FINAL REPORT

HARBOR GENERATING STATION

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

Prepared by

MBC Applied Environmental Sciences
Tenera Environmental, Inc.
URS Corporation

for

City of Los Angeles Department of Water and Power
111 N. Hope Street
Los Angeles, California 90012-2607

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LIST OF ACRONYMS AND ABBREVIATIONS

ADCP	acoustic Doppler current profiler
AEL	adult equivalent loss
BMPs	best management practices
BTA	best technology available
CDFG	California Department of Fish and Game
CDS	Comprehensive Demonstration Study
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CIQ	*Clevelandia, Ilypnus, Quietula*
cm	centimeters
cm/s	centimeters per second
CPFV	commercial passenger fishing vessels
CWA	Clean Water Act
CWIS	cooling water intake system
DML	dorsal mantle length
EAM	equivalent adult model
EFH	Essential Fish Habitat
El.	Elevation (relative to mean sea level)
EPA	United States Environmental Protection Agency
ETM	Empirical Transport Model
FH	fecundity hindcasting
FMP	Fishery Management Plan
ft	feet
ft/s	feet per second
g	grams
gal	gallons
GIS	Geographic Information System
gpm	gallons per minute
HGS	Harbor Generating Station
ILAH	Inner Los Angeles Harbor
IM&E	Impingement Mortality and Entrainment
in	inches
kg	kilograms
km	kilometers
LADWP	Los Angeles Department of Water and Power
LARWQCB	Los Angeles Regional Water Quality Control Board
lbs	pounds
m	meter
m^3	cubic meters
mgd	million gallons per day
ml	milliliter
ML	mantle length
MLLW	mean lower low water
mm	millimeters
m/s	meters per second
MSL	mean sea level
MW	megawatts
NL	notochord length
NMFS	National Marine Fisheries Service

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
PacFIN	Pacific Fisheries Information Network
PDO	Pacific Decadal Oscillation
PE	proportional entrainment
PFMC	Pacific Fisheries Management Council
PIC	Proposal for Information Collection
P_M	probability of mortality
POLA	Port of Los Angeles
PSU	practical salinity units
QA/QC	Quality Assurance/Quality Control
QC	quality control
RecFIN	Recreational Fisheries Information Network
rpm	revolutions per minute
RWQCB	California Regional Water Quality Control Board
SCB	Southern California Bight
SL	standard length
SWRCB	State Water Resources Control Board
TLF	total lifetime fecundity
USFWS	U.S. Fish and Wildlife Service
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 Harbor Generating Station (HGS) Impingement Mortality and Entrainment (IM&E) Characterization Study. This study was designed and performed to comply with the United States Environmental Protection Agency (EPA) 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 cost-benefits in reducing IM&E at the facility. However, in March 2007, the 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 EPA'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 only consider the question of BTA 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 HGS 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 HGS. This report provides a characterization of the fish and invertebrate species subject to entrainment and impingement at the HGS, information on the current levels of IM&E at the HGS, and a discussion on the level of significance of the IM&E losses.

1.1 ENTRAINMENT

The composition and abundance of ichthyoplankton and shellfish larvae entrained at HGS 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 8,692 entrainable fish larvae from 45 separate taxonomic categories was collected during the 26 entrainment surveys. The most abundant larval fish taxon in the samples was unidentified gobies, which comprised 49.3% of the total larvae collected, followed by yellowfin goby (25.2%) and white croaker (12.0%). Densities of fish larvae peaked in early March at an average concentration of approximately 6,000 per 1,000 m^3 [264,172 gal]. Unidentified goby larvae occurred year-round in the samples whereas yellowfin goby larvae were mainly found only in samples collected during February and March. White croaker primarily occurred in spring while another common taxon, combtooth blennies, were predominantly summer spawners.

In addition to the fish larvae, 14,845 fish eggs from 10 taxa were enumerated from the surveys. The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 46.6% of the total eggs collected, followed by croaker eggs (15.7%). Fish eggs had peak abundances in late February and early May with concentrations of approximately 8,000 per 1,000 m^3. Larvae were substantially more abundant in samples collected at night than those collected during the day in nearly every survey, while egg abundances were more evenly distributed between day and night surveys. Total annual entrainment was estimated to be 65.3 million fish larvae and 99.9 million fish eggs during 2006 using the HGS CWIS actual flows as the basis for calculations. Using the design (maximum capacity) CWIS flows, total annual entrainment was estimated to increase to 153.3 million fish larvae and 269.4 million fish eggs.

A total of 2,262 larval target shellfishes (late-stage larvae of crabs, spiny lobsters, and market squid) representing 16 taxa (combined species designations) was collected from the HGS entrainment station (E1) during 26 bi-weekly surveys in 2006. The most abundant target shellfish larvae in the samples were kelp crab megalops (*Pugettia* spp.) followed by spider crab megalops (Majidae unid.), which made up 63.4% and 16.8%, respectively of the total target shellfish larvae collected. Total annual entrainment was estimated to be 18.9 million target shellfish larvae based on actual cooling water flows. Using the design CWIS flows, total annual entrainment was estimated to increase to 41.3 million target shellfish larvae.

1.2 SOURCE WATER

To determine composition and abundance of the early life stages of fish and shellfish in the source waters of the HGS, sampling at six stations in the waters of the Los Angeles–Long Beach Harbor Complex was conducted once monthly on the same day that the entrainment station (E1) was sampled.

A total of 13,986 larval fishes representing 72 taxa was collected from HGS source water stations during 12 monthly surveys in 2006. White croaker, combtooth blennies, unidentified gobies (CIQ goby complex), anchovies, bay goby, unidentified croakers and yellowfin goby were the most abundant taxa and comprised nearly 90% of all specimens collected. The greatest concentrations of larval fishes occurred during May 2006 (ca. 2,400/1,000 m^3) and the fewest in November 2006 (ca. 400/1,000 m^3). Seasonality in the taxa with the most abundant larvae was similar to the entrainment samples.

A total of 6,942 larval target shellfishes representing 20 taxa was collected from the HGS source water stations. Megalops of kelp crabs, pea crabs, spider crabs, unidentified megalops, California spiny lobster, and cancer crabs were the most abundant taxa and comprised over 90% of all specimens collected.

1.3 IMPINGEMENT

During 2006, normal operation impingement surveys were performed during 50 of 52 weeks at the HGS between January 5 and December 29, 2006, from the single screening facility. The two weeks with no samples collected (in late-April and early-May) represent periods when no circulating water pumps were operating due to a facility outage. A total of 1,290 fishes representing 25 species and weighing 188.85 kg (416.41 lbs) was collected during impingement sampling in 2006. The estimated annual total impingement, based on cooling water flow volumes in 2006, was 8,851 individuals weighing 1,316 kg (2,903 lbs) (Table 5.5-1). Round stingray was the most abundant species, with 877 individuals collected (68% of the abundance total) and an estimated annual impingement of 6,150 individuals weighing

1,231 kg (2,715 lbs). The annual impingement of round stingray represented 70% of the total impingement abundance and 94% of the biomass. The next most abundant species in impingement samples were black perch, specklefin midshipman, shiner perch, barred sand bass, and giant kelpfish. Combined these taxa accounted for 91.2% of the sampled impinged fish abundance.

The estimated annual total impingement of fish based on actual cooling water flow volumes in 2006 was 8,851 individuals weighing 1,316 kg (2,903 lbs). The estimated annual impingement based on design flows was 19,861 fishes weighing 2,938 kg (6,477 lbs). Impingement abundance and biomass in 2006 were highest in fall months (September−November). In general, fish impingement abundance and biomass were greater during nighttime surveys than daytime surveys.

A total of 1,014 macroinvertebrates representing at least 41 distinct taxa and weighing 37.3 kg (82.3 lbs) was collected during impingement sampling in 2006. The nudibranch *Hermissenda crassicornis* was the most abundant species, with 271 individuals collected (27% of the abundance total) and an estimated annual impingement of 1,840 individuals weighing 0.6 kg (1.4 lbs). The next most abundant species in impingement samples were unidentified sea spiders (Pycnogonida), tuberculate pear crab, California spiny lobster (*Panulirus interruptus*), intertidal coastal shrimp, and California two-spot octopus. Combined these species accounted for 82.6% of the sampled impinged macroinvertebrate abundance.

The estimated annual total impingement of macroinvertebrates based on actual cooling water flow volumes in 2006 was 6,753 individuals weighing 260 kg (574 lbs) (Table 5.5-2). The estimated annual impingement based on design flow was 13,538 macroinvertebrates weighing 575 kg (1,268 lbs). Invertebrate impingement abundance was greatest in summer (June through August), while biomass had peaks in early-March and early-September.

1.4 IMPACT ASSESSMENT

The data collected from the entrainment, source water, and impingement sampling was used to assess the potential for AEI to fish and shellfish populations. The assessment was limited to the taxa that were sufficiently abundant to provide a reasonable assessment of impacts. The list of taxa was reviewed and approved by the Los Angeles Regional Water Quality Control Board (LARWQCB) and other stakeholders. The most abundant taxa typically had the greatest frequency of occurrence among surveys and among stations. Since the most abundant organisms may not necessarily be those that experience the greatest IM&E 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 taxa with commercial or recreational fisheries, taxa with limited habitats, and any threatened or endangered fish or shellfish species. The National Marine Fisheries Service (NMFS) requested that all species managed under the Magnuson-Stevens Fishery Conservation and Management Act be included in the impingement results. None of these species was 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 HnGS during the study.

The assessment was done primarily by calculating impingement and entrainment estimates for individual taxa based on CWIS actual and design flow volumes, 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 used 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 assessment included twelve taxonomic groups or species of fishes and two taxonomic groups or species of shellfishes (Tables 1.4-1 and 1.4-2). These taxa were categorized into four habitat types that were simplified from a more detailed categorization of habitats developed by Allen and Pondella (2006b) (Table 1.4-3). Taxa that occurred in more than one habitat were included in the habitat group that best reflected the primary distribution for those taxa. This approach was used because it focused the assessment on the taxa and habitats that were most at risk to CWIS effects.

Impacts to Southern California Bight (SCB) fish and invertebrate populations caused by the entrainment of planktonic larvae through the HGS CWIS can only be assessed indirectly through modeling. These impacts are additive with the direct impingement losses. Three taxa (CIQ goby complex, yellowfin goby and white croaker) comprised 86% of all entrained fish larvae. Of the ten most abundant fish taxa entrained at HGS, only two (croakers [including white croaker] and anchovies) have any direct commercial or recreational fishery value. All of the abundantly entrained species can be considered forage species for larger predatory fishes, sea birds, or marine mammals. Approximately 40% of the 45 different fish taxa entrained belonged to species with some direct fishery value (e.g., northern anchovies, croakers, sand basses, and California halibut) even though most of those (except northern anchovies and white croaker) were in very low abundance in the samples and, as a result, were not assessed for potential impacts.

The *ETM* procedure estimated the annual probability of mortality due to entrainment (P_M). It puts the entrainment estimate into context by comparing it with a known source population at risk of entrainment. The greatest P_M estimate for a target taxon was for the CIQ goby complex with a predicted fractional larval loss of 2.6% based on actual cooling water flows. The next greatest probabilities of mortality were for northern anchovy (0.7%) and yellowfin goby (0.7%). The distance of shoreline potentially affected by entrainment was directly proportional to the estimate of time that the larvae are exposed to entrainment. Both goby taxa had local populations associated with the soft-bottom habitats of the Los Angeles-Long Beach Harbor Complex, and most larvae were entrained at sizes that indicated they were recently hatched. The modeled species with primarily nearshore (non-bay) distributions included white croaker and northern anchovy, and these had P_M estimates well below 1%. These levels of additional mortality are considered low, especially when the populations of these species are known to extend over a much larger geographic range than the extrapolated source water bodies. No shellfish taxa were modeled for entrainment impacts due to the low abundance of the target taxa (e.g., spiny lobsters, *Cancer* crabs).

Fish impingement has been routinely measured for decades at several coastal power plants in southern California, and these data are reported annually as part of their NPDES receiving water monitoring studies. The same core group of fish species continues to be impinged at these power plants, and there is no measurable effect on fish populations from the operation of the cooling water systems. For species that are harvested commercially, such as northern anchovy, and others that are the target of sport fisheries, such as barred sand bass, the biomass of fish impinged is orders of magnitude less than annual landings.

Compared to the IM&E study conducted at HGS in 1978–1979 (IRC 1981), concentrations of northern anchovy, unidentified gobies, and queenfish larvae were an order of magnitude less abundant in 2006 while combtooth blennies and white croaker were approximately the same (Table 6.4-1). Anchovy larvae in particular were significantly more abundant in the earlier study, due in part to the cooler water climatic regime in the SCB that favored anchovy populations at that time. The most abundantly impinged species in 1978–1979 were Pacific pompano (*Peprilus simillimus*), white croaker, and queenfish, which combined accounted for 76% of the total impingement abundance. In the 2006 samples, the most abundant species were round stingray, black perch and specklefin midshipman with round stingray accounting for 75% of all impinged fishes. The estimated annual fish impingement (normal operations and heat treatments) was 2,827 kg (6,232 lbs) in 1978–1979 compared to 1,317 kg (2,903 lbs) in 2006. In the 1978-1979 study HGS was operating Units 1–5 with a combined flow of 86,652 MG, whereas in 2006 only Unit 5 was operational with an annual flow of 17,885 MG, an 80% reduction in flows between studies. Therefore, changes in total impingement and entrainment through time were affected not only by natural changes in biological and oceanographic factors but also by changes in plant operation.

No federal/state threatened or endangered fish/shellfish species were identified in entrainment and impingement samples collected from HGS. This is consistent with past entrainment and impingement sampling conducted at HGS. Off southern California, species managed under the Magnuson-Stevens Fishery Conservation and Management Act are listed in the Coastal Pelagic Fishery Management Plan (FMP) and the Pacific Groundfish FMP. Essential fish habitat (EFH) includes all waters off southern California offshore to the Exclusive Economic Zone. Five species covered under the two FMPs that occurred in entrainment and/or impingement samples at HGS included Pacific sanddab, northern anchovy, Pacific hake, Pacific sardine, and market squid. None of these species was significantly impacted by HGS operations.

Although it seems clear that there is very low risk of any AEI to taxa that are not primarily distributed in the Harbor Complex, the potential risk to the fishes included in the assessment that are primarily associated with bay and harbor habitats (e.g. gobies and blennies) was also low, particularly compared to other power plants situated in embayments in southern California. This is a reflection of both the lower abundances of these fishes in the Inner Los Angeles Harbor (ILAH) and the low cooling water volumes of HGS relative to other facilities. Larvae potentially lost due to entrainment at small sizes near the plant may be replaced by larvae transported into the ILAH that were spawned in similar habitats which are abundant in the Harbor Complex area.

Table 1.4-1. Summary of HGS entrainment and impingement sampling results and model output for common fish and shellfish species 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)
Fishes								
Gobiidae unid.	CIQ gobies	33.29	0	2.65	86,720[L]	36,231[L]	0	
Acanthogobius flavimanus	yellowfin goby	15.41	0	0.65	1,936[L]		163	3.15
Genyonemus lineatus[1]	white croaker	7.16	17.87	0.19	20[E]		25	0.20
Lepidogobius lepidus	bay goby	2.38	0	0.24			0	
Hypsoblennius spp.	combtooth blennies	2.26	0	0.06	2,826[L]	6,024[L]	0	
Engraulis mordax.	northern anchovy	0.94	0.8	0.71	11,506[C]	25,863[L]	24	0.02
Urobatis halleri	round stingray	–	–				6,150	1,231.68
Embiotoca jacksoni	black perch	–	–				646	18.49
Porichthys myriaster	specklefin midshipman	–	–				484	11.96
Cymatogaster aggregata	shiner perch	–	–				390	3.36
Paralabrax spp.[2]	sand bass	0.12	–				209	7.51
Heterostichus rostratus	giant kelpfish	0	–				192	15.73
Shellfishes								
Panulirus interruptus	spiny lobster	0.22	–				717	169.37
Octopus spp.	two-spot octopus	–	–				184	36.25

[1] larval entrainment estimate includes white croaker and unidentified croakers combined
[2] only barred sand bass collected in abundance in impingement sampling
** Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).*

Table 1.4-2. Summary of HGS entrainment and impingement sampling results and model output for common fish and shellfish species 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)
Fishes								
Gobiidae unid.	gobies	75.94	0	5.70	197,812[L]	82,665[L]	0	
Acanthogobius flavimanus	yellowfin goby	37.60	0	1.54	4,724[L]		399	7.48
Genyonemus lineatus[1]	white croaker	18.78	43.11	0.42	48[E]		48	0.43
Lepidogobius lepidus	bay goby	5.07	0	0.50			0	
Hypsoblennius spp.	combtooth blennies	4.36	0	0.12	5,466[L]	11,650[L]	0	
Engraulis mordax.	northern anchovy	2.07	1.93	1.53	25,306[C]	56,879[L]	36	0.03
Urobatis halleri	round stingray	–	–				13,771	2,756.09
Embiotoca jacksoni	black perch	–	–				1,371	41.03
Porichthys myriaster	specklefin midshipman	–	–				1,379	26.84
Cymatogaster aggregata	shiner perch	–	–				719	6.77
Paralabrax spp.[2]	sand bass	0.27	–				442	16.20
Heterostichus rostratus	giant kelpfish	0	–				424	32.60
Shellfishes								
Panulirus interruptus	spiny lobster	0.36	–				1,544	369.56
Octopus spp.	two-spot octopus	–	–				428	85.96

[1] larval entrainment estimate includes white croaker and unidentified croakers combined
[2] only barred sand bass collected in abundance in impingement sampling
** 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 HGS.

Scientific name	Common name	Fishery S-Sport, C-Comm.	Habitats bays, harbors	reefs, kelp beds	coastal pelagic	shelf
Fishes						
Acanthogobius flavimanus	yellowfin goby		**X**			
Cymatogaster aggregata	shiner perch	S	**X**	x		
Embiotoca jacksoni	black perch	S, C	x	**X**		
Engraulidae unid.	anchovies	C			**X**	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Gobiidae unid.	CIQ goby complex		**X**			
Heterostichus rostratus	giant kelpfish			**X**		
Hypsoblennius spp.	combtooth blennies		**X**	x		
Lepidogobius lepidus	bay goby		**X**			
Paralabrax nebulifer	Barred sand bass	S	x	**X**		
Porichthys myriaster	specklefin midshipman		**X**	x		x
Sciaenidae unid.	croakers	S, C			**X**	x
Urobatis halleri	round stingray		**X**			
Shellfishes						
Octopus spp.	two-spot octopus	C	x	**X**		
Panulirus interruptus	California spiny lobster	S		**X**		

Primary habitat in bold, upper case and secondary habitat in lower case.

2.0 INTRODUCTION

The Harbor Generating Station (HGS) is a fossil-fueled steam electric power generating station that began operation in 1954. HGS is owned and operated by the Los Angeles Department of Water and Power (LADWP) and is located in the Inner Los Angeles Harbor (ILAH), in Wilmington, CA, near Long Beach. HGS has seven natural gas-fired units, which do not require circulating water and one steam turbine, Unit 5, which requires cooling water that is drawn from the ILAH through an intake structure along the shore of Slip 5. After passing through the plant, the water is discharged into the West Basin of the ILAH.

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 HGS, which withdraws a maximum of 0.41 million m^3 per day (108 mgd) for Unit 5, it was subject to these new regulations that required submittal of a comprehensive plan for compliance by January 2008. The new regulations were challenged by a coalition of environmental groups 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 new regulations and directing that all permits for Phase II facilities implement 316(b) on a case-by-case basis using "best professional judgment" (BPJ). The language of the memorandum was expanded and published in the Federal Register in July 2007 (Volume 72, 130:37107-37109).

The studies presented in this report were conducted in partial fulfillment of the requirements of the new regulations. With the suspension of the Phase II regulations, the results of the studies will be used to determine if impingement and entrainment losses pose any significant risk of adverse environmental impact (AEI) to the species and life stages of fish and shellfish impinged or entrained. The absence of any significant impacts would be a technically sound basis under BPJ for determining that the cooling water intake structure represents the best technology available. 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 CWISs 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 HGS to the Los Angeles Regional Water Quality Control Board (LARWQCB) in October 2005 (LADWP 2005). The PIC included the study plan for the HGS Impingement Mortality and Entrainment (IM&E) Characterization Study.

2.1.1 Section 316(b) of the Clean Water Act

The suspended Section 316(b) of the CWA required 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 suspended 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 suspended 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 was installing one of the approved EPA technologies for IM&E reduction, it must submit information documenting its existing levels of IM&E. These data can come from existing data that may have previously been collected at the facility or a similar facility nearby. The data were then required to be submitted in an IM&E Characterization Study that was one component of the §316(b) Comprehensive Demonstration Study (CDS) required under the suspended Phase II regulations. The impingement mortality component of the studies was not required if the through-screen intake velocity was less than or equal to 15 centimeters (cm) (0.5 ft) per second. The entrainment characterization component is 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 the IM&E components of the study were required at the HGS. Previous §316(b) CDSs were conducted at HGS from October 1978 through November 1979 (IRC 1981). The entrainment sampling was conducted biweekly at the intake while impingement samples were collected on approximately a weekly basis. A detailed summary of the historical IM&E studies is provided in Sections 4.2 and 5.2. 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, 2007.

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 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 suspended 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 for 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 suspended 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 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 require 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 was used in characterizing the existing levels of IM&E, then the PIC must demonstrate that the data were representative of current conditions and were collected using appropriate QA/QC procedures.

The HGS 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 entrainment and impingement studies performed in California in recent years for California Energy Commission relicensing studies (such as those at the AES Huntington Beach, Duke Morro Bay, Duke Moss Landing, and Duke South Bay Power Plants), and 316(b) Demonstrations (such as at the PG&E Diablo Canyon and NRG Encina Power Plants). All of these studies were performed with input from technical working groups, comprised of representatives from the project applicants, the California Regional Water Quality Control Board (RWQCB), 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:

- An agreement to identify and enumerate all fish eggs (to the extent practicable) from entrainment samples; and
- An agreement to identify and enumerate all crab megalopae (to the extent practicable) 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 HGS IM&E Characterization Study, and determine the fish and shellfish species that would be assessed in the IM&E 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 HGS 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 were calculated for all species, and no additional modeling was proposed.

2.1.3 Study Plan Objectives

Under the suspended §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 suspended Phase II §316(b) regulations provided the 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 was based on a given technology, restoration or site-specific standards, the level of detail in terms of the quantification of the baseline could be tailored to the compliance alternative selected and did not have to address all species and life stages. Logically it could 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 HnGS required under the suspended Phase II regulations. The calculation baseline is defined in the suspended 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-inch 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 HGS CWIS does not conform to the calculation baseline. Significant deviations from the calculation baseline are:

- The intake is submerged, rather than at or near the surface;
- The traveling screens are located more than 305 meters (m) (1,000 feet [ft]) from the shoreline rather than at the shoreline; and

The suspended Phase II regulations allow facilities to request that the calculation baseline be modified due to deviations from the calculation baseline if it can be demonstrated that these deviations provide reduced levels of IM&E. After the calculation baseline has been determined, then potential credits from the calculation baseline could be requested. A potential credit is the use of closed-cycle cooling for Units 10-14. 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 is to provide data that can be used in meeting different alternatives for 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 HGS were designed to examine losses resulting from both impingement of juvenile and adult fish and shellfishes on traveling screens at the intake during normal operations and from entrainment of larval fishes and shellfishes into the CWIS. The sampling methodologies and analysis techniques were designed to collect the data necessary for compliance with the suspended §316(b) Phase II Final Rule and were similar to recent impingement and entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera 2007). The studies at Huntington Beach were performed as part of the California Energy Commission California Environmental Quality Act (CEQA) process for permitting power plant modernization projects, while the

South Bay and Encina projects were for §316(b) compliance. The study plans for these projects were subject to review by state and federal resource agency staff and independent scientists from various environmental organizations.

The impingement sampling methods used in the study are similar to the National Pollutant Discharge Elimination System (NPDES) monitoring program, conducted at the HGS since 2003. The existing NPDES permit for the plant requires impingement sampling semiannually during heat treatments. However, since heat treatments are not conducted at the HGS, NPDES samples were collected during periods of normal operations. The sampling frequency for the IM&E characterization study was increased to weekly to capture 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 suspended §316(b) regulations. If the use of restoration had not been disallowed as a result of the court decision, the entrainment data would have been used in baseline calculations of losses that would be required to estimate the commercial and recreational values of adult fish losses in a cost benefit analysis of various technology and operational alternatives being considered to comply with required reductions in entrainment mortality. Larval fish and shellfish abundances can vary greatly through the year and therefore biweekly sampling was used for characterizing entrainment. If the restoration option had been upheld in the Second Circuit Court decision, models of the conditional mortality due to entrainment could have been 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 HGS 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 provides 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 HGS 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 Quality Assurance/Quality Control (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 entry and analysis.

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

3.1 DESCRIPTION OF THE GENERATING STATION

The Harbor Generating Station (HGS) is located in the city of Wilmington, CA (Figure 3.1-1). The total plant output is 450 megawatts (MW) with Units 1 and 2 rated at 80 MW each, Unit 5 at 75 MW, and Units 10–14 each at 43 MW. Units 1 and 2 are natural gas-fired combustion turbines with a heat recovery steam generator (combined-cycle with one steam turbine, Unit 5). Units 10-14 are natural gas-fired combustion turbines equipped with cooling towers. Only Unit 5 requires circulating water from the harbor as the other units utilize alternative cooling methods. Two circulating water pumps provide a total of 408,824 m^3 per day (108 mgd; 75,000 gpm) of cooling water for Unit 5 at full load. In addition, a 38,157 m^3 per day (10.1 mgd; 7,000 gpm) auxiliary pump is operated intermittently that also utilizes seawater from the same CWIS. Ocean water for cooling purposes for Unit 5 is conveyed to the generating station from the northwest corner of Slip 5 in the ILAH. Water flows from a curtain wall intake structure (17 m wide by 3 m high, [56 ft by 10 ft]) in the bulkhead of the harbor through two 2.4 m (8 ft) diameter closed conduits approximately 335 m (1,100 ft) to the screen and pump chamber at HGS. After passing through the condensers, the cooling water is discharged into a two-sided chamber running the length of the generating station. From this chamber, the water is conveyed through two 2.4 m (8 ft) diameter underground conduits approximately 490 m (1,600 ft) to a submerged, multi-port discharge structure located in the pier-head in the northeast corner of West Basin of ILAH.

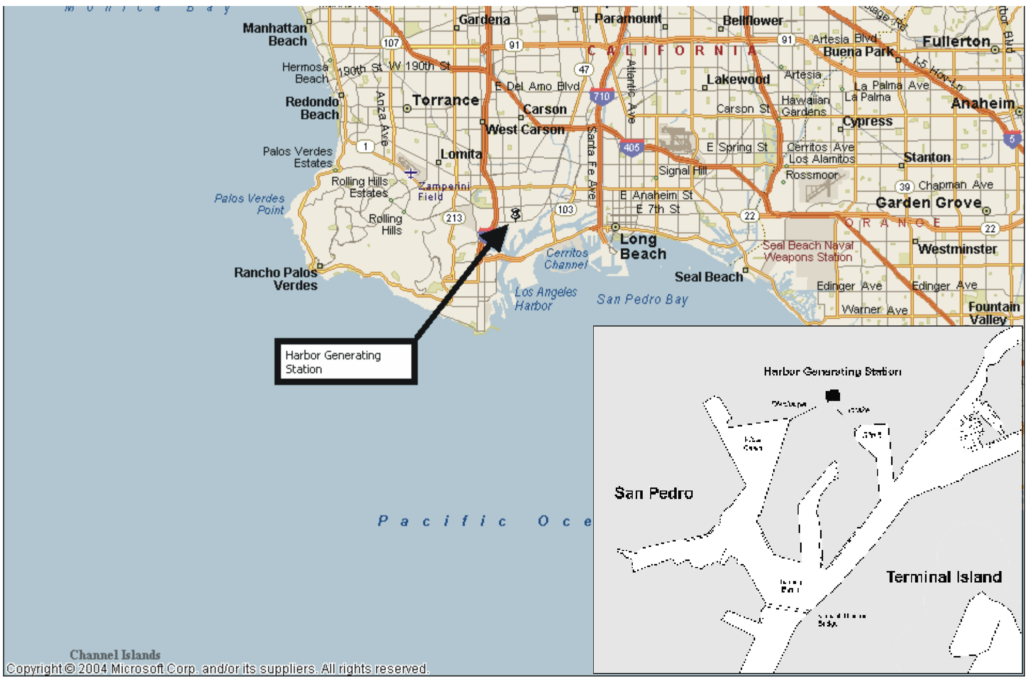


Figure 3.1-1. Location of the LADWP Harbor Generating Station (HGS).

3.2 DESCRIPTION OF THE COOLING WATER INTAKE SYSTEM

Cooling water for Unit 5 is withdrawn from the ILAH through an intake structure located in the northwest corner of Slip 5 (Figures 3.2-1 and 3.2-2). The mean water depth in front of the intake is 11 m (35 ft) mean lower low water (MLLW) level. The Unit 5 CWIS is equipped with six vertical bar racks to deflect large debris (Figure 3.2-3). The bar racks are 0.95 cm by 7.6 cm (3/8 in by 3 in) bars spaced 11.4 cm (4.5 in) on center. Cleaning of the bar racks is done on a weekly basis or as needed. The screenhouse is located onshore, and connected to the intake structure by two 2.4 m (8 ft) internal diameter pipes, each 333.8 m (1,095 ft) long (Figure 3.2-4). The screenhouse has six screenbays; however, there is no flow in four of the screenbays as they are blocked with stop logs. The other two screenbays are equipped with functioning traveling water screens. Two of the blocked screenbays are equipped with spare traveling water screens.

The screenbays are approximately 2.4 m (7.9 ft) wide, with the bottom at elevation[1] (El.) –4.9 m (-16.0 ft). The top of the intake pipes are at El. –2.4 m (–8.0 ft) when they enter the screenhouse. The traveling water screen is located about 10.2 m (33.5 ft) downstream from where the intake pipes enter the screenhouse. The screens are 1.9 m (6.2 ft) wide and extend from the bottom of the screenhouse to the top deck. The mesh size on the screen baskets ranges from 9.5 mm to 15.9 mm (3/8 in to 5/8 in). The two operating screens are rotated once for 30 minutes during every 8-hour shift. A backwash system providing up to 3.0 m^3 per minute (800 gpm) of cleaning water at 70 pounds per square inch gauge is used to remove debris from the screens. Fish and debris removed from the screens are collected in a rectangular sump for disposal.

Circulating water to Unit 5 is provided by two single-stage vertical mixed-flow pumps. The inlet of these pumps is at El. –4.4 m (–14.5 ft). Each of the pumps is rated at 142 m^3 per minute (37,500 gpm). Chlorine is added to the pump suctions to prevent biofouling in the condenser system. After passing through the condensers, warmed cooling water flows through a 424.6 m (1,393 ft) long pipe to the discharge structure in ILAH’s West Basin. The location and setup of the discharge canal prevents discharged water from re-circulating into the intake.

[1] All elevations refer to mean sea level which is 0.86 m (2.82 ft) above the Mean Lower Low Water (MLLW) zero tide level.

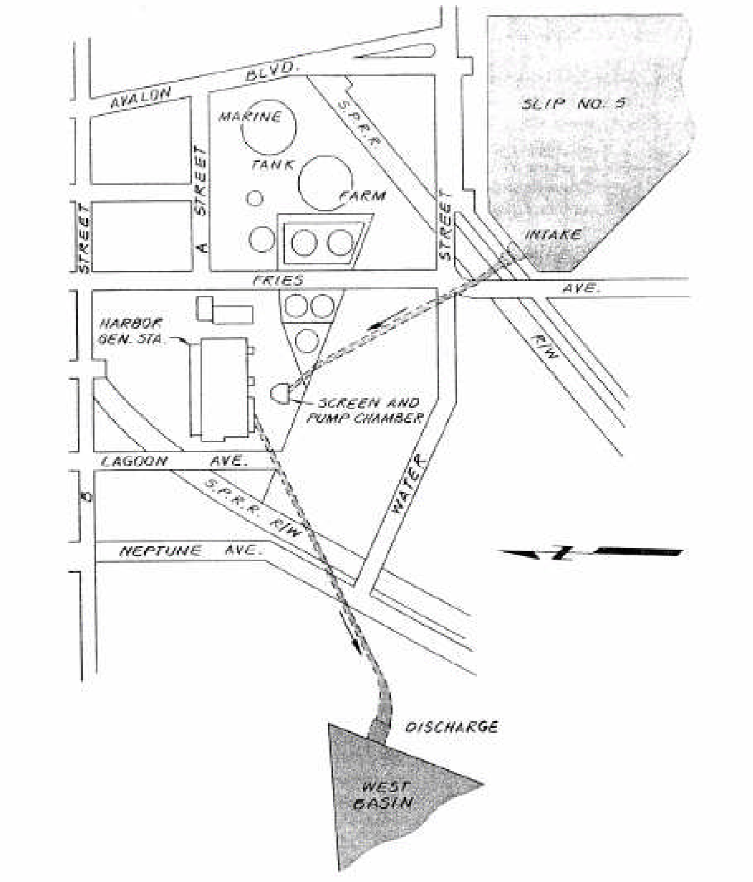
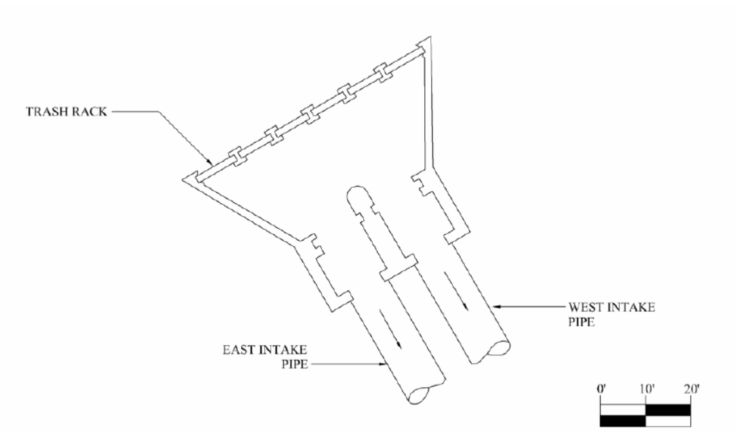
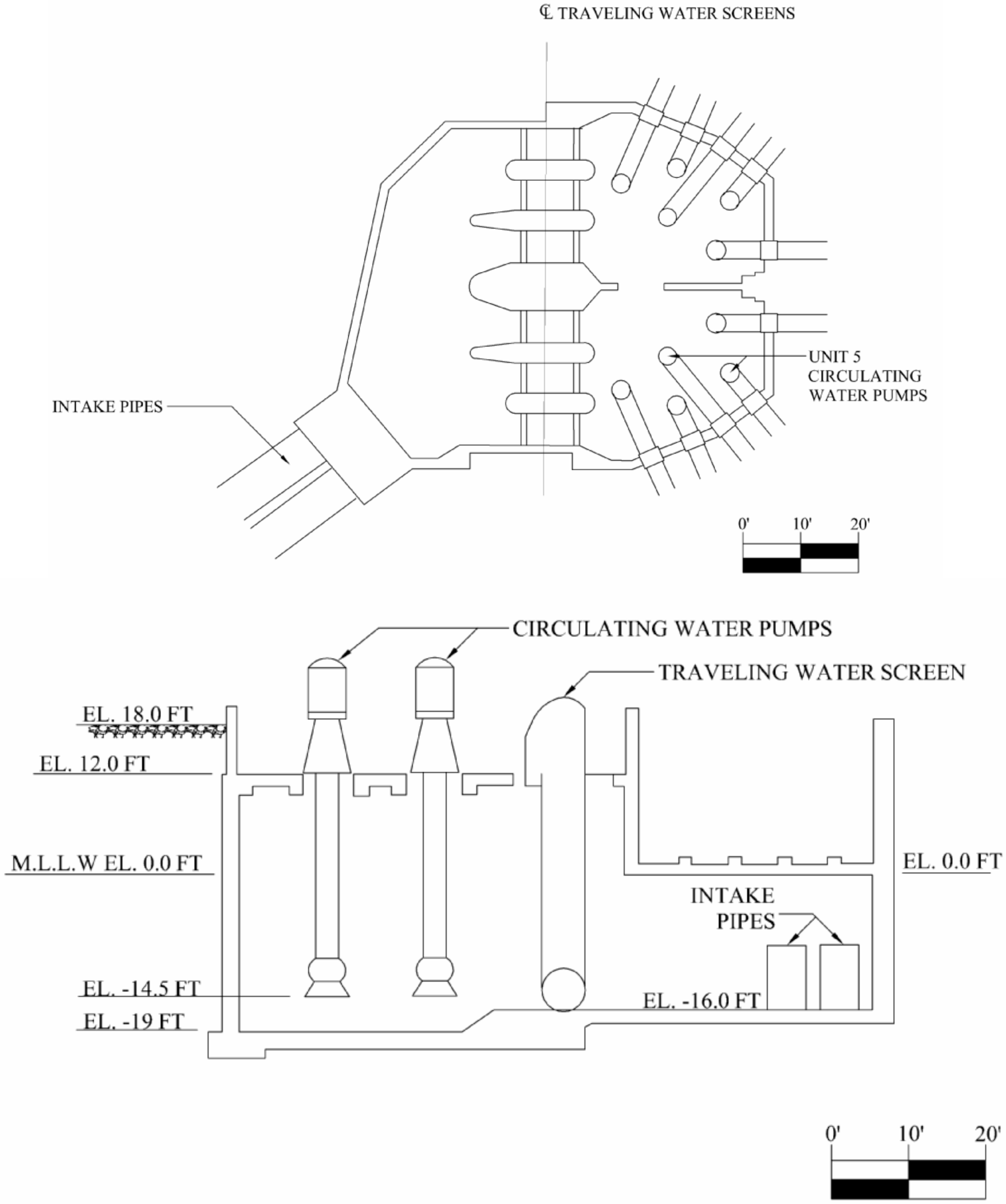


Figure 3.2-1. General configuration of LADWP HGS.



Note that all measurements in drawing are in feet and do not include metric conversions.

Figure 3.2-2. Diagram of HGS intake structure at Slip 5 in ILAH.



Note that all measurements in drawing are in feet and do not include metric conversions.

Figure 3.2-3. Plan view and cross section of HGS intake screenhouse.

3.2.1 Circulating Water Pump Flows

The HGS CWIS withdraws a maximum of 363,356 m^3 per day (96.0 mgd) of cooling water from the ILAH. Velocities inside the circulating water system were calculated using the previous design flow of the facility (408,780 m^3 per day, or 108.0 mgd), flow through two screenbays, and the water level at MLLW. The water velocity at the trash racks was calculated to be 0.09 meters per second (m/s), or 0.3 ft/s, velocity in the intake pipes was calculated to be 0.5 m/s (1.7 ft/s), and at a location just prior to traveling screens was calculated to be 0.1 m/s (0.4 ft/s). A conservative estimate of the through-screen velocity would be 0.2 m/s (0.8 ft/s), or twice the screen approach velocity. Intake structure characteristics, formulas, and velocity calculations for HGS are provided in Appendix B of the HGS PIC.

Daily cooling water flow volumes at the HGS from January 2006 to January 2007 are shown in Figure 3.2-4. Highest flows generally occurred in late spring and summer, although there was substantial variation throughout the year. One of the two circulating water pumps was always in operation, except for the outage at the end of April and again after completion of the study in January 2007. Lowest flows generally occurred during the first three months of 2006. Daily cooling flow in 2006 averaged 185,296 m^3 per day (49.0 mgd), or about 51% of maximum design flow of 363,356 m^3 per day (96.0 mgd).

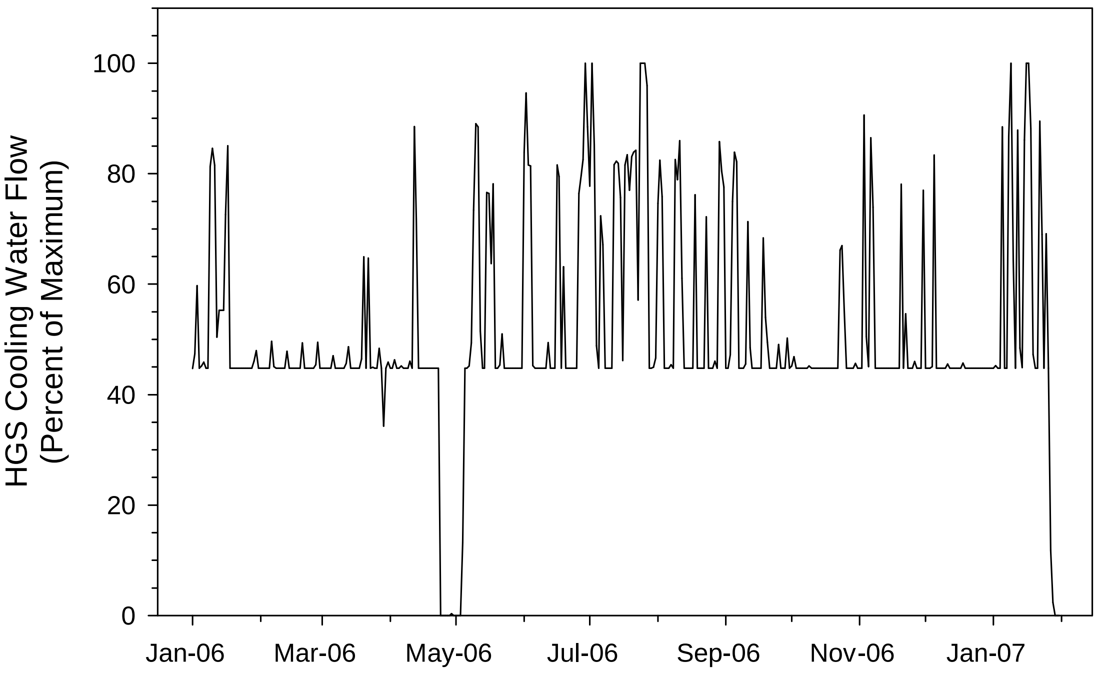


Figure 3.2-4. Daily cooling water flow volumes at the HGS from January 2006 through January 2007.

3.3 ENVIRONMENTAL SETTING

The following section describes the physical and biological environments in the vicinity of the HGS. The HGS withdraws cooling water from the ILAH, which is hydraulically connected to Long Beach Harbor and San Pedro Bay. Cooling water is discharged into the West Basin of the ILAH.

3.3.1 Physical Description

The harbor complex was historically an estuary formed at the mouth of the San Gabriel and Los Angeles Rivers with extensive mudflats and marsh areas (Figure 3.3-1). The natural mudflats and marshlands provided habitat for birds, fish, and invertebrates, and the barrier beach of Rattlesnake Island (now Terminal Island) served as nesting habitat for terns and shorebirds. Urbanization and development led to the construction and modifications associated with the Los Angeles-Long Beach Harbor complex. Dredging, filling, channelization, and construction over the past 100 years has completely altered the local estuarine physiography. The Los Angeles River course and the harbor area are no longer true estuaries because they do not maintain significant year-round fresh water input, and the biota are not distributed along salinity gradients as in most estuarine systems.

The habitats available for plants and animals have also changed as a result of harbor modifications. Very little sandy beach and shallow subtidal habitats remain, and salt marsh habitat is essentially absent within the harbor. Dredge and fill activities have resulted in changes to the benthic (bottom) habitat. The placement of shoreline structures, such as bulkheads, riprap, and pier pilings, has greatly increased the hard substrate available for fouling organisms, including mussels and barnacles. The construction of the breakwaters greatly affected water movement patterns within the harbors, which in turn affected overall circulation and water quality.

Figure 3.3-1. Aerial view (looking south) of Harbor Generating Station and the vicinity of Los Angeles and Long Beach Harbors.

3.3.1.1 Physical Features

The Los Angeles-Long Beach Harbor Complex consists of inner, middle, and outer harbors. Just north of the breakwaters, the outer harbors consist of deeper, open water habitat, and channels that lead to basins and slips in the middle and inner harbors. The channels, basins, and slips vary in size and distance from the harbor entrances. In Los Angeles Harbor, the channels were recently dredged to -16.2 m (-53 ft).

During the mid-1900s, three breakwaters (i.e., San Pedro, Middle, and Long Beach) were constructed to protect the harbors from damaging wave action. From that point on, the development of the harbor has continued with a series of dredge and fill operations to deepen channels and accommodate deep draft vessels, and provide fill for additional shoreline areas necessary for terminal development.

3.3.1.1.1 Climate and Weather

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

A subtropical high-pressure system offshore the Southern California Bight (defined as the nearshore coastal region from Point Conception south into Baja California) 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 kilometers (km) per hour (6.2 miles per hour). 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 and fall, but can occur any time of year.

3.3.1.2 Temperature and Salinity

Waters within the Harbor Complex are primarily marine, though there are fresh water inputs from regulated discharges, urban runoff, and Dominguez Channel, which enters Los Angeles Harbor approximately three kilometers northeast of the HGS intake. Results of recent water quality studies within the ILAH (near the HGS intake structure) indicated water temperatures averaged 16° to 18°C (61° to 64°F), dissolved oxygen averaged 6 to 7 mg/l, pH averaged 7.9, salinity averaged 32.7 to 33.4 parts per thousand (ppt), and light transmission averaged 64 to 68% (MEC 2002). In winter 2006, temperatures in West Basin (Los Angeles Harbor) ranged from 13.4 to 15.2°C (56 to 59°F) throughout the water column. In summer 2006, temperatures were between 17.9 and 24.7°C (64 and 76°F) in West Basin. Salinity ranged between 27.3 and 33.1 practical salinity units (psu) in winter and 33.3 and 33.9 psu in summer, and generally increased with depth (MBC 2007a).

3.3.1.3 Tides and Currents

Tides in southern California are classified as mixed, semi-diurnal, with two unequal high tides (high water and higher high water) and two unequal low tides (low water and lower low water) each lunar day (approximately 24.5 hr). Between 1997 and 2002, water level extremes in Outer Los Angeles Harbor ranged from -0.6 m to +2.35 m (-1.97 ft to + 7.71 ft) above MLLW.

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

Maximum flood and ebb current patterns in the Ports of Los Angeles and Long Beach under typical tidal conditions are shown on Figure 3.3-2. The tidal currents shown on the figures were predicted by a depth-averaged two-dimensional hydrodynamic model, RMA2, developed by the U.S. Army Corps of

Engineers (USACE). The model was calibrated against field data collected by the National Oceanic and Atmospheric Administration (NOAA) at the Port of Long Beach, as well as against a more sophisticated three-dimensional model. On the Long Beach side nearest Alamitos Bay, flood currents enter the harbor through the Queen’s Gate, as well as the opening near the eastern tip of the Federal Breakwall. Flood currents passing through Queen’s Gate flow to either side of Pier J.

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

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 HGS cooling water intake, and 2) be representative of the nearshore habitats in the vicinity of the HGS intake.

3.3.2.1 Study Requirements and Rationale

The primary approach for assessing the effects of entrainment by the HGS 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. Information on circulation within the Los Angeles Harbor Complex (“Harbor Complex”) was collected from several sources (McGehee et al. 1989a; McGehee et al. 1989b; Vemulakonda and Butler 1990; Vemulakonda et al. 1991; Seabergh et al. 1994; Moffatt & Nichol and Reed Int. 2001; USACE 1992; LACSTF 2005) during the initial phases of the study to determine the need for additional current meter data to determine the extent of the source water. The following points summarize the information on currents in the ILAH from the sources reviewed:

- Currents in the Harbor Complex are primarily driven by tides and to a lesser extent by winds.
- Tidal circulation in the Harbor Complex is far more important than any weak vertical circulation associated with salinity stratification and inflow effects. Currents are stronger in the outer harbor than in the Harbor Complex.
- Tidal dispersion is likely a major avenue for transport of planktonic larvae when the net current flow is slight.

This information was used to determine that a reasonable estimate of the source water was possible using existing bathymetry, current meter and model data to characterize the general current and circulation patterns in the vicinity of HGS and Harbor Complex. Due to the low current velocities and highly variable currents within the Harbor Complex, a more accurate estimate of the source populations would require current measurements at multiple locations combined with the use of a numerical model or analysis of tidal dispersion.

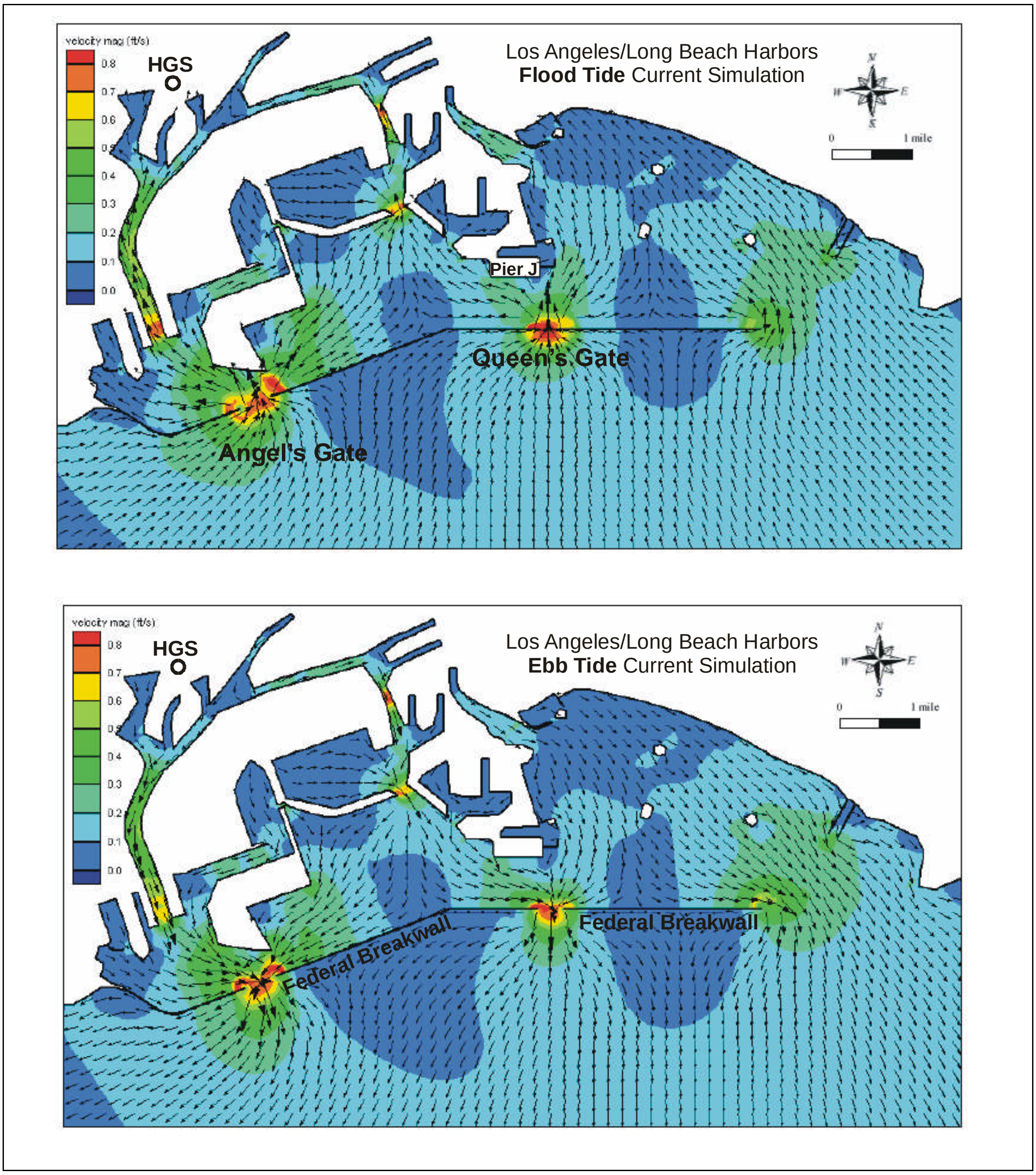


Figure 3.3-2. Current patterns in Los Angeles and Long Beach Harbors predicted by a depth-averaged two-dimensional hydrodynamic model developed by the USACE.

Because the limits of larval transport may primarily result from mechanisms other than currents (e.g., tidal dispersion), a first-order analysis appears sufficient for defining source water inside the breakwaters. There is slight net circulation through the U-channel comprised of the Los Angeles Main Channel, East Basin Channel, Cerritos Channel, and Long Beach Channel. Net plankton transport into the Slip 5 region of the HGS intake thus occurs mainly by dispersive processes combined locally with HGS CWIS water withdrawals. The distance from the outer harbor breakwaters to HGS is 6.4–8.0 km (4–5 mi) depending on the direction, east or west. About half of that distance is restricted to smaller width inner harbor channels.

The first order analysis justifies the use of the outer breakwater as the source water boundary. If only advection were considered, a typical larval duration of 30 days would require an advection-only net circulation of 3.0 mm per second (0.01 ft/s) to reach HGS from the outer breakwaters. Vemulakonda et al. (1991) concluded that the magnitude of net circulation is rather slight to static and most likely clockwise. Modeling done for the Harbor Complex by Moffatt & Nichol and Reed International (2001) also showed clockwise circulation. The data from Vemulakonda et al. (1991) showed that net velocity was very low, 0.5 mm per second (0.00174 ft/s), and at that rate it would take 175 days to reach HGS from the San Pedro breakwater. However, if other processes are included, the transport duration is lessened considerably. In additional to shear flow dispersion, Fischer et al. (1979) suggested that tidal pumping and tidal trapping can be important transport mechanisms. Jay and Largier (2004) also describe tidal pumping as important determinants in a study to determine the source volume at South Bay Power Plant in San Diego Bay. For example, based on data from Fischer et al. (1979) shear flow effects may increase the estimated speed of larval dispersion, lessening time to travel the distance along the Main Channel and Slip 5 considerably. Dispersion coefficients in estuaries such as San Diego Bay are typically much higher. Other constituents of tidal dispersion such as those due to curvature were considered there. Therefore, tidal transport of larvae would occur quickly in the stronger outer harbor currents and other processes would add to net advection in the inner channels

In summary, there is sufficient information available to define the boundaries of the source water for the HGS as the waters of the Harbor Complex that are enclosed by the San Pedro Breakwater and Middle Breakwater, including an imaginary line extending from the easternmost edge of the Middle Breakwater to the southeast corner of Pier J (Figure 3.3-3).. The past 316(b) study (IRC 1981) concluded that the ILAH is the primary source of cooling water for the plant and that the waters of the outer harbor, and even the waters of San Pedro Bay, exchange water with the inner harbor over a time scale of weeks. This time period is consistent with the upper limits of larval durations for the species that were collected during both this and the previous 316(b) studies.

3.3.2.2 Methods for Calculating HGS Source Water

All of the depths and elevations used for determining source water volumes and planimetric surface areas for the Harbor Complex were relative to mean sea level (MSL) as measured at the tide gauge at Station 9410660 Los Angeles, CA. A coastline Geographic Information System (GIS) layer of the source water was created from a U.S. Geological Survey (USGS) topographic chart at 1:24,000 scale and manually edited in ArcGIS to approximate the available NOAA GIS coastline themes and latest aerial images from Google Earth (March 2004) due to the new construction and landfill areas that were not present on the

USGS coastline. This coastline GIS layer was used for representing the elevations relative to MSL for creating a surface grid that was subsequently used to calculate areas and volumes.

Depth and elevations were derived from NOAA navigation data that included coverage for all of the harbor and surrounding ENC Charts. Electronic Navigation Chart (ENC) Coastline information and ENC Sounding depths were used for Harbor Complex bathymetry. The NOAA data were derived from a combination of charted information, as well as original 'source' information. NOAA used a number of sources in compiling this dataset including USACE surveys, drawings, and permits, U.S. Coast Guard Local Notices to Mariner, National Imagery and Mapping Agency Notices to Mariners, NOAA hydrographic surveys, and the largest scale paper chart of an area.

Depth data points were identified and selected from all the source datasets that fell within the water portions of the source water regions for Harbor Complex. MLLW depths were adjusted to MSL (shallower by 0.86 m [2.82 ft] per the tide gauge at Station 9410660 Los Angeles, CA). The corrected depth data was then merged and exported to a new depth point GIS layer relative to MSL. A 20 m (65.6 ft) surface grid representing the bathymetry relative to MSL was constructed from this new set of combined points and contours constructed at 1.0 m (3.3 ft) intervals. This new grid was converted into a polygon shapefile for area and volume calculations. An assumption made was that the depths in the channels adjacent at the shoreline were deeper than MSL as a result of channelization for vessel traffic. The resulting bathymetry surface grids were then clipped by the coastline of the source water boundary and used for the area and volume calculations. The final calculations identified a source water volume of 431,694,503 m^3.

3.3.3 Biological Resources

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

3.3.3.1 Habitat Variation

The habitats available for plants and animals within Los Angeles and Long Beach Harbors have changed through time as a result of harbor modifications. Very little sandy beach and shallow subtidal habitats remain, and salt marsh habitat is essentially absent within the harbor. Dredge and fill activities have resulted in changes to the benthic (bottom) habitat. Giant kelp (*Macrocystis pyrifera*) grows along the breakwaters, and eelgrass (*Zostera marina*) occurs in a few places in Los Angeles Harbor (Cabrillo and Pier 300). The placement of shoreline structures, such as bulkheads, riprap, and pier pilings, has greatly increased the hard substrate available for fouling organisms, including mussels and barnacles. A photograph of the HGS intake structure is presented in Figure 3.3-4. The construction of the breakwaters greatly affected water movement patterns within the harbors, which in turn affected overall circulation and water quality.

