FINAL REPORT

HAYNES GENERATING STATION

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

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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	gallonsGIS Geographic Information System
gpm	gallons per minute
HnGS	Haynes Generating Station
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	meter per second
MSL	mean sea level
MW	megawatts
NL	notochord length
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration

NPDES	National Pollutant Discharge Elimination System
PacFIN	Pacific Fisheries Information Network
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 Haynes Generating Station (HnGS) Impingement Mortality and Entrainment (IM&E) Characterization Study. This study was designed and performed to comply with EPA's 2004 316(b) Phase II regulations. Originally, results from the study were to be used in determining impingement mortality and entrainment from once-through cooling, evaluating potential fish protection technologies and operational measures at the facility, scaling potential restoration projects, and/or evaluating the cost-benefits in reducing IM&E at the facility. However, in March 2007, the United States Environmental Protection Agency (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 HnGS 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 HnGS. This report provides a characterization of the fish and invertebrate species subject to entrainment and impingement at the HnGS, information on the current levels of IM&E at the HnGS, and a discussion on the level of significance of the IM&E losses.

1.1 ENTRAINMENT

Composition and abundance of ichthyoplankton and shellfish larvae entrained by HnGS 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 12,651 entrainable fish larvae from 35 separate taxonomic categories was collected during the 26 entrainment surveys. The most abundant larval fish taxon in the samples was unidentified gobies, which comprised 51.3% of the total larvae collected, followed by silversides (23.9%) and combtooth blennies (20.1%). Densities of fish larvae peaked in late May at an average concentration of approximately 17,000 per 1,000 m^3 (264,172 gal), although seasonal peaks in spawning differed among the most abundantly entrained larvae. For example, anchovies (mainly northern anchovy), silversides, and white croaker had peak spawning periods in spring, while combtooth blennies were mainly summer spawners. Gobies spawned year-round, with peaks in both spring and summer, reflecting the multispecies composition of the group. In addition to fish larvae, 5,941 fish eggs from 13 taxa were enumerated from the surveys. The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 69.4% of the total eggs collected, followed by sand flounder eggs (11.4%). Fish eggs peaked in abundance in March–April prior to the peak abundance of fish larvae in May, and also had a secondary peak in August. Larvae and eggs were substantially more abundant in samples collected at night than those collected during the day in nearly every survey. Total annual entrainment was estimated to be 3.65 billion fish larvae and 1.68 billion fish eggs during 2006 using the HnGS CWIS actual flows as the basis for calculations. Using the design (maximum capacity) CWIS flows, total annual entrainment was estimated to increase to 4.53 billion fish larvae and 2.12 billion fish eggs.

A total of 50 larval target invertebrates representing 9 taxa was collected from the HnGS entrainment station during the bi-weekly surveys in 2006. The most abundant target shellfish larvae in the samples were shore crab megalops (Grapsidae unid.) followed by kelp crab megalops (*Pugettia* spp.), which made up 28.0% and 24.0%, respectively of the total target invertebrate larvae collected. Total annual entrainment was estimated to be 14.9 million target invertebrate larvae based on actual cooling water flows. Using the design CWIS flows, total annual entrainment was estimated to increase to 18.5 million target invertebrates.

1.2 SOURCE WATER

To determine composition and abundance of the early life stages of fish and shellfish in the source waters of the HnGS, sampling at nine stations in the coastal waters in Alamitos Bay and San Pedro Bay was conducted once monthly on the same day that the entrainment station (E3) was sampled.

A total of 41,319 larval fishes representing 68 taxa was collected from HnGS source water stations during 12 monthly surveys in 2006. Unidentified gobies (*Clevelandia, Ilypnus, Quietula* (CIQ) goby complex), white croaker, combtooth blennies, and anchovies were the most abundant taxa and comprised over 90% of all specimens collected. The greatest concentrations of larval fishes occurred during April 2006 (ca. 5,800 per m^3 [264 gal]) and the fewest in October 2006 (ca. 600 per m^3 [264 gal]). Spawning peaks occurred predominantly in spring and summer for the major species groups and were similar to those described for the entrainment samples.

A total of 2,291 larval target invertebrates (developmentally advanced larvae of crabs, spiny lobsters, and market squid) representing 20 taxa was collected from HnGS source water stations in and near Alamitos Bay during 12 monthly surveys in 2006. Megalops of kelp crabs, pea crabs, shore crabs, spider crabs, and unidentified megalops were the most abundant taxa and comprised nearly 90% of all specimens collected.

1.3 IMPINGEMENT

Weekly impingement surveys were performed during all 52 weeks at the HnGS between January 2006 and January 2007. Additionally, five marine growth control (heat treatment) surveys were performed in 2006.

A total of 6,580 fishes representing at least 53 distinct taxa and weighing 72.5 kg (159.9 lbs) was collected during impingement sampling in 2006. Queenfish was the most abundant species, with 3,708 individuals collected (56% of the total) and an estimated annual impingement based on actual cooling water flow of 30,946 individuals weighing 19.5 kg (42.9 lbs). The annual impingement of queenfish represented 58% of the total impingement abundance but only 4% of the biomass. The next most abundant species in impingement samples were topsmelt, northern anchovy, bay pipefish, unidentified pipefishes, shiner perch, and specklefin midshipman (*Porichthys myriaster*). Combined these taxa accounted for 91.2% of the sampled impingement abundance. The estimated annual total impingement based on cooling water flow volumes in 2006 was 53,442 individuals weighing 529.8 kg (1,168 lbs). The estimated annual impingement based on design flows was 56,613 fishes weighing 556.5 kg (1,227.0 lbs). Impingement abundance in 2006 was highest in summer (July–September) and impingement biomass was greatest in spring (April–May). Highest impingement was recorded in summer (July and August 2006), corresponding to an increase in impingement of juvenile queenfish. The small size of the queenfish impinged (most in the 30-mm size class) suggested they were probably spawned in spring since individuals usually reach 100 mm by the end of their first year. In general, fish impingement abundance was greatest during nighttime, though biomass was greater during the day.

A total of 2,682 macroinvertebrates representing at least 49 distinct taxa and weighing 37.0 kg (81.6 lbs) was collected during impingement sampling in 2006. Of this total, only 12 individuals from seven taxa weighing 0.2 kg (0.4 lbs) were impinged during the five marine growth control procedures. Red jellyfish was the most abundant species, with 621 individuals collected (23% of the total) and an estimated annual impingement of 4,562 individuals weighing 16.6 kg (37 lbs). The next most abundant species in impingement samples were the nudibranch *Hermissenda crassicornis*, tuberculate pear crab, and yellow shore crab. Combined these species accounted for 59.1% of the sampled impingement abundance. The estimated annual total impingement based on actual cooling water flow volumes in 2006 was 20,346 individuals weighing 268.8 kg (592.7 lbs). The estimated annual impingement based on design flow was 21,773 macroinvertebrates weighing 293.8 kg (647.9 lbs). Invertebrate impingement abundance was greatest from January through June, with highest abundance recorded in spring (April–May). Invertebrate biomass was much more variable throughout the year, with peaks in late-March, late-April, and early-August.

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 reasonable assessment of impacts. The list of species included in the assessment were reviewed and approved by the Los Angeles Regional Water Quality Control Board (LARWQCB) and other stakeholders. The most abundant taxa had the greatest frequency of occurrence among surveys and among stations. Since the most abundant organisms may not necessarily be the organisms that experience the greatest effects on the population level, the data were also examined to determine if additional taxa should be included in the assessment. For example, this might include commercially or recreationally important taxa, taxa with limited habitats, and any threatened or endangered fish or shellfish species. The National Marine Fisheries Service requested that all species managed under the Magnuson-Stevens Fishery Conservation and Management Act be included in the impingement results. None of these species were included in the entrainment assessment since they were scarce in entrainment and source water samples. No species listed as threatened or endangered by the state or federal governments were entrained or impinged at the HnGS during the study.

The assessment was primarily done by calculating impingement and entrainment estimates based on CWIS actual and design flow volumes for individual taxa, and then using these results to model the losses to adult and larval source populations using two general modeling approaches and three different models. One approach uses species life history information in two different demographic models to estimate the equivalent number of adults (adult equivalent loss [*AEL*]) or adult females (fecundity hindcasting [*FH*]) lost due to entrainment or impingement. The other modeling approach was only used with the entrainment data. This model (empirical transport model [*ETM*]) estimates the conditional mortality on a population resulting from entrainment. The demographic model estimates from entrainment and impingement were added together to evaluate the combined effects of the CWIS. The life history information necessary for the modeling was not available for most species so combined assessments were only done for northern anchovy.

The assessment included 13 taxonomic groups or species of fishes and 3 taxonomic groups or species of shellfishes (Tables 1.4-1 and 1.4-2). These taxa were categorized into five habitat types that were simplified from a more detailed categorization of habitats used by Allen and Pondella (2006) (Table 1.4-3). Taxa that occur in more than one habitat were included in the habitat group that best reflected the primary distribution for the taxa. This approach was used because it focused the assessment on the taxa and habitats that were most at risk to CWIS effects.

Impacts to Southern California Bight (SCB) fish and invertebrate populations caused by the entrainment of planktonic larvae through the HnGS CWIS can only be assessed indirectly through modeling. These impacts are additive with the direct impingement losses. Three taxa (CIQ goby complex, combtooth blennies, and silversides) comprised 95% of all entrained fish larvae. Of the ten most abundant fish species entrained at HnGS, 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 45% of the 33 different fish taxa entrained belonged to species with some direct fishery value (e.g., anchovies, silversides, croakers, sand basses, and California halibut) even though most of those (except silversides, white croaker and anchovies) 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 silverside complex with a predicted fractional larval loss of 40.9%. The next greatest probabilities of mortality were for CIQ gobies (25.2%) and combtooth blennies (13.9%). The distance of shoreline potentially affected by entrainment was directly proportional to the estimate of time that the larvae are exposed to entrainment. All three of these species had local populations primarily located in the habitats of Alamitos Bay, and most larvae were entrained at sizes that indicated they were recently hatched. For example, the relatively high silverside mortality estimate resulted from a single large pulse of larvae entrained in late May, probably from eggs that had been deposited on dock structures in the marina adjacent to the HnGS intakes. 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).

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

Compared to the IM&E study conducted at HnGS in 1978–1979 (IRC 1981), silverside larvae were nearly two orders of magnitude more abundant in the recent 2006 entrainment samples while other taxa analyzed in both studies were less abundant in 2006. Anchovy and croaker 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 populations of these taxa. The most abundant impinged species in 1978–1979 were shiner perch (38%), Pacific pompano (14.9%), and white seaperch (12.5%), while in the 2006 samples queenfish, topsmelt and northern anchovy were the numerically dominant species accounting for 75% of all impinged fishes. The estimated annual fish biomass impingement (normal operations and heat treatments) was 1,344 kg (2,964 lbs) in 1978–1979 compared to 529.8 kg (1,168 lbs) in 2006. The operations and configuration of the HnGS cooling water system have remained largely unchanged since all units went into service with the exception of the replacement of the cooling water pumps at Units 3 & 4 (now Unit 8). Therefore, changes in impingement and entrainment through time are most likely due to natural biological changes and not due to substantial changes in plant operation.

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

Species	**Common Name**	**Est. Annual Larval Ent. (millions)**	**Est. Annual Egg Ent. (millions)**	***ETM*** **P_M (%)**	**2*FH**	***AEL***	**Annual Imping. Estimate**	**Imping. Weight (kg)**	***EAM*[1]**
Fishes									
Gobiidae[2]	gobies	1,828.4	0	25.15	3,932,562^{L}	1,671,266^{L}	7	0.01	
Atherinopsidae unid.[3]	silversides	920.3	11.5	40.95			6,315	29.44	
Hypsoblennius spp.	combtooth blennies	732.0	0	13.89	836,002^{L}	1,783,945^{L}	32	0.35	
Genyonemus lineatus	white croaker	75.4	57.8	0.63	64^{E}		861	5.78	
Engraulis mordax	northern anchovy	22.7	11.1	0.76	8,600^{C}	20,634^{L}	5,794[4]	6.25[4]	1,840
Seriphus politus	queenfish	2.5	0				30,946	19.47	13,971
Syngnathus spp.	pipefishes	3.1	–				4,553	5.70	
Porichthys myriaster	specklefin midshipman	–	–				620	157.23	
Cymatogaster aggregata	shiner perch	–	–				582	12.03	
Sardinops sagax	Pacific sardine	0.3	0				90	0.61	69
Raja inornata	California skate	–	–				8	1.11	
Trachurus symmetricus	jack mackerel	0	0				7	0.48	
Sebastes miniatus	vermilion rockfish	0	0				7	0.01	
Invertebrates									
Octopus spp.	California two-spot octopus	–	–				337	54.78	
Aplysia californica	California seahare	–	–				195	79.41	
Loligo opalescens	market squid	0.2	–				78	1.37	

[1] *standardized impingement adult equivalent mortality*

[2] *only cheekspot goby collected in impingement samples*

[3] *only topsmelt was collected in abundance in impingement samples*

[4] *Engraulis mordax larvae collected from impingement sampling are combined with adults*

**Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).*

Table 1.4-2. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on design flows at HnGS in 2006.*

Species	Common Name	Est. Annual Larval Ent. (millions)	Est. Annual Egg Ent. (millions)	*ETM* P_M (%)	2*FH	*AEL*	Annual Imping. Estimate	Imping. Weight (kg)	*EAM*[1]
Fishes									
Gobiidae[2]	gobies	2,334.2	0	31.7	5,020,588^{L}	2,133,657^{L}	7	0.01	
Atherinopsidae unid.[3]	silversides	1,062.8	20.8	46.9			6,747	32.40	
Hypsoblennius spp.	combtooth blennies	915.3	0	17.7	1,045,330^{L}	2,230,628^{L}	32	0.35	
Genyonemus lineatus	white croaker	96.2	86.5	0.79	96^{E}		877	7.48	
Engraulis mordax	northern anchovy	27.3	14.0	0.92	10,364^{C}	24,845^{L}	6,513[4]	7.31[4]	2,117
Seriphus politus	queenfish	2.9	0				32,389	20.36	14,595
Syngnathus spp.	pipefishes	3.8	–				4,801	5.97	
Porichthys myriaster	specklefin midshipman	–	–				632	161.77	
Cymatogaster aggregata	shiner perch	–	–				628	13.33	
Sardinops sagax	Pacific sardine	0.3	0				98	0.66	75
Raja inornata	California skate	–	–				9	1.24	
Trachurus symmetricus	jack mackerel	0	0				7	0.48	
Sebastes miniatus	vermilion rockfish	0	0				7	0.01	
Invertebrates									
Octopus spp.	California two-spot octopus	–	–				353	57.88	
Aplysia californica	California seahare	–	–				221	93.13	
Loligo opalescens	market squid	0.3	–				78	1.37	

[1] *standardized impingement adult equivalent mortality*
[2] *only cheekspot goby collected in impingement samples*
[3] *only topsmelt was collected in abundance in impingement samples*
[4] *Engraulis mordax larvae collected from impingement sampling are combined with adults*
**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 HnGS.

		Fishery	**Habitats**			
Scientific name	**Common name**	**S-Sport, C-Comm.**	**bays, harbors**	**reefs, kelp beds**	**coastal pelagic**	**shelf**
Fishes						
Atherinopsidae unid.	silversides	S, C	**X**		x	
Cymatogaster aggregata	shiner perch	S	**X**	x		
Engraulidae unid.	anchovies	C			**X**	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Gobiidae unid.	CIQ goby complex		**X**			
Hypsoblennius spp.	combtooth blennies		**X**	x		
Porichthys myriaster	specklefin midshipman		**X**	x		
Raja inornata	California skate	C	x			**X**
Sardinops sagax	Pacific sardine	C	x		**X**	
Sebastes miniatus	vermilion rockfish	S, C		**X**		
Seriphus politus	queenfish	S			**X**	x
Syngnathidae	pipefishes		**X**			
Trachurus symmetricus	jack mackerel	S, C		x	**X**	
Shellfishes/Invertebrates						
Aplysia californica	California seahare	C	x	**X**		
Loligo opalescens	market squid	S			**X**	
Octopus spp.	California two-spot octopus	C	x	**X**		

Primary habitat in bold, upper case and secondary habitat in lower case. Taxa also designated as to whether they are targeted by a sport (S) or commercial (C) fishery.

2.0 INTRODUCTION

The Haynes Generating Station (HnGS) is a fossil-fueled steam electric power generating station that is owned and operated by the Los Angeles Department of Water and Power (LADWP). HnGS is located in the city of Long Beach on the eastern side of the San Gabriel River flood control channel. The plant uses a once through cooling water system for five of its seven generating units with a total maximum permitted flow of approximately 1,014 million gallons per day (mgd). These five units withdraw cooling water from a common bulkhead intake in Long Beach Marina, Alamitos Bay that is connected to the plant through an earthen intake channel that runs 1.5 miles parallel to the east bank of the San Gabriel River to the intake screenhouses. The cooling water from the plant is discharged into the lower San Gabriel River flood control channel.

Cooling water intake systems (CWIS) are regulated under §316(b) of the federal Clean Water Act (CWA). In July 2004, 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 HnGS, which withdraws a maximum of 967.7 mgd, it was subject to these new regulations that required submittal of comprehensive plan for compliance by January 2008. The new regulations were challenged by a coalition of environmental groups that was heard by the Second U.S. Circuit Court of Appeals. The court rendered a decision in January 2007 that remanded several key componenets of the regulations back to the EPA. In March 2007, EPA issued a memorandum suspending the rule and directing that all permits for Phase II facilities implement 316(b) on a case-by-case basis using “best professional judgement” (BPJ). The language of the memorandum was expanded and published in the Federal Register in July 2007 (Volume 72, 130:37107-37109).

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

2.1 BACKGROUND AND OVERVIEW

On July 9, 2004, the USEPA 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) each with a CWIS that withdraw at least 50 mgd from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. Pursuant to the Phase II regulations, the LADWP submitted the Proposal for Information Collection (PIC) for HnGS to the Los Angeles Regional Water Quality Control Board (LARWQCB) in October 2005 (LADWP 2005). The PIC included the study plan for the HnGS 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 due to the impingement mortality (IM) of aquatic organisms (i.e., fish, shellfish, and other forms of aquatic life) on intake structures and the entrainment (E) of eggs and larvae through cooling water systems. 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 water body flow determined 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 can show that it can meet the standards using the existing intake design or is 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 HnGS. Previous §316(b) Demonstration studies were done at HnGS in 1978–1979 (IRC 1981). Entrainment and field (source water) plankton samples were collected biweekly, and impingement samples were collected at varying intervals (daily to weekly) at all of the intake screening structures. A summary of the historical IM&E studies is provided in Sections 4.2 and 5.2 of this report. 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 "Best Professional Judgment" (BPJ) basis until the issues raised by the Court decision are resolved. EPA is currently considering several alternatives for responding to the Court decision and it may be several years before it is resolved either through further litigation and/or Rulemaking. The guidance in this memorandum was published in the Federal Register on July 9, 2007 (Volume 72, 130:37107-37109).

The information in this report is being submitted to assist in the evaluation of fish protection technologies and operational measures described in the PIC so that when the issues with the 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 to compliance, the assessment of the IM&E study focuses on determining if impingement and entrainment losses pose any significant risk of AEI to the species and life stages of fish and shellfish impinged or entrained. The AEI assessment in this report is based on previous EPA guidance on 316(b) (USEPA 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 water body. The sampling plan must also include a description of the study area (including the area of influence of the CWIS), and provide for taxonomic identifications of the sampled or evaluated biological assemblages (including all life stages of fish and shellfish) that are known to be relevant to the development of the plan.

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

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

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

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

The revisions to the study plan only affected sample processing and did not affect the sampling that started in January 2006. On January 30, 2007, representatives from the LADWP, URS, MBC, and Tenera met with representatives from the LARWQCB, USEPA Region IX, State Water Resources Control Board (SWRCB), CDFG, and NMFS to review preliminary data from the HnGS 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 HnGS IM&E report. Off southern California, these species are listed in the Coastal Pelagics Fishery Management Plan (FMP) and the Pacific Groundfish FMP. It was agreed that for entrainment, additional demographic or *ETM* calculations would only be performed on these species if they were collected in sufficient abundance in entrainment and source water samples, and if sufficient life history information was available to permit those calculations. For impingement, it was agreed that only market squid would need additional assessment since impingement estimates are calculated for all species, and no additional modeling was proposed.

2.1.3 Study Plan Objectives

Under the 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-in mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody; and the baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls, including flow or velocity reductions, implemented in whole or in part for the purposes of reducing impingement mortality and entrainment. You may also choose to use the current level of impingement mortality and entrainment as the calculation baseline. The calculation baseline may be estimated using: historical impingement mortality and entrainment data from your facility or another facility with comparable design, operational, and environmental conditions; current biological data collected in the waterbody in the vicinity of your cooling water intake structure;*

> *or current impingement mortality and entrainment data collected at your facility. You may request that the calculation baseline be modified to be based on a location of the opening of the cooling water intake structure at a depth other than at or near the surface if you can demonstrate to the Director that the other depth would correspond to a higher baseline level of impingement mortality and/or entrainment."*

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

- The intake system includes a long intake canal rather than screens located at the shoreline; and
- Units 1 and 2 have fixed panel rather than traveling screens.

The suspended Phase II regulations allowed facilities to request that the calculation baseline be modified due to deviations from the calculation baseline if it could 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 pertains to flow reductions which occurred when the cooling water pumps for Units 3 and 4, rated at 48,000 gpm were replaced in 2005 with four smaller pumps, rated at 40,000 gpm, resulting in a 32,000 gpm decrease in flows. 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 HnGS 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.

Impingement sampling has been conducted at the HnGS since 2000. The impingement sampling methods used in this study are similar to the National Pollutant Discharge Elimination System (NPDES) monitoring program, but the sampling frequency has been increased to weekly to capture any seasonal variation and to collect additional data on diel variation.

The entrainment sampling was designed to reflect the uncertainties surrounding the use of restoration for compliance with the suspended §316(b) regulations. If the use of restoration was not allowed as a result of the court decision, the entrainment data would be used in baseline calculations of losses that would be required to estimate the commercial and recreational values of adult fish losses in a cost benefit analysis of various technology and operational alternatives being considered to comply with required reductions in entrainment mortality. Larval fish and shellfish abundances can vary greatly through the year and therefore biweekly sampling was used for characterizing entrainment. If the restoration option was upheld in the court decision, models of the conditional mortality due to entrainment could be used in designing appropriate restoration projects for offsetting entrainment losses. These models were based on proportional comparisons of entrainment and source water abundances and were 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 HnGS 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 impingement mortality and entrainment presented in other sections of the report. Section 3.0 also includes a description of the environmental setting for the plant including the physical oceanographic data used to support the boundaries of the source water potentially affected by the plant's CWIS. The methods and results for the entrainment and source water sampling are presented in Section 4.0 and the methods and results for the impingement sampling are presented in Section 5.0. The results from the entrainment and impingement sampling are integrated into an overall impact assessment for the HnGS CWIS in Section 6.0. The references used in the report are presented in Section 7.0. Appendices include detailed summaries of 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:

- <u>EPRI Solutions</u>
    - Input on sampling design
- <u>MBC Applied Environmental Sciences</u>
    - Study design

  - Field sampling
  - Impingement Mortality data entry and analysis
  - Reporting
- <u>Tenera Environmental</u>
  - 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
- <u>URS Corporation</u>
  - 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 HnGS is located on the coast of the Pacific Ocean in the City of Long Beach, California (Figure 3.1-1). The HnGS uses a once-through cooling water system for five of its generating units. Units 1 and 2 each have a rated capacity of 222 megawatts electric(MW), Unit 5 is rated at 341 MW, Unit 6 is rated at 259 MW, and Unit 8, which recently replaced Units 3 and 4, is rated at 235 MW. Units 9 and 10 are gas-fired turbines rated at 170 MW each. The total net generating capacity of HnGS is now 1,619 MW. For the years 2000 through 2004, the capacity factor of Unit 1 was 30%, Unit 2 had a capacity factor of 34%, Unit 5 had a capacity factor of 26%, and Unit 6 had a capacity factor of 17%. Unit 8 went into operation in December 2004 and underwent shakedown testing in early 2005. As a result, reliable capacity factor data for Unit 8 is not available. The HnGS withdraws 1,497.3 cfs (672,000 gallons per minute [gpm]) of cooling water when all units are in operation.

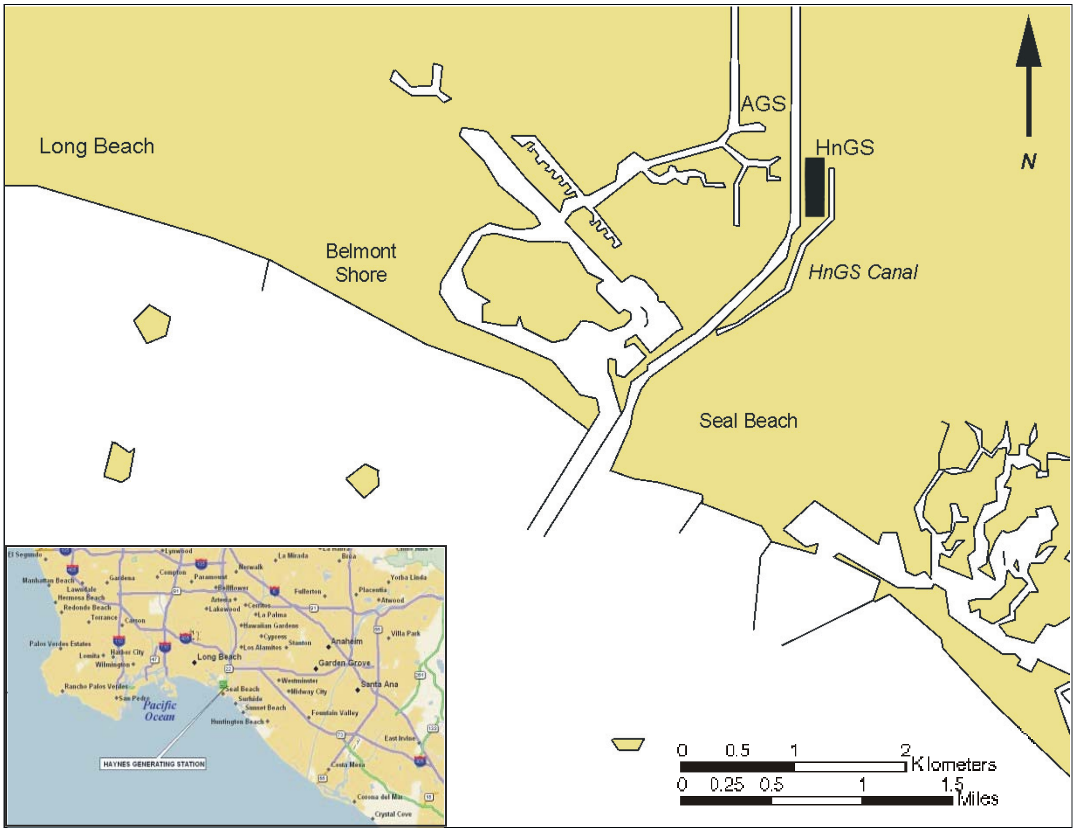


Figure 3.1-1. Location of the HnGS and AES Alamitos Generating Station (AGS).

3.2 DESCRIPTION OF THE COOLING WATER INTAKE SYSTEM

3.2.1 System Configuration and Operation

Circulating water for the five units is withdrawn from a single CWIS, located in the Long Beach Marina, about 2.4 kilometers (km) (1.5 miles) southeast of the facility. The normal depth of the marina at the site of the intake openings is 3 meters (m) (10 feet [ft]). There are seven intake openings in the marina's northwest facing bulkhead wall, below the gangways (Figure 3.2-1). Each opening is 2.3 m (7.5 ft) tall and 15.2 m (50 ft) wide. The upper edge of each opening is located at elevation (El. [relative to Mean Sea Level]) –0.6 m (2 ft), and the lower edge is at El. –2.9 m (9.5 ft). To keep large debris from entering the intake bays, 0.9 cm (3/8 inch) by 7.6 cm (3 inches) trash bars centered every 15.2 cm (6 inches) are located at the face of each intake bay. The calculated intake velocity at the marina opening is 0.5 meter per second (m/s) (1.6 ft). Each of the seven openings leads to a 2.4 m (8 ft) diameter conduit pipe that travels 335 m (1,100 ft) under the San Gabriel River into the intake channel. Only six of the intake tunnels are used during normal operation. Flow to the seventh pipe is blocked with stop logs to eliminate any biofouling. The velocities through the intake conduit pipes are 5.0 ft/s. The calculated velocity of the intake channel is 1.0 (3.2 ft) m/s. Intake structure characteristics, formulas, and velocity calculations for the HnGS CWIS are provided in Appendix B of the HnGS PIC.

A manmade, earthen intake channel runs 2.4 km (1.5 miles) along the east bank of the San Gabriel River to the screenhouses (Figure 3.2-2). The channel bottom is at El. –5.8 m (19 ft), and its upper banks rise to El. 2.4 m (8 ft). The width of the channel bottom is 9.1 m (30 ft), and the distance between the opposing banks is 50.3 m (165 ft). The end of the channel runs parallel to the east side of the plant. Along the channel, there are six screenhouses.

The Unit 1 and 2 screenhouses each have two screenbays with an invert El. –2.6 m (15 ft) and a top deck El. 2.0 m (6.7 ft) (Figure 3.2-3). Each screenbay is equipped with stationary screens. The screens are 3.0 m (10 ft) wide, and are made of 0.9 cm (3/8 inch) wire mesh. Circulating water pumps, two per unit, are located just downstream of the screens. The vertical, single-stage pumps are rated at 3.0 m^3 (107 ft^3) per second [48,000 gpm].

Units 5 and 6 withdraw water from separate, but identical, screenhouses, each with four traveling water screens. Each bay is about 2.7 m (9.0 ft) wide with an invert El. –5.2 m (17 ft) and a top deck El. 2.0 m (6.7 ft). The screens are 2.4 m (8.0 ft) wide with standard 0.9 cm (3/8 inch) square mesh and rotate at a speed of 1.54 revolutions per minute (rpm). There are two pumps for each unit located downstream of the traveling water screens. The vertical, single stage pumps for Units 5 and 6 are rated at 5 cubic meters (m^3) (178.2 ft^3) per second (80,000 gpm) each.

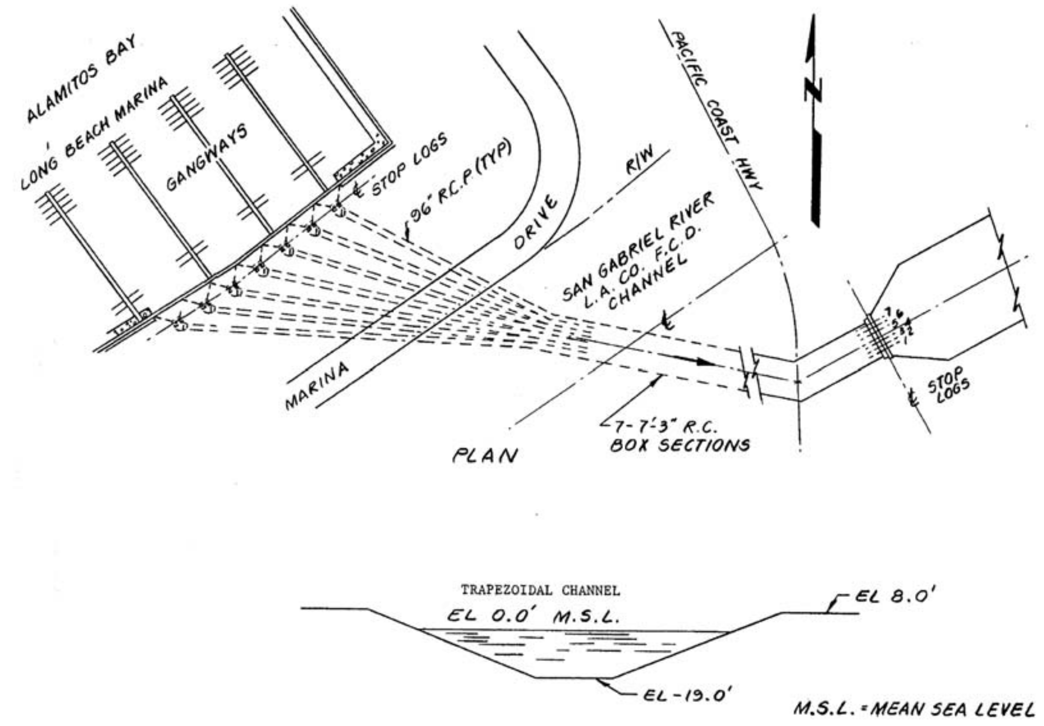
Unit 8 draws water from the two screenhouses formerly used by Units 3 and 4. Each screenhouse has two screenbays that are about 3.3 m (11 ft) wide with a bottom elevation of El. –4.9 m (16.0 ft) and a top deck at El. 2.0 m (6.7 ft). The bays are equipped with 3.0 m (10.0 ft) wide traveling water screens with 0.9 cm (3/8 inch) square mesh. The screens rotate at 1.4 rpm. Downstream of each screen is a circulating water pump. Each of these four pumps is rated at 2.5 m^3 (89.1 ft^3) per second (40,000 gpm).

Velocities at the screen bays were calculated to be 0.9 ft/s for Units 1 and 2, 0.3 m/s (0.8 ft/s) for Units 5 and 6, and 0.2 m/s (0.7 ft/s) for Unit 8 (formerly Units 3 and 4). All velocities were calculated at mean lower low water level (MLLW), El. -0.8 m (2.7 ft), and full flow conditions.

The screens for Units 5, 6 and 8 are usually washed once every eight hours. High-pressure nozzles (2.5 m^3/minute [400 gpm]) spray fish and debris from the screens. The debris travels through a debris trough and into a trash bucket at the north end of each structure for disposal. Circulating water is discharged through six conduits into three discharge stations. These stations discharge the water into the San Gabriel River flood control channel, which runs along the west side of the station. This channel is also used as the discharge for the AES Alamitos Generating Station. Downstream of the discharge point, the San Gabriel River enters the Pacific Ocean.

Marine growth control procedures (heat treatments) are performed periodically at some of the units to help prevent biofouling. This occurs by creating a semi-closed system in which the cooling water is allowed to recirculate through the system at a constantly maintained temperature of 46°C (115°F). In addition to marine growth control procedures, chlorine is injected into the system every eight hours at the rate of 0.2 kilograms (kg) (0.5 pounds [lbs]) per minute for 20 minutes.

At Units 1 and 2, backflushing is conducted periodically (usually once per shift) to prevent introduction of debris into the condenser systems. During backflushing, one of the two circulating water pumps is shut down, and a stoplog is partially inserted into the unit's discharge conduit. This shunts cooling water, forcing it to back up and back out the intake screens. Any debris built up on the screens is subsequently discharged into the intake canal. This process typically takes between five and thirty minutes.



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

Figure 3.2-1. Top view of the beginning of the Haynes Generating Station intake adjacent to the Long Beach Marina (not to scale).

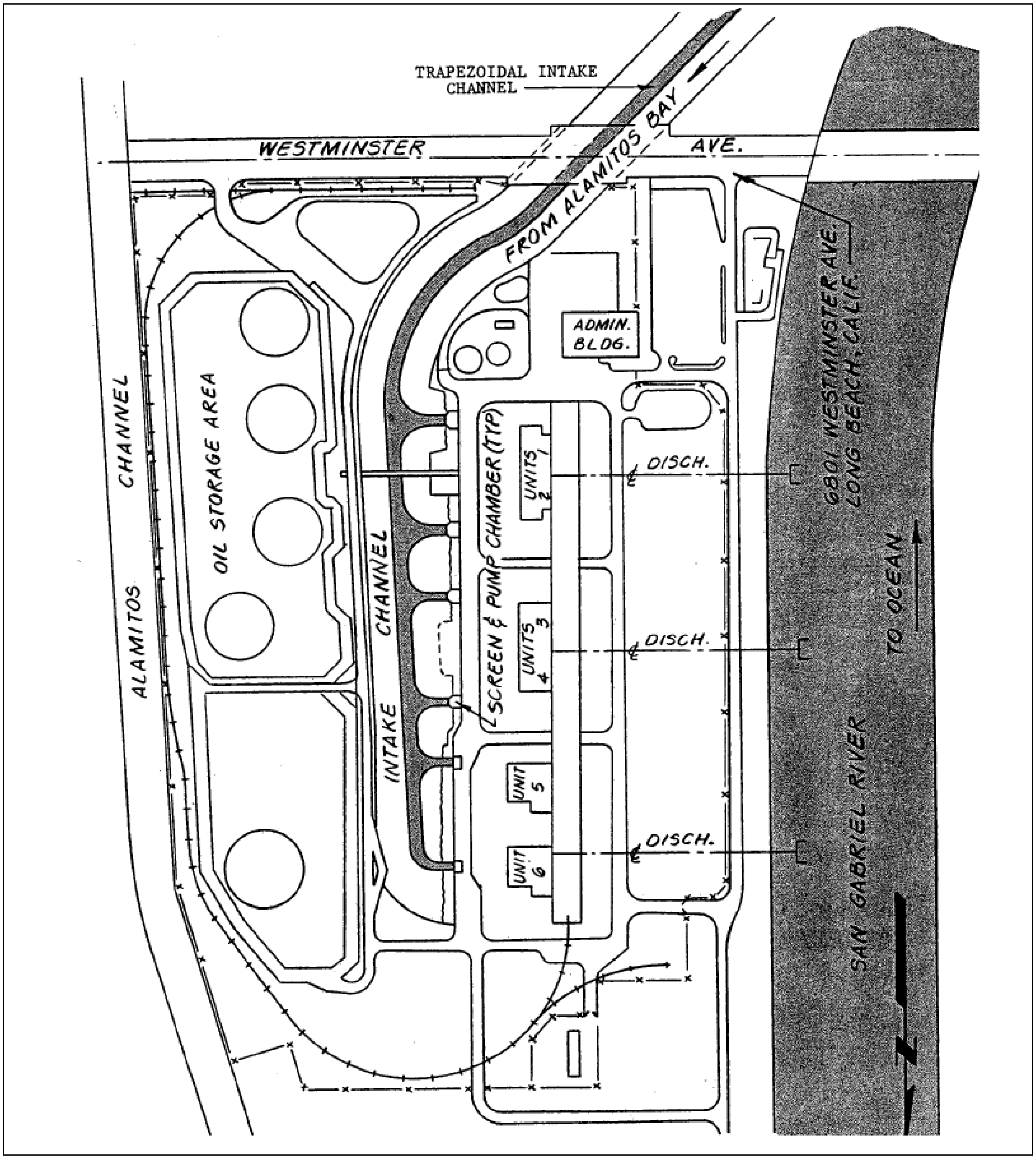
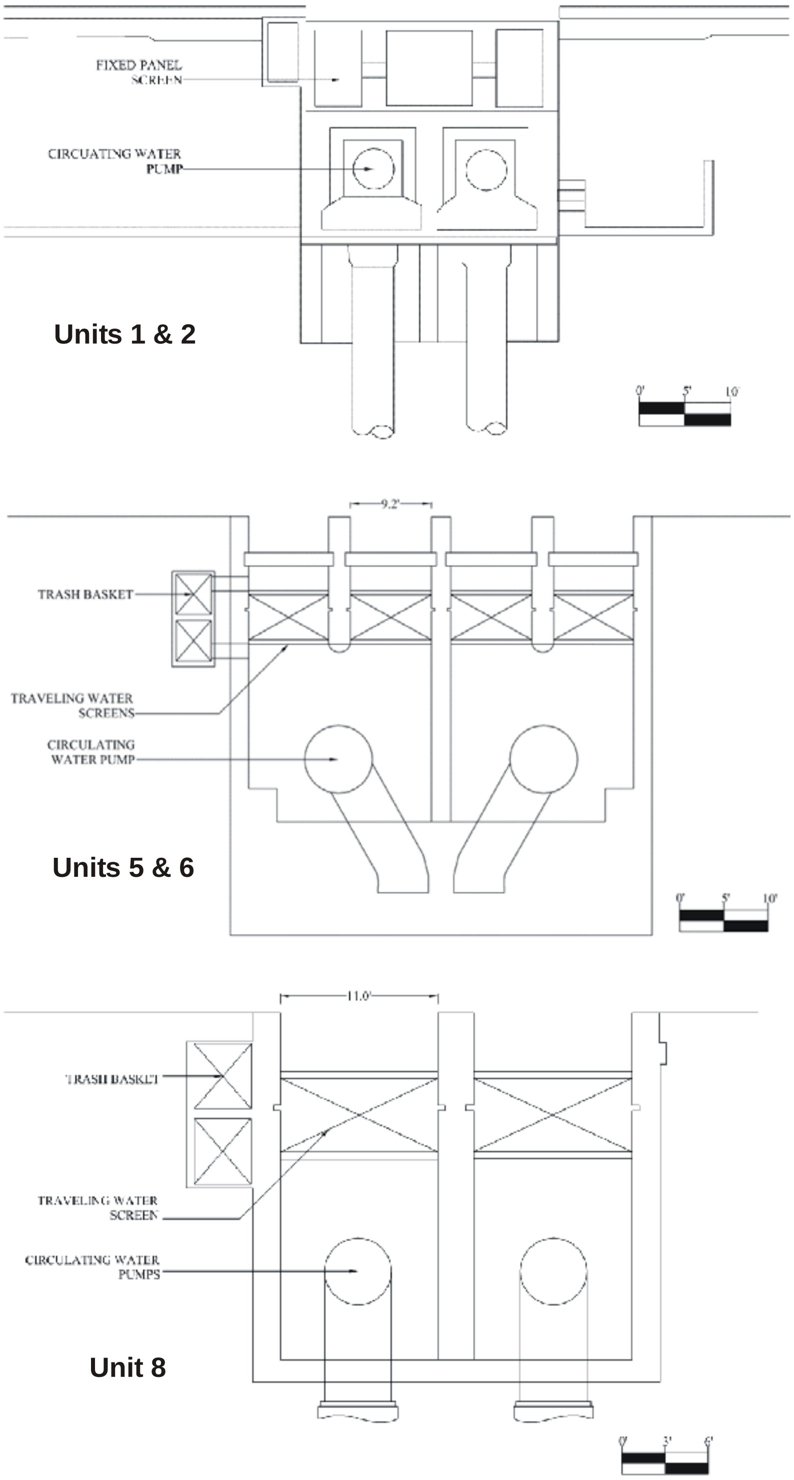


Figure 3.2-2. Site plan of the Haynes Generating Station (not to scale).



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

Figure 3.2-3. Plan view of Haynes Generating Station screenhouses.

3.2.2 Circulating Water Pump Flows

The HnGS CWIS withdraws 2,544 m^3 per minute (672,000 gpm) of cooling water from the Long Beach Marina when all units are in operation. Daily cooling water flow volumes at the HnGS during 2006 are depicted in Figure 3.2-4. Highest flows generally occurred in spring and summer, with facility flow greater than 99% of maximum during extended periods in May, July, and September. Lowest flows occurred in early July when Units 5 and 6 were not operating, and in mid-November when Units 5 and 8 were not operating. Daily cooling flow in 2006 averaged about 2,925,868 m^3 per day (773.0 mgd), or about 80% of maximum design flow (Maximum = 3,662,669 m^3 per day, or 967.7 mgd).

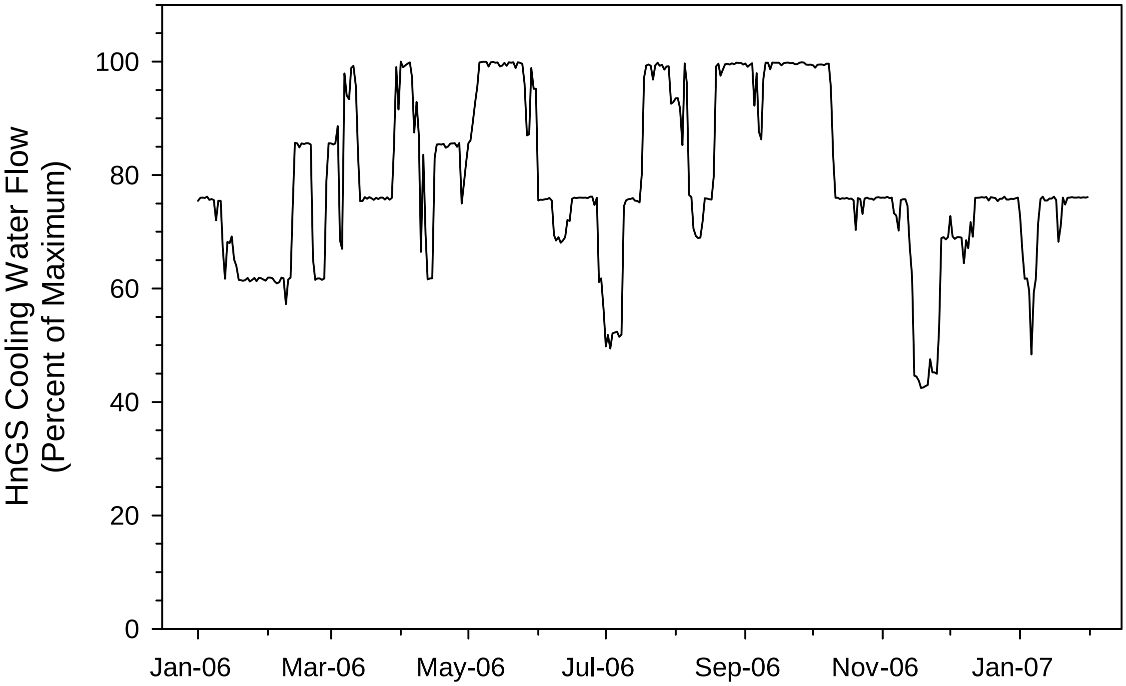


Figure 3.2-4. Daily cooling water flow volumes at the HnGS from January 2006 to February 2007.

Daily average cooling water flow was highest at Units 5 and 6, which have larger cooling water pumps than the other units (Table 3.2-1). Flows at Units 1 and 2 were similar to each other, and slightly higher than flows at Unit 8 (former Units 3 and 4).

Table 3.2-1. Daily average cooling water flow volumes by unit at HnGS in 2006.

	U1	U2	U8 (formerly U3)	U8 (formerly U4)	U5	U6
Daily average flow (m^3)	441,824	445,280	405,758	406,436	579,984	646,587
Daily average flow (gallons)	116,730,345	117,643,397	107,201,534	107,380,603	153,232,219	170,828,712
Percent of maximum	84.44	85.10	93.06	93.21	66.51	74.14

3.3 ENVIRONMENTAL SETTING

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

3.3.1 Physical Description

Alamitos Bay is a man-made, small-vessel harbor that was constructed at the mouth of the San Gabriel River, beginning mainly in the 1920s. Prior to this time, it was a seasonal estuary with extensive areas of tidal marshes and mud flats. Alamitos Bay is relatively shallow with water depths throughout most of the bay from 3.6–5.5 m (12–18 ft) MLLW. The bay is exposed to semidiurnal tides with a mean range of 1.1 m (3.6 ft). Sediments within the bay consist of sand, silt, and clay. Eelgrass (*Zostera marina*) is present at locations near the entrance channel, near the west end of Naples Island, and in the Marine Stadium arm of the bay (Valle et al. 1999).

The lower San Gabriel River empties into San Pedro Bay just downcoast, and adjacent to, the Alamitos Bay entrance jetty (Figure 3.3-1). The river originates in the San Gabriel Mountains, and historically flowed to the Los Angeles River. In 1867, flooding altered the river’s course, causing it to empty into Alamitos Bay. Catastrophic flooding in 1914 prompted flood protection measures on a basin-wide scale. During the 1920s, 1930s, and 1940s, several rivers, including the San Gabriel, were substantially dammed and channelized to prevent flooding and allow basin recharging. After this, most of the flow in the San Gabriel was reduced to the point that significant amounts of fresh water occurred in the lower reaches only during periods of rainfall.

3.3.1.1 Physical Features

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

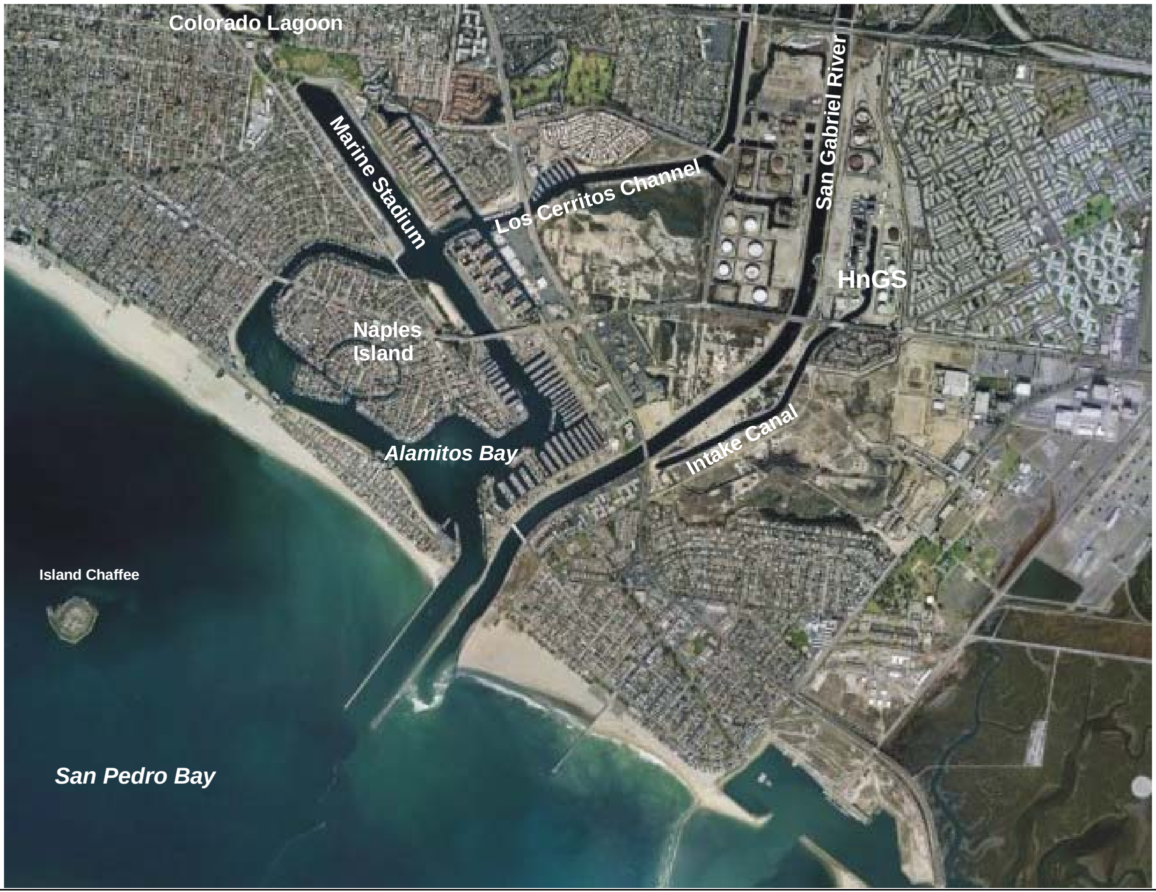


Figure 3.3-1. Aerial view of Alamitos Bay and San Gabriel River outlet vicinity.

Los Cerritos Channel is a flood control channel that connects with Alamitos Bay through the Marine Stadium. The tidal prism extends from Alamitos Bay to Anaheim Road. The channel was put on the USEPA 303(d) list of impaired water bodies by the LARWQCB due to elevated ammonia, sediment contamination, and elevated coliform levels (SWRCB et al. 1998). The AES Alamitos Generating Station withdraws cooling water from Los Cerritos Channel via two rock-lined canals. The Los Cerritos Wetlands are located at the point where Los Cerritos Channel joins Alamitos Bay. The wetlands currently consist of about 0.5 km^2 (130 acres) of wetlands, with nearly 3.2 km^2 (800 acres) of degraded wetland habitat proposed for restoration. Historically the wetlands consisted of about 9.7 km^2 (2,400 acres) and included what is now Alamitos Bay. Since much of the site was modified due to former oil development activities, most of the land was privately held. In 2006, the California Coastal Conservancy was one of several agencies that purchased 0.3 km^2 (66 acres) of the wetlands, and hopes to acquire more.

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

3.3.1.1.1 Climate and Weather

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

A subtropical high-pressure system offshore the Southern California Bight, defined as the nearshore coastal areas 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 km/hr (6 miles/hr). Wind speeds diminish with proximity to the coast, averaging about one-half the speeds offshore. Coastal winds in southern California are about one-half those found off central and northern California. However, strong winds occasionally accompany the passage of a storm. A diurnal land breeze is typical, particularly during summer, when a thermal low forms over the deserts to the east of the Los Angeles area. On occasion, a high-pressure area develops over the Great Basin, reversing the surface pressure gradient and resulting in strong, dry, gusty offshore winds in the coastal areas. These Santa Ana winds are most common in late summer, but can occur any time of year.

3.3.1.2 Temperature and Salinity

Waters within Alamitos Bay are primarily marine (30–35 practical salinity units [PSU]) with water temperatures ranging from about 13°C (55°F) in winter to 25°C (77°F) in summer (Allen and Horn 1975; IRC 1981). The bay has undergone extensive changes in the last 100 years. Originally an estuary and wetland system prior to the 1920s, it is now highly developed.

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

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

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

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

Additional water quality monitoring was performed at the HnGS intake structure during spring and summer (April–June) 2004 (MBC 2004). Water temperatures at the surface and a depth of one meter ranged from about 17.9°C (64.2°F) to 21.4°C (70.5°F) during sampling, with little or no difference between the two depths. Salinity consistently ranged between 33.2 and 34.2 PSU.

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. The tidal prism of Alamitos Bay (defined as the body of water contained within the mean tidal range) is approximately 1.96 x 10^6 m^3 (517.8 million gallons) (IRC 1981).

3.3.1.3.1 Historical Overview

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

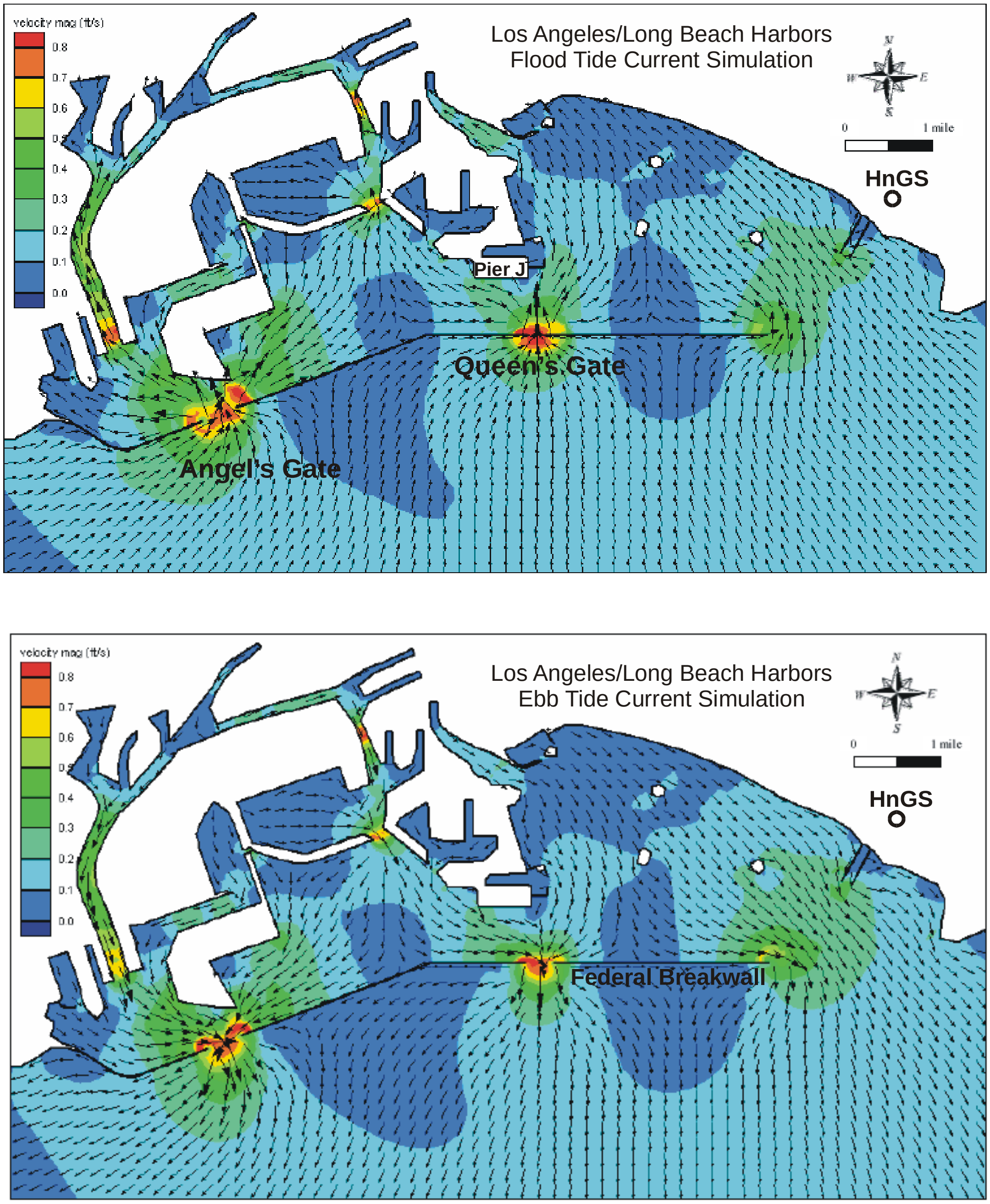
At the entrance to Alamitos Bay, currents are bi-directional, with a strong bias toward in-flowing over out-flowing currents, and speeds ranging to about 40 centimeters per second (cm/s) (1.4 feet per second [ft/s]) (IRC 1981). Current speeds diminish in mid-bay, with most current speeds less than 20 cm/s (0.7 ft/s). At the HnGS intake structure in Long Beach Marina, surface waters flow away from the intake structure approximately one-third of the time; however, mid-depth or below, waters flow directly toward the intake approximately 80% of the time.

