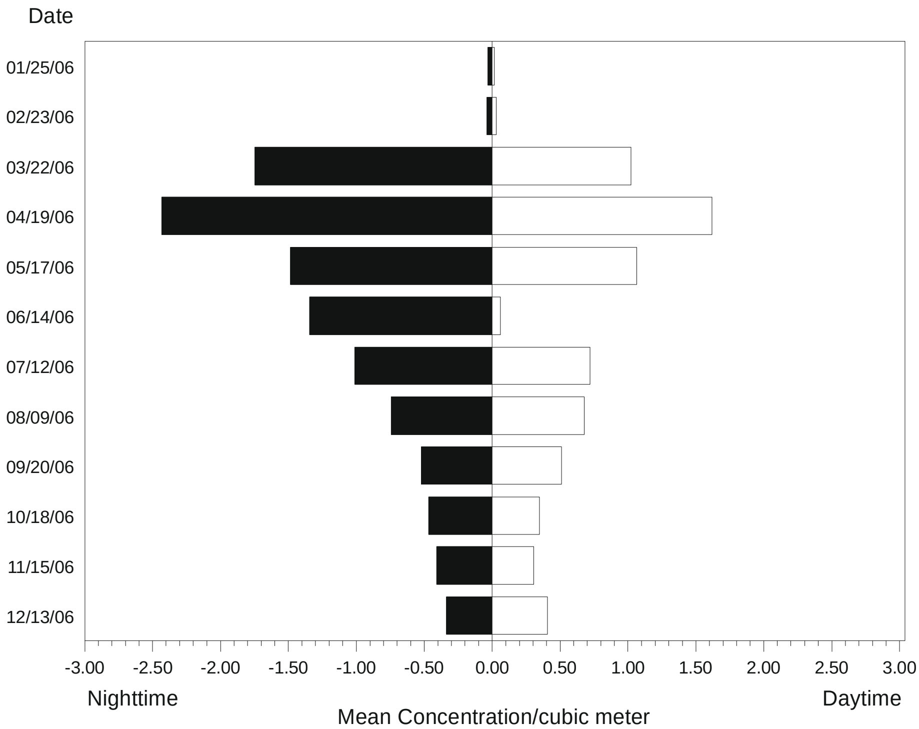


Figure 4.5-6. Mean concentration (#/1.0 m^3 [264 gal]) of all fish larvae at the SGS source water stations during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

Shellfishes

A total of 3,500 larval invertebrates (shellfishes) representing 20 taxa was collected from the SGS 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 also collected.

Table 4.5-6. Average concentration of target shellfish larvae in samples collected at the SGS 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	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**		

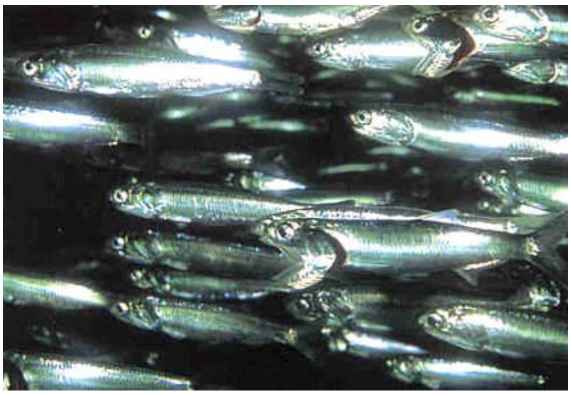
4.5.3 Results by Species for Cooling Water Intake Structure Entrainment

The following fish taxa were selected for detailed evaluation of entrainment effects based on their abundance in entrainment samples or status as a Pacific Fisheries Management Council (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 nearly 90% of the larvae entrained at SGS 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)
- senorita (*Oxyjulis californica*)
- combtooth blennies (*Hypsoblennius* spp.)
- CIQ gobies (Gobiidae)
- Pacific barracuda (*Sphyraena argentea*)
- sanddabs (*Citharichthys* spp.)
- California halibut (*Paralichthys californicus*)
- English sole (*Parophrys vetulus*)
- diamond turbot (*Pleuronichthys guttulatus*)
- spotted turbot (*Pleuronichthys ritteri*)
- Market squid (*Loligo opalescens*)

4.5.3.1 Anchovies (Engraulidae)

Three species of anchovy (Family Engraulidae) inhabit nearshore areas of southern California: northern anchovy (*Engraulis mordax*), deepbody anchovy (*Anchoa compressa*) and slough anchovy (*Anchoa delicatissima*). This analysis of entrainment effects on anchovies will concentrate on life history aspects of the northern anchovy because all of the Engraulid larvae collected that were large enough to be positively identified were northern anchovies. Seventy-one percent of the specimens identified in the entrainment samples as Engraulidae were northern anchovy. The remainder were very small specimens still in their recently-hatched yolk-sac stage and some that were damaged to an extent that they could not be positively identified to the species level.



Mark Conlin

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.

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

Northern anchovy is very important in the trophic ecology of marine food webs. They are random planktonic feeders, filtering plankton as they swim (Fitch and Lavenberg 1971). Juveniles and adults feed mainly at night on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971, Hart 1973, Allen and DeMartini 1983). Numerous fish and marine mammal species feed on northern anchovy. Elegant tern and California brown pelican reproduction is strongly correlated with the annual abundance of this species (Emmett et al. 1991). 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 PFMC; the other species include Pacific sardine, Pacific mackerel, and jack mackerel. Northern anchovy in the northeastern Pacific is divided into three subpopulations, or stocks: northern, central, and southern. Since 1978, the PFMC has managed northern anchovy from the central and northern subpopulations. The central subpopulation includes landings from San Francisco to Punta Baja, Baja California.

Three separate commercial fisheries target northern anchovy in California and Mexico waters: 1) the reduction fishery, 2) the live bait fishery, and 3) a 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 earlier 316(b) study of the SGS in 1978–1979 (IRC 1981) estimates of average concentrations of engraulid species complex larvae at the near-field station found highest densities from January through April and lowest densities from August through November. Mean densities were 360 larvae per 1,000 m^3 (264,172 gal) in day surveys and 1,350 larvae per 1,000 m^3 (264,172 gal) in night surveys. Mean concentrations in 1978–1979 were approximately seven times greater than the concentrations estimated from the 2006 entrainment sampling near the SGS intakes.

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 kilograms (kg) (318,000 lbs) were landed (Pacific Fishery Information Network [PacFIN] 2007). In 2004, there were 147,417 kg (325,000 lbs) landed in the Los Angeles area as compared to 2.75 million kg (6.07 million lbs) in the Santa Barbara area, and 3.89 million kg (8.58 million lbs) in the Monterey area for a total value of $750,000. Annual landings in the Los Angeles region since 2000 have varied from a high of 3.9 million kg (8.6 million lbs) in 2001, to a low of 0.14 million kg (0.3 million lbs) in 2004, with an average of 1.4 million kg (3 million lbs) 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 (lbs)	Revenue
2000	1,279,437	2,820,677	$145,579
2001	3,656,509	8,061,223	$319,628
2002	1,205,307	2,657,247	$100,716
2003	327,468	721,944	$37,750
2004	147,003	324,087	$35,699
2005	1,979,989	4,365,130	$185,579
2006	865,971	1,909,139	$75,104

4.5.3.1.3 Sampling Results

Engraulid larvae (predominantly northern anchovy) were the second most abundant taxon at the entrainment station with a mean concentration of 114 larvae per 1,000 m^3 over all surveys, while engraulid eggs had an average concentration of 633 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 1,550 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 in the range of 2–3 mm (0.08–0.12 in) 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) notochord length (NL).

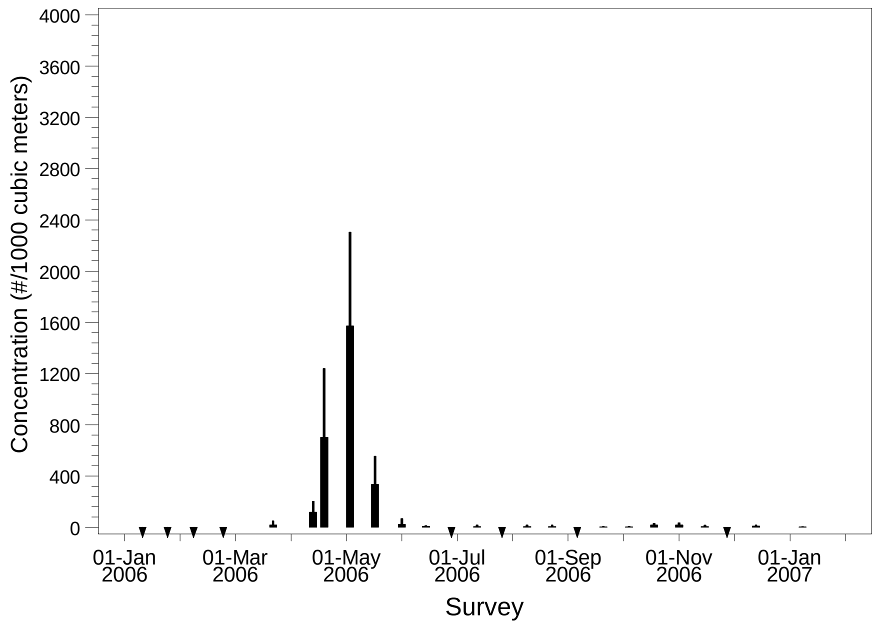


Figure 4.5-7. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of anchovy larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

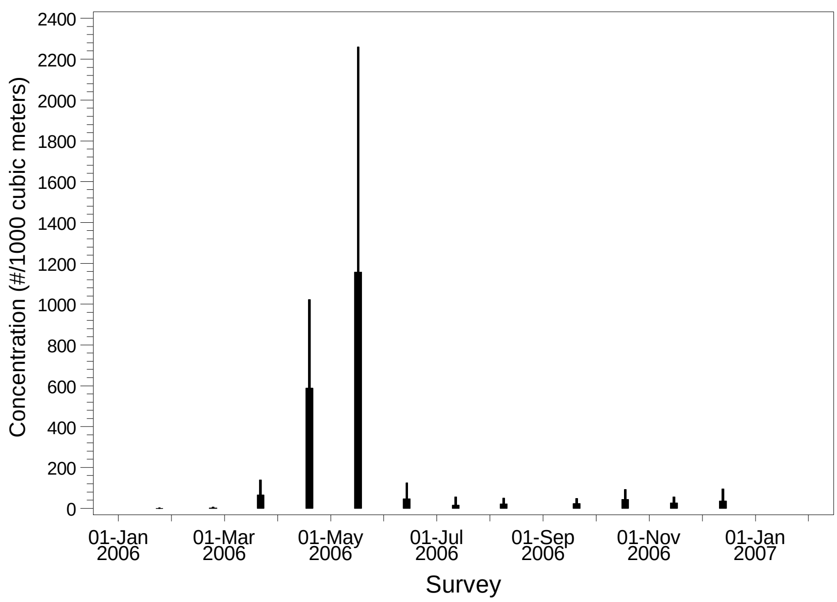


Figure 4.5-8. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of anchovy larvae collected at SGS source water stations during 2006.

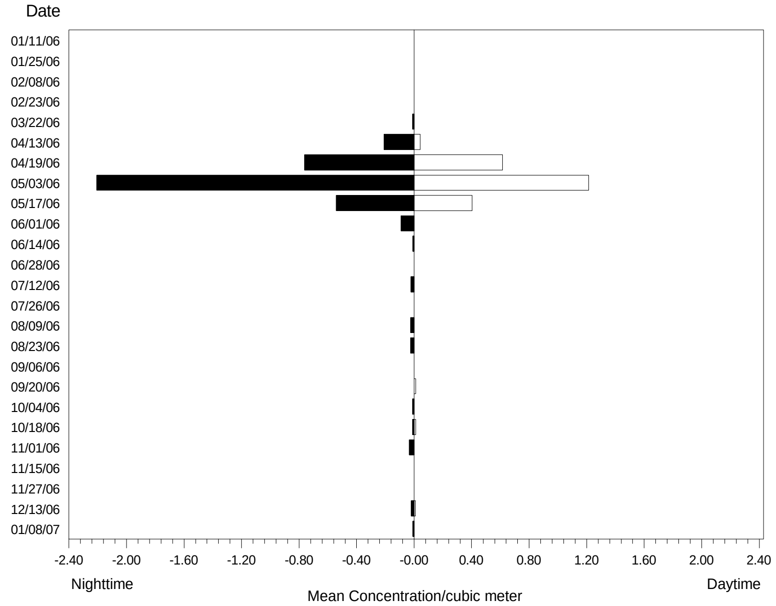


Figure 4.5-9. Mean concentration (#/1.0 m^3 [264 gal]) of anchovy larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.

Note: Negative nighttime values are a plotting artifact

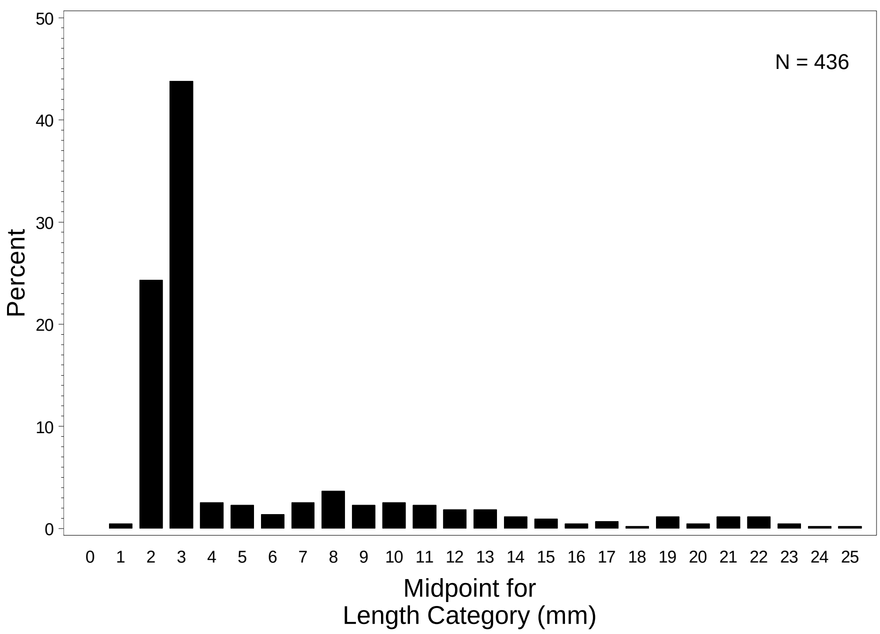


Figure 4.5-10. Length (mm) frequency distribution for larval anchovy collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

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 SGS was estimated at 236,042,601 eggs (standard error of 10,339,278) and 44,584,991 larvae (standard error of 2,050,508) using the measured cooling water flows during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flows, annual entrainment estimates increased to 382,782,525 eggs (standard error 15,117,656) and 70,732,578 larvae (standard error of 3,143,338) (Table 4.5-2). 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 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 millimeters per day (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).

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

Z = instantaneous daily mortality; S = finite survival rate.

Clark and Phillips (1952) reported age at sexual maturity as 1–2 years. Similarly, Leet et al. (2001) reported that 47% to 100% of one-year olds may be mature in a given year, while all are mature by two years. For modeling purposes, we used a mid-value of 1.5 years. For longevity, Hart (1973) reported a value of seven years, but Leet et al. (2001) stated that northern anchovy in the fished population rarely exceed four years of age. The survivorship values in Table 4.5-9 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**

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

The estimated numbers of reproductive age adult female northern anchovies whose lifetime reproductive output was entrained through the SGS CWIS for 2006 were 1,949 based on the egg entrainment and 16,273 based on the larval entrainment using the actual cooling water flows during the period (Table 4.5-10). Using the design cooling water flows, the numbers of reproductive age adult females increased to 3,161 due to egg entrainment and to 25,816 due to larval entrainment. The sensitivity analysis, based on the 90% confidence intervals, shows 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 (maximum) CWIS flows.

Parameter	**Estimate**	**Std. Error**	***FH* Lower Estimate**	***FH* Upper Estimate**	***FH* Range**
Actual Flows					
Eggs					
FH Estimate	**1,949**	1,381	608	6,252	5,645
Total Entrainment	236,042,601	10,339,278	1,809	2,090	281
Larvae					
FH Estimate	**16,273**	14,113	3,907	67,770	63,863
Total Entrainment	44,584,991	2,050,508	15,042	17,504	2,462
Design Flows					
Eggs					
FH Estimate	**3,161**	2,239	986	10,135	9,149
Total Entrainment	382,782,525	15,117,656	2,956	3,367	411
Larvae					
FH Estimate	**25,816**	22,387	6,200	107,500	101,301
Total Entrainment	70,732,578	3,143,338	23,929	27,704	3,775

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 4.5-10). 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 1.0 year, the age at 50% maturity in the population. The equivalent number of adult northern anchovies calculated from the number of larvae entrained through the SGS CWIS for 2006 was 79,220 based on actual flows during the period, and increased to 125,680 based on the design flow volumes (Table 4.5-11).

Table 4.5-11. Results of *AEL* modeling for northern anchovy larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
Actual Flows					
AEL Estimate	**79,220**	91,707	11,798	531,935	520,137
Total Entrainment	44,584,991	2,050,508	73,227	85,214	11,987
Design Flows					
AEL Estimate	**125,680**	145,483	18,719	843,813	825,094
Total Entrainment	70,732,578	3,143,338	116,493	134,868	18,375

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 0.00261 using actual flows during the period, and ranged from 0 to 0.00368 using the design flows (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 *PE* estimates were used to calculate a P_M estimate of 0.0019 based on actual flows and 0.0030 based on design flows using the offshore extrapolated estimate of the total source population. 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 over the same time period was 50.81 km (31.6 mi) limited by the boundaries of Santa Monica Bay, and the total average alongshore displacement was 54.6 km (33.9 mi). The small estimate of P_M (Table 4.5-12) is a direct result of the large source population potentially subject to entrainment.

Table 4.5-12. *ETM* data and results for northern anchovy larvae based on actual and design (maximum) CWIS flows. P_M calculated using the **offshore** extrapolated estimate of total source population and average P_S of 0.0668.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0.00032
23-Feb-06	0	0	0	0	0.00007
22-Mar-06	0.00039	0.00033	0.00057	0.00047	0.03226
19-Apr-06	0.00261	0.00102	0.00368	0.00143	0.19195
17-May-06	0.00025	0.00009	0.00052	0.00018	0.64365
14-Jun-06	0.00011	0.00006	0.00021	0.00012	0.03532
12-Jul-06	0.00048	0.00054	0.00064	0.00072	0.00902
9-Aug-06	0.00046	0.00048	0.00064	0.00065	0.01216
20-Sep-06	0.00017	0.00017	0.00025	0.00025	0.01431
18-Oct-06	0.00064	0.00026	0.00091	0.00037	0.01928
15-Nov-06	0.00027	0.00027	0.00039	0.00040	0.01448
13-Dec-06	0.00034	0.00016	0.00052	0.00025	0.02718
P_M	**0.0019**	0.0008	**0.0030**	0.0033	–

Alongshore extrapolation averaged 50.81 km limited by SM Bay, and 54.61 km using total displacement. Onshore displacement averaged 21.68 km.

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.

Summary of silverside distribution and life history attributes.

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

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

Habitat: Bays, estuaries, nearshore surface waters to depths of 9-29 m (30-95 ft).
Fishery: Incidental commercial and limited recreational take on hook and line or with nets.

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). Plankton sampling conducted in Santa Monica Bay during the earlier 316(b) study at SGS (IRC 1981) found that nearly all silverside larvae were collected in surface samples indicating a strong behavioral tendency for these larvae to actively maintain their position in surface strata, possibly through a phototatic response.

The spawning activity of grunion is quite different from the other silversides. Spawning occurs only three or four nights following each full or new moon, and then only for 1–3 hours immediately after the high tide, from late February to early September (peaking late March to early June) (Love 1996). The female swims onto the beach and digs into the wet sand, burying herself up to her pectoral fins or above. The male or males curve around her with vents touching her body, and when the female lays her eggs beneath the sand, males emit sperm, which flows down her body and fertilizes the eggs (Love 1996). Females spawn four to eight times per season at about 15-day intervals, producing 1,000–3,000 eggs. Hatch length for grunion ranges from 6.5–7.0 mm (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).

The earlier 316(b) study of the SGS in 1978–1979 (IRC 1981) estimated average concentrations of silverside species complex larvae that were highest from March to August and relatively low from September to mid-January. Peak concentrations occurred in April and from mid-June to August. Survey means for the near-field varied from 0 to 2,403 larvae per 1,000 m^3 (264,172 gal) with a mean of 770 per 1,000 m^3 (264,172 gal). These concentrations are two orders of magnitude greater than the concentrations estimated from the 2006 samples (see Section 4.5.3.2.3–*Sampling Results*).

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 lbs) in 1945 to 1,148 kg (2,530 lbs) 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 lbs) of jacksmelt with a revenue of $75 were landed in the Santa Monica Bay area in 2006, while 0.9 kg (2 lbs) of topsmelt with a revenue of $20 were landed according to specific CDFG 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 Recreational Fishery Information Network (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 8 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). Jacksmelt was the most abundant species within the family at 75% by mean concentration, with topsmelt only comprising 1% (Table 4.5-14). Several specimens could not be identified to species and were classified as unidentified silversides (23%), and no grunion (*Leuresthes tenuis*) were identified. 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 90 per 1,000 m^3 (264,172 gal). They were absent or very low in abundance in samples from July through November. Monthly source water concentrations followed a similar seasonal pattern (Figure 4.5-12), but were much 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 (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.

Table 4.5-14. Average concentrations and annual entrainment mortality of silverside taxa at SGS.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	% of Total	Annual Entrainment (Actual Flows)	Annual Entrainment (Design Flows)
Larval Fishes						
Atherinopsis californiensis	jacksmelt	5.93	46	75.17	2,388,721	3,667,240
Atherinopsidae unid.	silversides unid.	1.87	16	23.67	802,352	1,347,739
Atherinops affinis	topsmelt	0.09	1	1.16	71,472	103,128

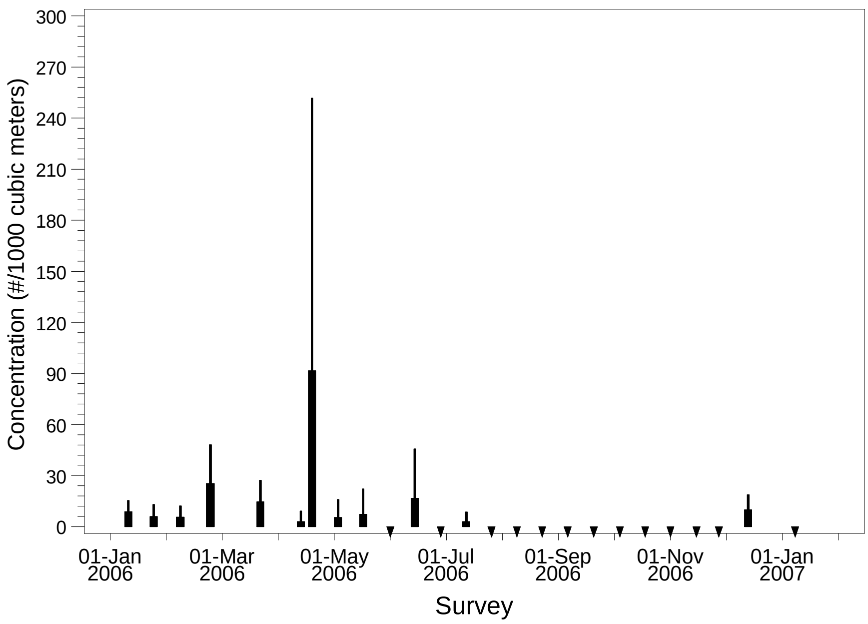


Figure 4.5-11. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of silverside larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

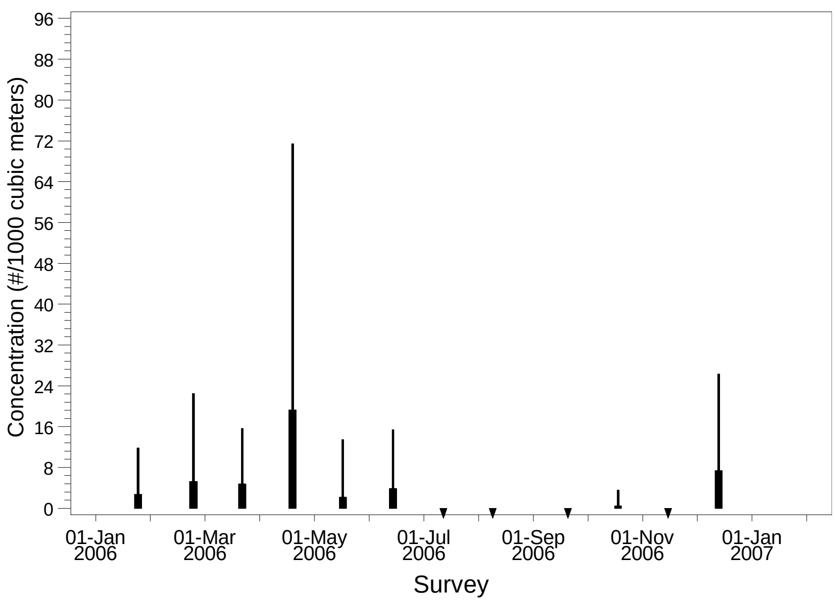


Figure 4.5-12. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of silverside larvae collected at SGS source water stations during 2006.

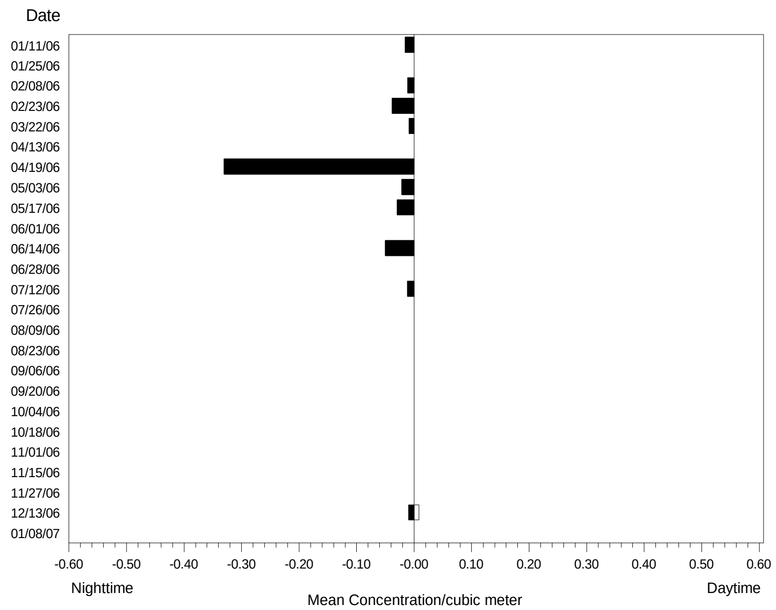


Figure 4.5-13. Mean concentration (#/1.0 m^3 [264 gal]) of silverside larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.

Note: Negative nighttime values are a plotting artifact

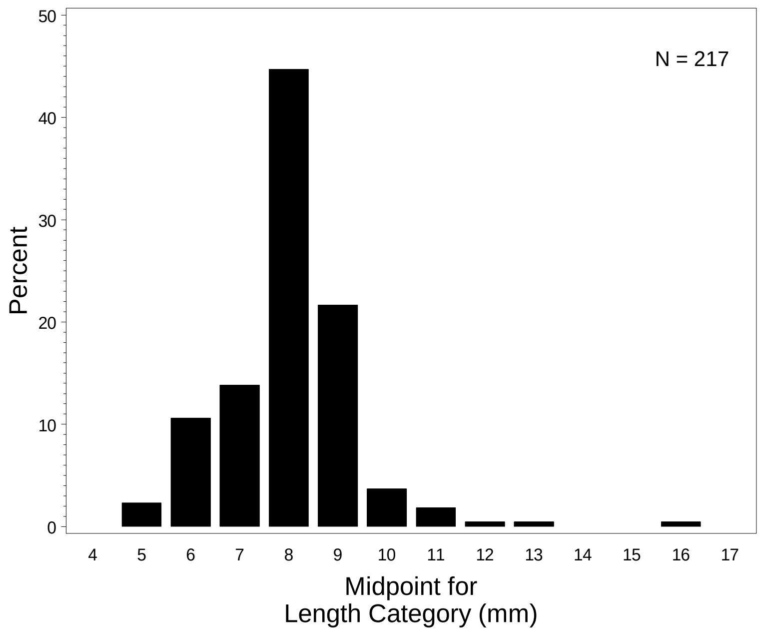


Figure 4.5-14. Length (mm) frequency distribution for larval silversides collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

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*. Total annual larval silverside entrainment at SGS was estimated at 3,262,545 (standard error of 354,131) using measured cooling water flows during 2006. If the CWIS pumps were run at the design (maximum capacity) cooling water flows, annual entrainment estimates increased to 5,118,106 larvae (standard error of 508,953) (Table 4.5-2). No silverside eggs were identified from the entrainment samples as the eggs are usually demersal and would not be subject to entrainment.

Empirical Transport Model (ETM)

A larval growth rate of 0.44mm/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 *PE* for silversides for 2006 ranged from 0 to 0.06824 based upon actual flows during the period and from 0 to 0.09168 based upon the design flows (Table 4.5-15). The largest estimate was calculated for the July survey, but the largest proportion of the source population was present during the April survey (f_i = 0.369 or 36.9%). The values in the table were used to calculate a P_M estimate of 0.0304, with a standard error of 0.024 based upon the actual flows and using the alongshore extrapolated estimate of the total source population. Using the design flows, a P_M estimate of 0.0475 was calculated, with a standard error of 0.0372. 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 coastal distance of 26.1 km (16.2 mi) within the Santa Monica Bay based on the number of days that the larvae are potentially exposed to entrainment.

Table 4.5-15. *ETM* data and results for silverside larvae based upon actual and design (maximum) CWIS flows. P_M calculated using the **alongshore** extrapolated estimate of total source population and an average P_S of 0.3830.

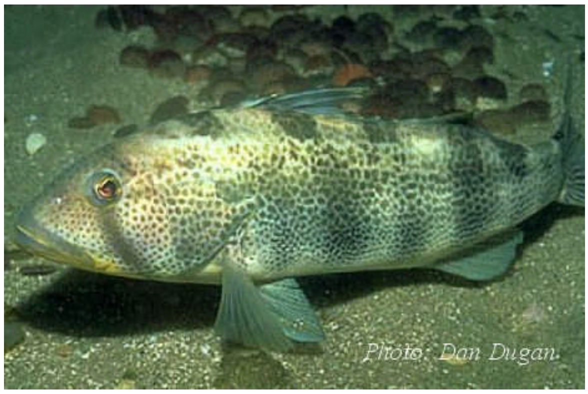
	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	***fi***
25-Jan-06	0.00290	0.00212	0.00579	0.00423	0.10922
23-Feb-06	0.01057	0.00608	0.01730	0.00986	0.14363
22-Mar-06	0.00879	0.00507	0.01269	0.00730	0.10888
19-Apr-06	0.01723	0.01617	0.02431	0.02274	0.36953
17-May-06	0.00686	0.00816	0.01444	0.01697	0.05030
14-Jun-06	0.01539	0.01785	0.03030	0.03425	0.05415
12-Jul-06	0.06824	0.09667	0.09168	0.12966	0.00310
9-Aug-06	0	0	0	0	0
20-Sep-06	0	0	0	0	0

Table 4.5-15 (continued). *ETM* data and results for silverside larvae based upon actual and design (maximum) CWIS flows. P_M calculated using the **alongshore** extrapolated estimate of total source population and an average P_S of 0.3830.

	Actual Flows		Design Flows		
Survey Date	*PE* Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.	*fi*
18-Oct-06	0	0	0	0	0.00542
15-Nov-06	0	0	0	0	0
13-Dec-06	0.00612	0.00349	0.00929	0.00527	0.15577
P_M	**0.0304**	0.0240	**0.0475**	0.0372	–

Alongshore extrapolation averaged 26.1 km. Onshore displacement averaged 6.9 km.

4.5.3.3 Sea Basses (*Paralabrax* spp.)



Three species of 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 years 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. (1996b) 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 grams (g) (0.99 lbs) fish to >185,000 eggs in a 2,625 g (5.8 lbs) fish. The smallest fish, a 148 g (0.3 lbs) 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 lbs; 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 (200 ft) (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, where 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. 1996a). 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 commercial passenger fishing vessels (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 4.5-16). 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 4.5-16. 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 three species of sea basses were grouped together for analysis purposes. The sea bass larvae complex was the third most abundant taxon at the entrainment station with a mean concentration of 61 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 September at 1,053 per 1,000 m^3 at the entrainment station. Monthly average source water concentrations followed a similar seasonal pattern (Figure 4.5-16), but were about a fourth the number of larvae than the entrainment station. Average sea bass concentrations peaked 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.

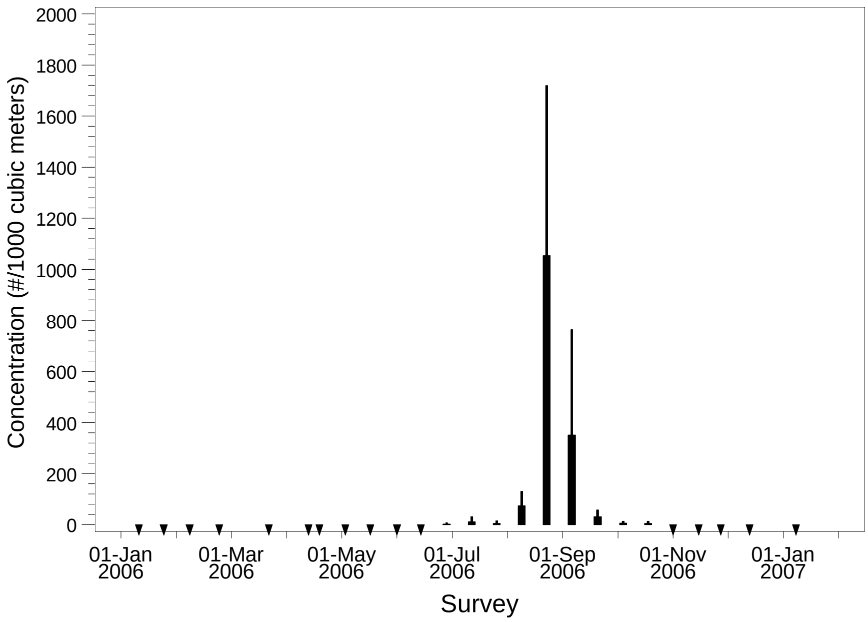


Figure 4.5-15. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of sea bass larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

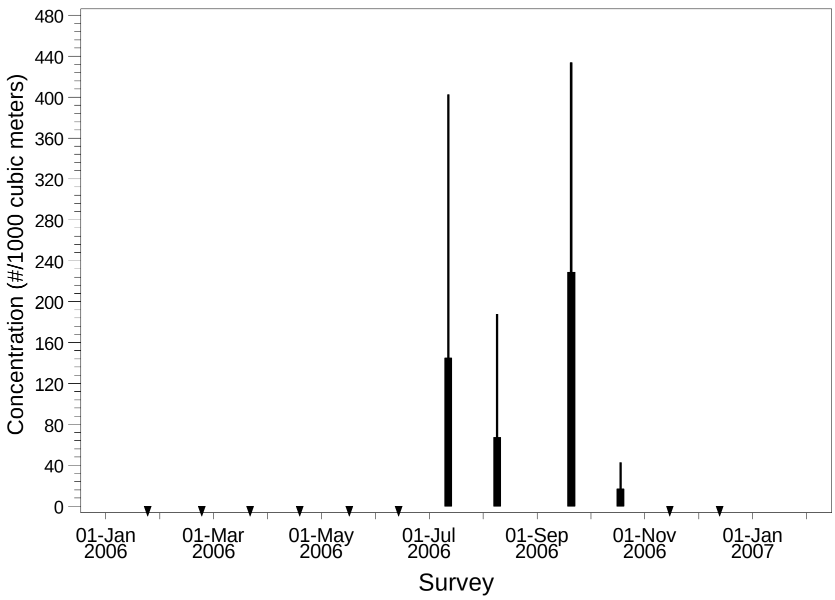


Figure 4.5-16. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of sea bass larvae collected at SGS source water stations during 2006.

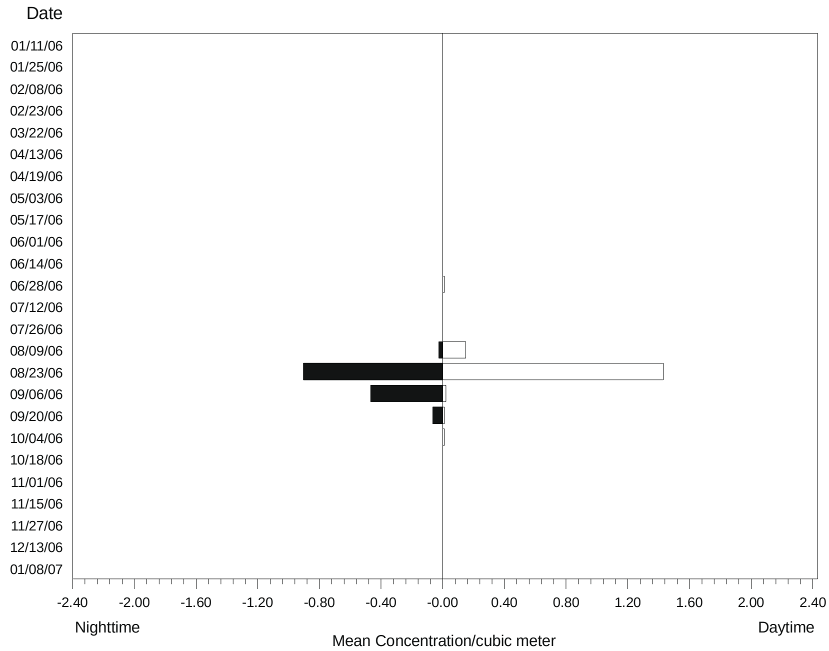


Figure 4.5-17. Mean concentration (#/1.0 m^3 [264 gal]) of sea bass larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.

Note: Negative nighttime values are a plotting artifact

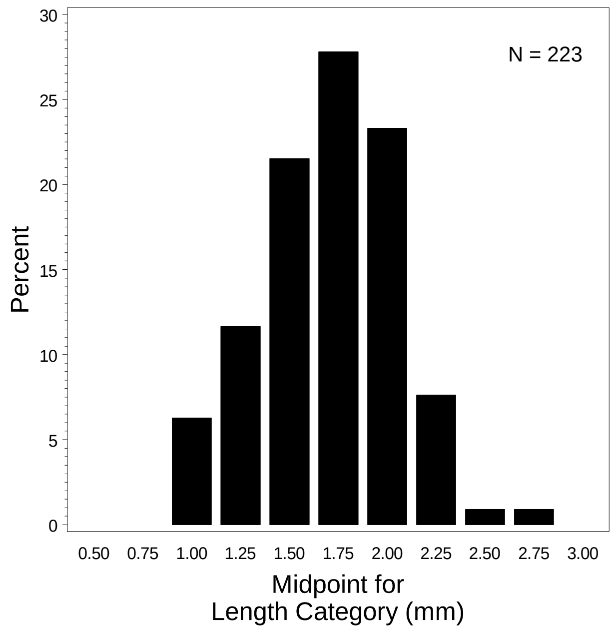


Figure 4.5-18. Length (mm) frequency distribution for sea bass larvae collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

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. This family exhibits a planktonic egg stage with a duration estimated at three days (Cordes and Allen 1979). 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 larval sea bass entrainment at SGS was estimated at 272,775 eggs (standard error of 73,152) and 29,681,768 larvae (standard error of 2,045,706) using measured cooling water flows during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flow volumes, annual larval sea bass entrainment estimates increased to 366,476 eggs (standard error of 97,945) and 40,350,936 larvae (standard error of 2,759,901) (Table 4.5-2).

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 95^{th} 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 3days was added to this value for a total period of exposure of 6.2 days.

The monthly estimates of *PE* for sea basses for 2006 ranged from 0 to 0.0051using actual cooling water flows during the period and ranged from 0 to 0.00703 using the design flows (Table 4.5-17). 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 = 0.569 or 56.9%). The values in the table were used to calculate a P_M estimate of 0.0017 (standard error of 0.0012) based upon actual flows and an estimate of 0.0024 (standard error of 0.0016) based upon design flows using the alongshore extrapolated estimate of the total source population. 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.

Table 4.5-17. *ETM* data and results for sea bass larvae based upon actual and design (maximum) CWIS flows. P_M calculated using the **alongshore** extrapolated estimate of total source population and average P_S of 0.8242.

	Actual Flows		**Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0
22-Mar-06	0	0	0	0	0
19-Apr-06	0	0	0	0	0
17-May-06	0	0	0	0	0
14-Jun-06	0	0	0	0	0
12-Jul-06	0.00011	0.00011	0.00015	0.00015	0.33955
9-Aug-06	0.00510	0.00216	0.00703	0.00294	0.06448
20-Sep-06	0.00023	0.00011	0.00033	0.00015	0.56952
18-Oct-06	0.00060	0.00063	0.00087	0.0009	0.02645
15-Nov-06	0	0	0	0	0
13-Dec-06	0	0	0	0	0
P_M	**0.0017**	0.0012	**0.0024**	0.0016	–

Alongshore extrapolation averaged 21.9 km limited by SM Bay and using total displacement. Onshore Transport (km) averaged 5.6 km.

4.5.3.4 White Croaker (*Genyonemus lineatus*)

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*).

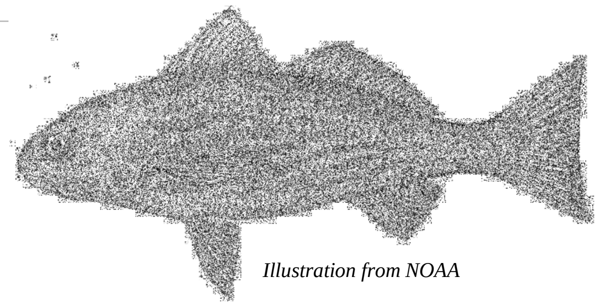


Illustration from NOAA

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, M. (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, M. 1982).

White croakers are oviparous broadcast spawners. They mature between 130 and 190 mm (5.1 and 7.5 in) total body length (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 mi) 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, M. 1982). Important prey items include polychaetes, amphipods, shrimps, and chaetognaths (Allen, M. 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 lbs) annually, exceeding 0.45 million kg (1 million lbs) 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 lbs) and steadily declined to an all-time low of 64,637 kg (142,500 lbs) in 1998. Landings by recreational fishermen aboard CPFV 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 polychlorinated biphenyls (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).

The earlier 316(b) study of the SGS in 1978–1979 (IRC 1981) found that white croaker larvae occurred predominantly from January through May with lower concentrations recorded from June to November. Survey means at the near field station averaged 700 larvae per 1,000 m^3 (264,172 gal). These concentrations were approximately 10 times the concentrations estimated from the 2006 entrainment samples.

Annual commercial landings in the Los Angeles region since 2000 have been variable with an average of 19,686 kg (43,400 lbs) and an average net worth of $29,385 annually (Table 4.5-18). 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 4.5-18. Annual landings and revenue for white croaker in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	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 fourth most abundant taxon at the entrainment station with a mean concentration of 64 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). White croaker larvae was present sporadically throughout the year at the entrainment station, and was most abundant in spring, (Figure 4.5-19). Average abundances also increased in November. Concentrations of white croaker were greater overall at the entrainment station except in the fall when concentrations of white croaker were higher at the source water stations. Average concentrations of white croaker peaked at 826 larvae per 1,000 m^3 (264,172 gal) in April at the entrainment station and decreased to less than 10 per 1,000 m^3 (264,172 gal) in the summer months. In November, white croaker concentrations increased to 52 per

1,000 m^3 (264,172 gal). Source water average abundances followed the same seasonal pattern, but the peak average concentration in November was more pronounced than that of the entrainment samples, with an average concentration of white croaker at approximately 250 per 1,000 m^3 (264,172 gal) (Figure 4.5-20). Almost all white croaker larvae were collected during nighttime samples (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). The mean length of specimens from the entrainment station samples was 3.1 mm (0.12 in) NL.

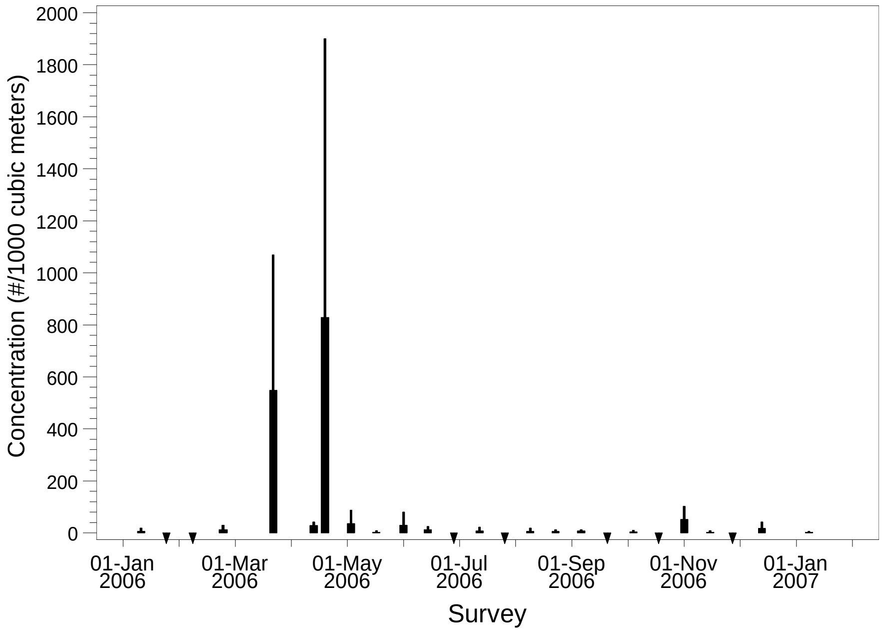


Figure 4.5-19. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of white croaker larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

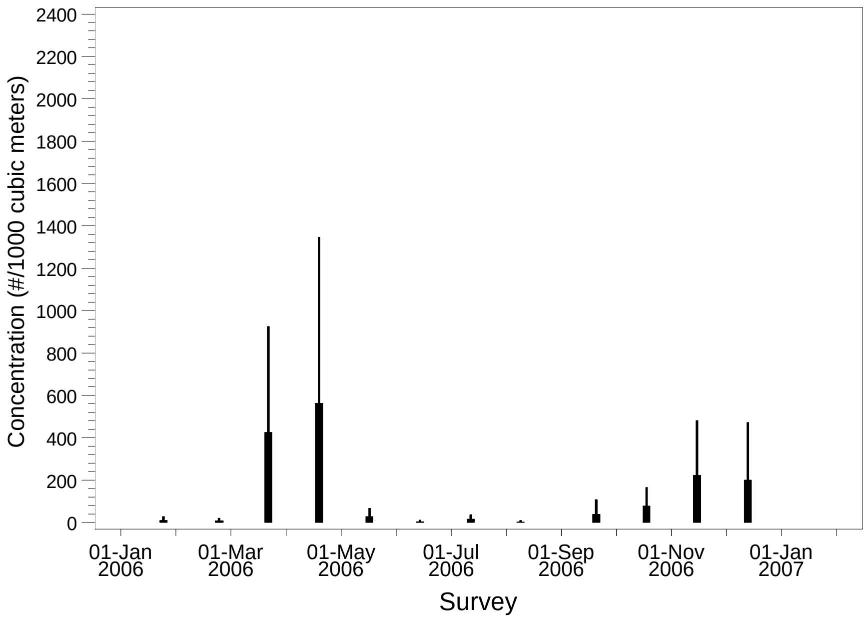


Figure 4.5-20. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of white croaker larvae collected at SGS source water stations during 2006.

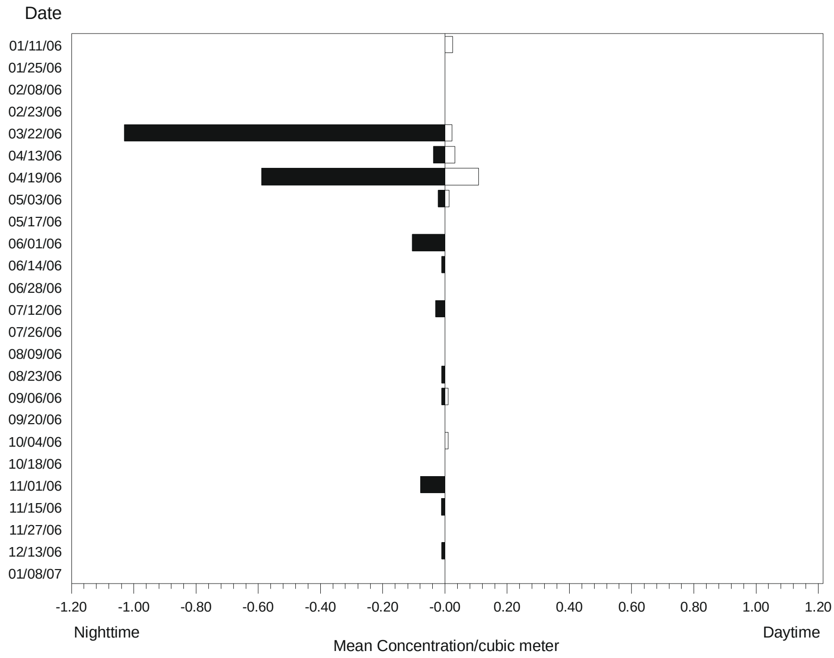


Figure 4.5-21. Mean concentration (#/1.0 m^3 [264 gal]) of white croaker larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

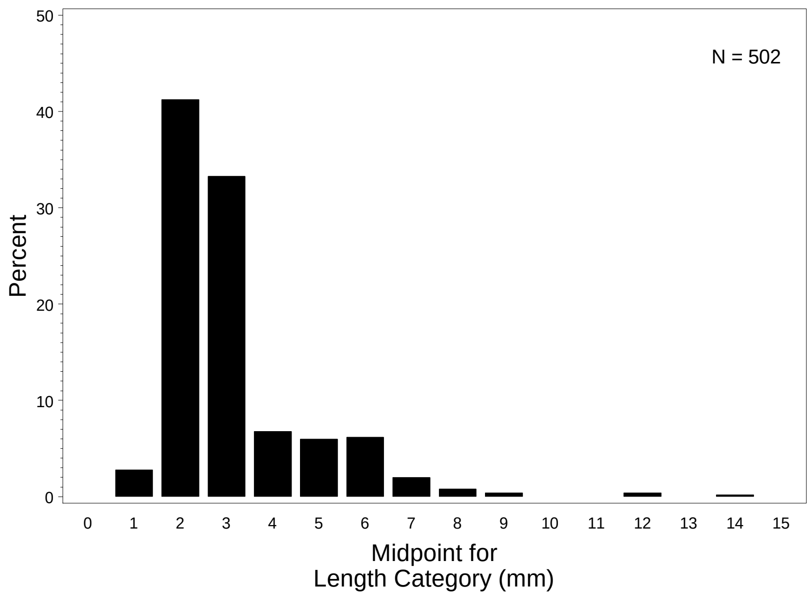


Figure 4.5-22. Length (mm) frequency distribution for white croaker larvae collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.4.4 Modeling Results

The following section presents the results for the demographic and 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 for larvae, but enough information was available to estimate *FH* based on numbers of eggs entrained. Total annual entrainment at SGS was estimated at 32,104,891 (standard error of 2,816,731) larvae and 34,295,926 (standard error of 2,437,843) eggs using measured cooling water flows during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flows, annual entrainment estimates increased to 46,634,188 larvae (standard error of 3,995,679) and 68,597,355 eggs (standard error of 5,174,405) (Table 4.5-2). 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.

<u>Fecundity Hindcasting (*FH*)</u>

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 whose lifetime reproductive output was entrained through the SGS CWIS for the 2006 period was estimated as 19 based upon the actual flows and increased to 38 based on the design flows (Table 4.5-19). 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 4.5-19. Results of *FH* modeling for white croaker eggs based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
<u>**Actual Flows**</u>					
FH Estimate	**19**	14	6	62	56
Total Entrainment	34,295,926	2,437,843	17	21	4
<u>**Design Flows**</u>					
FH Estimate	**38**	27	12	123	111
Total Entrainment	68,597,355	5,174,405	34	43	9

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 and larval lengths 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 and all of the 98 measured unidentified croakers 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 and unidentified croakers 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 *PE* for white croaker for 2006 ranged from 0 to 0.00372 based upon the actual flows during the period and from 0 to 0.00598 based upon the design flows (Table 4.5-20). The largest estimate was calculated for the August survey, but the largest proportion of the source population was 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 0.0037, with a standard error of 0.0024 based upon actual flows and a P_M estimate of 0.0053 with a standard error 0.0034 based on design flows using the offshore extrapolated estimate of the total source population. 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 boundaries of Santa Monica 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 the bay may be subject to entrainment. Total average alongshore displacement was 39.7 km (24.7 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 4.5-20. *ETM* data and results for white croaker larvae based upon actual and design (maximum) CWIS flow volumes. P_M calculated using the **offshore** extrapolated estimate of total source population and average P_S of 0.1813.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0.00833
23-Feb-06	0.00258	0.00196	0.00422	0.00318	0.00447
22-Mar-06	0.00292	0.00146	0.00421	0.00209	0.19126
19-Apr-06	0.00363	0.00241	0.00512	0.00339	0.24673
17-May-06	0.00012	0.00012	0.00025	0.00025	0.01877
14-Jun-06	0.00304	0.00258	0.00598	0.00498	0.00307
12-Jul-06	0.00074	0.00076	0.00099	0.00101	0.01130
9-Aug-06	0.00372	0.00417	0.00513	0.00569	0.00223
20-Sep-06	0	0	0	0	0.04390
18-Oct-06	0	0	0	0	0.05826
15-Nov-06	0.00002	0.00002	0.00002	0.00002	0.19222
13-Dec-06	0.00012	0.00009	0.00019	0.00013	0.21946
P_M	**0.0037**	0.0024	**0.0053**	0.0034	–

Alongshore extrapolation averaged 38.66 km limited by SM Bay and 39.36 using total displacement.
Onshore displacement averaged 13.51 km.

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

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.

Milton Love

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, M. (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 lbs]) 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 1968; Hobson and Chess 1976; Hobson et al. 1981; Feder et al. 1974). They are a forage species that is probably consumed by a wide variety of larger piscivorous fishes, such as halibut, kelp bass, Pacific bonito, Pacific mackerel, and sharks, as well as sea lions and cormorants.

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 6.1-12.2 m. Queenfish were also major constituents in beam trawl surveys and made up 50% of catches in exposed coastal sites and 72% of the catch in semi-protected coastal along with white croaker (Allen and Herbinson 1991).

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

The earlier 316(b) study of the SGS in 1978–1979 (IRC 1981) found that queenfish larvae occurred predominantly from spring and summer with the highest concentrations from April to mid-October. Mean concentrations were 10 larvae per 1,000 m^3 for the near-field daytime samples and 140 larvae per 1,000 m^3 for the nighttime samples. The overall mean concentrations were approximately three times the 2006 entrainment densities.

Although queenfish is not considered a highly desired species compared to other sciaenids, it is caught in fairly substantial numbers by both recreational and commercial fisheries. No specific landings were reported in commercial landing statistics for southern California from 2000–2006 (PacFIN 2007), although they may have been grouped as ‘unspecified croakers’. Recent population trends indicate a decline in shore landings by over 75% in the 1990s compared to the 1980s (Jarvis et al. 2004). Sport fishery catch estimates of queenfish in the southern California region from 2000–2006 ranged from 66,000 to 942,000 fish, with an average of 270,000 fish caught annually (Table 4.5-21).

Table 4.5-21. 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 seventh most abundant taxon at the entrainment station with a mean concentration of 24 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 second most abundant taxon with a mean concentration of 92 per 1,000 m^3 (264,172 gal). Queenfish larvae were present in the summer entrainment surveys from May to September (Figure 4.5-23). Average larval queenfish concentrations peaked at 122 larvae per 1,000 m^3 (264,172 gal) in mid-June and then peaked again in late August at 346 per 1,000 m^3 (264,172 gal). Larvae were present from late March through late September in the source water samples and peaked in June and July at about 140 per 1,000 m^3 (264,172 gal) (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). Concentrations of unidentified croaker averaged over 100 per 1,000 m^3 (264,172 gal) in summer months, peaking in August at 1,084 larvae per 1,000 m^3 (264,172 gal) at the entrainment station. Concentrations peaked in June at about 240 per 1,000 m^3 (264,172 gal) at the source water stations. Queenfish and unidentified croaker larvae were 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 a relatively unimodal curve with over 90% of sampled larvae smaller than 2.5 mm (0.10 in) and about a 1-2% 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 in the entrainment station samples. 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.

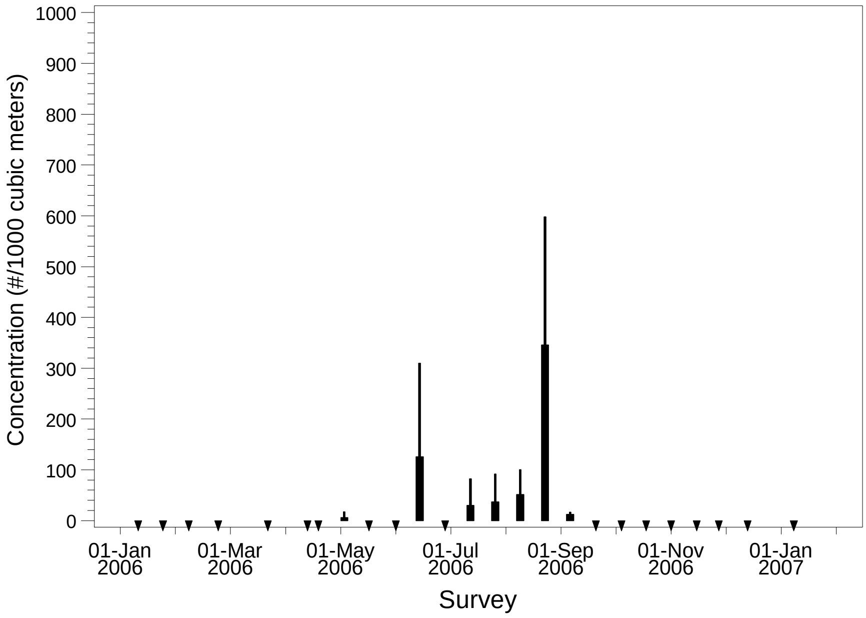


Figure 4.5-23. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of queenfish larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

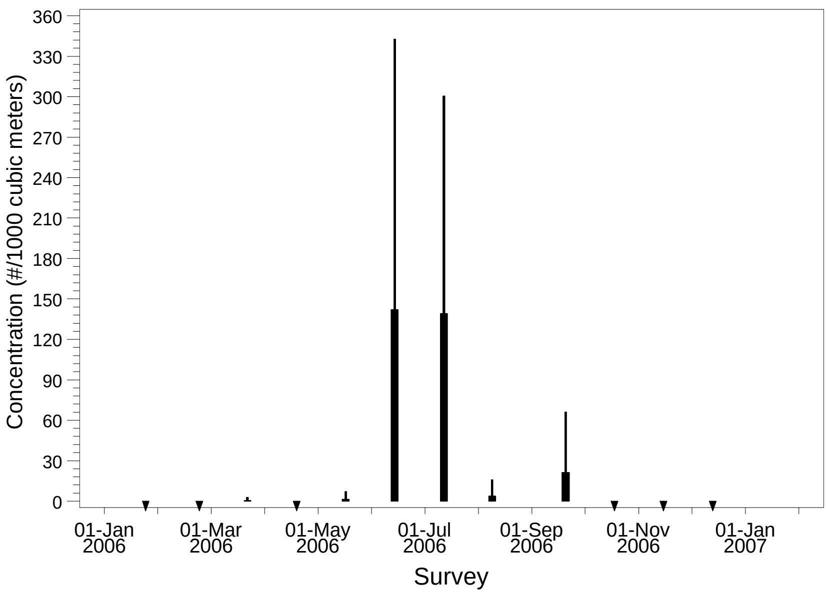


Figure 4.5-24. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of queenfish larvae collected at SGS source water stations during 2006.

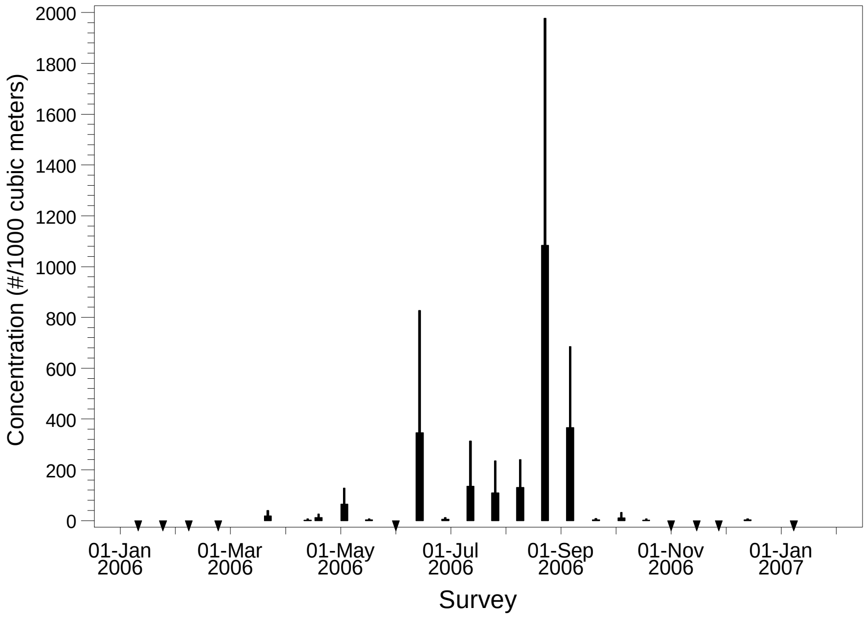


Figure 4.5-25. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of unidentified croaker larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

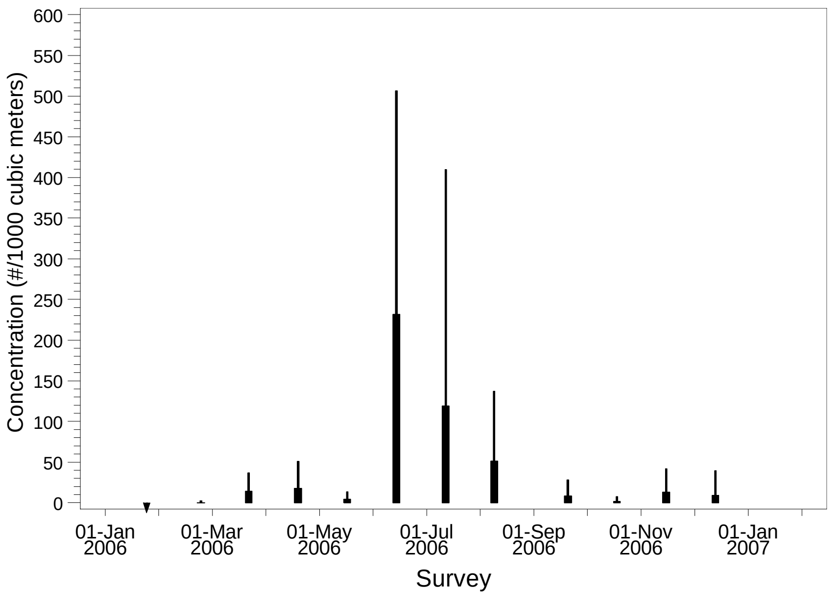


Figure 4.5-26. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of unidentified croaker larvae collected at SGS source water stations during 2006.

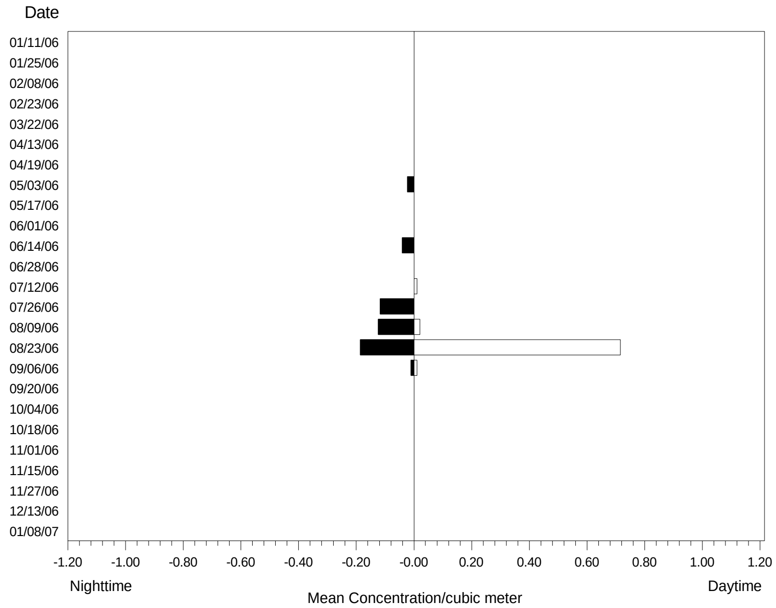


Figure 4.5-27. Mean concentration (#/1.0 m^3 [264 gal]) of queenfish larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

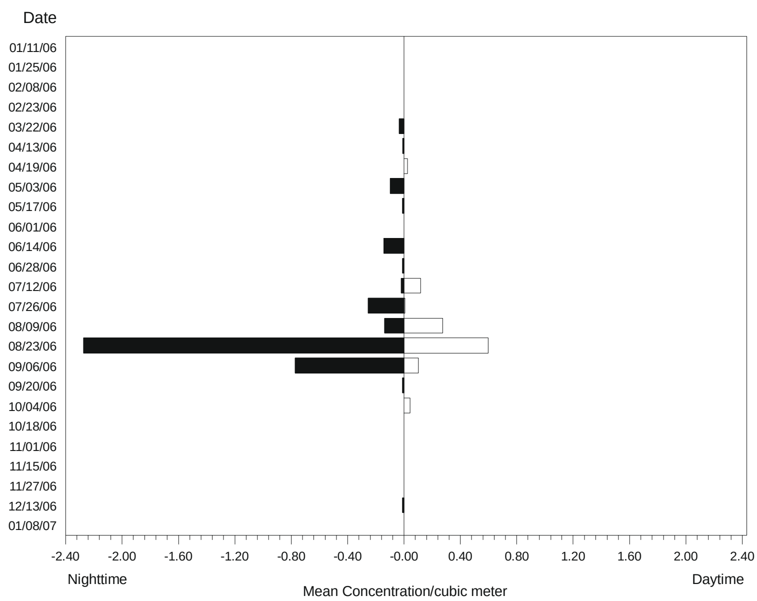


Figure 4.5-28. Mean concentration (#/1.0 m^3 [264 gal]) of unidentified croaker at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

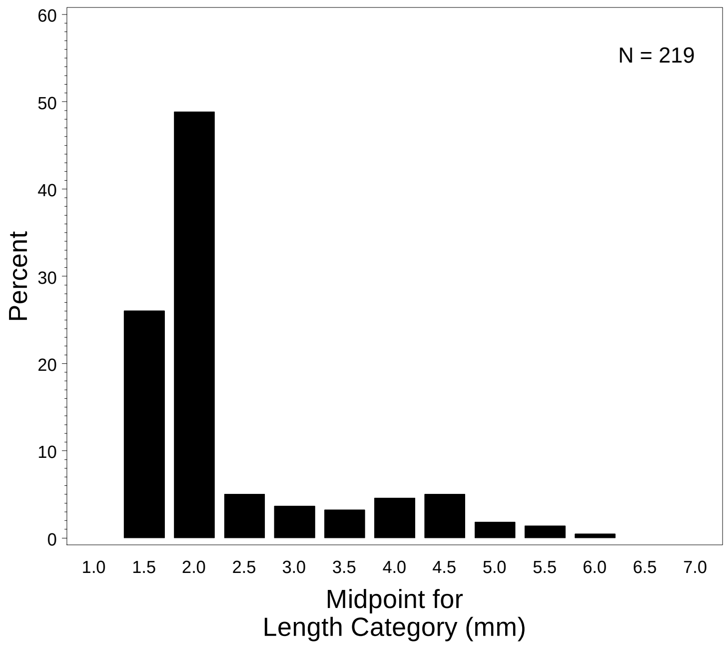


Figure 4.5-29. Length (mm) frequency distribution for larval queenfish collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

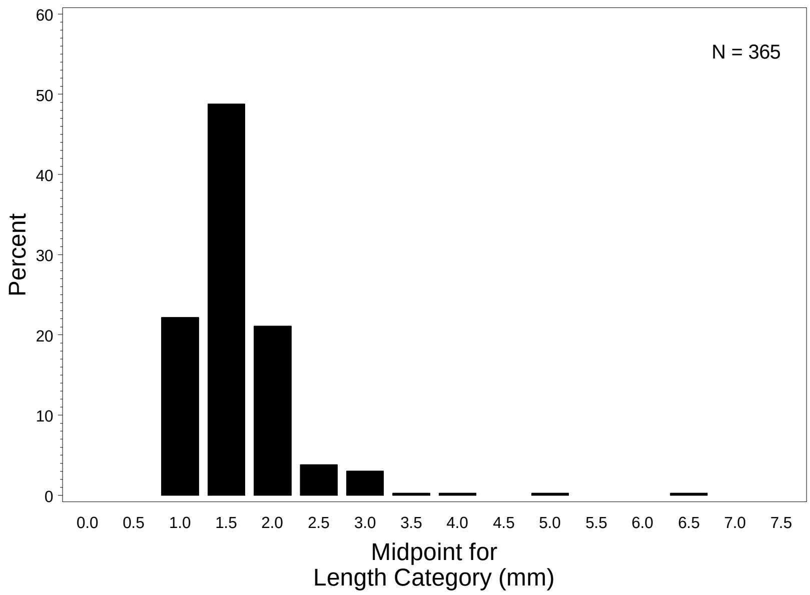


Figure 4.5-30. Length (mm) frequency distribution for larval unidentified croakers collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

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 SGS was estimated at 10,845,071 (standard error of 786,287) for queenfish larvae and 42,076,568 (standard error of 2,723,106) for unidentified croaker larvae using measured cooling water flows during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flows, total annual entrainment estimates increased to 15,732,743 (standard error of 1,182,109) for queenfish larvae and to 59,935,823 (standard error of 3,925,418) for unidentified croaker larvae (Table 4.5-2). 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.

<u>Empirical Transport Model (*ETM*)</u>

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 *PE* for queenfish for 2006 ranged from 0 to 0.0280 using the actual cooling water flows during the period, or from 0 to 0.03860 using the design cooling water flows (Table 4.5-22). 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 all of the surveys between March and October with the largest proportion of the source population present during the June and July surveys (f_i = 0.460 and 0.442 or 46.0 and 44.2%, respectively). The values in the table were used to calculate a P_M estimate of 0.0006 with a standard error of 0.0005 based on the actual cooling water flows using the offshore extrapolated estimate of the total source population. A P_M estimate of 0.0010 with a standard error of 0.0008 was calculated using the design flows during the period. 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 boundaries of Santa Monica 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 the bay may be subject to entrainment. Total average alongshore displacement 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 4.5-22. *ETM* data and results for queenfish larvae based upon actual and design (maximum) CWIS flows. P_M calculated using the **offshore** extrapolated estimate of total source population, and average P_S of 0.0563.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0
22-Mar-06	0	0	0	0	0.00116
19-Apr-06	0	0	0	0	0
17-May-06	0	0	0	0	0.00269
14-Jun-06	0.00087	0.00077	0.00170	0.00146	0.45977
12-Jul-06	0.00031	0.00028	0.00042	0.00037	0.44230
9-Aug-06	0.02800	0.01666	0.03860	0.02279	0.01035
20-Sep-06	0	0	0	0	0.08372
18-Oct-06	0	0	0	0	0
15-Nov-06	0	0	0	0	0
13-Dec-06	0	0	0	0	0
P_M	**0.0006**	0.0005	**0.0010**	0.0008	–

Alongshore extrapolation averaged 35.17 km limited by SM Bay and 35.87 using total displacement.
Onshore displacement averaged 9.76 km.

The monthly estimates of *PE* for unidentified croakers for 2006 ranged from 0 to 0.00982 using the actual cooling water flows during the period, and ranged from 0 to 0.01353 using the design flows (Table 4.5-23). 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 = 0.373 or 37.3%). The values in the table were used to calculate a P_M estimate of 0.0064 with a standard error of 0.0048 based on the actual flows and an estimate of 0.0100 with a standard error 0.0074 based on the design flows using the offshore extrapolated estimate of the total source population. 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 percent) is a direct result of the large source population potentially subject to entrainment.

Table 4.5-23. *ETM* data and results for unidentified croaker larvae based upon actual and design (maximum) CWIS flow volumes. P_M calculated using the **offshore** extrapolated estimate of total source population and average Ps of 0.2480.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0.00145
22-Mar-06	0.00171	0.00110	0.00247	0.00158	0.04771
19-Apr-06	0.00125	0.00078	0.00177	0.00110	0.04497
17-May-06	0.00077	0.00083	0.00162	0.00173	0.00994
14-Jun-06	0.00313	0.00266	0.00617	0.00508	0.37326
12-Jul-06	0.00221	0.00162	0.00297	0.00217	0.30505
9-Aug-06	0.00982	0.00464	0.01353	0.00633	0.08039
20-Sep-06	0.00052	0.00056	0.00074	0.00079	0.03042
18-Oct-06	0.00314	0.00380	0.00450	0.00544	0.00356
15-Nov-06	0	0	0	0	0.05309
13-Dec-06	0.00032	0.00038	0.00049	0.00057	0.05016
P_M	**0.0064**	0.0048	**0.0100**	0.0074	–

Alongshore extrapolation averaged 28.49 km limited by SM Bay and using total displacement. Onshore displacement averaged 7.38 km.

4.5.3.6 Señorita (*Oxyjulis californica*)

Señorita (*Oxyjulis californica*) is a small wrasse (Family Labridae) with a range from southern Baja California (De La Cruz-Agüero et al. 1996) to Salt Point State Park in Sonoma County, California (Eschmeyer and Herald 1983). However, they are uncommon north of Santa Cruz, California (Miller and Lea 1972). Señorita is a diurnal species that inhabits shallow rocky habitats and kelp forests. Adults are found as deep as 97 m (318 ft), but generally inhabit shallower waters from the surface to 73 m (240 ft) (Love 1996).

4.5.3.6.1 Life History and Ecology

Señorita is a pelagic species that is a broadcast spawner (Gruber et al. 1982). Eggs hatch relatively quickly with larvae emerging in 48 hours (Bolin 1930), and with a larval development duration of 36–43 days (Victor 1986). Peak spawning has been reported to occur between May and August (Bolin 1930; Fitch and Lavenberg 1975), although spawning behavior has not yet been described. YOY typically settle into inshore waters between June and November where they feed on small crustaceans (Love 1996). Señoritas reach maturity in one year and may reach lengths up to 25 cm (9.8 in) (Fitch and Lavenberg

1975). The species is important ecologically in that it engages in cleaning behavior by removing ectoparasites from an array of predatory fishes (Fitch and Lavenberg 1975). It is also reported to be almost exclusively diurnal, burying beneath sand and shell debris at dusk and emerging at dawn.

4.5.3.6.2 Population Trends and Fishery

Señorita is one of the most ubiquitous fishes in kelp forests and shallow rocky areas. It was present at over 90% of all diver transects conducted at 88 nearshore survey stations from Santa Cruz to San Diego, including the Channel Islands (Tenera 2006). Larvae have been reported at densities between 0.0 and 358 per 1,000 m^3 from nearshore plankton tows in Santa Monica Bay (Stephens et al. 1986). Long-term records of larval abundance in King Harbor from 1974–1997 showed high densities in the early 1980s and very low densities in the 1990s (Stephens and Pondella 2002). This species has no direct commercial or recreational fishery importance.

4.5.3.6.3 Sampling Results

Señorita larvae was the twelfth most abundant taxon at the entrainment station with a mean concentration of 7 per 1,000 m^3 (264,172 gal) over all the surveys (Table 4.5-1). Señorita larvae were present in the entrainment samples from May to September (Figure 4.5-31). Average larval senorita concentrations peaked at 127 larvae per 1,000 m^3 (264,172 gal) in September. Larvae were present in the source water samples from June through late September and peaked in August at about 12 per 1,000 m^3 (264,172 gal) (Figure 4.5-32). There was no consistent trend in abundance between daytime and nighttime samples (Figures 4.5-33). The length frequency plot for senorita showed a bimodal curve with the largest concentrations of measured larvae from 1.0–1.8 mm (0.04–0.07 in) NL and 1.8–2.3 mm (0.07–0.09 in) NL (Figure 4.5-34). Lengths ranged from 1.0 mm (0.04 in) NL to 2.5 mm (0.10 in) NL with a mean length of 1.8 mm (0.07 in) NL from the entrainment station samples.

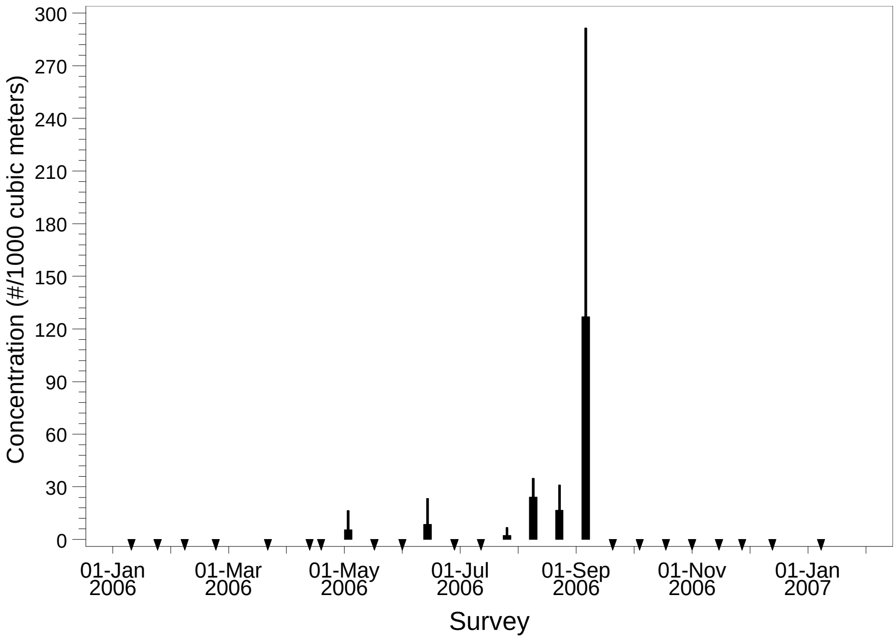


Figure 4.5-31. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of señorita larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

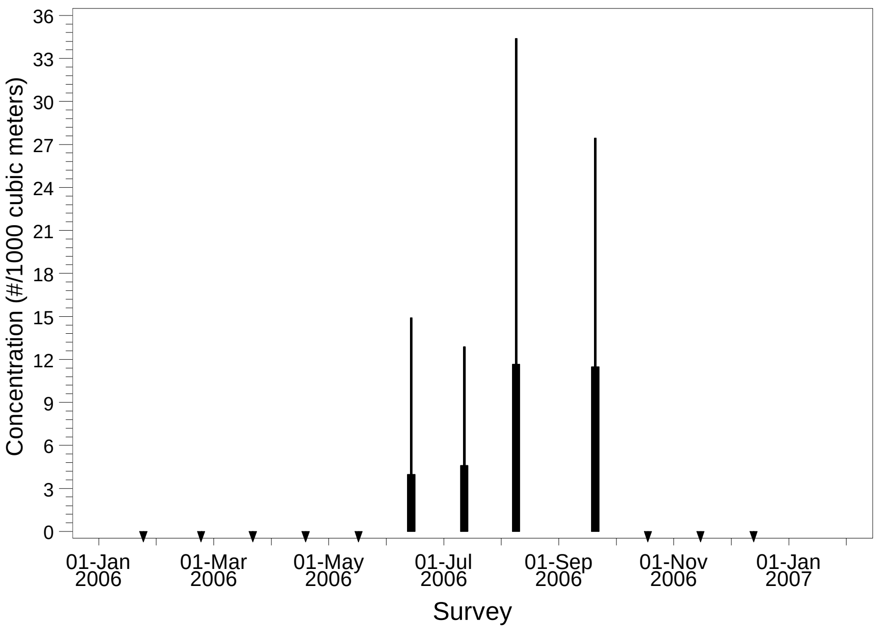


Figure 4.5-32. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of señorita larvae collected at SGS source water stations during 2006.