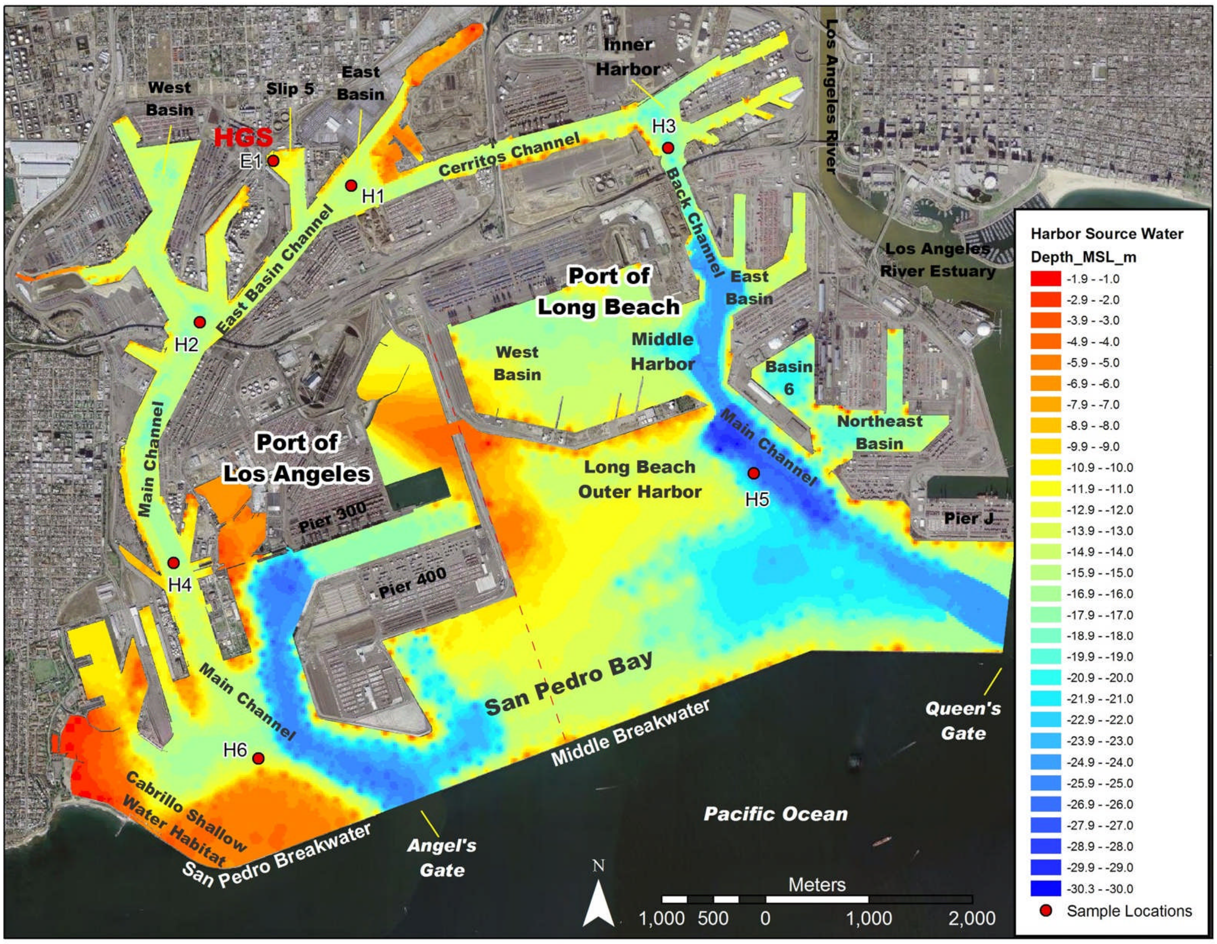


Figure 3.3-3. HGS source water boundaries and bathymetry.

Figure 3.3-4. HGS intake structure near East Basin Channel in Inner Los Angeles Harbor.

3.3.3.2 Nursery Grounds

The role as a nursery grounds for juveniles of coastal fish species is probably the most widely recognized and accepted function of bays and estuaries in their status as important fish habitats (Allen et al. 2006). In southern California, harbors provide nearshore habitats that supplement, but do not adequately replace, the habitats of natural bays and estuaries (Cross and Allen 1993). The subtidal areas of Los Angeles and Long Beach Harbors provide several habitat types that support a diverse and abundant fish community. Due to its physiography and biological assemblages, the harbor complex is also considered a nursery for several fish species. MEC (2002) found that juvenile white croaker (*Genyonemus lineatus*) prefer deepwater basins and slips within the harbor complex, although a greater variety of fish use the shallow waters of the harbors as nursery grounds, such as bat rays (*Myliobatis californica*), California halibut (*Paralichthys californicus*), diamond turbot (*Pleuronichthys guttulatus*), queenfish (*Seriphus politus*), and topsmelt (*Atherinops affinis*).

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

3.3.3.3 Fish Diversity

The 2000 Biological Baseline Study (MEC 2002), as well as long-term monitoring data from the West Basin (MBC 2007a) where the discharge for the plant is located, documented a fish community that appears to have changed little in decades. The 2000 surveys of MEC (2002) used several gear types to adequately characterize different habitat types within the harbor complex. The long-term trawl surveys in West Basin used otter trawls, which target demersal (epibenthic) fish (MBC 2007a). In various biological studies, more than 130 fish species have been collected within the harbor complex, with 60 to 70 of those species commonly occurring (MEC 1988).

MEC (2002) found little variability in the abundance of pelagic, schooling fishes, between the inner and outer harbor areas. In contrast, deepwater habitats of the outer and middle harbors generally had greater number, biomass, and diversity of demersal fishes than inner harbor areas. However, species diversity was generally consistent throughout the year. In 2000, a total of 76 taxa, representing 74 unique species, was collected from the harbor complex using a combination of gear types designed to capture demersal, pelagic, and schooling fishes. Non-indigenous species comprised about 15% of the invertebrate species that inhabit the harbor complex.

Long-term surveys of demersal fishes and invertebrates have been conducted in the West Basin area near the HGS discharge (MBC 2007a). At least 38 species of fishes have been collected since 1978, although only about 14 species are collected annually. Abundance has been dominated by white croaker, northern anchovy (*Engraulis mordax*), queenfish, and bay goby (*Lepidogobius lepidus*), which combined account for 95% of the long-term abundance from the trawls. In 2006, abundance in summer was similar to that in winter, and species richness was the same between surveys. The most abundant fish species collected in 2006 included white croaker, specklefin midshipman (*Porichthys myriaster*), California tonguefish, and yellowchin sculpin (*Icelinus quadriseriatus*). White croaker was the most abundant species during both seasons.

A similar trawl program has been conducted in Long Beach Harbor, near the Long Beach Generating Station discharge (MBC 2007b). At least 54 species of fish have been collected since 1980, although about 18 species are collected during each seasonal survey. Abundance has been dominated by white croaker, northern anchovy, bay goby, and queenfish, which combined account for 94% of the long-term abundance. In 2006, abundance in summer was substantially greater than that in winter, and species richness was similar between surveys (19 species in winter and 21 in summer). The most abundant fish species collected in 2006 included white croaker, yellowchin sculpin, specklefin midshipman, and California tonguefish. In general, fish abundance is usually higher near the outer harbor in winter, and in the inner harbor in summer, while species richness is generally highest in the inner harbor.

In 2000, 49 taxa representing 44 unique species of fish larvae and 13 categories of fish eggs were collected from the harbor complex (MEC 2002). The most abundant fish larvae was Goby type A (arrow, cheekspot, and shadow gobies [C*levelandia ios*, *Ilypnus gilberti*, and *Quietula y-cauda*]), which represented 33% of the total number of larvae collected. Other abundant taxa included bay goby (16%), northern anchovy (14%), California clingfish (*Gobiesox rhessodon*) (13%), queenfish (10%), combtooth blennies (*Hypsoblennius* spp.) (5%), and white croaker (5%). The most dominant taxa from fish eggs were unidentifiable eggs (57%), which likely included large numbers of California halibut eggs and sciaenid (croaker) eggs (35%). Larval abundance was generally higher in Long Beach Harbor than Los Angeles Harbor, which followed a similar pattern for adult fish caught in lampara nets. Sciaenid eggs were generally more abundant in deepwater areas. Unidentified goby larvae were more abundant in shallow areas, while bay gobies were collected in higher abundance at deepwater stations, as were most flatfishes. Larval abundance was significantly higher in spring and summer, while peak egg abundance occurred in winter.

3.3.3.4 Shellfish Diversity

Since 1978, a total of 5,811 macroinvertebrates representing 57 taxa have been collected in demersal fish and invertebrate surveys in the West Basin area of the ILAH near the HGS discharge (MBC 2007a). The most abundant macroinvertebrates were blackspotted bay shrimp (*Crangon nigromaculata*; 48% of total abundance), tuberculate pear crab (*Pyromaia tuberculata*; 5%), New Zealand snail (*Philine auriformis*; 2%), and yellow crab (*Cancer anthonyi*; less than 1 percent). In 2006, blackspotted bay shrimp and tuberculate pear crab comprised 92% of the annual trawl catch; both were more abundant in summer than in winter. In the Back Channel of Long Beach Harbor, blackspotted bay shrimp comprised 78% of the trawl-caught abundance in 32 surveys between 1980 and 2006 (MBC 2007b). Blackspotted bay shrimp and New Zealand snail comprised 11% and 3% of the total abundance, respectively.

During the biological baseline surveys of 2000, a total of 63 epibenthic macroinvertebrate taxa representing 61 unique species were collected throughout the harbor complex (MEC 2002). Five species comprised 95% of total abundance: blackspotted bay shrimp (51%), tuberculate pear crab (28%), Xantus swimming crab (*Portunus xantusii*; 10%), New Zealand snail (5%), and spotwrist hermit crab (*Pagurus spilocarpus*; 1 percent). On average, mean abundance was higher at deep-water stations than at shallow stations, and abundance and species richness were significantly greater in winter (February) than any other season.

3.3.3.5 Protected Species

Some fish and invertebrate species (e.g., 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 HGS and that have planktonic larvae potentially at risk of entrainment include garibaldi (*Hypsypops rubicundus*), tidewater goby (*Eucyclogobius newberryi*), and California grunion (*Leuresthes tenuis*).

Garibaldi, designated as the California state marine fish, is a bright orange shallow-water species that is relatively common around natural and artificial rock reefs in southern California. Because of its territorial behavior it is an easy target for fishers and could be significantly depleted if not protected. Garibaldi spawn from March through October, and the female deposits demersal adhesive eggs in a nest that may contain up to 190,000 eggs deposited by several females (Fitch and Lavenberg 1975). Larval duration ranges from 18–22 days (mean of 20 days) based on daily incremental marks on otoliths in recently settled individuals (Wellington and Victor 1989). The larvae are susceptible to entrainment, particularly in summer months when spawning is at its peak.

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

California grunion is a species with special status not because the population is threatened or endangered, but because their spring-summer spawning activities on southern California beaches puts them at risk of 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 to 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 incorporated two design elements: 1) CWIS sampling, and 2) source water sampling. Sampling at the intake provided estimates of the total numbers of each larval species entrained through the CWIS on a biweekly basis depending on pumping capacity. The source water populations of fish and shellfish larvae were sampled to estimate proportional entrainment losses for selected species. Abundances of larval fishes and shellfishes vary throughout the year due to changes in composition and the oceanographic environment. Because it is desirable from an impact modeling standpoint to have a higher resolution of temporal changes in the composition of entrained taxa than source water taxa, entrainment sampling was conducted bi-weekly while source water sampling was conducted monthly. The monthly source water sampling frequency was consistent with other recently completed entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera 2007).

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

- What are the species composition and abundance of the larval fishes, fish eggs, crab megalops, and spiny lobster larvae entrained by HGS?
- What are the local species composition and abundance of the entrainable larval fishes, fish eggs, crab megalops, and spiny lobster larvae in the ILAH and other areas of the Harbor Complex (source water)?
- 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 traveling screen system mesh 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 (‘shellfish’) species including all crabs, market squid (*Loligo opalescens*), and California spiny lobster (*Panulirus interruptus*). None of the holoplanktonic forms (such as copepods) were enumerated because these populations are typically widespread, the species have short generation times, and the small population-level impacts are difficult to accurately estimate. All target taxa in the samples were identified to the lowest practical taxonomic level, but some specimens were combined into broader taxonomic groups because the morphological characteristics of some species are not distinct at smaller stages, descriptions are lacking for some of the larvae (particularly for many of the crab megalops), or specimens were damaged and could not be positively identified. Although all target taxa specimens were enumerated in the samples, including uncommon species and those with no direct fishery value, detailed impact analysis was only done for a few of the more abundant species or species-groups, in addition to the specific shellfish taxa (e.g., spiny lobsters, market squid) regardless of abundance.

4.1.1.1 Fishes

Many of the marine fishes in the vicinity of the CWIS have free-floating larvae, with the notable exception being 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 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 lobsters, 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 descriptions of their complete larval development, which makes accurate identifications problematical and increases the uncertainty associated with the impact analyses since they are based on broad taxonomic groupings. 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 managed 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 over 12,000 larvae collected during the entrainment surveys. At the January 30 meeting, NMFS agreed that demographic or *ETM* calculations would only be done for these species if they were collected in sufficient abundance in entrainment and source water samples, and if sufficient life history information was available to permit those calculations. Of five taxa on the list, only anchovies were in sufficient abundance at HGS to justify a more detailed analysis of potential IM&E impacts.

4.2 HISTORICAL DATA

4.2.1 Summary of Historical Data

The entrainment sampling program at HGS 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 (EPA 1977). These taxa were defined as those that supported fisheries, provided significant habitat to aquatic communities, or constituted 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.

Zooplankton densities, including fish eggs and larvae, were measured bi-weekly at an entrainment station, and two source water stations: a near-field and a far-field station (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 far-field station was located in outer Los Angeles Harbor and the near-field station was in the north end of Slip 5 near the HGS intake structure. The entrainment station was located at the west end of Slip 5 in front of the HGS intake structure.

Table 4.2-1 summarizes the entrainment densities of critical taxa recorded at the entrainment station over the 12-month study. The mean cooling water flow rate at the generating station during sampling varied from 200,605 to 1,502,645 m^3 per day (53 to 397 mgd), with a total annual flow of approximately 327,977,820 m^3 (86.652 billion gallons [gal]). Gobies had the greatest concentrations in the entrainment samples with densities averaging 4,700 larvae per 1,000 m^3 (264,000 gallons). This translated to an annual entrainment mortality of 520 million larvae. Entrainment estimates for all of the critical taxa combined was approximately 700 million larvae annually, including relatively small numbers of queenfish and diamond turbot.

Fish eggs were enumerated for three taxa: *Engraulis mordax* (northern anchovy), *Anchoa* spp. (bay anchovies), and the Sciaenid (croaker) species complex (Table 4.2-1). Both *Engraulis mordax* and *Anchoa* spp. eggs were relatively scarce in samples compared to densities of Sciaenid species complex eggs. Croaker complex egg entrainment was estimated at 390 million eggs annually, while anchovy eggs were too infrequent in the samples to calculate a reasonable estimate of annual entrainment.

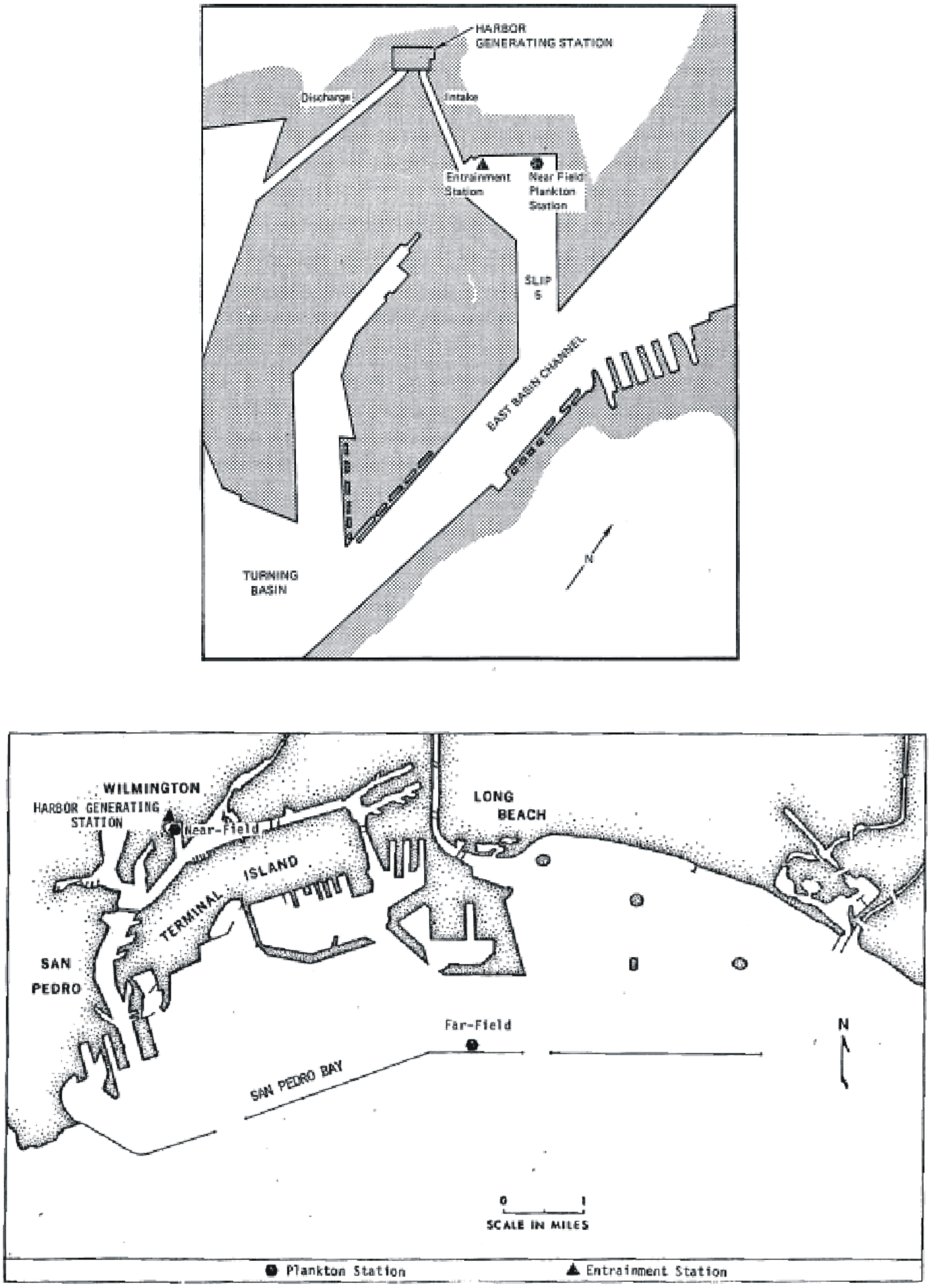


Figure 4.2-1. Locations of entrainment and near-field (top) and far-field (bottom) plankton sampling stations in IRC (1981) study of HGS.

Non-critical fish larvae were identified and enumerated to provide additional information about the ichthyoplankton community, but these data were not statistically analyzed. The non-critical taxa included Atherinopsidae species complex, *Pleuronichthys* spp. Sciaenidae unid. complex, and total unidentified teleost larvae. Unidentified teleost larvae occurred in samples from 56% of the day surveys and 64% of the night surveys. Maximum larval concentrations were observed for the period between mid-December and mid-June and lowest values were observed from summer through mid-winter. Mean concentrations varied from 0–130 larvae per 1,000 m^3 (264,000 gal) for the day surveys and from 0–1,000 larvae per 1,000 m^3 (264,000 gal) for the night surveys. Unidentified teleost larvae occurred with greater frequency and at greater concentrations at night.

Estimates of larval concentrations were also calculated for several 'critical' planktonic invertebrate taxa, including three species of mysid shrimps, larval rock crab, larval ghost shrimp, and the adults and larvae of one taxon of copepod. *Acartia* spp. copepodites (larval stage) were the most abundant of the critical taxa and were present year-round. These seven taxa accounted for estimated annual losses of 426.5 billion organisms from the HGS CWIS, assuming 100% through-plant mortality.

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

Taxon	Common Name	Mean Day Density (#/1,000 m^3)	Mean Night Density (#/1,000 m^3)	Percent Freq. (Day)	Percent Freq. (Night)	Entrainment Estimate (# /year)
Larval Fishes						
Engraulidae	anchovies	60	470	76	84	1.0×10^8
Gobiidae	gobies	2,190	7,220	100	100	5.2×10^8
Hypsoblennius spp.	combtooth blennies	50	50	60	64	1.9×10^7
Genyonemus lineatus	white croaker	120	150	40	52	5.2×10^7
Seriphus politus	queenfish	<10	20	12	24	–[a]
Pleuronichthys guttulatus	diamond turbot	<1	–	8	–	–[a]
Fish Eggs						
Engraulis mordax	northern anchovy	<1	<1	8	12	–[a]
Anchoa spp.	bay anchovies	<10	<10	12	12	–[a]
Sciaenid complex	croakers	1,180	970	68	60	3.9×10^8

[a] annual estimate not calculated due to low densities of larvae or eggs.
A volume of 1,000 m^3 is equal to 264,000 gallons.

Table 4.2-2. Summary of planktonic invertebrate densities and annual entrainment mortality estimates for critical taxa for HGS in 1978 –1979 (from IRC 1981).

Taxon	Common Name	Mean Day Density (#/1,000 m^3)	Mean Night Density (#/1,000 m^3)	Percent Freq. (Day)	Percent Freq. (Night)	Entrainment Estimate (# /year)
Acartia spp. (adult) [a]	copepods	1,445,600	1,892,070	100	100	2.7×10^{11}
Acartia spp. (larvae) [a]	copepods	916,610	1,166,880	100	100	1.5×10^{11}
Cancer spp. (zoeae)	rock crabs	13,630	48,820	100	96	3.6×10^{9}
Neotrypaea spp. (zoeae)	ghost shrimp	920	2,510	84	84	3.0×10^{8}
Acanthomysis necropsis	mysid shrimp	2,360	11,400	88	100	1.9×10^{9}
Neomysis kadiakensis	mysid shrimp	110	1,280	48	96	2.3×10^{8}
Metamysidopsis elongata	mysid shrimp	1,360	3,450	72	96	4.3×10^{8}

[a] densities based on 202 µ net collections from January–September 1979.
A volume of 1,000 m^3 is equal to 264,000 gallons.

The following conclusions were noted for the plankton entrainment portion of the study:

- The seasonal period of highest overall abundance occurred from January through August. An exception to this was *Acartia* spp., which was abundant throughout the study and showed no real seasonal trend. A decline in the abundance of almost all plankton taxa occurred from September through December.

- Diel differences in abundance were significant for several plankton taxa. Mysids, *Cancer* spp. zoeae, the engraulid larvae, *G. lineatus* larvae, and gobiid larvae were significantly more abundant at night than during the day. The upward movement of mysids and fish larvae through the water column at night may result in an increased susceptibility to entrainment.

- Greater numbers of larger sized engraulid and *G. lineatus* larvae were collected during night sampling. For gobiid and *Hypsoblennius* spp., the smaller 0-5 mm size class was dominant throughout the yearly sampling. Spawning peaks were evidenced by large influxes of small larvae. Surveys following these peaks generally showed increasingly greater proportions of later stage (larger) larvae.

Sciaenid species complex were the most numerous entrained fish eggs. Two species of sciaenids, *G. lineatus* and *S. politus* dominated the species complex. Spawning of *G. lineatus* begins in October or November and peaks between January and March and continues into April. *Seriphus politus* spawning begins in April and continues through the summer. Egg entrainment peaked from January to April suggesting that *G. lineatus* dominated the entrained eggs of the sciaenid population.

4.2.2 Relevance to Current Conditions

The historical impingement data presented in Section 4.2 is relevant for historical comparisons. During the 1978–1979 study, the maximum cooling water flow of the HGS CWIS was 1,504,310 m^3 per day (397 mgd), and the average flow during the study year was 62% of maximum. Flow during the 2006 study averaged about 185,296 m^3 per day (49 mgd), or 51% of current design flow, which was less than design flow in the previous study due to the modifications to the CWIS.

Some differences in study methods may affect the 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 nets used in the present study. Even though there may be some systematic bias in each type of sampling method (differences in avoidance behavior, for example), the overall relative abundances and seasonality patterns of the planktonic larvae were adequately sampled by both methods. The earlier study used a 335µ mesh for the first seven surveys (as in the present study), but switched to a finer 202µ mesh in later surveys, mainly to provide better estimates of *Acartia* spp. copepodites densities.

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).

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 HGS were determined by sampling in the immediate proximity of the cooling water intake every two weeks. Entrainment samples were collected using an oblique tow through the water column at a station located just offshore from the intake structure. The samples were collected using an oblique tow that sampled the water column from the surface down to approximately 13 cm (6 in) off the bottom, and back to the surface. Two replicate tows were taken at the intake with a target sample volume of 15–20 m^3 (4,000–5,300 gal) for each net on the bongo frame. The net was redeployed if the target volume was not collected during the initial tow. Sampling was conducted four times per 24-hour period—once every six hours.

The wheeled bongo frame used for sampling consisted of 60 cm (2 ft) diameter net rings with plankton nets constructed of 333 µm (0.013 in) Nitex® nylon mesh, similar to the nets used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Each net was fitted with a Dacron sleeve and a plastic cod-end container to retain the organisms. Each net was equipped with a calibrated General Oceanics 2030R flowmeter, allowing the calculation of the amount of water filtered. Coordinates of each sampling station were determined using a differential global positioning system. At the end of each tow, nets were retrieved and the contents of the net gently rinsed into the cod-end with seawater. Contents were washed down from the outside of the net to avoid the introduction of plankton from the wash-down water. Samples were then carefully transferred to pre-labeled jars with preprinted internal labels and preserved 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 HGS cooling water intake, and 2) represent larval forms present in the nearshore habitats in the harbor complex in the vicinity of the HGS intake.

To determine composition and abundance of ichthyoplankton in the source water, sampling was conducted monthly on the same day that the entrainment station was sampled. Source water was sampled at six stations located in the channels and inner and outer harbors of the Los Angeles and Long Beach Harbor Complex (Figure 4.3-1).

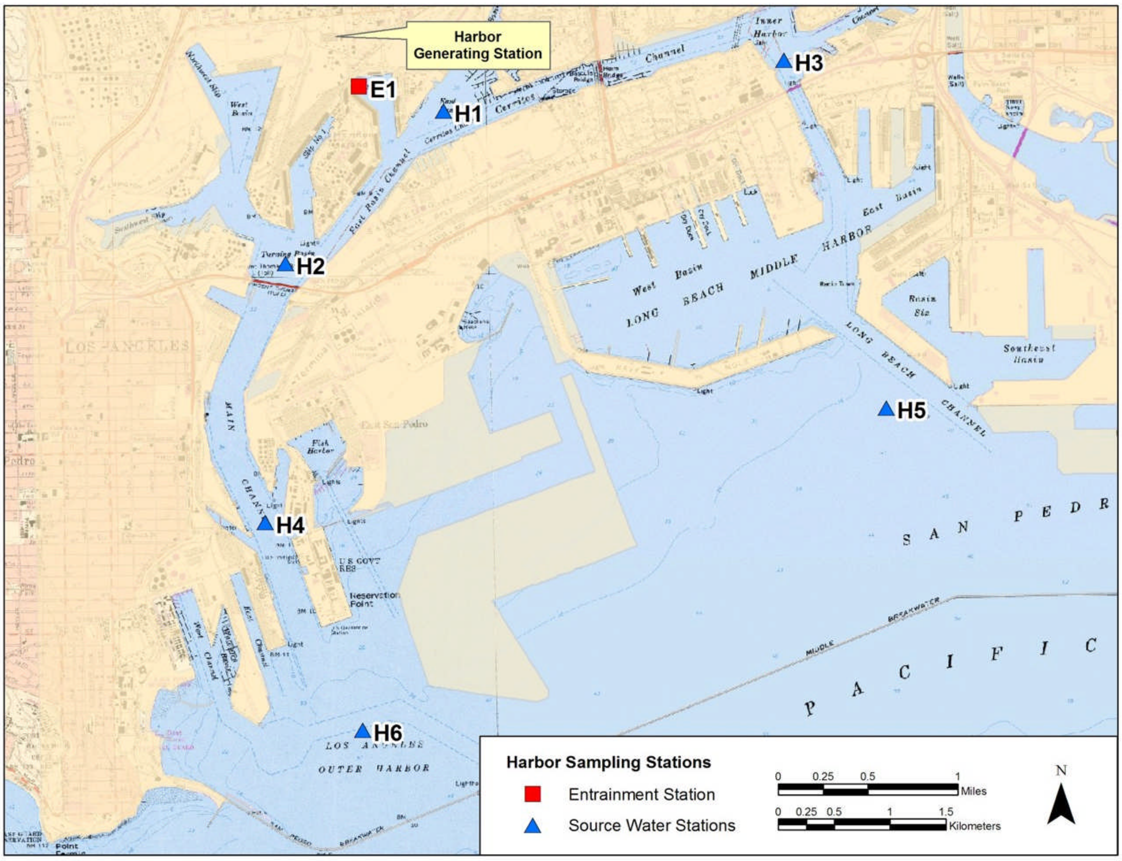


Figure 4.3-1. Locations of the HGS entrainment and source water sampling stations.

All stations were sampled using a wheeled bongo plankton net using the same oblique tows described for the entrainment sampling. Samples were also processed using the same procedures described for entrainment sampling. During each source water survey, the six source water stations were sampled four times per 24-hour period at 6-hour intervals. This interval allowed adequate time for one vessel and crew to conduct all source water and entrainment sampling, while also partitioning samples into day-night blocks for analysis of diel trends. During each sampling cycle, the order in which the stations were sampled was varied to avoid introducing a systematic bias into the data. Detailed stepwise procedures are presented in Appendix A.

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 milliliter (ml) (13.5 oz) jars and processed separately, but the data from the two nets were combined for analysis. If the quantity of material exceeded 200 ml (6.8 oz), 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. 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 0.1 millimeter (mm) (0.004 in).

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. The dates of the QA/QC reviews of the entrainment field sampling were February 7, April 10, August 14, and October 9, 2006. 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 laboratory processing of all the entrainment and source water samples. 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 percent. 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 checked per ten sorted.

A similar QC program was conducted for the taxonomists identifying the samples. The first 10 samples of fish or shellfish identified by an individual taxonomist were completely re-identified by a designated QC taxonomist. A total of at least 50 individual fish or shellfish larvae from at least five taxa must have been present in these first ten samples. If not, additional samples were re-identified until this criterion was met. Taxonomists were required to maintain a 95% identification accuracy level in these first 10 samples.

After the taxonomist identified ten 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 Environmental, 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 can be 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 through December 2006 at HGS 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*) models. Data for the same target taxa from sampling of the entrained larvae and potential source populations of larvae was used to calculate estimates of proportional entrainment (*PE*) that were used to estimate the probability of mortality (P_M) due to entrainment using the *ETM*. 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 B.

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:

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

This calculated value was used because of the large variation in size among larvae smaller than the average length that 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 anchovies and yellowfin gobies did not follow this pattern and a hatch size calculated as above resulted in a large value that far exceeded reported hatch sizes. Therefore the length of the 10th percentile of the distribution was used as the hatch length for these two 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. Two different, but related, demographic approaches were used in assessing entrainment effects at HGS: 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 (age at which 50% of the females are mature) 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 not available for many of the taxa collected during the study. These rates, when available, were inferred from the literature. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported. Because the accuracy of the estimated entrainment effects from AEL and FH will depend on the accuracy of age-specific mortality and fecundity estimates, lack of demographic information may limit the utility of these approaches.

The precursor to the AEL and FH calculations is an estimate of total annual larval entrainment. Estimates of larval entrainment at HGS were based on bi-weekly sampling where ET is the estimate of total entrainment for the study period and Ei is the entrainment estimate for the individual survey periods.

Estimates of entrainment for the study period were based on two-stage sampling designs, with days within surveys, and cycles (four six-hour collection periods per day) within days. The within-day sampling was based on a stratified random sampling scheme with four temporal cycles and two replicates per cycle. Estimates of variation for each survey were computed from the four temporal cycles.

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

Fecundity Hindcasting (*FH*)

The FH approach compares larval entrainment losses with adult fecundity to estimate the amount of adult female reproductive output eliminated by entrainment, hindcasting the numbers of adult females at the age of maturity effectively removed from the reproductively active population. The accuracy of these estimates of effects 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 to 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 allowing a comparison of the estimate with the AEL model.

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 model 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 to female ratio.

In the FH approach, the total larval entrainment for a species, ET, was projected backward from the average age at entrainment to estimate the number of females at the age of maturity (age at which 50% of the females are mature) that would produce over their lifetime the numbers of larvae seen in the entrainment samples. The estimated number of breeding females at the age of maturity, FH, whose fecundity is equal to the total loss of entrained larvae was calculated as follows:

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

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 be limited for many species and are a possible limitation of the method. *TLF* was estimated in these studies using survivorship and fecundity tables that account for changes in fecundity with age. The fecundity data used in calculating *TLF* is described below for each taxon.

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

The *AEL* model 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 lost *AEL* at some specified age class from the formula:

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

where:

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

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

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

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

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

where:

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

The average age at entrainment was estimated from lengths of a representative sample of larvae as described above. For some commercial species, natural survival rates are known after the fish recruit into the commercial fishery. For the earlier years of development, this information is not well known for commercial species and may not exist for some non-commercial species.

4.3.4.3 Empirical Transport Model (*ETM*)

As an alternative to the demographic models described above, the *ETM* was proposed by the USFWS to estimate mortality rates resulting from circulating water withdrawals by power plants (Boreman et al. 1978, and subsequently in Boreman et al. 1981). The *ETM* model provides an estimate of the incremental (a conditional estimate in absence of other mortality, Ricker 1975) mortality imposed by HGS on local Los Angeles Harbor Complex 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 of 431,694,503 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:

$$PE_i = \frac{N_{Ei}}{N_{Si}}$$

where:

$N_{Ei} =$ estimated average number of larvae entrained during the day in survey i, calculated as (estimated density 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 density 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:

$$P_M = 1 - \sum_{i=1}^{12} f_i (1 - PE_i)^d \qquad (4)$$

where:

PE_i = estimate of proportional entrainment for the *i*th survey,
f_i = proportion of the total annual source water population present during the *i*th survey, and
d = the estimated number of days the larvae are exposed to entrainment.

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 each study period, the sum of the proportions equals one:

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

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

Assumptions associated with the estimation of P_M include the following:

- The samples at each survey period represent a new and independent cohort of larvae;
- The estimates of larval abundance for each survey represent a proportion of total annual larval production during that survey;
- The conditional probability of entrainment PE_i is constant within survey periods; 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 deviation to the mean) from the estimates of PE_i as follows:

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

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

4.4 SAMPLING SUMMARY

A total of 26 surveys were conducted at the entrainment station between January 10 and December 18, 2006 (Table 4.4-1). Sampling efforts alternated between surveys where only entrainment samples were collected and surveys where both entrainment and source water samples were collected. A total of 408 entrainment samples and 576 source water samples were processed for data analysis.

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

		Entrainment Samples		Source Water Samples	
Survey Number	Date	Number Collected	Number Processed	Number Collected	Number Processed
HGSEA01	1/10/06	16	16	–	–
HGSEA02	1/23/06	16	16	48	48
HGSEA03	2/7/06	16	16	–	–
HGSEA04	2/21/06	16	16	48	48
HGSEA05	3/8/06	16	15 [a]	–	–
HGSEA06	3/20/06	16	16	48	48
HGSEA07	4/3/06	16	16	–	–
HGSEA08	4/17/06	16	16	48	48
HGSEA09	5/1/06	16	16	–	–
HGSEA10	5/15/06	16	16	48	48
HGSEA11	5/30/06	16	16	–	–
HGSEA12	6/12/06	16	16	48	48
HGSEA13	6/26/06	16	16	–	–
HGSEA14	07/12/06	16	16	48	48
HGSEA15	07/24/06	16	15 [a]	–	–
HGSEA16	08/07/06	16	16	48	48
HGSEA17	08/21/06	16	16	–	–
HGSEA18	09/05/06	16	14 [b]	48	48
HGSEA19	09/18/06	16	16	–	–
HGSEA20	10/02/06	16	16	–	–
HGSEA21	10/16/06	16	16	48	48
HGSEA22	10/30/06	16	16	–	–
HGSEA23	11/13/06	16	16	48	48

(table continued)

Table 4.4-1 (continued). Entrainment and source water surveys and number of samples collected from January through December 2006.

		Entrainment Samples		Source Water Samples	
Survey Number	**Date**	**Number Collected**	**Number Processed**	**Number Collected**	**Number Processed**
HGSEA24	11/29/06	16	16	–	–
HGSEA25	12/11/06	16	16	48	48
HGSEA26	12/26/06	12 [c]	12	–	–
		412	**408**	**576**	**576**

[a] *One sample from Station E1 not preserved properly and could not be processed.*
[b] *Two samples were lost (spilled) in transit (Stations H4 & H5).*
[c] *One complete cycle (4 samples) was not collected due to adverse sea conditions.*

4.5 RESULTS

4.5.1 Cooling Water Intake Structure Entrainment Summary

4.5.1.1 Fishes

A total of 8,692 larval fishes representing 48 taxa was collected from the HGS entrainment station (E1) during 26 bi-weekly surveys in 2006 (Table 4.5-1 and Appendix C). In addition, 14,845 fish eggs from 10 taxa were enumerated in the 408 entrainment samples. Unidentified gobies (*Clevelandia, Ilypnus, Quietula* [CIQ] goby complex), yellowfin goby, white croaker, and bay goby were the four most abundant taxa and comprised nearly 90% of all specimens collected. The greatest concentrations of larval fishes occurred during March 2006 and the fewest occurred in September (Figure 4.5-1). Fish eggs had a peak in abundance in late February prior to the peak abundance of fish larvae (Figure 4.5-2). Fish eggs also had increased abundances in early June that did not appear to be reflected in the larval concentrations. Larvae tended to be more abundant in samples collected at night than those collected during the day, although daytime collections occasionally yielded higher concentrations (Figure 4.5-3). As expected, there was less difference between day and night concentrations of fish eggs (Figure 4.5-4), which act as passive particles and would be unable to vertically migrate through the water column or exhibit net avoidance, as can occur with developmentally advanced larvae. Damaged larval fishes that could not be positively identified comprised 1.0% of the total catch. Total annual entrainment was estimated to be 65.30 million fish larvae and 99.88 million fish eggs during 2006 using the HGS CWIS actual flows (Table 4.5-2). Using the design (or maximum capacity) CWIS flows, the total annual entrainment was estimated to be 153.33 million larvae and 269.42 million eggs (Table 4.5-2). Commercially and recreationally important taxa comprised 16.7% of the total larvae collected.

Table 4.5-1. Average concentration of larval fishes and fish eggs in entrainment samples collected at HGS (Station E1) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Gobiidae unid.	CIQ gobies	516.10	4,340	49.32	49.32
Acanthogobius flavimanus	yellowfin goby	263.17	2,068	25.15	74.47
Genyonemus lineatus	white croaker	125.26	1,090	11.97	86.44
Lepidogobius lepidus	bay goby	34.02	294	3.25	89.70
Hypsoblennius spp.	combtooth blennies	29.63	239	2.83	92.53
Sciaenidae unid.	croakers	19.36	161	1.85	94.38
Engraulidae unid.	anchovies	13.97	114	1.33	95.71
unidentified larvae, damaged	unidentified damaged larvae	10.51	90	1.00	96.72
unidentified larvae, yolksac	unidentified yolksac larvae	4.58	37	0.44	97.15
Gillichthys mirabilis	longjaw mudsucker	3.70	38	0.35	97.51
Gobiesocidae unid.	clingfishes	3.49	28	0.33	97.84
Icelinus spp.	sculpins	2.93	25	0.28	98.12
Paralichthys californicus	California halibut	2.83	25	0.27	98.39
Paralabrax spp.	sea basses	1.96	16	0.19	98.58
Cheilotrema saturnum	black croaker	1.45	13	0.14	98.72
Seriphus politus	queenfish	1.23	10	0.12	98.84
Gibbonsia spp.	clinid kelpfishes	1.17	9	0.11	98.95
Leptocottus armatus	Pacific staghorn sculpin	1.13	8	0.11	99.06
Semicossyphus pulcher	California sheephead	1.01	8	0.10	99.15
Rhinogobiops nicholsii	blackeye goby	0.96	8	0.09	99.24
larval/post-larval fish unid.	larval fishes	0.79	7	0.08	99.32
Citharichthys spp.	sanddabs	0.76	6	0.07	99.39
Clinocottus spp.	sculpins	0.67	10	0.06	99.46
Pleuronichthys guttulatus	diamond turbot	0.61	6	0.06	99.52
Pleuronichthys spp.	turbots	0.50	4	0.05	99.56
Labrisomidae unid.	labrisomid blennies	0.47	4	0.05	99.61
Oxyjulis californica	senorita	0.37	3	0.04	99.64
Pleuronectidae unid.	righteye flounders	0.36	3	0.03	99.68
Ruscarius creaseri	roughcheek sculpin	0.32	3	0.03	99.71
Pleuronectiformes unid.	flatfishes	0.25	2	0.02	99.73
Clupeidae unid.	herrings	0.25	2	0.02	99.76
Orthonopias triacis	snubnose sculpin	0.23	2	0.02	99.78
Lythrypnus zebra	zebra goby	0.23	2	0.02	99.80
Cottidae unid.	sculpins	0.21	2	0.02	99.82
Sardinops sagax	Pacific sardine	0.20	2	0.02	99.84
Typhlogobius californiensis	blind goby	0.19	1	0.02	99.86
Roncador stearnsii	spotfin croaker	0.14	1	0.01	99.87
Merluccius productus	Pacific hake	0.14	1	0.01	99.89
Syngnathus spp.	pipefishes	0.14	1	0.01	99.90
Paralichthyidae unid.	sand flounders	0.14	1	0.01	99.91
Girella nigricans	opaleye	0.13	1	0.01	99.93

(table continued)

Table 4.5-1 (continued). Average concentration of larval fishes and fish eggs in entrainment samples collected at HGS (Station E1) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Pleuronichthys verticalis	hornyhead turbot	0.13	1	0.01	99.94
Chitonotus / Icelinus	sculpins	0.13	1	0.01	99.95
Artedius spp.	sculpins	0.12	1	0.01	99.96
Bathymasteridae unid.	ronquils	0.11	1	0.01	99.97
Atherinopsidae unid.	silversides	0.10	1	0.01	99.98
Bathylagidae unid.	blacksmelt	0.10	1	0.01	99.99
Lythrypnus spp.	gobies	0.08	1	0.01	100.00
		1,046.36	**8,692**		
Fish Eggs					
fish eggs unid.	unidentified fish eggs	878.99	6,922	48.52	48.52
Sciaenidae unid.	croaker eggs	283.99	2,334	15.68	64.20
Genyonemus lineatus	white croaker eggs	281.18	2,560	15.52	79.72
Paralichthyidae unid.	sand flounder eggs	207.24	1,683	11.44	91.16
Sciaenidae/Paralich./Labridae	SPL fish eggs	78.00	616	4.31	95.46
Citharichthys spp.	sanddab eggs	35.52	317	1.96	97.42
Pleuronichthys spp.	turbot eggs	20.11	167	1.11	98.53
Paralichthys californicus	California halibut eggs	13.20	139	0.73	99.26
Engraulidae unid.	anchovy eggs	13.08	106	0.72	99.98
Atherinopsidae unid.	silverside eggs	0.27	1	0.01	100.00
		1,811.60	**14,845**		

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

Taxon	Common Name	Annual Entrainment (Actual Flows)	Annual Entrainment (Design Flows)
Larval Fish			
Gobiidae unid.	gobies	33,290,815	75,938,007
Acanthogobius flavimanus	yellowfin goby	15,407,999	37,604,336
Genyonemus lineatus	white croaker	7,164,843	18,777,752
Lepidogobius lepidus	bay goby	2,376,260	5,070,071
Hypsoblennius spp.	combtooth blennies	2,255,907	4,362,576
Sciaenidae unid.	croakers	995,438	2,856,932
Engraulidae unid.	anchovies	940,784	2,068,979
unidentified fish, damaged	unidentified damaged fish	646,175	1,571,226
larvae, unidentified yolksac	unidentified yolksac larvae	288,308	679,015
Gillichthys mirabilis	longjaw mudsucker	254,865	558,887
Gobiesocidae unid.	clingfishes	236,654	515,917
Icelinus spp.	sculpins	190,484	446,021
Paralichthys californicus	California halibut	165,782	424,529
Paralabrax spp.	sand bass	122,010	271,192
Cheilotrema saturnum	black croaker	94,525	200,992
Seriphus politus	queenfish	83,731	176,487
Gibbonsia spp.	clinid kelpfishes	77,308	173,122
Rhinogobiops nicholsii	blackeye goby	71,631	145,314
Leptocottus armatus	Pacific staghorn sculpin	68,768	160,195
Semicossyphus pulcher	California sheephead	64,438	141,346
larval/post-larval fish unid.	larval fishes	58,152	119,578
Clinocottus spp.	sculpins	55,826	112,731
Citharichthys spp.	sanddabs	41,222	115,405
Pleuronichthys spp.	turbots	36,951	73,078
Pleuronichthys guttulatus	diamond turbot	36,799	93,021
Labrisomidae unid.	labrisomid blennies	29,483	71,609
Oxyjulis californica	senorita	24,673	52,620
Pleuronectidae unid.	righteye flounders	23,120	52,521
Ruscarius creaseri	roughcheek sculpin	20,616	50,242
Pleuronectiformes unid.	flatfishes	16,347	40,493
Cottidae unid.	sculpins	15,756	31,607
Lythrypnus zebra	zebra goby	14,795	34,416
Syngnathus spp.	pipefishes	14,250	20,766
Orthonopias triacis	snubnose sculpin	13,806	32,367
Sardinops sagax	Pacific sardine	11,836	29,933
Artedius spp.	sculpins	10,653	17,916
Typhlogobius californiensis	blind goby	10,523	26,455
Clupeidae unid.	herrings	8,864	36,966
Roncador stearnsii	spotfin croaker	8,735	21,531

(table continued)

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

Taxon	Common Name	Annual Entrainment (Actual Flows)	Annual Entrainment (Design Flows)
Larval Fish			
Pleuronichthys verticalis	hornyhead turbot	8,693	19,596
Merluccius productus	Pacific hake	8,421	19,741
Girella nigricans	opaleye	7,894	19,963
Bathylagidae unid.	blacksmelt	6,622	14,928
Lythrypnus spp.	gobies	6,249	11,481
Bathymasteridae unid.	ronquils	5,843	14,511
Paralichthyidae unid.	sand flounders	1,926	20,449
Chitonotus / Icelinus	sculpins	1,798	19,097
Atherinopsidae unid.	silversides	1,422	15,096
	Total Larval Fish	**65,298,000**	**153,331,013**
Fish Eggs			
fish eggs unid.	unidentified fish eggs	49,261,253	130,894,994
Genyonemus lineatus	white croaker eggs	17,867,461	43,114,182
Sciaenidae unid.	croaker eggs	14,562,519	41,351,239
Paralichthyidae unid.	sand flounder eggs	8,780,223	30,684,631
Sciaenidae/Paralichthyidae/Labridae	SPL fish eggs	5,208,682	11,085,521
Citharichthys spp.	sanddab eggs	1,499,868	5,319,639
Pleuronichthys spp.	turbot eggs	1,018,933	2,987,271
Paralichthys californicus	California halibut eggs	860,518	2,013,440
Engraulidae unid.	anchovy eggs	803,290	1,932,617
Atherinopsidae unid.	silverside eggs	22,147	40,690
	Total Fish Eggs	**99,884,894**	**269,424,224**

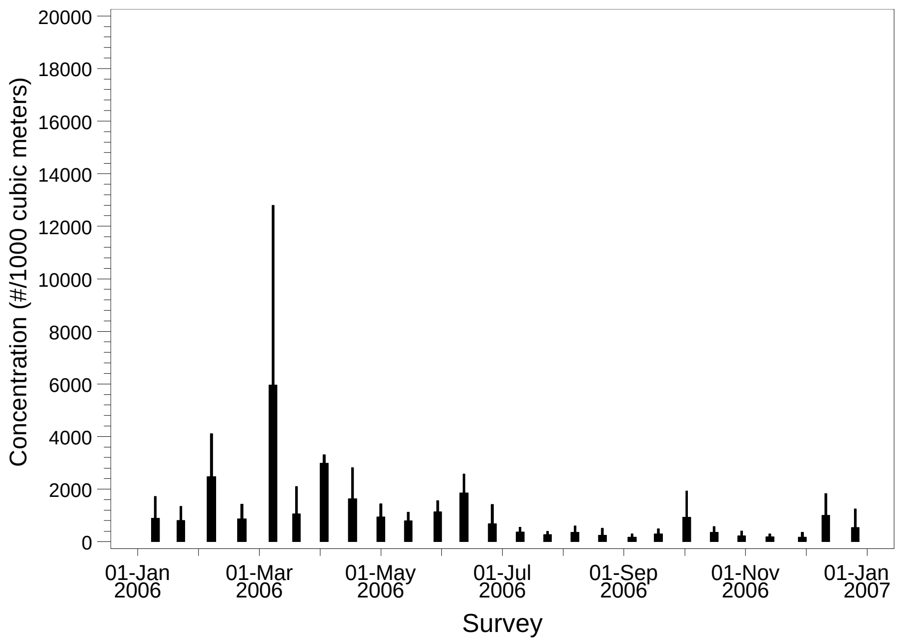


Figure 4.5-1. Mean concentration (#/1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of all larval fishes collected at HGS entrainment Station E1 during 2006.

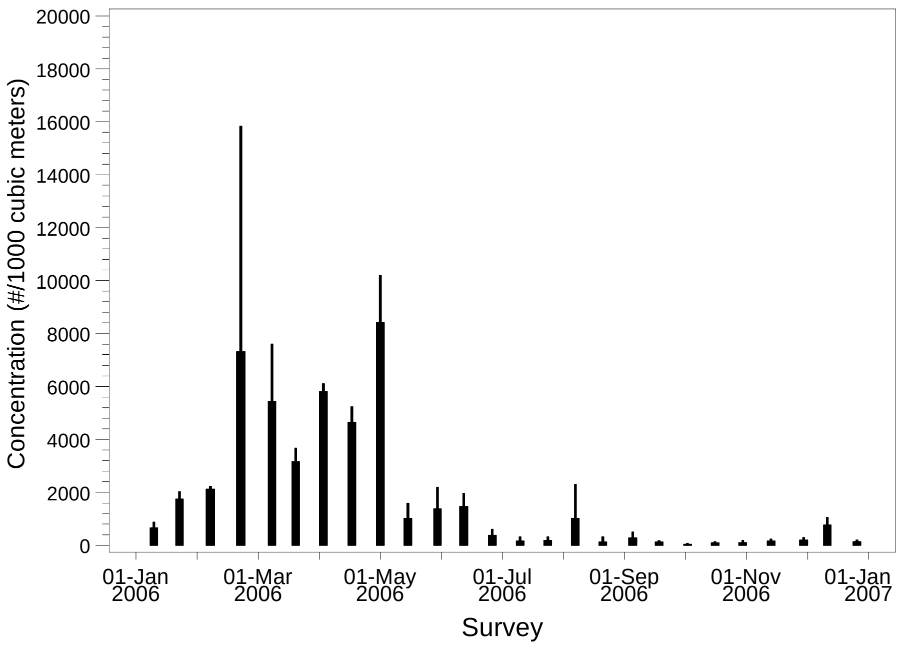
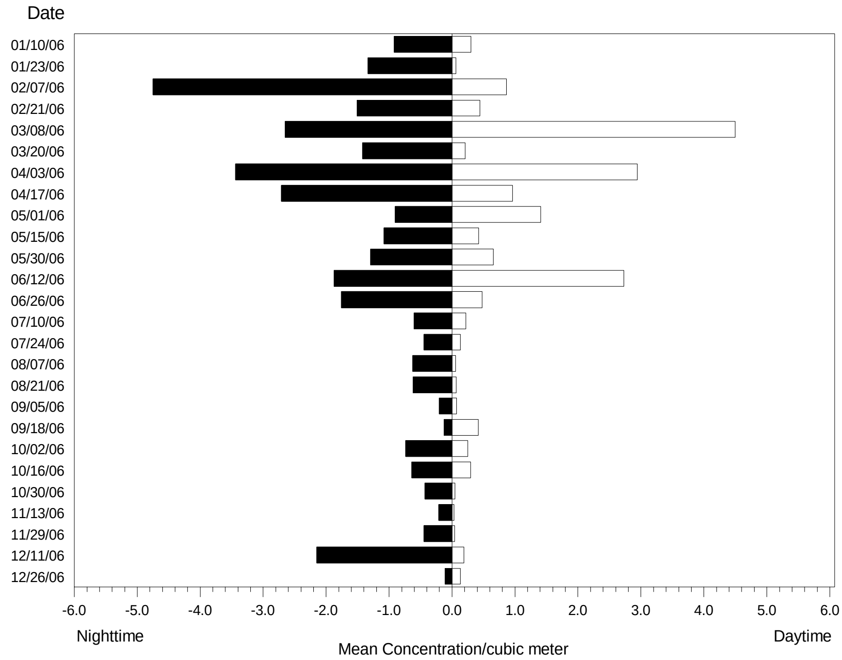
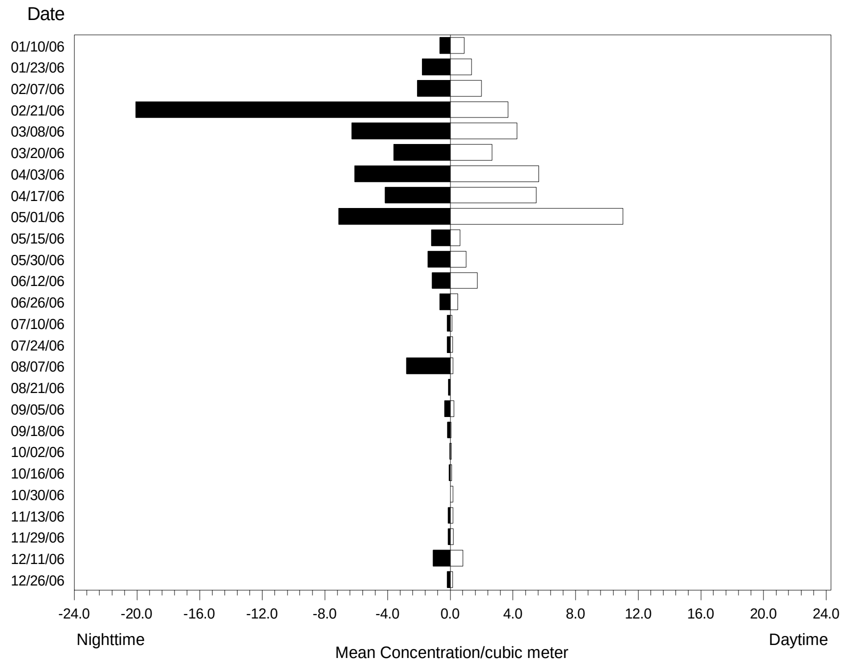


Figure 4.5-2. Mean concentration (#/1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of all fish eggs collected at HGS entrainment Station E1 during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-3. Mean concentration (#/1.0 m^3 [264 gal]) of all fish larvae at 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 entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

4.5.1.2 Shellfishes

A total of 2,262 larval target shellfishes (late-stage larvae of crabs, spiny lobsters, and market squid) representing 16 taxa was collected from the HGS entrainment station (E1) during 26 bi-weekly surveys in 2006 (Table 4.5-3 and Appendix C). The highest concentrations were collected during Survey 10 in May (Appendix C). The megalops stage of kelp crabs, spider crabs, and pea crabs comprised over 90% of all specimens collected. Advanced larvae of species with commercial fishery value (i.e., Cancer crabs, California spiny lobster, market squid) each comprised less than 1% of the target shellfish. Total annual entrainment was estimated to be 18.9 million target shellfish larvae using the actual cooling water flows, including 217,477 California spiny lobster phyllosomes and 26,676 market squid paralarvae (Table 4.5-4). Using the design (or maximum) capacity CWIS flows, entrainment increased to 41.3 million shellfish larvae.