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

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

Maximum flood and ebb current patterns in the Ports of Los Angeles and Long Beach under typical tidal conditions are shown in Figure 3.3-2. A depth-averaged two- dimensional hydrodynamic model, RMA2, developed by the US Army Corps of Engineers was used to predict the tidal currents shown in the figures. The model was calibrated against field data collected by 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 and HnGS, 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 as a potential flow toward the exits. Ebb currents leaving the Los Angeles Harbor flow mainly through the Angel's Gate. On the Long Beach side, ebb currents exit either through the Queen's Gate or the eastern opening passing the tip of the Federal Breakwall. Tidal currents within the Ports of Los Angeles and Long Beach are generally very small. Typical maximum tidal currents within the harbor are in general less than 0.5 ft/s. Tidal currents entering and exiting Angel's Gate and Queen's Gate are higher, but are still in general less than 0.8 ft/s. Significant offshore flows from flood control channels such as the San Gabriel River can also occur during winter storms.



Note that the scales used in the figures are in feet and do not include metric conversions. (Figures from Los Angeles CSTF [2005]).

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

3.3.1.3.2 2006 ADCP Deployments

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

Table 3.3-2. ADCP deployment parameters for current meters in the vicinity of HnGS (Stations CM 1 and CM 2).

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

Figure 3.3-3 shows the net displacements at the current meter stations from January 2006 to January 2007 relative to the current meter locations. The net displacement of water at Station CM 1 was to the north and to a lesser extent to the east. At Station CM 2 net displacement varied east to west and slightly south. The sum of the hourly upcoast components of each current measurement was maximized to estimate a rotation of 39º at Station CM 1. This rotation oriented alongshore currents to 321º true. After rotating current velocities and averaging over the water column, plots of cumulative current vectors showed that currents at the inshore station (CM 1) moved predominantly in an upcoast and onshore direction during 2006 with few seasonal reversals (Figure 3.3-4). Small-scale changes in net direction may be attributed to tidally induced currents flowing into and out of the Los Angeles-Long Beach Harbor complex. In contrast, currents at Station CM 2 located outside of the Long Beach Breakwater and in slightly deeper water than the inshore station displayed frequent upcoast-downcoast reversals (Figure 3.3-5). Net downcoast currents prevailed in January–April 2006 and in October 2006–January 2007, whereas net upcoast transport occurred from May–September 2006 but with frequent reversals during summer months. Over the year net transport was downcoast at CM 2. Current vector frequencies, water temperatures and tidal elevation

data from the ADCP units are presented in Appendix A as monthly plots for each station. Over the year water depths at CM 1 varied from 11.75 m (38.6 ft) to 14.59 m (47.9 ft) with an average of 13.27 m (43.6 ft). At CM 2 water depths varied from 15.64 m (51.2 ft) to 18.41 m (60.4 ft) and averaged 17.09 m (56.1 ft).

The extent of source populations of larval organisms was estimated from December 2005 to January 2007 using a combination of cross-shelf and alongshore components from the two stations, and with reproduction of December 2006 and January 2007 data for the data missing in December 2005 and early January 2006. A combined plot of data from the two locations using the upcoast-downcoast vector from CM 1 and the onshore-offshore vector from CM 2 showed a net upcoast transport direction with a slight onshore component (Figure 3.3-6). Estimates of source populations were therefore based on a combination of currents measured at the two stations and also subject to the rotations that were used to estimate alongshore and onshore water excursions.

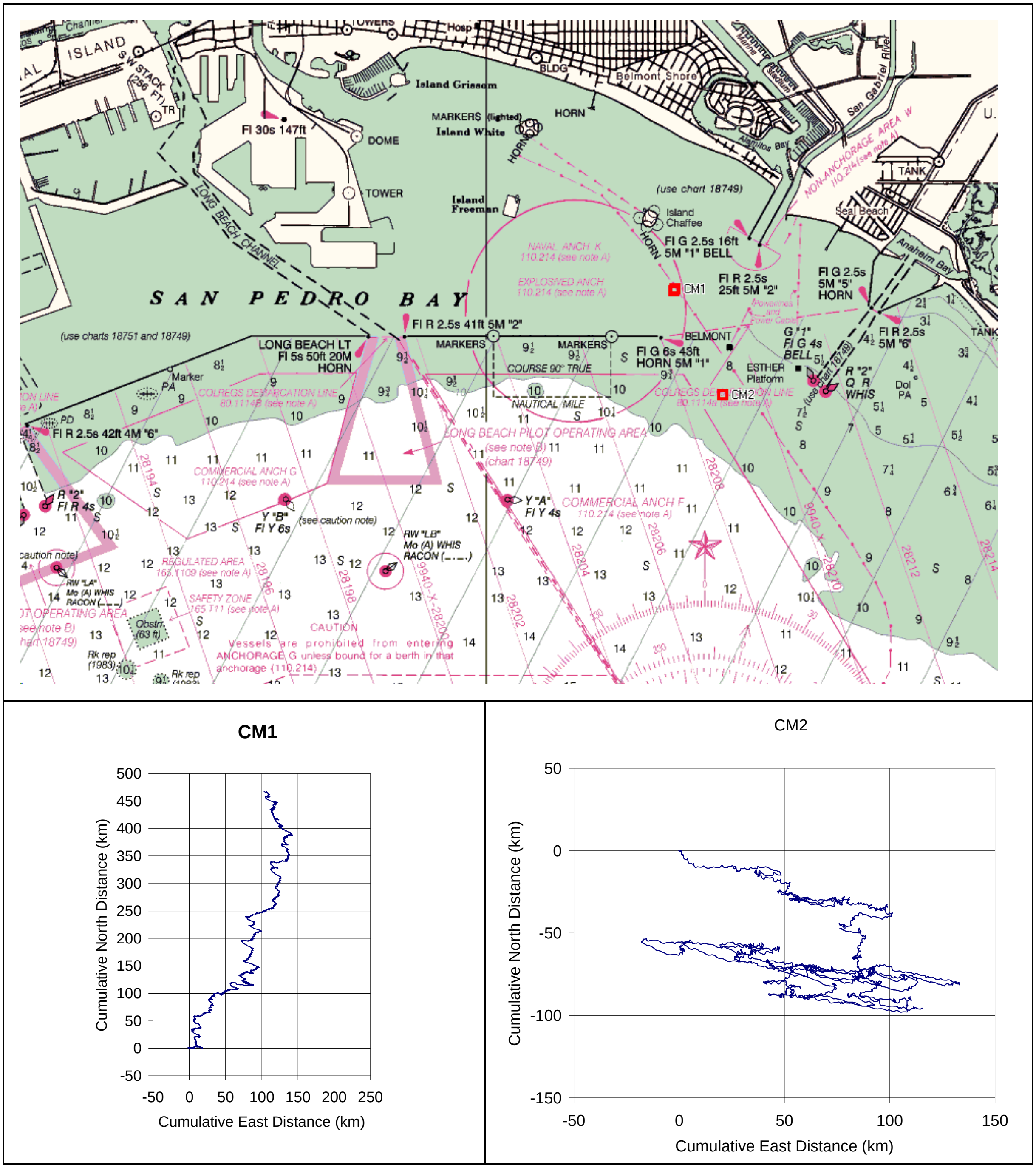


Figure 3.3-3. Net displacement at current meter stations CM 1 and CM 2 from January 2006 to January 2007.

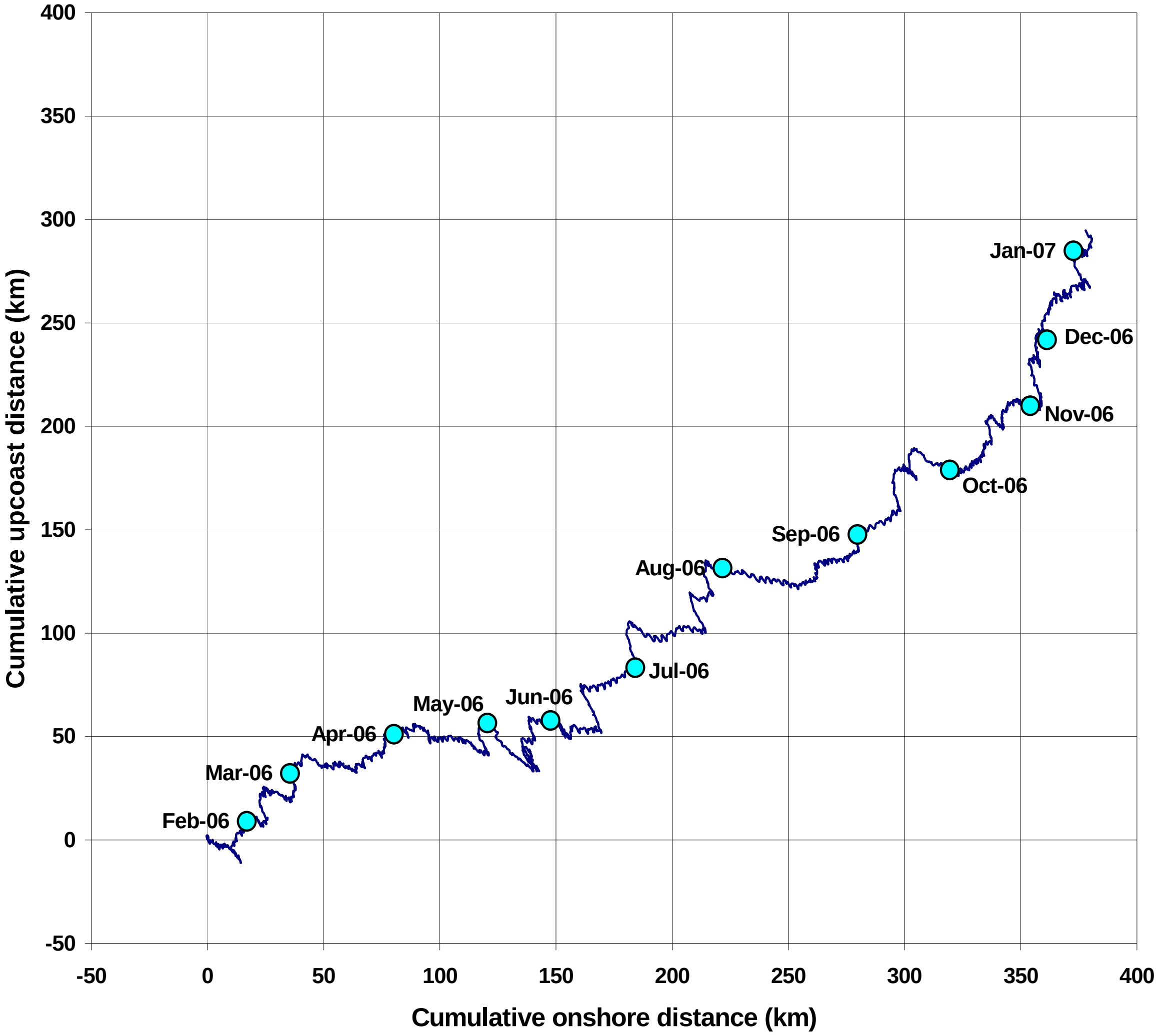


Figure 3.3-4. Cumulative current vectors from Station CM 1 in San Pedro Bay from January 2006 to January 2007.

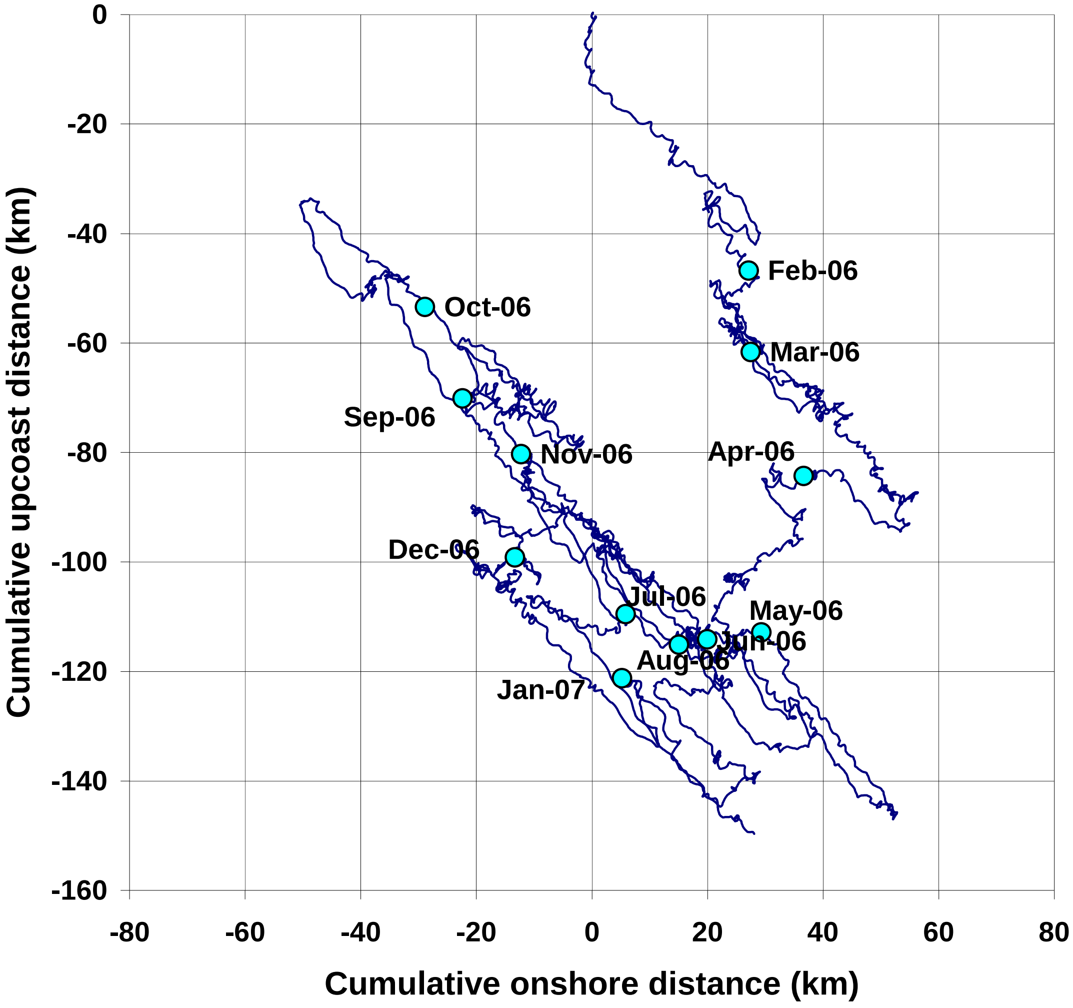
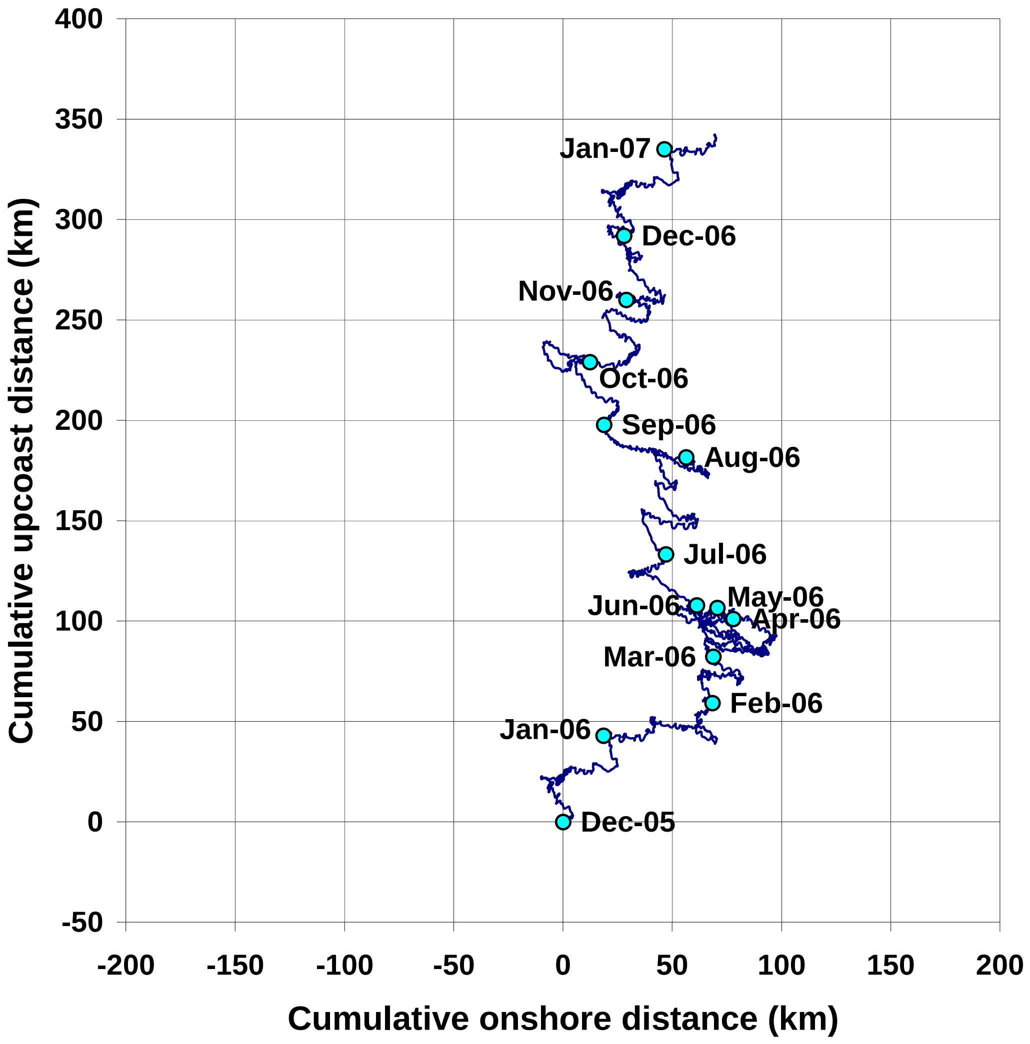


Figure 3.3-5. Cumulative current vectors from Station CM 2 in San Pedro Bay from January 2006 to January 2007.



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

Figure 3.3-6. Composite cumulative current vectors from Stations CM 1 (upcoast) and CM 2 (onshore) in San Pedro Bay from January 2006 to January 2007.

3.3.2 Source Water Definition

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

3.3.2.1 Study Requirements and Rationale

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

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

3.3.2.2 Methods for Calculating HnGS Source Water

Two sources were used in gathering the data necessary for estimating the volume of Alamitos Bay and the nearshore source water stations. The inshore and nearshore bathymetry data were from Moffatt & Nichol (2004) and from NOAA ENC chart data. Some editing of these data was done to more closely match the depths and elevations derived from NOAA navigation data that included coverage for the entire harbor and surrounding ENC charts. NOAA used a number of sources in compiling these data including U.S. Army Corps of Engineers surveys, drawings, and permits, U.S. Coast Guard Local Notices to Mariner, National Imagery and Mapping Agency Notices to Mariners, NOAA hydrographic surveys, and the largest scale paper chart of an area. Depth data points were identified and selected from the source datasets that fell within the water portions of the source water area. This area was identified using a coastline Geographic Information System (GIS) layer created from a U.S. Geological Survey topographic quad map at 1:24,000 scale and manually edited in ArcGIS to approximate the available NOAA GIS coastline themes and latest aerial images from Google Earth (March 2004). MLLW depths were adjusted to MSL (shallower by 0.86 m (2.8 ft) per the tide gauge at Station 9410660 Los Angeles, CA). The corrected depth data were merged and exported to a new depth point GIS layer relative to MSL. A 20 m (65.6 ft) surface grid representing the bathymetry relative to MSL was constructed from this new set of combined points resulting in contours at 1 m (3.3 ft) intervals. The resulting bathymetry surface grids were then converted into a polygon shapefile, clipped to the coastline, boundary of the source water, and used for area and volume calculations.

The Alamitos Bay source water region consisted of two areas: 1) an inshore area including the Alamitos Bay waters inshore, northeast of the coastline, and portions of Colorado Lagoon, and Los Cerritos Channel, and 2) the 0.4 km (1.5 mile) long Haynes Intake Canal (Figure 3.3-7). The volume of the intake canal was calculated as 330,237 m^3 (87.2 million gal) based on cross-sectional engineering drawings of the canal indicating a bottom depth of –5.8 m (19 ft) MSL, bottom width of 9.1 m (30 ft), and distance between opposing banks of 50.3 m (165 ft) at an elevation of 2.4 m (8.0 ft) MSL (see Figure 3.2-1).

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

The three components of the source water are used with the estimates of larval entrainment and HnGS CWIS flows to calculate impacts on larval fish populations due to entrainment, as described in Section 4.3.4.3 - Empirical Transport Model.

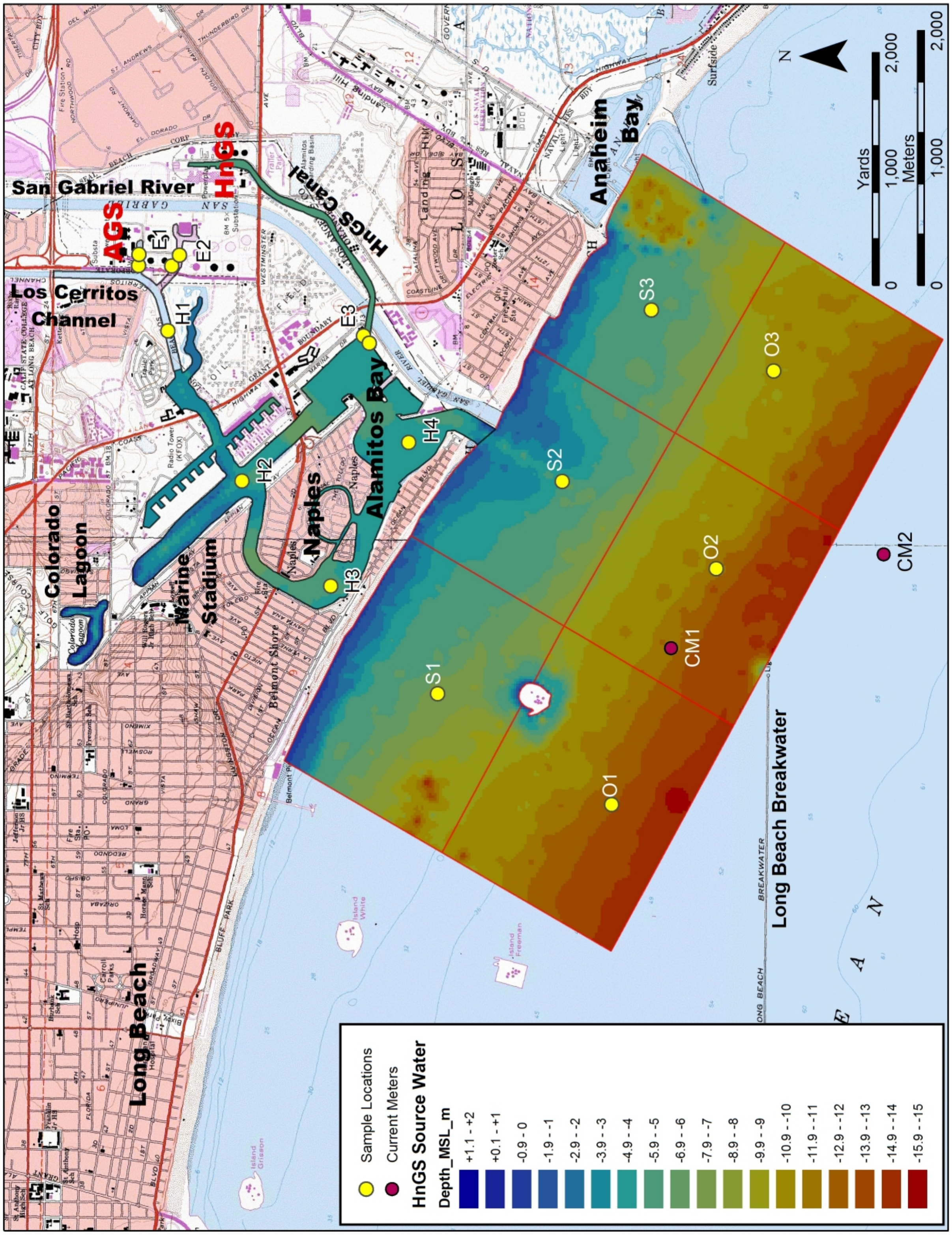


Figure 3.3-7. Source water boundaries and bathymetry defined for ETM modeling effects of HnGS.

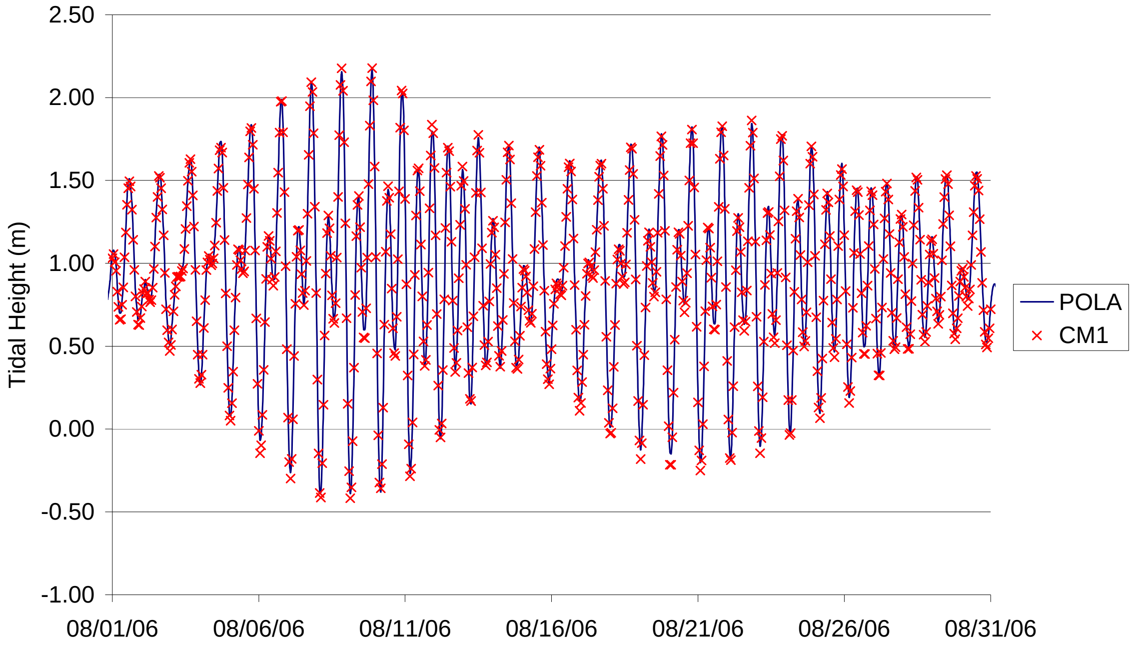


Figure 3.3-8. Correspondence of tidal heights estimated at Station CM 1 and at Port of Los Angeles Outer Harbor (POLA), August 2006.

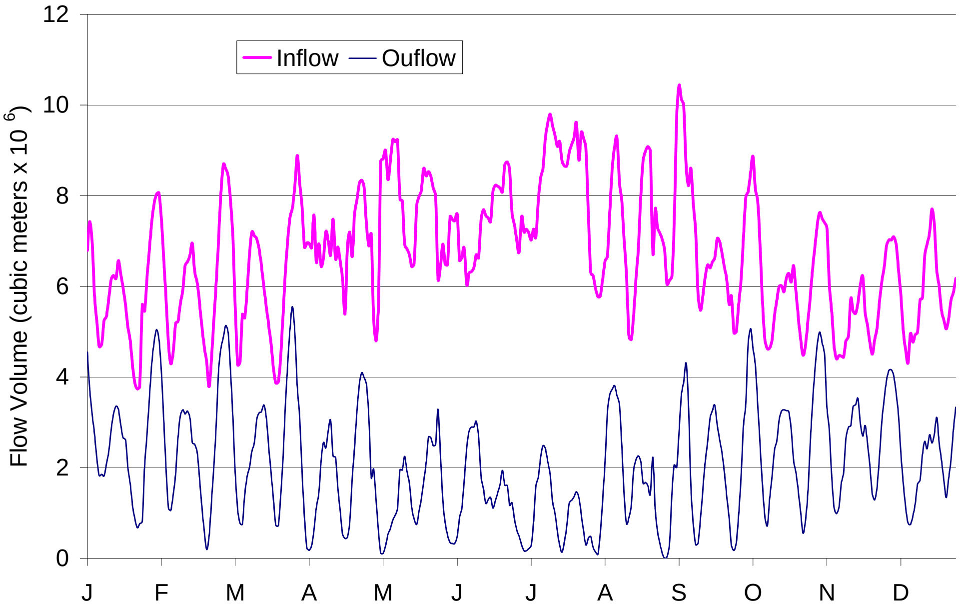


Figure 3.3-9. Estimates of Alamitos Bay daily tidal inflow and outflow volumes from January to December 2006.

3.3.3 Biological Resources

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

3.3.3.1 Habitat Variation

Subtidal sediments in Alamitos Bay consist primarily of sand and mud, and waters are primarily saline (Allen and Horn 1975). Subtidal vegetation (eelgrass [*Zostera marina*]) is present at locations near the entrance channel, near the west end of Naples Island, and in the Marine Stadium arm of the Bay (Valle et al. 1999). Depths throughout most of the bay are shallow, ranging from 3.6–5.5 m (12–18 ft). Most of the shoreline is developed, and consists of hard intertidal and subtidal substrates, such as concrete bulkheads and piers. Long Beach Marina consists of numerous floating docks, including several in the vicinity of the HnGS bulkhead intake structure (Figure 3.3-10). The HnGS intake is submerged under the concrete walkway at left.

Figure 3.3-10. View of Long Beach Marina and HnGS intake structure below water surface along concrete bulkhead.

3.3.3.2 Nursery Grounds

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

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

3.3.3.3 Fish Diversity

Bay and estuarine fish assemblages in California tend to be dominated in abundance by few (usually five or less) species and have low diversity even though many other species are typically encountered (Allen et al. 2006). A total of 44 fish species were documented from Alamitos Bay by Allen (1976), and 46 taxa were collected by Valle et al. (1999) (see Section 3.3.2.2). In the Colorado Lagoon are of the Bay, four species comprised 99% of the total abundance: northern anchovy (*Engraulis mordax*), topsmelt, slough anchovy (*Anchoa delicatissima*), and shiner perch (Allen and Horn 1975). Species diversity and abundance at Colorado Lagoon were highest during summer (May–September) and both were highly correlated with water temperature, which ranged between 12.8–25.0°C (55–77°F).

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

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

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

Between April and July 2004, at least 13 larval fish taxa from 11 families were collected from the HnGS intake structure, and at least 10 larval fish taxa from nine families were collected from the AES Alamitos intake canals (MBC 2004, 2005). At the HnGS intake, combtooth blennies (*Hypsoblennius* spp.), gobies, and silversides accounted for 93% of the larval densities, while gobies and blennies accounted for 97% of the density at Alamitos. At HnGS, topsmelt and northern anchovy each represented an additional 2% of the total larval density. Combtooth blennies were the dominant taxa during the first half of the study, with goby densities increasing substantially from late May to June. Nearly all of the goby and blenny larvae were preflexion, indicating they were in the relatively early stage of larval development. Overall, nighttime larval densities were significantly higher than daytime densities. Two California spiny lobster phyllosoma were also collected during the study.

3.3.3.4 Shellfish Diversity

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

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

3.3.3.5 Protected Species

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

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

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

California grunion is a species with special status not because the population is threatened or endangered, but because their spring-summer spawning activities on southern California beaches puts them at risk of over harvesting, and CDFG actively manages the fishery to ensure sustainability. Spawning occurs only three or four nights following each full or new moon, and then only for 1–3 hours immediately after the high tide, from late February to early September (Love 1996). The female swims onto the beach, digs tail-first into the wet sand, and deposits her eggs, which are then fertilized by the male. After the eggs hatch, the larvae are carried offshore and can be susceptible to entrainment for approximately 30 days as they develop in the plankton.

Off southern California, the species 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 collie*i), finescale codling (*Antimora microlepis*), Pacific rattail (*Coryphaenoides acrolepis*), three species of sharks, three skates, six species of groundfish, 62 species of scorpionfishes and thornyheads, and 12 species of flatfishes. For both the Coastal Pelagics and Pacific Groundfish, essential fish habitat (EFH) includes all waters off southern California offshore to the Exclusive Economic Zone.

4.0 COOLING WATER INTAKE STRUCTURE ENTRAINMENT AND SOURCE WATER STUDY

4.1 INTRODUCTION

The entrainment study incorporates two design elements: 1) CWIS sampling, and 2) source water sampling. Sampling at the intake provides estimates of the total numbers of each larval species entrained through the CWIS on a biweekly basis depending on pumping capacity. The source water populations of fish and shellfish larvae were sampled to estimate proportional entrainment (*PE*) losses for selected species. Abundances of larval fishes and shellfishes vary throughout the year due to changes in composition and the oceanographic environment. Because it is desirable from an impact modeling standpoint to have a higher resolution of temporal changes in the composition of entrained taxa than source water taxa, entrainment sampling was conducted biweekly while source water sampling was conducted monthly. The 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 HnGS?
- What are the local species composition and abundance of the entrainable larval fishes, fish eggs, crab megalops, and spiny lobster larvae in Alamitos Bay and adjacent nearshore areas?
- What are the potential impacts of entrainment losses on these populations due to operation of the CWIS?

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

4.1.1 Discussion of Species to be Analyzed

Planktonic organisms in the source water body that are smaller than the CWIS screening system mesh (0.9 cm [3/4 in]) are susceptible to entrainment. These include species that complete their entire life cycle as planktonic forms (holoplankton) and those with only a portion of their life cycle in the plankton as eggs or larvae (meroplankton). This study estimated entrainment effects on meroplanktonic species including all fish eggs and larvae, and the advanced larval stages of several invertebrate species including all crabs, market squid (*Loligo opalescens*), and California spiny lobster (*Panulirus interruptus*). None of the holoplanktonic forms (such as copepods) were enumerated because these populations are typically widespread over large oceanic areas and the species have short generation times resulting in very low potential for population-level impacts. All target taxa in the samples were identified to the lowest practical taxonomic level, but some specimens were combined into broader taxonomic groups because the morphological characteristics of some species are not distinct at smaller stages, descriptions are lacking for some of the larvae (particularly for many of the crab megalops), or specimens were damaged and could not be positively identified. Although all target taxa specimens were enumerated in the samples, including uncommon species and those with no direct fishery value, detailed impact analysis was only applied to a few of the more abundant species or species-groups, in addition to the specific shellfish taxa (spiny lobsters, market squid) regardless of abundance.

4.1.1.1 Fish

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

4.1.1.2 Shellfish

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

4.1.1.3 Protected Species

Larvae and eggs of some species protected under Federal, State, or Tribal Law (discussed in Section 3.3.3.5–*Protected Species*) 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 sampling. At the January 30 meeting, NMFS staff agreed that demographic or *ETM* calculations would only be done for species that were collected in sufficient abundance in entrainment and source water samples, and if sufficient life history information was available to permit those calculations. Although calculations of these models can be done provided the appropriate life history data exist, the level of uncertainty associated with the estimates is very high unless a species is collected in adequate numbers during several surveys. Of the taxa on the list only northern anchovy (*Engraulis mordax*) was in sufficient abundance at HnGS 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 HnGS in 1978–79 (IRC 1981) focused on sampling ‘critical taxa’ which provided representative information regarding the effects of the generating station on the marine community, based upon criteria described in Federal and State 316(b) Guidelines at the time (USEPA 1977). These taxa were defined as those that can or do support fisheries, provided significant habitat to aquatic communities, or constitute significant trophic links. Within this framework, critical taxa were selected using information obtained from literature reviews, prior field experience in the region, and data collected during sampling efforts conducted for a preliminary report. The critical taxa list for larval fishes was reviewed by the CDFG and submitted to the LARWQCB for approval.

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 San Pedro Bay and the near-field station in Alamitos Bay. The primary entrainment station (E1) was located at the intake structure. Another entrainment station was also located at the screens of selected units of the generating station to measure differences in plankton concentrations between the entrance and terminus of the 2.4 km (1.5 mile) intake canal, and provide data for survival studies of plankton transiting the HnGS cooling water system.

Table 4.2-1 summarizes the entrainment densities of critical taxa recorded at Station E1 over the 12-month study. The mean cooling water flow rate at the generating station varied from 1,892,500 – 3,406,500 m^3 per day (500–900 mgd) during the study. Combtooth blennies had the greatest concentrations in the entrainment samples with densities averaging 4,000 larvae per 1,000 m^3 (264,172 gal). This translated to an annual entrainment mortality of 4.4 billion larvae for combtooth blennies. Entrainment estimates for all of the critical taxa combined was 8.46 billion larvae annually. Croakers had an annual entrainment estimate of 2.6 billion eggs while northern anchovy egg entrainment was estimated at 230 million eggs annually.

The period of maximum larval abundance for most taxa occurred from December through early July. Gobiid larvae, however, were present all year and displayed no pronounced seasonality. Fish eggs were enumerated for 3 taxa: northern anchovy, *Anchoa* spp. (bay anchovies), and the Sciaenid (croaker) species complex (Table 4.2-1). The greatest numbers of entrained northern anchovy eggs were in February, with another peak in summer months. *Anchoa* spp. was relatively scarce in samples compared to densities that had been recorded in other southern California bays.

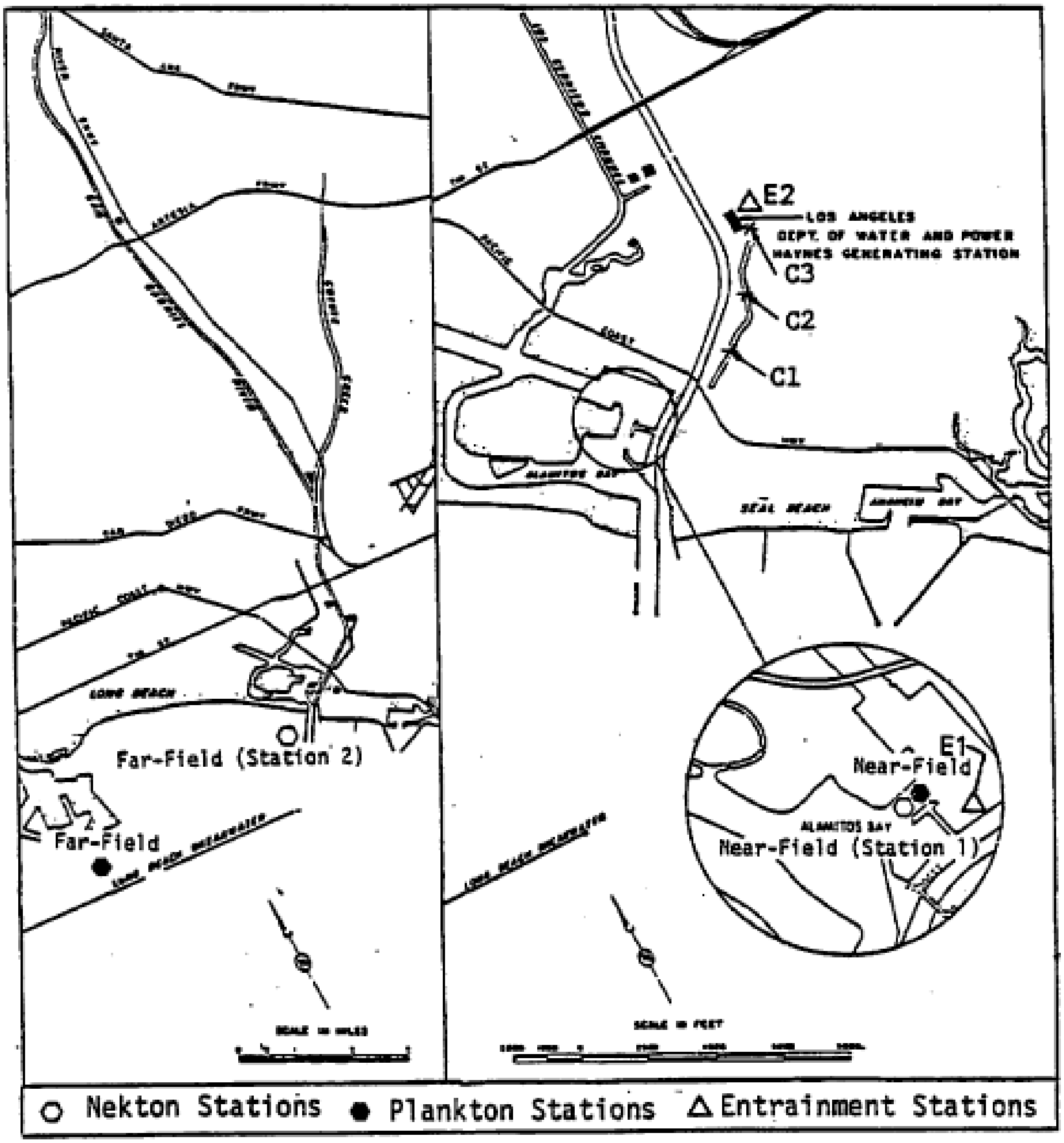


Figure 4.2-1. Locations of entrainment, near-field and far-field sampling stations for 1978–79 316(b) study [figure from IRC (1981)].

Non-critical fish larvae were identified and enumerated to provide additional information about the ichthyoplankton community but these data were not statistically analyzed. Unidentified teleost larvae occurred in samples from 84% of the day surveys and 92% of the night surveys. Maximum concentrations were observed for the period between mid-December and mid-June and lowest values were observed for the summer through mid-winter. Mean concentrations values varied from 0–230 larvae per 1,000 m^3 (264,172 gal) for the day surveys and from 0–390 larvae per 1,000 m^3 (264,172 gal) for the night surveys. Average concentrations during the night exceeded daytime values for 80% of the surveys.

Table 4.2-1. Summary of larval fish and fish egg densities, and annual entrainment mortality estimates for critical taxa for HnGS in 1979−1980 (from IRC 1981).

Taxon	**Common Name**	**Mean Day Concentration (#/1,000m^3)**	**Mean Night Concentration (#/1,000m^3)**	**% Freq. (Day)**	**% Freq. (Night)**	**Entrainment Estimate (# /year)**
Larval Fishes						
Atherinopsidae	silversides	<10	<10	12	35	1.2×10^7
Engraulidae	anchovies	190	930	72	88	5.8×10^8
Gobiidae	gobies	2,500	3,450	100	100	3.2×10^9
Hypsoblennius spp.	combtooth blennies	4,070	3,910	88	92	4.4×10^9
Genyonemus lineatus	white croaker	190	240	52	65	2.1×10^8
Seriphus politus	queenfish	50	70	36	42	5.3×10^7
Pleuronichthys guttulatus	diamond turbot	<10	<10	16	19	4.9×10^6
Fish Eggs						
Engraulis mordax	northern anchovy	450	390	48	50	2.3×10^8
Anchoa spp.	bay anchovies	10	10	28	23	1.2×10^7
Sciaenid complex	croakers	2,120	2,990	80	96	2.6×10^9

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

Concentrations were also calculated for several ‘critical’ planktonic invertebrate taxa, including four species of mysid shrimps, larval rock crab, larval ghost shrimp, and the adults and larvae of one species of copepod. *Acartia* spp. copepodites (larval stage) were the most abundant of the critical taxa and were present year-round. These eight taxa accounted for estimated annual losses of 2.24 trillion organisms from the HnGS cooling water intake system, assuming 100% through-plant mortality.

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

Taxon	**Common Name**	**Mean Day Concentration (#/1,000m^3)**	**Mean Night Concentration (#/1,000m^3)**	**% Freq. (Day)**	**% Freq. (Night)**	**Entrainment Estimate (# /year)**
Acartia spp. (adult) [a]	copepods	1,104,860	1,369,600	100	100	8.1×10^{11}
Acartia spp. (larvae) [a]	copepods	1,880,300	1,903,770	100	100	1.3×10^{12}
Cancer spp. (zoeae)	rock crabs	590	640	77	77	5.1×10^8
Neotrypaea spp.	ghost shrimp	18,360	41,180	100	100	2.7×10^{10}
Acanthomysis necropsis	mysid shrimp	4,720	21,060	92	96	1.2×10^{10}
Neomysis kadiakensis	mysid shrimp	90	1,200	36	58	8.4×10^8
Metamysidopsis	mysid shrimp	22,420	168,410	96	96	8.6×10^{10}
Mysidopsis spp.	mysid shrimp	30	320	24	62	1.8×10^8

[a] *densities based on 202 µ net collections from January–September 1979.*

Note: A volume of 1,000 is equal to 264,172 gallons.

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

- The seasonal period of highest overall abundance occurred from January through June, with the exceptions of *Acartia spp.* and gobiid larvae, which were 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. The ghost shrimp *Callianassa* spp., mysids, sciaenid eggs, Engraulid species complex larvae, and Gobiid species complex larvae were significantly more abundant at night than during the day. Upward movement of zooplankton and ichthyolarvae through the water column at night can result in an increased susceptibility to entrainment.
- With the exception of *Hypsoblennius* spp. larvae, larger sized larvae were collected with greater frequency at night. Spawning peaks were evidenced by large influxes of small larvae. Surveys following spawning peaks generally showed increasingly greater proportions of later stage (larger) larvae.

4.2.2 Relevance to Current Conditions

The operations and configuration of the HnGS cooling water system have remained largely unchanged since all units went into service with the exception of the replacement of the cooling water pumps at Units 3 & 4 (now Unit 8). Therefore, changes in entrainment through time are most likely due to natural biological changes and not due to substantial changes in cooling water flow. Flow during the 1978–1979 study averaged about 2,802,487 m^3 per day (740 mgd), or 73% of the design flow (IRC 1981). From 1982 to 1995, cooling water flow averaged 2,751,695 m^3 per day (727 mgd) (MBC 1997). Flow during the 2006 study averaged about 2,925,870 m^3 per day (773 mgd), or 80% of current design flow, which is less than design flow in the previous study due to the replacement of cooling water pumps at Units 3 & 4.

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 entrainment samples in the earlier study in contrast to the towed plankton net used in the present study. Even though there may be some systematic bias in each type of sampling method, 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 HnGS was determined by sampling in the immediate proximity of the cooling water intake (Station E3, Figure 4.3-1) every two weeks from January through December 2006. During the previous 316(b) demonstration, horizontal inflow at the intake structure was measured at all intake depths (-0.6 to –2.9 m [-2 ft to –9.5 ft]), though velocities were highest just above bottom (IRC 1981). Therefore, entrainment samples were collected using an oblique tow through the water column at two stations along the bulkhead intake. At each station, a 0.5 m (1.6 ft) diameter 333 µm (0.013 inches) mesh plankton net was towed by hand from the docks (parallel to the bulkhead) approximately 3 m (10 ft) upcurrent from the intake. The net was towed until a volume of 15–20 m^3 (4,000–5,300 gal) was filtered. The net was equipped with a calibrated General Oceanics 2030R flowmeter, allowing the calculation of the amount of water filtered. At the end of each tow, the contents of the net were gently rinsed into the cod-end with seawater. Contents were washed down from the outside of the net to avoid the introduction of plankton from the wash-down water. Samples were then carefully transferred to prelabeled jars with preprinted internal labels and preserved in 4–10% buffered formalin-seawater. Sampling was conducted four times per 24-hr period--once every six hours.

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

Source water was sampled at nine stations located in Alamitos Bay and San Pedro Bay (Figure 4.3-1). All stations were sampled using a wheeled bongo plankton net using the same oblique towing method described for the entrainment sampling. Sampling was conducted once monthly on the same day that the entrainment station was sampled. Samples were also processed using the same procedures described for entrainment sampling. During each source water survey, the nine source water stations were sampled four times per 24-hr period at 6-hr intervals. This interval allowed adequate time for one vessel and crew to conduct all source water and entrainment sampling while also partitioning samples into day-night blocks for analysis of diel trends. During each sampling cycle the order in which the stations were sampled was varied to avoid introducing a systematic bias into the data. Detailed stepwise procedures are presented in Appendix B.

4.3.2 Laboratory Analysis

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

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

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

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 mm (0.004 inches).

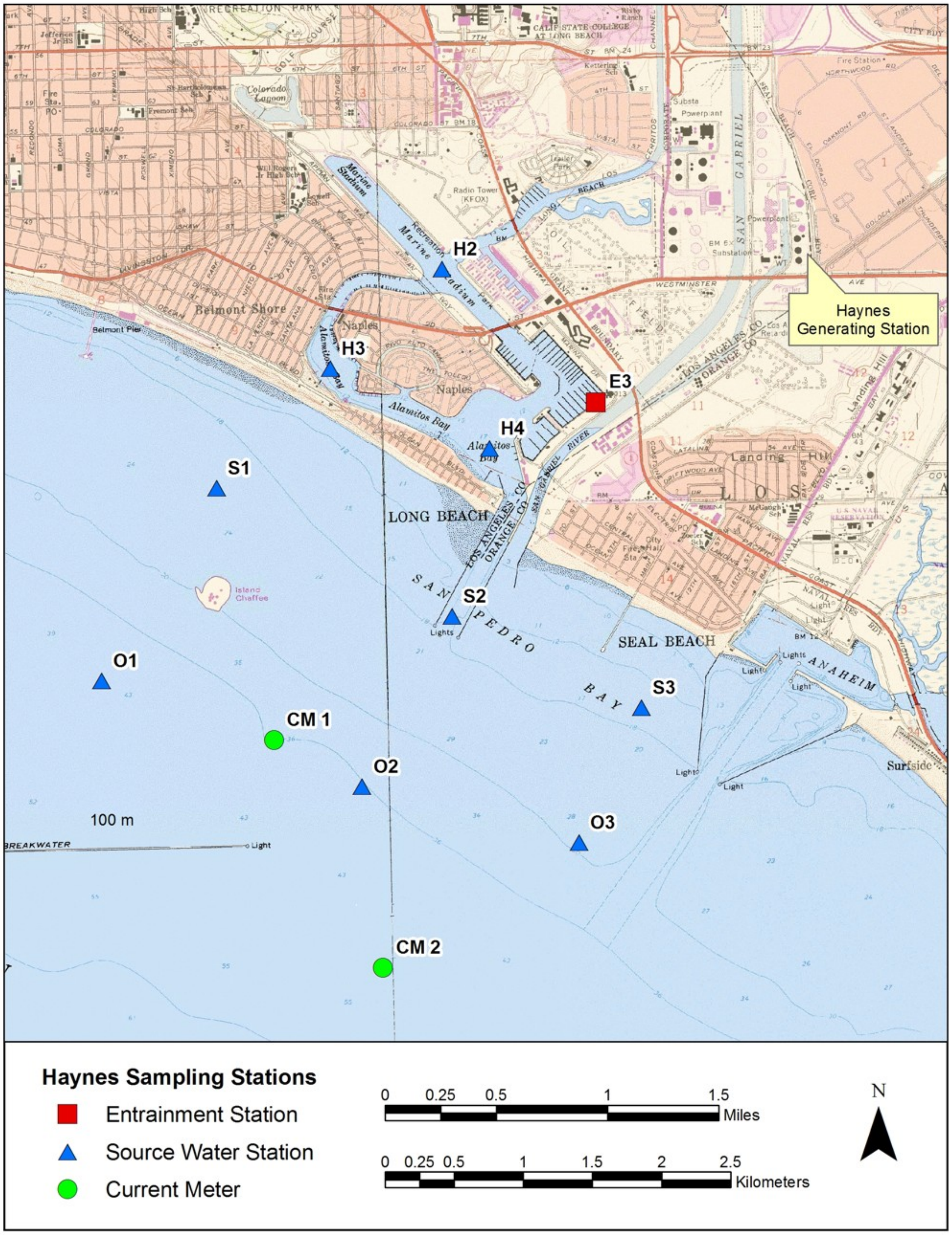


Figure 4.3-1. Location map of HnGS entrainment (E3) and source water sampling stations.

4.3.3 QA/QC Procedures & Data Validation

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

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

A similar QC program was conducted for the taxonomists identifying the samples. The first ten samples of fish or invertebrates identified by an individual taxonomist were completely re-identified by a designated QC taxonomist. A total of at least 50 individual fish or invertebrate larvae from at least five taxa must have been present in these first ten samples; if not, additional samples were re-identified until this criterion was met. Taxonomists were required to maintain a 95% identification accuracy level in these first ten samples. After the taxonomist identified ten consecutive samples with greater than 95% accuracy, they had one of their next ten samples checked by a QC taxonomist. If the taxonomist maintained an accuracy level of 95% then they continued to have one of each ten samples checked by a QC taxonomist. If one of the checked samples fell below the minimum accuracy level then ten more consecutive samples were identified by the QC taxonomist until ten consecutive samples met the 95% criterion. Identifications were cross-checked against taxonomic voucher collections maintained by MBC and Tenera Environmental, and specialists were consulted for problem specimens. Occasionally, outside experts were consulted to assist in the identification of the fish eggs. Due to the large overlap in diagnostic characteristics of several species of fishes in the egg and early embryo stages, egg identification is highly subjective and therefore no QC program was conducted to verify the egg identification.

4.3.4 Data Analysis

4.3.4.1 Entrainment Estimates

Estimates of daily larval entrainment for the sampling period from January 2006 through December 2006 at HnGS were calculated from data collected at the entrainment station and data on daily cooling water flow from the power plant. Estimates of average larval concentration for the day when entrainment samples were collected were extrapolated across the days between surveys to calculate total entrainment during the days when no samples were collected. The total estimated daily entrainment for the survey periods and across the entire year were then summed to obtain estimates of total survey and annual entrainment, respectively. The annual entrainment estimates, in conjunction with demographic data collected from the fisheries literature, were used in modeling CWIS effects using adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*). Data for the same target taxa from sampling of the entrained larvae and potential source populations of larvae were used to calculate estimates of proportional entrainment (*PE*) that were used to estimate the probability of mortality (P_M) due to entrainment using the *ETM*. Each approach (e.g., *AEL*, *FH*, and *ETM*), as appropriate for each target taxon, was used to assess effects of power plant losses. The results from the models were used in determining the magnitude of the CWIS losses relative to source water data from other sources and evaluating the potential for adverse environmental impacts. Parameters of the models used in the analyses are detailed in Appendix C.

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

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

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

4.3.4.2 Demographic Approaches

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

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

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

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa collected during the study. These rates, when available, were inferred from the literature along with estimates of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported. Because the accuracy of the estimated entrainment effects from *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 HnGS were based on bi-weekly sampling where E_T is the estimate of total entrainment for the one-year study period and E_i is the entrainment estimate for the individual survey periods. Estimates of entrainment for the study period were based on two-stage sampling designs, with days within surveys, and cycles (four six-hour collection periods per day) within days. The within-day sampling was based on a stratified random sampling scheme with four temporal cycles and two replicates per cycle. Estimates of variation for each survey were computed from the four temporal cycles.

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

Fecundity Hindcasting (*FH*)

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

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

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

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

Where:

E_T = total entrainment estimate;
S_j = survival rate from eggs to entrained larvae of the j^{th} stage;
TLF = average total lifetime fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

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

Adult Equivalent Loss (*AEL*)

The *AEL* approach uses estimates of the abundance of the entrained or impinged organisms to project the loss of equivalent numbers of adults based on mortality schedules and age-at-recruitment. The primary advantage of this approach is that it translates power plant-induced early life-stage mortality into numbers of adult fishes, which is the life-stage most dealt with by resource managers. This latter advantage may be offset by the need to gather age-specific mortality rates to predict adult losses and the need for information on the adult population of interest for estimating population-level effects (i.e., fractional losses).

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

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

Where:

n = number of age classes from the average age at entrainment to adult recruitment;
E_j = estimated number of larvae lost in age class j; and
S_j = survival probability for the jth class to adulthood (Goodyear 1978).

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

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

Where:

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

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

Equivalent Adult Model (EAM)

For the HnGS impact assessment, annual impingement totals were converted to numbers of equivalent adults for several species. Similar to demographic modeling performed with entrainment estimates, conversion of impingement totals was limited to species with sufficient life history information. Conversion of numbers of juveniles/adults collected in impingement sampling to numbers of equivalent adults has not been performed in recent impingement studies in California. However, the methods described below are similar to those used by EPA in developing the Phase I and Phase II 316(b) regulations.

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

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

Annual (daily) age was calculated as

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

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

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

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

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

where:

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

Equivalent adults were summed across all surveys. Equivalent adults of those individuals collected during normal operations were subjected to flow adjustment calculations to estimate the annual normal operation impingement. No adjustments were made to individuals collected during heat treatments.

4.3.4.3 Empirical Transport Model

As an alternative to the demographic models described above, the *ETM* was proposed by the USFWS to estimate mortality rates resulting from circulating water withdrawals by power plants (Boreman et al. 1978, and subsequently in Boreman et al. 1981). The *ETM* model provides an estimate of incremental mortality (a conditional estimate in absence of other mortality, Ricker 1975) caused by HnGS 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 proportional entrainment (*PE*) for each survey that can then be expanded to predict regional effects on appropriate adult populations using *ETM*, as described below. *ETM* estimates were calculated using actual and design (maximum capacity) cooling water flows and a sampling volume in the nearshore of 140,698,222 m^3 (37.2 billion gal).

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

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

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

Where:

$N_{Ei} =$ estimated average number of larvae entrained during the day in survey i, calculated as (estimated density of larvae in the water entrained that day) × (average daily cooling flow volume during the survey period),

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

The PE_i value represents the effects of a number of processes operating over a day and is estimated for each survey. Since actual cooling water flow was used in calculating entrainment estimates, the PE_i estimate was calculated using the average daily cooling water flow over each entrainment survey period, an approximate period of two weeks.