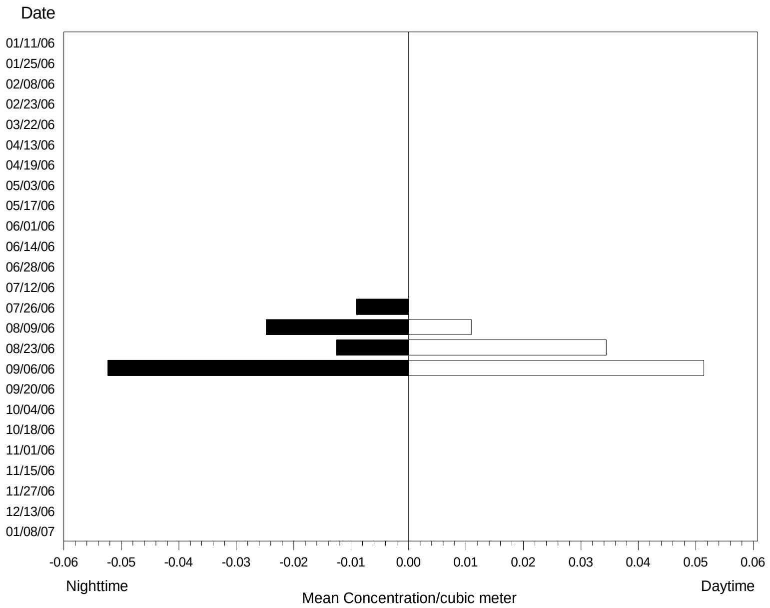


Figure 4.5-33. Mean concentration (#/1.0 m^3 [264 gal]) of señorita larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

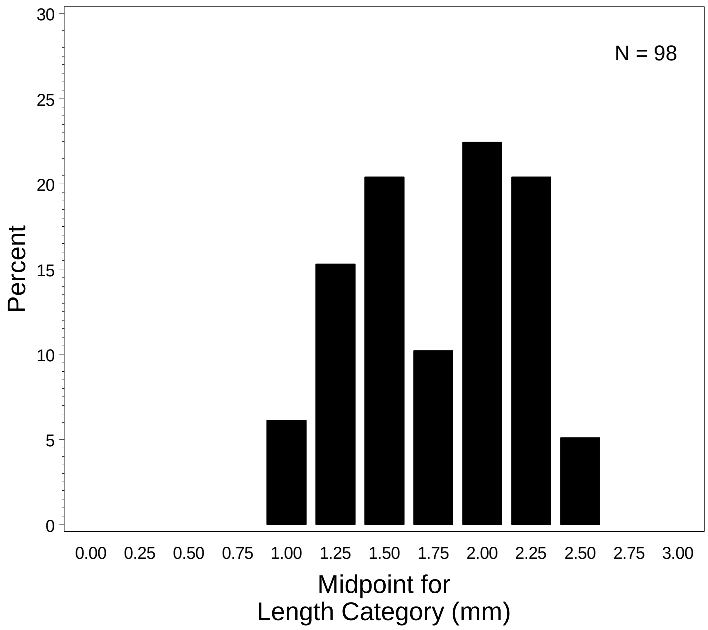


Figure 4.5-34. Length (mm) frequency distribution for larval señorita collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.6.4 Modeling Results

The following section presents the results for empirical transport modeling of entrainment effects on señorita. No age-specific estimates of survival for larval and later stages of development were available from the literature for senorita, and therefore no estimates of *FH* or *AEL* were calculated. Total annual entrainment at SGS was estimated at 3,557,915 (standard error of 446,417) for senorita larvae using the actual cooling water flows during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flows, annual entrainment estimates increased to 4,808,587 (standard error of 585,441) using the design cooling water flows (Table 4.5-2). 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*)

Although there is very little information on the early life history of señorita, there has been extensive research on labrids found in coral reef habitats as well as off of the northeast United States and Japan. A growth rate for señorita was derived from data on three species of labrids found off of Japan since these species are found in comparable habitat, water temperatures, and exhibit similar life histories to the senorita. Kimura et al. (1998) described larval development and provided length at age data of reared species of *Thalassoma cupido* and *Halichoeres poecilopterus*, subtropical labrids, which grow to lengths of 34.0 cm (13.4 in) and 20.0 cm (7.9 in) TL, respectively. *T. cupido* hatches at about 1.5 mm (0.06 in) and *H. poecilopterus* hatches at 1.6 mm (0.06 in), while señorita hatch at 2.0 mm (0.08 in). Growth of larval *H. poecilopterus* was calculated to 0.13 mm/day (0.005 in/day) for up to 21 days post hatch (dph). Growth of *T. cupido* was calculated to 0.11 mm/day (0.004 in/day) for up to 6 dph. These growth rates were averaged together to provide an estimated growth rate of 0.12 mm/day (0.005 in/day) for señorita. A sample of 98 lengths from collected señorita larvae were used to calculate a difference between the 10^{th} and 95^{th} percentile values of the measurements to estimate that senorita larvae were exposed to entrainment for a period of approximately 8.2 days. The two-day duration of the planktonic egg stage was added to the periods for the larvae to estimate a total period of exposure of 10.2 days.

The monthly estimates of *PE* for senorita for 2006 ranged from 0 to 0.0631 using actual cooling water flows during the period and ranged from 0 to 0.00870 using the design flows (Table 4.5-24). Señorita larvae were only collected from the entrainment station during two of the paired entrainment-source water surveys, and were only collected at the source water stations during four of the surveys with the largest proportion of the source population present during the September survey (f_i = 0.437 or 43.7%). The values in the table were used to calculate a P_M estimate of 0.0056 (standard error of 0.0013) based on the actual cooling water flows and an estimate of 0.0085 (standard error 0.0019) based on the design flows using only the alongshore extrapolated estimate of the total source population. The model calculations are based on only two estimates of *PE* increasing the uncertainty associated with the estimate for this species. The period of larval exposure to entrainment allows larvae to be transported an average distance alongshore over the 12 surveys of 29.1 km (18.1 mi) limited by the boundaries of Santa Monica Bay, indicating that larvae from almost half of the 60 km (37 mi) coastline of the bay may be subject to entrainment. Total average displacement was 29.5 km (18.3 mi). The small estimate of *PM* (less than half of one percent) is a direct result of the large source population potentially subject to entrainment.

Table 4.5-24. *ETM* data and results for senorita larvae based upon actual and design (maximum) CWIS flow volumes. P_M was calculated using the **alongshore** extrapolated estimate of total source population and average P_S of 0.105.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0
22-Mar-06	0	0	0	0	0
19-Apr-06	0	0	0	0	0
17-May-06	0	0	0	0	0
14-Jun-06	0.00342	0.00399	0.00673	0.00766	0.10955
12-Jul-06	0	0	0	0	0.15550
9-Aug-06	0.00631	0.00215	0.00870	0.00295	0.29756
20-Sep-06	0	0	0	0	0.43739
18-Oct-06	0	0	0	0	0
15-Nov-06	0	0	0	0	0
13-Dec-06	0	0	0	0	0
P_M	**0.0056**	0.0013	**0.0085**	0.0019	–

Alongshore extrapolation averaged 29.07 km limited by SM Bay and 29.52 using total displacement.

4.5.3.7 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).

4.5.3.7.1 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 SGS 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 1m (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).

Summary of combtooth blenny distribution and life history attributes.

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

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

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

Fishery: None

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).

4.5.3.7.2 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.

4.5.3.7.3 Sampling Results

Combtooth blenny was the ninth most abundant taxon at the entrainment station with a mean concentration of 22 larvae per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were present in the entrainment samples from March through December, with a peak in June and a second smaller peak in late August (Figure 4.5-35). During periods of maximum abundance in early June 2006, combtooth blennies were present at average concentrations of 114 per 1,000 m^3 (264,172 gal). Source water abundances followed the same seasonal pattern, with a peak in average concentration in June at approximately 80 per 1,000 m^3 (264,172 gal) (Figure 4.5-36). There were substantially more larvae in the nighttime samples than daytime samples (Figure 4.5-37). 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 4.5-38). 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.

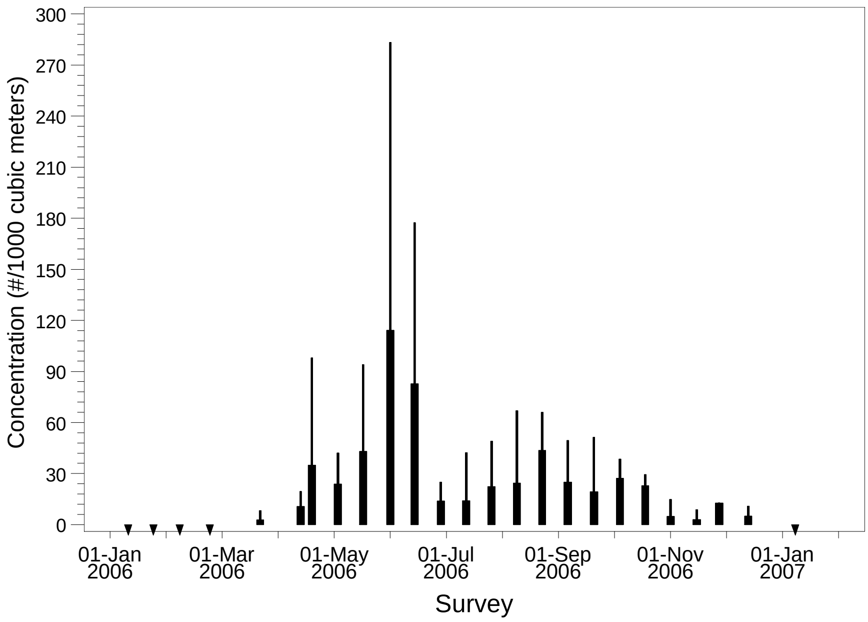


Figure 4.5-35. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of combtooth blenny larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

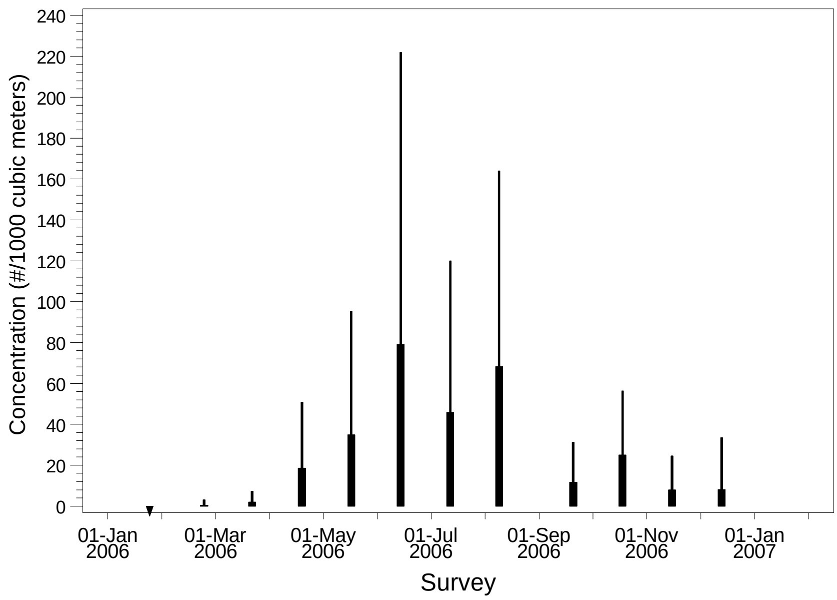


Figure 4.5-36. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of combtooth blenny larvae collected at SGS source water stations during 2006.

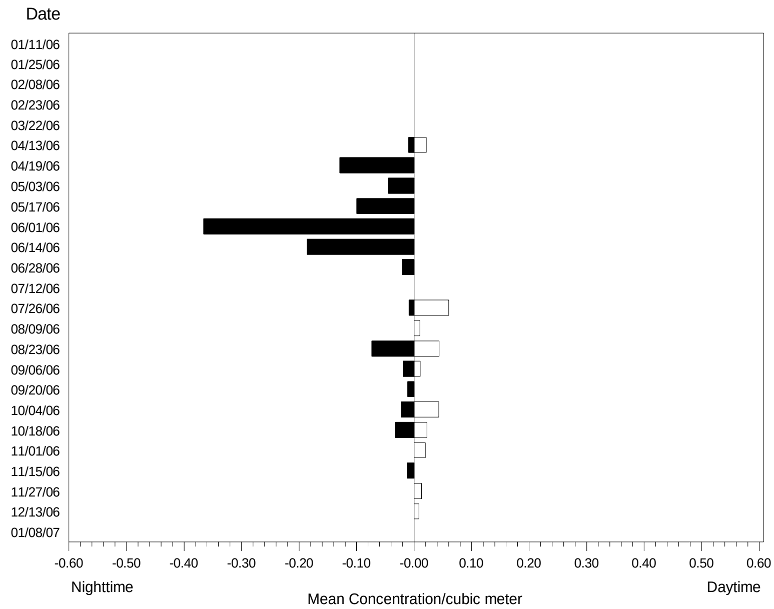


Figure 4.5-37. Mean concentration (#/1.0 m^3 [264 gal]) of combtooth blenny larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

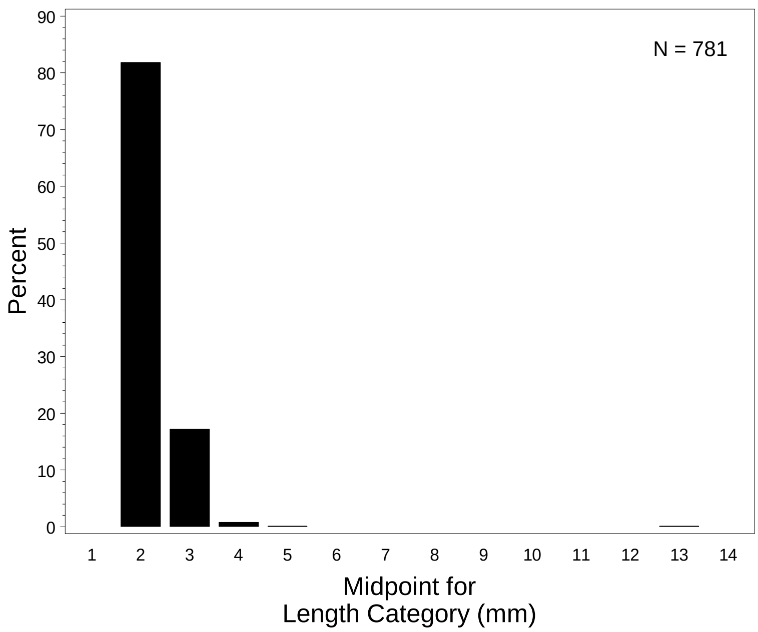


Figure 4.5-38. Length (mm) frequency distribution for combtooth blenny larvae collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.7.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of CWIS 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 SGS was estimated at 8,324,912 (standard error of 389,829) using actual cooling water flows during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flow volumes, annual entrainment estimates increased to 14,230,416 (standard error 797,487) larvae using the design flow volumes during 2006 (Table 4.5-2).

Fecundity Hindcasting (*FH*)

The annual entrainment estimate for combtooth blenny larvae was used to estimate the number of breeding females at the age of maturity needed to produce the estimated number of larvae entrained. 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 0.20mm/day (0.008in/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 4.5-25) 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 4.5-25. Survivorship table for adult combtooth blenny from data in Stephens (1969) showing spawners (L_x) surviving to the age interval and numbers of eggs spawned annually (M_x).

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

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

The estimated number of female combtooth blennies at the age of maturity (0.5 years) whose lifetime reproductive output was entrained through the SGS CWIS during 2006 was 4,757 based on entrainment estimates calculated using actual cooling water flows during the period (Table 4.5-26). Using the design flows during the period, an estimated 8,132 reproductive age female gobies were lost due to larval entrainment (Table 4.5-26). 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 4.5-26. Results of *FH* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
Actual Flows					
FH Estimate	**4,757**	4,126	1,142	19,813	18,671
Total Entrainment	8,324,912	389,829	4,391	5,124	733
Design Flows					
FH Estimate	**8,132**	7,057	1,951	33,898	31,948
Total Entrainment	14,230,416	797,487	7,382	8,881	1,499

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 equivalent number of adult combtooth blennies calculated from the number of larvae entrained through the SGS CWIS for the sampling period was 20,302, based on actual cooling water flows during 2006, and increased to 34,704 based on design flows during the period (Table 4.5-27). 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 4.5-27. Results of *AEL* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
Actual Flows					
AEL Estimate	**20,302**	24,883	2,704	152,461	149,758
Total Entrainment	8,324,912	389,829	18,738	21,866	3,128
Design Flows					
AEL Estimate	**34,704**	42,548	4,618	260,779	256,161
Total Entrainment	14,230,416	797,487	31,505	37,904	6,399

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 *PE* for combtooth blennies for the 2006 period ranged from 0 to 0.00631 using actual flows during the period and ranged from 0 to 0.00890 using the design flows (Table 4.5-28). 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 = 0.392 or 39.2%). As the results for the February survey show, there were periods when combtooth blenny larvae were collected at the source water stations but not at the entrainment station (i.e., $PE_i = 0$ and $f_i > 0$). The values in the table were used to calculate a P_M estimate of 0.0039 (standard error of 0.0031) based on the actual cooling water flows and an estimate of 0.0063 (standard error of 0.005) based on the design flows using only the alongshore extrapolated estimate of the total source population. 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 Santa Monica Bay. 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 4.5-28. *ETM* data and results for blenny larvae based upon actual and design CWIS flow volumes. P_M was calculated using the **alongshore** extrapolated estimate of total source population and average P_S of 0.7413.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0.00187
22-Mar-06	0.00283	0.00317	0.00408	0.00456	0.00494
19-Apr-06	0.00631	0.00585	0.00890	0.00823	0.02957
17-May-06	0.00187	0.00117	0.00394	0.00243	0.08232
14-Jun-06	0.00081	0.00063	0.00159	0.00120	0.39224
12-Jul-06	0.00067	0.00068	0.00090	0.00092	0.11831
9-Aug-06	0.00073	0.00065	0.00100	0.00089	0.22941
20-Sep-06	0.00318	0.00274	0.00455	0.00390	0.04010
18-Oct-06	0.00202	0.00045	0.00290	0.00064	0.05961
15-Nov-06	0.00064	0.00068	0.00094	0.00099	0.02323
13-Dec-06	0.00201	0.00148	0.00305	0.00223	0.01840
P_M	**0.0039**	0.0031	**0.0063**	0.0050	–

Alongshore extrapolation averaged 12.97 km limited by SM Bay and using total displacement. Onshore transport averaged 3.52 km.

4.5.3.8 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.

4.5.3.8.1 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, L. 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.

Summary of CIQ goby distribution and life history attributes.

Range: Vancouver Island, British Columbia to Gulf of California

Life History:
- Size up to 57 mm (2.1 in) (arrow goby); 64 mm (2.5 in) (cheekspot goby); 70 mm (2.75 in) (shadow goby)
- Age at maturity from 0.7–1.5 years
- Life span ranges from <3 years (arrow goby) to 5 years (shadow goby)
- Spawns year-round in bays and estuaries; demersal, adhesive eggs with fecundity from 225–1,400 eggs per female and multiple spawning of 2–5 times per year
- Juveniles from 14.0–29.0 mm are < 1 year old

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

Fishery: None.

The reproductive biology is similar among the three species in the CIQ complex. Arrow goby typically mature sooner than the other two species, attaining 50% maturity in the population after approximately 8 months as compared to 16–18 months 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 years of age based on otolith records, whereas cheekspot and shadow gobies commonly lived for 4 years (Brothers 1975).

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

4.5.3.8.2 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 SGS, provides habitat for both arrow goby and shadow goby and may be a source of larvae entrained at SGS. There is no fishery for CIQ goby species because of their small size.

4.5.3.8.3 Sampling Results

Unidentified (CIQ complex) goby larvae were the fifth most abundant taxon at the entrainment station with a mean concentration of 35 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were present in almost all surveys with peaks in concentrations in the spring and winter (Figure 4.5-39). During periods of maximum abundance in April 2006, CIQ complex gobies were present in the entrainment samples at average concentrations of 276 per 1,000 m^3 (264,172 gal). Concentrations peaked again in November at 183 per 1,000 m^3 (264,172 gal). Gobies were also present at the source water stations during all months of the year with a peak average concentration in April 2006 at 280 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-40) and at 190 per 1,000 m^3 (264,172 gal) in November. The larvae were more abundant in nighttime samples during almost all surveys (Figure 4.5-41). 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 4–12 mm (0.16–0.47 in) size classes (Figure 4.5-42). The mean length of measured specimens from the entrainment station samples was 3.0 mm (0.12 in) NL with a size range from 1.7–15.3 (0.07–0.60) mm NL.

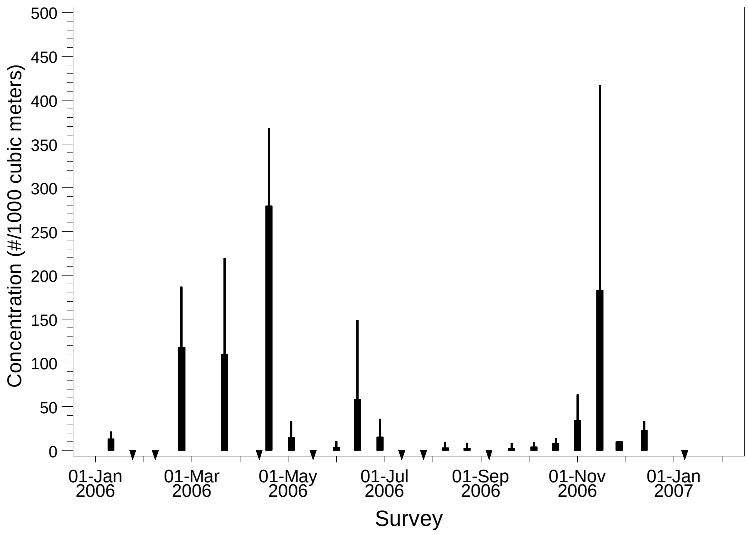


Figure 4.5-39. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of CIQ goby larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

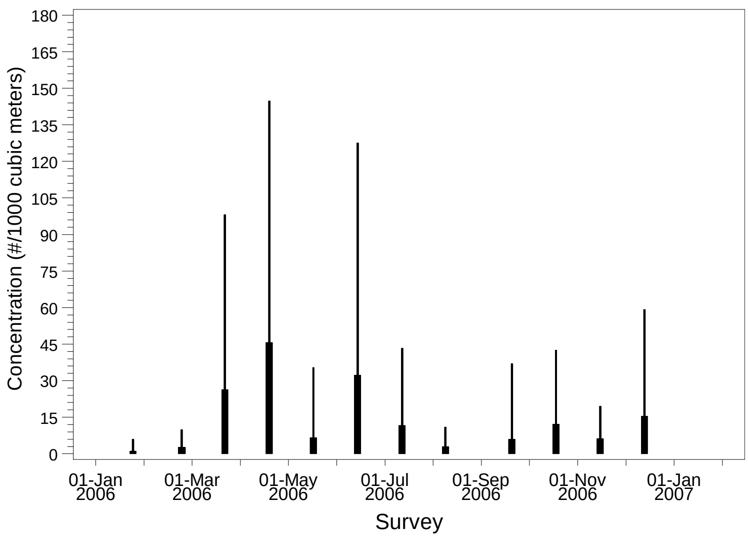


Figure 4.5-40. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of CIQ goby larvae collected at SGS source water stations during 2006.

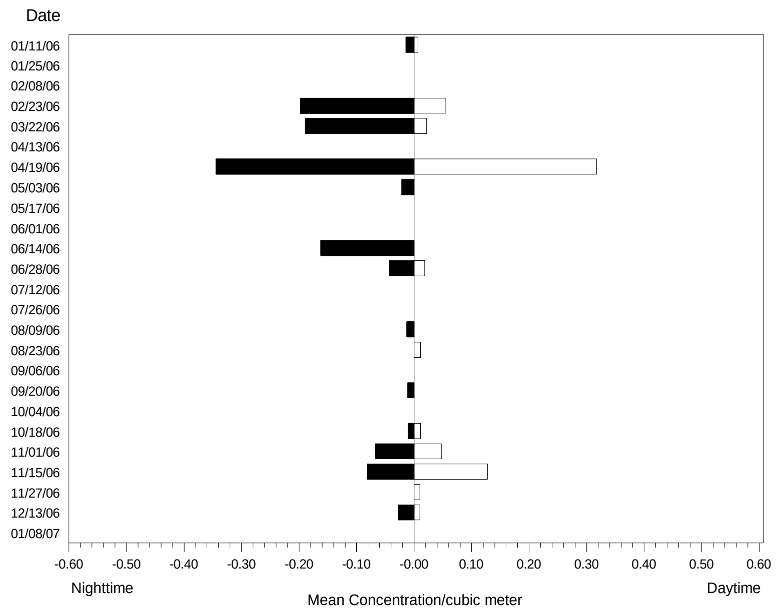


Figure 4.5-41. Mean concentration (#/1.0 m^3 [264 gal]) of CIQ goby larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

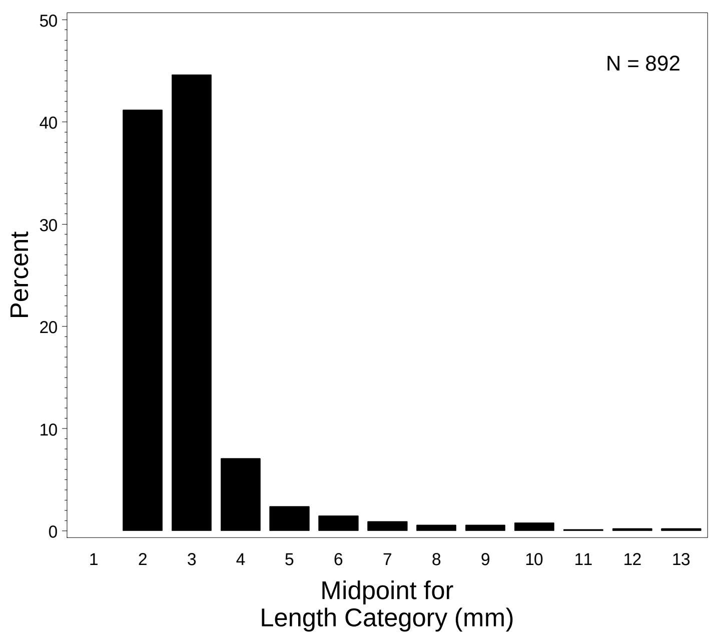


Figure 4.5-42. Length (mm) frequency distribution for CIQ goby larvae collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.8.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of CWIS 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 SGS was estimated to be 16,188,141 (standard error of 725,797) using actual measured cooling water flows during 2006. If the CWIS pumps were run at the design (maximum capacity) flows, annual entrainment estimates increased to 24,432,450 (standard error of 1,086,316) larvae (Table 4.5-2).

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 4.5-29). 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 SGS CWIS for the 2006 period was estimated at 15,452 using actual flows and at 23,321 using the design flow volumes (Table 4.5-30). 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. 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 4.5-30. Results of *FH* modeling for CIQ goby complex larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
Actual Flows					
FH Estimate	**15,452**	13,400	3,711	64,345	60,634
Total Entrainment	16,188,141	725,797	14,312	16,592	2,279
Design Flows					
FH Estimate	**23,321**	20,224	5,601	97,112	91,511
Total Entrainment	24,432,450	1,086,316	21,616	25,027	3,411

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 years 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 equivalent number of adult CIQ gobies estimated from the number of larvae entrained through the SGS CWIS for the 2006 sampling period was 13,272 based on an entrainment estimate calculated using actual CWIS flows, and 20,031 based on design flows (Table 4.5-31). 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 4.5-31. Results of *AEL* modeling for CIQ goby complex larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
Actual Flows					
AEL Estimate	**13,272**	14,916	2,089	84,303	82,214
Total Entrainment	16,188,141	725,797	12,293	14,251	1,958
Design Flows					
AEL Estimate	**20,031**	22,512	3,154	127,234	124,081
Total Entrainment	24,432,450	1,086,316	18,566	21,496	2,930

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*)

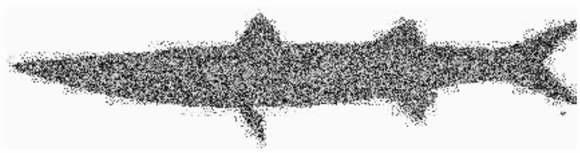
The larval duration used to calculate the *ETM* estimates for CIQ gobies was based on the lengths of entrained larvae. The difference between the lengths of the 95th percentile (4.7 mm [0.32 in]) and the estimated hatch length of the estimated hatch length of 2.2 mm (0.09 in) based on the length of the 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 three of the surveys (Table 4.5-32). The monthly estimates of *PE* for the 2006 period ranged from 0 to 0.03727 using the actual flows during the period and ranged from 0 to 0.06099 using the design flows. The largest estimate occurred during the November survey, with the largest proportion of the source population occurring during the previous spring in April (f_i = 0.208 or 20.8%). The values in the table were used to calculate a P_M estimate of 0.0507 (standard error of 0.0278) based on the actual cooling water flows and an estimate of 0.0741 (standard error of 0.0403) based on the design flows using only the alongshore extrapolated estimate of the total source population. 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 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 north of the power plant. Onshore transport averaged 10.48 km and total average displacement was 37.2 km (23.1 mi).

Table 4.5-32. *ETM* data and results for unidentified goby larvae based upon actual and design (maximum) CWIS flow volumes. P_M was calculated using the **alongshore** extrapolated estimate of total source population and average P_S of 0.3059.

	Actual Flows		Design Flows		
Survey Date	*PE* Estimate	*PE* Std. Err.	*PE* Estimate	*PE* Std. Err.	f_i
25-Jan-06	0	0	0	0	0.00316
23-Feb-06	0.03727	0.01441	0.06099	0.02340	0.04516
22-Mar-06	0.01669	0.00958	0.02409	0.01377	0.10368
19-Apr-06	0.02235	0.00495	0.03153	0.00698	0.20800
17-May-06	0.00000	0	0.00000	0	0.04493
14-Jun-06	0.00728	0.00734	0.01433	0.01406	0.09569
12-Jul-06	0.00000	0	0.00000	0	0.07556
9-Aug-06	0.00243	0.00272	0.00335	0.00372	0.02804
20-Sep-06	0.00050	0.00068	0.00072	0.00097	0.11133
18-Oct-06	0.00188	0.00083	0.00270	0.00118	0.07264
15-Nov-06	0.03843	0.02914	0.05629	0.04263	0.07645
13-Dec-06	0.00399	0.00166	0.00605	0.00252	0.13535
P_M	**0.0507**	0.0278	**0.0741**	0.0403	–

4.5.3.9 Pacific Barracuda (*Sphyraena argentea*)



Calif. Dept. Fish Game

Pacific barracuda (*Sphyraena argentea*), also known as the California barracuda, has been an important part of California's recreational fishery and was formerly also an important commercial species (Ally et al. 2001; Starr et al. 1998). It ranges from Kodiak Island, Gulf of Alaska to Cabo San Lucas, southern Baja California (Miller and Lea 1972), and the southwestern Gulf of California and the Islas Revillagigedos (Robertson and Allen 2002). In warm water years, it is commonly found off central California, but it mostly occurs south of Point Conception. It is considered a nearshore epipelagic species and occurs from the surface to approximately 38 m (125 ft) and also may occur in the surf zone (Love et al. 2005). A related species, the Mexican barracuda (*Sphyraena ensis*), occurs rarely in southern California but generally has a more tropical distribution than the Pacific barracuda.

4.5.3.9.1 Life History and Ecology

The earliest account of the fishery and life history of Pacific barracuda in southern California was done by Walford (1932), followed by more detailed fishery (Schutze 1983) and tagging studies (Pinkas 1966). Pacific barracuda are rapidly growing fish that mature in their second year (males), while females spawn by their third year. They can live to an age of at least 12 years and attain a total length of 122 cm (48 in), although fish larger than 89 cm (35 in) are rare (Love 1996). Younger fish tend to remain near shore, while older fish are more common over shallow banks farther from shore and at offshore islands.

Spawning season begins in April, peaks in early summer, and tapers off in August–September. The ovaries of spawning females contain opaque, yellow eggs as well as mature and immature ones throughout the season, and since no spent females appear during the heights of the spawning season, it was concluded that a female spawns more than once during a season. Newly mature females weighing approximately 500 g (1.1 lbs) had fecundities of 40,000-60,000 eggs per female whereas the largest females that weighed over 3000 g (6.6 lbs) produced nearly 500,000 eggs per spawn. A 6–7 year old fish produces 300,000–400,000 eggs per season. Eggs are pelagic and yolk sac larvae are approximately 3.4 mm (0.13 in) at hatching. Larvae have been collected throughout the year but have a maximum concentrations in July–September (Moser 1996).

Most studies on growth of barracuda have focused on juveniles and adults due to the fishing interest. No studies have been conducted on the growth of larval Pacific barracuda. Houde (1972) studied the larval growth and development of the northern barracuda, *Sphyraena borealis*. Although this species is found in the Atlantic Ocean, it has a similar larval development sequence as the Pacific barracuda and grows to approximately the same size. Larvae of the northern barracuda hatch at about 2.6 mm (0.10 in) SL, while Pacific barracuda hatch at 2.3 mm (0.09 in) (Moser 1996). Flexion in the northern barracuda begins at about 7.4 mm (0.29 in) SL, while flexion in the California barracuda ranges from 5.5–7.2 mm (0.22–0.28 in). In the study on northern barracuda, larvae were described from the time of transformation to the juvenile stage. A growth rate of 0.545 mm/day (0.021 in/day) was calculated through transformation for the larvae used in this study by comparing length at age. The larvae used in this study were reared at a higher temperature than typically found in southern California; thus, the growth rate may be greater than would typically be observed in local barracuda populations.

Pacific barracuda eat mostly small fishes such as anchovies, sardines, and silversides. They in turn are prey for larger fishes such as giant seabass (*Stereolepis gigas*); and marine mammals such as sea lions and harbor seals (Frey 1971), although previous reports of marine mammals consuming barracuda have not been substantiated by gut analysis (Ally et al. 2001).

An annual northward migration of Pacific barracuda along the northern Baja California and southern California coast during late spring and early summer has been well documented through tag-recapture investigations (Pinkas 1966). This northward movement coincides with seasonal warming of nearshore coastal waters. Pacific barracuda, along with other coastal pelagic species such as bonito, have been found to be attracted to the warm water discharges of power plants in southern California (Squire 1967).

4.5.3.9.2 Population Trends and Fishery

Pacific barracuda have played a major role in California's commercial and recreational fisheries (Ally et al. 2001). Commercial landings of barracuda date back as early as 1889, with most of the landings traditionally coming from the purse seine fishery. Gill net and trolling vessels entered the fishery in the 1920s, with more recent commercial catches taken primarily by gillnets. Barracuda have been an important component in both the southern California CPFV and private boat fisheries since the mid 1920s.

The earliest attempt to manage this species began in 1915 when a 46 cm (18 in) size limit was enacted for hook and line fishermen. Since then, numerous changes have occurred for both commercial and recreational fisheries including gear restrictions, varying seasonal lengths, weight and size restrictions, and bag limits changes. Results from a 1966 CDFG study by Pinkas (1966) recommended a size limit of 71 cm (28 in) for recreational and commercial fisheries, which was later enacted in 1971, and remains in effect today. Most commercially caught barracuda are now taken primarily by gillnet with a 9 cm (3.5 in) mesh size net.

Early commercial landings for Pacific barracuda were high from the 1920s–1940s and fluctuated between 1,000–3,000 metric tons (2.2–6.6 million lbs) per year. Landings steadily declined following the Second World War and have remained relatively low since 1969, despite efforts to manage the fishery (Schultze 1983). Although commercial landings have been insignificant for the past 30 years, averaging 272 kg (600 lbs) annually, the decline was mainly attributed to increasingly restrictive regulations by Mexico for both Mexican and California fishermen fishing in waters south of California (Ally et al. 2001).

Recreational landings of Pacific barracuda rapidly declined in the late 1960s, but have steadily increased since the early 1980s (Dotson and Charter 2003). On average, over half of the total barracuda catch is from CPFVs and about 45% from private and rental boats, while only 1% are landed from shore according to data from the Marine Recreational Fisheries Statistics Survey. A late 1980s CDFG study determined that 60% of CPFV-caught barracuda were released (most were <71 cm [<28 in]), and that roughly 58% of the fish caught came from Los Angeles County (Ally et al. 1991). Higher catch success during spring and summer months and during El Nino compared to La Nina years off southern California appear to be influenced by warmer sea surface temperatures (Dotson and Charter 2003).

Table 4.5-33. Annual landings and revenue for Pacific barracuda in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	Revenue
2000	70,081	154,502	$76,201
2001	63,907	140,890	$68,240
2002	28,268	62,321	$41,890
2003	27,945	61,609	$40,717
2004	21,599	47,618	$36,266
2005	32,491	71,631	$51,826
2006	23,232	51,218	$31,945

Annual commercial landings of Pacific barracuda in the Los Angeles region since 2000 have varied from a high of 70,081 kg (154,502 lbs) in 2000 to a low of 21,599 kg (47,618 lbs) in 2006, with an average of 38,238 kg (84,300 lbs) and average net worth of $49,583 annually (Table 4.5-33). In the Santa Monica Bay area in 2006, 835 kg (1,840 lbs) were landed for a revenue of $1,670 according to specific CDFG catch block data from the area. Sport fishery catch estimates in the southern California region from 2000 to 2006 ranged from 42,000 to 313,000 fish, with an average of 170,000 fish caught annually (RecFIN 2007).

4.5.3.9.3 Sampling Results

Barracuda larvae was the sixth most abundant taxon at the entrainment station with a mean concentration of 24 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were present in the surveys from June through September. During periods of maximum abundance in September 2006, barracuda were present in the entrainment samples at average concentrations of 283 per 1,000 m^3 (264,172 gal) (Figure 4.5-43). Barracuda concentrations at the source water stations followed a similar trend with a peak average concentration in September 2006 at 280 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-44). The larvae were more abundant in nighttime samples during almost all surveys (Figure 4.5-45). The length-frequency distribution for measured samples of barracuda larvae was relatively normally distributed with most larvae from 1.75–2.75 mm (0.07–0.11 in) NL (Figure 4.5-46). The mean length of measured specimens from the entrainment station samples was 2.3 mm (0.09 in) NL with a size range from 1.2–3.1 mm (0.05–0.12 in) NL.

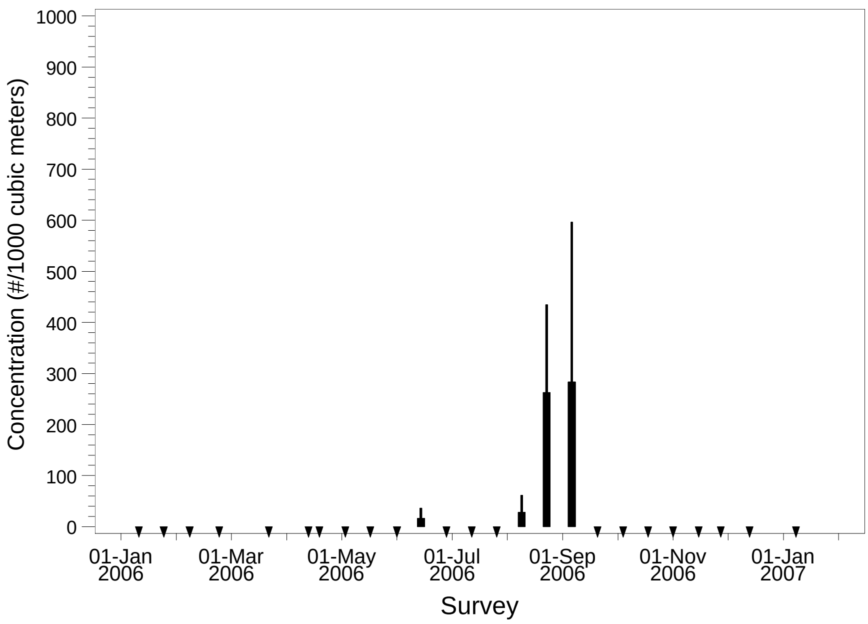


Figure 4.5-43. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of Pacific barracuda larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

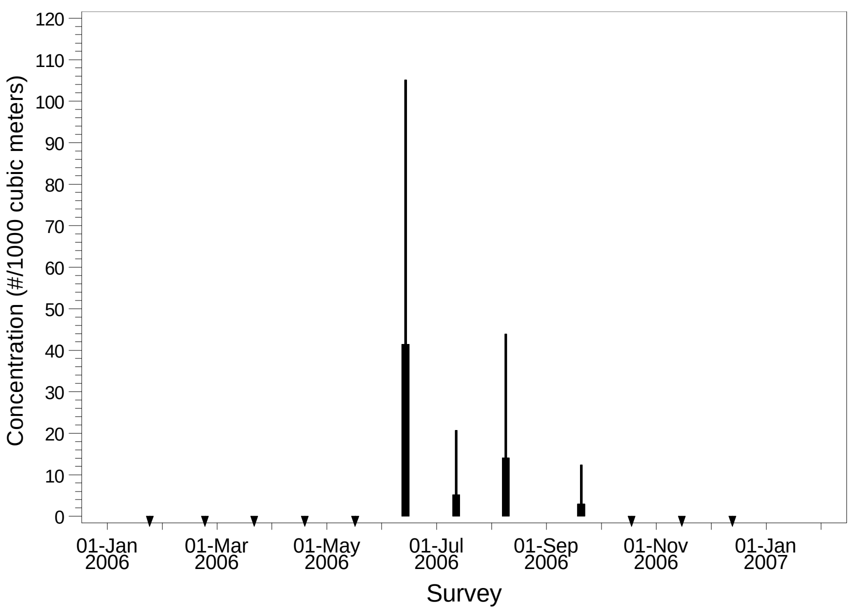


Figure 4.5-44. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of Pacific barracuda larvae collected at SGS source water stations during 2006.

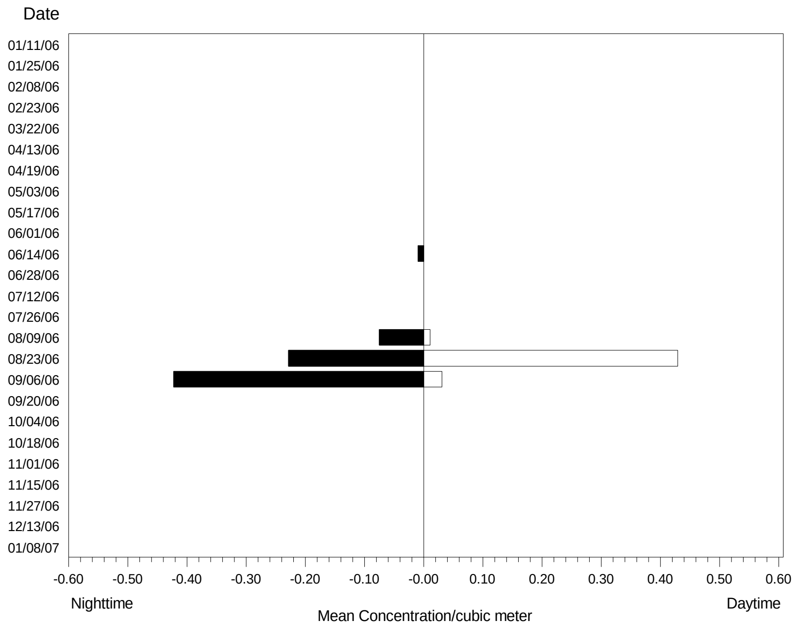


Figure 4.5-45. Mean concentration (#/1.0 m^3 [264 gal]) of Pacific barracuda larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

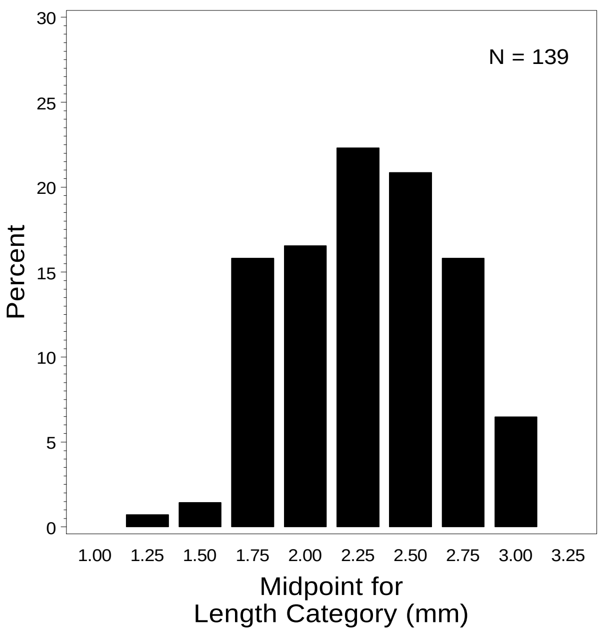


Figure 4.5-46. Length (mm) frequency distribution for larval Pacific barracuda collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.9.4 Modeling Results

The following section presents the results for empirical transport modeling of entrainment effects on Pacific barracuda. 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 SGS was estimated at 2,921,818 and 11,426,718 (standard errors of 325,670 and 953,759), respectively for Pacific barracuda using the actual cooling water flow s (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flow volumes, annual entrainment estimates increased to 3,927,243 eggs (standard error of 437,133) and 15,454,497 larvae (standard error of 1,260,305) (Table 4.5-2). 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*)

Research on the larval growth and development of the northern barracuda, *Sphyraena borealis* (Houde (1972), was used to estimate a larval growth rate of 0.545 mm/day (0.02 in/day) that was used in calculating the period of time the Pacific barracuda larvae are vulnerable to entrainment. A sample of 139 lengths from the collected Pacific barracuda larvae were 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 (2.9 mm [0.011 in]) to estimate that the larvae were exposed to entrainment for a period of approximately 1.8 days. The 0.8 day duration of the planktonic egg stage was added to the periods for the larvae to estimate a total period of exposure of 2.7 days.

The monthly estimates of *PE* for Pacific barracuda for 2006 ranged from 0 to 0.00975 based on actual cooling water flows during the period and ranged from 0 to 0.01345 based on the design flows (Table 4.5-34). Barracuda larvae were only collected from the entrainment station during two of the paired entrainment-source water surveys, and were only collected at the source water stations during four of the surveys with the largest proportion of the source population present during the June survey (f_i = 0.764 or 76.4%). The values for the actual flows in the table were used to calculate a P_M estimate of 0.0036 with a standard error of 0.0025, using the extrapolated offshore estimate of the total source population. Using the design flows, a P_M estimate of 0.0052 was calculated with a standard error of 0.0034. The model calculations are based on only two estimates of *PE* greatly increasing the uncertainty associated with the estimate for this species. The short period of larval exposure to entrainment allows larvae to be transported an average distance from offshore over the 12 surveys of 2.7 km (1.7 mi) and from alongshore of 9.2 km (5.7 mi). The small area of the extrapolated source water population is a direct result of the short period of time that the larvae were estimated to be exposed to entrainment. The level of uncertainty associated with the estimate of larval duration is also very high since the larvae collected during the study were in a limited size range and were much smaller than the size at flexion (5.5–7.2 mm [0.22–0.28 in]) reported by Moser (1996).

Table 4.5-34. *ETM* data and results for Pacific barracuda larvae based upon actual and design (maximum) CWIS flow volumes. P_M was calculated using the **offshore** extrapolated estimate of total source population and average P_S of 0.4176.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0
22-Mar-06	0	0	0	0	0
19-Apr-06	0	0	0	0	0
17-May-06	0	0	0	0	0
14-Jun-06	0.00040	0.00032	0.00079	0.00062	0.76383
12-Jul-06	0	0	0	0	0.10381
9-Aug-06	0.00975	0.00622	0.01345	0.00848	0.09700
20-Sep-06	0	0	0	0	0.03536
18-Oct-06	0	0	0	0	0
15-Nov-06	0	0	0	0	0
13-Dec-06	0	0	0	0	0
P_M	**0.0036**	0.0025	**0.0052**	0.0034	–

Alongshore extrapolation averaged 9.21 km limited by SM Bay and using total displacement. Onshore displacement averaged 2.69 km.

4.5.3.10 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).

4.5.3.10.1 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 months 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 lbs) (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).

4.5.3.10.2 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 mi from shore) since 1915, with a few seasonal and area closures since then. Today trawling is permitted in federal waters (3-200 nautical mi from shore) with a minimum mesh size of 4.5 in, 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 SCB 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 lbs) [3.9 million adult fish] and the central California biomass was 1.0 million kg (2.3 million lbs) [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 lbs (0.54 million kg) per year statewide. In southern California the commercial landings for halibut averaged 365,330 lbs (165,697 kg) between 2000 and 2006 landed for an average annual revenue of $1,370,368 (PacFIN 2007) (Table 4.5-35). In Los Angeles County, in particular, commercial catches have varied from a high of 190,464 lbs in 2000 to a low of 55,800 lbs 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 4.5-35. 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 (lbs)**	**Commercial Landings (kg)**	**Value**	**Commercial Landings (lbs)**	**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

4.5.3.10.3 Sampling Results

Halibut larvae was the eighth most abundant taxon at the entrainment station with a mean concentration of 21 per 1,000 m^3 (264,172 gal) from all the surveys (Table 4.5-1). They were collected at the entrainment station from March to November and sporadically throughout the winter months (Figure 4.5-47). Average peak abundance of halibut larvae in the entrainment samples occurred from June through October with a high of 240 larvae per 1,000 m^3 (264,172 gal) collected during one survey in late August 2006. Average concentrations of halibut in other summer surveys ranged from 25–65 larvae per 1,000 m^3 (264,172 gal). Halibut larvae were present in all surveys of the source water stations with peak average abundance occurring in July at approximately 110 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-48). There was no significant trend in abundance between daytime and nighttime samples (Figure 4.5-49). 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 4.5-50) (Moser 1996). 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.

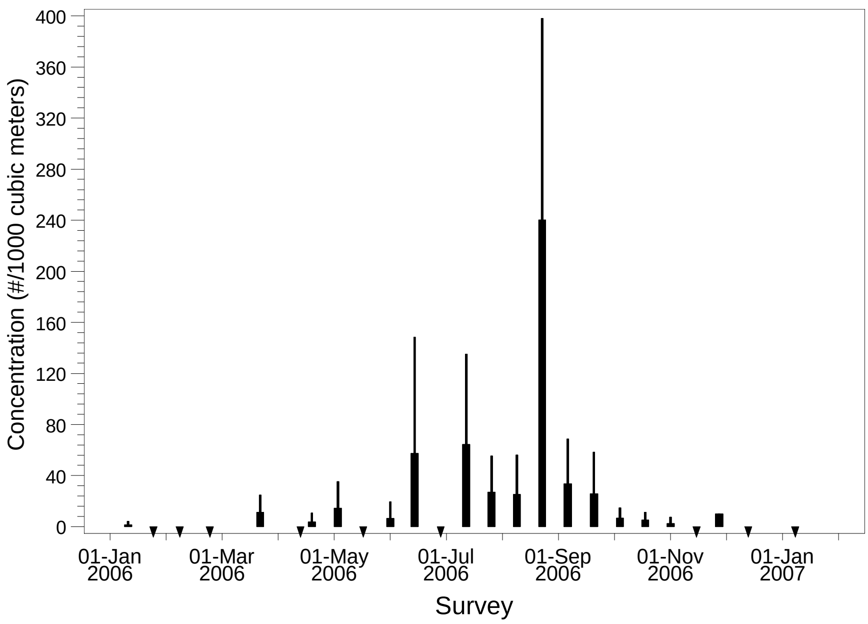


Figure 4.5-47. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of California halibut larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

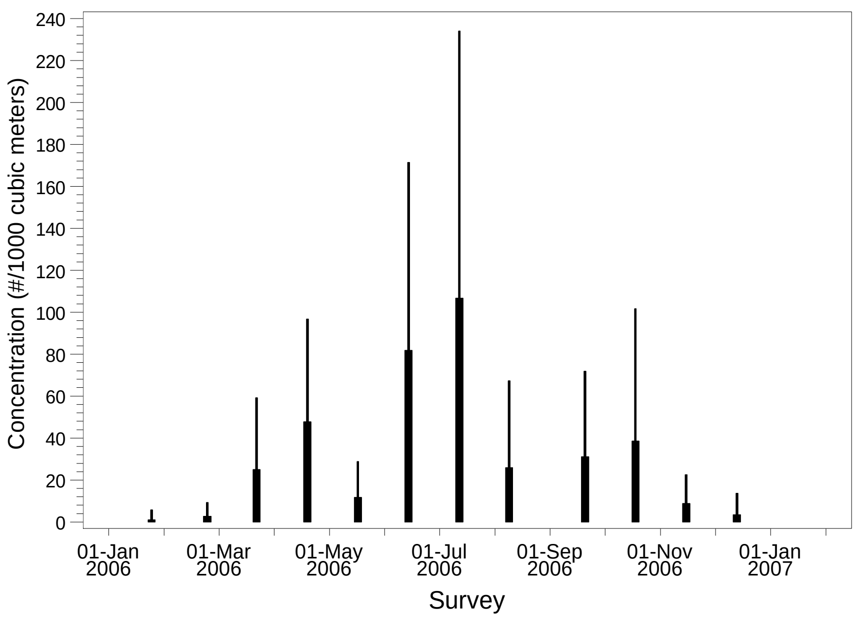


Figure 4.5-48. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of California halibut larvae collected at SGS source water stations during 2006.

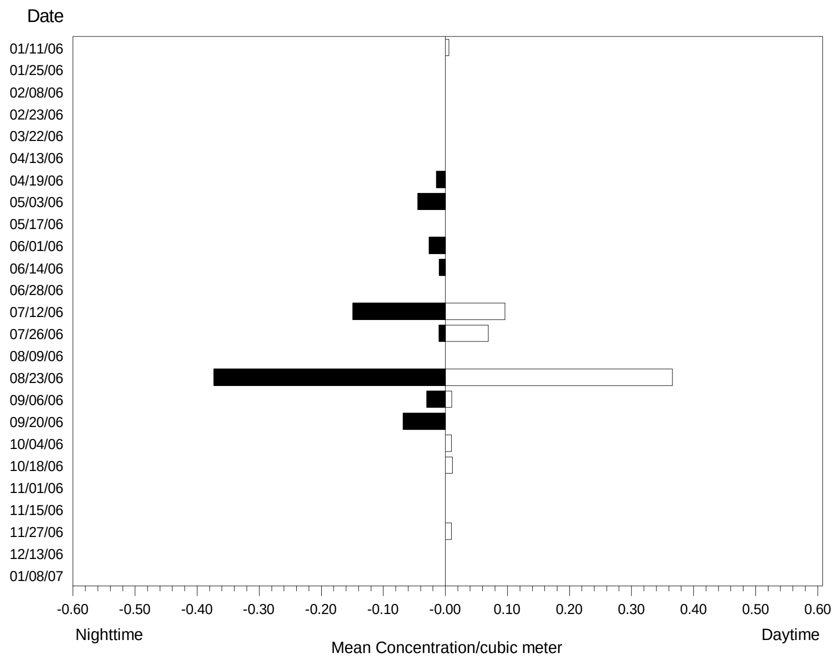


Figure 4.5-49. Mean concentration (#/1.0 m^3 [264 gal]) of California halibut larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.

Note: Negative nighttime values are a plotting artifact

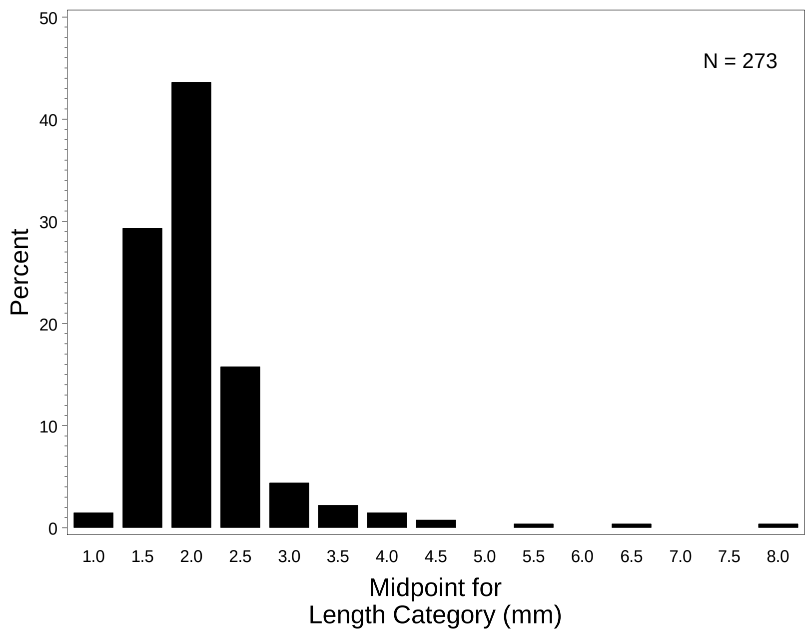


Figure 4.5-50. Length (mm) frequency distribution for larval California halibut collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.10.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of CWIS 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 SGS was estimated at 1,240,920 and 9,901,902 (standard errors of 69,969 and 515,914), respectively using actual cooling water flow during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flow volumes, annual entrainment estimates of halibut eggs and larvae increased to 2,653,308 and 14,119,061 (standard errors of 149,108 and 746,557), respectively (Table 4.5-2). 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.

<u>Fecundity Hindcasting (*FH*)</u>

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; and Gadomski and Cadell 1996). 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 12 female California halibut using the actual cooling water flows in 2006. Based on the design flow during the period, 18 adult female California halibut were lost due to the numbers of entrained eggs and larvae (Table 4.5-36). 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 4.5-36 Results of *FH* modeling for California halibut eggs and larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
Actual Flows					
Eggs					
FH Estimate	**1**	1	0	3	2
Total Entrainment	1,240,920	69,969	1	1	0
Larvae					
FH Estimate	**11**	10	3	47	44
Total Entrainment	9,901,902	515,914	10	12	2
Design Flows					
Eggs					
FH Estimate	2	1	1	6	5
Total Entrainment	2,653,308	149,108	2	2	0
Larvae					
FH Estimate	16	14	4	67	63
Total Entrainment	14,119,061	746,557	15	18	3

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 12.1days when the duration of the egg stage is added to the estimate.

The monthly estimates of *PE* for California halibut for 2006 ranged from 0 to 0.00254 using the actual cooling water flows during the period and ranged from 0 to 0.00350 using the design flows (Table 4.5-37). Although halibut larvae were only collected from the entrainment station during seven of the paired entrainment/source water surveys, they were collected at the source water stations during all of the surveys reflecting the capacity of individual females to spawn up to 13 times through 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 0.0026 (standard error of 0.0018) based on the actual flows and an estimate of 0.0037 (standard error 0.0025) based on the design flows using the extrapolated offshore estimate of the total source population. The estimate based on the actual flows using only a source water population using only extrapolated alongshore currents the estimate increased to 0.004 with a standard error of 0.005. 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) limited by the boundaries of 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. Total average displacement was 32.9 km (20.4 mi).

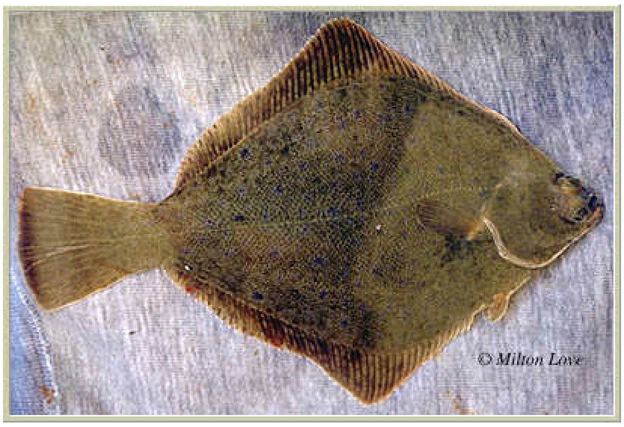
Table 4.5-37. *ETM* data and results for California halibut larvae based upon actual and design (maximum) CWIS flow volumes. P_M calculated using the **offshore** extrapolated estimate of total source population and average P_S of 0.2350.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0.00264
23-Feb-06	0	0	0	0	0.00713
22-Mar-06	0.00078	0.00052	0.00113	0.00075	0.05371
19-Apr-06	0.00012	0.00013	0.00018	0.00018	0.11455
17-May-06	0.00000	0	0.00000	0	0.03820
14-Jun-06	0.00086	0.00084	0.00169	0.00160	0.18977
12-Jul-06	0.00091	0.00052	0.00122	0.00070	0.29553
9-Aug-06	0.00254	0.00167	0.00350	0.00228	0.05077
20-Sep-06	0.00119	0.00080	0.00170	0.00114	0.10590
18-Oct-06	0.00019	0.00012	0.00027	0.00017	0.10709
15-Nov-06	0	0	0	0	0.02319
13-Dec-06	0	0	0	0	0.01152
P_M	**0.0026**	0.0018	**0.0037**	0.0025	–

Alongshore extrapolation averaged 32.19 km limited by SM Bay and 32.89 km using total displacement. Onshore displacement averaged 8.24 km.

4.5.3.11 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).



4.5.3.11.1 Life History and Ecology

Diamond turbot is found in bays and shallow coastal waters with sandy or muddy bottoms. The diamond turbot occurs in water depths between less than 1 m and 50 m, 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 the 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).

4.5.3.11.2 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. CDFG reported annual landings of 'turbot' in California of about 5,900 kg (13,000 lbs) and 3,000 kg (6,600 lbs) for the years 2001 and 2002, respectively. The proportion of this total contributed by diamond turbot is not known.

4.5.3.11.3 Sampling Results

Diamond turbot larvae was the fourteenth most abundant taxon at the entrainment station with a mean concentration of 9 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were present throughout the year in most surveys with increased abundance in the fall and early winter (Figure 4.5-51). Peak abundance in the entrainment samples occurred in late November at 45 larvae per 1,000 m^3 (264,172 gal). Source water samples followed a similar trend with peak abundance occurring in October at approximately 20 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-52). There was no significant trend in abundance between daytime and nighttime samples (Figure 4.5-53). 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 4.5-54). 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.

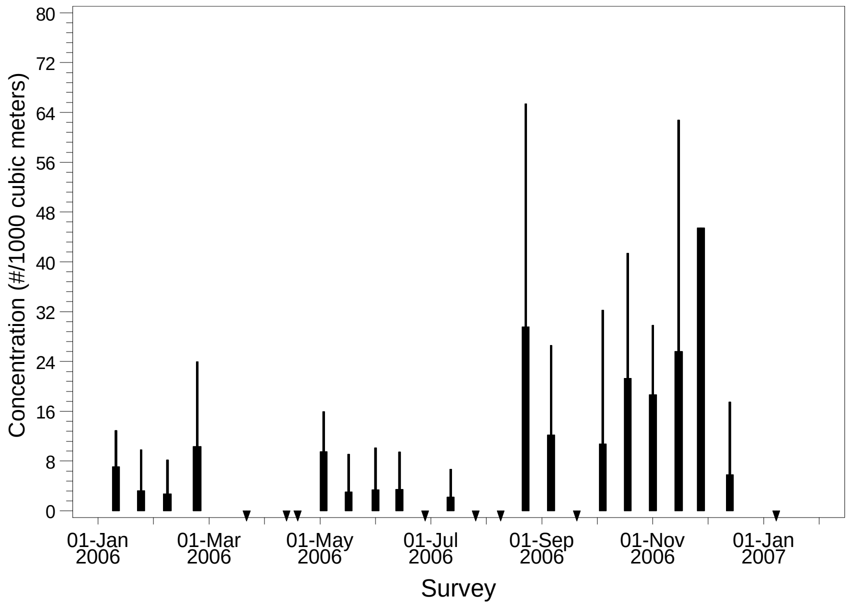


Figure 4.5-51. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of diamond turbot larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

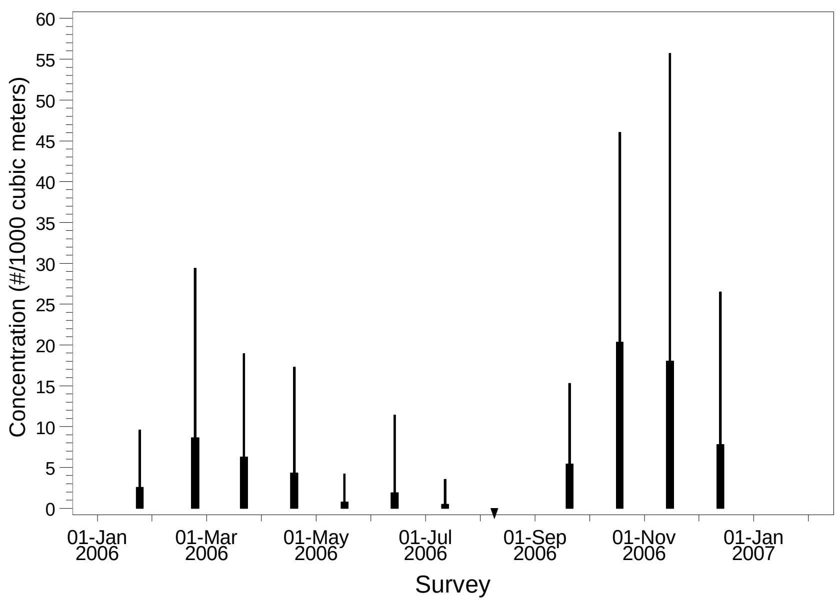


Figure 4.5-52. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of diamond turbot larvae collected at SGS source water stations during 2006.

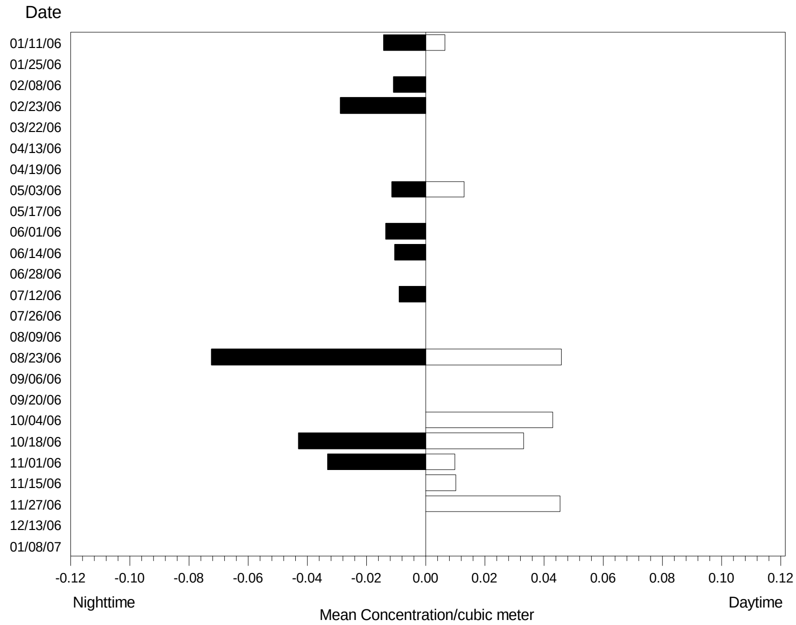


Figure 4.5-53. Mean concentration (#/1.0 m^3 [264 gal]) of diamond turbot larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

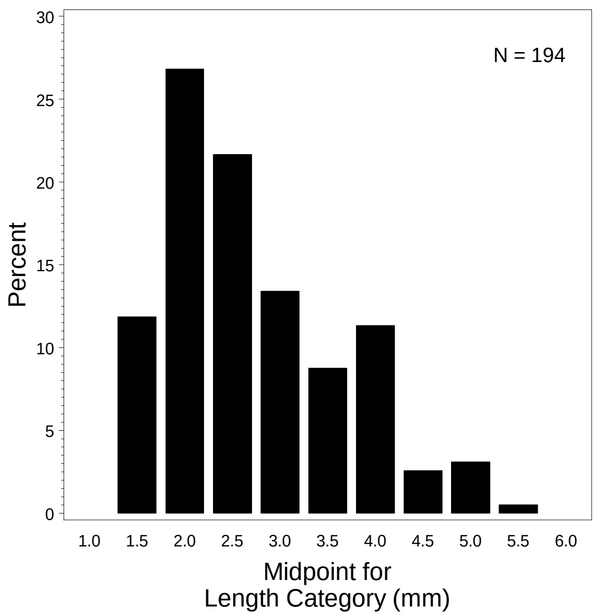


Figure 4.5-54. Length (mm) frequency distribution for larval diamond turbot collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.11.4 Modeling Results

The following section presents 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 SGS was estimated at 57,905 and 3,849,543 (standard errors of 15,813 and 161,624), respectively, for diamond turbot (Table 4.5-2), although many of the unidentified Pleuronectidae eggs may have also been diamond turbot eggs. If the CWIS plumps were run at the design (maximum capacity) flows, annual entrainment estimates of eggs and larvae increased to 94,696 (standard error of 25,309) and 5,715,338 (standard error of 236,224), respectively (Table 4.5-2). 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 the values of 2.2 days and 0.19 mm/day (0.01 in/day) from California halibut were 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 95^{th} 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 was added to the period for the larvae to estimate a total period of exposure of 15.4 days.

The monthly estimates of *PE* for diamond turbot for 2006 ranged from 0 to 0.00802 using the actual cooling water flows during the period and ranged from 0 to 0.01578 using the design flows (Table 4.5-38). Diamond turbot larvae were collected during eight 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 = 0.276 or 27.6%). The values in the table were used to calculate a P_M estimate of 0.0135 (standard error of 0.0075) based on actual cooling water flows and an estimate of 0.0203 (standard error 0.0112) based on the design flows using the alongshore extrapolation of the total source population. The period of larval exposure to entrainment allows larvae to be transported an average distance alongshore of 36.3 km (22.6 mi) limited by the boundaries of the Santa Monica Bay, indicating that larvae over a large portion of the total 60 km (37 mi) coastline of the bay may be subject to entrainment. Total average displacement was 37.0 km (23.0 mi).

Table 4.5-38. *ETM* data and results for diamond turbot larvae based upon actual and design (maximum) CWIS flow volumes. P_M calculated using the **alongshore** extrapolated estimate of total source population and average P_S of 0.2459.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0.00153	0.00171	0.00307	0.00343	0.05535
23-Feb-06	0.00347	0.00257	0.00567	0.00416	0.08804
22-Mar-06	0	0	0	0	0.10309
19-Apr-06	0	0	0	0	0.06846
17-May-06	0.00249	0.00287	0.00523	0.00597	0.02808
14-Jun-06	0.00802	0.01070	0.01578	0.02067	0.01067
12-Jul-06	0.00619	0.00840	0.00832	0.01126	0.01303
9-Aug-06	0	0	0	0	0
20-Sep-06	0	0	0	0	0.11231
18-Oct-06	0.00260	0.00133	0.00373	0.00190	0.27624
15-Nov-06	0.00644	0.00486	0.00943	0.00711	0.13137
13-Dec-06	0.00246	0.00266	0.00373	0.00400	0.11336
P_M	**0.0135**	0.0075	**0.0203**	0.0112	–

Alongshore extrapolation averaged 36.27 km limited by SM Bay and 36.96 km using total displacement. Onshore transport averaged 10.46 km.

4.5.3.12 Sanddabs (*Citharichthys* spp.)

Dan Dugan

There are three common species of sanddabs in Californian 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).

4.5.3.12.1 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, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, 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).

4.5.3.12.2 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 SCB by the 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 lbs) (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 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 lbs) in 2000 to a low of 6,800 kg (15,000 lbs) in 2006, with an average of 19,700 kg (43,400 lbs) 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 lbs) of sanddabs were landed with a total value of $62.50 according to specific CDFG catch block data from the area.

4.5.3.12.3 Sampling Results

Sanddab larvae was the tenth most abundant taxon at the entrainment station with a mean concentration of 15 per 1,000 m^3 (264,172 gal) from all of the surveys (Table 4.5-1). Speckled sanddab was the most abundant species within the family at 97% by mean concentration, with Pacific sanddab only comprising 3%, and unidentified sanddabs comprising less than 1% (Table 4.5-39). They were present at the entrainment station from February to November in most surveys with peak average abundance in September at 126 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-55). Sanddab larvae were present in all source water surveys throughout the year with peak average abundance occurring in late June at approximately 130 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-56). Sanddab larvae were more common in the nighttime samples than in daytime samples (Figure 4.5-57). 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 4.5-58; 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.

Table 4.5-39. Average concentrations and annual entrainment mortality of sanddab taxa at SGS.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	% of Total	Annual Entrainment (Actual Flow)	Annual Entrainment (Design Flow)
Larval Fishes						
Citharichthys stigmaeus	speckled sanddab	14.40	131	96.65	6,550,044	9,385,364
Citharichthys sordidus	Pacific sanddab	0.41	3	2.74	160,534	259,946
Citharichthys spp.	sanddabs	0.09	1	0.61	41,541	59,611
		14.90	135			
Fish Eggs						
Citharichthys spp. (eggs)	sanddab eggs	574.02	4,194	100.00	264,262,380	407,681,780

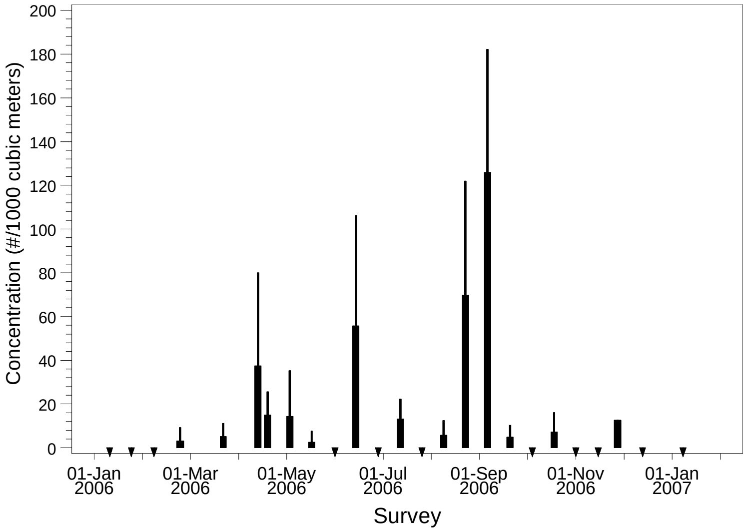


Figure 4.5-55. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of sanddab larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

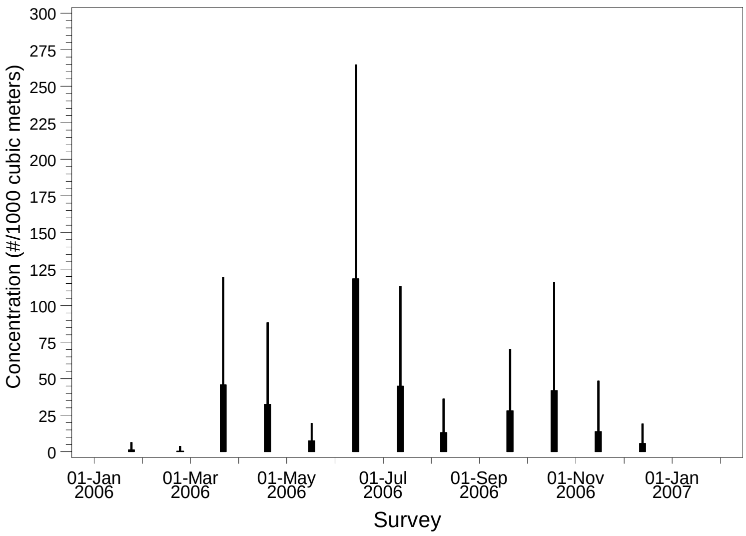


Figure 4.5-56. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of sanddab larvae collected at SGS source water stations during 2006.

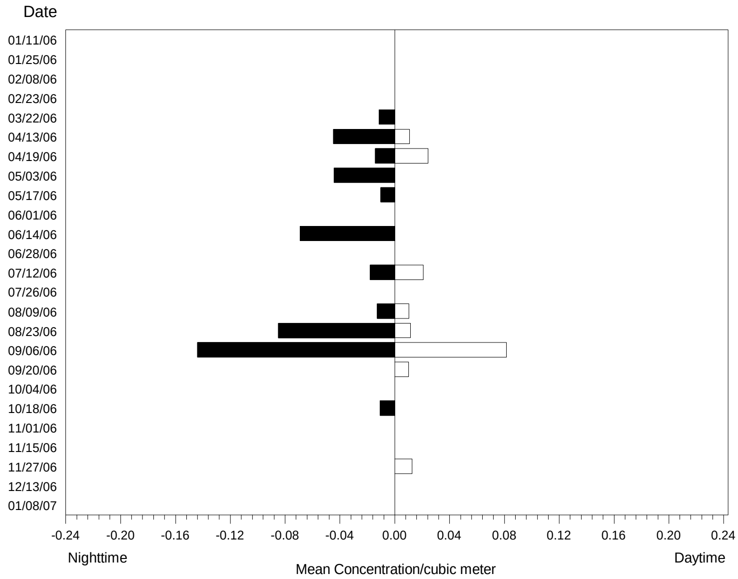


Figure 4.5-57. Mean concentration (#/1.0 m^3 [264 gal]) of sanddab larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.
Note: Negative nighttime values are a plotting artifact

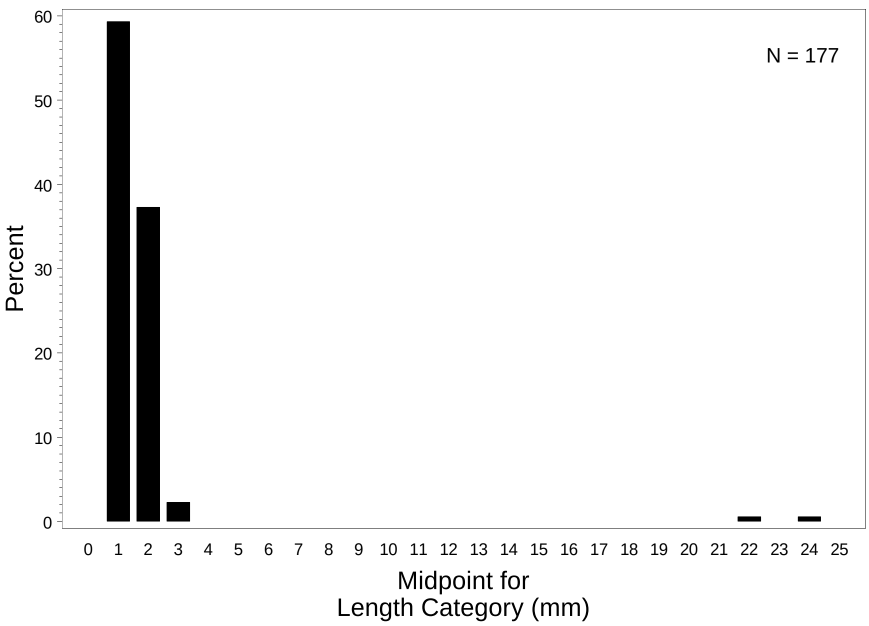


Figure 4.5-58. Length (mm) frequency distribution for larval sanddabs collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.12.4 Modeling Results

The following section presents 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, but enough information was available to estimate *FH* based on numbers of eggs entrained. Total annual entrainment of eggs and larvae at SGS using the actual cooling water flow volume was estimated at 264,262,380 and 6,752,119 (standard errors of 8,657,737 and 258,709), respectively (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flow volumes, annual entrainment estimates increased to 407,681,780 eggs and 9,704,922 larvae (standard errors of 12,825,952 and 380,216 respectively). 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 2.17 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 an average age in the population of 4.25 years (Ford 1965, Love 1996).