Table 4.5-3. Average concentration of target shellfish larvae in entrainment samples collected at HGS (Station E1) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percent of Total	Cumul. Percent.
Pugettia spp. (megalops)	kelp crabs megalops	175.14	1,434	63.73	63.73
Majidae unid. (megalops)	spider crab megalops	47.96	380	17.45	81.19
Pinnixa spp. (megalops)	pea crabs megalops	30.05	265	10.94	92.12
unidentified crab (megalops)	unidentified crab megalops	9.95	86	3.62	95.74
Grapsidae unid. (megalops)	shore crab megalops	3.48	29	1.27	97.01
Paguridae unid. (megalops)	hermit crab megalops	2.83	23	1.03	98.04
Panulirus interruptus (phyllosome)	California spiny lobster (larval)	2.42	20	0.88	98.92
Brachyura unid. (megalops)	unidentified crab megalops	0.88	7	0.32	99.24
Pinnotheres spp. (megalops)	pea crab megalops	0.57	5	0.21	99.45
Loligo opalescens	market squid	0.43	4	0.16	99.60
Lophopanopeus spp. (megalops)	black-clawed crab megalops	0.36	3	0.13	99.73
Cancer spp. (megalops)	cancer crabs megalops	0.24	2	0.09	99.82
Grapsidae / Cancridae (megalops)	unidentified crab megalops	0.14	1	0.05	99.87
Diogenidae (megalops)	left-handed hermit crabs megalops	0.13	1	0.05	99.92
Pinnotheridae (megalops)	pea crab megalops	0.11	1	0.04	99.96
Pachygrapsus crassipes (megalops)	striped shore crab megalops	0.11	1	0.04	100.00
		274.80	**2,262**		

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

Taxon	Common Name	Annual Entrainment (Actual Flows)	Annual Entrainment (Design Flows)
Pugettia spp. (megalops)	kelp crabs megalops	12,009,598	26,357,647
Majidae unid. (megalops)	spider crab megalops	3,520,320	7,285,587
Pinnixa spp. (megalops)	pea crabs megalops	1,810,300	4,467,908
unidentified crab (megalops)	unidentified crab megalops	727,346	1,480,727
Grapsidae unid. (megalops)	shore crab megalops	241,523	526,881
Panulirus interruptus (phyllosome)	California spiny lobster (larval)	217,477	360,853
Paguridae unid. (megalops)	hermit crab megalops	165,787	422,270
Brachyura unid. (megalops)	unidentified crab megalops	64,917	134,388
Pinnotheres spp. (megalops)	pea crab megalops	38,804	84,172
Lophopanopeus spp. (megalops)	black-clawed crab megalops	27,081	51,987
Loligo opalescens	market squid	26,676	62,179
Cancer spp. (megalops)	cancer crabs megalops	15,625	35,225
Grapsidae / Cancridae (megalops)	unidentified crab megalops	12,015	21,990
Pinnotheridae (megalops)	pea crab megalops	9,749	17,843
Diogenidae (megalops)	left-handed hermit crabs megalops	7,894	19,963
Pachygrapsus crassipes (megalops)	striped shore crab megalops	6,224	15,456
		18,901,336	**41,345,075**

4.5.2 Source Water Summary

4.5.2.1 Fishes

A total of 14,025 larval fishes representing 72 taxa was collected from HGS source water stations in the Los Angeles–Long Beach Harbor Complex (Stations H1–H6) during 12 monthly surveys in 2006 (Table 4.5-5 and Appendix C). White croaker, combtooth blennies, unidentified gobies (CIQ goby complex), anchovies, bay goby, unidentified croakers and yellowfin goby were the most abundant taxa and comprised nearly 90% of all specimens collected. The greatest concentrations of larval fishes occurred during May 2006 (ca. 2,400/1,000 m^3 [264,172 gal]) and the fewest in November 2006 (ca. 400/1,000 m^3 [264,172 gal]) (Figure 4.5.5). Damaged fishes that could not be positively identified comprised 2.0% of the total catch.

Table 4.5-5. Average concentration of larval fishes collected at HGS source water stations in the Los Angeles–Long Beach Harbor Complex (Stations H1–H6) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Genyonemus lineatus	white croaker	367.16	5,022	34.22	34.22
Hypsoblennius spp.	combtooth blennies	208.17	2,614	19.40	53.62
Gobiidae unid.	gobies	202.31	2,493	18.86	72.48
Engraulidae unid.	anchovies	54.12	765	5.04	77.52
Lepidogobius lepidus	bay goby	40.43	531	3.77	81.29
Sciaenidae unid.	croakers	29.70	377	2.77	84.06
Acanthogobius flavimanus	yellowfin goby	23.26	353	2.17	86.23
unidentified larvae, damaged	unidentified damaged larvae	22.38	291	2.09	88.32
unidentified larvae, yolksac	unidentified yolksac larvae	18.56	232	1.73	90.05
Seriphus politus	queenfish	17.79	221	1.66	91.70
Gobiesocidae unid.	clingfishes	7.44	94	0.69	92.40
Paralichthys californicus	California halibut	7.29	94	0.68	93.08
Atherinopsidae unid.	silversides	4.84	56	0.45	93.53
Rhinogobiops nicholsii	blackeye goby	4.56	54	0.43	93.95
Icelinus spp.	sculpins	4.32	54	0.40	94.35
Ruscarius creaseri	roughcheek sculpin	4.27	58	0.40	94.75
Pleuronichthys guttulatus	diamond turbot	3.46	45	0.32	95.07
Pleuronichthys ritteri	spotted turbot	3.08	38	0.29	95.36
Orthonopias triacis	snubnose sculpin	2.89	36	0.27	95.63
Bathymasteridae unid.	ronquils	2.45	33	0.23	95.86
Stenobrachius leucopsarus	northern lampfish	2.40	31	0.22	96.08
Cheilotrema saturnum	black croaker	2.32	29	0.22	96.30
Gillichthys mirabilis	longjaw mudsucker	2.27	31	0.21	96.51
Parophrys vetulus	English sole	2.17	27	0.20	96.71
Clinocottus spp.	sculpins	2.09	27	0.19	96.91
Labrisomidae unid.	labrisomid blennies	2.03	26	0.19	97.10
Semicossyphus pulcher	California sheephead	2.01	23	0.19	97.28
Cottidae unid.	sculpins	1.96	26	0.18	97.47
Artedius spp.	sculpins	1.90	22	0.18	97.64
Citharichthys spp.	sanddabs	1.72	18	0.16	97.80
Oxyjulis californica	senorita	1.58	20	0.15	97.95
Sebastes spp.	rockfishes	1.49	18	0.14	98.09
Paralabrax spp.	sand bass	1.41	18	0.13	98.22
Sphyraena argentea	Pacific barracuda	1.30	17	0.12	98.34
Zaniolepis spp.	combfishes	1.26	16	0.12	98.46
Pleuronichthys spp.	turbots	1.03	14	0.10	98.55
Pleuronectidae unid.	righteye flounders	1.02	13	0.10	98.65
Hypsypops rubicundus	garibaldi	1.02	13	0.10	98.74
Pleuronichthys verticalis	hornyhead turbot	1.02	14	0.10	98.84
Typhlogobius californiensis	blind goby	1.01	15	0.09	98.93
Chitonotus / Icelinus	sculpins	0.98	12	0.09	99.03

(table continued)

Table 4.5-5 (continued). Average concentration of larval fishes and fish eggs collected at HGS source water stations in the Los Angeles–Long Beach Harbor Complex (Stations H1–H6) in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Larval Fish					
Gibbonsia spp.	clinid kelpfishes	0.92	12	0.09	99.11
Syngnathus spp.	pipefishes	0.92	11	0.09	99.20
Paralichthyidae unid.	sand flounders	0.85	10	0.08	99.28
larval/post-larval fish unid.	larval fishes	0.73	10	0.07	99.34
Merluccius productus	Pacific hake	0.67	10	0.06	99.41
Leuroglossus stilbius	California smoothtongue	0.63	8	0.06	99.47
Roncador stearnsii	spotfin croaker	0.62	8	0.06	99.52
Pleuronectiformes unid.	flatfishes	0.54	7	0.05	99.57
Oxylebius pictus	painted greenling	0.49	6	0.05	99.62
Lythrypnus spp.	gobies	0.46	6	0.04	99.66
Bathylagidae unid.	blacksmelt	0.35	4	0.03	99.69
Umbrina roncador	yellowfin croaker	0.33	4	0.03	99.73
Oligocottus / Clinocottus	sculpins	0.32	4	0.03	99.76
Lyopsetta exilis	slender sole	0.29	4	0.03	99.78
Myctophidae unid.	lanternfishes	0.26	3	0.02	99.81
Chitonotus pugetensis	roughback sculpin	0.25	3	0.02	99.83
Scorpaenichthys marmoratus	cabezon	0.20	2	0.02	99.85
Chaenopsidae unid.	tube blennies	0.19	3	0.02	99.87
Menticirrhus undulatus	California corbina	0.19	2	0.02	99.88
Pomacentridae unid.	damselfishes	0.16	2	0.01	99.90
Stichaeidae unid.	pricklebacks	0.15	2	0.01	99.91
Peprilus simillimus	Pacific butterfish	0.15	2	0.01	99.93
Isopsetta isolepis	butter sole	0.14	2	0.01	99.94
Sardinops sagax	Pacific sardine	0.14	2	0.01	99.95
Xystreurys liolepis	fantail sole	0.09	1	0.01	99.96
Diaphus theta	California headlight fish	0.08	1	0.01	99.97
Oligocottus spp.	sculpins	0.08	1	0.01	99.97
Triphoturus mexicanus	Mexican lampfish	0.07	1	0.01	99.98
Hexagrammidae unid.	greenlings	0.07	1	0.01	99.99
Labridae unid.	wrasses	0.07	1	0.01	99.99
Halichoeres semicinctus	rock wrasse	0.06	1	0.01	100.00
	Total Larval Fish	**1,072.90**	**14,025**		

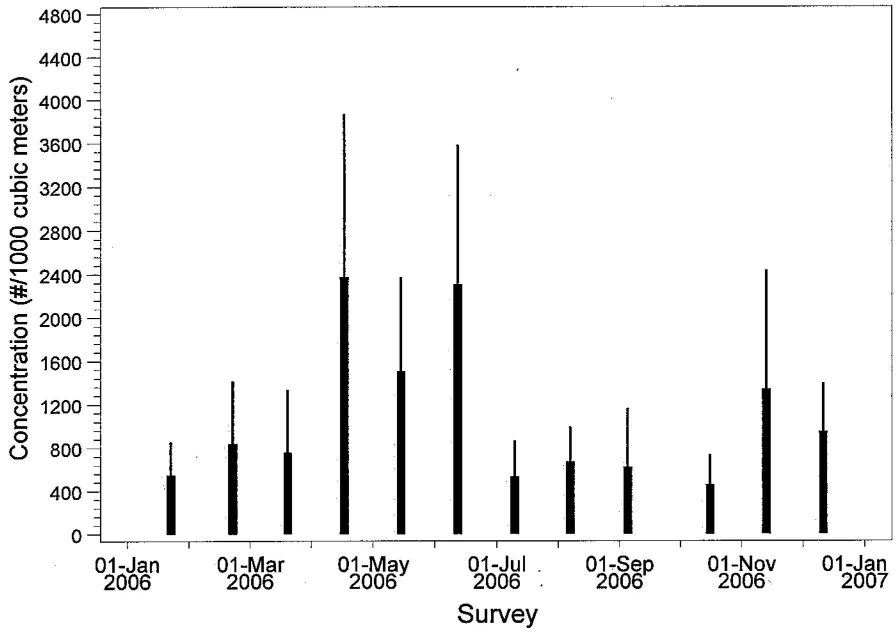
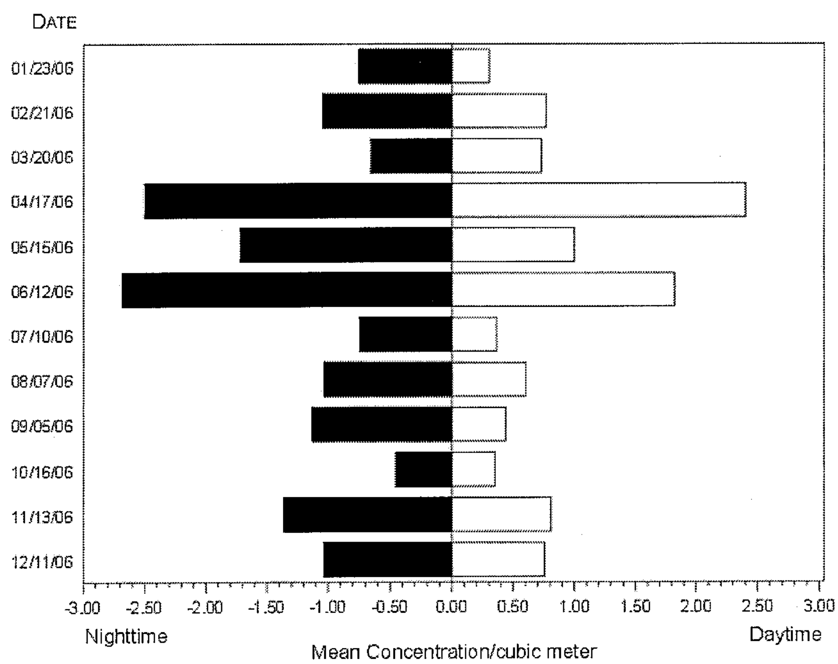


Figure 4.5-5. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of all larval fishes collected at HGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-6. Mean concentration (#/1.0 m^3 [264 gal]) of all fish larvae at HGS source water stations during night (Cycle 3) and day (Cycle 1) sampling.

4.5.2.2 Shellfishes

A total of 6,942 larval target shellfishes representing 20 taxa (combined species designations) was collected from HGS source water stations in the Harbor Complex during 12 monthly surveys in 2006 (Table 4.5-6 and Appendix C). The highest concentrations were collected during the May survey (Appendix C). Megalops of kelp crabs, pea crabs, spider crabs, unidentified megalops, California spiny lobster, and cancer crabs were the most abundant taxa and comprised over 90% of all specimens collected. Data presented in Appendix C includes abundances for the uncombined species designations by survey.

Table 4.5-6. Average concentration of larval target shellfishes in samples collected at HGS source water stations in Los Angeles-Long Beach Harbor Complex in 2006.

Taxon	Common Name	Avg. Conc. (per 1,000 m^3)	Total Count	Percentage of Total	Cumulative Percentage
Pugettia spp.	kelp crabs megalops	276.76	3,708	53.52	53.52
Pinnixa spp.	pea crabs megalops	62.59	872	12.10	65.63
Majidae unid.	spider crabs megalops	56.42	705	10.91	76.54
unidentified crab	unidentified crab megalops	32.04	411	6.20	82.73
Panulirus interruptus	California spiny lobster (larval)	24.40	351	4.72	87.45
Cancer spp.	cancer crabs megalops	23.97	332	4.64	92.09
Grapsidae unid	shore crabs megalops	10.69	149	2.07	94.15
Paguridae unid.	hermit crabs megalops	9.37	130	1.81	95.97
Pinnotheres spp.	pea crabs megalops	4.96	74	0.96	96.93
Loligo opalescens	market squid	3.61	50	0.70	97.62
Brachyura unid.	unidentified true crab megalops	3.33	44	0.64	98.27
Lophopanopeus spp.	black-clawed crabs megalops	2.11	27	0.41	98.68
Diogenidae	left-handed hermit crabs meg.	2.09	27	0.40	99.08
Pinnotheridae unid.	pea crabs megalops	1.72	23	0.33	99.41
Porcellanidae unid.	porcelain crabs megalops	0.94	12	0.18	99.59
Pachycheles rudis	thickclaw porcelain crab meg.	0.85	13	0.16	99.76
Petrolisthes spp.	porcelain crabs megalops	0.67	6	0.13	99.89
Pachycheles pubescens	pubescent porcelain crab meg.	0.44	6	0.08	99.97
Petrolisthes cinctipes	flat porcelain crab meg.	0.07	1	0.01	99.99
Petrolisthes eriomerus	flattop crab megalops	0.07	1	0.01	100.00
		517.11	**6,942**		

4.5.3 Results by Species for Cooling Water Intake Structure Entrainment

The following seven fish taxa were selected for detailed evaluation of entrainment effects based on their abundance in entrainment samples. Together they comprised over 95% of the larvae entrained at HGS in 2006 (Table 4.5-1). In taxonomic order these are:

- anchovies (primarily *Engraulis mordax*);
- croakers (Sciaenidae unid.);
- white croaker (*Genyonemus lineatus*);
- combtooth blennies (*Hypsoblennius* spp.);
- unidentified gobies (mainly CIQ goby complex);
- yellowfin goby (*Acanthogobius flavimanus*); and
- bay goby (*Lepidogobius lepidus*).

The unidentified croakers are discussed along with the white croakers because a significant proportion of these larvae were likely yolk-sac stage white croaker that could not be positively identified to the species level. No shellfishes were included in the detailed evaluation because of the low numbers of larvae relative to the fishes and the very low numbers of species with commercial or recreational importance. This methodology was approved by the LARWQCB, SWRCB, EPA Region IX, NMFS, and CDFG during a January 30, 2006 meeting at the LARWQCB offices.

4.5.3.1 Anchovies (Engraulidae)

Mark Conlin

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-five percent of the specimens identified in the entrainment samples as Engraulidae were northern anchovy. The remainder were very small specimens still in their recently-hatched yolk-sac stage and some that were damaged to an extent that they could not be positively identified to the species level.

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 miles) 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 ft) 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 miles) of shore (MBC 1987). On average, female anchovies off Los Angeles spawn every 7 to 10 days during peak spawning periods, approximately 20 times per year (Hunter and Macewicz 1980; MBC 1987). 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 47–100% depending on the water temperature during development (Bergen and Jacobsen 2001). Love (1996) reported that they release 2,700–16,000 eggs per batch, with an annual fecundity of up to 130,000 eggs per year in southern California. Parrish et al. (1986) and Butler et al. (1993) stated that the total annual fecundity for one-year old females was 20,000–30,000 eggs, while a five-year old could release up to 320,000 eggs per year.

The northern anchovy egg hatches in two to four days, has a larval phase lasting approximately 70 days, and undergoes transformation into a juvenile at about 35–40 mm (1.4–1.6 in) (Hart 1973; MBC 1987; Moser 1996). Larvae begin schooling at 11–12 mm (0.4–0.5 in) SL (Hunter and Coyne 1982). Northern anchovy on average reach 102 mm (4 in) in their first year, and 119 mm (4.7 in) in their second (Sakagawa and Kimura 1976). Larval survival is strongly influenced by the availability and density of phytoplankton species (Emmett et al. 1991). Storms and strong upwelling reduce larval food availability, and strong upwelling may transport larvae out of the Southern California Bight (Power 1986). However, strong upwelling may benefit juveniles and adults by increasing food resources. Growth in length is most rapid during the first four months, and growth in weight is most rapid during the first year (Hunter and Macewicz 1980; PFMC 1983). They mature at 78–140 mm (3.1–5.5 in) in length, in their first or second year (Frey 1971; Hunter and Macewicz 1980). Maximum size is about 230 mm (9.1 in) and 60 g (2.1 oz) (Fitch and Lavenberg 1971; Eschmeyer and Herald 1983). Maximum age is about seven years (Hart 1973), though most live less than four years (Fitch and Lavenberg 1971).

Northern anchovy are very important in the trophic ecology of marine food webs. They are random planktonic feeders, filtering plankton as they swim (Fitch and Lavenberg 1971). Juveniles and adults feed mainly at night on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971; Hart 1973; Allen and DeMartini 1983). Numerous fish and marine mammal species feed on northern anchovy. Elegant tern and California brown pelican reproduction is strongly correlated with the annual abundance of this species (Emmett et al. 1991).

4.5.3.1.2 Population Trends and Fishery

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

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

Northern anchovy populations began to increase following the collapse of the Pacific sardine (Sardinops sagax) fishery in 1952. Landings remained fairly low throughout the 1950s, but increased rapidly in the mid 1960s when reduction of anchovy without associated canning was permitted (Bergen and Jacobson 2001). The demand for this fishery was highly linked to the production and price of fish meal worldwide (Mason 2004). A drastic decline of 40% in fish meal prices worldwide during the early 1980s (Durand 1998) and the decline in anchovy abundance nearly ended the anchovy reduction market by 1983.

Estimates of the central subpopulation averaged about 325 million kg (359,000 tons) from 1963 through 1972, increased to over 1.5 billion kilograms (kg) (1.7 million tons) in 1974, then declined to 325 million kg (359,000 tons) in 1978 (Bergen and Jacobsen 2001). Anchovy biomass in 1994 was estimated at 391 million kg (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).

Northern anchovy were one of the most abundant larvae in various surveys conducted in the Los Angeles-Long Beach Harbor Complex in the 1970s (Brewer 1983; HEP 1976, 1979). Northern anchovy larvae comprised 14% of the total catch in a survey conducted in the harbor area in 2000 (MEC 2002). Northern anchovy was one of the most abundant species, along with topsmelt (Atherinopsis affinis), in purse seine and beach seine sampling in the harbor complex in the early 1980s (Allen et al. 2006). Seasonally the greatest population abundances typically occur in summer and early fall as a result of large numbers of young-of-the-year. Northern anchovy were also the most abundant species collected by lampara net and otter trawl in a survey of the harbor complex in 2000, and were more abundant in nighttime samples (MEC 2002).

The earlier 316(b) study of the HGS in 1978–1979 (IRC 1981) measured average concentrations of engraulid species complex larvae that were lowest from July through October and greatest from January through June. Survey means for the near-field varied from 0 to 6,510 larvae/1,000 m3 (1,000 m3 = 264,172 gal) (average 265/1,000 m3) and from 1 to 12,500 larvae/1,000 m3 (average 1,116/1,000 m3) for the far-field. These concentrations are approximately 20 times greater than the 2006 values. The annual mean nighttime concentration was significantly higher than the average daytime concentration. In addition, the far-field mean abundance was significantly greater than the near-field value.

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 144,200 kg (318,000 pounds [lbs]) were landed (Pacific Fishery Information Network [PacFIN] 2007). In 2004, there were 147,400 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 3.66 million kg (8.1 million lbs) in 2001 to a low of 147,003 kg (0.3 million lbs) in 2004, with an average of 1.35 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) was the seventh most abundant taxon at the entrainment station with a mean concentration of 14 per 1,000 m^3 (1,000 m^3 = 264,172 gal) over all surveys while engraulid eggs had an average concentration of 13 per 1,000 m^3 (Table 4.5-1). The seasonal occurrence of larvae was divided between two periods of abundance, the greater being in March–July and a lesser peak in October–December (Figure 4.5-6). During periods of maximum abundance in late May 2006, anchovies were present in the entrainment samples at average concentrations of 75 per 1,000 m^3. They were absent from samples in January–February and August–September. Monthly source water concentrations followed a similar seasonal pattern with maximum concentrations exceeding 200 per 1,000 m^3 in May 2006 (Figure 4.5-7). Anchovies were substantially more abundant in nighttime samples than daytime samples, including 8 out of 13 surveys (62%) in which anchovies were collected in nighttime samples (Cycle 3), but not daytime samples (Cycle 1) (Figure 4.5-8). The length frequency distribution of measured northern anchovy larvae showed a bi-modal distribution with one peak consisting of recently hatched larvae based on the reported hatch length of 2–3 mm (0.08-0.1 in) (Moser 1996), and another in the range of 10–14 mm (0.4-0.6 in) (Figure 4.5-9). The lengths of the larvae from the entrainment station samples ranged from 1.7–22.5 mm (0.07-0.9 in) with a mean of 10.6 mm (0.4 in) notochord length (NL).

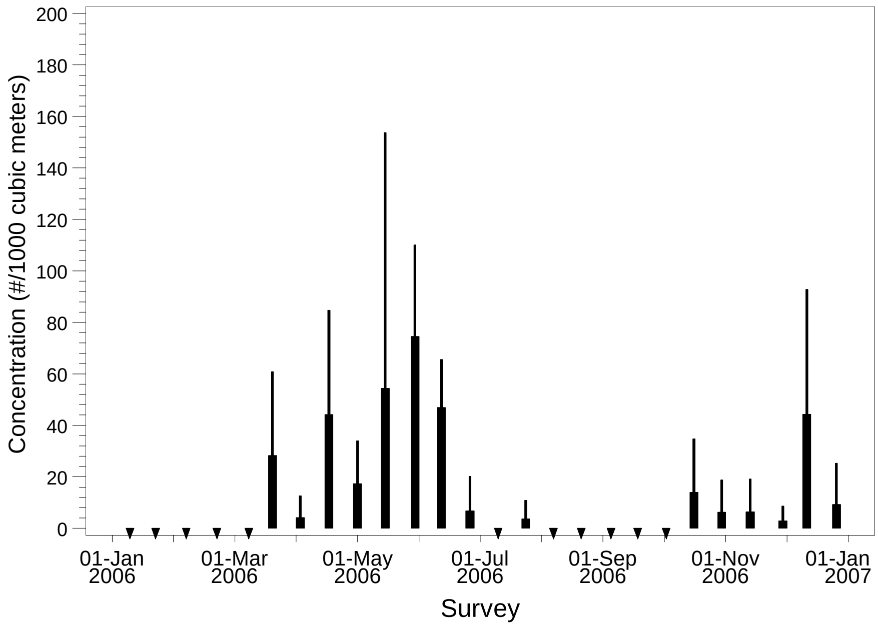


Figure 4.5-7. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of anchovy larvae collected at HGS entrainment Station E1 during 2006.

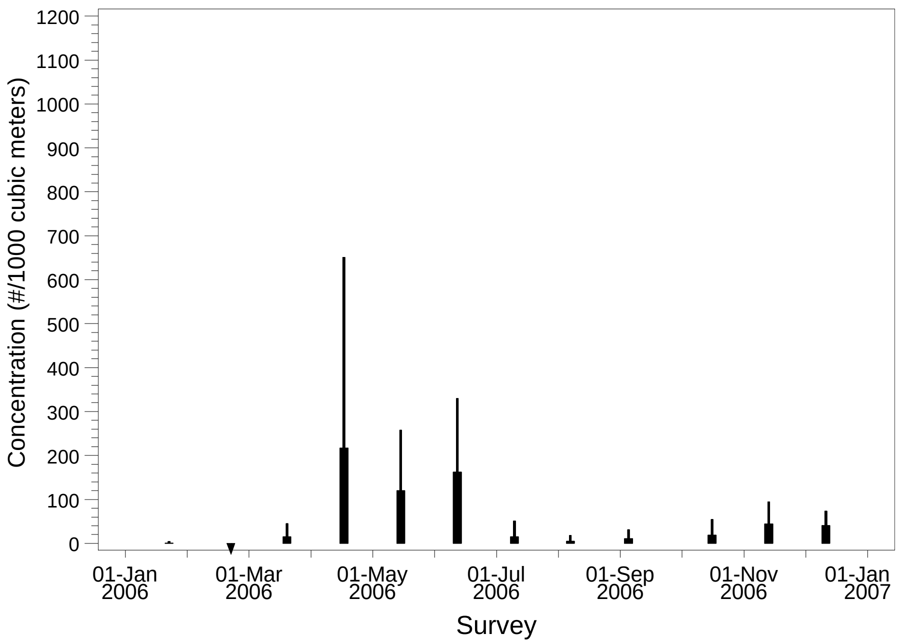
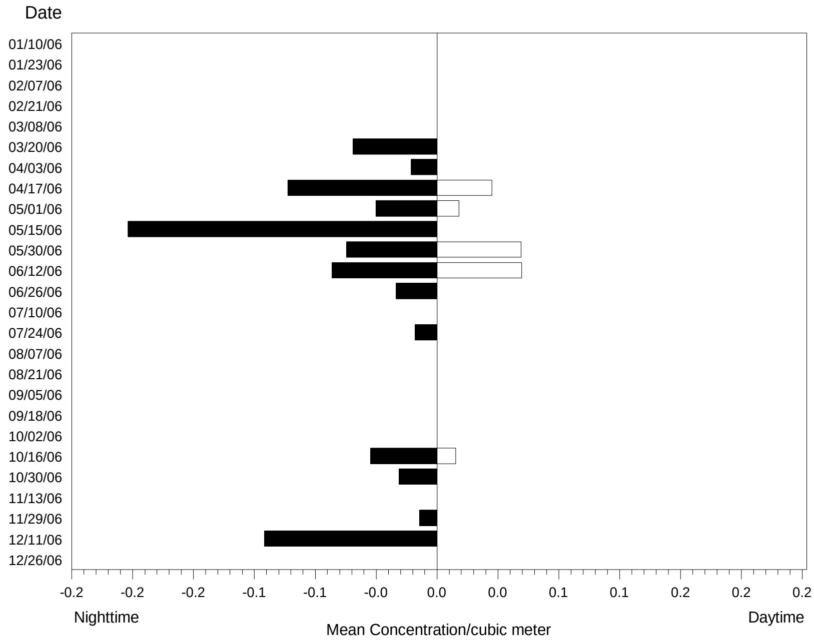


Figure 4.5-8. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of anchovy larvae collected at HGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

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.

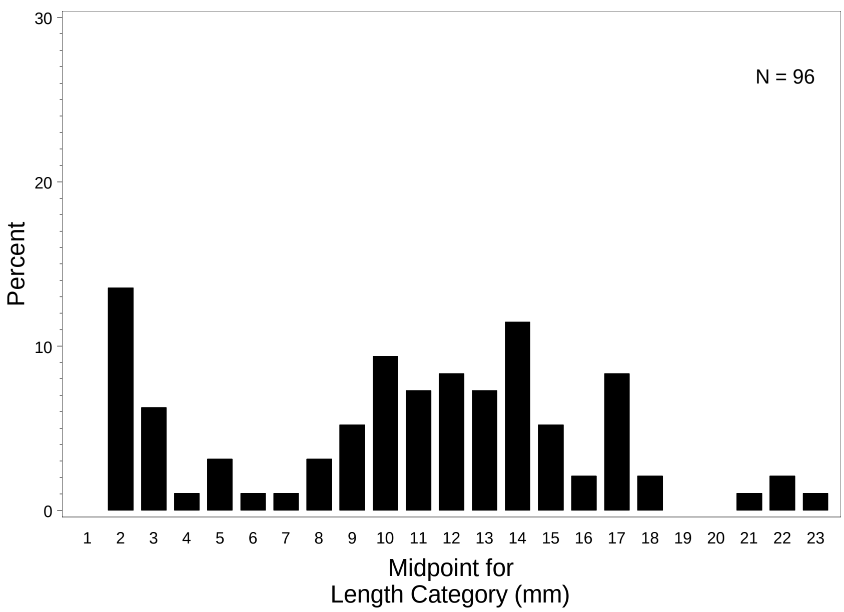


Figure 4.5-10. Length (mm) frequency distribution for larval anchovy collected at entrainment Station E1.

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. *FH* modeling estimates for both egg and larval stages were calculated separately, since the modeling approach was based on average ages of the egg and larvae entrained. The two estimates were then added to obtain the total estimated adult female losses. The *FH* model has the advantage that the eggs only need to be extrapolated back to the time at which they are released from spawning females. An *AEL* estimate for anchovy eggs would require extrapolating the number of eggs from the average age of entrainment to a mature adult increasing the uncertainty of the estimate compared to *FH*. Therefore, only an *FH* estimate for anchovy eggs was calculated. Total annual entrainment at HGS was estimated at 803,290 eggs (standard error of 23,311) and 940,784 larvae (standard error of 54,597) using measured cooling water flows during 2006 (Table 4.5-2). Based on the design (or maximum) flows, total annual entrainment was estimated at 1,932,617 eggs (standard error of 58,079) and 2,068,979 larvae (standard error of 105,000).

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

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 numbers of eggs and 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). These estimates were used to calculate that the average age of the entrained anchovy eggs was 1.3 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 0.002 up to the mean age at entrainment (20.6 days). This was calculated by dividing a larval growth rate of 0.41 mm/day (0.02 in/day) into the difference between the mean length (10.6 mm [0.42 in]) and the value of the 10^{th} percentile (2.2 mm [0.09 in]), which was used to represent the size at hatching.

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	0.2310	2.9		0.512	0.142
Yolk-sac larva	0.3660	3.6	6.5	0.093	0.240
Early larva	0.2860	12	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 value of one year. For longevity, Hart (1973) reported a value of seven years, but Leet et al. (2001) stated that northern anchovy in the fished population rarely exceed four years of age. The survivorship values in Table 4.5-9 were used to estimate an average annual fecundity of 163,090 eggs produced over a seven-year period using the data presented in Butler et al. (1993).

The estimated numbers of reproductive age adult female northern anchovies whose lifetime reproductive output was entrained through the HGS CWIS for 2006, based on the total annual entrainment of anchovy eggs, was seven using actual cooling water flows during the period or 16, based on the design cooling water flows (Table 4.5-10). The estimated numbers of reproductive age adult female northern anchovies, based on the total annual entrainment of larvae, was 5,746, based on the actual flows or 12,637, based on the design flows. Combining the two estimates based on the actual flows increases the estimated numbers of reproductive age adult female northern anchovies to 5,753 or 12,653, based on the actual and design flows, respectively. The sensitivity analysis based on the 90% confidence intervals for both eggs and larvae show that the variation in the estimates of entrainment had much less of an effect on the variation of the *FH* estimate than the life history parameters used in the models.

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

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

Table 4.5-10. Results of *FH* modeling for anchovy 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	**7**	5	2	21	19
Total Entrainment	803,290	23,311	6	7	1
Larvae					
FH Estimate	**5,746**	4,988	1,378	23,959	22,581
Total Entrainment	940,784	54,597	5,198	6,295	1,097
Design Flows					
Eggs					
FH Estimate	**16**	11	5	51	46
Total Entrainment	1,932,617	58,079	15	17	2
Larvae					
FH Estimate	**12,637**	10,963	3,033	52,652	49,619
Total Entrainment	2,068,979	105,000	11,582	13,692	2,110

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 4.5-11). The early larval stage survival was adjusted to the mean age at entrainment (20.6 days) and used to calculate a finite survival through age 63.5 days of 0.174 using the daily survival rates for late stage larvae. The other finite survival rates from Butler et al. (1993) were used to estimate the number of adults of age one year, the age of first maturity when 50% of the females are sexually mature. The equivalent number of adult northern anchovies calculated from the number of larvae entrained through the HGS CWIS for the sampling period was 25,863 based on actual flows during the period. Based on design flows, the number of larvae entrained increased to 56,879 (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	**25,863**	29,954	3,848	173,818	169,969
Total Entrainment	940,784	54,597	23,394	28,332	4,938
Design Flows					
AEL Estimate	**56,879**	65,856	8,468	382,046	373,578
Total Entrainment	2,068,979	105,000	52,130	61,627	9,497

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 of the 10th and 95th percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of approximately 37.7 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 40.6 days.

The monthly estimates of PE for northern anchovies for 2006 ranged from 0 to 0.00067 using the actual cooling water flows, and from 0 to 0.00157 using the design flows during the period (Table 4.5-12). The largest estimate was calculated for the March survey, but the largest proportion of the source population was present during the April survey (f_i = 0.325 or 32.5%). The values in the table were used to calculate a P_M estimate of 0.0071 with a standard error of 0.0043 based on the actual cooling water flows and an estimate of 0.0153 with a standard error of 0.009 based on the design flows.

Table 4.5-12. *ETM* data and results for northern anchovy larvae based upon actual and design (maximum) CWIS flow volumes using the fixed source water volume of 431,694,503 m^3.

Survey Date	Actual Flows *PE* Estimate	Actual Flows *PE* Std. Err.	Design Flows *PE* Estimate	Design Flows *PE* Std. Err.	f_i
23-Jan-06	0	0	0	0	0.00099
21-Feb-06	0	0	0	0	0
20-Mar-06	0.00067	0.00045	0.00157	0.00104	0.02672
17-Apr-06	0.00010	0.00006	0.00022	0.00013	0.32493
15-May-06	0.00025	0.00024	0.00046	0.00043	0.20117
12-Jun-06	0.00014	0.00004	0.00030	0.00009	0.22969
10-Jul-06	0	0	0	0	0.02214
7-Aug-06	0	0	0	0	0.00774
5-Sep-06	0	0	0	0	0.01580
16-Oct-06	0.00029	0.00023	0.00074	0.00059	0.03038
13-Nov-06	0.00007	0.00007	0.00016	0.00016	0.07035
11-Dec-06	0.00043	0.00025	0.00101	0.00058	0.07009
P_M	**0.0071**	0.0043	**0.0153**	0.0090	–

4.5.3.2 White croaker (*Genyonemus lineatus*)

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

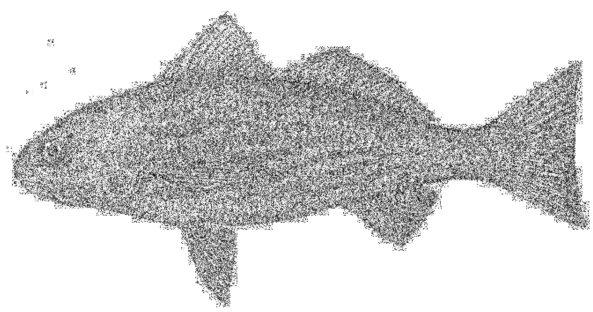


Illustration from NOAA

4.5.3.2.1 Life History and Ecology

The reported depth range of white croaker is from near the surface to depths of 238 m (781 ft) (Love et al. 2005); however, in southern California, Allen (1982) found white croaker over soft bottoms between 10 and 130 m (32.8-426.5 ft), and it was collected most frequently at 10 m. It is nocturnally active, and is considered a benthic searcher that feeds on a wide variety of benthic invertebrate prey. Adults feed on polychaetes and crustaceans, while juveniles feed during the day in midwater on zooplankton (Allen 1982).

White croakers are oviparous broadcast spawners. Detailed information on maturation, fecundity and spawning of white croaker was provided in studies by Love et al. (1984) and Love (1996). They mature between about 130 and 190 mm (5-7.5 in) TL, between their first to fourth year; approximately 50% spawn at age one year. About one-half of males mature by 140 mm (5.5 in) TL, and one-half of females by 150 mm (5.9 in) TL, and all fish are mature by 190 mm (7.5 in) TL in their third to fourth year. Off Long Beach, white croakers spawn primarily from November through August, with peak spawning from January through March. However, some spawning can occur year-round. Batch fecundities ranged from about 800 eggs in a 155 mm (6.1 mm) female to about 37,200 eggs in a 260 mm (10.2 mm) female, with spawning taking place as often as every five days. In their first and second year, 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. The nearshore waters from Redondo Beach (Santa Monica Bay) to Laguna Beach are considered an important spawning center for this species. 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 miles) from shore, and as they develop tend to move shoreward and into the epibenthos (Schlotterbeck and Connally 1982). 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 lengths at various numbers 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 0.248 mm/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). Maximum reported size is 414 mm (16.3 mm) (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 croakers are primarily nocturnal benthic feeders, though juveniles may feed in the water column during the day (Allen 1982). Important prey items include polychaetes, amphipods, shrimps, and chaetognaths (Allen 1982). In outer Los Angeles Harbor, Ware (1979) found that important prey items included polychaetes, benthic crustaceans, free-living nematodes, and zooplankton. Younger individuals feed on holoplankonic crustaceans and polychaete larvae. White croaker may move offshore into deeper water during winter months (Allen and DeMartini 1983); however, this pattern is apparent only south of Redondo Beach (Herbinson et al. 2001).

4.5.3.2.2 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 310,700 kg (685,000 lbs) annually, exceeding 453,600 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 have averaged 209,100 kg (461,000 lbs) and steadily declined to a low of 64,640 kg (142,500 lbs) in 1998. Landings by recreational fishermen aboard commercial passenger fishing vessels 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 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).

White croaker larvae predominantly occurred from November to early June in the earlier 316(b) study of the HGS in 1978-1979 (IRC 1981). Highest concentrations were recorded for the period December to March. Survey means varied from 0 to 700 larvae/1,000 m^3 (1,000 m^3 = 264,172 gal) at the near-field station (average 260/1,000 m^3) and from 0 to 6,200 larvae/1,000 m^3 (average 420/1,000 m^3) at the far-field station. These concentrations are approximately twice the 2006 values for the near-field area. Concentrations were significantly greater at the far field station indicating a larger population of spawning adults in the outer harbor area.

White croaker larvae have been collected in abundance in the Los Angeles and Long Beach Harbor complex in surveys conducted since the 1970s (HEP 1976, 1979; Brewer 1983; MBC 1984; MEC 1988). White croaker larvae comprised 5% of the total catch in a survey of the harbor complex in 2000 and exhibited peaks in abundance in May and again in November (MEC 2002). Sciaenid eggs collected in this survey comprised 35% of the total catch; white croaker eggs were most abundant in February and November trawls.

Annual commercial landings in the Los Angeles region since 2000 have varied from a high of 40,020 kg (88,200 lbs) in 2000 to a low of 6,809 kg (15,011 lbs) in 2006, with an average of 19,690 kg (43,400 lbs) and average net worth of $29,385 annually (Table 4.5-13). Sport fishery catch estimates of white croaker in the southern California region from 2000 to 2006 ranged from 64,000 to 253,000 fish, with an average of 189,400 fish caught annually (Recreational Fishery Information Network [RecFIN] 2007). In the Los Angeles-Long Beach area in 2006, 13,680 kg (30,166 lbs) were landed for revenue of $26,630 according to specific CDF&G catch block data from the area.

Table 4.5-13. 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	40,020	88,240	$50,688
2001	23,390	51,560	$36,086
2002	25,880	57,056	$41,816
2003	21,770	48,000	$33,837
2004	8,894	19,608	$14,653
2005	11,180	24,652	$17,531
2006	6,809	15,011	$11,079

4.5.3.2.3 Sampling Results

White croaker larvae was the third most abundant taxon at the entrainment station with a mean concentration of 125 per 1,000 m^3 (1,000 m^3 = 264,172 gal) over all surveys (Table 4.5-1). Unidentified croaker (Sciaenidae), which consisted of a combination of newly-hatched white croaker, queenfish, and several other croaker species, was the sixth most abundant taxon with a mean concentration of 19 per 1,000 m^3. White croaker larvae were most abundant in late winter through spring, absent in summer and fall, and began appearing again in November–December 2006 (Figure 4.5-10). During periods of maximum abundance in early April 2006 white croaker was present in entrainment samples at average concentrations of 800 per 1,000 m^3. Source water abundances followed the same seasonal pattern, but the peak average concentration in April was twice that of the entrainment samples (Figure 4.5-11). Unidentified croaker larvae were also most abundant in spring samples at both the entrainment and source water stations (Figures 4.5-12 and 4.5-13). There was no substantial difference in entrainment abundance between daytime and nighttime samples for either white croaker or unidentified croaker larvae (Figures 4.5-14 and 4.5-15). With a sample size of 711 measured white croaker larvae, the length frequency plot for larvae showed a strongly unimodal curve with over one-third of sampled larvae in the 2.0 mm (0.08 in) size class and a rapid decline in frequency of occurrence at larger size classes to 9.0 mm (0.35 in) (Figure 4.5-16). Over 90% of the unidentified croakers were 2.0 mm (0.08 in) or smaller (Figure 4.5-17) 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 2.4 mm (0.09 in) NL for white croaker and 1.5 mm (0.06 in) NL for unidentified croakers.

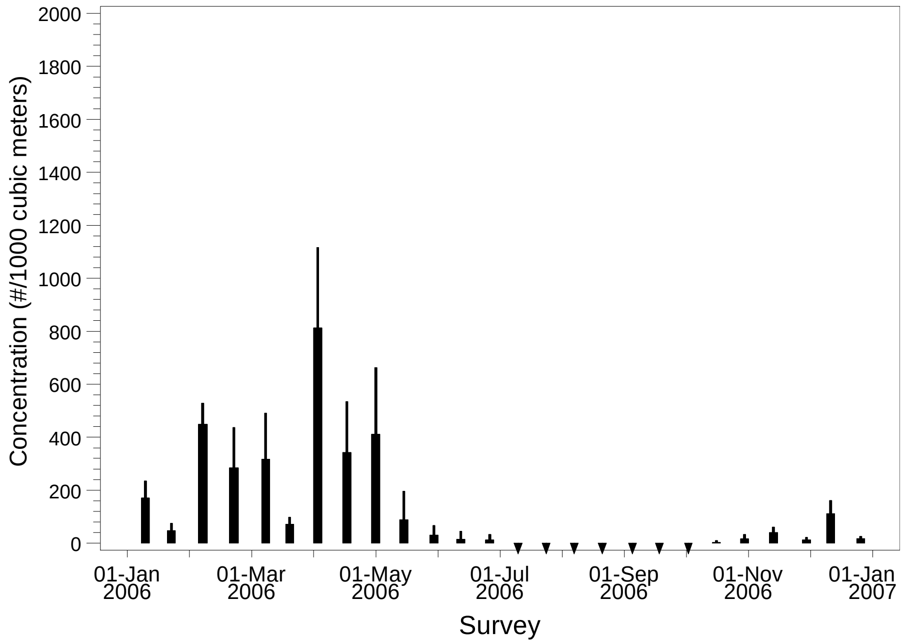


Figure 4.5-11. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of white croaker larvae collected at HGS entrainment Station E1 during 2006.

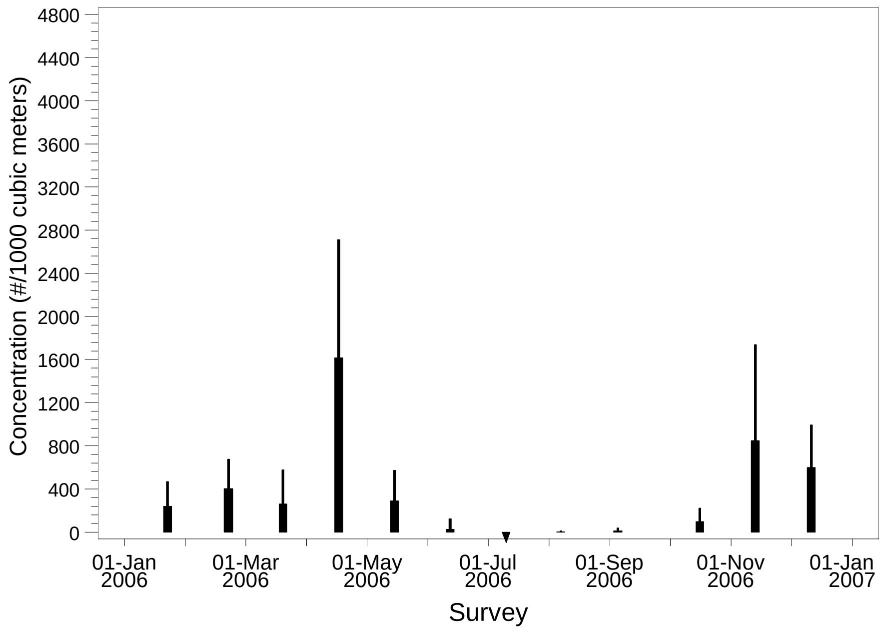


Figure 4.5-12. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of white croaker larvae collected at HGS source water stations during 2006.

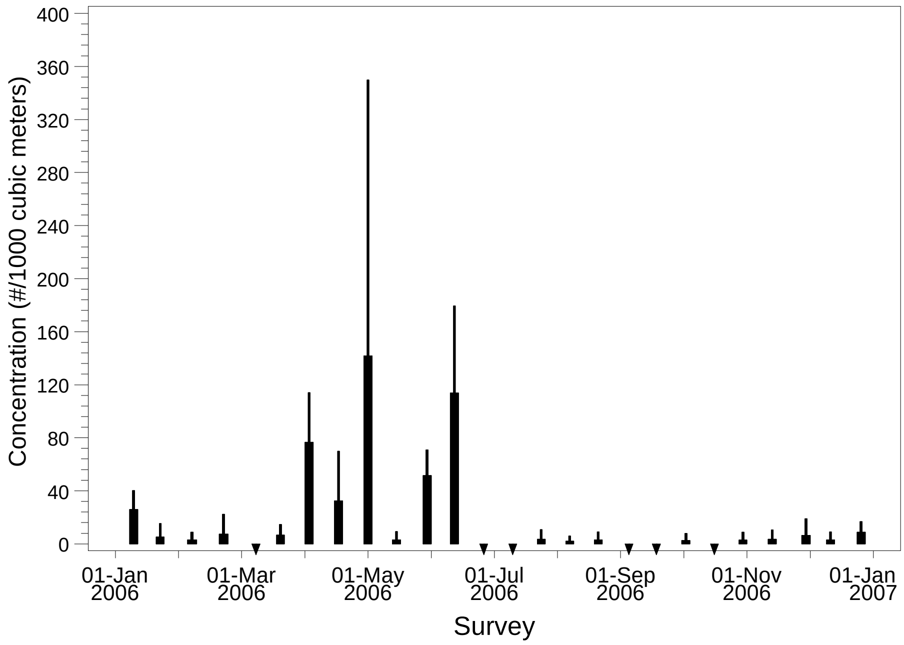


Figure 4.5-13. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of unidentified croaker larvae collected at HGS entrainment Station E1 during 2006.

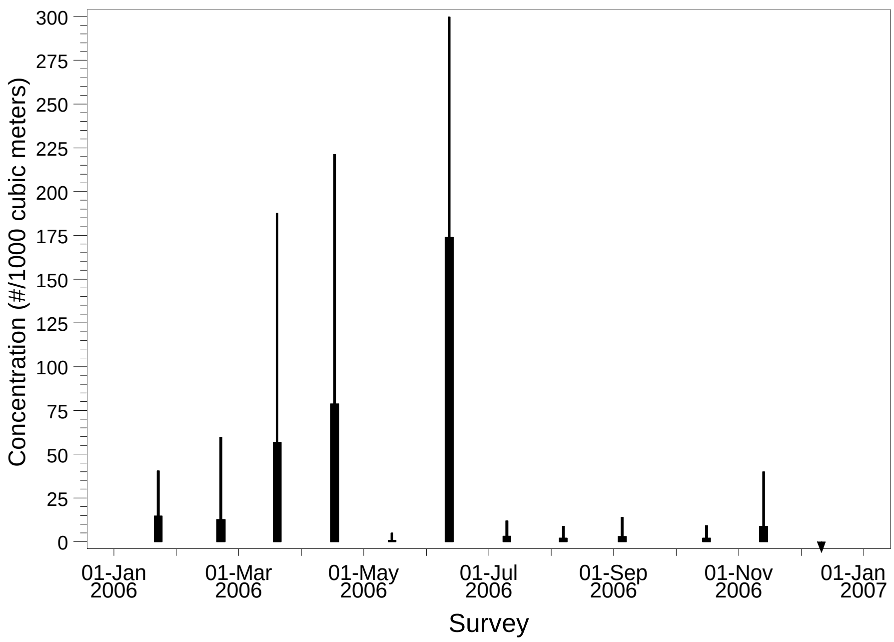
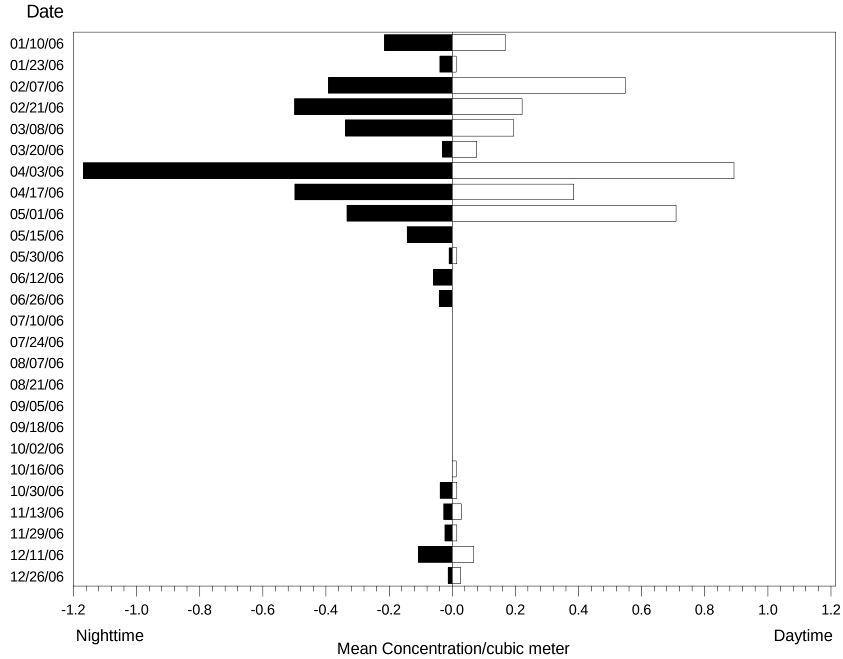
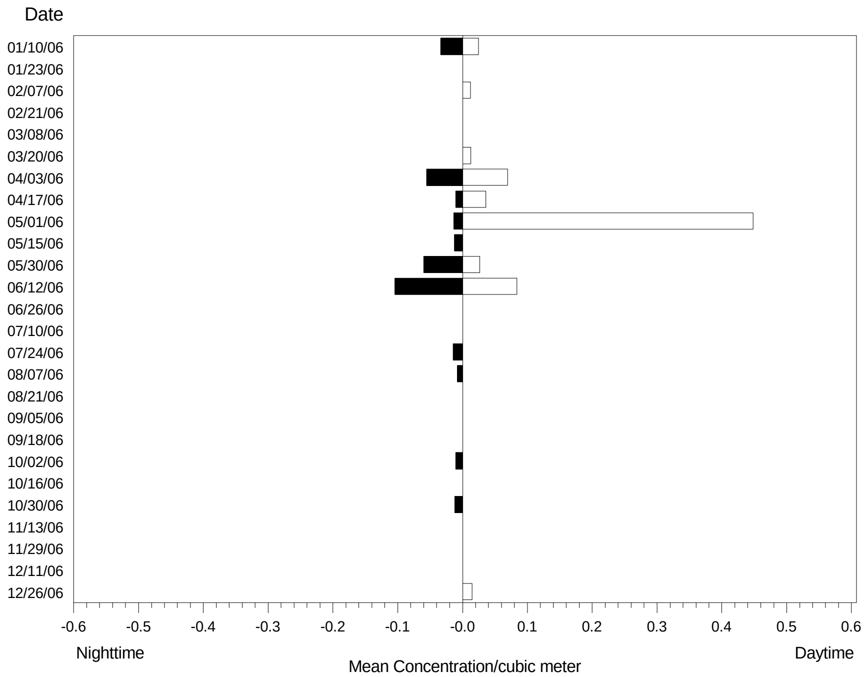


Figure 4.5-14. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of unidentified croaker larvae collected at HGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-15. 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.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-16. Mean concentration (#/1.0 m^3 [264 gal]) of unidentified croaker at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

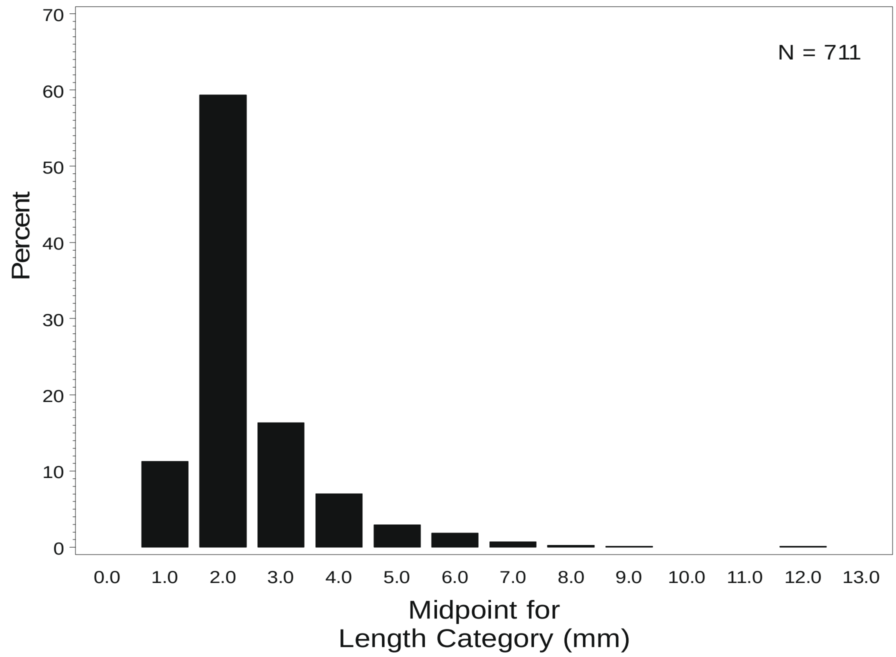


Figure 4.5-17. Length (mm) frequency distribution for larval white croaker collected at entrainment Station E1.

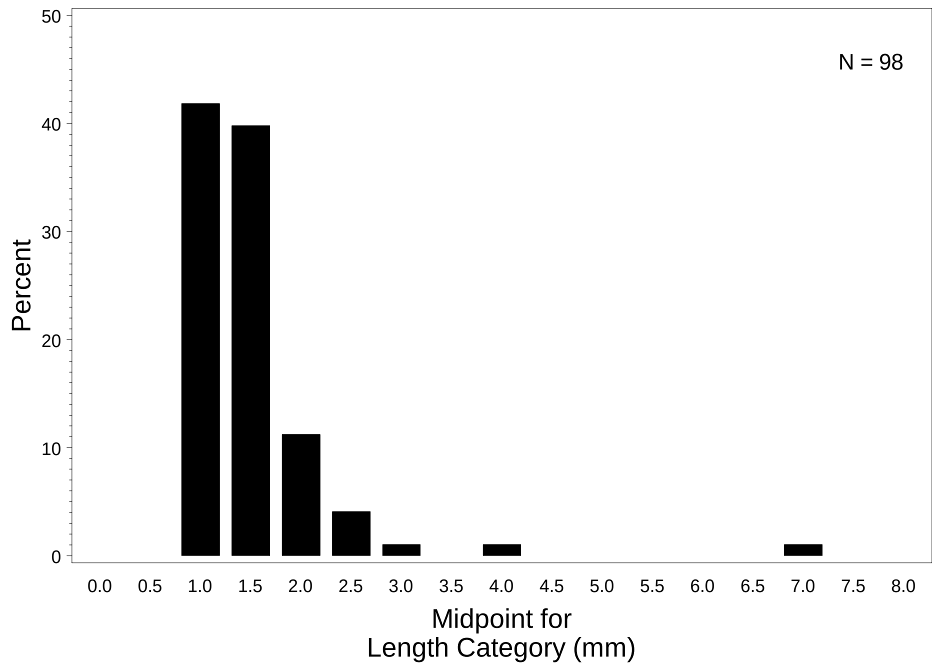


Figure 4.5-18. Length (mm) frequency distribution for larval unidentified croakers collected at entrainment Station E1.

4.5.3.2.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of entrainment effects on white croaker and unidentified croaker eggs and larvae. No age-specific estimates of survival for larval and later stages of development were available from the literature for white croaker; therefore, no estimates of *FH* or *AEL* were calculated, but enough information was available to estimate *FH* for white croaker based on numbers of eggs entrained. Total annual entrainment of white croaker eggs and larvae was 17,867,461 (standard error of 901,215) and 7,164,843 (standard error of 154,612), respectively, based on the actual cooling water flows (Table 4.5-2). Based on the design, or maximum, flows, a total of 43,114,182 white croaker eggs (standard error of 2,226,295) and 18,777,752 (standard error of 401,199) white croaker larvae were entrained. A total of 14,562,519 (standard error of 607,258) unidentified croaker eggs and 995,438 (standard error of 43,751) larvae was calculated using measured cooling water flows during 2006 (Table 4.5-2). Based on the design cooling water flows, the total annual entrainment was estimated at 41,351,239 unidentified croaker eggs (standard error of 1,519,856) and 2,856,932 (standard error of 173,898) for larvae.