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

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

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

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

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

where:

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

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

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

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

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

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

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

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

The sizes of N_{NS}, N_{AB}, and N_E were calculated as the product of larval concentration and volume as in Equation 5. The estimate, N_{NS}, for the nearshore sampling area for each i^{th} survey used in the *ETM* calculations included six areas (Figure 4.3-1) with component densities and volumes. The sampled nearshore area, N_{NS}, for each i^{th} survey represents a proportion of the total nearshore source water potentially affected by entrainment over the number of days, q, that the larvae are exposed to entrainment. The proportion of the sampled nearshore area to the total source water, P_S, was estimated for each i^{th} survey using current displacement measured using current meters deployed offshore from Alamitos Bay (Figure 4.3-1). The incorporation of P_S into the *ETM* model is typically defined by the ratio of the area or volume of the study grid to a larger area or volume containing the population of inference (Parker and DeMartini 1989). However, if an estimate of the larval (or adult) population in the larger area is available, then P_S can also be computed using an estimate of the proportion of the larval or adult population in the study area. If the distribution in the larger area is assumed to be uniform or the same as the nearshore sampling area, then the value of P_S for the proportion of the population will be the same as the proportion computed using area or volume. The current displacement measured over q days was used to estimate the distance alongshore or offshore that larvae could have been transported into the nearshore areas around Alamitos Bay where they would be subject to entrainment. The ratio of the alongshore distance of the nearshore sampling area to the alongshore current displacement, P_S, measured using data from the current meter at Station CM1 was used to adjust the nearshore population estimate, N_{NS}, for the size of the total source water population for taxa that are primarily distributed in nearshore areas and embayments such as gobies and blennies. The data from the current meter at CM1 included both alongshore and onshore-offshore component vectors, but its location inside the Los Angeles-Long Beach Harbor breakwaters primarily provided data on alongshore movement in, and out of, the harbor complex.

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

To establish independent survey estimates, it was assumed that during each survey a new and distinct cohort of larvae was subject to entrainment. Each of the surveys was weighted by f_i and estimated as the proportion of the total annual source water population present during each *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.
- Lengths and applied growth rates of larvae accurately estimate larval duration.

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

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

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

4.4 SAMPLING SUMMARY

Twenty-six surveys were completed at the entrainment station between January 11 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. Totals of 208 entrainment samples and 863 source water samples were processed for data analysis.

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

		Entrainment Samples		Source Water Samples	
Survey Number	Date	Number Collected	Number Processed	Number Collected	Number Processed
ABEA01	1/5/06	8	8	–	–
ABEA02	1/17/06	8	8	72	72
ABEA03	1/31/06	8	8	–	–
ABEA04	2/14/06	8	8	72	72
ABEA05	2/27/06	8	8		
ABEA06	3/13/06	8	8	72	71 [a]
ABEA07	3/26/06	8	8	–	–
ABEA08	4/10/06	8	8	72	72
ABEA09	4/24/06	8	8	–	–
ABEA10	5/8/06	8	8	72	72
ABEA11	5/22/06	8	8	–	–
ABEA12	6/5/06	8	8	72	72
ABEA13	6/19/06	8	8	–	–
ABEA14	7/05/06	8	8	72	72
ABEA15	7/17/06	8	8	–	–
ABEA16	7/31/06	8	8	–	–
ABEA17	8/14/06	8	8	72	72
ABEA18	8/28/06	8	8		
ABEA19	9/11/06	8	8	72	72
ABEA20	9/25/06	8	8	–	–
ABEA21	10/09/06	8	8	72	72
ABEA22	10/23/06	8	8	–	–
ABEA23	11/06/06	8	8	72	72
ABEA24	11/20/06	8	8	–	–
ABEA25	12/04/06	8	8	72	72
ABEA26	12/18/06	8	8	–	–
		208	**208**	**864**	**863**

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

4.5 RESULTS

4.5.1 Cooling Water Intake Structure Entrainment Summary

4.5.1.1 Fishes

A total of 12,651 entrainable fish larvae from 35 separate taxonomic categories was collected from Station E3 during the 26 entrainment surveys (Table 4.5-1). The most abundant larval fish taxon in the samples was unidentified gobies, which comprised 51.3% of the total larvae collected, followed by silversides (23.9%) and combtooth blennies (20.1%). Densities of fish larvae peaked in late May at an average concentration of approximately 17,000 per 1,000 m^3 (264,172 gal) (Figure 4.5-1). In addition, 5,941 fish eggs from 13 taxa were enumerated in the 208 entrainment samples. The most abundant taxonomic group of fish eggs in the samples was unidentified eggs, which made up 69.4% of the total eggs collected, followed by sand flounder eggs (11.4%). Fish eggs peaked in abundance in March–April prior to the peak abundance of fish larvae in May, and also had a secondary peak in August (Figure 4.5-2). Larvae and eggs were substantially more abundant in samples collected at night than those collected during the day in nearly every survey (Figure 4.5-3 and 4.5-4). Damaged larval fishes that could not be positively identified comprised 0.2% of the total catch. Total annual entrainment was estimated to be 3.65 billion fish larvae and 1.68 billion fish eggs during 2006 using the HnGS CWIS actual flows as the basis for calculations (Table 4.5-2). Using the design (maximum capacity) CWIS flows, total annual entrainment increases to 4.53 billion fish larvae and 2.12 billion fish eggs. Commercially and recreationally important taxa comprised 2.6% of the total larvae collected.

Table 4.5-1. Average concentration of larval fishes and fish eggs in entrainment samples collected at HnGS (Station E3) in 2006.

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Larval Fish					
Gobiidae unid.	gobies	1,667.51	6,354	51.31	51.31
Atherinopsidae unid.	silversides	778.19	3,263	23.94	75.25
Hypsoblennius spp.	combtooth blennies	651.69	2,444	20.05	95.31
Genyonemus lineatus	white croaker	67.68	267	2.08	97.39
Engraulidae unid.	anchovies	19.54	76	0.60	97.99
Labrisomidae unid.	labrisomid blennies	14.11	52	0.43	98.42
Gobiesocidae unid.	clingfishes	8.33	32	0.26	98.68
unidentified fish, damaged	unid. damaged fish	8.04	30	0.25	98.93
Sciaenidae unid.	croakers	6.54	25	0.20	99.13
Gibbonsia spp.	clinid kelpfishes	3.86	14	0.12	99.25
Syngnathus spp.	pipefishes	2.57	10	0.08	99.33
Pleuronichthys guttulatus	diamond turbot	2.33	9	0.07	99.40
larvae, unidentified yolksac	unidentified yolksac larvae	2.18	8	0.07	99.46
Seriphus politus	queenfish	2.10	8	0.06	99.53
Acanthogobius flavimanus	yellowfin goby	2.05	8	0.06	99.59
Gillichthys mirabilis	longjaw mudsucker	1.83	7	0.06	99.65
Typhlogobius californiensis	blind goby	1.78	7	0.05	99.70
larval/post-larval fish unid.	larval fishes	1.32	5	0.04	99.74
Paralichthys californicus	California halibut	1.09	4	0.03	99.78
Leptocottus armatus	Pacific staghorn sculpin	1.07	4	0.03	99.81
Hypsypops rubicundus	garibaldi	1.01	4	0.03	99.84
Citharichthys spp.	sanddabs	0.74	3	0.02	99.86
Rhinogobiops nicholsii	blackeye goby	0.59	2	0.02	99.88
Cheilotrema saturnum	black croaker	0.53	2	0.02	99.90
Umbrina roncador	yellowfin croaker	0.52	2	0.02	99.91
Pleuronectidae unid.	righteye flounders	0.30	1	0.01	99.92
Haemulidae unid.	grunts	0.28	1	0.01	99.93
Xenistius californiensis	salema	0.28	1	0.01	99.94
Paralabrax spp.	sand bass	0.28	1	0.01	99.95
Chaenopsidae unid.	tube blennies	0.25	1	0.01	99.96
Roncador stearnsii	spotfin croaker	0.25	1	0.01	99.97
Stenobrachius leucopsarus	northern lampfish	0.24	1	0.01	99.97
Parophrys vetulus	English sole	0.23	1	0.01	99.98
Sardinops sagax	Pacific sardine	0.23	1	0.01	99.99
Clupeiformes unid.	herrings and anchovies	0.22	1	0.01	99.99
Merluccius productus	Pacific hake	0.22	1	0.01	100.00
		3,249.97	**12,651**		

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

(table continued)

Table 4.5-1 (continued). Abundance of fish larvae and fish eggs sampled at HnGS Entrainment Station E3 from January through December 2006

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Fish Eggs					
fish eggs unid.	unidentified fish eggs	1,054.48	4,159	69.44	69.44
Paralichthyidae unid.	sand flounder eggs	172.37	669	11.35	80.79
Sciaenidae / Paralich / Labr	SPL fish eggs	78.33	288	5.16	85.95
Genyonemus lineatus	white croaker eggs	63.01	239	4.15	90.10
Citharichthys spp.	sanddab eggs	57.94	229	3.82	93.92
Sciaenidae unid.	croaker eggs	36.68	140	2.42	96.33
Pleuronichthys spp.	turbot eggs	25.54	96	1.68	98.01
Atherinopsidae unid.	silverside eggs	10.49	43	0.69	98.70
Engraulidae unid.	anchovy eggs	10.03	41	0.66	99.36
Paralichthys californicus	California halibut eggs	4.44	17	0.29	99.66
Atherinops affinis	topsmelt eggs	3.90	15	0.26	99.91
Blenniidae	blenny eggs	0.79	3	0.05	99.96
Labridae unid.	wrasse eggs	0.54	2	0.04	100.00
		1,518.53	**5,941**		

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

Table 4.5-2. Calculated total annual entrainment of larval fishes and fish eggs at HnGS 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			
Gobiidae unid.	gobies	1,828,364,516	2,334,220,376
Atherinopsidae unid.	silversides	920,323,104	1,062,818,072
Hypsoblennius spp.	combtooth blennies	732,022,349	915,313,887
Genyonemus lineatus	white croaker	75,425,299	96,188,344
Engraulidae unid.	anchovies	22,673,541	27,301,289
Labrisomidae unid.	labrisomid blennies	15,068,186	19,493,190
Gobiesocidae unid.	clingfishes	9,088,713	11,712,226
unidentified fish, damaged	unidentified damaged fish	8,705,487	11,578,027
Sciaenidae unid.	croakers	7,187,066	9,313,532
Gibbonsia spp.	clinid kelpfishes	3,583,074	5,590,130
Syngnathus spp.	pipefishes	3,111,275	3,765,987
Pleuronichthys guttulatus	diamond turbot	2,664,083	3,409,219
Seriphus politus	queenfish	2,490,643	2,937,768
larvae, unidentified yolksac	unidentified yolksac larvae	2,415,796	3,051,218
Acanthogobius flavimanus	yellowfin goby	2,024,413	2,715,310
Gillichthys mirabilis	longjaw mudsucker	1,977,286	2,550,861
Typhlogobius californiensis	blind goby	1,961,918	2,453,304
larval/post-larval fish unid.	larval fishes	1,184,545	1,620,620
Paralichthys californicus	California halibut	1,153,745	1,520,648
Hypsypops rubicundus	garibaldi	985,374	1,381,248
Leptocottus armatus	Pacific staghorn sculpin	876,157	1,491,536
Citharichthys spp.	sanddabs	821,712	1,026,911
Rhinogobiops nicholsii	blackeye goby	703,083	823,133
Cheilotrema saturnum	black croaker	626,312	764,490
Umbrina roncador	yellowfin croaker	506,822	721,836
Pleuronectidae unid.	righteye flounders	385,901	414,783
Haemulidae unid.	grunts	375,837	396,576
Xenistius californiensis	salema	375,837	396,576
Paralabrax spp.	sand bass	359,420	388,533
Roncador stearnsii	spotfin croaker	332,942	351,314
Stenobrachius leucopsarus	northern lampfish	268,400	332,364
Parophrys vetulus	English sole	260,975	323,169
Sardinops sagax	Pacific sardine	255,242	319,095
Clupeiformes unid.	herrings and anchovies	243,832	301,941
Merluccius productus	Pacific hake	243,832	301,941
Chaenopsidae unid.	tube blennies	161,673	354,629
		3,649,208,392	**4,527,644,084**

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

(table continued)

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

Taxon	**Common Name**	**Annual Entrainment (Actual Flows)**	**Annual Entrainment (Design Flows)**
Fish Eggs			
fish eggs unid.	unidentified fish eggs	1,191,101,773	1,474,924,676
Paralichthyidae unid.)	sand flounder eggs	183,531,130	236,704,432
Sciaenidae / Paralichthyidae / Labridae	SPL fish eggs	90,493,059	109,555,973
Citharichthys spp.	sanddab eggs	63,124,903	80,387,665
Genyonemus lineatus	white croaker eggs	57,836,910	86,480,192
Sciaenidae unid.	croaker eggs	40,580,902	51,237,429
Pleuronichthys spp.	turbot eggs	28,681,415	36,053,832
Atherinopsidae unid.	silverside eggs	11,560,935	14,653,846
Engraulidae unid.	anchovy eggs	11,128,912	14,029,527
Atherinops affinis	topsmelt eggs	4,427,698	5,441,190
Paralichthys californicus	California halibut eggs	3,894,210	6,151,903
Labridae unid.	wrasse eggs	733,860	950,979
Blenniidae	blenny eggs	500,220	1,097,230
		1,687,595,926	**2,117,668,875**

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

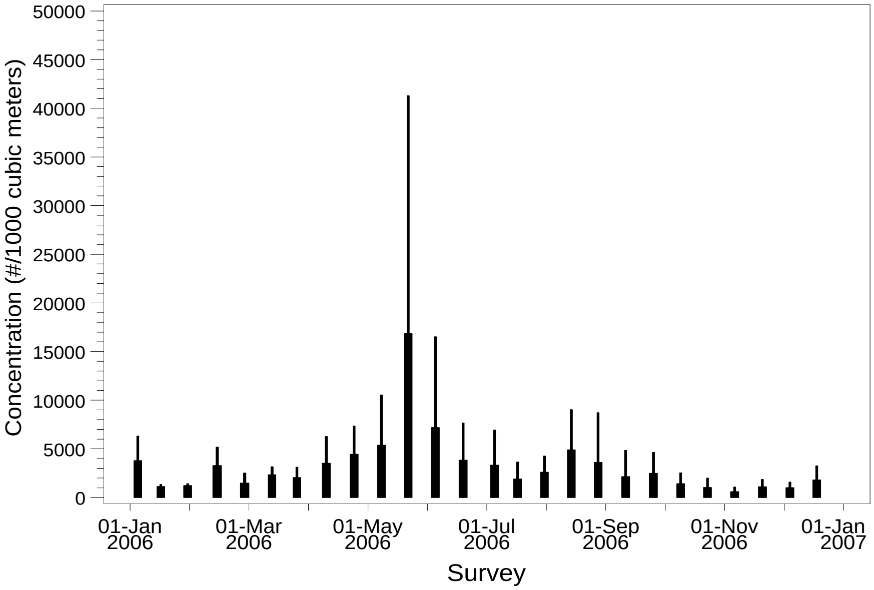


Figure 4.5-1. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of all larval fishes collected at entrainment Station E3 during 2006.

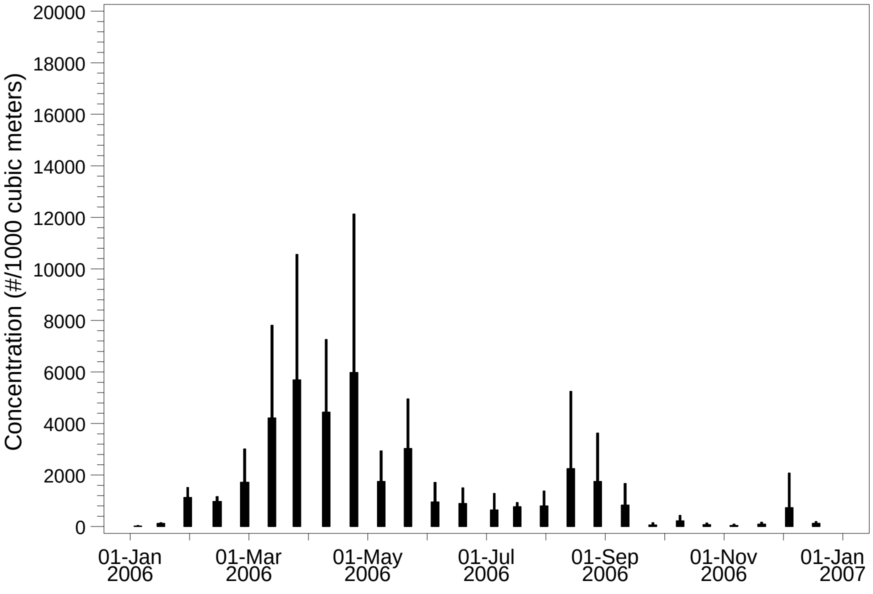
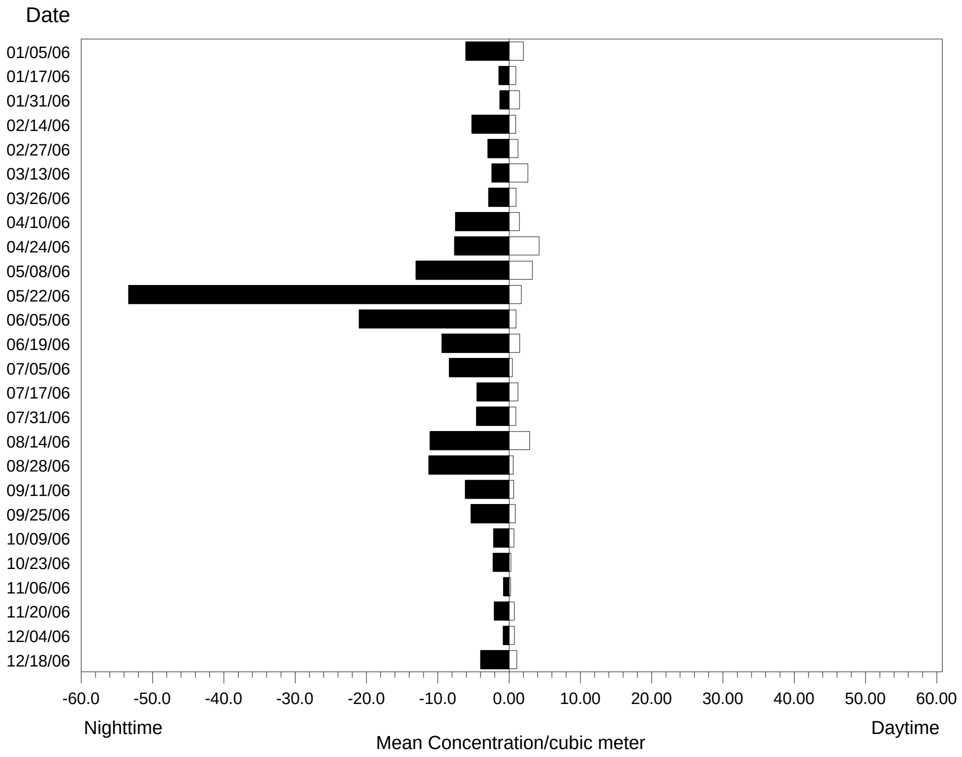
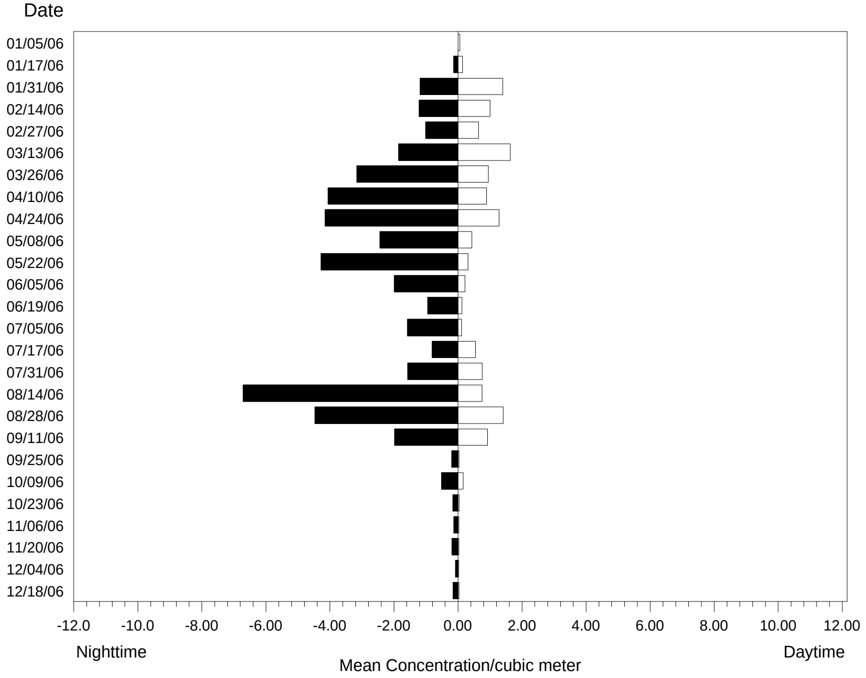


Figure 4.5-2. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of fish eggs collected at entrainment Station E3 during 2006.



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 E3 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 E3 during night (Cycle 3) and day (Cycle 1) sampling.

4.5.1.2 Shellfishes

A total of 50 larval target invertebrates representing 9 taxa was collected from the HnGS entrainment station (E3) during 26 bi-weekly surveys in 2006 (Table 4.5-3 and Appendix D). The most abundant target shellfish larvae in the samples were shore crab megalops (Grapsidae unid.) followed by kelp crab megalops (*Pugettia* spp.), which made up 27.4% and 25.0%, respectively of the total target invertebrate larvae collected. Unidentified crab and unidentified brachyura megalops included species for which there were no descriptions as well as specimens that had some type of damage that prevented identification to a lower taxonomic category. There was no seasonality apparent in the abundance of the larvae although Grapsidae was present from April through December. The only target species larvae with commercial fishery value was market squid, which had only a single entrained larva. Total annual entrainment was estimated to be 14.8 million target invertebrate larvae using the actual cooling water flows (Table 4.5-4). Using the design (maximum capacity) CWIS flows, total annual entrainment increases to 18.5 million target invertebrates.

Table 4.5-3. Average concentration of target invertebrate larvae in entrainment samples collected at HnGS (Station E3) in 2006.

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Grapsidae unid. (megalops)	shore crab megalops	3.59	14	27.36	27.36
Pugettia spp. (megalops)	kelp crabs megalops	3.28	12	25.00	52.36
Pinnixa spp. (megalops)	pea crabs megalops	1.84	7	14.02	66.39
unidentified crab (megalops)	unid. crab megalops	1.76	7	13.41	79.80
Brachyura unid. (megalops)	unid. crab megalops	1.33	5	10.14	89.94
Loxorhynchus spp.	spider crabs	0.57	2	4.34	94.28
Paguridae unid. (megalops)	hermit crab megalops	0.30	1	2.29	96.57
Majidae unid. (megalops)	spider crab megalops	0.24	1	1.83	98.40
Loligo opalescens	market squid	0.21	1	1.60	100.00
		13.12	**50**		

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

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

Taxon	**Common Name**	**Annual Entrainment (Actual Flow)**	**Annual Entrainment (Design Flow)**
Grapsidae unid. (megalops)	shore crab megalops	4,264,792	5,217,248
Pugettia spp. (megalops)	Kelp crabs megalops	3,629,771	4,586,866
Pinnixa spp. (megalops)	pea crabs megalops	2,031,387	2,574,200
unidentified crab (megalops)	unidentified crab megalops	1,949,343	2,464,009
Brachyura unid. (megalops)	unidentified crab megalops	1,549,133	1,826,174
Loxorhynchus spp.	spider crabs	565,680	790,366
Paguridae unid. (megalops)	hermit crab megalops	325,547	412,641
Majidae unid. (megalops)	spider crab megalops	307,149	334,557
Loligo opalescens	market squid	231,898	289,912
		14,854,700	**18,495,973**

4.5.2 Source Water Summary

4.5.2.1 Fishes

A total of 41,319 larval fishes representing 68 taxa was collected from HnGS source water stations in and near Alamitos Bay (Stations H2–H4, S1–S3 and O1–O3) during 12 monthly surveys in 2006 (Table 4.5-5 and Appendix D). Unidentified gobies (*Clevelandia, Ilypnus, Quietula* (CIQ) goby complex), white croaker, combtooth blennies, and anchovies were the most abundant taxa and comprised over 90% of all specimens collected. Damaged fishes that could not be positively identified comprised 1.0% of the total catch. The greatest concentrations of larval fishes occurred during April 2006 (ca. 5,800 per m^3 [264 gal]) and the fewest in October 2006 (ca. 600 per m^3 [264 gal]) (Figure 4.5.5). Larvae were more abundant in samples collected at night than those collected during the day in nearly every survey (Figure 4.5-6).

Table 4.5-5. Average concentration of larval fishes in samples collected at HnGS source water stations in and near Alamitos Bay (Stations H2–H4, S1–S3 and O1–O3) in 2006.

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Larval Fish					
Gobiidae unid.	Gobies	1,071.51	19,916	47.36	47.36
Genyonemus lineatus	white croaker	450.11	7,865	19.89	67.25
Hypsoblennius spp.	Combtooth blennies	369.87	6,861	16.35	83.60
Engraulidae unid.	Anchovies	168.79	3,015	7.46	91.06
larvae, unidentified yolksac	unidentified yolksac larvae	39.85	698	1.76	92.82
Sciaenidae unid.	Croakers	30.70	563	1.36	94.18
unidentified fish, damaged	unidentified damaged fish	22.09	407	0.98	95.15
Atherinopsidae unid.	Silversides	17.84	331	0.79	95.94
Paralichthys californicus	California halibut	10.28	188	0.45	96.39
Acanthogobius flavimanus	yellowfin goby	9.43	165	0.42	96.81
Gobiesocidae unid.	Clingfishes	8.66	163	0.38	97.19
Seriphus politus	queenfish	7.60	137	0.34	97.53
Labrisomidae unid.	Labrisomid blennies	7.22	135	0.32	97.85
Pleuronichthys guttulatus	diamond turbot	5.54	96	0.24	98.09
Hypsypops rubicundus	garibaldi	4.71	90	0.21	98.30
Gillichthys mirabilis	longjaw mudsucker	4.05	79	0.18	98.48
Paralabrax spp.	Sand bass	3.45	56	0.15	98.63
Typhlogobius californiensis	blind goby	3.24	56	0.14	98.78
Pleuronichthys verticalis	hornyhead turbot	2.21	37	0.10	98.87
Syngnathus spp.	Pipefishes	1.83	34	0.08	98.96
Citharichthys spp.	Sanddabs	1.83	33	0.08	99.04
Parophrys vetulus	English sole	1.83	34	0.08	99.12
Gibbonsia spp.	Clinid kelpfishes	1.80	32	0.08	99.20
Lepidogobius lepidus	bay goby	1.73	33	0.08	99.27
Pleuronichthys ritteri	spotted turbot	1.56	27	0.07	99.34
Leptocottus armatus	Pacific staghorn sculpin	1.51	30	0.07	99.41
Stenobrachius leucopsarus	northern lampfish	1.22	20	0.05	99.46
Cheilotrema saturnum	black croaker	1.22	22	0.05	99.52
Pleuronichthys spp.	Turbots	1.19	22	0.05	99.57

(table continued)

Table 4.5-5 (continued). Average concentration of larval fishes in samples collected at HnGS source water stations in and near Alamitos Bay (Stations H2–H4, S1–S3 and O1–O3) in 2006.

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Larval Fish					
Roncador stearnsii	spotfin croaker	0.83	16	0.04	99.61
Merluccius productus	Pacific hake	0.81	14	0.04	99.64
larval/post-larval fish unid.	larval fishes	0.79	13	0.03	99.68
Clinocottus spp.	sculpins	0.67	11	0.03	99.71
Sebastes spp.	rockfishes	0.64	13	0.03	99.73
Pleuronectidae unid.	righteye flounders	0.55	10	0.02	99.76
Heterostichus rostratus	giant kelpfish	0.42	8	0.02	99.78
Menticirrhus undulatus	California corbina	0.36	7	0.02	99.79
Ruscarius creaseri	roughcheek sculpin	0.36	6	0.02	99.81
Peprilus simillimus	Pacific butterfish	0.34	6	0.01	99.82
Symphurus atricaudus	California tonguefish	0.30	5	0.01	99.84
Pleuronectiformes unid.	flatfishes	0.28	5	0.01	99.85
Oxyjulis californica	senorita	0.27	5	0.01	99.86
Triphoturus mexicanus	Mexican lampfish	0.24	4	0.01	99.87
Oxylebius pictus	painted greenling	0.22	4	0.01	99.88
Blennioidei unid.	blennies	0.20	3	0.01	99.89
Paralichthyidae unid.	sand flounders	0.19	4	0.01	99.90
Ophidiidae unid.	cusk-eels	0.18	3	0.01	99.91
Umbrina roncador	yellowfin croaker	0.18	3	0.01	99.91
Scorpaenidae unid.	scorpionfishes	0.17	3	0.01	99.92
Ophidion scrippsae	basketweave cusk-eel	0.17	3	0.01	99.93
Rhinogobiops nicholsii	blackeye goby	0.17	3	0.01	99.94
Sphyraena argentea	Pacific barracuda	0.17	3	0.01	99.95
Semicossyphus pulcher	California sheephead	0.13	2	0.01	99.95
Girella nigricans	opaleye	0.12	2	0.01	99.96
Sardinops sagax	Pacific sardine	0.12	2	0.01	99.96
Chaenopsidae unid.	tube blennies	0.10	2	<0.01	99.97
Zaniolepis spp.	combfishes	0.09	2	<0.01	99.97
Cottidae unid.	sculpins	0.09	2	<0.01	99.97
Icelinus spp.	sculpins	0.07	1	<0.01	99.98
Halichoeres semicinctus	rock wrasse	0.07	1	<0.01	99.98
Pomacentridae unid.	damselfishes	0.07	1	<0.01	99.98
Bathylagidae unid.	blacksmelt	0.06	1	<0.01	99.99
Neoclinus spp.	fringeheads	0.06	1	<0.01	99.99
Myctophidae unid.	lanternfishes	0.06	1	<0.01	99.99
Haemulidae unid.	grunts	0.05	1	<0.01	99.99
Artedius spp.	sculpins	0.05	1	<0.01	99.99
Hexagrammidae unid.	greenlings	0.05	1	<0.01	99.99
Scorpaenichthys marmoratus	cabezon	0.04	1	<0.01	100.00
		2,262.63	**41,319**		

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

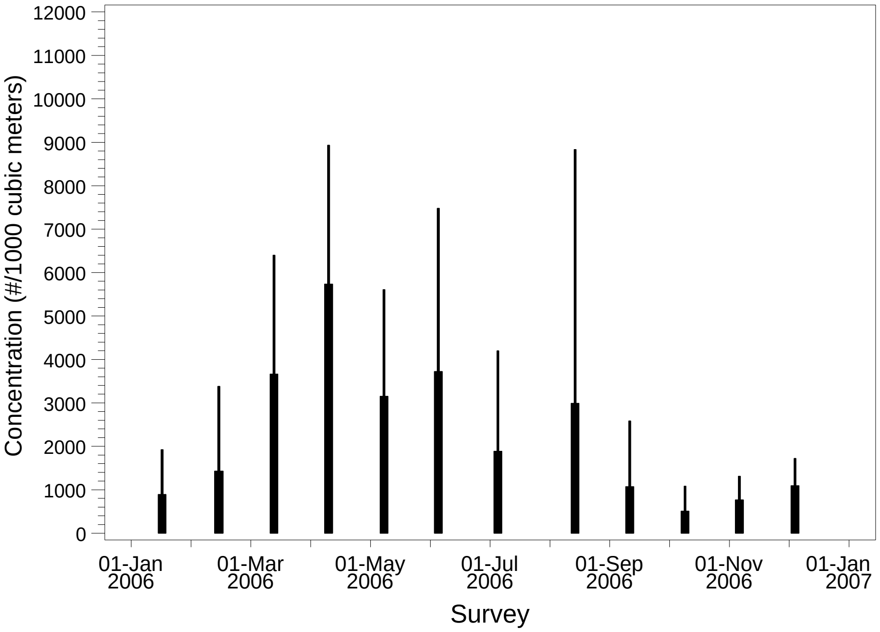
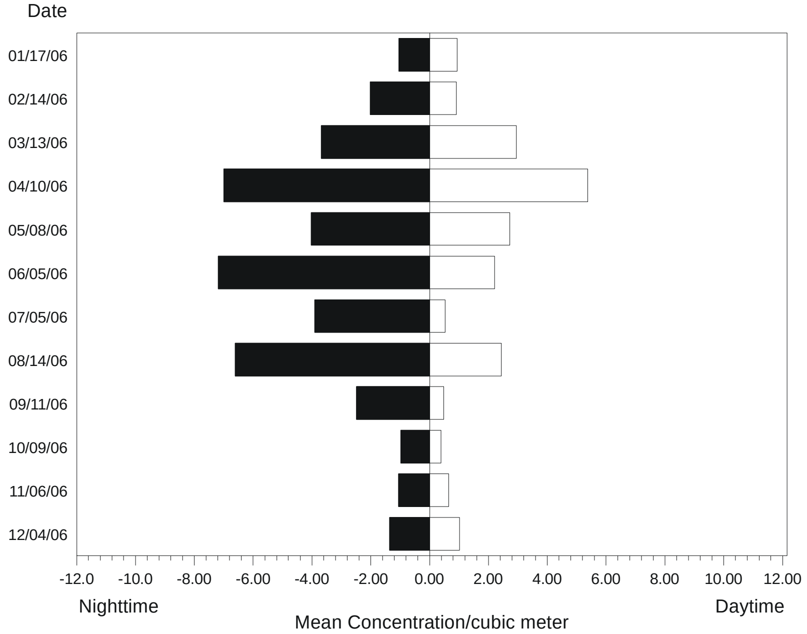


Figure 4.5-5. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of all larval fishes collected at HnGS source water stations during 2006.



Note: Negative nighttime values are a plotting artifact

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

4.5.2.2 Shellfishes

A total of 2,291 larval target invertebrates (developmentally advanced larvae of crabs, spiny lobsters, and market squid) representing 20 taxa (combined species designations) was collected from HnGS source water stations in and near Alamitos Bay (Stations H2–H4, S1–S3 and O1–O3) during 12 monthly surveys in 2006 (Table 4.5-6 and Appendix D). Megalops of kelp crabs, pea crabs, shore crabs, spider crabs, and unidentified megalops were the most abundant taxa and comprised nearly 90% of all specimens collected. Data presented in Appendix D includes abundances for the uncombined species designations by survey.

Table 4.5-6. Average concentration of larval target invertebrates in samples collected at HnGS source water stations in and near Alamitos Bay (Stations H2–H4, S1–S3 and O1–O3) in 2006.

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**Percentage of Total**	**Cumulative Percentage**
Pugettia spp.	kelp crabs megalops	69.73	1,253	55.33	55.33
Pinnixa spp.	pea crabs megalops	16.27	309	12.91	68.24
Grapsidae unid.	shore crab megalops	11.40	208	9.04	77.28
unidentified crab	unidentified crab megalops	8.01	144	6.35	83.63
Majidae unid.	spider crab megalops	4.50	80	3.57	87.21
Brachyura unid.	unidentified crab megalops	3.43	65	2.72	89.92
Paguridae unid.	hermit crab megalops	2.90	51	2.30	92.23
Pinnotheres spp.	pea crab megalops	2.39	45	1.90	94.13
Cancer spp.	cancer crabs megalops	1.80	32	1.43	95.56
Petrolisthes spp.	porcelain crab megalops	1.15	20	0.92	96.47
Porcellanidae unid. (megalops)	porcelain crab megalops	1.15	22	0.91	97.38
Lophopanopeus spp. (megalops)	black-clawed crab megalops	1.07	22	0.85	98.23
Pachycheles spp.	porcelain crabs megalops	1.04	18	0.83	99.06
Diogenidae	left-handed hermit crabs	0.36	7	0.29	99.34
Pachycheles rudis	thickclaw porcelain crab	0.36	7	0.29	99.63
Panulirus interruptus (phyllosome stage)	California spiny lobster (larval)	0.17	3	0.13	99.76
Loligo opalescens	market squid	0.12	2	0.10	99.86
Pachygrapsus crassipes	striped shore crab megalops	0.07	1	0.06	99.92
Hippoidea	mole crab megalops	0.07	1	0.05	99.97
Panulirus interruptus (puerulus stage)	California spiny lobster (larval)	0.04	1	0.03	100.00
		126.03	**2,291**		

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

4.5.3 Results by Species for Cooling Water Intake Structure Entrainment

The following five fish taxa were selected for detailed evaluation of entrainment effects based on their abundance in entrainment samples. Together they comprised over 98% of the larvae entrained at HnGS in 2006 (Table 4.5-1). In taxonomic order these are:

- anchovies (Engraulis mordax and Engraulidae) + eggs
- silversides (Atherinopsidae)
- white croaker (Genyonemus lineatus)
- combtooth blennies (Hypsoblennius spp.)
- unidentified gobies (Gobiidae)

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

4.5.3.1.1 Life History and Ecology

The reported depth range of northern anchovy is from the surface to depths of 310 m (1,017 ft) (Davies and Bradley 1972). Juveniles are generally more common inshore and in estuaries. Eggs are elliptical and occur from the surface to depths of about 50 m (164 ft), while larvae are found from the surface to about 75 m (246 m) in epipelagic and nearshore waters (Garrison and Miller 1982). Northern anchovy larvae feed on dinoflagellates, rotifers, and copepods (MBC 1987).

Northern anchovies spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978) although this may vary annually and also geographically. Most spawning takes place within 100 km (62 mi) of shore (MBC 1987). On average, female anchovies off Los Angeles spawn every 7–10 days during peak spawning periods, approximately 20 times per year (Hunter and Macewicz 1980; MBC 1987). Most spawning occurs at night and is completed by dawn (Hunter and Macewicz 1980). Anchovies are all sexually mature by age two, and the fraction of the population that is sexually mature at one year of age can range from 47 to 100% depending on the water temperature during development (Bergen and Jacobsen 2001). Love (1996) reported that they release 2,700–16,000 eggs per batch, with an annual fecundity of up to 130,000 eggs per year in southern California. Parrish et al. (1986) and Butler et al. (1993) stated that the total annual fecundity for one-year old females was 20,000–30,000 eggs, while a five-year old could release up to 320,000 eggs per year.

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

Northern anchovy is very important in the trophic ecology of marine food webs. They are random planktonic feeders, filtering plankton as they swim (Fitch and Lavenberg 1971). Juveniles and adults feed mainly at night on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971; Hart 1973; Allen and DeMartini 1983). Numerous fish and marine mammal species feed on northern anchovy. Elegant tern and California brown pelican reproduction is strongly correlated with the annual abundance of this species (Emmett et al. 1991). Juveniles and adults avoid temperatures above 25°C (Brewer 1974).

4.5.3.1.2 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 anchovy reduction by 1983.

Estimates of the central subpopulation averaged about 359,000 tons from 1963 through 1972, increased to over 1.7 million tons in 1974, and then declined to 359,000 tons in 1978 (Bergen and Jacobsen 2001). Anchovy biomass in 1994 was estimated at 432,000 tons. The stock is thought to be stable, and the size of the anchovy resource is largely dependent on natural influences such as ocean temperatures related to a cold regime in the Pacific Decadal Oscillation (Chavez et al. 2003).

In the Los Angeles-Long Beach Harbor complex, northern anchovy was one of the most abundant species, along with topsmelt (*Atherinopsis affinis*), in purse seine and beach seine sampling in the early 1980s (Allen et al. 2006). Seasonally the greatest population abundances typically occur in summer and early fall as a result of large numbers of young-of-the-year. The earlier 316(b) study of the HnGS in 1978–1979 (IRC 1981) measured mean density values of engraulid species complex larvae that were lowest from July through September and greatest from January through June. Survey means for the near-field varied from 0 to 880 larvae per 1,000 m^3 (264,172 gal) for day surveys and from 0 to 4,250 larvae per 1,000 m^3 (264,172 gal) for night surveys. During the period of peak abundance for January–June, the average survey density was 13,650 per 1,000 m^3 (264,172 gal). These densities are over fifty times greater than the highest 2006 densities recorded in April (see Section 4.5.3.1.3–*Sampling Results*).

The California commercial fishery for northern anchovy varies substantially by region and year. There have not been any landings of northern anchovy recorded from San Diego County since 1996 when 318,000 lbs were landed (PacFIN 2007). In 2004 there were 325,000 lbs landed in the Los Angeles area as compared to 6.07 million lbs. in the Santa Barbara area, and 8.58 million lbs. in the Monterey area for a total value of $750,000. Annual landings in the Los Angeles region since 2000 have varied from a high of 8.6 million lbs in 2001 to a low of 0.3 million lbs in 2004, with an average of 3 million lbs annually (Table 4.5-7).

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

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

4.5.3.1.3 Sampling Results

Engraulid larvae (predominantly northern anchovy) were the fifth most abundant taxon at the entrainment station with a mean concentration of 20 per 1,000 m^3 (264,172 gal) over all surveys while engraulid eggs had an average concentration of 10 per 1,000 m^3 (264,172 gal) (Table 4.5-1). Almost all larvae occurred in April–May (Figure 4.5-7). During periods of maximum abundance in early April 2006 anchovies were present in the entrainment samples at average concentrations of 255 per 1,000 m^3 (264,172 gal). They were absent from samples in almost all other months except September and November. Monthly source water concentrations followed a similar seasonal pattern with maximum concentrations exceeding 1,000 per 1,000 m^3 (264,172 gal) in April 2006 (Figure 4.5-8). There was no consistent trend in abundance between daytime and nighttime samples (Figure 4.5-9). The length frequency distribution of measured northern anchovy larvae showed a bi-modal distribution with the predominant peak consisting of recently-hatched larvae, ranging from 3-5 mm notochord length (NL), and a smaller peak in the range of 10–14 mm (Figure 4.5-10), reflecting growth of the initial strong cohort from the early April spawning event (Figure 4.5-7). The lengths of the larvae from the entrainment station samples ranged from 2.3–28.7 mm with a mean of 5.3 mm NL.

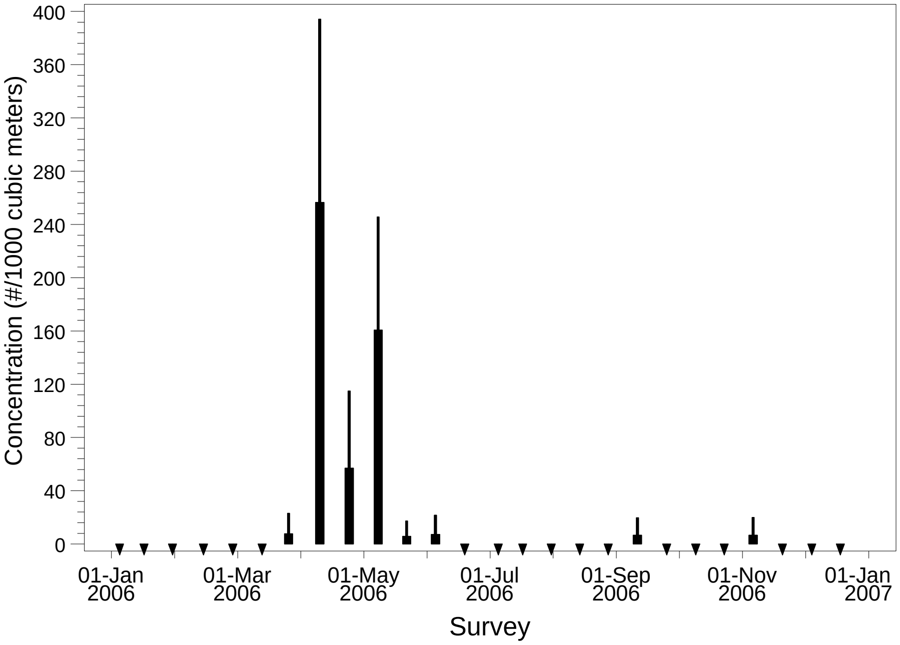


Figure 4.5-7. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of anchovy larvae collected at HnGS entrainment Station E3 during 2006.

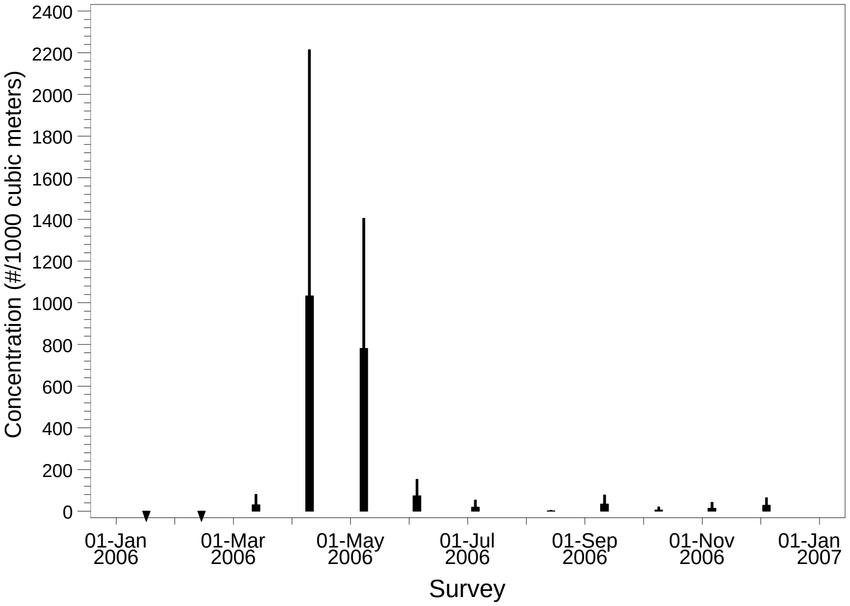


Figure 4.5-8. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of anchovy larvae collected at HnGS source water stations during 2006.

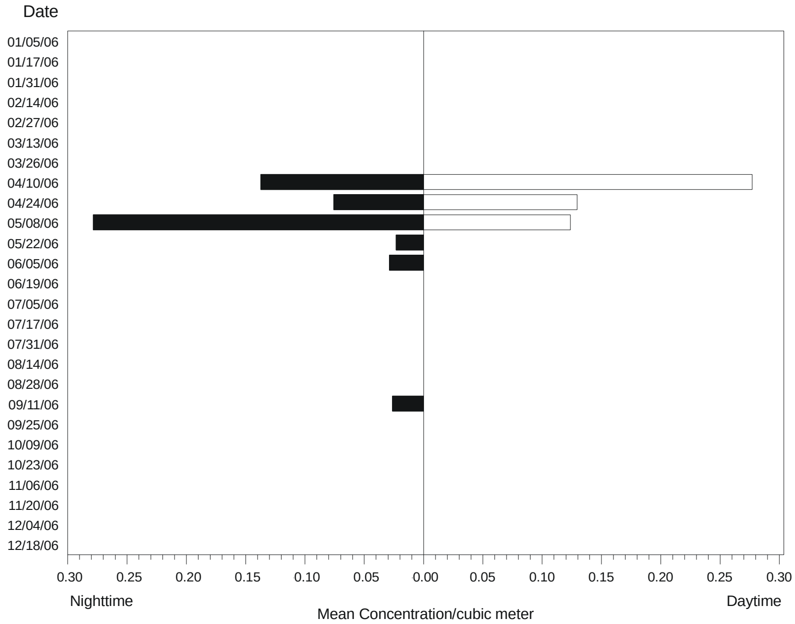


Figure 4.5-9. Mean concentration (#/1.0 m^3 [264 gal]) of anchovy larvae at entrainment Station E3 during night (Cycle 3) and day (Cycle 1) sampling.

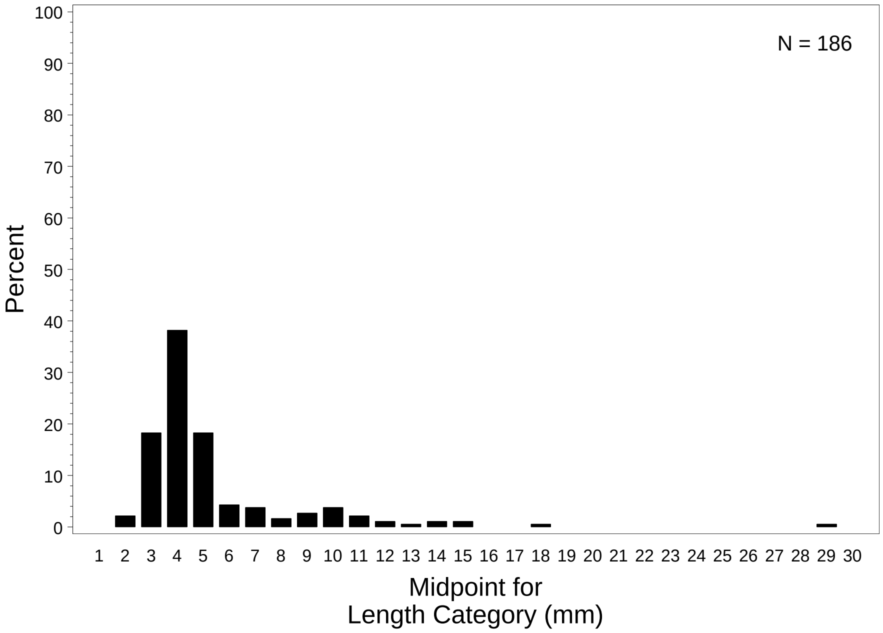


Figure 4.5-10. Length (mm) frequency distribution for larval anchovy collected at entrainment stations in Alamitos Bay.

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. Total annual entrainment at HnGS was estimated at 22,673,541 (standard error of 1,037,682) larvae and 11,128,912 (standard error of 846,961) eggs using measured cooling water flows during 2006 (Table 4.5-2). If the CWIS pumps were run at the design (maximum capacity) flows, annual entrainment estimates increased to 27,301,289 larvae (standard error of 1,252,501) and 14,029,527 eggs (standard error 1,092,083; Table 4.5-2).

Fecundity Hindcasting (*FH*)

The entrainment estimate for northern anchovy for the 2006 sampling period was used to estimate the number of breeding females at the age of maturity needed to produce the estimated number of larvae entrained. Butler et al. (1993) modeled annual fecundity and egg and larval survivorship for northern anchovy. Their "best" estimate can be derived by fitting the range of mortality estimates from field collections to the assumption of a stable and stationary population age structure. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage (Table 4.5-8). Fish at the mean age of entrainment include yolk sac, early stage and late stage larvae. Therefore, survival estimates for all three stages were combined to obtain a finite survival value of 0.002 up to the mean age at entrainment (5.0 days). This was calculated by dividing a larval growth rate of 0.41 mm/day (0.02 inches/day) into the difference between the mean length (5.29 mm [0.21 inches]) and the calculated hatch length of 3.28 mm [0.13 inches]).

Table 4.5-8. Stage-specific life history parameters for northern anchovy (*Engraulis mordax*) modified from Butler et al. (1993). Z = instantaneous daily mortality; S = finite survival rate.

Stage	Z_{best}	Stage duration (days)	Age (days)	S_{best}	CV_{best}
Egg	0.231	2.9		0.512	0.142
Yolk-sac larva	0.366	3.6	6.5	0.093	0.240
Early larva	0.286	12	18.5	0.032	0.071
Late larva	0.0719	45	63.5	0.039	0.427
Early juvenile	0.0141	62	125.5	0.417	0.239
Late Juvenile	0.0044	80	205.5	0.703	0.033
Pre-recruit	0.0031	287	492.5	0.411	0.088

Clark and Phillips (1952) reported age at sexual maturity as 1–2 years. Similarly, Leet et al. (2001) reported that 47% to 100% of one-year olds may be mature in a given year while all are mature by two years. For modeling purposes we used a mid-value of 1.5 years. For longevity, Hart (1973) reported a value of seven years, but Leet et al. (2001) stated that northern anchovy in the fished population rarely exceed four years of age. The survivorship values in Table 4.5-9 were used to estimate an average annual fecundity of 163,090 eggs produced over a seven-year period using the data presented in Butler et al. (1993).

Table 4.5-9. Survivorship table for adult northern anchovy (*Engraulis mordax*) from Butler et al. (1993) showing spawners (Lx) surviving at the start of age interval and numbers of eggs spawned annually (Mx).

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

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

The estimated number of reproductive age adult female northern anchovies whose lifetime reproductive output was entrained through the HnGS CWIS for 2006 was 4,300 based on the actual cooling water flows during the period (Table 4.5-10). Using the design flows, an estimated 5,182 eggs and larvae were entrained during the period. The sensitivity analysis, based on the 90% confidence intervals, shows that the variation in estimates of entrainment had much less of an effect on the variation of the *FH* estimate than the life history parameters used in the model.

Table 4.5-10. 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	**92**	65	29	296	268
Total Entrainment	11,128,912	846,961	80	103	23
Larvae					
FH Estimate	**4,208**	3,649	1,010	17,522	16,512
Total Entrainment	22,673,541	1,037,682	3,891	4,524	634
Design Flows					
Eggs					
FH Estimate	116	82	36	373	337
Total Entrainment	14,029,527	1,092,083	101	131	30
Larvae					
FH Estimate	5,066	4,394	1,217	21,099	19,882
Total Entrainment	27,301,289	1,252,501	4,684	5,449	765

The upper and lower estimates are based on a 90% confidence interval of the mean. FH estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Adult Equivalent Loss (*AEL*)

The parameters required for formulation of *AEL* estimates include larval survival from entrainment to settlement and survival from settlement to the age of maturity. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage (Table 4.5-10). The early larval stage survival was adjusted to the mean age at entrainment (5.0 days) and used to calculate a finite survival through age 63.5 days of 0.174 using the daily survival rates for late stage larvae. The other finite survival rates from Butler et al. (1993) were used to estimate the number of adults of age one year, the age of first maturity when 50% of the females are sexually mature. The equivalent number of adult northern calculated from the number of larvae entrained through the HnGS CWIS for 2006 was 20,684 based on actual flows during the period (Table 4.5-11). Using the design flows, the equivalent number of adults entrained during the period was projected as 24,845 larvae.

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	**20,634**	23,886	3,073	138,548	135,475
Total Entrainment	22,673,541	1,037,682	19,081	22,187	3,107
Design Flows					
AEL Estimate	**24,845**	28,762	3,700	166,827	163,127
Total Entrainment	27,301,289	1,252,501	22,970	26,720	3,750

The upper and lower estimates are based on a 90% confidence interval of the mean. AEL estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Empirical Transport Model (*ETM*)

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

The monthly estimates of proportional entrainment (*PE)* for northern anchovies for 2006 ranged from 0 to 0.0005 using the actual flows and ranged from 0 to 0.0007 based on the design flows, and were only collected during five of the paired entrainment-source water surveys (Table 4.5-12). The largest estimate was calculated for the November survey, but the results also show that anchovy larvae were collected during almost all of the source water surveys with the largest proportion was present during the April survey (f_i = 0.551 or 55.1%). The values in the table were used to calculate a P_M estimate of 0.0076 with a standard error of 0.0031 based on the actual flows during the sampling period and an estimate of 0.0092 (standard error of 0.0037) based on the design flows Estimates were calculated using the alongshore extrapolated estimate of the total source population. The average alongshore displacement over the period of exposure was 27.02 km (16.8 mi) and the average onshore transport was 24.43 km (15.2 mi).

Table 4.5-12. *ETM* data and results for northern anchovy larvae based on actual and design (maximum) cooling water flows and a sampling volume in the nearshore of 140,698,222 m^3.

	Actual Flows		**Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
17-Jan-06	0	0	0	0	0
14-Feb-06	0	0	0	0	0
13-Mar-06	0	0	0	0	0.01710
10-Apr-06	0.00037	0.00152	0.00047	0.00192	0.55074
8-May-06	0.00039	0.00197	0.00042	0.00214	0.31753
5-Jun-06	0.00010	0.00151	0.00014	0.00201	0.04618
5-Jul-06	0	0	0	0	0.01338
14-Aug-06	0	0	0	0	0.00036
11-Sep-06	0.00016	0.00374	0.00017	0.00404	0.02109
9-Oct-06	0	0	0	0	0.00261
6-Nov-06	0.00050	0.00789	0.00070	0.01103	0.00889
4-Dec-06	0	0	0	0	0.02212
P_M	**0.0076**	0.0031	**0.0092**	0.0037	–

4.5.3.2 Silversides (Atherinopsidae)

Jamie Siler

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

4.5.3.2.1 Life History and Ecology

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

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

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

The spawning activity of topsmelt corresponds to changes in water temperature (Middaugh et al. 1990). In Newport Bay, topsmelt spawn from February to June peaking in May and June (Love 1996). Females deposit the eggs on marine plants and other floating objects where fertilization occurs (Love 1996). Fecundity is a function of female body size with individuals in the 11–12 cm (4.3–4.7 inches) range spawning approximately 200 eggs per season, and fish 16 cm (6.3 inches) or greater spawning 1,000 eggs per season (Fronk 1969). The spawning season for jacksmelt is from October through March (Clark 1929), with peak activity from January through March (Allen et al. 1983). Individuals may spawn multiple times during the reproductive season and reproductive females have eggs of various sizes and maturities present in the ovary (Clark 1929). Fecundity has not been well documented but is possibly over 2,000 eggs per female (Emmett et al. 1991). Females lay eggs on marine plants and other floating objects where fertilization by males occurs (Love 1996). Hatch length for topsmelt ranges from 4.3–5.4 mm (0.17–0.21 inches), and 6–9 mm (0.24–0.35 inches) for jacksmelt (Moser 1996). Larval growth rate averages approximately 0.37 mm/day (0.01 inches/day) for both species based on data from Middaugh et al. (1990). Plankton sampling conducted during the earlier 316(b) study (IRC 1981) found that nearly all silverside larvae were collected in surface samples indicating a strong behavioral tendency for these larvae to actively maintain their position in surface strata, possibly through a phototatic response.

Summary of silverside distribution and life history attributes.