The estimated numbers of female sanddabs whose lifetime reproductive output was entrained through the SGS CWIS for the 2006 period was estimated as 1,605 based on the actual cooling water flows during the period and was estimated at 2,477 based on the design flows (Table 4.5-40). 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 4.5-40. Results of *FH* modeling for sanddab eggs based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
Actual Flows					
FH Estimate	**1,605**	1,140	499	5,163	4,664
Total Entrainment	264,262,380	17,285,291	1,433	1,778	345
Design Flows					
FH Estimate	**2,477**	1,758	770	7,962	7,191
Total Entrainment	407,681,780	25,577,909	2,221	2,732	511

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.

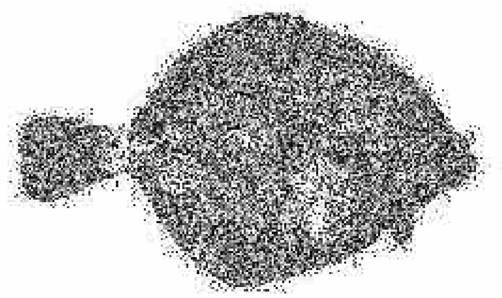
The monthly estimates of *PE* for sanddabs for 2006 ranged from 0 to 0.00643 using the actual flows during the period and ranged from 0 to 0.01052 using the design flows (Table 4.5-41). Sanddab larvae were collected during all nine of the paired entrainment/source water surveys from February through October 2006 with the largest proportion of the source population present during the October survey (f_i = 0.085 or 8.5%). The values in the table were used to calculate a P_M estimate of 0.0008 (standard error of 0.0005) based on the actual flows and an estimate of 0.0013 (standard error of 0.0007) based on the design flows, using the offshore extrapolation value for the estimate of the total source population. 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 4.5-41. *ETM* data and results for sanddab larvae based upon actual and design (maximum) CWIS flow volumes. P_M calculated using the **offshore** extrapolated estimate of total source population and average P_S of 0.3755.

	Actual Flows		**Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0.00553
23-Feb-06	0.00643	0.00868	0.01052	0.01411	0.00193
22-Mar-06	0.00014	0.00009	0.00020	0.00013	0.16159
19-Apr-06	0.00095	0.00043	0.00134	0.00061	0.07308
17-May-06	0.00028	0.00029	0.00059	0.00061	0.02814
14-Jun-06	0.00056	0.00033	0.00111	0.00063	0.32993
12-Jul-06	0.00046	0.00019	0.00062	0.00026	0.13955
9-Aug-06	0.00139	0.00089	0.00191	0.00122	0.02463
20-Sep-06	0.00027	0.00016	0.00038	0.00023	0.10332
18-Oct-06	0.00041	0.00026	0.00059	0.00037	0.08039
15-Nov-06	0	0	0	0	0.02618
13-Dec-06	0	0	0	0	0.02573
P_M	**0.0008**	0.0005	**0.0013**	0.0007	–

Alongshore extrapolation averaged 23.93 km limited by SM Bay and using total displacement. Onshore displacement averaged 6.19 km.

4.5.3.13 Spotted Turbot (*Pleuronichthys ritteri*)



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Spotted turbot (*Pleuronichthys ritteri*) is classified in the family of right-eyed flatfishes (Pleuronectidae). It is one of twenty pleuronectid species that occur off California. The species ranges from Bahia Magdalena, southern Baja California, to northern California (Love et al. 2005); however, is considered rare north of Santa Barbara.

4.5.3.13.1 Life History and Ecology

Spotted turbot are found in shallow coastal waters over soft bottom substrate. They occur in the intertidal zone to 197 m (646 ft) (Love et al. 2005). They feed primarily on benthic invertebrates such as polychaetes, anemones, clams or amphipods (Fitch 1963; Luckinbill 1969). Predators include piscivorous fish, California sea lions, Pacific angel shark, and leopard sharks (Luckinbill 1969).

Life history traits of the spotted turbot have not been extensively studied. Spotted turbot are sexually mature at 15 cm (5.9 in) and grow to about 29 cm (11.5 in) (Love 1996). Age and growth studies of a closely related species hornyhead turbot, *Pleuronichthys verticalis*, suggest a maximum age of 25 years (Cooper 1996). This species, which has a similar diet to the spotted turbot, has a slow growth rate of 10–15 mm (0.4–0.6 in) SL per year, with females maturing at a larger size than males (Cooper 1994; Cooper 1996).

Spawning occurs year-round and peaks July through October (Love 1996; Moser 1996). Eggs are typically 0.9–1.1 mm (0.04 in) in diameter. Larvae of spotted turbot hatch at about 2.1 mm (0.08 in). Age and growth studies have not been conducted for spotted turbot, but some work has been done on the hornyhead turbot. These two species have similar larval development stages, hatching at about 2.0 mm (0.08 in) and undergoing flexion at about 5.0 mm (0.2 in) (Moser 1996). Transformation to the adult stage occurs from 6.4–10.0 mm (0.25–0.40 in) for spotted turbot and between 7.9–11.0 mm (0.31–0.43 in) for the hornyhead turbot. Farris (1953) determined growth rates for laboratory-raised hornyhead turbot (n = 68) up to 10 dph. A growth rate of 0.06 mm/day (0.002 in/day) was calculated by evaluating length at age. This value likely under-estimates natural growth rates since larvae were not fed once the yolk sac stage was depleted (day 4). The growth rate for the yolk sac larvae (0–4 dph, n = 24) was calculated to be 0.26 mm/day (0.01 in/day).

The pelagic larval duration is not known; however, Cooper (1994) suggests a planktonic larval duration of 30 days for hornyhead turbot. This species settles at 19 mm (0.75 in), whereas spotted turbot settle at 38 mm (1.5 in), suggesting a longer larval duration period (Love 1996). Newly settled larvae are found in the subtidal zone down to 9.1 m (30 ft). Larvae have been collected as far as 160 km (100 mi) offshore, but most occur within 64 km (40 mi) of the coast (Love 1996).

4.5.3.13.2 Population Trends and Fishery

Spotted turbot is common to the coastal areas of southern California and has been collected in many surveys of coastal fish communities. They are common to the open coastal areas of Mission Bay in San Diego (Kramer 1991b), and were the third most abundant flatfish in a survey of shallow-water coastal areas of San Diego County. They occurred in 50% or more of all coastal samples in a beam trawl survey off of Los Angeles County (Allen and Herbinson 1991). It was the dominant species in trawls of the semi-protected coastal areas (off of Hermosa Beach as well as Long Beach). They contributed to the highest biomass (25%) in this study.

The earlier 316(b) study of the SGS in 1978–1979 (IRC 1981) measured mean density values of *Pleuronichthys* species complex larvae. Larvae were not identified to the species level; thus, it is not known what percentage of larvae were *Pleuronichthys verticalis* versus *P. ritteri*. *Pleuronichthys guttulatus* larval abundances were treated separately and were not analyzed due to low abundances. Larvae were present sporadically throughout the study, with highest concentrations from February to May. Survey means for the near-field station varied from 0 to 380 larvae per 1,000 m^3 (264,172 gal) with a mean of 20 per 1,000 m^3 (264,172 gal). These concentrations are more than double the mean concentrations recorded in 2006 for *Pleuronichthys ritteri*.

A total of 30 inner shelf and 16 bay and harbor stations were sampled during 2003 within the SCB by the SCCWRP (Allen et al. 2007). Species abundance was 0.75 fish per station for spotted turbot at bay and harbor stations during 5–10 minute trawls. This species was not as abundant at inner shelf stations as the abundance was 0.47 fish per station.

Spotted turbot are of little interest to recreational or commercial fishermen. It is occasionally taken incidentally in otter trawls. It is usually reported under the grouping of 'unspecified turbot' along with several other flatfish species. CDFG reported average annual landings of 'turbot' in California of about 2.6 metric tons (mt) (57,320 lbs) between 2000–2005, with a high of 5.9 mt (130,000 lbs) in 2001 (PacFIN 2007). The proportion of this total contributed by spotted turbot is not known.

4.5.3.13.3 Sampling Results

Spotted turbot larvae was the thirteenth most abundant taxon at the entrainment station with a mean concentration of 8 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were collected sporadically throughout the year at the entrainment station except from July through October when they were present at much larger average concentrations. Average abundance of spotted turbot larvae peaked in September 2006 at 110 larvae per 1,000 m^3 (264,172 gal), which was over four times greater than in previous surveys (Figure 4.5-59). They were present at the source water station throughout the year except in January with peak average abundance in July 2006 at 25 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-60). There was no apparent trend in abundance between daytime and nighttime samples (Figure 4.5-61). The length frequency plot for the 82 larvae measured from the Santa Monica Bay entrainment samples was skewed toward the lower size classes of 1.5-2.5 mm (0.06–0.10 in) NL, indicating that most sampled larvae were newly hatched based on the reported hatch size of 2 mm (0.08 in) (Figure 4.5-62; Moser 1996). Few larvae in the 3.0–6.5 mm (0.12–0.25 in) size classes were also sampled. The mean length of measured specimens from the entrainment station samples was 2.1 mm (0.08 in) NL, with a size range from 1.3 mm (0.05 in) to 6.6 mm (0.26 in) NL.

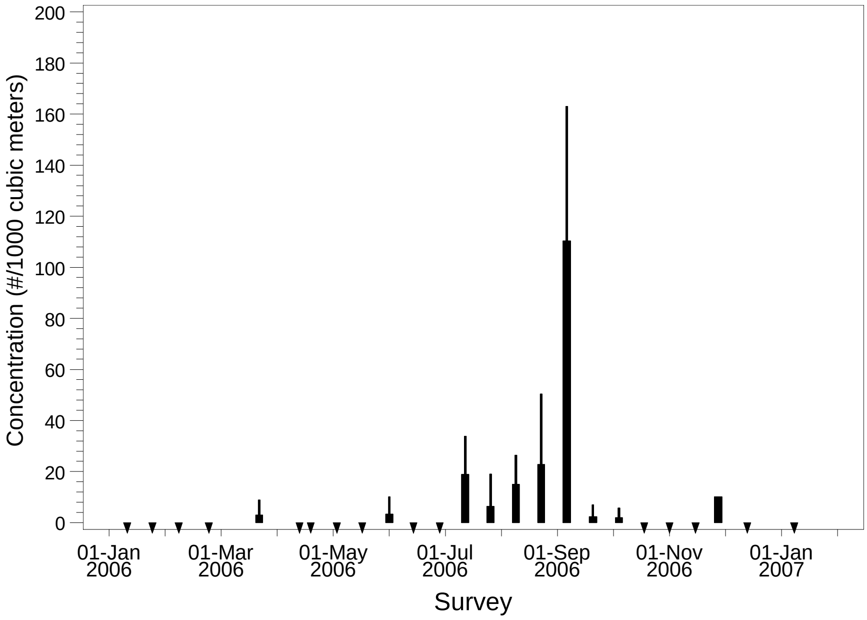


Figure 4.5-59. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of spotted turbot larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

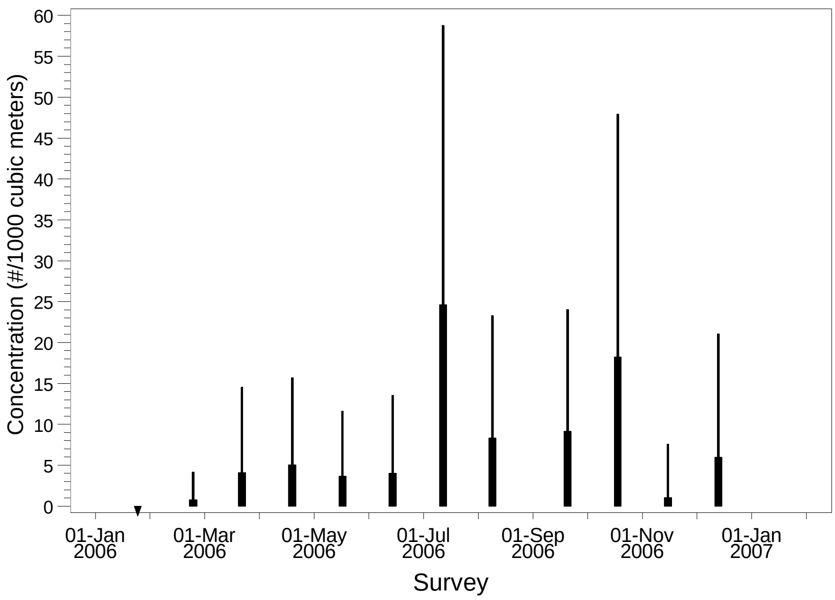


Figure 4.5-60. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of spotted turbot larvae collected at SGS source water stations during 2006.

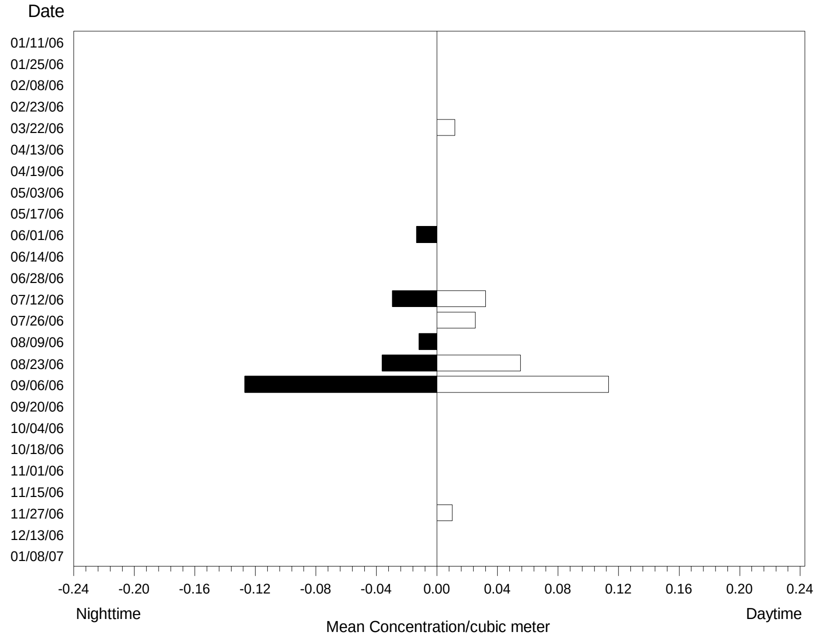


Figure 4.5-61. Mean concentration (#/1.0 m^3 [264 gal]) of spotted turbot larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling from January 2006 through January 2007.

Note: Negative nighttime values are a plotting artifact

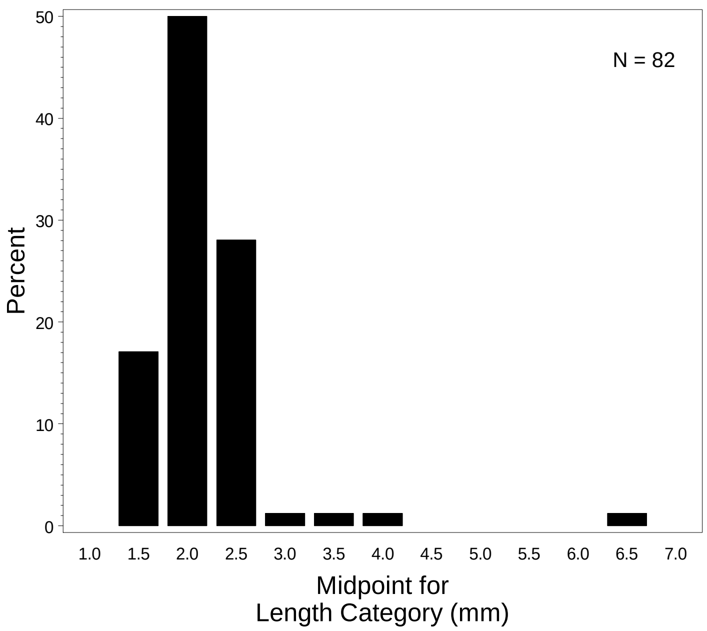


Figure 4.5-62. Length (mm) frequency distribution for larval spotted turbot collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.13.4 Modeling Results

The following section presents the results for empirical transport modeling of entrainment effects on spotted 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 larvae at SGS was estimated at 3,819,479 (standard error of 171,028) using the actual cooling water flow (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flow volumes, annual entrainment estimates increased to 5,149,021 larvae (standard error of 227,060) (Table 4.5-2). Although spotted turbot eggs are likely to be entrained at SGS, they are not distinguishable from other Pleuronectidae eggs. 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 the planktonic duration of the egg stage or larval growth for spotted turbot, so estimates from a closely related species, hornyhead turbot were used in the model calculations. Although Farris (1953) determined a growth rate for laboratory-raised hornyhead turbot at up to 10 days post hatch (dph) of 0.06 mm/day (0.002 in/day), most of the larvae collected from this study were small and newly hatched, so his growth rate of 0.26 mm/day (0.01 in/day) for yolk sac larvae up to 4 dph was used in calculating larval exposure to entrainment. A sample of 82 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 1.7 mm (0.07 in) and the 95th percentile value of the measurements (2.7 mm [0.11 in]) to estimate that the larvae were exposed to entrainment for a period of approximately 4.0 days. The 4.0 day duration of the planktonic egg stage was added to the period for the larvae to estimate a total period of exposure of 8.0 days.

The monthly estimates of *PE* for spotted turbot for 2006 ranged from 0 to 0.00375 using the actual flows during the period and from 0 to 0.00517 using the design flows (Table 4.5-42). Spotted turbot larvae were only collected during four of the paired entrainment/source water surveys although they were collected from the source water stations during all but one survey. The largest proportion of the source population was present during the July survey (f_i = 0.308 or 30.8%). The values in the table were used to calculate a P_M estimate of 0.0024 (standard error of 0.0008) based on the actual flows during the period and an estimate of 0.0033 (standard error of 0.0011) based on the design flows, using the offshore extrapolation for the estimate of the total source population. The period of larval exposure to entrainment allows larvae to be transported an average distance onshore of 6.9 km (4.3 mi) and alongshore of 26.3 km (16.3 mi) within 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.

Table 4.5-42. *ETM* data and results for spotted turbot larvae based upon actual and design (maximum) CWIS flow volumes. P_M calculated using the **alongshore** extrapolated estimate of total source population and average P_S of 0.3266.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0.01188
22-Mar-06	0.00101	0.00112	0.00146	0.00160	0.04234
19-Apr-06	0	0	0	0	0.04624
17-May-06	0	0	0	0	0.04710
14-Jun-06	0	0	0	0	0.05944
12-Jul-06	0.00099	0.00045	0.00133	0.00060	0.30779
9-Aug-06	0.00375	0.00164	0.00517	0.00225	0.07856
20-Sep-06	0.00036	0.00037	0.00051	0.00052	0.12331
18-Oct-06	0	0	0	0	0.19942
15-Nov-06	0	0	0	0	0.00264
13-Dec-06	0	0	0	0	0.08129
P_M	**0.0024**	0.0008	**0.0033**	0.0011	–

4.5.3.14 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).

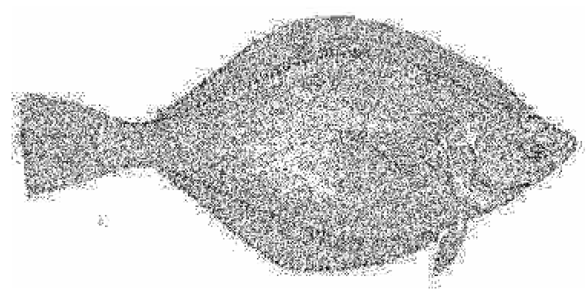


Illustration credit: NOAA

4.5.3.14.1 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 years) while males mature at 29 cm (11.5 in, 2–3 years).

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, M. 1982; Emmett et al. 1991; Love 1996).

4.5.3.14.2 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 lbs) and in 1948 in the northern area (Eureka to Vancouver) at 4,008 mt (8.84 million lbs) (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 lbs) in 2003) to 199 mt (438,700 lbs) in 2001 in the southern area, and ranged from 569 mt (1.25 million lbs) in 2000 to 1,067 mt (2.35 million lbs) 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).

4.5.3.14.3 Sampling Results

English sole larvae was the seventeenth 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). They were collected in entrainment samples during only two surveys in March and April (Figure 4.5-63), and at the source water stations from February through June (Figure 4.5-64). The low numbers of larvae collected during only two surveys did not allow for an evaluation of day-night patterns in abundance. The length frequency plot for the 97 larvae measured from all of the Santa Monica Bay entrainment samples was skewed toward the lower size classes of 2.5–3.5 mm NL, indicating that most sampled larvae were newly hatched based on the reported hatch size of 2.4 mm (Figure 4.5-65; Moser 1996). The mean length of measured specimens from the entrainment station samples was 3.1 mm NL with a size range of 1.9–13.8 mm NL.

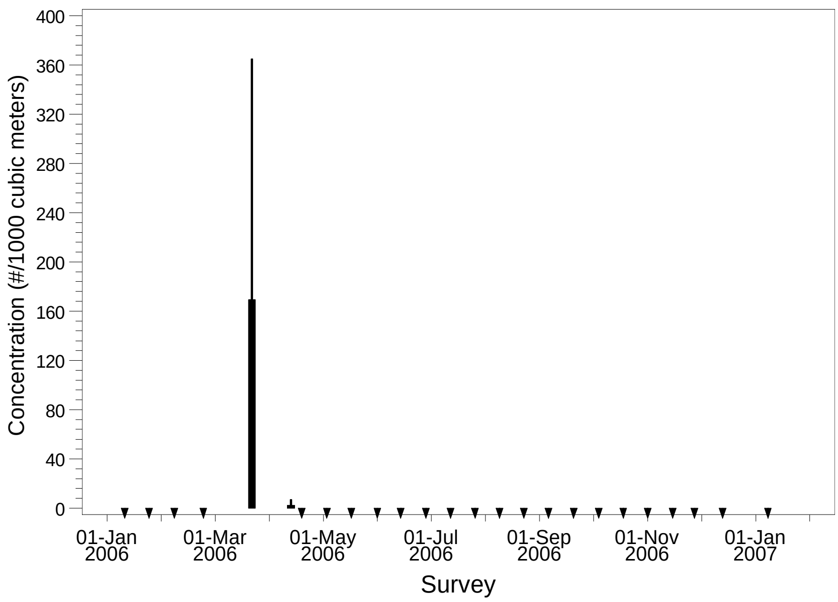


Figure 4.5-63. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of English sole larvae collected at SGS entrainment Station E1 from January 2006 through January 2007.

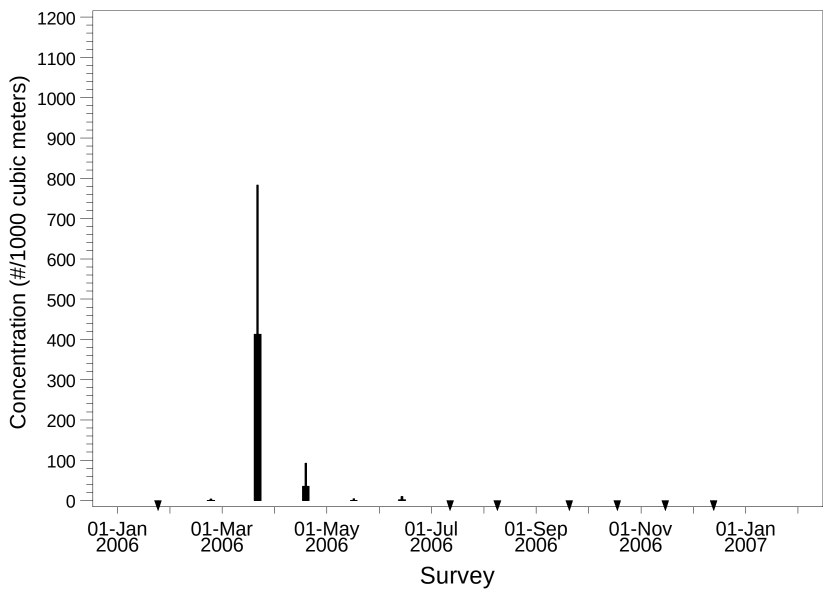


Figure 4.5-64. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of English sole larvae collected at SGS source water stations during 2006.

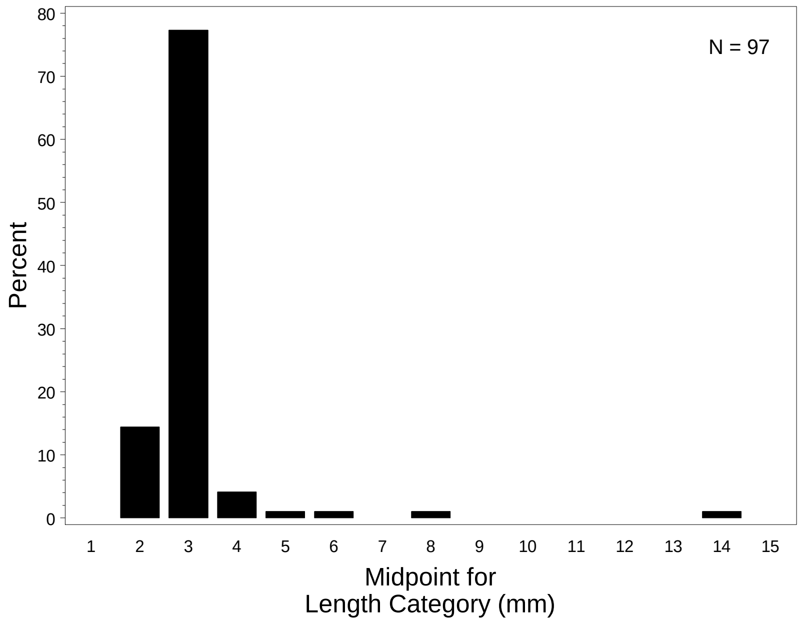


Figure 4.5-65. Length (mm) frequency distribution for larval English sole collected at entrainment stations in Santa Monica Bay from January 2006 through January 2007.

4.5.3.14.4 Modeling Results

English sole were present at both the entrainment and source water stations during only one survey (March) allowing only a single estimate of *PE* to be computed (Table 4.5-43). Therefore, no estimate of P_M was calculated. Total annual entrainment of larvae at SGS was estimated at 5,321,852 (standard error of 625,397) based on the actual cooling water flow during the period, and if the CWIS pumps were run at the design (maximum capacity) flows, annual entrainment estimates increased to 7,679,874 larvae (standard error of 898,531) (Table 4.5-2). Although English sole eggs are likely to be entrained at SGS, they are not distinguishable from other Pleuronectidae eggs.

Table 4.5-43. *ETM* data for English sole larvae.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0
23-Feb-06	0	0	0	0	0.00116
22-Mar-06	0.00056	0.00033	0.00080	0.00047	0.90556
19-Apr-06	0	0	0	0	0.08392
17-May-06	0	0	0	0	0.00242
14-Jun-06	0	0	0	0	0.00694
12-Jul-06	0	0	0	0	0
9-Aug-06	0	0	0	0	0
20-Sep-06	0	0	0	0	0
18-Oct-06	0	0	0	0	0
15-Nov-06	0	0	0	0	0
13-Dec-06	0	0	0	0	0
P_M*	–	–	–	–	–

* P_M estimates and standard errors were not calculated because only a single estimate of PE was available from the field data.

4.5.3.15 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 is managed under the Coastal Pelagic Species FMP (PFMC 1998).

4.5.3.15.1 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 4,000–9,000 eggs per female (MBC 1987). Macewicz et al. (2004) report an average fecundity of 3,844 oocytes based on an average female length of 129 mm (5.1 in) dorsal mantle length (DML).

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

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

Squid 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 56–84 g (0.123–0.185 lbs) (Vojkovich 1998), with spawning males normally being larger than females. Males reach 19 cm DML (7.5 in), a maximum weight of about 130 g (0.287 lbs), and have larger heads and thicker arms than females (PFMC 1998). Females reach about 17 cm DML (6.7 in) and a maximum weight of 90 g (0.198 lbs).

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

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

4.5.3.15.2 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 364, which not only initiated closures and established a fishery permit fee, but designated funds from the permits to be used for squid research and management.

The California fishery for market squid began in Monterey Bay in the late-1800s (Vojkovich 1998). It expanded into southern California only after the 1950s, and prior to 1987, catches in southern California rarely exceeded 20,000,000 kg (44,100,000 lbs). After that, landings increased four-fold until the fishery collapsed in 1998, and California squid fishers sought federal disaster assistance (Zeidberg et al. 2004). In California, most squid marketed for human consumption is frozen, but smaller amounts are canned or sold fresh (PFMC 1998). Squid are also sold live and frozen for bait. Los Angeles area commercial landings have varied substantially since 2000, ranging between 7.7 and 44.8 million kg (16.9 and 98.8 million pounds) annually (PacFIN 2007), with both the total catch and market value increasing substantially the last two years (Table 4.5-44). Los Angeles area landings in 2005 totaled 31,59,678 kg (69,573,734 lbs) 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 lbs) at an estimated value of $169,920 (CDFG 2007b).

Table 4.5-44. Annual landings and revenue for squid in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	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

4.5.3.15.3 Sampling Results

Market squid hatchlings were the third most abundant invertebrate taxon collected at the entrainment station with a mean concentration of 8 per 1,000 m^3 (264,172 gal) from all of the surveys (Table 4.5-3). They were collected in entrainment samples during only three surveys in April and early May (Figure 4.5-66). They were collected in lower concentrations at the source water stations, but in a greater number of surveys (Figure 4.5-67). The low numbers of larvae collected during two of the three surveys did not allow for an evaluation of day-night patterns in abundance. The lengths of the squid hatchlings were not measured.

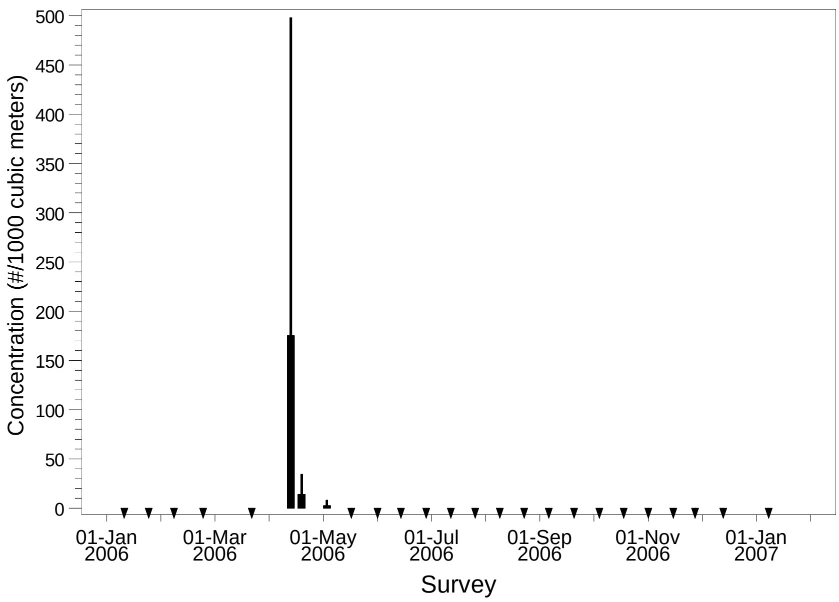


Figure 4.5-66. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of market squid hatchlings collected at SGS entrainment Station E1 from January 2006 through January 2007.

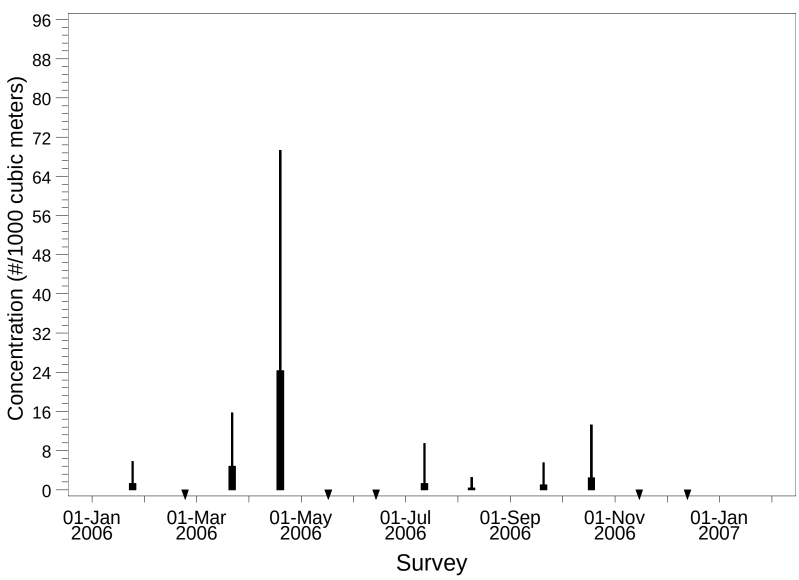


Figure 4.5-67. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of market squid hatchlings collected at SGS source water stations during 2006.

4.5.3.15.4 Modeling Results

Modeling of entrainment effects on market squid hatchlings was not done since the larvae were only collected during three surveys at the entrainment station and 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 4.5-45). Therefore, no estimate of P_M was calculated. Total annual entrainment of squid hatchlings at SGS was estimated at 3,367,525 (standard error of 779,783) based on actual cooling water flow during the period and at 4,929,707 (standard error of 1,134,986) based on the design (maximum capacity) flow volume (Table 4.5-2).

Table 4.5-45. *ETM* data for market squid hatchlings.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
25-Jan-06	0	0	0	0	0.03880
23-Feb-06	0	0	0	0	0
22-Mar-06	0	0	0	0	0.12287
19-Apr-06	0.00062	0.00047	0.00087	0.00067	0.67935
17-May-06	0	0	0	0	0
14-Jun-06	0	0	0	0	0
12-Jul-06	0	0	0	0	0.03979
9-Aug-06	0	0	0	0	0.01299
20-Sep-06	0	0	0	0	0.03338
18-Oct-06	0	0	0	0	0.07282
15-Nov-06	0	0	0	0	0
13-Dec-06	0	0	0	0	0
P_M*	–	–	–	–	–

* P_M estimates and standard errors were not calculated because only a single estimate of PE was available from the field data.

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 CWIS at the SGS on fishes and selected invertebrates. Impingement occurs when organisms larger than the traveling screen mesh size (9.5 mm or 3/8 in) 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 three survey types in the impingement study: *weekly IM&E* sampling, *heat treatment* (*marine growth control*) sampling, and *velocity cap* sampling. Samples collected during weekly IM&E and velocity cap sampling were used to characterize fish losses resulting from the day-to-day operation of the generating station. These samples were collected once weekly over a 24-hour period to determine daily losses from operation of the CWIS. Samples were also collected during marine growth control procedures, a periodic plant maintenance operation, when waters within the CWIS were heated and fishes and invertebrates succumbed to the higher temperatures. The weekly IM&E, velocity cap, and heat treatment samples were used in combination to develop estimates of the annual losses of juvenile and adult fishes and shellfishes due to operation of the CWIS.

In an effort to quantify the effectiveness of the SGS velocity cap in reducing impingement, a special study was conducted from October 2006 to January 2007. During this study, the SGS operated in both the normal flow configuration (with the velocity cap) and in reverse flow configuration (without the velocity cap). Regardless of flow direction, all incoming cooling water was directed through the forebay, bar racks, and traveling screens.

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

5.2 HISTORICAL DATA

Impingement sampling was conducted during the 1978–1979 316(b) demonstration (IRC 1981) and from 1990–2005 as required by the SGS NPDES permit (MBC 2007). These data are summarized to provide information on historical impingement at the SGS.

5.2.1 Summary of Historical Data

A total of 4,345 kg (9,580 lbs) of fishes was impinged during the heat treatment impingement sampling at SGS in 1978–1979 (IRC 1981). The mean cooling water flow rate at the generating station during the study year was approximately 1,460,201 m^3 (385.786 mgd). Abundance was recorded for three fish taxa: queenfish (89,230 individuals), white croaker (19,437 individuals), and walleye surfperch (*Hyperprosopon argenteum*; 9,939 individuals). Biomass was recorded for four species: queenfish (2,498 kg [5,507 lbs]), white croaker (1,061 kg [2,340 lbs]), walleye surfperch (707 kg [1,558 lbs]), and northern anchovy (79 kg [175 lbs]). It was reported that flow rate did not appear to affect impingement; however, there was an increase in impingement during storm periods.

Additionally, 10 day/night impingement surveys were conducted in April 1979 to evaluate the effect of varying cooling water flow on fish impingement. Flow volumes ranged from 651 m^3 per minute (172,000 gpm) to 1,302 m^3 per minute (344,000 gpm). During the 12-hour daytime surveys, impingement totals ranged between 64 and 1,490 individuals impinged, with both occurring during higher flow rates. Dominant species included queenfish, white croaker, and walleye surfperch, which comprised 92% of the total impingement abundance. During the 12-hour nighttime surveys, impingement totals ranged between 17 and 281 individuals impinged, with the lowest total occurring during a medium flow regime (1,007 m^3 per minute [266,000 gpm]) and the highest occurring during the higher flow rate. Dominant species included queenfish, white croaker, and walleye surfperch. There was no consistent diel pattern of impingement.

During the last six years of heat treatment impingement monitoring at the SGS (2000–2005), a total of 676,726 fish were impinged (MBC 2007). The most abundant fish species impinged were topsmelt and Pacific sardine, which combined accounted for 59% of impingement abundance. In 2005, the most abundant species were queenfish (50% of total abundance), northern anchovy (13%), shiner perch (*Cymatogaster aggregata*; 11%), and topsmelt (7%). A total of 3,922 macroinvertebrates weighing 165.3 kg (364.5 lbs) was also impinged. The most abundant invertebrates impinged were Pacific rock crab (*Cancer antennarius*; 48% of total abundance), yellow crab (*Cancer anthonyi*; 25%), and red rock shrimp (*Lysmata californica*; 9%), which together comprised 82% of the impingement abundance.

5.2.2 Relevance to Current Conditions

The historical impingement data are applicable for historical comparisons. During the 1978–1979 study, the average flow during the study year was 1,460,201 m^3 per day (385.786 mgd), or 78% of maximum. From 1982 to 1995, cooling water flow averaged 1,105,365 m^3 per day (292.038 mgd) (MBC 1997). Flow during the 2006 study averaged about 1,199,687 m^3 per day (316.958 mgd), or 64% of design flow.

5.2.3 QA/QC Procedures and Data Validation

The sampling program during the 1978–1979 study was conducted with the approval of the LARWQCB, and detailed procedures and methodologies, as well as QA/QC methods, can be found in Appendices G (Biological Field Procedures), H (Laboratory Procedures), and I (Statistical and Analytical Procedures) of IRC (1981).

5.3 METHODS

The following sections provide information on the impingement sample collection and data analysis methods. The impingement sampling program was designed to provide the necessary information for the impingement mortality characterization and development of the calculation baseline. The impingement sampling provided current estimates of the taxonomic composition, abundance, biomass, seasonality, and diel periodicity of organisms impinged at the SGS. 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 gals] cooling water flowing into the CWIS).

The SGS has one screen and pump chamber that consists of bar racks, traveling screens, and the circulating water pumps. Seawater drawn into the SGS CWIS 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 CWIS is presented in Section 3.2.

5.3.1 Field Sampling

There were three different impingement survey types conducted during the study. These survey types are discussed in further detail in the following sections. Detailed stepwise procedures are presented in Appendix B.

5.3.1.1 IM&E Characterization Study Sampling

Weekly IM&E Characterization Study impingement sampling at the SGS was conducted over one 24-hour period each week from January 10, 2006 to January 2, 2007. 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), Cycle 2 (approx. 1300–1900), Cycle 3 (approx. 1900–0100), and Cycle 4 (approx. 0100–0700). 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-in) mesh.

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

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

- The appropriate linear measurement for individual fish and shellfish was determined and recorded. These measurements were recorded to the nearest 1 mm (0.04 in). The following standard linear measurements were used for the animal groups indicated:
  - Fishes - 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, and
  - Squid –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 oz).
- 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 procedure 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 were used for fishes and shellfishes when the number of individuals per species was greater than 30:

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

5.3.1.2 Velocity Cap Study Sampling

The SGS Velocity Cap Study (VCS) began on October 11, 2006, and continued to January 3, 2007. The purpose of the study was to assess the effectiveness of the velocity cap at the SGS cooling water intake structure in reducing fish impingement. VCS sampling/processing procedures were similar to those from the weekly IM&E Characterization Study sampling, except samples were collected over approximately 24-hour survey periods without the 6-hour sampling cycles since diel variation in impingement rates was already being assessed as part of the IM&E Characterization Study. VCS sampling was performed three to four times per week in addition to the weekly IM&E Characterization Study sampling.

The VCS required that the SGS operate in two flow modes: normal flow where cooling water is withdrawn from the intake structure with a velocity cap, and reverse flow where cooling water is withdrawn from the discharge structure without a velocity cap. Normal flow direction is the normal mode of operation for the SGS. The transition from normal to reverse flow required the opening and closing of the circulating water intake and discharge valves within the SGS CWIS. The opening and closing of the intake and discharge valves resulted in the SGS withdrawing cooling water from the discharge structure (without the velocity cap), and discharging cooling water through the intake structure. Flow reversals were performed after the completion of heat treatments. Regardless of flow direction, all incoming cooling water was directed through the forebay, bar racks, and traveling screens.

5.3.1.3 Heat Treatment Study Sampling

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 IM&E Characterization and VCS sampling.

5.3.2 QA/QC Procedures & Data Validation

During the NPDES impingement surveys (2000–2005), 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 (mechanical and electronic) were calibrated every three months.

A quarterly QA/QC program was implemented during the current study to verify compliance with the field sampling procedures. Random cycles were chosen for QA/QC re-sorting to verify that all the collected organisms were removed from the impinged material. QC surveys of normal operation sampling were conducted on the following dates: February 7, April 11, August 1, and October 10. A QC survey of the VCS was conducted on October 13 and on October 10 for heat treatment sampling. 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 is 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.

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; and
- After data were entered, copies of the spreadsheets were checked against the field data sheets;
- In the prior studies, data were submitted annually to the LARWQCB, EPA Region IX, and the CDFG.

5.3.3 Data Analysis

5.3.3.1 Field Data Summaries

A log with hourly observations of each of the circulating water pumps for the entire study period was obtained from the LADWP. 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. Annual impingement estimates are presented in this report based on both (1) actual flow using flow volumes obtained from LADWP, and (2) design flow volume based on the maximum permitted cooling water intake flow at the SGS (1,875,142 m^3 per day, or 495.360 mgd).

For the period January 1 through October 10, 2006, the estimated daily impingement rate was used to calculate the weekly and annual impingement. The days between the impingement collections were assigned to a weekly survey period by setting the collection day as the median day within the period and designating the days before and after the collection date to the closest sampling day to create a weekly survey period. The total calculated flow for each survey period was multiplied by the taxon-specific impingement rates for both abundance and biomass. The estimated impingement rate for each weekly survey period was summed to determine the annual normal operation impingement estimates for each taxon.

For the periods October 11 to October 23, November 9 to November 20, and December 11, 2006 to January 3, 2007, no such extrapolations were necessary since all impinged organisms were quantified during IM&E Characterization, Velocity Cap Study, and heat treat sampling. The generating station operated in the normal flow configuration (with the velocity cap) during these time periods. However, during October 23 to November 9, and November 20 to December 11, 2006, when the SGS operated in reverse flow configuration (without the velocity cap), impingement was estimated from the weekly IM&E Characterization Study surveys conducted prior to and immediately following these reverse flow periods.

During impingement sampling, all fishes and invertebrates that were retained on the traveling screens were rinsed from the screens, flowed along a water-filled sluiceway, and were deposited into the impingement collection baskets for processing. Data are presented for all impinged taxa, but a subset of species was selected for more detailed analysis. This included fish that together comprised the top 90% or more of the total abundance in impingement samples. In addition, commercially or recreationally important invertebrates that were also impinged were selected for additional analysis. This methodology was approved by the LARWQCB, SWRCB, EPA Region IX, NMFS, and CDFG during our January 30, 2006 meeting.

To put the impingement results in context, losses were compared with (1) known population estimates where available, (2) commercial fishing landings for those species harvested commercially, and (3) sport fishing landings for those species targeted by recreational anglers. Commercial landing data were derived from three potential sources: (1) the 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 RecFIN, which included all marine areas in southern California.

5.3.3.2 Equivalent Adult Modeling (EAM)

For an assessment of the SGS 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.

Ages were assigned to individual recorded lengths for impinged queenfish, Pacific sardine, and northern anchovy 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 using literature sources for the parameters L_∞, k, t_0: The von Bertalanffy growth equation is:

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

where:

L_t = length of impinged fish with estimated age t
L_∞ = asymptotic maximum length of fish
k = growth rate constant
t_0 = theoretical age at 0 length; intercept of growth curve with age axis

Annual (daily) age was calculated as:

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

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

$$\Delta t = t_{50\%} - t_{est} = \frac{\ln\left(L_\infty - L_{50\%}\right) - \ln\left(L_\infty - L_{t_{est}}\right)}{-k} \qquad (2)$$

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 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)

$$AE = \sum_{i=1}^{N} S^{\left(t_{50\%} - t_{est}\right)} = \sum_{i=1}^{N} S^{\Delta t} \qquad (3)$$

where:

AE = number of target age equivalents killed
N = number of individuals impinged
S = total annual instantaneous survival
$t_{50\%}$ = age at female 50% maturity
t_{est} = estimated age of impinged fish

The estimate of AE is generally robust to errors in scaling age estimates by t_0 because Δt does not depend on t_0. Younger aged fish at smaller lengths are most subject to such errors if the von Bertalanffy equation fits older and larger fish better. Therefore, comparison of age distributions to age at 50% maturity should be viewed as a relative relationship.

Equivalent adults were summed across all surveys. Adult equivalent abundances attributed to heat treatments or normal operation surveys during the velocity cap study period, normal flow configuration only, were not adjusted for flow. Adult equivalents attributed to normal weekly impingement characterization surveys prior to the velocity cap study (surveys 1-40) were extrapolated based on cooling water flows as described previously for normal operation estimated abundance.

5.4 SAMPLING SUMMARY

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

5.4.1 Data Summary of Processed Samples

Weekly IM&E Characterization impingement surveys were performed during all 52 weeks at the SGS between January 10, 2006 and January 3, 2007. An additional 24 VCS impingement surveys and 3 marine growth control (heat treatment) surveys were performed during that time period with the plant operating in normal flow configuration (Table 5.4-1). Four marine growth control surveys were performed between January 10 and October 3, 2006. However, the procedure conducted on August 10, 2006 was incomplete. It was rescheduled and performed five days later on August 15, 2006. Seven marine growth control procedures were performed during the VCS period. However, the procedure conducted on December 4, 2006 was incomplete. It was rescheduled and performed seven days later on December 11, 2006.

Table 5.4-1. Summary of SGS surveys from January 10, 2006 to January 3, 2007, during periods prior to and during the Velocity Cap Study. Note: Only surveys conducted during normal flow configuration.

Survey Type	Unit 1	Unit 2	Unit 3	Total
Pre- VCS (1/10/06 to 10/3/06)				
Weekly IM&E Characterization Surveys	38	31	34	39
Marine Growth Control (Heat Treatment)	–	–	–	4*
VCS (10/4/06 to 1/3/07) – Normal Flow Direction Only				
Weekly IM&E Characterization Surveys	7	7	7	7
Velocity Cap Study 24-hr Surveys	24	24	24	24
Marine Growth Control (Heat Treatment)	–	–	–	3

*Marine Growth Control on 8/10/06 not completed but included in total.

Only three of four 6-hour cycles were completed at the Unit 3 traveling screens on February 21, 2006 due to miscommunication between the biologist and operations personnel. On August 8, 2006, only one of four cycles was completed at all units due to a large influx of shell debris from cleaning of the bar racks. This led to mechanical failure of two traveling screens and impingement basket liners.

5.5 RESULTS

The following sections summarize results from the 2006 impingement sampling at the SGS. 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. The 316(b) regulations require a characterization and estimate of annual impingement based on "periods of representative operational flows". Therefore, the data presented in Section 5 includes only data collected during periods of normal flow operation (with the velocity cap).

5.5.1 Impingement Summary

Weekly IM&E Characterization impingement surveys were performed during all 52 weeks at the SGS between January 10, 2006 and January 3, 2007. An additional 24 Velocity Cap Study impingement surveys and 7 heat treatment surveys were performed during that time period (in normal flow configuration). Only three of four 6-hour cycles were completed at the Unit 3 traveling screens on February 21, 2006 due to miscommunication between the biologist and operations personnel. On August 8, 2006, only one of four cycles was completed at all units due to a large influx of shell debris from cleaning of the bar racks. This led to mechanical failure of two traveling screens and impingement basket liners. The August 10, 2006 heat treatment was aborted due to mechanical problems with the Unit 3 traveling screens; however it was rescheduled and performed on August 15, 2006.

5.5.1.1 Fishes

During the one-year impingement study, a total of 78,635 fish weighing 3,165.555 kg (6,980.049 lbs) from at least 82 species were collected in impingement samples (Table 5.5-1 and Appendix E). Of this total, 7,551 fish weighing 662.660 kg (1,461 lbs) from at least 66 separate taxa were collected during weekly IM&E Characterization Study and Velocity Cap Study impingement samples, and the remaining 71,084 fish weighing 2,502.895 kg (5,518.883 lbs) from at least 65 separate taxa were collected during marine growth control (heat treatment) impingement samples. A List of the species collected during the study are presented in Appendix F.

The most abundant species in weekly IM&E Characterization Study and Velocity Cap Study impingement samples were Pacific sardine (*Sardinops sagax*; 2,142 individuals), jacksmelt (*Atherinopsis californiensis*; 1,425 individuals), and topsmelt (*Atherinops affinis*; 1,127 individuals) (Table 5.5-1). The species contributing most to biomass during the weekly IM&E Characterization Study and Velocity Cap Study impingement samples were Pacific electric ray (*Torpedo californica*; 224.880 kg [495.860 lbs]), jacksmelt (137.673 kg [303.569 lbs]), and bat ray (*Myliobatis californica*; 126.400 kg [278.712 lbs]).

The most abundant species in heat treatment impingement samples were queenfish (*Seriphus politus*; 29,470 individuals), Pacific sardine (22,204 individuals), and northern anchovy (*Engraulis mordax*; 8,144 individuals) (Table 5.5-1). The species contributing most to biomass during the heat treatment samples were Pacific sardine (889.227 kg [1,960.746 lbs]), queenfish (590.871 kg [1,302.871 lbs]), and bat ray (208.954 kg [460.744 lbs]). For all survey types combined, the most abundant species were queenfish (38.8% of total abundance), Pacific sardine (31.0%), and northern anchovy (11.0%). Species contributing most to total sampled biomass were Pacific sardine (29.6% of total biomass), queenfish (19.0%), and bat ray (10.6%). Heat treatment abundance and biomass peaked during the January 25, 2006 procedure (32,618 fishes weighing 955.440 kg [2,106.745 lbs]).

Annual fish impingement estimates at the SGS were 95,241 individuals weighing 4,273.703 kg (9,423.515 lbs) based on actual cooling water flow, and 108,843 individuals weighing 5,270.418 kg (11,621.272 lbs) based on design cooling water flow (Table 5.5-2). The most abundant species impinged were queenfish, Pacific sardine, northern anchovy, and jacksmelt. Species contributing most to biomass were Pacific sardine, bat ray, and jacksmelt.

5.5.1.2 Invertebrates

During the one-year impingement study, a total of 24,298 macroinvertebrates weighing 317.446 kg (699.968 lbs) from at least 73 species were collected in impingement samples (Table 5.5-3 and Appendix E). Of this total, 20,449 macroinvertebrates weighing 169.875 kg (374.574 lbs) from at least 70 separate taxa were collected during weekly IM&E Characterization Study and Velocity Cap Study impingement samples, and the remaining 3,849 individuals weighing 147.571 kg (325.394 lbs) from at least 25 separate taxa were collected during marine growth control (heat treatment) impingement samples.

The most abundant species in weekly IM&E Characterization Study and Velocity Cap Study impingement samples were intertidal coastal shrimp (*Heptacarpus palpator*; 7,860 individuals), the nudibranch hermissenda (*Hermissenda crassicornis*; 5,502 individuals), and red rock shrimp (*Lysmata californica;* 1,670 individuals) (Table 5.5-3). The species contributing most to biomass during the weekly IM&E Characterization Study and Velocity Cap Study impingement samples were yellow crab (*Cancer anthonyi*; 54.689 kg [120.986 lbs]), California spiny lobster (*Panulirus interru*ptus; 33.941 kg [74.840 lbs]), and sheep crab (*Loxorhynchus grandis*; 26.251 kg [57.8832 lbs]).

The most abundant macroinvertebrate species in heat treatment impingement samples were red rock shrimp (1,850 individuals), intertidal coastal shrimp (875 individuals), and Pacific rock crab (*Cancer antennarius*; 385 individuals) (Table 5.5-3). The species contributing most to biomass during the heat treatment samples were California spiny lobster (97.338 kg [214.630 lbs]), California two-spot octopus (*Octopus bimaculatus/bimaculoides*; 26.115 kg [57.5841 lbs]), and Pacific rock crab (14.615 kg [32.226 lbs]). For all survey types combined, the most abundant species were intertidal coastal shrimp (35.9% of total abundance), the nudibranch hermissenda (22.6%), and red rock shrimp (14.5%). Species contributing most to total sampled biomass were California spiny lobster (41.4% of total biomass), yellow crab (18.4%), and California two-spot octopus (10.7%). Heat treatment abundance peaked during the October 4, 2006 procedure (1,853 macroinvertebrates), and highest biomass was recorded during the August 15, 2006 heat treatment (51.118 kg [112.715 lbs]).

Annual macroinvertebrate impingement estimates at the SGS were 145,640 individuals weighing 1,418.337 kg (3,127.433 lbs) based on actual cooling water flow, and 225,449 individuals weighing 2,133.595 kg (4,704.577 lbs) based on design cooling water flow (Table 5.5-4). The most abundant species impinged were intertidal coastal shrimp, the nudibranch Hermissenda, red rock shrimp, and yellow crab. Species contributing most to biomass were yellow crab, California spiny lobster, and sheep crab.

Table 5.5-1. SGS fish impingement sampled abundance and biomass during normal flow configuration from January 10, 2006 to January 3, 2007.

		Sampled Normal Op.		Sampled Heat Treatment		Total Sampled	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Seriphus politus	queenfish	1,020	10.495	29,470	590.871	30,490	601.366
Sardinops sagax	Pacific sardine	2,142	47.845	22,204	889.227	24,346	937.072
Engraulis mordax	northern anchovy	512	2.406	8,144	43.556	8,656	45.962
Atherinops affinis	topsmelt	1,127	36.478	1,806	55.436	2,933	91.914
Atherinopsis californiensis	jacksmelt	1,425	137.673	1,493	182.841	2,918	320.514
Hyperprosopon argenteum	walleye surfperch	10	0.382	2,903	138.804	2,913	139.186
Peprilus simillimus	Pacific pompano	59	1.971	1,544	31.661	1,603	33.632
Genyonemus lineatus	white croaker	137	1.638	1,397	161.859	1,534	163.497
Myliobatis californica	bat ray	120	126.400	184	208.954	304	335.354
Xenistius californiensis	salema	11	0.244	259	1.107	270	1.351
Anchoa compressa	deepbody anchovy	59	0.340	192	1.162	251	1.502
Cymatogaster aggregata	shiner perch	49	0.492	199	1.621	248	2.113
Embiotoca jacksoni	black perch	12	0.558	157	11.425	169	11.983
Citharichthys stigmaeus	speckled sanddab	131	0.579	1	0.029	132	0.608
Paralabrax nebulifer	barred sand bass	11	4.539	109	34.837	120	39.376
Atherinopsidae	silverside, unid.	113	2.780	-	-	113	2.780
Paralabrax clathratus	kelp bass	3	0.110	105	7.064	108	7.174
Trachurus symmetricus	jack mackerel	8	0.341	92	3.673	100	4.014
Pleuronichthys ritteri	spotted turbot	43	0.907	44	4.672	87	5.579
Hypsoblennius gilberti	rockpool blenny	20	0.203	64	0.755	84	0.958
Cheilotrema saturnum	black croaker	-	-	83	5.463	83	5.463
Synodus lucioceps	California lizardfish	73	0.758	-	-	73	0.758
Menticirrhus undulatus	California corbina	8	1.266	63	8.914	71	10.180
Chromis punctipinnis	blacksmith	12	3.006	57	7.975	69	10.981
Scomber japonicus	Pacific chub mackerel	35	2.636	34	2.475	69	5.111
Platyrhinoidis triseriata	thornback	46	19.732	21	12.490	67	32.222
Rhacochilus toxotes	rubberlip seaperch	-	-	59	9.859	59	9.859
Scorpaena guttata	California scorpionfish	25	1.116	31	3.781	56	4.897
Urobatis halleri	round stingray	15	3.082	39	18.352	54	21.434
Syngnathus californiensis	kelp pipefish	48	0.142	3	0.006	51	0.148
Phanerodon furcatus	white seaperch	17	1.713	33	1.955	50	3.668
Umbrina roncador	yellowfin croaker	7	0.998	34	2.383	41	3.381
Torpedo californica	Pacific electric ray	36	224.880	2	19.000	38	243.880
Sebastes auriculatus	brown rockfish	1	0.179	34	13.789	35	13.968
Atractoscion nobilis	white seabass	-	-	32	4.438	32	4.438
Anisotremus davidsonii	sargo	9	5.438	18	0.154	27	5.592
Scorpaenichthys marmoratus	cabezon	7	0.825	20	3.872	27	4.697
Halichoeres semicinctus	rock wrasse	-	-	24	3.507	24	3.507
Pleuronichthys verticalis	hornyhead turbot	22	0.791	1	0.084	23	0.875
Heterostichus rostratus	giant kelpfish	12	0.287	11	0.479	23	0.766
Oxyjulis californica	senorita	1	0.051	20	0.449	21	0.500
Paralichthys californicus	California halibut	12	0.970	7	1.035	19	2.005
Porichthys myriaster	specklefin midshipman	19	1.295	-	-	19	1.295

(table continued)

Table 5.5-1 (continued). SGS fish impingement sampled abundance and biomass during normal flow configuration from January 10, 2006 to January 3, 2007.

		Sampled Normal Op.		Sampled Heat Treatment		Total Sampled	
Taxon	Common Name	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)
Syngnathus sp.	pipefish, unid.	18	0.027	-	-	18	0.027
Rhacochilus vacca	pile perch	1	0.011	16	2.483	17	2.494
Syngnathus leptorhynchus	bay pipefish	16	0.030	-	-	16	0.030
Odontopyxis trispinosa	pygmy poacher	16	0.029	-	-	16	0.029
Brachyistius frenatus	kelp perch	3	0.030	12	0.319	15	0.349
Heterodontus francisci	horn shark	11	2.491	2	1.641	13	4.132
Chilara taylori	spotted cusk-eel	-	-	13	0.214	13	0.214
Pleuronichthys guttulatus	diamond turbot	7	0.794	3	0.829	10	1.623
Oxylebius pictus	painted greenling	2	0.026	8	0.307	10	0.333
Anchoa delicatissima	slough anchovy	10	0.071	-	-	10	0.071
Ophidion scrippsae	basketweave cusk-eel	6	0.242	3	0.086	9	0.328
Leuresthes tenuis	California grunion	3	0.048	4	0.086	7	0.134
Ophichthus zophochir	yellow snake eel	5	0.979	1	0.144	6	1.123
Sebastes paucispinis	bocaccio	6	0.043	-	-	6	0.043
Hypsoblennius jenkinsi	mussel blenny	4	0.011	2	0.007	6	0.018
Sphyraena argentea	Pacific barracuda	-	-	5	0.383	5	0.383
Girella nigricans	opaleye	-	-	4	3.731	4	3.731
Leptocottus armatus	Pacific staghorn sculpin	2	0.035	2	0.058	4	0.093
Rathbunella alleni	stripefin ronquil	2	0.018	2	0.010	4	0.028
Sebastes rastrelliger	grass rockfish	1	0.556	2	1.381	3	1.937
Parophrys vetulus	English sole	3	0.142	-	-	3	0.142
Micrometrus minimus	dwarf perch	3	0.008	-	-	3	0.008
Triakis semifasciata	leopard shark	2	11.011	-	-	2	11.011
Semicossyphus pulcher	California sheephead	-	-	2	0.134	2	0.134
Symphurus atricaudus	California tonguefish	2	0.070	-	-	2	0.070
Porichthys notatus	plainfin midshipman	2	0.039	-	-	2	0.039
Artedius corallinus	coralline sculpin	1	0.009	1	0.003	2	0.012
Hypsypops rubicundus	garibaldi	-	-	1	0.436	1	0.436
Mustelus henlei	brown smoothhound	-	-	1	0.296	1	0.296
Gymnura marmorata	California butterfly ray	1	0.184	-	-	1	0.184
Sebastes chrysomelas	black-and-yellow rockfish	-	-	1	0.165	1	0.165
Embiotocidae	surfperch, unid.	1	0.156	-	-	1	0.156
Medialuna californiensis	halfmoon	-	-	1	0.103	1	0.103
Amphistichus argenteus	barred surfperch	-	-	1	0.051	1	0.051
Zalembius rosaceus	pink seaperch	1	0.027	-	-	1	0.027
Dorosoma petenense	threadfin shad	1	0.013	-	-	1	0.013
Sebastes miniatus	vermilion rockfish	1	0.011	-	-	1	0.011
Gibbonsia elegans	spotted kelpfish	-	-	1	0.007	1	0.007
Hermosilla azurea	zebraperch	-	-	1	0.003	1	0.003
Anchoa sp.	deepbody/slough anchovy	-	-	1	0.002	1	0.002
Branchiostoma californiense	California lancelet	-	-	1	0.002	1	0.002
Clinidae	kelp blenny, unid.	1	0.001	-	-	1	0.001
Gobiesox rhessodon	California clingfish	1	0.001	-	-	1	0.001
Ruscarius creaseri	roughcheek sculpin	1	0.001	-	-	1	0.001
		7,551	**662.660**	**71,084**	**2,502.895**	**78,635**	**3,165.555**

Table 5.5-2. Annual SGS fish impingement estimates based on both actual and design (maximum) cooling water flow.

				Estimated Annual Impingement			
		Total Sampled		Actual Flow		Design Flow	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Seriphus politus	queenfish	30,490	601.366	34,085	649.245	36,683	682.101
Sardinops sagax	Pacific sardine	24,346	937.072	25,582	964.302	27,483	1,006.558
Engraulis mordax	northern anchovy	8,656	45.962	10,214	55.565	11,379	62.324
Atherinops affinis	topsmelt	2,933	91.914	4,297	172.113	5,699	237.785
Atherinopsis californiensis	jacksmelt	2,918	320.514	7,107	668.336	10,267	941.600
Hyperprosopon argenteum	walleye surfperch	2,913	139.186	2,937	139.695	2,956	140.197
Peprilus simillimus	Pacific pompano	1,603	33.632	1,915	43.370	2,124	49.960
Genyonemus lineatus	white croaker	1,534	163.497	2,309	170.051	2,822	174.662
Myliobatis californica	bat ray	304	335.354	976	717.807	1,422	1,004.218
Xenistius californiensis	salema	270	1.351	276	1.851	286	2.270
Anchoa compressa	deepbody anchovy	251	1.502	313	1.848	381	2.234
Cymatogaster aggregata	shiner perch	248	2.113	540	5.143	732	7.125
Embiotoca jacksoni	black perch	169	11.983	225	14.228	263	15.806
Citharichthys stigmaeus	speckled sanddab	132	0.608	269	2.205	420	3.430
Paralabrax nebulifer	barred sand bass	120	39.376	173	65.162	209	82.231
Atherinopsidae	silverside, unid.	113	2.780	113	2.780	177	4.345
Paralabrax clathratus	kelp bass	108	7.174	115	7.202	121	7.280
Trachurus symmetricus	jack mackerel	100	4.014	100	4.014	105	4.206
Pleuronichthys ritteri	spotted turbot	87	5.579	254	9.353	372	11.988
Hypsoblennius gilberti	rockpool blenny	84	0.958	248	2.869	352	4.059
Cheilotrema saturnum	black croaker	83	5.463	83	5.463	83	5.463
Synodus lucioceps	California lizardfish	73	0.758	451	4.642	705	7.255
Menticirrhus undulatus	California corbina	71	10.180	71	10.180	76	10.893
Chromis punctipinnis	blacksmith	69	10.981	118	25.434	152	35.261
Scomber japonicus	Pacific chub mackerel	69	5.111	110	9.506	153	13.463
Platyrhinoidis triseriata	thornback	67	32.222	144	56.670	213	81.537
Rhacochilus toxotes	rubberlip seaperch	59	9.859	59	9.859	59	9.859
Scorpaena guttata	California scorpionfish	56	4.897	157	9.167	228	12.199
Urobatis halleri	round stingray	54	21.434	109	37.033	148	47.548
Syngnathus californiensis	kelp pipefish	51	0.148	212	0.659	330	1.027
Phanerodon furcatus	white seaperch	50	3.668	140	13.998	200	20.776
Umbrina roncador	yellowfin croaker	41	3.381	47	4.740	54	6.067
Torpedo californica	Pacific electric ray	38	243.880	38	243.880	58	370.455
Sebastes auriculatus	brown rockfish	35	13.968	41	15.043	45	15.749
Atractoscion nobilis	white seabass	32	4.438	32	4.438	32	4.438
Anisotremus davidsonii	sargo	27	5.592	70	39.102	99	61.024
Scorpaenichthys marmoratus	cabezon	27	4.697	54	7.452	73	9.467
Halichoeres semicinctus	rock wrasse	24	3.507	24	3.507	24	3.507
Pleuronichthys verticalis	hornyhead turbot	23	0.875	114	3.767	178	5.840
Heterostichus rostratus	giant kelpfish	23	0.766	52	1.829	75	2.589
Oxyjulis californica	senorita	21	0.500	21	0.500	22	0.529
Paralichthys californicus	California halibut	19	2.005	81	8.486	123	12.680
Porichthys myriaster	specklefin midshipman	19	1.295	31	2.073	48	3.240

(table continued)

Table 5.5-2 (continued). Annual SGS fish impingement estimates based on both actual and design (maximum) cooling water flow.

				Estimated Annual Impingement			
		Total Sampled		Actual Flow		Design Flow	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Syngnathus sp.	pipefish, unid.	18	0.027	177	0.26	277	0.406
Rhacochilus vacca	pile perch	17	2.494	24	2.568	29	2.616
Syngnathus leptorhynchus	bay pipefish	16	0.03	201	0.372	314	0.581
Odontopyxis trispinosa	pygmy poacher	16	0.029	72	0.146	113	0.228
Brachyistius frenatus	kelp perch	15	0.349	38	0.566	53	0.705
Heterodontus francisci	horn shark	13	4.132	26	19.954	40	30.262
Chilara taylori	spotted cusk-eel	13	0.214	13	0.214	13	0.214
Pleuronichthys guttulatus	diamond turbot	10	1.623	22	3.462	33	4.944
Oxylebius pictus	painted greenling	10	0.333	28	0.635	39	0.820
Anchoa delicatissima	slough anchovy	10	0.071	40	0.378	63	0.591
Ophidion scrippsae	basketweave cusk-eel	9	0.328	32	1.041	48	1.579
Leuresthes tenuis	California grunion	7	0.134	7	0.134	9	0.161
Ophichthus zophochir	yellow snake eel	6	1.123	12	2.252	18	3.439
Sebastes paucispinis	bocaccio	6	0.043	74	0.432	116	0.675
Hypsoblennius jenkinsi	mussel blenny	6	0.018	25	0.072	38	0.109
Sphyraena argentea	Pacific barracuda	5	0.383	5	0.383	5	0.383
Girella nigricans	opaleye	4	3.731	4	3.731	4	3.731
Leptocottus armatus	Pacific staghorn sculpin	4	0.093	4	0.093	5	0.113
Rathbunella alleni	stripefin ronquil	4	0.028	17	0.150	25	0.229
Sebastes rastrelliger	grass rockfish	3	1.937	15	8.802	22	12.979
Parophrys vetulus	English sole	3	0.142	3	0.142	5	0.222
Micrometrus minimus	dwarf perch	3	0.008	22	0.058	34	0.091
Triakis semifasciata	leopard shark	2	11.011	8	11.078	13	17.313
Semicossyphus pulcher	California sheephead	2	0.134	2	0.134	2	0.134
Symphurus atricaudus	California tonguefish	2	0.070	2	0.07	3	0.109
Porichthys notatus	plainfin midshipman	2	0.039	8	0.257	13	0.402
Artedius corallinus	coralline sculpin	2	0.012	8	0.070	12	0.108
Hypsypops rubicundus	garibaldi	1	0.436	1	0.436	1	0.436
Mustelus henlei	brown smoothhound	1	0.296	1	0.296	1	0.296
Gymnura marmorata	California butterfly ray	1	0.184	1	0.184	2	0.288
Sebastes chrysomelas	black-and-yellow rockfish	1	0.165	1	0.165	1	0.165
Embiotocidae	surfperch, unid.	1	0.156	1	0.156	2	0.244
Medialuna californiensis	halfmoon	1	0.103	1	0.103	1	0.103
Amphistichus argenteus	barred surfperch	1	0.051	1	0.051	1	0.051
Zalembius rosaceus	pink seaperch	1	0.027	6	0.165	9	0.258
Dorosoma petenense	threadfin shad	1	0.013	1	0.013	2	0.020
Sebastes miniatus	vermilion rockfish	1	0.011	7	0.079	11	0.123
Gibbonsia elegans	spotted kelpfish	1	0.007	1	0.007	1	0.007
Hermosilla azurea	zebraperch	1	0.003	1	0.003	1	0.003
Anchoa sp.	deepbody/slough anchovy	1	0.002	1	0.002	1	0.002
Branchiostoma californiense	California lancelet	1	0.002	1	0.002	1	0.002
Clinidae	kelp blenny, unid.	1	0.001	6	0.006	9	0.009
Gobiesox rhessodon	California clingfish	1	0.001	7	0.007	11	0.011
Ruscarius creaseri	roughcheek sculpin	1	0.001	7	0.007	11	0.011
		78,635	**3,165.555**	**95,241**	**4,273.703**	**108,843**	**5,270.418**

Table 5.5-3. SGS macroinvertebrate impingement sampled abundance and biomass during normal flow configuration from January 10, 2006 to January 3, 2007.

		Sampled Normal Op.		Sampled Heat Treatment		Total Sampled	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Heptacarpus palpator	intertidal coastal shrimp	7,860	2.872	875	1.518	8,735	4.390
Hermissenda crassicornis	hermissenda	5,502	2.163	1	0.001	5,503	2.164
Lysmata californica	red rock shrimp	1,670	1.776	1,850	1.833	3,520	3.609
Cancer anthonyi	yellow crab	1,425	54.689	194	3.848	1,619	58.537
Cancer antennarius	Pacific rock crab	488	6.717	385	14.615	873	21.332
Polyorchis penicillatus	red jellyfish	627	1.919	-	-	627	1.919
Portunus xantusii	Xantus swimming crab	518	6.316	51	0.350	569	6.666
Cancer jordani	hairy rock crab	451	1.373	24	0.059	475	1.432
Crangon nigromaculata	blackspotted bay shrimp	410	0.793	-	-	410	0.793
Cancer productus	red rock crab	254	8.071	6	0.084	260	8.155
Flabellina trilineata	threeline aeolis	213	0.023	-	-	213	0.023
Panulirus interruptus	California spiny lobster	52	33.941	160	97.338	212	131.279
Pyromaia tuberculata	tuberculate pear crab	135	0.182	22	0.030	157	0.212
O. bimaculatus/bimaculoides	California two-spot octopus	44	7.941	79	26.115	123	34.056
Pachygrapsus crassipes	striped shore crab	53	0.182	46	0.261	99	0.443
Dendronotus frondosus	leafy dendronotid	89	0.028	-	-	89	0.028
Cancer sp.	cancer crab, unid.	80	0.335	6	0.013	86	0.348
Leptopecten sp.	scallop, unid.	73	0.090	-	-	73	0.090
Cancer gracilis	graceful crab	17	0.505	45	0.194	62	0.699
Pinnixa sp.	pea crab, unid.	62	0.035	-	-	62	0.035
Pugettia producta	northern kelp crab	52	0.272	9	0.095	61	0.367
Lophopanopeus bellus	blackclaw crestleg crab	36	0.050	17	0.017	53	0.067
Loligo opalescens	California market squid	51	1.256	-	-	51	1.256
Loxorhynchus grandis	sheep crab	43	26.251	3	0.833	46	27.084
Alpheus clamator	twistclaw pistol shrimp	1	0.001	34	0.069	35	0.070
Pachycheles pubescens	pubescent porcelain crab	29	0.027	-	-	29	0.027
Navanax inermis	California aglaja	4	0.011	22	0.066	26	0.077
Pachycheles rudis	thick claw porcelain crab	20	0.020	-	-	20	0.020
Astropecten armatus	spiny sand star	16	0.057	3	0.029	19	0.086
Aeolidiidae	aeolid nudibranch	15	0.009	-	-	15	0.009
Puggetia dalli	spined kelp crab	12	0.013	-	-	12	0.013
Aeolidia papillosa	shag-rug aeolis	12	0.012	-	-	12	0.012
Loxorhynchus crispatus	moss crab	10	0.437	-	-	10	0.437
Octopus rubescens	East Pacific red octopus	10	0.317	-	-	10	0.317
Scyra acutifrons	sharpnose crab	1	0.003	9	0.030	10	0.033
Pinnixa tomentosa	pea crab 2	10	0.005	-	-	10	0.005
Conus californicus	California cone	7	0.014	1	0.005	8	0.019
Ophiothrix spiculata	shiny brittle star	7	0.005	-	-	7	0.005
Ophioderma panamense	Panama brittle star	6	0.002	-	-	6	0.002
Chrysaora colorata	purple-striped jellyfish	5	5.581	-	-	5	5.581
Blepharipoda occidentalis	spiny mole crab	5	0.073	-	-	5	0.073
Paraxanthias taylori	lumpy rubble crab	1	0.001	4	0.008	5	0.009
Triopha maculata	spotted triopha	5	0.005	-	-	5	0.005

(table continued)

Table 5.5-3 (continued). SGS macroinvertebrate impingement sampled abundance and biomass during normal flow configuration from January 10, 2006 to January 3, 2007.

		Sampled Normal Op.		Sampled Heat Treatment		Total Sampled	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Pagurus sp.	hermit crab, unid.	4	0.004	-	-	4	0.004
Porcellanidae	porcelain crab, unid.	4	0.003	-	-	4	0.003
Ophiuroidea	brittle star, unid.	4	0.002	-	-	4	0.002
Loxorhynchus sp.	moss/sheep crab, unid.	3	2.501	-	-	3	2.501
Pilumnus spinohirsutus	retiring hairy crab	3	0.009	-	-	3	0.009
Cancer amphioetus	bigtooth rock crab	3	0.007	-	-	3	0.007
Pisaster giganteus	giant-spined sea star	2	2.564	-	-	2	2.564
Salpa sp.	salp, unid.	2	0.057	-	-	2	0.057
Caudina arenicola	sweet potato sea cucumber	2	0.022	-	-	2	0.022
Lepidopa californica	California mole crab	2	0.018	-	-	2	0.018
Neotrypaea gigas	giant ghost shrimp	2	0.017	-	-	2	0.017
Podochela hemphill	hemphill kelp crab	2	0.005	-	-	2	0.005
Nudibranchia	nudibranch, unid.	2	0.004	-	-	2	0.004
Hemigrapsus nudus	purple shore crab	2	0.002	-	-	2	0.002
Heptacarpus sp.	coastal shrimp, unid.	2	0.002	-	-	2	0.002
Pachycheles holosericus	sponge porcelain crab	2	0.002	-	-	2	0.002
Polyonyx quadriungulatus	western tube crab	2	0.002	-	-	2	0.002
Pugettia richii	cryptic kelp crab	2	0.002	-	-	2	0.002
Thetys vagina	common salp	1	0.184	-	-	1	0.184
Parastichopus californicus	California sea cucumber	-	-	1	0.102	1	0.102
Farfantepenaeus californiensis	yellowleg shrimp	-	-	1	0.037	1	0.037
Scrippsia pacifica	giant bell jelly	1	0.032	-	-	1	0.032
Asterina miniata	bat star	1	0.028	-	-	1	0.028
Pisaster brevispinus	short-spined sea star	-	-	1	0.021	1	0.021
Dendraster excentricus	Pacific sand dollar	1	0.008	-	-	1	0.008
Cnidaria	sea jelly, unid.	1	0.003	-	-	1	0.003
Lamellaria diegoensis	San Diego lamellaria	1	0.003	-	-	1	0.003
Pteropurpura festiva	festive murex	1	0.003	-	-	1	0.003
Dendronotus sp.	nudibranch, unid.	1	0.002	-	-	1	0.002
Pugettia sp.	kelp crab, unid.	1	0.002	-	-	1	0.002
Amphissa versicolor	variegate amphissa	1	0.001	-	-	1	0.001
Aphrodita sp.	sea mouse, unid.	1	0.001	-	-	1	0.001
Astropecten verrilli	sand star	1	0.001	-	-	1	0.001
Dirona picta	spotted dirona	1	0.001	-	-	1	0.001
Doto amyra	hammerhead doto	1	0.001	-	-	1	0.001
Haminoea virescens	green glassy bubble	1	0.001	-	-	1	0.001
Heptacarpus stimpsoni	Stimpson coastal shrimp	1	0.001	-	-	1	0.001
Herbstia parvifrons	crevice spider crab	1	0.001	-	-	1	0.001
Heteracrypta occidentalis	sandflat elbow crab	1	0.001	-	-	1	0.001
Kelletia kelletii	Kellet's whelk	1	0.001	-	-	1	0.001
Majidae	spider crab, unid.	1	0.001	-	-	1	0.001
Nassarius perpinguis	fat western nassa	1	0.001	-	-	1	0.001
Pachycheles sp.	porcelain crab, unid.	1	0.001	-	-	1	0.001
Pagurus redondoensis	unnamed hermit crab	1	0.001	-	-	1	0.001
		20,449	**169.875**	**3,849**	**147.571**	**24,298**	**317.446**

Table 5.5-4. Annual SGS macroinvertebrate impingement estimates based on both actual and design (maximum) cooling water flow.