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

The annual entrainment estimate for white croaker eggs was used to calculate the number of breeding females at the age of maturity needed to produce the estimated number of larvae entrained. An estimate of egg survival of 0.781 was based on 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 an average age in the population of 5.75 years. Life history information presented in Love et al. (1984) is summarized in Section 4.5.3.5.1—*Life History and Ecology*. The estimated numbers of female white croakers whose lifetime reproductive output was entrained through the HGS CWIS for the 2006 period was estimated at 10 fish based on the actual cooling water flows and at 24, based on the design cooling water flows (Table 4.5-14).

Table 4.5-14. 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	**10**	7	3	32	29
Total Entrainment	17,867,461	901,215	9	11	2
<u>Design Flows</u>					
FH Estimate	**24**	17	7	77	70
Total Entrainment	43,114,182	2,226,29	22	26	4

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 0.248 mm/day derived from data on five species of Sciaenidae (croakers) that were raised in the laboratory by Southwest Fisheries Science Center staff (Moser 1996). A random sample of 200 lengths from the 711 measured white croaker larvae and all of the 98 measured unidentified croakers were used to calculate a difference between the estimated hatch lengths and the 95th percentiles of the measurements to estimate that white croaker and unidentified croakers were exposed to entrainment for periods of approximately 15.2 and 6.1 days, respectively. The duration of the planktonic egg stage, 2.2 days, was added to the periods for the larvae to estimate total periods of exposure of 17.4 and 8.2 days, respectively.

The monthly estimates of *PE* for white croaker for 2006 ranged from 0 to 0.00028 using the actual cooling water flows during the period and from 0 to 0.00070 using the design flows (Table 4.5-15). The largest estimate was calculated for the February survey, but the largest proportion of the source population was present during the April survey (f_i = 0.360 or 36.0%). The values in the table were used to calculate a P_M estimate of 0.0019 with a standard error of 0.0006 based on the actual flows and an estimate of 0.0042 with a standard error of 0.0014 based on the design flows.

Table 4.5-15. *ETM* data and results for white croaker larvae based upon actual and design (maximum) CWIS flow volumes using the fixed source water volume of 431,694,503 m^3.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
23-Jan-06	0.00009	0.00003	0.00021	0.00007	0.05264
21-Feb-06	0.00028	0.00008	0.00070	0.00020	0.10309
20-Mar-06	0.00012	0.00003	0.00029	0.00008	0.05394
17-Apr-06	0.00010	0.00003	0.00023	0.00007	0.35871
15-May-06	0.00018	0.00011	0.00032	0.00020	0.07015
12-Jun-06	0.00025	0.00031	0.00056	0.00068	0.00582
10-Jul-06	0	0	0	0	0
7-Aug-06	0	0	0	0	0.00064
5-Sep-06	0	0	0	0	0.00229
16-Oct-06	0.00001	0.00001	0.00004	0.00004	0.02081
13-Nov-06	0.00002	0.00001	0.00005	0.00001	0.19697
11-Dec-06	0.00008	0.00002	0.00019	0.00005	0.13494
P_M	**0.0019**	0.0006	**0.0042**	0.0014	–

The monthly estimates of *PE* for unidentified croakers for 2006 ranged from 0 to 0.00281 using the actual cooling water flows and from 0 to 0.00663 based on the design flows (Table 4.5-16). The largest estimate was calculated for the December 2006 survey, but the largest proportion of the source population was present during the June survey (f_i = 0.484 or 48.4%). The values in the table were used to calculate a P_M estimate of 0.0019 with a standard error of 0.0011 based on the actual cooling water flows and an estimate of 0.0041 with a standard error of 0.0023 based on the design flows.

Table 4.5-16. *ETM* data and results for unidentified croaker larvae based upon actual and design (maximum) CWIS flow volumes and fixed source water volume of 431,694,503 m^3.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
23-Jan-06	0.00016	0.00017	0.00037	0.00039	0.04196
21-Feb-06	0.00024	0.00029	0.00059	0.00072	0.04043
20-Mar-06	0.00006	0.00004	0.00013	0.00009	0.14532
17-Apr-06	0.00019	0.00013	0.00043	0.00029	0.22753
15-May-06	0.00137	0.00173	0.00251	0.00310	0.00395
12-Jun-06	0.00029	0.00010	0.00065	0.00021	0.48384
10-Jul-06	0.00000	0	0.00000	0	0.00856
7-Aug-06	0.00051	0.00062	0.00095	0.00112	0.00633
5-Sep-06	0.00000	0	0.00000	0	0.00803
16-Oct-06	0.00000	0	0.00000	0	0.00563
13-Nov-06	0.00019	0.00024	0.00042	0.00051	0.02706
11-Dec-06	0.00281	0.00401	0.00663	0.00938	0.00137
P_M	**0.0019**	0.0011	**0.0041**	0.0023	–

4.5.3.3 Combtooth blennies (*Hypsoblennius* spp.)

Gerald Allen

Combtooth blennies comprise a large group of subtropical and tropical fishes that inhabit inshore rocky habitats throughout much of the world. The family Blenniidae, the combtooth blennies, contains about 345 species in 53 genera (Nelson 1994, Moser 1996). They derive their common name from the arrangement of closely spaced teeth in their jaws. Three species of the genus Hypsoblennius occur in the vicinity of HGS: 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).

4.5.3.3.1 Life History and Ecology

Combtooth blennies are all relatively small fishes that typically grow to a total length of less than 200 mm (7.9 in) (Moser 1996). Most have blunt heads that are topped with some arrangement of cirri (Moyle and Cech 1988; Moser 1996). Their bodies are generally elongated 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 HGS 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 species.

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.

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 inches) TL, mussel blenny to 13 cm (5.1 inches), rockpool blenny to 17 cm (6.8 inches)
- Age at maturity: all species ≈0.5 years
- 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 submerged aquatic vegetation and mussels on mooring buoys; to 24 m (80 ft)
- Mussel blenny—empty worm tubes and barnacle tests on pilings, mussel beds, crevices in shallow rock reefs; to 21 m (70 ft)
- Rockpool blenny—under rocks, in crevices on shallow rock reefs; to 18 m (60 ft)

Fishery: None

The California blennies have different habitat preferences. The mussel blenny is only found subtidally and inhabits mussel beds, the empty drill cavities of boring clams, barnacle tests, or in crevices among the vermiform snail tubes *Serpulorbis* spp. (Stephens 1969; Stephens et al. 1970). They generally remain within one meter of their chosen refuge (Stephens et al. 1970). The bay blenny is usually found subtidally, but appears to have general habitat requirements and may inhabit a variety of intertidal and subtidal areas (Stephens et al. 1970). They are commonly found in mussel beds and on encrusted floats, buoys, docks, and even fouled boat hulls (Stephens 1969; Stephens et al. 1970). Bay blennies are also typically found in bays as the common name implies and are tolerant of estuarine conditions (Stephens et al. 1970). They are among the first resident fish species to colonize new or disturbed marine habitats such as new breakwaters or mooring floats after the substrate is first colonized by attached invertebrates (Stephens et al. 1970; Moyle and Cech 1988). Rockpool blennies are mainly found along shallow rocky shorelines, along breakwaters, and in shallow kelp forests along the outer coast.

Female blennies mature quickly and reproduce within the first year, reaching peak reproductive potential in the third year (Stephens 1969). The spawning season typically begins in the spring and may extend into September (Stephens et al. 1970). Blennies are oviparous and lay demersal eggs that are attached to the nest substrate by adhesive pads or filaments (Moser 1996). Males tend the nest and developing eggs. Females spawn three to four times over a period of several weeks (Stephens et al. 1970). Males guard the nest aggressively and will often chase the female away; however, several females may occasionally spawn with a single male. The number of eggs a female produces varies proportionately with size (Stephens et al. 1970). The mussel blenny spawns approximately 500 eggs in the first reproductive year and up to 1,500 eggs by the third year (Stephens et al. 1970). Total lifetime fecundity may be up to 7,700 eggs (Stephens 1969).

Larvae are pelagic and average approximately 2.7 mm (0.11 in) in length two days after hatching (Stephens et al. 1970). The planktonic phase for *Hypsoblennius* spp. larvae may last for three 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 blennies 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).

4.5.3.3.2 Population Trends and Fishery

Average concentrations of Hypsoblennius species complex larvae were lowest from mid-January through the end of March and greatest from April through September in the earlier 316(b) study of the HGS in 1978−1979 (IRC 1981). Concentrations at the near-field station varied from 0 to 1,880 larvae per 1,000 m3 (average 70 per 1,000 m3) and from 1 to 1,800 larvae per 1,000 m3 (average 120 per 1,000 m3) at the far-field station. The near-field concentrations were approximately three times greater than the 2006 values measured at the entrainment station while the far field station concentrations were about half of the 2006 values. There was no significant difference in concentration between day and night samples.

Combtooth blenny larvae have been collected in high abundance in surveys of the Los Angeles and Long Beach Harbor Complex since the 1970s (HEP 1976, 1979; Brewer 1983; MBC 1984; MEC 1988). Abundances of Hypsoblennius spp. larvae ranged from 5–20 % of the total catch. In a survey in the harbor complex conducted in 2000, combtooth blenny larvae comprised 5% of the total catch (MEC 2002).

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

4.5.3.3.3 Sampling Results

Combtooth blenny was the fifth most abundant taxon at the entrainment station with a mean concentration of 30 per 1,000 m3 over all surveys (Table 4.5-1). They were most abundant in summer, peaking in June, with a smaller peak in early fall (Figure 4.5-18). They were largely absent from winter samples. During periods of maximum abundance in early June 2006, combtooth blennies were present in the entrainment samples at average concentrations of 165 per 1,000 m3. Source water abundances followed the same seasonal pattern, but the peak average concentration in June was much higher at 1,056 per 1,000 m3 (Figure 4.5-19). There was no substantial difference in entrainment abundance between daytime and nighttime samples (Figure 4.5-20). The length frequency range for larvae was small, with over 95% in the 2.0–4.0 mm (0.08-0.16 in) size classes (Figure 4.5-21). The mean length of specimens from the entrainment station samples was 2.7 mm (0.11 in) NL.

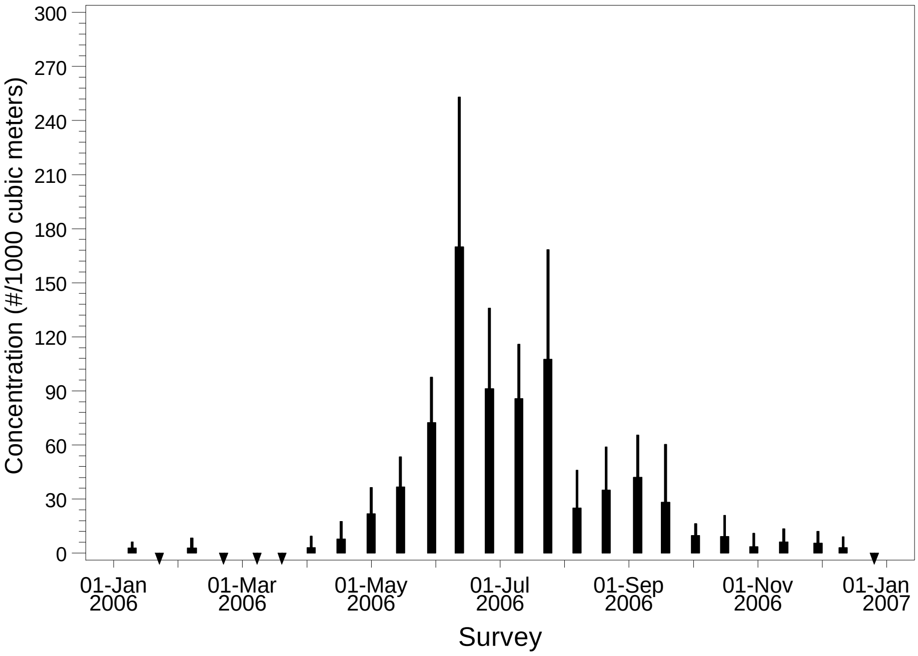


Figure 4.5-19. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of combtooth blenny larvae collected at HGS entrainment Station E1 during 2006.

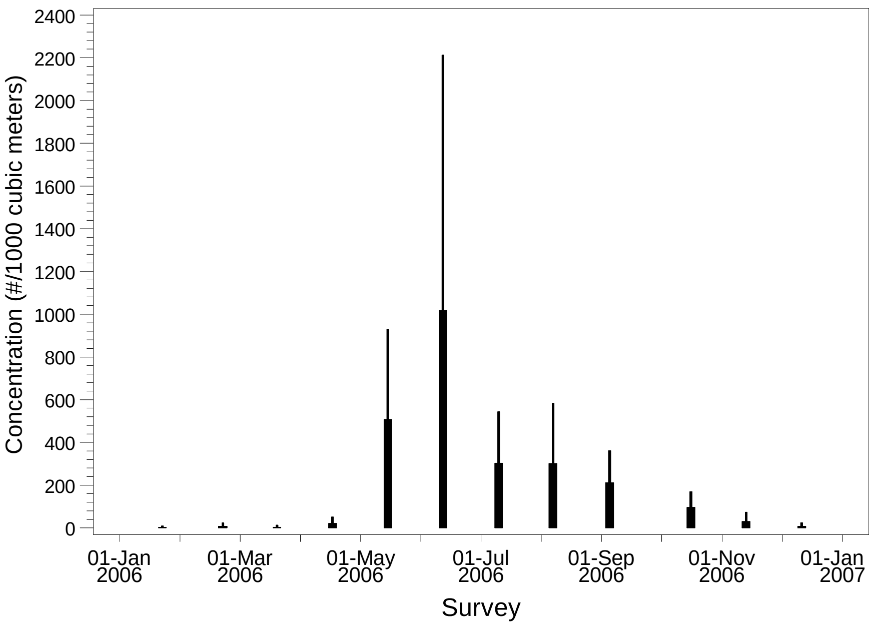
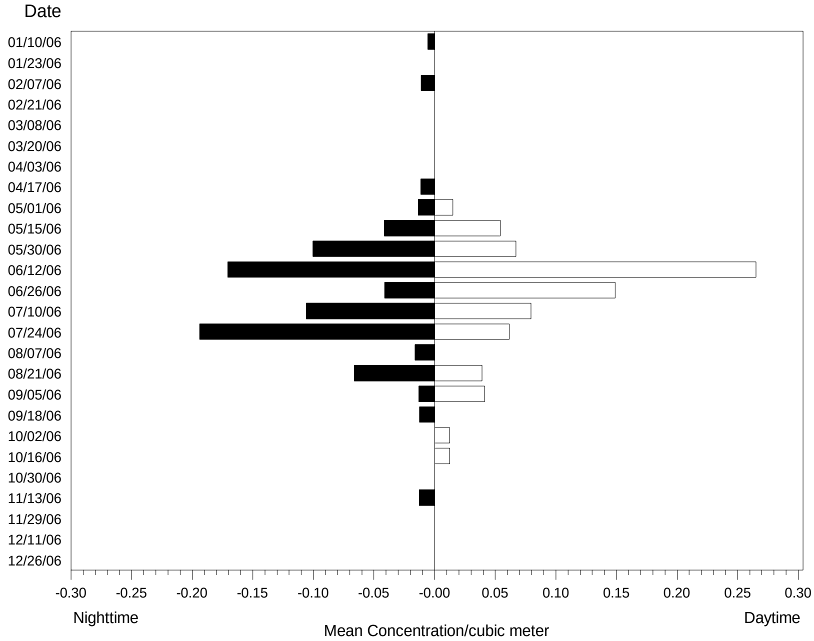


Figure 4.5-20. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of combtooth blenny larvae collected at HGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-21. Mean concentration (#/1.0 m^3 [264 gal]) of combtooth blenny larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

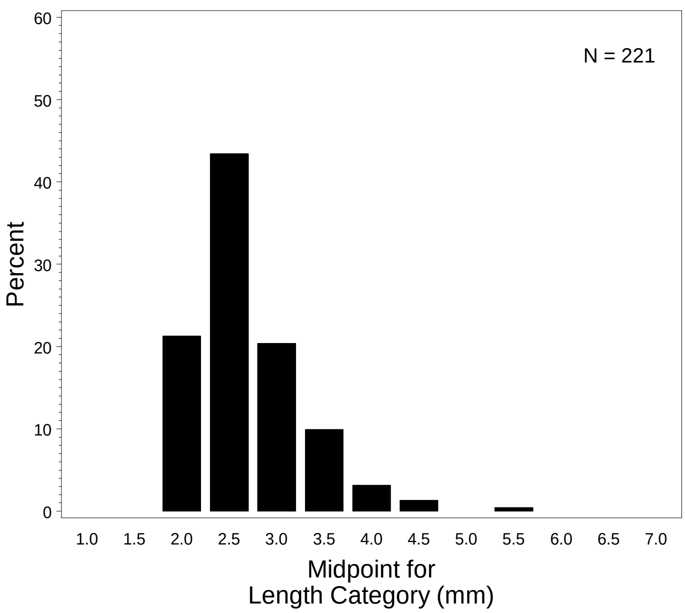


Figure 4.5-22. Length (mm) frequency distribution for combtooth blenny larvae collected at entrainment Station E1.

4.5.3.3.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of CWIS effects on combtooth blennies. There was very little species-specific life history information available for combtooth blennies. Larval survival was estimated using data from Stephens (1969) and Stevens and Moser (1982), and there was enough other information on reproduction to calculate both *FH* and *AEL* estimates. Larval growth was estimated from information from Stevens and Moser (1982). Total annual entrainment of combtooth blenny larvae at HGS was estimated at 2,255,907 (standard error of 55,768) using actual cooling water flows during 2006 and using the design (or maximum) flows, annual entrainment was estimated at 4,362,576 (standard error of 100,491) (Table 4.5-2).

Fecundity Hindcasting *(FH)*

The annual entrainment estimate for combtooth blenny larvae was used to estimate the number of females at the age of maturity needed to produce this number of larvae over their lifetimes. No estimates of egg survival for combtooth blenny were available, but because egg masses are attached to the substrate and guarded by the male (Stephens et al. 1970), egg survival is probably high and was conservatively assumed to be 100%. The mean length from a random sample of 200 combtooth blenny larvae was 2.7 mm (0.11 in). A larval growth rate of 0.20 mm/day (0.008 in/day) was derived from data in Stevens and Moser (1982). The mean length and estimated hatch length of 2.2 mm (0.09 in) were used with the growth rate to estimate that the mean age at entrainment was 2.3 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 $0.89^{2.3} = 0.76$. A quadratic equation was used to estimate adult survival *S* at age in days *x* using Figure 17 in Stephens (1969):

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

An adult survivorship table (Table 4.5-17) 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 4.5-17. 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 numbers of female combtooth blennies at the age of maturity (0.5 year) whose lifetime reproductive output was entrained through the HGS CWIS during 2006 was 1,413 based on entrainment estimates calculated using actual cooling water flows during the period and increased to 2,733 based on the design flows (Table 4.5-18). 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 4.5-18. 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	**1,413**	1,225	340	5,878	5,538
Total Entrainment	2,255,90	55,768	1,356	1,471	115
Design Flows					
FH Estimate	**2,733**	2,368	657	11,366	10,708
Total Entrainment	4,362,57	100,491	2,630	2,837	207

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 $0.89^{(50-2.3)} = 0.003$ 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 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 to the age at first maturity of 0.5 years.

The equivalent number of adult combtooth blennies calculated from the number of larvae entrained through the HGS CWIS for the sampling period was 6,024 based on actual cooling water flows and 11,650 based on the design flows during 2006 (Table 4.5-19). 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 4.5-19. Results of *AEL* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual and design CWIS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
Actual Flows					
AEL Estimate	**6,024**	7,379	803	45,190	44,387
Total Entrainment	2,255,907	55,768	5,779	6,269	490
Design Flows					
AEL Estimate	**11,650**	14,270	1,553	87,385	85,832
Total Entrainment	4,362,576	100,491	11,208	12,091	883

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 random sample of 200 lengths from the 221 measured larvae was used to calculate the difference between the estimated hatch lengths and the 95th percentiles of the measurements. This value and a growth rate of 0.20 mm/day (0.008 in/day) were used to estimate that blennies were exposed to entrainment for a period of approximately 7.5 days.

The monthly estimates of *PE* for combtooth blennies for the 2006 period varied among surveys and ranged from 0 to 0.00017 based on the actual flows and ranged from 0 to 0.00041 based on the design flows (Table 4.5-20). The largest estimates were calculated for the April and December surveys, but the largest proportion of the source population was present during the June survey (f_i = 0.381 or 38.1%). As the results for the January–March surveys 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 0.0006 with a standard error of 0.0002 based on the actual cooling water flows. Using the design flows, an estimate of 0.0012 with a standard error of 0.0004 was calculated.

Table 4.5-20. *ETM* data and results for combtooth blenny larvae based upon actual and design (maximum) CWIS flow volumes using the fixed source water volume of 431,694,503 m^3.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
23-Jan-06	0	0	0	0	0.00094
21-Feb-06	0	0	0	0	0.00327
20-Mar-06	0	0	0	0	0.00129
17-Apr-06	0.00017	0.00011	0.00038	0.00024	0.00904
15-May-06	0.00004	0.00001	0.00008	0.00002	0.21583
12-Jun-06	0.00008	0.00002	0.00018	0.00005	0.38149
10-Jul-06	0.00016	0.00003	0.00030	0.00006	0.12500
7-Aug-06	0.00005	0.00002	0.00009	0.00004	0.12077
5-Sep-06	0.00012	0.00004	0.00021	0.00006	0.08589
16-Oct-06	0.00004	0.00003	0.00010	0.00007	0.04028
13-Nov-06	0.00010	0.00007	0.00022	0.00014	0.01293
11-Dec-06	0.00017	0.00019	0.00041	0.00044	0.00326
P_M	**0.0006**	0.0002	**0.0012**	0.0004	–

4.5.3.4 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.

4.5.3.4.1 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. 1978), Anaheim Bay (MacDonald 1975) and Newport Bay (Allen 1982). Arrow and cheekspot gobies were reported as abundant from the Cabrillo Beach area in outer Los Angeles Harbor based on beach seine sampling (Allen et al. 1983). The life history of the arrow goby was reviewed by Emmett et al. (1991) and the comparative ecology and behavior of all three species were studied by Brothers (1975) in Mission Bay.

Arrow goby have the most northerly range of the three species, occurring from Vancouver Island, British Columbia to southern Baja California (Eschmeyer and Herald 1983). The reported northern range limits of both shadow goby *Quietula y-cauda* and cheekspot goby *Ilypnus gilberti* are in central California with sub-tropical southern ranges that extend well into the Gulf of California (Robertson and Allen 2002). Their physiological tolerances reflect their geographic distributions with arrow goby less tolerant of warmer temperatures compared to cheekspot goby. When exposed to temperatures of 32.1°C (89.8°F) for three days in a laboratory experiment, no arrow gobies survived but 95% of cheekspot goby did survive

(Brothers 1975). The species inhabits burrows of ghost shrimps (*Neotrypaea* spp.) and other burrowing invertebrates, such as the fat innkeeper worm (*Urechis caupo*), and gobies exposed to warm temperatures on mudflats can seek refuge in their burrows where temperatures can be several degrees cooler than surface temperatures.

The reproductive biology is similar among the three species in the CIQ complex. Arrow goby typically mature sooner than the other two species, attaining 50% maturity in the population after approximately 8 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 of the CIQ complex deposit 2–5 batches of eggs per year.

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 inches) (arrow goby); 64 mm (2.5 inches) (cheekspot goby); 70 mm (2.75 inches) (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.

CIQ complex larvae hatch at a size of 2–3 mm (0.08-1.1 in) (Moser 1996). Data from Brothers (1975) were used to estimate an average growth rate of 0.16 mm/day (0.006 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 (0.4-0.6 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.

4.5.3.4.2 Population Trends and Fishery

Average concentrations of gobiid species complex larvae were lowest from October through December and greatest from February through June in the earlier 316(b) study of the HGS in 1978–1979 (IRC 1981). Average survey concentrations for the near-field station varied from 0 to 17,170 larvae per 1,000 m^3 (1,000 m^3 = 264,172 gal) (average 2,190 per 1,000 m^3) and from 1 to 4,310 larvae per 1,000 m^3 (average 320 per 1,000 m^3) for the far-field station. The near-field concentrations were over 30 times greater than the 2006 concentrations at the entrainment station, while the far field station concentrations were only about 50% greater. There was no significant difference in abundance between day and night samples at the near-field station.

Larval CIQ gobies have been one of the most abundant species collected in previous surveys of the Los Angeles-Long Beach Harbor Complex area (HEP 1976; Brewer 1983; MEC 2002). In a survey conducted in 2000, CIQ goby was the most abundant species group collected, comprising 33% of the total catch (MEC 2002). In a 5-year study of fishes in San Diego Bay from 1994–1999, approximately 75% of the estimated 4.5 million (standing stock) gobies were juveniles (Allen et al. 2002). Seasonal peaks in population abundance generally occurred in summer and fall and were associated with settlement of young-of-the-year although high abundances were also recorded in January and April of some years. Population abundances vary among years and may be correlated to the severity of winter rainfall events and urban runoff that may impact the water quality of seasonal estuaries in southern California. There is no fishery for these goby species because of their small size.

4.5.3.4.3 Sampling Results

CIQ complex goby larvae were the most abundant taxon at the entrainment station with a mean concentration of 516 per 1,000 m^3 (1,000 m^3 = 264,172 gal) over all surveys (Table 4.5-1). They were present during all surveys, but tended to be most abundant in the March–April period and during June (Figure 4.5-22). During periods of maximum abundance in early April 2006, CIQ complex gobies were present in the entrainment samples at average concentrations of 1,750 per 1,000 m^3. Gobies were also present at the source water stations during all months of the year, with a peak average concentration in May 2006 of 368 per 1,000 m^3 (Figure 4.5-23). The larvae tended to be more abundant in nighttime samples, particularly from July through December (Figure 4.5-24). 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). The size classes of most larvae were in the 2.0–5.0 mm (0.08–0.20 in) range with a small proportion in the 6.0–14.0 mm (0.2–0.6 in) size classes (Figure 4.5-25). The mean length of specimens from the entrainment station samples was 4.1 mm (0.16 in) NL.

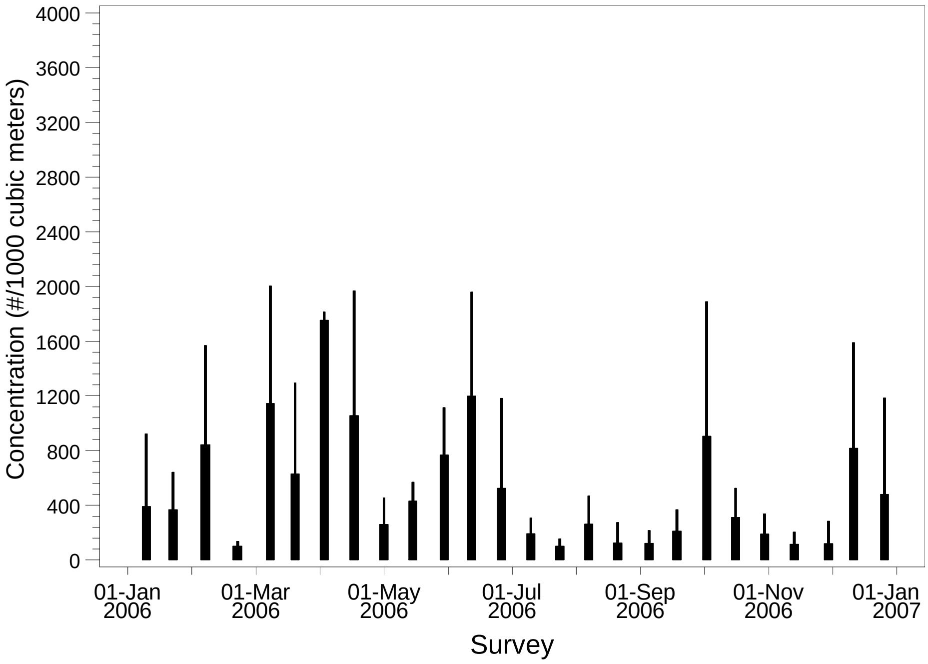


Figure 4.5-23. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of unidentified goby larvae (CIQ gobies) collected at HGS entrainment Station E1 during 2006.

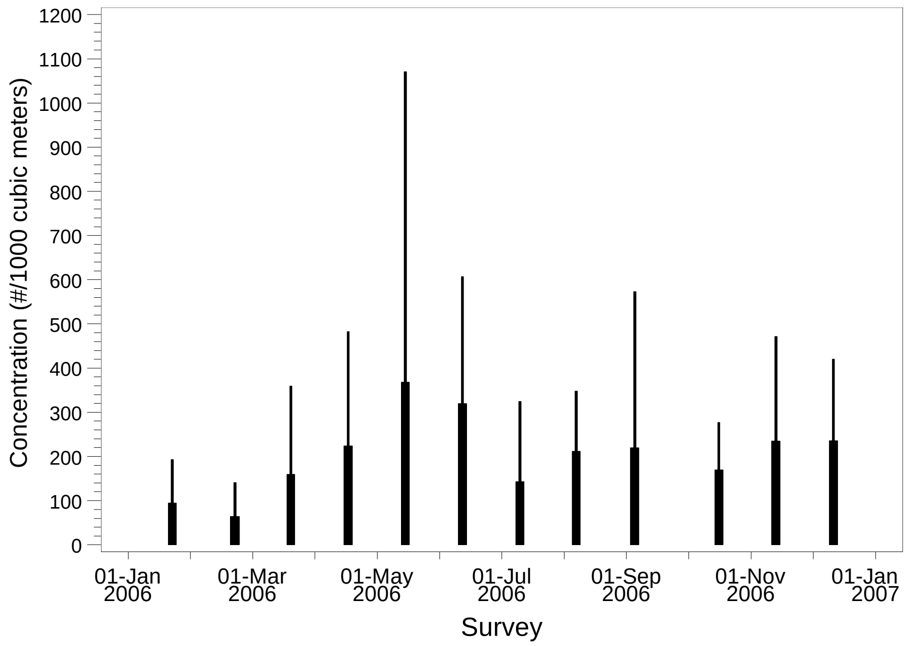
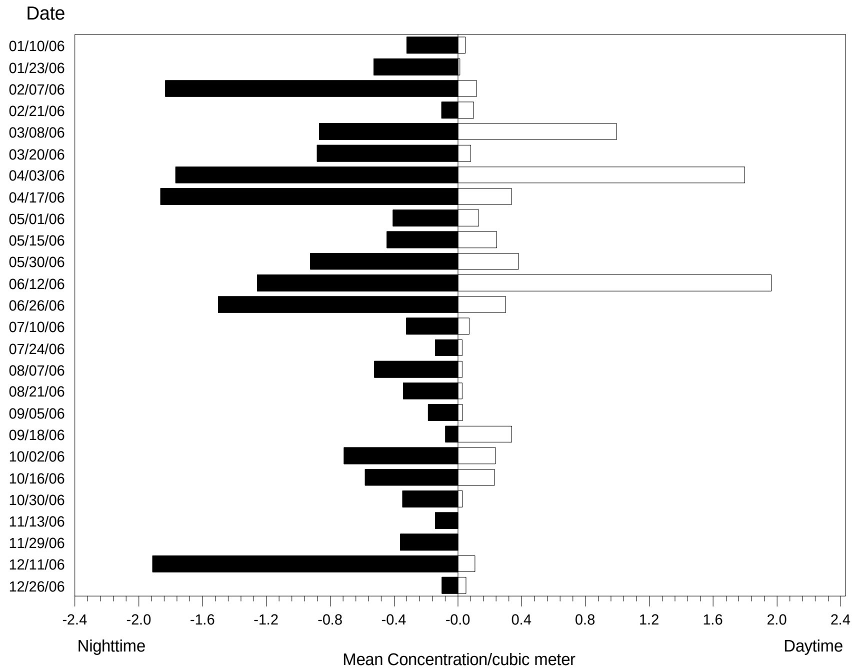


Figure 4.5-24. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of unidentified goby larvae (CIQ gobies) collected at HGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-25. Mean concentration (#/1.0 m^3 [264 gal]) of unidentified goby larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

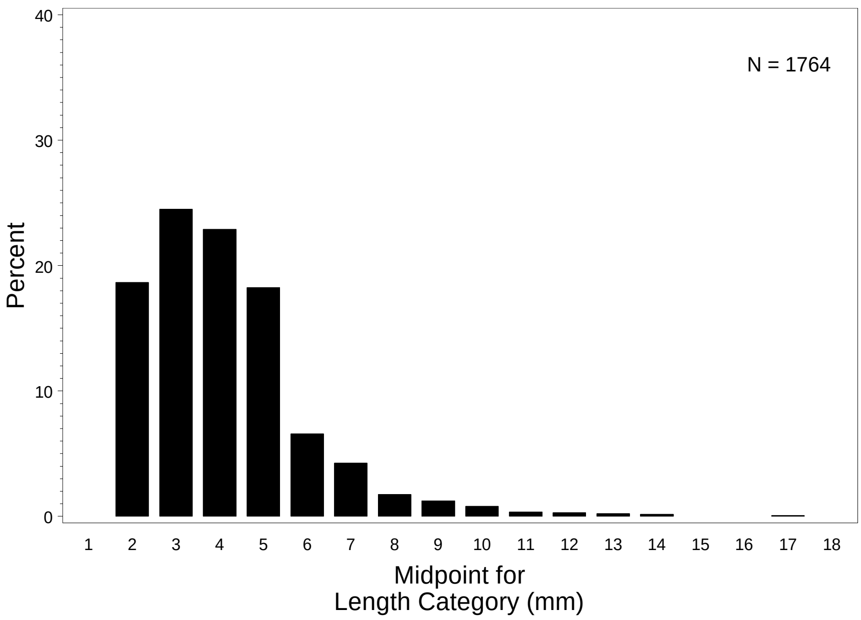


Figure 4.5-26. Length (mm) frequency distribution for unidentified goby larvae collected at entrainment Station E1.

4.5.3.4.4 Modeling Results

The following sections present 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) provided the necessary life history information for both *FH* and *AEL* models. Total annual entrainment of CIQ goby larvae at HGS was estimated to be 33,290,815 (standard error of 869,904), using actual measured cooling water flows and using the design flows was estimated at 75,938,007 (standard error of 1,933,837) during 2006 (Table 4.5-2).

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

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 percent. 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 (4.2 mm [0.16 in]) and the estimated hatch length of 2.84 mm (0.11 in) from a random sample of 200 of the measured larvae were used with the calculated growth rate to estimate that the mean age at entrainment was 8.4 days. Survival to the average age at entrainment was then estimated as $0.93^{8.4} = 0.55$. A survivorship table was constructed using data from Brothers (1975) and was used to estimate a total lifetime fecundity of 1,400 eggs (Table 4.5-21). The age when at 50% of the female population was reproductive averaged 1.67 years.

The estimated numbers of female gobies at the age of maturity, whose lifetime reproductive output was entrained through the HGS circulating water system for the 2006 period, was 43,360 based on the actual cooling water flows and 98,906 based on the design flows (Table 4.5-22). The results of the sensitivity analysis show that the greatest uncertainty associated with the estimate is related to the life history parameters in the model and not the entrainment estimate.

Table 4.5-21. 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 4.5-22. 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	**43,360**	37,568	10,42	180,331	169,90
Total Entrainment	33,290,81	869,904	41,49	45,224	3,728
Design Flows					
FH Estimate	**98,906**	85,692	23,78	411,330	387,54
Total Entrainment	75,938,00	1,933,83	94,76	103,049	8,287

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 $0.93^{60-8.4} = 0.02$ using the same daily survival rate used in formulating *FH*. Brothers (1975) estimated that mortality in the first year following settlement was 99% for arrow, 66–74% for cheekspot, and 62–69% for shadow goby. These estimates were used to calculate a daily survival of 0.995 that was used to estimate a finite survival of 0.21 for the first year following settlement. Daily survival through the average female age of 2.21 years, from life table data for the three species, was estimated as 0.994 and was used to calculate a finite survival over the period of 0.21.

The estimated number of adult CIQ gobies equivalent to the number of larvae entrained through the HGS CWIS for the 2006 sampling period was 36,231 based on an entrainment estimate calculated using actual CWIS flows and was 82,665 based on the design cooling water flows (Table 4.5-23). 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 4.5-23. 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	**36,231**	40,708	5,711	229,972	224,261
Total Entrainment	33,290,815	869,904	34,682	37,798	3,116
Design Flows					
AEL Estimate	**82,665**	92,855	13,027	524,564	511,537
Total Entrainment	75,938,007	1,933,837	79,202	86,128	6,926

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 (8.1 mm [0.32 in]) and the estimated hatch length of 2.8 mm (0.11 in) 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 32.7 days.

CIQ gobies larvae were present in the entrainment and source water samples throughout the year. The monthly estimates of *PE* for the 2006 period ranged from 0.00023 to 0.00130 using the actual cooling water flows (Table 4.5-24). Based on the design flows during the period, the estimates ranged from 0.00050 to 0.00292. The largest estimates occurred during the April survey with the largest proportion of the source population occurring slightly later in the year in the June survey (f_i = 0.143 or 14.3 percent). The values in the table were used to calculate a P_M estimate of 0.0265, with a standard error of 0.0112 based on the actual flows and an estimate of 0.0570 with a standard error of 0.0236 based on the design flow volumes.

Table 4.5-24. *ETM* data and results for CIQ goby larvae based upon actual and design (maximum) CWIS flow volumes using the fixed source water volume of 431,694,503 m^3.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
23-Jan-06	0.00111	0.00047	0.00261	0.00107	0.04614
21-Feb-06	0.00056	0.00013	0.00138	0.00031	0.02558
20-Mar-06	0.00112	0.00065	0.00263	0.00151	0.07270
17-Apr-06	0.00130	0.00063	0.00292	0.00139	0.11825
15-May-06	0.00059	0.00020	0.00108	0.00036	0.13925
12-Jun-06	0.00114	0.00041	0.00254	0.00088	0.14297
10-Jul-06	0.00067	0.00023	0.00121	0.00040	0.05170
7-Aug-06	0.00061	0.00026	0.00112	0.00046	0.07611
5-Sep-06	0.00031	0.00016	0.00057	0.00028	0.07090
16-Oct-06	0.00062	0.00022	0.00155	0.00056	0.06600
13-Nov-06	0.00023	0.00010	0.00050	0.00021	0.08033
11-Dec-06	0.00103	0.00053	0.00242	0.00124	0.11007
P_M	**0.0265**	0.0112	**0.0570**	0.0236	–

4.5.3.5 Yellowfin Goby (*Acanthogobius flavimanus*)

Yellowfin goby (Acanthogobius flavimanus) is native to Japan, South Korea, and China, where it ranges from nearshore marine to coastal fresh water habitats (Brittan et al. 1963; Haaker 1979). This goby is catadromous in Japan, moving from fresh water to saline mudflats to spawn (Herbold et al. 1989). Yellowfin goby is an introduced (non-indigenous) species now common in many bays and estuaries of California. The first documented collection of a yellowfin goby in California occurred in January 1963 in a midwater trawl from the San Joaquin River (Brittan et al. 1963), and they were first found in Los Angeles Harbor around 1977 (Moyle 2002). Explanations for its introduction into California harbors include transport of adults in the fouled seawater system of ships, transport of eggs or larvae in ballast water or on fouling organisms on ships' hulls, and import of eggs with oyster spat from Japan. Due to transport of their pelagic larval stage by nearshore currents they are now widespread in bays and coastal lagoons in southern California (Schroeter and Moyle 2006).

4.5.3.5.1 Life History and Ecology

The early life history of yellowfin goby is similar to other members of the family Gobiidae. Females are oviparous, laying demersal, adhesive eggs in burrows guarded by males until the planktonic larvae hatch (Moser 1996). Spawning occurs mainly in winter and spring. Female yellowfin goby in Japan lay between 6,000 and 32,000 eggs and may be terminal spawners, with many dying after the eggs are released

(Miyazaki 1940, cited in Wang 1986). Wang's (1986) fecundity estimate of 18,000 eggs per female falls within the range reported by Miyazaki (1940).

Yellowfin goby larvae initially remain near the bottom before moving up into the water column (Jahn and Lavenberg 1986; Moser 1996). The larvae hatch at 4.5 to 4.6 mm NL (approximately 0.18 in), begin to have limited swimming ability between 6.7-8.5 mm (0.26-0.33 in), and transform at around 16-18 mm (0.6-0.7 in) (Moser 1996). Upon transformation they settle to the benthos and begin their juvenile life stage (Baker 1979).

Reported estimates for yellowfin goby longevity, age at maturity, and other demographic parameters vary in the scientific literature. Hoshino et al. (1993) indicate that yellowfin goby in Japan live to three years while Baker (1979) calculated an estimate of four years for populations in the San Francisco Bay Area. Age at maturity was found to be less than one year (Baker 1979 [San Francisco Bay]) greater than one year (Miyazaki 1940 [Japan]; Middleton 1982 [Australia]; Wang 1986 [California]); and as high as two to three years (Brittan et al. 1970 [California]).

No estimates of larval growth or survivorship have been reported for yellowfin goby. Brothers (1975) estimates a time period of 60 days from hatching to settlement for three sympatric gobies (i.e., arrow goby, cheekspot goby, and shadow goby) from Mission Bay, California. Brothers (1975) calculated a finite mortality estimate of 0.983 for arrow goby over the two-month time period from egg laying through settlement, and this mortality estimate was used in the present study for calculating yellowfin goby survivorship. The larval growth rate for arrow goby from Brothers (1975) and estimates of hatch size and transformation length derived from Moser (1996) for yellowfin goby were used to estimate a larval growth rate of 0.25 mm (0.01 in) per day.

4.5.3.5.2 Population Trends and Fishery

Yellowfin goby larvae have been collected in studies of the Los Angeles and Long Beach harbors since 1983 (MBC 1984) and ranked 8th in abundance in surveys conducted in 2000 (MEC 2002). Yellowfin goby is commercially valuable in their native range more so than in California. Although small, this goby is considered a delicacy in Japan (Eschmeyer and Herald 1983), but in California, particularly the San Francisco Bay Area, it is used primarily as bait for striped bass (Cohen and Carlton 1995). There are no recent records of commercial or recreational catches of this species for Los Angeles or Orange counties.

4.5.3.5.3 Sampling Results

Yellowfin goby larvae were the second most abundant taxon at the entrainment station with a mean concentration of 263 per 1,000 m3 (1,000 m3 = 264,172 gal) over all surveys (Table 4.5-1). They were mainly present at the entrainment station in January–March and largely absent during all other months of the year (Figure 4.5-26). During periods of maximum abundance in early March 2006 yellowfin goby larvae were present in the entrainment samples at average concentrations of 4,385 per 1,000 m3. Yellowfin gobies were far less abundant at the source water stations with a peak average concentration in late February 2006 of 161 per 1,000 m3 for all stations combined (Figure 4.5-27). The larvae were significantly more abundant in nighttime samples, except during early March when there was a high abundance of recently-hatched larvae in the water column (Figure 4.5-28). The size classes of most larvae were in the 4.0–5.0 mm (0.16-0.2 in) range (Figure 4.5-29) and the mean length of 668 specimens was 4.7 mm (0.2 in) NL.

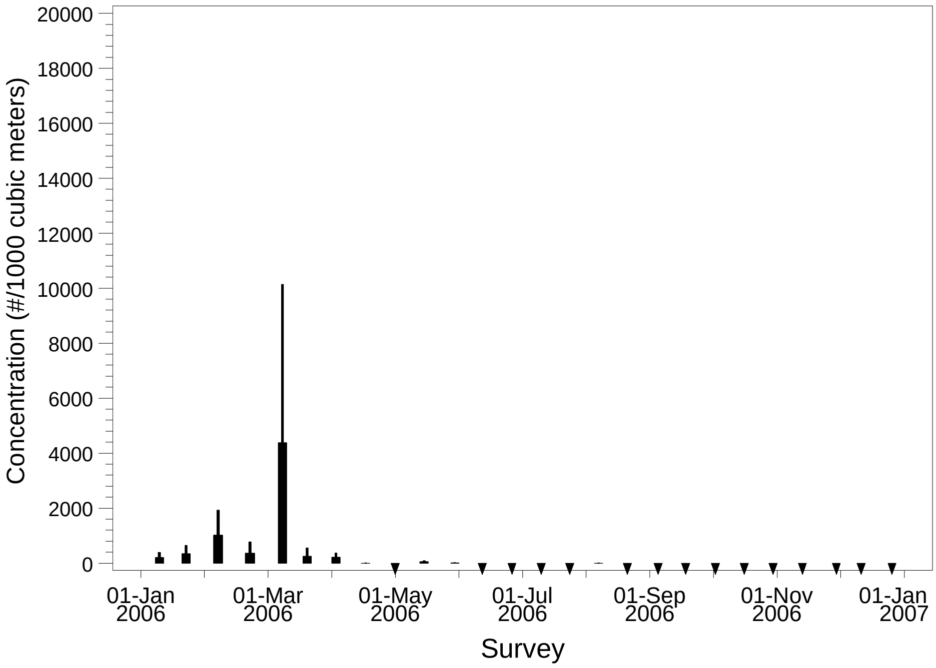


Figure 4.5-27. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of yellowfin goby larvae collected at HGS entrainment Station E1 during 2006.

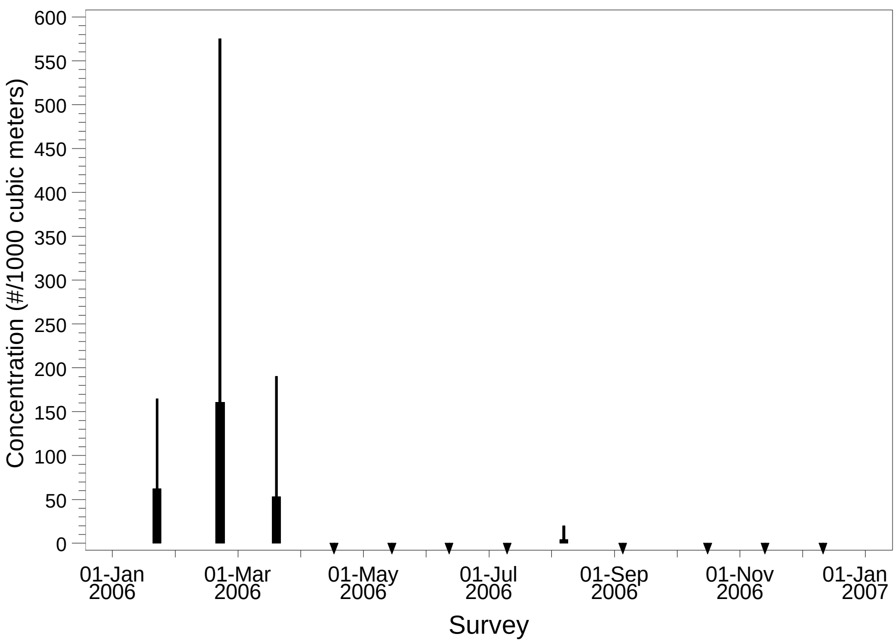
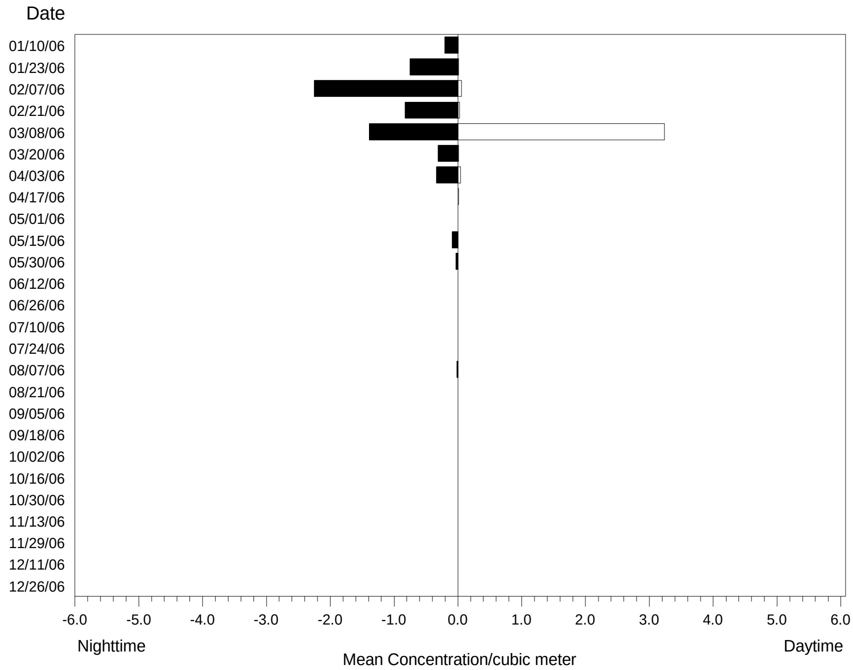


Figure 4.5-28. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of yellowfin goby larvae collected at HGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-29. Mean concentration (#/1.0 m^3 [264 gal]) of yellowfin goby larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

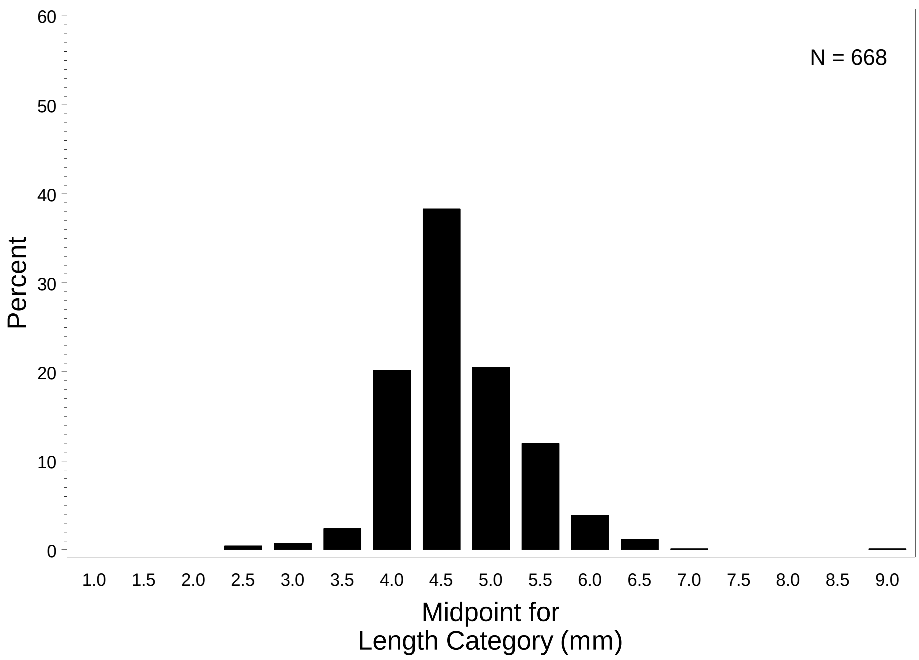


Figure 4.5-30. Length (mm) frequency distribution for yellowfin goby larvae collected at entrainment Station E1.

4.5.3.5.4 Modeling Results

The following sections present the results for demographic and empirical transport modeling of CWIS entrainment effects on yellowfin goby populations. Total annual entrainment of yellowfin goby larvae at HGS was estimated to be 15,407,999 (standard error of 1,744,298 using actual measured cooling water flows during 2006 and 37,604,336 (standard error of 4,325,986) using the design (or maximum) cooling water flows (Table 4.5-2).

Fecundity Hindcasting (*FH*)

The values required to estimate *FH* for yellowfin goby were substituted from reported life histories of other species of gobies (Brothers 1975; Wang 1986). No estimates of egg mortality for gobies were available, but goby egg masses are typically attached in burrows that are guarded by the male (Wang 1986; Moser 1996); therefore, egg survival is probably high and is conservatively assumed to be 100% for the purpose of this analysis. Larval yellowfin goby survivorship estimates were also not available from the literature. Therefore, we used an estimate of 98.3% larval arrow goby mortality over two months from Brothers (1975) to calculate a daily survival estimate of 0.93 ($[1\text{-}0.98]^{6\,/\,365.25} = 0.93$) for yellowfin goby. Survival to entrainment was then estimated using the average number of days to entrainment (2.5 days) as $0.93^{2.5} = 0.85$. The average age at entrainment was calculated by taking the difference between the mean length (4.6 mm [0.18 in]) and the length of the 10th percentile (4.0 mm [0.16 in]) from a random sample of 200 larvae and dividing this value by the estimated growth rate of 0.25 mm (0.01 in) per day. The value of the 10th percentile was used as the length at hatch size rather than the calculated value due to the length frequency distribution that approximated a normal curve. A batch fecundity estimate of 19,000 eggs was derived from Miyazaki (1940) and Wang (1986). This value was used as the estimate of lifetime fecundity based on the observation by Miyazaki (1940) that yellowfin goby may be terminal spawners and probably deposit a single egg batch per lifetime.

The estimated number of yellowfin goby larvae entrained over the one-year sampling period in 2006 (Table 4.5-2) was used to calculate the number of breeding females needed to produce the number of larvae entrained. The number of adult females needed to produce the number of larvae entrained was 968 based on the actual cooling water flows and was 2,362 based on the design cooling water flows (Table 4.5-25). 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 4.5-25. Results of *FH* modeling for yellowfin goby 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	**968**	845	230	4,072	3,842
Total Entrainment	15,407,999	1,744,298	788	1,148	361
Design Flows					
FH Estimate	**2,362**	2,064	561	9,942	9,381
Total Entrainment	37,604,336	4,325,986	1,915	2,809	894

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 formulation of *AEL* requires estimates of survival from settlement to maturity. No survival estimates were available from the literature for these life stages of yellowfin goby. Therefore, we did not calculate an *AEL* estimate for this species.

Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for yellowfin gobies was based on the lengths of entrained larvae. The difference between the lengths of the 95th (5.6 mm [0.22 in]) and 10th percentile (4.0 mm [0.16 in]) was used with a growth rate of 0.25 mm/day (0.01 in/day) to estimate that yellowfin goby larvae were vulnerable to entrainment for a period of 6.3 days.

Yellowfin goby larvae were present in entrainment and source water samples during the first half of the year with the greatest proportion occurring during the February survey (f_i = 0.52 or 52%). The monthly estimates of *PE* for the 2006 period ranged from 0 to 0.00362 based on the actual flows and ranged from 0 to 0.00663 based on the design flows (Table 4.5-26). The values in the table were used to calculate a P_M estimate of 0.0065 with a standard error of 0.0044 using the actual flows and an estimate of 0.0154 (standard error of 0.0101) based on the design cooling water flow volumes.

Table 4.5-26. *ETM* data and results for yellowfin goby larvae based upon actual and design (maximum) CWIS flow volumes using the fixed source water volume of 431,694,503 m^3.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
23-Jan-06	0.00136	0.00071	0.00318	0.00163	0.26052
21-Feb-06	0.00073	0.00051	0.00180	0.00126	0.51765
20-Mar-06	0.00124	0.00091	0.00290	0.00211	0.19089
17-Apr-06	0.00294	0.00423	0.00663	0.00938	0.00111
15-May-06	0.00362	0.00233	0.00663	0.00419	0.01971
12-Jun-06	0	0	0	0	0
10-Jul-06	0	0	0	0	0
7-Aug-06	0.00044	0.00055	0.00080	0.00099	0.01012
5-Sep-06	0	0	0	0	0
16-Oct-06	0	0	0	0	0
13-Nov-06	0	0	0	0	0
11-Dec-06	0	0	0	0	0
P_M	**0.0065**	0.0044	**0.0154**	0.0101	–

4.5.3.6 Bay Goby (*Lepidigobius lepidus*)

The bay goby *Lepidogobius lepidus* is a common bottom dweller of bays and estuaries along the Pacific coast of North America. It ranges from southeastern Alaska to Cedros Island, Baja California (Love et al. 2005). It is generally considered a shallow-water marine species, but may occur on mud and sand substrata down to depths of 305 m (1,000 ft) (Love et al. 2005).

Neil McDaniel

4.5.3.6.1 Life History and Ecology

Bay gobies are common on intertidal mudflats where they may remain in invertebrate burrows and shallow pools when the tide recedes (Grossman 1979). Like many marine-estuarine species, they are tolerant of variations in salinity and temperature. During population monitoring studies in the San Francisco Bay-Delta, bay goby occasionally (during periods of low Delta outflow) moved from marine waters upstream through the Carquinez Strait into the lower salinity waters of Suisun Bay (Baxter et al. 1999).

Reports differ on the longevity of bay goby. They are reported to live for about seven years, which is considered unusually long for a small fish species (Grossman 1979). Life span estimates of two to three years have been derived from length-frequency data collected by CDFG in San Francisco Bay.

Bay goby have been characterized as asynchronous multiple spawners (Wang 1986). Most bay goby do not become reproductively mature until their second year, but a few mature during their first year (Wang 1986). Because bay goby use invertebrate burrows for predator avoidance and protection against dehydration during low tides, it is thought that this species, like many other goby species, may also use burrows for spawning (Grossman 1979; Wang 1986). No fecundity information is available for bay goby. Eggs are demersal, spherical/elliptical in shape, and have an adhesive anchoring point (Wang 1986).

Newly hatched larvae are small (3 mm [0.12 in] or less) and nearly transparent (Wang 1986) and may have a planktonic life phase of 3 to 4 months (Grossman 1979; Wang 1986). McGowen (1993) characterized bay goby larvae as part of the "*Stenobrachius*" group of the coastal ichthyoplankton assemblage of the Southern California Bight since the larvae impinge upon the continental shelf. Completion of the transformation stage (beginning of the juvenile phase) for bay goby larvae occur around 29 mm (1.1 in) (Moser 1996). Juveniles (and adults) occupy the burrows of blue mud shrimp (*Upogebia pugettensis*), geoduck clams (*Panope generosa*) and other burrowing invertebrates for shelter and predator avoidance (Grossman 1979).