***Range*:**

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

Life History:

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

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

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

The spawning activity of grunion is quite different from the other silversides. Spawning occurs only three or four nights following each full or new moon, and then only for 1–3 hours immediately after the high tide, from late February to early September (peaking late March to early June) (Love 1996). The female swims onto the beach and digs into the wet sand, burying herself up to her pectoral fins or above. The male or males curve around her with vents touching her body, and when the female lays her eggs beneath the sand, males emit sperm, which flows down her body and fertilizes the eggs (Love 1996). Females spawn four to eight times per season at about 15-day intervals, producing 1,000–3,000 eggs. Hatch length for grunion ranges from 6.5–7.0 mm (0.25–0.27 inches) (Moser 1996).

4.5.3.2.2 Population Trends and Fishery

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

Topsmelt were the most common fish collected in a study of Anaheim Bay, just south of Alamitos Bay (Klingbeil et al. 1975). In a series of trawls conducted in Alamitos Bay from 1992-1995, topsmelt wre the fifth most dominant species (Valle et al. 1999). They were present year round in both areas and likely used the habitat as spawning grounds. Potential population trends of silversides can be examined from areas outside of the Alamitos Bay area to evaluate variability over time. There were no consistent trends for the recreational catch in southern California from 1980-2006 (Figure 4.5-11a). A time series analysis of silversides was conducted at King Harbor in Redondo Beach by the Vantuna Research Group. From 1974-2006, two trends emerge. First, the density of silversides was generally higher prior to the regime shift associated with the PDO (Figure 4.5-11b). Secondly, the density of silversides declined from the early 1970’s to the early 1990s, then remained fairly constant through 2006. Overall, the density of silversides declined significantly from 1974-2006. In the OREHP time series (Figure 4.5-11c), catch per sampling period from 1995-2006 varied around an average of 10.7 fish/station in Santa Monica Bay and 15.3 fish/station in the rest of the Southern California Bight. The difference between the two time series were high catches of jacksmelt in the April samples at Seal Beach in 1995, 1999, 2001. Jacksmelt move into this area in the spring to lay their eggs. Overall, since the mid 1990s silversides have been increasing in catch throughout the southern California bight including Santa Monica Bay.

A limited fishery exists for silversides in which they are marketed fresh for human consumption or for bait (Gregory 2001a). The commercial fishery for silversides has been conducted with a variety of gears including gillnets, lampara nets, and round haul nets. Historically, set-lines were used in San Francisco Bay for jacksmelt, and during the 1920s beach nets were used at Newport Beach (Gregory 2001a). Commercial catches of jacksmelt have varied sharply over the past 80 years fluctuating from more than 900,000 kg (2,000,000 lbs) in 1945 to 1,150 kg (2,500 lbs) in 1998 and 1999. Silversides, in general, are an incidental fishery and the large fluctuations in the catch records reflect demand rather than relative abundances.

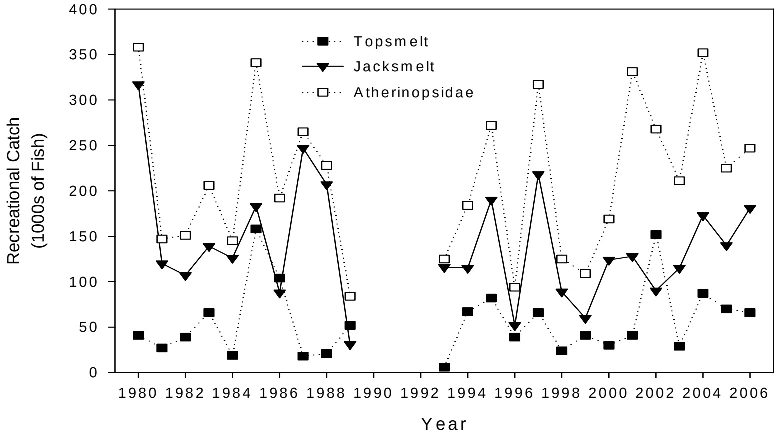
Grunion are primarily harvested by recreational fishers by hand when these fish spawn on wet sandy beaches during spring and summer. They are also taken incidentally in bait nets and other round haul nets in limited quantities and are used as live bait, although no commercial landings have been reported (Gregory 2001b). In the 1920s, the recreational fishery was showing signs of depletion, and a regulation was passed in 1927 establishing a closed season of three months, April through June. The fishery improved, and in 1947, the closure was shortened to April through May.

Both topsmelt and jacksmelt make up a significant portion of the catch from piers and along shores. Jacksmelt shore landings declined by over 75% in the 1990s compared to the 1980s (Jarvis et al. 2004) Recent catch estimates of jacksmelt by recreational anglers in southern California from 2000 to 2006 ranged from 29,000 to 152,000 fish, with an average of 67,900 fish caught annually (Table 4.5-13). Sport fishery catch estimates for topsmelt in southern California from 2000 to 2006 ranged from 90,000 to 181,000 fish, with an average of 135,900 fish caught annually. A total of 28 kg (62 lbs) of jacksmelt with a revenue of $35 were landed in the Los Angeles-Long Beach area in 2006, while 4.5 kg (10 lbs) of topsmelt with a revenue of $50 were landed according to specific CDFG catch block data from the area.

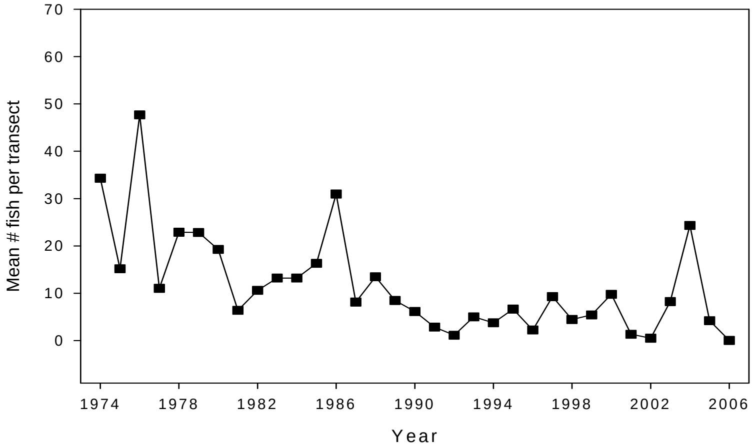
Table 4.5-13. Annual landings for jacksmelt and topsmelt in the Southern California region based on RecFIN data (values are numbers of fish).

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

a) recreational catch



b) King Harbor



c) OREHP

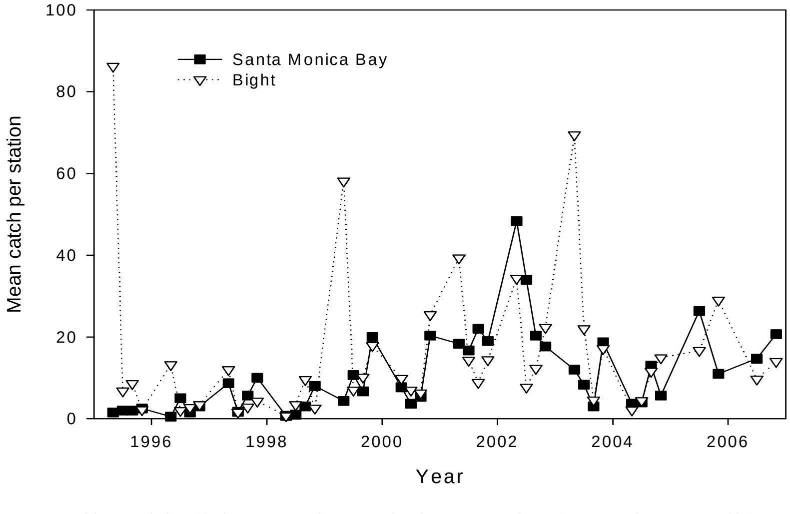


Figure 4.5-11. Silverside fishery and population trends: a) Southern California recreational landings, b) King Harbor observational data, and c) Ocean Resource Enhancement Hatchery Program (OREHP) gill net monitoring data. Error bars are ± 1 S.E.

4.5.3.2.3 Sampling Results

Silverside larvae were the second most abundant taxon at the entrainment station with a mean concentration of 778 per 1,000 m^3 (264,172 gal) over all surveys while silverside eggs had an average concentration of 14 per 1,000 m^3 (264,172 gal) (Table 4.5-1 and Table 4.5-14). Nearly 70% of the silverside larvae in the entrainment samples could not be positively identified to the species level, but of those that could be positively identified, jacksmelt was the most abundant followed by California grunion, and topsmelt. The larvae occurred sporadically in December–May (Figure 4.5-12), but during periods of maximum abundance in late May 2006 silversides were present in the entrainment samples at very dense average concentrations approaching of 12,000 per 1,000 m^3 (264,172 gal). They were absent or very low in abundance in samples from July through November. Monthly source water concentrations followed a similar seasonal pattern (Figure 4.5-13) but were much lower (ca. average of 20–80 per 1,000 m^3 [264,172 gal]) during spring than the entrainment concentrations. They tended to be much more abundant in nighttime samples than daytime samples (Figure 4.5-14). The length frequency distribution of measured silverside larvae showed a unimodal distribution with most larvae in the range of 8–10 mm (0.3–0.4 inches) (Figure 4.5-15). The lengths of the larvae from the entrainment station samples ranged from 2.5–24.4 mm (0.1–1.0 inches) with a mean of 9.5 mm (0.4 inches) NL.

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

Taxon	**Common Name**	**Avg. Conc. (per 1,000 m^3)**	**Total Count**	**% of Total**	**Annual Entrainment (Actual Flows)**	**Annual Entrainment (Design Flows)**
Larval Fishes						
Atherinopsidae unid.	unid. silversides	539.22	2,308	69.29	684,325,416	763,444,182
Atherinopsis californiensis	jacksmelt	135.77	523	17.45	112,462,389	157,508,063
Leuresthes tenuis	California grunion	71.60	306	9.20	90,595,407	100,018,997
Atherinops affinis	topsmelt	31.60	126	4.06	32,939,893	41,846,831
		778.19	**3,263**		**920,323,105**	**1,062,818,073**
Fish Eggs						
Atherinopsidae unid. (eggs)	silverside eggs	10.49	43	72.90	11,560,935	14,653,846
Atherinops affinis (eggs)	topsmelt eggs	3.90	15	27.10	4,427,698	4,441,190
		14.39	**58**		**15,988,633**	**19,095,036**

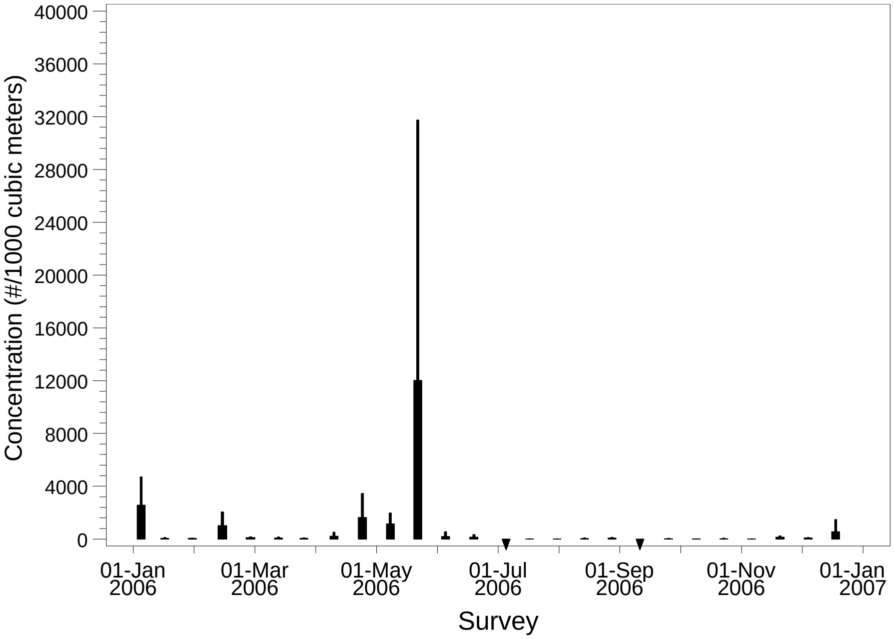


Figure 4.5-12. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of silverside larvae collected at HnGS entrainment Station E3 during 2006.

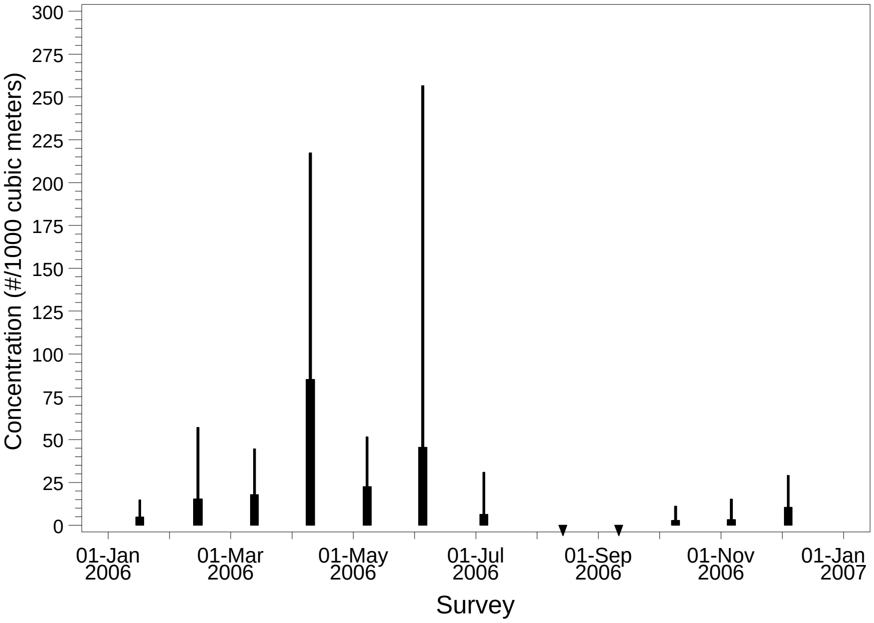


Figure 4.5-13. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of silverside larvae collected at HnGS source water stations during 2006.

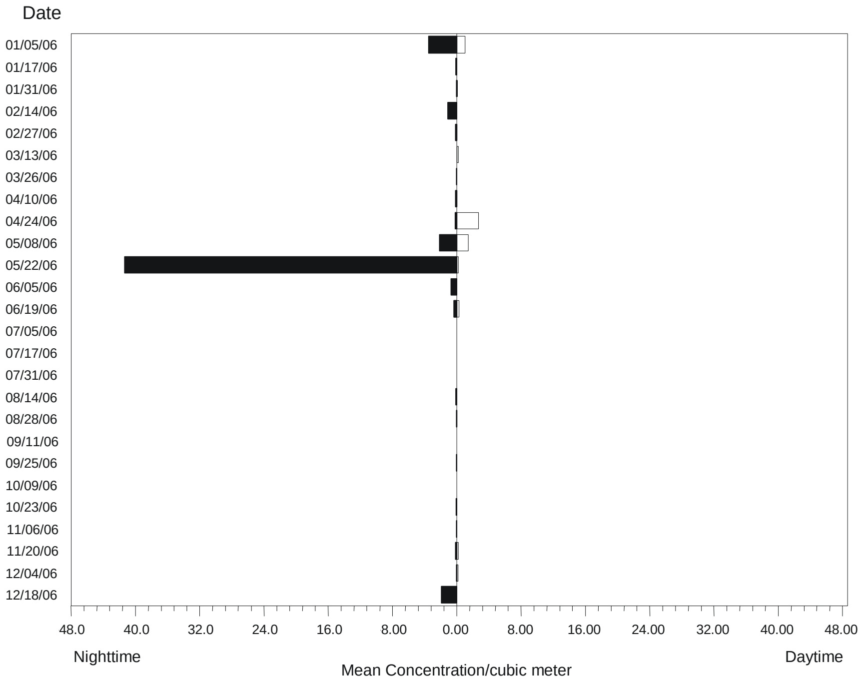


Figure 4.5-14. Mean concentration (#/1.0 m^3 [264 gal]) of silverside larvae at entrainment Station E3 during night (Cycle 3) and day (Cycle 1) sampling.

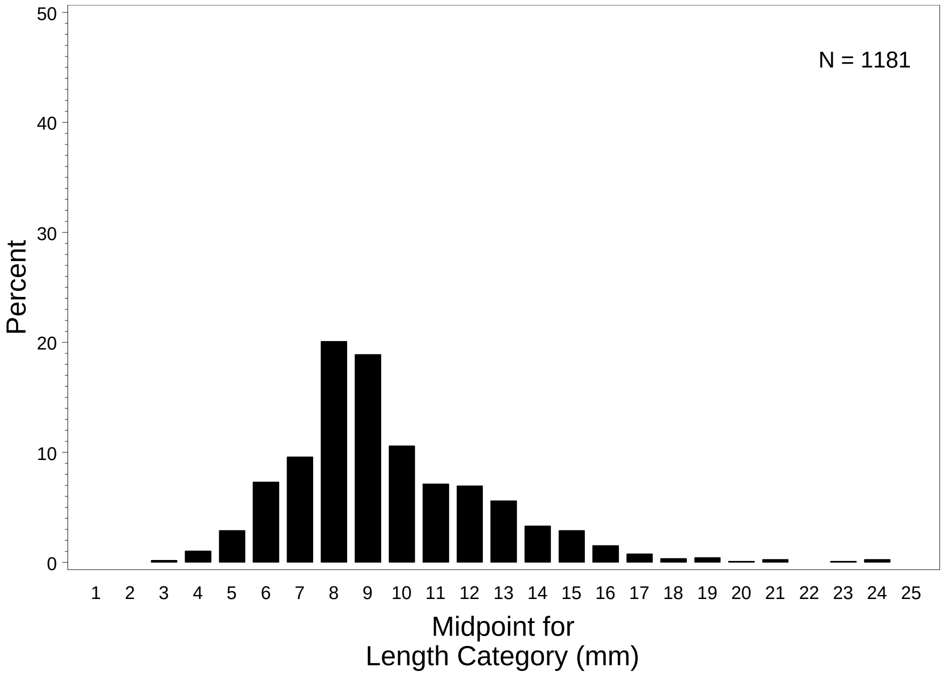


Figure 4.5-15. Length (mm) frequency distribution for larval silversides collected at entrainment stations in Alamitos Bay.

4.5.3.2.4 Modeling Results

The following section presents the results for empirical transport modeling of entrainment effects on Atherinopsidae complex (silverside) eggs and larvae. Although there was information on the early life history for California grunion, there was very little species-specific information available for the other two species, topsmelt and jacksmelt, that were collected in greater abundances during the study. Therefore, circulating water system effects were estimated using only the *ETM* and neither of the demographic models. Total annual entrainment at HnGS was estimated at 11,560,935 silverside eggs (all species combined) (standard error of 3,111,232) and 920,323,104 silverside larvae (all species combined) (standard error of 132,981,650) using measured cooling water flows during 2006 (Table 4.5-2). Using the design flows, total annual entrainment increased to 14,653,846 silverside eggs (standard error of 3,916,405) and 1,062,818,073 silverside larvae (standard error of 143,372,928).

Empirical Transport Model (*ETM)*

A larval growth rate of 0.44 mm/day (0.02 inches/day) for silversides was estimated from laboratory studies by Middaugh et al. (1990) and used with the difference between the calculated hatch length (6.7 mm [0.26 inches]) and the length of the 95th percentile of the measurements (14.2 mm [0.56 inches]) to estimate that the larvae were exposed to entrainment for a period of approximately 17.1 days.

The monthly estimates of *PE* for silversides for 2006 ranged from 0 to 0.31110 based on the actual flows and ranged from 0 to 0.42120 using the design flows (Table 4.5-15). The largest estimate was calculated for the August survey, but the largest proportion of the source population was present during the April survey (f_i = 0.322 or 32.2%). The values in the table were used to calculate a P_M estimate of 0.4095 with a standard error of 0.4014 using the actual CWIS flows during the sampling period and an estimate of 0.4685 with a standard error of 0.4571 using the design flows. Estimates were calculated using the alongshore extrapolated estimate of the total source population. The average alongshore displacement over the period of exposure was 22.88 km (14.2 mi).

Table 4.5-15. *ETM* data and results for silverside larvae based on actual and design (maximum) cooling water flows sampling volume in the nearshore of 140,698,222 m^3.

	Actual Flows		**Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
17-Jan-06	0.05777	0.15792	0.09294	0.25386	0.01928
14-Feb-06	0.11282	0.51574	0.15576	0.70934	0.12048
13-Mar-06	0.02327	0.07671	0.02882	0.09455	0.05413
10-Apr-06	0.01664	0.04369	0.02122	0.05516	0.32212
8-May-06	0.19478	0.54355	0.21216	0.59176	0.11606
5-Jun-06	0.01330	0.08372	0.01784	0.11193	0.25485
5-Jul-06	0	0	0	0	0.03498
14-Aug-06	0.31110	2.00357	0.42120	2.70245	0.00182
11-Sep-06	0	0	0	0	0
9-Oct-06	0.01501	0.05541	0.01756	0.06462	0.01508
6-Nov-06	0.01525	0.06643	0.02130	0.09281	0.00990
4-Dec-06	0.02945	0.08058	0.04477	0.12248	0.05131
P_M	**0.4095**	0.4014	**0.4685**	0.4571	–

4.5.3.3 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*).

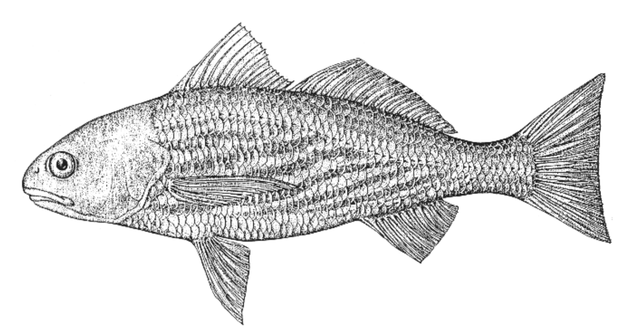


Illustration from NOAA

4.5.3.3.1 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 (33 and 427 ft), and it was collected most frequently at 10 m (33 ft). It is nocturnally active, and is considered a benthic searcher that feeds on a wide variety of benthic invertebrate prey. Adults feed on polychaetes and crustaceans, while juveniles feed during the day in midwater on zooplankton (Allen 1982).

White croakers are oviparous broadcast spawners. They mature between about 130 and 190 mm (5 and 7.5 inches) TL, between their first to fourth year; approximately 50% spawn at age one year (Love 1996). About one-half of males mature by 140 mm (5.5 inches) TL, and one-half of females by 150 mm (5.9

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

Newly hatched white croaker larvae are 1–2 mm (0.04–0.08 inches) 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 length at various numbers of days after birth presented in Moser (1996) were used to calculate an average daily growth rate of 0.25 mm/day (0.01 inches/day) from hatching through the flexion stage for these species of Sciaenidae. Although the species did not include white croaker this estimate was used for both white croaker 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 inches) (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 one (Moore 2001). No mortality estimates are available for any of the life stages of this species.

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

4.5.3.3.2 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 311,000 kg (685,000 lbs) annually, exceeding 450,000 kg (1 million lbs) for several years (Moore and Wild 2001). High landings in 1952 probably occurred due to the collapse of the Pacific sardine fishery. Since 1991, landings averaged 209,000 kg (461,000 lbs) and steadily declined to an all-time low of 65,000 kg (142,500 lbs) in 1998. Landings by recreational fishermen aboard commercial passenger fishing vessels (CPFVs) averaged about 12,000 fish per year from 1990 to 1998, with most of the catch coming from southern California.

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

The earlier 316(b) study of the HnGS in 1978–1979 (IRC 1981) measured mean density values of white croaker larvae and found that the greatest densities occurred from mid-December to May, with maximum values from mid-February through mid-March. From late fall through early winter, and late spring through late fall, very low numbers of larvae were collected or they were not present. Mean density values varied from 0 to 2,060 larvae per 1,000 m^3 (264,172 gal) for the day surveys and from 0 to 2,310 larvae per 1,000 m^3 (264,172 gal) for the night surveys. These densities are over thirty times greater than the densities measured during the 2006 sampling period in the present study. A statistical comparison of mean density values for the winter-spring period of peak abundance in 1978–1979 indicated that the numbers of larvae collected on day and night surveys were not significantly different.

Annual commercial landings in the Los Angeles region since 2000 have varied from a high of 40,000 kg (88,200 lbs) in 2000 to a low of 6,800 kg (15,000 lbs) in 2006, with an average of 19,700 kg (43,400 lbs) and average net worth of $29,385 annually (Table 4.5-16). 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 (RecFIN 2007). In the Los Angeles-Long Beach area in 2006, 13,680 kg (30,166 lbs) were landed for a revenue of $26,630 according to specific CDFG catch block data from the area.

Table 4.5-16. Annual landings and revenue for white croaker in the Los Angeles region based on PacFIN data.

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

4.5.3.3.3 Sampling Results

White croaker larvae was the fourth most abundant taxon at the entrainment station with a mean concentration of 68 per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were most abundant in spring, absent in summer and fall, and began appearing again in December 2006 (Figure 4.5-16). During periods of maximum abundance in March 2006 white croaker was present in the entrainment samples at average concentrations of 531 per 1,000 m^3 (264,172 gal). Source water abundances followed the same seasonal pattern, but the peak average concentration in March was over four times greater than the entrainment samples (Figure 4.5-17). There was no consistent relationship in entrainment abundance between daytime and nighttime samples for white croaker larvae (Figure 4.5-18). With a sample size of 233 measured white croaker larvae, the length frequency plot for larvae showed a strongly unimodal curve with most of sampled larvae in the 1.5–2.5 mm (0.06–0.10 inches) size classes and a rapid decline in frequency of occurrence at larger size classes to 9.5 mm (0.37 inches) (Figure 4.5-19). The mean length of specimens from the entrainment station samples was 2.6 mm NL (0.01 inches) for white croaker.

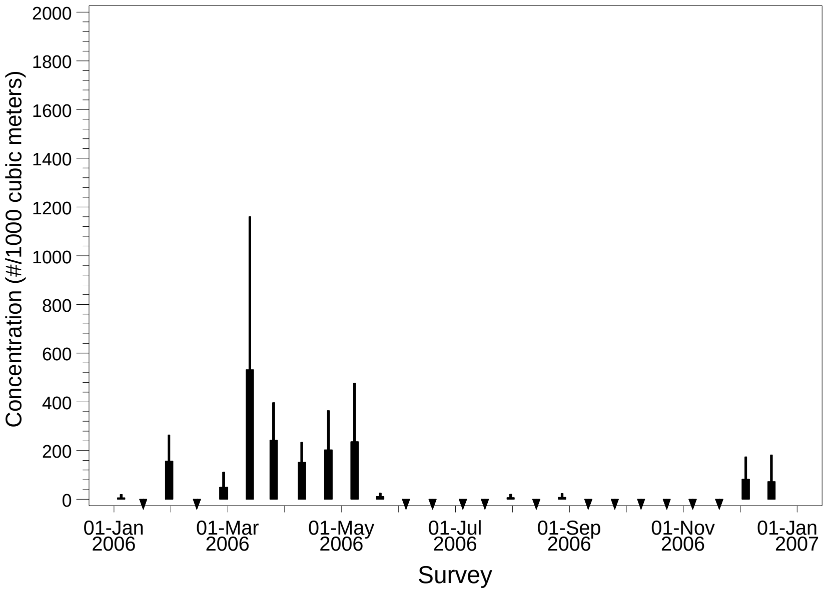


Figure 4.5-16. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of white croaker larvae collected at HnGS entrainment Station E1 during 2006.

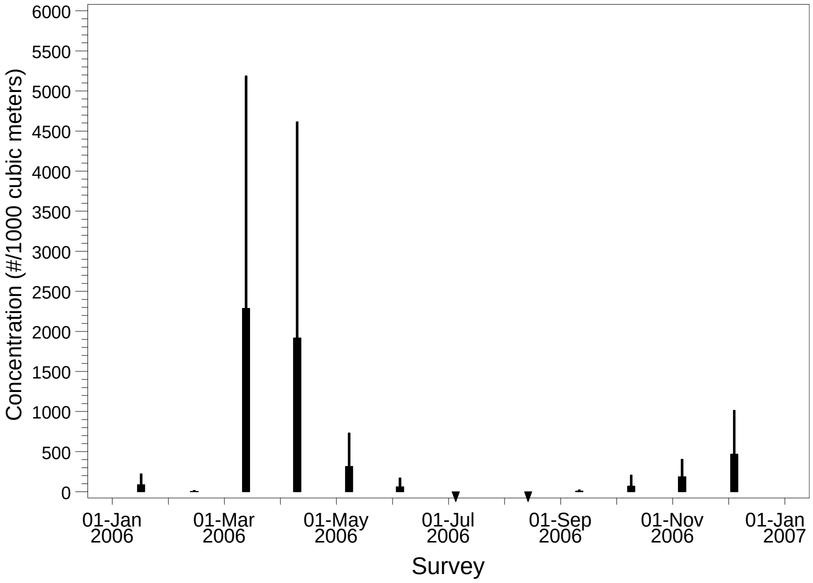


Figure 4.5-17. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of white croaker larvae collected at HnGS source water stations during 2006.

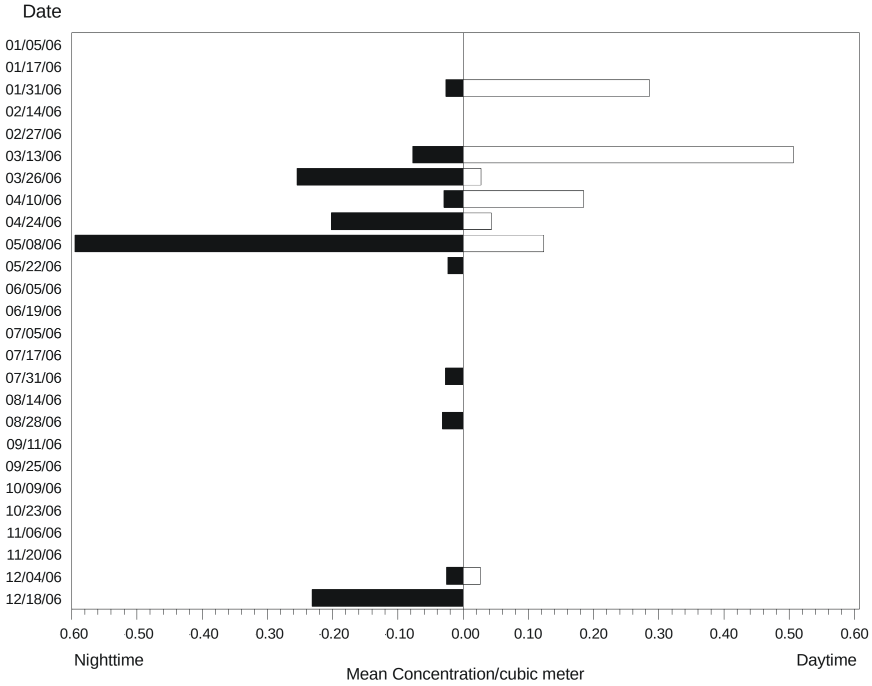


Figure 4.5-18. Mean concentration (#/1.0 m^3 [264 gal]) of white croaker larvae at entrainment Station E1 during night (Cycle 3) and day (Cycle 1) sampling.

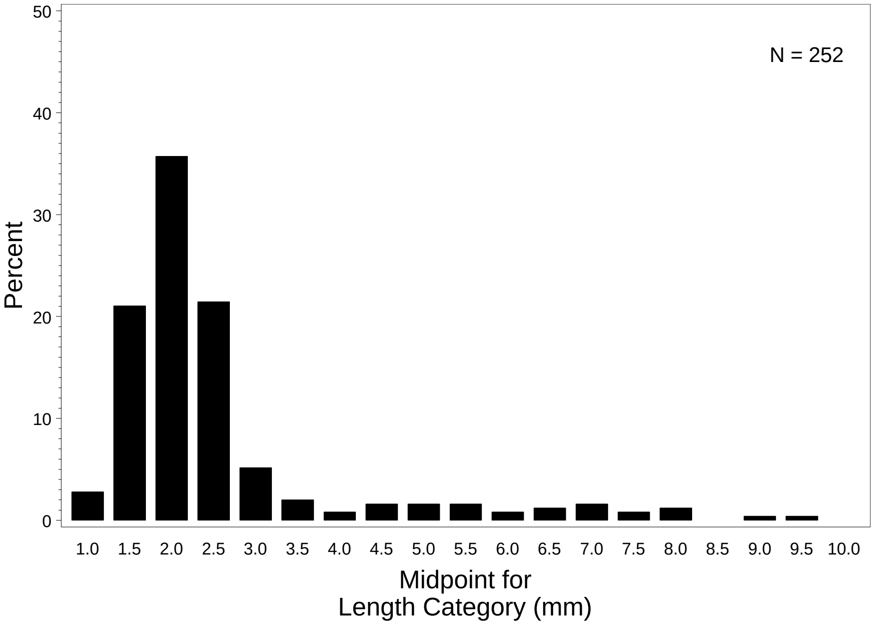


Figure 4.5-19. Length (mm) frequency distribution for larval white croaker collected at entrainment Station E1.

4.5.3.3.4 Modeling Results

The following section presents the results for empirical transport modeling of entrainment effects on white croaker 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* based on numbers of eggs entrained. Total annual entrainment at HnGS was estimated at 57,836,910 white croaker eggs (standard error of 2,103,521) and 75,425,299 white croaker larvae (standard error of 4,341,458) using measured cooling water flows during 2006 (Table 4.5-2). Using the design flows, total annual entrainment increased to 86,480,192 eggs (standard error of 3,219,014) and 96,188,344 larvae (standard error of 5,330,046).

Fecundity Hindcasting (*FH)*

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

The estimated numbers of reproductive age adult female white croakers whose lifetime reproductive output was entrained through the HnGS CWIS for the 2006 period was 32 using the cooling water flows and 48 using the design flow volumes (Table 4.5-17). 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 4.5-17. 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
Actual Flows					
FH Estimate	**32**	23	10	103	93
Total Entrainment	57,836,910	2,103,521	30	34	4
Design Flows					
FH Estimate	**48**	34	15	155	140
Total Entrainment	86,480,192	3,219,014	45	51	6

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 of 0.25 mm/day (0.01 inches/day) derived from data on five species of Sciaenidae (croakers) that were raised in the laboratory by Southwest Fisheries Science Center staff (Moser 1996) was used with the calculated hatch length (1.6 mm [0.06 inches]) and the length at the 95th percentile (6.2 mm [0.24 inches]) to estimate that white croaker were exposed to entrainment for a period of approximately 18.7 days. The duration of the planktonic egg stage, 2.2 days, was added to the period for the larvae to estimate a total exposure duration of 20.8 days.

The monthly estimates of *PE* for white croaker for 2006 ranged from 0 to 0.00169 using actual cooling water flows and from 0 to 0.00184 using the design flows (Table 4.5-18). Estimates were only collected during four of the paired entrainment-source water surveys. White croaker larvae are more common in nearshore waters and were collected in all but two of source water surveys with the largest proportion of the source population present during the March survey (f_i = 0.409 or 40.9%). The values in the table were used to calculate a P_M estimate of 0.0063 with a standard error of 0.0033 using the actual flows during the sampling period and an estimate of 0.0079 with a standard error of 0.004 using the design flows. Estimates were calculated using the alongshore extrapolated estimate of the total source population. The average alongshore displacement over the period of exposure was 26.19 km (16.3 mi) and the average onshore transport was 23.66 km (14.7 mi).

Table 4.5-18. *ETM* data and results for white croaker larvae based on actual and design (maximum) cooling water flows sampling volume in the nearshore of 140,698,222 m^3.

	Actual Flows		**Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
17-Jan-06	0	0	0	0	0.01795
14-Feb-06	0	0	0	0	0.00068
13-Mar-06	0.00041	0.00243	0.00051	0.00299	0.40907
10-Apr-06	0.00011	0.00041	0.00014	0.00052	0.35228
8-May-06	0.00169	0.01399	0.00184	0.01523	0.03572
5-Jun-06	0	0	0	0	0.00718
5-Jul-06	0	0	0	0	0
14-Aug-06	0	0	0	0	0
11-Sep-06	0	0	0	0	0.00118
9-Oct-06	0	0	0	0	0.01249
6-Nov-06	0	0	0	0	0.03490
4-Dec-06	0.00029	0.00149	0.00044	0.00226	0.12856
P_M	**0.0063**	0.0033	**0.0079**	0.0040	–

4.5.3.4 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 HnGS: 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).

4.5.3.4.1 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 inches) (Moser 1996). Most have blunt heads that are topped with some arrangement of cirri (Moyle and Cech 1988; Moser 1996). Their bodies are generally elongate and without scales. Dorsal fins are often continuous and contain more soft rays than spines (Moyle and Cech 1988). Coloration in the group is quite variable, even among individuals of the same species (Stephens et al. 1970).

The three species of *Hypsoblennius* found in California waters are morphologically similar as early larvae (Moser 1996; Ninos 1984). For this reason most *Hypsoblennius* identified in the HnGS 316(b) plankton collections were identified as *Hypsoblennius* spp. Certain morphological features (e.g., preopercular spines) develop at larger sizes and allow taxonomists to identify some larvae to the species level.

Blennies inhabit a variety of hard substrates in the intertidal and shallow subtidal zones of tropical and subtropical marine habitats throughout the world. They may occur to depths of 24 m (80 ft) but are more frequently found in water depths of less than 5 m (15 ft) (Love 1996). Combtooth blennies are common in rocky tidepools, reefs, breakwaters, and on pier pilings. They are also frequently observed on encrusted buoys and boat hulls.

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

Summary of combtooth blenny distribution and life history attributes.

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

Life History:
- Size: bay blenny to 14.7 cm (5.8 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

Female blennies mature quickly and reproduce within the first year, reaching peak reproductive potential in the third year (Stephens 1969). The spawning season typically begins in the spring and may extend into September (Stephens et al. 1970). Blennies are oviparous and lay demersal eggs that are attached to the nest substrate by adhesive pads or filaments (Moser 1996). Males tend the nest and developing eggs. Females spawn 3–4 times over a period of several weeks (Stephens et al. 1970). Males guard the nest aggressively and will often chase the female away, however, several females may occasionally spawn with a single male. The number of eggs a female produces varies proportionately with size (Stephens et al. 1970). The mussel blenny spawns approximately 500 eggs in the first reproductive year and up to 1,500 eggs by the third year (Stephens et al. 1970). Total lifetime fecundity may be up to 7,700 eggs (Stephens 1969).

Larvae are pelagic and average approximately 2.7 mm (0.11 inches) in length two days after hatching (Stephens et al. 1970). The planktonic phase for *Hypsoblennius* spp. larvae may last for 3 months (Stephens et al. 1970; Love 1996). Captured larvae released by divers have been observed to use surface water movement and near-surface currents to aid swimming (Ninos 1984). After release the swimming larvae orient to floating algae, bubbles on the surface, or the bottoms of boats or buoys. The size at settlement ranges from 12–14 mm (0.5–0.6 inches). After the first year mussel and bay blenny averaged 40 mm and 45 mm (1.6 in and 1.8 inches) total length, respectively (Stephens et al. 1970). Bay blenny grow to a slightly larger size and live longer than mussel blenny, reaching a size of 15 cm (5.9 inches) and living for 6–7 years (Stephens 1969; Stephens et al. 1970; Miller and Lea 1972). Mussel blennies grow to 13 cm (5.1 inches) 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).

4.5.3.4.2 Population Trends and Fishery

Combtooth blennies were common in the eelgrass habitat sampled within Alamitos Bay in a series of trawls conducted from 1992-1995. The Bay blenny was more common in the outer part of the bay (Valle et al. 1999). Stephens and Pondella (2002) measured annual larval densities at King Harbor in Redondo Beach from 1974–1997 and found an overall decline in combtooth blennies from highest densities in the mid 1970s to lowest densities in the mid 1990s. Part of the decline was attributed to a period of warmer water temperatures throughout the region beginning in the late 1970s, but other localized disturbances to nesting habitat from storm damage, breakwater renovation, and channel dredging may have had an effect on larval production.

Long-term data on abundances of combtooth blennies from King Harbor in Redondo Beach were collected from surveys of quarry rock boulders from 1984–2006 (Pondella unpubl. data). An average of 1.62 blennies was collected per boulder each year. At the beginning of the study, they were found in the highest densities (9.57 individuals/boulder) and then declined until 1995 when the density recorded was 0.143/boulder (Figure 4.5-20). Since 1995, the density increased to 1.57 individuals/boulder in 2005. Annual average densities of combtooth blennies in King Harbor were correlated with average annual sea surface temperatures. This is shown in the decline in densities following major El Niño periods in 1983, 1987, 1992–1993, and 1997. The period of warm seawater temperatures resulted in declines in combtooth blenny larvae in King Harbor in the 1990s (Stephens and Pondella 2002). The correlation between adult density and sea surface temperature suggests that the abundance of this short-lived species was dependent on successful recruitment in response to optimal oceanographic conditions.

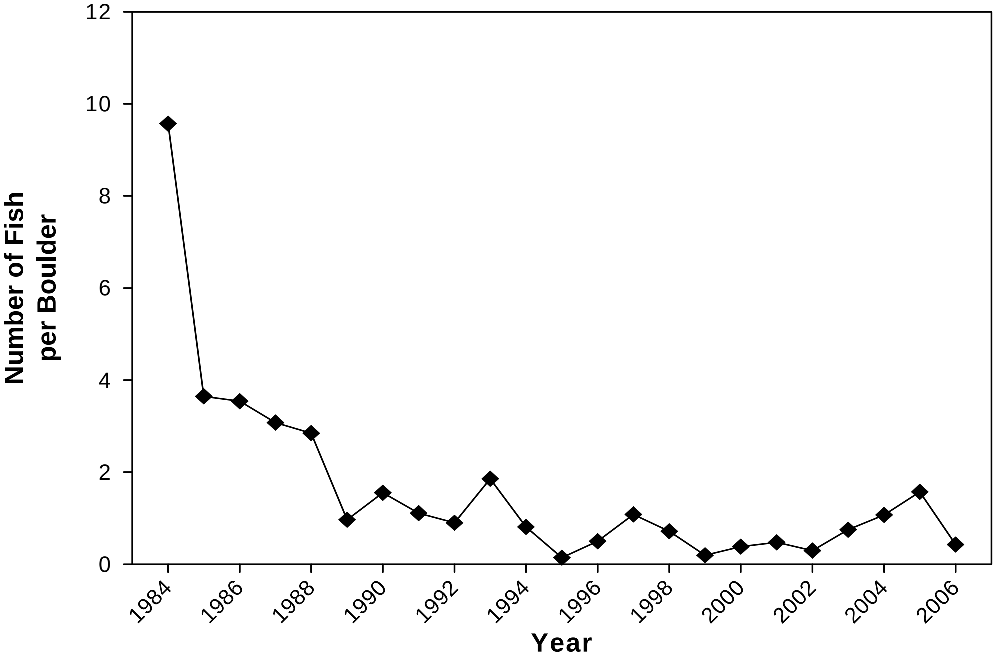


Figure 4.5-20. Abundance of combtooth blennies collected per boulder at King Harbor, Redondo Beach, California from 1984–2006 (from Pondella, unpubl. data).

The earlier 316(b) study of the HnGS in 1978–1979 (IRC 1981) measured mean density values of *Hypsoblennius* species complex larvae that were lowest from mid-January through the end of March and relatively high for the remainder of the year. Survey means for the near-field varied from 0 to 20,493 larvae per 1,000 m^3 (264,172 gal) (average 2,725 per 1,000 m^3 [264,172 gal]) and from 1 to 1,800 larvae per 1,000 m^3 (264,172 gal) (average 120 per 1,000 m^3 [264,172 gal]) for the far-field. These near-field densities were approximately four times greater than the 2006 densities measured at the entrainment station while the far field station densities were about one-third of the 2006 source water densities.

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

4.5.3.4.3 Sampling Results

Combtooth blenny was the third most abundant taxon at the entrainment station with a mean concentration of 652 larvae per 1,000 m^3 (264,172 gal) over all surveys (Table 4.5-1). They were most abundant in summer, peaking in June, with a smaller peak in early fall (Figure 4.5-21). 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 3,000 per 1,000 (264,172 gal). Source water abundances followed the same seasonal pattern, but the peak average concentration in June was approximately 1,200 per 1,000 m^3 (264,172 gal) (Figure 4.5-22). There were substantially more larvae in the nighttime samples than daytime samples (Figure 4.5-23). The length frequency range for larvae was small with almost all measured specimens within the 2.0–3.0 mm (0.08–0.12 inches) size classes (Figure 4.5-24). The mean length of specimens from the entrainment station samples was 2.38 mm (0.09 inches) NL with a size range from 1.7 mm to 11.1 mm (0.07 to 0.44 inches).

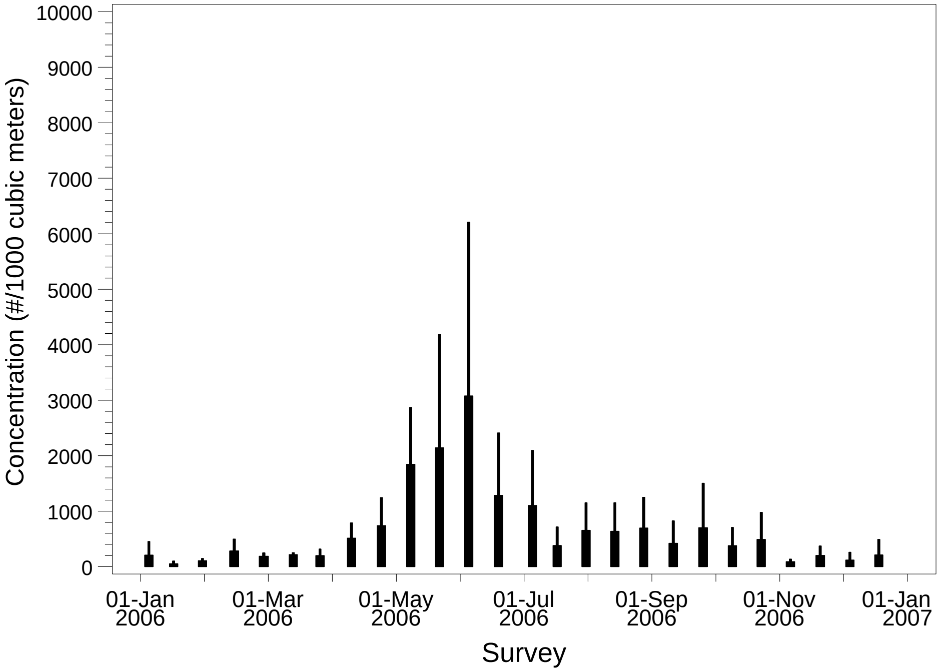


Figure 4.5-21. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of combtooth blenny larvae collected at HnGS entrainment Station E3 during 2006.

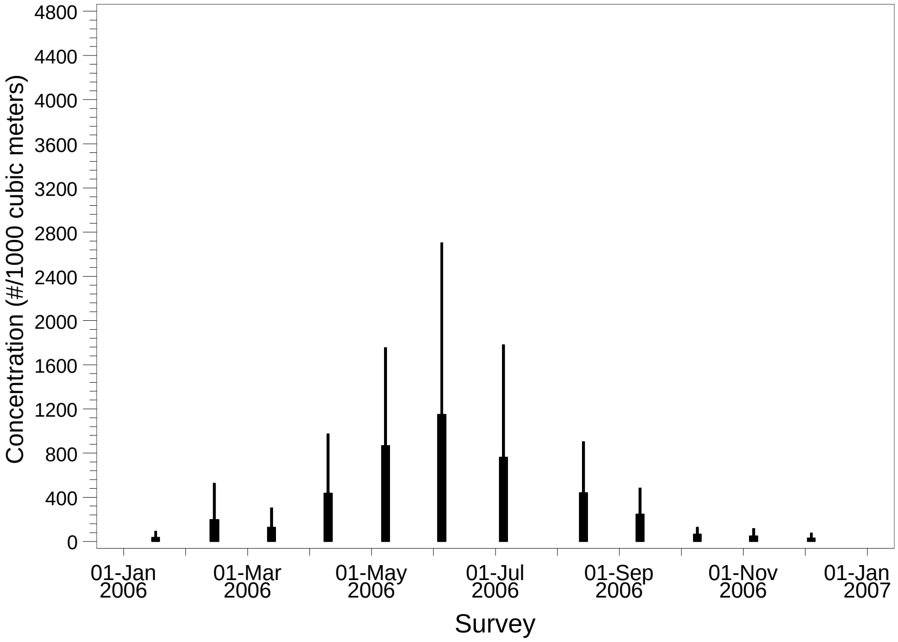


Figure 4.5-22. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of combtooth blenny larvae collected at HnGS source water stations during 2006.

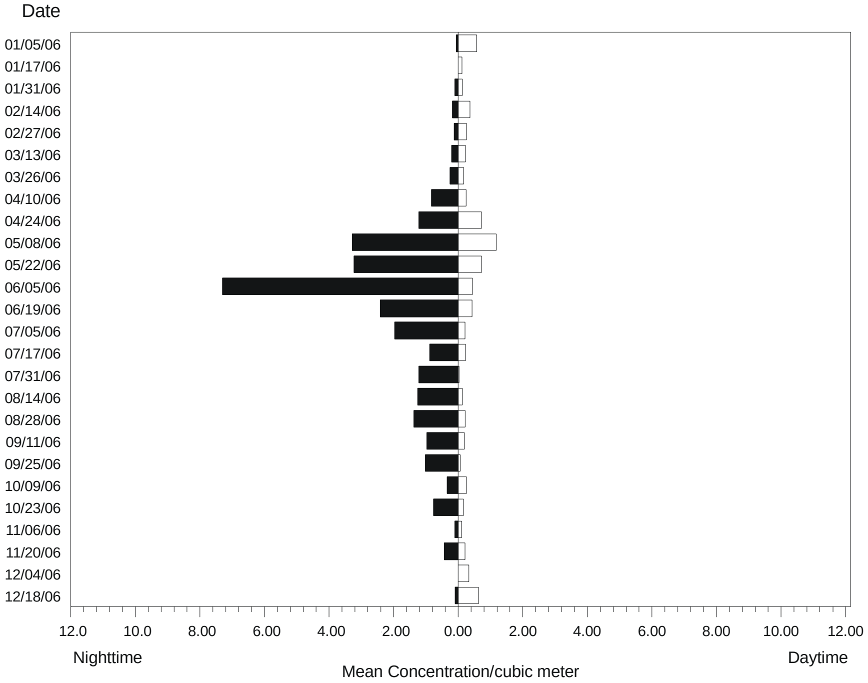


Figure 4.5-23. Mean concentration (#/1.0 m^3 [264 gal]) of combtooth blenny larvae at entrainment Station E3 during night (Cycle 3) and day (Cycle 1) sampling.

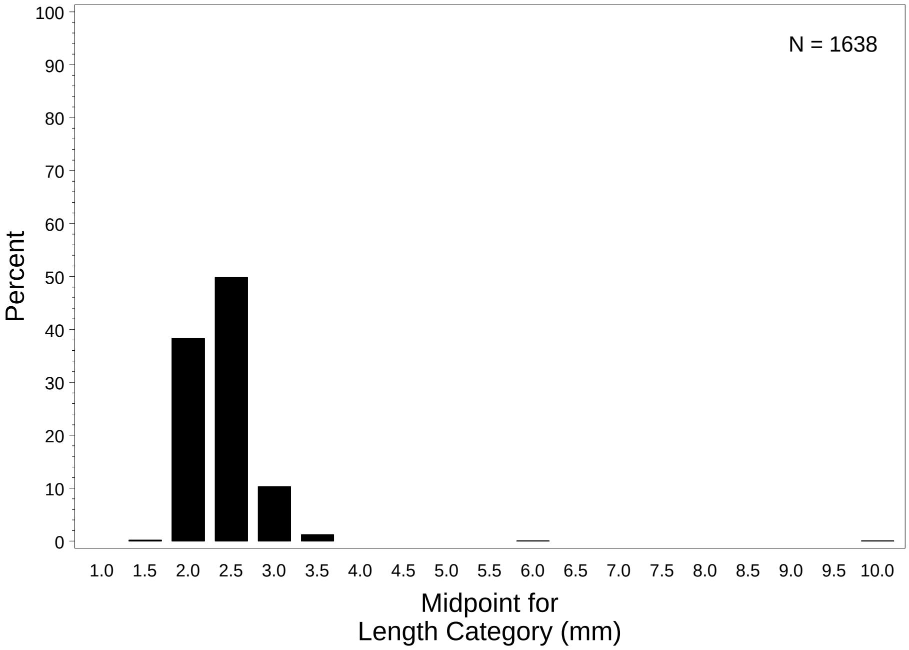


Figure 4.5-24. Length (mm) frequency distribution for combtooth blenny larvae collected at entrainment stations in Alamitos Bay.

4.5.3.4.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of 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. Total annual entrainment of combtooth blenny larvae at HnGS was estimated at 732,022,349 (standard error of 25,578,857) using actual cooling water flows during 2006 (Table 4.5-2). Using the design flows, total annual entrainment increased to 915,313,887 larvae (standard error of 31,887,073).

Fecundity Hindcasting *(FH)*

The annual entrainment estimate for combtooth blenny larvae was used to estimate the number of females at the age of maturity needed to produce this number of larvae over their lifetimes. No estimates of egg survival for combtooth blenny were available, but because egg masses are attached to the substrate and guarded by the male (Stephens et al. 1970), egg survival is probably high and was conservatively assumed to be 100%. The mean length from a random sample of 200 combtooth blenny larvae was 2.4 mm (0.09 inches). A larval growth rate of 0.20 mm/day (0.008 inches/day) was derived from data in Stevens and Moser (1982). The mean length of 2.4 mm (0.09 inches) from 200 randomly selected lengths from the almost 1500 larvae measured and calculated hatch length of 2.1 mm (0.08 inches) were used with the growth rate to estimate that the mean age at entrainment was 1.5 days. A daily survival rate of 0.89 computed from data in Stephens (1969) was used to calculate survival to the average age at entrainment as 0.891.5 = 0.84. A quadratic equation was used to estimate adult survival S at age in days x using Figure 17 in Stephens (1969):

$$S = 8.528\times10^{-8}x^{2} - 3.918\times10^{-4}x + 0.4602 \tag{5}$$

An adult survivorship table (Table 4.5-19) 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 4.5-19. Survivorship table for adult combtooth blenny from data in Stephens (1969) showing spawners (Lx) surviving to the age interval and numbers of eggs spawned annually (Mx).

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 LxMx divided by 1,000.

The estimated numbers of reproductive age adult female combtooth blennies whose lifetime reproductive output was entrained through the HnGS CWIS during 2006 was 418,001 based on entrainment estimates calculated using actual cooling water flows during the period (Table 4.5-20). Using the design flows, the number increases to 522,665 reproductive age adults lost during the 2006 sampling period. The range of estimates based on the 90% confidence intervals shows that the variation in the estimate of entrainment abundance had much less of an effect on the variation of the *FH* estimate than the life history parameters used in the model.

Table 4.5-20. 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	**418,001**	362,294	100,455	1,739,330	1,638,875
Total Entrainment	732,022,349	25,578,857	393,974	442,028	48,054
Design Flows					
FH Estimate	**522,665**	453,007	125,609	2,174,827	2,049,218
Total Entrainment	915,313,887	31,887,073	492,712	552,617	59,905

The upper and lower estimates are based on a 90% confidence interval of the mean. FH estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Adult Equivalent Loss (*AEL*)

The parameters required for formulation of *AEL* include larval survival from entrainment to settlement and survival from settlement to the average age of reproduction for a mature female. Larval survival from entrainment through settlement at 50 days was estimated as $0.89^{(50-1.5)} = 0.004$ using the same daily survival rate used in formulating *FH*. Juvenile and adult survival was calculated from observed age group abundances in Stephens (1969). Daily survival through the average female age of 2.7 years for the three species was estimated as 0.99 and was used to calculate a finite survival of 0.79.

The equivalent number of adult combtooth blennies calculated from the number of larvae entrained through the HnGS CWIS for the 2006 sampling period was 1,783,945 based on actual cooling water flows and 2,230,628 based on the design flows (Table 4.5-21). 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 4.5-21. Results of *AEL* modeling for combtooth blenny larvae based on entrainment estimates calculated using actual and design (maximum) CWIS flows.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
Actual Flows					
AEL Estimate	**1,783,945**	2,185,766	237,711	13,387,911	13,150,200
Total Entrainment	732,022,349	25,578,857	1,681,402	1,886,487	205,085
Design Flows					
AEL Estimate	**2,230,628**	2,733,055	297,234	16,740,036	16,442,802
Total Entrainment	915,313,887	31,887,073	2,102,796	2,358,459	255,663

The upper and lower estimates are based on a 90% confidence interval of the mean. AEL estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Empirical Transport Model *(ETM)*

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

The monthly estimates of *PE* for combtooth blennies for the 2006 period varied among surveys and ranged from 0.00740 to 0.08288 based on the actual cooling water flows and from 0.01329 to 0.01586 using the design flow volumes during the period. Combtooth blennies were collected during all of the paired entrainment-source water surveys (Table 4.5-22). The largest estimate was calculated for the October survey, but the largest proportion of the source population was present during the June survey (f_i = 0.309 or 30.9%). The values in the table were used to calculate a P_M estimate of 0.1389 with a standard error of 0.0761 using the actual flows in 2006 and an estimate of 0.1770 with a standard error of 0.0965 using the design flows. Estimates were calculated using the alongshore extrapolated estimate of the total source population. The average alongshore displacement over the period of exposure was 9.61 km (6.0 mi).

Table 4.5-22. *ETM* data and results for combtooth blenny larvae based on actual and design (maximum) cooling water flows sampling volume in the nearshore of 140,698,222 m^3.