				Estimated Annual Impingement			
		Total Sampled		Actual Flow		Design Flow	
Taxa	Common Name	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)
Heptacarpus palpator	intertidal coastal shrimp	8,735	4.390	57,739	22.386	89,745	34.132
Hermissenda crassicornis	hermissenda	5,503	2.164	33,044	12.557	51,642	19.624
Lysmata californica	red rock shrimp	3,520	3.609	13,522	14.392	20,092	21.461
Cancer anthonyi	yellow crab	1,619	58.537	13,434	544.830	20,886	849.325
Cancer antennarius	Pacific rock crab	873	21.332	4,066	61.517	6,138	87.916
Polyorchis penicillatus	red jellyfish	627	1.919	4,277	12.973	6,684	20.275
Portunus xantusii	Xantus swimming crab	569	6.666	2,838	40.809	4,407	63.582
Cancer jordani	hairy rock crab	475	1.432	3,896	11.829	6,075	18.454
Crangon nigromaculata	blackspotted bay shrimp	410	0.793	1,965	4.263	3,071	6.662
Cancer productus	red rock crab	260	8.155	1,789	57.779	2,793	90.253
Flabellina trilineata	threeline aeolis	213	0.023	1,613	0.169	2,521	0.264
Panulirus interruptus	California spiny lobster	212	131.279	450	276.768	613	377.761
Pyromaia tuberculata	tuberculate pear crab	157	0.212	960	1.267	1,488	1.963
O. bimaculatus/bimaculoides	Calif. two-spot octopus	123	34.056	375	75.292	542	102.972
Pachygrapsus crassipes	striped shore crab	99	0.443	379	1.362	566	1.982
Dendronotus frondosus	leafy dendronotid	89	0.028	360	0.158	563	0.247
Cancer sp.	cancer crab, unid.	86	0.348	491	2.056	764	3.206
Leptopecten sp.	scallop, unid.	73	0.090	539	0.657	842	1.027
Cancer gracilis	graceful crab	62	0.699	138	3.118	190	4.764
Pinnixa sp.	pea crab, unid.	62	0.035	631	0.341	986	0.533
Pugettia producta	northern kelp crab	61	0.367	366	1.508	567	2.303
Lophopanopeus bellus	blackclaw crestleg crab	53	0.067	292	0.396	447	0.609
Loligo opalescens	California market squid	51	1.256	300	7.506	469	11.731
Loxorhynchus grandis	sheep crab	46	27.084	306	182.265	477	284.385
Alpheus clamator	twistclaw pistol shrimp	35	0.070	41	0.076	45	0.080
Pachycheles pubescens	pubescent porcelain crab	29	0.027	201	0.187	314	0.292
Navanax inermis	California aglaja	26	0.077	50	0.142	66	0.185
Pachycheles rudis	thick claw porcelain crab	20	0.020	100	0.093	156	0.145
Astropecten armatus	spiny sand star	19	0.086	140	0.507	217	0.776
Aeolidiidae	nudibranch, unid.	15	0.009	120	0.076	188	0.119
Puggetia dalli	spined kelp crab	12	0.013	97	0.104	152	0.163
Aeolidia papillosa	shag-rug aeolis	12	0.012	91	0.091	142	0.142
Loxorhynchus crispatus	moss crab	10	0.437	64	2.702	100	4.223
Octopus rubescens	East Pacific red octopus	10	0.317	56	1.329	88	2.077
Scyra acutifrons	sharpnose crab	10	0.033	13	0.043	15	0.050
Pinnixa tomentosa	pea crab 2	10	0.005	67	0.032	105	0.050
Conus californicus	California cone	8	0.019	63	0.122	98	0.188
Ophiothrix spiculata	shiny brittle star	7	0.005	81	0.054	127	0.084
Ophioderma panamense	Panama brittle star	6	0.002	80	0.027	125	0.042
Chrysaora colorata	purple-striped jellyfish	5	5.581	34	41.405	53	64.710
Blepharipoda occidentalis	spiny mole crab	5	0.073	5	0.073	8	0.114
Paraxanthias taylori	lumpy rubble crab	5	0.009	9	0.013	12	0.016
Triopha maculata	spotted triopha	5	0.005	36	0.036	56	0.056

(table continued)

Table 5.5-4 (continued). Annual SGS macroinvertebrate impingement estimates based on both actual and design (maximum) cooling water flow.

				Estimated Annual Impingement			
		Total Sampled		Actual Flow		Design Flow	
Taxa	Common Name	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)
Pagurus sp.	hermit crab, unid.	4	0.004	28	0.028	44	0.044
Porcellanidae	porcelain crab, unid.	4	0.003	29	0.022	45	0.034
Ophiuroidea	brittle star, unid.	4	0.002	28	0.014	44	0.022
Loxorhynchus sp..	moss/sheep crab unid	3	2.501	18	15.297	28	23.907
Pilumnus spinohirsutus	retiring hairy crab	3	0.009	34	0.08	53	0.125
Cancer amphioetus	bigtooth rock crab	3	0.007	15	0.038	23	0.059
Pisaster giganteus	giant-spined sea star	2	2.564	13	16.702	20	26.103
Salpa sp..	salp, unid.	2	0.057	13	0.33	20	0.516
Caudina arenicola	sweet potato sea cucumber	2	0.022	2	0.022	3	0.034
Lepidopa californica	California mole crab	2	0.018	23	0.188	36	0.294
Neotrypaea gigas	giant ghost shrimp	2	0.017	17	0.165	27	0.258
Podochela hemphill	hemphill kelp crab	2	0.005	14	0.035	22	0.055
Nudibranchia unid	nudibranch unid	2	0.004	14	0.028	22	0.044
Hemigrapsus nudus	purple shore crab	2	0.002	15	0.015	23	0.023
Heptacarpus sp..	coastal shrimp, unid.	2	0.002	27	0.027	42	0.042
Pachycheles holosericus	sponge porcelain crab	2	0.002	14	0.014	22	0.022
Polyonyx quadriungulatus	western tube crab	2	0.002	20	0.02	31	0.031
Pugettia richii	cryptic kelp crab	2	0.002	13	0.013	20	0.020
Thetys vagina	common salp	1	0.184	5	0.982	8	1.535
Parastichopus californicus	California sea cucumber	1	0.102	1	0.102	1	0.102
Farfantepenaeus californiensis	yellowleg shrimp	1	0.037	1	0.037	1	0.037
Scrippsia pacifica	giant bell jelly	1	0.032	8	0.246	13	0.384
Asterina miniata	bat star	1	0.028	13	0.374	20	0.585
Pisaster brevispinus	short-spined sea star	1	0.021	1	0.021	1	0.021
Dendraster excentricus	Pacific sand dollar	1	0.008	1	0.008	2	0.013
Cnidaria	sea jelly, unid.	1	0.003	18	0.042	28	0.066
Lamellaria diegoensis	San Diego lamellaria	1	0.003	7	0.022	11	0.034
Pteropurpura festiva	festive murex	1	0.003	7	0.021	11	0.033
Dendronotus sp.	nudibranch, unid.	1	0.002	1	0.002	2	0.003
Pugettia sp.	kelp crab, unid.	1	0.002	10	0.02	16	0.031
Amphissa versicolor	variegate amphissa	1	0.001	7	0.007	11	0.011
Aphrodita sp.	sea mouse, unid.	1	0.001	13	0.013	20	0.020
Astropecten verrilli	sand star	1	0.001	7	0.007	11	0.011
Dirona picta	spotted dirona	1	0.001	7	0.007	11	0.011
Doto amyra	hammerhead doto	1	0.001	9	0.009	14	0.014
Haminoea virescens	green glassy bubble	1	0.001	7	0.007	11	0.011
Heptacarpus stimpsoni	Stimpson coastal shrimp	1	0.001	7	0.007	11	0.011
Herbstia parvifrons	crevice spider crab	1	0.001	7	0.007	11	0.011
Heteracrypta occidentalis	sandflat elbow crab	1	0.001	7	0.007	11	0.011
Kelletia kelletii	Kellet's whelk	1	0.001	7	0.007	11	0.011
Majidae	spider crab, unid.	1	0.001	7	0.007	11	0.011
Nassarius perpinguis	fat western nassa	1	0.001	13	0.013	20	0.020
Pachycheles sp.	porcelain crab, unid.	1	0.001	7	0.007	11	0.011
Pagurus redondoensis	unnamed hermit crab	1	0.001	7	0.007	11	0.011
		24,298	**317.446**	**145,640**	**1,418.337**	**225,449**	**2,133.595**

Table 5.5-5. Summary of SGS normal flow configuration heat treatment impingement totals.

Heat Treatment Date	Fishes		Macroinvertebrates	
	No.	Wt. (kg)	No.	Wt. (kg)
1/25/2006	32,618	955.440	83	7.981
8/10/2006*	174	10.654	1,225	32.605
8/15/2006	17,773	845.814	569	51.118
10/4/2006	7,893	395.662	1,853	33.144
10/10/2006	408	14.544	15	7.141
10/23/2006	1,011	33.479	19	5.808
11/20/2006	395	10.810	6	2.238
1/3/2007	10,812	236.492	79	7.536
	71,084	**2,502.895**	**3,849**	**147.571**

* The August 10, 2006 heat treatment was aborted due to mechanical problems with the Unit 3 traveling screens.

5.5.1.3 Seasonal Variation

Fish impingement abundance during the weekly diel normal operation surveys peaked in May 2006, (Figures 5.5-1), while biomass was highest in August and December 2006 (Figure 5.5-3). During the VCS period when the SGS operated in normal flow configuration, fish abundance and biomass was highest in mid-December 2006 (Figures 5.5-2 and 5.5-4).

Macroinvertebrate impingement was substantially higher during spring and summer 2006, and greatly reduced during the VCS period. Peak impingement rates for abundance were recorded during late spring (Figure 5.5-5), while impingement biomass peaked in summer, with the highest total recorded on August 8, 2006 (Figure 5.5-7). The survey on August 8, 2006 was, however, truncated with only one of four sampling events occurring during the 24-hour period due to mechanical problems with the traveling screens. It should be noted that both impinged abundance and biomass declined substantially after the August 8, 2006 survey, principally due to the heat treatment that was conducted on August 10, 2006, which effectively cleared the CWIS of nearly all macroinvertebrates. During the VCS period when the SGS operated in normal flow configuration, macroinvertebrate abundance was highest in December 2006 (Figure 5.5-6), while biomass was peaked in October and November 2006 (Figure 5.5-8).

5.5.1.4 Diel Variation

Fish impingement abundance and biomass showed no consistent pattern with respect to diel variation recorded during nighttime surveys (Figures 5.5-9 and 5.5-10). Invertebrate impingement was slightly more consistent, with slightly higher abundance during nighttime surveys (Figure 5.5-11), while biomass was relatively equal between daytime and nighttime surveys (Figure 5.5-12).

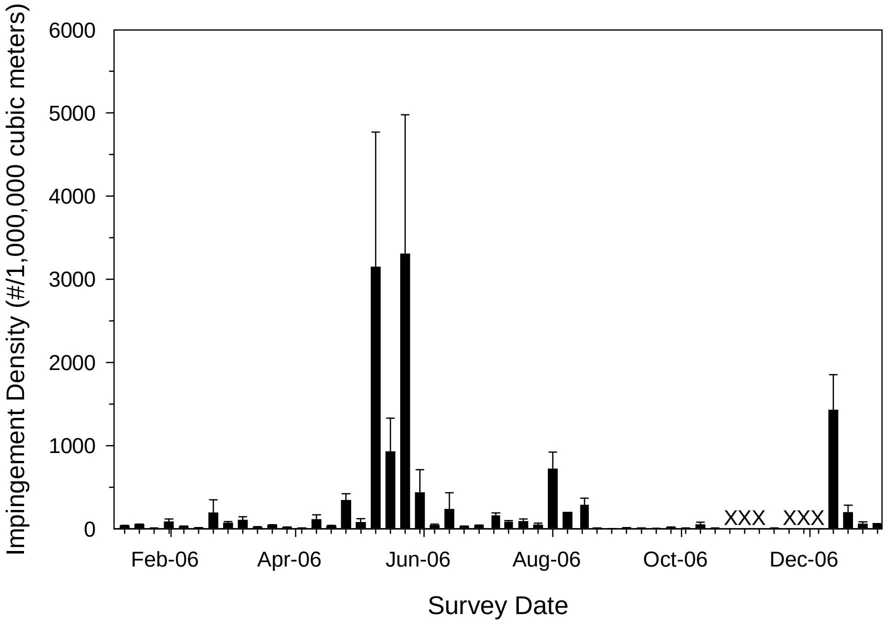


Figure 5.5-1. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of fishes collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

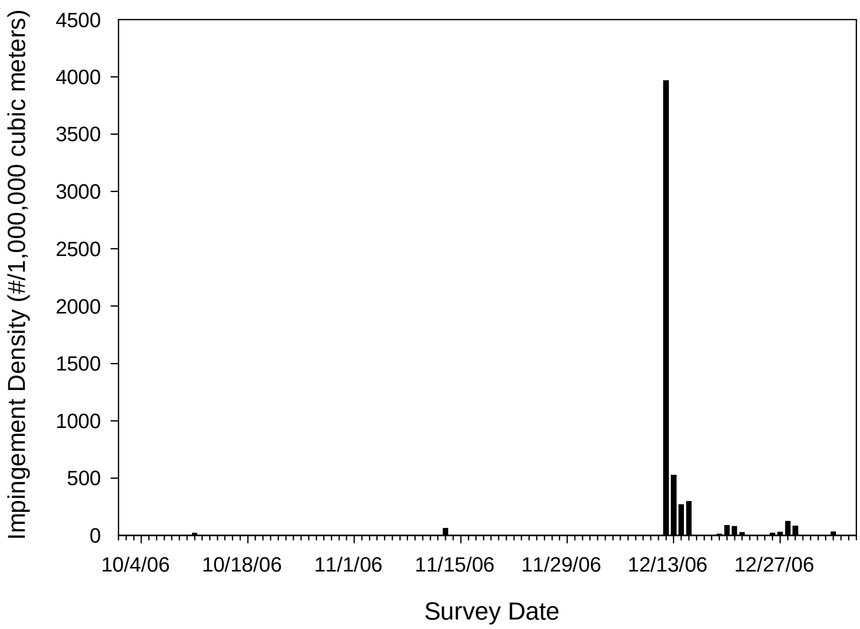


Figure 5.5-2. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of fishes collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

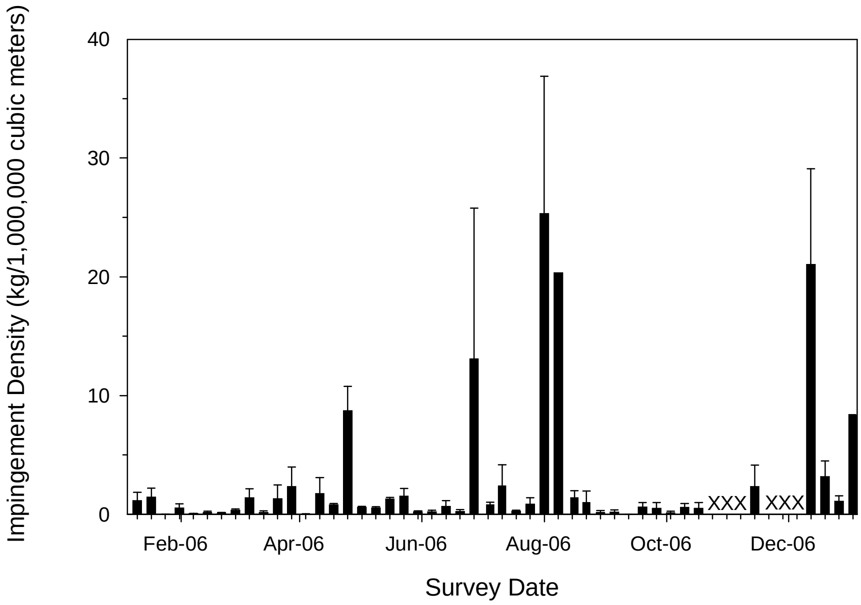


Figure 5.5-3. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of fishes collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

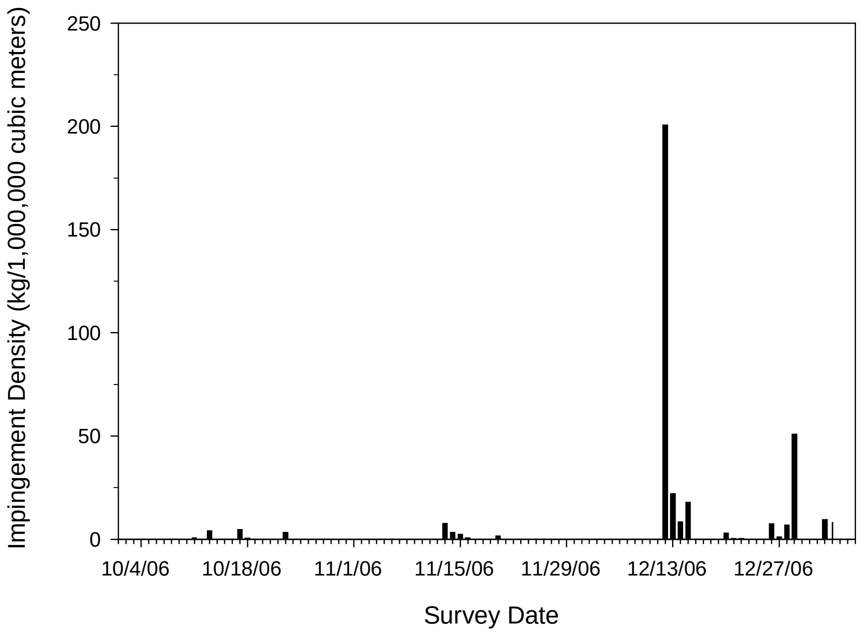


Figure 5.5-4. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of fishes collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

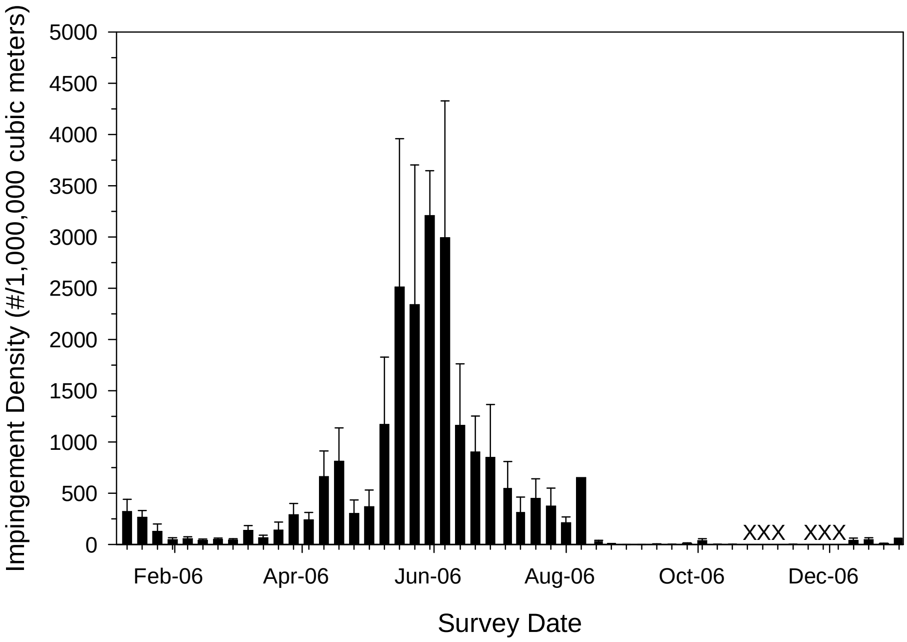


Figure 5.5-5. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]– wide bars) and standard error (narrow bars) of invertebrates collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

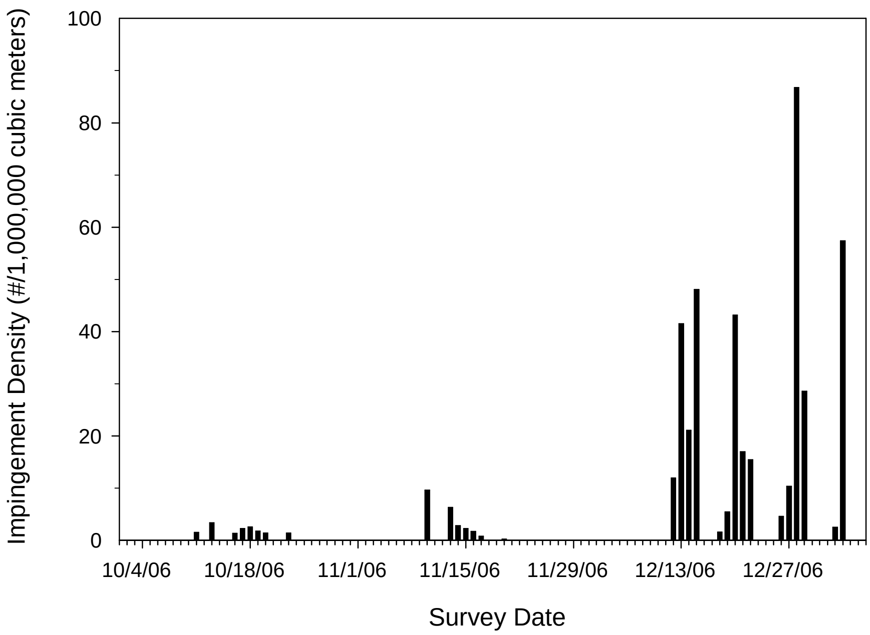


Figure 5.5-6. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of invertebrates collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

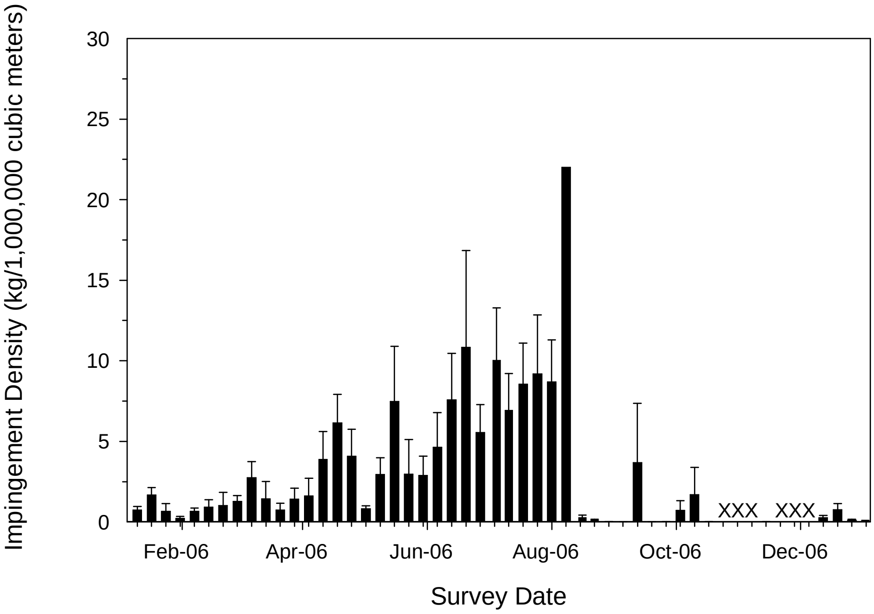


Figure 5.5-7. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of invertebrates collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

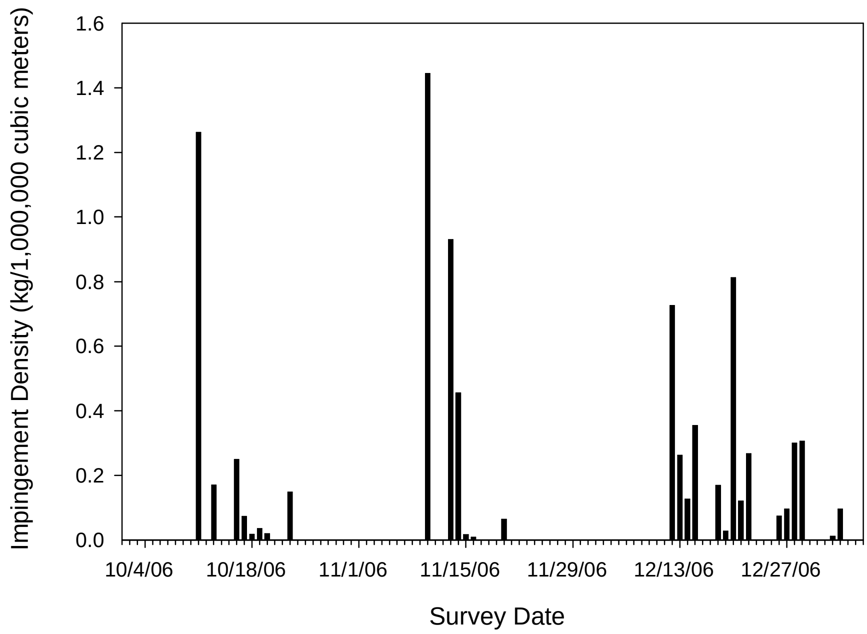


Figure 5.5-8. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of invertebrates collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

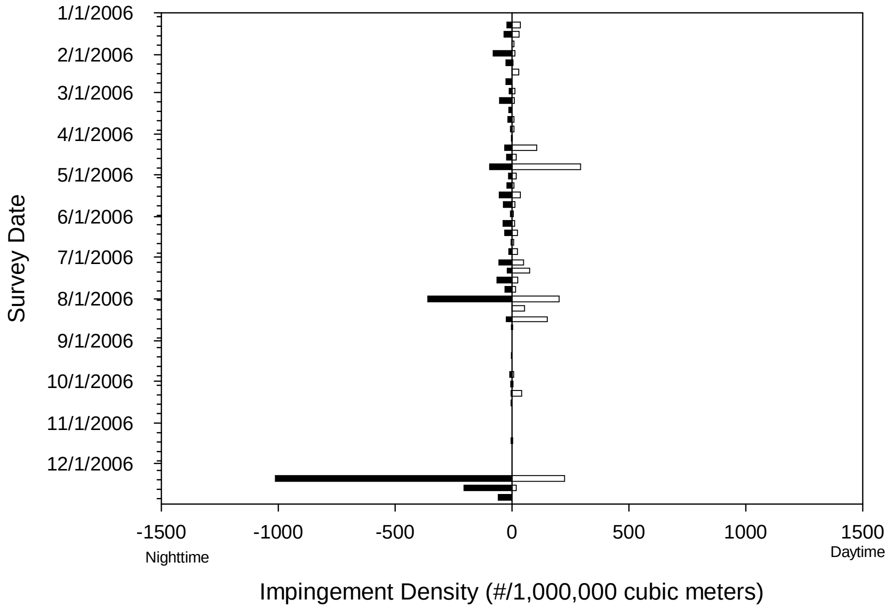


Figure 5.5-9. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of fishes in impingement samples during normal flow night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

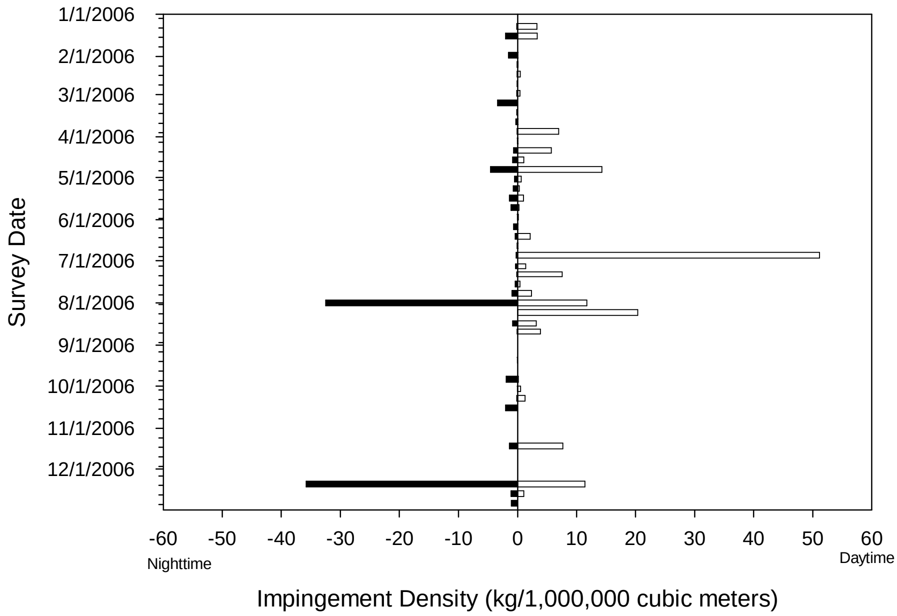


Figure 5.5-10. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of fishes in impingement samples during normal flow night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

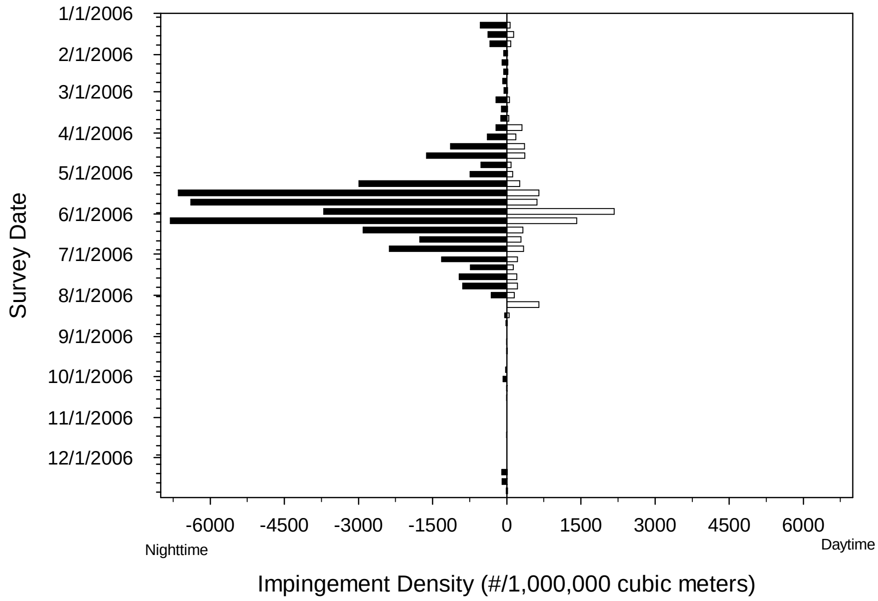


Figure 5.5-11. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of invertebrates in impingement samples during normal flow night (Cycle 3) and day (Cycle 1) sampling.

Note: Negative nighttime values are a plotting artifact

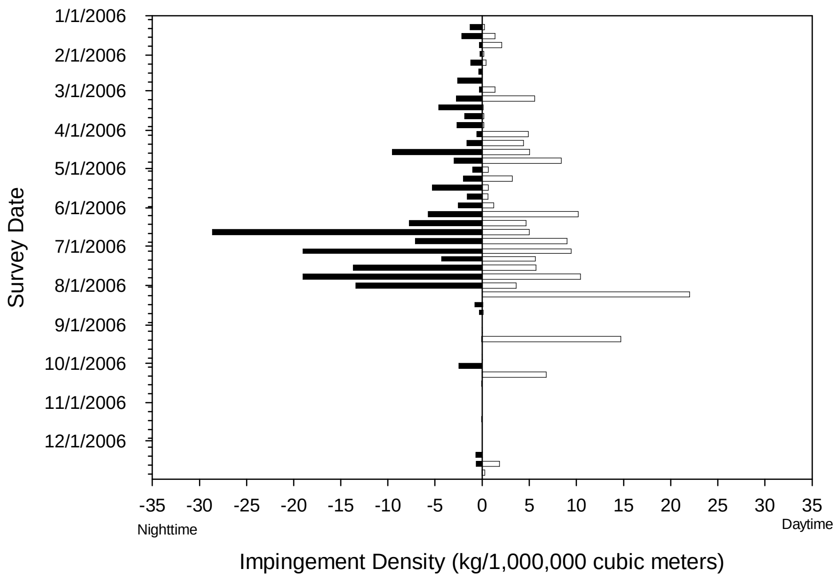


Figure 5.5-12. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of invertebrates in impingement samples during normal flow night (Cycle 3) and day (Cycle 1) sampling.

Note: Negative nighttime values are a plotting artifact

5.5.2 Fishes

Six fish taxa were impinged in sufficient numbers to warrant further analysis. These taxa were: queenfish (39% of sampled abundance), Pacific sardine (31%), northern anchovy (11%), topsmelt (4%), jacksmelt (4%), and walleye surfperch (4%). Combined, these taxa comprised 91.9% of the fishes in impingement samples. Two additional species were analyzed in further detail due to their inclusion in the Coastal Pelagics Fishery Management Plan: jack mackerel (100 individuals collected in samples) and Pacific chub mackerel (69 individuals). Nine other fish species were analyzed in further detail due to their inclusion in the Pacific Groundfish Fishery Management Plan: California scorpionfish (56 individuals), brown rockfish (35 individuals), cabezon (27 individuals), bocaccio (6 individuals), grass rockfish and English sole (3 individuals each), leopard shark (2 individuals), and black-and-yellow rockfish and vermilion rockfish (1 individual each).

5.5.2.1 Queenfish (*Seriphus politus*)

Information on the life history, ecology, population trends, and fishery for queenfish is summarized in Section 4.5.3.5.

5.5.2.1.1 Sampling Results

Queenfish was the most abundant species impinged with an estimated 34,085 individuals calculated using actual cooling water flow, or 35.8% of the annual total, weighing 649.245 kg (1,431.585 lbs) (Tables 5.5-1 and 5.5-2). Impingement of queenfish was frequently observed prior to August 10, 2006, with seasonal peaks in both abundance and biomass recorded during spring, although peak biomass was recorded in early August (Figures 5.5-13 through 5.5-16). During the VCS, abundance and biomass were consistently higher during mid- to late-December 2006. Impingement declined precipitously after the August 10, 2006 heat treatment, although it peaked again in December. Overall heat treatment abundance and biomass were highest during the January 25, 2006 survey at 20,984 individuals weighing 441 kg (973 lbs) (Table 5.5-6). Overall, higher abundance and biomass were recorded during nighttime impingement surveys (Figures 5.5-17 and 5.5-18).

Table 5.5-6. Summary of impingement for queenfish during normal flow direction heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	20,984	441.40	973.12
8/10/2006	4	0.14	0.30
8/15/2006	9	0.23	0.50
10/4/2006	9	0.14	0.31
10/10/2006	42	0.20	0.45
10/23/2006	121	0.58	1.27
11/20/2006	136	0.77	1.70
1/3/2007	8,165	147.42	325.00
	29,470	**590.87**	**1,302.87**

Length frequency analysis of 1,628 measured individuals indicated a mean standard length of 78 mm (3.1 in). Individuals ranged widely from the 20- to 180-mm SL size classes, with peaks at 60 mm and 120 mm (2.4 in and 4.7 in) (Figure 5.5-19), or young of the year and 1-year old, respectively. Of the 789 individuals that were evaluated for condition factor, 98.1% were dead and 1.9% was mutilated.

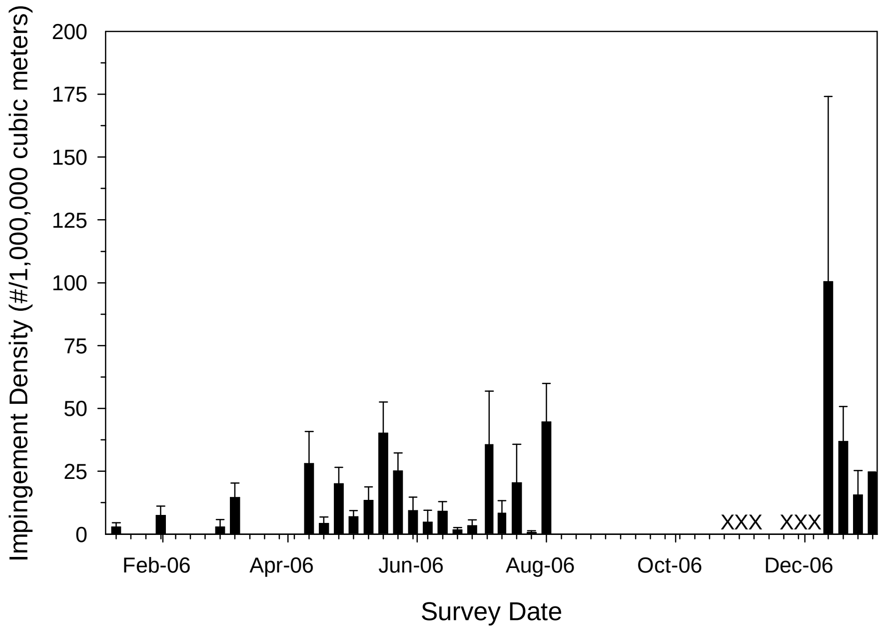


Figure 5.5-13. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of queenfish collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

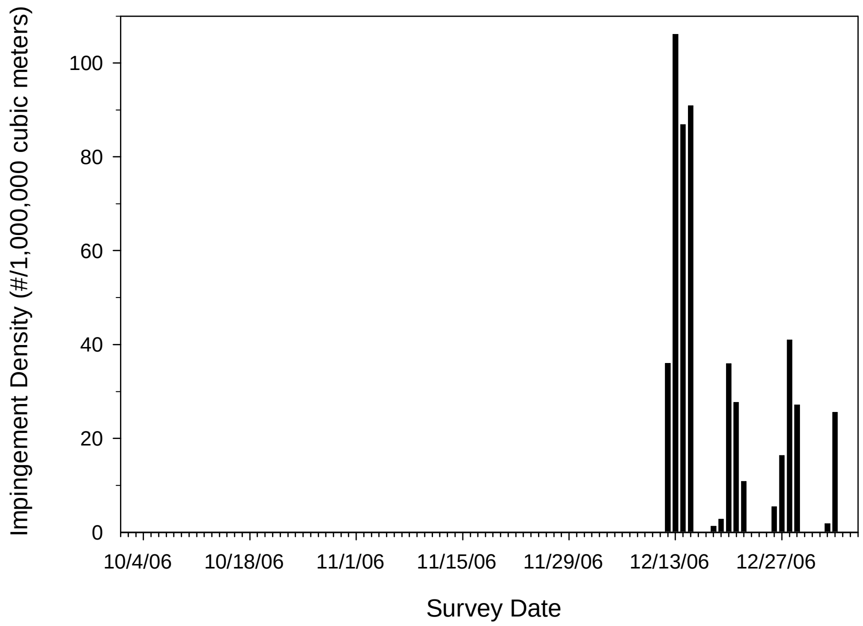


Figure 5.5-14. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of queenfish collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

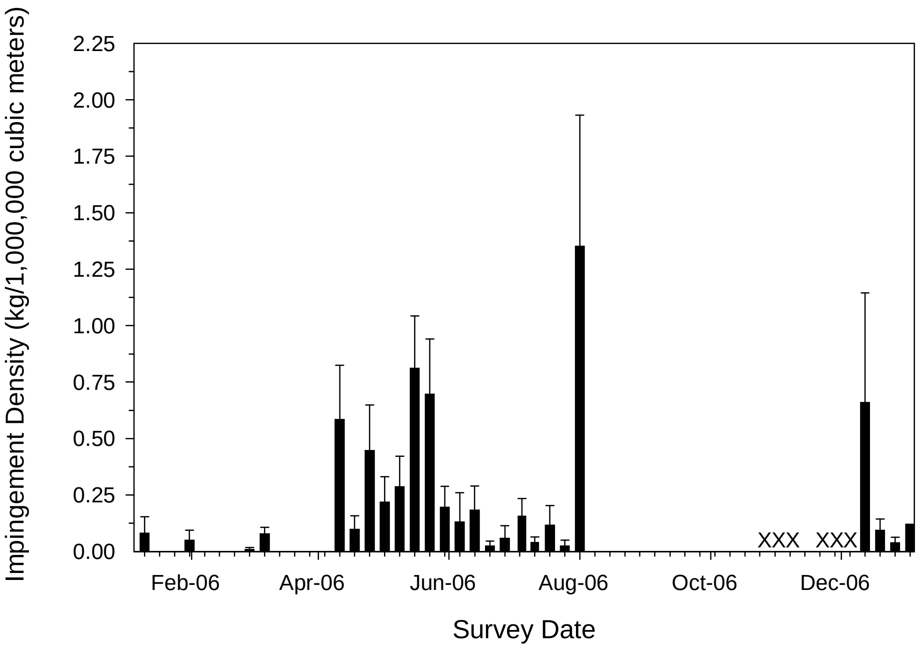


Figure 5.5-15. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of queenfish collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

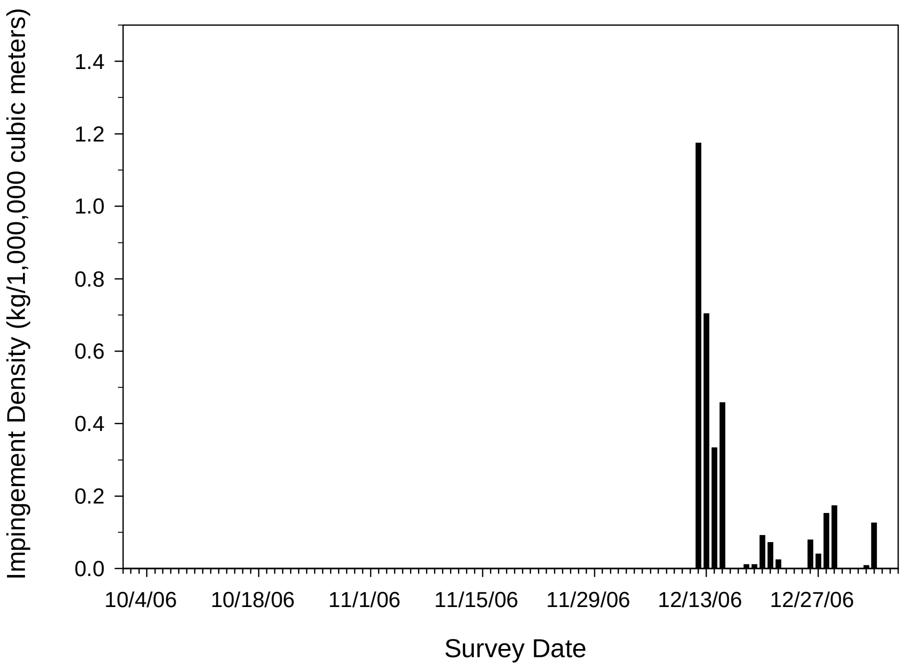


Figure 5.5-16. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of queenfish collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

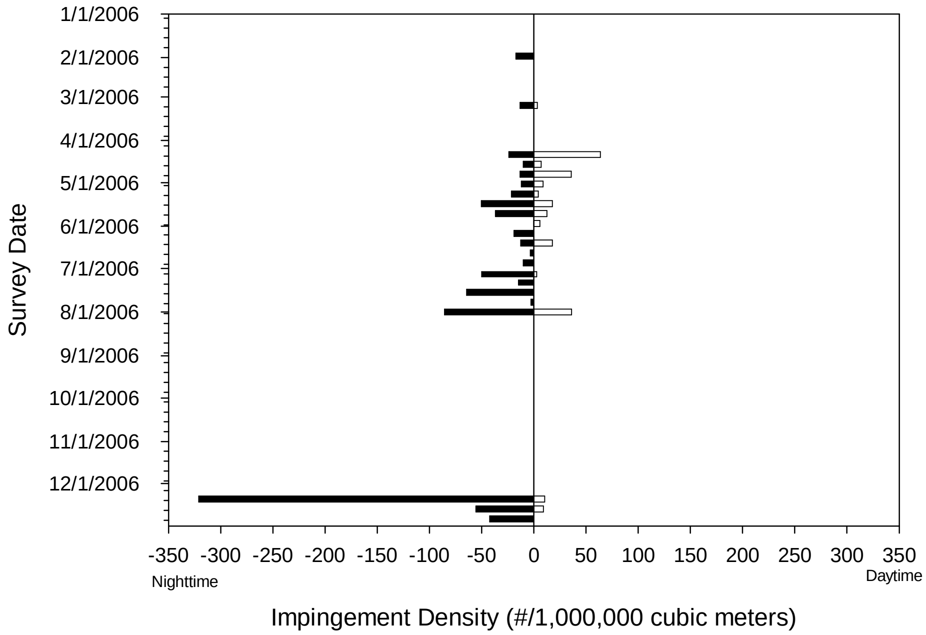


Figure 5.5-17. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of queenfish in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

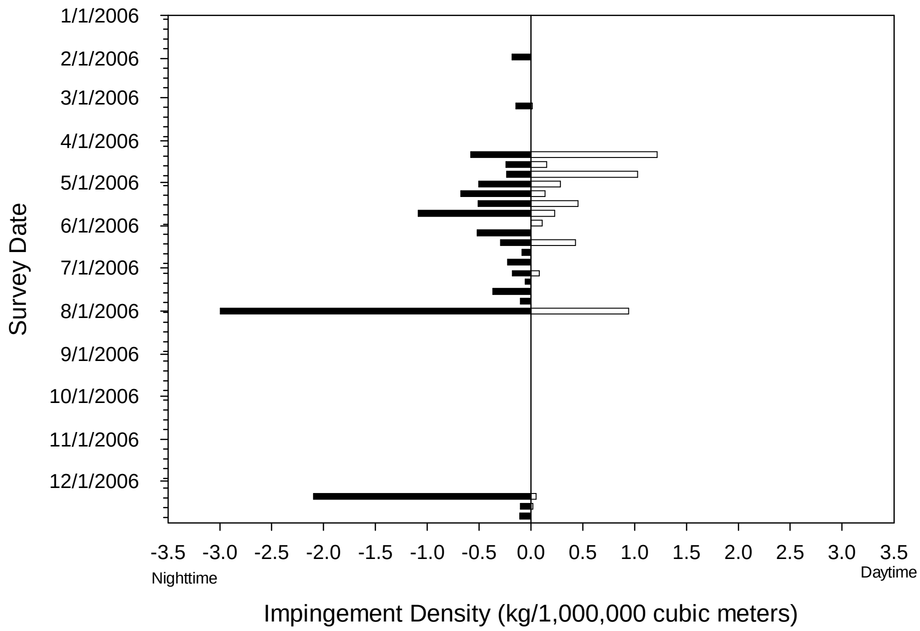


Figure 5.5-18. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of queenfish in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

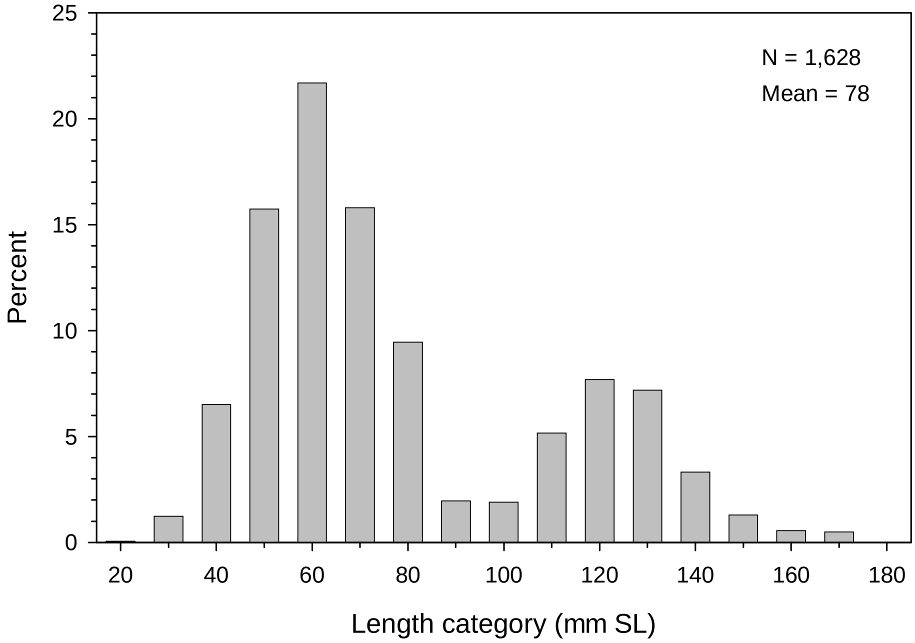


Figure 5.5-19. Length (mm) frequency distribution for queenfish collected in impingement samples.

5.5.2.1.2 Modeling Results

Queenfish life history parameters are presented in Table 5.5-7. Unpublished research by MBC and the Occidental College Vantuna Research Group (VRG) provided the adult life history parameters to calculate an age at 50% maturity of 1.76 years. A total of 36,199 adult equivalents were taken over the year based on actual cooling water flow. Of these 32,403 were directly attributable to heat treatments while an estimated 3,316 were contributed by normal operation of the cooling water system prior to the velocity cap study. The remaining 480 individuals were taken during the velocity cap study period during normal operation surveys. Recalculating the actual flow estimates to plant design flow equated to a total loss of 38,335 adult equivalents. The distribution of queenfish age classes of the 1,628 measured individuals is presented in Figure 5.5-20.

Table 5.5-7. Queenfish life history parameters used in equivalent adult modeling.

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

* Data from MBC and VRG unpublished data

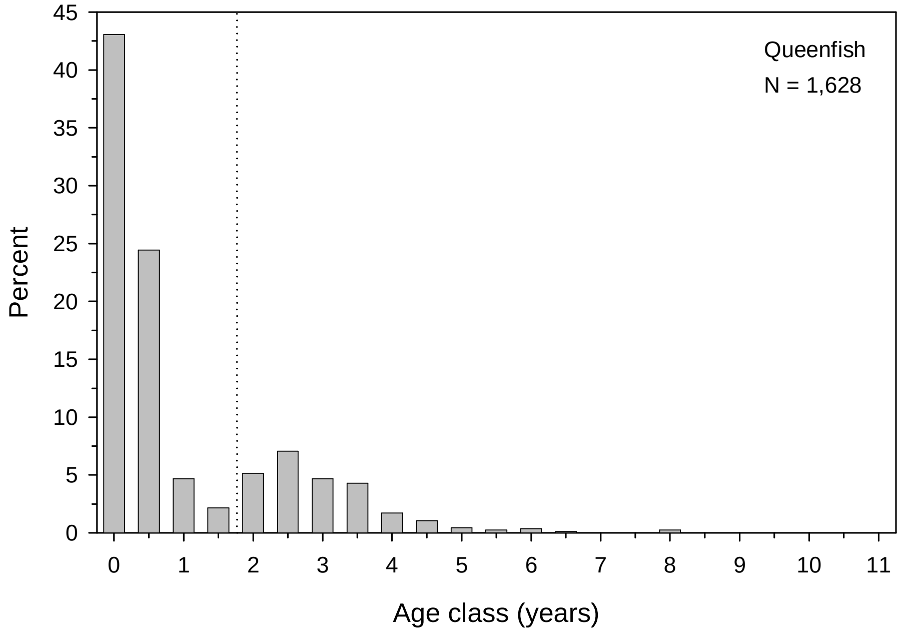
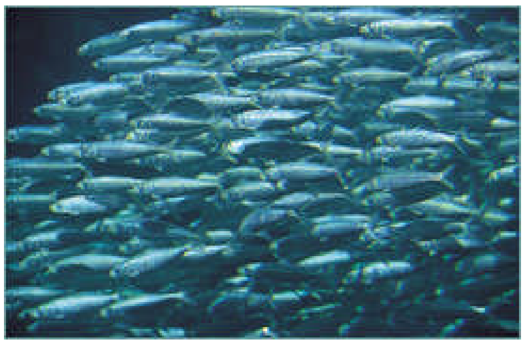


Figure 5.5-20. Distribution of queenfish age classes in SGS impingement samples. Vertical dotted line denotes age at 50% maturity.

5.5.2.2 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 SGS.

5.5.2.2.1 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) off shore, though they are known to spawn as far off shore 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/s (10.2 to 20.1 in/s) (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 has been estimated as 0.4/year (MacCall 1979).

5.5.2.2.2 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 mt (Hill et al. 2006; NMFS 2007).

Sardine landed in the U.S. fishery are mostly frozen and sold overseas as bait and aquaculture feed, with smaller amounts canned or sold for human consumption and animal food (Hill et al. 2006). Commercial landings of Pacific sardine in 2006 in Santa Monica Bay catch blocks totaled 3,591,016 kg (9,134,600 lbs) at a value of $426,626 (CDFG 2007b). Los Angeles area landings (between Dana Point and Santa Monica) for 2005 totaled 24,143,616 kg (53,236,674 lbs) at a value of $2,344,817 (CDFG 2006). Los Angeles area landings based on the PacFIN database declined slightly after 2002, and annual landings since have ranged between 23,000,000 and 27,000,000 kg (50,715,000 and 59,535,000 lbs) (Table 5.5-8). Between 2000 and 2005, annual sardine impingement at the SGS ranged between 24 individuals (2002) and 146,723 individuals (2004) (MBC 2006).

Table 5.5-8. Annual landings and revenue for Pacific sardine in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	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

5.5.2.2.3 Sampling Results

Pacific sardine was the second most abundant species impinged with an estimated 25,582 individuals, or 26.9% of the annual total, weighing 889.227 kg (1,960.746 lbs) (Tables 5.5-1 and 5.5-2). Impingement of Pacific sardine was highest in December 2006 (Figures 5.5-21 through 5.5-24). The highest peak observed during the VCS period in December 2006 occurred immediately after a heat treatment, which was suggestive of individuals that perished during the heat treatment, but were not impinged until the following survey. Highest heat treatment impingement was recorded in August 2006 (Table 5.5-9). Overall, higher abundance and biomass were recorded during daytime impingement surveys (Figures 5.5-25 and 5.5-26).

Length frequency analysis of 1,310 measured individuals indicated a mean SL of 134 mm (5.3 in). Individuals generally ranged in size from 40 mm SL to 190 mm SL with size distribution peaking at 150-mm SL (5.9-in) (Figure 5.5-27) representing individuals in their first and second years. Of the 442 individuals that were evaluated for condition factor, 84.8% were dead and 15.2% were mutilated.

Table 5.5-9. Summary of Pacific sardine impingement during normal flow direction heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	10	0.62	1.36
8/10/2006	28	0.96	2.11
8/15/2006	13,689	521.54	1,149.79
10/4/2006	7,595	341.71	753.33
10/10/2006	52	1.27	2.80
10/23/2006	607	16.41	36.17
11/20/2006	34	0.88	1.94
1/3/2007	189	5.85	12.90
	22.204	**889.23**	**1,960.75**

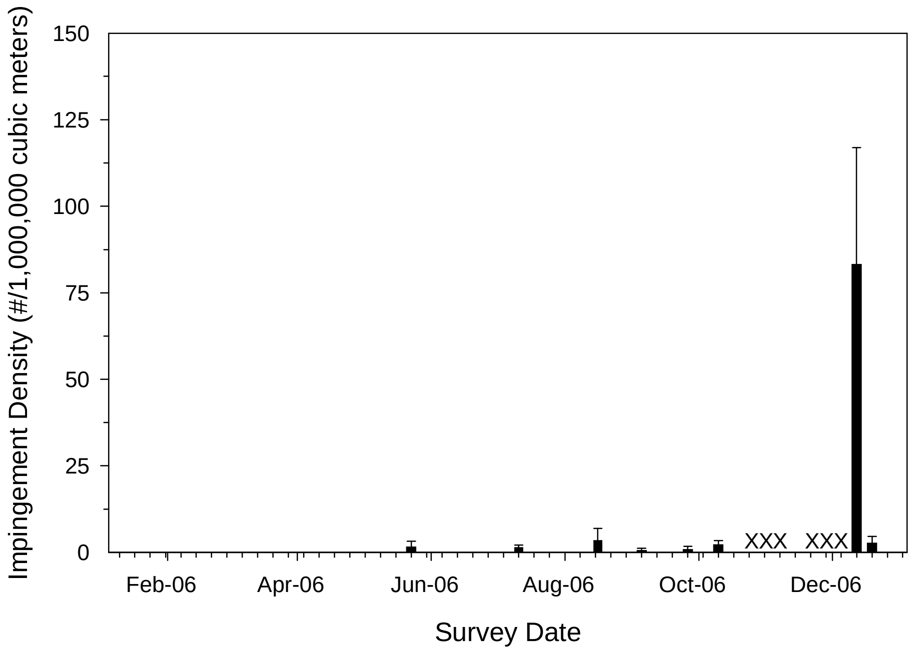


Figure 5.5-21. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of Pacific sardine collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

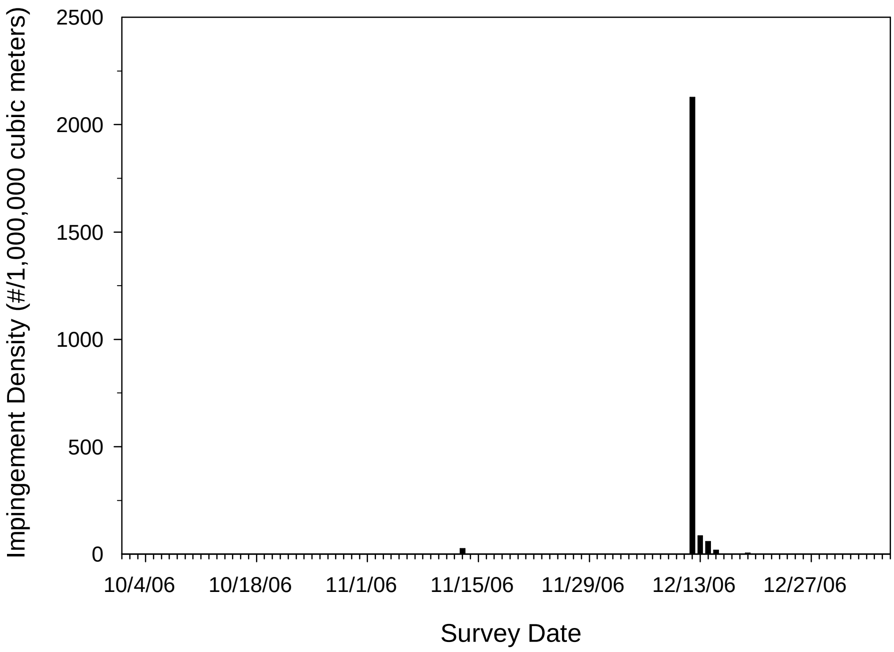


Figure 5.5-22. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of Pacific sardine collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

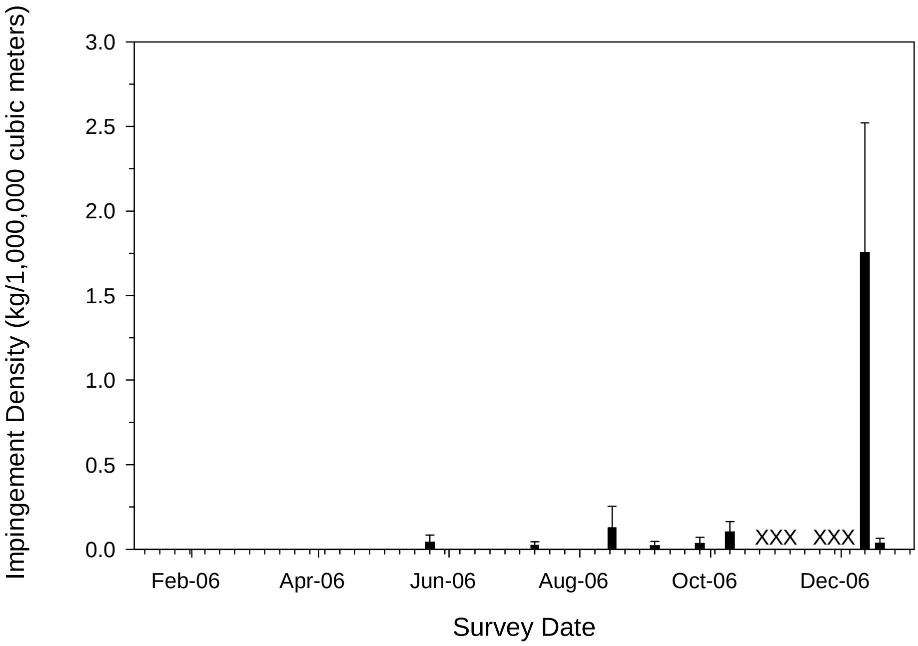


Figure 5.5-23. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of Pacific sardine collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

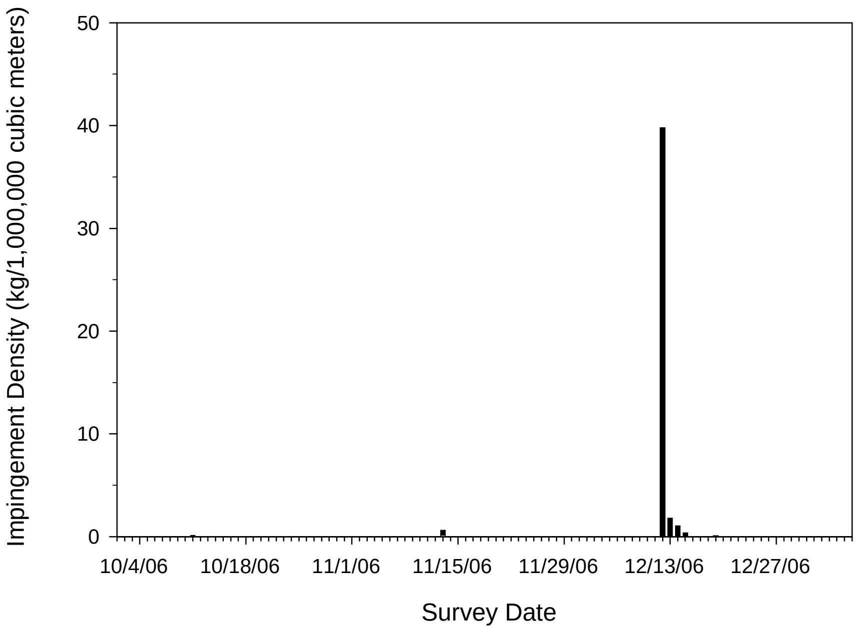


Figure 5.5-24. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of Pacific sardine collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

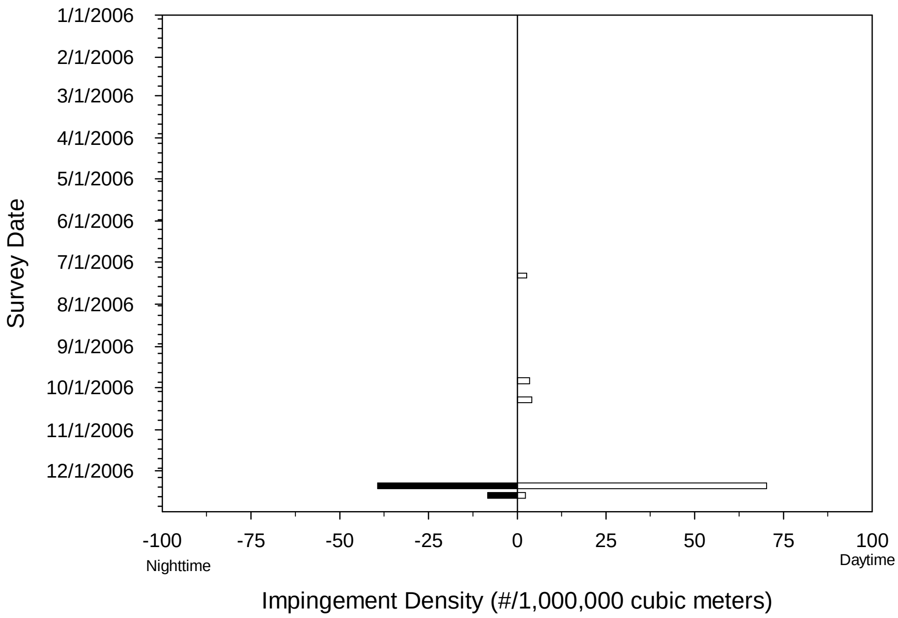


Figure 5.5-25. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of Pacific sardine in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

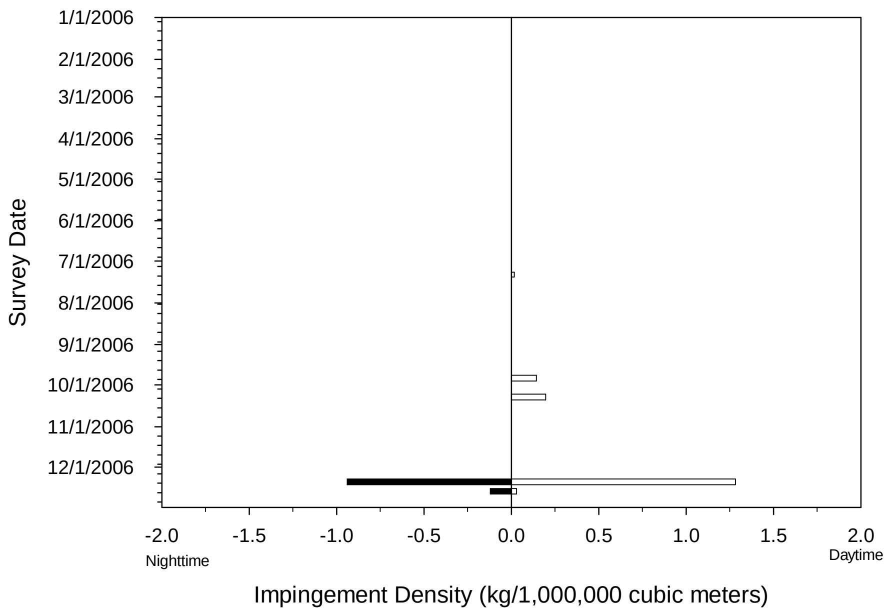


Figure 5.5-26. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of Pacific sardine in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

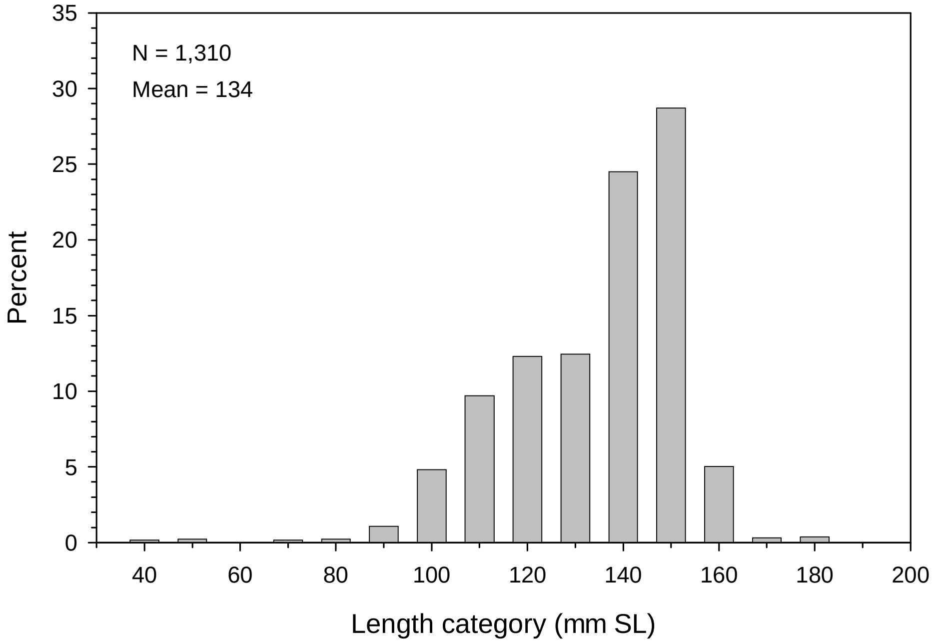


Figure 5.5-27. Length (mm) frequency distribution for Pacific sardine collected in impingement samples.

5.5.2.2.4 Modeling Results

Pacific sardine life history parameters are presented in Table 5.5-9. The von Bertalanffy parameters used were those reported by Hill et al. (2006). Annual survival estimates were calculated based on daily mortality rates (daily survival=0.998901) summarized in Butler et al. (1993). Age at 50% maturity was -0.25208 (relative to the age of other impinged individuals) based on the length at 50% maturity (125 mm SL) first published by Ahlstrom (1996 cited in Butler et al. 1996). Adult equivalents taken during actual operation of the cooling water system totaled 31,126 individuals. Heat treatments accounted for the majority of these losses (28,985) while velocity cap normal operation surveys accounted for an additional 1,962 individuals. Weekly normal operation surveys for the overall impingement characterization estimated 81 individuals lost prior to October and an additional 98 from October through the first week of January 2007. Recalculation of these estimations based on design flow of the cooling water pumps indicates 32,331 adult equivalent Pacific sardines would have been taken at continuous full flow operation for the year. The distribution of Pacific sardine age classes of the 1,310 measured individuals is presented in Figure 5.5-28.

Table 5.5-10. Pacific sardine life history parameters used in equivalent adult modeling.

Annual Adult Mortality (Z)*	Annual Survival (S)*	von Bertalanffy growth parameters** L_{inf}	k	t_0	Relative Age at 50% Maturity***	Length at 50% Maturity***
0.4014	0.6693	244 mm SL	0.319	-2.503	-0.25208	125 mm SL

* Calculated from Butler et al. 1993

** Hill et al. 2006

***Ahlstrom 1960 cited in Butler et al. 1996; Age at 50% maturity is relative to other ages of impinged individuals as estimated by a von Bertalanffy equation; Hill et al. 2006 report that Age 0 fish are 30% mature and Age 1 fish are 53% mature

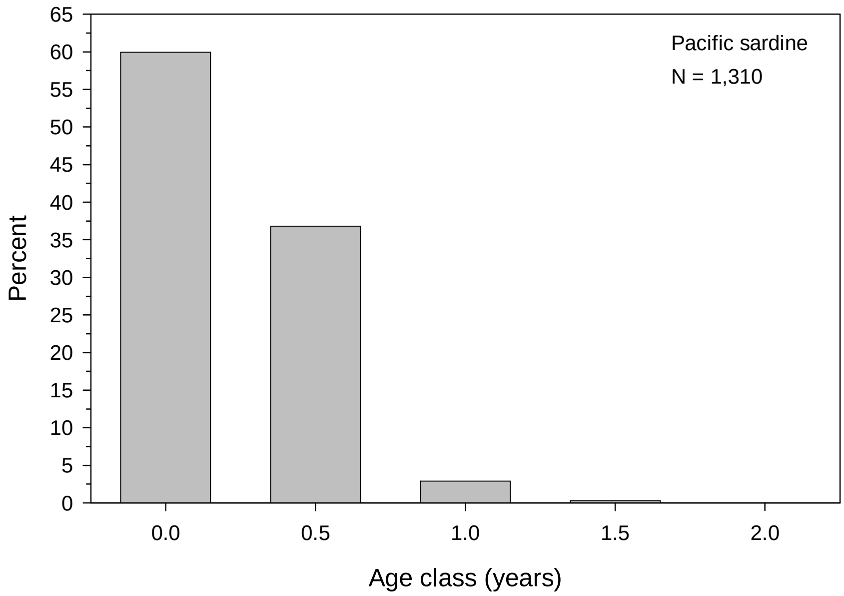


Figure 5.5-28. Distribution of Pacific sardine age classes in SGS impingement samples.

5.5.2.3 Northern Anchovy (*Engraulis mordax*)

Information on the life history, ecology, population trends, and fishery of northern anchovy is summarized in Section 4.4.3.1. From 2000 through 2005, annual impingement of northern anchovy at the SGS ranged between 2 individuals (2002) and 10,330 individuals (2005) (MBC 2006).

5.5.2.3.1 Sampling Results

Northern anchovy was the third most abundant species impinged with an estimated 10,214 individuals, or 10.7% of the annual total calculated using actual cooling water flow, weighing 43.556 kg (96.040 lbs) (Tables 5.5-1 and 5.5-2). This species was frequently observed from late winter through spring, with a peak in abundance recorded in late December and a peak in biomass in late April (Figures 5.5-29 through 5.5-32). Heat treatment abundance peaked with the January 25, 2006 survey, which recorded 4,784 individuals (Table 5.5-11). There was no consistent pattern of impingement with respect to diel variation, although the peak impingement rates were recorded during the April 11, 2006 daytime survey (Figures 5.5-33 and 5.5-34).

Table 5.5-11. Summary of northern anchovy impingement during normal flow direction heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	4,784	33.99	74.93
8/10/2006	–	–	–
8/15/2006	2,048	4.87	10.75
10/4/2006	–	–	–
10/10/2006	2	0.01	0.01
10/23/2006	81	0.32	0.71
11/20/2006	7	0.03	0.07
1/3/2007	1,222	4.33	9.55
	8,144	**43.56**	**96.04**

Length frequency analysis of 1,140 measured individuals indicated a mean SL of 76 mm (3.0 in). Most individuals ranged from 60 mm SL to 90 mm (2.4 in to 3.5 in) with a peak in the 70-mm (2.8-in) SL size class (Figure 5.5-35), corresponding to young of the year. Of the 455 individuals that were evaluated for condition factor, 92.3% were dead and 7.7% were mutilated.

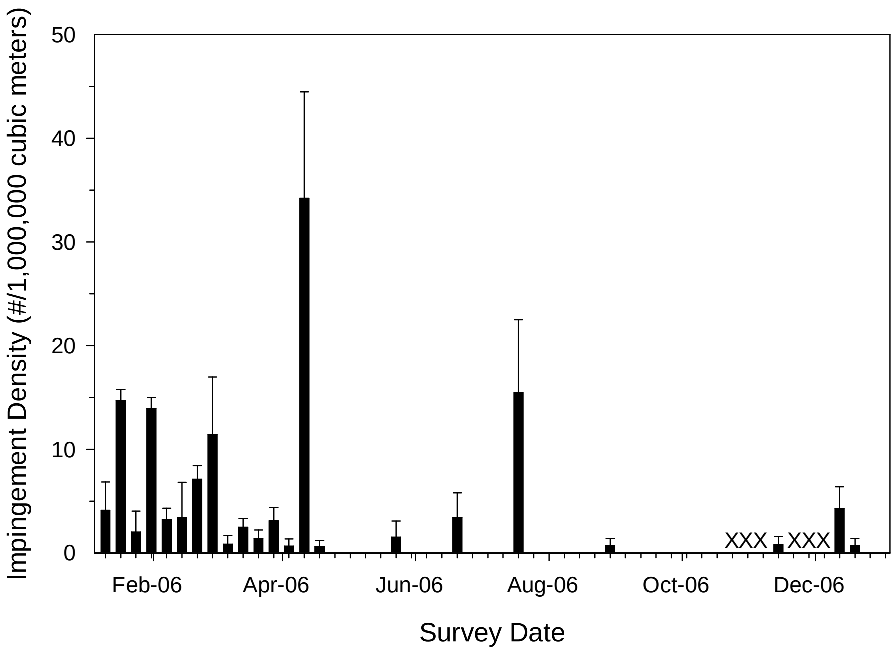


Figure 5.5-29. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of northern anchovy collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

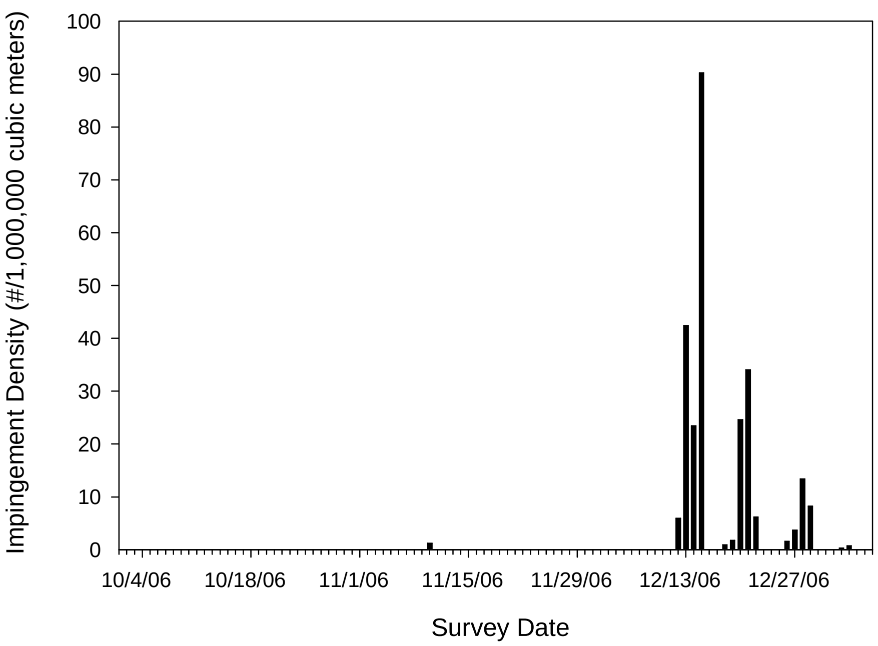


Figure 5.5-30. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of northern anchovy collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

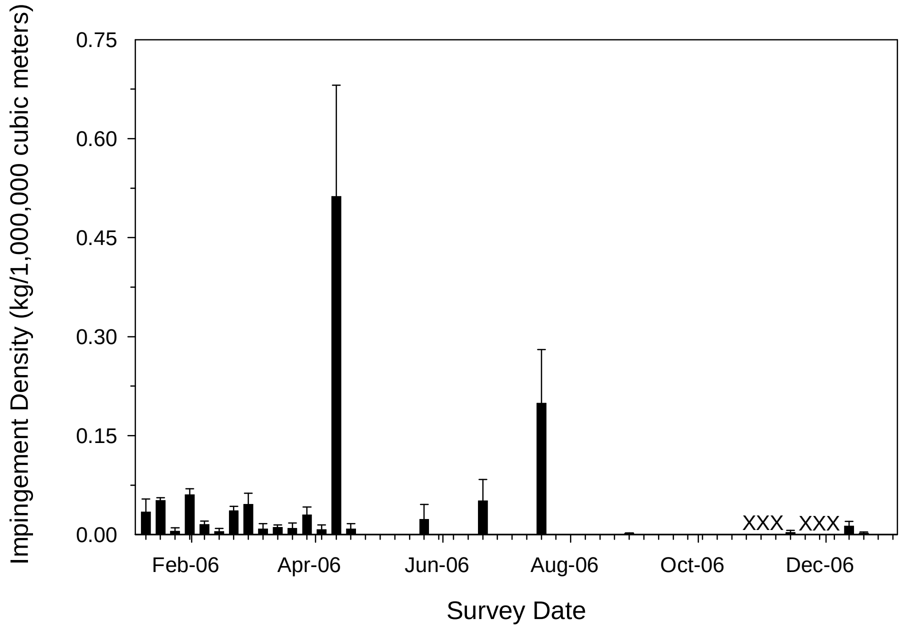


Figure 5.5-31. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of northern anchovy collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

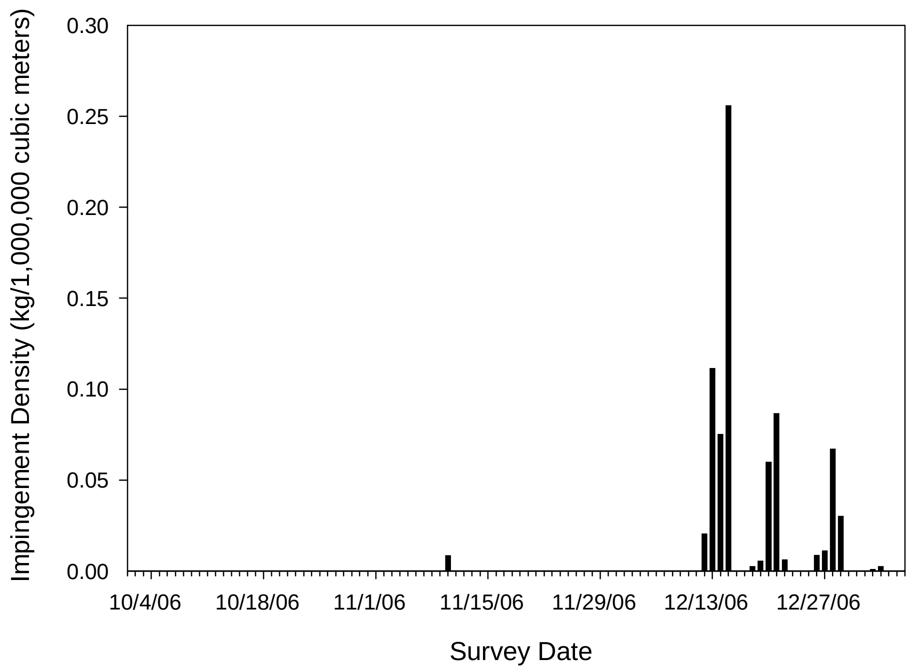


Figure 5.5-32. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of northern anchovy collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

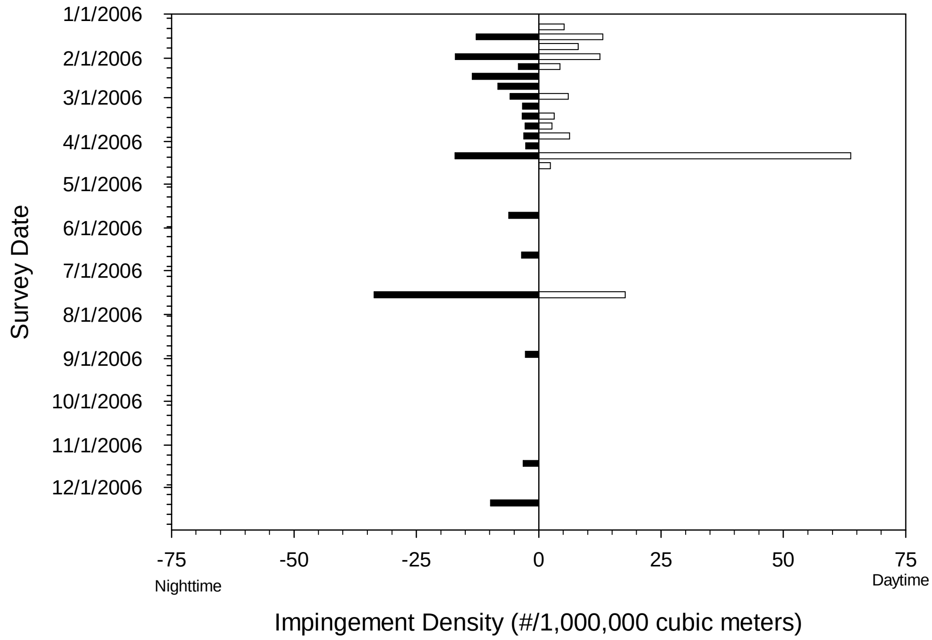


Figure 5.5-33. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of northern anchovy in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

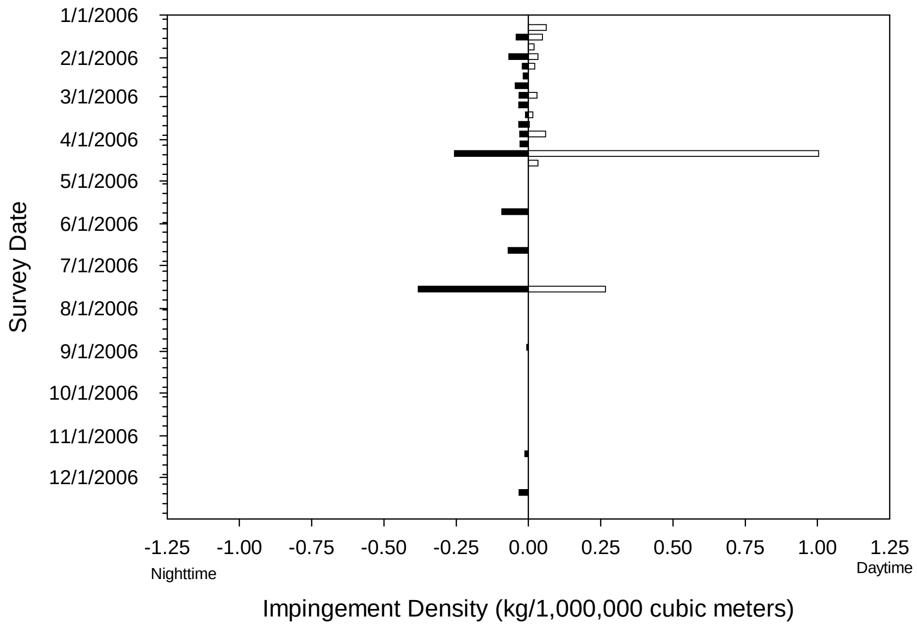


Figure 5.5-34. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of northern anchovy in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

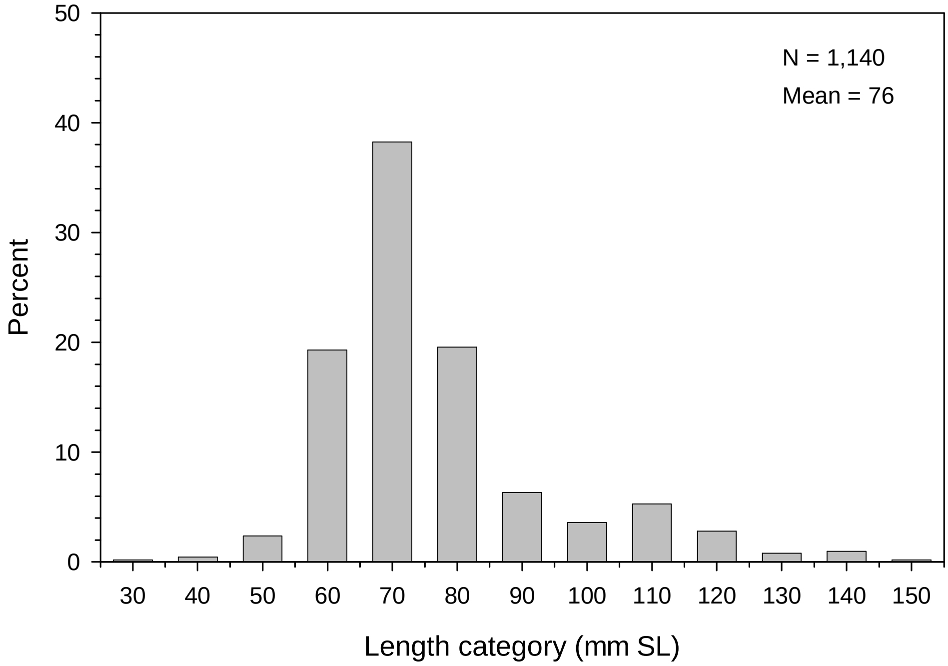


Figure 5.5-35. Length (mm) frequency distribution for northern anchovy collected in impingement samples.