Juvenile and adult bay goby growth was described by Grossman (1979). Growth is initially rapid, with 50% of their total growth (length) occurring within the first two years. Following this period of rapid growth, increases in length slow to about 6 mm (0.24 in) per year. Maximum length is reported to 10.2 cm (4 in).

Bay goby is thought to be an important food item in the diet of a variety of vertebrate and invertebrate predators. Their abundance, small size, and extended planktonic duration make bay goby larvae an important link in the food web of bay/estuarine systems (Wang 1986). Their abundance as juveniles and adults suggests that they remain an important forage species throughout all life stages. Pacific staghorn sculpin (*Leptocottus armatus*) and California halibut (*Paralichthys californicus*) are among the many fish predators of other adult gobies (Brothers 1975) and it is assumed that these fishes, and sharks and rays that inhabit estuarine systems, also prey on bay gobies (Grossman 1979). Bay goby are also a prey item for birds (Reeder 1951; Grossman 1979).

4.5.3.6.2 Population Trends and Fishery

Bay goby larvae was the second most abundant species collected in a survey of Los Angeles and Long Beach Harbors in 2000; comprising 16% of the total catch (MEC 2002). Larvae were more abundant in the area of the ILAH nearest to HGS and in the deeper stations. Due to its small size, bay goby is not harvested commercially for human consumption or targeted by recreational anglers. There is no reference in the current literature of their harvest or use as bait. Bay goby occur commonly in beach seine and otter trawl samples from Los Angeles-Long Beach Harbors (Allen and Pondella 2006a), but there is no specific information available on long-term population trends.

4.5.3.6.3 Sampling Results

Bay goby was the fourth most abundant taxon at the entrainment station with a mean concentration of 34 per 1,000 m^3 (1,000 m^3 = 264,172 gal) over all surveys (Table 4.5-1). They were present in variable concentrations during most surveys but tended to have lowest abundances in the October–December period (Figure 4.5-30). During periods of maximum abundance in early February 2006, bay gobies were present in the entrainment samples at average concentrations of 95 per 1,000 m^3. Bay gobies were also present at the source water stations during all months of the year, except April with a peak average concentration in August 2006 of 90 per 1,000 m^3 (Figure 4.5-31). The larvae tended to be more abundant in nighttime samples although several surveys had greater numbers collected during daytime (Figure 4.5-32). The length-frequency distribution for a representative sample of bay goby larvae (Figure 4.5-33) showed that the majority of the sampled larvae were recently hatched based on the reported hatch size of 2–3 mm (0.8-0.1 in) (Moser 1996). The mean length of specimens from the entrainment station samples was 3.2 mm (0.13 in) NL.

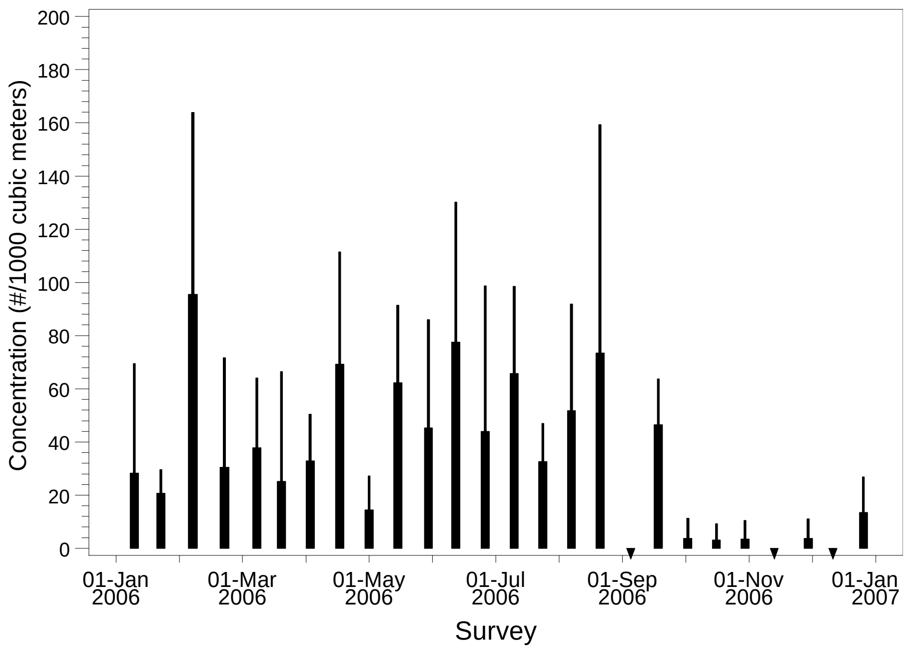


Figure 4.5-31. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of bay goby larvae collected at HGS entrainment Station E1 during 2006.

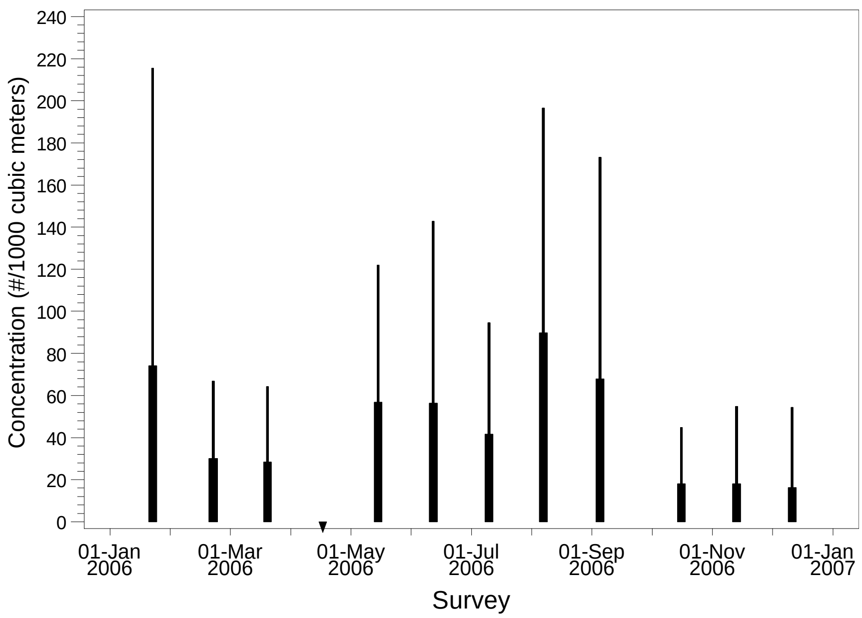
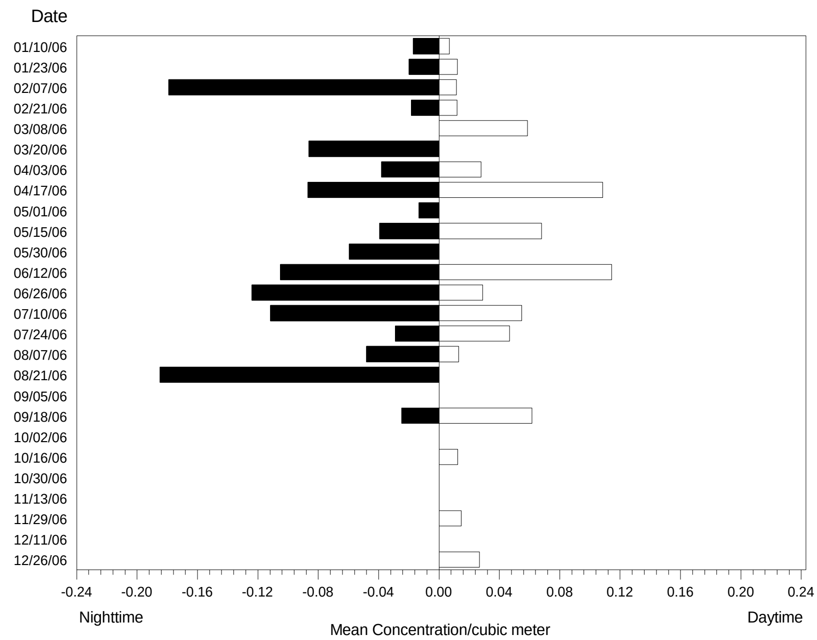


Figure 4.5-32. Mean concentration (#/1,000 m^3 [264,172 gal]) – wide bars) and standard deviation (narrow bars) of bay goby larvae collected at HGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 4.5-33. Mean concentration (#/1.0 m^3 [264 gal]) of bay goby larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

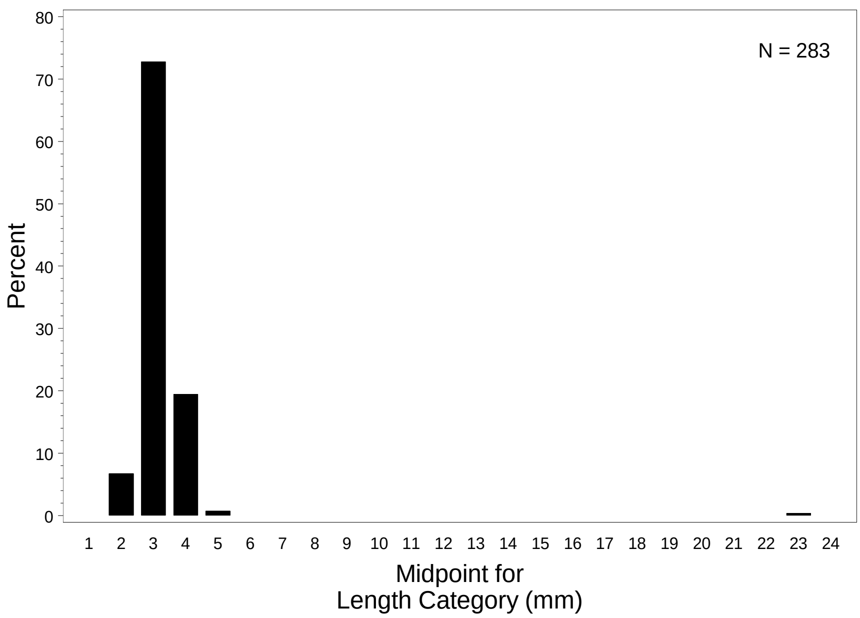


Figure 4.5-34. Length (mm) frequency distribution for bay goby larvae collected at entrainment Station E1.

4.5.3.6.4 Modeling Results

The following sections present the results for the empirical transport modeling of CWIS entrainment effects on bay goby populations. There were no published data on larval survival, or the reproductive biology of bay goby that could be used in demographic modeling of entrainment effects. Bay goby are also larger and occur over different habitats than the CIQ goby complex that was used as a source of life history information for yellowfin goby. Based on these differences it was decided that the life history information was not appropriate for use with bay goby. Total annual entrainment of bay goby larvae at HGS was estimated to be 2,376,260 (standard error of 66,436) using actual measured cooling water flows and was estimated at 5,070,071 (standard error of 138,207) using the design flows during 2006 (Table 4.5-2).

Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for bay gobies was based on the lengths of entrained larvae. There are no reported larval growth rates for bay goby, but a growth rate of 0.23 mm/day (0.01 in/day) was calculated by using the size difference between hatch length (2.85 mm [0.1 in]) and transformation length (26.5 mm [1.0 in]) (Moser 1996; Wang 1986) divided by an average planktonic duration of 3–4 months (105 days) from Grossman (1979). The difference between the lengths of the 95th (4.1 mm [0.16 in]) and the estimated hatch length of 2.7 mm [0.11 in]) was used with the growth rate to estimate that bay goby larvae were vulnerable to entrainment for a period of 6.3 days.

Bay goby larvae were present in entrainment and source water samples during most of the year except during the fall and early winter months (Table 4.5-27) with the greatest proportion occurring during the August survey (f_i = 0.17 or 17%). As the results for the September, November, and December surveys show, there were times when larvae were collected from the source water stations but not from the entrainment stations (i.e., PE_i=0 and f_i > 0). The monthly estimates of *PE* for the 2006 period ranged from 0 to 0.00294 using the actual flow and ranged from 0 to 0.00663 using the design flows. The values in the table were used to calculate a P_M estimate of 0.0024 with a standard error of 0.0009 using the actual flows and an estimate of 0.0050 (standard error of 0.0018) based on the design flows.

Table 4.5-27. *ETM* data and results for bay goby larvae based upon actual and design (maximum) CWIS flow volumes using the fixed source water volume of 431,694,503 m^3.

	Actual Flows		**Design Flows**		
Survey Date	***PE*** **Estimate**	***PE*** **Std. Err.**	***PE*** **Estimate**	***PE*** **Std. Err.**	f_i
23-Jan-06	0.00013	0.00004	0.00029	0.00008	0.13704
21-Feb-06	0.00039	0.00028	0.00096	0.00068	0.06635
20-Mar-06	0.00036	0.00031	0.00085	0.00072	0.05346
17-Apr-06	0.00294	0.00129	0.00663	0.00286	0.02037
15-May-06	0.00056	0.00017	0.00102	0.00030	0.12701
12-Jun-06	0.00056	0.00022	0.00124	0.00047	0.11371
10-Jul-06	0.00076	0.00023	0.00138	0.00042	0.09277
7-Aug-06	0.00032	0.00014	0.00058	0.00025	0.17368
5-Sep-06	0	0	0	0	0.11997
16-Oct-06	0.00007	0.00008	0.00018	0.00019	0.03267
13-Nov-06	0	0	0	0	0.03421
11-Dec-06	0	0	0	0	0.02875
P_M	**0.0024**	0.0009	**0.0050**	0.0018	–

5.0 IMPINGEMENT STUDY

5.1 INTRODUCTION

The purpose of the impingement study was to determine the extent of potential impacts from the operation of the CWIS of the HGS on fishes and selected invertebrates. Impingement occurs when organisms larger than the traveling screen mesh size (9.5 mm [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. Normal operations impingement samples were collected over a 24-hour period to determine the daily loss from operation of the CWIS. Data from these surveys were used to estimate annual impingement at the HGS.

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 abundant fish taxa that together comprised 90% of all juveniles and adults collected at HGS. 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 2003–2005 as required by the HGS NPDES permit (MBC 2007a). These data are summarized to provide information on historical impingement at the HGS.

5.2.1 Summary of Historical Data

During 1978–1979, a total of 17,632 fish representing 41 taxa and weighing 311 kg (685 lbs) was impinged during the 316(b) study at HGS (IRC 1981). Sampling was conducted for a total of 34 days during the study. The mean cooling water flow rate at the generating station during sampling varied from 200,605 to 1,502,645 m^3 (53 to 397 mgd), with a total annual flow of approximately 327,977,820 m^3 (86.652 billion gallons). The estimated annual impingement based on extrapolations of impingement rates was 164,225 fish weighing 2,827 kg (6,234 lbs).

During the 1978–1979 year-long study, abundance and biomass peaked in December, January, and February, although no samples were collected in April or May due to a maintenance outage (IRC 1981). The most abundant species were Pacific pompano (*Peprilus simillimus*), white croaker, and queenfish, which combined accounted for 76% of the total impingement abundance. Pacific pompano was the most abundant species overall, accounting for 31% of the impingement abundance. A total of 17,632 fish weighing 310.4 kg (684.3 lbs) was impinged during the year-long study. An estimated 1,080 fish were impinged following an intake tunnel cleaning event in March 1979. It was hypothesized that when stop logs were removed following an outage, the incoming rush of cooling water created velocity fields near the intake that could not be avoided by fishes that were accustomed to the calmer waters.

During the last two years of impingement monitoring at HGS (2003–2005), a total of 10 normal operation impingement surveys was performed (MBC unpublished data). During these surveys, a total of 90 fish weighing 11.6 kg (26 lbs) was collected. The most abundant fishes were round stingray (*Urobatis halleri*), giant kelpfish (*Heterostichus rostratus*), and shiner perch (*Cymatogaster aggregata*), which, when combined, accounted for 78% of impingement abundance. A total of 62 macroinvertebrates weighing 5.3 kg (12 lbs) was also impinged. The most abundant invertebrates were tuberculate pear crab, intertidal coastal shrimp (*Heptacarpus palpator*), and California two-spot octopus (*Octopus bimaculatus/bimaculoides*), which together comprised 73% of the impingement abundance.

5.2.2 Relevance to Current Conditions

The historical impingement data presented in Section 5.4 is relevant for historical comparisons. During the 1978–1979 study, the maximum cooling water flow of the HGS CWIS was 1,504,310 m^3 per day (397 mgd), and the average flow during the study year was 62% of maximum. From 1982 to 1995, cooling water flow averaged 457,985 m^3 per day (121 mgd) (MBC 1997). Flow during the 2006 study averaged about 185,296 m^3 per day (49 mgd), or 51% of current design flow, which is less than design flow in the previous study due to the modifications to the CWIS.

5.2.3 QA/QC Procedures & 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 HGS. The sampling program also documented the size, sex, and physical condition of fish and shellfish impinged. The abundance and biomass of organisms impinged was used to calculate impingement rates (e.g., the number of organisms impinged per $1x10^6$ m^3 [264,200,793 gallons] of cooling water flowing through the CWIS).

The HGS has one screening facility consisting of bar racks, traveling screens, and the circulating water pumps. Seawater drawn into the HGS first 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

Impingement sampling at the HGS was conducted over a 24-hour period one day per week from January 5 to December 29, 2006. Surveys were performed at the HGS when at least one circulating water pump was operating at the beginning of each survey. Before each sampling effort, the traveling screens were rotated and washed clean of all impinged debris and organisms. The sluiceways and collection baskets were also cleaned before the start of each sampling effort. The operating status of the circulating water pumps was recorded on an hourly basis during the study year. During each survey, the 24-hour sampling period was divided into four 6-hour cycles. Initiation of sample collection occurred as follows: Cycle 1 (approx. 0700–1300 hr), Cycle 2 (approx. 1300–1900 hr), Cycle 3 (approx. 1900–0100 hr), and Cycle 4 (approx. 0100–0700 hr). During this time, the traveling screens were stationary for a period of approximately 5.75 hours and then they were 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 6.4 mm (0.25 in) mesh liners.

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

All fishes and macroinvertebrates collected at the end of each cycle were removed from any other impinged debris, then 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:
  - <u>Fishes</u> - Total body length for sharks and rays and standard lengths for bony fishes.
  - <u>Crabs</u> - Maximum carapace width.
  - <u>Shrimp & Lobsters</u> - Carapace length, measured from the anterior margin of carapace between the eyes to the posterior margin of the carapace.
  - <u>Octopus</u> - Maximum “tentacle” spread, measured from the tip of one tentacle to the tip of the opposite tentacle.
  - <u>Squid</u> – Dorsal mantle length, 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 gram (0.035 ounce).
- Determination of sex was made for fishes where such determination could be made by external morphology (such as surfperches, sharks, and rays).

- The qualitative body condition of individual fish and shellfish was determined and recorded, using codes for decomposition and physical damage.
- 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 noted by writing specific comments in the "Notes" section of the data sheet. Information on weather was also recorded during each collection.

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

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

5.3.2 QA/QC Procedures & Data Validation

During the NPDES impingement surveys (2003–2005), sampling was conducted in accordance with specifications set forth by the LARWQCB in the NPDES permit for the plant. Specimens of uncertain identity were cross-checked against taxonomic voucher collections maintained by MBC, as well as available taxonomic literature. Occasionally, outside experts were consulted to assist in the identification of species whose identification was difficult. Scales used to measure biomass (spring and electronic) were calibrated every three months.

During the current study, QA/QC checks were conducted on a quarterly basis to verify compliance with the field sampling procedures. QC surveys were conducted on February 9, April 13, August 3-4, and October 12, 2006. Random cycles were chosen for QA/QC re-sorting to verify that all the collected organisms were removed from the impinged material. 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 would be checked. In all cases, impingement sampling was conducted properly following the written procedures. All impinged materials were removed from the collection baskets and sorted properly, all organisms were identified correctly and all length and weight measurements were recorded properly, and the data sheets were filled out accurately and legibly. 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 the computer databases and spreadsheets:

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

5.3.3 Data Analysis

A log with hourly observations of each of the circulating water pumps for the entire study period was obtained from 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 to determine CWIS flow during each cycle.

The estimated daily impingement rate was then 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 daily impingement rates for both abundance and biomass. The estimated impingement rate for each survey period was summed to determine the annual normal operation impingement estimates for each taxon. 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 HGS (408,824 m^3 per day, or 108.0 mgd).

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 comprised the top 90% or more of the total abundance in impingement samples, and commercially or recreationally important invertebrates that were also impinged in sufficient numbers to warrant analysis. This methodology was approved by the LARWQCB, SWRCB, EPA Region IX, NMFS, and CDFG during a January 30, 2006 meeting at the LARWQCB offices.

To put the impingement results in context, losses were compared against (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 Long Beach area catch blocks in 2006. The five catch blocks included in this analysis included: 718, 719, 738, 739, and 740. Sport fishing landings were derived from the RecFIN, which included all marine areas in southern California.

5.4 SAMPLING SUMMARY

The following sections summarize results from the 2006 impingement weekly sampling at the HGS. 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 (Cycle 1) and nighttime (Cycle 3) impingement collections.

During 2006, normal operation impingement surveys were performed during 50 of 52 weeks at the HGS between January 5 and December 29, 2006, from the single screening facility. The two weeks with no samples collected (in late April and early May) represent periods when no circulating water pumps were operating due to a facility outage.

5.5 RESULTS

5.5.1 Impingement Results

A total of 1,290 fishes representing 25 species and weighing 188.85 kg (416.41 lbs) was collected during impingement sampling in 2006. The estimated annual total impingement based on cooling water flow volumes in 2006 was 8,851 individuals weighing 1,316 kg (2,903 lbs) (Table 5.5-1). Round stingray (*Urobatis halleri*) was the most abundant species, with 877 individuals collected (68% of the abundance total) and an estimated annual impingement of 6,150 individuals weighing 1,231 kg (2,715 lbs). The annual impingement of round stingray represented 70% of the total impingement abundance and 94% of the biomass. The next most abundant species in impingement samples were black perch (*Embiotoca jacksoni*), specklefin midshipman (*Porichthys myriaster*), shiner perch (*Cymatogaster aggregata*), barred sand bass (*Paralabrax nebulifer*), and giant kelpfish (*Heterostichus rostratus*). Combined these taxa accounted for 91.2% of the sampled impinged fish abundance. When these estimates were calculated using the design (maximum) cooling water flows, total projected numbers increased to 19,861 individuals with a weight of 2,938 kg (6,479 lbs) (Table 5.5-2). Impingement results by survey are presented in Appendix D. A list of all species collected during the study is presented in Appendix E.

A total of 1,014 macroinvertebrates representing at least 41 distinct taxa and weighing 37.3 kg (82.3 lbs) was collected during impingement sampling in 2006. The estimated annual total impingement based on cooling water flow volumes in 2006 was 6,753 individuals weighing 260 kg (573 lbs) (Table 5.5-3). The nudibranch *Hermissenda crassicornis* was the most abundant species, with 271 individuals collected (27% of the abundance total) and an estimated annual impingement of 1,840 individuals weighing 0.6 kg (1.4 lbs). The next most abundant species in impingement samples were unidentified sea spiders (Pycnogonida), tuberculate pear crab, California spiny lobster (*Panulirus interruptus*), intertidal coastal shrimp, and California two-spot octopus. Combined these species accounted for 82.6% of the sampled impinged macroinvertebrate abundance. When these estimates were calculated using the design (maximum) cooling water flows, total projected numbers increased to 13,538 individuals with a weight of 575 kg (1,269 lbs) (Table 5.5-4).

Table 5.5-1. Summary of HGS fish impingement from January through December 2006, and estimated annual impingement based on actual cooling water flows.

		Sampled Impingement		Estimated Annual Impingement		% of Total	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Urobatis halleri	round stingray	877	176.577	6,150	1,231.676	69.5	93.5
Embiotoca jacksoni	black perch	102	2.718	646	18.487	7.3	1.4
Porichthys myriaster	specklefin midshipman	74	1.913	484	11.955	5.5	0.9
Cymatogaster aggregata	shiner perch	65	0.559	390	3.359	4.4	0.3
Paralabrax nebulifer	barred sand bass	31	1.113	209	7.513	2.4	0.6
Heterostichus rostratus	giant kelpfish	27	2.204	192	15.731	2.2	1.2
Acanthogobius flavimanus	yellowfin goby	23	0.442	163	3.146	1.8	0.2
Gibbonsia elegans	spotted kelpfish	22	0.211	158	1.489	1.8	0.1
Phanerodon furcatus	white seaperch	19	0.565	115	4.117	1.3	0.3
Porichthys notatus	plainfin midshipman	9	0.034	62	0.234	0.7	<0.1
Tridentiger trigonocephalus	chameleon goby	7	0.038	52	0.278	0.6	<0.1
Rhacochilus vacca	pile perch	6	0.887	44	6.357	0.5	0.5
Pleuronichthys verticalis	hornyhead turbot	5	0.581	34	3.974	0.4	0.3
Genyonemus lineatus	white croaker	4	0.026	25	0.196	0.3	<0.1
Engraulis mordax	northern anchovy	4	0.003	24	0.019	0.3	<0.1
Paralichthys californicus	California halibut	3	0.885	23	7.452	0.3	0.6
Syngnathus leptorhynchus	bay pipefish	3	0.011	20	0.072	0.2	<0.1
Leptocottus armatus	Pacific staghorn sculpin	2	0.013	10	0.063	0.1	<0.1
Hyperprosopon argenteum	walleye surfperch	1	0.006	8	0.051	0.1	<0.1
Atherinops affinis	topsmelt	1	0.029	7	0.204	0.1	<0.1
Paralabrax maculatofasciatus	spotted sand bass	1	0.022	7	0.154	0.1	<0.1
Icelinus quadriseriatus	yellowchin sculpin	1	0.005	7	0.035	0.1	<0.1
Embiotocidae	surfperch, unid.	1	0.004	7	0.028	0.1	<0.1
Gillichthys mirabilis	longjaw mudsucker	1	0.001	7	0.007	0.1	<0.1
Gobiesox rhessodon	California clingfish	1	0.001	7	0.007	0.1	<0.1
	Total impinged fish	**1,290**	**188.848**	**8,851**	**1,316.604**	**100.0**	**100.0**

Table 5.5-2. Estimated annual fish impingement at the HGS from January through December 2006 based on both actual and design (maximum) cooling water flows.

		Sampled Impingement		Estimated Annual Impingement			
				Actual Flows		Design Flows	
Taxa	Common Name	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)
Urobatis halleri	round stingray	877	176.577	6,150	1,231.676	13,771	2,756.092
Porichthys myriaster	specklefin midshipman	74	1.913	484	11.955	1,379	26.841
Embiotoca jacksoni	black perch	102	2.718	646	18.487	1,371	41.034
Cymatogaster aggregata	shiner perch	65	0.559	390	3.359	719	6.770
Paralabrax nebulifer	barred sand bass	31	1.113	209	7.513	442	16.203
Heterostichus rostratus	giant kelpfish	27	2.204	192	15.731	424	32.598
Acanthogobius flavimanus	yellowfin goby	23	0.442	163	3.146	399	7.479
Gibbonsia elegans	spotted kelpfish	22	0.211	158	1.489	354	3.235
Phanerodon furcatus	white seaperch	19	0.565	115	4.117	221	7.799
Porichthys notatus	plainfin midshipman	9	0.034	62	0.234	175	0.662
Tridentiger trigonocephalus	chameleon goby	7	0.038	52	0.278	127	0.690
Rhacochilus vacca	pile perch	6	0.887	44	6.357	83	12.520
Pleuronichthys verticalis	hornyhead turbot	5	0.581	34	3.974	76	8.907
Paralichthys californicus	California halibut	3	0.885	23	7.452	51	15.554
Genyonemus lineatus	white croaker	4	0.026	25	0.196	48	0.426
Syngnathus leptorhynchus	bay pipefish	3	0.011	20	0.072	48	0.196
Engraulis mordax	northern anchovy	4	0.003	24	0.019	36	0.027
Atherinops affinis	topsmelt	1	0.029	7	0.204	18	0.512
Gillichthys mirabilis	longjaw mudsucker	1	0.001	7	0.007	18	0.018
Icelinus quadriseriatus	yellowchin sculpin	1	0.005	7	0.035	18	0.089
Paralabrax maculatofasciatus	spotted sand bass	1	0.022	7	0.154	18	0.386
Embiotocidae unid.	surfperch unid	1	0.004	7	0.028	17	0.070
Hyperprosopon argenteum	walleye surfperch	1	0.006	8	0.051	17	0.103
Leptocottus armatus	Pacific staghorn sculpin	2	0.013	10	0.063	16	0.104
Gobiesox rhessodon	California clingfish	1	0.001	7	0.007	15	0.015
	Total impinged fish	**1,290**	**188.848**	**8,851**	**1,316.604**	**19,861**	**2,938.330**

Table 5.5-3. Summary of HGS invertebrate impingement from January through December 2006, and estimated annual impingement based on actual cooling water flows.

Taxa	Common Name	Sampled Impingement No.	Sampled Impingement Wt. (kg)	Estimated Annual Impingement No.	Estimated Annual Impingement Wt. (kg)	% of Total No.	% of Total Wt. (kg)
Hermissenda crassicornis	hermissenda	271	0.092	1,840	0.622	27.2	0.2
Pycnogonida	sea spider, unid.	213	0.022	1,258	0.136	18.6	0.1
Pyromaia tuberculata	tuberculate pear crab	124	0.166	801	1.086	11.9	0.4
Panulirus interruptus	California spiny lobster	105	24.547	717	169.370	10.6	65.1
Heptacarpus palpator	intertidal coastal shrimp	101	0.072	711	0.511	10.5	0.2
O. bimac./bimaculoides	Calif. two-spot octopus	24	4.790	184	36.249	2.7	13.9
Heptacarpus paludicola	Calif. coastal shrimp	19	0.017	138	0.122	2.1	<0.1
Diaulula sandiegensis	ring-spotted dorid	18	0.021	128	0.145	1.9	0.1
Triopha maculata	spotted triopha	16	0.012	116	0.083	1.7	<0.1
Polycera atra	orange-spike polycera	14	0.007	111	0.053	1.7	<0.1
Parastichopus parvimensis	warty sea cucumber	14	1.131	91	7.413	1.4	2.8
Leptopecten spp.	scallop, unid.	11	0.011	70	0.065	1.0	<0.1
Dirona picta	spotted dirona	7	0.003	57	0.023	0.8	<0.1
Parastichopus californicus	California sea cucumber	6	0.232	38	1.617	0.6	0.6
Ammothea hilgendorfi	sea spider	5	0.003	37	0.023	0.5	<0.1
Cancer antennarius	Pacific rock crab	5	1.468	34	9.919	0.5	3.8
Heptacarpus spp.	coastal shrimp, unid.	5	0.005	34	0.033	0.5	<0.1
Portunus xantusii	Xantus swimming crab	5	0.150	31	0.972	0.5	0.4
Polycera hedgpethi	Hedgpeth's polycera	3	0.002	24	0.015	0.4	<0.1
Flabellina trilineata	threeline aeolis	3	0.003	22	0.021	0.3	<0.1
Pandalus danae	dock shrimp	3	0.008	22	0.049	0.3	<0.1
Lysmata californica	red rock shrimp	3	0.003	21	0.021	0.3	<0.1
Anisodoris nobilis	Pacific sea-lemon	3	0.022	21	0.153	0.3	0.1
Parastichopus spp	sea cucumber, unid.	3	0.003	21	0.021	0.3	<0.1
Aplysia californica	California seahare	3	0.858	21	5.855	0.3	2.2
Hemigrapsus oregonensis	yellow shore crab	3	0.015	20	0.093	0.3	<0.1
Cnidaria	sea jelly, unid.	2	0.029	16	0.210	0.2	0.1
Crangon nigromaculata	blackspotted bay shrimp	2	0.002	15	0.015	0.2	<0.1
Dendronotus frondosus	leafy dendronotid	2	0.001	14	0.007	0.2	<0.1
Pisaster spp	sea star, unid.	2	1.337	14	9.480	0.2	3.6
Holothuroidea	sea cucumber, unid.	2	0.004	13	0.023	0.2	<0.1
Scrippsia pacifica	giant bell jelly	1	0.044	8	0.346	0.1	0.1
Dendronotus iris	giant-frond-aeolis	1	0.019	8	0.149	0.1	0.1
Ctenophora	comb jelly, unid.	1	0.006	8	0.047	0.1	<0.1
Pinnixa spp	pea crab, unid.	1	0.001	8	0.008	0.1	<0.1
Pleurobranchaea calif.	California sea slug	1	1.778	7	12.779	0.1	4.9
Cancer anthonyi	yellow crab	1	0.039	7	0.278	0.1	0.1
Discodorididae	nudibranch, unid.	1	0.002	7	0.014	0.1	<0.1
Archidoris montereyensis	Monterey sea-lemon	1	0.012	7	0.085	0.1	<0.1
Cuthona lagunae	orange-faced nudibranch	1	0.001	7	0.007	0.1	<0.1

(table continued)

Table 5.5-3 (continued). Summary of HGS invertebrate impingement from January through December 2006, and estimated annual impingement based on actual cooling water flows.

		Sampled Impingement		Estimated Annual Impingement		% of Total	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Navanax inermis	California aglaja	1	0.031	7	0.217	0.1	0.1
Gastropoda	gastropod, unid.	1	0.007	7	0.049	0.1	<0.1
Farfantepenaeus calif.	yellowleg shrimp	1	0.006	7	0.039	0.1	<0.1
Aplysia spp.	seahare, unid.	1	0.310	6	1.744	0.1	0.7
Aurelia aurita	moon jelly	1	0.010	6	0.056	0.1	<0.1
Pandalus stenolepis	roughpatch shrimp	1	0.002	6	0.011	0.1	<0.1
Heptacarpus stimpsoni	Stimpson coastal shrimp	1	0.001	5	0.005	0.1	<0.1
Mopalia muscosa	mossy chiton	1	0.001	5	0.005	0.1	<0.1
	Total impinged invertebrates	**1,014**	**37.306**	**6,753**	**260.244**	**100.0**	**100.0**

Note: Weights are only presented in kg.

Table 5.5-4. Estimated annual invertebrate impingement at the HGS from January through December 2006 based on both actual and design (maximum) cooling water flows.

				Estimated Annual Impingement			
		Sampled Impingement		Actual Flows		Design Flows	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Hermissenda crassicornis	hermissenda	271	0.092	1,840	0.622	3,625	1.244
Pycnogonida	sea spider, unid.	213	0.022	1,258	0.136	2,139	0.248
Heptacarpus palpator	intertidal coastal shrimp	101	0.072	711	0.511	1,600	1.15
Panulirus interruptus	California spiny lobster	105	24.547	717	169.37	1,544	369.563
Pyromaia tuberculata	tuberculate pear crab	124	0.166	801	1.086	1,535	2.25
O. bimac/bimaculoides	Calif. two-spot octopus	24	4.79	184	36.249	428	85.961
Heptacarpus paludicola	Calif. coastal shrimp	19	0.017	138	0.122	315	0.28
Diaulula sandiegensis	ring-spotted dorid	18	0.021	128	0.145	267	0.310
Triopha maculata	spotted triopha	16	0.012	116	0.083	234	0.172
Polycera atra	orange-spike polycera	14	0.007	111	0.053	233	0.112
Parastichopus parvimensis	warty sea cucumber	14	1.131	91	7.413	176	15.242
Leptopecten spp	scallop, unid.	11	0.011	70	0.065	145	0.127
Dirona picta	spotted dirona	7	0.003	57	0.023	111	0.042
Ammothea hilgendorfi	sea spider	5	0.003	37	0.023	94	0.055
Heptacarpus spp	coastal shrimp, unid.	5	0.005	34	0.033	79	0.079
Parastichopus californicus	California sea cucumber	6	0.232	38	1.617	71	3.291
Portunus xantusii	Xantus swimming crab	5	0.15	31	0.972	68	2.139
Cancer antennarius	Pacific rock crab	5	1.468	34	9.919	67	18.929
Lysmata californica	red rock shrimp	3	0.003	21	0.021	53	0.053
Anisodoris nobilis	Pacific sea-lemon	3	0.022	21	0.153	52	0.387
Polycera hedgpethi	Hedgpeth's polycera	3	0.002	24	0.015	52	0.035
Parastichopus sp	sea cucumber, unid.	3	0.003	21	0.021	49	0.049
Aplysia californica	California seahare	3	0.858	21	5.855	47	11.381
Hemigrapsus oregonensis	yellow shore crab	3	0.015	20	0.093	45	0.203
Pandalus danae	dock shrimp	3	0.008	22	0.049	44	0.094
Flabellina trilineata	threeline aeolis	3	0.003	22	0.021	43	0.043
Dendronotus frondosus	leafy dendronotid	2	0.001	14	0.007	36	0.018
Pisaster sp	sea star, unid.	2	1.337	14	9.480	35	23.412
Crangon nigromaculata	blackspotted bay shrimp	2	0.002	15	0.015	35	0.035
Cnidaria	sea jelly, unid.	2	0.029	16	0.210	33	0.513
Holothuroidea	sea cucumber, unid.	2	0.004	13	0.023	28	0.049
Archidoris montereyensis	Monterey sea-lemon	1	0.012	7	0.085	18	0.212
Ctenophora	comb jelly, unid.	1	0.006	8	0.047	18	0.105
Cuthona lagunae	orange-faced nudibranch	1	0.001	7	0.007	18	0.018
Dendronotus iris	giant-frond-aeolis	1	0.019	8	0.149	18	0.333
Pleurobranchaea calif.	California sea slug	1	1.778	7	12.779	18	31.596
Scrippsia pacifica	giant bell jelly	1	0.044	8	0.346	18	0.771
Cancer anthonyi	yellow crab	1	0.039	7	0.278	18	0.695
Pinnixa sp	pea crab, unid.	1	0.001	8	0.008	18	0.018
Discodorididae	nudibranch, unid.	1	0.002	7	0.014	17	0.035

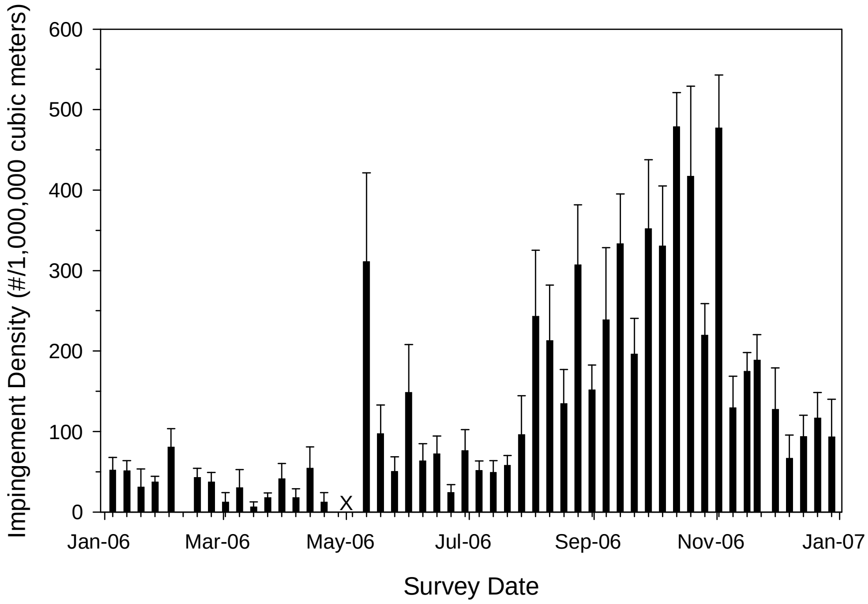
(table continued)

Table 5.5-4 (continued). Estimated annual invertebrate impingement at the HGS from January through December 2006 based on both actual and design (maximum) cooling water flows.

				Estimated Annual Impingement			
		Sampled Impingement		Actual Flows		Design Flows	
Taxa	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Gastropoda	Gastropod, unid.	1	0.007	7	0.049	17	0.122
Navanax inermis	California aglaja	1	0.031	7	0.217	17	0.540
Aplysia spp	seahare, unid.	1	0.310	6	1.744	11	3.367
Aurelia aurita	moon jelly	1	0.010	6	0.056	10	0.099
Mopalia muscosa	mossy chiton	1	0.001	5	0.005	10	0.010
Heptacarpus stimpsoni	Stimpson coastal shrimp	1	0.001	5	0.005	10	0.01
Pandalus stenolepis	roughpatch shrimp	1	0.002	6	0.011	10	0.02
Farfantepenaeus calif.	yellowleg shrimp	1	0.006	7	0.039	9	0.056
	Total impinged invertebrates	**1,014**	**37.306**	**6,753**	**260.244**	**13,538**	**575.473**

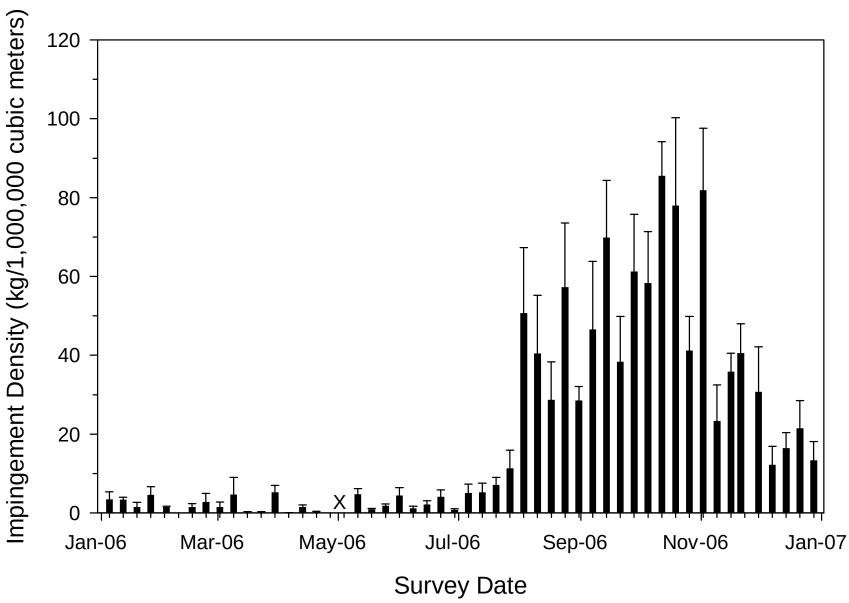
Note: Weights are only presented in kg.

Figures 5.5-1 and 5.5-2 present the fish impingement rates (based on abundance and biomass) during the 50 weeks of sampling during 2006. Impingement abundance was highest from August to November (Figure 5.5-1), which corresponded with an increase in round stingray impingement. Biomass was greatest during the same period (Figure 5.5-2). Invertebrate abundance was greatest from June through August, with highest abundance recorded from late-June through early-August (Figure 5.5-3). Invertebrate biomass was much more variable throughout the year, with peaks from January through March (Figure 5.5-4), corresponding to the impingement of large individuals of certain species. Biomass increased again from June through August, but in a steadier ascent than during the winter months. In general, fish impingement abundance and biomass was greatest during nighttime (Figures 5.5-5 and 5.5-6). The same general trend was observed in invertebrate impingement (Figures 5.5-7 and 5.5-8).



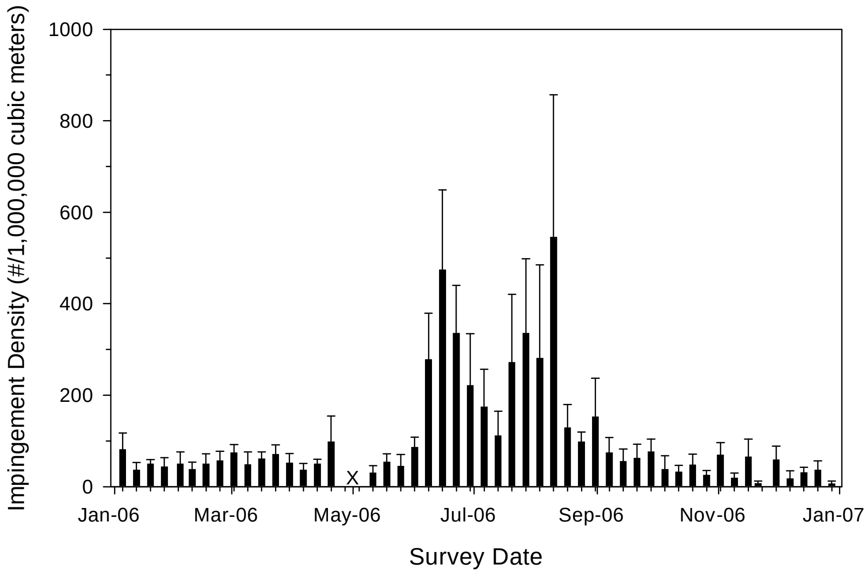
"X" denotes a two-week period of no sample collection.

Figure 5.5-1. Mean concentration (#/1,000,000 m^3 [264.2 million gallons] – wide bars) and standard error (narrow bars) of fishes collected in HGS impingement samples during 2006.



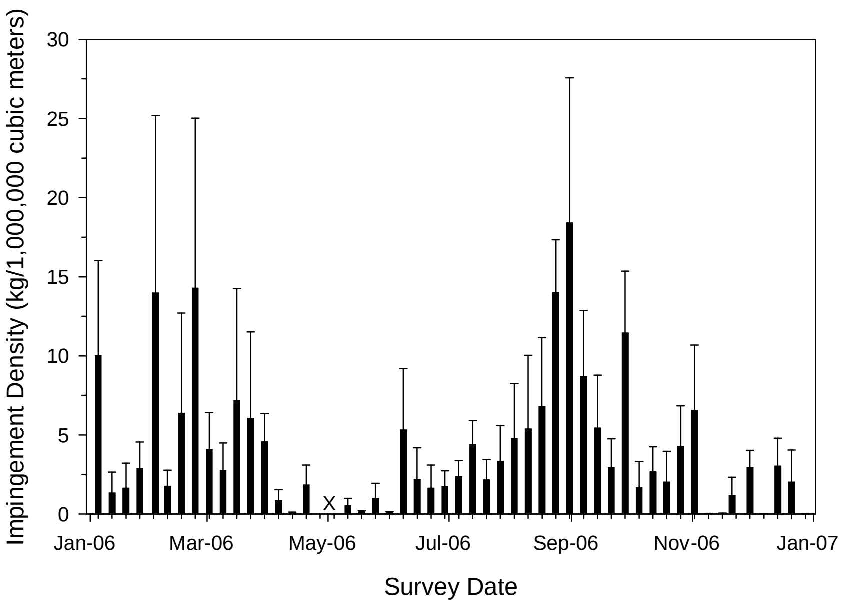
"X" denotes a two-week period of no sample collection.

Figure 5.5-2. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of fishes collected in HGS impingement samples during 2006.



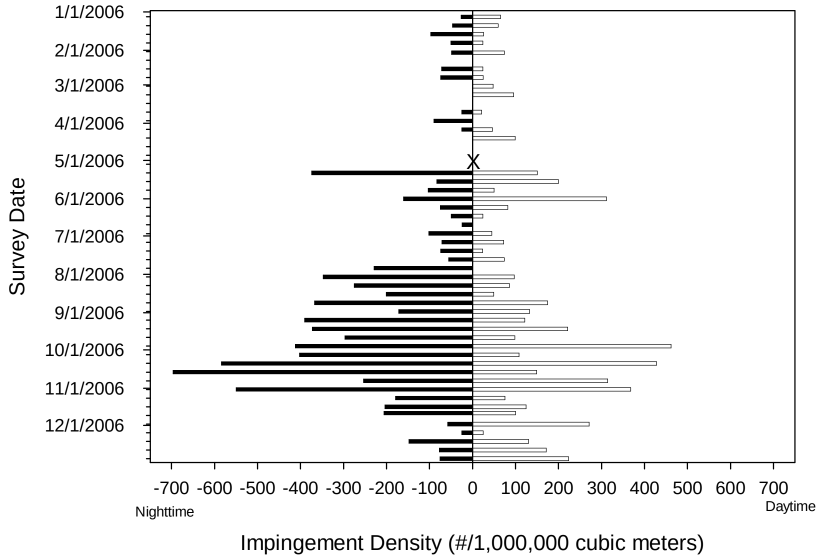
"X" denotes a two-week period of no sample collection.

Figure 5.5-3. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of invertebrates collected in HGS impingement samples during 2006.



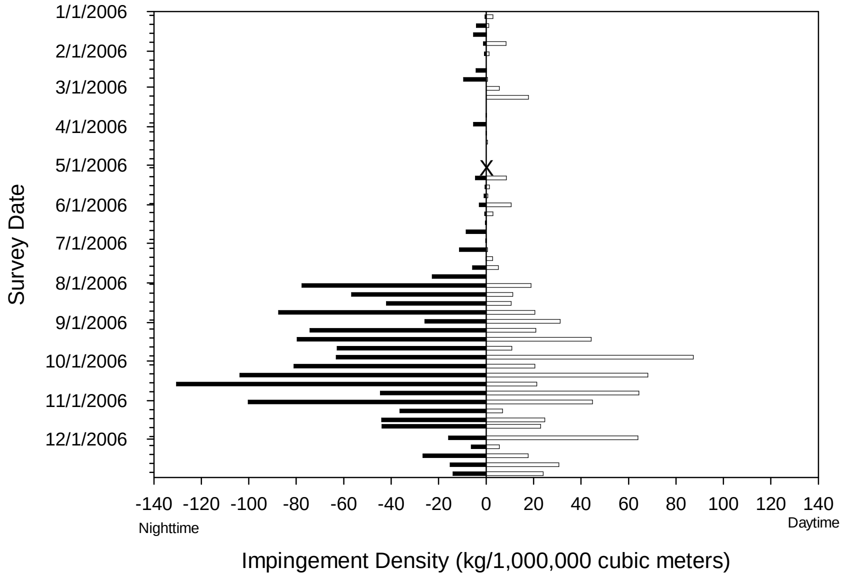
"X" denotes a two-week period of no sample collection.

Figure 5.5-4. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of invertebrates collected in HGS impingement samples during 2006.



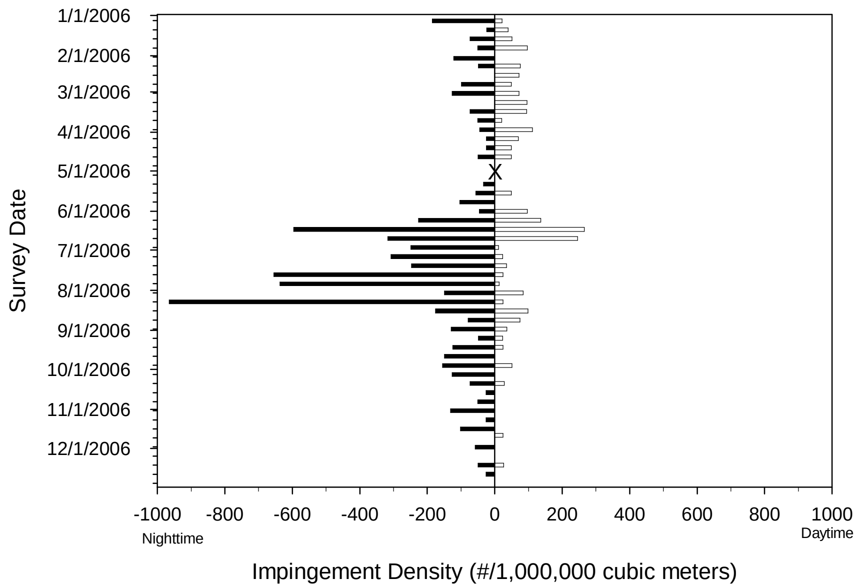
"X" denotes a two-week period of no sample collection.
Negative nighttime values are a plotting artifact.

Figure 5.5-5. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of fishes in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



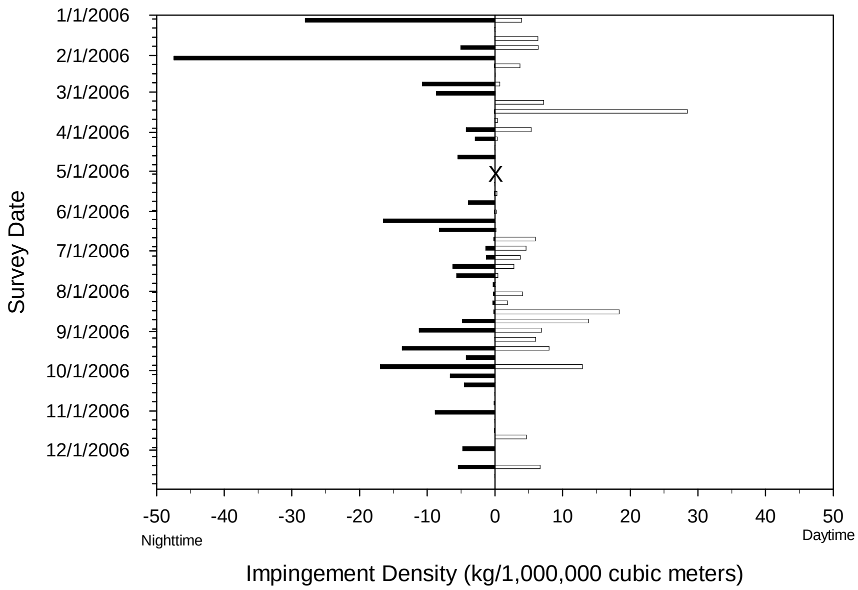
"X" denotes a two-week period of no sample collection.
Negative nighttime values are a plotting artifact.

Figure 5.5-6. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of fishes in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Negative nighttime values are a plotting artifact.

Figure 5.5-7. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of invertebrates in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Negative nighttime values are a plotting artifact.

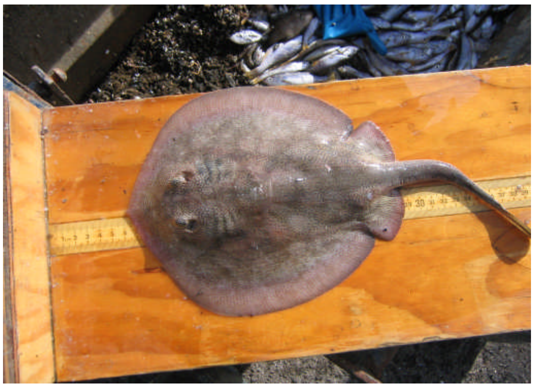
Figure 5.5-8. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of invertebrates in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

5.5.2 Fish Impingement Results by Species

Six fish taxa comprised 91.2% of the fishes in impingement samples and were selected for more detailed analysis based on their total abundances in the samples. These taxa were: round stingray (68% of sampled abundance), black perch (8%), specklefin midshipman (6%), shiner perch (5%), barred sand bass (2%), and giant kelpfish (2%). A seventh species, northern anchovy (<1%), was also analyzed in further detail due to its inclusion in the Coastal Pelagics Fishery Management Plan.

5.5.2.1 Round stingray (*Urobatis halleri*)

The round stingray, *Urobatis halleri*, is the most common stingray found off the California coast. It is distributed from Eureka, northern California to Panama. It is most commonly found in shallow, coastal water bodies (Love 1996; Zorzi et al. 2001). Round stingrays are the single species belonging to the family Urolophidae, which is one of eight families in the order Myliobatiformes. Rays in this order are all warm-water organisms found close to shore (Bond 1996).



5.5.2.1.1 Life History and Ecology

The habitat distribution of the round stingray is fairly limited. They can be found off beaches and in protected bays and channels, where they inhabit soft, loose sand or muddy bottoms. They are commonly found in shallow coastal areas at depths of 1–30 m (3–98 ft), but are more commonly found in waters less than 15 m (49 ft) deep. Mature females are more common further offshore, usually occurring in waters 12–18 m (39–59 ft) deep, whereas males prefer waters less than 12 m (39 ft) deep. Adults are not commonly found in very shallow waters in the winter months (Love 1996; Zorzi et al. 2001).

Round stingrays bear live young, with a gestation period of approximately three months (Babel 1967). In June, females move to shallow, inshore waters just for the time required to breed with males. They return to these same waters to spawn in August and September. A female can produce up to eight young per litter with an average of three per litter. Individuals measure about 100 mm (3.9 in) in length at birth (Love 1996).

There is not much information on age and growth for the round stingray due to the absence of bony otoliths or scales. They can reach a maximum length of 558 mm (22 in), and are considered mature at 254–266 mm (10.0–10.5 in) in length. At birth, the young remain in water shallower than about 4 m (13 ft) until they reach approximately 152–177 mm (6–7 in) in length (Love 1996). The round stingray uses its stinging spine in defense against predators. Due to the shallow nature of their coastal habitat, they often incidentally sting beach goers that wade in these shallow waters (Love 1996; Zorzi et al. 2001). Stingrays shed and regenerate their spines each year during fall, but can also regenerate a spine that is lost during other times of years (Johansson et al. 2004).

Due to the limited habitat where round stingrays are found, their food source is also limited. Smaller stingrays will feed on invertebrates such as worms, shrimps, crabs, and amphipods. Larger stingrays primarily feed on clams (Love 1996).