	Actual Flows		Design Flows		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
17-Jan-06	0.04470	0.04000	0.07191	0.06429	0.00428
14-Feb-06	0.05030	0.04437	0.06944	0.06085	0.01889
13-Mar-06	0.07279	0.02515	0.09014	0.03113	0.01756
10-Apr-06	0.05091	0.02259	0.06490	0.02859	0.05672
8-May-06	0.04379	0.03225	0.04770	0.03509	0.14543
5-Jun-06	0.03961	0.04184	0.05312	0.05583	0.30923
5-Jul-06	0.00740	0.01774	0.01329	0.03164	0.22852
14-Aug-06	0.03993	0.01983	0.05407	0.02671	0.11707
11-Sep-06	0.01467	0.02764	0.01586	0.02985	0.06371
9-Oct-06	0.08288	0.07396	0.09699	0.08610	0.01882
6-Nov-06	0.05102	0.02336	0.07129	0.03263	0.00974
4-Dec-06	0.04841	0.07499	0.07358	0.11397	0.01004
P_M	**0.1389**	0.0761	**0.1770**	0.0965	–

4.5.3.5 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.

4.5.3.5.1 Life History and Ecology

All three species have overlapping ranges in southern California and occupy similar habitats. Arrow goby is the most abundant of the three species in bays and estuaries from Tomales Bay to San Diego Bay, including Elkhorn Slough (Cailliet et al. 1977), Anaheim Bay (MacDonald 1975) and Newport Bay (Allen 1982). Arrow and cheekspot gobies were reported as abundant from the Cabrillo Beach area in outer Los Angeles Harbor based on beach seine sampling (Allen et al. 1983). The life history of the arrow goby was reviewed by Emmett et al. (1991) and the comparative ecology and behavior of all three species were studied by Brothers (1975) in Mission Bay

Arrow goby have the most northerly range of the three species, occurring from Vancouver Island, British Columbia to southern Baja California (Eschmeyer and Herald 1983). The reported northern range limits of both shadow goby *Quietula y-cauda* and cheekspot goby *Ilypnus gilberti* are in central California with sub-tropical southern ranges that extend well into the Gulf of California (Robertson and Allen 2002). Their physiological tolerances reflect their geographic distributions with arrow goby less tolerant of warmer temperatures compared to cheekspot goby. When exposed to temperatures of 32.1°C (89.8°F) for three days in a laboratory experiment, no arrow gobies survived but 95% of cheekspot goby did survive (Brothers 1975). The species inhabits burrows of ghost shrimps (*Neotrypaea* spp.) and other burrowing invertebrates such as the fat innkeeper worm (*Urechis caupo*), and gobies exposed to warm temperatures on mudflats can seek refuge in their burrows where temperatures can be several degrees cooler than surface temperatures.

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.

The reproductive biology is similar among the three species in the CIQ complex. Arrow goby typically mature sooner than the other two species, attaining 50% maturity in the population after approximately 8 months as compared to 16–18 months for cheekspot and shadow gobies (Brothers 1975). Mature females for all three of these species are oviparous and produce demersal eggs that are elliptical in shape, adhesive, and attached to a nest substratum at one end (Matarese et al. 1989; Moser 1996). Hatched larvae are planktonic with the duration of the planktonic stage estimated at 60 days for populations in Mission Bay (Brothers 1975). Arrow goby mature more quickly and spawn a greater number of eggs at a younger age than either the cheekspot or shadow gobies. As with most fishes fecundity is dependent on age and size of the female. Fecundity of gobies in Mission Bay ranged from 225–750 eggs per batch for arrow gobies, 225–1,030 eggs for cheekspot, and 340–1,400 for shadow, for a mean value of 615 per batch for the CIQ complex. Mature females for the CIQ complex deposit 2–5 batches of eggs per year.

CIQ complex larvae hatch at a size of 2–3 mm (0.08–0.11 inches) (Moser 1996). Data from Brothers (1975) were used to estimate an average growth rate of 0.16 mm/day (0.006 inches) 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 inches) 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.

4.5.3.5.2 Population Trends and Fishery

The earlier 316(b) study of the HnGS in 1978–1979 (IRC 1981) found that gobiid larvae were comparatively abundant throughout the year except during a late August survey. The range of mean density values was 2 to 20,640 larvae per 1,000 m^3 (264,172 gal) for the day surveys and 7 to 24,890 larvae per 1,000 m^3 (264,172 gal) for the night surveys. These were substantially greater than the average densities of 1,661 larvae per 1,000 m^3 (264,172 gal) measured during the present study in 2006 indicating a long-term decline in population abundances over time.

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

4.5.3.5.3 Sampling Results

CIQ complex goby larvae were the most abundant taxon at the entrainment station with a mean concentration of 1,668 per 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 June and August (Figure 4.5-25). During periods of maximum abundance in early August 2006 CIQ complex gobies were present in the entrainment samples at average concentrations exceeding 4,000 per 1,000 m^3 (264,172 gal). Gobies were also present at the source water stations during all months of the year with a peak average concentration in August 2006 of over 2,000 larvae per 1,000 m^3 (264,172 gal) (Figure 4.5-26). The larvae were significantly more abundant in nighttime samples during almost all surveys (Figure 4.5-27). 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 (0.08–0.11 inches) (Moser

1996). The size classes of most larvae were in the 2.0–5.0 mm (0.08–0.20 inches) range with a very small proportion greater than 6.0 mm (0.24 inches) (Figure 4.5-28). The mean length of 1,741 specimens from the entrainment station samples was 3.4 mm (0.13 inches) NL with a size range from 1.8 mm to 21.3 mm (0.07 to 0.84 inches).

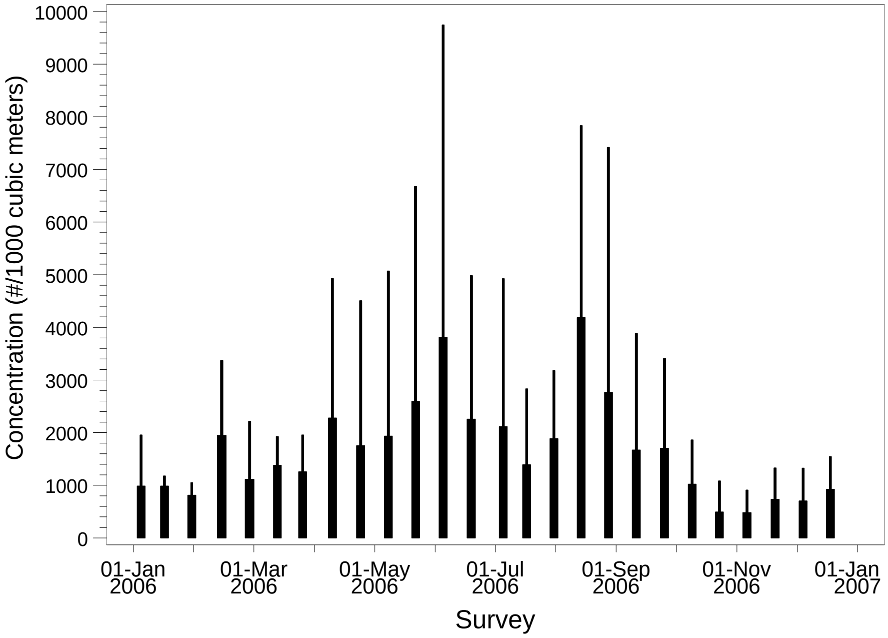


Figure 4.5-25. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) of unidentified goby larvae (CIQ gobies) collected at HnGS entrainment Station E3 during 2006.

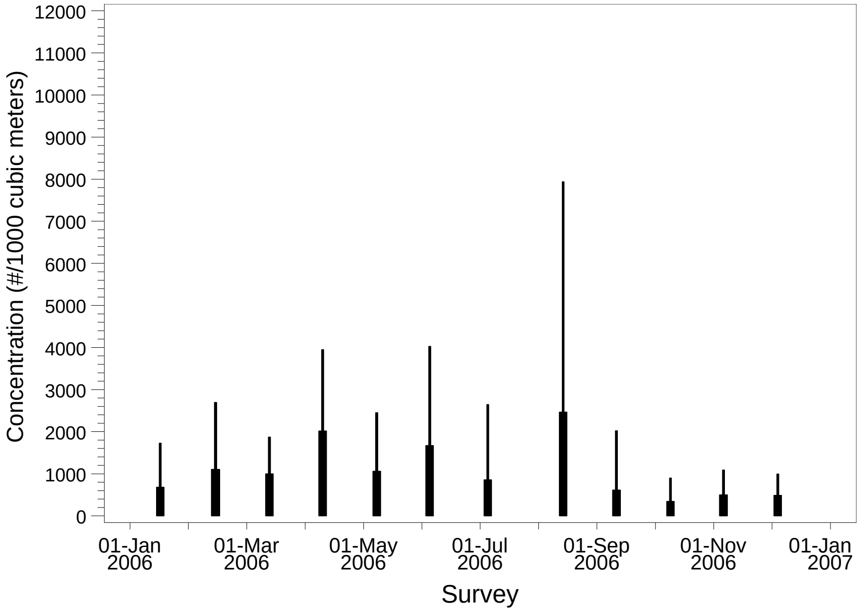


Figure 4.5-26. Mean concentration (# / 1,000 m^3 [264,172 gal] – wide bars) and standard deviation (narrow bars) unidentified goby larvae (CIQ gobies) collected at HnGS source water stations during 2006.

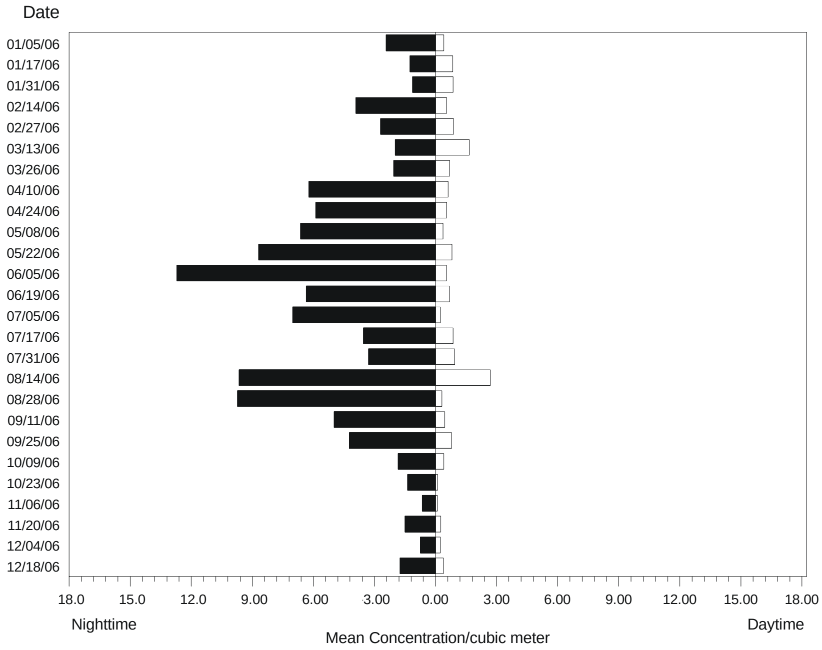


Figure 4.5-27. Mean concentration (#/1.0 m^3 [264 gal]) of unidentified goby larvae at entrainment Station E3 during night (Cycle 3) and day (Cycle 1) sampling.

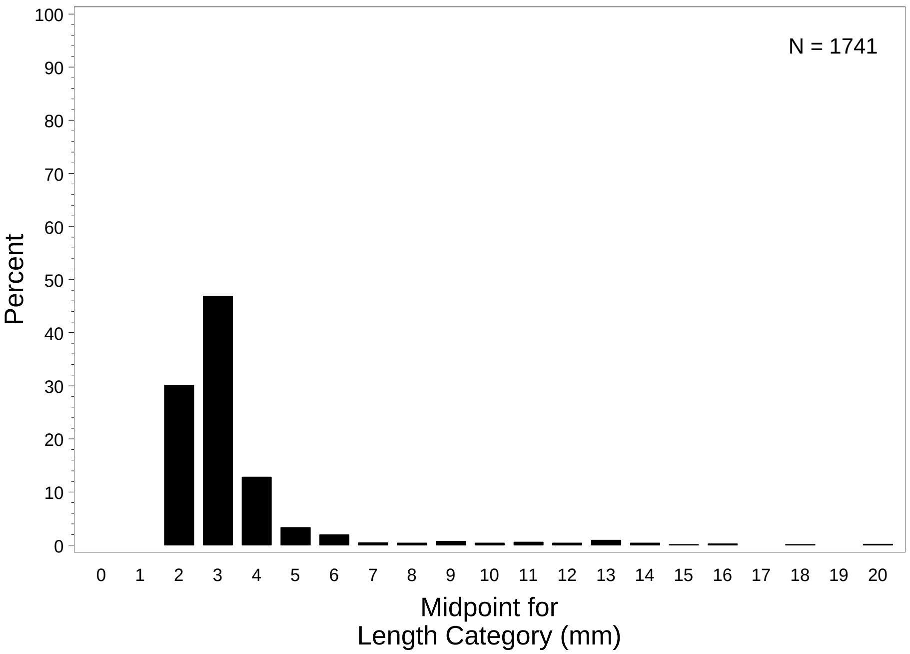


Figure 4.5-28. Length (mm) frequency distribution for unidentified goby larvae collected at entrainment stations in Alamitos Bay.

4.5.3.5.4 Modeling Results

The following section presents the results for demographic and empirical transport modeling of CWIS entrainment effects on CIQ goby populations. A comprehensive comparative study of the three goby species in the CIQ complex by Brothers (1975) provided the necessary life history information for both the *FH* and *AEL* demographic models. Total annual entrainment of CIQ goby larvae at HnGS was estimated to be 1,828,364,516 (standard error of 71,589,462) using actual measured cooling water flows during 2006 (Table 4.5-2). Using the design flows, total annual entrainment increased to 2,334,220,376 larvae (standard error of 87,312,721).

Fecundity Hindcasting (*FH*)

The annual entrainment estimate for CIQ gobies was used to estimate the number of females at the age of maturity needed to produce the number of larvae entrained during their lifetime. No estimates of egg survival for gobies were available, but because gobies deposit demersal egg masses (Wang 1986) and exhibit parental care, usually provided by the adult male, egg survival is generally high and was conservatively assumed to be 100%. Estimates of larval survival for the three species from Brothers (1975) were used to compute an average daily survival of 0.93. A larval growth rate of 0.16 mm/day (0.006 inches/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 (3.3 mm [0.16 inches]) and the calculated hatch length of 2.4 mm (0.09 inches) from a random sample of 200 of the measured larvae were used with the calculated growth rate to estimate that the mean age at entrainment was 5.7 days. Survival to the average age at entrainment was then estimated as $0.93^{5.7} = 0.66$. A survivorship table was constructed using data from Brothers (1975) and was used to estimate a total lifetime fecundity of 1,400 eggs (Table 4.5-23). The age when at 50% of the female population was reproductive averaged 1.67 years.

The estimated numbers of reproductive age adult female gobies whose lifetime reproductive output was entrained through the HnGS circulating water system for the 2006 period ranged was 1,966,281 using the actual cooling water intake flows during the period and 2,510,294 using the design flows (Table 4.5-24). The sensitivity analysis shows 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. 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 4.5-24. 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
<u>Actual Flows</u>					
FH Estimate	**1,966,281**	1,704,589	472,403	8,184,245	7,711,842
Total Entrainment	1,828,364,516	71,589,462	1,839,633	2,092,929	253,296
<u>Design Flows</u>					
FH Estimate	**2,510,294**	2,176,006	603,180	10,447,263	9,844,083
Total Entrainment	2,334,220,376	87,312,721	2,355,831	2,664,758	308,927

The upper and lower estimates are based on a 90% confidence interval of the mean. FH estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Adult Equivalent Loss (AEL)

The parameters required for formulation of *AEL* estimates include larval survival from entrainment to settlement, and survival from settlement to the average age of reproduction for a mature female. Larval survival from entrainment through settlement was estimated as $0.93^{60-5.3} = 0.02$ using the same daily survival rate used in formulating *FH*. Brothers (1975) estimated that mortality in the first year following settlement was 99% for arrow, 66–74% for cheekspot, and 62–69% for shadow goby. These estimates were used to calculate a daily survival of 0.995 that was used to estimate a finite survival of 0.21 for the first year following settlement. Daily survival through the average female age of 2.21 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 equivalent number of adult CIQ gobies calculated from the number of larvae entrained through the HnGS circulating water system for the 2006 sampling period was 1,671,266 based using actual CWIS flows (Table 4.5-25). Using the design flows, the equivalent number of adult CIQ gobies increased to 2,133,657 lost due to entrainment in 2006.

Table 4.5-25. 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	**1,671,266**	1,877,936	263,200	10,612,193	10,348,993
Total Entrainment	1,828,364,516	71,589,462	1,563,620	1,778,912	215,292
Design Flows					
AEL Estimate	**2,133,657**	2,397,380	336,053	13,546,953	13,210,901
Total Entrainment	2,334,220,376	87,312,721	2,002,368	2,264,945	262,577

The upper and lower estimates are based on a 90% confidence interval of the mean. AEL estimates were also calculated using the upper and lower confidence estimates from the entrainment estimates.

Empirical Transport Model (ETM)

The larval duration used to calculate the *ETM* estimates for CIQ gobies was based on the lengths of entrained larvae. The difference between the lengths of the 95th percentile (5.9 mm [0.23 inches]) and the calculated hatch length of 2.4 mm (0.09 inches) was used with a growth rate of 0.16 mm/day (0.006 inches/day) to estimate that CIQ goby larvae were vulnerable to entrainment for a period of 21.8 days.

CIQ gobies larvae were present in the entrainment and source water samples throughout the year. The monthly estimates of *PE* for the 2006 period ranged from 0.00737 to 0.03408 using the actual cooling water intake flows (Table 4.5-26). Using the design flows, the *PE* estimates ranged from 0.00940 to 0.03988 during the sampling period. The largest estimates occurred during the October survey with the largest proportion of the source population occurring earlier in the year during the April survey (fi = 0.208 or 20.8%). The values in the table were used to calculate a P_M estimate of 0.2515 with a standard error of 0.1672 using the actual flow volumes and an estimate of 0.3174 with a standard error of 0.2098 using the design flow volumes during the period. Estimates were calculated using the alongshore extrapolated estimate of the total source population. The average alongshore displacement over the period of exposure was 26.88 km (16.7 mi).

Table 4.5-26. *ETM* data and results for CIQ goby larvae based on actual and design (maximum) cooling water flows sampling volume in the nearshore of 140,698,222 m^3.

	Actual Flows		**Design Flows**		
Survey Date	***PE* Estimate**	***PE* Std. Err.**	***PE* Estimate**	***PE* Std. Err.**	f_i
17-Jan-06	0.01090	0.02217	0.01753	0.03567	0.03595
14-Feb-06	0.01293	0.05291	0.01786	0.07275	0.05762
13-Mar-06	0.00852	0.01168	0.01055	0.01441	0.09862
10-Apr-06	0.00737	0.01941	0.00940	0.02443	0.20807
8-May-06	0.02030	0.08267	0.02211	0.08993	0.06801
5-Jun-06	0.01892	0.07526	0.02537	0.10030	0.12369
5-Jul-06	0.00841	0.06306	0.01510	0.11236	0.07901
14-Aug-06	0.02287	0.06195	0.03097	0.08362	0.14845
11-Sep-06	0.01774	0.11196	0.01918	0.12094	0.04008
9-Oct-06	0.03408	0.07485	0.03988	0.08722	0.02234
6-Nov-06	0.00751	0.01308	0.01049	0.01827	0.04867
4-Dec-06	0.00754	0.01869	0.01146	0.02840	0.06948
P_M	**0.2515**	0.1672	**0.3174**	0.2098	–

5.0 IMPINGEMENT STUDY

5.1 INTRODUCTION

The purpose of the impingement study is to determine the extent of potential impacts from the operation of the cooling water system of the HnGS on fishes and selected invertebrates. Impingement occurs when organisms larger than the traveling/slide screen mesh size (9.5 mm or 3/8 inch) become trapped against the screens, either because they are too fatigued to swim against the intake flows at the screens or they are dead.

There are two facets to the impingement study: *normal operation* sampling and *marine growth control* (or *heat treatment*) sampling. Samples collected during normal operations were used to characterize fish loss from the day-to-day operation of the generating station. Normal operations samples were collected over a 24-hr period to determine the daily loss from operation of the cooling water system. Samples were also collected during marine growth control procedures, when waters within the CWIS were heated and fishes and invertebrates without the ability to avoid those temperatures succumbed. A total of five marine growth control procedures were carried out in 2006 to control biofouling within the CWIS. Combined, normal operation and heat treatment samples were used to estimate the annual loss of juvenile and adult fishes and shellfishes due to operation of the CWIS.

5.1.1 Species to be Analyzed

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

5.2 HISTORICAL DATA

5.2.1 Summary of Historical Data

During 1978-1979, a total of 17,637 fish representing 73 taxa and weighing 782 kg (1,725 lbs) was impinged during the impingement sampling program at Haynes (IRC 1981). The fish were impinged during 191 individual 24-hour impingement samples. No impingement sampling was conducted during heat treatments due to the intake configuration and the negligible effects on impingement. Mean daily impingement (based on both abundance and biomass) was highest throughout the year at Unit 6. In descending order of annual impingement abundance and biomass were Units 6, 5, 1, 2, 4, and 3, respectively. However, Unit 3 was off-line most of the year. The mean cooling water flow rate at the generating station varied from 1,892,500–3,406,500 m^3 per day (500–900 mgd) during the study. The estimated annual impingement based on extrapolations of impingement rates was 30,290 fish weighing 1,344 kg (2,964 lbs).

During the year-long study, abundance and biomass peaked in December 1978, February, June, and September 1979. The most abundant species were shiner perch, Pacific pompano (*Peprilus simillimus*), and white seaperch (*Phanerodon furcatus*), which combined accounted for 65% of the total impingement abundance. Shiner perch was the most abundant species overall, accounting for 38% of the impingement abundance.

During the last five years of impingement monitoring at HnGS (2001–2005), a total of 54 marine growth control (heat treatment) impingement surveys was performed. During these surveys, a total of 522 fish weighing 7.8 kg (17 lbs) was impinged. The most abundant fish species impinged were queenfish, deepbody anchovy (*Anchoa compressa*), and California grunion (*Leuresthes tenuis*), which combined accounted for 79% of impingement abundance. A total of 275 macroinvertebrates weighing 7.0 kg (16 lbs) was also impinged. The most abundant invertebrates impinged were spiny cup-and-saucer (*Crucibulum spinosum*), tuberculate pear crab, and California two-spot octopus (*Octopus bimaculatus /bimaculoides*), which together comprised 68% of the impingement abundance.

5.2.2 Relevance to Current Conditions

The operations and configuration of the HnGS cooling water system have remained largely unchanged since all units went into service with the exception of the replacement of the cooling water pumps at Units 3 & 4 (now Unit 8). Therefore, changes in impingement through time are most likely due to natural biological changes and not due to substantial changes in cooling water flow. Flow during the 1978–1979 study averaged about 2,802,487 m^3 per day (740 mgd), or 73% of design flows (IRC 1981). From 1982 to 1995, cooling water flow averaged 2,751,695 m^3 per day (727 mgd) (MBC 1997). Flow during the 2006 study averaged about 2,925,870 m^3 per day (773 mgd), or 80% of current design flow, which is less than design flow in the previous study due to the replacement of cooling water pumps at Units 3 & 4.

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 HnGS. 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 10^6 m^3 [264.172 million gal] cooling water flowing into the CWIS).

The HnGS consists of six separate screen and pump chambers: one each for Units 1, 2, 5, and 6, and two screen and pump chambers for Unit 8 (former chambers for Units 3 and 4). These chambers consist of bar racks, traveling or slide screens, and the circulating water pumps. Seawater drawn into each unit first passes through the bar racks, followed by the traveling or slide screens, and is then pumped to the condensers. All material that was impinged on the traveling/slide screens during the surveys was subsequently rinsed from the screens by a high-pressure wash system into a collection basket. A more complete description of the cooling water system is presented in Section 3.2.

5.3.1 Field Sampling

Impingement sampling at HnGS was conducted over a 24-hour period one day per week from January 4 to December 27, 2006. Surveys were performed at all units within HnGS that had circulating water pumps operating at the beginning of each survey. Before each sampling effort, the traveling/slide 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. At Units 3–6, each 24-hour sampling period was divided into four 6-hour cycles. Initiation of sample collection occurred as follows: Cycle 1 (approx. 0700-1300 hr), Cycle 2 (approx. 1300-1900 hr), Cycle 3 (approx. 1900-0100 hr), and Cycle 4 (approx. 0100-0700 hr). During this time, the traveling screens were stationary for a period of approximately 5.75 hours and then they were rotated and washed for 15 minutes. At the Units 1 and 2 slide screens, sampling occurred only once per 24-hr period. At all units, the rinse period allowed the entire screen to be rinsed of all material impinged since the last screen wash cycle. The impinged material was rinsed from the screens into the collection baskets associated with each set of screens. The collection baskets were fitted with plastic liners of 6.4 mm (1/4 inches) mesh.

On some occasions, the screen wash systems were operated (automatically or manually) prior to end of each cycle. The material that was rinsed on these occasions was combined with the material collected at the end of each cycle. All debris and organisms rinsed from each unit was processed separately from other units. During backflushing operations (described in Section 3.2), the slide/traveling screens were always rinsed prior to these procedures so impinged organisms could be processed.

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

- The appropriate linear measurement for individual fish and shellfish was determined and recorded. These measurements were recorded to the nearest 1 mm (0.04 inch). The following standard linear measurements were used for the animal groups indicated:
    - Fishes - Total body length for sharks and rays and standard lengths for bony fishes.
    - Crabs - Maximum carapace width.
    - Shrimps & Lobsters - Carapace length, measured from the anterior margin of carapace between the eyes to the posterior margin of the carapace.
    - Octopus - Maximum “tentacle” spread, measured from the tip of one tentacle to the tip of the opposite tentacle.
    - Squid – Dorsal mantle length, measured from the edge of the mantle to the posterior end of the body.

- The wet body weight of individual fish and shellfish was determined after shaking loose water from the body. Total weight of all individuals combined was determined in the same manner. All weights were recorded to the nearest 1 g (0.035 ounce).
- 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.

Impingement sampling was also conducted during marine growth control operations. Prior to the start of marine growth control surveys, traveling/slide screens were rotated and rinsed. At the end of the marine growth control procedure, normal pump operation was resumed and the traveling/slide screens rinsed to collect any impinged debris and organisms. Processing of the samples was performed using the same procedures for normal operation impingement sampling.

5.3.2 QA/QC Procedures & Data Validation

During the NPDES impingement surveys (2000–2005), sampling was done in accordance with specifications set forth by the LARWQCB in the NPDES permit for the plant. Specimens of uncertain identity were crosschecked against taxonomic voucher collections maintained by MBC, as well as available taxonomic literature. Occasionally, outside experts were consulted to assist in the identification of species whose identification was difficult. Scales used to measure biomass (spring and electronic) were calibrated every three months.

A quarterly QA/QC program was implemented for the current study to verify compliance with the field sampling procedures. Random cycles were chosen for QA/QC re-sorting to verify that all the collected organisms were removed from the impinged material. QC surveys were conducted on the following dates: February 8-9, April 12, August 2, and October 10-11. If the count of any of individual taxon made during the QA/QC survey varied by more than 5% (or one individual if the total number of individuals was less than 20) from the count recorded by the observer, then the next three sampling cycles for that observer were checked. The survey procedures were reviewed with all personnel prior to the start of the study and all personnel were given printed copies of the procedures.

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

- Upon returning from the field, all field data sheets were checked by the Project Manager for completeness and any obvious errors;
- Data were entered into pre-formatted spreadsheets;
- After data were entered, copies of the spreadsheets were checked against the field data sheets;
- In the prior studies, data were submitted annually to the LARWQCB, USEPA 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 the LADWP. Impingement rates were calculated using the circulating water flow during each of the cycles of each 24-hour survey. The total time for each cycle was multiplied by the known flow rate of each of the circulating water pumps in operation during each cycle. In a few surveys, traveling/slide screens or the screen wash systems were not operational. In those instances, the cooling water flow for the pump associated with those screens was not added to the total, since impinged organisms could not be collected from that screen.

The estimated daily impingement rate was then used to calculate 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 for each unit. The total calculated flow for each survey period was multiplied by the taxon-specific impingement rates for both abundance and biomass. The estimated impingement rate for each survey period was summed to determine the annual normal operation impingement estimates for each taxon for each unit. These were added to impingement totals from marine growth control procedures to estimate total annual impingement. 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 HnGS (3,837,499 m^3 per day, or 1,013.760 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, USEPA Region IX, NMFS, and CDFG during our January 30, 2006 meeting.

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

5.4 SAMPLING SUMMARY

The following sections summarize results from the 2006 impingement weekly sampling at HnGS. 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 all 52 weeks of 2006 at HnGS between January 4 and December 28, 2006, consisting of 252 surveys from the six screening facilities. Additionally, five marine growth control (heat treatment) surveys were performed in 2006. The number of surveys by unit is presented in Table 5.4-1. Mechanical malfunctions precluded sample collection at Unit 1 twice, at Unit 2 three times, at Unit 8 area formerly Unit 3 twice, at Unit 8 area formerly Unit 4 four times, and at Unit 6 twice. The remaining surveys with no samples collected represent periods when the circulating water pumps for each respective unit were not operational.

Table 5.4-1. Number of impingement surveys at HnGS in 2006 by unit.

Survey Type	**Unit 1**	**Unit 2**	**Unit 8 (formerly U3)**	**Unit 8 (formerly U4)**	**Unit 5**	**Unit 6**
Normal Operation	45	42	48	45	35	37
Marine Growth Control	1	3	-	-	1	-
	46	**45**	**48**	**45**	**36**	**37**

5.5 RESULTS

5.5.1 Impingement Results

A total of 6,580 fishes representing at least 53 distinct taxa and weighing 72.5 kg (159.9 lbs) was collected during impingement sampling in 2006 (Table 5.5-1 and Appendix E). Of this total, only 33 individuals from at least seven taxa weighing 0.3 kg (0.8 lbs) were impinged during the five marine growth control procedures. The estimated annual total impingement based on cooling water flow volumes in 2006 was 53,442 individuals weighing 529.8 kg (1,168 lbs) (Table 5.5-2). The estimated annual impingement based on design flow was 56,613 fishes weighing 556.5 kg (1,227.0 lbs). Queenfish was the most abundant species, with 3,708 individuals collected (56% of the total) and an estimated annual impingement based on actual cooling water flow of 30,946 individuals weighing 19.5 kg (42.9 lbs). The annual impingement of queenfish represented 58% of the total impingement abundance but only 4% of the biomass. The next most abundant species in impingement samples were topsmelt, northern anchovy, bay pipefish, unidentified pipefishes, shiner perch, and specklefin midshipman (*Porichthys myriaster*). Combined these taxa accounted for 91.2% of the sampled impingement abundance. A list of the species collected during the study are presented in Appendix F.

A total of 2,682 macroinvertebrates representing at least 49 distinct taxa and weighing 37.0 kg (81.6 lbs) was collected during impingement sampling in 2006 (Table 5.5-3 and Appendix E). Of this total, only 12 individuals from seven taxa weighing 0.2 kg (0.4 lbs) were impinged during the five marine growth control procedures. The estimated annual total impingement based on actual cooling water flow volumes in 2006 was 20,346 individuals weighing 268.8 kg (592.7 lbs) (Table 5.5-4). The estimated annual impingement based on design flow was 21,773 macroinvertebrates weighing 293.8 kg (647.9 lbs). Red jellyfish was the most abundant species, with 621 individuals collected (23% of the total) and an estimated annual impingement of 4,562 individuals weighing 16.6 kg (37 lbs). The next most abundant species in impingement samples were the nudibranch *Hermissenda crassicornis*, tuberculate pear crab, and yellow shore crab. Combined these species accounted for 59.1% of the sampled impingement abundance.

Table 5.5-1. HnGS fish impingement sampled abundance and biomass during 2006.

		Sampled Normal Operation		**Sampled Heat Treatment**		**Total Sampled**		**Percent of Total**	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Seriphus politus	queenfish	3,699	2.463	9	0.010	3,708	2.473	56.35	3.41
Atherinops affinis	topsmelt	780	3.976	8	0.044	788	4.020	11.98	5.54
Engraulis mordax	northern anchovy	422	0.731	10	0.018	432	0.749	6.57	1.03
Syngnathus leptorhynchus	bay pipefish	408	0.495	1	0.001	409	0.496	6.22	0.68
Engraulis mordax larvae	northern anchovy larvae	314	0.03	-	-	314	0.030	4.77	0.04
Syngnathus spp.	pipefish, unid.	184	0.25	2	0.002	186	0.252	2.83	0.35
Cymatogaster aggregate	shiner perch	83	1.779	-	-	83	1.779	1.26	2.45
Porichthys myriaster	specklefin midshipman	78	21.261	-	-	78	21.261	1.19	29.32
Genyonemus lineatus	white croaker	72	0.668	-	-	72	0.668	1.09	0.92
Leptocottus armatus	Pacific staghorn sculpin	67	1.272	-	-	67	1.272	1.02	1.75
Heterostichus rostratus	giant kelpfish	59	0.644	-	-	59	0.644	0.90	0.89
Anchoa delicatissima	slough anchovy	59	0.152	-	-	59	0.152	0.90	0.21
Urobatis halleri	round stingray	53	13.732	-	-	53	13.732	0.81	18.94
Leuresthes tenuis	California grunion	51	0.077	-	-	51	0.077	0.78	0.11
Pleuronichthys guttulatus	diamond turbot	18	1.345	-	-	18	1.345	0.27	1.85
Pleuronichthys ritteri	spotted turbot	16	0.168	-	-	16	0.168	0.24	0.23
Gibbonsia elegans	spotted kelpfish	15	0.144	1	0.020	16	0.164	0.24	0.23
Myliobatis californica	bat ray	13	3.44	1	0.248	14	3.688	0.21	5.09
Sardinops sagax	Pacific sardine	12	0.082	-	-	12	0.082	0.18	0.11
Atherinopsis californiensis	jacksmelt	11	1.635	-	-	11	1.635	0.17	2.25
Gibbonsia metzi	striped kelpfish	10	0.11	-	-	10	0.110	0.15	0.15
Gillichthys mirabilis	longjaw mudsucker	10	0.014	-	-	10	0.014	0.15	0.02
Xenistius californiensis	salema	10	0.013	-	-	10	0.013	0.15	0.02
Phanerodon furcatus	white seaperch	9	0.083	-	-	9	0.083	0.14	0.11
Atherinopsidae	silverside, unid.	9	0.055	-	-	9	0.055	0.14	0.08
Embiotoca jacksoni	black perch	8	0.246	-	-	8	0.246	0.12	0.34
Fundulus parvipinnis	California killifish	8	0.018	-	-	8	0.018	0.12	0.02
Gobiesox rhessodon	California clingfish	7	0.009	-	-	7	0.009	0.11	0.01
Porichthys notatus	plainfin midshipman	6	0.565	-	-	6	0.565	0.09	0.78
Symphurus atricaudus	California tonguefish	5	0.072	-	-	5	0.072	0.08	0.10
Hyperprosopon argenteum	walleye surfperch	5	0.023	-	-	5	0.023	0.08	0.03
Cheilotrema saturnum	black croaker	5	0.009	-	-	5	0.009	0.08	0.01
Sphyraena argentea	Pacific barracuda	4	0.012	-	-	4	0.012	0.06	0.02
Hypsoblennius gilberti	rockpool blenny	3	0.041	-	-	3	0.041	0.05	0.06
Anisotremus davidsonii	sargo	3	0.007	-	-	3	0.007	0.05	0.01
Syngnathus californiensis	kelp pipefish	3	0.003	-	-	3	0.003	0.05	0.00
Porichthys spp.	midshipman, unid.	2	0.955	-	-	2	0.955	0.03	1.32
Umbrina roncador	yellowfin croaker	2	0.671	-	-	2	0.671	0.03	0.93
Anchoa compressa	deepbody anchovy	1	0.008	1	0.002	2	0.010	0.03	0.01
Odontopyxis trispinosa	pygmy poacher	2	0.006	-	-	2	0.006	0.03	0.01
Anchoa spp.	deepbody/slough anchovy	2	0.005	-	-	2	0.005	0.03	0.01
Torpedo californica	Pacific electric ray	1	13.700	-	-	1	13.700	0.02	18.89
Rhinobatos productus	shovelnose guitarfish	1	0.700	-	-	1	0.700	0.02	0.97

(table continued)

Table 5.5-1 (continued). HnGS fish impingement sampled abundance and biomass during 2006.

Taxon	Common Name	Normal Operation		Heat Treatment		Combined Impingement		Percent of Total	
		No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)
Raja inornata	California skate	1	0.133	-	-	1	0.133	0.02	0.18
Ophidion scrippsae	basketweave cusk-eel	1	0.107	-	-	1	0.107	0.02	0.15
Trachurus symmetricus	jack mackerel	1	0.067	-	-	1	0.067	0.02	0.09
Mustelus californicus	grey smoothhound	1	0.047	-	-	1	0.047	0.02	0.06
Pleuronichthys verticalis	hornyhead turbot	1	0.045	-	-	1	0.045	0.02	0.06
Peprilus simillimus	Pacific pompano	1	0.037	-	-	1	0.037	0.02	0.05
Ophichthus zophochir	yellow snake eel	1	0.03	-	-	1	0.030	0.02	0.04
Citharichthys stigmaeus	speckled sanddab	1	0.01	-	-	1	0.010	0.02	0.01
Paraclinus integripinnis	reef finspot	1	0.005	-	-	1	0.005	0.02	0.01
Hypsoblennius jenkinsi	mussel blenny	1	0.004	-	-	1	0.004	0.02	0.01
Paralichthys californicus	California halibut	1	0.003	-	-	1	0.003	0.02	0.00
Synodus lucioceps	California lizardfish	1	0.003	-	-	1	0.003	0.02	0.00
Cottidae	sculpin, unid.	1	0.003	-	-	1	0.003	0.02	0.00
Sebastes miniatus	vermilion rockfish	1	0.002	-	-	1	0.002	0.02	0.00
Ilypnus gilberti	cheekspot goby	1	0.001	-	-	1	0.001	0.02	0.00
Gobiesocidae	clingfish, unid.	1	0.001	-	-	1	0.001	0.02	0.00
Clinidae	kelp blenny, unid.	1	0.001	-	-	1	0.001	0.02	0.00
	Totals	**6,547**	**72.168**	**33**	**0.345**	**6,580**	**72.513**	**100.00**	**100.00**
	No. of Taxa	**60**		**8**		**60**			

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

				Estimated Annual Impingement			
		Total Sampled		**Actual Flow**		**Design Flow**	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Seriphus politus	queenfish	3,708	2.473	30,946	19.465	32,389	20.358
Atherinops affinis	topsmelt	788	4.020	6,315	29.436	6,747	32.398
Engraulis mordax	northern anchovy	432	0.749	3,443	6.033	3,923	7.084
Syngnathus leptorhynchus	bay pipefish	409	0.496	3,157	3.846	3,286	3.957
Engraulis mordax larvae	northern anchovy larvae	314	0.030	2,351	0.212	2,590	0.222
Syngnathus spp.	pipefish, unid.	186	0.252	1,373	1.828	1,490	1.986
Genyonemus lineatus	white croaker	72	0.668	861	5.783	877	7.478
Porichthys myriaster	specklefin midshipman	78	21.261	620	157.234	632	161.765
Cymatogaster aggregata	shiner perch	83	1.779	582	12.025	628	13.332
Heterostichus rostratus	giant kelpfish	59	0.644	462	5.000	517	5.763
Anchoa delicatissima	slough anchovy	59	0.152	482	1.137	503	1.195
Leptocottus armatus	Pacific staghorn sculpin	67	1.272	475	9.108	489	9.505
Urobatis halleri	round stingray	53	13.732	381	98.052	427	105.662
Leuresthes tenuis	California grunion	51	0.077	382	0.580	396	0.599
Pleuronichthys guttulatus	diamond turbot	18	1.345	126	9.626	128	9.639
Pleuronichthys ritteri	spotted turbot	16	0.168	115	1.137	119	1.209
Gibbonsia elegans	spotted kelpfish	16	0.164	100	0.975	110	1.097
Sardinops sagax	Pacific sardine	12	0.082	90	0.606	98	0.656
Myliobatis californica	bat ray	14	3.688	92	24.635	92	24.655
Gillichthys mirabilis	longjaw mudsucker	10	0.014	73	0.105	90	0.130
Atherinopsis californiensis	jacksmelt	11	1.635	77	11.533	89	13.804
Xenistius californiensis	salema	10	0.013	87	0.108	87	0.110
Atherinopsidae	silverside, unid.	9	0.055	64	0.375	75	0.391
Embiotoca jacksoni	black perch	8	0.246	71	2.017	74	2.046
Phanerodon furcatus	white seaperch	9	0.083	63	0.589	71	0.624
Gibbonsia metzi	striped kelpfish	10	0.110	66	0.728	67	0.738
Fundulus parvipinnis	California killifish	8	0.018	56	0.125	64	0.146
Gobiesox rhessodon	California clingfish	7	0.009	54	0.069	55	0.071
Porichthys notatus	plainfin midshipman	6	0.565	44	3.722	50	4.170
Symphurus atricaudus	California tonguefish	5	0.072	42	0.607	43	0.627
Sphyraena argentea	Pacific barracuda	4	0.012	37	0.114	40	0.117
Hyperprosopon argenteum	walleye surfperch	5	0.023	40	0.175	40	0.176
Cheilotrema saturnum	black croaker	5	0.009	35	0.063	35	0.063
Porichthys spp.	midshipman, unid.	2	0.955	24	11.294	27	13.012
Syngnathus californiensis	kelp pipefish	3	0.003	23	0.023	25	0.025
Hypsoblennius gilberti	rockpool blenny	3	0.041	25	0.318	25	0.318
Anisotremus davidsonii	sargo	3	0.007	22	0.050	24	0.052
Anchoa spp.	deepbody/slough anchovy	2	0.005	17	0.043	17	0.043
Odontopyxis trispinosa	pygmy poacher	2	0.006	14	0.041	14	0.043
Umbrina roncador	yellowfin croaker	2	0.671	14	4.750	14	4.750
Raja inornata	California skate	1	0.133	8	1.111	9	1.239
Peprilus simillimus	Pacific pompano	1	0.037	7	0.271	9	0.328
Cottidae	sculpin, unid.	1	0.003	7	0.022	9	0.026

(table continued)

Table 5.5-2 (continued). HnGS fish impingement sampled abundance and biomass during 2006.

				Estimated Annual Impingement			
		Total Sampled		Actual Flow		Design Flow	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Anchoa compressa	deepbody anchovy	2	0.010	8	0.057	8	0.057
Ophidion scrippsae	basketweave cusk-eel	1	0.107	7	0.743	7	0.752
Paralichthys californicus	California halibut	1	0.003	7	0.022	7	0.022
Ilypnus gilberti	cheekspot goby	1	0.001	7	0.007	7	0.007
Gobiesocidae	clingfish, unid.	1	0.001	7	0.007	7	0.007
Mustelus californicus	gray smoothhound	1	0.047	7	0.336	7	0.336
Pleuronichthys verticalis	hornyhead turbot	1	0.045	7	0.321	7	0.322
Trachurus symmetricus	jack mackerel	1	0.067	7	0.477	7	0.477
Clinidae	kelp blenny, unid.	1	0.001	7	0.007	7	0.007
Hypsoblennius jenkinsi	mussel blenny	1	0.004	7	0.028	7	0.028
Torpedo californica	Pacific electric ray	1	13.700	7	97.594	7	97.594
Paraclinus integripinnis	reef finspot	1	0.005	7	0.033	7	0.033
Rhinobatos productus	shovelnose guitarfish	1	0.700	7	4.910	7	4.917
Citharichthys stigmaeus	speckled sanddab	1	0.010	7	0.070	7	0.071
Sebastes miniatus	vermilion rockfish	1	0.002	7	0.014	7	0.014
Ophichthus zophochir	yellow snake eel	1	0.030	7	0.211	7	0.212
Synodus lucioceps	California lizardfish	1	0.003	6	0.019	6	0.019
	Totals	**6,580**	**72.513**	**53,442**	**529.827**	**56,613**	**556.484**

Table 5.5-3. HnGS macroinvertebrate impingement sampled abundance and biomass during 2006.

Taxon	Common Name	Sampled Normal Operation		Sampled Heat Treatment		Total Sampled		Percent of Total	
		No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)
Polyorchis penicillatus	red jellyfish	621	2.274	-	-	621	2.274	23.15	6.15
Hermissenda crassicornis	hermissenda	392	0.175	1	0.001	393	0.176	14.65	0.48
Pyromaia tuberculata	tuberculate pear crab	295	0.225	-	-	295	0.225	11.00	0.61
Hemigrapsus oregonensis	yellow shore crab	275	0.248	1	0.001	276	0.249	10.29	0.67
Navanax inermis	California aglaja	234	4.565	2	0.074	236	4.639	8.80	12.54
Aurelia aurita	moon jelly	158	8.006	-	-	158	8.006	5.89	21.64
Portunus xantusii	Xantus swimming crab	90	1.244	-	-	90	1.244	3.36	3.36
Leptopecten spp.	scallop, unid.	83	0.145	4	0.002	87	0.147	3.24	0.40
Heptacarpus palpator	intertidal coastal shrimp	67	0.043	1	0.001	68	0.044	2.54	0.12
Phyllaplysia taylori	zebra leafslug	54	0.047	-	-	54	0.047	2.01	0.13
O. bimaculatus/bimaculoides	Calif. two-spot octopus	44	6.728	2	0.075	46	6.803	1.72	18.39
Crangon nigromaculata	blackspotted bay shrimp	38	0.041	-	-	38	0.041	1.42	0.11
Bulla gouldiana	California bubble	34	0.501	-	-	34	0.501	1.27	1.35
Polycera atra	orange-spike polycera	33	0.019	-	-	33	0.019	1.23	0.05
Flabellina trilineata	threeline aeolis	30	0.014	-	-	30	0.014	1.12	0.04
Diaulula sandiegensis	ring-spotted dorid	29	0.270	-	-	29	0.270	1.08	0.73
Aplysia californica	California seahare	28	11.511	-	-	28	11.511	1.04	31.11
Flabellina iodinea	Spanish shawl	26	0.069	-	-	26	0.069	0.97	0.19
Neotrypaea gigas	giant ghost shrimp	15	0.070	-	-	15	0.070	0.56	0.19
Pachygrapsus crassipes	striped shore crab	10	0.188	1	0.007	11	0.195	0.41	0.53
Loligo opalescens	California market squid	11	0.193	-	-	11	0.193	0.41	0.52
Protothaca staminea	Pacific littleneck	10	0.031	-	-	10	0.031	0.37	0.08
Cnidaria	sea jelly, unid.	8	0.046	-	-	8	0.046	0.30	0.12
Polycera hedgpethi	Hedpeth's polycera	8	0.008	-	-	8	0.008	0.30	0.02
Hemigrapsus nudus	purple shore crab	8	0.008	-	-	8	0.008	0.30	0.02
Pugettia producta	northern kelp crab	7	0.035	-	-	7	0.035	0.26	0.09
Dendronotus frondosus	leafy dendronotid	7	0.005	-	-	7	0.005	0.26	0.01
Haminoea virescens	green glassy bubble	6	0.014	-	-	6	0.014	0.22	0.04
Gastropoda	gastropod, unid.	4	0.006	-	-	4	0.006	0.15	0.02
Haminoea spp.	glassy bubble, unid.	4	0.004	-	-	4	0.004	0.15	0.01
Dendronotus subramosus	stubby dendronotus	4	0.003	-	-	4	0.003	0.15	0.01
Hemigrapsus spp.	shore crab, unid.	3	0.004	-	-	3	0.004	0.11	0.01
Nudibranchia	nudibranch, unid.	3	0.003	-	-	3	0.003	0.11	0.01
Octopus spp.	octopus, unid.	3	0.002	-	-	3	0.002	0.11	0.01
Dendronotus iris	giant-frond-aeolis	2	0.010	-	-	2	0.010	0.07	0.03
Kelletia kelletii	Kellet's whelk	2	0.006	-	-	2	0.006	0.07	0.02
Chrysaora colorata	purple-striped jellyfish	2	0.005	-	-	2	0.005	0.07	0.01
Ceratostoma nuttalli	Nuttall's thornmouth	2	0.004	-	-	2	0.004	0.07	0.01
Triopha maculata	spotted triopha	2	0.002	-	-	2	0.002	0.07	0.01
Crepidula onyx	onyx slippersnail	2	0.001	-	-	2	0.001	0.07	0.00
Molpadia intermedia	unnamed sea cucumber	1	0.024	-	-	1	0.024	0.04	0.06
Strongylocentrotus purpuratus	purple sea urchin	1	0.021	-	-	1	0.021	0.04	0.06
Philine auriformis	New Zealand snail	1	0.002	-	-	1	0.002	0.04	0.01

(table continued)

Table 5.5-3 (continued). HnGS macroinvertebrate impingement sampled abundance and biomass during 2006.

Taxon	Common Name	Normal Operation No.	Normal Operation Wt. (kg)	Heat Treatment No.	Heat Treatment Wt. (kg)	Combined Impingement No.	Combined Impingement Wt. (kg)	Percent of Total No.	Percent of Total Wt. (kg)
Polyorchis haplus	jellyfish	1	0.002	-	-	1	0.002	0.04	0.01
Pisaster spp.	sea star, unid.	1	0.002	-	-	1	0.002	0.04	0.01
Cancer anthonyi	yellow crab	1	0.002	-	-	1	0.002	0.04	0.01
Neotrypaea californiensis	bay ghost shrimp	1	0.001	-	-	1	0.001	0.04	0.00
Acanthodoris rhodoceras	black-tipped spiny doris	1	0.001	-	-	1	0.001	0.04	0.00
Heptacarpus paludicola	California coastal shrimp	1	0.001	-	-	1	0.001	0.04	0.00
Berthella californica	California sidegill slug	1	0.001	-	-	1	0.001	0.04	0.00
Argopecten ventricosus	Pacific calico scallop	1	0.001	-	-	1	0.001	0.04	0.00
Lysmata californica	red rock shrimp	1	0.001	-	-	1	0.001	0.04	0.00
Aplysia spp.	seahare, unid.	1	0.001	-	-	1	0.001	0.04	0.00
Aeolidia papillosa	shag-rug aeolis	1	0.001	-	-	1	0.001	0.04	0.00
Dirona picta	spotted dirona	1	0.001	-	-	1	0.001	0.04	0.00
Dendrodoris fulva	yellow prorostome	1	0.001	-	-	1	0.001	0.04	0.00
	Totals	**2,670**	**36.836**	**12**	**0.161**	**2,682**	**36.997**	**100.00**	**100.00**
	No. of Taxa	**56**		**7**		**56**			

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

				Estimated Annual Impingement			
		Total Sampled		**Actual Flow**		**Design Flow**	
Taxon	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Polyorchis penicillatus	red jellyfish	621	2.274	4,562	16.553	4,850	17.427
Hermissenda crassicornis	hermissenda	393	0.176	2,900	1.313	3,020	1.391
Pyromaia tuberculata	tuberculate pear crab	295	0.225	2,560	1.903	2,794	2.073
Hemigrapsus oregonensis	yellow shore crab	276	0.249	2,272	1.988	2,482	2.184
Navanax inermis	California aglaja	236	4.639	1,697	32.292	1,878	35.915
Aurelia aurita	moon jelly	158	8.006	1,102	57.375	1,165	59.599
Portunus xantusii	Xantus swimming crab	90	1.244	691	9.263	712	9.556
Leptopecten spp.	scallop, unid.	87	0.147	624	1.057	683	1.118
Heptacarpus palpator	intertidal coastal shrimp	68	0.044	506	0.333	536	0.355
Phyllaplysia taylori	zebra leafslug	54	0.047	446	0.387	484	0.425
O. bimaculatus/bimaculoides	Calif. two-spot octopus	46	6.803	337	54.777	353	57.877
Crangon nigromaculata	blackspotted bay shrimp	38	0.041	290	0.308	310	0.326
Diaulula sandiegensis	ring-spotted dorid	29	0.270	275	2.493	308	2.800
Bulla gouldiana	California bubble	34	0.501	237	3.515	241	3.585
Polycera atra	orange-spike polycera	33	0.019	227	0.133	233	0.137
Flabellina trilineata	threeline aeolis	30	0.014	212	0.102	222	0.106
Aplysia californica	California seahare	28	11.511	195	79.414	221	93.128
Flabellina iodinea	Spanish shawl	26	0.069	184	0.490	185	0.491
Neotrypaea gigas	giant ghost shrimp	15	0.070	107	0.495	111	0.522
Hemigrapsus nudus	purple shore crab	8	0.008	83	0.063	88	0.064
Cnidaria	sea jelly, unid.	8	0.046	69	0.371	80	0.434
Loligo opalescens	California market squid	11	0.193	78	1.366	78	1.368
Pachygrapsus crassipes	striped shore crab	11	0.195	71	1.309	74	1.352
Protothaca staminea	Pacific littleneck	10	0.031	68	0.211	70	0.219
Polycera hedgpethi	Hedpeth's polycera	8	0.008	59	0.059	63	0.063
Pugettia producta	northern kelp crab	7	0.035	55	0.291	58	0.311
Dendronotus frondosus	leafy dendronotid	7	0.005	48	0.035	50	0.036
Haminoea virescens	green glassy bubble	6	0.014	44	0.105	48	0.111
Gastropoda	gastropod, unid.	4	0.006	27	0.041	29	0.044
Haminoea spp.	glassy bubble, unid.	4	0.004	28	0.028	28	0.028
Dendronotus subramosus	stubby dendronotus	4	0.003	27	0.021	27	0.021
Hemigrapsus spp.	shore crab, unid.	3	0.004	24	0.033	25	0.034
Nudibranchia	nudibranch, unid.	3	0.003	21	0.021	21	0.021
Octopus spp.	octopus, unid.	3	0.002	20	0.014	21	0.014
Triopha maculata	spotted triopha	2	0.002	14	0.014	17	0.017
Kelletia kelletii	Kellet's whelk	2	0.006	14	0.043	16	0.049
Chrysaora colorata	purple-striped jellyfish	2	0.005	14	0.033	15	0.039
Dendronotus iris	giant-frond-aeolis	2	0.010	14	0.066	14	0.068
Ceratostoma nuttalli	Nuttall's thornmouth	2	0.004	14	0.028	14	0.028
Dendrodoris fulva	yellow prorostome	1	0.001	6	0.006	14	0.014
Crepidula onyx	onyx slippersnail	2	0.001	13	0.007	13	0.007
Argopecten ventricosus	Pacific calico scallop	1	0.001	9	0.009	12	0.012
Pisaster spp.	sea star, unid.	1	0.002	7	0.014	12	0.024

(table continued)

Table 5.5-4 (continued). HnGS macroinvertebrate impingement sampled abundance and biomass during 2006.

Taxon	Common Name	Total Sampled No.	Total Sampled Wt. (kg)	Estimated Annual Impingement: Actual Flow No.	Estimated Annual Impingement: Actual Flow Wt. (kg)	Estimated Annual Impingement: Design Flow No.	Estimated Annual Impingement: Design Flow Wt. (kg)
Heptacarpus paludicola	California coastal shrimp	1	0.001	10	0.010	10	0.010
Philine auriformis	New Zealand snail	1	0.002	8	0.015	9	0.018
Acanthodoris rhodoceras	black-tipped spiny doris	1	0.001	8	0.008	8	0.008
Polyorchis haplus	jellyfish	1	0.002	7	0.014	8	0.017
Neotrypaea californiensis	bay ghost shrimp	1	0.001	7	0.007	7	0.007
Berthella californica	California sidegill slug	1	0.001	6	0.006	7	0.007
Strongylocentrotus purpuratus	purple sea urchin	1	0.021	7	0.149	7	0.150
Lysmata californica	red rock shrimp	1	0.001	7	0.007	7	0.007
Aplysia spp.	seahare unid	1	0.001	7	0.007	7	0.007
Aeolidia papillosa	shag-rug aeolis	1	0.001	7	0.007	7	0.007
Dirona picta	spotted dirona	1	0.001	7	0.007	7	0.007
Molpadia intermedia	unnamed sea cucumber	1	0.024	7	0.173	7	0.174
Cancer anthonyi	yellow crab	1	0.002	7	0.014	7	0.014
	Totals	**2,682**	**36.997**	**20,346**	**268.803**	**21,773**	**293.826**

Fish impingement was generally greatest at Units 1 and 6, which accounted for 77% of abundance and 84% of biomass (Table 5.5-5). Abundance was greater at Unit 1 than at Unit 6, but biomass was highest at Unit 6. Invertebrate abundance was highest at Units 1 & 6, though biomass was highest at Units 5 & 6.

Table 5.5-5. Percent of total impingement by unit at HnGS in 2006.

Type	Unit 1	Unit 2	Unit 8 (formerly U3)	Unit 8 (formerly U4)	Unit 5	Unit 6
Fish abundance	42.5	14.0	0.9	1.1	7.0	34.6
Fish biomass	10.6	2.9	1.9	2.2	9.2	73.2
Invertebrate abundance	27.3	10.4	5.4	4.5	19.3	33.1
Invertebrate biomass	19.8	11.9	6.2	2.8	29.6	29.7

Impingement abundance in 2006 was highest in summer (July–September), which corresponded with an increase in queenfish impingement (Figures 5.5-1 and 5.5-2). Impingement biomass was greatest in spring (April–May). Invertebrate impingement abundance was greatest from January through June, with highest abundance recorded in spring (April–May) (Figures 5.5-3 and 5.5-4). Invertebrate biomass was much more variable throughout the year, with peaks in late-March, late-April, and early-August.

In general, fish impingement abundance was greatest during nighttime, though biomass was greater during the day (Figures 5.5-5 and 5.5-6). However, there were exceptions to this, including daytime surveys in April with higher abundance, and nighttime surveys during several months with greater biomass. The same general trend was observed in invertebrate impingement (Figures 5.5-7 and 5.5-8).