5.5.2.3.2 Modeling Results

Northern anchovy life history parameters are presented in Table 5.5-12. The von Bertalanffy parameters were derived from data presented for San Pedro Channel, California in Parrish et al. (1985). Annual survival estimates were based on a daily survival rate (0.997902) calculated from Butler et al. (1993). Age and size at 50% maturity, 0.98 years and 96 mm SL, respectively, were taken from Hunter and Macewicz (1980). Over the survey year approximately 18,465 adult equivalent northern anchovies were taken during the actual operation of the cooling water system. Of these, 11,234 individuals were contributed by normal operation of the system prior to October 2006 with an additional 64 individuals taken during the remaining normal operation surveys. Heat treatments contributed the next highest abundance with 6,993 adult equivalents impinged followed by an estimated 174 equivalents impinged during normal operation surveys conducted in association with the assessment of the velocity cap. Recalculating the data under the assumption that the cooling water system operated at full (design) capacity indicates an estimated 24,922 adult equivalents would have been taken during the survey period. The distribution of northern anchovy age classes of the 1,440 measured individuals is presented in Figure 5.5-36.

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

Annual Adult Mortality (Z)*	Annual Survival (S)	von Bertalanffy growth parameters** L_{inf}	k	t_0	Age at 50% Maturity***	Length at 50% Maturity***
0.7666	0.4646	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)

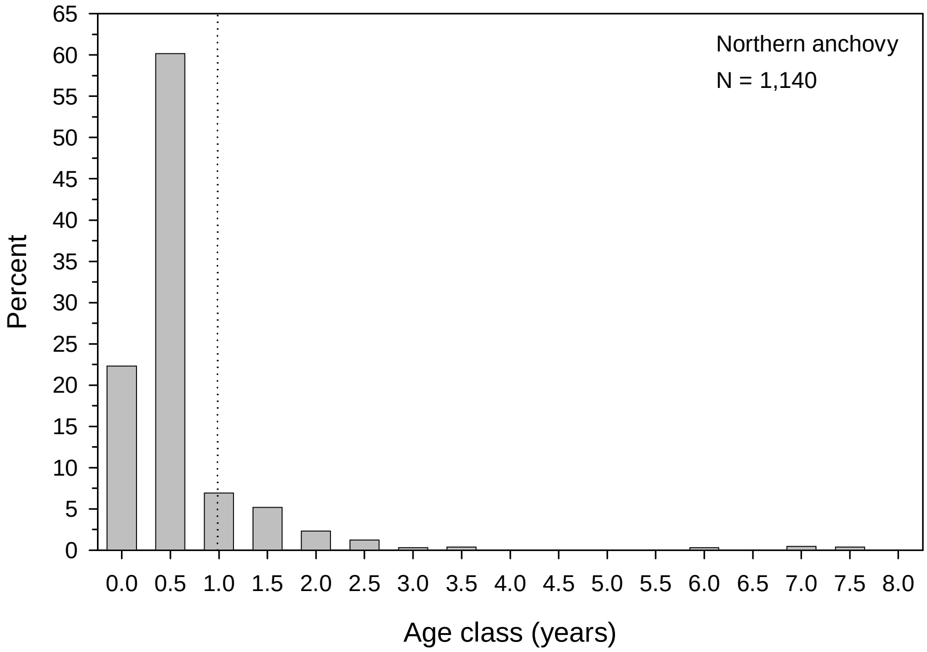


Figure 5.5-36. Distribution of northern anchovy age classes in SGS impingement samples. Vertical dotted line denotes age at 50% maturity.

5.5.2.4 Topsmelt (*Atherinops affinis*)

Information on the life history, ecology, population trends, and fishery of topsmelt is summarized in Section 4.5.3.2.

5.5.2.4.1 Sampling Results

Topsmelt was the fourth most abundant species impinged with an estimated 4,297 individuals, or 4.5% of the annual total calculated using actual cooling water flow volumes, weighing 172.113 kg (379.509 lbs) (Tables 5.5-1 and 5.5-2). Impinged sporadically throughout the year, topsmelt were substantially more abundant from August through December 2006, in comparison to the first seven months of the year (Figure 5.5-37). Biomass followed a pattern consistent with that observed for abundance (Figure 5.5-39). During the VCS, abundance and biomass was generally low, less than 50 individuals (2 kg) per 1,000,000 m^3, except for the survey on December 12, 2006, where density was greater than 700 individuals per 1,000,000 m^3 and approximately 20 kg per 1,000,000 m^3 (Figures 5.5-38 and 5.5-40). The small peaks observed during the VCS period in mid-December 2006 occurred immediately after a reverse-flow heat treatment, which was suggestive of individuals that perished during the heat treatment, but were not impinged until subsequent surveys. Heat treatment impingement peaked during the August 15, 2006 survey, with 783 individuals weighing 22.832 kg (50.345 lbs) (Table 5.5-11). Overall, higher abundance and biomass was recorded during daytime impingement surveys, although peak abundance was recorded during the nighttime survey on December 12, 2006 (Figures 5.5-41 and 5.5-42).

Table 5.5-13. Summary of topsmelt impingement during normal flow direction heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	322	11.68	25.74
8/10/2006	79	2.10	4.63
8/15/2006	783	22.83	50.34
10/4/2006	49	2.15	4.74
10/10/2006	244	6.42	14.16
10/23/2006	48	1.51	3.32
11/20/2006	95	2.73	6.02
1/3/2007	186	6.02	13.27
	1,806	**55.44**	**122.24**

Length frequency analysis of 1,470 measured individuals indicated a mean standard length of 135 mm (5.3 in) (Figure 5.5-43). Individuals ranged in size from the 60-mm to 290-mm (2.4-in to 11.4-in) size classes, with most between the 120-mm and 150-mm (4.7-in and 5.9-in) size classes, corresponding to fish in their second year. Of the 423 individuals that were evaluated for condition factor, 1.9% was alive, 95.3% were dead, and 2.8% were mutilated.

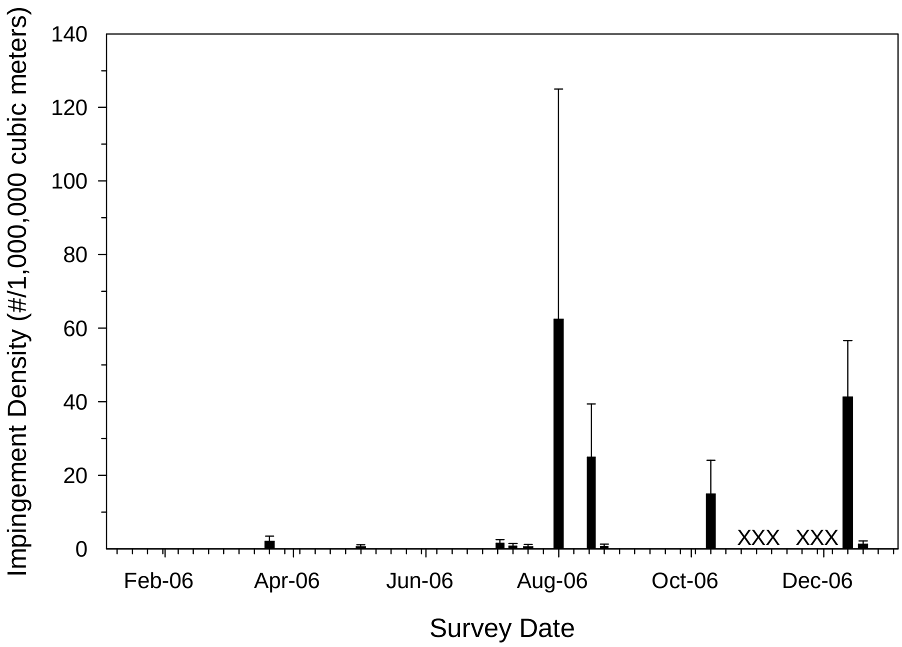


Figure 5.5-37. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of topsmelt collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

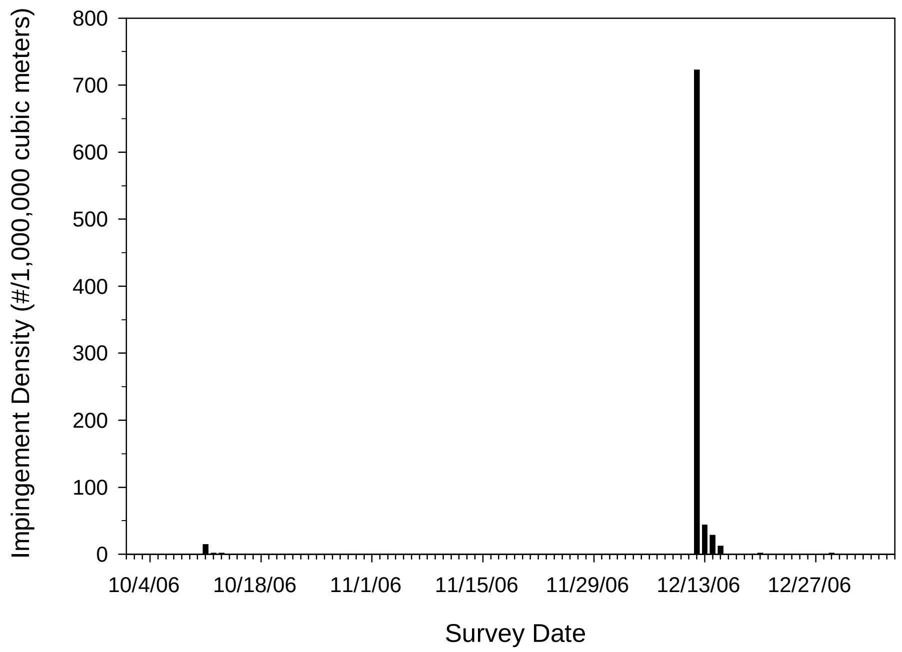


Figure 5.5-38. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of topsmelt collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

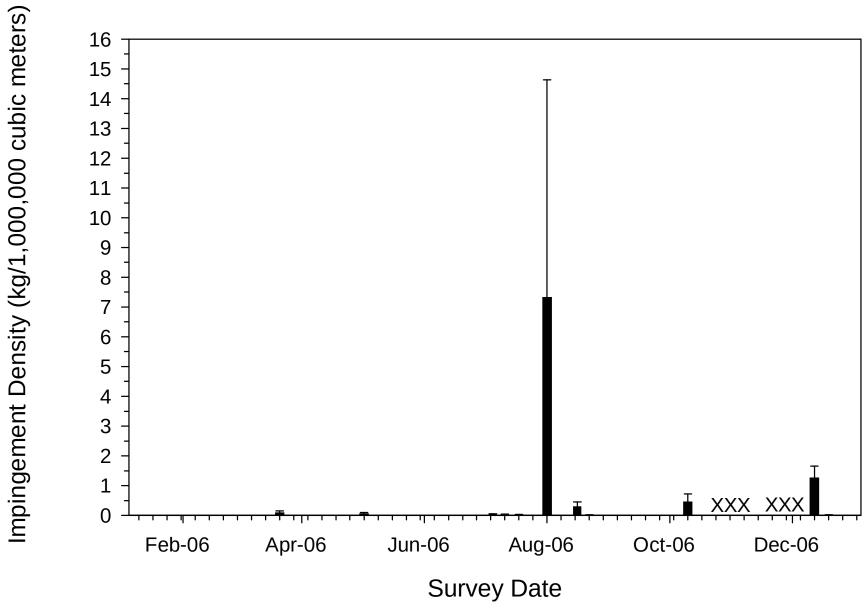


Figure 5.5-39. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of topsmelt collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

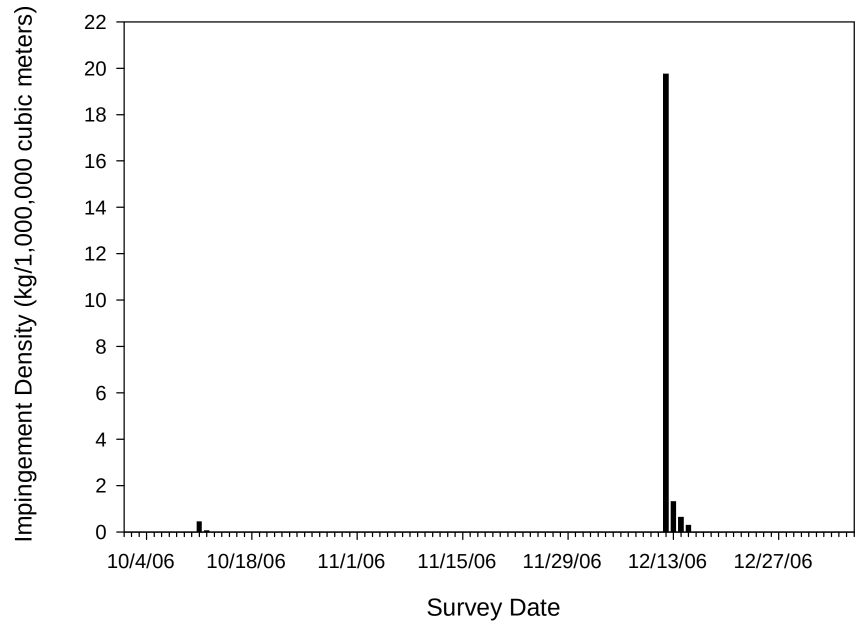


Figure 5.5-40. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of topsmelt collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

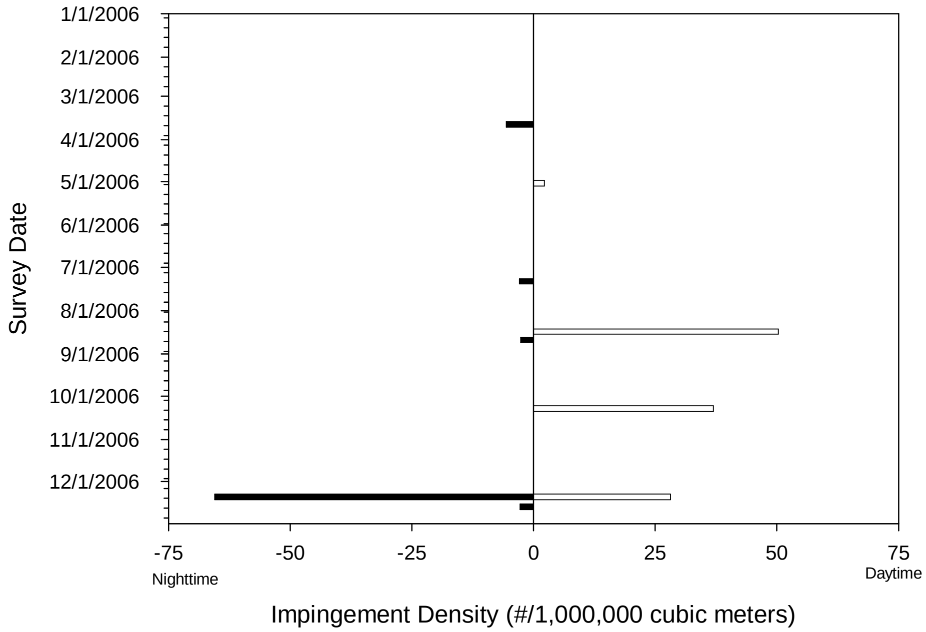


Figure 5.5-41. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of topsmelt in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

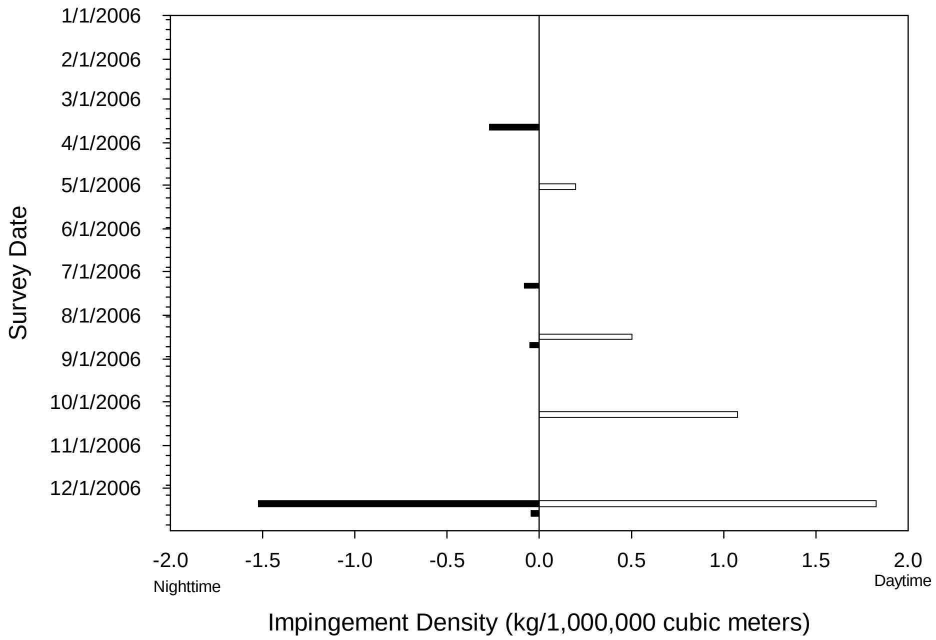


Figure 5.5-42. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of topsmelt in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

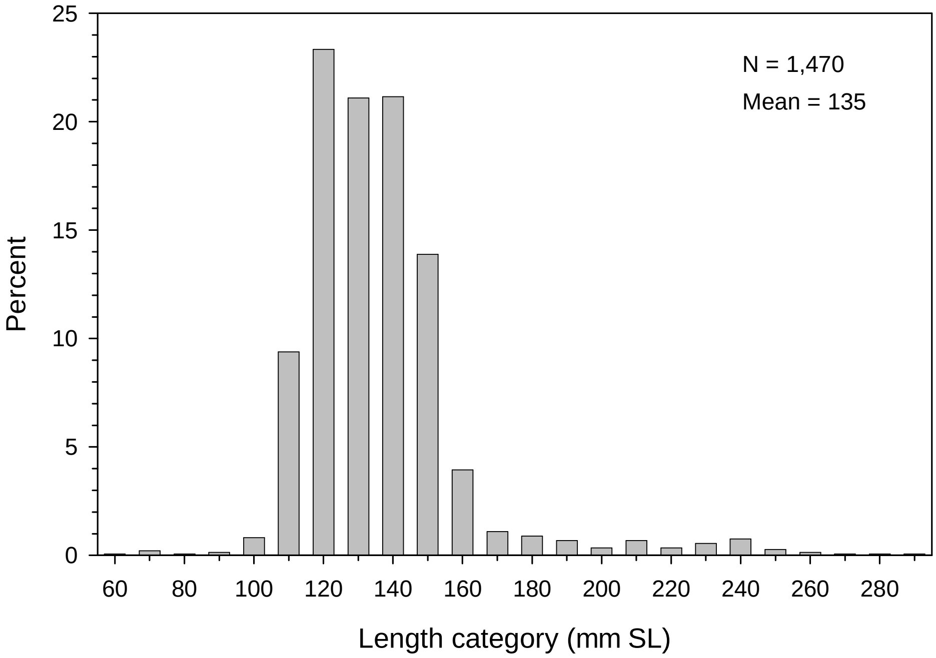


Figure 5.5-43. Length (mm) frequency distribution for topsmelt collected in impingement samples.

5.5.2.5 Jacksmelt (*Atherinopsis californiensis*)

Three species of silversides (Family Atherinopsidae), all similar morphologically, occur in the waters off southern California: topsmelt, jacksmelt, and California grunion. Topsmelt was discussed in Section 5.5.2.4. 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).

5.5.2.5.1 Life History and Ecology

Jacksmelt occur over much of the nearshore areas of California, and are common 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).

5.5.2.5.2 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 lbs) 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 lbs) at a value of $1,777 (CDFG 2006). From 2000 through 2005, annual impingement of jacksmelt at the SGS ranged from 981 individuals (2002) to 16,548 individuals (2000) (MBC 2006).

5.5.2.5.3 Sampling Results

Jacksmelt was the fifth most abundant species impinged with an estimated 7,107 individuals, or 7.5% of the annual total calculated using actual cooling water flow volumes, weighing 668.336 kg (1,473.681 lbs) (Tables 5.5-1 and 5.5-2). This species was observed sporadically in high abundances and biomass throughout the year, with peaks in both parameters measured in mid-December (Figures 5.5-44 through 5.5-47). During the VCS, abundance and biomass were relatively low throughout most of the study period, with a dramatic increase recorded on December 12, 2006, with abundance and biomass slowly tapering off with time (Figures 5.5-45 and 5.5-47). This peak may be directly related to the reverse flow heat treatment of December 11, 2006, and the individuals collected over the next couple of days may have perished during the heat treatment, but were not impinged until subsequent surveys. Highest heat treatment abundance and biomass were recorded during August 2006 (Table 5.5-14). There was no consistent diel pattern of impingement (Figures 5.5-48 and 5.5-49).

Table 5.5-14. Summary of jacksmelt impingement during normal flow direction heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	456	50.77	111.94
8/10/2006	1	0.06	0.13
8/15/2006	785	106.93	235.74
10/4/2006	–	–	–
10/10/2006	–	–	–
10/23/2006	–	–	–
11/20/2006	2	0.30	0.65
1/3/2007	249	24.78	54.64
	1,493	**182.84**	**403.16**

Length frequency analysis of 1,102 measured individuals indicated a mean standard length of 208 mm (8.2 in) (Figure 5.5-50). Individuals ranged widely from the 70-mm to 320-mm (2.8-in and 12.6-in) size classes, with a peak at the 220-mm (8.7-in) SL size class, corresponding to individuals greater than two years old. Of the 488 individuals that were evaluated for condition factor, 97.1% were dead and 2.9% were mutilated.

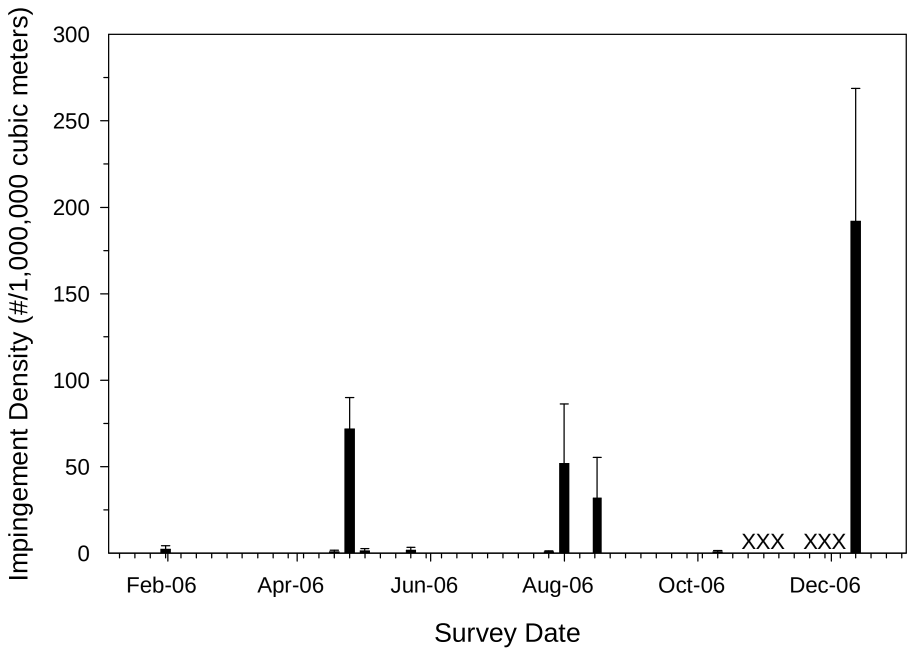


Figure 5.5-44. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of jacksmelt collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

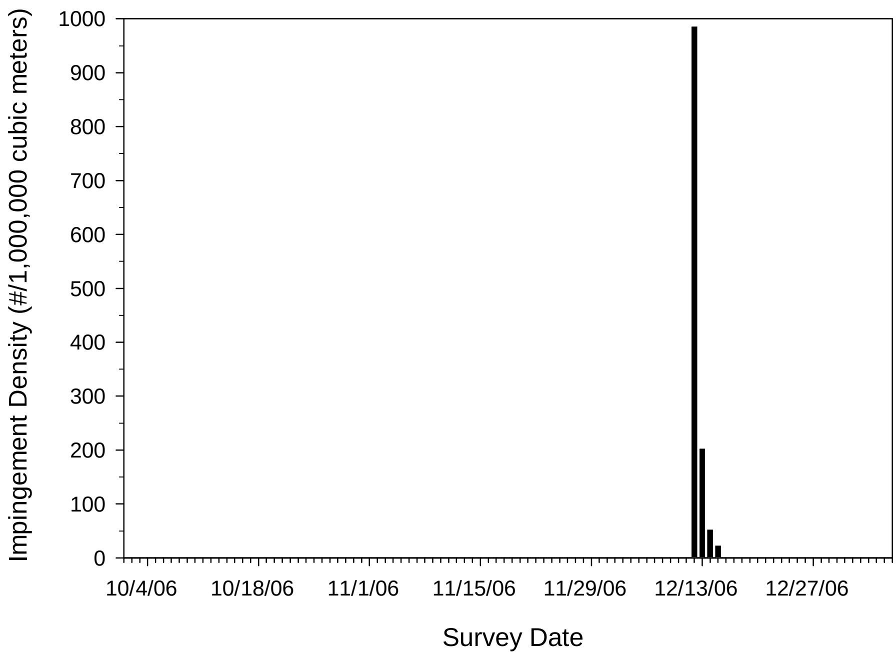


Figure 5.5-45. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of jacksmelt collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

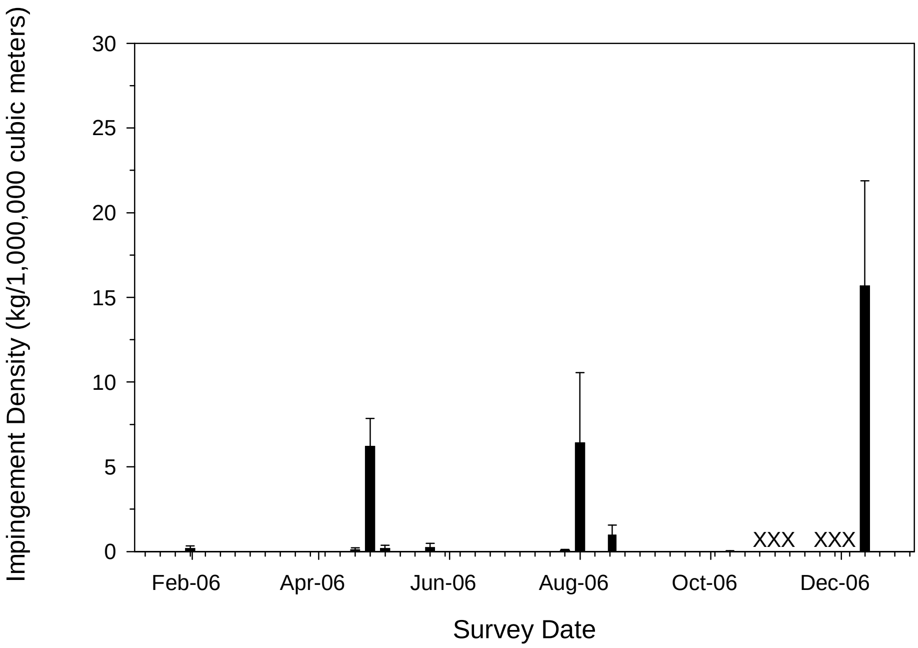


Figure 5.5-46. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of jacksmelt collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

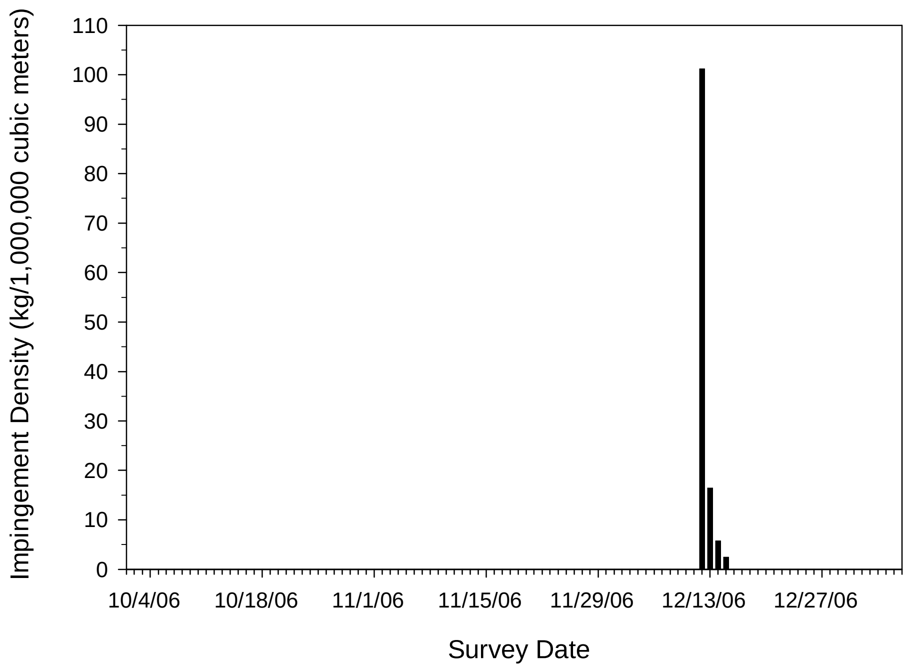


Figure 5.5-47. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of jacksmelt collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

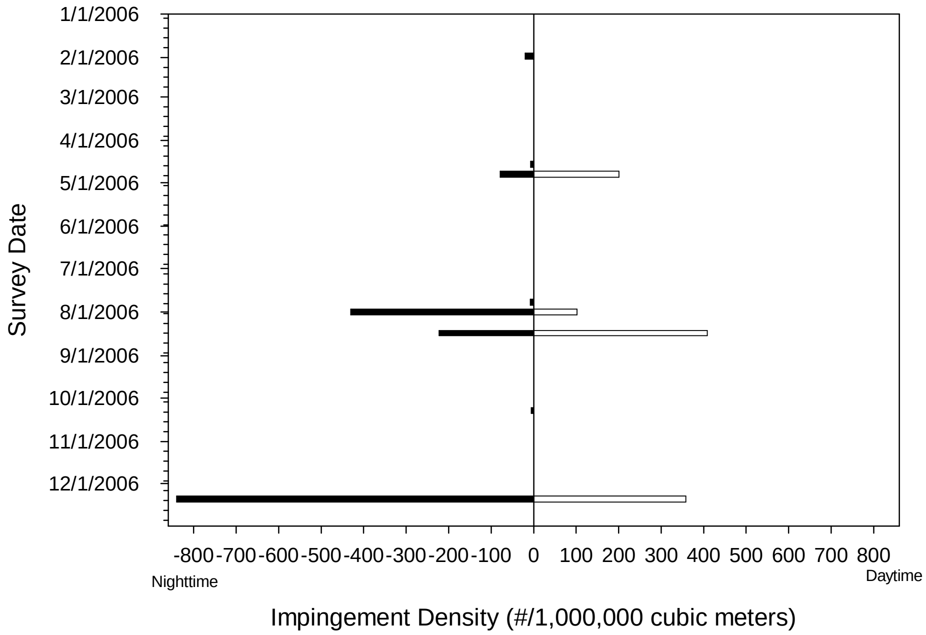


Figure 5.5-48. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of jacksmelt in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

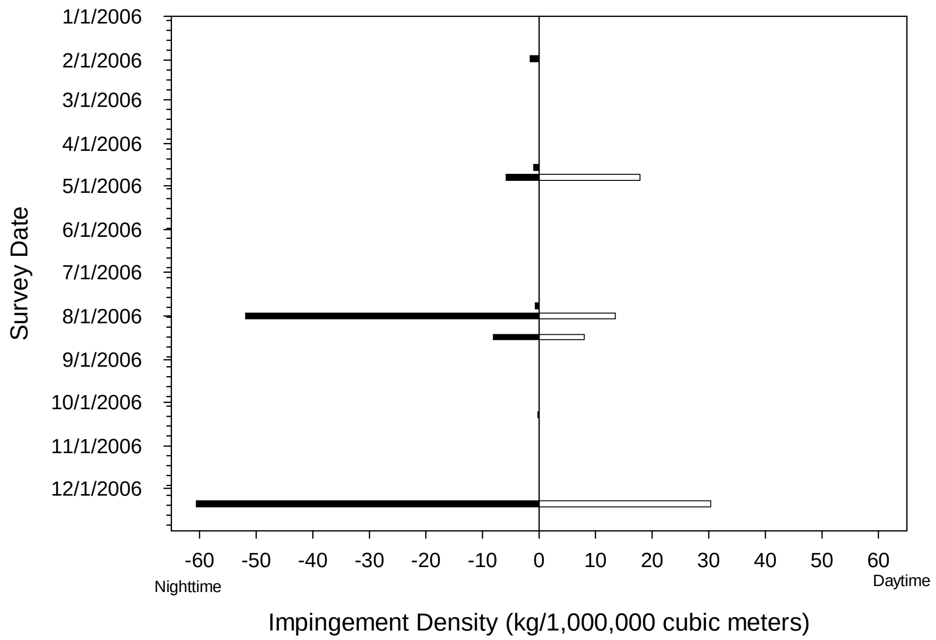


Figure 5.5-49. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of jacksmelt in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

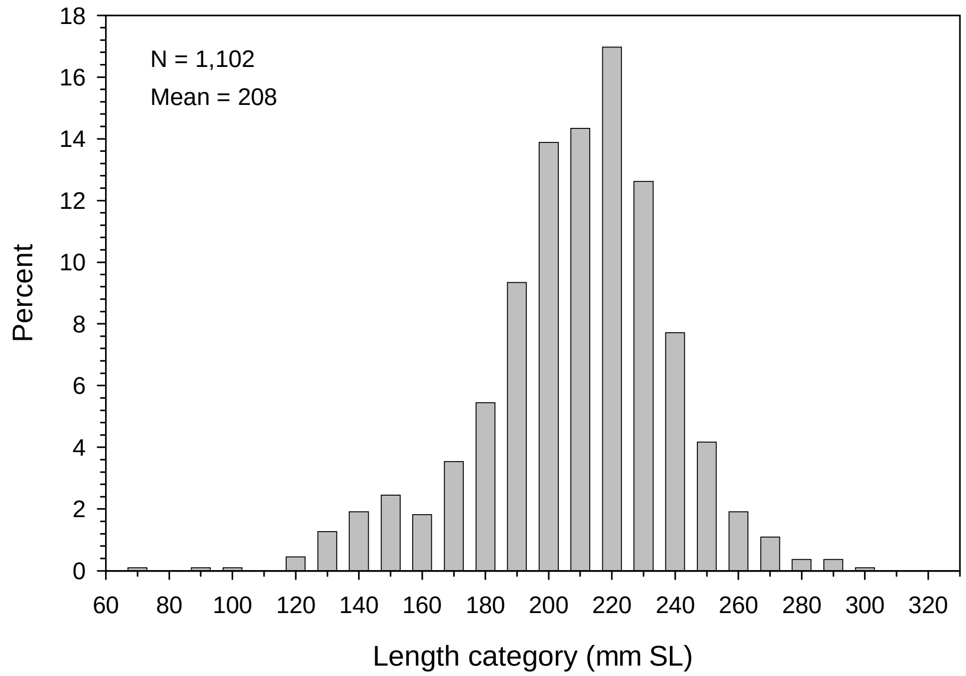
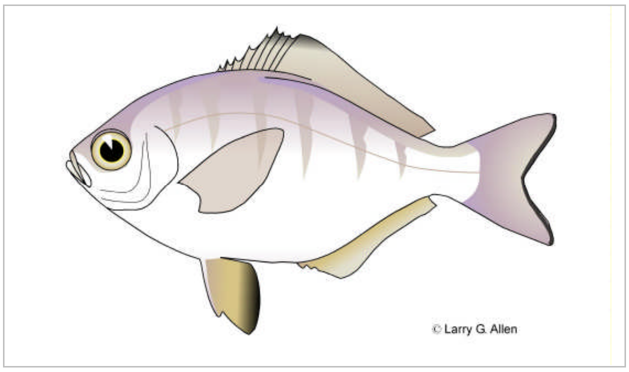


Figure 5.5-50. Length (mm) frequency distribution for jacksmelt collected in impingement samples.

5.5.2.6 Walleye Surfperch *(Hyperprosopon argenteum)*



Walleye surfperch (*Hyperprosopon argenteum*) is a member of the Family Embiotocidae, the surfperches (Eschmeyer et al. 1983; Fritzsche and Collier 2001). Fish of this family are compressed laterally with an elliptical shape and forked tail. Most species occurring off California are found in beaches, rocky reefs, and kelp beds. Surfperches are characterized by their reproduction, 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 et al. 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).

5.5.2.6.1 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 et al. 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 et al. 1983; Fritzsche and Collier 2001).

5.5.2.6.2 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 lbs) (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). From 2000 through 2005, annual impingement of walleye surfperch impinged at the SGS ranged from 323 individuals (2001) to 1,474 individuals (2002) (MBC 2006).

5.5.2.6.3 Sampling Results

Walleye surfperch was the sixth most abundant species impinged with an estimated 2,937 individuals, or 3.1% of the annual total calculated using actual cooling water flow volumes, weighing 139.695 kg (308.027 lbs) (Tables 5.5-1 and 5.5-2). Only 10 individuals were collected during normal operations sampling, with the peak in spring and summer 2006. Heat treatment impingement accounted for 99.7% of the sampled abundance, with most individuals occurring in the January 25, 2006 heat treatment (Table 5.5-15). Eighty percent of the individuals collected in normal operation occurred during daytime surveys, although about eighty percent of the biomass occurred during nighttime.

Table 5.5-15. Summary of walleye surfperch impingement during normal flow heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	2,829	135.93	299.73
8/10/2006	-	-	
8/15/2006	34	0.66	1.45
10/4/2006	3	0.09	0.19
10/10/2006	-	-	
10/23/2006	-	-	
11/20/2006	-	-	
1/3/2007	37	2.13	4.69
	2,903	**138.80**	**306.06**

Length frequency analysis of 308 measured individuals indicated a mean standard length of 107 mm (4.2 in), with lengths ranging from 45 to 169 mm SL (1.8 to 6.7 in), which includes young of the year and reproductively capable adults (Figure 5.5-51). Of the 157 individuals assessed, 63.1% were female, 34.4% were male, 1.9% were juvenile, and less than 1% could not be determined. Of the 105 individuals that were evaluated for condition factor, all were dead.

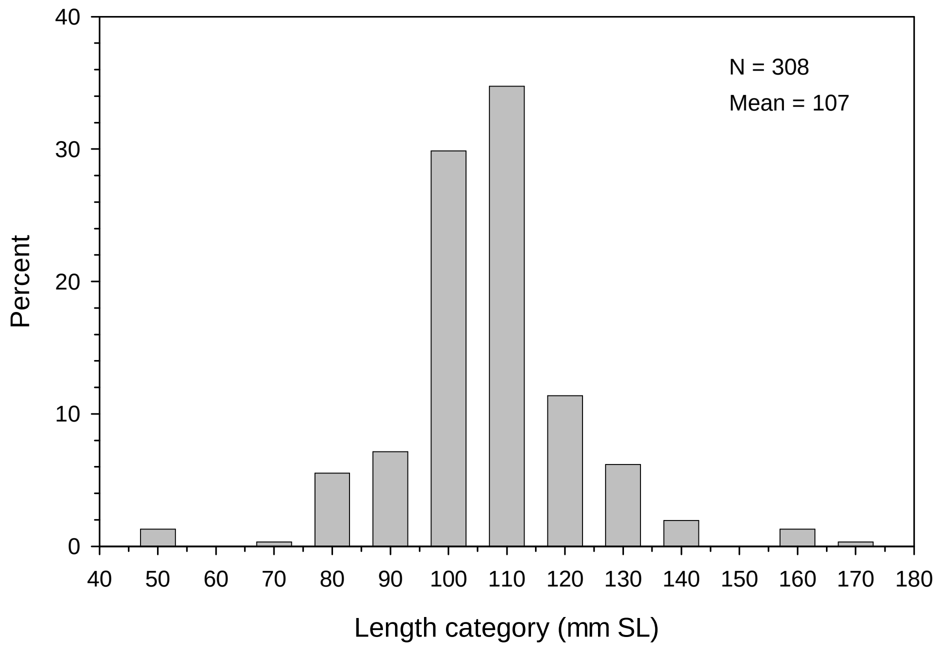


Figure 5.5-51. Length (mm) frequency distribution for walleye surfperch collected in impingement samples.

5.5.2.7 Jack Mackerel (*Trachurus symmetricus*)

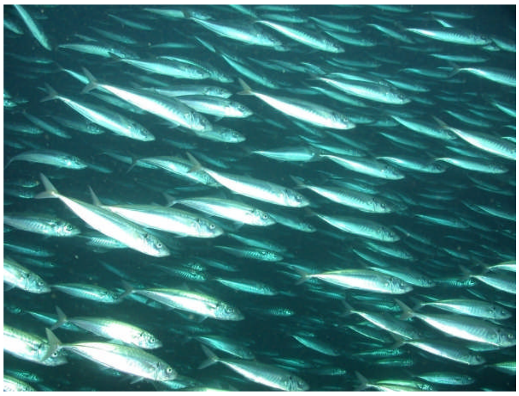


Photo credit: NOAA

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 et al. 1983). Most jacks are streamlined, fast-swimming fish with deeply forked tails and narrow caudal peduncles. About 200 species in the jack family occur worldwide, mostly in warm seas. Most species school, and many are important sport or food fishes.

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

5.5.2.7.1 Life History and Ecology

Jack mackerel have a lifespan of about 35 years, reaching a length of 81 cm (32 in) (Eschmeyer et al. 1983; Love 1996). They grow fast to about 20 cm (8 in) in their first year, then growth slows, with a 36-cm (14 in) fish about four-years old (Love 1996). Most (70%) 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.

5.5.2.7.2 Population Trends and Fishery

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

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

Jack mackerel from the U.S. Fishery are generally canned; however, fresh jack mackerel are occasionally found in markets (Love 1996). The recreational fishery for jack mackerel is small when compared to the commercial fishery. Most of the landings derive from commercial passenger fishing vessel, with additional catches from anglers on fishing piers (Mason and Bishop 2001). This fishery remains a small contributor to the total catch of jack mackerel and high variability in the number of catches since 1980, numbering from 5,000 to over 350,000 fish. Landings reported in the Los Angeles region in the PacFIN (2007) database have fluctuated between about 100,000 and 3.6 million kg (220,000 and 7.9 million lbs) annually (Table 5.5-16). 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). From 2000 through 2005, annual impingement of jack mackerel impinged at the SGS ranged from 0 individuals (2003) to 520 individuals (2005) (MBC 2006).

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

Year	Landed Weight (kg)	Landed Weight (lbs)	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

5.5.2.7.3 Sampling Results

Jack mackerel was the eighteenth most abundant species impinged with an estimated 100 individuals, or 0.1% of the annual total calculated using actual cooling water flow volumes, weighing 4.014 kg (8.850 lbs) (Tables 5.5-1 and 5.5-2). Only eight individuals were collected during normal operations sampling, while heat treatment impingement accounted for 92% of the sampled abundance. Most of the individuals impinged during heat treatments occurred in the fall and winter 2006. There was no diel pattern of impingement, with equal abundance at daytime and nighttime.

Length frequency analysis of 92 measured individuals indicated a mean standard length of 139 mm (5.5 in), with lengths ranging from the 80- to 200-mm SL (3.1 to 7.9 in) size classes, indicating fish all in their first year (Figure 5.5-52). Of the 88 individuals that were evaluated for condition factor, all were dead.

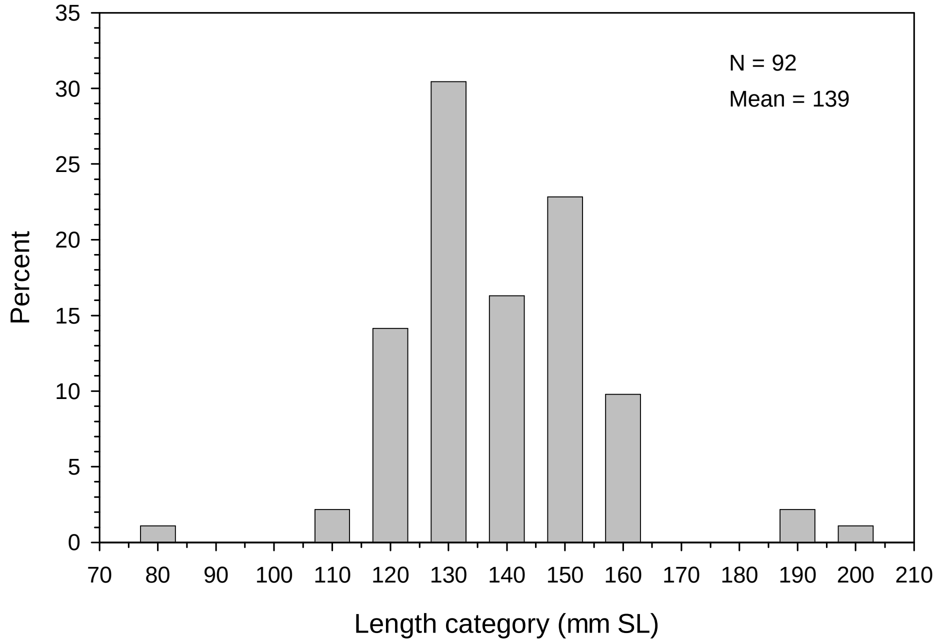


Figure 5.5-52. Length (mm) frequency distribution for jack mackerel collected in impingement samples.

5.5.2.8 Pacific Chub Mackerel (*Scomber japonicus*)

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

Photo credit: NOAA

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

5.5.2.8.1 Life History and Ecology

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

Pacific mackerel may reach a maximum length of 64 cm (25 in), but adults typically average between 41 and 46 cm (16 and 18 in) (Eschmeyer et al. 1983; Love 1996). Records from otolith readings identified a large fish that was twelve years old 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, with twenty-five percent mature by the first year and all mature by the second or third year (Bergen 2001). Pacific mackerel have three spawning stocks in the northeastern Pacific. Along the California coast, females spawn about eight or more times a year, and have a fecundity of at least 68,000 eggs at each release. In California, spawning occurs from 3 to 322 km (2 to 200 mi) offshore in late April through July, while spawning off Baja California takes place from June through October. Pacific mackerel eggs hatch four to five days after spawning, wherein the larvae remain in the surface waters as plankton (Love 1996). Growth appears to be density-dependent, with fish weight-at-age being higher in smaller populations, and populations seem to have three- to seven-year cycles of reproductive success (Bergen 2001).

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

5.5.2.8.2 Population Trends and Fishery

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

Following a moratorium, legislation imposed landing quotas based on age one-plus biomass in 1972 (Bergen 2001). The population showed signs of increase in the late 1970s and, in 1977, the fishery reopened. A quota system was implemented and the stock remained relatively stable. Thus the state imposed a moratorium in 1985 on directed fishing whenever total biomass reached a low of 18,143,695 kg (40 million lbs) or less. Incidental catches were set at 18% during the moratorium as well. Biomasses between 18,143,695 and 136,077,711 kg (40 million and 300 million lbs) within the season of July 1 through June 30 of the following year allowed a seasonal quota of 30% 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 lbs) was set as the quota between 1992 and 2000. As a result, the 1990 through 1999 fishery was comprised of 87% Pacific mackerel landings of the total California mackerel landings; and in California finfish landings, it was third in volume.

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

Pacific mackerel from the U.S. Fishery have been sold frozen, fresh, or canned for human consumption while also being sold for pet food and as live and dead bait (Bergen 2001). In 2005, commercial landings in Santa Monica Bay catch blocks totaled 110,174.9 kg (242,890 lbs) 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 lbs) 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 lbs) (Bergen 2001). Thereafter, the recreational fishery increased to an average of 1,360,777 kg (3,000,000 lbs) between 1977 and 1991. After a peak in 1980 when commercial passenger fishing vessels caught over 1.31 million Pacific mackerel, total landings began a steady decline and, in the California recreational fishery, the 2004-2005 season, landings totaled 56,000 kg (123,459 lbs) (Bergen 2001; Hill and Crone 2005). From 2000 through 2005, annual impingement of jack mackerel impinged at the SGS ranged from 0 individuals (2003) to 29 individuals (2005) (MBC 2006).

5.5.2.8.3 Sampling Results

Pacific chub mackerel was the twenty-fifth most abundant species collected in impingement samples with an estimated annual impingement of 110 individuals, or 0.1% of the annual total calculated using actual cooling water flow volumes, weighing 9.506 kg (20.961 lbs) (Tables 5.5-1 and 5.5-2). Impingement was almost equal between normal operations and heat treatments. Of the 34 individuals recorded in heat treatments, 20 occurred in November 2006 and 7 in January 2007. Of the 35 individuals recorded during normal operations, most occurred during in winter (October through December 2006). Eighty percent of the individuals impinged during normal operation surveys were recorded at nighttime.

Length frequency analysis of 66 measured individuals indicated a mean standard length of 181 mm (7.1 in), with lengths ranging from the 150- to 240-mm SL (5.9- to 9.4-in) size classes (Figure 5.5-53). Of the 46 individuals that were evaluated for condition factor, 93% were dead and 7% were mutilated.

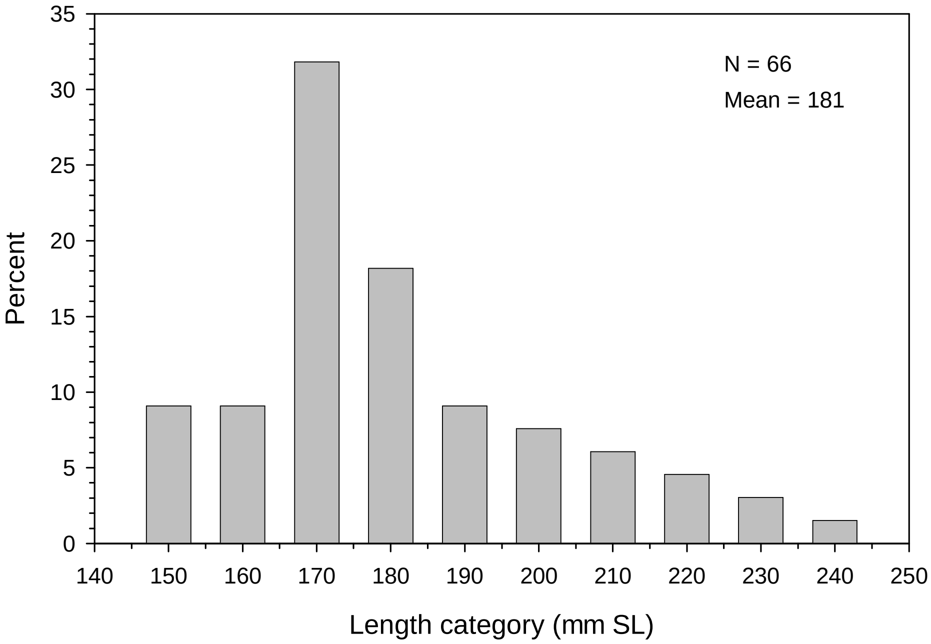
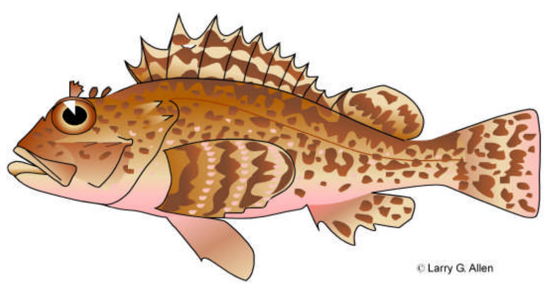


Figure 5.5-53. Length (mm) frequency distribution for Pacific chub mackerel collected in impingement samples.

5.5.2.9 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).

5.5.2.9.1 Life History and Ecology

Love et al. (1987) reported that California scorpionfish were often found sheltering in crevices of rocky reefs, but they also aggregated over sand and muddy bottoms seasonally. 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 tag recoveries off Dago Bank (Horseshoe Kelp) being from fish that were initially tagged and released there. They further noted that few individuals were found on the bank year round but dense aggregations formed in late spring and summer.

California scorpionfish generally mature near 180 mm (7.1 in) 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).

5.5.2.9.2 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 lbs) 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 lbs) in 2006, at an estimated value of $206 (CDFG 2007b). From 2000 through 2005, annual impingement of California scorpionfish impinged at the SGS ranged from 22 individuals (2001) to 125 individuals (2005) (MBC 2006).

5.5.2.9.3 Sampling Results

California scorpionfish was the twenty-eighth most abundant species collected in impingement samples with an estimated annual impingement of 157 individuals, or 0.2% of the annual total calculated using actual cooling water flow volumes, weighing 9.167 kg (20.213 lbs) (Tables 5.5-1 and 5.5-2). Impingement was almost equal between normal operations and heat treatments. Of the 31 individuals recorded in heat treatments, 13 occurred in January 2007. The individuals impinged during normal operations occurred throughout the study year in low numbers. Two-thirds of the individuals impinged during normal operation surveys were recorded at nighttime.

Length frequency analysis of 55 measured individuals indicated a mean standard length of 100 mm (3.9 in), with lengths ranging widely from the 30- to 250-mm SL (1.2- to 9.8-in) size classes (Figure 5.5-54). Of the 52 individuals that were evaluated for condition factor, 38% were alive and 62% were dead.

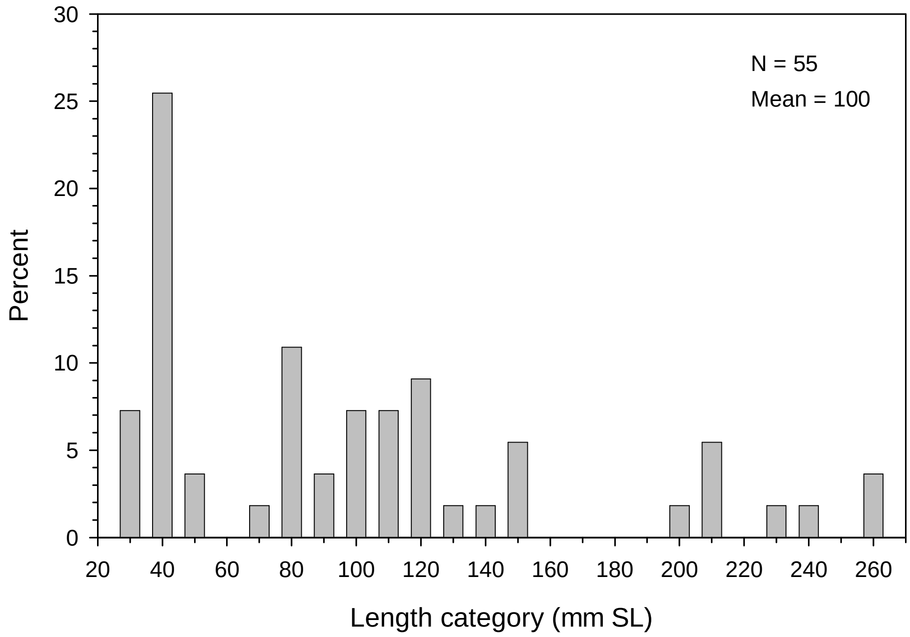
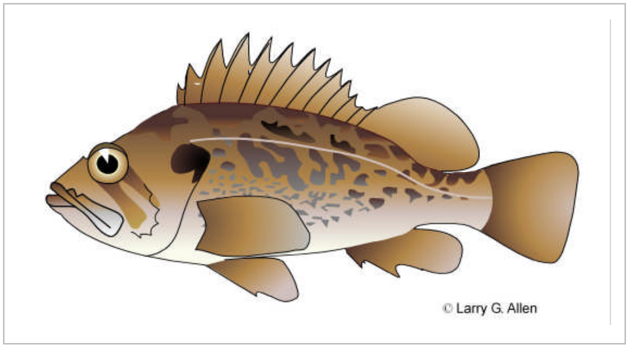


Figure 5.5-54. Length (mm) frequency distribution for California scorpionfish collected in impingement samples.

5.5.2.10 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).

5.5.2.10.1 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 (9.4 and 12.2 in). 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.

5.5.2.10.2 Population Trends and Fishery

Historically, brown rockfish, along with nearly all other *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 lbs) 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 lbs) in 2006, at an estimated value of $523 (CDFG 2007b). From 2000 through 2005, annual impingement of brown rockfish impinged at the SGS ranged from 0 individuals (2002) to 33 individuals (2005) (MBC 2006).

5.5.2.10.3 Sampling Results

Thirty-five brown rockfish were collected in impingement samples at the SGS, and the estimated annual total calculated using actual cooling water flow volumes was 41 individuals weighing 15.043 kg (33.170 lbs) (Tables 5.5-1 and 5.5-2). All but one individual was impinged during heat treatments. Of the 34 individuals recorded in heat treatments, 26 occurred in January 2006.

Length frequency analysis of 34 measured individuals indicated a mean standard length of 221 mm (8.7 in), with lengths ranging from the 160- to 320-mm SL (6.3- to 12.6-in) size classes (Figure 5.5-55). Of the 34 individuals that were evaluated for condition factor, 91% were dead and 9% were alive.

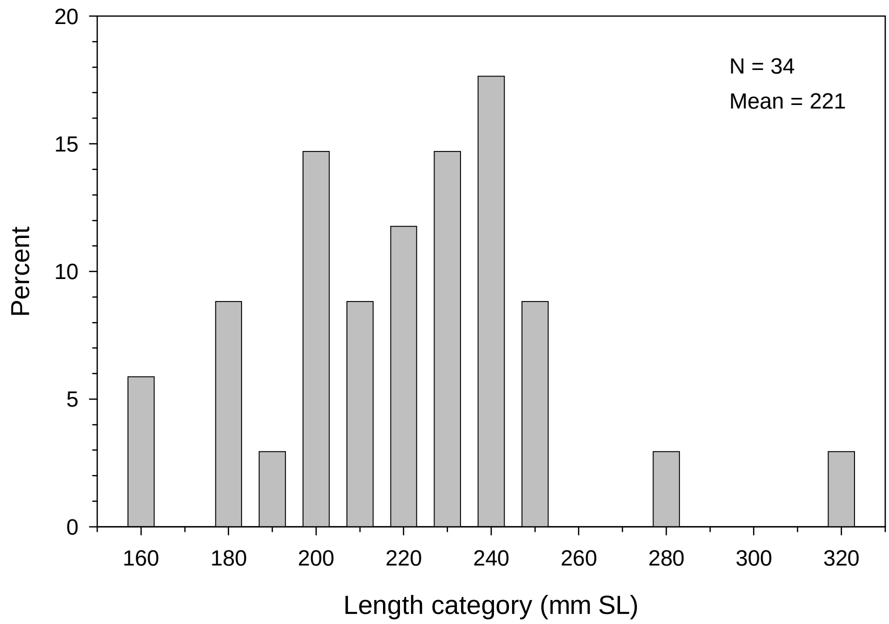
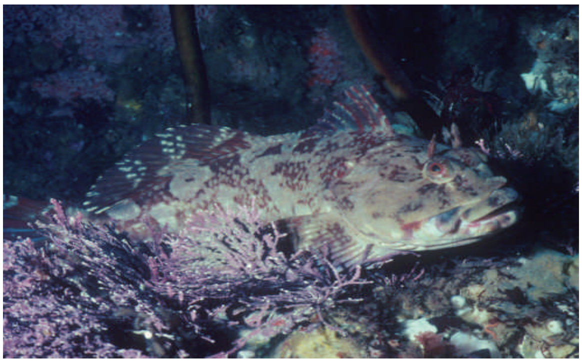


Figure 5.5-55. Length (mm) frequency distribution for brown rockfish collected in impingement samples.

5.5.2.11 Cabezon (*Scorpaenichthys marmoratus*)



Jay Carroll

Cabezon (*Scorpaenichthys marmoratus*) belong to the family Cottidae, the sculpins. This scaleless species exhibits brown, red, or green coloration interspersed with intense dark and light mottling, often with reddish adult males and greenish adult females (Eschmeyer et al. 1983; Miller and Lea 1982; Love 1996).

5.5.2.11.1 Life History and Ecology

Cabezon can be found from Sitka, Alaska to central Baja California, Mexico, but are most abundant from Washington to southern California. Cabezon inhabit depths from the intertidal zone to 76 m (250 ft). Cabezon are solitary, hard bottom dwellers, but can occasionally be found around rocky reefs, structures (oil platforms, wrecks), and in the kelp canopy (Love 1996; Wilson-Vandenberg and Hardy 2001). The largest cabezon was recorded at 99 cm (39 in) (Eschmeyer et al. 1983).

Cabezon sexual maturity has limited information and show differences in size and age at maturity variable by latitude (Wilson-Vandenberg and Hardy 2001). In general, females reach maturity between 3 to 5 years of age (Love 1996). However, all females are mature by age-4 with lengths between 47 cm (19 in) and 59 cm (23 in) (Wilson-Vandenberg and Hardy 2001). Cabezon fecundity can reach counts of up to 152,000 eggs in a female of 76 cm (30 in). These sculpin are oviparous, with the female spawning the eggs into an intertidal nest that is guarded by the male. Off California, spawning occurs from late October to April with a peak in January (Love 1996). Once the larvae hatch, they become pelagic and spend three to four months feeding on zooplankton (Wilson-Vandenberg and Hardy 2001). Upon reaching about 4 cm (1.5 in) in length, juvenile cabezon become demersal and appear in shallow water habitats from April to June. Cabezon diets differ amongst juveniles and adults. Juveniles prey primarily on amphipods and smaller crustaceans such as shrimp and crabs, while adults have a diet composed of crabs, fish, small lobsters, mollusks, and fish eggs (Love 1996; Wilson-Vandenberg and Hardy 2001).

5.5.2.11.2 Population Trends and Fishery

The cabezon commercial fishery had been recorded as a small but consistent market until the late 1990s when the live-fish market began (Love 1996; Wilson-Vandenberg and Hardy 2001). In 1998, commercial landings reached over 169,190 kg (373,000 lbs.) using primarily trap and hook-and-line gear. Sampled catches from 1995-1998 suggested the majority of the catch was comprised of immature fish. Due to concerns of overfishing, NMFS implemented a Nearshore Fishery Management Plan in 1999 to prevent cabezon and other nearshore fish from becoming endangered. In 2004, the commercial fishery landed 49,313 kg (108,716 lbs), and showed successful adherence to the Total Available Catch for the years 2002, 2003, and 2004 (CDFG 2006). Cabezon is covered under the Pacific Groundfish FMP.

Commercial landings in the Los Angeles area have fluctuated between about 50 and 700 kg (100 and 1,500 lb.) per year since 2000 (Table 5.5-17). In 2005, cabezon landings in the Los Angeles area totaled

331.1 kg (730 lbs) at a value of $1,300 (CDFG 2006). Commercial landings of cabezon reported from catch blocks in the Santa Monica Bay area totaled 20.2 kg (45 lbs) in 2006, at an estimated value of $263 (CDFG 2007b). From 2000 through 2005, annual impingement of cabezon impinged at the SGS ranged from 4 individuals (2002) to 283 individuals (2004) (MBC 2006).

Table 5.5-17. Annual landings and revenue for cabezon in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	Revenue
2000	141	311	$960
2001	678	1,494	$6,457
2002	87	191	$564
2003	52	114	$278
2004	96	211	$1,017
2005	312	687	$2,585
2006	268	592	$2,046

5.5.2.11.3 Sampling Results

Twenty-seven cabezon were collected in impingement samples at the SGS, and the estimated annual total calculated using actual cooling water flow volumes was 54 individuals weighing 7.452 kg (16.432 lbs) (Tables 5.5-1 and 5.5-2). Three-quarters of the individuals impinged occurred during heat treatments. Cabezon occurred throughout the year in relatively low numbers.

Length frequency analysis of 26 measured individuals indicated a mean standard length of 167 mm (6.6 in), with lengths ranging from the 80- to 260-mm SL (3.1- to 10.2-in) size classes (Figure 5.5-56). Of the 26 individuals that were evaluated for condition factor, 69% were dead and 31% were alive.

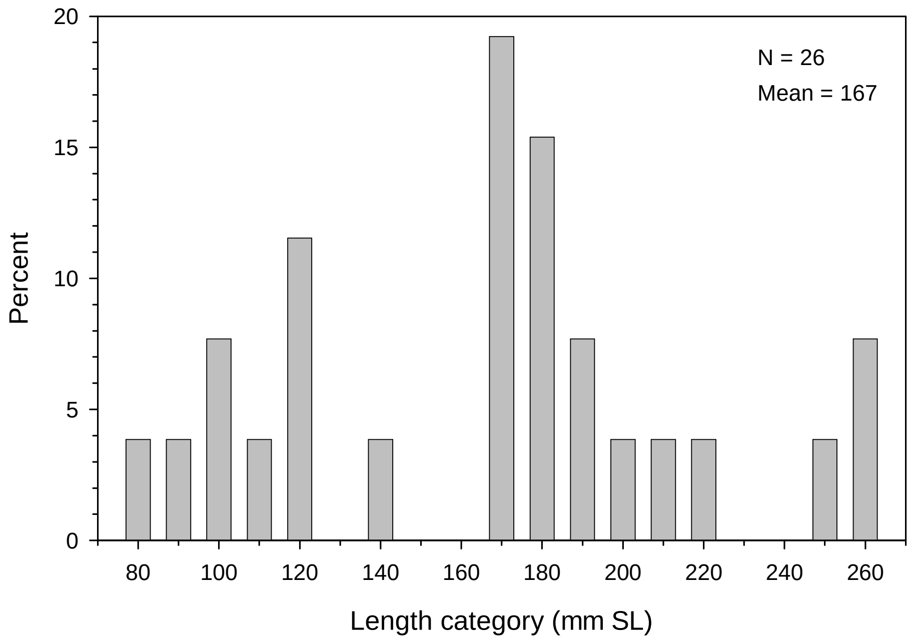
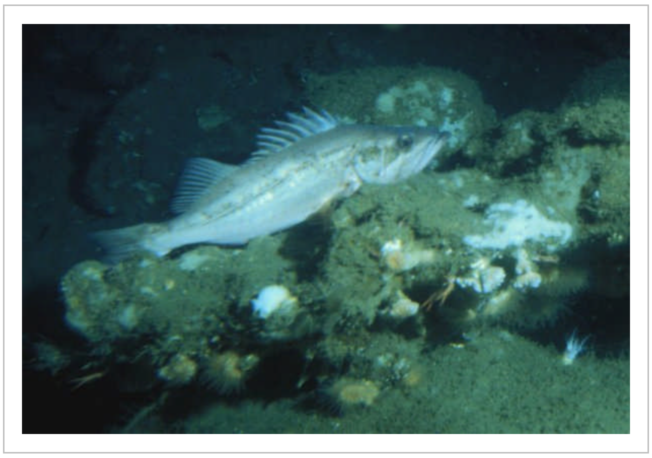


Figure 5.5-56. Length (mm) frequency distribution for cabezon collected in impingement samples.

5.5.2.12 Bocaccio (*Sebastes paucispinis*)



Bocaccio (*Sebastes paucispinis*) belong to the family Scorpaenidae, which is comprised of scorpionfish and rockfish. Coloration in bocaccio varies from olive-brown to dusky-red with pinkish-orange sides (Fitch and Lavenberg 1971). The species ranges from as far north as the Alaskan Peninsula to central Baja California, Mexico. Bocaccio occur between the surface and 478 m (1,578 ft), but are most commonly found in depths between 50 to 250 m (165 to 825 ft) (Miller and Lea 1972; Love et al. 2002). Adult bocaccio generally inhabit high relief boulder fields and rocky substrata, but have been found hovering over mudflats (Love 1996; Love et al. 2002). Young bocaccio can be found under flotsam at the surface, then recruit to rocks where they school with other rockfish, such as widow rockfish and yellowtail rockfish. Bocaccio have been recorded at lengths up to 91 cm (36 in) (Eschmeyer et al. 1983; Love 1996; Love et al. 2002).

5.5.2.12.1 Life History and Ecology

Female bocaccio mature at various lengths from as small as 36 cm (14 in), with size at maturity and spawning season variable by latitude (Love 1996; Love et al. 2002). Fecundity of bocaccio ranges from 20,000 to 2,298,000 eggs, depending on size of the fish (Thomas and MacCall 2001). Compared to other California rockfish, off southern California bocaccio have a longer spawning season. Bocaccio are primitively viviparous, releasing well-developed larvae about 1 cm (0.25 in) in length from October to July, with a January peak (Thomas and MacCall 2001; Love et al. 2002). Young-of-year larvae (YOY) and juvenile bocaccio remain in the upper water column feeding on zooplankton until recruitment occurs. Off southern California, it was noted that recruitment occurred in January. Adult bocaccio and larger juveniles feed on rockfish, hake, sablefish, northern anchovies, lanternfish, and squid.

5.5.2.12.2 1.1.1.1.2 Population Trends and Fishery

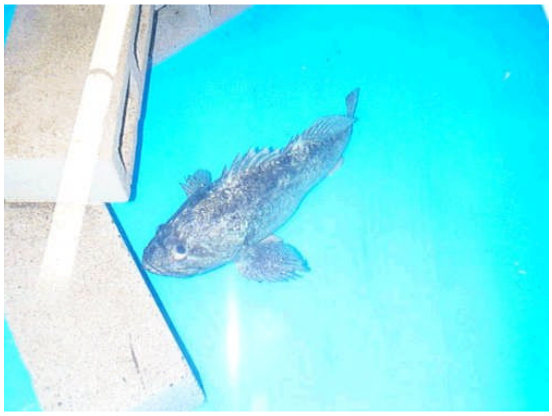
Historically, bocaccio were an important commercial species, particularly off California, being caught by gillnet, hook and line, and trawls (Thomas and MacCall 2001; Love et al. 2002). However, recruitment failures from 1989 to 1998, possibly due to a combination of intense fishing and a shift to a warm-water environment which caused a severe depletion of the population. In 1999, the National Marine Fishery Service declared bocaccio as an “overfished” and a “species of concern” on the behest of the Pacific Fishery Management Council (NMFS 2007). By 2003, the Council suggested complete closure of the commercial and recreational fishery for bocaccio, with the exception of commercial bycatch. As of March 5, 2004, the Commission continues to restrict the recreational bocaccio fishery in the Southern Rockfish and Lingcod Management Areas (RLMA) (CDFG 2004). Consequently, a current stock assessment in 2005 showed the population was in better condition when compared to the 2003 stock assessment (NMFS 2007).

In 2005, bocaccio landings in the Los Angeles area totaled 1,823.6 kg (4,021 lbs) at a value of $5,007 (CDFG 2006). Commercial landings of bocaccio reported from catch blocks in the Santa Monica Bay area totaled 165.3 kg (364 lbs) in 2006, at an estimated value of $754 (CDFG 2007b). From 2000 through 2005, annual impingement of bocaccio impinged at the SGS ranged from 0 individuals (2001) to 35 individuals (2002) (MBC 2006).

5.5.2.12.3 Sampling Results

Six bocaccio were collected in impingement samples at the SGS, and the estimated annual total calculated using actual cooling water flow volumes was 74 individuals weighing 0.432 kg (0.953 lbs) (Tables 5.5-1 and 5.5-2). All six bocaccio were impinged during normal operations surveys: one individual was impinged in August 2006, and the other five occurred during December 2006. Two individuals were measured: one was in the 60-mm (2.4-in) size class and the other was in the 100-mm (3.9-in) size class. Both individuals were dead upon collection.

5.5.2.13 Grass Rockfish (*Sebastes rastrelliger*)



Grass rockfish (*Sebastes rastrelliger*) belong to the family Scorpaenidae, which is comprised of scorpionfish and rockfish. As the common name suggests, the grass rockfish exhibits olive green to almost black coloration mottled with a lighter greenish-gray along the sides; however, two orange morphs have been reported (Eschmeyer et al. 1983; Love et al. 2002). The species covers a range from Yaquina Bay, Oregon to central Baja California, Mexico. Green rockfish are known to occur between the intertidal and 46 m (150 ft), but are most commonly found in tidepools to depths of 6 m (20 ft) (Love 1996; Love et al. 2002). Adult grass rockfish generally favor rocky bottoms with caves and crevices, but have been found over cobble areas and in kelp and eelgrass beds (Eschmeyer et al. 1983; Love et al. 2002). The juvenile rockfish are most commonly found in tidepools; however, adult rockfish have been sighted in larger tidepools (Love et al. 2002). The largest length recorded for grass rockfish is 56 cm (22 in) (Eschmeyer et al. 1983, Love et al. 2002).

5.5.2.13.1 Life History and Ecology

Grass rockfish differ in size and age at maturity variable by latitude (Love et al. 2002). Off southern California, some females have been recoded as mature at the length of 22 cm (8.6 in) at two years. In general, all females are mature by 28 cm (11 in) and five years. Fecundity ranges from 80,000 to 760,000 eggs. Grass rockfish undergo internal fertilization and extrude all live larvae at the same time. This extrusion period occurs from January to March, with a peak in January. When released, larvae are 4.3 mm (0.2 in) in length and are generally found in tidepools during spring and summer where they progressively move to deeper depths (Love 1996; Love et al. 2002). Grass rockfish feed primarily on benthic organisms including crabs, shrimp, snails, octopi, and small fishes (e.g., midshipmen).