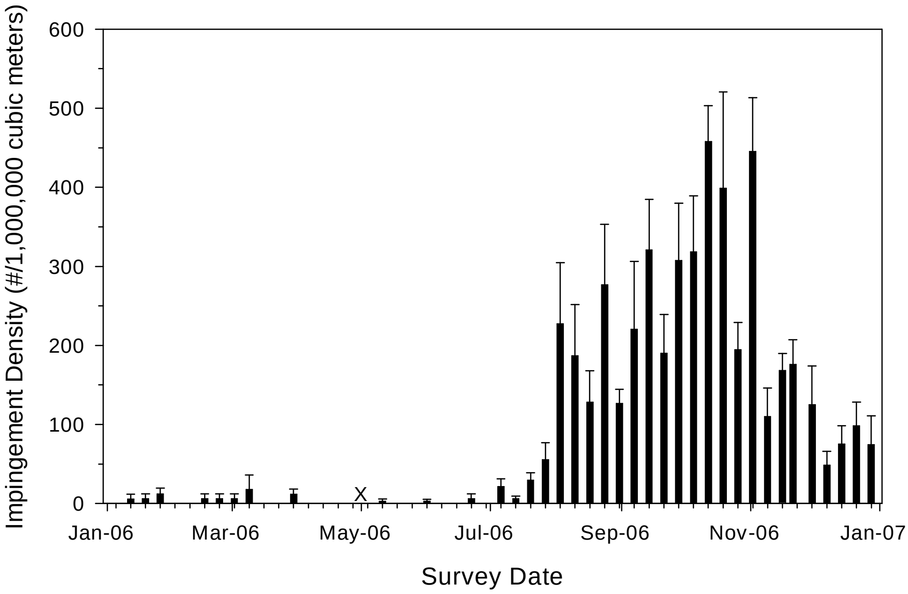
5.5.2.1.2 Population Trends and Fishery

Round stingrays are incidentally caught by pier and shore anglers. There is currently not a market for this species in California. In 2005, "stingray" landings in the Los Angeles area totaled 649 kg (1,430 lbs) at a value of $292 (CDFG 2006). All of the landings were reported in the spring and summer (April–August 2005). Commercial landings of "stingray" reported from catch blocks in the Long Beach area totaled 9.1 kg (20 lbs) in 2006, with an estimated value of less than one dollar (CDFG 2007). During 1978-79, a total of 163 round stingrays was impinged at HGS, equivalent to about five individuals per day (IRC 1981). It comprised only 0.9% of impingement abundance, and abundance was highest from July through September. From 2003 through 2005, a total of 57 round stingrays were collected in 10 impingement samples (MBC 2006). Average annual impingement ranged from 1 to 21 stingrays per survey, and averaged about 6 stingrays per survey (MBC 2006).

5.5.2.1.3 Sampling Results

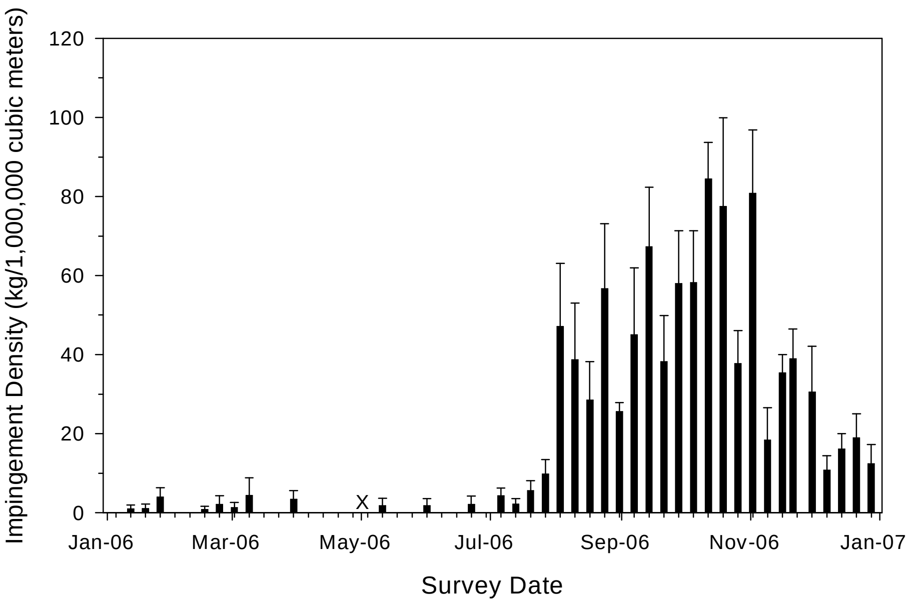
Round stingray was the most abundant species impinged, with an estimated 6,150 individuals calculated using actual cooling water flow volumes, or 69.5% of the annual total, weighing 1,231.68 kg (2,715.85 lbs) (Table 5.5-1). Impinged sporadically throughout the first half of the year, round stingrays were very abundant in impingement surveys during the second half of the year, with individuals collected in nearly every survey (Figure 5.5-9). Biomass followed a pattern consistent with that seen in abundance (Figure 5.5-10). Overall, generally higher abundance and biomass was recorded during nighttime impingement surveys (Figures 5.5-11 and 5.5-12).

Length frequency analysis of 817 measured individuals indicated a mean disc width (DW) of 161 mm (6.3 in) (Figure 5.5-13). (Disc width is reported here since rays without tails are sometimes collected). Individuals ranged in size from 110 mm (4.3 in) DW to 250 mm (9.8 in) DW in a nearly normal distribution peaking with the 160 mm (6.3 in) DW size class, or approximately 3 years old (Babel 1967). A total of 817 individuals were sexed, with 42% female, 58% male, and less than 1% of undetermined sex due to the physical condition of the animal. Of the 784 individuals that were evaluated for condition factor, 67% were alive, 30% were dead, and 3% were mutilated.



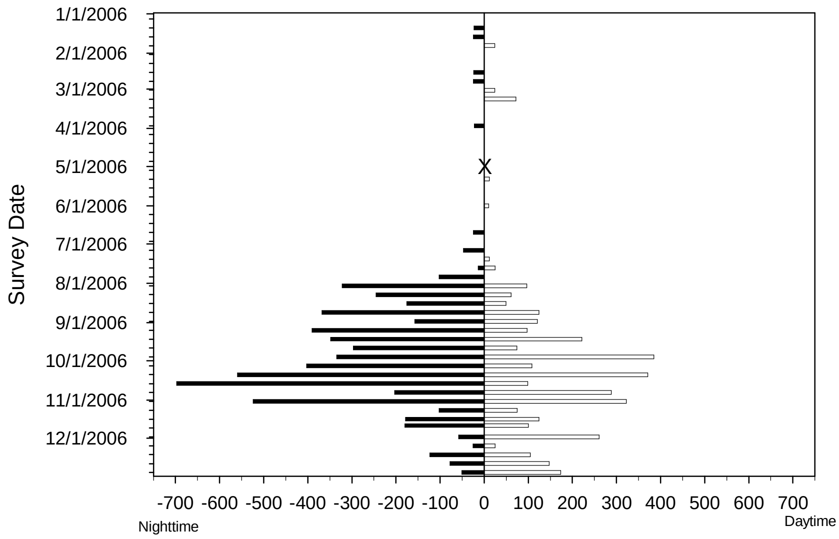
"X" denotes a two-week period of no sample collection.

Figure 5.5-9. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) and standard error of round stingray collected in HGS impingement samples during 2006.



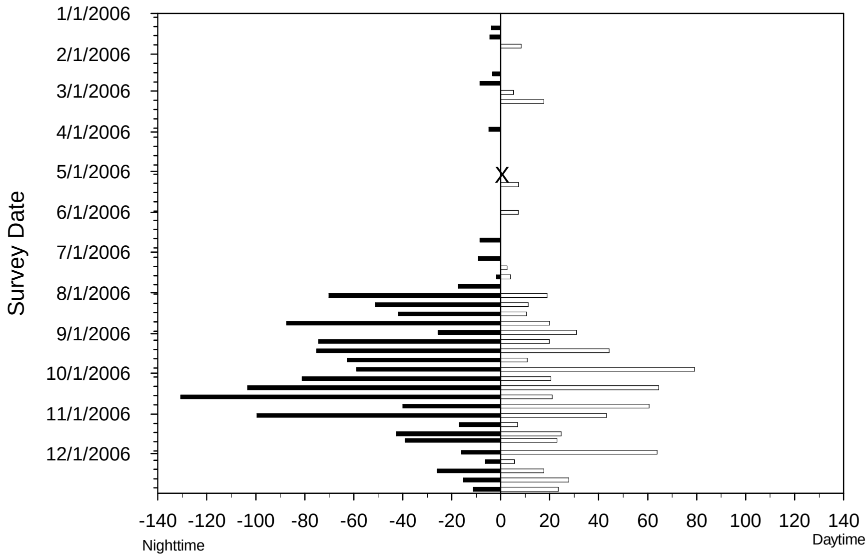
"X" denotes a two-week period of no sample collection.

Figure 5.5-10. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) and standard error of round stingray collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact

Figure 5.5-11. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of round stingray in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact

Figure 5.5-12. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of round stingray in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

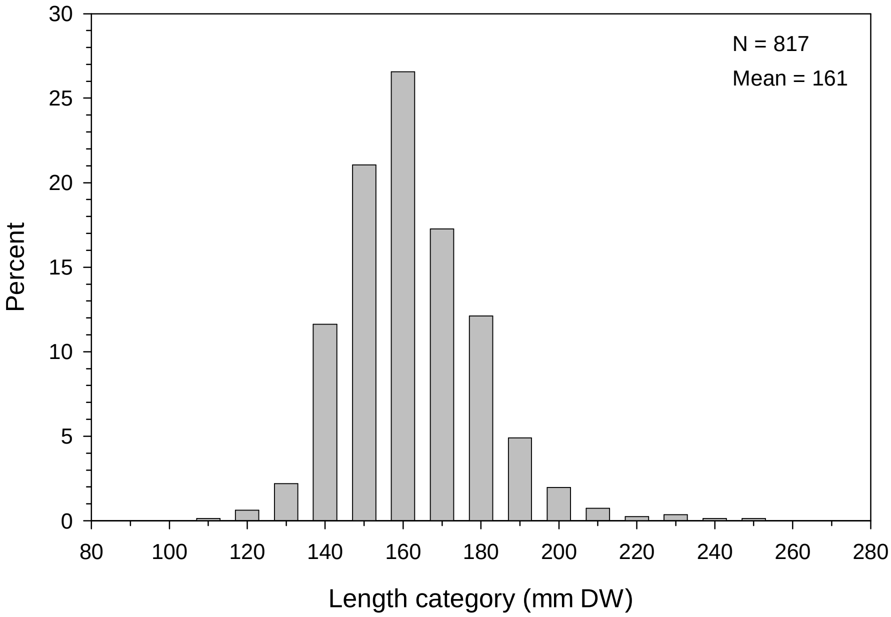


Figure 5.5-13. Disc width (mm) frequency distribution for round stingray collected in impingement samples.

5.5.2.2 Black perch (*Embiotoca jacksoni*)

Jay Carroll

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

5.5.2.2.1 Life History and Ecology

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

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

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

5.5.2.2.2 Population Trends and Fishery

Surfperch commercial landings, overall, steadily declined from the peak in 1982, with some research indicating the decline may partially be attributable to increased water temperature that dominated the northeast Pacific Ocean throughout much of the 1980s and 1990s (Fritzsche and Collier 2001). The NMFS Los Angeles Times recreational fishing database recorded an annual mean landing of 50 black perch from all landings ranging from Paradise Cove on the northwestern edge of the Santa Monica Bay south to San Diego, California over the period 1991–2003 (NMFS 2007). Due to the random nature of the recreational fishing data, no real population trends can be determined for black perch. Total statewide recreational landings of “surfperches” were 489,000 fish in 1999, with most of the catch in central and northern California (Fritzche and Collier 2001). Commercial landings in the Los Angeles area have fluctuated between about 136 and 1,361 kg (300 and 3,000 lbs) per year since 2000 (Table 5.5-5). In 2005, “surfperch” landings in the Los Angeles area totaled 21.3 kg (47 lbs) with a value of $86 (CDFG 2006). Commercial landings of “surfperches” in 2006 reported from catch blocks in the Long Beach area totaled 74.9 kg (165 lbs), at an estimated value of $660 (CDFG 2007).

During 1978-79, a total of 77 black perch were impinged at HGS, equivalent to about two black perch per survey (IRC 1981). They were present year-round, but highest impingement occurred in February (10 individuals during February 1, 1979). From 2003 through 2005, only four black perch were collected in 10 impingement samples at the HGS (MBC 2006). Average annual impingement ranged from 0 to 1 black perch per survey, and averaged 0.4 fish per survey (MBC 2006).

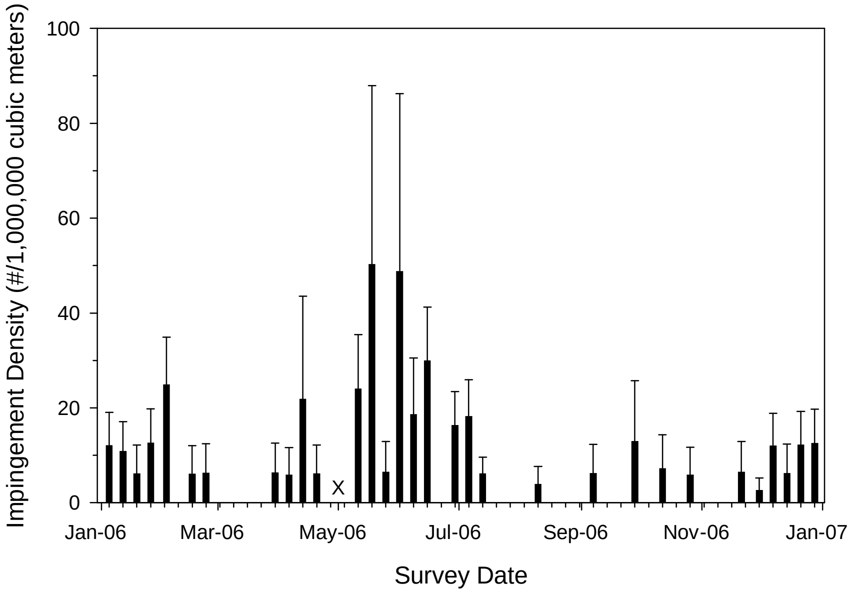
Table 5.5-5. Annual landings and revenue for surfperches in the Los Angeles region based on PacFIN data.

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

5.5.2.2.3 Sampling Results

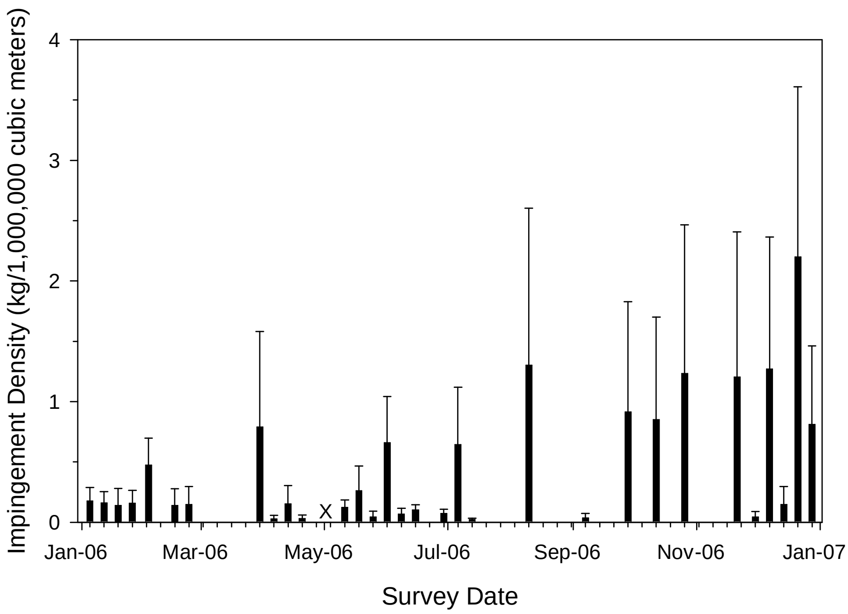
Black perch was the second most abundant species impinged with an estimated 646 individuals calculated using actual cooling water flow volumes, or 7.3% of the annual total, weighing 18.49 kg (40.76 lbs) (Table 5.5-1). Black perch were impinged consistently during the late-spring/early-summer, although impingement occurred throughout the year (Figure 5.5-14). Lowest impingement occurred from late-July through mid-November. Highest biomass occurred during the second half of the year during a more sporadic period (Figure 5.5-15). This was due to impingement of larger individuals during surveys when impingement abundance was relatively low. Black perch were impinged with greater frequency during the nighttime, but the greatest single-survey impingement rates were observed during the daytime (Figure 5.5-16). Conversely, biomass was more consistent and often greater during nighttime surveys than was recorded during daytime surveys (Figure 5.5-17).

Length frequency analysis of 98 measured individuals was used to calculate a mean standard length of 75 mm (Figure 5.5-18). Individual lengths were recorded in a wide range of sizes, ranging from 50–200 mm SL (2.0 to 7.9 in). Despite the widespread distribution, the majority of recorded lengths were spread between the 50 to 70 mm (2.0 to 2.8 in) size classes, with peak abundance in the 60 mm (2.4 in) size class, corresponding to young-of-the-year. Ninety-nine individuals were sexed, with 10% female, 6% male, and 69% juvenile. Sexes of the remaining 15% could not be determined. The disposition of 102 individuals was evaluated for condition factor: 6% were alive, 89% were dead, and 5% were mutilated.



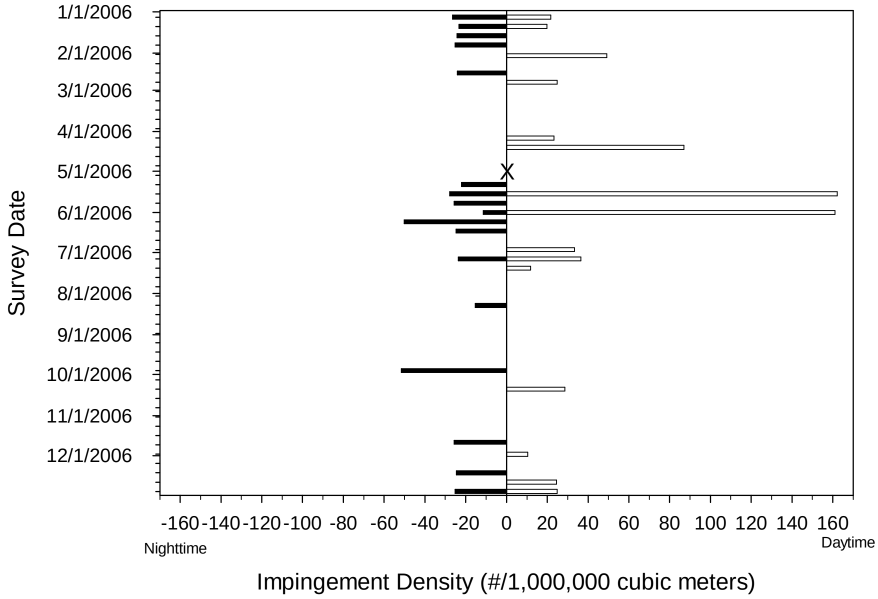
"X" denotes a two-week period of no sample collection.

Figure 5.5-14. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of black perch collected in HGS impingement samples during 2006.



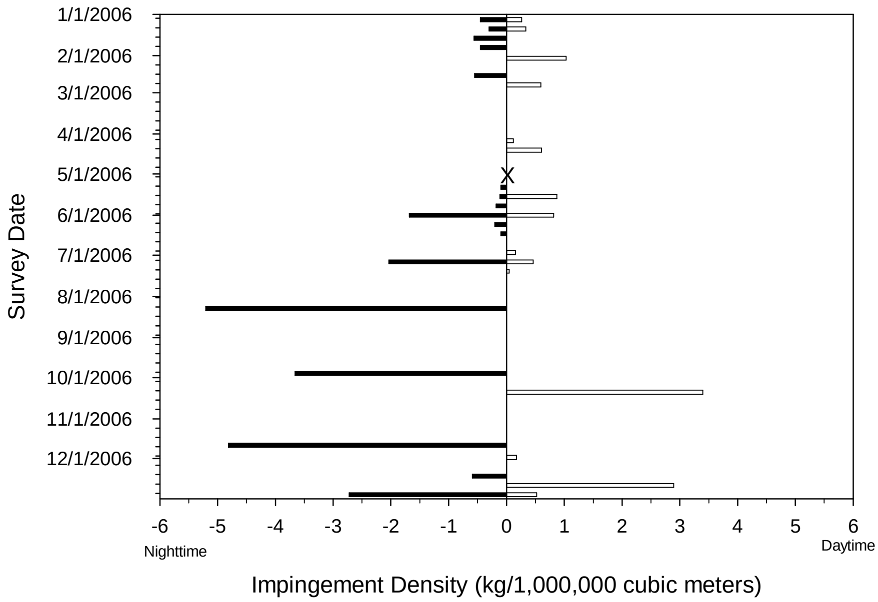
"X" denotes a two-week period of no sample collection.

Figure 5.5-15. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of black perch collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-16. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of black perch in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-17. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of black perch in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

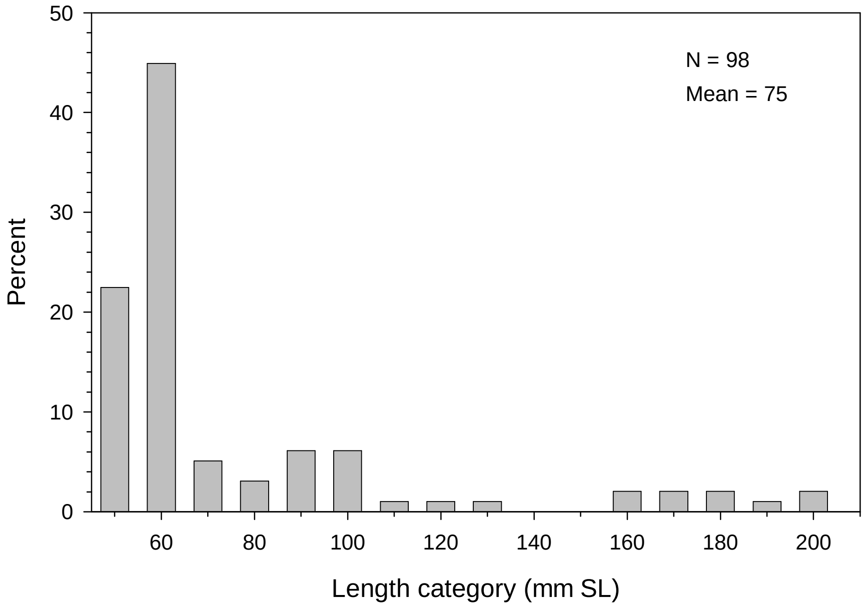
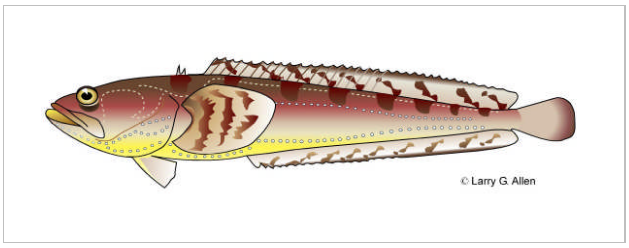


Figure 5.5-18. Length (mm) frequency distribution for black perch collected in impingement samples.

5.5.2.3 Specklefin midshipman (*Porichthys myriaster*)



The specklefin midshipman, *Porichthys myriaster*, is one of two species of midshipman found off the California coast (the other being plainfin midshipman [*Porichthys notatus*]). The specklefin midshipman is most commonly found in muddy and sandy areas ranging from Point Conception, California, to Magdalena Bay, Baja California (Hubbs and Schultz. 1939; Fitch and Lavenberg 1975). Specklefin midshipman belongs to the family Batrachoididae, which is in the order Batrachoidiformes. Fish in this order are usually broad-headed, big-mouthed, benthic organisms of tropical and temperate waters (Bond 1996).

5.5.2.3.1 Life History and Ecology

The common habitat of the specklefin midshipman is typically found to be muddy and sandy bays, and along the open shore to depths of 126 m (413 ft). Although the range of the specklefin midshipman and the plainfin midshipman overlap, the specklefin prefers to live in shallower waters than the plainfin (Hubbs et al. 1939).

The specklefin's primary habitat is muddy and sandy bottoms; except, during April to June when they will move to rocky areas for spawning. Females will attach their eggs, 200-400, to the underside of rocks and remain with the eggs for a day or two along with the male to guard the eggs. The male will stay with the eggs for the month or more it takes them to hatch. During this time the male does not feed, and can become emaciated and diseased. Many males may succumb to the stress and die before or after the eggs hatch (Fitch and Lavenberg 1975).

There is not much documentation on the growth rate of the specklefin midshipman, but it is estimated they can grow to 508 mm (20 in) in length (Allen 1982). Males will grow much larger than females. There is no information on their maximum age, but a 457 mm (18 in) male weighing about 0.9 kg (2 lbs) was reported to be eight years old (Fitch and Lavenberg 1975).

Midshipmen in general are not selective feeders, and will eat anything they come across that they can get their mouth around, both alive and dead. Crustaceans, octopus, squid, and small fish make up the majority of their diet. Giant seabass, sea lions, and porpoises have been known to feed on midshipmen. During daylight hours when in muddy areas they bury themselves and emerge to feed at night (Fitch and Lavenberg 1975). At night they use photophores to display light for use in courtship (Bond 1996). They are most active at night and have been known to make humming and grunting sounds (Eschmeyer and Herald 1983).

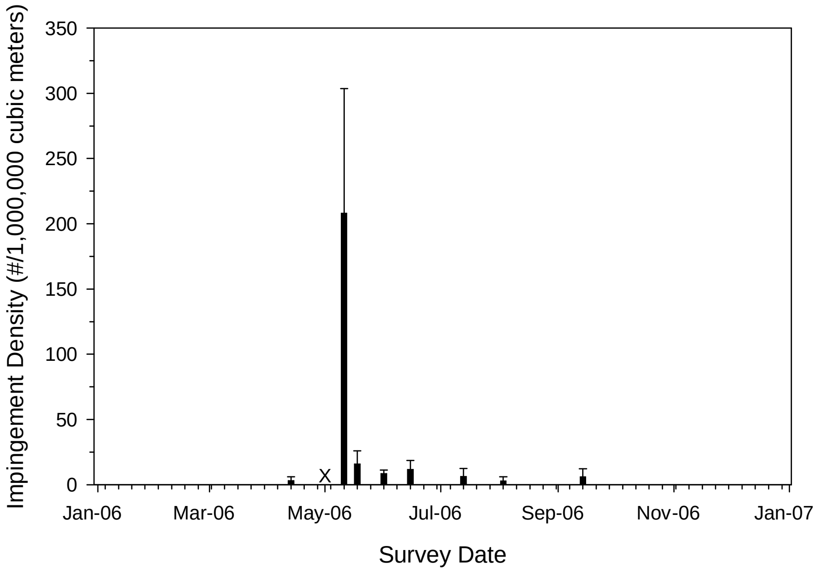
5.5.2.3.2 Population Trends and Fishery

There is currently no market for midshipmen. Anglers catch midshipmen incidentally, probably due to the fact that they will eat anything. No specklefin midshipman landings were reported in the commercial fishing databases queried (CDFG 2006, 2007). During 1978-79, a total of 29 specklefin midshipman was impinged at HGS, equivalent to less than one individual per survey (IRC 1981). They were impinged throughout the year, with highest numbers occurring in February and March. During 10 impingement surveys at the HGS from 2003 through 2005, only one individual was impinged (MBC 2006).

5.5.2.3.3 Sampling Results

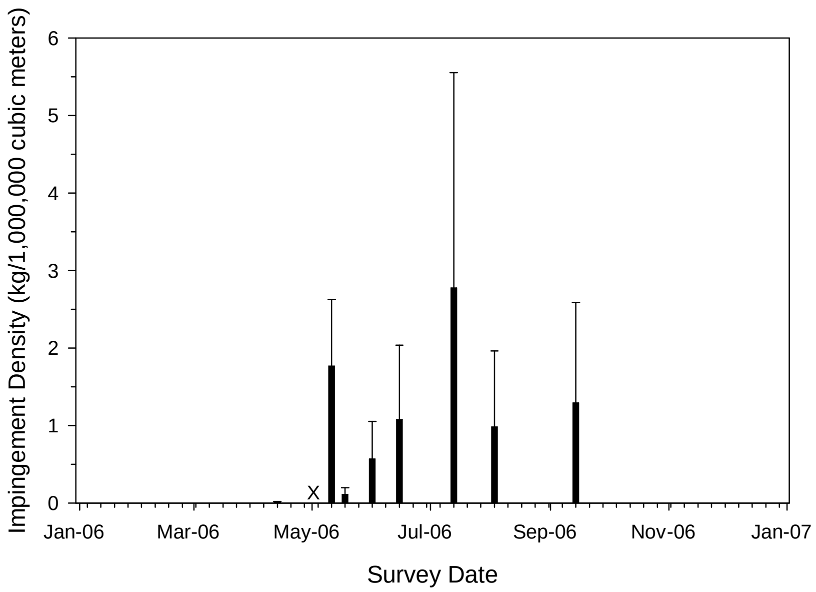
Specklefin midshipman was the third most abundant species impinged with an estimated 484 individuals calculated using actual cooling water flow volumes, or 5.5% of the annual total, weighing 12.0 kg (26.4 lbs) (Table 5.5-1). The majority of specklefin midshipman was collected during the May 11-12, 2006 survey, with a mean impingement rate of greater than 200 individuals per 1,000,000 m^3 (Figure 5.5-19). This was the first survey after the maintenance outage. During the rest of the year, impingement densities were consistently less than 25 individuals per 1,000,000 m^3. Biomass exhibited a different pattern, with highest biomass occurring on the July 14th survey (Figure 5.5-20). This was due to impingement of larger individuals during that survey. During periods of peak impingement, higher abundance and biomass was generally observed during daylight hours (Figures 5.5-21 and 5.5-22), with the exception of Survey 28.

Length frequency analysis of 74 measured individuals was used to calculate a mean standard length of 99 mm (3.9 in) (Figure 5.5-23). Although individuals were collected representing size classes up to 330 mm SL (13 in), the majority of recorded lengths were in the 40–170 mm (1.6–6.7 in) size classes. Peak abundance was recorded in the 60 mm SL (2.4 in) size class. Of the 73 individuals that were evaluated for condition factor, 79% were alive and 21% were dead.



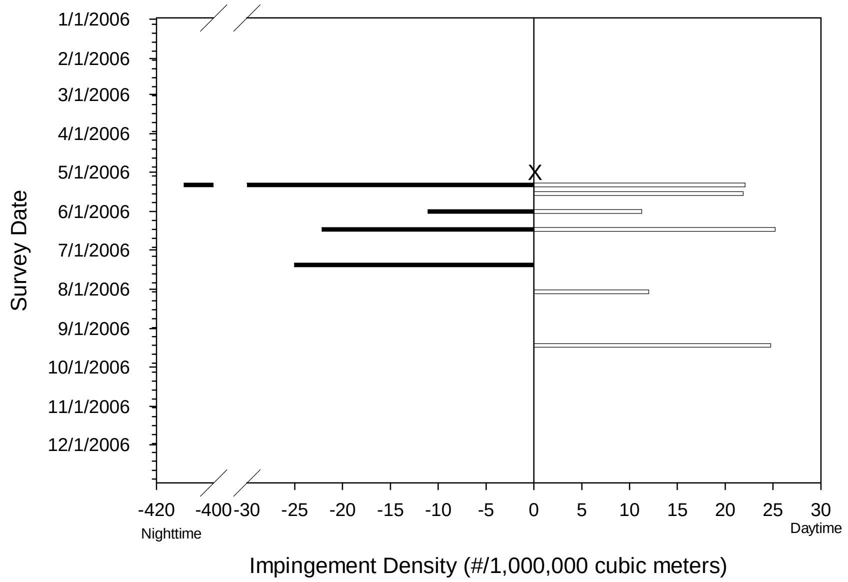
"X" denotes a two-week period of no sample collection.

Figure 5.5-19. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of specklefin midshipman collected in HGS impingement samples during 2006



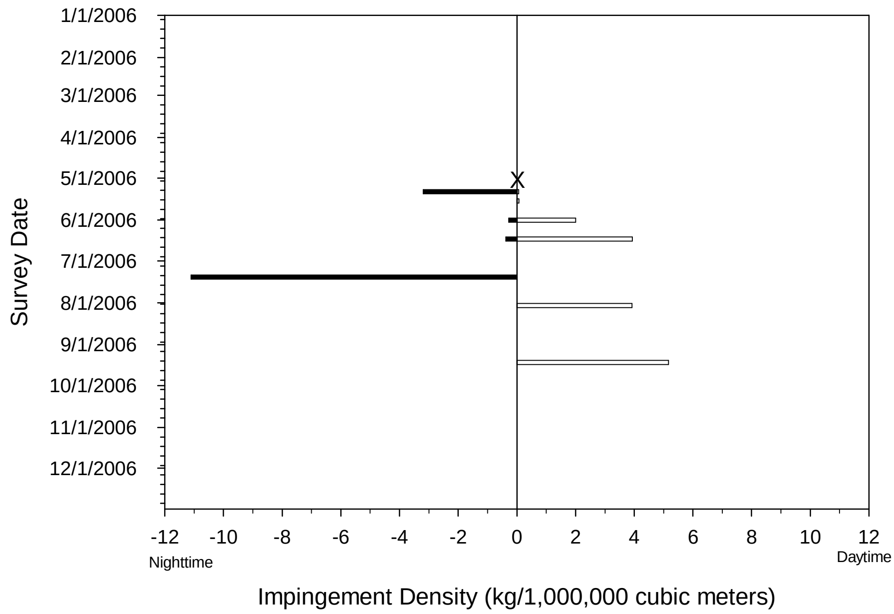
"X" denotes a two-week period of no sample collection.

Figure 5.5-20. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of specklefin midshipman collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-21. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of specklefin midshipman in impingement samples during night (Cycle 4) and day (Cycle 2) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-22. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of specklefin midshipman in impingement samples during night (Cycle 4) and day (**C**ycle 2) sampling.

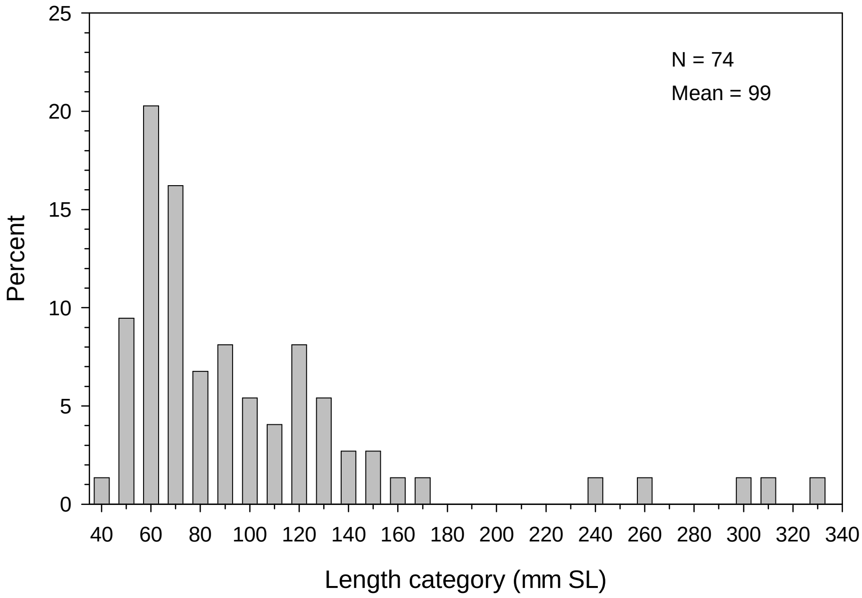


Figure 5.5-23. Length (mm) frequency distribution for specklefin midshipman collected in impingement samples.

5.5.2.4 Shiner perch (*Cymatogaster aggregata*)

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

5.5.2.4.1 Life History and Ecology

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

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

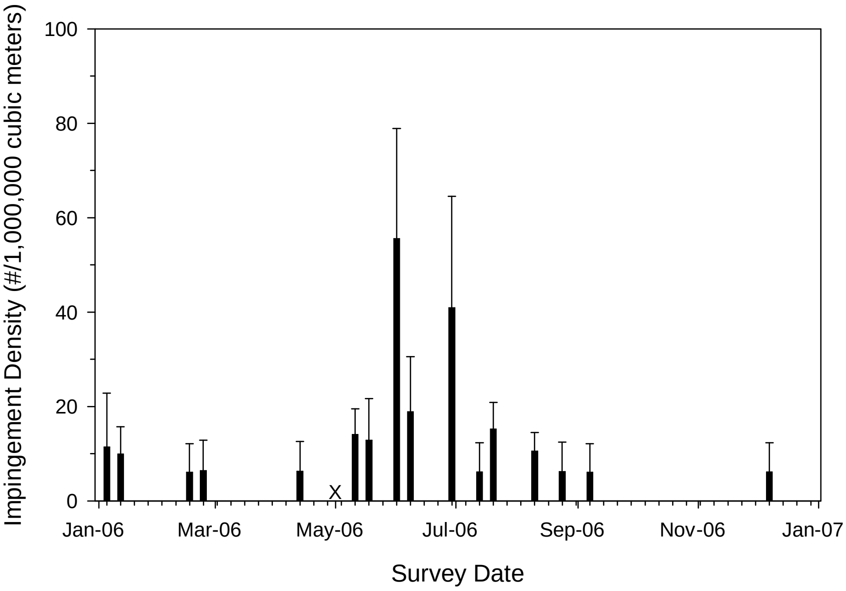
5.5.2.4.2 Population Trends and Fishery

This species is not commercially important, but some shiner perch are landed for bait and human consumption (Emmett et al. 1991). Shiner perch are fished recreationally, especially from piers and in bays and estuaries. Total statewide recreational landings of "surfperches" were 489,000 fish in 1999, with most of the catch in central and northern California (Fritzche and Collier 2001). Commercial landings in the Los Angeles area have fluctuated between about 136 and 1,361 kg (300 and 3,000 lbs) per year since 2000. In 2005, "surfperch" landings in the Los Angeles area totaled 21.3 kg (47 lbs) at a value of $86 (CDFG 2006). Commercial landings of "surfperches" reported from catch blocks in the Long Beach area totaled 74.9 kg (165 lbs) in 2006, at an estimated value of $660 (CDFG 2007). Numbers of shiner perch in southern California waters declined after the mid-1970s, and this is likely related to warming ocean temperature, decreased zooplankton biomass, and reduced upwelling (Stull and Tang 1996, Beck and Herbinson 2003, Allen et al. 2004). During 1978-79, a total of 1,873 shiner perch were impinged at HGS, equivalent to about 55 shiner perch per survey (IRC 1981). It was the fourth most abundant species during the yearlong study, and abundance was highest in February. From 2003 through 2005, six shiner perch were collected in 10 impingement samples (MBC 2006). Average annual impingement ranged from 0 to 5 shiner perch per survey, and averaged about 0.6 fish per survey.

5.5.2.4.3 Sampling Results

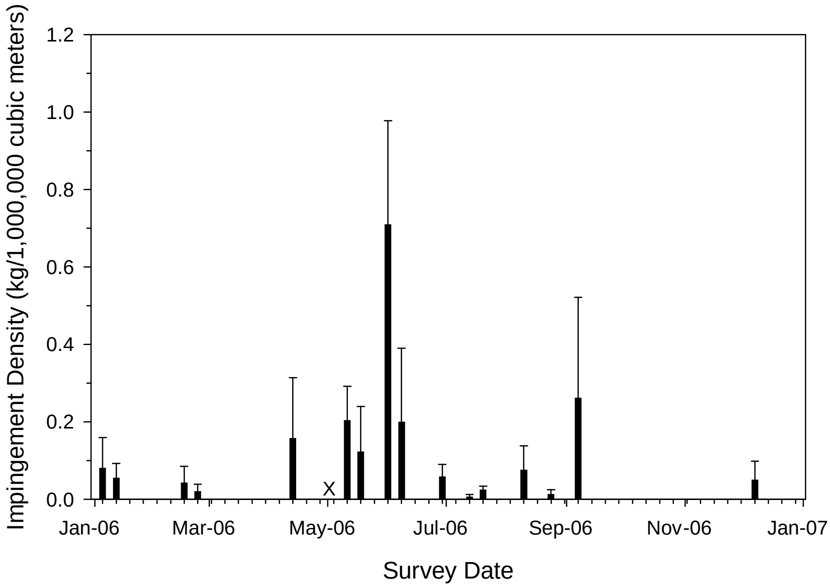
Shiner perch was the fourth most abundant species impinged with an estimated 390 individuals calculated using actual cooling water flow volumes, or 4.4% of the annual total, weighing 3.4 kg (7.4 lbs) (Table 5.5-1). The majority of shiner perch was impinged consistently during the first nine months of the year, with peak impingement during the late-spring/early-summer period (Figure 5.5-24). This species only occurred in one impingement survey during the fourth quarter of the year. Biomass generally followed a pattern consistent with that seen in abundance (Figure 5.5-25). Shiner perch were impinged with greater frequency during the daytime than during nighttime (Figure 5.5-26). This same pattern was more pronounced with biomass (Figure 5.5-27).

Length frequency analysis of 64 measured individuals was used to calculate a mean standard length of 61 mm SL (2.4 in) (Figure 5.5-28). A wide range of size fishes were collected, ranging from the 30 to 130 mm (1.2 to 5.1 in) size classes. Despite the wide range of sizes, the majority of recorded lengths were in the 40 mm SL (1.6 in) size class, corresponding to young-of-the-year. Fifty-seven individuals were sexed, with 19% female, 12% male, and 51% juvenile. Sexes of the remaining 18% could not be determined. These same 57 individuals were evaluated for condition factor: 98% were dead and 2% were mutilated.



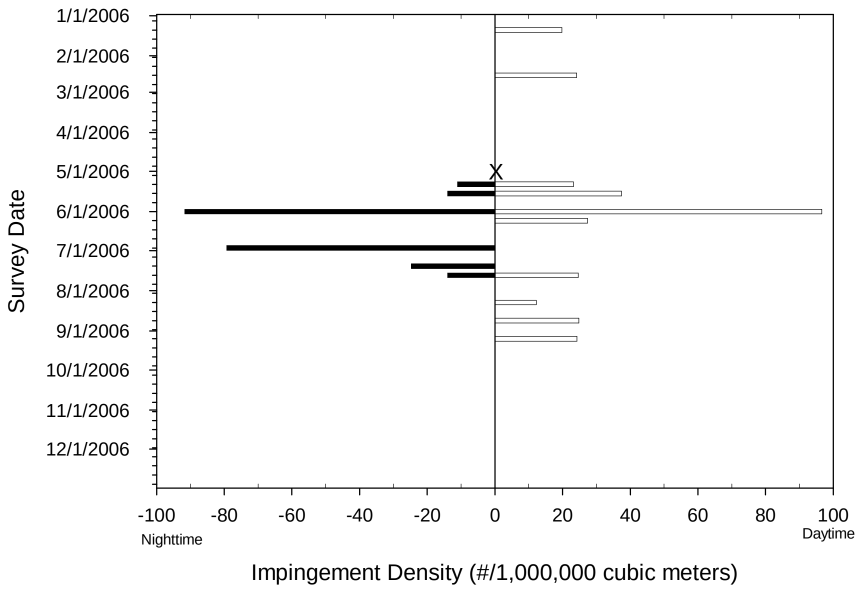
"X" denotes a two-week period of no sample collection.

Figure 5.5-24. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of shiner perch collected in HGS impingement samples during 2006.



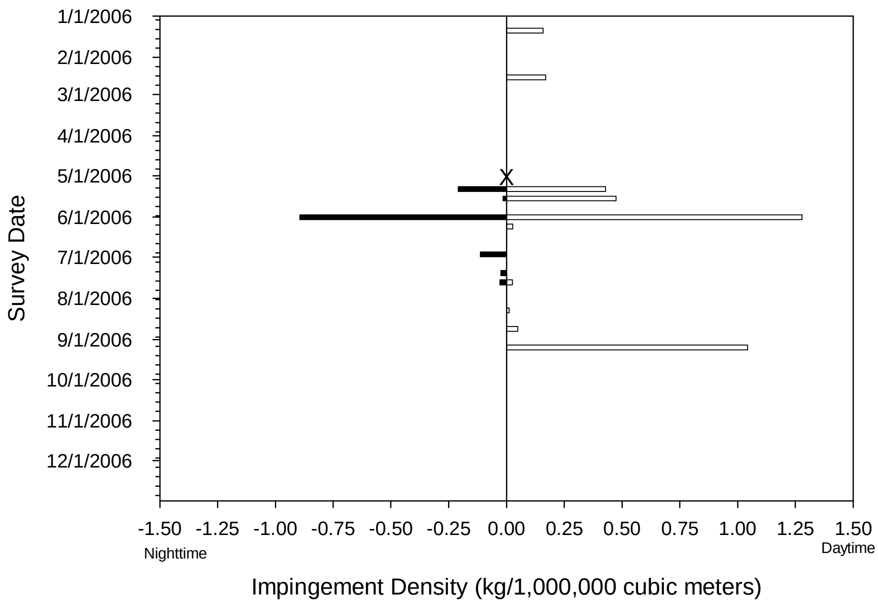
"X" denotes a two-week period of no sample collection.

Figure 5.5-25. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of shiner perch collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-26. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of shiner perch in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-27. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of shiner perch in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

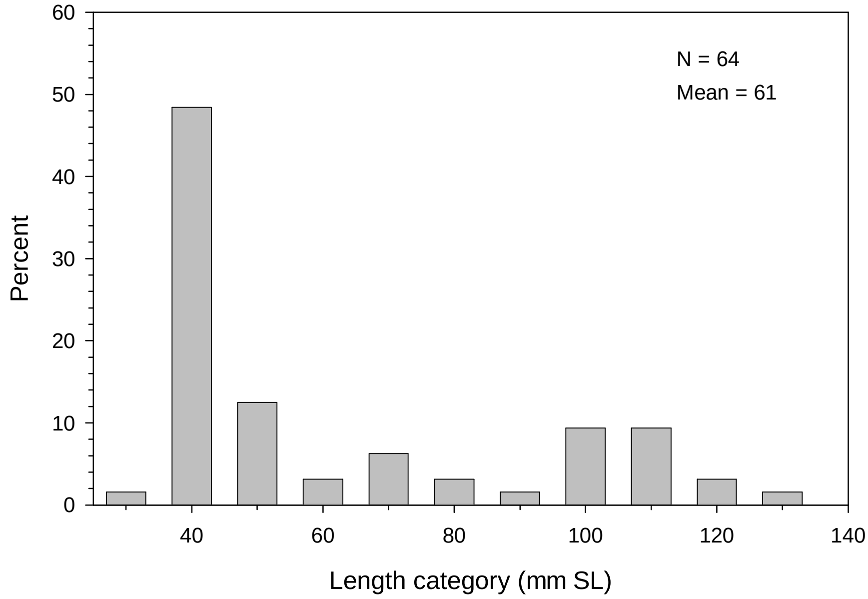
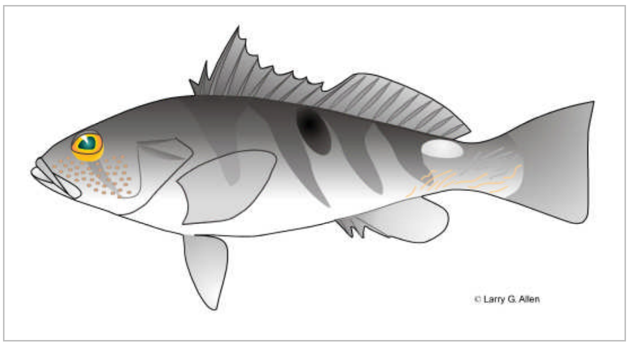


Figure 5.5-28. Length (mm) frequency distribution for shiner perch collected in impingement samples.

5.5.2.5 Barred sand bass (*Paralabrax nebulifer*)



The barred sand bass (*Paralabrax nebulifer*) range from Bahia Magdalena, Baja California, Mexico to Santa Cruz, California in depths from the surfzone to 183 m (600 ft) (Miller and Lea 1972). In addition to barred sand bass, two other species of the genus *Paralabrax* are commonly observed in central and southern California, including kelp bass (*P. clathratus*) and spotted sand bass (*P. maculatofasciatus*) (Miller and Lea 1972; Allen and Pondella 2006b). Allen and Pondella (2006b) included barred sand bass in their shallow rock sand species group, along with kelp bass. Barred sand bass have been frequently observed in impingement sampling throughout southern California since 1990 (MBC unpubl. data).

5.5.2.5.1 Life History and Ecology

The more cosmopolitan of the three, barred sand bass are frequently taken by recreational anglers in widely varied habitats ranging from bays and harbors to nearshore low-relief hard bottom to sand-reef ecotone throughout southern California (Allen and Hovey 2001; Hovey et al. 2002). Contrary to their name, barred sand bass have been more frequently been reported in association with bottom structures, than over featureless, sandy bottoms, outside of the spawning season (Allen and Hovey 2001). During spawning season, however, barred sand bass frequently form large aggregations, often over low-relief sandy bottom, such as offshore of Huntington Beach, California (Hovey et al. 2002). Regardless of the season, barred sand bass have been noted to rarely venture more than 3 m (10 ft) above the bottom (Love et al. 1996), with the possible exception of short duration vertical spawning rushes, similar to what has been observed in the other two *Paralabrax* species (Miller and Allen 2006; Erisman and Allen 2006). Although they have been taken as deep as 183 m (600 ft), the greatest density of individuals has typically been observed at less then 30 m (98 ft) water depth (Allen and Hovey 2001).

In trawl sampling of Alamitos Bay, California, Valle et al. (1999) reported that nearly all collections of barred sand bass occurred in eelgrass beds. Furthermore, all individuals were juveniles, with the average individual less than 40 mm SL (1.6 in), ranging from 16–92 mm SL (0.6–3.6 in). Similar surveys by Allen and Herbinson (1990) designed to determine the distribution of juvenile California halibut (*Paralichthys californicus*) reported nearly 114 barred sand bass per hectare within bay habitats of southern California, but less than one individual per hectare in semi-exposed and fully exposed nearshore habitat in water depths less than 15 m (49 ft). By targeting California halibut, soft bottom sandy habitat was primarily sampled, which may have resulted in a programmatic bias against late juvenile/adult barred sand bass, which would be more associated with structures in the exposed areas. A mean length of 46 mm SL (1.8 in) recorded during these surveys suggested the majority of individuals collected were juveniles, which would be consistent with the bay collections made by Valle et al. (1999). Further emphasizing the use of bay habitat as nursery grounds for barred sand bass, Allen et al. (2002) indicated that 97% of all individuals taken in San Diego Bay, California were juveniles.

All three *Paralabrax* species common to southern California have been characterized as broadcast spawners (Love et al. 1996; Erisman and Allen 2006; Miller and Allen 2006), meaning they produce pelagic eggs that are carried by ocean currents rather than being attached to benthic substrate. Barred sand bass, specifically, spawn from April to November, with a peak in July (Allen and Hovey 2001). Typically, they form dense breeding aggregations over sandy bottoms in depths from 15 to 30 m during the summer months (Hovey et al. 2002). Based on histological examination of the gonads Oda et al. (1993) reported that barred sand bass were capable of daily spawning, while in season. Unfortunately, batch fecundity for barred sand bass could not be determined during this study due to an insufficient sample size.

Each sex reaches maturity at slightly different rates in barred sand bass, with one half of all males reaching maturity by 219 mm TL (8.6 in), while females were delayed until 239 mm TL (9.4 in), or two and three years, respectively (Love et al. 1996). Initially believed to be gonochoric (1:1 sex ratio, no sex change), Oda et al. (1993) hypothesized that barred sand bass may in fact be a protogynous hermaphrodite, similar to spotted sand bass (Hastings 1989). Hovey et al. (2002) further investigated this and identified two transitional individuals, supporting the notion that hermaphroditic biology was possible, but concluded that barred sand bass were functioning gonochores with the potential to change sex. These data, and recent studies by Sadovy and Domier (2005), suggest these hermaphroditic possibilities were more representative of passing through a non-functional bisexual juvenile stage than changing sex from a functional female to functional male.

Age and growth of barred sand bass suggest they grow at a faster rate over the first five years than the remaining years of life (Love et al. 1996). These authors noted that the average barred sand bass grow from approximately 100 mm TL (3.9 in) at less than one year to approximately 300 mm TL (11.8 in) by age 5. Barred sand bass were aged to 24 years by these authors, but they noted the predominance of individuals were less than 15 years old.

5.5.2.5.2 Population Trends and Fishery

Since 1953, only recreational fishing, with no commercial take, has been allowed for *Paralabrax* species by the CDFG (Allen and Hovey 2001). Dotson and Charter (2003) reported that the complex of barred sand bass and kelp bass has ranked among the top two recreationally landed groups in an area ranging from Goleta, California to the U.S.-Mexico border for the period 1959–1998. For the period 1993–2003, an annual mean recreational landing of 344,014 barred sand bass was reported (NMFS 2007). In southern California, annual recreational landings have ranged between 139,000 and 1,130,000 fish per year, with a declining trend since 2002 (Table 5.5-6). During 1978-79, a total of 49 barred sand bass was impinged at HGS, equivalent to about 1.4 individuals per survey (IRC 1981). It was most abundant in February 1979. From 2003 through 2005, one barred sand bass was collected in 10 impingement samples (MBC 2006).

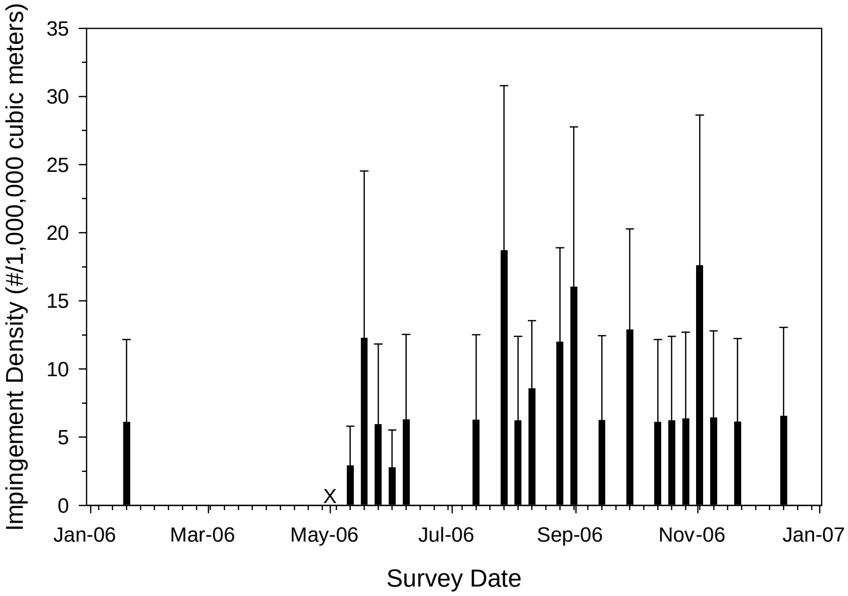
Table 5.5-6. Annual recreational landings (numbers) of barred sand bass in southern California based on RecFIN data.

Year	Landings
2000	1,130,000
2001	806,000
2002	1,062,000
2003	892,000
2004	704,000
2005	307,000
2006	139,000

5.5.2.5.3 Sampling Results

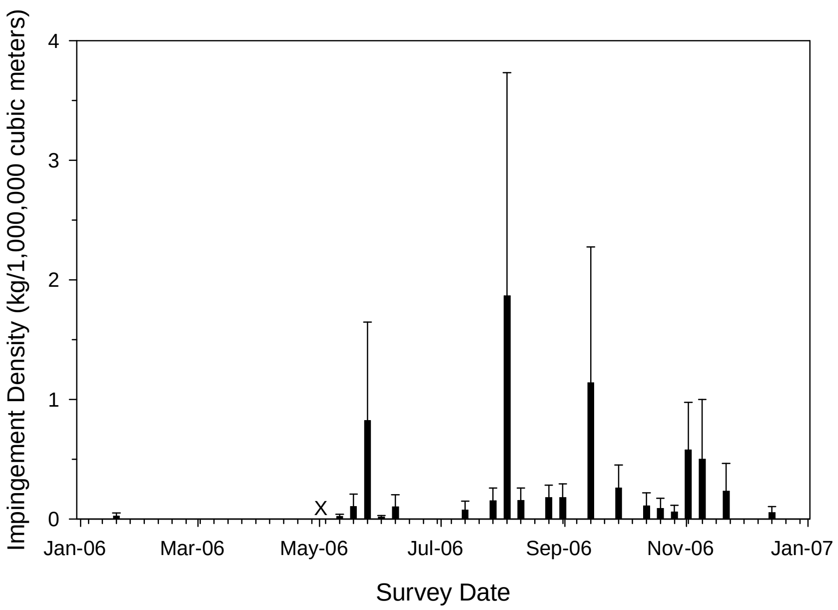
Barred sand bass was the fifth most abundant species impinged with an estimated 209 individuals calculated using actual cooling water flow volumes, or 2.4% of the annual total, weighing 7.5 kg (16.6 lbs) (Table 5.5-1). Barred sand bass was more frequently impinged from spring through fall (Figure 5.5-29). Biomass exhibited a similar pattern with definitive peaks in impingement occurring during the summer months (Figure 5.5-30). This was due to larger individuals impinged during this period in comparison to the rest of the year. During periods of peak impingement, higher abundance and biomass were consistently recorded during nighttime hours (Figures 5.5-31 and 5.5-32).

Length frequency analysis of 31 measured individuals was used to calculate a mean standard length of 106 mm SL (4.2 in) (Figure 5.5-33). Although size classes as high as 270 mm SL (10.6 in) were represented, the majority of individuals were in the 70–100 mm (2.8 to 3.9 in) size classes with a peak centered at 70–80 mm SL (2.8–3.1 in), indicating a principally juvenile assemblage, or approximately one-year old based on Love et al. (1996). Of the 31 individuals that were evaluated for condition factor, 55% were alive and 45% dead.