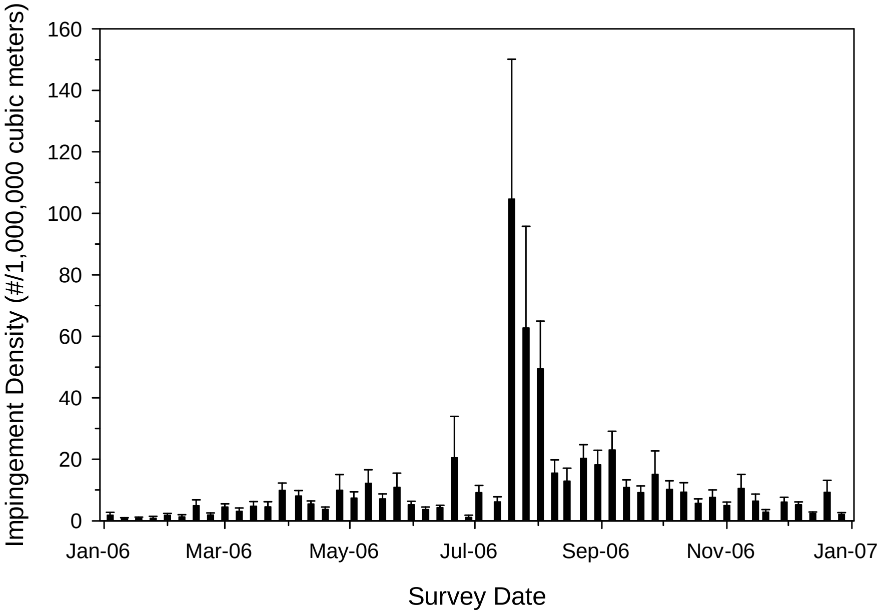


Figure 5.5-1. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of fishes in HnGS normal operation impingement samples during 2006.

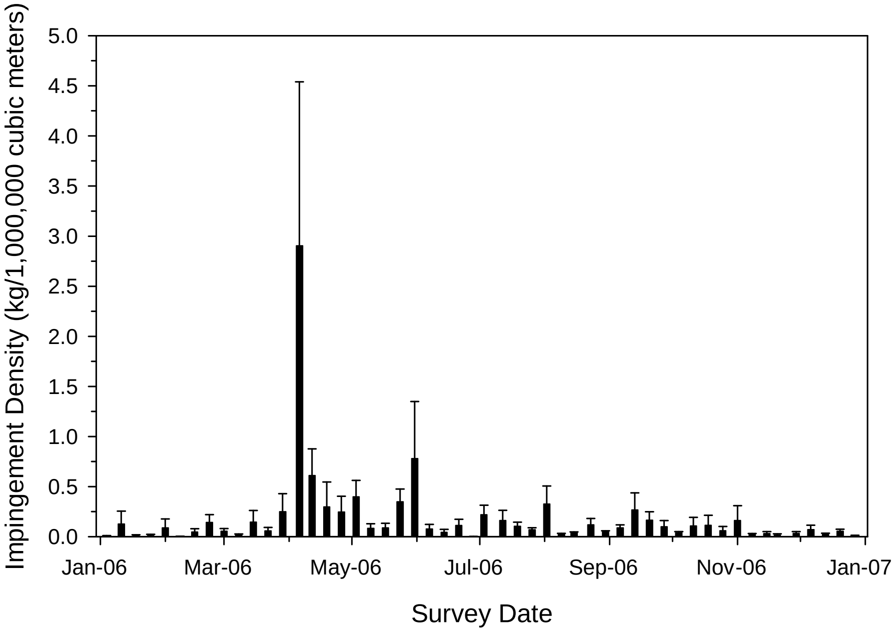


Figure 5.5-2. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of fishes in HnGS normal operation impingement samples during 2006.

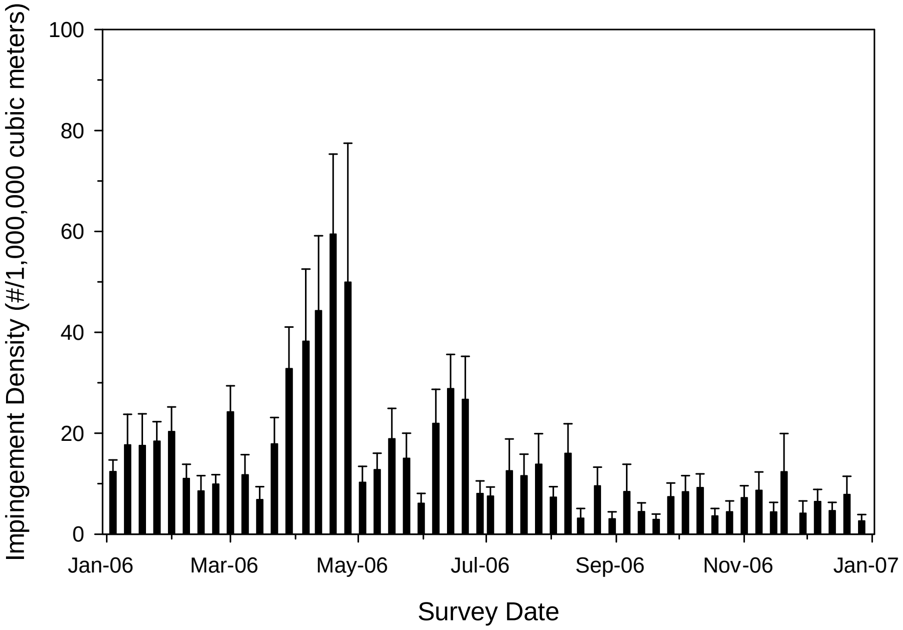


Figure 5.5-3. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of invertebrates in HnGS normal operation impingement samples during 2006.

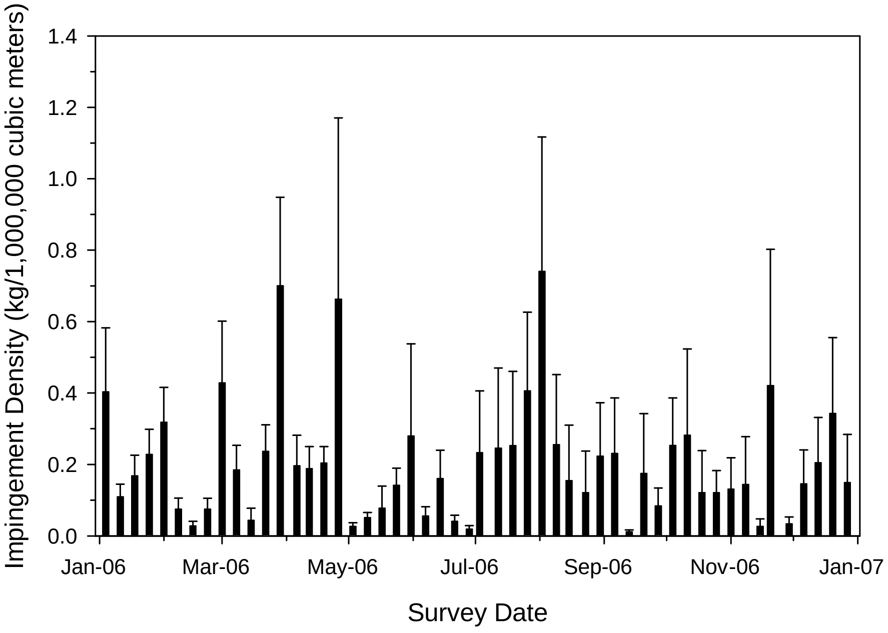
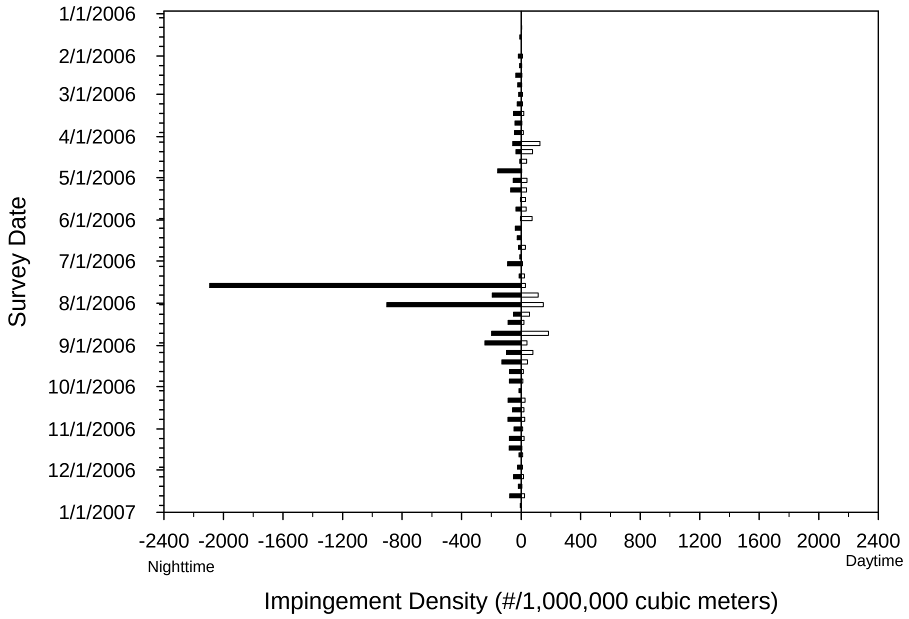
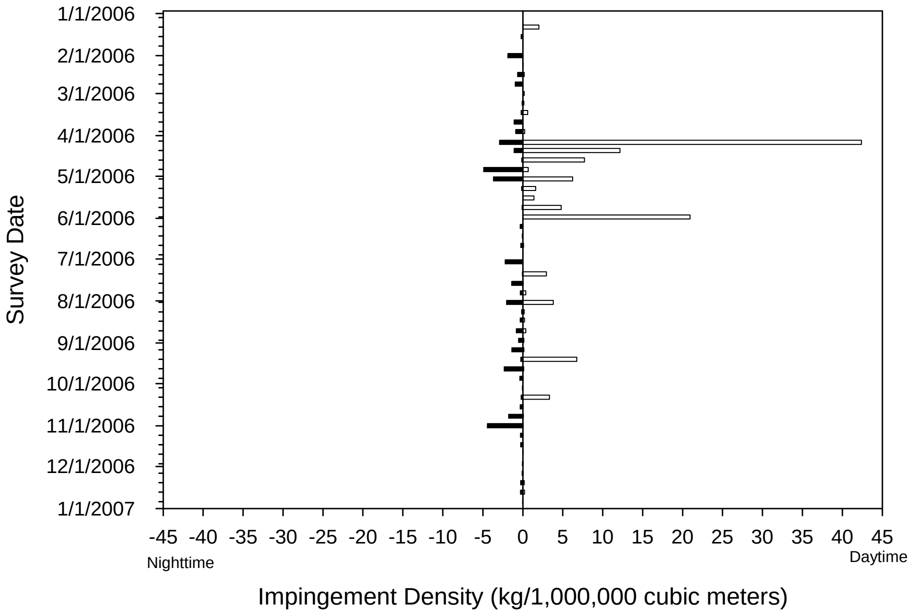


Figure 5.5-4. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of invertebrates in HnGS normal operation impingement samples during 2006.



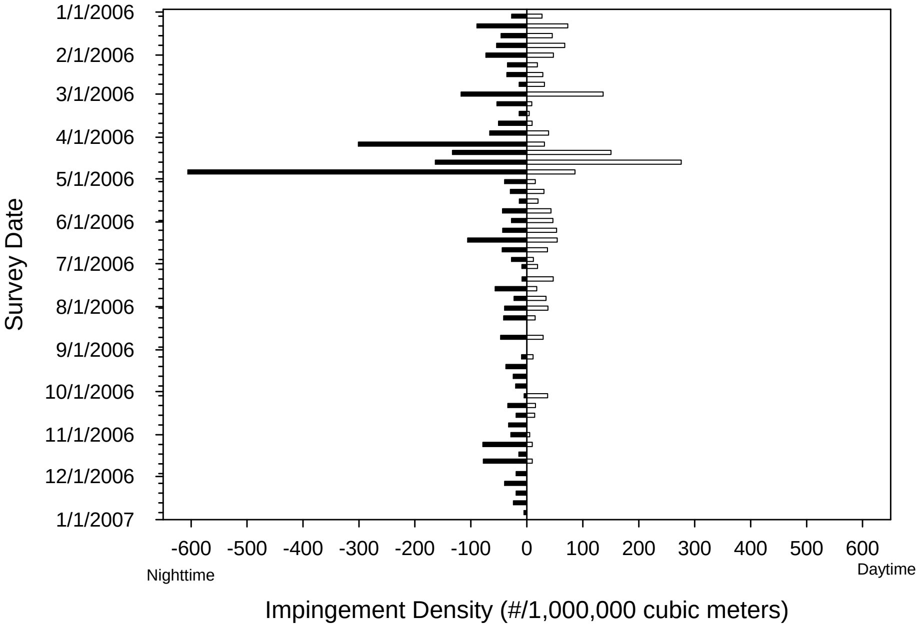
Note: Negative nighttime values are a plotting artifact

Figure 5.5-5. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of fishes in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



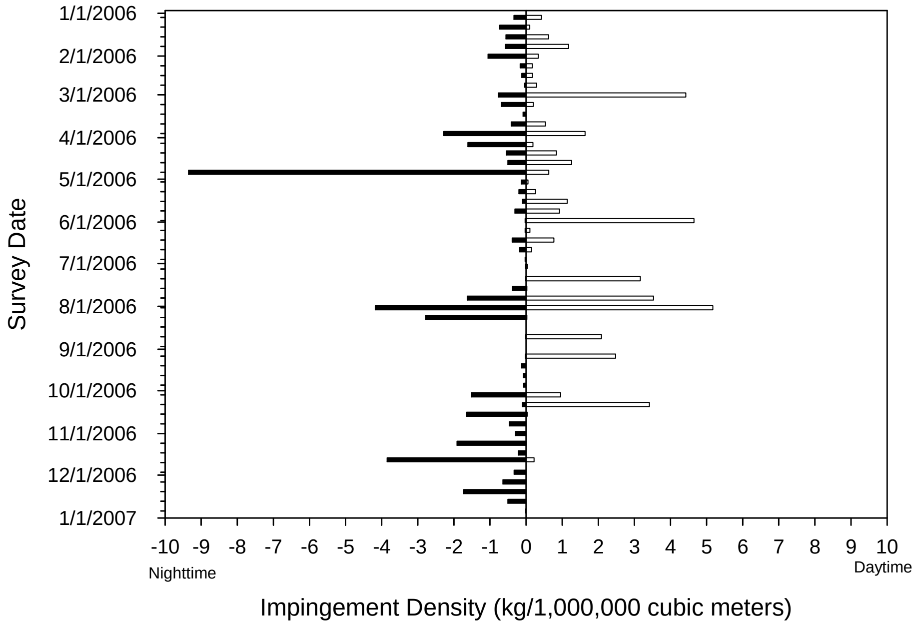
Note: Negative nighttime values are a plotting artifact

Figure 5.5-6. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of fishes in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-7. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of invertebrates in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



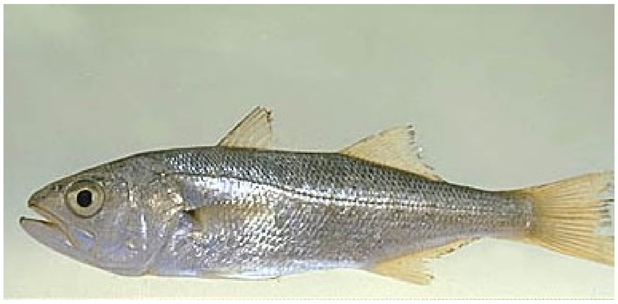
Note: Negative nighttime values are a plotting artifact

Figure 5.5-8. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of invertebrates in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

5.5.2 Fish Impingement Results by Species

Six fish taxa were impinged in sufficient numbers to warrant further analysis. These taxa were: queenfish (55% of sampled abundance), topsmelt (12%), northern anchovy (juvenile and adults – 7%, larval individuals – 6%), pipefishes (bay pipefish – 6%, and unidentified pipefish – 3%), shiner perch (1%), and specklefin midshipman (1%). Combined, these taxa comprised 91% of the fishes in impingement samples. The juvenile/adult northern anchovy and impinged larval anchovies were combined for analysis, as were all impinged pipefishes. Four additional fish species were analyzed in further detail due to their inclusion in the Coastal Pelagic Fishery Management Plan (Pacific sardine [12 individuals collected] and jack mackerel [one individual]) and the Pacific Groundfish Fishery Management Plan (California skate and vermilion rockfish [one individual each]).

5.5.2.1 Queenfish (*Seriphus politus*)


Milton Love

Queenfish (*Seriphus politus* Ayres 1860) range from west of Uncle Sam Bank, Baja California, north to Yaquina Bay, Oregon (Miller and Lea 1972). Queenfish are common in southern California, but rare north of Monterey. They are one of eight species of croaker or 'drums' (Family Sciaenidae) found off California. The other croakers include: white seabass (*Atractoscion nobilis*), black croaker (*Cheilotrema saturnum*), white croaker, California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), and shortfin corvina (*Cynoscion parvipinnis*). Shortfin corvina was common off the California coast as far north as San Pedro in the late 1800s (Jordan and Evermann 1896), but has not been common off the California coast since the 1930s (Miller and Lea 1972). It presently occurs as far north as Carlsbad, CA (Tenera 2007).

5.5.2.1.1 Life History and Ecology

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

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

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

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

5.5.2.1.2 Population Trends and Fishery

Queenfish was the most abundant sciaenid impinged at five generating stations in southern California from 1977 to 1998, and accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). Annual abundance fluctuated from year to year, with notable declines during the strong El Niño events of 1982-83, 1986-87, and 1997-98. However, abundance remained relatively high throughout the over 20-year study period. There were no reported commercial landings of queenfish in the commercial CDFG or PacFIN records (CDFG 2006, 2007; PacFIN 2007). Annual recreational landings (RecFIN 2007) have averaged about 270,000 fish per year since 2000, with a notable increase in 2002 (Table 5.5-6). During 1978-79, a total of 513 queenfish were impinged at HnGS, equivalent to about 1.5 queenfish per day (IRC 1981). Abundance was highest in November and December. From 2001 through 2005, annual queenfish impingement ranged from 0.1 to 13.6 queenfish per survey, and averaged about 5 fish per survey (MBC 2006).

Table 5.5-6. Annual recreational landings for queenfish in the Los Angeles region based on RecFIN data.

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

5.5.2.1.3 Sampling Results

Queenfish was the most abundant fish species impinged (based on actual cooling water flows) with an estimated 30,946 individuals, or 58% of the annual total, weighing 19.47 kg (42.92 lbs) (Table 5.5-2). Normal operation impingement represented all but nine impinged individuals, which were recorded during marine growth control procedures. Specifically, all queenfish impinged during marine growth control were recorded during August 21, 2006 at Unit 5 (9 individuals) and an additional three individuals during the August 22, 2006, procedure at Unit 2. Highest normal operation impingement was recorded at Unit 1, which accounted for 44% of the total abundance, followed by Unit 6 (35%), Unit 2 (16%), Unit 5 (4%) and Unit 8 (formerly Unit 3) and Unit 8 (formerly Unit 4) (less than 1% each). Biomass was highest at Unit 1 with 49% of the total, followed by Unit 6 (32%), Unit 2 (12%), Unit 5 (6%), Unit 8 (formerly Unit 4) (1%), and Unit 8 (formerly Unit 3) (less than 1%).

Queenfish impingement density peaked in late-July through early-August (Figure 5.5-9). Few queenfish were impinged during the first six months of the year, and after August occurrences were low and variable. Biomass followed a pattern similar to abundance, although the sporadic instances during the first six months were more pronounced compared to abundance, principally due to the impingement of larger individuals (Figure 5.5-10).

Substantial diel periodicity was observed in the impingement of queenfish (Figures 5.5-11 and 5.5-12). Insufficient numbers of fish were impinged during the first six months to warrant any comparisons, but the second half of the year saw substantial increases during both diel periods. Daylight impingement reached a peak of nearly 100 individuals per 1,000,000 m^3 (264.172 million gal), which was less than the four highest peaks observed during nighttime surveys, one of which exceeded 1,750 individuals per 1,000,000 m^3 (264.172 million gal). A similar pattern was observed in the diel comparisons of biomass. Very little biomass was impinged during the night over the first six months of the year, after which impingement increased markedly. Over the second half of the year, daylight impinged biomass never exceeded 0.1 kg (0.22 lbs) per 1,000,000 m^3 (264.172 million gal), while five surveys during the night recorded impingement rates greater than 0.1 kg (0.22 lbs) per 1,000,000 m^3 (264.172 million gal), with density during one survey at nearly 0.7 kg (1.5 lbs) per 1,000,000 m^3 (264.172 million gal).

Length frequency analysis of 2,359 measured individuals indicates a mean standard length of 35 mm (1.4 inches) (Figure 5.5-13). The distribution of length classes confirmed this with greater than 50% of all individuals represented in the 30 mm (1.2 inches) size class, followed by the 40 mm and 50 mm (1.6 in and 2.0 inches) size classes. The majority of these measured individuals were young of the year, with queenfish reaching age one at approximately 100 mm SL (3.9 inches) (MBC and VRG unpubl. data[1]). Of the 1,538 individuals that were evaluated for condition factor, 99% were dead and the remaining 1% was mutilated, with no individuals collected alive.

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

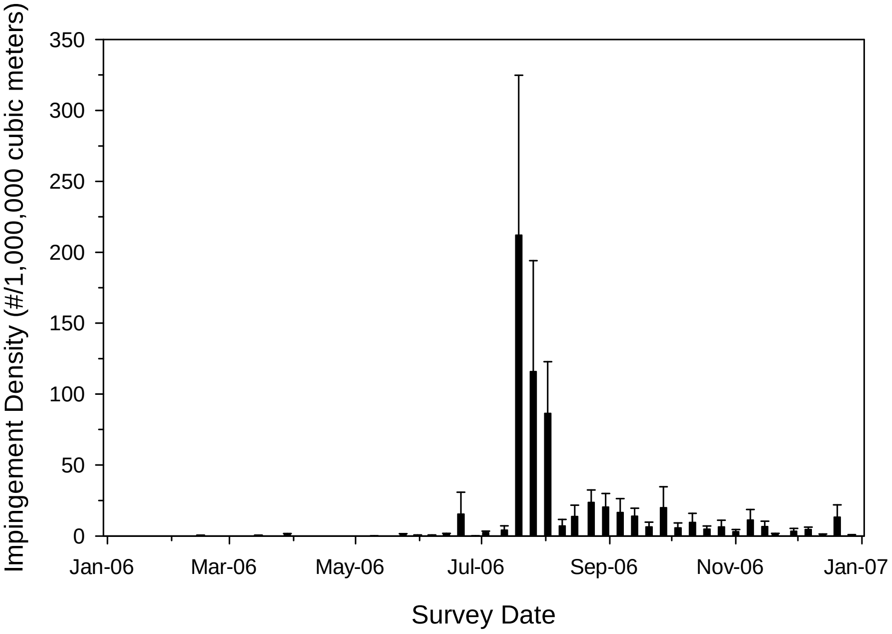


Figure 5.5-9. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of queenfish in HnGS normal operation impingement samples during 2006.

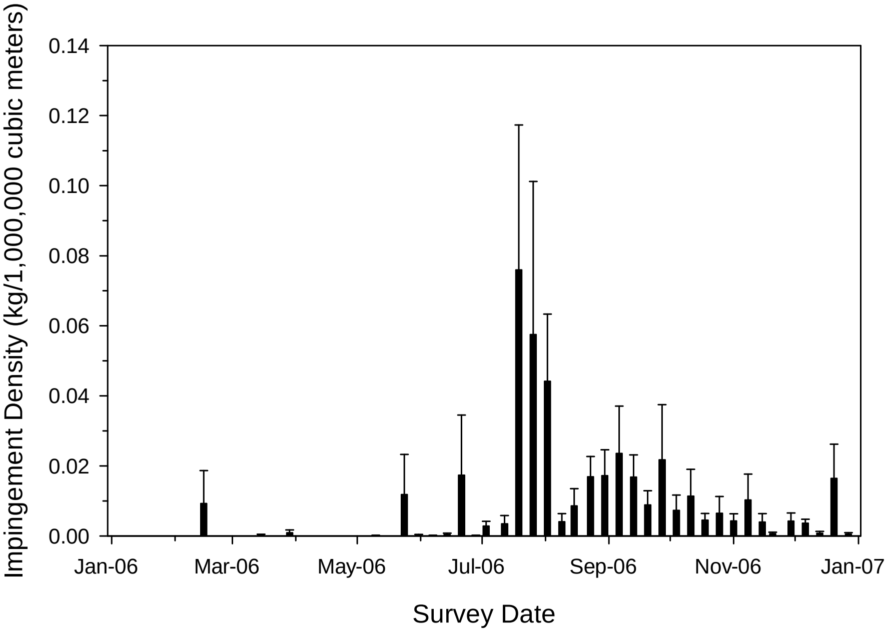
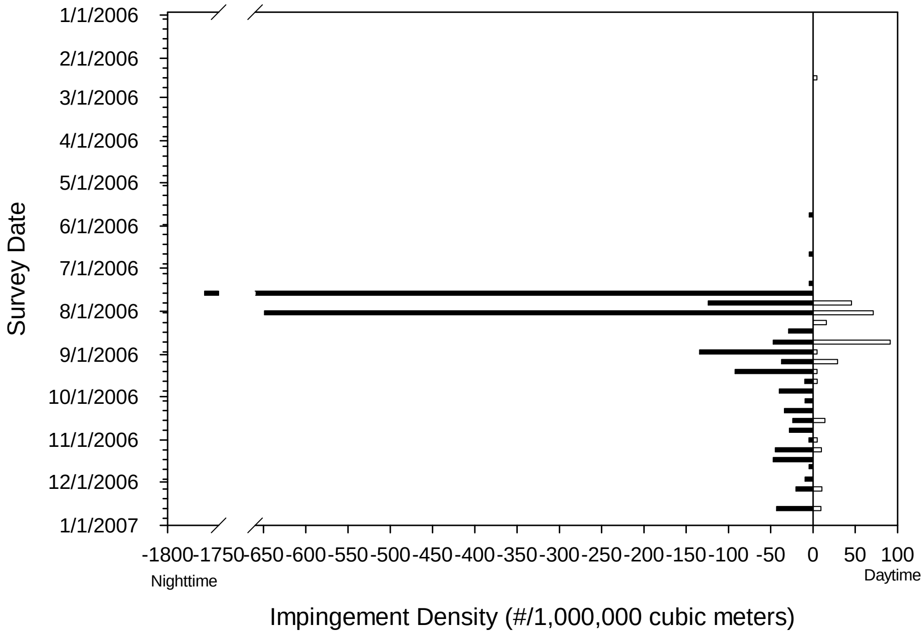
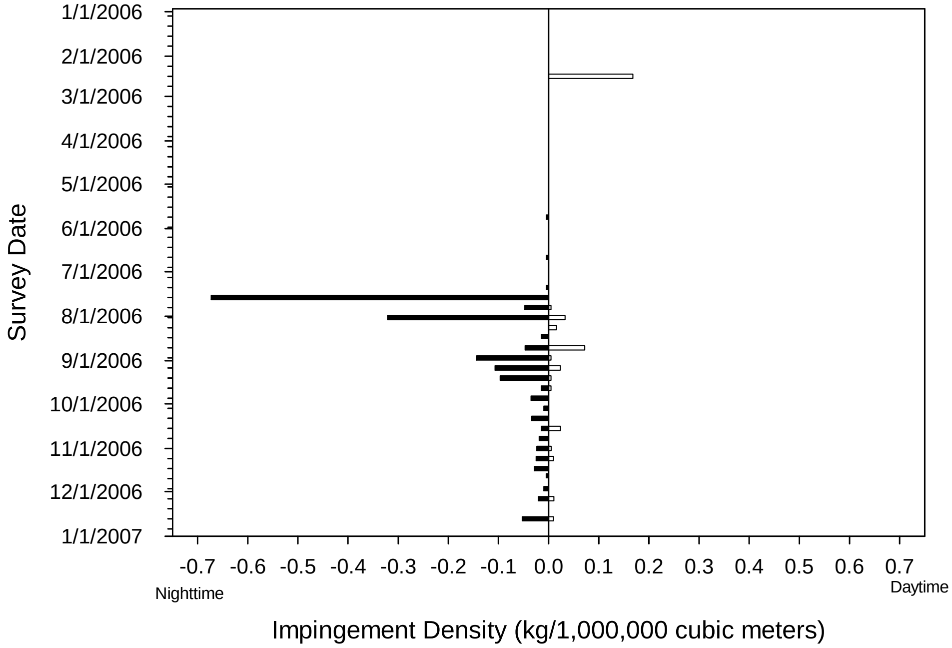


Figure 5.5-10. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of queenfish in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

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



Note: Negative nighttime values are a plotting artifact

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

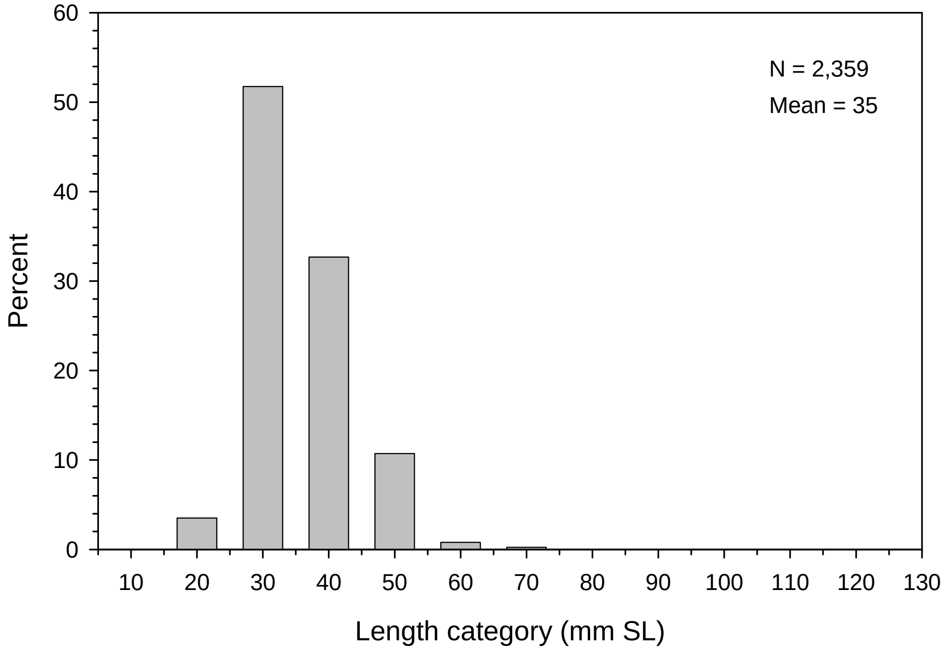


Figure 5.5-13. Length (mm) frequency distribution for queenfish collected in impingement samples.

5.5.2.1.4 Modeling Results

Queenfish life history parameters are presented in Table 5.5-7. Unpublished research by MBC and the Occidental College Vantuna Research Group (VRG) provided all of the applicable adult life history parameters that indicate the age at 50% maturity is 1.76642 years. Age class frequency analysis indicated the majority of individuals collected were less than 0.6 years old (Figure 5.5-14). A total of 13,971 adult equivalents were taken over the year based on actual cooling water flow. Of these four were directly attributable to heat treatments while an estimated 13,967 were impinged during normal operation of the cooling water system calculated using actual flow rates. Recalculating the actual flow estimates to plant design (maximum) flow equated to a total loss of 14,595 adult equivalents.

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

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

**Data from MBC and VRG unpublished data*

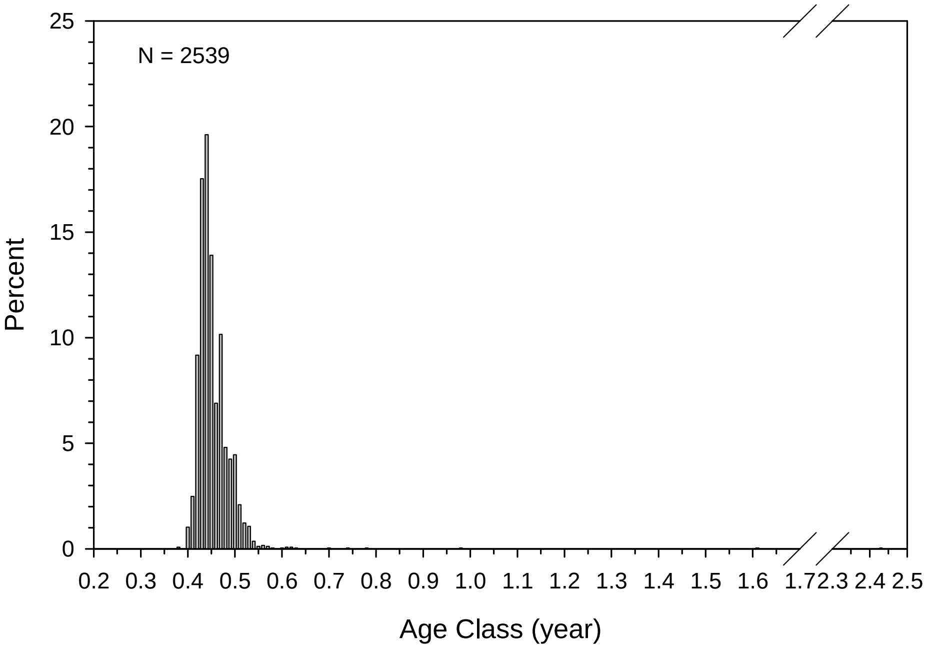


Figure 5.5-14. Age class distribution of queenfish collected in HnGS impingement samples.

5.5.2.2 Topsmelt (*Atherinops affinis*)


Jamie Siler

Information on the life history, ecology, population trends, and fishery of silversides (Atherinopsidae) is summarized in Section 4.4.3.2. The section includes information on topsmelt, which was one of three species of silversides entrained as larvae at HnGS.

There were no commercial landings of topsmelt in the Los Angeles area in 2005 (CDFG 2006); however, there were 4.5 kg (10 lbs) landed in Long Beach area catch blocks during 2006 at an estimated value of $50 (CDFG 2007). During 1978-79, a total of 821 topsmelt were impinged at HnGS, equivalent to about 2.5 topsmelt per day (IRC 1981). Abundance was highest in May and June. From 2001 through 2005, annual topsmelt impingement ranged from 0 to 0.5 topsmelt per survey, and averaged about 0.2 fish per survey (MBC 2006).

5.5.2.2.1 Sampling Results

Topsmelt was the second most abundant fish species impinged (based on actual cooling water flows) with an estimated 6,315 individuals, or 12% of the annual total, weighing 29.44 kg (64.91 lbs) (Table 5.5-2). Normal operation impingement represented all but eight impinged individuals, which were recorded during marine growth control procedures. Three topsmelt weighing 0.02 kg (0.05 lbs) were impinged during the marine growth control procedure at Unit 5 on August 21, 2006, and five more topsmelt weighing 0.02 kg (0.04 lbs) were impinged during the procedure at Unit 2 on November 14, 2006. Highest normal operation impingement was recorded at Unit 6, which accounted for 39% of the total abundance, followed by Unit 1 (38%), Unit 5 (11% each), Unit 2 (10%), Unit 8 (formerly Unit 3) (2%), and Unit 8 (formerly Unit 4) (1%). Biomass was highest at Unit 6 with 62% of the total, followed by Unit 5 (12%), Unit 1 (11%), Unit 2 (8%), Unit 8 (formerly Unit 4) (5%), and Unit 8 (formerly Unit 3) (1%).

Topsmelt were impinged throughout the year, though peak impingement densities were recorded from July through September (Figure 5.5-15). However, highest impingement biomass occurred in April (Figure 5.5-16). Substantial diel periodicity was observed in the impingement of topsmelt (Figures 5.5-17 and 5.5-18). During the first six months of 2006, impingement was relatively low, and daytime impingement was generally higher than nighttime impingement. However, during the second half of 2006, there were alternating periodicities, but highest biomass was recorded during nighttime surveys.

Length frequency analysis of 572 measured individuals indicated a mean standard length of 75 mm (3 inches). There was a wide distribution of size classes, although most of the measured fishes were between the 50 mm and 80 mm (2.0 and 3.1 inches) size classes (Figure 5.5-19). Considering topsmelt mature at two years and 100 mm (3.9 inches) or greater (Love 1996), most of the individuals impinged were in their first year. Of the 506 individuals that were evaluated for condition factor, 98% were dead and the remaining 2% were mutilated, with no individuals collected alive.

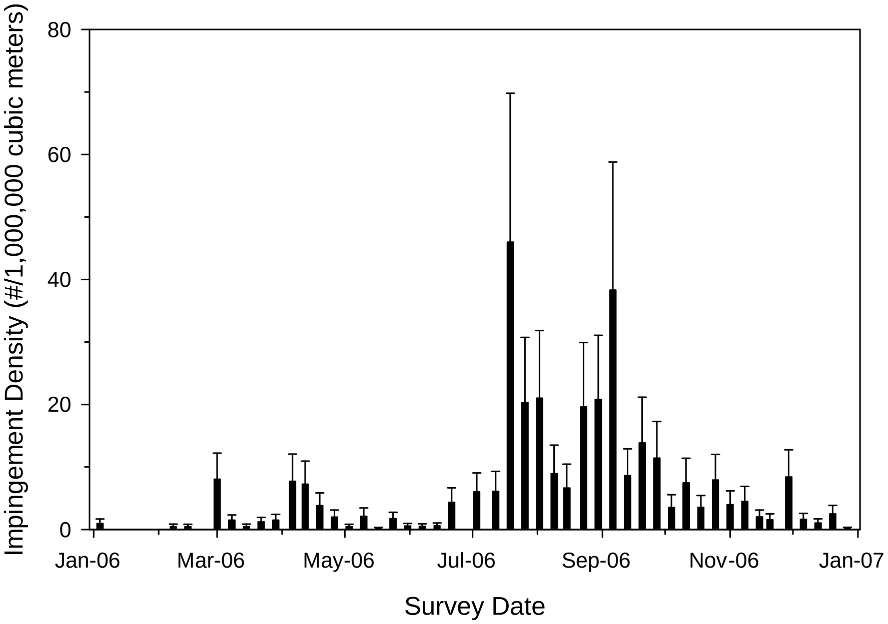


Figure 5.5-15. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of topsmelt in HnGS normal operation impingement samples during 2006.

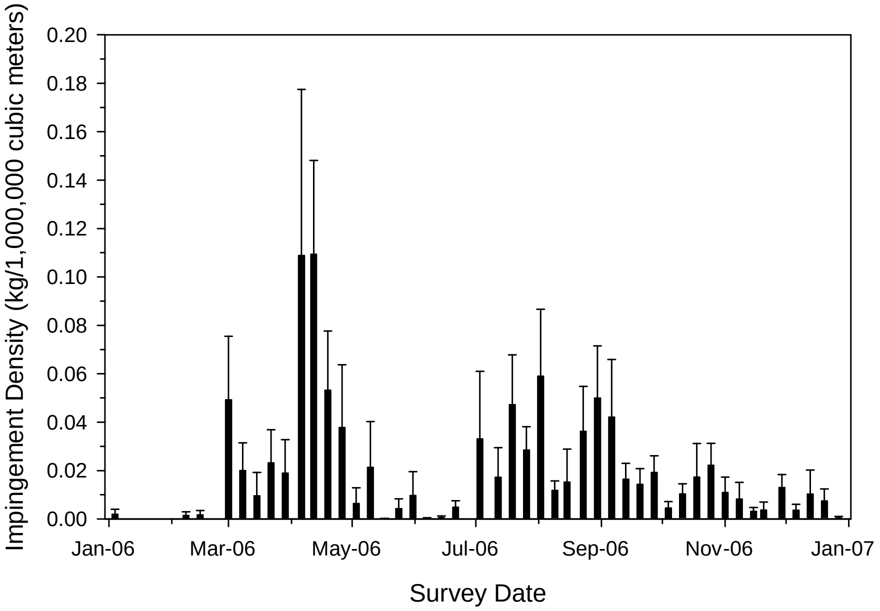
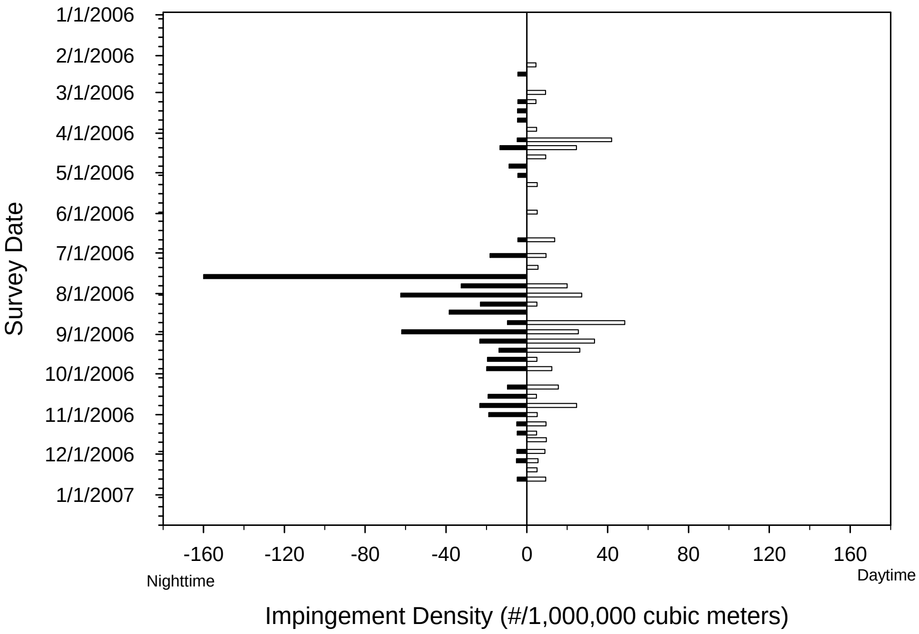
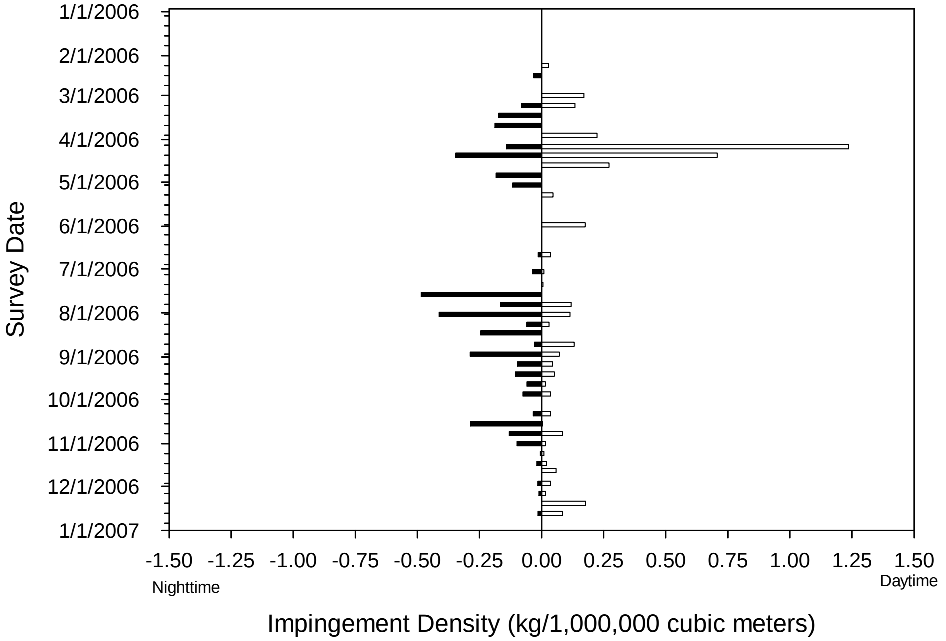


Figure 5.5-16. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of topsmelt in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-17. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of topsmelt in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling



Note: Negative nighttime values are a plotting artifact

Figure 5.5-18. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of topsmelt in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

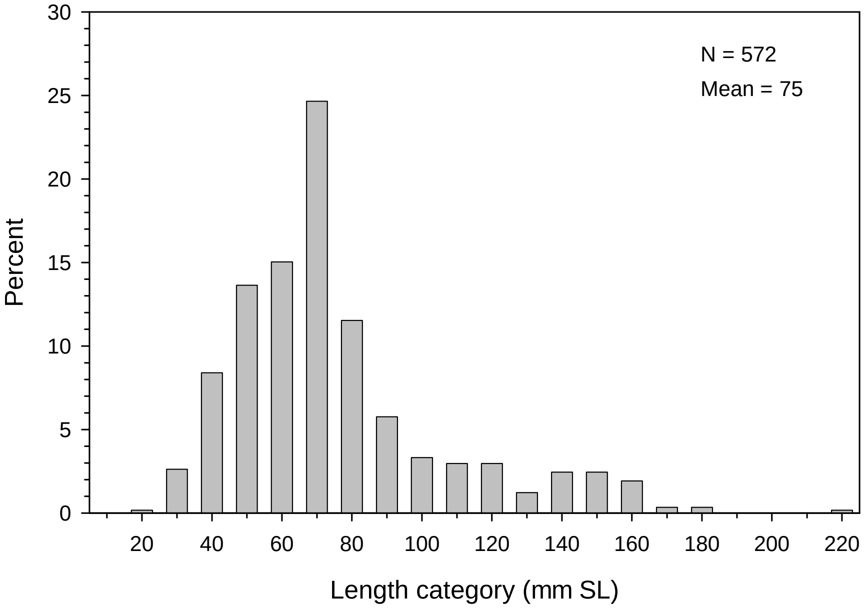


Figure 5.5-19. Length (mm) frequency distribution for topsmelt collected in impingement samples.

5.5.2.3 Northern anchovy (*Engraulis mordax*)

Mark Conlin

Information on the life history, ecology, population trends, and fishery of northern anchovy is summarized in Section 4.4.3.1.

Commercial landings of northern anchovy in the Los Angeles area in 2005 totaled 1,992,064 kg (4,392,501 lbs) at a value of $191,664 (CDFG 2006). Commercial landings in Long Beach area catch blocks in 2006 totaled 392,446 kg (865,180 lbs) at an estimated value of 40,732 (CDFG 2007). During 1978-79, a total of 99 northern anchovy were impinged at HnGS, equivalent to about 0.3 anchovies per day (IRC 1981). Abundance was highest in May and June. From 2001 through 2005, annual impingement of northern anchovy ranged from 0.1 to 1.3 fish per survey, and averaged about 0.4 fish per survey (MBC 2006).

5.5.2.3.1 Sampling Results

Northern anchovy was the third most abundant fish species impinged (based on actual cooling water flows) with an estimated 3,443 individuals, or 6% of the annual total, weighing 6.0 kg (13.3 lbs) (Table 5.5-2). Normal operation impingement represented all but 10 impinged individuals, which were recorded during marine growth control procedures. Additionally, an estimated 2,351 anchovy larvae were estimated to be impinged in 2006. Four northern anchovy weighing 0.01 kg (0.02 lbs) were impinged during a marine growth control on August 21, 2006 procedure at Unit 5, and an additional six individuals weighing 0.01 kg (0.02 lbs) were impinged during the August 22, 2006 procedure at Unit 2. Highest normal operation impingement was recorded at Unit 1, which accounted for 37% of the total abundance, followed by Unit 6 (27%), Unit 5 (21%), Unit 2 (11%), Unit 8 (formerly Unit 4) (2%), and Unit 8 (formerly Unit 3) (1%). Impinged biomass was highest at Unit 6 with 38% of the total, followed by Unit 1 (36%), Unit 5 (19percent), Unit 2 (4%), Unit 8 (formerly Unit 4) (2%), and Unit 8 (formerly Unit 3) (1%).

Northern anchovy were impinged throughout the year, though peak impingement densities were recorded in July and August (Figure 5.5-20). Impingement biomass followed a similar pattern to abundance (Figure 5.5-21). During periods of highest abundance, impingement abundance and biomass were usually higher during nighttime (Figures 5.5-22 and 5.5-23).

Length frequency analysis of 266 measured individuals indicated a mean standard length of 60 mm (2.4 inches). There was a wide distribution of size classes, although most of the measured fishes were between the 60 and 80 mm (2.4 and 3.1 inches) size classes (Figure 5.5-24), indicating most were in their first year. Of the 285 individuals that were evaluated for condition factor, 90% were dead and the remaining 10% were mutilated.

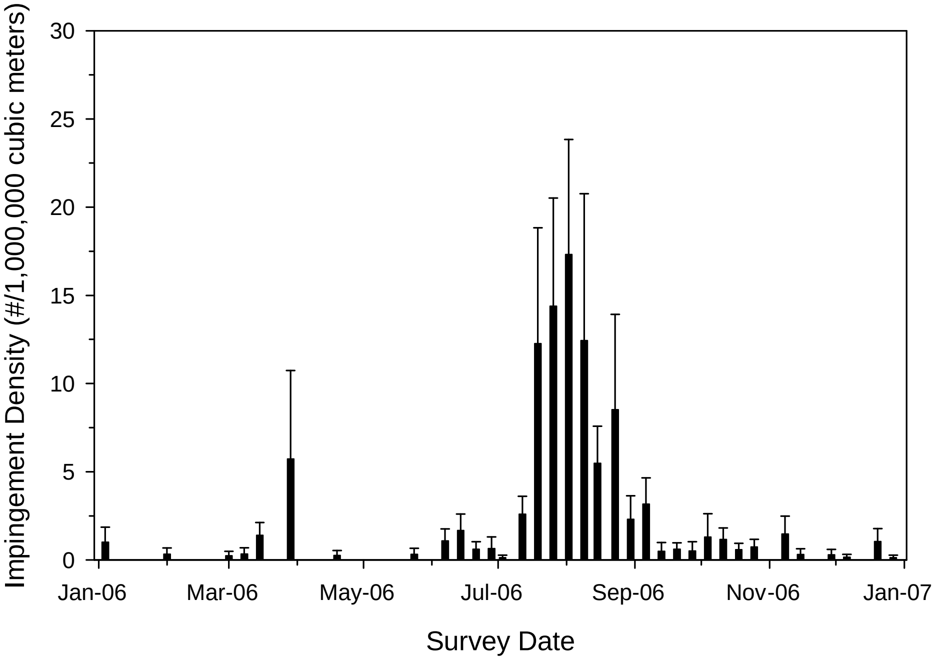


Figure 5.5-20. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of northern anchovy in HnGS normal operation impingement samples during 2006.

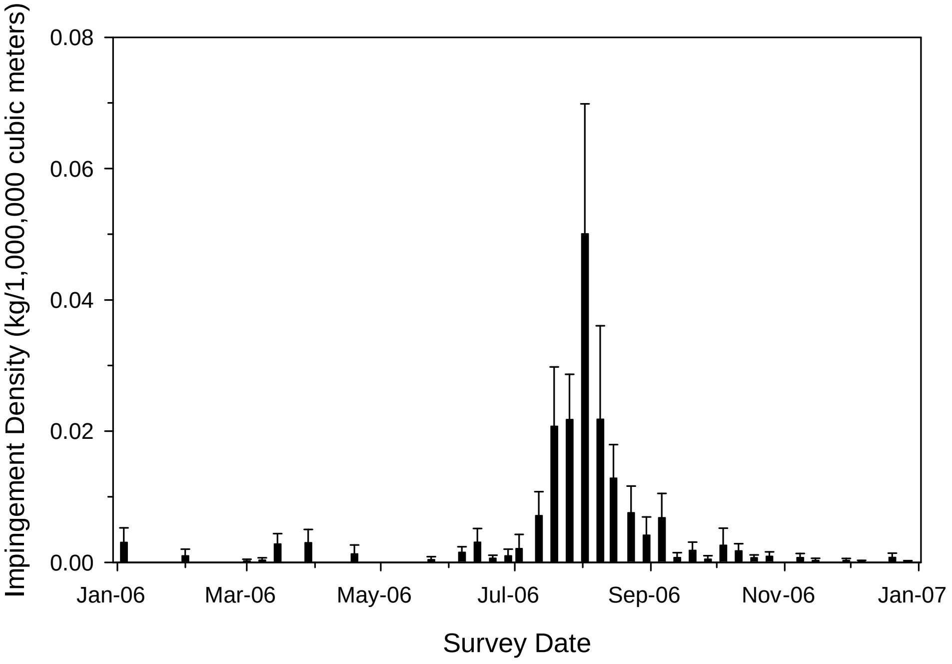
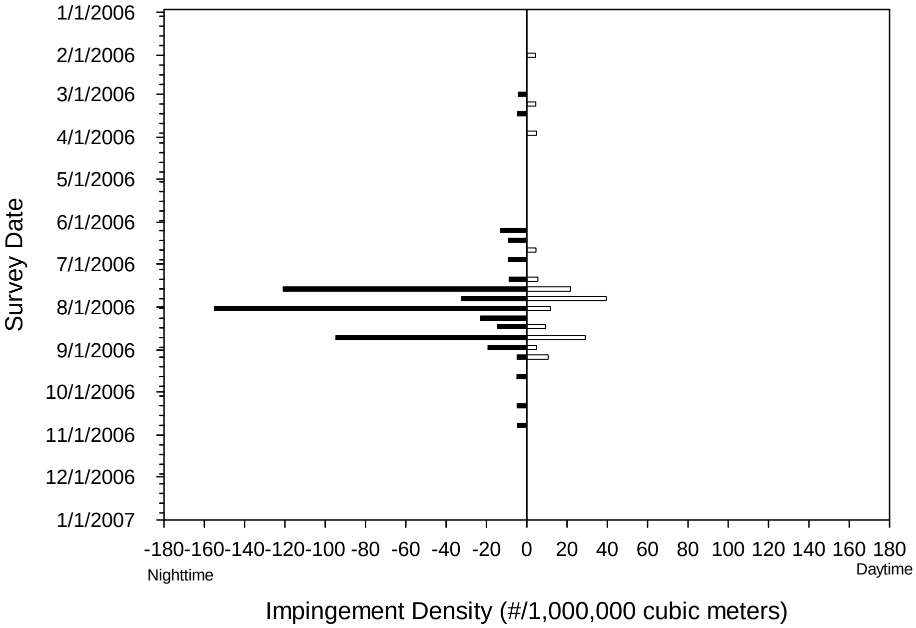
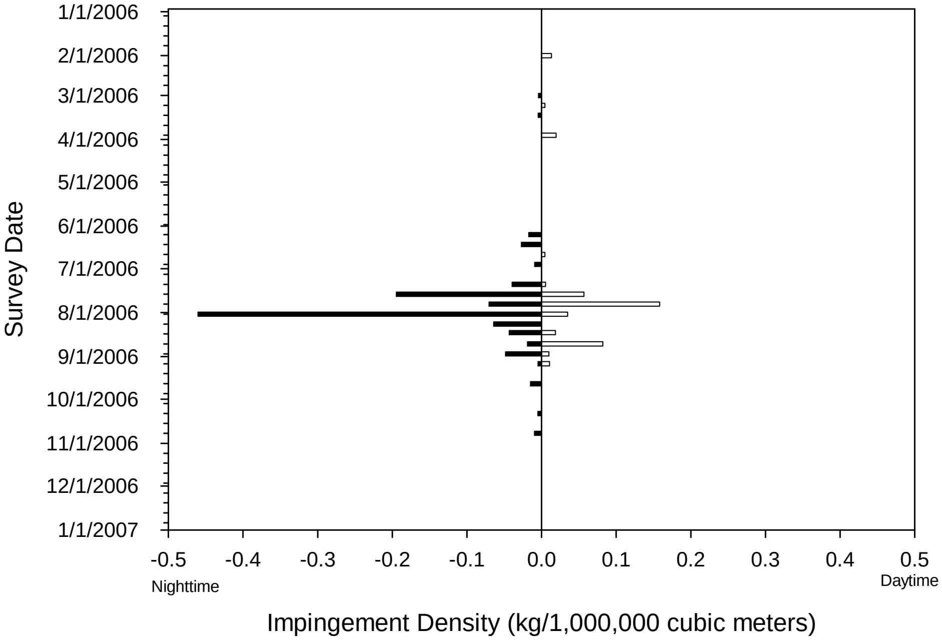


Figure 5.5-21. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of northern anchovy in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-22. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of northern anchovy in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-23. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of northern anchovy in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

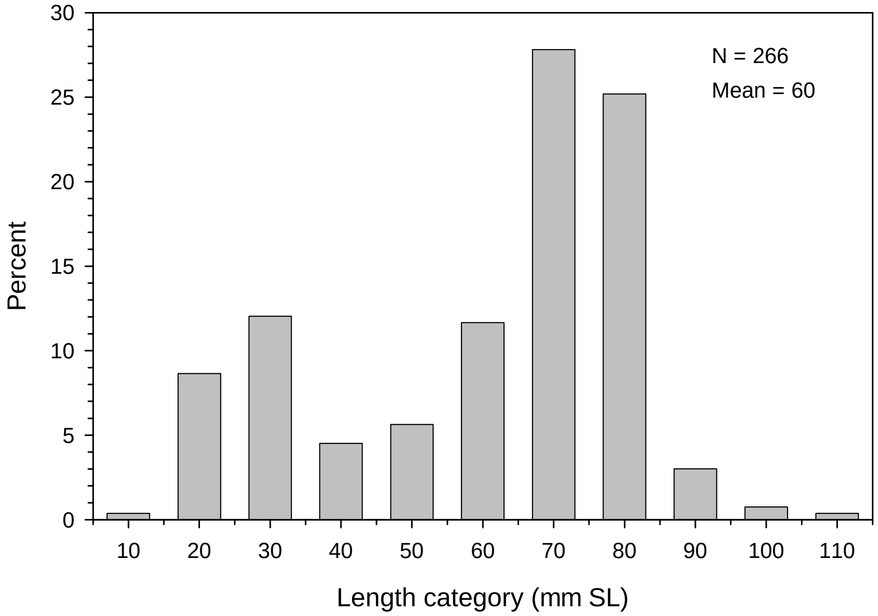


Figure 5.5-24. Length (mm) frequency distribution for northern anchovy collected in impingement samples.