5.5.2.13.2 Population Trends and Fishery

Historically, grass rockfish were commercially fished in abundance (Love et al. 2002). However, demand and commercial fishing for the species declined in the early 1990s until the development of the live-fish fisheries, which primarily implement line gear and pot and trap gear, increased the commercial value of grass rockfish up to $4.84 average price per pound in 1998 (Larson and Wilson-Vandenberg 2001, Love et al. 2002). Recreational fishery followed a similar pattern. In 2004, the total amount of grass rockfish brought in recreationally in California was 6,447.73 kg (14,251 lbs) whereas commercial landings totaled 13,729.55 kg (30,205 lbs) (CDFG 2006).

In 2005, grass landings in the Los Angeles area totaled 4.1 kg (9 lbs) at a value of $35 (CDFG 2006). No commercial landings of grass rockfish were reported from catch blocks in the Santa Monica Bay area in 2006 (CDFG 2007b). From 2000 through 2005, only one grass rockfish was collected at the SGS (2001) (MBC 2006).

5.5.2.13.3 Sampling Results

Three grass rockfish were collected in impingement samples at the SGS in 2006, and the estimated annual total calculated using actual cooling water flow volumes was 15 individuals weighing 8.802 kg (19.408 lbs) (Tables 5.5-1 and 5.5-2). One grass rockfish occurred during normal operations, while the other two occurred during heat treatments. All three individuals were collected in January 2006. Three individuals were measured: two were in the 260-mm (10.2-in) size class and the other was in the 280-mm (11.0-in) size class. Of the three individuals assessed for condition factor, one was alive and the other two were dead.

5.5.2.14 English Sole (*Parophrys vetulus*)

Information on the life history, ecology, population trends, and fishery of English sole is summarized in Section 4.5.3.14. From 2000 through 2005, only one English sole was impinged at the SGS (2005) (MBC 2006).

5.5.2.14.1 Sampling Results

The estimated annual total impingement of English sole calculated using actual cooling water flow volumes was three individuals weighing 0.142 kg (0.313 lbs) (Tables 5.5-1 and 5.5-2). All three individuals in impingement samples were collected in December 2006. The individuals measured were in the 80-mm (3.1-in), 130-mm (5.1-in), and 210-mm (8.3-in) size classes. Of the three individuals assessed for condition factor, all were dead.

5.5.2.15 Leopard Shark (*Triakis semifasciata)*

The leopard shark is found in shallow waters ranging from Mazatlan, Mexico northward to Oregon and in the northern Gulf of California. They are also known as “tiger shark” and “cat shark”, but should not be confused with the tiger shark (*Galeocerdo cuvier*). They are most commonly found in intertidal waters to about 5 m (15 ft) (Love 1996; Smith 2001). The leopard shark belongs to the family Carcharhinidae, which is one of eight families in the order Carcharhiniformes. Sharks in this order are found to be of the more familiar species of shark (Miller and Lea 1972; Bond 1996).

5.5.2.15.1 Life History and Ecology

The habitat distribution of the leopard shark is widely ranged. They commonly prefer muddy and sandy bottoms in bays as well as in open coastal kelp beds and flat bottoms near rocky reefs. They range from intertidal waters to 91 m (300 ft), although they are more commonly found in waters less than about 6 m (20 ft). They tend to be mobile, not remaining in one place for very long. Although San Francisco Bay seems to be the exception where they live year around, it is also a location for leopard shark research. They are a schooling species, at times aggregating with smoothhounds or dogfish (Eschmeyer et al. 1983; Love 1996).

Leopard sharks bear live young. The gestation period is estimated to last anywhere from ten to twelve months with spawning occurring from March through June, with the peak being between April and May. A female can produce anywhere from four to thirty-three young in an annual reproductive cycle with individuals ranging from 203 to about 229 mm (8.0-in to 9.0-in) in length (Love 1996; Smith 2001).

Females and males both reach sexual maturity at about 914 to 1067 mm (36.0-in to 42.0-in) in length. However the growth rate of males, maturing at seven years, is faster than that of females, maturing at ten years (Love 1996; Smith 2001). They can reach lengths of up to two meters but sharks over 1.8 meters are rare. They are estimated to live up to 30 years.

Being an opportunistic benthic feeder leopard sharks are know to feed on invertebrates such as crabs, ghost shrimp, clam siphons, worms, especially the fat innkeeper worms, and octopuses. How the leopard shark feeds on benthic organisms is a bit of a mystery. They also feed on fish such as herring, anchovy, topsmelt, croakers, surfperches, gobies, rockfish, midshipman, flatfishes, bat rays, and smoothhounds. Seasonally they will feed heavily on fish eggs of herring, topsmelt, jacksmelt, and midshipman (Bond 1996; Love 1996; Smith 2001). White sharks and sevengill sharks will feed on leopard sharks.

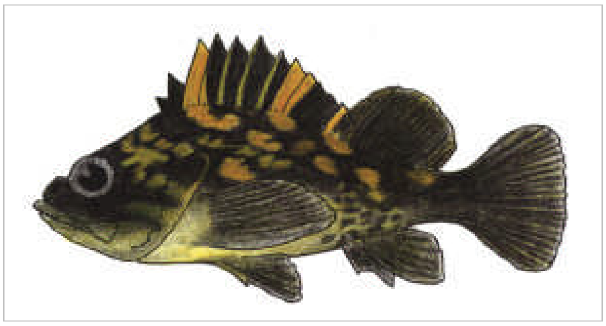
5.5.2.15.2 Population Trends and Fishery

In the past, shore and pier anglers would incidentally catch leopard shark. Due to their increased popularity, leopard sharks have more recently become a targeted fish by sport fishermen. Commercially they are being taken in substantial numbers by gillnets and longlines, generating a steady market for this species of shark. California commercial landings have reported catches of leopard sharks ranging from 9,270 pounds in 1958, to a high in 1983 of 101,309 pounds since publication in 2001 (Love 1996; Smith 2001). There are most likely others taken under a general “shark, unspecified” category as well. The average commercial take per year is 31,000 pounds since 1991. Sport catches have been estimated to be greater than commercial catches. From 1980 to 1988, California sports catches of leopard sharks have averaged over 52,000 individuals per year, with a low of 33,000 in 1980 and a high of 59,000 in 1988. Since 1993, there appears to have been somewhat of a decline with a low of 34,000 in 1993 and 1994, and an increase in catch in 1997 with a high of 58,000 (Smith 2001). In 2005, leopard shark landings in the Los Angeles area totaled 1,455.3 kg (3,209 lbs) at a value of $3,141 (CDFG 2006). Commercial landings of leopard shark reported from catch blocks in the Santa Monica Bay area totaled 555.23 kg (1,224 lbs) in 2006, at an estimated value of $1,093 (CDFG 2007b). From 2000 through 2005, between zero and five leopard sharks were impinged annually (MBC 2006).

5.5.2.15.3 Sampling Results

Two leopard sharks were collected during normal operations samples, resulting in an estimated annual impingement of eight individuals (calculated using actual cooling water flow volumes) weighing 11.078 kg (24.427 lbs) (Tables 5.5-1 and 5.5-2). One individual was collected in February 2006, and the other in December 2006. Of the two individuals assessed for condition factor, one was dead and one was mutilated. One leopard shark was measured (1.33 m).

5.5.2.16 Black-and-Yellow Rockfish (*Sebastes chrysomelas*)



Black-and-yellow rockfish (*Sebastes chrysomelas*) is a member of the family Scorpaenidae. These fish are dark brown to black with yellow blotches along the sides and back (Love et al. 2002). Black-and-yellow rockfish range from Cape Blanco, Oregon to central Baja California, Mexico in depths from the intertidal to 27 m (89 ft), but are most commonly found in depths shallower than 18 m (60 ft) (Miller and Lea 1982; Love 1996). Black-and-yellow rockfish are often found within kelp beds and rocky areas as solitary and territorial individuals (Love 1996; Love et al. 2002). Black-and-yellow rockfish may grow up to 39 cm (15.3 in) in length (Eschmeyer et al. 1983; Love et al. 2002).

5.5.2.16.1 Life History and Ecology

Female black-and-yellow rockfish mature at various lengths from as small as 16 cm (6 in) and three years, with fecundity and size at maturity variable by latitude (Love 1996; Love et al. 2002). One study reported fecundity in a southern California fish at about 175,000 eggs (Love et al. 2002). Following courtship, female black-and-yellow rockfish females undergo internal fertilization and release well developed larvae (parturition). Parturition occurs in the early spring from January to May, with a peak in March (Love et al. 2002). Females release one brood per season. Young-of-year larvae with lengths of 2 cm (0.8 in) or less settle on kelp fronds, feeding on copepods and other zooplankton. Adult rockfish are night feeders that feed primarily on benthic invertebrates (crabs, shrimp) and occasionally fishes and cephalopods.

5.5.2.16.2 Population Trend and Fishery

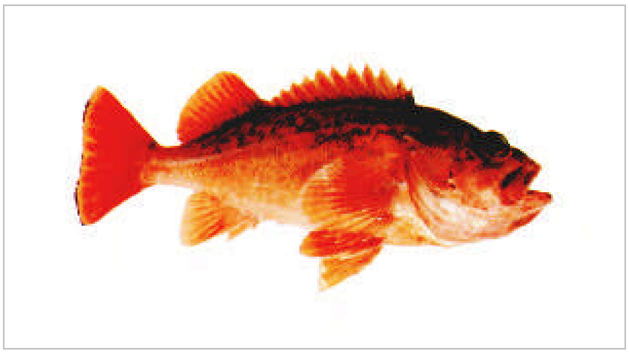
Recreational anglers from boats and piers or from rocky shores occasionally catch black-and-yellow rockfish (Love 1996). They are more commonly taken in California and northern Baja California than in the northern extent of their range. While historically these rockfish were not fished commercially, they were increasingly targeted as live fishery species in the late 1990s. By 1998, concerns about overfishing of nearshore species and its impacts were rising. In response, NMFS implemented a Nearshore Fishery Management Plan in 1999, which restricted commercial and recreation total catches in order to help alleviate fishing stress on the nearshore fish populations (CDFG 2006). As of 2004, statewide commercial landings were down to 10,515 kg (23,180 lbs) while recreation landings were 2,510 kg (5,532 lbs).). No black-and-yellow rockfish were reported in the commercial catch from the Los Angeles area in 2005, or from Santa Monica Bay catch blocks in 2006 (CDFG 2006, 2007). This species was not impinged at the SGS between 2000 and 2005 (MBC 2006).

5.5.2.16.3 Sampling Results

One black-and-yellow rockfish weighing 0.165 kg (0.364 lbs) was collected during the January 25, 2006 heat treatment (Tables 5.5-1 and 5.5-2). The individual was collected alive and was in the 150-mm size class.

5.5.2.17 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 et al. 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.



5.5.2.17.1 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 (Miller and Lea 1982; Love 1996; Love et al. 2002). 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 et al. 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.

5.5.2.17.2 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 lbs]) remained higher than commercial landings (5,000 kg [11,024 lbs]) (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 5.5-18). In 2005, vermilion rockfish landings in the Los Angeles area totaled 1,671.6 kg (3,686 lbs) 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 lbs) in 2006, at an estimated value of $913 (CDFG 2007b).

Table 5.5-18. Annual landings and revenue for vermilion rockfish in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	Revenue
2000	78	172	$367
2001	-	-	-
2002	-	-	-
2003	-	-	-
2004	-	-	-
2005	-	-	-
2006	-	-	-

5.5.2.17.3 Sampling Results

One vermilion rockfish weighing 0.011 kg (0.024 lbs) and in the 70-mm size class was collected during the August 1, 2006 normal operation survey (Table 5.5-1). The individual was collected dead. Estimated annual impingement based on actual cooling water flow volumes at the SGS was seven individuals weighing 0.079 kg (0.174 lbs) (Table 5.5-2).

5.5.3 Shellfishes

Nine shellfish taxa were impinged in sufficient numbers, and considered commercially/recreationally important, to warrant further analysis. The most abundant group analyzed were rock crabs (*Cancer* spp), which comprised 13.9% of the invertebrates in impingement samples. This included yellow crab (6.7% of total abundance), Pacific rock crab (3.6%), hairy rock crab (2.0%), red rock crab (1.1%), and unidentified rock crabs (0.4%). Other taxa selected for analysis were California spiny lobster (0.9%), California two-spot octopus (0.6%), California market squid (0.2%), and sheep crab (0.2%). Combined, these taxa comprised nearly 16% of the macroinvertebrates in impingement samples, and 90% of the biomass.

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 (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 SGS. All but Dungeness crab occurred in impingement samples at the SGS in 2006.

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 SGS 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 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 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 lbs) (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.

Hairy rock crab

Hairy rock crab occurs primarily between Coos Bay, Oregon and Cabo Thurloe, Baja California, and is primarily found among rocks, in the low intertidal zone, and subtidally to 104 m (341 ft). Ovigerous females have been noted to occur in Monterey Bay in October and November (Morris et al. 1980). The hairy rock crab is a small *Cancer* species with males measuring up to 39.3 mm (1.5 in) CW and females to 19.5 mm (0.7 in) (Jensen 1995). The life span of the species and the age/size at maturity is unknown.

Information on the life history of the hairy rock crab is scarce. Reproductive behavior can be assumed to follow the pattern of other rock crabs. Ovigerous females have been found in Monterey Bay during October and November. The eggs and larvae of hairy rock crab are similar in size to those of larger rock crab species (J. Carroll, Tenera, pers. comm.). Hairy rock crab larvae have been reported to be larger than those of Pacific (brown) rock crab in the same stage (J. Carroll, Tenera, pers. comm.). Because of the small size of adult female hairy rock crab, and the proportionally large size of individual eggs, it has been suggested that the species is probably less prolific than larger *Cancer* species (J. Carroll, Tenera, pers. comm.). Based on these observations, the fecundity would probably be on a scale of thousands or tens of thousands of eggs instead of the hundreds of thousands or millions typical of larger cancer crab species. It is likely that the larval, juvenile, and adult hairy rock crab are preyed upon by the same assemblage of fishes and invertebrates that consume the larvae and early crab stages of other cancrid species. Because of their small size, adult hairy rock crab probably remain vulnerable to predation by fish species such as cabezon (*Scorpaenichthys marmoratus*) and rockfishes (*Sebastes* spp.), and small octopi (*Octopus* spp) throughout their lives. The species is not harvested commercially or recreationally.

Red rock crab

Red rock crab ranges between Kodiak Island, Alaska, and Magdalena Bay, Baja California (Schmitt 1921). The abundance of red rock crab, relative to the other rock crab species, increases with latitude within the state. Red rock crab inhabits a variety of substrata including intertidal and subtidal rocky areas, gravel, coarse sand, and mud (Carroll and Winn 1989). They are commonly found in close association with hard substratum such as rocky reefs, well-protected boulder-strewn beaches, and gravel beds (Morris et al. 1980; Carroll and Winn 1989; Jensen 1995). Red rock crab occurs from the lower intertidal zone to depths of at least 91 m (299 ft) (Winn 1985; Carroll and Winn 1989). Juvenile red rock crabs inhabiting the intertidal zone survive exposure to the air during low tide by sheltering themselves under rocks and algae (Ricketts 1985). Red rock crab are often collected in bays, estuaries, and sloughs; however, their distribution in these areas is affected by salinity gradients because the species lacks the ability to osmoregulate (Morris et al. 1980).

Like the brown rock crab and yellow crab, adult red rock crab is sexually dimorphic, with males attaining a larger size and growing larger, more robust chelae. Male crabs grow to a maximum size (CW) of 200 mm (7.8 in), while females reach 158 mm (6.2 in) (Jensen 1995). No estimates of the life span of red rock crab were cited in the literature reviewed. The size of a female's egg mass is variable and can contain from 560,000 to 1.01 million eggs (Carroll and Winn 1989). No information about the development and subsequent hatching of red rock crab eggs was available in reviewed literature. Trask (1970) found that red rock crab larvae developed to the megalopal stage in 97 days at a temperature of 11°C (52° F); however, none of his laboratory-reared larvae survived to the first crab instar.

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 crab 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.

5.5.3.1.2 Population Trends and Fishery

Rock crabs are fished along the entire California coast with 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, statewide rock crab landings (including claws) averaged 1.2 million lbs 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 lbs) and $110,000 (Table 5.5-19). Commercial landings of rock crabs in 2006 in Santa Monica Bay catch blocks totaled 21,328 kg (47,020 lbs) 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 lbs) at a value of $134,622, while landings for red rock crab totaled 325 kg (716 lbs) at a value of $1,184 (CDFG 2006).

Table 5.5-19. Annual landings and revenue for red rock crab in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	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

In 2005, four species of rock crabs were impinged: Pacific rock crab (1,885 individuals at 13.223 kg [29.157 lbs]), yellow crab (974 individuals at 5.814 kg [12.820 lbs]), red rock crab (101 individuals at 0.123 kg [0.271 lbs]), and slender (graceful) crab (96 individuals at 0.223 kg [0.492 lbs]) (MBC 2006). Abundance was generally highest during February and April heat treatments. From 2000 through 2005, annual impingement of yellow crab ranged between 224 and 2,614 individuals, Pacific rock crab ranged between 104 and 1,885 individuals, slender (graceful) crab ranged between 34 and 535 individuals, bigtooth rock crab ranged between 0 and 20 individuals, and red rock crab ranged between 3 and 101 individuals.

5.5.3.1.3 Sampling Results

Yellow crab was the fourth most abundant invertebrate, and the third most abundant shellfish, with an estimated annual impingement of 13,434 individuals weighing 544.830 kg (1,201.350 lbs) (Tables 5.5-3 and 5.5-4). It was most abundant in summer months (June through August), and abundance declined considerably following the mid-August heat treatments (Figures 5.5-57 through 5.5-60). Impingement was relatively low during the VCS (Figures 5.5-58 and 5.5-60). There was also no clear diel pattern of impingement (Figures 5.5-75 and 5.5-76). Almost all of the individuals impinged during heat treatments occurred during the first three procedures in January and August 2006 (Tables 5.5-18 and 5.5-19).

Pacific rock crab was the fifth most abundant invertebrate with an estimated annual impingement of 4,066 individuals weighing 61.517 kg (135.645 lbs) (Table 5.5-3 and 5.5-4). Pacific rock crab was most abundant in spring and summer (April through August), and similar to yellow crab, abundance declined considerably following the mid-August heat treatments (Figures 5.5-61 through 5.5-64). Impingement was relatively low during the VCS (Figures 5.5-62 and 5.5-64). Pacific rock crab was impinged in slightly higher numbers during nighttime than during daytime (Figures 5.5-77 and 5.5-78). Almost all of the individuals impinged during heat treatments occurred during the first three procedures in January and August 2006 (Tables 5.5-18 and 5.5-19).

Hairy rock crab was the eighth most abundant invertebrate with an estimated annual impingement of 3,896 individuals weighing 11.829 kg (26.083 lbs) (Table 5.5-3 and 5.5-4). Hairy rock crab was most abundant in spring and summer (April through August), and similar to yellow crab, abundance declined considerably following the mid-August heat treatments (Figures 5.5-65 through 5.5-68). Impingement was relatively low during the VCS (Figures 5.5-66 and 5.5-68). Hairy rock crabs were impinged in slightly higher numbers during nighttime than during daytime (Figures 5.5-79 and 5.5-80). Almost all of the individuals impinged during heat treatments occurred in August and October 2006 (Tables 5.5-18 and 5.5-19).

Red rock crab was the tenth most abundant invertebrate with an estimated annual impingement of 1,789 individuals weighing 57.779 kg (127.403 lbs) (Table 5.5-3 and 5.5-4). Red rock crab was most abundant in spring and summer (April through August), and similar to other rock crabs, abundance declined considerably following the mid-August heat treatments (Figures 5.5-69 through 5.5-72). Impingement was relatively low during the VCS (Figures 5.5-70 and 5.5-72). Red rock crabs were impinged in slightly higher numbers during nighttime than during daytime (Figures 5.5-81 and 5.5-82). Only six individuals were impinged during heat treatments (Tables 5.5-18 and 5.5-19).

Unidentified rock crab was the seventeenth most abundant invertebrate category with an estimated annual impingement of 491 individuals weighing 2.056 kg (4.533 lbs) (Table 5.5-3 and 5.5-4). Unidentified rock crab was most abundant in spring (April and May), and there were no occurrences during the VCS (Figures 5.5-73 and 5.5-74). Unidentified rock crabs were impinged in higher numbers during nighttime than during daytime (Figures 5.5-83 and 5.5-84). Only three individuals were impinged during heat treatments (Tables 5.5-20 and 5.5-21).

Red rock crabs were the largest individuals impinged, on average (53 mm CW), although yellow rock crabs with carapace widths as large as 200 mm were impinged (Figures 5.5-85 through 5.5-89). Hairy rock crabs and unidentified rock crabs were the smallest individuals impinged, with mean carapace widths of 22 mm and 25 mm, respectively. The majority of individuals of all rock crabs were male (61–66%), with the minority being female (33–37%) or sex undetermined (0–2%). For most of the *Cancer* species, more individuals were impinged alive than dead or mutilated (hairy rock crab – 62% alive, unidentified rock crab – 59% alive, yellow crab – 59% alive, red rock crab – 55% alive, and Pacific rock crab – 47% alive). The percentage of dead rock crabs ranged between 35% (hairy rock crab) and 48% (Pacific rock crab). The percentage of mutilated rock crabs ranged between 0% (unidentified rock crabs) and 4% (Pacific rock crab).

Table 5.5-20. Summary of rock crab impingement abundance during normal flow direction heat treatments.

Heat Treatment Date	Yellow crab	Pacific rock crab	Hairy rock crab	Red rock crab	Unid. rock crab
1/25/2006	60	52	–	4	3
8/10/2006	72	300	7	–	–
8/15/2006	39	27	–	2	–
10/4/2006	15	–	15	–	–
10/10/2006	–	2	–	–	–
10/23/2006	–	–	–	–	–
11/20/2006	–	–	–	–	–
1/3/2007	8	4	2	–	–
	194	**385**	**24**	**6**	**3**

Table 5.5-21. Summary of rock crab impingement biomass (kg) during normal flow direction heat treatments.

Heat Treatment Date	Yellow crab	Pacific rock crab	Hairy rock crab	Red rock crab	Unid. rock crab
1/25/2006	0.194	0.082	–	0.013	0.833
8/10/2006	2.018	13.186	0.036	–	–
8/15/2006	1.555	1.313	–	0.071	–
10/4/2006	0.036	–	0.015	–	–
10/10/2006	–	0.006	–	–	–
10/23/2006	–	–	–	–	–
11/20/2006	–	–	–	–	–
1/3/2007	0.045	0.028	0.008	–	–
	3.848	**14.615**	**0.059**	**0.084**	**0.833**

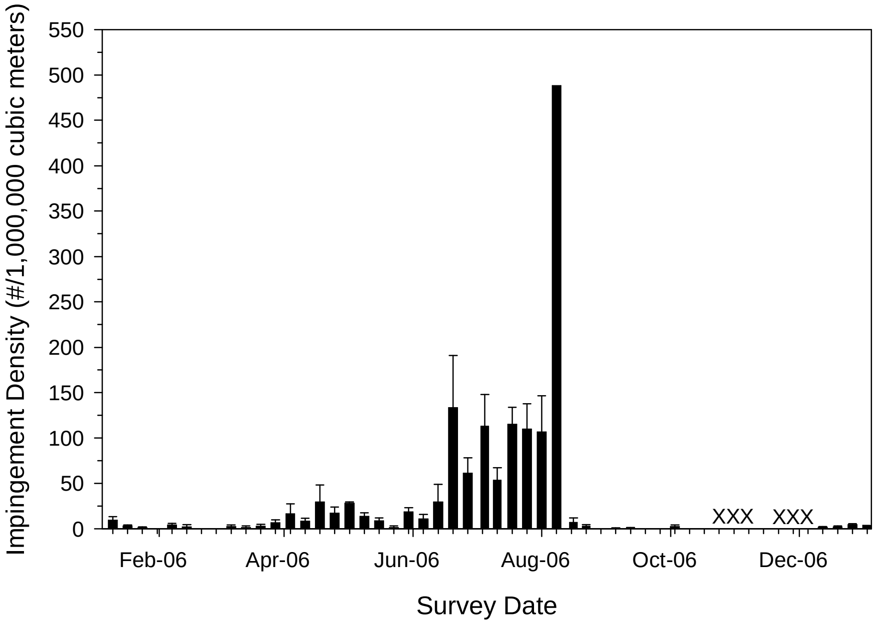


Figure 5.5-57. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of yellow crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

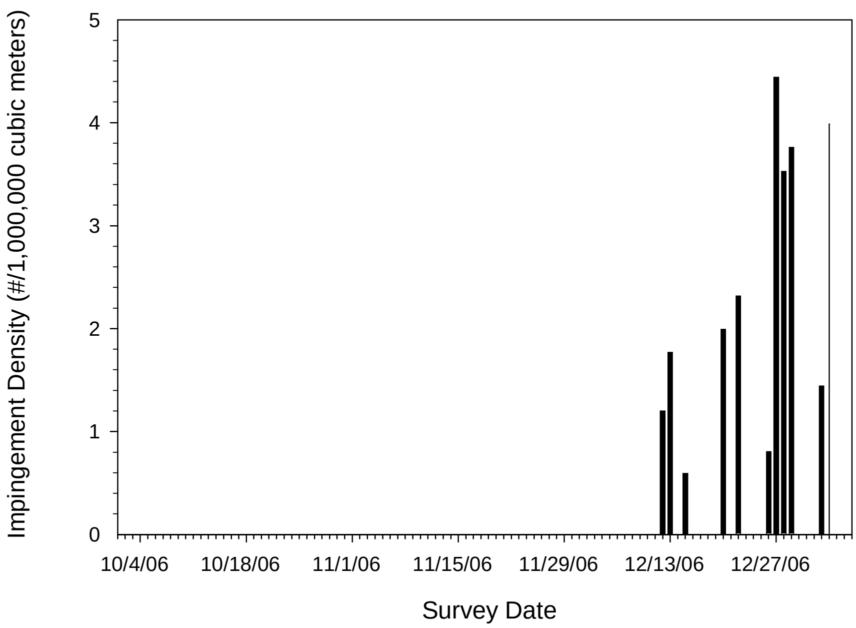


Figure 5.5-58. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of yellow crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

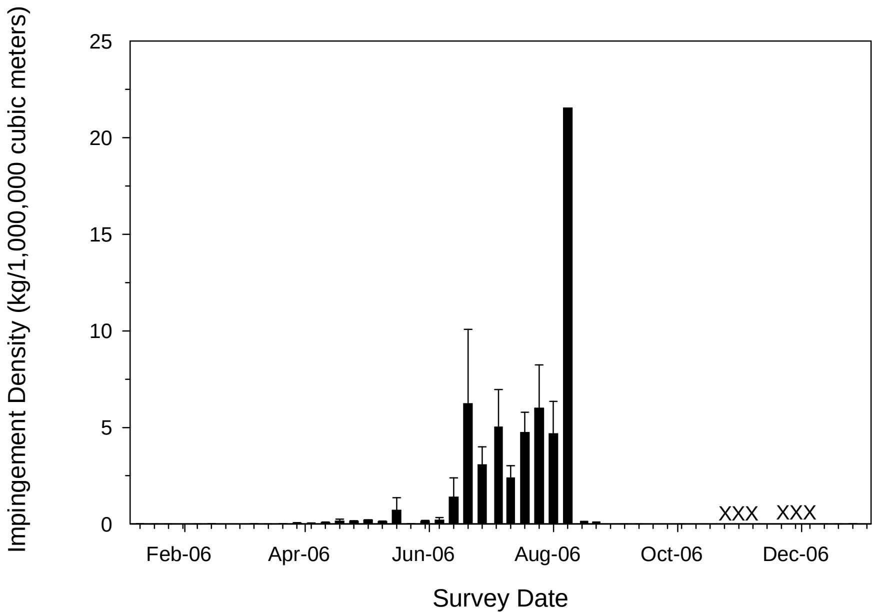


Figure 5.5-59. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of yellow crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

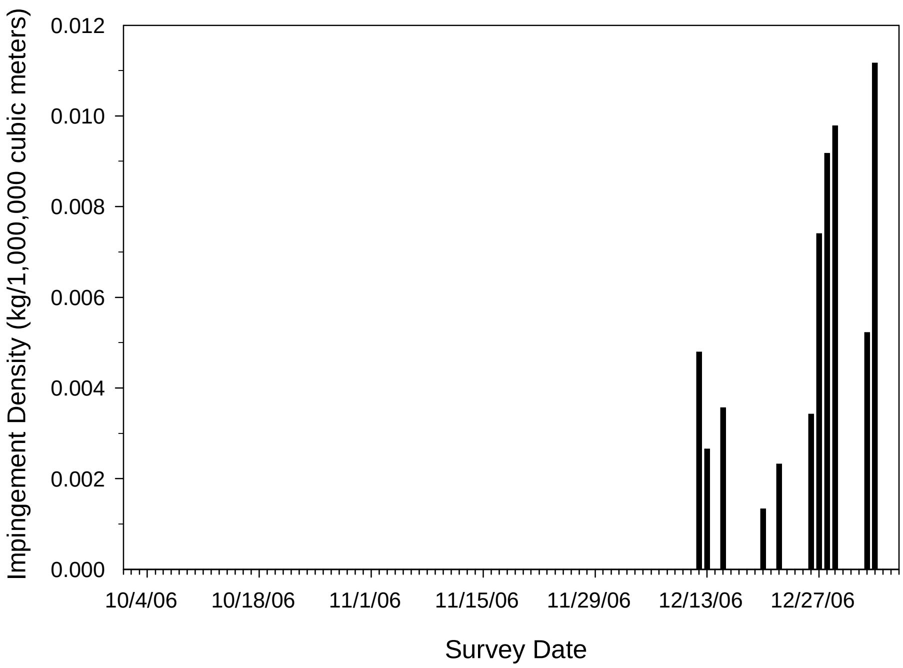


Figure 5.5-60. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of yellow crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

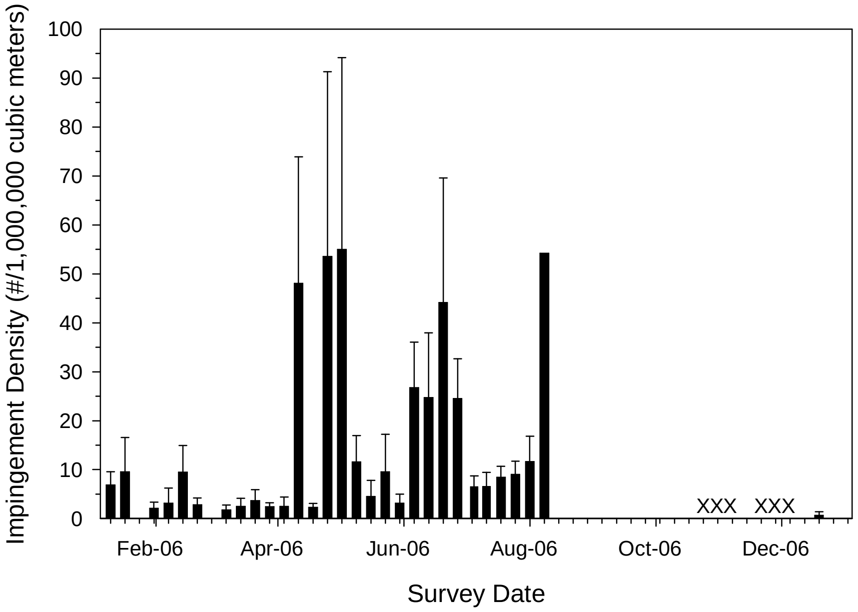


Figure 5.5-61. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of Pacific rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

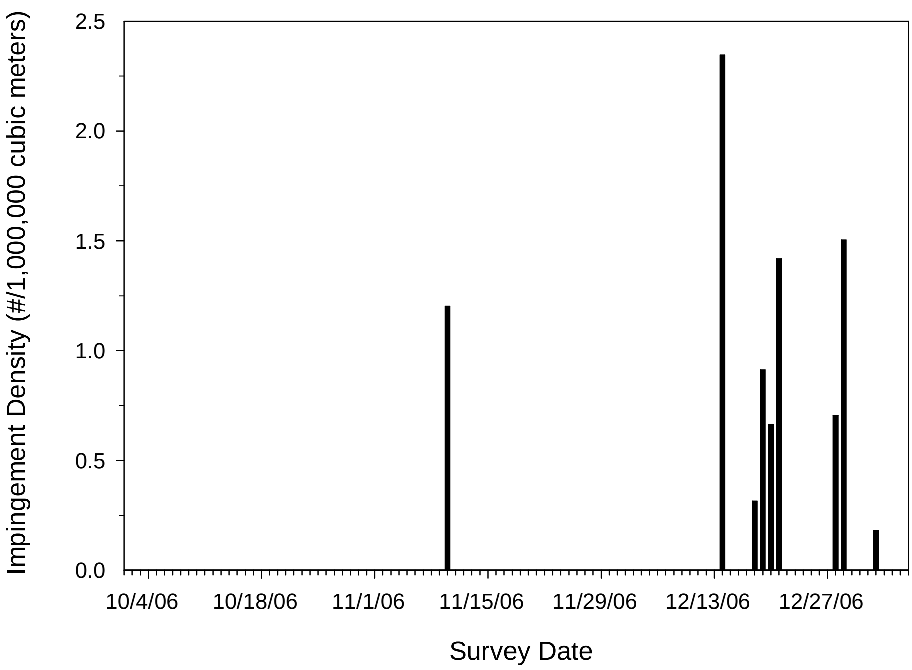


Figure 5.5-62. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of Pacific rock crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

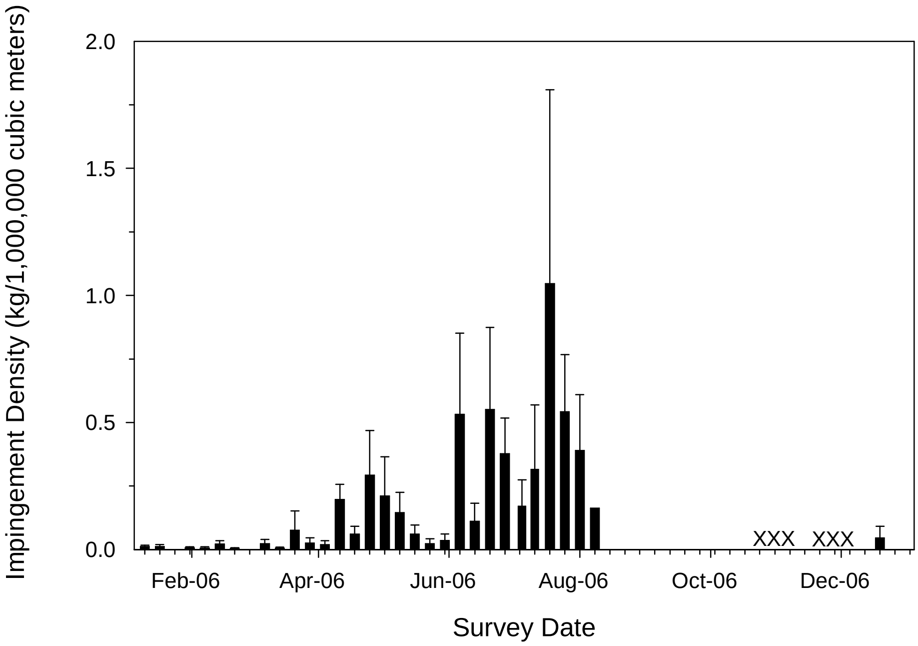


Figure 5.5-63. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of Pacific rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

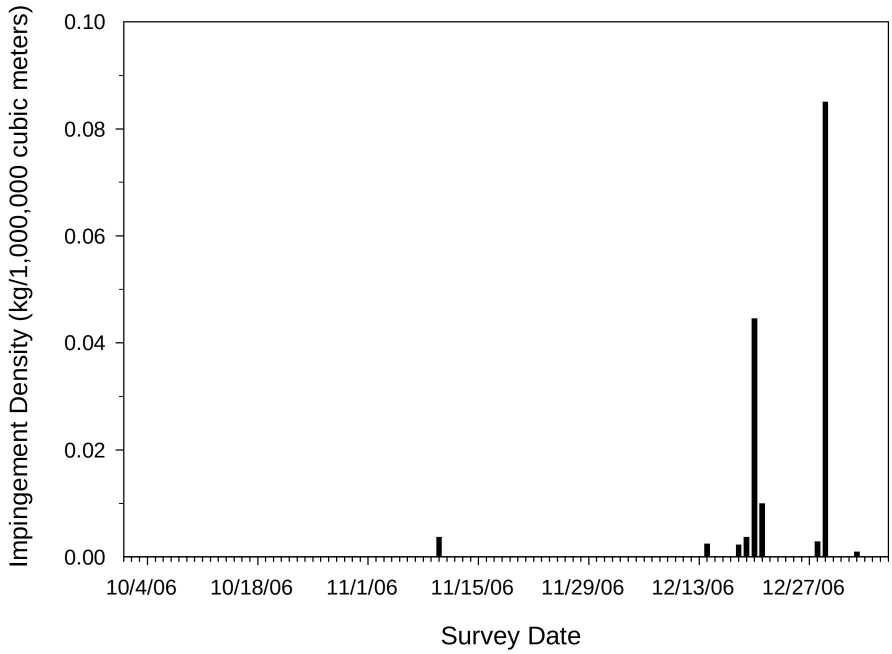


Figure 5.5-64. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of Pacific rock crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

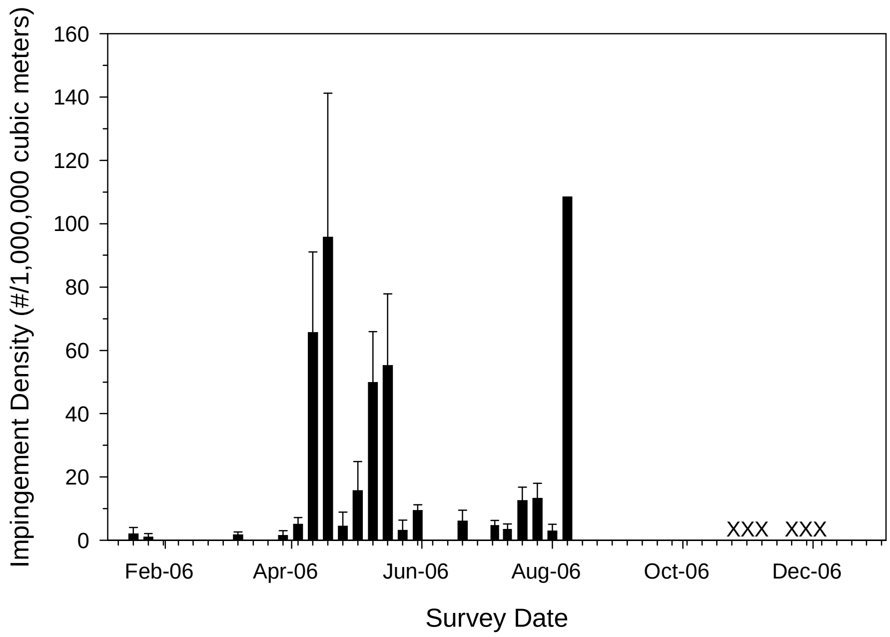


Figure 5.5-65. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of hairy rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

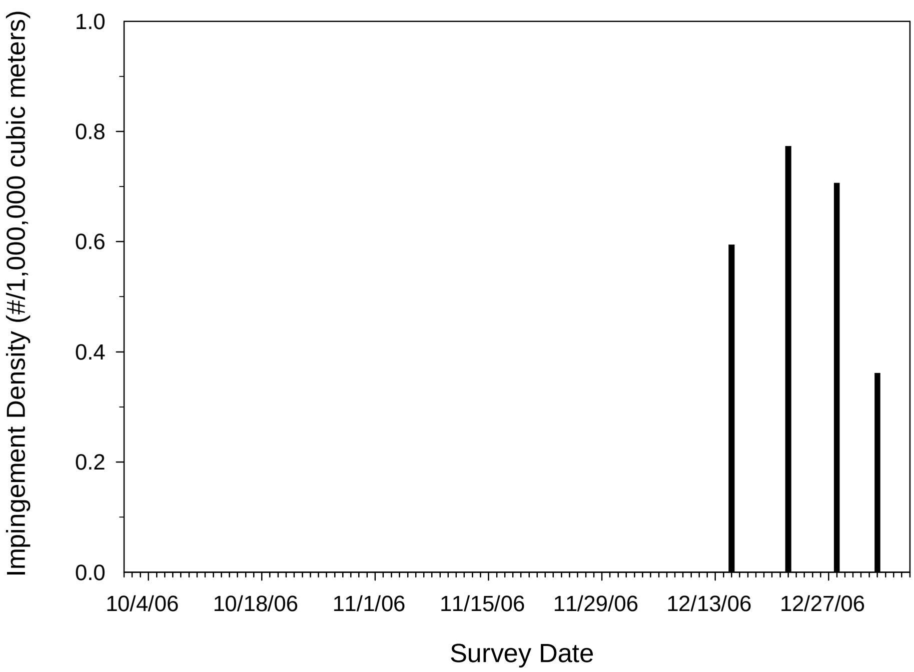


Figure 5.5-66. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of hairy rock crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

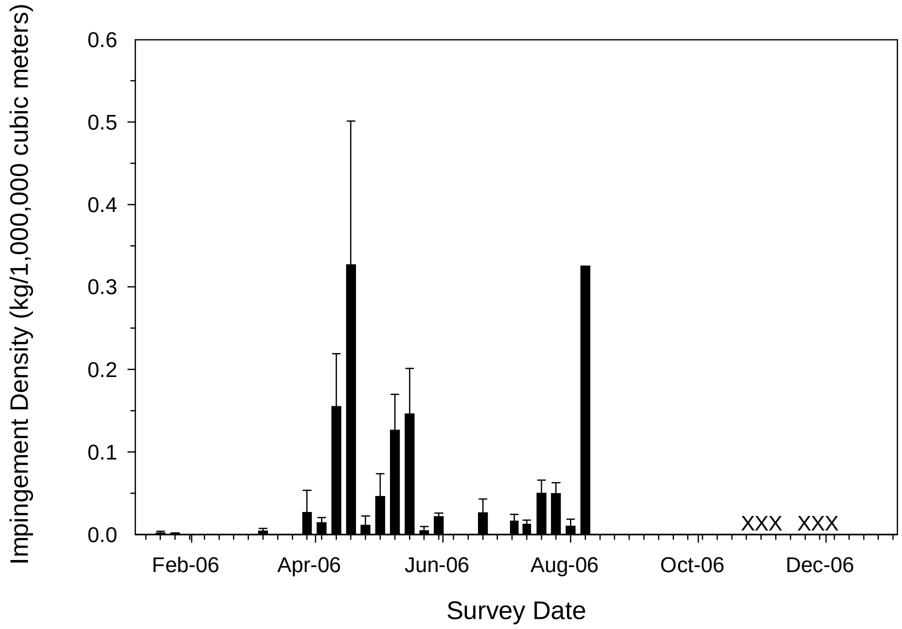


Figure 5.5-67. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of hairy rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

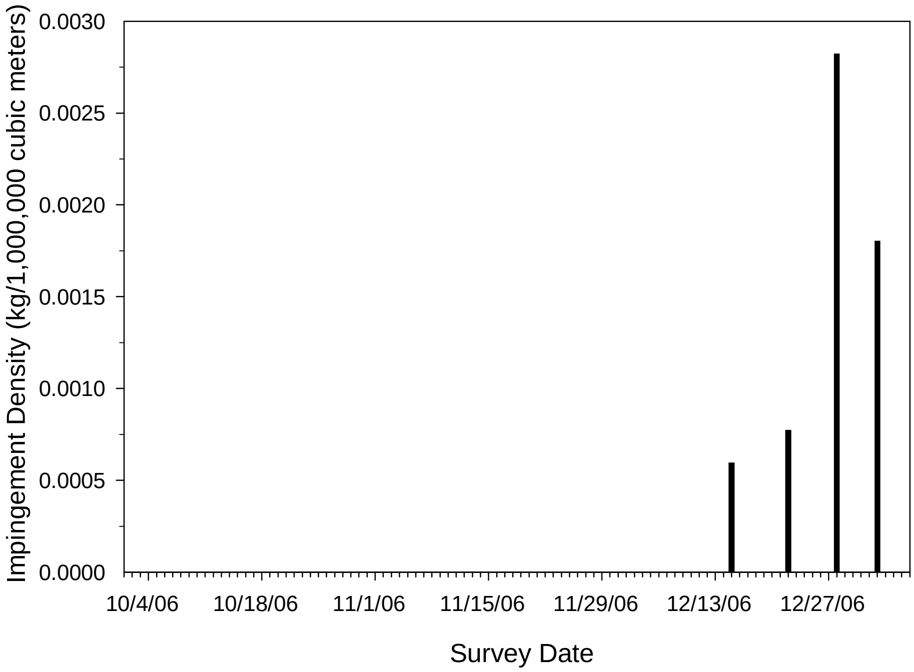


Figure 5.5-68. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of hairy rock crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

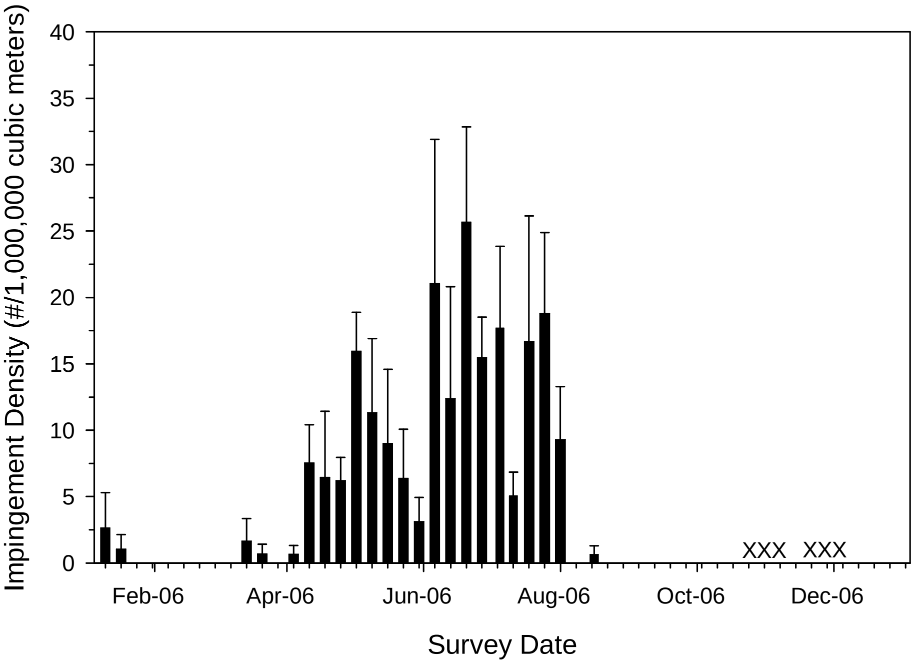


Figure 5.5-69. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of red rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

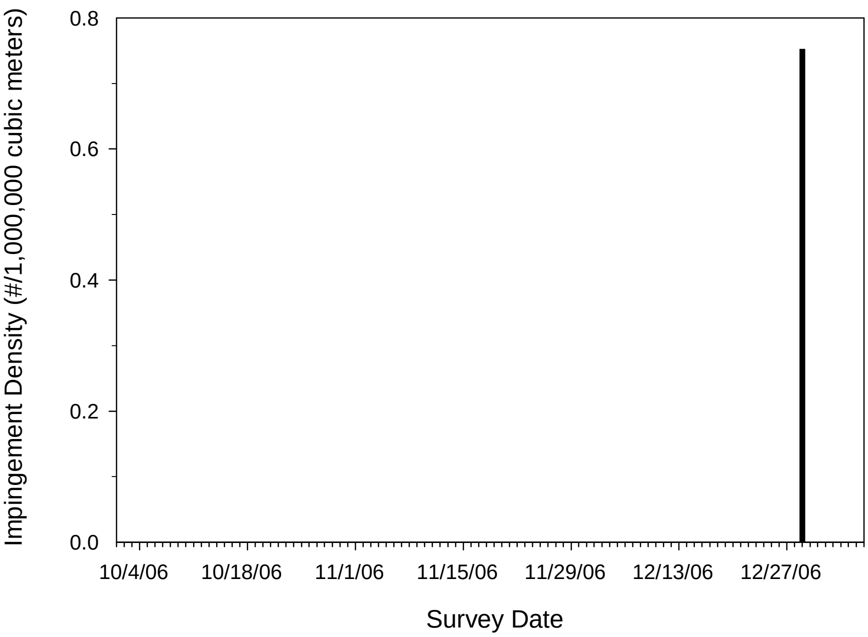


Figure 5.5-70. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of red rock crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

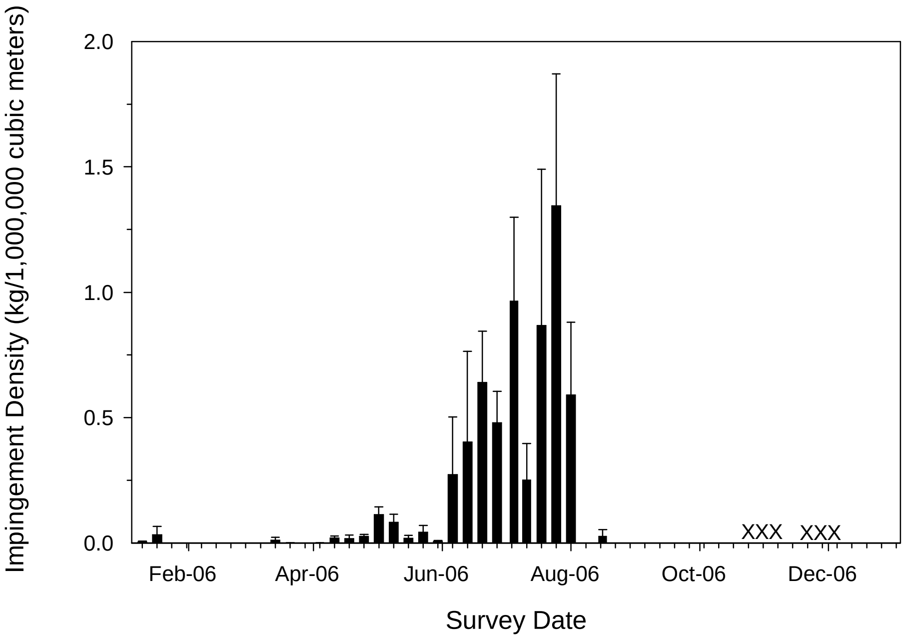


Figure 5.5-71. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of red rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

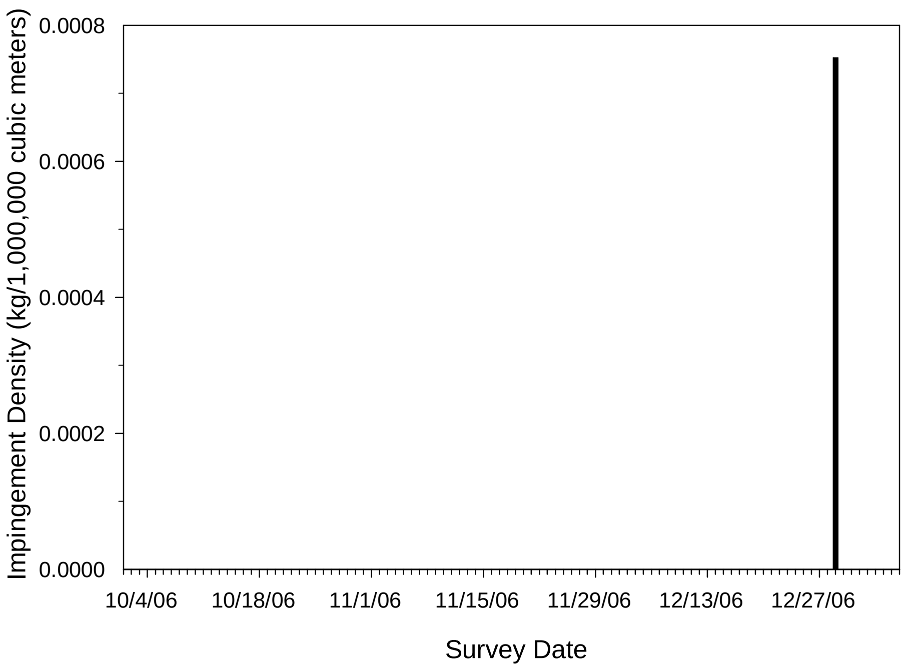


Figure 5.5-72. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of red rock crab collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

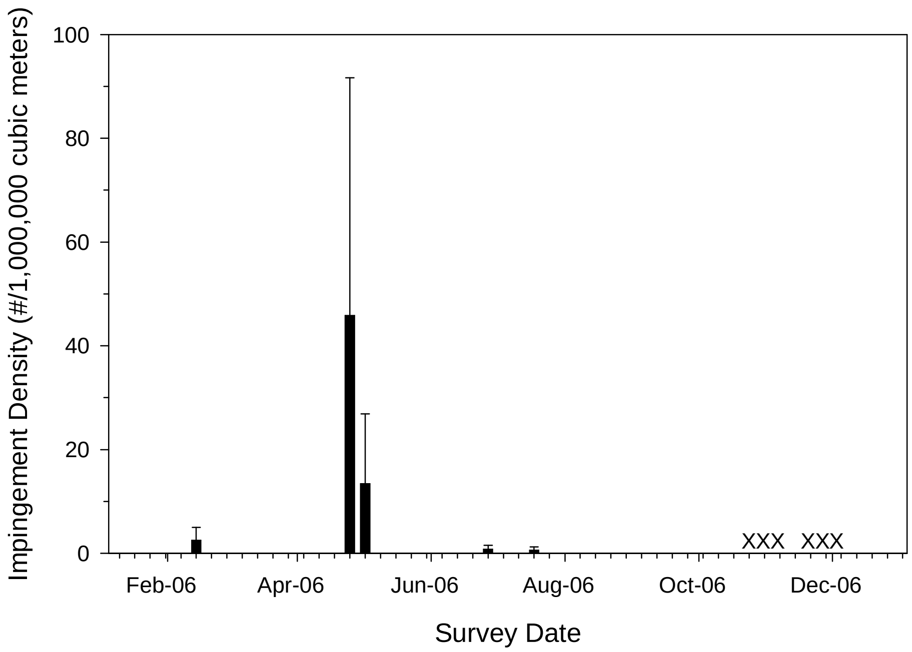


Figure 5.5-73. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of unid. rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

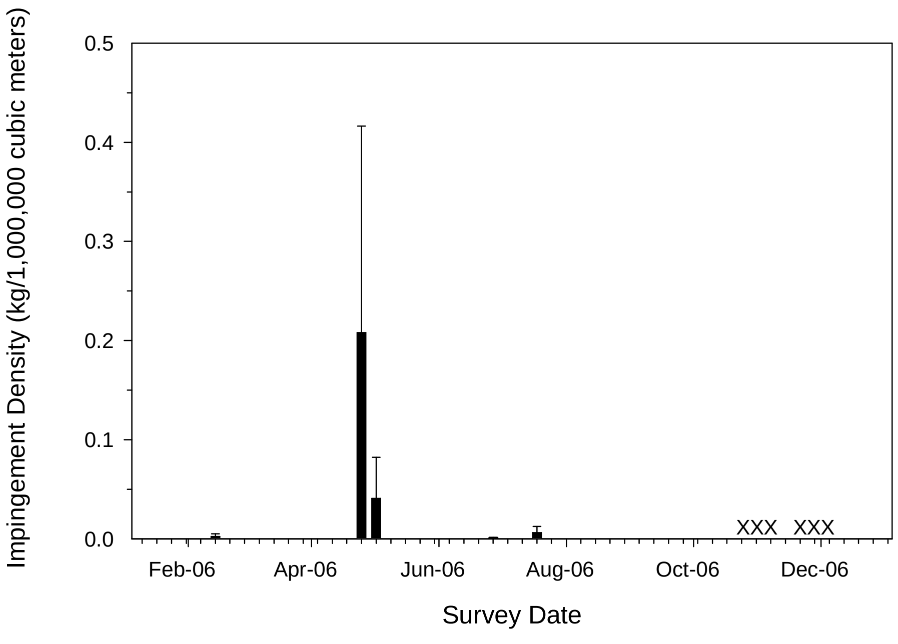


Figure 5.5-74. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of unid. rock crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

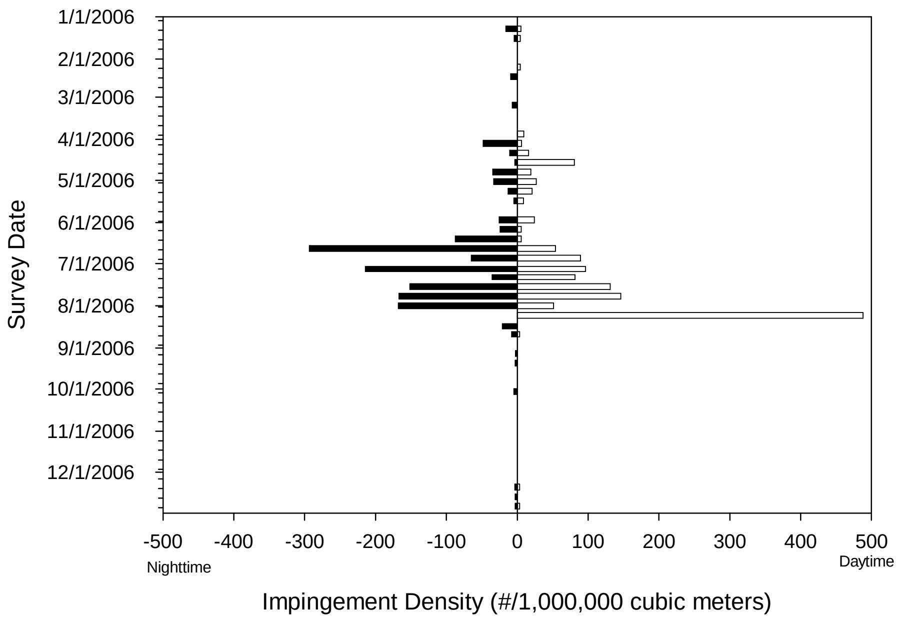


Figure 5.5-75. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of yellow crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

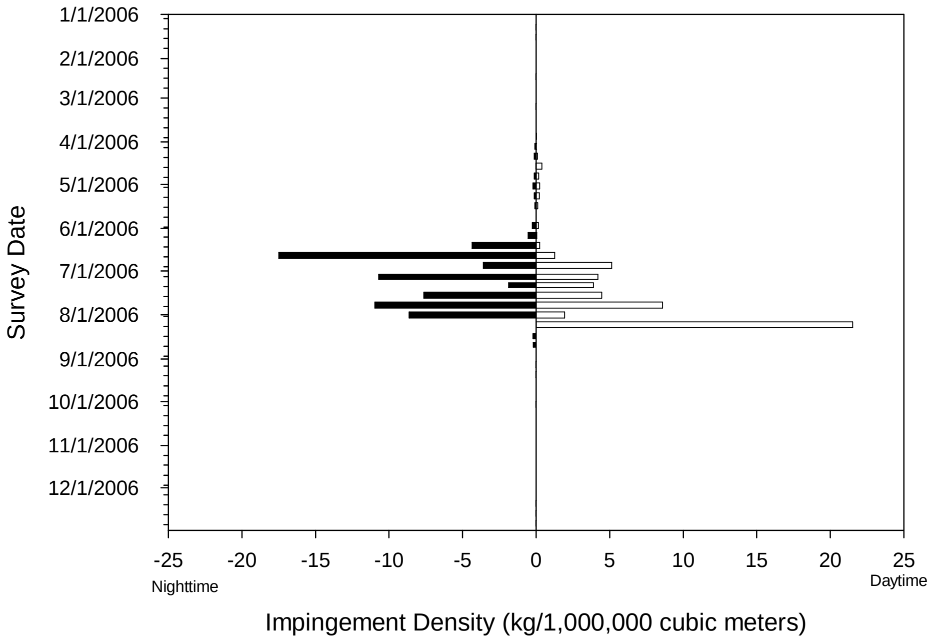


Figure 5.5-76. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of yellow crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

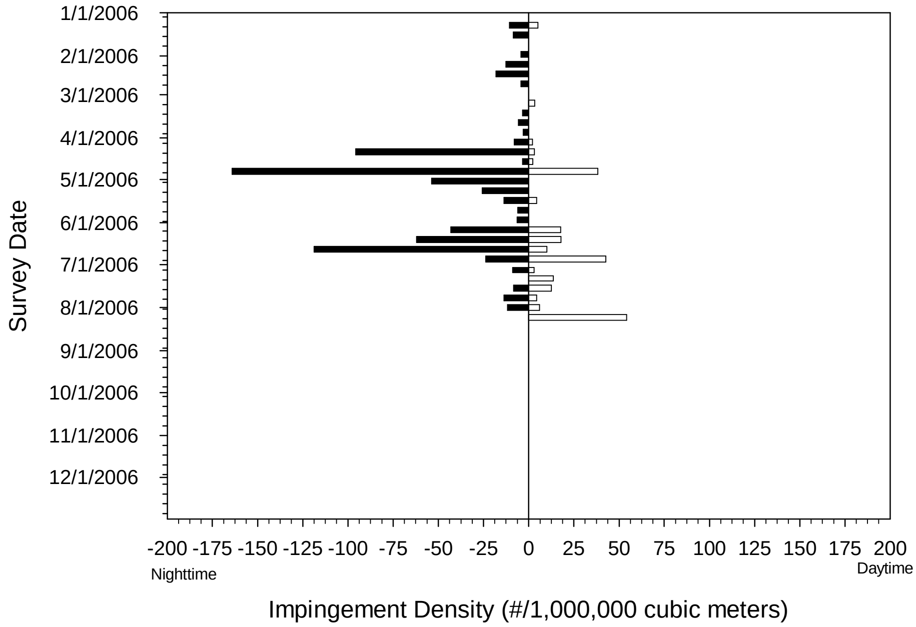


Figure 5.5-77. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of Pacific rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

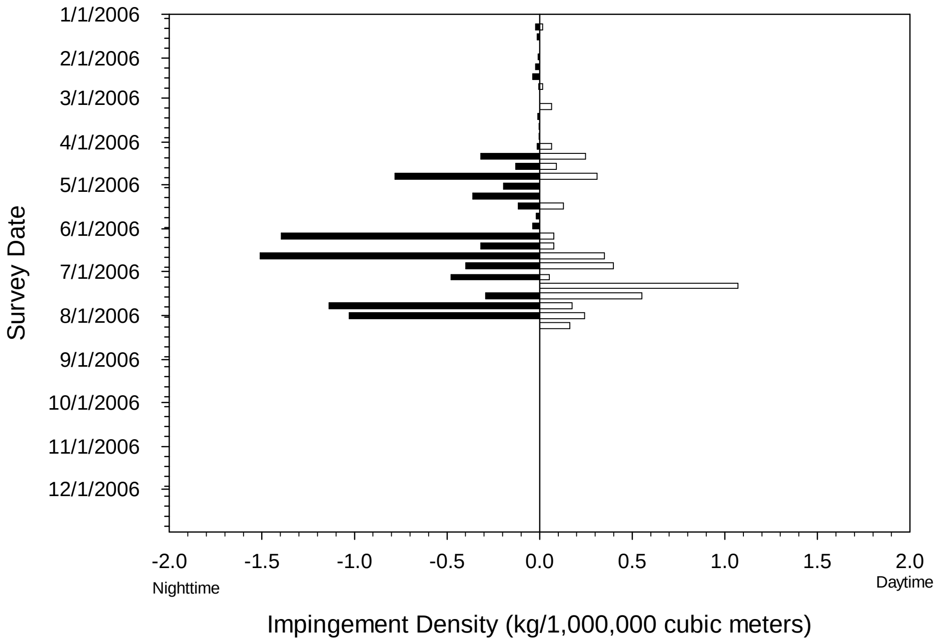


Figure 5.5-78. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of Pacific rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

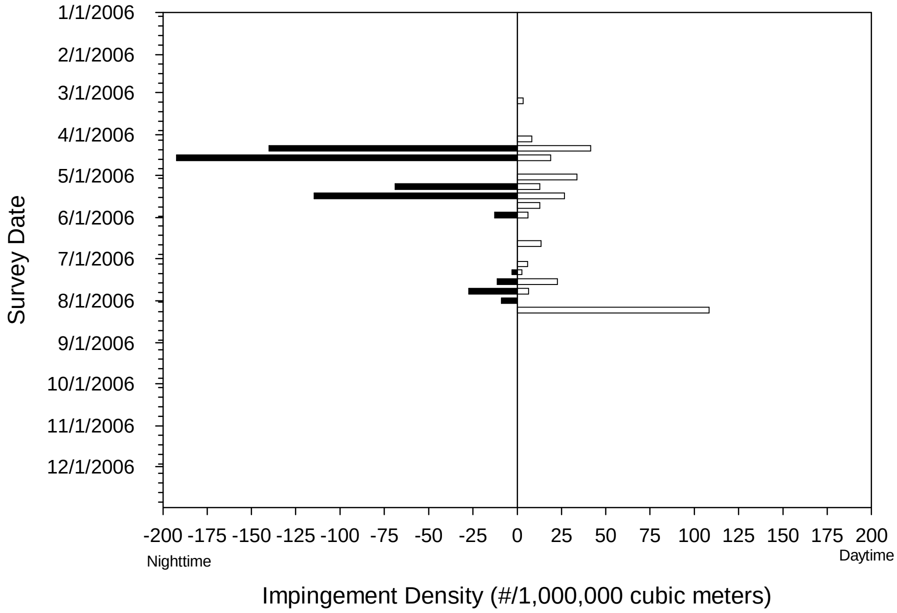


Figure 5.5-79. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of hairy rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

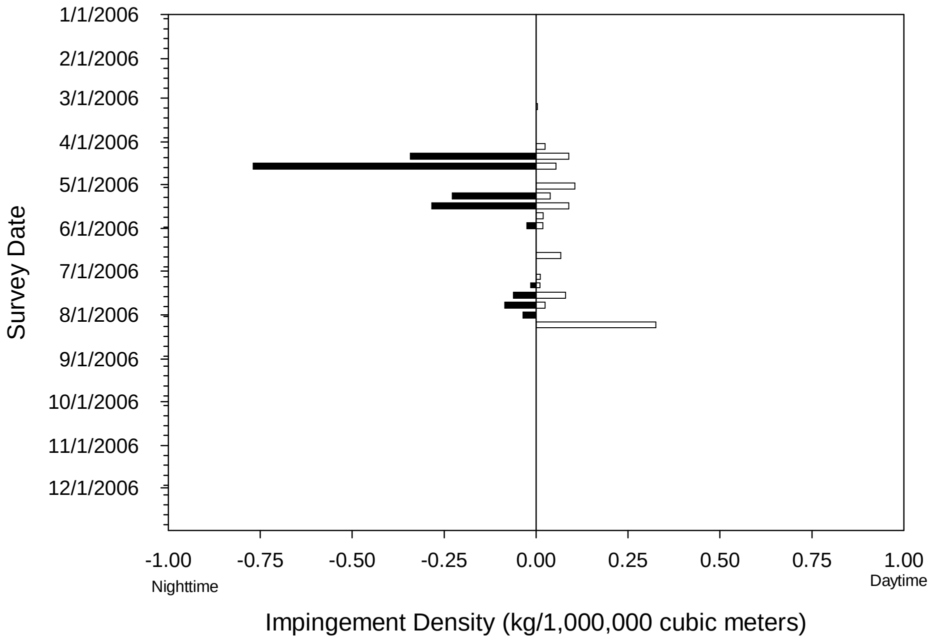


Figure 5.5-80. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of hairy rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

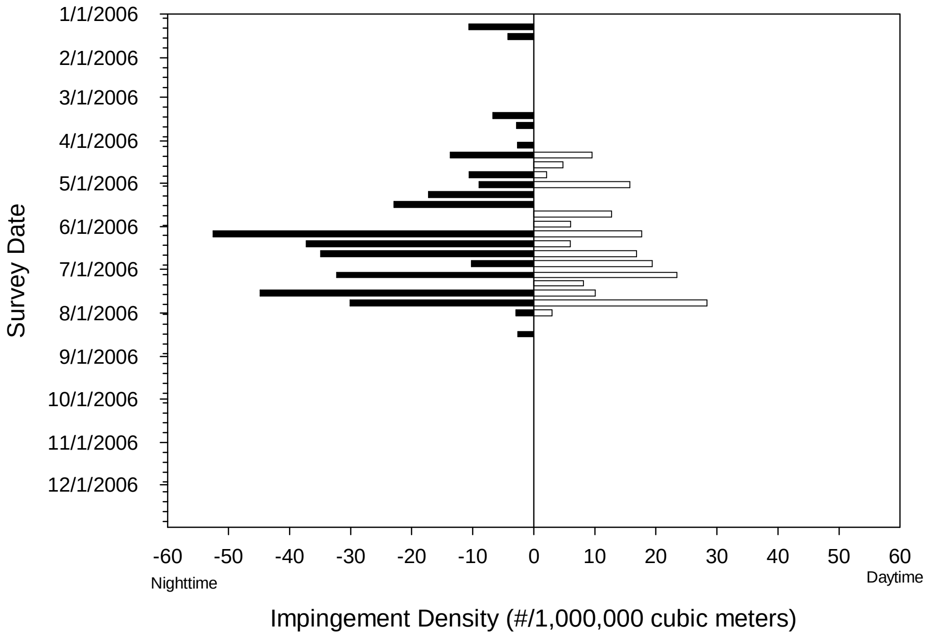


Figure 5.5-81. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of red rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

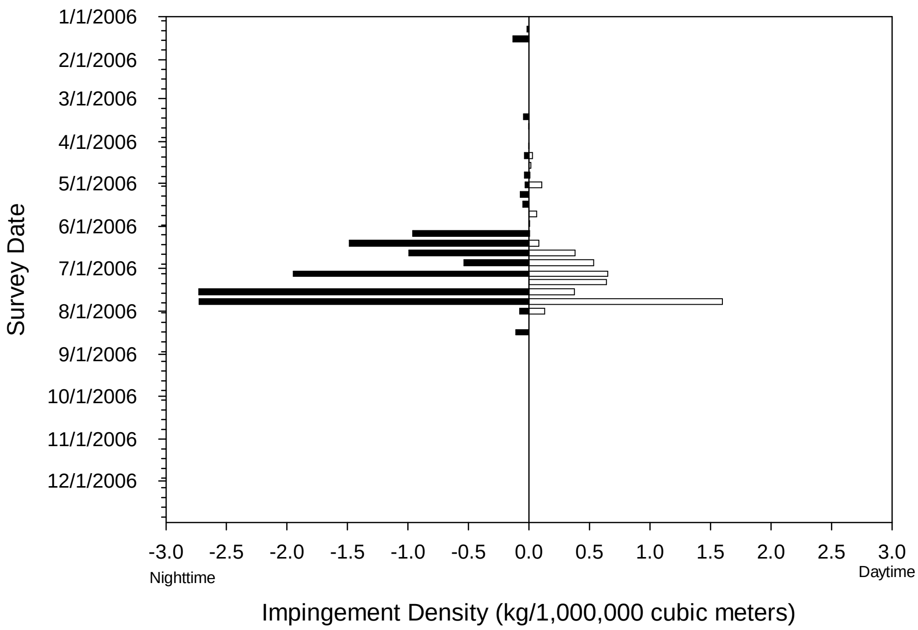


Figure 5.5-82. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of red rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

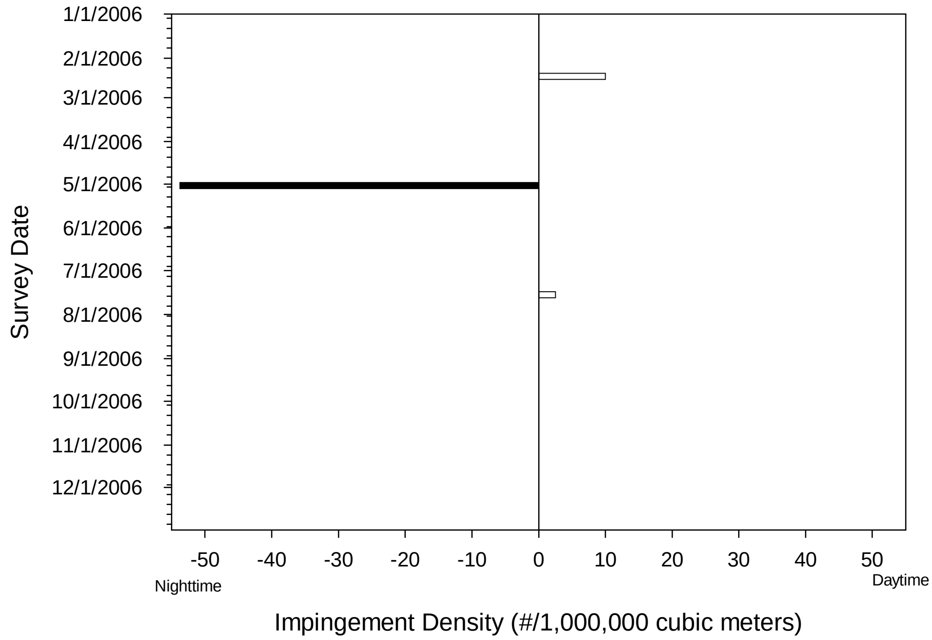


Figure 5.5-83. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of unid. rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

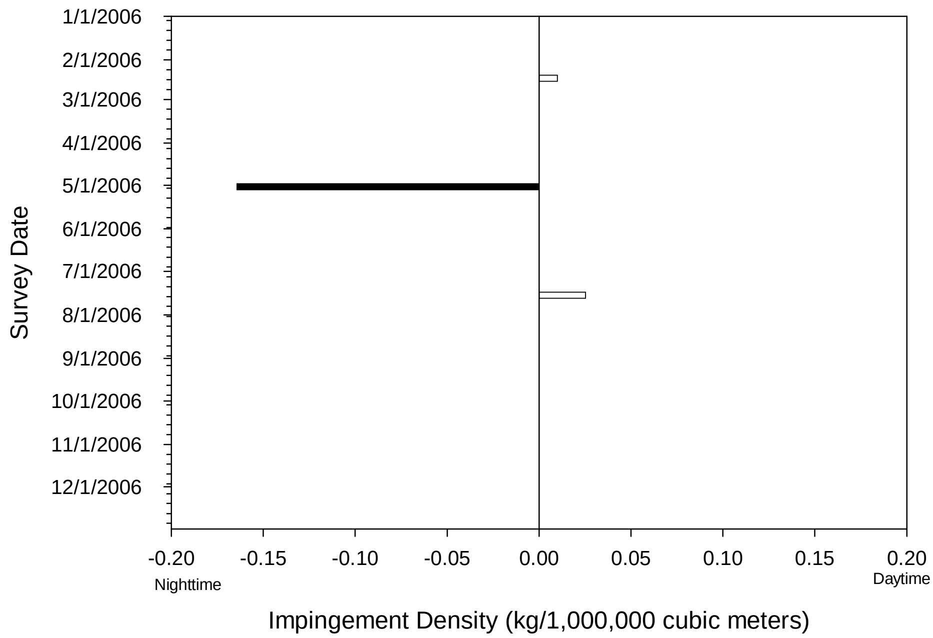


Figure 5.5-84. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of unid. rock crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

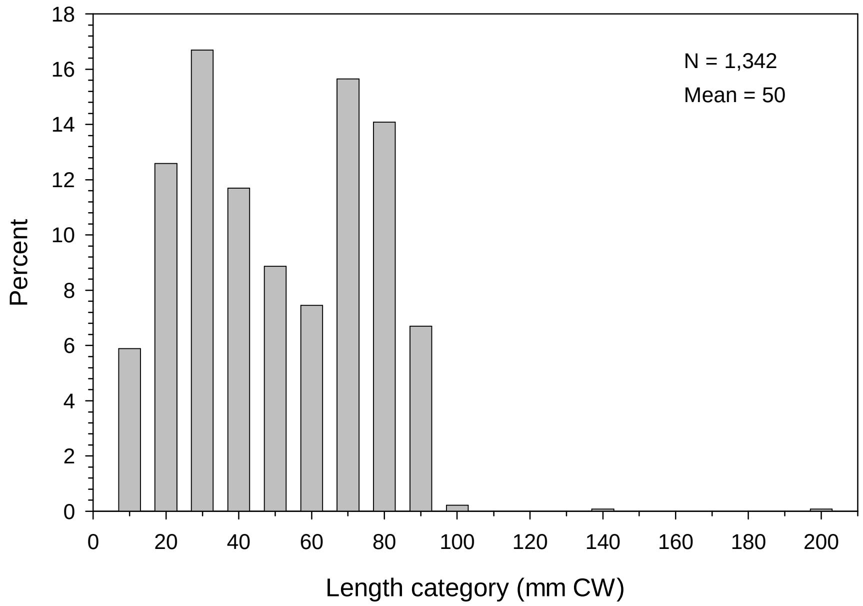


Figure 5.5-85. Carapace width (mm) frequency distribution for yellow crab collected in impingement samples.

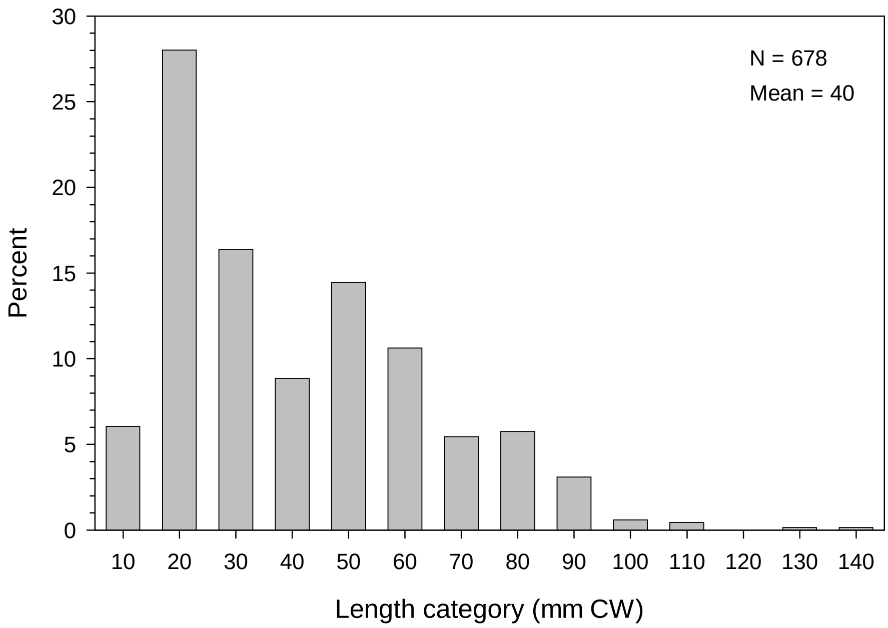


Figure 5.5-86. Carapace width (mm) frequency distribution for Pacific rock crab collected in impingement samples.