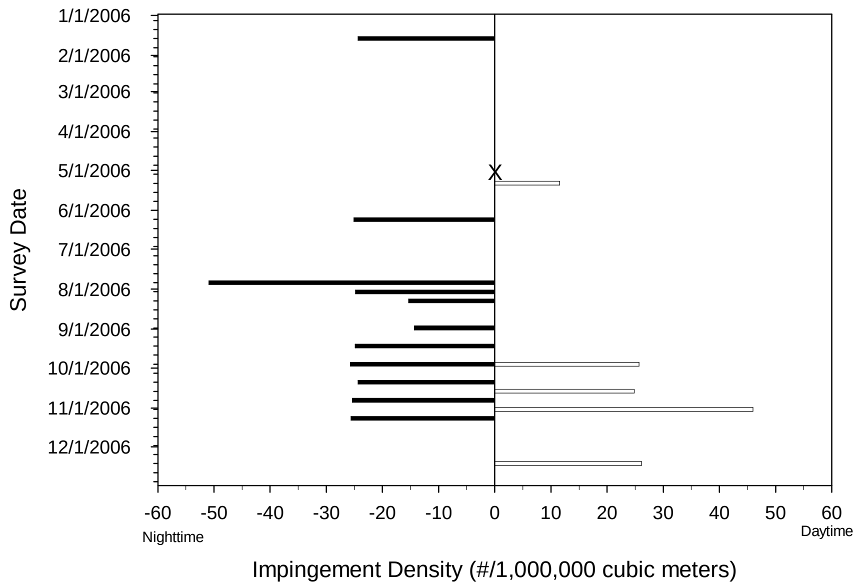
"X" denotes a two-week period of no sample collection.

Figure 5.5-29. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of barred sand bass collected in HGS impingement samples during 2006.



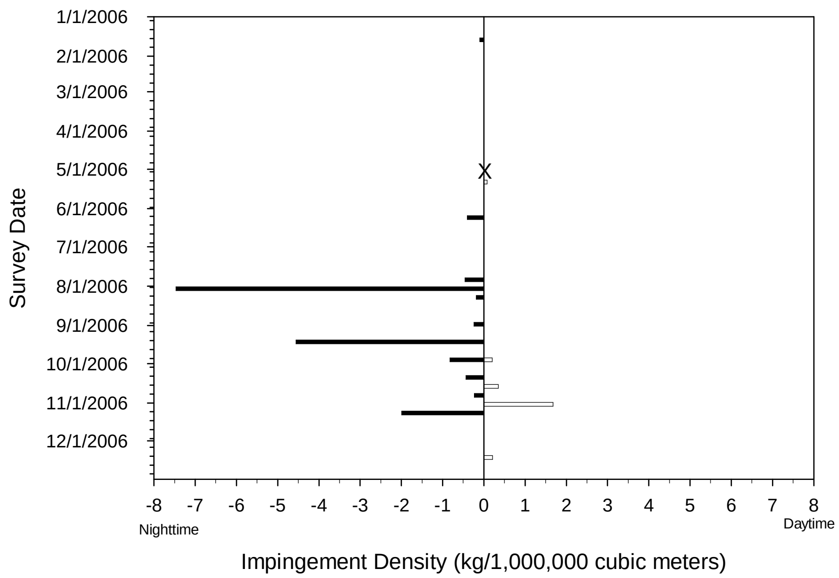
"X" denotes a two-week period of no sample collection.

Figure 5.5-30. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of barred sand bass collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-31. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of barred sand bass in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-32. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of barred sand bass in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

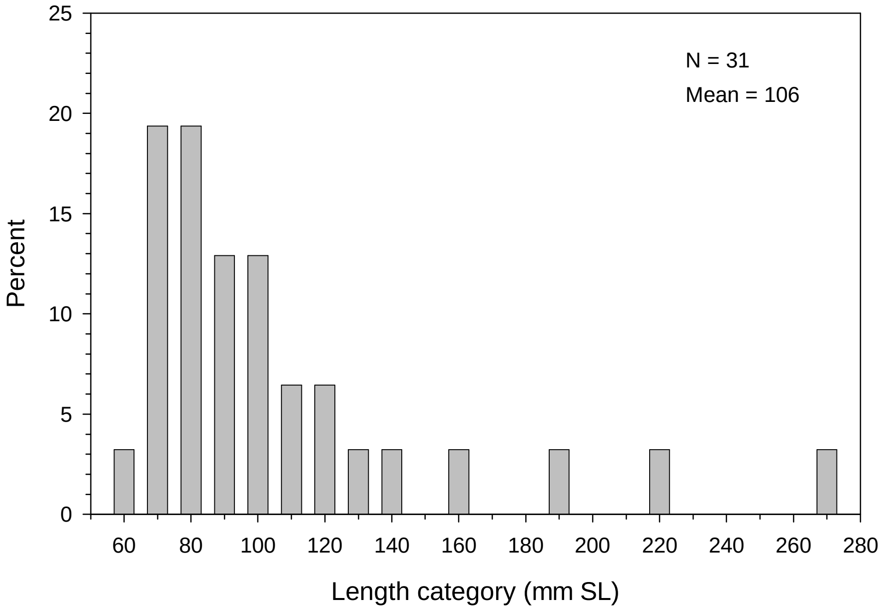


Figure 5.5-33. Length (mm) frequency distribution for barred sand bass collected in impingement samples.

5.5.2.6 Giant kelpfish (*Heterostichus rostratus*)

Giant kelpfish (*Heterostichus rostratus*) ranges from Cape San Lucas, Baja California, Mexico to British Columbia, Canada from the surface to depths of 40 m (131 ft) (Miller and Lea 1972). Allen and Pondella (2006b) included giant kelpfish in their southern nearshore reef and soft bottom species group. Giant kelpfish have been frequently observed in low abundances during impingement sampling throughout southern California since 1990 (MBC unpubl. data).

Jay Carroll

5.5.2.6.1 Life History and Ecology

Quast (1968a) included giant kelpfish in his Zone I classification for their common occurrence in and about the kelp fronds. Within this zone, Quast (1968a) reported giant kelpfish commonly feed on small “microscopic” prey items such as various planktonic organisms (copepods, mysids, and crustacean eggs). Giant kelpfish were only reported for collections made along the mainland, in relatively low abundances, in fish assemblages sampled by gillnet from 1996 to 1998, suggestive of a greater distribution along the mainland than at Santa Catalina Island (Pondella and Allen 2000). Stephens et al. (2006) further noted that giant kelpfish have been recorded throughout much of the nearshore waters of California, typically around the lower depths of the kelp bed near the stipes.

Giant kelpfish lay eggs in closely guarded nests created by the males, often interspersed among red and brown algae (Stepien 1986). The author confirmed previous behavioral observations noting that once the eggs are laid, the female is chased off while the male continues to guard the nest. Giant kelpfish were reported to appear in large numbers in the spring and summer months, consistent with a principal spawning season of January through May.

Stepien (1986) confirmed a previously reported maximum age of 5+ years (Feder et al. 1974). Giant kelpfish grow at a relatively consistent rate throughout their life span, reaching approximately 180 mm TL (7.1 in) by age one (Stepien 1986). Larval individuals reach flexion by nine days after hatch with settlement by 60 days after hatch.

5.5.2.6.2 Population Trends and Fishery

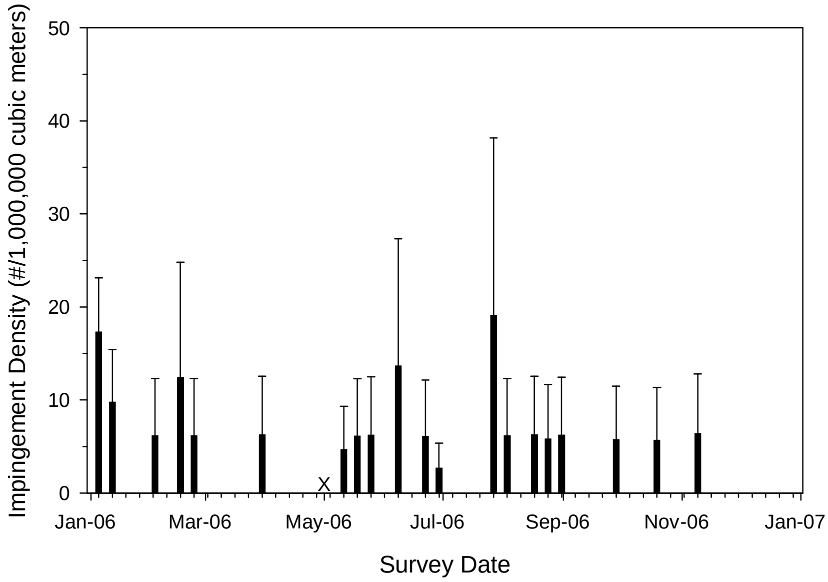
There were no recent landings of giant kelpfish in the PacFIN or RecFIN databases (PacFIN 2007; RecFIN 2007). Anecdotally, giant kelpfish are incidentally taken by recreational anglers while targeting other kelp bed associated species. In 2005, “kelpfish” landings in the Los Angeles area totaled 34.0 kg (75 lbs) at a value of $75 (CDFG 2006). Commercial landings of giant kelpfish reported from catch blocks in the Long Beach area totaled 79.4 kg (175 lbs) in 2006, at an estimated value of $175 (CDFG 2007).

During 1978-79, a total of 69 giant kelpfish was impinged at HGS, equivalent to about two individuals per survey (IRC 1981). It was collected in relatively low numbers year-round, with a strong peak during a February 1979 survey with 26 individuals. From 2003 through 2005, a total of seven giant kelpfish were impinged during 10 normal operation surveys (MBC 2006).

5.5.2.6.3 Sampling Results

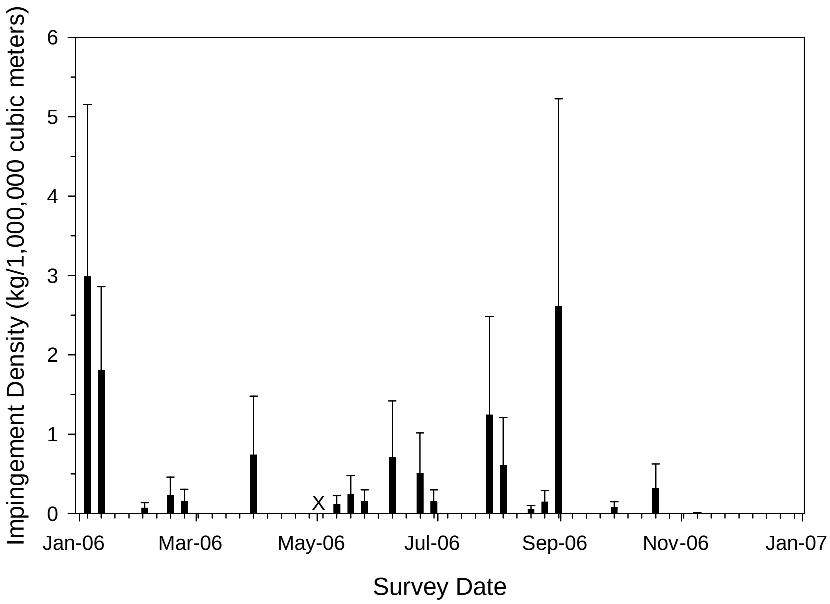
Giant kelpfish was the sixth most abundant species impinged with an estimated 192 individuals calculated using actual cooling water flow volumes, or 2.2% of the annual total, weighing 15.7 kg (34.7 lbs) (Table 5.5-1). The majority of giant kelpfish was impinged sporadically throughout the first three quarters of the year, with a slight seasonal increase during late spring through summer (Figure 5.5-34). Biomass generally followed a pattern consistent with that seen in abundance, except peak biomass rates were seen in early winter and late summer (Figure 5.5-35). This was due to larger individuals impinged during surveys when abundance was relatively low. Overall, generally higher abundances were recorded during nighttime, with the exception of a single survey in February (Figures 5.5-36). Biomass was generally greater during nighttime hours, with the exception of the first two surveys (Figure 5.5-37).

Length frequency analysis of 27 measured individuals was used to calculate a mean standard length of 182 mm (7.2 in) (Figure 5.5-38). Although individuals were collected representing size classes as small as 30 mm SL (1.2 in), the majority of recorded lengths were in the 100–330 mm SL (3.9–13.0 in) size classes. Peak abundance was recorded in the 190 mm SL (7.5 in) size class, representing individuals one-year old. Of the 27 individuals that were evaluated for condition factor, 70% were alive and 30% were dead.



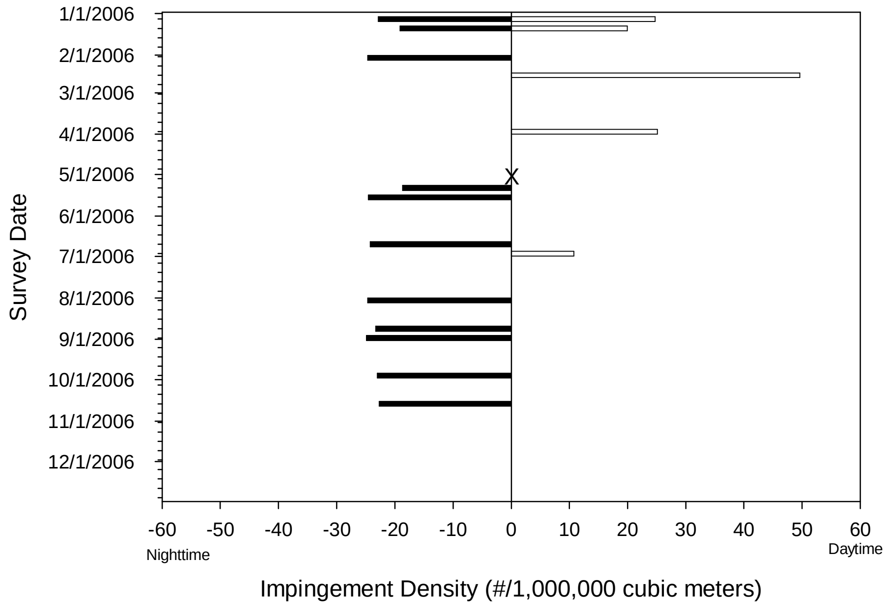
"X" denotes a two-week period of no sample collection.

Figure 5.5-34. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of giant kelpfish collected in HGS impingement samples during 2006.



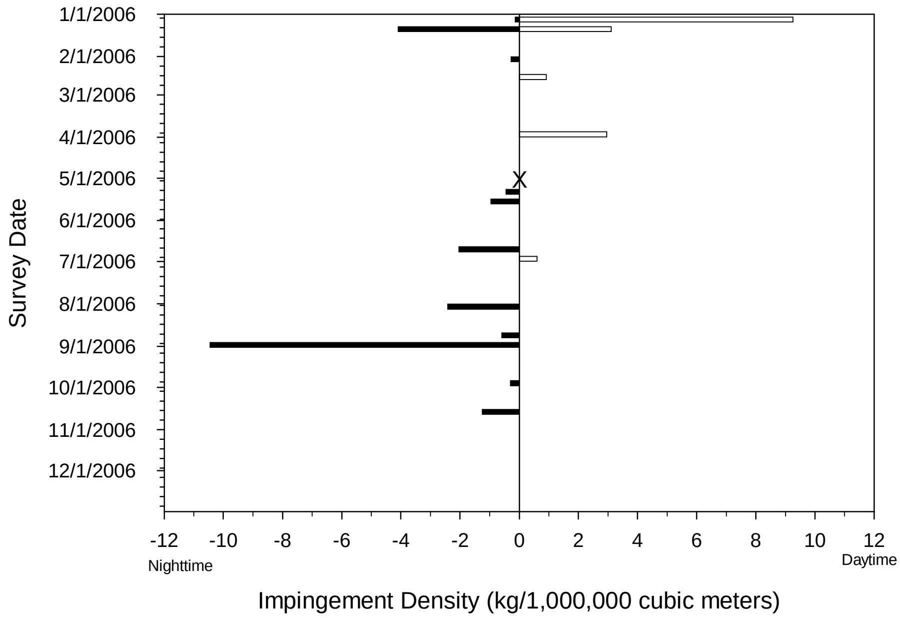
"X" denotes a two-week period of no sample collection.

Figure 5.5-35. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of giant kelpfish collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-36. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of giant kelpfish in impingement samples during night (Cycle 4) and day (Cycle 2) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-37. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of giant kelpfish in impingement samples during night (Cycle 4) and day (Cycle 2) sampling.

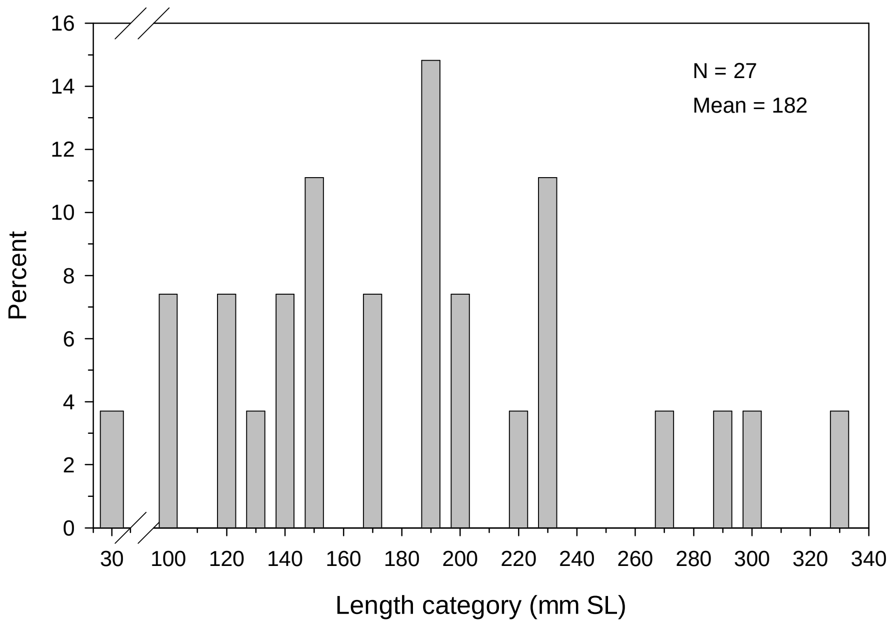


Figure 5.5-38. Length (mm) frequency distribution for giant kelpfish collected in impingement samples.

5.5.2.7 Northern anchovy (*Engraulis mordax*)

Information on the life history, ecology, population trends, and fishery for northern anchovy is summarized in Section 4.5.3.1.

During 1978-79, a total of 48 northern anchovy was impinged at HGS, equivalent to about 0.3% of the estimated annual abundance (IRC 1981). During that study 79% of the individuals were impinged in June and August 1979. From 2003 through 2005, only one northern anchovy was collected at the HGS in 10 impingement samples (MBC 2006).

5.5.2.7.1 Sampling Results

Northern anchovy was the fourteenth most abundant species impinged with an estimated 24 individuals calculated using actual cooling water flow volumes, or 0.3% of the annual total, weighing 0.02 kg (0.04 lbs) (Table 5.5-1). A total of four individuals was collected during the study, all between June 30 and July 21, 2006. The four individuals ranged in length from 32 to 38 mm SL, with an average of 34 mm, the approximate length of transformation (Moser 1996). All four individuals were dead when collected.

5.5.3 Shellfish Impingement Results by Species

Two shellfish taxa were impinged in sufficient numbers, and considered commercially/recreationally important, to warrant further analysis. These taxa were: California spiny lobster (10% of total sampled macroinvertebrate abundance), and California two-spot octopus (2 percent). Combined, these taxa comprised nearly 13% of the macroinvertebrates in impingement samples, and 79% of the biomass.

5.5.3.1 California spiny lobster (*Panulirus interruptus*)

Courtesy of NOAA Central Library Photo Collection

California spiny lobster ranges from Monterey Bay, California, to Manzanillo, Mexico, and there is also a small population along the northwestern shore of the Gulf of California (MBC 1987). They are the only representative of the spiny lobster family (Palinuridae) in southern California.

5.5.3.1.1 Life History and Ecology

During the 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 offshore islands and banks, such as Cortez and Tanner (MBC 1987). Females move inshore to depths less than 10 m (33 ft) to extrude and fertilize the eggs. At San Clemente Island, females carried between 120,000 eggs (66 mm [2.6 in] CL) and 680,000 eggs (91 mm [3.6 in] CL) (Barsky 2001).

Hatching occurs from March to December. Larvae are pelagic and are found from the surface to depths of 137 m (449 ft), and within 530 km (329 miles) of shore (MBC 1987). Upon hatching, transparent larvae (phyllosoma) go through 12 molts, increasing in size in each subsequent molt. Phyllosoma larvae are infrequently collected in the Southern California Bight (Johnson 1956; MBC 1987). After five to ten months, the phyllosoma transforms into the puerulus larval stage that 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 estimated that the puerulus stage of California spiny lobster lasts approximately two to three months (Serfling and Ford 1975).

A 6.1 mm CL (0.2 in) juvenile specimen molts 20 times to reach 45.7 mm CL (1.8 in) 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 CL (1.6 in) molt once yearly. Both sexes reach maturity at approximately 5–6 years at a mean size of 63.5 mm CL (2.5 in) (Barsky 2001). It takes a spiny lobster 7–11 years to reach the legal fishery size of 83 mm CL (3.3 in). 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 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 offshore migration in winter, and an inshore migration in late-spring and early summer (Mitchell et al. 1969, Barsky 2001). By the end of August, berried females and juveniles comprise the bulk of the shallow-water population. Warmer water temperatures shorten the development time of lobster eggs. By late September, the thermocline breaks down and lobsters move to deeper water (10–30 m) where they remain for the winter (MBC 1987).

5.5.3.1.2 Population Trends and Fishery

California spiny lobsters have been fished commercially in southern California since the late 1800s (Barsky 2001). They are fished with traps, most of which are constructed of wire mesh. Most traps are fished in shallow rocky areas in waters shallower than 31 m (100 ft) deep. Commercial landings in the Los Angeles area have fluctuated and ranged between 43,084 kg and 62,585 kg (95,000 lbs and 138,000 lbs) per year since 2000 (Table 5.5-7). 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 Long Beach area catch blocks in 2006 totaled 21,875 kg (48,225 lbs) at an estimated value of $448,844 (CDFG 2007). From 2003 through 2005, no spiny lobsters were collected in 10 impingement samples at the HGS (MBC 2006).

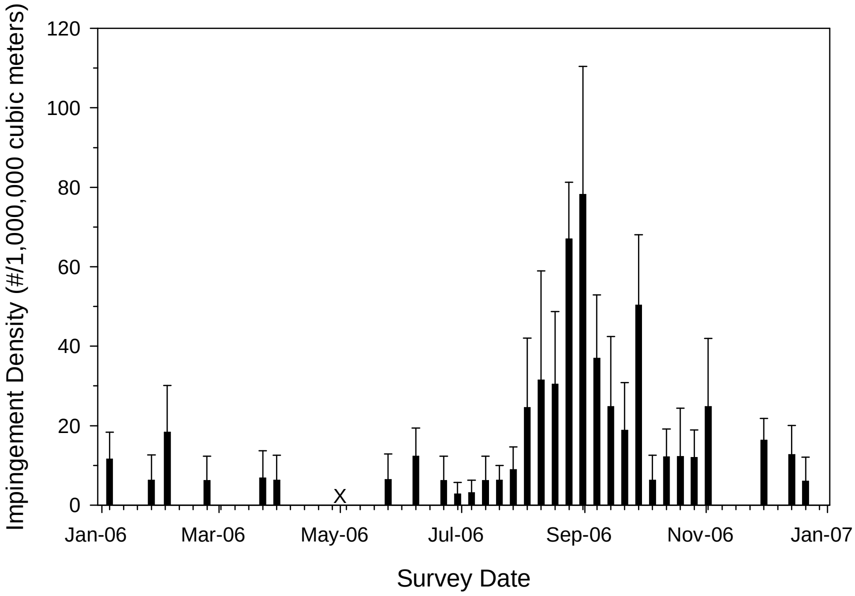
Table 5.5-7. Annual landings and revenue for California spiny lobster in the Los Angeles region based on PacFIN data.

	Landed Weight		
Year	**kilograms**	**pounds**	**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

5.5.3.1.3 Sampling Results

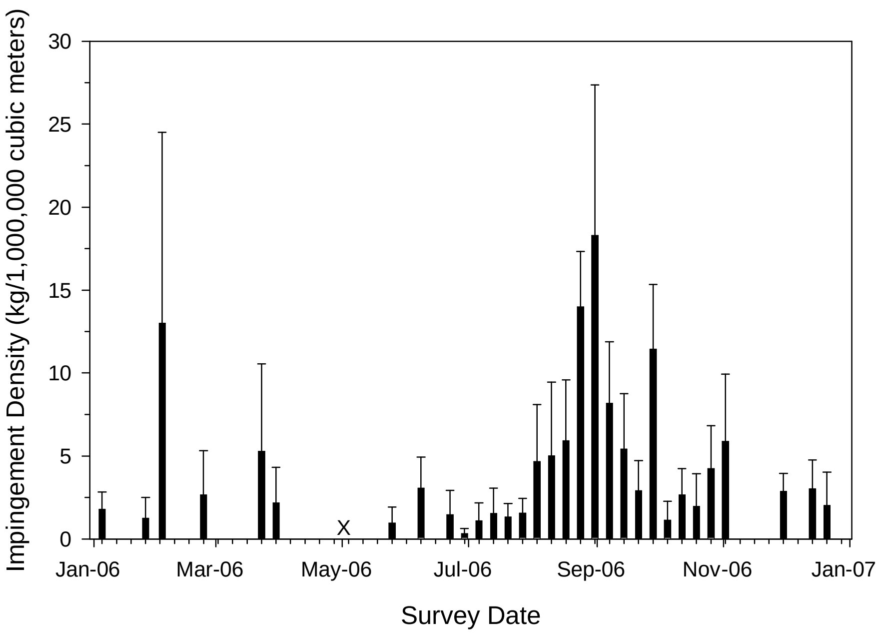
California spiny lobster was the second most abundant shellfish species impinged with an estimated 717 individuals calculated using actual cooling water flow volumes, or 10.6% of the annual total count, weighing 169.4 kg (373.5 lbs) (Table 5.5-3). Impinged sporadically throughout the first six months of 2006, California spiny lobsters were more abundant and consistent in surveys from summer into early fall, with a distinct peak during late summer (Figure 5.5-39). Biomass followed a pattern consistent with that seen in abundance, except the survey on February 3, when the impingement sample was comprised of relatively small numbers of large individuals (Figure 5.5-40). Abundance was relatively equal between daytime and nighttime samples (Figure 5.5-41). A similar pattern was generally observed for biomass, although peak biomass was recorded during a survey in early February due to the larger individuals collected (Figure 5.5-42).

Length frequency analysis of 105 measured individuals was used to calculate a mean carapace length of 62 mm (2.4 in). Individuals predominantly ranged in size from 50 mm to 90 mm (2.0 in to 3.5 in) carapace length (CL), with individuals also representing the 110 and 150 mm CL (4.3 and 5.9 in) size classes (Figure 5.5-43). Nearly 61% of the individuals measured were in the 60 mm CL (2.4 in) size class, and the majority of individuals impinged were smaller than the legal size limit. A total of 105 individuals were sexed, of which 33% were female, 51% were male, and 15% were juvenile. Of the 105 individuals that were evaluated for condition factor, 99% were alive and the remaining 1% was dead.



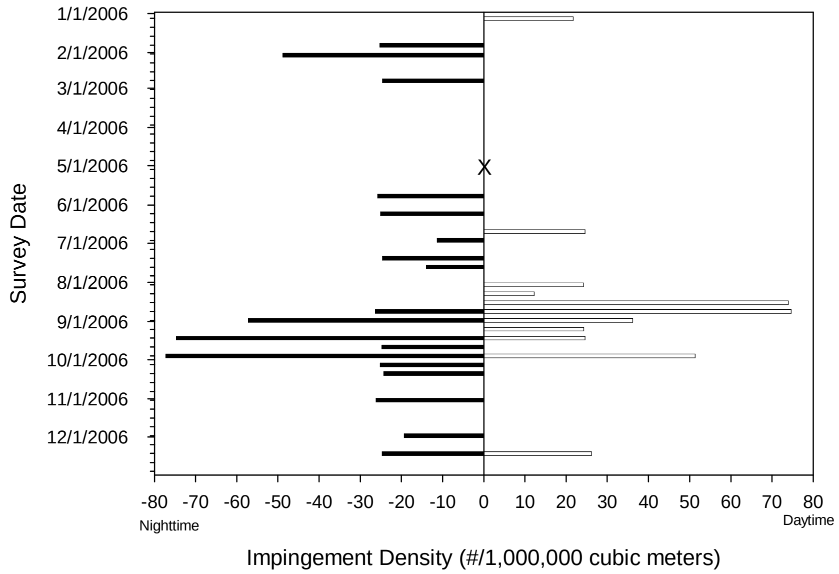
"X" denotes a two-week period of no sample collection.

Figure 5.5-39. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of California spiny lobster collected in HGS impingement samples during 2006.



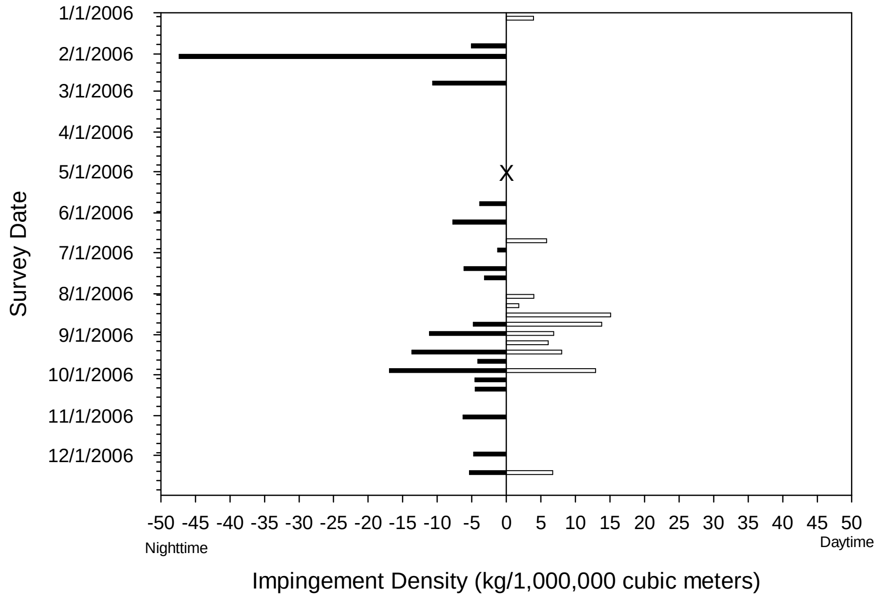
"X" denotes a two-week period of no sample collection.

Figure 5.5-40. Mean biomass (kg / 1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of California spiny lobster collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-41. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of California spiny lobster in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-42. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of California spiny lobster in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

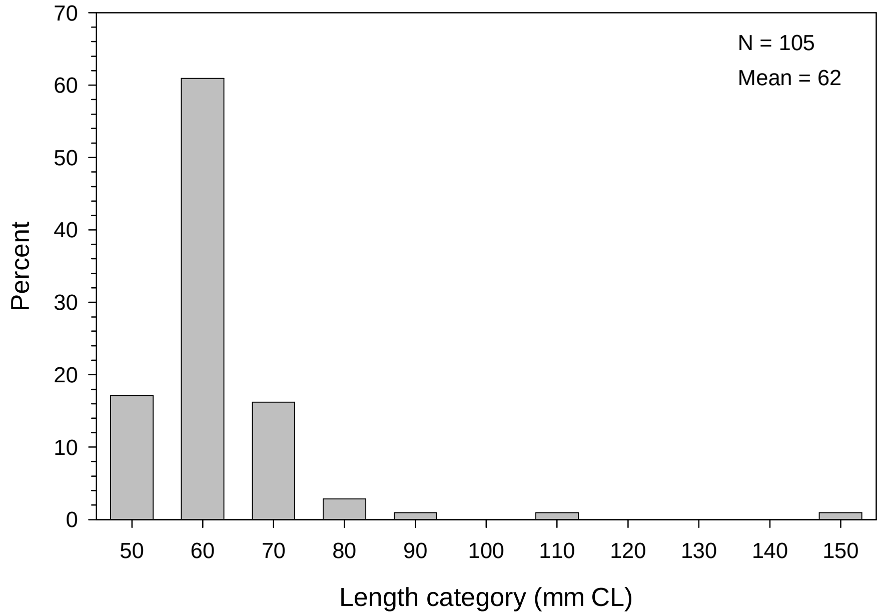


Figure 5.5-43. Length (mm) frequency distribution for California spiny lobster collected in impingement samples.

5.5.3.2 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).

5.5.3.2.1 Life History and Ecology

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

O. bimaculatus spawns throughout most of the year, though there is a distinct seasonal peak from April through July (Lang and Hochberg 1997). Hatching takes place in a relatively short time-frame since there is an inverse relationship between development time and water temperature (Ambrose 1981). Ambrose (1981) also reported an average clutch size of about 20,000 eggs for a female weighing about 260 g (0.57 lbs). After hatching, young octopuses are planktonic for several months, and then settle to the bottom (Lang and Hochberg 1997). Juvenile *O. bimaculatus* feed on small crustaceans, while adults consume a wide variety of motile benthic invertebrates.

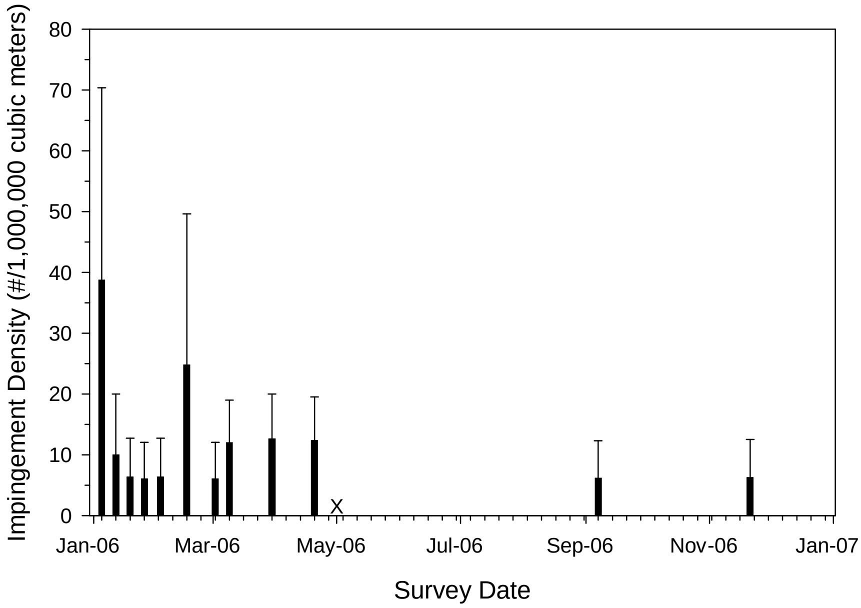
5.5.3.2.2 Population Trends and Fishery

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 Long Beach area catch blocks in 2006 totaled 17.7 kg (39 lbs) at an estimated value of $105. From 2003 through 2005, a total of six two-spot octopus was impinged at the HGS, and annual impingement ranged from 0 to 0.8 individuals per survey, averaging about 0.5 individuals per survey (MBC 2006).

5.5.3.2.3 Sampling Results

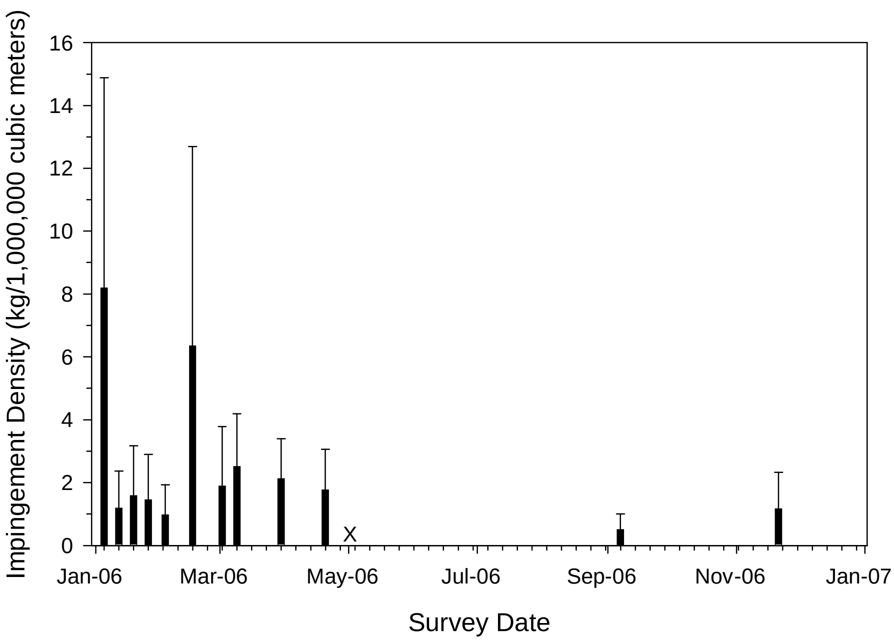
California two-spot octopus was the fourth most abundant shellfish species impinged with an estimated 184 individuals calculated using actual cooling water flow volumes, or 2.7% of the annual total, weighing 36.3 kg (79.9 lbs) (Table 5.5-3). Peak abundance and biomass were recorded from winter through spring, with occurrences during only two surveys after April (Figures 5.5-44 and 5.5-45). Overall, California two-spot octopus was impinged more frequently during daytime surveys, but the highest abundance and biomass were recorded during the first nighttime survey (Figures 5.5-46 and 5.5-47).

Length frequency analysis of 22 measured individuals was used to calculate a mean of 384 mm (15.1 in) arm spread (AS) (Figure 5.5-48). Although measurements varied widely from 190–630 mm AS (7.5–24.8 in), the predominance of individuals had maximum arm spans between 290–440 mm (11.4–17.3 in). A total of 22 individuals were sexed, of which 32% were female, 27% were male, and 41% could not be determined. Of the 22 individuals that were evaluated for condition factor, 86% were alive, 5% were dead, and 9% were mutilated.



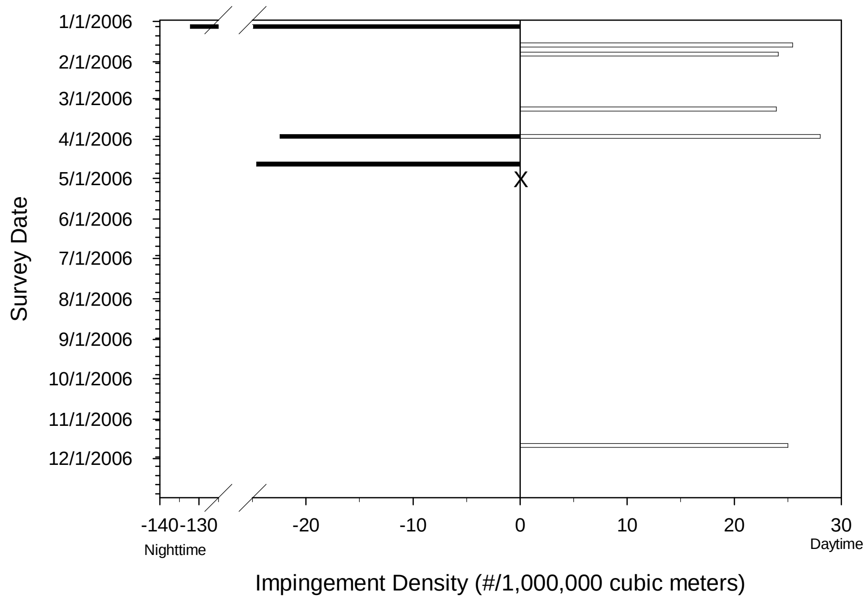
"X" denotes a two-week period of no sample collection.

Figure 5.5-44. Mean concentration (#/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of California two-spot octopus collected in HGS impingement samples during 2006.



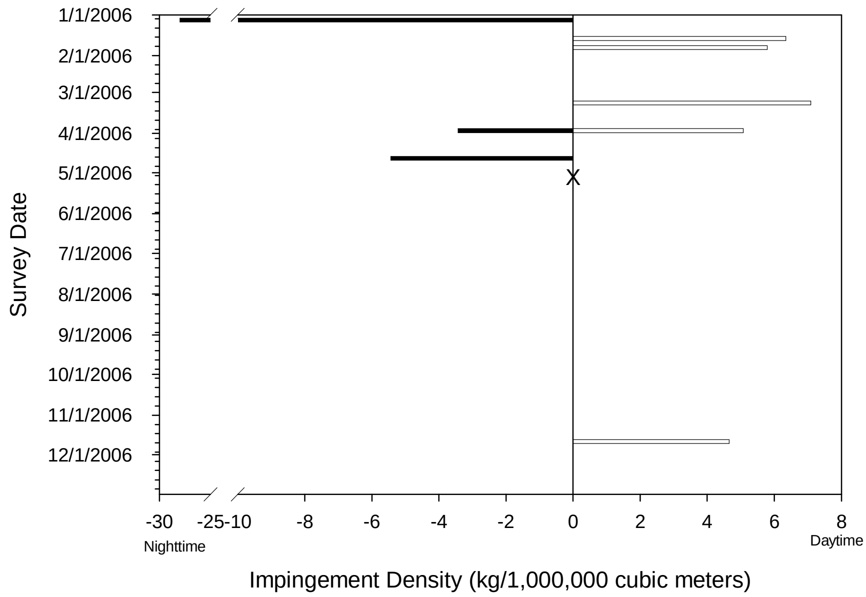
"X" denotes a two-week period of no sample collection.

Figure 5.5-45. Mean biomass (kg/1,000,000 m^3 [264.2 million gal] – wide bars) and standard error (narrow bars) of California two-spot octopus collected in HGS impingement samples during 2006.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-46. Mean concentration (#/1,000,000 m^3 [264.2 million gal]) of California two-spot octopus in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



"X" denotes a two-week period of no sample collection.
Note: Negative nighttime values are a plotting artifact.

Figure 5.5-47. Mean biomass (kg/1,000,000 m^3 [264.2 million gal]) of California two-spot octopus in impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

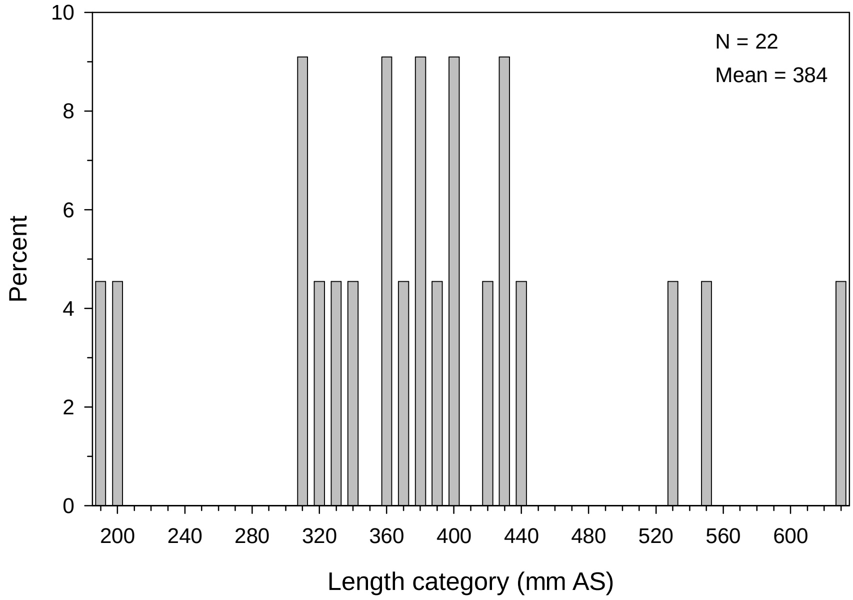


Figure 5.5-48. Arm spread (mm AS) length frequency distribution for California two-spot octopus collected in impingement samples.

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).

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 HGS, 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, and
2. Assigning a relative level of impact for each taxon analyzed.

Under the 1978–1979 316(b) evaluation, impact analyses were conducted using several techniques. Entrainment losses were compared to source water populations, and estimates of ichthyoplankton entrainment were evaluated using an equivalent adult model. Impingement losses were compared with source populations calculated from demersal fish surveys, and also compared to recreational and commercial fishing landings. Lastly, impingement mortality was compared with instantaneous mortality rates for three fish species. In summary, there were no significant effects from the HGS on the standing crop and natural mortality rates of the taxa analyzed. The ultimate conclusion of the HGS 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 HGS, and the configuration of the intakes represented BTA for minimizing AEI.

Since the suspended Phase II regulations were based on performance standards for reducing entrainment and impingement and did not explicitly rely on determining whether existing levels represented an AEI, EPA determined the "…*performance standards reflect the best technology available for minimizing adverse environmental impacts determined on a national categorical basis.*" Although AEI was not intended to be used in assessing compliance under the new regulations, the potential for AEI was still considered in determining the types of plants and water body where the new performance standards would apply. Plants with low capacity factors and low cooling water volumes were considered to be BTA since their cooling systems had a low potential for AEI.

In its 1977 draft guidance document, EPA 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 at the HGS unit's screens for impingement sampling and in the vicinity of the intakes within Slip 5 in ILAH for entrainment sampling. The purpose of this impact assessment is to put the measured losses into context, and to evaluate the potential for AEI due to the CWIS.

6.1.1 CWIS impacts

There are three general types of effects associated with cooling water intake structures: (1) thermal effects, (2) impingement effects, and (3) entrainment effects. Thermal effects are regulated under Section 316(a) of the Clean Water Act and the *Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays of California (California Thermal Plan)*. The recent NPDES permit for the HGS 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 HGS. Organisms large enough to become trapped on the traveling screens are impinged.

In discussing the potential effects of the HGS CWIS on fish and shellfish populations the first thing that needs to be considered is the life history of the species in the communities. First of all, several fish species in the nearshore coastal areas around HGS 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 HGS 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 comprised almost half of the total estimated fish larvae 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 less 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 suspended 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 HGS. 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 suspended Rule's entrainment performance standard focused on addressing impacts to fish and shellfish rather than lower trophic 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 were 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 included 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 trophic level organisms are not soft bodied as is the case for finfish and are better able to tolerate passage through the cooling system.

The impingement and entrainment sampling was therefore focused on fishes and shellfishes as required in the suspended 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 suspended 316(b) Phase II regulations provided latitude for focusing on the set of species that could be accurately quantified and that provided the necessary detail to support development of other aspects of the CDS, and therefore, allowed for negotiating an acceptable compromise between the regulating agency and the discharger. The target group of organisms that were included in the entrainment sample processing was finalized at a January 12, 2006 meeting with staff from the LARWQCB and other resource agencies.

The specific taxa (species or group of species) that were included in the assessment were limited to the taxa that were sufficiently abundant to provide reasonable assessments of impacts. For the purposes of this study plan, the taxa analyzed in the assessment were limited to the most abundant taxa that together comprised 90–95% of all larvae entrained and/or juveniles and adults impinged by the generating station. The most abundant taxa were used in the assessment because they provided the most robust and reliable estimates for the purpose of assessing impacts. Since the most abundant organisms may not necessarily have been the organisms that experienced the greatest effects on the population level, the data were also examined to determine if additional taxa should have been 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 HGS 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 was unavailable for most species so combined assessments were only possible for CIQ gobies, combtooth blennies, and northern anchovy. No *EAM* (equivalent adult modeling) was done on impingement estimates due to the low numbers of fishes collected and the lack of necessary life history parameters for most species.

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 HGS, the permit applicant is obligated to provide the LARWQCB with the "best information reasonably available" to assist it in fulfilling its decision-making responsibility. To make Section 316(b) decisions, permit writers have relied on precedent from other cases and on EPA's (1977) draft "Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500."

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

1. Whether or not an AEI is caused by the 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.

6.1.3.1 Adverse Environmental Impact (AEI) Standard

Since there were no regulations defining AEI, permit decisions must be based on the EPA's AEI interpretations provided in guidance documents issued since the 1970's. In those documents, the EPA has indicated that assessment of AEI should be based on an evaluation of population level effects, not just losses of individual organisms. In its 1977 Draft BTA Guidelines, the EPA 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) draft guidelines, the EPA 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 EPA (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 (EPA 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 EPA (1977), additional criteria can be evaluated that are specific to the marine environment around HGS 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, the extent of the impact that the loss of these animals has on the local environment and the population as a whole could be better assessed.

6.1.4 Relating measured impacts to source populations

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

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

The criteria used to evaluate the potential for AEI need to be placed into a larger context using the characteristics of the source water and the biological community. This assessment focuses on a set of 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 depends on many factors, as listed above, 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 area around the HGS intake in the Los Angeles–Long Beach Harbor Complex (Harbor Complex). Species at least risk are those such as northern anchovies that are widely distributed in offshore habitats and produce larvae that are primarily distributed in offshore waters.

The focus of the assessment will be on species with adult populations in the nearshore areas of the Harbor Complex that are directly affected by entrainment and impingement at the HGS CWIS. Therefore the following criteria from the list in the previous section can be used to focus the assessment on species with adult and larval distributions that would place them at greatest risk to entrainment and impingement effects:

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

These criteria relate directly to the habitats associated with the fish and shellfish potentially affected by entrainment and impingement. This approach to classification has been taken in recent studies of marine fishes of California (Horn and Allen 1978; Allen 1985; Allen and Pondella 2006b) and will be used to organize the taxa included in this assessment. We have simplified the more detailed categorization of habitats used by Allen and Pondella (2006b) which included several habitats used to define deeper offshore areas (Figure 6.1-1). These deeper offshore habitat types can be combined for the purposes of our assessment since the taxa associated with those habitats are generally not at risk due to entrainment and impingement and were collected in very low numbers. The habitats defined by Allen and Pondella (2006b) have been simplified for this assessment to the following habitat types:

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

The taxa included in this assessment were categorized into these habitat types (Table 6.1-1). Taxa that occur in more than one habitat were included in the habitat group that best reflected the primary distribution for the taxa and if a primary habitat could not be identified, the one where they are at greatest risk to the effects of entrainment and impingement. For example, silversides occur in both bay and harbor, and coastal pelagic habitats but since their occurrence in bay and harbor habitats places them at greater risk to power plant effects they 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 at less risk from power plant impacts especially if at least one of the habitats is not directly affected by entrainment and impingement. For example, white croakers occur in bays and harbors where they are directly at risk to impingement and entrainment at HGS but also in sandy shallow nearshore areas where they are not at risk.

This approach to assessing AEI is consistent with a recent trend in fisheries management 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.

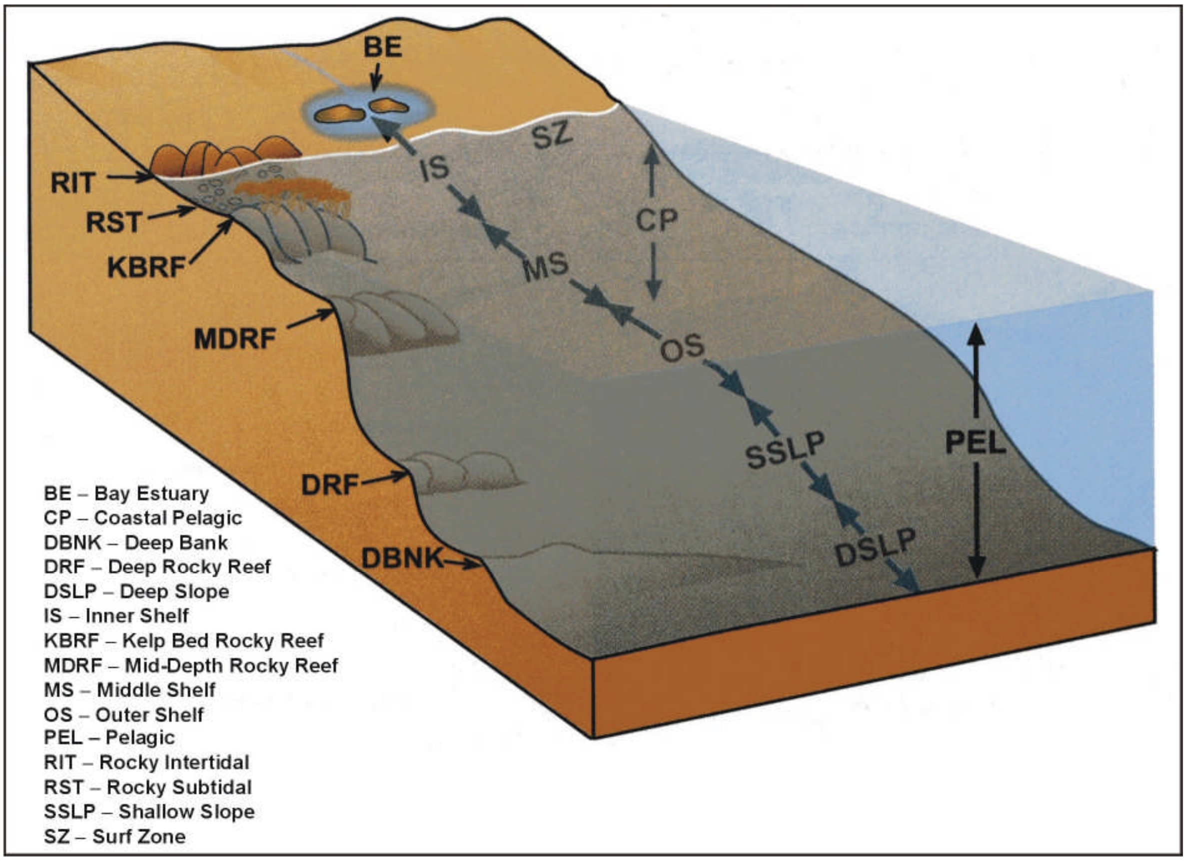


Figure 6.1-1. Marine habitat types in California (from Allen and Pondella [2006b]).

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

		Fishery	Habitats			
Scientific name	**Common name**	**S-Sport, C-Comm.**	**bays, harbors**	**reefs, kelp beds**	**coastal pelagic**	**shelf**
Fishes						
Acanthogobius flavimanus	yellowfin goby		**X**			
Cymatogaster aggregata	shiner perch	S	**X**	x		
Embiotoca jacksoni	black perch	S, C	x	**X**		
Engraulidae unid.	anchovies	C			**X**	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Gobiidae unid.	CIQ goby complex		**X**			
Heterostichus rostratus	giant kelpfish			**X**		
Hypsoblennius spp.	combtooth blennies		**X**	x		
Lepidogobius lepidus	bay goby		**X**			
Paralabrax nebulifer	barred sand bass	S	x	**X**		
Porichthys myriaster	specklefin midshipman		**X**	x		x
Sciaenidae unid.	croakers	S, C			**X**	x
Urobatis halleri	round stingray		**X**			
Shellfishes						
Octopus spp.	two-spot octopus	C	x	**X**		
Panulirus interruptus	California spiny lobster	S		**X**		

6.2 SUMMARY OF ENTRAINMENT AND IMPINGEMENT RESULTS

The following section summarizes the combined results of the entrainment and impingement studies at HGS to provide an overview of annual impacts to marine life that are directly attributable to operations at the generating station. Earlier sections of the report provide greater detail and explanation of the results on individual species, and the information in this section provides an overview of the major results. In addition, for those species such as northern anchovy that were affected by both entrainment of eggs and larvae and impingement of juveniles and adults, the data are summarized together for all life stages. In later sections, the information on calculated losses is compared to long-term population trends and then discussed in terms of adverse environmental impacts.

6.2.1 Taxa Composition

Data from the bi-weekly entrainment surveys conducted at the HGS cooling water intakes were used to calculate that an estimated 65.3 million fish larvae and 99.9 million 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 135% to 153.3 million, and egg entrainment would have increased by 170% to 269.4 million. Approximately 51% of the larvae were CIQ gobies, 24% were yellowfin gobies, 11% were white croakers, 4% were bay gobies, 3% were combtooth blennies and forty-three other species combined contributed nearly 8% of the annual total. Larvae from 48 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. The most abundant taxonomic group of fish eggs in the samples were unidentified eggs (49%), followed by white croaker eggs (18%), and unidentified croaker eggs (15%). Eggs of approximately 10 fish taxa were represented in the collections. A complete listing of all of the taxonomic categories identified during the study is presented in Appendix E.

There were an estimated 18.9 million target shellfish larvae entrained represented by 16 taxa (Table 6.2-1). Kelp crab megalops comprised 64% of the annual entrainment of target shellfish larvae and spider crab megalops comprised about 19% of the total. Species with commercial fishery value included market squid with approximately 26,676 paralarvae (hatchlings) entrained under actual flow (62,179 for design flows) while cancer crabs had 15,625 megalops entrained under actual flows (35,225 for design flows).

Data from the weekly normal operations sampling were used to estimate that annual fish impingement at the HGS from a total of 25 taxa groups was 8,851 individuals weighing 1,317 kg (2,903 lbs) based on actual cooling water flow, and 19,861 individuals weighing 2,938 kg (6,479 lbs) based on design cooling water flow (Table 6.2-2). The most abundant species impinged by number and biomass were round stingray and black perch.

Annual macroinvertebrate impingement estimates at the HGS were 6,753 individuals weighing 260 kg (573 lbs) based on actual cooling water flow, and 13,538 individuals weighing 575 kg (1,269 lbs) based on design cooling water flow (Table 6.2-3). The most abundant species impinged by numbers included the nudibranch hermissenda, sea spiders, tuberculate pear crab, California spiny lobster, and intertidal coastal shrimp. The remaining 43 species each comprised less than 3% individually to the total. The species contributing most to impingement biomass California spiny lobster, California two-spot octopus, and the California sea slug.

Table 6.2-1. Rank and estimated annual entrainment of common fish larvae, fish eggs and target shellfish larvae at HGS in 2006.