5.5.2.3.2 Modeling Results

Northern anchovy life history parameters are presented in Table 5.5-8. von Bertalanffy parameters were derived from data presented for San Pedro Channel, California in Parrish et al. (1986). Annual survival estimates were calculated based on daily mortality rates (0.997902) summarized in Butler et al. (1993). Age and size at 50% maturity, 0.986614 years and 96 mm SL, respectively, were taken from Hunter and Macewicz (1980). The 266 northern anchovies measured over the year exhibited a bimodal age class distribution with one peak at approximately 0.2 years of age and a larger peak at approximately 0.5 years of age (Figure 5.5-25). Over the survey year approximately 1,840 adult equivalent northern anchovies were taken during the actual operation of the cooling water system. Of these, 1,834 individuals were impinged during normal operation of the cooling water system with an additional six individuals taken during heat treatments. Recalculation of these values based on design (maximum) flow volume of the cooling water system amounted to 2,117 individuals.

Table 5.5-8. Northern anchovy life history parameters used in equivalent adult modeling.

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

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

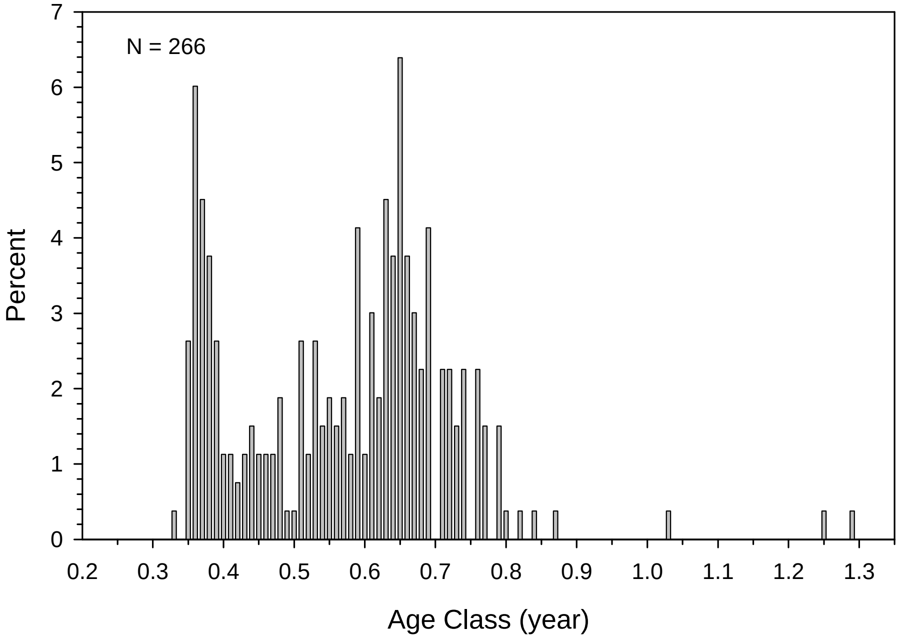


Figure 5.5-25. Age class distribution of northern anchovy collected in HnGS impingement samples.

5.5.2.4 Pipefishes (Syngnathidae)

Three species of pipefish commonly occur throughout the nearshore waters of southern California, including; kelp pipefish (*Syngnathus californiensis*), bay pipefish (*S. leptorhynchus*), and barcheek pipefish (*S. exilis*) (Love et al. 2005). As a group, these three species generally range from at least central Baja California, Mexico to northern California, with varying depth ranges (Love et al. 2005). All species have an upper depth limit reaching the surface extending to depths of 5 m (16 ft) for bay pipefish, 10 m (33 ft) for barcheek pipefish, and 15 m (49 ft) for kelp pipefish (Love et al. 2005). Ecologically, the three species exhibit two distinct habitat affinities. Allen and Pondella (2006) included bay pipefish in their southern nearshore and bay/estuary species group, while both kelp and barcheek pipefish were included in the nearshore algal bed and soft bottom species group. Kelp pipefish have been the most commonly observed of the three species in impingement sampling throughout the Los Angeles and Orange County areas, while bay pipefish has been largely limited to inshore embayments (MBC unpubl. data). Barcheek pipefish has been very uncommon in impingement sampling throughout the Los Angeles and Orange County areas. Two additional pipefish species, barred pipefish (*Syngnathus auliscus*) and snubnose pipefish (*Cosmocampus arctus*), have been reported to occur within southern California, but neither has been observed in impingement samples in Los Angeles or Orange Counties with any regularity (MBC unpubl. data).

5.5.2.4.1 Life History and Ecology

Each pipefish species occupies a somewhat distinct habitat. Kelp pipefish have been most commonly associated with anchored or drifting algae, often exhibiting cryptic coloration matching the surrounding material (Fitch and Lavenberg 1975). Additionally, kelp pipefish have been observed more frequently during open coast surveys than each of the remaining species (MBC unpubl. data).

Eschmeyer and Herald (1983) noted bay pipefish to commonly inhabit eelgrass beds within bays, harbors, and estuaries within southern California. Two recent studies of the fish communities of bays within southern California reported bay pipefish in abundances far exceeding that of kelp pipefish (Valle et al. 1999, Allen et al. 2002). In surveys of Alamitos Bay, California, Valle et al. (1999) reported bay pipefish as the third most abundant species collected, occurring in 49% of all sampling events, while kelp pipefish was absent from the surveys. In a similar study in San Diego Bay, California, Allen et al. (2002) recorded bay pipefish as the tenth most abundant species, accounting for 0.69% of the total abundance, while kelp pipefish represented 0.01% of the total abundance.

The last of the three common species, barcheek pipefish, prefers similar habitat types as kelp pipefish, namely drift algae (Eschmeyer and Herald 1983; Allen and Pondella 2006). In surveys of Alamitos Bay, California, no barcheek pipefish were collected (Valle et al. 1999), while in San Diego Bay, California, they were collected in lower abundance than kelp pipefish (Allen et al. 2002).

Pipefish as a group have been reported to exhibit unique reproductive activities. Fitch and Lavenberg (1975) suggest that fertilization of the eggs occurs as the female transfers the eggs to a brood pouch located on the male's abdomen, after which the male provides all parental care and broods the eggs until hatching. The authors further report that "pregnant" male kelp pipefish have been observed from September to December in southern California. Similar patterns have been observed in the remaining pipefish species (Coleman 1999). Little information has been reported in the primary literature regarding age and growth of southern California pipefish. Surveys of online databases (www.fishbase.org) indicate bay pipefish reach a maximum age of two years. No further information was available on the remaining species.

5.5.2.4.2 Population Trends and Fishery

No commercial or recreational fishery currently exists for these three species of pipefish, outside of the occasional take for the aquarium trade. Other related species, such as seahorses (*Hippocampus* spp.), receive much greater attention for the aquarium trade. Trends in abundance have not been derived for pipefishes, due to the lack of either fishery dependent or independent data. During 1978-79, a total of 73 pipefishes were impinged at HnGS, equivalent to about 0.2 fish per day (IRC 1981). Of these pipefishes, 45 were bay pipefish, 11 were kelp pipefish, 1 was a barred pipefish, and 16 were unidentified. Abundance was highest from May through July. From 2001 through 2005, annual pipefish impingement ranged from 0 to 0.4 pipefish per survey, and averaged about 0.2 fish per survey (MBC 2006).

5.5.2.4.3 Sampling Results

Bay pipefish was the fourth most abundant fish species impinged (based on actual cooling water flows) with an estimated 3,157 individuals, or 6% of the annual total, weighing 3.85 kg (8.48 lbs) (Table 5.5-2). An additional 1,373 unidentified pipefishes weighing 1.83 kg (4.03 lbs), and 23 kelp pipefish weighing 0.02 kg (0.05 lbs), were also impinged. Normal operation impingement represented all but three impinged individuals. One bay pipefish weighing <0.01 kg (<0.01 lbs) was impinged during the May 10, 2006 marine growth control procedure at Unit 2, and two unidentified pipefishes weighing <0.01 kg (<0.01 lbs) were impinged during the March 7, 2006 procedure at Unit 1. Highest normal operation impingement of pipefishes was recorded at Unit 6, which accounted for 44% of the total abundance, followed by Unit 1 (33%), Unit 2 (14%), and Unit 5 (7%), and Units 8 (formerly Unit 3) and 8 (formerly Unit 4) (1% each). Biomass was highest at Unit 6 with 52% of the total, followed by Unit 1 (21%), Unit 5 (13%), Unit 2 (12%), and Units 8 (formerly Unit 3) and 8 (formerly Unit 4) (1% each).

Pipefishes were impinged throughout the year, though peak impingement densities were recorded in spring and summer (April–July), corresponding to results from IRC (1981) (Figure 5.5-26). Impingement biomass followed a similar pattern to abundance, with peak periods in May, June, and August (Figure 5.5-27). During periods of highest abundance, impingement abundance and biomass were usually higher during nighttime (Figures 5.5-28 and 5.5-29).

Length frequency analysis of 484 measured individuals indicated a mean standard length of 160 mm (6.3 inches). There was a wide distribution of size classes, although most of the measured fishes were between the 120 and 190 mm (4.7 and 7.5 inches) size classes (Figure 5.5-30). Fifty-one percent were males, 48% were females, and sex could not be determined on the remaining 1%. Of the 484 individuals that were evaluated for condition factor, 24% were alive, 74% were dead, and the remaining 2% were mutilated.

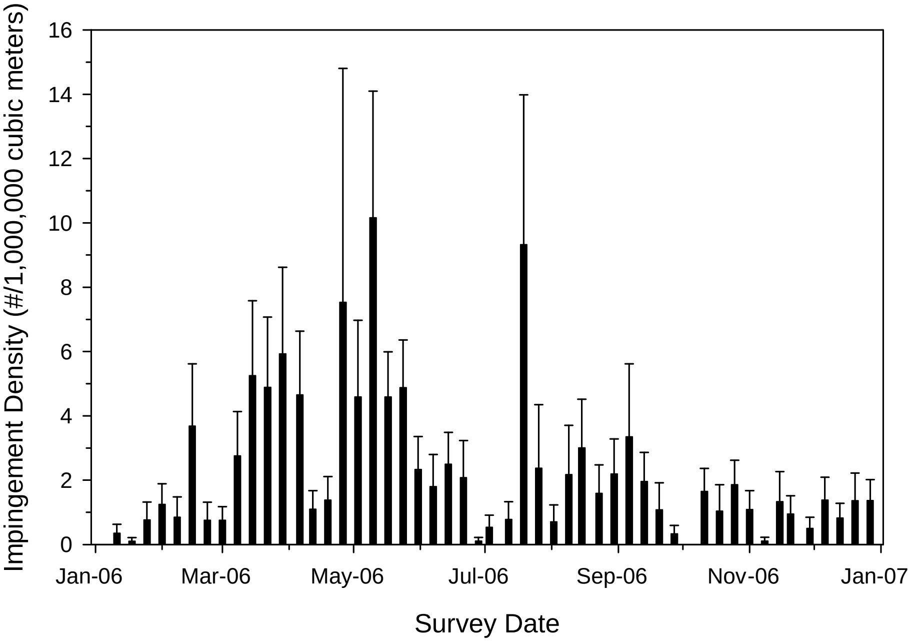


Figure 5.5-26. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of pipefishes in HnGS normal operation impingement samples during 2006.

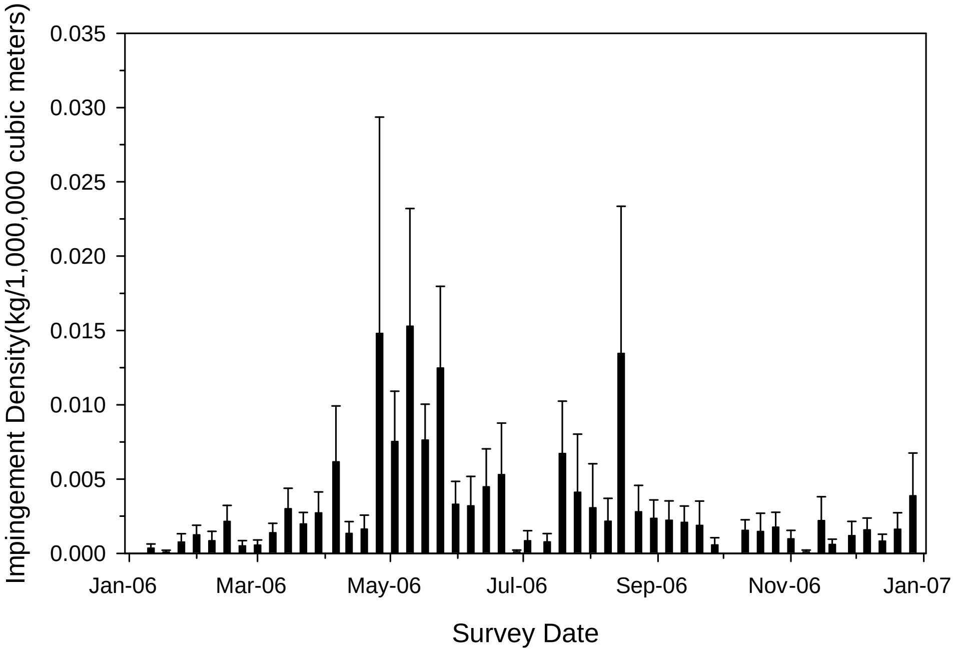
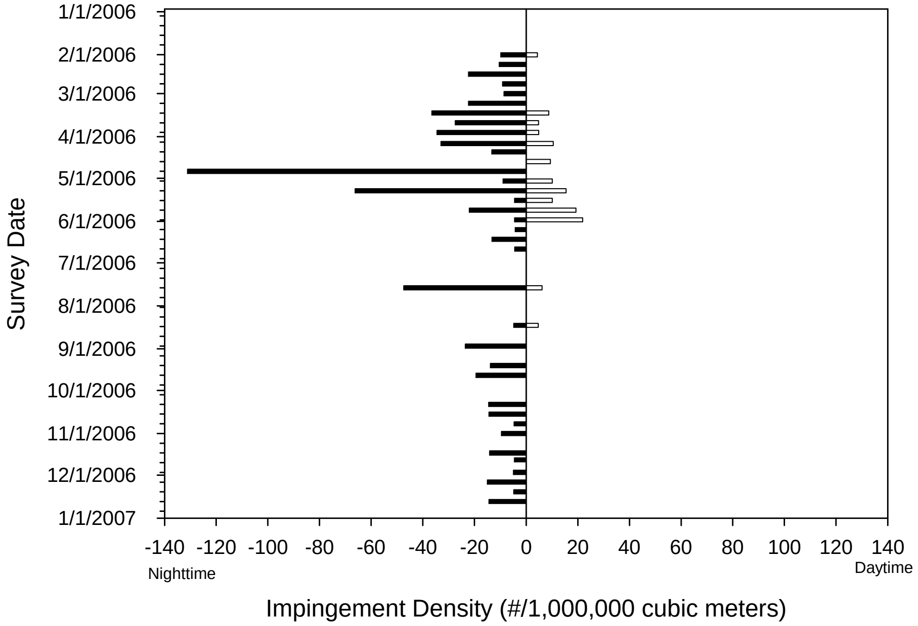
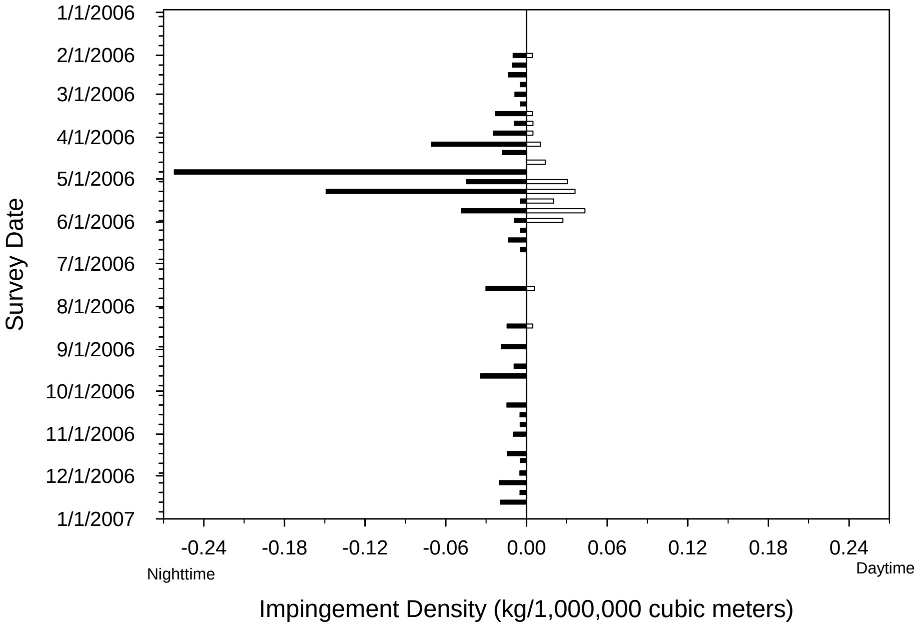


Figure 5.5-27. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of pipefishes in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-28. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of pipefishes in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-29. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal]) of pipefishes in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

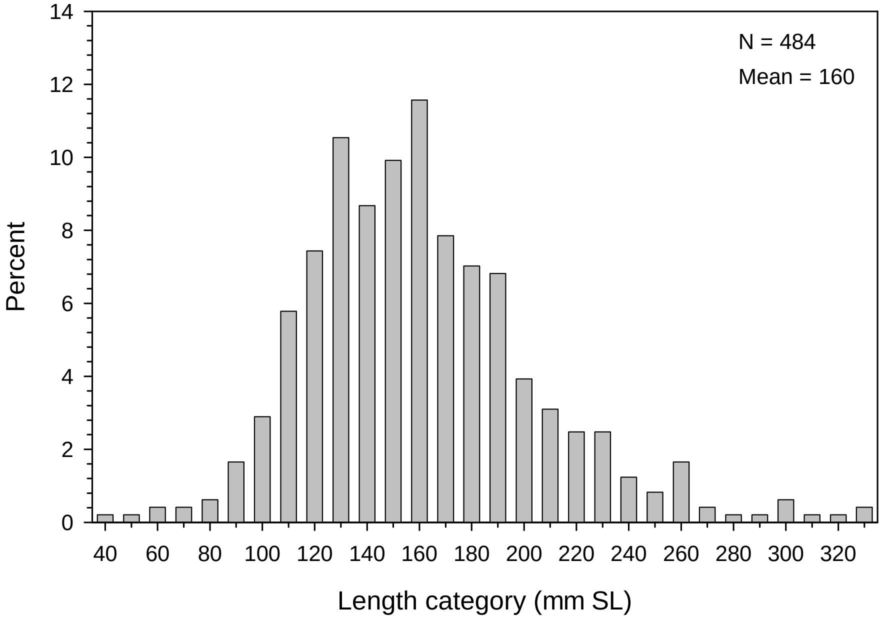


Figure 5.5-30. Length (mm) frequency distribution for pipefishes collected in impingement samples.

5.5.2.5 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.

5.5.2.5.1 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 (198 ft), and Allen (1982) reported most occur at about 70 m (154 ft). It has been reported to depths of 146 m (322 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 (1.3 to 3.1 inches) in length (Wilson and Millemann 1969; Hart 1973). Shiner perch live for about eight years and reach about 180 mm (7.1 inches) in length (Miller and Lea 1972; Hart 1973).

5.5.2.5.2 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 (Table 5.5-9). In 2005, "surfperch" landings in the Los Angeles area totaled 21 kg (47 lbs) at a value of $86 (CDFG 2006). Commercial landings of "surfperches" reported from catch blocks in the Long Beach area totaled 75 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. 2003). During 1978-79, a total of 6,672 shiner perch were impinged at HnGS, equivalent to about 20 shiner perch per day (IRC 1981). It was the most abundant species during the yearlong study, and abundance was highest in May and June. From 2001 through 2005, annual shiner perch impingement ranged from 0 to 0.4 shiner perch per survey, and averaged about 0.2 fish per survey (MBC 2006).

Table 5.5-9. Annual landings and revenue for surfperches in the Los Angeles region based on PacFIN data.

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

5.5.2.5.3 Sampling Results

Shiner perch was the fifth most abundant fish taxa impinged (based on actual cooling water flow volumes) with an estimated 582 individuals, or 1% of the annual total, weighing 12.03 kg (26.91 lbs) (Table 5.5-2). All individuals were impinged during normal operations. Highest normal operation impingement was recorded at Unit 1, which accounted for 26% of the total abundance, followed by Unit 6

(24%), Unit 8 (formerly Unit 4) (17%), Unit 5 (13%), Unit 2 (11%), and Unit 8 (formerly Unit 3) (9%). Impinged biomass was highest at Units 8 (formerly Unit 4) and 6, each with 26% of the total, followed by Unit 2 (15%), Unit 8 (formerly Unit 3) (13%), Unit 5 (12%), and Unit 1 (9%).

Shiner perch were absent from impingement collections from January through March, and there was a strong peak in impingement in early July (Figures 5.5-31 and 5.5-32), similar to the finding from 1978–79 (IRC 1981), when shiner perch was most abundant in June. During periods of highest abundance, impingement abundance and biomass were usually higher during nighttime (Figures 5.5-33 and 5.5-34).

Length frequency analysis of 69 measured individuals indicated a mean standard length of 95 mm (3.7 inches). Size distribution was bimodal, with peaks at the 60–120 mm (2.4–4.7 inches) size classes (Figure 5.5-35). Of the 70 individuals that were evaluated for condition factor, 96% were dead, 3% were mutilated and the remaining 1% was alive. Fifty-one percent of the individuals analyzed were females, 30% were males, and the remaining 19% were juveniles.

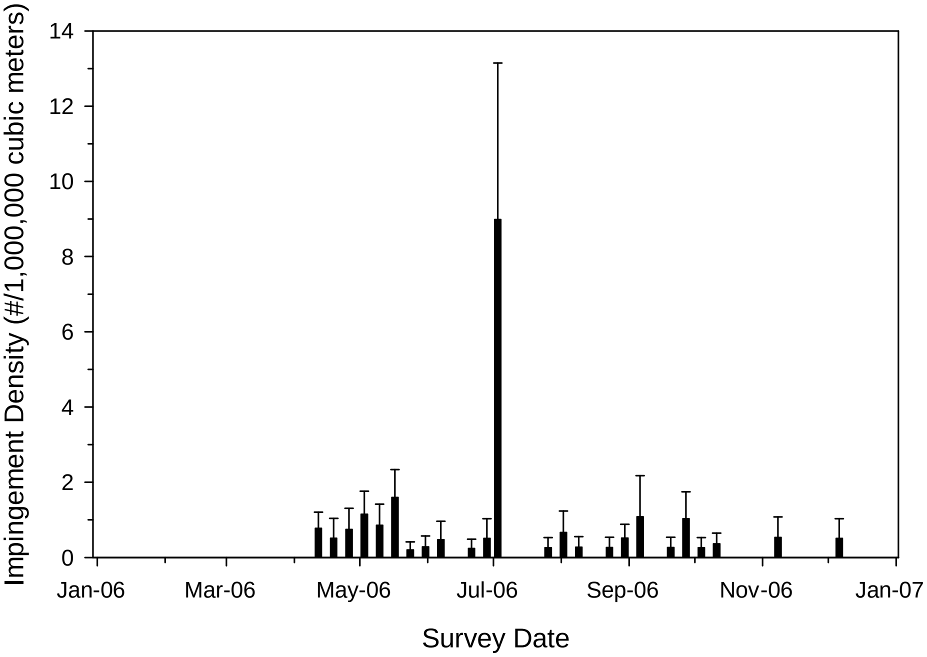


Figure 5.5-31. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of shiner perch in HnGS normal operation impingement samples during 2006.

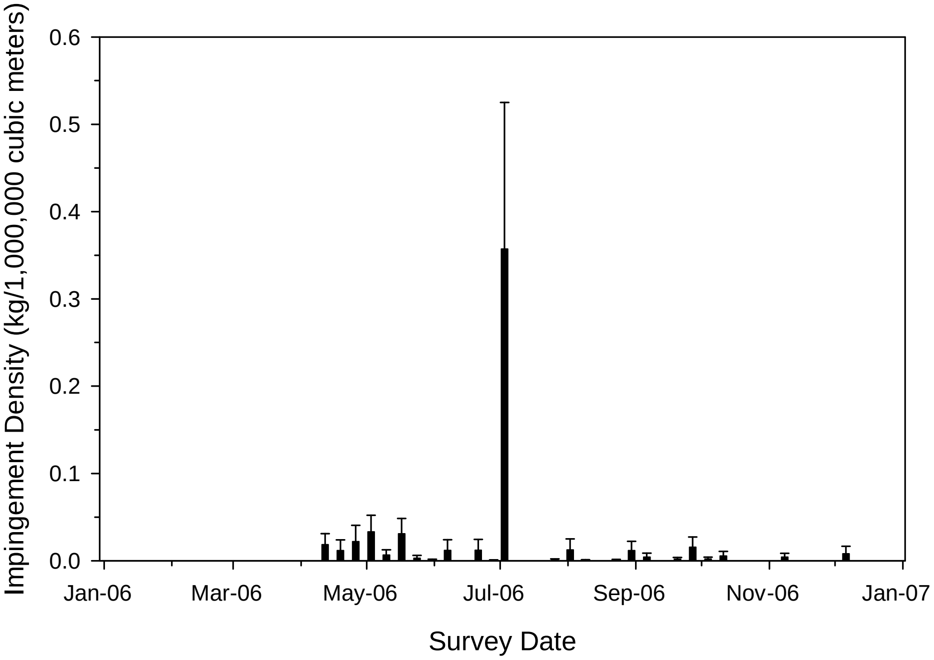
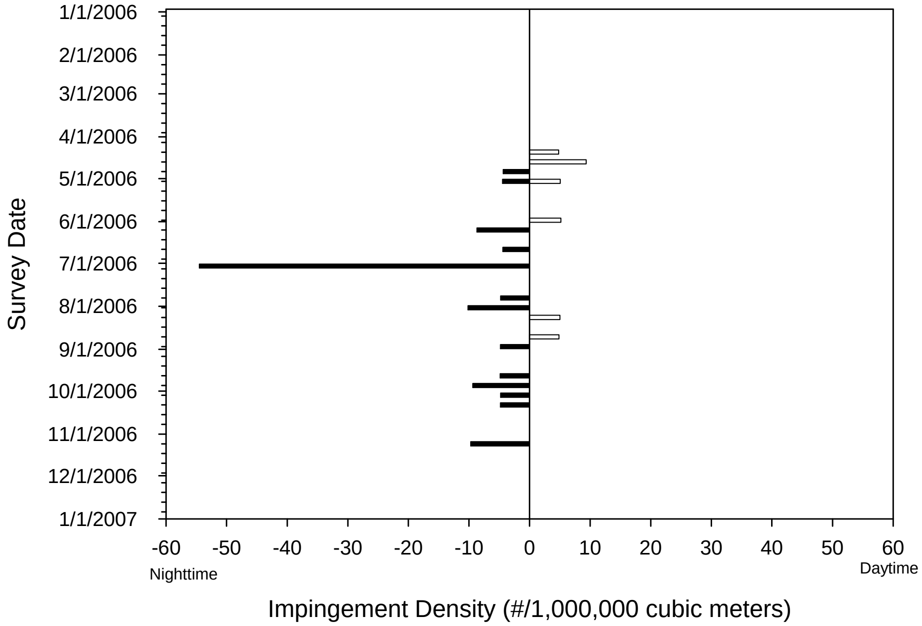
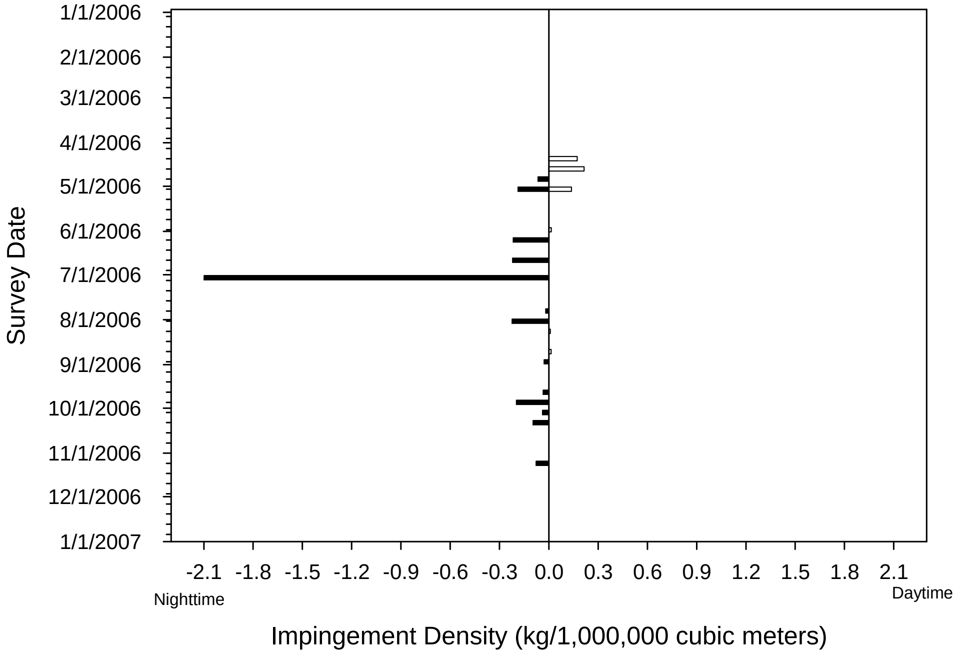


Figure 5.5-32. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of shiner perch in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-33. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of shiner perch in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-34. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of shiner perch in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

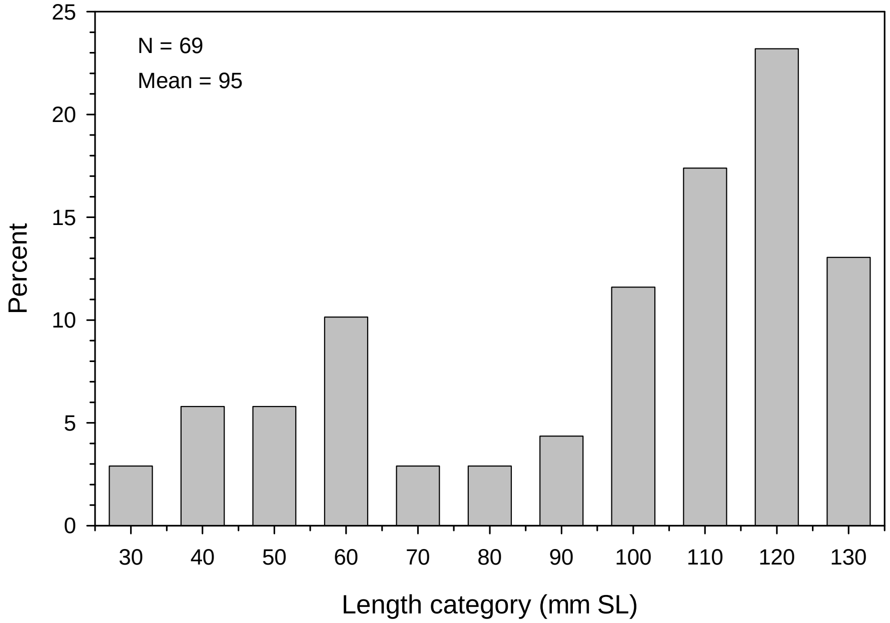
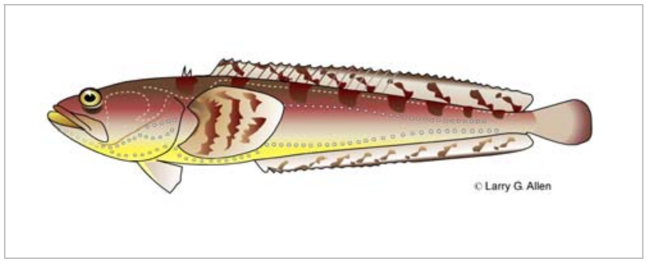


Figure 5.5-35. Length (mm) frequency distribution for shiner perch collected in normal operation impingement samples.

5.5.2.6 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*]). Specklefin midshipman is most commonly found in muddy and sandy areas ranging from Point Conception, California, to Magdalena Bay, Baja California (Hubbs et al. 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 dwellers of tropical and temperate waters (Bond 1996).

5.5.2.6.1 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 with depths reaching 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 midshipman's primary habitat is muddy and sandy bottoms; however, during April to June 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 inches) in length (Allen 1982). Males will grow much larger than females. There is no information on their maximum age, but a 457 mm (18 inches) male weighing about 0.9 kg (2 lbs) was eight years old (Fitch and Lavenberg 1975).

Midshipmen in general are non-selective carnivores and scavengers. Crustaceans, octopus, squid, and small fish make up the majority of their diet. Giant seabass, sea lions, and porpoises are some of the fauna that 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).

5.5.2.6.2 Population Trends and Fishery

There is currently no market for midshipmen. Anglers catch midshipmen incidentally while targeting other bottom species. No specklefin midshipman landings were reported in the commercial fishing databases queried (CDFG 2006, 2007). During 1978-79, a total of 126 specklefin midshipman was impinged at HnGS, equivalent to less than one individual per survey (IRC 1981). It was impinged throughout the year, with seasonal peaks in June and November-December. From 2001 through 2005, annual impingement of specklefin impingement ranged from 0 to 6 individuals per year (MBC 2006).

5.5.2.6.3 Sampling Results

Specklefin midshipman was the eighth most abundant species impinged (based on actual cooling water flow volumes) with an estimated 620 individuals, or 1.2% of the annual total, weighing 157.2 kg (346.7 lbs) (Table 5.5-2). All impingement was attributed to normal operation of the cooling water system, with no individuals recorded during marine growth controls. Normal operation impingement at Unit 6 contributed the greatest proportion of the annual total with 59% of all individuals, followed by Unit 1 (21%), Unit 5 (12%), Unit 2 (5%), Unit 8 (formerly Unit 3) (2%), and Unit 8 (formerly Unit 4) (1%). Impingement biomass was greatest at Unit 6, which contributed 71% to total annual biomass, followed by Unit 1 (12%), Unit 5 (11%), Units 8 (formerly Unit 3) and 8 (formerly Unit 4) (3% each), and Unit 2 (less than 1%).

Specklefin midshipman was impinged throughout the year with no definitive seasonality, although there were seasonal peaks in both spring (April and May) and fall (October and November) (Figure 5.5-36). Biomass exhibited a slightly different pattern with highest values recorded during April and June than during the remainder of the year (Figure 5.5-37). 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 was generally observed during daylight hours (Figures 5.5-38 and 5.5-39).

Length frequency analysis of 72 measured individuals indicated a mean standard length of 227 mm SL (8.9 inches) (Figure 5.5-40). There was a wide distribution of size classes, although there were peaks in two distinct size classes, 50 to 60 mm (2.0 to 2.4 inches) and 290 mm SL (11.4 inches), each constituting 10% or greater of the overall abundance. Of the 75 individuals that were evaluated for condition factor, 31% were alive, 64% dead and 5% mutilated.

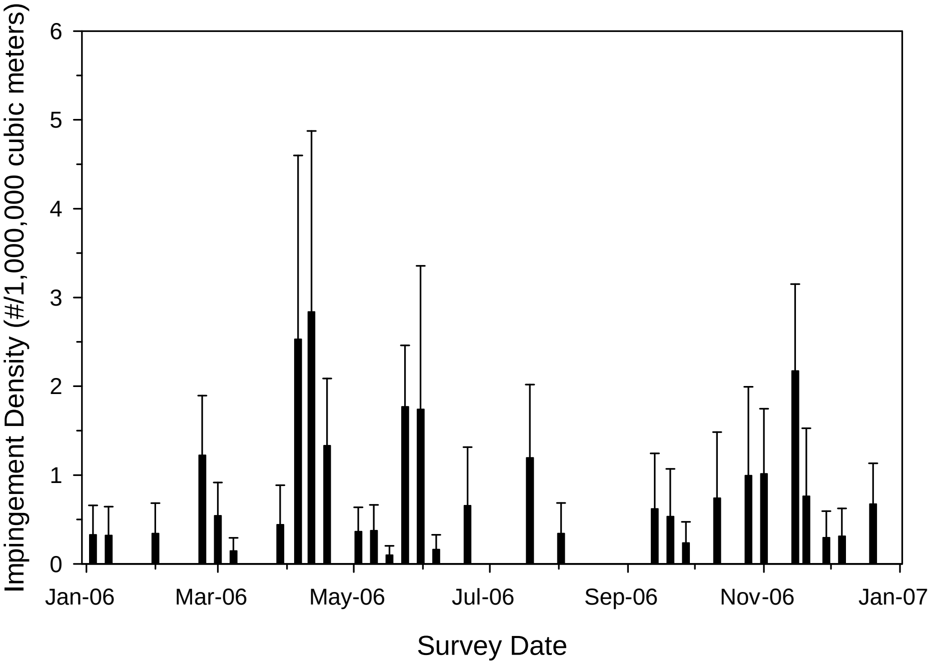


Figure 5.5-36. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of specklefin midshipman in HnGS normal operation impingement samples during 2006.

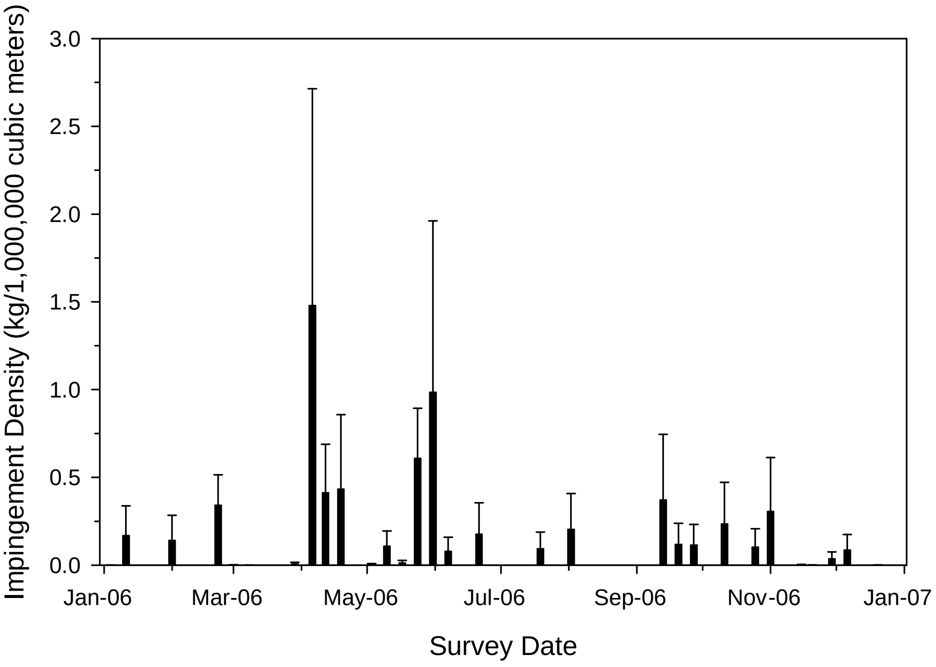
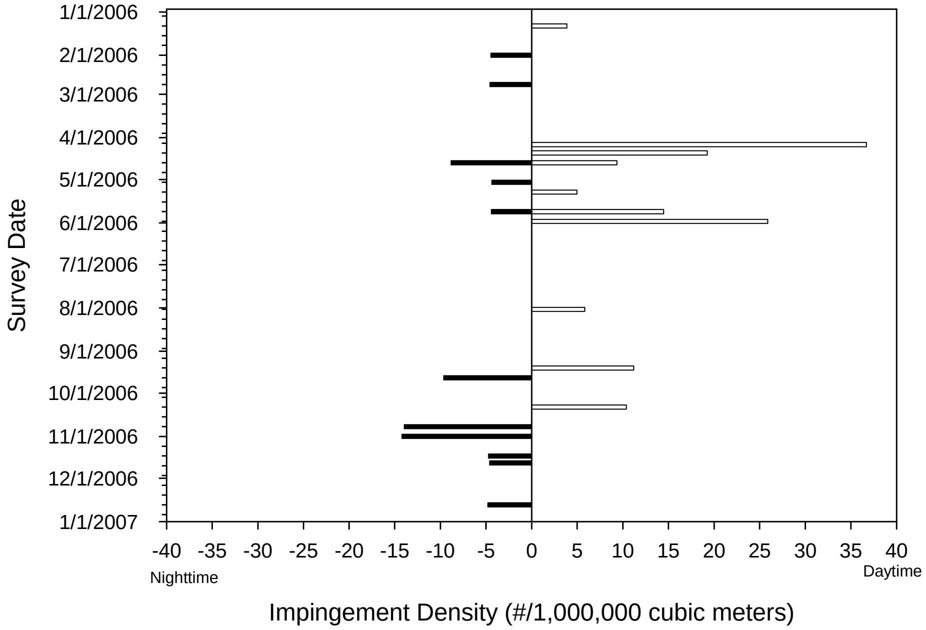
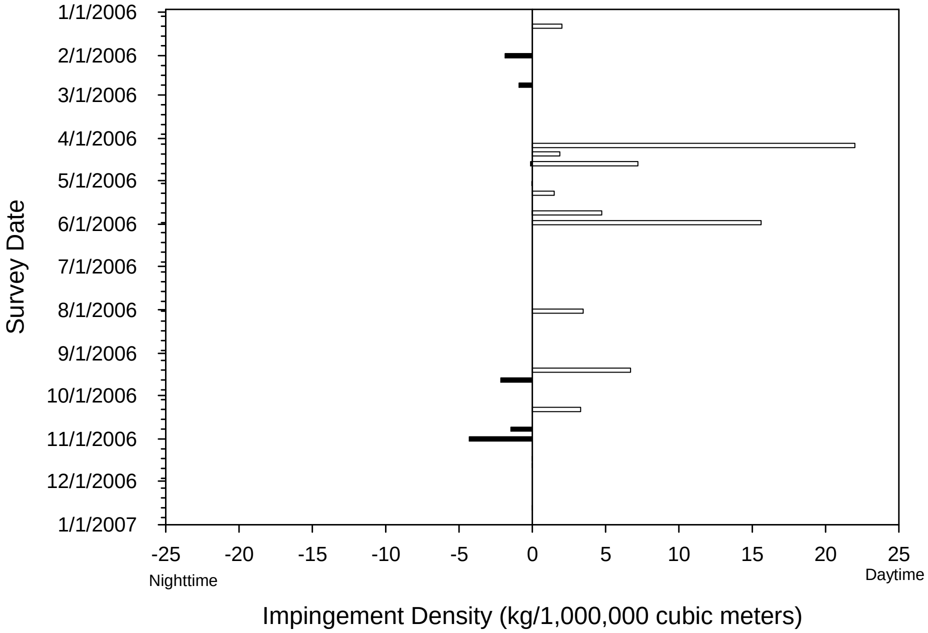


Figure 5.5-37. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of specklefin midshipman in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-38. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of specklefin midshipman in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-39. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of specklefin midshipman in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

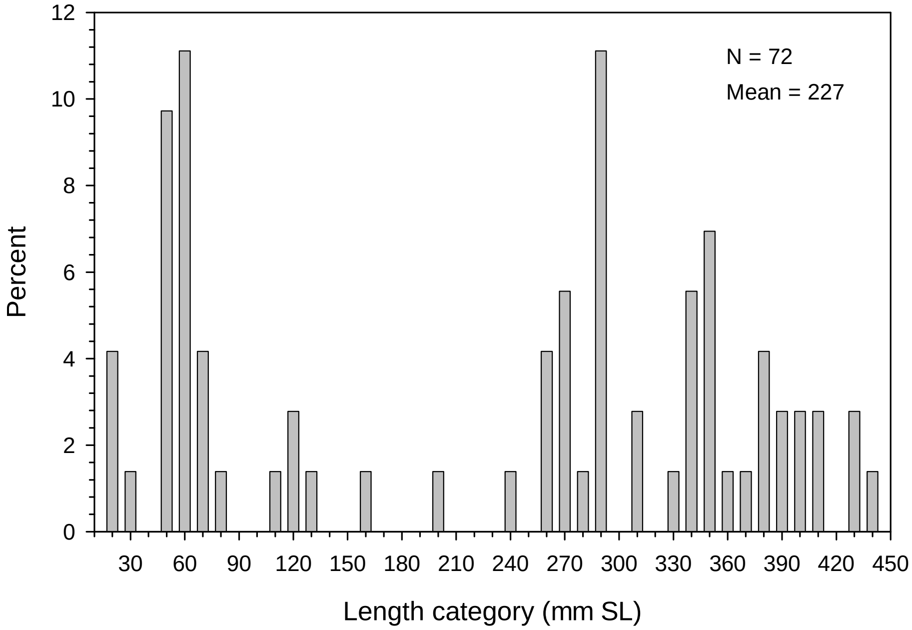
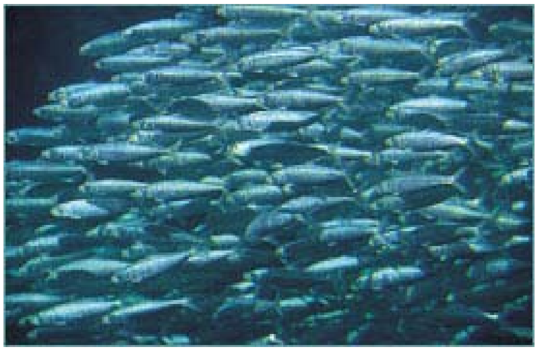


Figure 5.5-40. Length (mm) frequency distribution for specklefin midshipman collected in normal operation impingement samples.

5.5.2.7 Pacific sardine (*Sardinops sagax*)



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

5.5.2.7.1 Life History and Ecology

Pacific sardine is epipelagic, occurring in loosely aggregated schools (Wolf et al. 2001). Spawning occurs year-round in the upper 50 m (164 ft) of the water column, with seasonal peaks occurring from April to August between Point Conception, California and Magdalena Bay, Baja California. Adults are believed to spawn two to three times per season (Fitch and Lavenberg 1971). The primary spawning area for the principal northern subpopulation (ranging from northern Baja to Alaska) is between San Francisco and San Diego, California, and out to about 241 km (150 mi) off shore, though they are known to spawn as far off shore as 563 km (350 mi). Butler et al. (1993) estimated fecundity at 146,754 eggs to 2,156,600 eggs per two- and ten-year-old females, respectively, with longevity estimated at 13 years. Eggs and larvae occur near the sea surface, and eggs require about three days to hatch at 15°C (59°F).

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

5.5.2.7.2 Population Trends and Fishery

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

Sardine landed in the U.S. fishery are mostly frozen and sold overseas as bait and aquaculture feed, with smaller amounts canned or sold for human consumption and animal food (Hill et al. 2006). Commercial landings of Pacific sardine in 2006 in Long Beach area catch blocks totaled 14,106,375 kg (31,098,710 lbs) at a value of $1,629,681 (CDFG 2007). Los Angeles area landings (between Dana Point and Santa Monica) for 2005 totaled 24,143,616 kg (53,236,674 lbs) at a value of $2,344,817 (CDFG 2006). Los Angeles area landings based on the PacFIN database declined slightly after 2002, and annual landings since have ranged between 23,000,000 and 27,000,000 kg (50,715,000 and 59,535,000 lbs) (Table 5.5-10). Between 2000 and 2005, annual sardine impingement at the HnGS ranged between 24 individuals (2002) and 146,723 individuals (2004) (MBC 2006).

Table 5.5-10. Annual landings and revenue for Pacific sardine in the Los Angeles region based on PacFIN data.

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

During 1978-79, no Pacific sardine were impinged at HnGS (IRC 1981). It was the most abundant species during the yearlong study, and abundance was highest in May and June. From 2001 through 2005, only four sardines were impinged at the HnGS: one in 2002 and three in 2003 (MBC 2006).

5.5.2.7.3 Sampling Results

A total of 12 Pacific sardine were collected at the HnGS, resulting in an estimated annual impingement (calculated using actual cooling water flow volumes) of 90 Pacific sardine weighing 0.606 kg (1.336 lbs) (Table 5.5-2). Two individuals were impinged at Unit 6 (one on March 1, 2006 and one on September 13, 2006) and 10 individuals were impinged at Unit 5 on September 6, 2006. The three individuals measured ranged from 92 to 124 mm SL, with an average size of 104 mm SL, indicating they were all approximately one year old. All of the individuals assessed for condition factor were dead.

5.5.2.7.4 Modeling Results

Pacific sardine life history parameters are presented in Table 5.5-11. von Bertalanffy parameters were taken as reported by Hill et al. (2006). Annual survival estimates were calculated based on daily mortality rates (0.998901) summarized in Butler et al. (1993). Age at 50% maturity was -0.25208 based on the length at 50% maturity (125 mm SL) first published by Ahlstrom (1996 cited in Butler et al. 1996). Three Pacific sardines were measured with lengths recorded as 92, 95, and 125 mm SL. Adult equivalents taken during actual operation of the cooling water system totaled 69 individuals, all taken during normal operation surveys. Recalculation of these estimations based on design (maximum) flow of the cooling water pumps indicates 75 adult equivalent Pacific sardines would have been taken at continuous full flow operation for the year.

Table 5.5-11. Pacific sardine life history parameters used in equivalent adult modeling.

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

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

5.5.2.8 California Skate (*Raja inornata*)

The California skate (*Raja inornata*) belongs to the family Rajidae, the skates. This species is olive-brown on the dorsal side and tan on the ventral, occasionally with dark mottling and two dark eyespots (Eschmeyer and Herald 1983; Miller and Lea 1982). California skates range is between Vancouver, British Columbia to central Baja California, Mexico, up to depths of 671 m (2,200 ft); however these skates are commonly found inshore and in shallow bays of less than 18 m (60 ft). Adult skates are generally solitary and live on sea bottom. California skates grow to a total length of 76 cm (30 in) (Zorzi et al. 2001).

5.5.2.8.1 Life History and Ecology

Female California skates achieve sexual maturity at a total length of about 52 cm (21 in) and are oviparous, laying tough, permeable egg cases year-round after internal fertilization occurs (Ebert 2003; Zorzi et al. 2001). Little is known specifically regarding the California skate; however, typical elasmobranch reproductive strategies suggest late sexual maturity, small brood size, and low fecundity. The diet of the California skate is mainly composed of polychaete worms, shrimp, and other small benthic invertebrates.

5.5.2.8.2 Population Trend and Fishery

Commercial fishery for skates was historically minor but increased in the second half of the 1990s (Zorzi et al. 2001). California skates became an important commercial species in California, primarily caught as bycatch of other fisheries (Eschmeyer and Herald 1983; Ebert 2003). However in 1999, due to concerns of overfishing, the National Marine Fisheries Service implemented a Nearshore Fishery Management Plan to prevent depletion of commercially and recreationally important fish populations, including the California skate (NOAA 2006). During 1978-79, no California skates were impinged at HnGS (IRC 1981). From 2001 through 2005, no California skates were impinged at the HnGS (MBC 2006).

5.5.2.8.3 Sampling Results

One California skate was collected at the HnGS, resulting in an estimated annual impingement (calculated using actual cooling water flow volumes) of eight individuals weighing 1.111 kg (2.450 lbs) (Table 5.5-2). The individual was collected at Unit 5 on December 6, 2006. The individual measured was 175 mm TL, and was alive upon collection.

5.5.2.9 Jack Mackerel (*Trachurus symmetricus*)

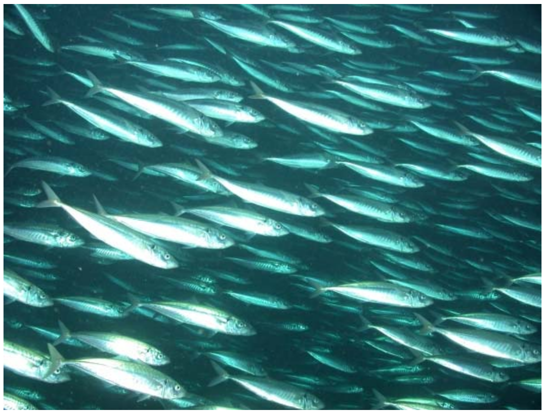


Photo Courtesy of NOAA

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

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

5.5.2.9.1 Life History and Ecology

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

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

5.5.2.9.2 Population Trends and Fishery

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

Awareness of overfishing, beginning with the collapse of the sardine and anchovy fishery, prompted the implementation of national programs to avoid future collapses (Mason and Bishop 2001). Jack mackerel were first categorized in the Pacific Coast Groundfish Fishery Management Plan in 1982 due to incidental landings of jack mackerel with Pacific whiting (hake) trawls, a species categorized as “groundfish”; yet fishery total catches were only restrained north of the 39° latitude. Concern for the jack mackerel population rose and pressure from southern California fishermen resulted in the inclusion of jack mackerel to the Coastal Pelagic Species Fisheries Management Plan (CPS FMP) in 1999. Currently, jack mackerel is a “monitored” species in the CPS FMP, meaning that stocks are monitored but federal fishery controls are not implemented (PFMC 2006). From the early 1990s on, jack mackerel landings have occurred from December to April at an average of 2% of CPS landings, less than 1,814,370 kg (4 million lbs) per year.

Jack mackerel from the U.S. Fishery are generally canned; however, fresh jack mackerel are occasionally found in markets (Love 1996). The recreational fishery for jack mackerel is small when compared to the commercial fishery. Most of the landings derive from commercial passenger fishing vessel, with additional catches from anglers on fishing piers (Mason and Bishop 2001). This fishery remains a small contributor to the total catch of jack mackerel and high variability in the number of catches since 1980, numbering from 5,000 to over 350,000 fish. Landings reported in the Los Angeles region in the PacFIN (2007) database have fluctuated between about 100,000 and 3.6 million kg (220,000 and 7.9 million lbs) annually (Table 5.5-12). Commercial landings of jack mackerel in 2005 in southern California totaled 115,719 kg (255,117 lbs) at a value of $16,367 (CDFG 2006). Landings from Long Beach catch blocks in 2006 totaled 106,092.5 kg (233,890 lbs) at a value of $11,443 (CDFG 2007). During 1978-79, two jack mackerel were impinged at HnGS (IRC 1981). From 2001 through 2005, no jack mackerel were impinged at the HnGS (MBC 2006).

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

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

5.5.2.9.3 Sampling Results

One jack mackerel was collected at the HnGS, resulting in an estimated annual impingement (calculated using actual cooling water flow volumes) of seven individuals weighing 0.477 kg (1.052 lbs) (Table 5.5-2). The individual was collected at Unit 5 on April 26, 2006. The single individual collected was mutilated.

5.5.2.10 Vermilion rockfish (*Sebastes miniatus*)

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

5.5.2.10.1 Life History and Ecology

Vermilion rockfish inhabit depths from the subtidal zone to 436 m (1,440 ft). Most adults are found between 50 m to 100 m (165-495 ft), while juveniles tend to be more subtidal (Miller and Lea 1982; Love 1996; Love et al. 2002). Adult vermilion rockfish generally aggregate in high relief areas, and can occasionally be found along the bottom of oil platforms or live solitarily in shallow-water caves (Love et al. 2002). Juvenile rockfish, however, are solitary and tend to inhabit sand patches between structures or near rocky substrata (Love et al. 2002). The largest length recorded for vermilion rockfish is 76 cm (30 in) (Eschmeyer and Herald 1983; Love et al. 2002).

Vermilion rockfish differ in size and age at maturity (Love et al. 2002). Some females have been recoded as mature at the length of 31 cm (12 in) at four years. However, all females are mature by 47 cm (19 in) and nine years. Recorded fecundity shows a range of 63,000 eggs in a female of 32 cm (12.5 in) to 2,600,000 eggs in a female of 55 cm (21.5 in) (VenTresca 2001). Vermilion rockfish have been recorded displaying courtship behavior, wherein females undergo internal fertilization. Release of larvae with lengths of about 4.3 mm (0.2 in) occurs from July to March in southern California. When released, larvae are generally found in pelagic waters and settle in May near protective structures in shallower waters until they progressively move to deeper depths (VenTresca 2001; Love et al. 2002). Vermilion rockfish prey primarily on fish and benthic organisms including northern anchovies, lanternfish, squid, crabs, and octopi, but have been recorded feeding on salps, shrimp, copepods, and polychaetes.

5.5.2.10.2 Population Trends and Fishery

Historically, the commercial and recreational fishery has viewed vermilion rockfish as a highly prized market species. However due to its inclusion of a general market category of “rockfish, Group Red”, historical data on catch abundances are unreliable previous to 1994, when “Rockfish, vermilion” became a printed market category (VenTresca 2001). During the late 1990s, annual landings of vermilion rockfish declined when the NMFS implemented a Nearshore Fishery Management Plan in 1999 in an attempt to rebuild the nearshore fish population. As of 2004, recreational fishery landings (167,000 kg [368,172 lbs]) remained higher than commercial landings (5,000 kg [11,024 lbs]) (MacCall 2005). The current recreational fishery often takes vermilion rockfish by hook-and-line anglers along California and is composed mostly of juvenile fishes (VenTresca 2001; Love et al. 2002). Vermilion rockfish is covered under the Pacific Groundfish FMP.

Commercial landings in the Los Angeles area were only recorded in 2000 in the PacFIN database (Table 5.5-13). In 2005, vermilion rockfish landings in the Los Angeles area totaled 1,671.6 kg (3,686 lbs) at a value of $3,686 (CDFG 2006). There were no commercial landings of vermilion rockfish reported from catch blocks in the Long Beach area, but landings in the Santa Monica Bay area catch blocks totaled 191.2 kg (422 lbs) in 2006, at an estimated value of $913 (CDFG 2007). During 1978-79, no vermilion rockfish were impinged at HnGS (IRC 1981). From 2001 through 2005, no vermilion rockfish were impinged at the HnGS (MBC 2006).