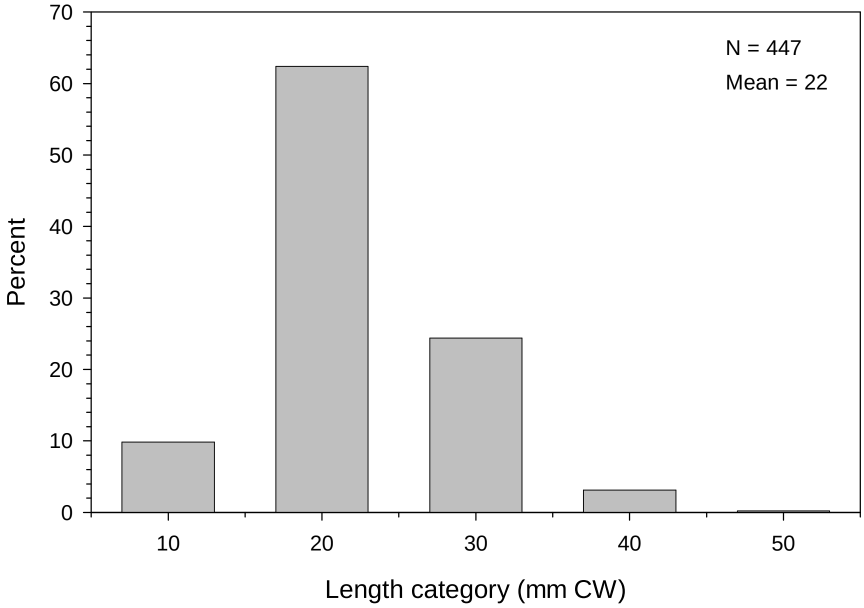


Figure 5.5-87. Carapace width (mm) frequency distribution for hairy rock crab collected in impingement samples.

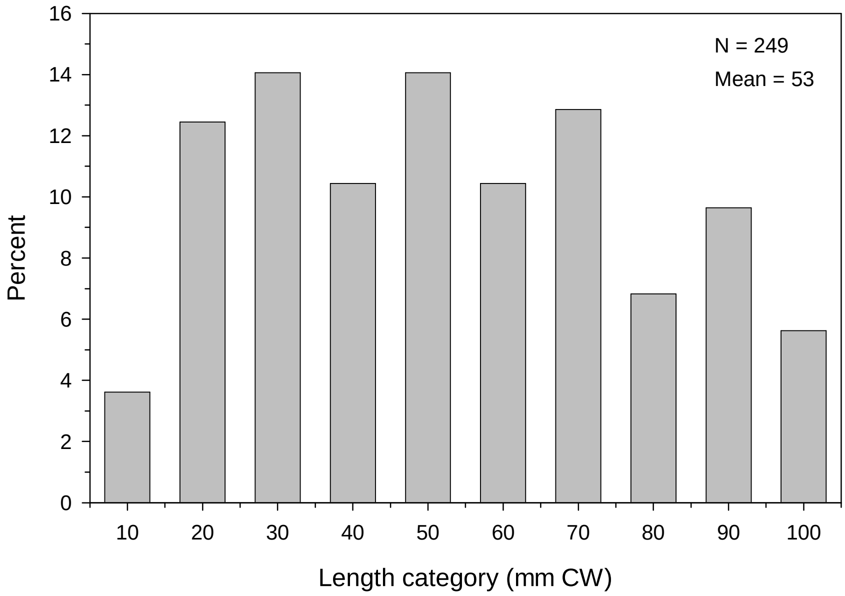


Figure 5.5-88. Carapace width (mm) frequency distribution for red rock crab collected in impingement samples.

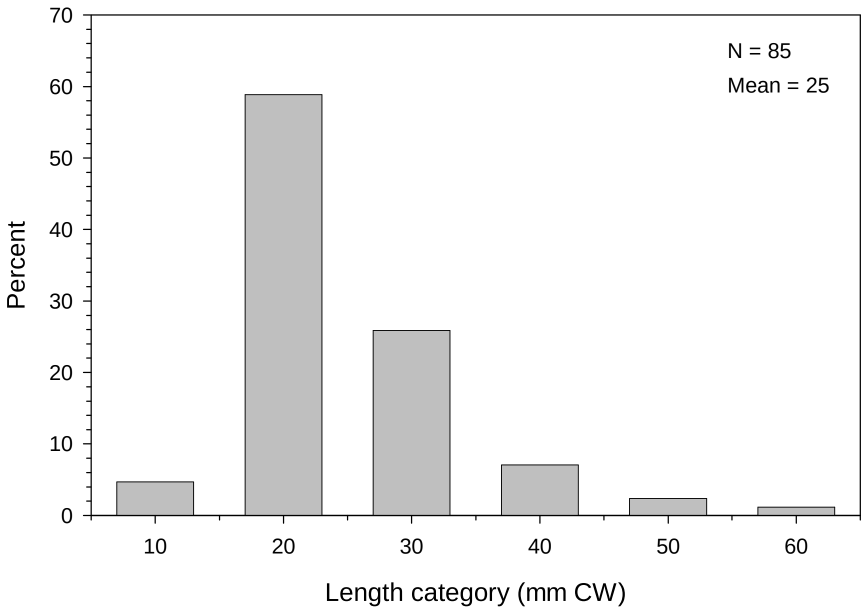


Figure 5.5-89. Carapace width (mm) frequency distribution for unidentified rock crab collected in impingement samples.

5.5.3.2 California Spiny Lobster (*Panulirus interruptus*)

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.

Photo credit: NOAA

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 is 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 10–30 m (33–98 ft) (Mitchell et al. 1969). Spawning occurs from the Channel Islands off southern California to Magdalena Bay, Baja California, including other off shore 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] carapace length [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 SCB (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 7–11 years to reach the legal fishery size of 83 mm (3.3 in) CL. Females grow faster (4.4 mm/year [0.2 in/year]) than males (3.7 mm/year [0.1 in/year]) (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 lbs). 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 lbs) (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 off shore 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 has 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 lbs and 138,000 lbs) per year since 2000 (Table 5.5-22). In 2005, commercial landings of spiny lobster in the Los Angeles area totaled 101,324 kg (223,420 lbs) 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 lbs) at an estimated value of $372,220 (CDFG 2007b). In 2005, a total of 104 spiny lobsters weighing 62.206 kg (137.164 lbs) was impinged at the SGS (MBC 2006). From 2000 through 2005, annual impingement of California spiny lobster ranged between 104 individuals (2005) and 464 individuals (2000).

Table 5.5-22. Annual landings and revenue for California spiny lobster in the Los Angeles region based on PacFIN data.

Year	Landed Weight (kg)	Landed Weight (lbs)	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

5.5.3.2.3 Sampling Results

California spiny lobster was the twelfth most abundant invertebrate species impinged with an estimated 450 individuals, or 0.3% of the annual total, weighing 276.768 kg (610.273 lbs) (Tables 5.5-3 and 5.5-4). This species was observed sporadically in high abundances and biomass throughout the year, with peaks in abundance measured in April and July (Figures 5.5-90 through 5.5-93). During the VCS, abundance and biomass were recorded at slightly lower levels than those between January and October 2006 (Figures 5.5-91 and 5.5-93). Impingement was more frequent at nighttime than during daytime (Figures 5.5-94 and 5.5-95). The highest heat treatment impingement total was recorded on August 10, 2006 (Table 5.5-23).

Length frequency analysis of 250 measured individuals indicated a mean CL of 82 mm (3.2 in) (Figure 5.5-96), corresponding to the approximate legal minimum size limit (83 mm) and an approximate age of 7–11 years old. Individuals ranged widely from the 10–350 mm (0.4–13.8 in) size classes, with a peak at the 70 mm (2.8 in) SL size class, corresponding to individuals approximately 5–6 years old. Of the 213 individuals that were evaluated for condition factor, 61% were alive, 39% were dead, and less than 1% was mutilated. Of the 243 individuals evaluated for sex, 52% were female, 42% were male, 5% were juveniles, and less than 1% was undeterminable.

Table 5.5-23. Summary of spiny lobster impingement during normal flow direction heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	22	10.87	23.97
8/10/2006	58	35.14	77.47
8/15/2006	9	5.02	11.07
10/4/2006	40	30.07	66.30
10/10/2006	8	7.09	15.62
10/23/2006	8	4.56	10.04
11/20/2006	1	0.35	0.78
1/3/2007	14	4.23	9.33
	160	**97.34**	**214.63**

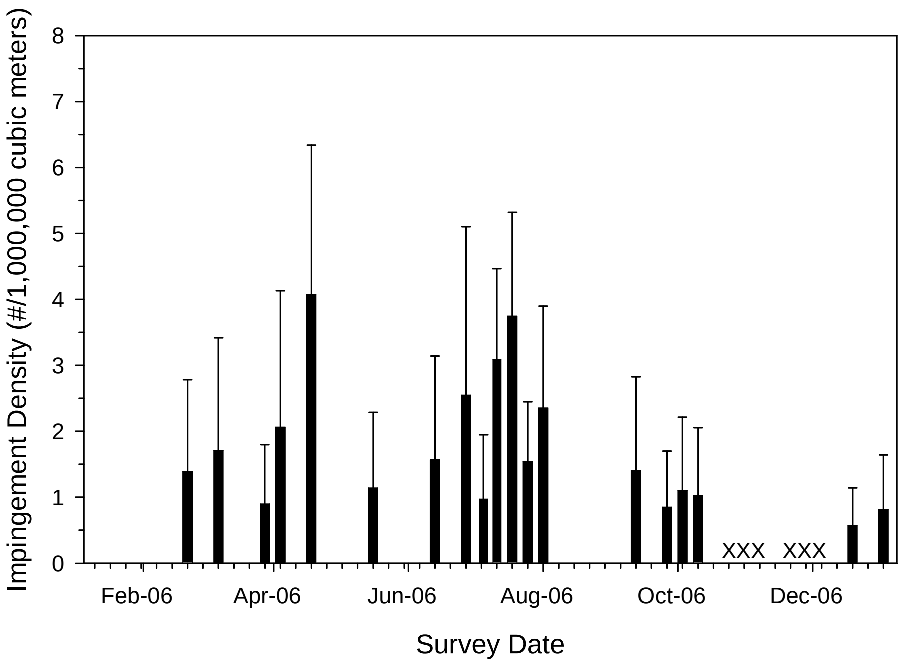


Figure 5.5-90. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of spiny lobster collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

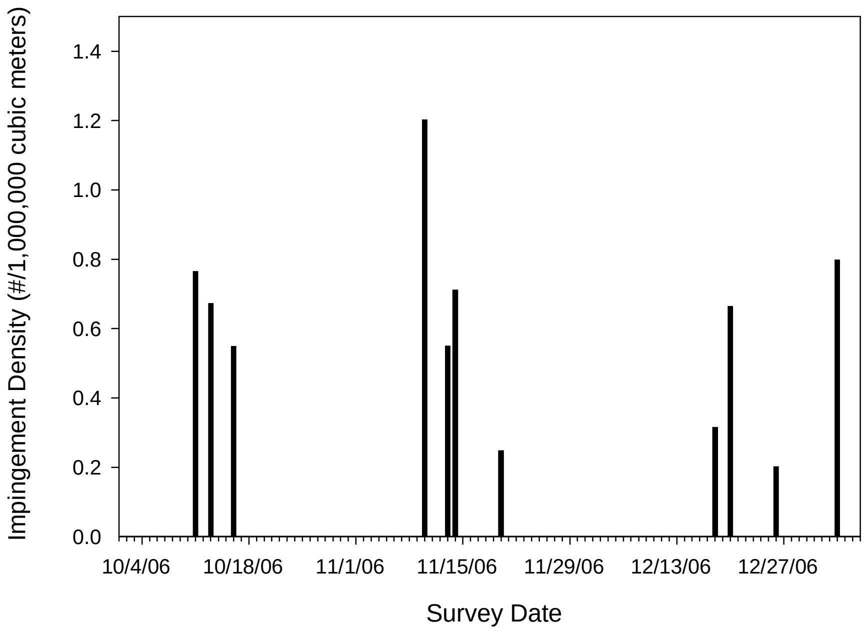


Figure 5.5-91. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of spiny lobster collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3,

2007).

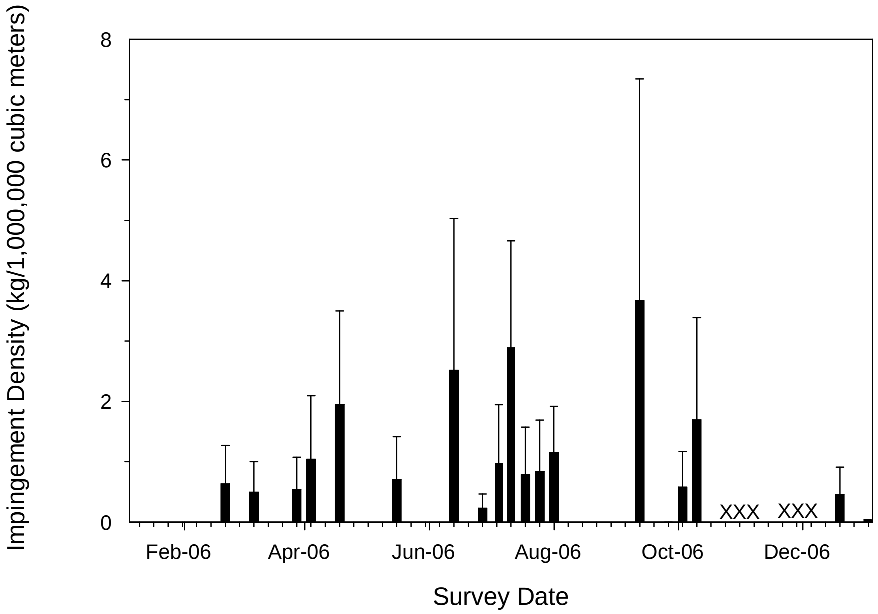


Figure 5.5-92. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of spiny lobster collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

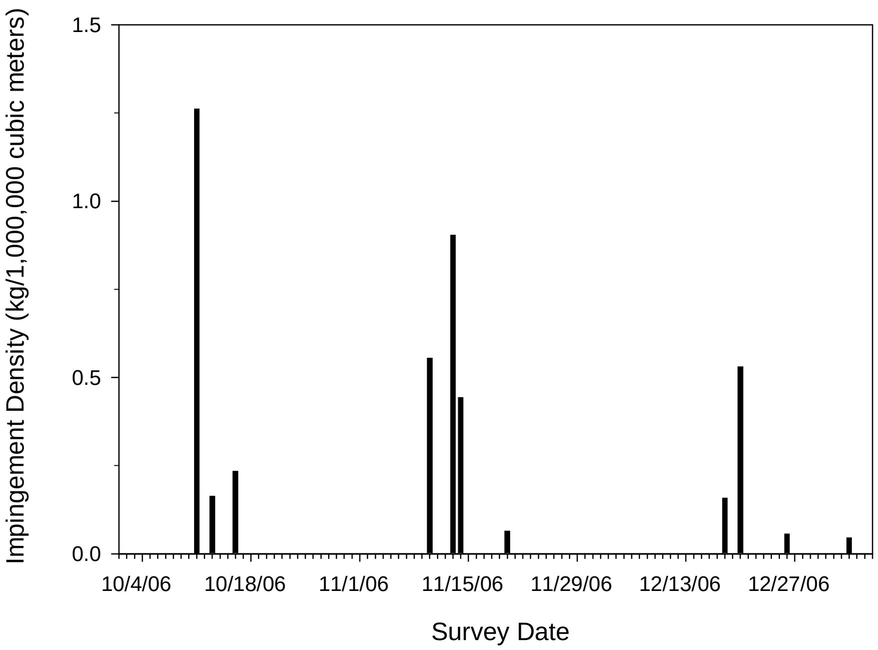


Figure 5.5-93. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of spiny lobster collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

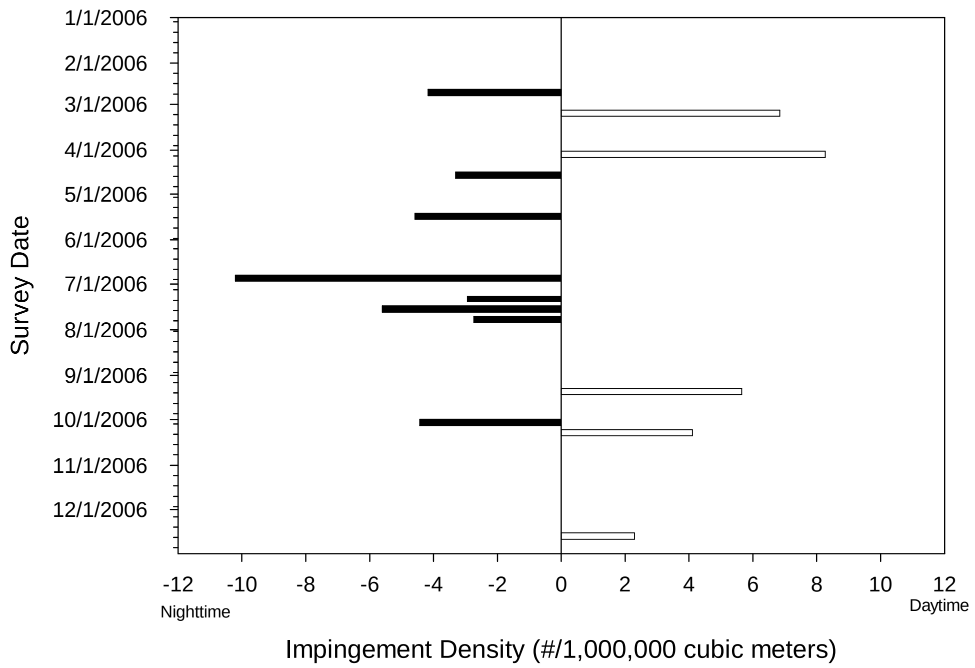


Figure 5.5-94. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of spiny lobster in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

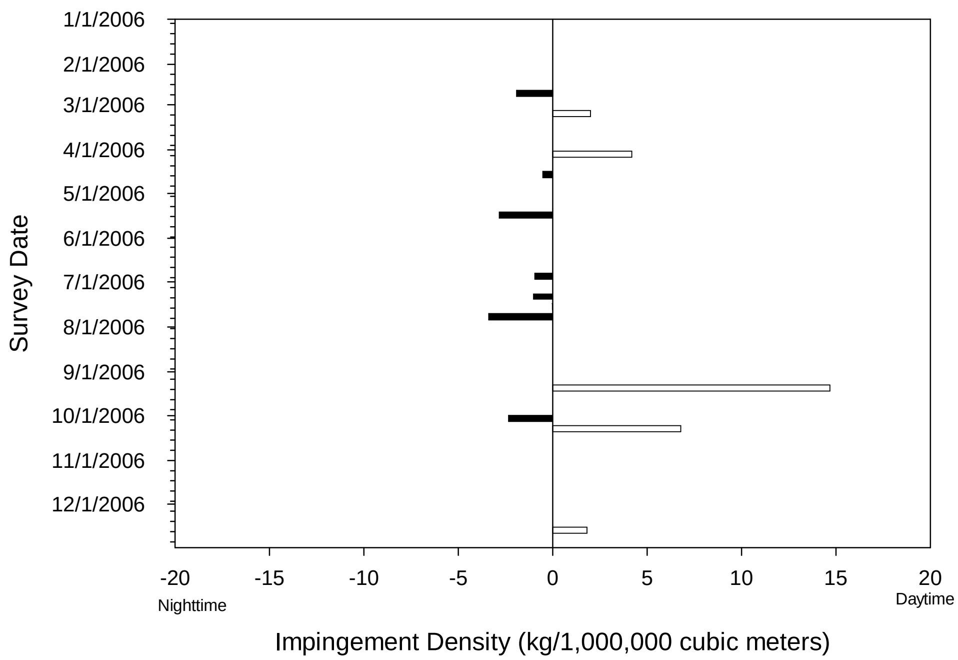


Figure 5.5-95. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of spiny lobster in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

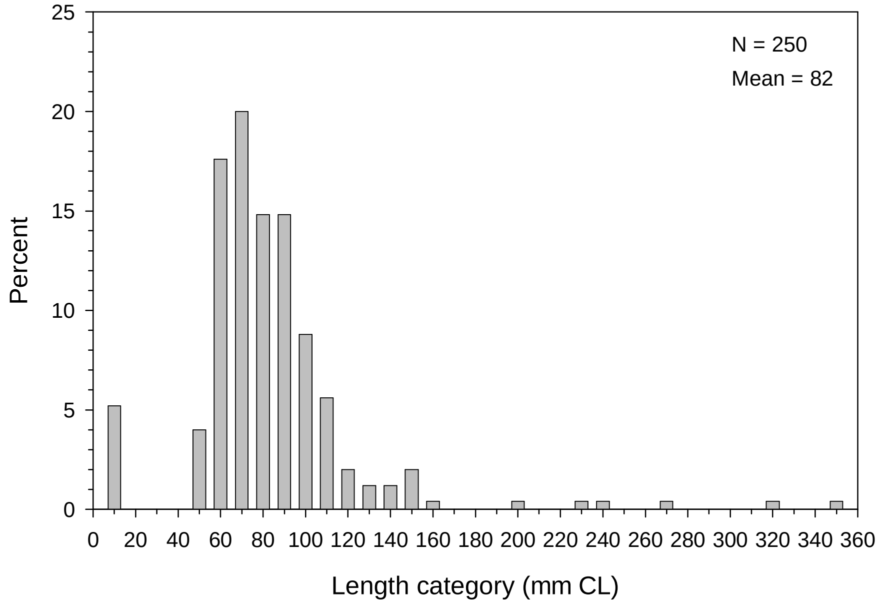


Figure 5.5-96. Carapace length (mm) frequency distribution for spiny lobster collected in impingement samples.

5.5.3.3 California Two-Spot Octopus (*Octopus* spp.)

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

5.5.3.3.1 Life History and Ecology

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

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

5.5.3.3.2 Population Trends and Fishery

Most California landings of octopus result from incidental catches in other fisheries (Lang and Hochberg 1997). In 2005, commercial landings of octopus in the Los Angeles area totaled 182.7 kg (403 lbs) at a value of $558 (CDFG 2006). Commercial landings from Santa Monica Bay area catch blocks in 2006 totaled 10.9 kg (24 lbs) at an estimated value of $10 (CDFG 2007b). In 2005, a total of 96 two-spot octopus weighing 16.785 kg (37.011 lbs) was impinged at the SGS (MBC 2006). Between 2000 and 2005, annual impingement of octopus at the SGS ranged between 0 individuals (2000) and 96 individuals (2005).

5.5.3.3.3 Sampling Results

California two-spot octopus was the fourteenth most abundant species impinged with an estimated 375 individuals, or 0.3% of the annual total, weighing 75.292 kg (166.019 lbs) (Tables 5.5-3 and 5.5-4). Highest abundance and biomass of this species in normal operations samples occurred during the first seven months of 2006 (Figures 5.5-97 through 5.5-100). During the VCS, abundance and biomass were recorded at somewhat reduced levels than those between January and October 2006 (Figures 5.5-98 and 5.5-100). Impingement was more frequent at nighttime than during daytime (Figures 5.5-101 and 5.5-102). This highest heat treatment impingement total was recorded on January 25, 2006 (Table 5.5-24).

Table 5.5-24. Summary of two-spot octopus impingement during normal flow direction heat treatments.

Heat Treatment Date	No.	Wt. (kg)	Wt. (lbs)
1/25/2006	38	18.05	39.80
8/10/2006	5	0.41	0.91
8/15/2006	–	–	–
10/4/2006	20	1.53	3.36
10/10/2006			
10/23/2006	4	1.20	2.65
11/20/2006	3	1.86	3.53
1/3/2007	9	3.06	3.36
	79	**26.12**	**57.58**

Length frequency analysis of 114 measured individuals indicated a mean tentacle spread (arm spread) of 482 mm (Figure 5.5-103). Individuals ranged in size from 10-mm to 1.1-m arm spread size classes. Of the 116 individuals that were evaluated for condition factor, 68% were dead, 28% were alive, and 4% were mutilated.

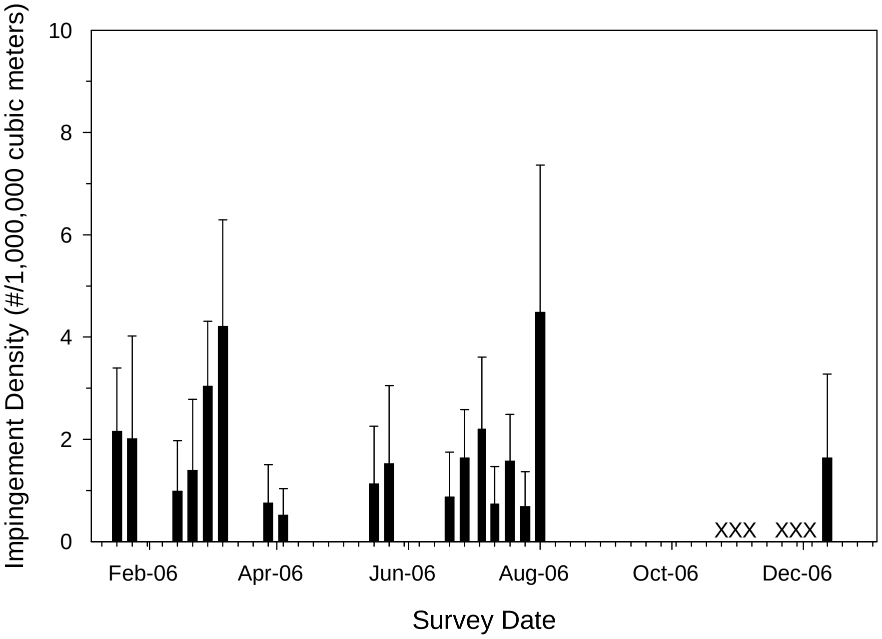


Figure 5.5-97. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of two-spot octopus collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

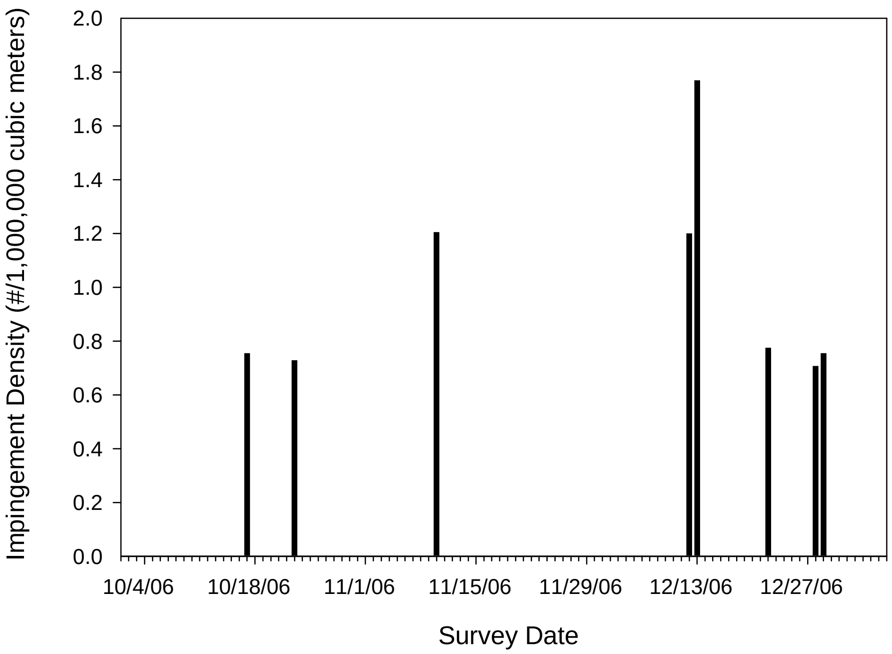


Figure 5.5-98. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of two-spot octopus collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

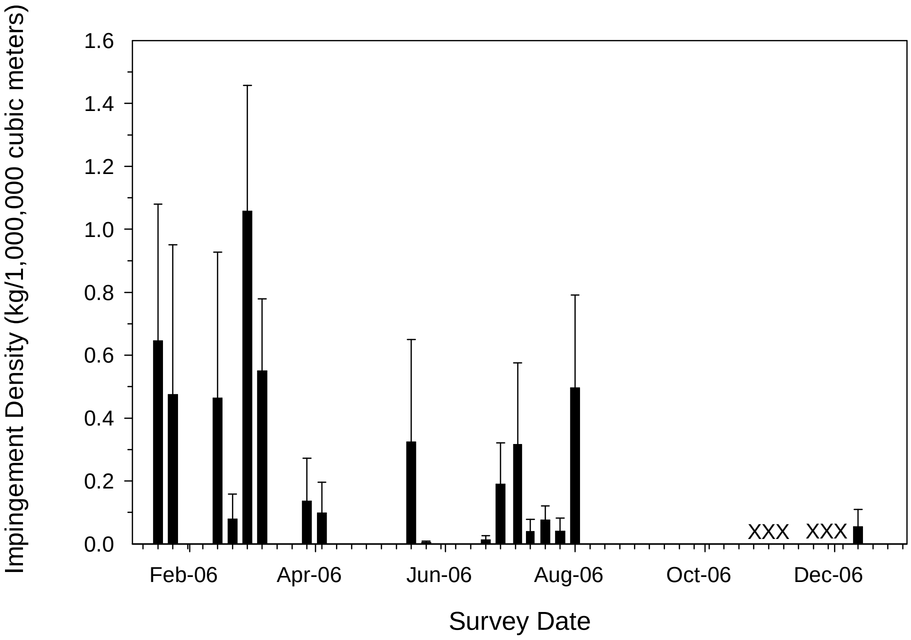


Figure 5.5-99. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of two-spot octopus collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

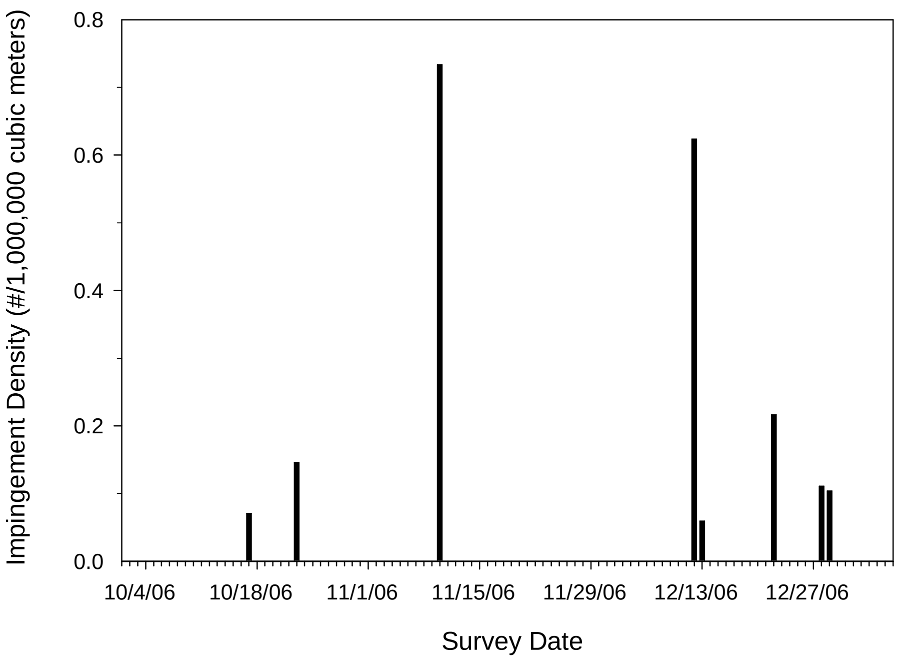


Figure 5.5-100. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of two-spot octopus collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

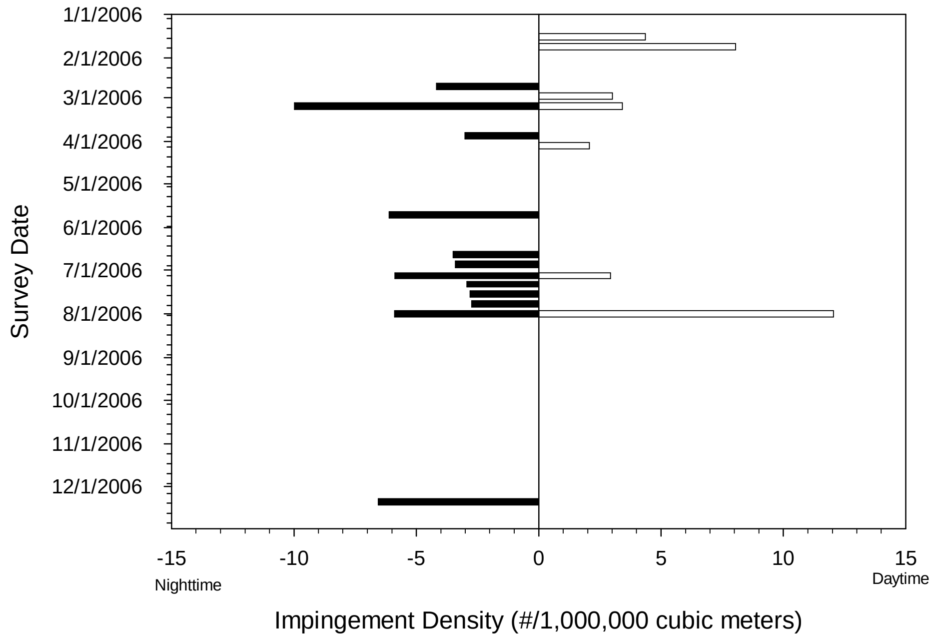


Figure 5.5-101. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of two-spot octopus in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

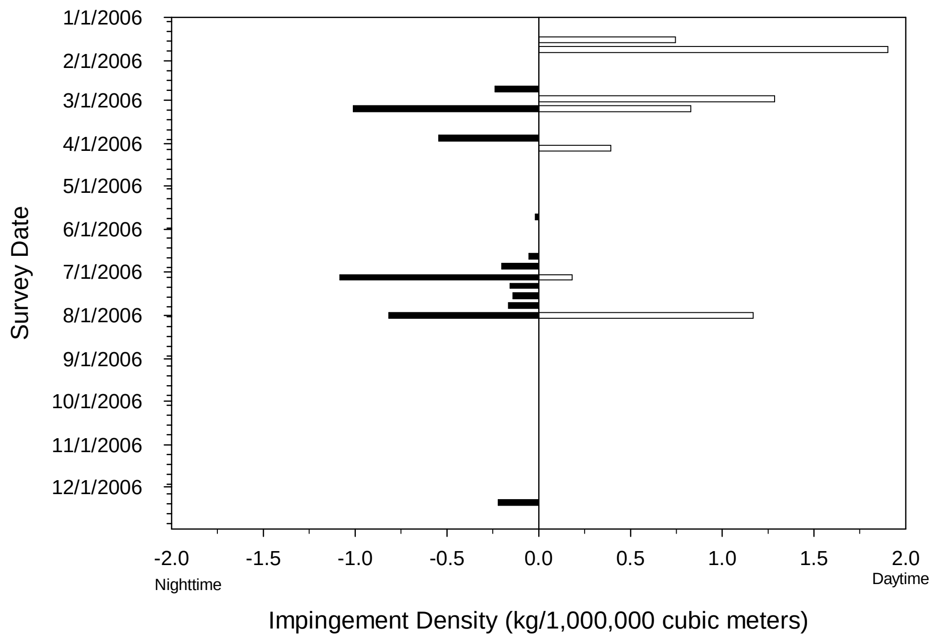


Figure 5.5-102. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of two-spot octopus in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

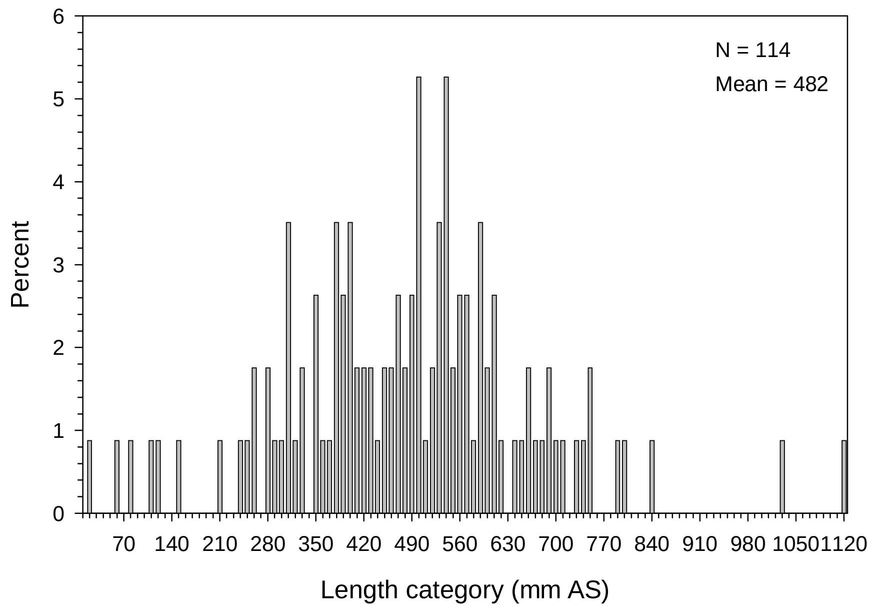


Figure 5.5-103. Size frequency distribution (arm spread in mm) for two-spot octopus collected in impingement samples.

5.5.3.4 Market Squid (*Loligo opalescens*)

Information on the life history, ecology, population trends and fishery for market squid are presented in Section 4.5.3.15—*Entrainment Results: Market Squid*.

5.5.3.4.1 Sampling Results

Market squid was the twenty-third most abundant species impinged with an estimated 300 individuals, or 0.2% of the annual total estimated using actual cooling water flow volumes, weighing 7.506 kg (16.550 lbs) (Tables 5.5-3 and 5.5-4). All individuals were impinged during normal operations. Highest abundance and biomass of this species in normal operations samples occurred in spring (March and April 2006); although some individuals were also impinged in December (Figures 5.5-104 through 5.5-107). During the VCS, abundance and biomass were recorded at lower levels than those measured in spring (Figures 5.5-105 and 5.5-107). There was no definitive diel pattern with respect to impingement of market squid (Figures 5.5-108 and 5.5-109).

Length frequency analysis of 40 measured individuals indicated a mean DML of 115 mm (4.5 in) (Figure 5.5-110). Individuals ranged in size from the 30–140 mm (1.2–5.5 in) mantle length size classes. Of the 38 individuals that were evaluated for condition factor, 94.7% were dead, 2.6% were alive, and 2.6% were mutilated. As noted previously, 0.017 kg of squid eggs were also impinged during the impingement survey on April 18–19, 2006.

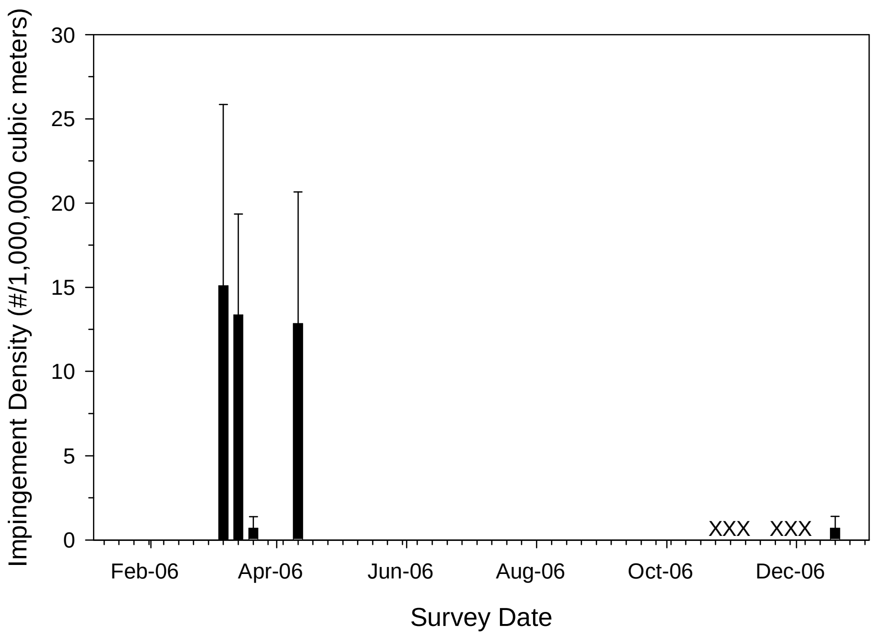


Figure 5.5-104. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of market squid collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

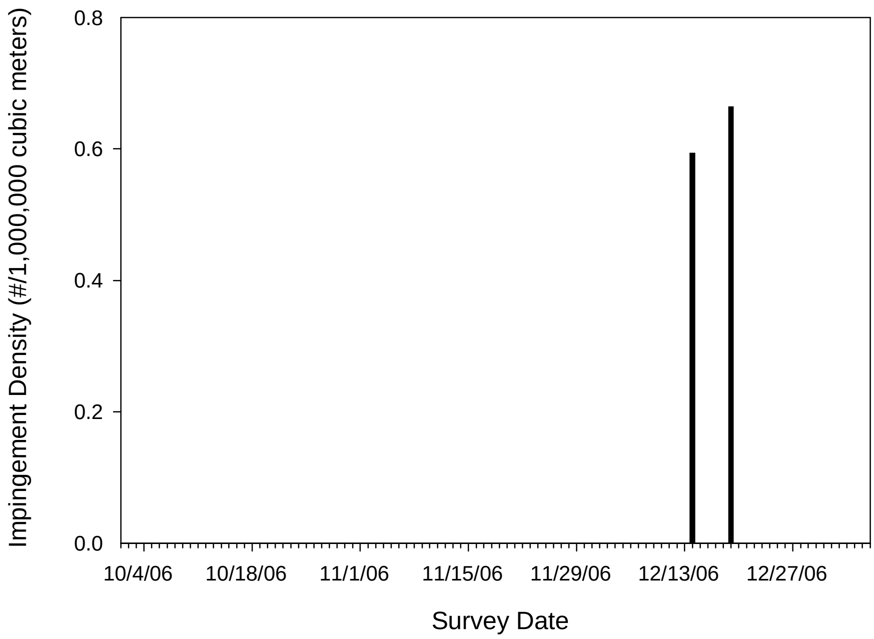


Figure 5.5-105. Concentration (# / 1,000,000 m^3 [264.172 million gal]) of market squid collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

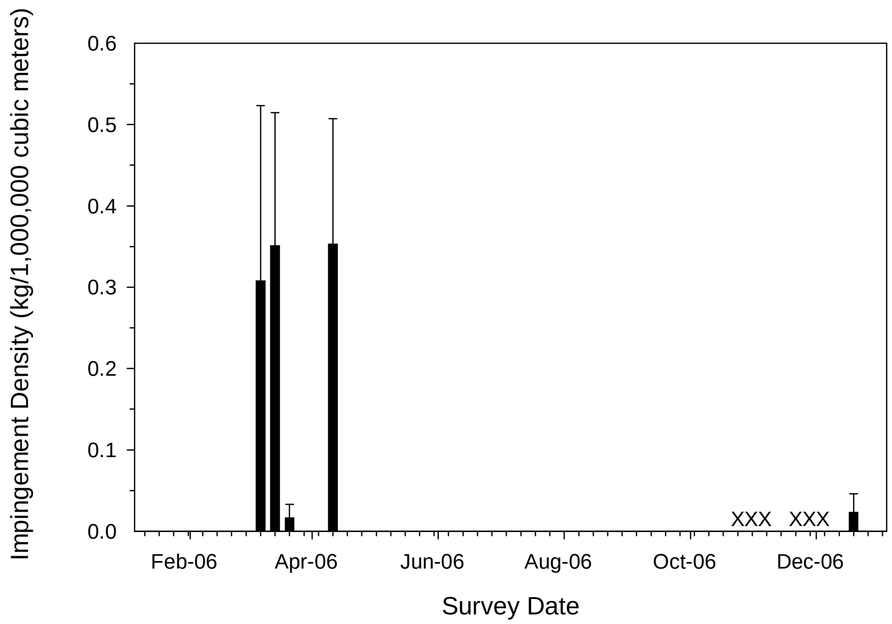


Figure 5.5-106. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of market squid collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

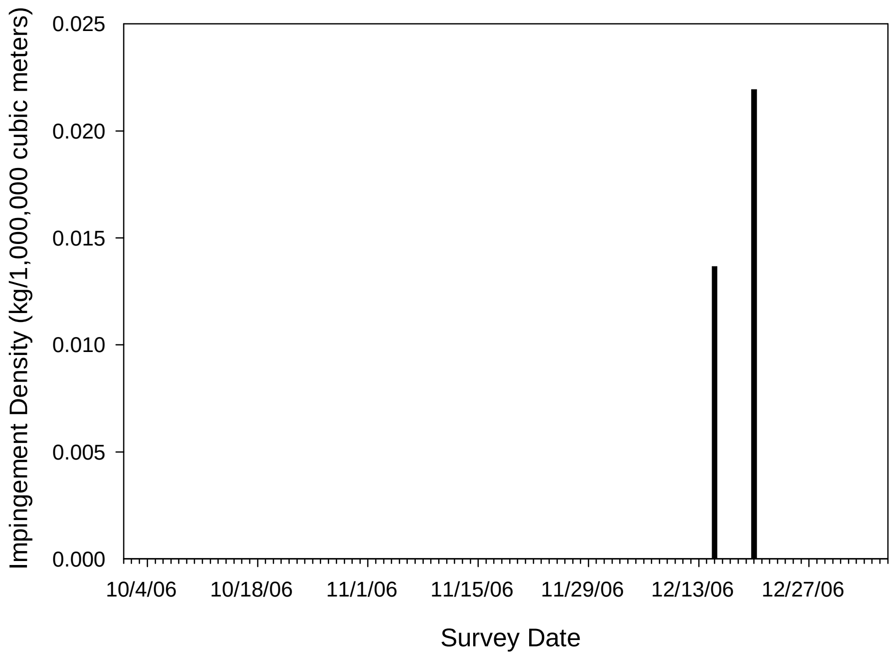


Figure 5.5-107. Concentration (kg / 1,000,000 m^3 [264.172 million gal]) of market squid collected in SGS VCS normal flow impingement samples (Oct. 4, 2006 – Jan. 3, 2007).

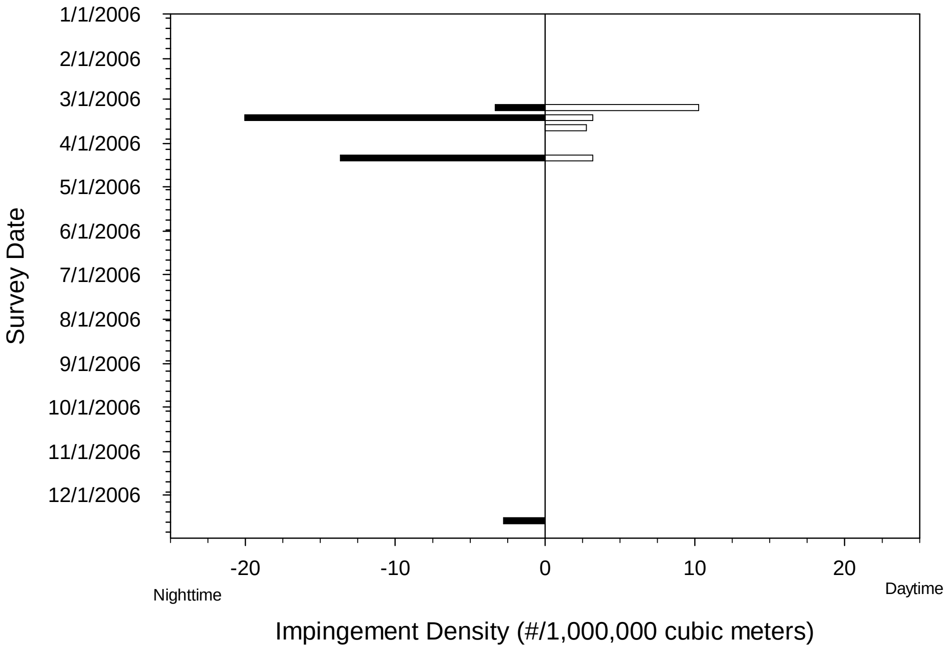


Figure 5.5-108. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of market squid in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

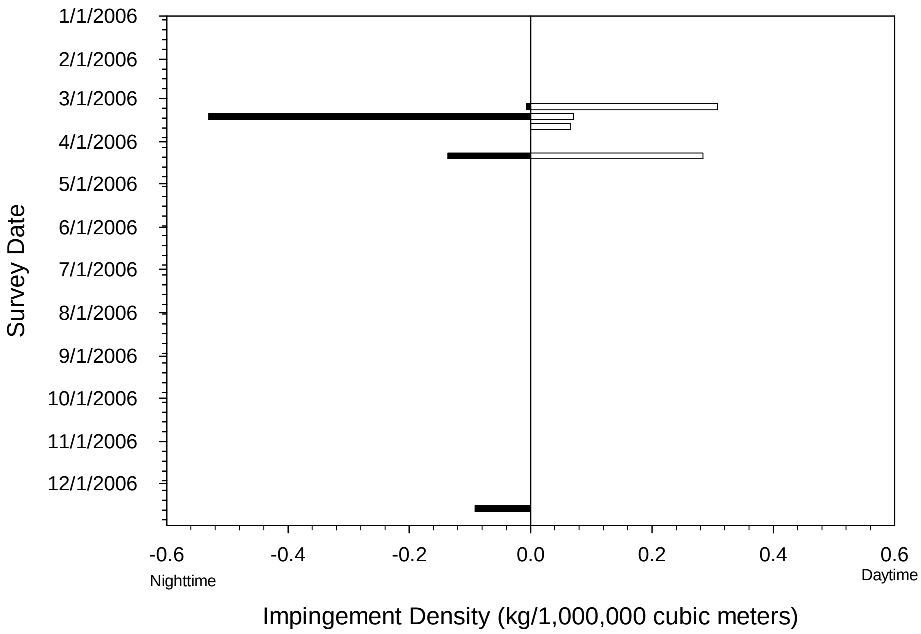


Figure 5.5-109. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of market squid in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

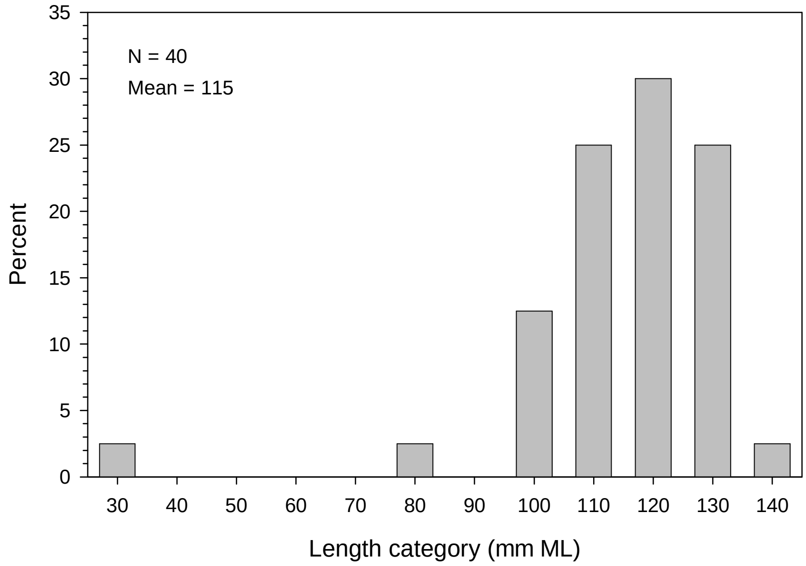


Figure 5.5-110. Mantle length (mm) frequency distribution for market squid collected in impingement samples.

5.5.3.5 Sheep Crab (*Loxorhynchus grandis*)

Sheep crab is the largest member of the spider crab family (Majidae) in California (Culver and Kuris 2001). Sheep crab range from Cordell Bank, Marin Co., California to Cape Thurloe, Baja California, and are most abundant off southern California. Another species in the same genus, masking crab (*Loxorhynchus crispatus*), occurs from Reading Rock, California to Isla Natividad, Baja California (Morris et al. 1980).

5.5.3.5.1 Life History and Ecology

These crabs are occasionally found intertidally, but are more characteristically found subtidally to depths of about 125 m (410 ft) (Morris et al. 1980; Culver and Kuris 2001). Carapace length in mature crabs may reach 173 mm (6.8 in) in females and 244 mm (9.6 in) in males. Size alone does not indicate maturity, which is ascertained by the relative width of the abdomen in females and by the length and morphology of the claw in males. Longevity of the sheep crab is unknown, but many mature adults appear to be at least four years old. Studies suggest that sheep crab stop molting upon maturity (terminal molt), after which the crabs can no longer grow in size nor regenerate limbs (Culver and Kuris 2001).

Berried (egg bearing) female sheep crabs can be found throughout the year, with peaks in abundance in spring through late summer (Morris et al. 1980; Hobday and Rumsey 1999; Culver and Kuris 2001). Males over-winter in deep water, and in early spring, both sexes migrate onshore. During spring and summer, the crabs demonstrate an aggregate mating phenomena with females, mostly gravid, found in piles on the seafloor. Large adult males display competitive behavior on the perimeter of the aggregations and pairs engage in back-to-back mating behavior (Culver and Kuris 2001). Adult females store sperm, allowing for multiple broods in the absence of males. Brood sizes range from 125,000–500,000 eggs, and probably increase with size of the female. Little is known of the duration the females carry the eggs, or how long the larval forms are in the plankton. Brooding eggs have been observed year-round, but seasonal recruitment has also been noted, suggesting variable transport of larvae before recruitment. At La Jolla, however, juvenile abundances were found to peak between March and May, approximately three to six months after possible spawning events (Hobday and Rumsey 1999). Sheep crab larvae undergo metamorphic development with the first post-embryonic phase as a zoea and settle as a megalops.

Juvenile sheep crabs disguise themselves with living barnacles, algae, sponges, and encrusting material to blend in with their background and avoid predation (Morris et al. 1980; Culver and Kuris 2001). Young crabs are preyed upon by cabezon, California sheephead (*Semicossyphus pulcher*), octopus, rays and sharks. Adult sheep crabs probably have few predators. As individuals grow, they loose the instinct to decorate and conceal themselves, and adults are often observed on open sandy bottoms. Sheep crabs are carnivores and scavengers, and have been observed in captivity feeding on dead fish, clams and mussels, sea stars, octopuses, and kelp.

5.5.3.5.2 Population Trends and Fishery

The population size of the sheep crab is unknown, but large populations have been reported off Los Angeles and San Diego (Culver and Kuris 2001). In Santa Barbara, the crab had been a by-catch of the nearshore gillnet fishery for years with no indication of a decline in the population. The sheep crab fishery was developed in 1984 in Santa Barbara in an attempt to provide value to the sheep crab by-catch. The fishery expanded following the development of a market for claws, and by 1988, 48,811 kg (107,609 lbs) of live sheep crab and 175,035 kg (385,886 lbs) of claws (75% sheep crab and 25% rock crab) were landed. The claw market was primarily a gillnet fishery since removing the animal from the net and taking the claws usually killed them. In 1990, California banned use of gillnets in shallow water. Following the phase out of gillnets, landings of claws were reduced to about 2,268 kg (5,000 lbs) per year, while live crab take by trap has remained consistent at about 34,020 kg (75,000 lbs) per year. Both males and females are taken for the live, whole body fishery, while only large adult males are utilized for the claw fishery. Abundance of the species appears stable; however, an overall decrease in crab size has been reported, likely due to pressure on large males for both the whole body and claw market. The market for sheep crab remains relatively low; however, landings may increase if new markets are expanded.

Commercial landings of sheep crab in Santa Monica Bay catch blocks in 2006 totaled 4,178 kg (9,211 lbs) at a value of $10,113.36 (CDFG 2007b). Off shore of Long Beach, totals for landings between Palos Verdes and Huntington Beach in 2006 were 7,872 kg (17,354 lbs) at a value of $16,838 for whole body crab and 250 kg (550 lbs) at a value of $575 for claws. In 2005, 67 sheep crab weighing 57.466 kg (126.713 lbs) were impinged during heat treatments at the SGS (MBC 2006). Between 2000 and 2005, annual impingement of sheep crab at the SGS ranged between 2 (2000–2001) and 67 individuals (2005).

5.5.3.5.3 Sampling Results

Sheep crab was the twenty-fourth most abundant species impinged with an estimated 306 individuals, or 0.2% of the annual total, weighing 182.265 kg (401.894 lbs) (Tables 5.5-3 and 5.5-4). Almost all of the individuals (303 of 306) were impinged during normal operations, and no impingement occurred after August 1, 2006 (Figures 5.5-111 and 5.5-112). Highest abundance and biomass of this species in normal operations samples occurred in spring and summer (April through July 2006). Impingement of sheep crab was slightly higher during daytime than during nighttime (Figures 5.5-113 and 5.5-114). Only 3 individuals with a total weight of less than 1 kg (2.2 lbs) were collected from heat treatment surveys, therefore no summary table is provided.

Length frequency analysis of 47 measured individuals indicated a mean CW of 94 mm (3.7 in) (Figure 5.5-115). Individuals ranged in size from the 10-mm to 160-mm (0.4-in to 6.3-in) size classes. Of the 38 individuals that were evaluated for condition factor, 83% were alive and 17% were dead.

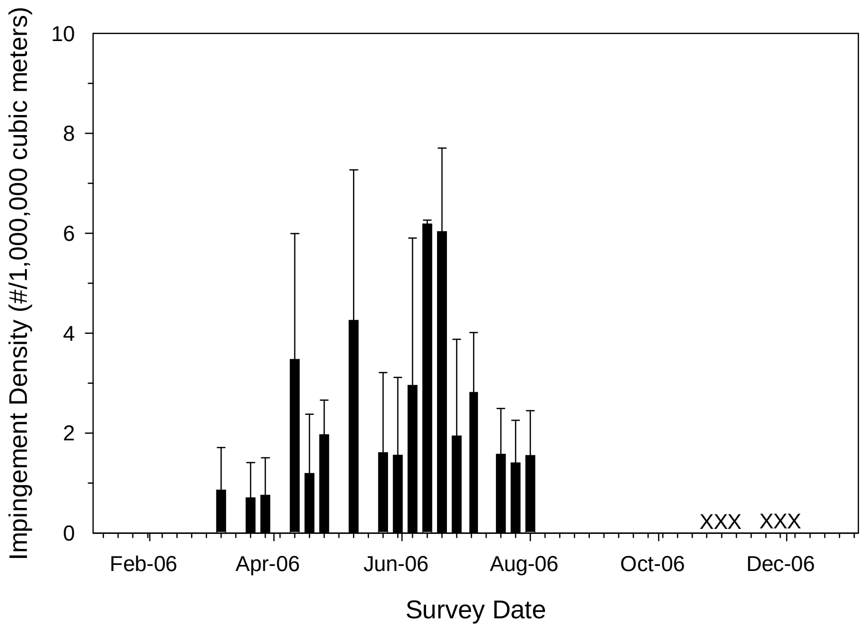


Figure 5.5-111. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of sheep crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

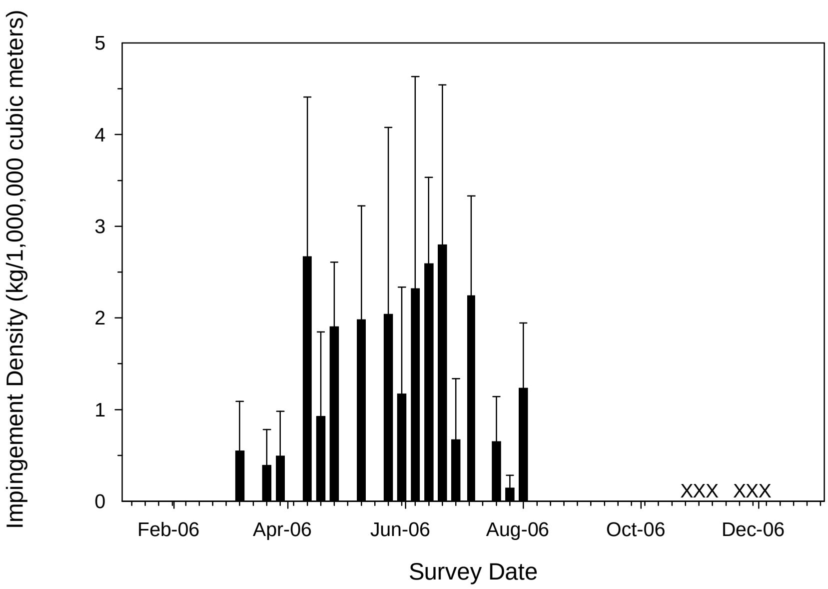


Figure 5.5-112. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of sheep crab collected in SGS weekly IM&E Characterization Study impingement samples during 2006–2007.

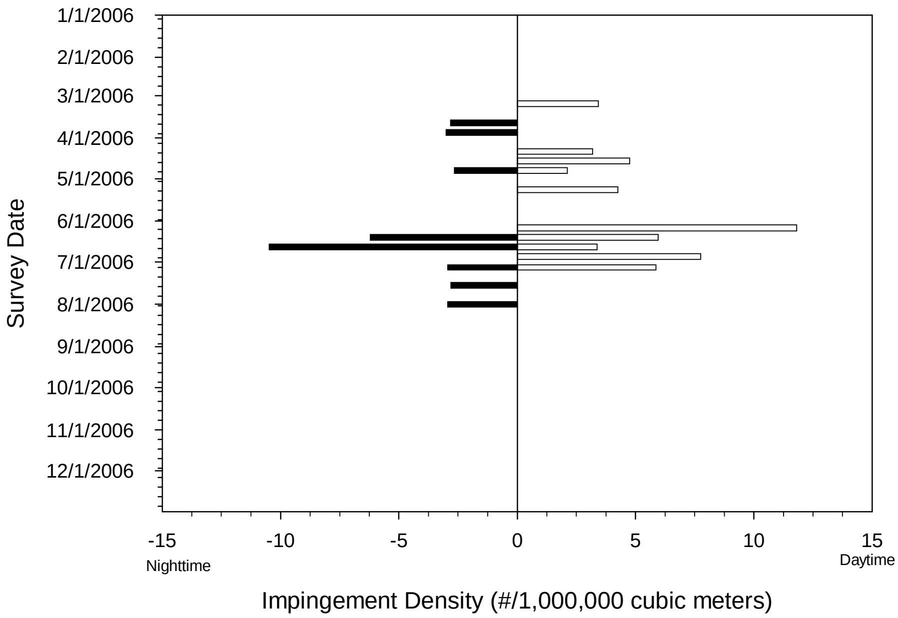


Figure 5.5-113. Mean concentration (#/1,000,000 m^3 [264.172 million gal]) of sheep crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

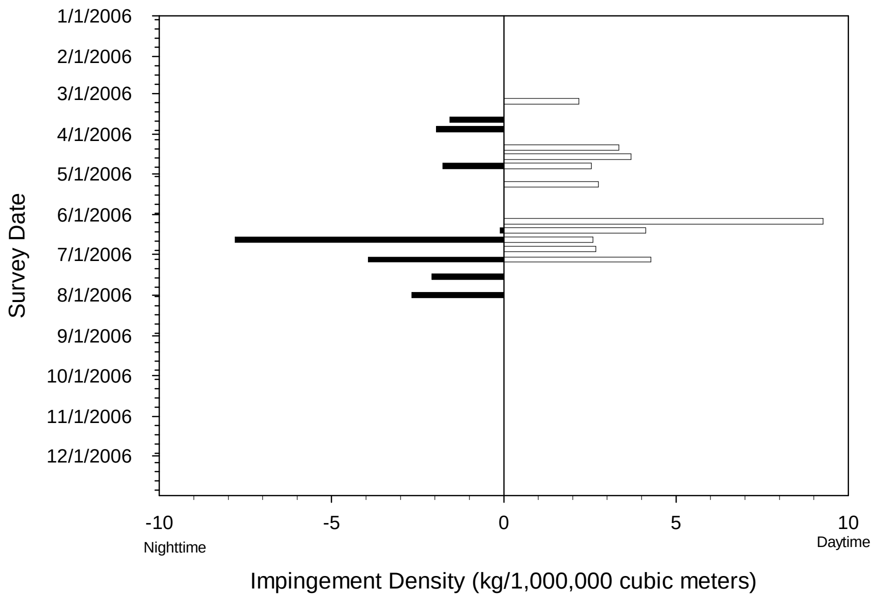


Figure 5.5-114. Mean concentration (kg/1,000,000 m^3 [264.172 million gal]) of sheep crab in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.
Note: Negative nighttime values are a plotting artifact

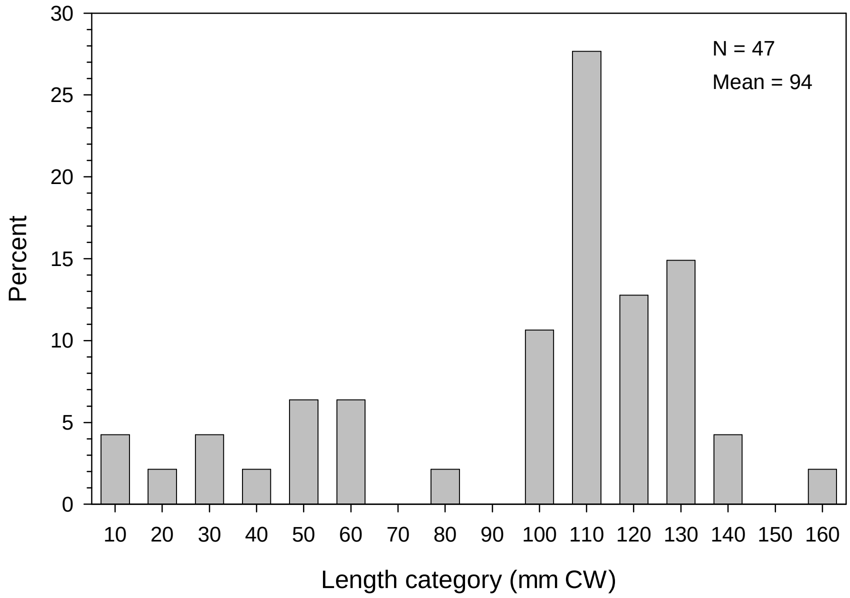


Figure 5.5-115. Carapace width (mm) frequency distribution for sheep crab collected in impingement samples.

6.0 IMPACT ASSESSMENT

6.1 IMPACT ASSESSMENT OVERVIEW: DATA AND APPROACH

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

The term 'environmental impact' arose from Section 102(c) of the National Environmental Policy Act of 1969, which required the analysis of effects in 'impact statements' (Voigtlander 1980). The prior SGS 316(b) demonstration (IRC 1981) distinguished 'effects' from 'impacts', noting that effects are the objective measurement resulting from some action (e.g. number of fish impinged) whereas "*impacts are the consequence of that action's effect on the environment, evaluated in terms of its acceptability using selected biological criteria and consideration of commercial and recreational uses of the resources.*"

Prior to the publication of the Phase II regulations in 2004, regulators relied on EPA's (1977) draft guidelines for evaluating adverse impacts of cooling water intake structures to determine compliance with Section 316(b). At the SGS, 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 based on the levels of impact was also assessed as part of the intake technology evaluation.

Impacts were further 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 SGS 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 SGS, 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 that the "…*performance standards reflect the best technology available for minimizing adverse environmental impacts determined on a national categorical basis.*" Although AEI was not intended to be used in assessing compliance under the new regulations, the potential for AEI was still considered in determining the types of plants and water body where the new performance standards would apply. Plants with low capacity factors and low cooling water volumes were considered to be BTA since their cooling systems had a low potential for AEI.

In its 1977 draft guidance document, EPA 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 SGS (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 determine if the existing intake results in AEI.

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 SGS indicated that the generating station continues to operate in compliance with the California Thermal Plan. Entrainment occurs when organisms are drawn into a cooling water intake structure and subsequently pass through the SGS. Organisms large enough to become trapped on the traveling screens are impinged.

In discussing the potential effects of the SGS CWIS on fish and shellfish populations the first thing that needs to be considered is the life history of the species in the community. First of all, several fish species in the nearshore coastal areas around SGS have early life stages that are not susceptible to entrainment. Live-bearers, such as surfperches, and some sharks and rays, produce young that are fully developed and too large to be affected by entrainment. In addition, for fishes with entrainable life stages, the period of time that they are vulnerable to entrainment may be relatively short. As the results for SGS 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 young post larval fishes begin searching for adult habitat, usually on the bottom, where they are not susceptible to entrainment. From the standpoint of impingement effects, 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 tend to be 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 SGS. 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 zooplankton. EPA recognized the low vulnerability of phyto- and zooplankton in its 1977 draft 316(b) guidance (EPA 1977). There are several reasons why there is a low potential for impacts to phyto- and zooplankton and why 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 provided latitude for focusing on the set of species that could be accurately quantified and that would provide the necessary detail to support development of other aspects of the CDS. The target group of organisms that were included in the entrainment sample processing was agreed to at a January 12, 2006 Regional Board meeting.

The specific taxa (species or group of species) that were included in the assessment are limited to the taxa that are sufficiently abundant to provide reasonable assessments of impacts. For the purposes of this study plan, the taxa analyzed in the assessment were limited to the most abundant taxa that together comprised 90–95% of all larvae entrained and/or juveniles and adults impinged by the generating station. The most abundant taxa were used in the assessment because they provide the most robust and reliable estimates for the purpose of assessing impacts. Since the most abundant organisms may not necessarily be the organisms that experience the greatest effects on the population level, the data were also carefully examined to determine if additional taxa should be included in the assessment. For example, this might include commercially or recreationally important taxa, taxa with limited habitats, and any threatened or endangered fish or shellfish species. No listed species were entrained or impinged at the SGS 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 average age of reproductive females in the population. Unfortunately, the life history information necessary for the modeling is unavailable for most species so combined assessments were only possible for northern anchovy.

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 SGS, 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) draft “Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500.”

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

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

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

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 1970's. In those documents, the USEPA has indicated that assessment of AEI should be based on an evaluation of population level effects, not just losses of individual organisms. In its 1975 Draft BTA Guidelines, the USEPA stated that "[a]dverse environmental impacts occur when the ecological function of the organism(s) of concern is impaired or reduced to a level which precludes maintenance of existing populations...". Additionally, in the 1976 Development Document, released in conjunction with the EPA's previous Section 316(b) rules, the USEPA said that "[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 SGS 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 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. The potential magnitude of the losses due to entrainment and impingement depend on many factors but specifically we will focus 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, species such as northern lampfish that occurs to depths of 2,900 m (9,500 ft) was entrained at the SGS, 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.

Data on water current flow and direction collected during the study was 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, all indicated that the source populations for the larvae were limited to 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.

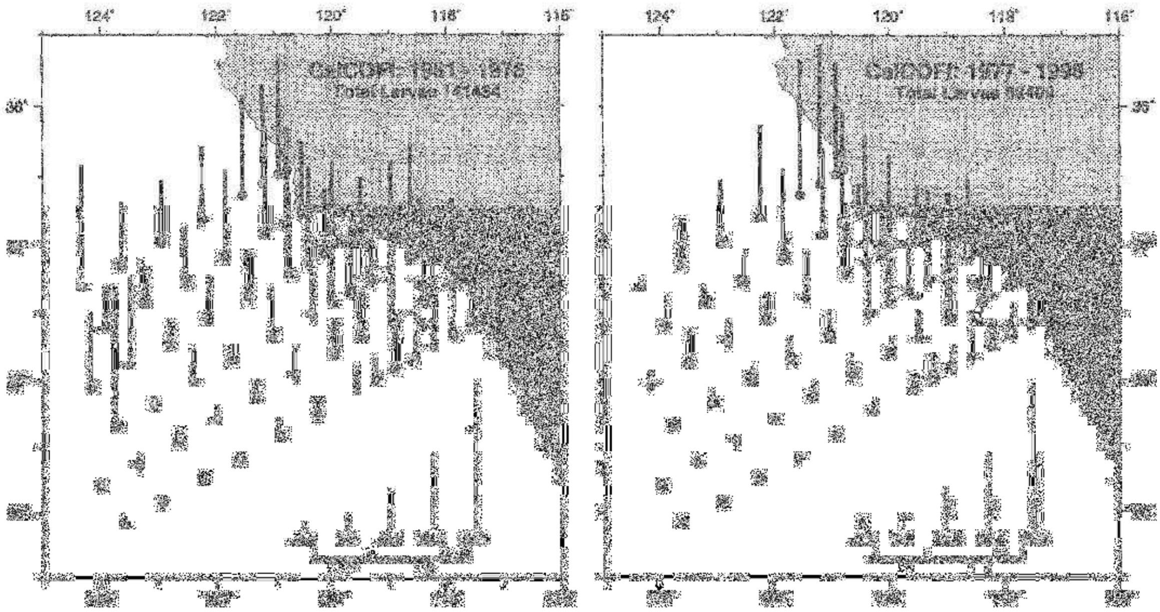


Figure 6.1-1. Distribution and abundance of northern lampfish larvae (*Stenobrachius leucopsarus*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

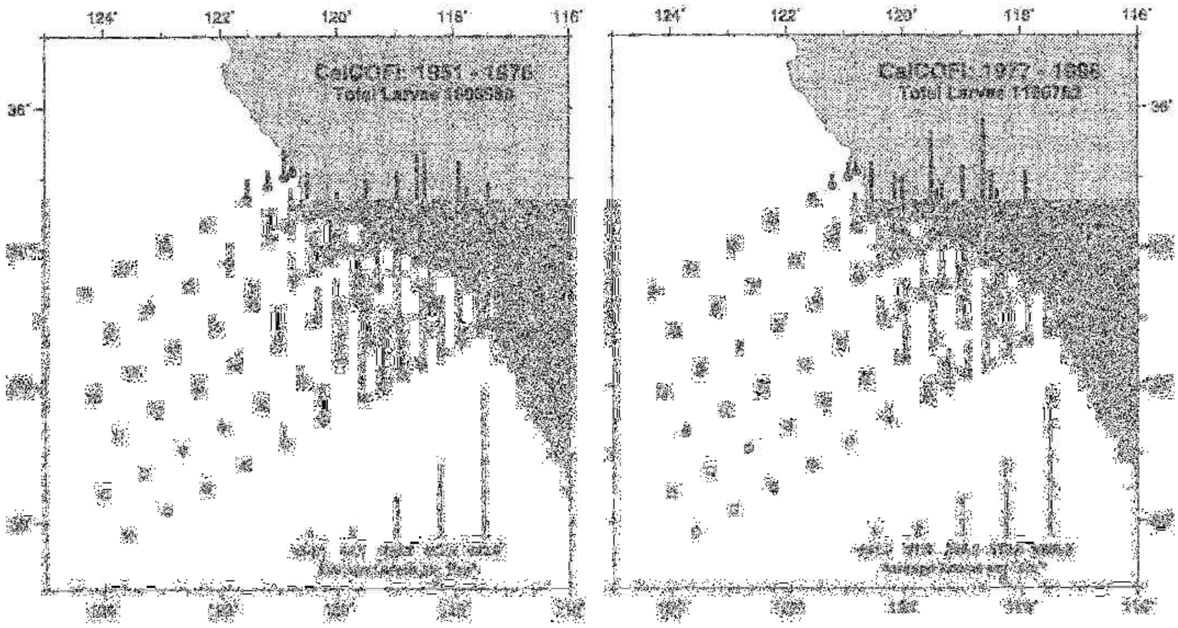
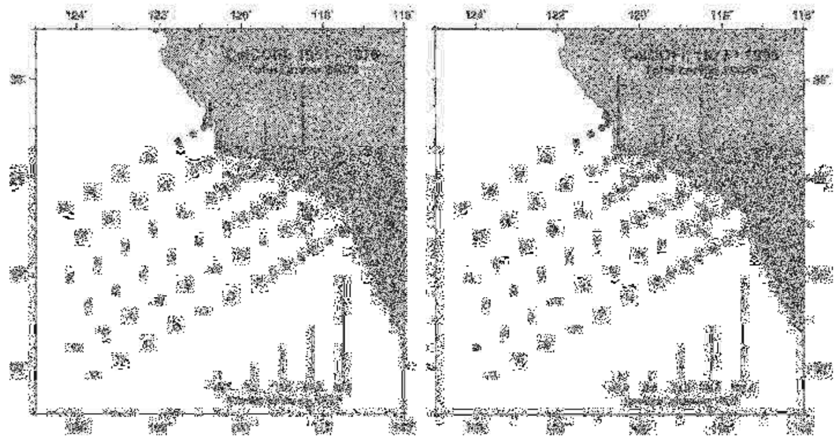


Figure 6.1-2. Distribution and abundance of northern anchovy larvae (*Engraulis mordax*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

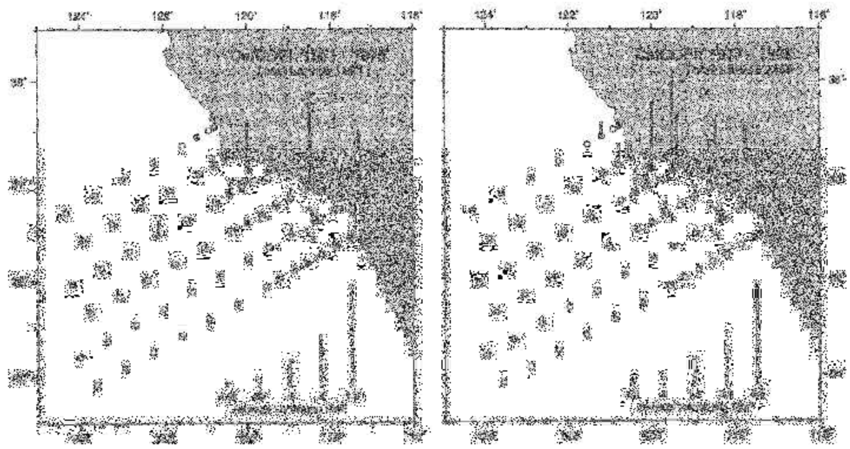
The use of Santa Monica Bay as the source water for examining the potential effects of entrainment and impingement does not make sense for gobies, blennies, and other species that are generally restricted to bay and harbor habitats as adults. Fishes from these habitats are similar to northern lampfish which are also transported out of their typical adult habitat, in their case from offshore, into the nearshore areas around SGS where they are subject to entrainment. Fishes that strictly occupy bay and harbor habitats are also rarely impinged as adults by SGS. The focus of the assessment should be on these and other species with adult populations in the nearshore areas of Santa Monica Bay that are directly affected by entrainment and impingement at the SGS 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 from the list in the previous section can be used to focus the assessment on species with adult and larval distributions that would place them at greatest risk to entrainment and impingement effects:

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

a) croakers



b) kelp and sand basses



c) California halibut

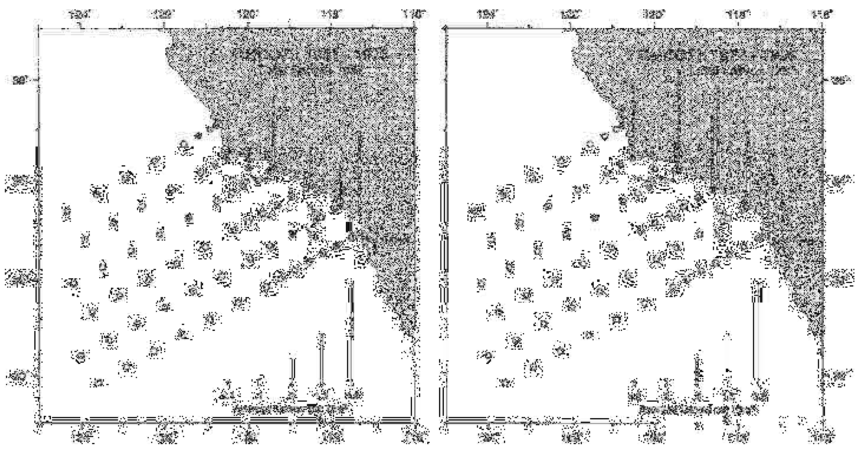


Figure 6.1-3. Distribution and abundance of larvae of a) croakers (Family Sciaenidae), b) kelp and sand basses (*Paralabrax* spp.), and c) California halibut (*Paralichthys californicus*) across permanent stations in the SCB from 1951 through 1998 (from Moser et al. 2001).