Rank	Taxon	Est. Annual Entrainment (actual flows)	Est. Annual Entrainment (design flows)	% Comp. (actual flows)	Cumulative % Comp. (actual flows)
	Fish Larvae				
1	gobies	33,290,815	75,938,007	50.98	50.98
2	yellowfin goby	15,407,999	37,604,336	23.60	74.58
3	white croaker	7,164,843	18,777,752	10.97	85.55
4	bay goby	2,376,260	5,070,071	3.64	89.19
5	combtooth blennies	2,255,907	4,362,576	3.45	92.65
6	croakers	995,438	2,856,932	1.52	94.17
	42 Other taxa	3,806,737	8,721,337	5.83	100.00
		65,297,999	**153,331,011**		
	Fish Eggs				
1	unidentified fish eggs	49,261,253	130,894,994	49.32	49.32
2	white croaker eggs	17,867,461	43,114,182	17.89	67.21
3	croaker eggs	14,562,519	41,351,239	14.58	81.79
4	sand flounder eggs	8,780,223	30,684,631	8.79	90.58
	6 Other taxa	9,413,438	23,379,179	9.42	100.00
		99,884,894	**269,424,225**		
	Target Shellfishes				
1	kelp crabs megalops	12,009,598	26,357,647	63.54	63.54
2	spider crab megalops	3,520,320	7,285,587	18.62	82.16
3	pea crabs megalops	1,810,300	4,467,908	9.58	91.74
	13 Other taxa	1,561,119	3,233,933	8.26	100.00
		18,901,337	**41,345,075**		

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

Rank	Common Name	Total No. Actual Flows	Total No. Design Flows	% Total Actual Flows	Cumulative % Total Actual Flows
1	round stingray	6,150	13,771	69.48	69.48
2	black perch	646	1,371	7.30	76.78
3	specklefin midshipman	484	1,379	5.47	82.25
4	shiner perch	390	719	4.41	86.66
5	barred sand bass	209	442	2.36	89.02
6	giant kelpfish	192	424	2.17	91.19
7	yellowfin goby	163	399	1.84	93.03
8	spotted kelpfish	158	354	1.79	94.81
9	white seaperch	115	221	1.30	96.11
10	plainfin midshipman	62	175	0.70	96.81
	15 Other taxa	282	606	3.19	100.00
		8,851	**19,861**		

Rank	Common Name	Total Wt. (kg) Actual Flows	Total Wt. (kg) Design Flows	% Total Actual Flows	Cumulative % Total Actual Flows
1	round stingray	1,232	2,756	93.55	93.55
2	black perch	18	41	1.40	94.95
3	giant kelpfish	16	33	1.19	96.15
4	specklefin midshipman	12	27	0.91	97.06
5	barred sand bass	8	16	0.57	97.63
6	California halibut	7	16	0.57	98.19
7	pile perch	6	13	0.48	98.68
8	white seaperch	4	8	0.31	98.99
9	hornyhead turbot	4	9	0.30	99.29
10	shiner perch	3	7	0.26	99.55
	15 Other taxa	6	14	0.45	100.00
		1,317	**2,938**		

Table 6.2-3. Rank and estimated annual impingement of top ten most common invertebrate taxa at HGS in 2006 by estimated abundance and weight for actual and design flows.

Rank	Common Name	Total No. Actual Flows	Total No. Design Flows	% Total Actual Flows	Cumulative % Total Actual Flows
1	hermissenda	1,840	3,625	27.24	27.24
2	sea spider, unid.	1,258	2,139	18.62	45.86
3	tuberculate pear crab	801	1,535	11.86	57.71
4	California spiny lobster	717	1,544	10.61	68.32
5	intertidal coastal shrimp	711	1,600	10.52	78.85
6	Calif. two-spot octopus	184	428	2.72	81.57
7	Calif. coastal shrimp	138	315	2.04	83.61
8	ring-spotted dorid	128	267	1.89	85.51
9	spotted triopha	116	234	1.72	87.23
10	orange-spike polycera	111	233	1.64	88.87
	38 Other Taxa	752	1,618	11.13	100.00
		6,756	**13,538**		
		Total Wt. (kg) Actual Flows	**Total Wt. (kg) Design Flows**	**% Total Actual Flows**	**Cumulative % Total Actual Flows**
1	California spiny lobster	169	370	65.00	65.00
2	Calif. two-spot octopus	36	86	13.85	78.85
3	California sea slug	13	32	5.00	83.85
4	Pacific rock crab	10	19	3.85	87.69
5	sea star, unid.	9	23	3.46	91.15
6	warty sea cucumber	7	15	2.69	93.85
7	California seahare	6	11	2.31	96.15
8	seahare, unid.	2	3	0.77	96.92
9	California sea cucumber	2	3	0.77	97.69
10	tuberculate pear crab	1	2	0.38	98.08
	38 Other taxa	5	10	1.92	100.00
		260	**574**		

6.2.1.1 Temporal Occurrence

The greatest concentrations of larval fishes occurred during March 2006 and the fewest occurred in September (Figure 4.5-1). Fish eggs had a peak in abundance in late February prior to the peak abundance of fish larvae (Figure 4.5-2). They also had increased abundances in early June that did not appear to be reflected in larval concentrations. Larvae tended to be more abundant in samples collected at night than those collected during the day, although daytime collections occasionally yielded higher concentrations (Figure 4.5-3).

Impingement abundance was highest from August to November (Figure 5.5-1), which corresponded with an increase in round stingray impingement. Biomass was greatest during the same period as the peak abundance (Figure 5.5-2). Invertebrate abundance was greatest from June through August, with highest abundance recorded from late-June through early-August (Figure 5.5-3). Invertebrate biomass was much more variable throughout the year, with peaks from January through March (Figure 5.5-4), corresponding to the impingement of large individuals of select species. Biomass increased again from June through August, but in a steadier ascent than during the winter months. In general, fish impingement abundance and biomass was greatest during nighttime (Figures 5.5-5 and 5.5-6).

6.2.2 Combined Analysis and Modeling Results for Selected Species

Several species of fishes and shellfishes that were abundant in either the entrainment or impingement samples, had recreational or commercial fishery value, or were federally managed species were analyzed in detail in Sections 4 and 5. Some of the larval taxa had sufficient information available on their life history to estimate losses based on conversion to adult equivalents. The results of these analyses are summarized using actual flow rates for the CWIS at HGS in 2006 (Table 6.2-4) and design flow rates for the CWIS (Table 6.2-5).

Table 6.2-4. Summary of HGS entrainment and impingement sampling results and model output for common fish and shellfish 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)
Fishes								
Gobiidae unid.	gobies	33.29	0	2.65	86,720[L]	36,231[L]	0	
Acanthogobius flavimanus	yellowfin goby	15.41	0	0.65	1,936[L]		163	3.15
Genyonemus lineatus[1]	white croaker	7.16	17.87	0.19	20[E]		25	0.20
Lepidogobius lepidus	bay goby	2.38	0	0.24			0	
Hypsoblennius spp.	combtooth blennies	2.26	0	0.06	2,826[L]	6,024[L]	0	
Engraulis mordax	northern anchovy	0.94	0.8	0.71	11,506[C]	25,863[L]	24	0.02
Urobatis halleri	round stingray	–	–				6,150	1,231.68
Embiotoca jacksoni	black perch	–	–				646	18.49
Porichthys myriaster	specklefin midshipman	–	–				484	11.96
Cymatogaster aggregata	shiner perch	–	–				390	3.36
Paralabrax spp.[2]	sand bass	0.12	–				209	7.51
Heterostichus rostratus	giant kelpfish	0	–				192	15.73
Shellfishes								
Panulirus interruptus	spiny lobster	0.22	–				717	169.37
Octopus spp.	two-spot octopus	–	–				184	36.25

[1] larval entrainment estimate includes white croaker and unidentified croakers combined
[2] only barred sand bass collected in abundance in impingement sampling

Table 6.2-5. Summary of HGS entrainment and impingement sampling results and model output for common fish and shellfish 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)
Fishes								
Gobiidae unid.	gobies	75.94	0	5.70	197,812[L]	82,665[L]	0	
Acanthogobius flavimanus	yellowfin goby	37.60	0	1.54	4,724[L]		399	7.48
Genyonemus lineatus[1]	white croaker	18.78	43.11	0.42	48[E]		48	0.43
Lepidogobius lepidus	bay goby	5.07	0	0.50			0	
Hypsoblennius spp.	combtooth blennies	4.36	0	0.12	5,466[L]	11,650[L]	0	
Engraulis mordax	northern anchovy	2.07	1.93	1.53	25,306[C]	56,879[L]	36	0.03
Urobatis halleri	round stingray	–	–				13,771	2,756.09
Embiotoca jacksoni	black perch	–	–				1,371	41.03
Porichthys myriaster	specklefin midshipman	–	–				1,379	26.84
Cymatogaster aggregata	shiner perch	–	–				719	6.77
Paralabrax spp.[2]	sand bass	0.27	–				442	16.20
Heterostichus rostratus	giant kelpfish	0	–				424	32.60
Shellfishes								
Panulirus interruptus	spiny lobster	0.36	–				1,544	369.56
Octopus spp.	two-spot octopus	–	–				428	85.96

[1] *larval entrainment estimate includes white croaker and unidentified croakers combined*
[2] *only barred sand bass collected in abundance in impingement sampling*

6.3 ASSESSMENT OF TAXA BY HABITAT TYPE

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

6.3.1 Background on Oceanographic Setting and Population Trends

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

The strength of the PDO varies annually and the most important phenomenon with respect to this variation is the El Niño Southern Oscillation (ENSO). This oscillation consists of two components, El Niño and La Niña periods. El Niño causes the California Current to weaken and move offshore as warm subtropical water moves into the bight. The rebound from this event is the shift to La Niña, which in effect is manifested as a strengthening of the California Current and generally cooler water in the bight. Either phase of an ENSO generally lasts 1–2 years, depending upon their strength, and are particularly important for understanding fish dynamics in the SCB for a variety of reasons. First, in the El Niño phase, the bight is warmed and mobile warm-water fishes and invertebrates immigrate or recruit into the region (Lea and Rosenblatt 2000; Pondella and Allen 2001). Cold water 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 mobile organisms may exhibit offshore versus onshore movements. However, the resident fauna tends not to be altered on such short time frames when compared to the magnitude of the PDO.

In the decade prior to this study there were three major events that affected the California Current System that need to be explained in order to understand the oceanographic setting of this study period. The first was the 1997–98 El Niño, the strongest recorded event of its kind (Figure 6.3-1). This was followed by a series of four cold water years (1999–2002) including the strongest La Niña on record (Schwing et al. 2000, Goericke et al. 2005). The possible return to the cold water phase of the PDO did not occur since 2003–2004 was described as a 'normal' year (Goericke et al. 2005). This normal year turned out to be the beginning of an extended warm phase that has persisted through 2006 (Peterson et al. 2006). 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.

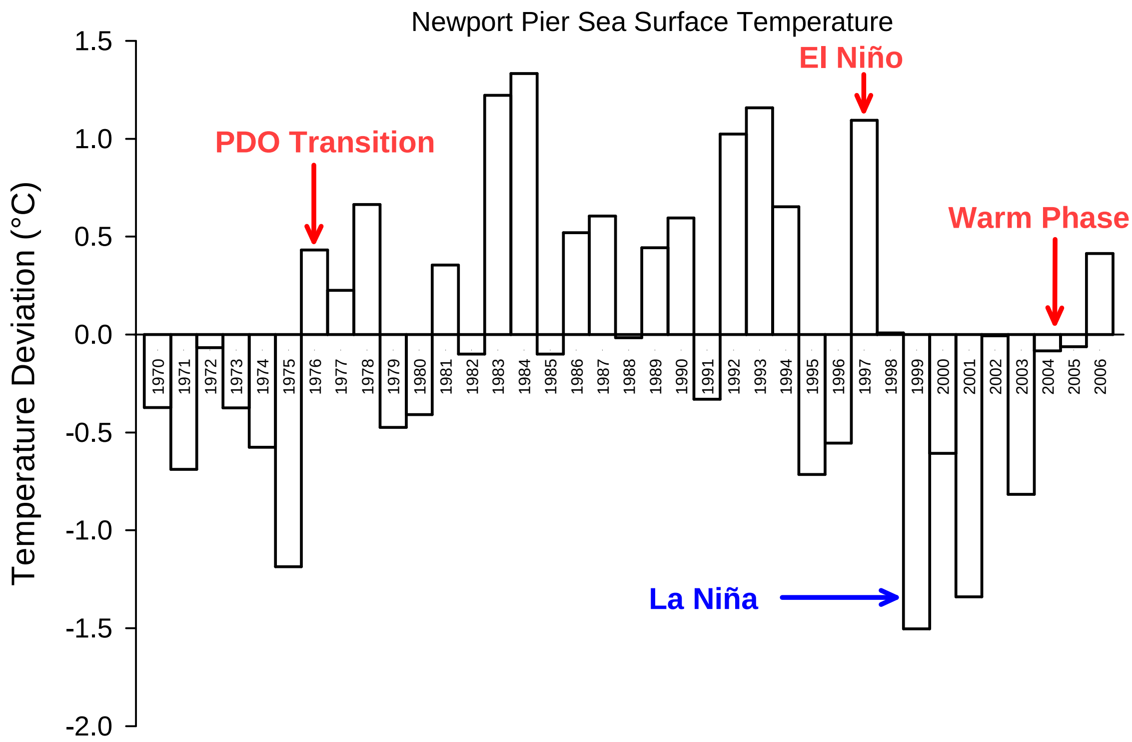


Figure 6.3-1. Sea surface temperature anomalies for Newport Pier, California. Values are ± the long-term average (1925–2006).

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 by species. Some fishes were reserved for recreational anglers (e.g. kelp bass, barred sand bass, etc.) as they were historically over-fished by commercial fishers (Young 1963); others were primarily commercial species (e.g. anchovies); while others are extracted by both fisheries (e.g. California halibut). Fishery data may or may not reflect actual population trends due to socioeconomic considerations such as market value, effort, management actions, etc. Fishery independent monitoring programs produce the best population time series metrics and also allow non-commercial species to be evaluated.

6.3.1.1 Habitat Associations and Fisheries

Entrained larvae were categorized in terms of the habitat types typically utilized by juveniles and adults, and the type of fishery, if any, that the species supports. Most larval taxa were from species typically found associated with the types of habitats in close proximity to the intake: bay, rocky reef, and shelf sand bottom. Species primarily associated with the bays and harbors habitat (e.g., gobies, blennies) had the highest number of taxa entrained and impinged (48.89% and 72.00% respectively; Table 6.3-1). Over 95% of the total number of larval fish entrained and impingement biomass was associated with the bays and harbors habitat. Sport fishery species accounted for approximately 13.8% of the total number of larvae entrained and commercial fishery species accounted for 14.8%, while species with no direct fishery value comprised the majority (84.7%) of the larvae entrained. (Note that some species such as white croaker were classified as both a sport and commercial fishery species). Approximately 96% of the impinged biomass was from fishes and rays that have no direct fishery value.

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

Attributes	Entrained % of taxa	Entrained % of abundance	Impinged % of taxa	Impinged % of biomass
Habitat Association				
Continental shelf / slope	35.56	13.95	32.00	1.79
Bays, Harbors	48.89	95.65	72.00	98.20
Rocky reef, Kelp	46.67	3.22	44.00	4.34
Coastal pelagic	20.00	17.86	16.00	0.04
Deep pelagic	4.44	0.02	0.00	0.00
Fishery				
Sport	40.00	13.84	48.00	3.94
Commercial	26.67	14.76	12.00	2.32
None	51.11	84.65	48.00	96.06

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

The percentages of taxa associated with different habitats are very similar for both entrainment and impingement with the largest percentage of the taxa being associated with the bay and harbor habitat where the intake is located (Table 6.3-1). The percentages for bay and harbor taxa increase for abundance and biomass since these taxa were entrained and impinged in much higher numbers than taxa from other habitats. As the percentages show, many of these are not targeted by sport or commercial fishing.

Although fishes and shellfishes from other habitats occur in bay and harbors, the taxa with the greatest potential for CWIS impacts will be the taxa that only occur in that habitat such as three taxa of gobies and round stingray (Table 6.1-1).

6.3.2 Bay and Harbor Habitats

This habitat type includes bays, harbors and estuaries that are either entirely marine and largely influenced by tidal movement of seawater, or estuarine areas where seasonal freshwater input lowers salinities in some areas of the habitat. Much of the nearshore habitat in the vicinity of HGS is of the bay and harbor type. Although no undisturbed wetland areas still exist within the highly developed Harbor Complex, shallow water habitats have been created near Cabrillo Beach and Piers 300 and 400. There is a small, natural wetlands area, Los Cerritos Wetland, inside the nearby Alamitos Bay, and extensive salt marsh areas within Anaheim Bay, located approximately two kilometers downcoast of Alamitos Bay. Characteristic fishes from these habitats in the Harbor Complex would include deepbody anchovy, bay pipefish, bay blenny, round stingray, and diamond turbot (Allen and Pondella 2006a). Approximately two-thirds of the fish species and almost all of the entrained fish larvae collected during the IM&E sampling had some dependency on bay and harbor habitats during at least some stage of their life, and it is considered the primary habitat for seven fish taxa included in this assessment: CIQ gobies, combtooth blennies, shiner perch, yellowfin goby, bay goby, round stingray, and specklefin midshipman (Table 6.1-1). While CIQ gobies yellowfin goby, and bay goby occur almost exclusively in these habitats, two species of combtooth blennies, the rockpool blenny (*Hypsoblennius gilberti*) and mussel blenny (*Hypsoblennius jenkinsi*), also inhabit shallow intertidal and subtidal rocky reef habitats, and specklefin midshipman, round stingray, and shiner perch also occur on the outer coast.

Annual entrainment of CIQ goby larvae was estimated to be 33.3 million larvae based on actual flow volumes and 75.9 million larvae based on design flow volumes (Tables 6.2-4 and 6.2-5). No goby eggs were entrained because eggs are attached in burrows and are not vulnerable to entrainment until they hatch as larvae. The entrainment and source water data on larval concentrations were used to estimate that approximately 3% of the larval CIQ goby population in the Harbor Complex source waters were potentially lost due to entrainment based on actual flows (Table 6.2-4). Based on the design flows, this estimate increases to about 6% (Table 6.2-5). The entrainment losses were also used to estimate that the annual larvae entrained would have resulted in the production of 36,231 and 86,720 adult CIQ gobies based on actual and design flow volumes, repectively. Two other species of gobies, the yellowfin and the bay goby were common in the entrainment samples in 2006. The estimated annual larval entrainment at HGS was 15.4 million and 37.6 million yellowfin goby based on actual and design flows, respectively (Tables 6.2-4 and 6.2-5). These numbers were used to estimate that 1,936 and 4,724 adult equivalent yellowfin gobies would be lost due to entrainment at HGS based on actual and design flows, respectively. The estimated annual larval entrainment at HGS in 2006 was 2.4 million and 5.1 million bay gobies, with an estimated 0.24% and 0.50% of the larval bay goby population potentially lost due to entrainment in 2006. Gobies were not common in impingement sampling because they generally occur on the bottom and not in the water column where they would be subject to impingement. The estimated annual impingement at HGS in 2006 was 163 and 399 yellowfin gobies based on actual and design flows, respectively (Table 5.5-2). No CIQ gobies were collected in the impingement sampling at HGS.

Annual entrainment of combtooth blenny larvae was estimated at 2.3 million based on actual flows and 4.4 million based on design flows. Using the actual flows, the estimated adult equivalents lost due to entrainment at HGS was 2,826 and 6,024 adult equivalents based on the FH and AEL model results, respectively, and approximately 0.06% of the larval blenny populations were lost due to entrainment. Using the design flow volumes, an estimated 5,466 and 11,650 adult equivalents were lost due to entrainment, and approximately 0.12% of the larval populations were lost due to the CWIS at HGS. Combtooth blennies are similar to gobies in that they have adhesive demersal eggs that are not vulnerable to entrainment. No combtooth blennies were impinged at HGS in 2006. Blennies, especially mussel blennies, utilize submerged artificial substrates (pier pilings, dock floats, breakwater material) and their associated fouling communities for shelter and spawning habitat. The extensive development within the Harbor Complex in support of shipping (piers, pilings, etc.) provides abundant habitat for a large population of blennies and this explains why their larvae were entrained in relatively large numbers. Most blenny larvae that were captured were recently hatched, based on size frequency distributions, and reached peak concentrations during summer months.

Round stingray was the most abundantly impinged species with an estimated 6,150 individuals weighing 1,232 kg (2,716 lbs) based on actual flows and 13,771 individuals weighing 2,756 kg (6,076 lbs) based on design flows. Impingement occurred primarily from August through December. There was no entrainment mortality because stingrays give birth to live young and individuals measure about 100 mm (3.9 in) in length at birth. Round stingrays are very common in bays and harbors throughout southern California and there is no directed fishery for the species, only incidental take while fishers target other bottom fishes. Most of the impinged rays were juveniles. Because round stingrays are so common in shallow, soft bottom habitats, it is unlikely that the numbers impinged at HGS have any adverse impact on the population.

Two additional bay and harbor species that were commonly collected in the impingement sampling, but were absent in entrainment sampling, included specklefin midshipman (no larvae entrained) and shiner perch (not susceptible to entrainment). Estimated annual impingement of specklefin midshipman was 484 and 1,379 individuals, based on actual and design flow, respectively. Biomass of specklefin midshipman was 11.955 kg (26.36 lbs) and 26.841 kg (59.18 lbs), based on actual or design flow, respectively. Shiner perch was also relatively abundant in the impingement sampling, with 390 and 719 individuals impinged using actual and design flows, respectively. While round stingray has been infrequently captured during regular NPDES otter trawl surveys within the Harbor Complex, specklefin midshipman and shiner perch frequently appear during the surveys (MBC 2007a, b). Both specklefin midshipman and shiner perch have shown recent increases in population levels based on these otter trawl sampling programs.

Bay and harbor species clearly have the highest risk of AEI of all habitat groups represented in the HGS IM&E sampling. Most of these organisms are affected through entrainment since the juveniles and adults of species such as gobies and blennies occupy benthic habitats within the bay where they are less susceptible to the effects of impingement. However, there is uncertainty regarding the magnitude of the impacts in relation to environmental variables and other stressors that can cause population changes. The earlier 316(b) study in 1978–79 documented average entrainment densities of goby larvae at 4,705 per 1,000 m^3, but in 2006 the average densities were only 516 per 1,000 m^3. Combtooth blenny densities, on the other hand, were comparatively stable ranging from 30–50 per 1,000 m^3 between the two study periods. In the case of gobies and blennies, habitat loss could reduce the reproductive output of the population by increasing the density dependent competition for viable substrate to attach their demersal eggs (Cowan and Shaw 2002). There are no long-term historical data available on blenny and goby populations within the Harbor Complex, although the higher larval density of gobies from the earlier study suggests a substantially greater spawning biomass in the late 1970s as compared to 2006.

Harbor construction projects, effects of pollution and continued loss of remaining wetland habitats in the vicinity have contributed to changes in the available habitat and water quality and undoubtedly has led to changes in the composition of the biological communities, including the possible decline in larval abundances. Stephens et al. (1994) and Stephens et al. (2006) noted a substantial decline in fish populations in King Harbor, Redondo Beach, California in association with the destruction and subsequent rebuilding of the breakwall, activities which included dredging the harbor. Although these authors concentrated on the impact to reef associated species, even greater impacts may occur to demersal soft-bottom species since they are directly affected by loss of habitat and mortality due to dredging and other activities associated with harbor expansion. Overall trends in trawl data from the Harbor Complex indicate a decline in total demersal fish abundance in 2000 near the HGS (Figure 6.3-2), coinciding with major dredging activities in 1994 and 2000. These data show abundances near HGS declined sharply after 1994 and remained low through 2004. In sampling near the Long Beach Generating Station, abundances declined after 1992, rebounded slightly in 1999 and 2000 before declining again and remaining low through 2003. The timing of actual dredging has varied throughout the Harbor Complex, indicating these patterns may, in fact, be coincidental at best. Insufficient data exist to conclusively evaluate the role dredging played in harbor-wide fish population trends. Abundance of fishes at both locations in 2005 and 2006 was similar to or greater than that measured at the onset of monitoring in 1980 (Figure 6.3-2).

The small fraction of the source larval production cropped by power plant entrainment (fractional losses below 3% for gobies) would not be expected to have any substantial effect on a population that is not targeted by any fishery take (Newbold and Iovanna 2007). The bay habitat continues to sustain a thriving population of gobies and blennies, as evidenced by their abundant larval concentrations. In a constructed harbor configuration such as the ILAH where HGS is located that is significantly affected by tidal exchange, many of the larvae are also inevitably lost to the system due to export by outgoing tidal currents, despite behavioral adaptations that cause larvae to migrate toward the bottom or move to areas with less current and minimize export (Barlow 1963; Pearcy and Myers 1974; Brothers 1975). Larvae that are transported into coastal waters can provide genetic exchange between estuarine areas along the coast by moving back into bays with incoming tidal currents (Dawson et al. 2002), but most of these exported larvae experience much higher mortality rates in the open ocean and deeper outer harbor areas than those that are retained in the ILAH.

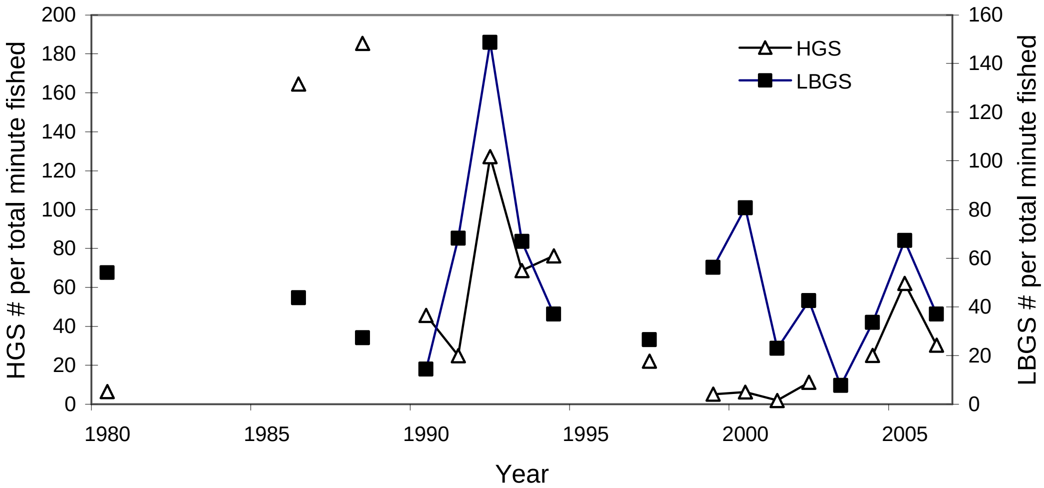


Figure 6.3-2. Abundance per minute fished for fish collected in HGS and LBGS NPDES monitoring otter trawl surveys, 1980-2006. Northern anchovy was excluded from this analysis.

Demographic-based estimates of projected losses assume that there is available habitat to support the additional production in the source water area, which is not usually the case in the example of substrate-oriented or territorial taxa like gobies. In contrast, species that live in open water environments, such as white croaker, are generally not limited by habitat availability but by other factors such as food availability, oceanographic conditions, or predation. , Density–dependent mortality may be a substantial factor affecting post-settlement recruits where there is a limited amount of benthic habitat (Brothers 1975; Steele and Forrester 2005), as in the Harbor Complex. Therefore, projections of adult equivalents based on larval entrainment likely overestimate actual adult losses. For example, much higher levels of entrainment mortality were estimated for the South Bay Power Plant in south San Diego Bay (Tenera Environmental 2004). It was estimated that the South Bay Power Plant entrained 22–27% of the CIQ gobies from the available source water population. However. data from a previous entrainment study and long-term data on adults indicated that the population in south San Diego Bay was stable and not affected by the additional larval mortality due to entrainment. Situations such as this further illustrate the complexity in estimating the overall impact to habitat-reliant species through demographic modeling. In *K*-strategy species (e.g., gobies that invest significant energy into maintaining territories and guarding nests), density-dependent forces can act upon the adult spawning population to limit the overall larval production (Cowan and Shaw 2002; Fuiman 2002). This, in itself, may artificially suggest reduced population abundances, while in fact, the habitat may be at or near its carrying capacity for the species in question, as may have occurred in the south San Diego Bay goby populations. Furthermore, the effect of unmeasured compensatory mechanisms naturally acting upon these early life stages help to regulate recruitment and population levels (Houde 2002). Unfortunately, complementary data on adult abundances in the HGS source waters are not available.

In terms of potential economic losses resulting from IM&E of bay and harbor associated species, there are no direct impacts because they have no fishery value, except for the occasional use of larger specimens as fishing bait or incidental sport catches. Larval reductions could have some effect on the trophic structure of the source water through the loss of available forage for predators. However, any potential effects would not be directly measurable due to the high natural variation in the system and the unknown compensatory response of other species present in the bay and nearshore environment.

6.3.3 Rocky Reef and Kelp Bed Habitats

Physical structure and food resources are essential factors in promoting fish abundance and diversity. Shallow rocky reefs and the giant kelp (*Macrocystis* spp.) forests often associated with them provide both factors. Much of the shoreline of the Los Angeles-Long Beach Harbor Complex consists of hard intertidal and subtidal substrates, such as concrete bulkheads and piers, and there is a limited attachment area for macrophytes such as giant kelp. Some of the common species in typical kelp bed habitats include kelp bass, black perch, opaleye, halfmoon, California sheephead, señorita, garibaldi, salema and zebraperch (Stephens et al. 2006). Although the presence and extent of giant kelp affects the abundance of some reef fishes, many other factors can also affect their distributions, and it is not unusual to find many of the species characteristic of kelp bed habitats in other shallow water locations. Common species of fishes and target invertebrates that are typically associated with rocky reef habitats that were impinged at HGS included the black perch, giant kelpfish, barred sand bass, octopus, and California spiny lobster (Table 6.1-1). Of these, only sand bass and California spiny lobster were entrained. Impacts to representative species from this habitat are briefly discussed.

Black perch was the second most abundant species impinged with an estimated 646 individuals calculated using actual cooling water flow volumes, or 7.3% of the annual total, weighing 18.49 kg (40.76 lbs). Like all species of surfperch, black perch are viviparous, producing free-swimming, fully developed young and are therefore not susceptible to entrainment. The majority of impinged individuals were in the 50 to 70 mm (2.0–2.8 in) size classes, which indicates that they were less than one year of age. The low levels of impingement would not be expected to have any adverse impacts on the populations of black perch which is much more abundant in other habitats outside the ILAH where they are not subject to the effects of the HGS CWIS.

An estimated 120,000 sand bass larvae (*Paralabrax* spp.) were entrained at HGS in 2006 based on actual flows, although they were not identified to species and may have been a mix of kelp bass, spotted sand bass and barred sand bass. An estimated 0.12% and 0.27% of the sea bass population in the HGS source water was lost due to entrainment at HGS, based on the actual and design flow entrainment estimates, respectively. No sand bass eggs were collected during the entrainment sampling perhaps indicating that the HGS intake is not near any areas were these fishes are spawning. The larvae may be transported into the ILAH where they are subject to entrainment. The total annual fecundity for this group, which can be as high as 4.1 million eggs depending on the species (Cailliet et al. 2000), indicates a low potential for adverse impacts to the population due to entrainment. Barred sand bass were the 5th most abundant species impinged at HGS in 2006 with an estimated 209 individuals weighing 7.5 kg (16.5 lbs), based on actual flows. The majority of individuals were 70–100 mm (2.8 to 3.9 in) in length, indicating a principally juvenile assemblage, or approximately one-year old based on Love et al. (1996). Since 2000 the recreational fishery for barred sand bass in southern California has averaged 720,000 fish exceeding the minimum size limit of 30.5 cm (12 in). The low levels of impingement would not be expected to have any adverse impacts on the populations of sand basses which are much more abundant in other habitats outside the ILAH where they are not subject to the effects of the HGS CWIS.

Giant kelpfish was one of the impinged species that is usually associated with rocky reef habitat that also contains kelp or other macrophytes, although it may also occur in seagrass beds over soft substrates. It was the sixth most abundant species impinged with an estimated 192 individuals calculated using actual cooling water flow volumes, or 2.2% of the annual total, weighing 15.7 kg (34.7 lbs). Peak abundance was recorded in the 190 mm SL (7.5 in) size class, representing individuals approximately one-year old. The absence of larvae in the samples indicated that the few impinged individuals probably migrated from elsewhere in the Harbor complex and were spawned in areas outside of the intake vicinity.

California spiny lobster was one of the target shellfish larvae 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 220,000 and 360,000 phyllosome larvae, respectively. However, it comprised such a small fraction of the entrained larvae that no demographic or *ETM* modeling was performed. California spiny lobster was the second most abundant shellfish species impinged with an estimated 717 individuals weighing 169 kg (373 lbs) based on actual flows and 1,544 individuals weighing 370 kg (816 lbs) based on design flows (Tables 6.2-4 and 6.2-5). The mean carapace length of 105 impinged lobsters was 62 mm (2.4 in), which is smaller than the legal minimum fishery size limit of 83 mm (3.25 in). In 2005, combined commercial landings of spiny lobster in the Los Angeles–Long Beach areas totaled 101,324 kg (223,420 lbs) at a value of $1,771,864 while landings from CDFG catch blocks in the immediate vicinity of the Harbor Complex in 2006 totaled 21,875 kg (48,225 lbs) at an estimated value of $448,844 (CDFG 2007). The estimate of impinged biomass based on actual flows represents approximately 0.8 percent of the 2006 landings from the local catch blocks with a value of $3,500.

The intake structure at HGS is located in a primarily mud bottom habitat with constructed hard substrate material around the perimeter of the basin. Species associated with rocky reef and kelp habitats can migrate between areas and occasionally find suitable habitat in bays and harbors due to the presence of algae and eelgrass, rock jetties, and other structures that provide shelter, especially for juveniles that may recruit into these habitats after being transported into the Harbor Complex as larvae. While some individuals may recruit and grow within small habitat patches it is more likely that most adults take up temporary residence when they encounter such habitat patches during their movements. Taxa such as barred sand bass, California spiny lobster, and others that occur across a number of habitats will be less susceptible to CWIS impacts than species with more specific associations with habitats directly affected by the CWIS. Fishes identified with the rocky reef and kelp bed habitats are not at risk of AEI from entrainment or impingement at HGS.

6.3.4 Coastal Pelagic Habitats

Two species entrained and impinged at HGS, northern anchovy and white croaker, are characteristic of the coastal pelagic zone (Table 6.1-1). Both species can be considered habitat generalists because they are also found in bays and a variety of other shallow water locations (Allen and Pondella 2006a). Juveniles tend to be more abundant in the shallower depths of the habitat range.

The estimated annual loss of northern anchovy due to operation of the HGS CWIS included 0.9 million larvae based on actual flow volumes, and 2.1 million based on design flow volumes (Tables 6.2-4 and 6.2-5). An estimated 0.8 million eggs were entrained using the actual flow volumes, or 1.9 million based on the design flow volumes. These estimates were used to calculate the estimated losses of age one equivalents, the age at which 50 percent of the adults are mature, was 11,506 and 25,863 adult equivalent using actual flows and 25,306 and 56,879 adult equivalents using design flows based on the FH and AEL model results, respectively. Annual impingement of northern anchovy was negligible. They are considered an important part of the marine food webs in California because of their use as a forage species by numerous species of fishes, birds, and marine mammals.

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 anchovies. Northern anchovy is one of 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 1982–1984 El Niño (Stephens et al. 1984; Holbrook et al. 1997), the largest El Niño recorded at that time. During the strong La Niña years (1999–2002) there was resurgence in catch of this stock. However, a return in catch of northern anchovy and a corresponding stock increase in Southern California will undoubtedly be delayed until the next cold phase of the PDO.

The difference in source water concentrations of northern anchovy between the 1978–1979 (IRC 1981) and the 2006 studies probably reflects changes in the oceanographic environment. Concentrations dropped from approximately 256 per 1,000 m^3 in the earlier study to only 14 per 1,000 m^3 in the 2006 study (0.5% of earlier concentrations), and the estimated annual entrainment dropped from 100 million to approximately 2 million eggs and larvae combined in the 2006 study. This reduction is similar to the large decrease in the landings from Los Angeles area ports over the same period which were 38,383,362 kg (84,620,828 lbs) in 1981 (data before 1981 was not available from PacFIN) and averaged only 1,351,669 kg (2,979,921 lbs) from 2000–2006 (Table 4.5-7), or 2% of the 1981 landings. The total estimated losses from entrainment in the 2006 study were extrapolated using the FH model results to 11,506 and 25,306 fishes at the age of 50% maturity based on actual and design flows, respectively. The length at that age, 95 mm (3.7 in), was used to predict a weight of 5.0 g (0.18 oz) using a best fit model ($\text{Weight}=0.0005e^{0.0242*\text{Length}}$) derived from length and weight data for the northern anchovy collected from the impingement samples. The total predicted weight of the CWIS losses amounted to approximately 0.01% of the average landings at Los Angeles area ports from 2000–2006 (Table 4.5-7), with a total value of $6 to $12. These values do not represent AEI to northern anchovy, especially since this species has a broad distribution extending well beyond the SCB.

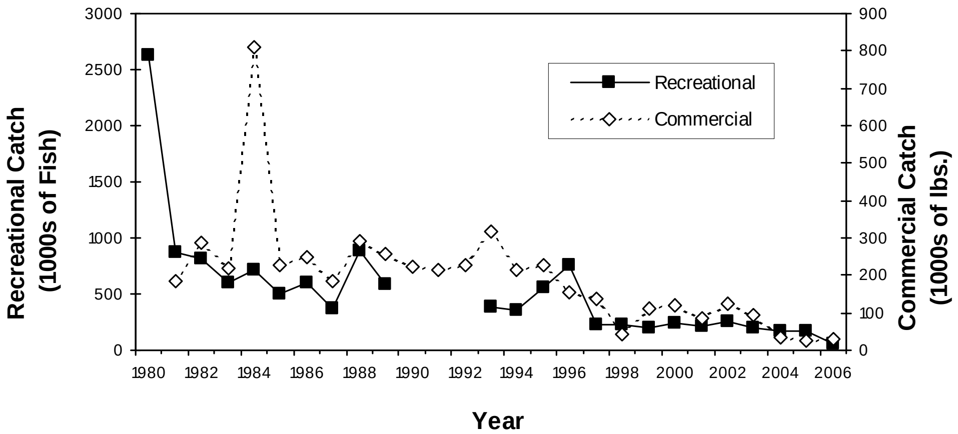
White croaker is a common member of the croaker family that is found in the Harbor Complex and also in the nearshore sand bottom habitats as a bottom-associated species. White croaker was the third most abundant larvae entrained with 7.2 to 18.8 million larvae entrained based on actual and design flows, respectively. An estimated 17.9 to 43.1 million white croaker eggs were also entrained at HGS in 2006. An estimated 25 to 48 individuals weighing 0.20 to 0.43 kg (0.40-0.95 lbs) were impinged in 2006 based on actual and design flows, respectively. Using the egg entrainment data, an estimated 20 to 48 adult equivalents were lost due to entrainment at HGS (Tables 6.2-4 and 6.2-5). Proportional mortality due to entrainment to the HGS source water population of larvae was less than 1% using either actual or design flows in the calculations.

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 from 1980-2006 (Figure 6.3-3a). Overall, the declines in white croaker recreational and commercial catch, especially in the late 1990s, show the same patterns from impingement data at southern California plants described by Herbinson et al. (2001). The impingement of white croaker at the Huntington Beach Generating Station (HBGS) just south of Alamitos Bay shows low impingement throughout the 1990s (Figure 6.3-3b). The impingement of white croaker in 2005 was similar to levels recorded during the early 1980s. Based on the analysis of long-term patterns of change in croakers relative to ocean warming events by Herbinson et al. (2001), the increase in white croaker may be in response to the prolonged cooler water temperatures that have persisted in the southern portion of the California current since 1999 (Peterson et al. 2006). In contrast to the fishery and impingement data, trawls collected as part of NPDES monitoring programs for the Huntington Beach Generating Station (HBGS) and the Haynes, Harbor, and Alamitos Generating Stations show fluctuations in abundance without any clear trends (Figure 6.3-3c). The Harbor trawls are collected in the ILAH, while the Haynes and Alamitos trawls are collected just outside Alamitos Bay, and show an increasing trend from 2003-2005. This increase is consistent with recent impingement data from HBGS that also show an increase over the same period.

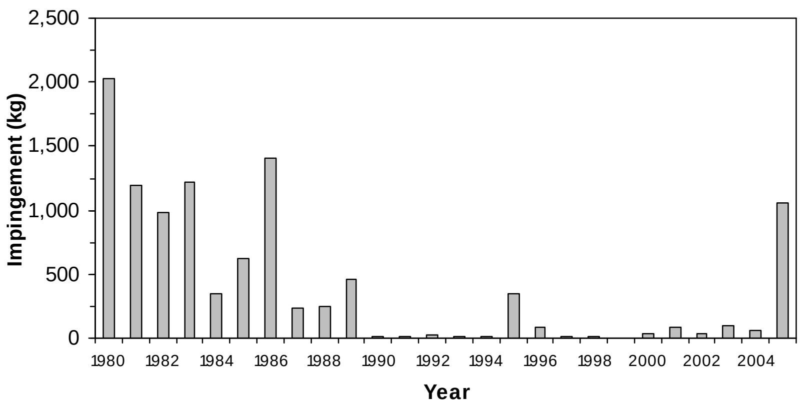
The results from both the fishery and fishery-independent studies (Figure 6.3-3) indicate higher numbers of adult white croaker in the period when the previous 316(b) study was conducted (IRC 1981). The potentially larger population of spawning adults in the outer harbor area may explain why the concentrations from that study were much higher at the near-field and far-field stations.

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. Since the HGS is located in the Harbor Complex, it does not affect this habitat directly and given the wide distributions of most of the component species, including distributions in other habitats where they are not as susceptible to CWIS effects, there is very low potential for any adverse impacts to these populations.

a) Recreational and Commercial Catch



b) HBGS Impingement



c) Huntington Beach and LA Harbor-Alamitos Trawls

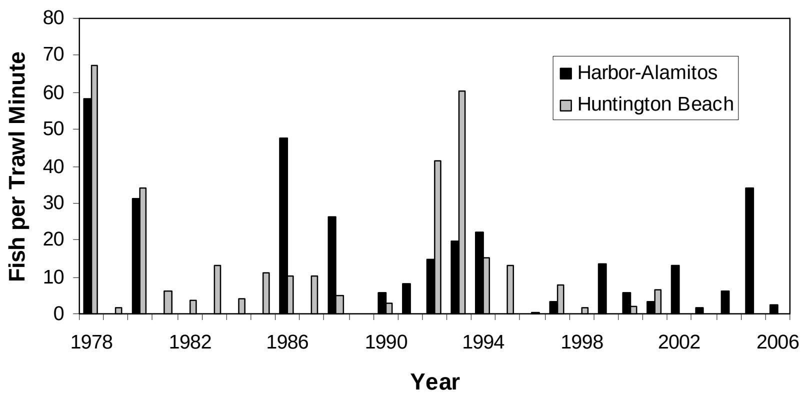


Figure 6.3-3. White croaker fishery and population trends

a) Recreational and commercial landings for Los Angeles area ports from RecFIN and PacFIN databases; b) Huntington Beach Generating Station (HBGS) impingement average annual biomass; and c) NPDES trawl data with average number of fish per trawl minute for HBGS and Harbor, Haynes and Alamitos Generating Stations, collected off Huntington Beach and inside the Los Angeles-Long Beach Harbor breakwaters, respectively.

6.3.5 Shelf Habitats

Shelf habitats include several different habitats from Allen and Pondella (2006b) including inner, middle, and outer shelf, and shallow slope habitats. The abundance, biomass, and other population attributes of the fish assemblages in these habitats increase from the inner to outer shelf (Allen 2006). This gradient is attributed to the increased variability in ocean conditions on the inner shelf due to runoff and pollution among other factors. A variety of flatfishes and other species dominate the fish assemblages on the soft mud and sandy bottoms in these habitats. Fishes characteristic of the inner and middle shelf include California halibut, bay goby, California tonguefish, bigmouth sole, hornyhead turbot, and California skate (Allen and Pondella 2006b). 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 2006b).

While species from this habitat comprised 16 out of 45 (36%) species collected in the entrainment samples and 8 out of 25 (32%) species collected in the impingement samples, none was selected for the assessment because their overall abundances were low (<14% of total larvae and <2% impinged biomass). Entrainment was very low for shelf species since the larvae would have to be transported from offshore areas into the Harbor Complex. Although this did occur for several species, the total numbers of shelf species entrained was very low relative to all of the other habitat assemblages that occur in closer proximity to the Harbor Complex (Table 6.3-1). Due to the location of the HGS intake the percentage of the total impingement biomass for the fishes from this habitat was much lower than the percentage for entrainment. As a result none of the species included in the assessment were primarily associated with this habitat type. Due to the low numbers fishes associated with shelf habitats that were entrained or impinged, there is very little risk of any adverse impacts to fish species from this habitat type.

6.3.6 Deep Pelagic Habitats

Deep pelagic habitats include several different habitats described by Allen and Pondella (2006b) including deep slope, deep bank, and deep rocky reef habitats. This category also includes open ocean pelagic habitats. Some of these habitats are extremely productive and the fishes inhabiting these areas are the basis of large commercial fisheries. The fisheries in the areas outside the three-mile limit of California state waters are federally managed by the PFMC. Fishes characteristic of the deep shelf, bank and slope habitats include Pacific hake, 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 tunas. 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. Only two larval fishes associated with the deep pelagic habitat (Bathymasteridae, 0.01%; Bathylagidae, 0.01%) were collected in this study, and no species from this habitat were collected in impingement sampling; therefore, there is a very low probability that CWIS impacts from HGS would affect species from this habitat type.

6.4 CONCLUSIONS AND DISCUSSION

Impacts to SCB fish and invertebrate populations caused by the entrainment of planktonic larvae through the HGS CWIS can only be assessed indirectly through modeling. The estimates from these models can be added to impingement losses of juveniles and adults to estimate the total losses due to the HGS CWIS. Three taxa (CIQ goby complex, yellowfin goby, and white croaker) comprised 86% of all entrained fish larvae. Of the ten most abundant fish species entrained at HGS, only two (white croaker and anchovies) have any direct commercial or recreational fishery value. All of the abundantly entrained species can be considered forage species for larger predatory fishes, sea birds, or marine mammals. Approximately half of the 48 different fish taxa entrained and the 25 taxa impinged belonged to species with some direct fishery value (e.g., anchovies, silversides, croakers, sea basses, California halibut) even though most of those (except white croaker and anchovies) were collected in very low abundance (less than 1% of the total abundance or biomass [Tables 5.4-1 and 5.5-1]) in the samples and, as a result, were not assessed for potential impacts. Only 15% and 4% of the total entrainment abundance and impingement biomass, respectively, were from fishes and rays that have some direct fishery value.

The *ETM* procedure estimates the annual probability of mortality due to entrainment (P_M). It puts the entrainment estimate into context by comparing it with a known source population at risk of entrainment. The greatest P_M estimate was for the CIQ goby complex with a predicted fractional larval loss of 2.65%. The next greatest probabilities of mortality were for northern anchovy (0.71%) and yellowfin goby (0.65%). The spatial extent of the habitats potentially affected by entrainment is directly proportional to the estimate of time that the larvae are exposed to entrainment. The two goby groups had local populations primarily located in the habitats of the Harbor Complex, while the anchovies are widely distributed and probably originated from eggs spawned in the outer harbor area or in nearshore areas of San Pedro Bay. Most larvae were entrained at sizes that indicated they were recently hatched. The modeled species with primarily nearshore (non-bay) distributions included white croaker and northern anchovy, and these had P_M estimates well below 1%. These levels of additional mortality would be considered low, especially when the populations of these species extend over a much larger geographic range than the extrapolated source water bodies. No invertebrate taxa were modeled for entrainment impacts due to the low abundance of the target taxa (e.g., spiny lobsters, *Cancer* crabs).

Changes in total impingement and entrainment through time were affected not only by natural changes in biological and oceanographic factors but also by changes in cooling water flow. Compared to the IM&E study conducted at HGS in 1978–1979 (IRC 1981), concentrations of northern anchovy, unidentified gobies, and queenfish larvae were an order of magnitude less abundant in 2006 than in 1978-1979 while combtooth blennies and white croaker were approximately the same (Table 6.4-1). Anchovy larvae in particular were significantly more abundant in the earlier study, due in part to the cooler water climatic regime in the SCB that favored anchovy populations at that time. The most abundantly impinged species in 1978–1979 were Pacific pompano (*Peprilus simillimus*), white croaker, and queenfish, which combined accounted for 76% of the total impingement abundance. In the 2006 samples, the most abundant species were round stingray, black perch and specklefin midshipman with round stingray accounting for 75% of all impinged fishes. Annual fish impingement (normal operations and heat treatments) was 2,827 kg (6,232 lbs) in 1978–1979 compared to 1,317 kg (2,903 lbs) in 2006. In the 1978-79 study HGS was operating Units 1–5 with a combined flow of 86,652 MG (62% of maximum design flows), whereas in 2006 only Unit 5 was operational with an annual flow of 17,885 MG (51% of maximum design flows) resulting in an 80% reduction in flows between studies.

Declines of numerous juvenile/adult fish stocks have been documented in southern California since the 1970s. Holbrook et al. (1997) estimated a 69% decrease in populations of 75 fish species at King Harbor and off Palos Verdes, California, between 1975 and 1993. Brooks et al. (2002) examined impingement data from four coastal generating stations in southern California, and determined that the abundance of 37 fish species declined an average of 41% from 1978 to 1992 which they attributed to a regional decline in productivity. From 1951 through the mid-1990s, macrozooplankton biomass in waters off southern California decreased by 80%, coinciding with a temperature increase in the oceanic surface layer (Roemmich and McGowan 1995). A combination of these natural temperature increases, reduced nutrient supplies, and changes in ocean circulation resulted in overall declines of phytoplankton and zooplankton in the southern California bight. Most of the fish species analyzed in the present study feed on zooplankton with the decrease possibly affecting overall fish abundance.

Shifts in species composition over the long term can also be attributed, in part, to regime shifts. For example, Hsieh et al. (2005) examined long-term larval abundance off southern California and its relationship with several factors. The Pacific Decadal Oscillation (PDO) is a pattern of Pacific climate variability that affects ocean surface temperatures, shifting phases on a 20-30 year time scale. When abundances between the cold period (1951-1976) and the warm period (1977-1998) of the PDO were compared, larval densities of Pacific sardine and Pacific chub mackerel increased significantly, while densities of northern anchovy larvae decreased slightly. Sand bass larvae increased significantly, and were positively correlated with shifts in the PDO. Allen et al. (2004) found a significant positive correlation in the abundance of several species, including spotted kelpfish, and shifts in the PDO. Other fish species, including combtooth blennies, northern anchovy, and deepbody anchovy, correlated negatively with the PDO.

Table 6.4-1. Comparison of larval fish densities and total annual entrainment at HGS from studies in 1978–1979 and studies in 2006.

		Mean Average Annual Density (#/1,000 m^3)		**Actual Annual Entrainment (millions)**	
Species	**Common Name**	**1978–79**	**2006**	**1978–79**	**2006**
Larval Fishes					
Engraulidae	anchovies	265	14	100	1
Gobiidae	gobies	4,705	516	520	33
Hypsoblennius spp.	combtooth blennies	50	30	19	2
Genyonemus lineatus	white croaker	135	125	52	7
Seriphus politus	queenfish	15	1	–[a]	<0.1
Pleuronichthys guttulatus	diamond turbot	1	<1	–[a]	<0.1
Fish Eggs					
Engraulis mordax	northern anchovy	<1	13[b]	–[a]	<1[b]
Anchoa spp.	bay anchovies	<10	–[b]	–[a]	–[b]
Sciaenid complex	croakers	1,075	284	390	14

[a] *Annual estimate not calculated due to low densities of larvae or eggs.*
[b] *Combined into Engraulidae and includes both northern anchovy and bay anchovies.*

6.4.1 IM&E Losses Relative to 1977 EPA AEI Criteria

EPA (1977) provided some general guidelines to determine the "relative biological value of the source water body zone of influence for selected species and the potential for damage by the intake structure" based on the following considerations of the value of a given area to a particular species:

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

Fishes in the vicinity of the HGS intake structure are characteristic to some extent of the fish assemblages found in other bays and harbors in southern California, although the unique position of HGS in the back reaches of the Harbor Complex affect the assemblage structure. The structural complexity of the Harbor Complex contributes to the habitat value of the area as a spawning and nursery ground for several species even though it is a highly modified, dredged embayment that was once part of a natural wetland system. However, the results indicate that there was a limited diversity of species in the samples compared to other bay/estuary areas in southern California. Two taxa (CIQ goby complex and yellowfin goby) comprised 75% of all entrained larvae, and both use embayments as their primary habitat. Yellowfin goby is an introduced species that may be out-competing native goby species, while CIQ gobies are abundant in quiet-water areas with soft substrates where they inhabit burrows and lay their eggs. Because these species have short life spans and their populations are likely limited by the availability of adult habitat, the additional mortality due to entrainment would not be expected to substantially affect their local populations. There was no evidence of population declines in gobies at the South Bay Power Plant in south San Diego Bay (Tenera Environmental 2004) where entrainment mortality levels were substantially higher. For the abundantly impinged species, size-frequency distributions indicated that most of the round stingrays and black perch were small, young-of-the-year fishes. Both of these fishes are not susceptible to entrainment impacts.

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 HGS intake is not located in such a corridor, this issue is not of concern for any of the species that were impinged.

The other points of concern relative to intake location and fish distribution are numbers of individuals present and other functions critical during the life history (i.e., high concentrations of individuals present in the area for reasons other than spawning, recruitment or migration). This may include a circumstance where, for example, prevailing currents or the proximity to certain bathymetric features attracts prey items for a predatory species and thus results in high concentrations of a species that may subsequently be at risk of impingement. None of the data collected during this study suggests that there are any species that are especially vulnerable to impingement or entrainment due to their behavior at any stage in their life history. This includes all common species as well as any special status species designated for protection under state or federal statutes.

No federal/state threatened or endangered fish/shellfish species were identified in entrainment and impingement samples collected from HGS. This is consistent with past entrainment and impingement sampling conducted at HGS. Off southern California, species managed under the Magnuson-Stevens Fishery Conservation and Management Act are listed in the Coastal Pelagic Fishery Management Plan (FMP) and the Pacific Groundfish FMP. EFH includes all waters off southern California offshore to the Exclusive Economic Zone. Five species covered under the two FMPs that occurred in entrainment and/or impingement samples at the HGS are shown in Table 6.4-2.

Table 6.4-2. Fish and shellfish species under NMFS federal management or with CDFG special status entrained and/or impinged at HGS 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)*
Citharichthys sordidus	Pacific sanddab	Pacific Groundfish	13,740	–
Engraulis mordax	northern anchovy	Coastal Pelagics	940,784	24
Loligo opalescens	market squid	Coastal Pelagics	26,676	–
Merluccius productus	Pacific hake	Pacific Groundfish	8,421	–
Sardinops sagax	Pacific sardine	Coastal Pelagics	11,836	–

* *Includes estimated numbers from normal impingement, and actual numbers from marine growth control 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 HGS included:

- distribution (pelagic, subtidal, nearshore subtidal & intertidal);
- range, density, and dispersion of population;
- population center (source or sink);
- magnitude of effects;
- long-term abundance trends (e.g., fishery catch data);
- long-term environmental trends (climatological or oceanographic); and
- life history strategies (e.g., longevity and fecundity).

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

The magnitudes of the CWIS losses were all relatively low, as expected, for taxa that are primarily associated with habitats not directly affected by HGS. Not only were the estimated effects low for these taxa, the broad geographic distributions throughout the SCB for fishes such as northern anchovy and white croaker further reduce the potential for any AEI. The Harbor Complex is not the source or primary habitat for many of the taxa and is not critical to these populations. Data on these fishes from other studies support the conclusion that there is very low risk of AEI due to the HGS CWIS.

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

These taxa seem to be responding to factors other than power plant impacts. Anchovies disappeared from the commercial fishery after the regime shift and were essentially absent during the last two decades. Any time series data that extends to before or during this regime shift has evidence of this change. Other fisheries were declining (white croaker) while catch in the fishery independent monitoring programs found them to be either increasing or extremely variable in abundance over time. After the faunal shift (i.e., post 1982–1984 El Niño), fishes that would be negatively affected by warming conditions were essentially extirpated from the nearshore environment of the San Pedro Bay area. This period was marked by general low fish productivity (Brooks et al. 2002) until the La Niña of 1999 and the following four-year cool water period.

The low potential for AEI for all of the taxa entrained and impinged at HGS is consistent with a recent review on population level effects of IM&E on harvested fish stocks (Newbold and Iovanna 2007). They modeled the potential effects of IM&E on populations of 15 East Coast fish stocks that are targeted by either commercial or recreational fisheries using empirical data on entrainment and impingement, life history, and stock size. For 12 of the 15 species, the effects of removing all of the sources of power plant entrainment and impingement were very low (less than 2.5%). For the other three species, the effects ranged from 22.3% for striped bass 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 mechanisms that are probably acting on the populations at some level. If there is strong density dependence acting on these populations during the life stages from the period when they are vulnerable to entrainment as larvae through the age of maturity, then they concluded that there should be very little potential for population level effects due to entrainment and impingement.

Although it seems clear that there is very low risk of AEI to taxa that are not primarily distributed in the Harbor Complex, the potential risk to the fishes included in the assessment that are primarily associated with bay and harbor habitats was also low, particularly compared to other power plants situated in embayments in southern California. This is a reflection of both the lower abundances of these fishes in the ILAH and the low cooling water volumes of HGS relative to other facilities. Data on adult populations available from south San Diego Bay indicated that much higher entrainment losses did not represent a significant risk to the population. Although no data on adult populations of these resident fishes are available for the Harbor Complex, the much lower entrainment losses would indicate that there is very low risk of adverse population impacts. This risk is reduced by the abundance of bay and harbor habitat in the areas surrounding the Harbor Complex. Larvae potentially lost due to entrainment at small sizes near the plant may be replaced by larvae transported into the ILAH that were spawned in similar habitats throughout the Harbor Complex area.

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