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 taxa included in this assessment. We have simplified the more detailed categorization of habitats used by Allen and Pondella (2006) which included several habitats used to define deeper offshore areas. These deeper offshore habitat types can be combined for the purposes of our assessment since the taxa associated with those habitats are generally not at risk due to entrainment and impingement and were collected in very low numbers. The habitats defined by Allen and Pondella (2006) have been simplified for this assessment to the following habitat types:

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

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 since their occurrence in rocky reef/kelp habitats places them at greater risk to power plant effects they will be treated along with other taxa specific to that habitat. This raises an important point in regards to impact assessment. Taxa that occupy several different habitats will be 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 a recent trend 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. If restoration were to be allowed as a compliance alternative, this approach to assessment would focus the restoration scaling with the appropriate species from the identified habitats.

Table 6.1-1. Habitat associations for taxa included in assessment of CWIS effects at the SGS. 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**
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		
Oxyjulis californica	señorita			**X**		
Paralabrax spp.	sand and kelp bass	S	x	**X**		
Paralichthys californicus	California halibut	S	x			**X**
Parophrys vetulus	English sole	C				**X**
Pleuronichthys guttulatus	diamond turbot	S	x			**X**
Pleuronichthys ritteri	spotted turbot	S	x			**X**
Sardinops sagax	Pacific sardine	C			**X**	
Sciaenidae unid.	croakers	S, C			**X**	x
Seriphus politus	queenfish	S			**X**	x
Sphyraena argentea	Pacific barracuda	S			**X**	
Cancer spp	cancer crabs	S	x	x		**X**
Loligo opalescens	market squid	S			**X**	
Panulirus interruptus	California spiny lobster	S		**X**		

6.2 SUMMARY OF ENTRAINMENT AND IMPINGEMENT RESULTS

6.2.1 Taxa Composition

Data from the bi-weekly entrainment surveys conducted at the SGS cooling water intakes were used to calculate that an estimated 365.3 million fish larvae and 4.92 billion fish eggs were entrained through the generating station CWIS in 2006 (Table 6.2-1). If all circulating water pumps had been in operation during the entire year, larval entrainment would have increased by 44% to 524.2 million, and egg entrainment would have increased by 56% to 7.69 billion. Approximately 19% of the larvae were unidentified yolk-sac larvae, 12% were northern anchovy, 11% were unidentified croakers, 9% were white croaker, 8% were sand basses and twelve other species each contributed from 1%–5% of the annual total. Larvae from 73 taxa were represented in the collections. Many of the larvae and eggs could not be positively identified to the species level, and this added some uncertainty to the estimates of annual entrainment for individual species. For example, the most abundant larval category was unidentified yolksac larvae 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 group of fish eggs in the samples were unidentified eggs (65%), followed by the composite category of sand flounder eggs (12%). Eggs of approximately 18 fish taxa were represented in the collections. A complete listing of all of the taxonomic categories identified during the study is presented in Appendix F.

There were an estimated 27.3 million target shellfish larvae entrained represented by 22 taxa (Table 6.2-1). Kelp crab megalops comprised 37% of the annual entrainment of target invertebrate larvae. Species with commercial fishery value included market squid with 3.4 million paralarvae (hatchlings) entrained under actual flow (4.9 million for design flows) while cancer crabs had 1.6 million megalops entrained under actual flows (2.4 million for design flows).

Data from the weekly normal operations sampling and the eight heat treatment surveys were used to estimate that annual fish impingement at the SGS from a total of 87 taxa groups was 95,241 individuals weighing 4,273 kg (9,423 lbs) based on actual cooling water flow, and 108,843 individuals weighing 5,270 kg (11,621 lbs) based on design cooling water flow (Table 6.2-2). The most abundant species by number impinged were queenfish, Pacific sardine, northern anchovy, jacksmelt, and topsmelt, while bat ray and Pacific electric ray contributed to these species to substantially increase the total biomass impinged.

Annual macroinvertebrate impingement estimates at the SGS were 145,640 individuals weighing 1,418 kg (3,127 lbs) based on actual cooling water flow, and 225,449 individuals weighing 2,133 kg (4,704 lbs) based on design cooling water flow (Table 6.2-3). Four species comprised 80% of the impinged individuals: intertidal coastal shrimp, the nudibranch hermissenda, red rock shrimp, and yellow crab. Yellow crab contributed the largest percentage of the total biomass, followed by California spiny lobster, sheep crab, octopus, and Pacific rock crab. These five species comprised 80% of the annual impinged biomass.

6.2.2 Temporal Occurrence

The peak in abundance of all the larval fish combined occurred in August, while the highest concentrations of eggs occurred during May. Although this is a typical pattern that is associated with spawning during spring upwelling periods in high productivity coastal waters, some species have well-defined seasonal spawning peaks that may occur in either winter or summer months. Larvae and eggs were generally more abundant in samples collected at night than those collected during the day in most surveys.

The highest fish abundance during weekly normal operation impingement surveys occurred in May 2006, while biomass was highest in August and December 2006. Macroinvertebrate impingement was highest during late spring, while biomass peaked in summer, with the highest total recorded on August 8, 2006. Overall, the fishes and macroinvertebrates collected during the heat treatment operation surveys accounted for over 90% by number and almost 80% by weight of all the fishes collected during the study, and 15% by number and over 45% by weight of the total macroinvertebrates collected.

Table 6.2-1. Rank and estimated annual entrainment of common fish larvae and eggs at SGS in 2006.

Rank	Taxon	Est. Annual Entrainment (actual flows)	Est. Annual Entrainment (design flows)	% Comp. (actual flows)	Cumulative % Comp.
	Fish Larvae				
1	unidentified yolksac larvae	71,105,628	97,034,455	19.47	19.47
2	northern anchovy	44,584,991	70,732,578	12.21	31.67
3	croakers	42,076,568	59,935,823	11.52	43.19
4	white croaker	32,104,891	46,634,188	8.79	51.98
5	sand basses	29,681,768	40,350,936	8.13	60.11
6	unidentified damaged fish	16,873,865	23,667,890	4.62	64.73
7	gobies	16,188,141	24,432,450	4.43	69.16
8	Pacific barracuda	11,426,718	15,454,497	3.13	72.29
9	queenfish	10,845,071	15,732,743	2.97	75.26
10	California halibut	9,901,902	14,119,061	2.71	77.97
11	combtooth blennies	8,324,912	14,230,416	2.28	80.25
12	northern lampfish	6,802,760	9,850,466	1.86	82.11
13	sanddabs	6,752,119	9,704,922	1.85	83.96
14	larval fishes	6,518,392	8,886,496	1.78	85.74
15	English sole	5,321,852	7,679,874	1.46	87.20
16	diamond turbot	3,849,543	5,715,338	1.05	88.26
17	spotted turbot	3,819,479	5,149,021	1.05	89.30
18	senorita	3,557,915	4,808,587	0.97	90.27
	55 other taxa	35,521,614	50,082,912	9.73	100.00
		365,258,129	**524,202,652**		
	Fish Eggs				
1	unidentified fish eggs	3,186,607,290	4,957,177,075	64.78	64.78
2	sand flounder eggs	581,532,916	943,922,353	11.82	76.60
3	SPL[1] fish eggs	363,868,587	546,560,618	7.40	83.99
4	sanddab eggs	264,262,380	407,681,780	5.37	89.37
5	anchovy eggs	236,042,601	382,782,525	4.80	94.16
	13 other taxa	287,108,252	453,052,992	5.84	100.00
		4,919,422,026	**7,691,117,343**		
	Target Shellfishes				
1	kelp crabs megalops	10,007,018	14,664,011	36.63	36.63
2	pea crabs megalops	4,328,231	6,809,148	15.84	52.47
3	market squid	3,367,525	4,929,707	12.32	64.79
4	cancer crabs megalops	1,634,850	2,380,819	5.98	70.77
5	porcelain crab (Petrolisthes) megalops	1,113,720	1,577,486	4.08	74.85
6	spider crab megalops	1,092,243	1,573,624	4.00	78.85
7	black-clawed crab megalops	1,074,059	1,537,121	3.93	82.78
8	shore crab megalops	1,047,391	1,553,225	3.83	86.61
9	hermit crab megalops	776,523	1,124,963	2.84	89.45
10	porcelain crabs (Pachycheles) megalops	719,490	992,034	2.63	92.09
	12 other taxa	2,161,787	3,486,760	7.91	7.91
		27,322,837	**40,628,898**	100.00	

[1] Combined taxon including Sciaenidae, Paralichthyidae, and Labridae (croakers, sand flounders, and wrasses).

Table 6.2-2. Rank and estimated annual impingement of top ten most common fish taxa at SGS in 2006 by estimated abundance and weight for actual and design normal flows. Heat treatment mortality included.

Rank	Common Name	Total No. Actual Flows	Total No. Design Flows	% Total	Cumulative % Total
1	queenfish	34,085	36,683	35.79	35.79
2	Pacific sardine	25,582	27,483	26.86	62.65
3	northern anchovy	10,214	11,379	10.72	73.37
4	jacksmelt	7,107	10,267	7.46	80.83
5	topsmelt	4,297	5,699	4.51	85.35
6	walleye surfperch	2,937	2,956	3.08	88.43
7	white croaker	2,309	2,822	2.42	90.85
8	Pacific pompano	1,915	2,124	2.01	92.87
9	bat ray	976	1,422	1.02	93.89
10	shiner perch	540	732	0.57	94.46
	77 others	5,279	7,276	5.54	100.00
		95,241	**108,843**		
		Total Wt. (kg) Actual Flows	**Total Wt. (kg) Design Flows**	**% Total**	**Cumulative % Total**
1	Pacific sardine	964.302	1,006.560	22.56	22.56
2	bat ray	717.807	1,004.220	16.80	39.36
3	jacksmelt	668.336	941.600	15.64	55.00
4	queenfish	649.245	682.101	15.19	70.19
5	Pacific electric ray	243.880	370.455	5.71	75.90
6	topsmelt	172.113	237.785	4.03	79.92
7	white croaker	170.051	174.662	3.98	83.90
8	walleye surfperch	139.695	140.197	3.27	87.17
9	barred sand bass	65.162	82.231	1.52	88.70
10	thornback	56.670	81.537	1.33	90.02
	77 others	426.442	549.074	9.98	100.00
		4,273.703	**5,270.422**		

Table 6.2-3. Rank and estimated annual impingement of top ten most common invertebrate taxa at SGS in 2006 by estimated abundance and weight for actual and design normal flows. Heat treatment mortality included.

Rank	Common Name	Total No. Actual Flows	Total No. Design Flows	% Total	Cumulative % Total
1	intertidal coastal shrimp	57,739	89,745	39.65	39.65
2	hermissenda	33,044	51,642	22.69	62.33
3	red rock shrimp	13,522	20,092	9.28	71.62
4	yellow crab	13,434	20,886	9.22	80.84
5	red jellyfish	4,277	6,684	2.94	83.78
6	Pacific rock crab	4,066	6,138	2.79	86.57
7	hairy rock crab	3,896	6,075	2.68	89.25
8	Xantus swimming crab	2,838	4,407	1.95	91.19
9	blackspotted bay shrimp	1,965	3,071	1.35	92.54
10	red rock crab	1,789	2,793	1.23	93.77
	77 other taxa	9,070	13,916	6.23	100.00
		145,640	**225,449**		
		Total Wt. (kg) Actual Flows	**Total Wt. (kg) Design Flows**	**% Total**	**Cumulative % Total**
1	yellow crab	544.830	849.325	38.41	38.41
2	California spiny lobster	276.768	377.761	19.51	57.93
3	sheep crab	182.265	284.385	12.85	70.78
4	Calif. two-spot octopus	75.292	102.972	5.31	76.09
5	Pacific rock crab	61.517	87.916	4.34	80.42
6	red rock crab	57.779	90.253	4.07	84.50
7	purple-striped jellyfish	41.405	64.710	2.92	87.42
8	Xantus swimming crab	40.809	63.582	2.88	90.29
9	intertidal coastal shrimp	22.386	34.132	1.58	91.87
10	giant-spined sea star	16.702	26.103	1.18	93.05
	77 other taxa	98.584	152.456	6.95	100.00
		1,418.337	**2,133.595**		

6.2.3 Combined Analysis and Modeling Results for Selected Species

Several species of fishes and shellfishes that were abundant in either the entrainment or impingement samples, had recreational or commercial fishery value, or were federally managed species were analyzed in detail in Sections 4.0 and 5.0. Some of the larval taxa had sufficient information available on their life history to estimate losses based on conversion to adult equivalents. In addition, some of the impinged taxa abundances could also be scaled to adult equivalents. The results of these analyses are summarized by actual flow rates at SGS in 2006 (Table 6.2-4) and design flow rates for the SGS CWIS (Table 6.2-5).

Table 6.2-4. Summary of SGS entrainment and impingement sampling results and model output for common fish and invertebrate species based on actual CWIS flows 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									
Seriphus politus [2]	queenfish	52.92	–	0.06			34,085	649.25	36,199
Engraulis mordax	northern anchovy	44.58	236.04	0.19	36,444^{C}	79,220^{L}	10,214	55.57	18,465
Genyonemus lineatus	white croaker	32.10	34.30	0.37	38^{E}		2,309	170.05	
Paralabrax spp.	sea basses	29.68	–	0.17			288	72.36	
Gobiidae unid.	CIQ gobies	16.19	–	5.07	30,904^{L}	13,272^{L}			
Sphyraena argentea	Pacific barracuda	11.43	2.92	0.36			5	0.38	
Paralichthys californicus	California halibut	9.90	1.24	0.26	22^{E}		81	8.49	
Hypsoblennius spp.	combtooth blennies	8.32	–	0.39	9,514^{L}	20,302^{L}	273	2.94	
Citharichthys spp.	sanddabs	6.75	264.26	0.08	3,210^{E}		269	2.21	
Parophrys vetulus	English sole	5.32	–	–			3	0.14	
Pleuronichthys guttulatus	diamond turbot	3.85	0.58	1.35			22	3.46	
Pleuronichthys ritteri	spotted turbot	3.82	–	0.24			254	9.35	
Oxyjulis californica	senorita	3.56	–	0.56			21	0.50	
Atherinopsidae unid. [3]	silversides	3.26	–	3.04			11,404	840.45	
Sardinops sagax	Pacific sardine	0.34	–				25,582	964.30	31,126
Hyperprosopon argenteum	walleye surfperch	–	–				2,937	139.70	
Shellfishes									
Cancer spp. [4]	cancer crabs	1.63	–				17,500	606.35	
Panulirus interruptus	spiny lobster	0.45	–				450	276.77	
Loxorhynchus grandis	sheep crab	–	–				306	182.27	
Octopus spp.	two-spot octopus	–	–				375	75.29	
Loligo opalescens	market squid	3.37	–	–			300	7.51	

1 standardized impingement equivalent adult mortality
2 larval entrainment estimate includes queenfish and unidentified croakers combined
3 topsmelt and jacksmelt combined for impingement
4 megalops larvae for entrainment

Table 6.2-5. Summary of SGS entrainment and impingement sampling results and model output for common fish and invertebrate species based on design CWIS flows 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									
Seriphus politus[2]	queenfish	75.67	–	0.10			36,683	682.10	38,335
Engraulis mordax	northern anchovy	70.73	382.78	0.30	57,974[C]	125,680[L]	11,379	62.32	24,922
Genyonemus lineatus	white croaker	46.64	68.60	0.53	76[E]		2,822	174.66	
Paralabrax spp.	sea basses	40.35.	–	0.24			330	89.51	
Gobiidae unid.	CIQ gobies	24.43	–	7.41	46,642[L]	20,031[L]			
Sphyraena argentea	Pacific barracuda	15.45	3.93	0.52			5	0.38	
Paralichthys californicus	California halibut	14.12	2.65	0.37	38[E]		123	12.68	
Hypsoblennius spp.	combtooth blennies	14.23	–	0.63	16,264[L]	34,704[L]	390	4.17	
Citharichthys spp.	sanddabs	9.70	407.68	0.13	4,954[E]		420	3.43	
Parophrys vetulus	English sole	7.68	–	–			5	0.22	
Pleuronichthys guttulatus	diamond turbot	5.72	94.70	2.03			33	4.94	
Pleuronichthys ritteri	spotted turbot	5.15	–	0.33			372	11.99	
Oxyjulis californica	senorita	4.81	–	0.85			22	0.53	
Atherinopsidae unid.[3]	silversides	5.12	–	4.75			15,966	1,179.39	
Sardinops sagax	Pacific sardine	0.44	–				27,483	1,006.56	32,331
Hyperprosopon argenteum	walleye surfperch	–	–				2,956	140.20	
Shellfishes									
Cancer spp.[4]	cancer crabs	2.38	–				27,024	937.00	
Panulirus interruptus	spiny lobster	0.67	–				613	377.76	
Loxorhynchus grandis	sheep crab	–	–				477	284.39	
Octopus spp.	two-spot octopus	–	–				542	102.97	
Loligo opalescens	market squid	4.93	–	–			469	11.73	

[1] standardized impingement equivalent adult mortality
[2] larval entrainment estimate includes queenfish and unidentified croakers combined
[3] topsmelt and jacksmelt combined for impingement
[4] megalops larvae for entrainment

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

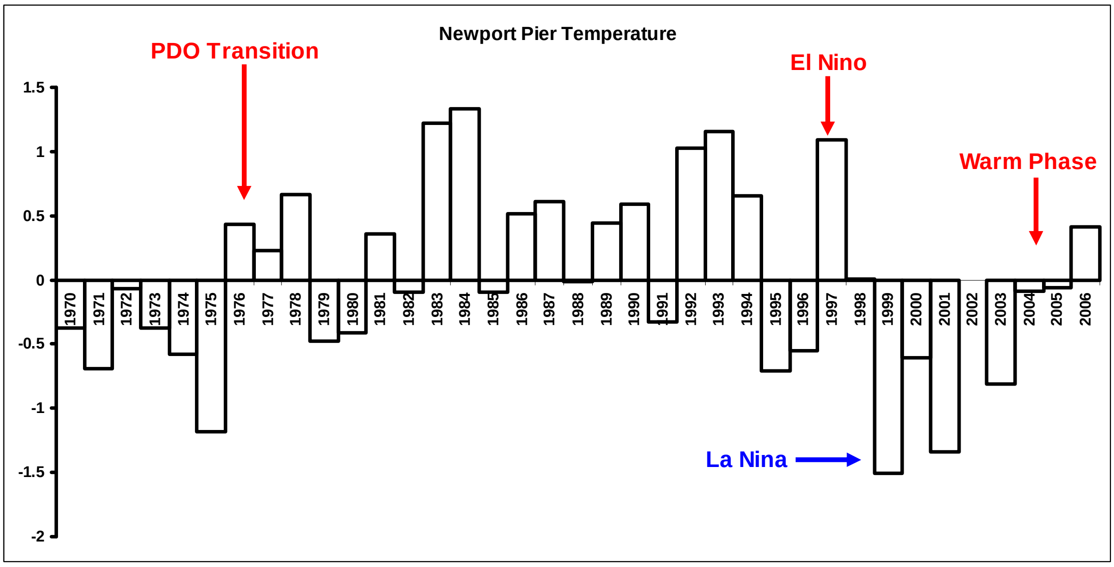


Figure 6.3-1. Sea surface temperature anomalies for Newport Pier, California.
Values are ± the long-term average (1925-2006).

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.

6.3.2 Habitat Associations

Most entrained larvae were from species typically found associated with the types of habitats in close proximity to the intakes: nearshore sand bottom, rock reefs, and coastal pelagic environments. Many of the larvae for these species, such as anchovies, are found in the same nearshore habitats occupied by the adults (Figure 6.1-2). The majority of the entrained larvae were from fishes associated with bay and harbor habitats, and coastal pelagic habitats which include the sandy nearshore areas found in the vicinity of the SGS intake (Table 6.3-1). The fewest number of taxa were from fishes associated with deep pelagic habitats, which were also collected in lowest numbers. Although almost 36% of the taxa were from fishes associated with shelf and slope habitats further offshore, these taxa were not collected in large numbers relative to the fishes from nearshore habitats. This would be expected since onshore currents may transport the larvae of these taxa onshore, but they occur in much greater abundances offshore where the adult habitat is located.

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 % of taxa	Entrained % of abundance	Impinged % of taxa	Impinged % of biomass
Habitat Association				
Continental shelf / slope	44.29	60.11	28.74	42.75
Bays, Harbors	41.43	50.36	49.43	58.28
Rocky reef, Kelp	37.14	19.75	52.87	7.59
Coastal pelagic	15.71	54.03	13.79	78.43
Deep pelagic	5.71	2.64	0.00	0.00
Fishery				
Sport	41.43	45.45	49.43	58.52
Commercial	32.86	46.57	37.93	91.98
None	52.86	14.78	45.98	3.89

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 coastal pelagic habitat 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 SGS intake where they are subject to entrainment.

6.3.3 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 only two fish taxa included in this assessment: CIQ gobies and combtooth blennies (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.

Annual entrainment of goby and blenny was estimated to be 16.2 and 8.3 million larvae, respectively, based on actual flow volumes and 24.2 and 14.2 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 5.1 – 7.4 and 0.4 – 0.6% of the larval goby and blenny populations, respectively, were lost due to entrainment (Table 6.2-4 and 6.2-5). The percentage losses to gobies were the highest for any of the taxa analyzed. The entrainment losses were also used to estimate that the larvae entrained would have resulted in an additional 13,300 – 31,000 adult gobies and 9,500 – 20,300 adult blennies based on actual flow volumes (Table 6.2-4) and 20,000 – 46,600 adult gobies and 16,300 - 34,700 adult blennies based on design flow volumes (Table 6.2-5).

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, where not collected during impingement sampling because they mostly occur along 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 273 to 390 fishes depending on whether actual or design flows were used in the calculations.

The effects on these two species 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 seventh 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 are produced in areas such as Marina del Rey and the Ballona Wetlands directly 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. 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. The abundances of goby and blenny larvae in these areas where they were spawned are much greater than the abundances in coastal waters.

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 SGS 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 1990's (Stephens and Pondella 2002). This coupled with the correlation in adult density with sea surface temperature were indicators that the success 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 SGS 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 SGS on blennies of less than one percent does not represent any risk of adverse environmental impacts since the intake structure is 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 SGS 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.

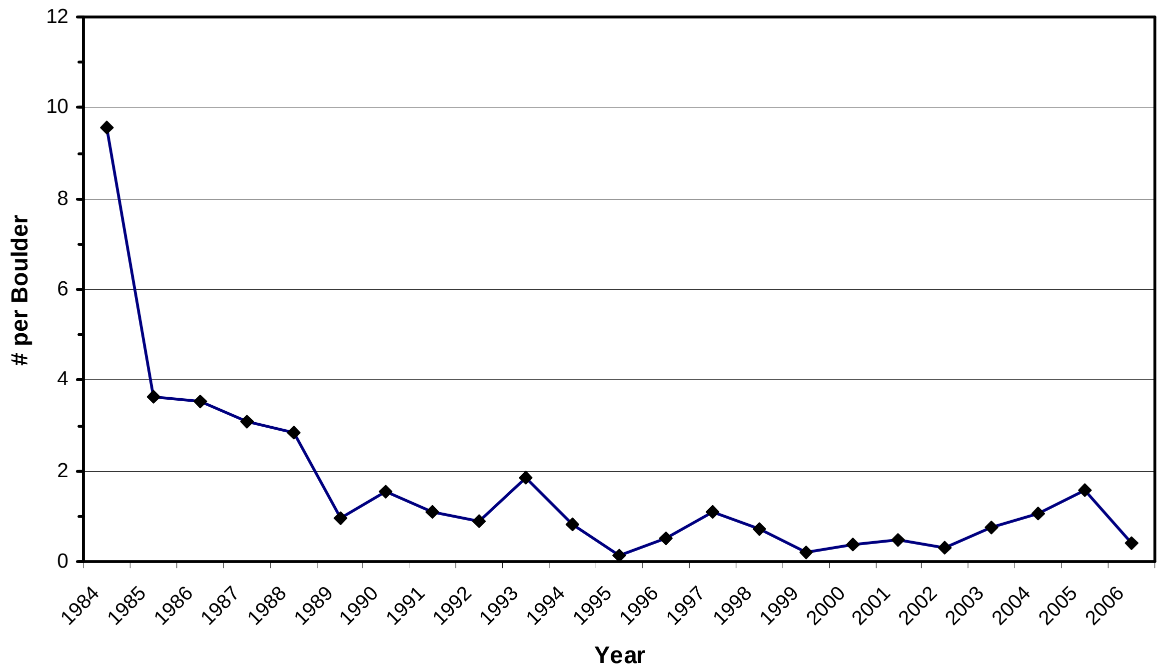


Figure 6.3-2. Abundance of combtooth blennies collected per boulder at King Harbor, Redondo Beach, California from 1984–2006 (from Pondella, unpubl. data).

6.3.4 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 SGS included the sea basses (*Paralabrax* spp. [includes kelp bass, *P. clathratus*, spotted sand bass, *P. maculatofasciatus*, and barred sand bass, *P. nebulifer*]), señorita (*Oxyjulis californica*), and California spiny lobster (*Panulirus interruptus* (Table 6.1-1).

The estimated annual loss of sea basses due to operation of the SGS CWIS included 29.6 million larvae, based on actual flow volumes, and 40.4 million based on design flow volumes (Table 6.2-1). Eggs were scarce—only two eggs that were positively identified as belonging to the genus *Paralabrax* were recorded in the entrainment samples. The entrainment and source water data on larval concentrations were used to estimate that 1.7% of the source water population of larval sea basses was entrained, based on actual flows (Table 6.2-4), and 2.4% based on design flows (Table 6.2-5). 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 288 individuals with a combined weight of 72 kg (159 lbs) based on actual flows (Table 6.2-4) and 330 individuals with a combined weight of 90 kg (198 lbs) based on design flows (Table 6.2-5).

Señorita, another species characteristic of rocky reef and kelp bed habitats, have pelagic larvae that were entrained in relatively low numbers (3.5 million per year based on actual flows and 4.8 million based on design flows]) that represented a loss of approximately 0.5% to 0.8% of the source water population. Again, there was not enough life history information available to model the number of adults this number of larvae would represent, but it would likely translate to very few mature adults, or the annual reproductive output of few females. Annual impingement of señorita was inconsequential with estimated losses of only 21 individuals due to CWIS normal operations.

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 450,000 and 670,000 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 450 individuals weighing 276 kg (610 lbs) based on actual flows and 613 individuals weighing 378 kg (832 lbs) based on design flows (Tables 6.2-4 and 6.2-5). However, in terms of biomass it was the most abundant species, accounting for over 40% of the annual macroinvertebrate biomass that was impinged. It was impinged sporadically throughout the year, with peaks in abundance measured in April and July. The mean carapace length (CL) of 250 impinged lobsters was 82 mm (3.2 in) corresponding to the approximate legal minimum fishery size limit (83 mm) and an approximate age of 7–11 years old.

The offshore intake structure at SGS provides 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 SGS intake conduit where they would be attracted as a shelter during the day, thus explaining their impingement. It was found that approximately 36% of the entrained larval taxa and 13% 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 20% of total entrainment, and the impingement biomass was dominated (78%) 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 dramatically at Palos Verdes, with similar trends at King Harbor. 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). The annual losses of both species at SGS was less than 0.05% of this take. 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 lbs) in 2005 (CDFG 2006). Commercial landings from Santa Monica Bay area catch blocks in 2006 totaled 18,213 kg (40,152 lbs) at an estimated value of $372,220 (CDFG 2007b). Because the intakes at SGS 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.

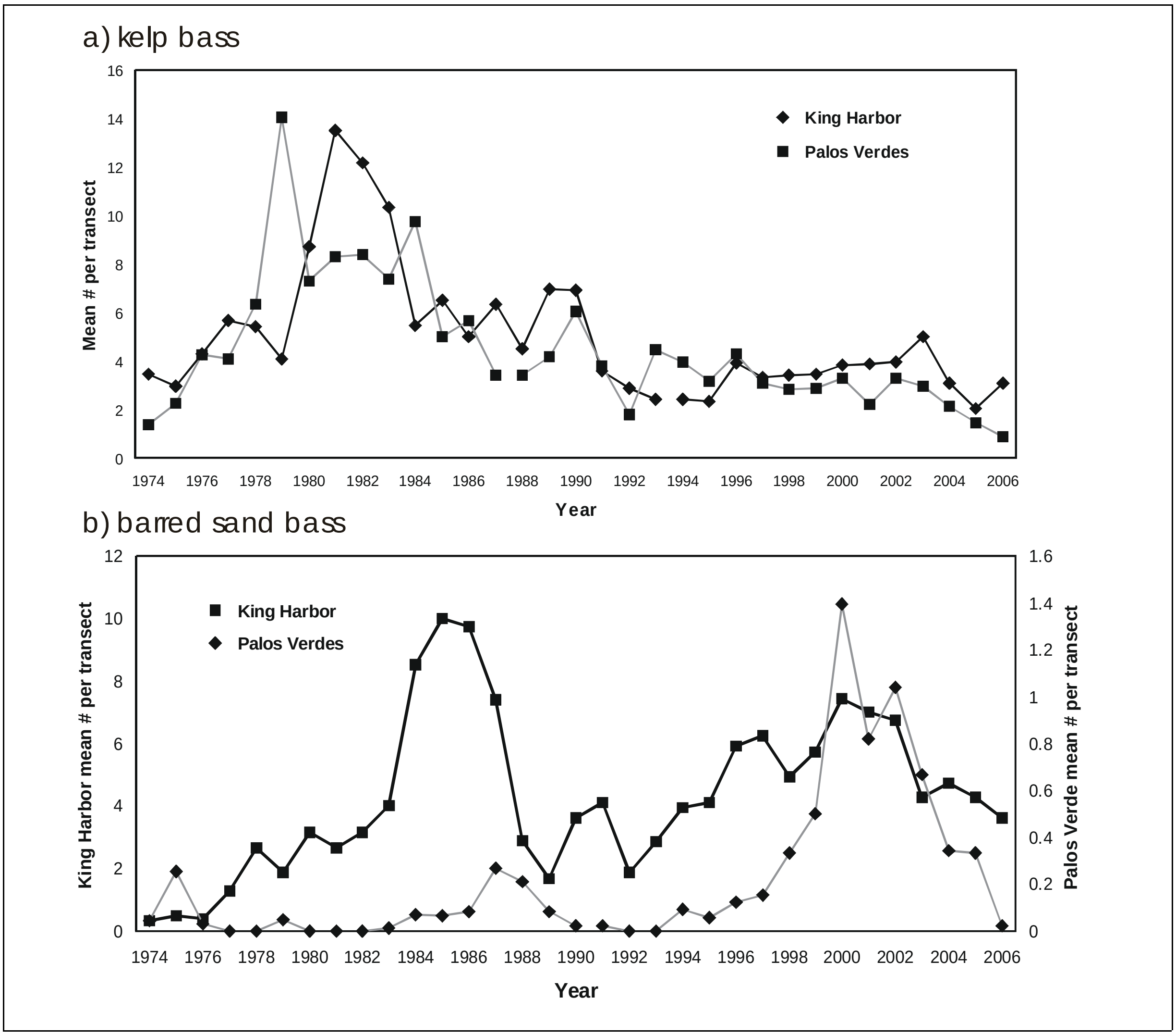


Figure 6.3-3. Abundance of a) kelp bass (*Paralabrax clathratus*) and b) barred sand bass (*P. nebulifer*) measured on diver transects at King Harbor and Palos Verdes from 1974–2006. Source: Vantuna Research Group.

6.3.5 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 and nearshore soft bottom habitats. Most of the shallow water areas of Santa Monica Bay are sand bottom with relatively few hard bottom relief features. This is the main habitat type in close proximity to the SGS intake and many of the species entrained or impinged are characteristic of the coastal pelagic zone. These mainly included northern anchovy, Pacific sardine, white croaker, Pacific barracuda, 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.

Northern anchovy was the second most abundantly entrained larval taxon behind unidentified yolk-sac larvae (a combination of newly hatched croaker species, flatfishes, and other unidentifiable taxa). Demographic models projected that a range of 36,000–79,000 adult equivalents were lost as a result of entrainment during actual flows in 2006 (Table 6.2-4), and 58,000–126,000 individuals under design flows of SGS (Table 6.2-5). Northern anchovy ranges widely throughout the southern California bight and the proportion of larvae entrained in the source waters from Santa Monica Bay were correspondingly low (0.2–0.3%) (Figure 6.1-2). Approximately 10,000 anchovies weighing 56 kg (123 lbs) were impinged under normal flows and over 11,000 anchovies weighing 62 kg (136 lbs) would have been impinged under design flows.

Very low numbers of Pacific sardine larvae were entrained but it was the second most abundant species impinged with an estimated 25,582 individuals, or 26.9% of the annual total, weighing 889.227 kg (1,960.746 lbs). Pacific sardine is a wide-ranging species with a maximum sustained fishery yield of approximately 250,000 tons annually. The projected losses of less than one ton per year as a result of entrainment and impingement at SGS are insignificant.

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

Another nearshore pelagic taxon characteristic of the coastal pelagic habitat is silversides, a family represented by topsmelt, jacksmelt and grunion. As with sardines, relatively few larvae of this taxon were entrained with annual entrainment estimated at 3.3–5.1 million larvae per year (75% were jacksmelt, 25 % topsmelt, and 0% grunion), but it was the fourth most abundant taxon that was impinged. Nevertheless, the annual impingement was less than one ton for actual flows and slightly over one ton for design flows. 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 SGS 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 1970's to the early 1990's, 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 1990's 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. Both species were abundant in both entrainment and impingement samples collected at SGS but together comprised less than one ton annually under both normal and design flows (maximum of 857 kg [1,885 lbs]). Other species of croaker such as spotfin croaker and black croaker, were 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).

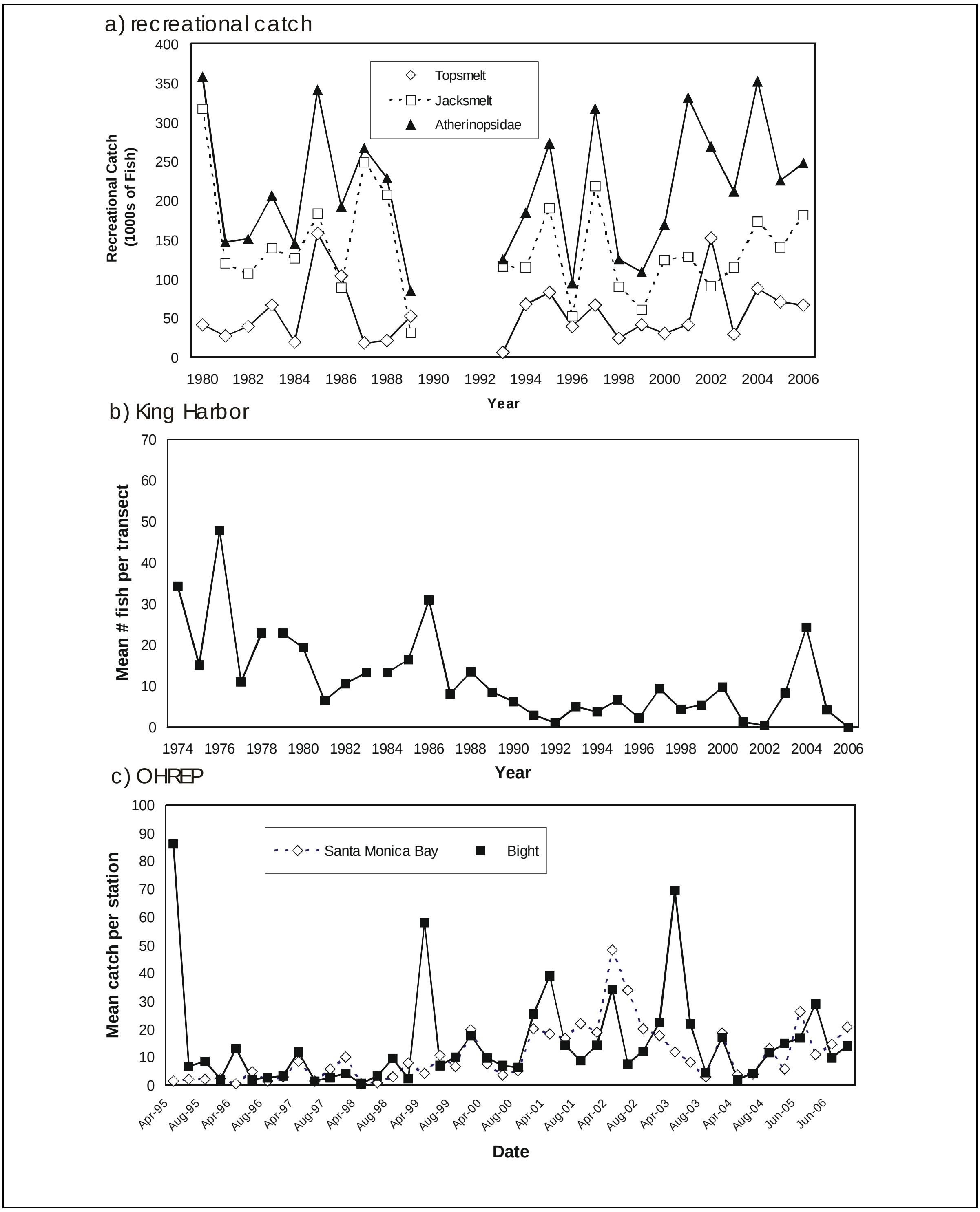


Figure 6.3-4. Silverside fishery and population trends: a) recreational landings, b) King Harbor observational data, and c) Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring data. Error bars are ± 1 S.E.

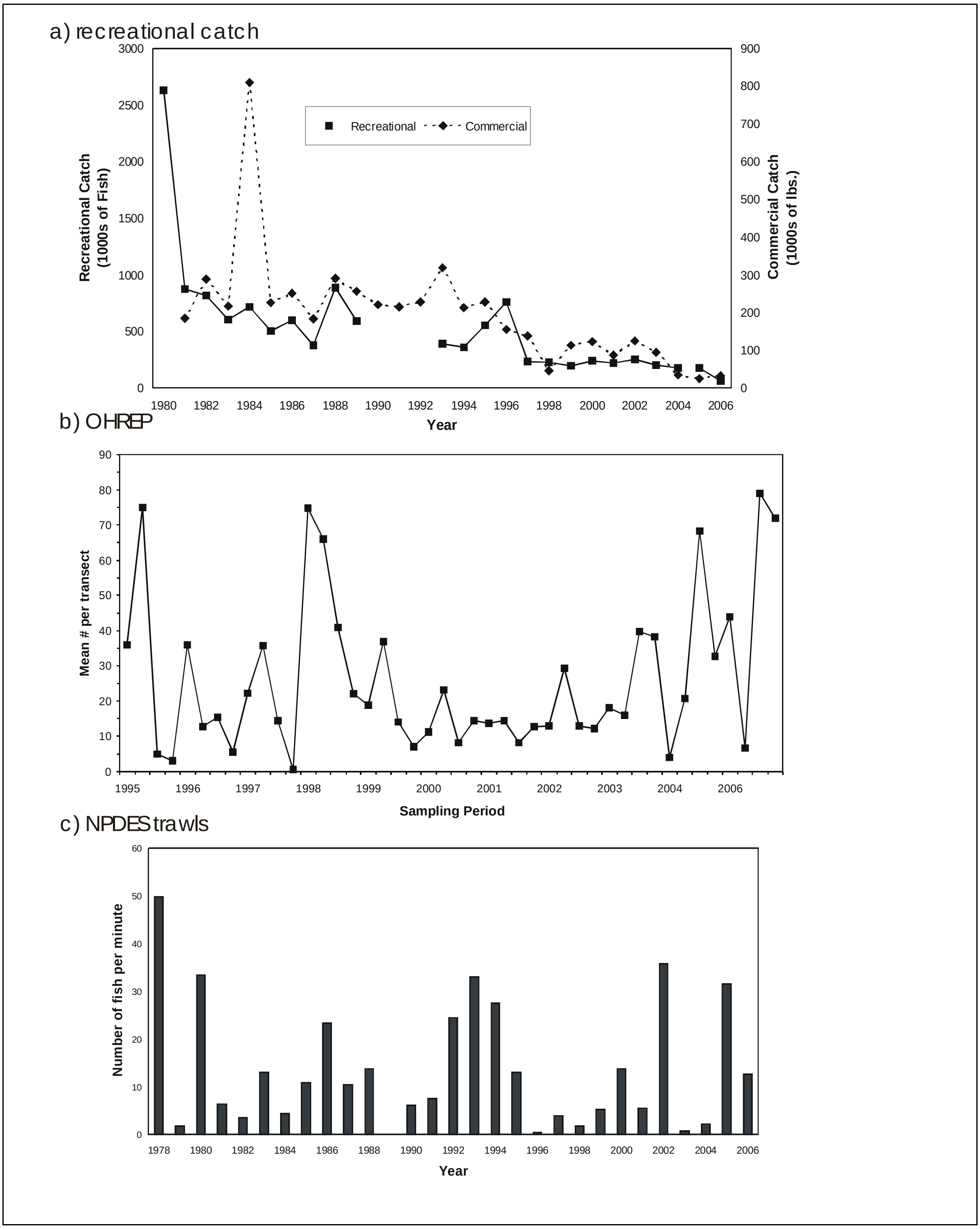


Figure 6.3-5. White croaker fishery and population trends: a) recreational and commercial landings, b) Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring data, and c) NPDES trawl programs. Error bars are ± 1 S.E.

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.

Pacific barracuda was included in the overall assessment because they have both recreational and commercial fishery importance, but the species was inconsequential in both the entrainment and impingement sampling with fewer than five impinged and a relatively small number of larvae found in the entrainment samples. The *ETM* estimate was less than 0.5%. This species ranges widely from Baja California to central California and like most of the other species found in the nearshore pelagic habitat it’s population would be largely unaffected by the SGS CWIS.

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 the sixth most abundant species impinged with an estimated 2,937 individuals, or 3.1% of the annual total calculated using actual cooling water flow volumes, weighing 140 kg (308 lbs). Only ten individuals were collected during normal operations sampling with heat treatment impingement accounting for 99.7% of the sampled abundance, and most individuals occurred in the January 2006 heat treatment. 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 lbs). Squid paralarvae (hatchlings) were present during spring months in the entrainment samples and the projected annual losses of larvae due to entrainment was from 3.4–4.9 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 300–500 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 SGS 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 there is no indication that the facility adversely impacts their populations.

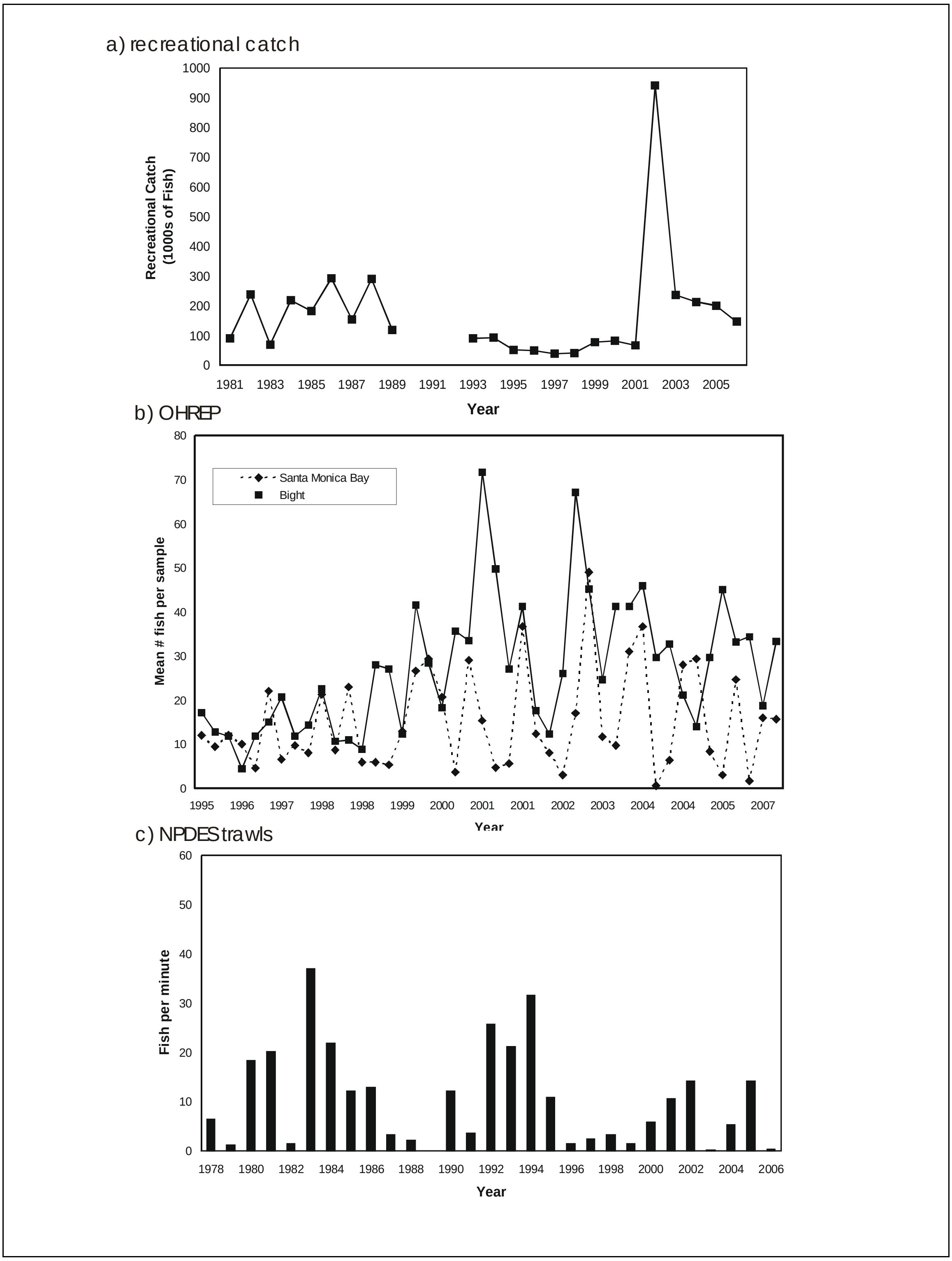


Figure 6.3-6. Queenfish fishery and population trends: a) recreational and commercial landings, b) Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring data, and c) NPDES trawl programs.

6.3.6 Shelf Habitats

Shelf habitats include several different habitats from Allen and Pondella (2006) including inner, middle, and outer shelf, and shallow slope habitats. The abundance, biomass, and other population attributes of the fish assemblages in these habitats increase from the inner to outer shelf (Allen 2006). Allen attributed this gradient to the increased variability in ocean conditions on the inner shelf due to runoff, pollution, and a variety of other factors. A variety of flatfishes and other species dominate the fish assemblages on the soft mud and sandy bottoms in these habitats. Fishes characteristic of the inner and middle shelf include white croaker, California halibut, bay goby, California tonguefish, bigmouth sole, hornyhead turbot, and California skate (Allen and Pondella 2006). Fishes characteristic of the outer shelf and slope include plainfin midshipman, Pacific sanddab, pink seaperch, curlfin turbot, Dover sole, longspine thornyhead, and California rattail (Allen and Pondella 2006).

The fishes from these habitats support a variety of commercially and recreationally important fishery species including rock and Dungeness crab fisheries. The species caught by commercial fisheries in these habitats are broadly categorized as groundfish and are jointly managed by the California Department of Fish and Game (CDFG), and the Pacific Fishery Management Council (PFMC) and NOAA Fisheries. Two periods of rapid growth in groundfish landings have been identified (Mason 2004). The first period was during the early 1940s when demand due to World War II led to increased landings with Dover sole as the most abundant component of the catch. The second period of increase occurred in the 1970s leading to the largest groundfish landing on record in the late 1970s and early 1980s with rockfishes, Dover sole, and sablefish being the largest components of the catch. Through the 1990s there was a general decline in landings. Mason (2004) identified market demand, variability in ocean conditions, and effects of exploitation as the three primary factors contributing to the changes in groundfish landings.

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 and spotted 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. 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 intake. For example, California halibut had the highest estimated larval entrainment of the shelf habitat species at 9.9–14.1 million larvae based on actual and design flows, respectively (Tables 6.2-4 and 6.2-5). This was the seventh highest of all of the taxa included in the assessment from all habitats. These levels of entrainment are low relative to the estimate of total lifetime fecundity of 1,973,371 eggs (estimated from data in MacNair et al. 1991) and estimates of annual fecundity of up to 6.5 million eggs (Caddell et al. 1990). The entrainment estimates for California halibut eggs and larvae represent the loss of 24–36 adult halibut, based on actual and design flows, respectively. The estimated mortality due to entrainment was lowest for sanddabs, which has a broad distribution over the entire shelf, and highest for diamond turbot which, similar to California halibut and spotted turbot, are primarily distributed along the inner shelf. No estimates were calculated for English sole because they were not collected at both entrainment and source water stations during the same surveys.

Impingement was highest for speckled sanddabs and spotted turbot, but these and the other shelf species totaled only 0.3% 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 intake is located. Entrainment of cancer crab megalops were too low to analyze, but impingement of cancer crabs of all species totaled more than 28% (90.510 kg [199.54 lbs]) 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 SGS intake. 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 lbs) 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 indicate that the population of sanddabs in the SCB is healthy and there no risk to the population from the low levels of entrainment and impingement losses from the SGS.

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 SGS intake 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 lbs) in 2003 to 199 mt (438,700 lbs) 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 no risk to the population from the low levels of entrainment and impingement losses from the SGS.

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 0.3% indicate very low potential for any AEI due to SGS intake effects, 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 lbs) in 1985 and a low of 14,511 kg (31,991 lbs) 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.

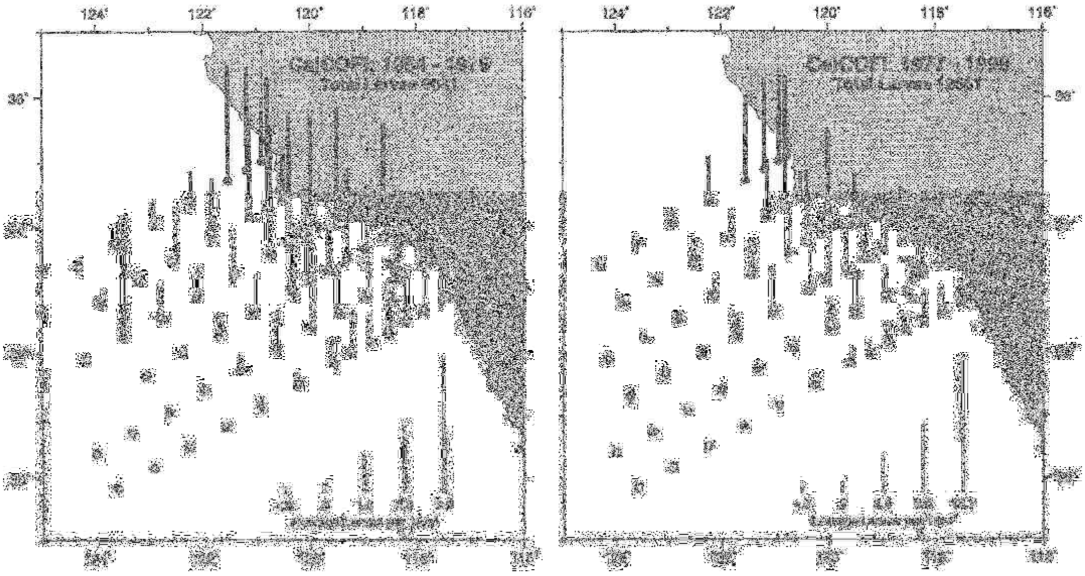
Although it is difficult to determine the status of California halibut populations in Santa Monica Bay the low levels of entrainment and impingement from the SGS represent very little risk to the healthy population indicated by results from the SCCWRP and OHREP studies.

Diamond and spotted turbot have limited value to recreational or commercial fishers, but both 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 1.3 to 2.0% of the source water larval population. Although this estimate is higher than other species it needs to be placed in context with the actual number of larvae entrained. 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). Catch of spotted turbot was consistent over the last two decades and it appears that they remain at relatively low densities today. 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 spotted and diamond turbot two additional factors need to be considered. First, both of these species also occur 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, neither are targeted by commercial and recreational fishing reducing one of the potential impacts 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

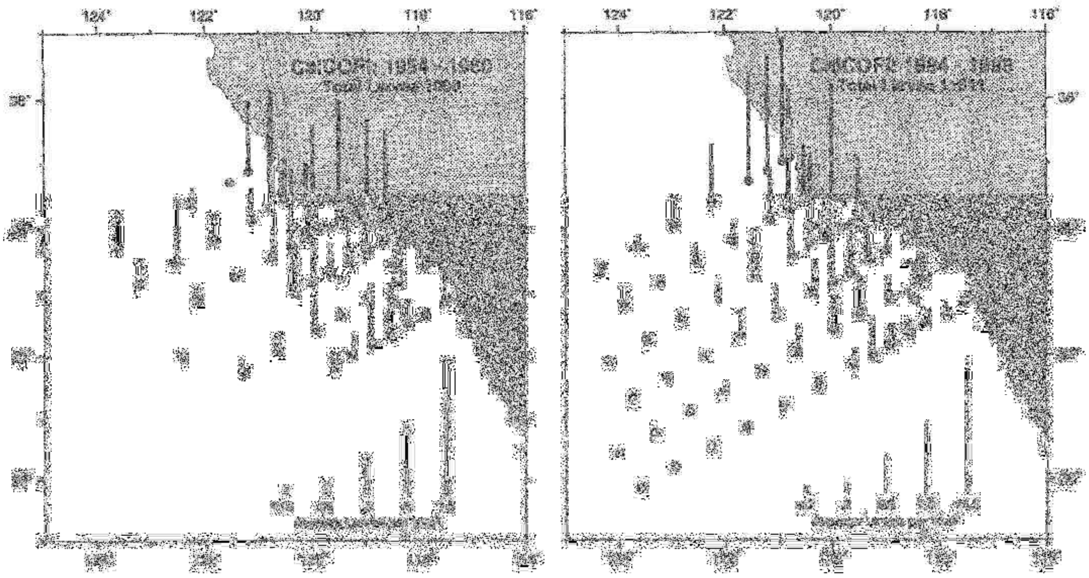
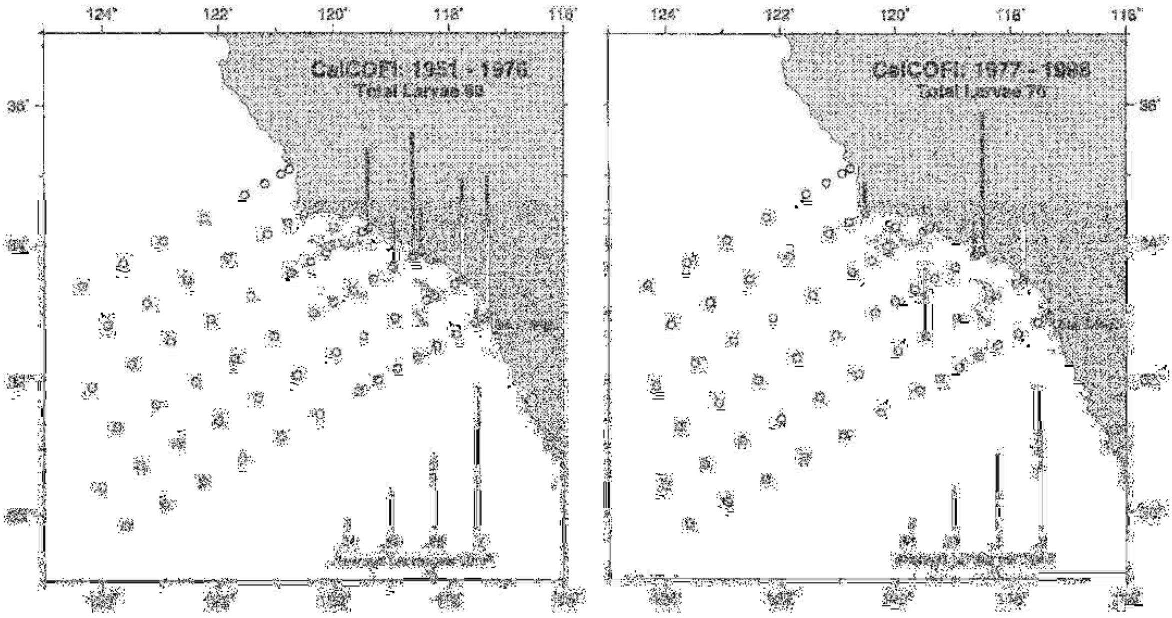


Figure 6.3-7. Distribution and abundance of two species of larval sanddabs a) speckled sanddab (*Citharichthys stigmaeus*), and b) Pacific sanddab (*Citharichthys sordidus*) across permanent stations in the SCB from 1951 through 1998 (from Moser et al. 2001).

a) diamond turbot



b) spotted turbot

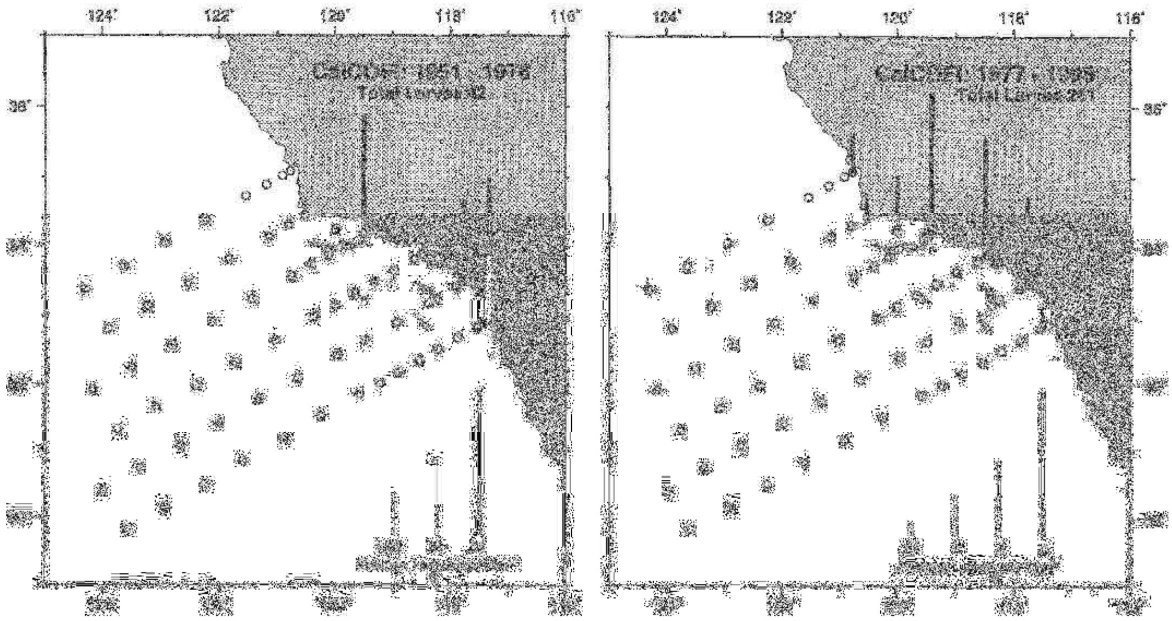


Figure 6.3-8. Distribution and abundance of larvae of a) diamond turbot (*Pleuronichthys guttulatus*), and b) spotted turbot (*Pleuronichthys ritteri*) across permanent stations in the SCB from 1951 through 1998 (from Moser et al. 2001).

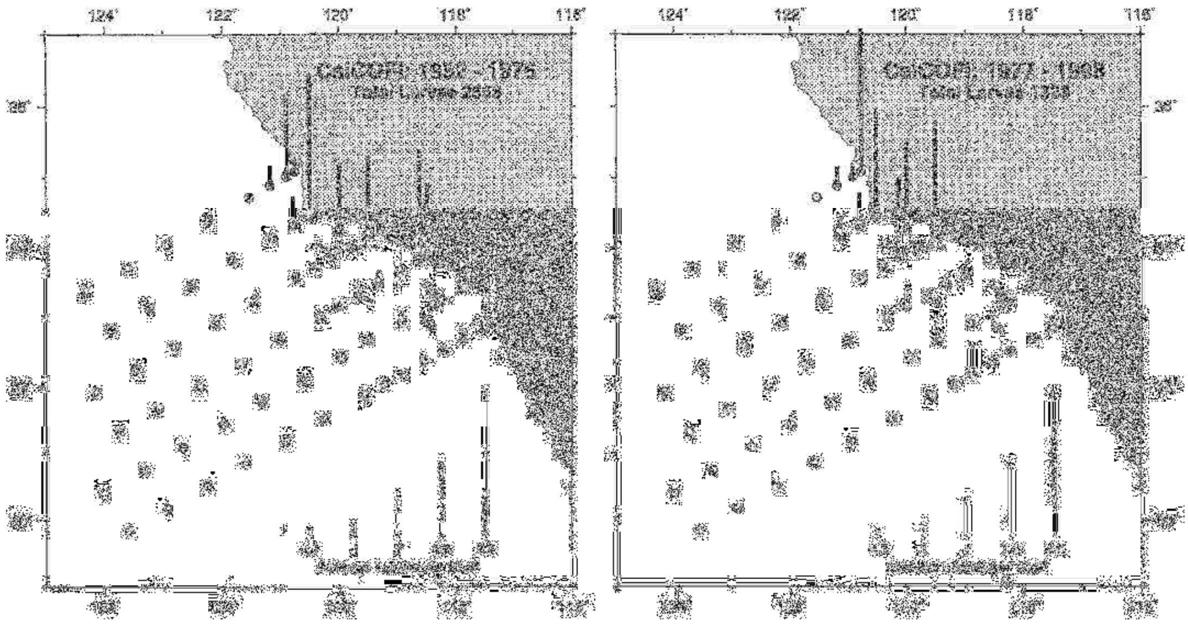


Figure 6.3-9. Distribution and abundance of larval English sole (*Parophrys vetulus*) at permanent stations sampled in the CalCOFI study in the SCB from 1951 through 1998 (from Moser et al. 2001).

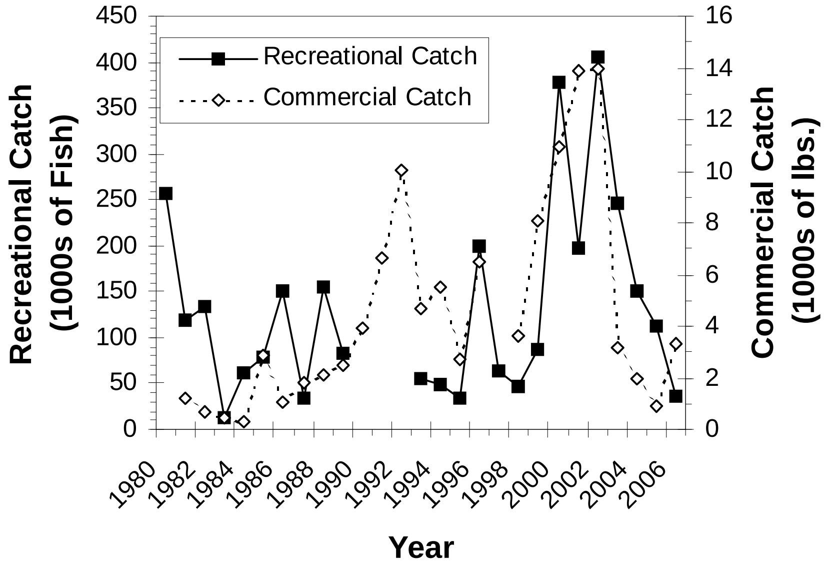


Figure 6.3-10. Recreational (1000s of fish) and commercial (1000s lbs) of sanddabs (*Citharichthys* spp.) from 1980-2006 (sources: PacFIN and RecFIN databases).

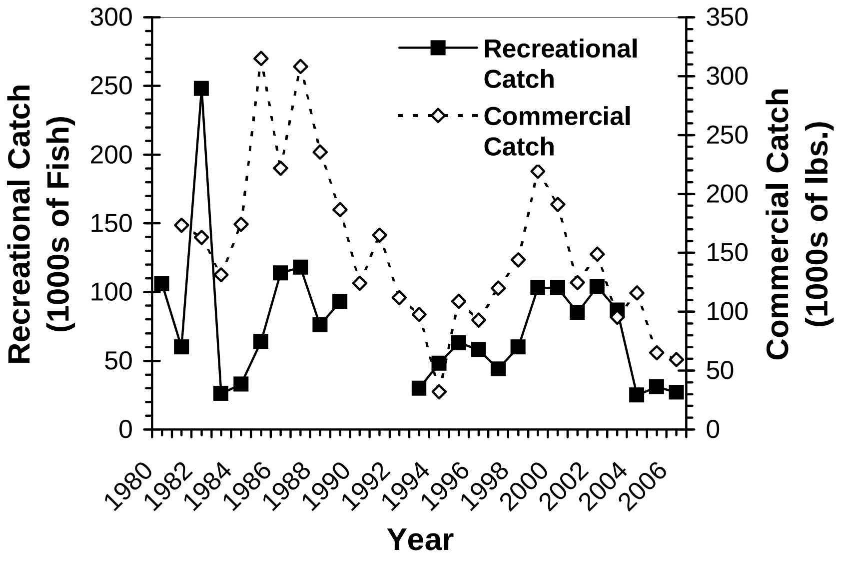


Figure 6.3-11. Recreational (1000's of fish) and commercial (1000's lbs) of California halibut (*Paralichthys californicus*) from 1980-2006 (sources: PacFIN and RecFIN databases).

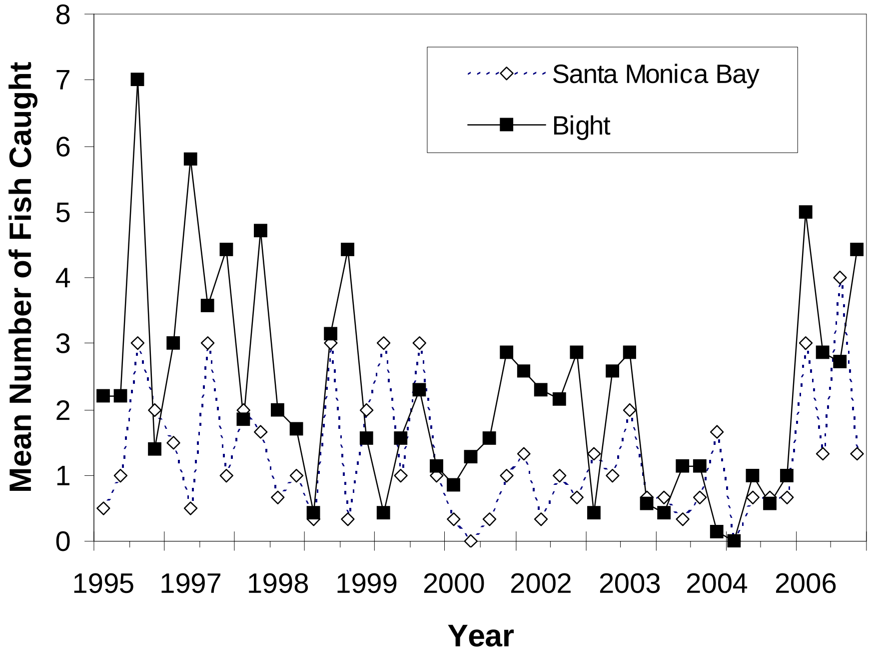
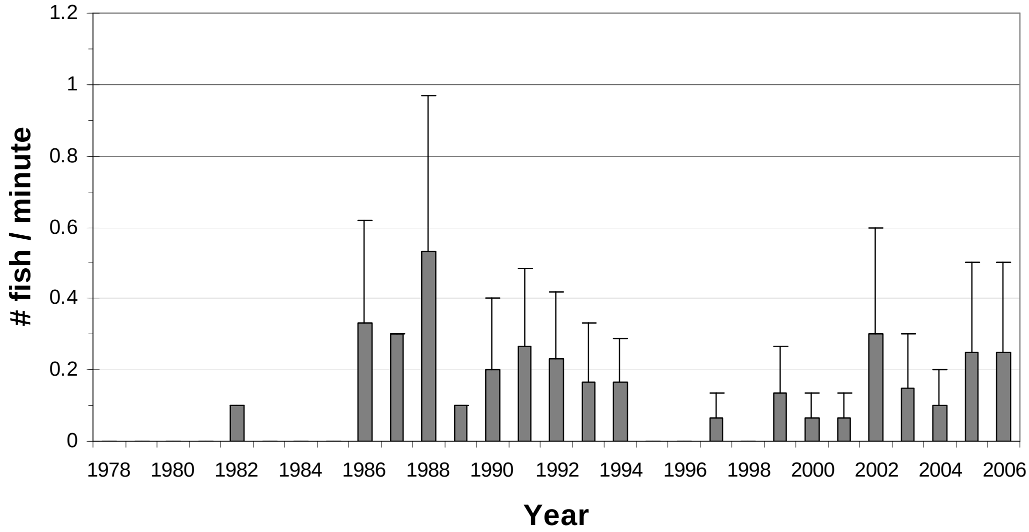


Figure 6.3-12. Mean catch (#fish/station) of California halibut in Santa Monica Bay and the remainder of the Southern California Bight from 1995-2006. Data are from the Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring program.

a) spotted turbot



b) diamond turbot

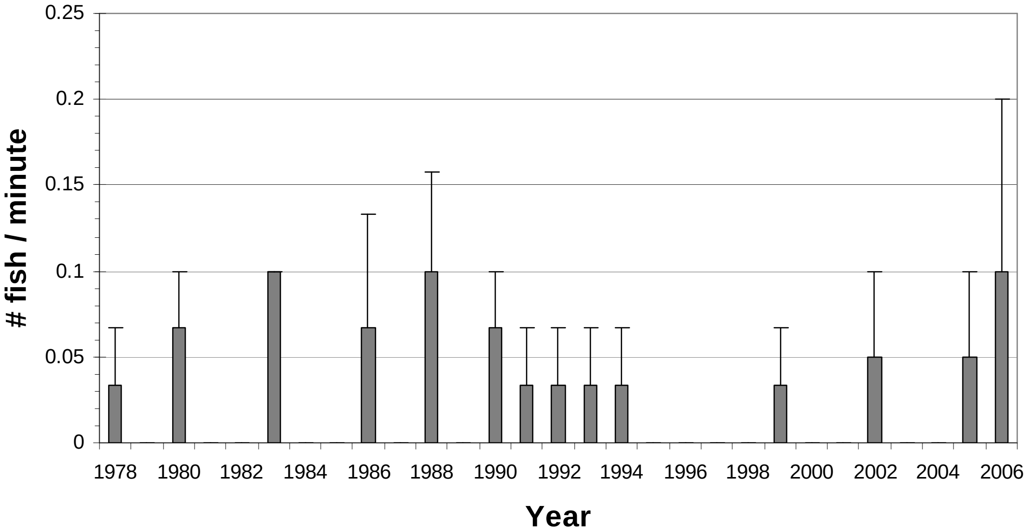


Figure 6.3-13. The mean catch per minute tow from NPDES trawl programs, 1978-2006 of a) spotted turbot (*Pleuronichthys ritteri*) and b) diamond turbot (*Pleuronichthys guttulatus*). Error bars are ± 1 S.E.

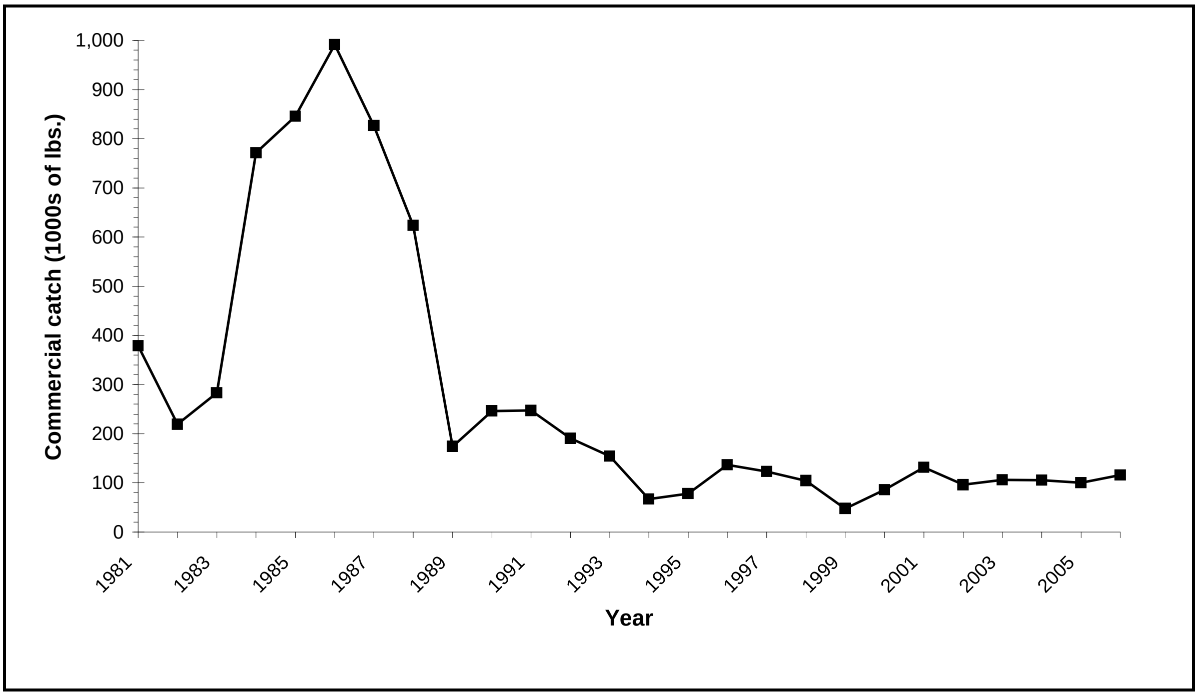


Figure 6.3-14. Commercial catches of rock crab (*Cancer* spp.) in the Los Angeles region, 1981–2006.

6.3.7 Deep Pelagic Habitats

Deep pelagic habitats include several different habitats from Allen and Pondella (2006) including deep slope, deep bank, and deep rocky reef habitats. This category also includes open ocean pelagic habitats. Some of these habitats are extremely productive and the fishes inhabiting these areas are the basis of large commercial fisheries. The fisheries in the areas outside the three-mile limit of California state waters are federally managed by the PFMC. Fishes characteristic of the deep shelf, bank and slope habitats include Pacific hake, splitnose rockfish, rex sole, sablefish, blackgill rockfish, and shortspine thornyhead. Several different species of rockfishes dominate the fish assemblages on the deep reef, shelf and canyon habitats including bocaccio, chilipepper, and greenspotted, greenstripe, rosethorn, and pinkrose rockfishes. Fishes characteristic of open ocean pelagic habitats include swordfish, striped marlin, several species of shark, albacore, and bluefin bigeye, and yellowfin tuna. Although the fishes characteristic of these habitats occasionally occur closer to shore their primary habitats are offshore in open water or at deep ocean depths.

Fishes from these habitats are not at risk due to entrainment or impingement by the SGS CWIS. No fishes or shellfishes characteristic of this habitat type were collected during impingement sampling. The larvae from these habitats are subject to entrainment, but once the larvae are transported into nearshore areas the likelihood of them maturing to adults is probably very low due to the unique adaptations many of these species have to life in deep water habitats which do not occur close to shore. One species from these habitats that was collected during entrainment samples was northern lampfish 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 it 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 SGS intake structure is 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 intake 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 SGS intake structure 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 SGS entrainment samples indicates that the vicinity of the SGS intake 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 SGS 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 SGS. This is consistent with past entrainment and impingement sampling conducted at SGS (IRC 1981; MBC 2004, 2007). 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 SGS 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 SGS in 2006 based on actual flow volumes.

Species	Common Name	Management Group	Estimated No. Larvae (based on Entrainment Samples)	Juveniles/Adults (based on Impingement Samples)*
Engraulis mordax	northern anchovy	Coastal Pelagics	44,584,991	10,214
Parophrys vetulus	English sole	Pacific Groundfish	5,321,852	3
Loligo opalescens	market squid	Coastal Pelagics	3,367,525	300
Hypsypops rubicundus	garibaldi	CDFG	342,045	1
Sardinops sagax	Pacific sardine	Coastal Pelagics	336,514	25,582
Merluccius productus	Pacific hake	Pacific Groundfish	320,228	–
Citharichthys sordidus	Pacific sanddab	Pacific Groundfish	160,533	–
Pleuronectes isolepis	butter sole	Pacific Groundfish	71,472	–
Sebastes spp.	rockfishes	Pacific Groundfish	47,244	–
Scorpaena guttata	California scorpionfish	Pacific Groundfish	–	157
Scomber japonicus	Pacific chub mackerel	Pacific Groundfish	–	110
Sebastes paucispinis	bocaccio	Pacific Groundfish	–	74
Sebastes auriculatus	brown rockfish	Pacific Groundfish	–	41
Triakis semifasciata	leopard shark	Pacific Groundfish	–	8
Leuresthes tenuis	California grunion	CDFG	–	7
Sebastes miniatus	vermilion rockfish	Pacific Groundfish	–	7
Sebastes chrysomelas	black & yellow r.f.	Pacific Groundfish	–	1

* Includes estimated numbers from normal impingement, and actual numbers from marine growth control surveys and normal flow velocity cap surveys.

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 SGS 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 SGS 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 SGS 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 fish populations potentially affected by entrainment from the facilities with intakes on the open coast like SGS 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 SGS, 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, Pacific barracuda, 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 detectable effect from the operation of the cooling water systems. For example, at the Huntington Beach Generating Station (Orange County, California) three fish species (queenfish, white croaker, and northern anchovy) have comprised over 80% of the long-term impingement abundance from 1979 to 2005 (MBC 2006a). At the AES Redondo Beach Generating Station (Los Angeles County, California), ten fish species have accounted for 83% of the impingement abundance from 1991 through 2005 (MBC 2006b). As expected, the relative abundance of these species fluctuated over time, but they continue to thrive in the study area. Furthermore, for species that are harvested commercially, such as northern anchovy, the biomass of fishes that are impinged is orders of magnitude below the reported commercial landings from the Los Angeles area.

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.

For the species in the detailed evaluation nearly every type of effect over time was found (Table 6.4-2). 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 suffered a similar decline. Spotted sand bass have suffered a similar decline. 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.

Table 6.4-2. Summary of positive time series findings for fish species in detail evaluation with respect to oceanographic variables (ENSO, SST, and PDO), fishing effects and the current population trends.

Taxon	ENSO	SST	PDO	Fishing Effects	Current Population Trend
Anchovies			Yes	Historic	stable
Silversides			Yes		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

After the faunal change (i.e. post the 1982-1984 El Niño) fishes that would be negatively affected by warming conditions were essentially extirpated from the near shore environment of the Santa Monica Bay. Other than the taxa that appear to be suffering from commercial and recreational fishing pressure, the remaining species are stable over time. This period was marked by general low fish productivity (Brooks et al. 2002) until the La Niña of 1999 and following four-year cool water period. At this point, the catch or density of these stocks appeared to either increase or remains stable through 2006.

The conclusion that the levels of entrainment and impingement at SGS 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 by the EPA (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 using empirical data on entrainment and impingement, life history, and stock size. For 12 of the 15 species, the effects of removing all of the sources of power plant entrainment and impingement were very low (less than 2.5%). For the other three species, the effects ranged from 22.3% for striped bass on the Atlantic coast to 79.4% for Atlantic croaker. Their overall conclusions were that population-level effects were negligible for most fish stocks but could be severe for a few. 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 harvested fishes analyzed by Newbold and Iovanna (2007), the largest effects of entrainment at SGS were for two non-harvested fishes that also occur in protected waters. They did conclude that significant effects could occur in some species. For example, they estimated the impacts for Atlantic croaker at over 43% largely due to high rates of entrainment mortality rate. These levels are much higher than any of the levels estimated from SGS. The mortality rates from entrainment for West Coast species of croakers are typically much lower and closer in value to the levels that Newbold and Iovanna concluded represented little risk to the populations.

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