5.5.2.10.3 Sampling Results

One vermilion rockfish was collected at the HnGS, resulting in an estimated annual impingement (calculated using actual cooling water flow volumes) of seven individuals weighing 0.014 kg (0.031 lbs) (Table 5.5-2). The individual was collected at Unit 6 on March 29, 2006. The single individual collected was dead upon collection, and was in the 40-mm size class.

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

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

5.5.3 Shellfish Impingement by Species

Three shellfish taxa were impinged in sufficient numbers, and considered commercially/recreationally important, to warrant further analysis. These taxa were: California two-spot octopus (1.7% of total sampled abundance), California sea hare (1.0%), and market squid (0.4%). Combined, these taxa comprised 3% of the macroinvertebrates in impingement samples, and 50% of the biomass.

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


Photo: J. Forsythe

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

5.5.3.1.1 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 (0.573 lbs). After hatching, young octopuses are planktonic for several months, then settle to the bottom (Lang and Hochberg 1997). Juvenile *O. bimaculatus* feed on small crustaceans, while adults consume a wide variety of motile benthic invertebrates.

5.5.3.1.2 Population Trends and Fishery

Most California landings of octopus result from incidental catches in other fisheries (Lang and Hochberg 1997). In 2005, commercial landings of octopus in the Los Angeles area totaled 183 kg (403 lbs) at a value of $558 (CDFG 2006). Commercial landings from Long Beach area catch blocks in 2006 totaled 18 kg (39 lbs) at an estimated value of $105. From 2001 through 2005, annual impingement of octopus ranged from 0 to 1.3 individuals per survey, and averaged about 0.6 individuals per survey (MBC 2006).

5.5.3.1.3 Sampling Results

A total of 46 California two-spot octopus was collected in impingement samples, with an estimated annual impingement of 337 individuals weighing 54.8 kg (120.8 lbs) (Table 5.5-2). Forty-four of the 46 individuals were collected during normal operations, with the other two collected during the marine growth control procedure at Unit 2 on November 14, 2006. Highest normal operation impingement abundance was recorded at Unit 1, which accounted for 56% of the total abundance, followed by Unit 6 (30%), Unit 5 (8%), Unit 8 (formerly Unit 3) (4%) and Unit 2 (2%). No California two-spot octopus were impinged at the Unit 8 (formerly Unit 4) traveling screens. Biomass was highest at Unit 6 with 60% of the total, followed by Unit 1 (22%), Unit 5 (12%), Unit 8 (formerly Unit 3) (7%), and Unit 2 (less than 1%).

California two-spot octopus was prevalent during the latter part of 2006, with peak impingement density recorded from July through early-September (Figure 5.5-41). Biomass followed a pattern similar to abundance, although the peak biomass occurred later in the year (in November and December) (Figure 5.5-42). There was no clear diel pattern of impingement with respect to abundance or biomass, which is likely a result of the low abundance of this species (Figures 5.5-43 and 5.5-44).

Length frequency analysis of 20 measured individuals indicated a mean arm spread (AS) of 370 mm (14.6 inches) (Figure 5.5-45). Of the 31 individuals that were evaluated for condition factor, 6% were alive, 58% were dead and the remaining 36% were mutilated.

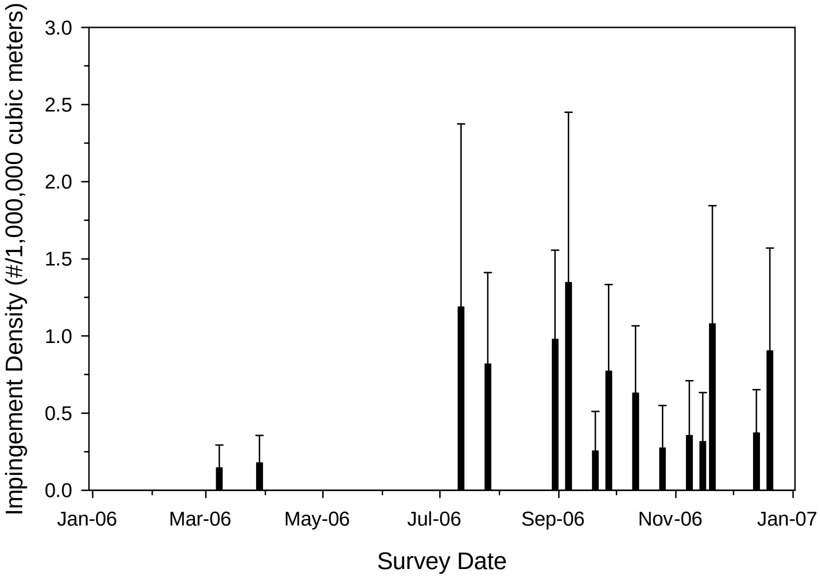


Figure 5.5-41. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of California two-spot octopus in HnGS normal operation impingement samples during 2006.

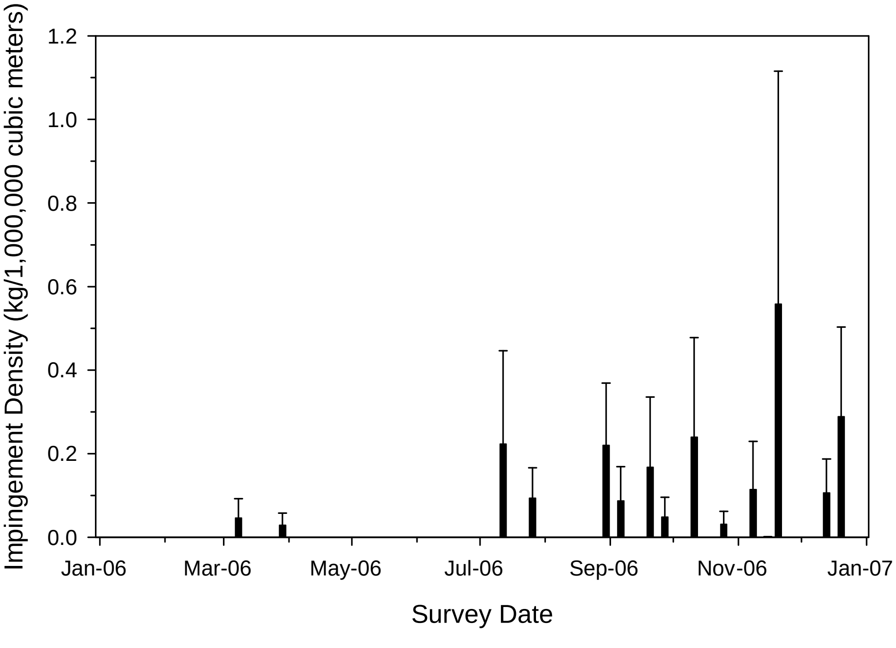
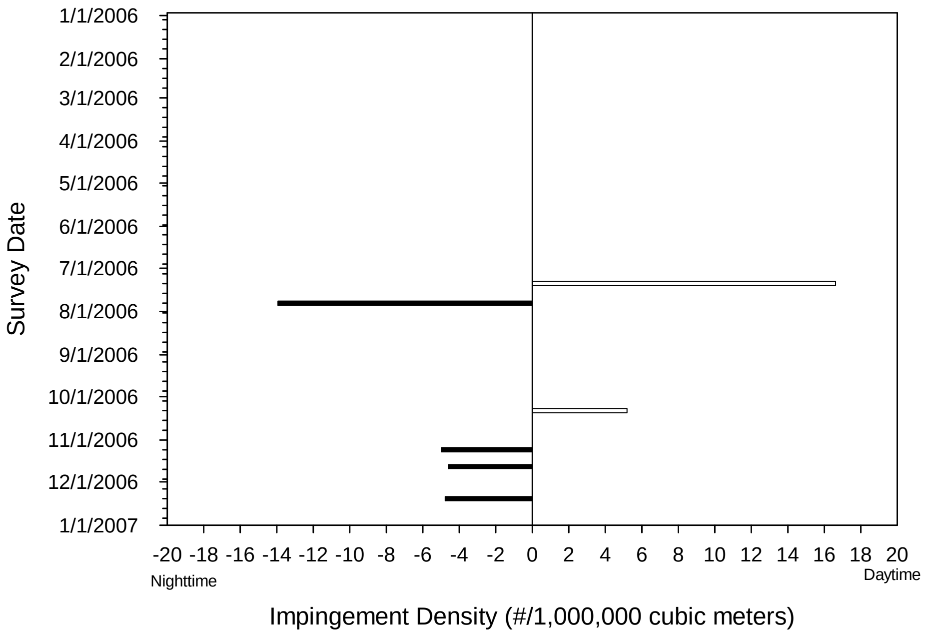
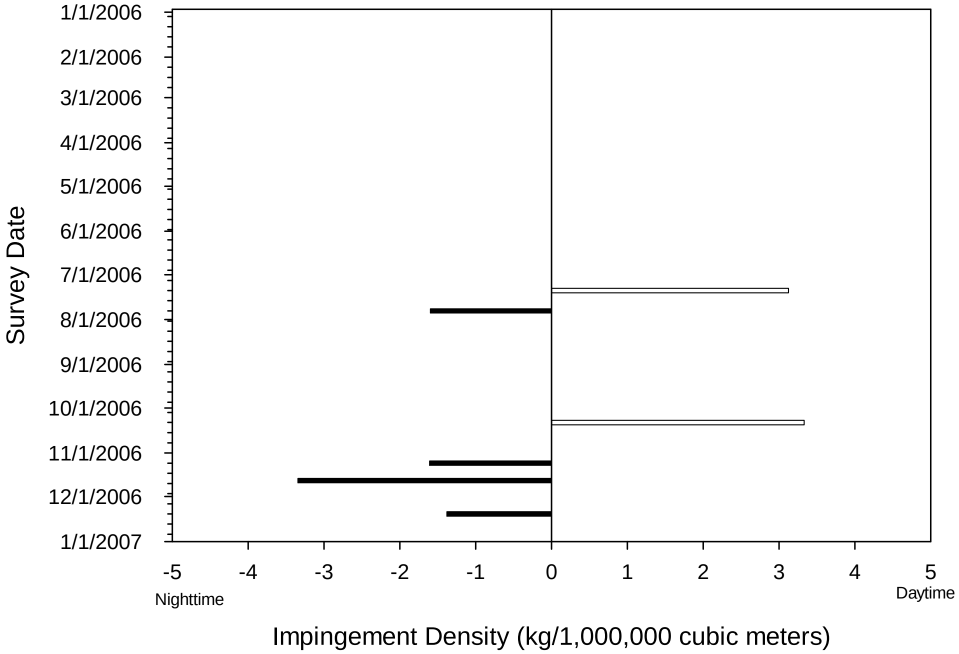


Figure 5.5-42. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of California two-spot octopus in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-43. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of California two-spot octopus in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-44. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of California two-spot octopus in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

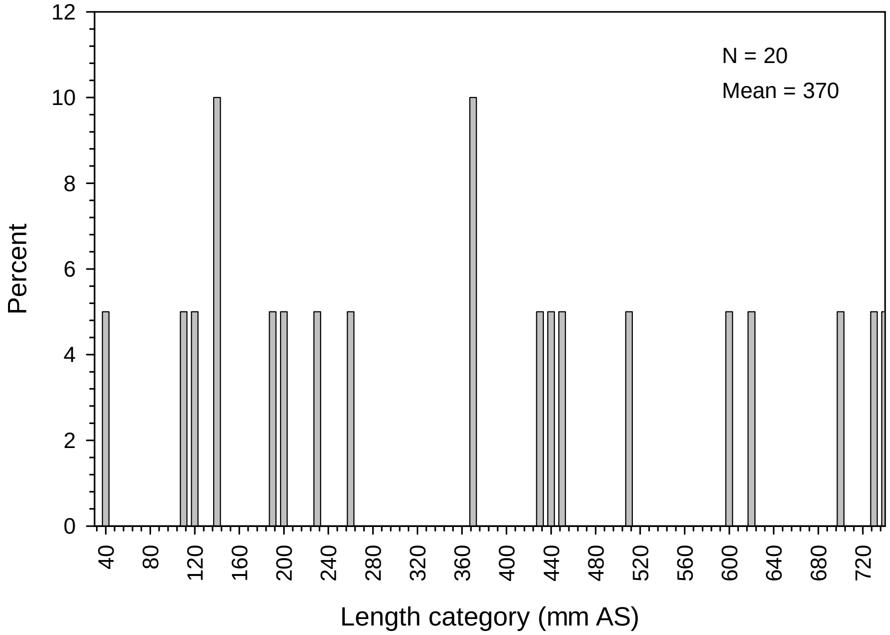


Figure 5.5-45. Length (mm) frequency distribution for California two-spot octopus collected in impingement samples.

5.5.3.2 California seahare (*Aplysia californica*)

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

5.5.3.2.1 Life History and Ecology

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

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

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

5.5.3.2.2 Population Trends and Fishery

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

As a result, researchers provide a steady market for California seahares, supporting both seahare mariculture and a wild-caught sea hare fishery (Silverstein and Campbell 1989; CDFG 2007). In 2005, Los Angeles area landing of seahares totaled 4,783 kg (10,547 lbs) at an estimated value of $35,352 (CDFG 2006). Commercial landings of seahares in 2006 in Long Beach area catch blocks totaled 1,947 kg (4,293 lbs) at a value of $33,523 (CDFG 2007). From 2001 through 2005, annual seahare impingement ranged from 0 to 0.3 individuals per survey, and averaged about 0.1 individuals per survey (MBC 2006).

5.5.3.2.3 Sampling Results

A total of 28 California seahares was collected in impingement samples, with an estimated annual impingement of 195 individuals weighing 79.4 kg (175.1 lbs) (Table 5.5-2). All of the individuals were collected during normal operations. Highest normal operation impingement abundance was recorded at Unit 5, which accounted for 29% of the total abundance, followed by Unit 1 (24%), Unit 2 (21%), Unit 3 (15%) and Unit 6 (11%). California seahare was not impinged at the Unit 8 (formerly Unit 4) traveling screens. Biomass was highest at Unit 5 with 42% of the total, followed by Unit 2 (24%), Unit 1 (21%), Unit 6 (9%), and Unit 8 (formerly Unit 3) (4%).

California seahare was most abundant during summer months, with peak impingement density recorded from June through August (Figure 5.5-46). Biomass followed a pattern similar to abundance (Figure 5.5-47). Seahares were more frequently impinged during daytime than during nighttime, although the analysis was based on relatively few individuals (Figures 5.5-48 and 5.5-49).

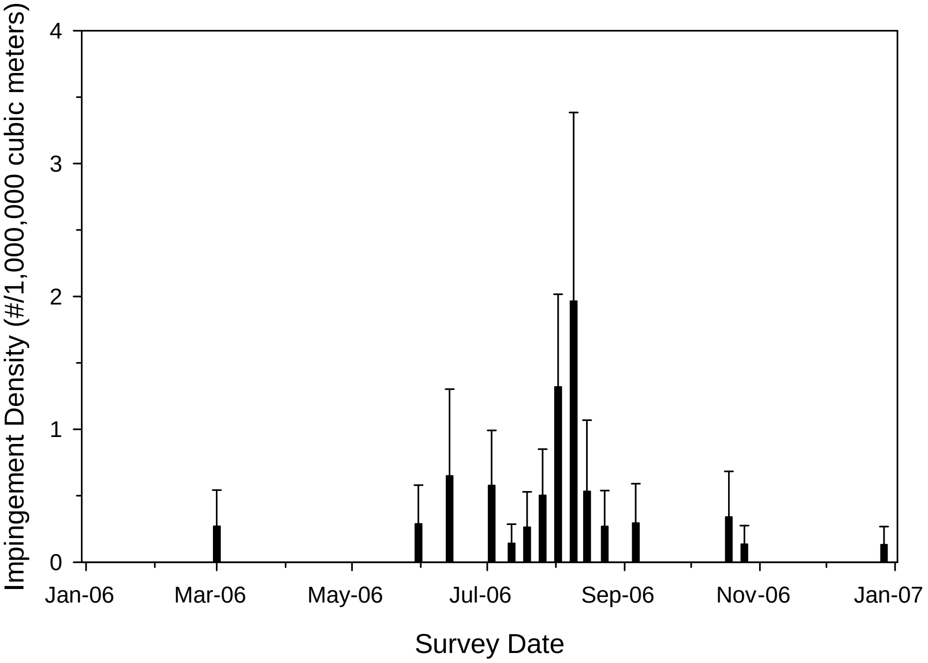


Figure 5.5-46. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of California seahare in HnGS normal operation impingement samples during 2006.

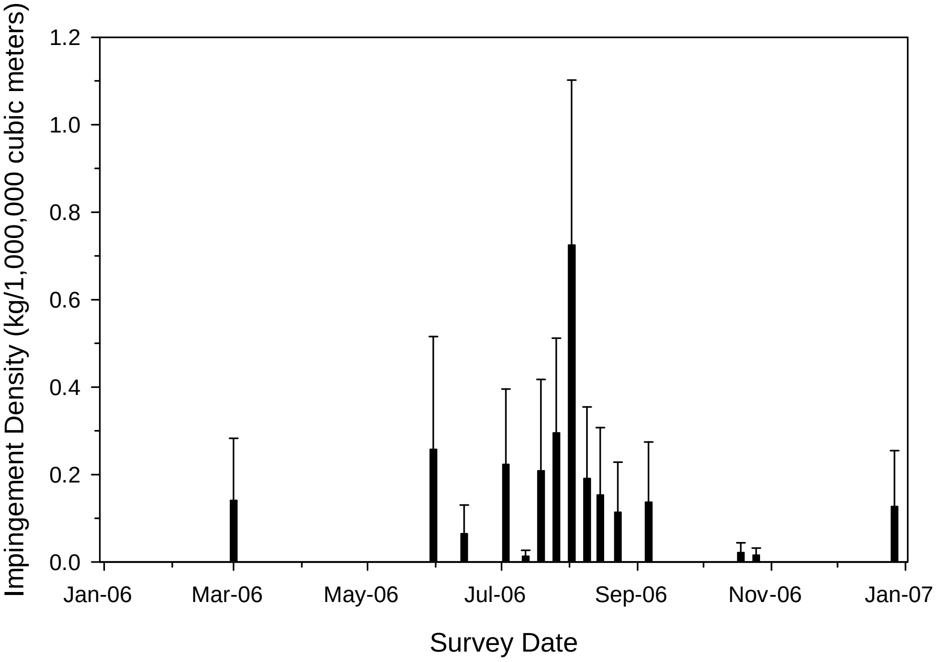
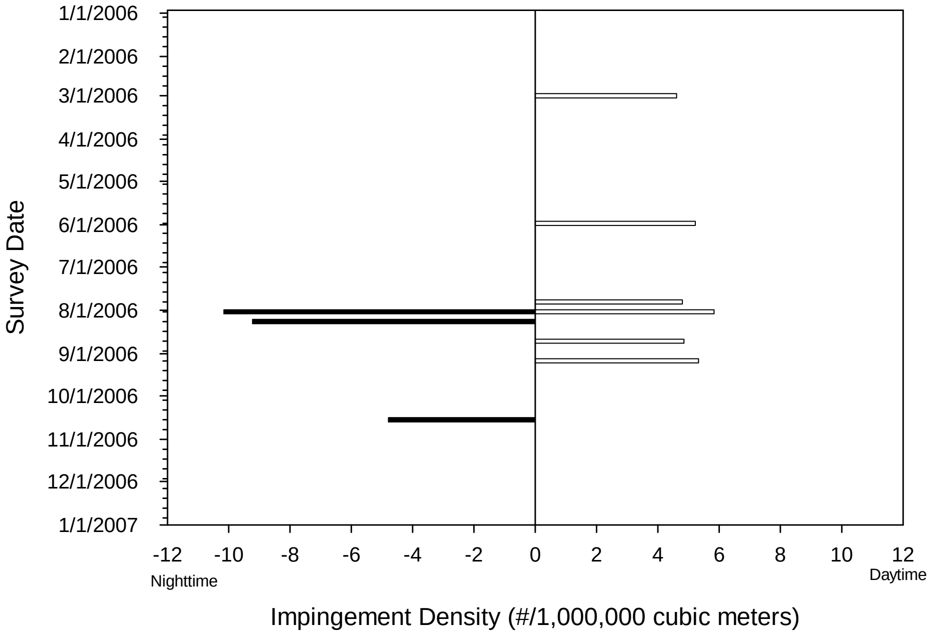
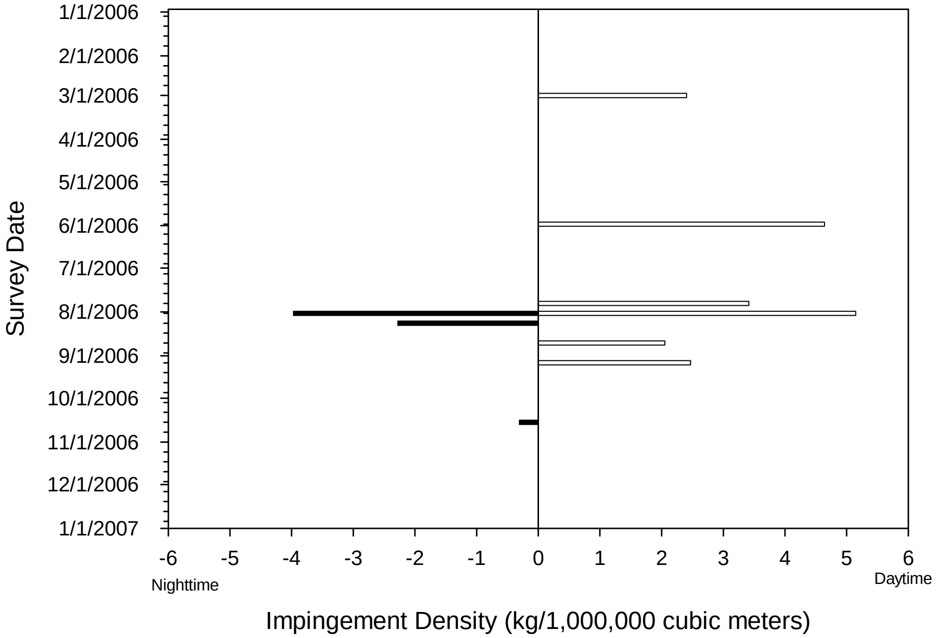


Figure 5.5-47. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of California seahare in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-48. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of California seahare in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-49. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal]) of California seahare in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

5.5.3.3 Market squid (*Loligo opalescens*)


Photo: Dan Dugan

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

5.5.3.3.1 Life History and Ecology

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

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

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

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

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

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

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

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

5.5.3.3.2 Population Trends and Fishery

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

The California fishery for market squid began in Monterey Bay in the late-1800s (Vojkovich 1998). It expanded into southern California only after the 1950s, and prior to 1987, catches in southern California rarely exceeded 20,000,000 kg (44,100,000 lbs). After that, landings increased four-fold until the fishery collapsed in 1998, and California squid fishers sought federal disaster assistance (Zeidberg et al. 2004). In California, most squid marketed for human consumption is frozen, but smaller amounts are canned or sold fresh (PFMC 1998). Squid are also sold live and frozen for bait. Los Angeles area commercial landings have varied substantially since 2000, ranging between 7.7 and 44.8 million kg (16.9 and 98.8 million pounds) annually (PacFIN 2007), with both the total catch and market value increasing substantially the last four years (Table 5.5-14). Los Angeles area landings in 2005 totaled 31,59,678 kg (69,573,734 lbs) at an estimated value of $18,511,585 (CDFG 2006). Landings in Long Beach area catch blocks in 2006 totaled 4,896,450 kg (10,794,643 lbs) at an estimated value of $2,647,959 (CDFG 2007). From 2001 through 2005, annual impingement of market squid ranged from 0 to 0.1 individuals per survey, and averaged less than 0.1 squid fish per survey (MBC 2006).

Table 5.5-14. Annual landings and revenue for market squid in the Los Angeles region based on PacFIN data.

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

5.5.3.3.3 Sampling Results

A total of 11 market squid was collected in impingement samples, with an estimated annual impingement of 78 individuals weighing 1.4 kg (3.0 lbs) (Table 5.5-2). All of the individuals were collected during normal operations. Almost all of the normal operation impingement occurred at Unit 6 (91% of annual abundance), with the other 8% recorded at Unit 1. Biomass was highest at Unit 6 with 98% of the total, with the other 2% recorded at Unit 1.

Impingement of squid occurred between March and June 2006, with peak impingement density recorded in mid-March and early-April (Figure 5.5-50). Biomass followed a pattern similar to abundance (Figure 5.5-51). There was no clear diel pattern of impingement with respect to abundance or biomass, which is likely a result of the low abundance of market squid (Figures 5.5-52 and 5.5-53).

Length frequency analysis of 11 measured individuals indicated a mean mantle length (ML) of 104 mm (4.1 inches), which roughly corresponds to squid five to six months old (Figure 5.5-54). Of the 11 individuals that were evaluated for condition factor, 91% were dead and the remaining 9% were mutilated; no squid were alive when they were processed.

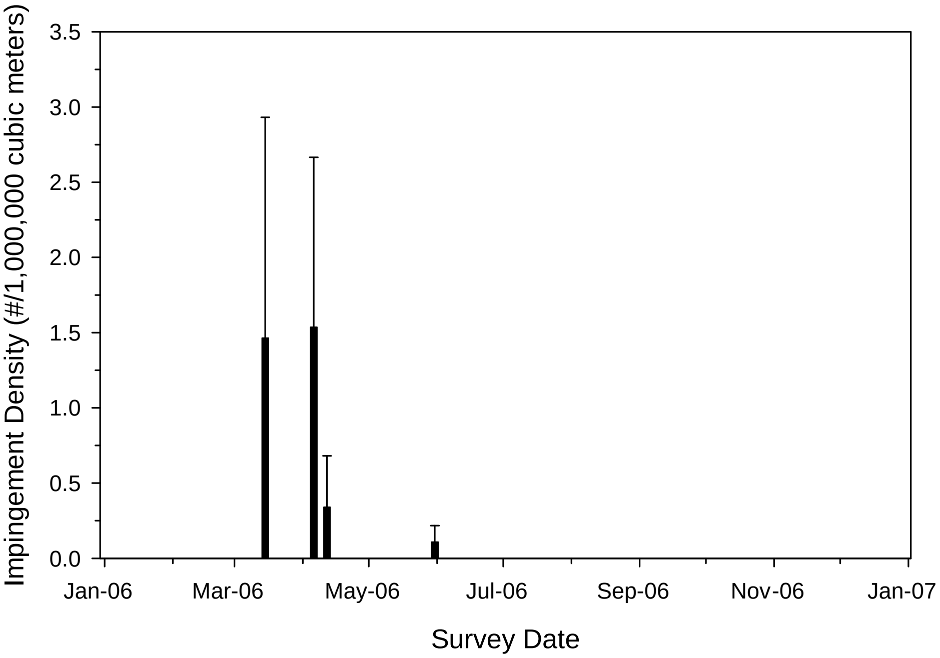


Figure 5.5-50. Mean concentration (# / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of market squid in HnGS normal operation impingement samples during 2006.

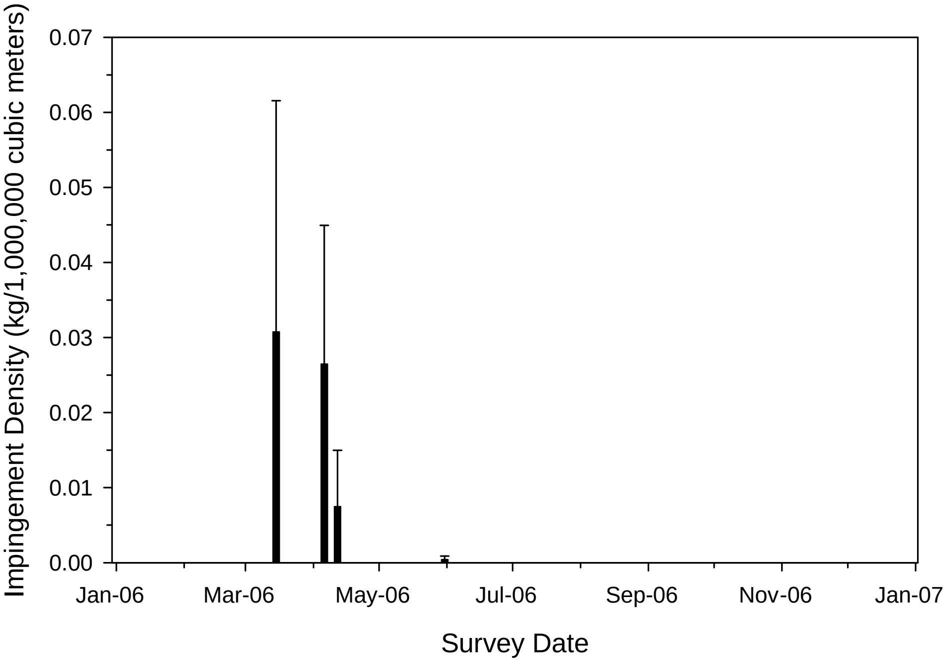
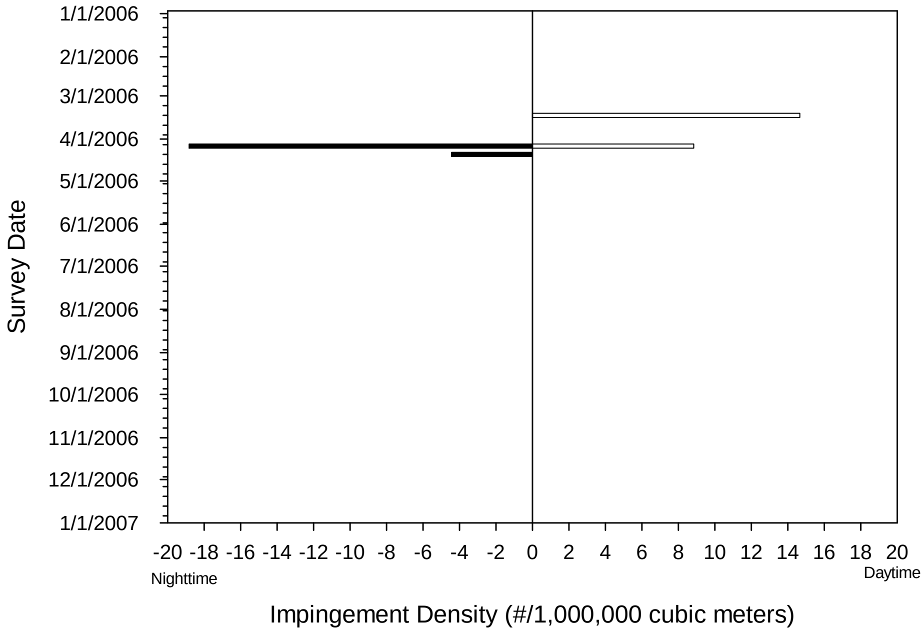
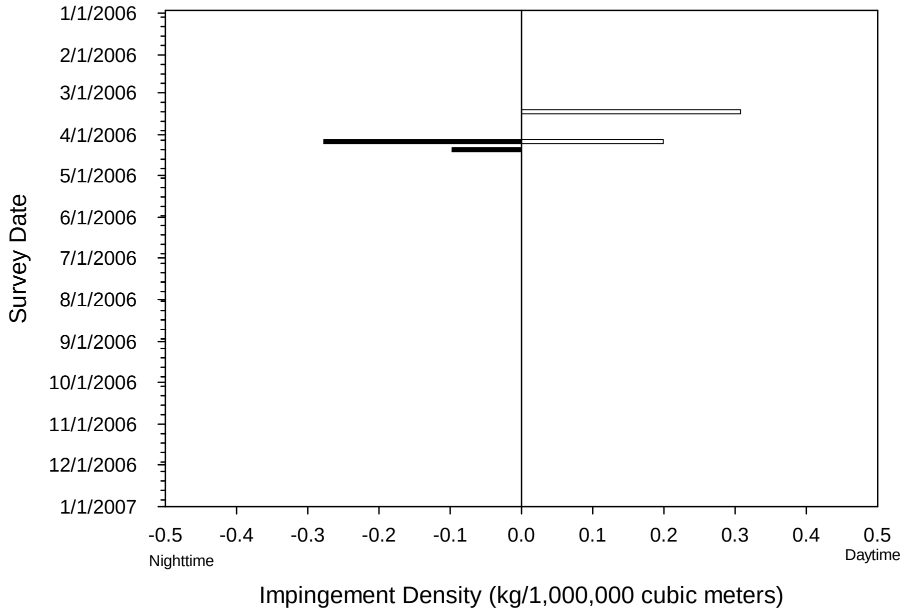


Figure 5.5-51. Mean biomass (kg / 1,000,000 m^3 [264.172 million gal] – wide bars) and standard error (narrow bars) of market squid in HnGS normal operation impingement samples during 2006.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-52. Mean concentration (# / 1,000,000 m^3 [264.172 million gal]) of market squid in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.



Note: Negative nighttime values are a plotting artifact

Figure 5.5-53. Mean concentration (kg / 1,000,000 m^3 [264.172 million gal]) of market squid in normal operation impingement samples during night (Cycle 3) and day (Cycle 1) sampling.

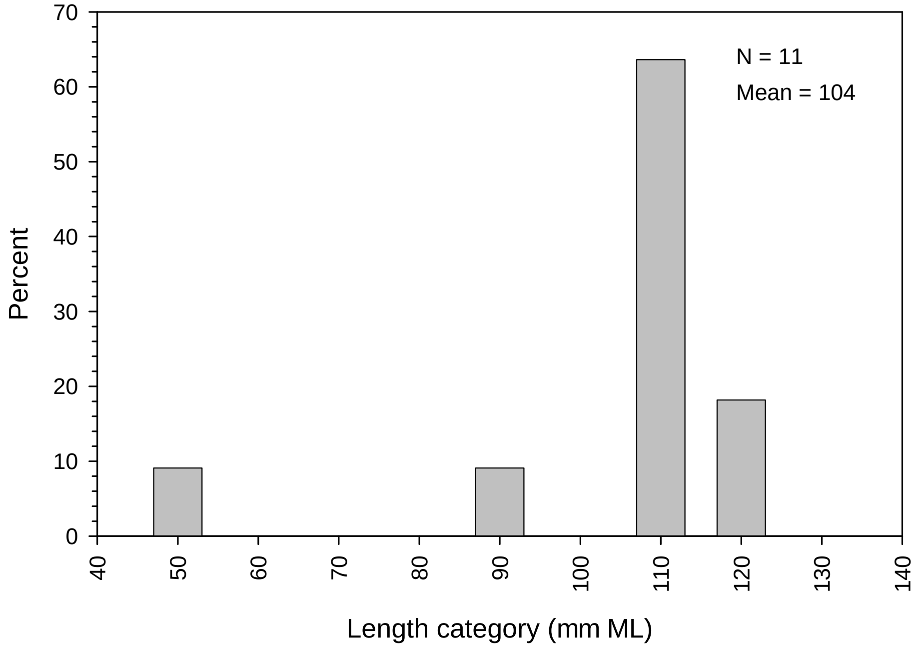


Figure 5.5-54. Frequency distribution of mantle length measurements (mm) for market squid collected in impingement samples.

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 60–90% and impingement mortality by 80–95%. However, the Phase II regulations were suspended by EPA in 2007. On May 20, 2007, EPA transmitted a memorandum to regional administrators informing them that the Phase II rule should be considered suspended, and that "*…all permits for Phase II facilities should include conditions under Section 316(b) of the Clean Water Act developed on a Best Professional Judgment basis. See 40 CFR 401.14.*" As written, the Clean Water Act does not specify required cooling water intake system (CWIS) technologies or methods by which EPA must make its determinations under Section 316(b).

Prior to the publication of the Phase II regulations in 2004, regulators relied on EPA's (1977) draft guidelines for evaluating adverse impacts of cooling water intake structures to determine compliance with Section 316(b). At the HnGS, 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 taxa analyzed.

Under the previous 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 HnGS on the standing crop and natural mortality rates of the taxa analyzed. The ultimate conclusion of the HnGS 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 HnGS, and the configuration of the intakes represented BTA for minimizing AEI. The intake technology evaluation in the previous report also included an assessment on the effects of switching to alternative intake technologies based on the levels of potential impact.

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

In its 1977 draft guidance document, EPA 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.*" USEPA also clarified in the guidance document: "*Regulatory agencies should clearly recognize that some level of intake damage can be acceptable if that damage represents a minimization of environmental impact.*"

In the 2006 IM&E study, entrainment and impingement losses were measured by collecting samples at the HnGS unit's screens for impingement sampling and in the vicinity of the intakes within Alamitos Bay 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 HnGS 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 HnGS. Organisms large enough to become trapped on the traveling screens are impinged.

In discussing the potential effects of the HnGS CWIS on fish and shellfish populations the first thing that needs to be considered is the life history of the species in the community. First of all, several fish species in the nearshore coastal areas around HnGS 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 HnGS show, many species are only vulnerable to entrainment for a few days when they are newly hatched since their swimming ability increases rapidly with age and development. Gobies, which were one of the most abundant taxa entrained, have demersal eggs, which are not subject to entrainment. Also, with increased age young post larval fishes begin searching for adult habitat, usually on the bottom, where they are not susceptible to entrainment. From the standpoint of impingement effects, one of the most abundant groups of species in protected bays and estuaries, gobies, are generally not susceptible to impingement after transformation to the juvenile life stage because they are bottom-dwelling species that typically do not move up into the water column. This is also true of many flatfishes, which are bottom-dwellers and also tend to be strong swimmers. Even fish species that swim in the water column are generally not susceptible to impingement effects as they mature because they are able to swim against the slow approach velocity of the cooling water inflow.

6.1.2 Review of IM&E Sampling Approach

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

The Rule's entrainment performance standard focused on addressing impacts to fish and shellfish rather than lower tropic levels such as phyto- and zooplankton. EPA recognized the low vulnerability of phyto- and zooplankton in its 1977 draft 316(b) guidance (USEPA 1977). There were several reasons why there is a low potential for impacts to phyto- and zooplankton and why it made sense for the USEPA 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 tropic level organisms are not soft bodied as is the case for finfish and are better able to tolerate passage through the cooling system.

The impingement and entrainment sampling was therefore focused on fishes and shellfishes as required in the 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 are limited to the taxa that are sufficiently abundant to provide reasonable assessments of impacts. For the purposes of this study plan, the taxa analyzed in the assessment were limited to the most abundant taxa that together comprised 90–95% of all larvae entrained and/or juveniles and adults impinged by the generating station. The most abundant taxa were used in the assessment because they provide the most robust and reliable estimates for the purpose of assessing impacts. Since the most abundant organisms may not necessarily be the organisms that experience the greatest effects on the population level, the data were also examined to determine if additional taxa should be included in the assessment. For example, this might include commercially or recreationally important taxa, taxa with limited habitats, and any threatened or endangered fish or shellfish species. No listed species were entrained or impinged at the HnGS during the study and no additional taxa beyond the taxa selected based on sampling abundance were included in the assessment.

Results for individual taxa from the impingement and entrainment sampling need to be combined, where possible, to evaluate the combined effects of the CWIS. This is done by extrapolating the numbers of adult and juvenile fishes impinged to the same age used in the adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*) models for the entrainment data and in the equivalent adult model (*EAM*) for the impingement data. The age used in the *AEL*, *FH*, and *EAM* modeling was the age of first maturity where approximately 50% of the females in the population are reproductive. Unfortunately, the life history information necessary for the modeling is unavailable for most species so combined assessments were only possible for a few species including northern anchovy, gobies, and combtooth blennies. *EAM* could only be calculated for queenfish, northern anchovy, and Pacific sardine.

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

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

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 1975 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) rules, 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."

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

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

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

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

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

6.1.4 Relating Measured Impacts to Source Populations

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

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

The criteria used to evaluate the potential for AEI need to be placed into a larger context using the characteristics of the source water and the biological community. This assessment focuses on a set of 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. While these factors contribute to the potential magnitude of the losses due to entrainment and impingement we will focus primarily on the distribution of the species and their habitats to organize the assessment and determine which species are at greatest risk of AEI. Using this approach, an example of a species at high risk would be a rare or endangered species with a distribution that was limited to the area around the HnGS intake in Alamitos Bay. In contrast, a species at low risk of AEI would be one such as northern anchovy that is abundant over a large expanse of coastline. To determine the spatial extent of the effective source populations of larvae for modeling entrainment effects, data on water current flow and direction were collected during the study.

The focus of the assessment will be on species with adult populations in the nearshore areas of Alamitos Bay that are directly affected by entrainment and impingement at the HnGS 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 2006) and will be used to organize the taxa included in this assessment. We have simplified the more detailed categorization of habitats used by Allen and Pondella (2006) which included several habitats used to define deeper offshore areas (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 (2006) have been simplified for this assessment to the following habitat types:

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

The taxa included in this assessment were categorized into these habitat types (Table 6.1-1). Taxa that occur in more than one habitat will be included in the habitat group that best reflects the primary distribution for the taxa and if a primary habitat cannot be identified, the one that places them at greatest risk to the effects of entrainment and impingement. For example, 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 less at risk from power plant impacts especially if at least one of the habitats is not directly affected by entrainment and impingement. For example, white croakers occur in bays and harbors where they are directly at risk to impingement and entrainment at HnGS 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.

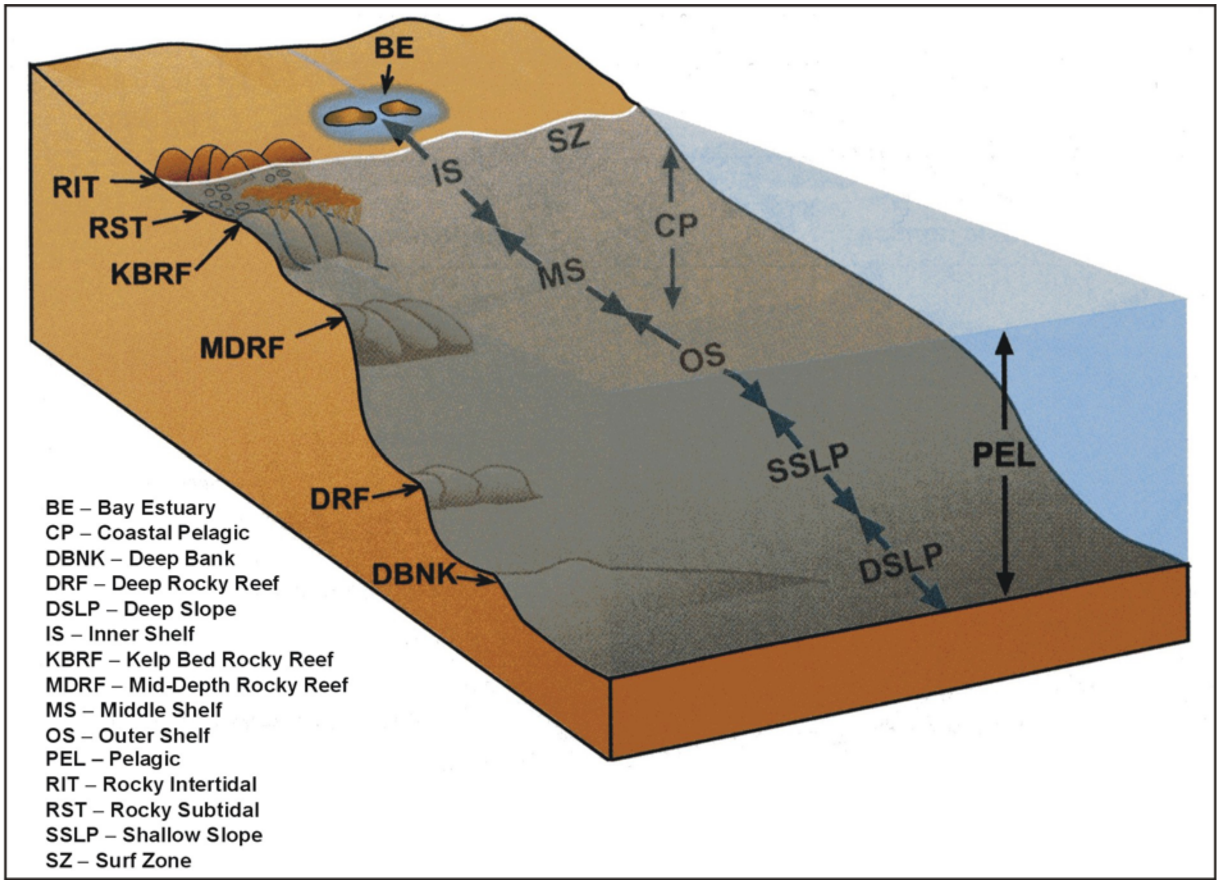


Figure 6.1-1. Marine habitat types in California (from Allen and Pondella [2006]).

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

		Fishery	**Habitats**			
Scientific name	**Common name**	**S-Sport, C-Comm.**	**bays, harbors**	**reefs, kelp beds**	**coastal pelagic**	**shelf**
Fishes						
Atherinopsidae unid.	silversides	S, C	**X**		x	
Cymatogaster aggregata	shiner perch	S	**X**	x		
Engraulidae unid.	anchovies	C			**X**	
Genyonemus lineatus	white croaker	S, C	x		**X**	x
Gobiidae unid.	CIQ goby complex		**X**			
Hypsoblennius spp.	combtooth blennies		**X**	x		
Porichthys myriaster	specklefin midshipman		**X**	x		
Raja inornata	California skate	C	x			**X**
Sardinops sagax	Pacific sardine	C	x		**X**	
Sebastes miniatus	vermilion rockfish	S, C		**X**		
Seriphus politus	queenfish	S			**X**	x
Syngnathidae	pipefishes		**X**			
Trachurus symmetricus	jack mackerel	S, C		x	**X**	
Shellfishes/Invertebrates						
Aplysia californica	California seahare	C	x	**X**		
Loligo opalescens	market squid	S			**X**	
Octopus spp.	California two-spot octopus	C	x	**X**		

6.2 SUMMARY OF ENTRAINMENT AND IMPINGEMENT RESULTS

The following section summarizes the combined results of the entrainment and impingement studies at HnGS 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 order to compare predicted effects of IM&E on such species, calculated losses are standardized to a common age-class that represents fishes at the age of maturity for that species. In later sections, the information on calculated losses is compared to long-term population trends and then discussed in terms of adverse environmental impacts.

6.2.1 Taxa Composition

Data from the bi-weekly entrainment surveys conducted at the HnGS cooling water intakes were used to calculate that an estimated 3.65 billion fish larvae and 1.69 billion fish eggs were entrained through the generating station CWIS in 2006 (Table 6.2-1). If all circulating water pumps had been in operation during the entire year, larval entrainment would have increased by 24% to 4.53 billion, and egg entrainment would have increased by 25% to 2.12 billion. Approximately 50% of the larvae were gobies, 25% were silversides, 20% were combtooth blennies, 2% were white croaker, and thirty-two other species each contributed about 1% or less of the annual total. Larvae from 36 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 (71%), followed by the composite category of sand flounder eggs (11%). Eggs of approximately 13 fish taxa were represented in the collections. A complete listing of all of the taxonomic categories identified during the study is presented in Appendix F.

There were an estimated 14.9 million target shellfish larvae entrained represented by 9 taxa (Table 6.2-1). Shore crab megalops comprised 29% of the annual entrainment of target invertebrate larvae. Species with commercial fishery value included spider crabs with 0.6 million megalops entrained under actual flows (0.8 million for design flows) while market squid hatchlings had 0.2 million paralarvae entrained under actual flows (0.3 million for design flows; Table 4.5-4).

Data from the weekly normal operations sampling and the five heat treatment surveys were used to estimate that annual fish impingement at the HnGS from a total of 60 taxa groups was 53,442 individuals weighing 529.8 kg (1,168 lbs) based on actual cooling water flows, and 56,613 individuals weighing 556.5 kg (1,227 lbs) based on design cooling water flows (Table 6.2-2). The most abundant species by number impinged were queenfish, topsmelt, northern anchovy, and bay pipefish while specklefin midshipman, round stingray, and Pacific electric ray contributed to these species to substantially increase the total biomass impinged.

Annual macroinvertebrate impingement estimates at the HnGS were 20,346 individuals weighing 268.8 kg (592.7 lbs) from 49 taxa based on actual cooling water flows, and 21,773 individuals weighing 293.8 kg (647.7 lbs) based on design cooling water flows (Table 6.2-3). Red jellyfish was the most abundant species, followed by the nudibranch *Hermissenda crassicornis*, tuberculate pear crab, and yellow shore crab. Combined these species accounted for 60% of the sampled impingement abundance.

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

Rank	**Taxa**	**Est. Annual Entrainment (actual flows)**	**Est. Annual Entrainment (designflows)**	**% Comp (actual flows)**	**Cumulative % Comp.**
	Fish Larvae				
1	gobies	1,828,364,516	2,334,220,376	50.10	50.10
2	silversides	920,323,104	1,062,818,072	25.22	75.32
3	combtooth blennies	732,022,349	915,313,887	20.06	95.38
4	white croaker	75,425,299	96,188,344	2.07	97.45
5	anchovies	22,673,541	27,301,289	0.62	98.07
	31 Other taxa	70,399,582	91,802,117	1.93	100.00
		3,649,208,392	**4,527,644,084**		
	Fish Eggs				
1	unidentified fish eggs	1,191,101,773	1,474,924,676	70.58	70.58
2	sand flounder eggs	183,531,130	236,704,432	10.88	81.46
3	fish eggs	90,493,059	109,555,973	5.36	86.82
4	sanddab eggs	63,124,903	80,387,665	3.74	90.56
5	white croaker eggs	57,836,910	86,480,192	3.43	93.99
	8 Other taxa	101,508,151	129,615,937	6.01	100.00
		1,687,595,926	**2,117,668,875**		
	Target Shellfishes				
1	shore crab megalops	4,264,792	5,217,248	28.71	28.71
2	kelp crabs megalops	3,629,771	4,586,866	24.44	53.15
3	pea crabs megalops	2,031,387	2,574,200	13.68	66.82
4	unidentified crab megalops	1,949,343	2,464,009	13.12	79.94
5	Brachyura crab megalops	1,549,133	1,826,174	10.43	90.37
	4 Other taxa	1,430,273	1,827,475	9.63	100.00
		14,854,700	**18,495,973**		

Table 6.2-2. Rank and estimated annual impingement of the most common fish taxa at HnGS in 2006 by estimated abundance and weight for actual and design normal flows. Heat treatment mortality included.

Rank	Common Name	Total No. Actual Flows	Total No. Design Flows	% Total Actual Flows	Cumulative % Total Actual Flows
1	queenfish	30,946	32,389	57.91	57.91
2	topsmelt	6,315	6,747	11.82	69.72
3	northern anchovy	3,443	3,923	6.44	76.16
4	bay pipefish	3,157	3,286	5.91	82.07
5	northern anchovy larvae	2,351	2,590	4.40	86.47
6	pipefish, unid.	1,373	1,490	2.57	89.04
7	white croaker	861	877	1.61	90.65
8	specklefin midshipman	620	632	1.16	91.81
9	shiner perch	582	628	1.09	92.90
10	giant kelpfish	462	517	0.86	93.77
	50 Other taxa	3,332	3,534	6.23	100.00
		53,442	**56,613**		

Rank	Common Name	Total Wt. (kg) Actual Flows	Total Wt. (kg) Design Flows	% Total Actual Flows	Cumulative % Total Actual Flows
1	specklefin midshipman	157.23	161.77	29.68	29.68
2	round stingray	98.05	105.66	18.51	48.18
3	Pacific electric ray	97.59	97.59	18.42	66.60
4	topsmelt	29.44	32.40	5.56	72.16
5	bat ray	24.64	24.66	4.65	76.81
6	queenfish	19.47	20.36	3.67	80.48
7	shiner perch	12.03	13.33	2.27	82.75
8	jacksmelt	11.53	13.80	2.18	84.93
9	midshipman, unid.	11.29	13.01	2.13	87.06
10	diamond turbot	9.63	9.64	1.82	88.88
	50 Other taxa	58.93	64.27	11.12	100.00
		529.83	**556.48**		

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

Rank	**Common Name**	**Total No. Actual Flows**	**Total No. Design Flows**	**% Total Acutal Flows**	**Cumulative % Total Actual Flows**
1	red jellyfish	4,562	4,850	22.42	22.42
2	hermissenda	2,900	3,020	14.25	36.68
3	tuberculate pear crab	2,560	2,794	12.58	49.26
4	yellow shore crab	2,272	2,482	11.17	60.42
5	California aglaja	1,697	1,878	8.34	68.77
6	moon jelly	1,102	1,165	5.42	74.18
7	Xantus swimming crab	691	712	3.40	77.58
8	scallop, unid.	624	683	3.07	80.64
9	intertidal coastal shrimp	506	536	2.49	83.13
10	zebra leafslug	446	484	2.19	85.32
	46 Other Taxa	2,986	3,169	14.68	100.00
		20,346	**21,773**		

		Total Wt. (kg) Actual Flows	**Total Wt. (kg) Design Flows**	**% Total Actual Flows**	**Cumulative % Total Actual Flows**
1	California seahare	79.41	93.13	29.54	29.54
2	moon jelly	57.38	59.60	21.34	50.89
3	Calif. two-spot octopus	54.78	57.88	20.38	71.27
4	California aglaja	32.29	35.92	12.01	83.28
5	red jellyfish	16.55	17.43	6.16	89.44
6	Xantus swimming crab	9.26	9.56	3.45	92.88
7	California bubble	3.52	3.59	1.31	94.19
8	ring-spotted dorid	2.49	2.80	0.93	95.12
9	yellow shore crab	1.99	2.18	0.74	95.86
10	tuberculate pear crab	1.90	2.07	0.71	96.57
	46 Other Taxa	9.23	9.68	3.43	100.00
		268.80	**293.83**		

6.2.2 Temporal Occurrence

Greatest densities of larval fishes occurred in May and August, and the least numbers of fishes occurred in November (Figure 4.5-1). Fish eggs also peaked in abundance from March–April with lows occurring in January and November (Figure 4.5-2). Although this is a typical pattern that is associated with spawning during spring upwelling periods in high productivity coastal waters, some species have well-defined seasonal spawning peaks that may occur in either winter or summer months. Larvae and eggs were generally more abundant in samples collected at night than those collected during the day in most surveys (Figure 4.5-3 and 4.5-4).

The highest fish abundance during weekly normal operation impingement surveys occurred from July to September 2006 (Figures 5.5-1 and 5.5-2), while biomass was highest from April to May 2006 (Figures 5.5-3 and 5.5-4). Invertebrate impingement was highest from April to May, while biomass was variable with peaks in late-March, late-April, and early-August. In general, fish impingement abundance was greatest during nighttime, though biomass was greater during the day (Figures 5.5-5 and 5.5-6).

6.2.3 Combined Analysis and Modeling Results for Selected Species

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

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

Species	**Common Name**	**Est. Annual Larval Ent. (millions)**	**Est. Annual Egg Ent. (millions)**	***ETM* P_M (%)**	**2*FH**	***AEL***	**Annual Imping. Estimate**	**Imping. Weight (kg)**	***EAM*[1]**
Fishes									
Gobiidae[2]	gobies	1,828.4	0	25.15	3,932,562^{L}	1,671,266^{L}	7	0.01	
Atherinopsidae unid.[3]	silversides	920.3	11.5	40.95			6,315	29.44	
Hypsoblennius spp.	combtooth blennies	732.0	0	13.89	836,002^{L}	1,783,945^{L}	32	0.35	
Genyonemus lineatus	white croaker	75.4	57.8	0.63	64^{E}		861	5.78	
Engraulis mordax	northern anchovy	22.7	11.1	0.76	8,600^{C}	20,634^{L}	5,794[4]	6.25[4]	1,840
Seriphus politus	queenfish	2.5	0				30,946	19.47	13,971
Syngnathus spp.	pipefishes	3.1	–				4,553	5.70	
Porichthys myriaster	specklefin midshipman	–	–				620	157.23	
Cymatogaster aggregata	shiner perch	–	–				582	12.03	
Sardinops sagax	Pacific sardine	0.3	0				90	0.61	69
Raja inornata	California skate	–	–				8	1.11	
Trachurus symmetricus	jack mackerel	0	0				7	0.48	
Sebastes miniatus	vermilion rockfish	0	0				7	0.01	
Invertebrates									
Octopus spp.	California two-spot octopus	–	–				337	54.78	
Aplysia californica	California seahare	–	–				195	79.41	
Loligo opalescens	market squid	0.2	–				78	1.37	

[1] *standardized impingement adult equivalent mortality*
[2] *only cheekspot goby collected in impingement samples*
[3] *only topsmelt was collected in abundance in impingement samples*
[4] Engraulis mordax *larvae collected from impingement sampling are combined with adults*
Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

Table 6.2-5. Summary of entrainment and impingement sampling results and model output for common fish and invertebrate species based on design flows at HnGS in 2006.

Species	Common Name	Est. Annual Larval Ent. (millions)	Est. Annual Egg Ent. (millions)	*ETM* P_M (%)	2**FH*	*AEL*	Annual Imping. Estimate	Imping. Weight (kg)	*EAM*[1]
Fishes									
Gobiidae[2]	gobies	2,334.2	0	31.7	5,020,588^{L}	2,133,657^{L}	7	0.01	
Atherinopsidae unid.[3]	silversides	1,062.8	20.8	46.9			6,747	32.40	
Hypsoblennius spp.	combtooth blennies	915.3	0	17.7	1,045,330^{L}	2,230,628^{L}	32	0.35	
Genyonemus lineatus	white croaker	96.2	86.5	0.79	96^{E}		877	7.48	
Engraulis mordax	northern anchovy	27.3	14.0	0.92	10,364^{C}	24,845^{L}	6,513[4]	7.31[4]	2,117
Seriphus politus	queenfish	2.9	0				32,389	20.36	14,595
Syngnathus spp.	pipefishes	3.8	–				4,801	5.97	
Porichthys myriaster	specklefin midshipman	–	–				632	161.77	
Cymatogaster aggregata	shiner perch	–	–				628	13.33	
Sardinops sagax	Pacific sardine	0.3	0				98	0.66	75
Raja inornata	California skate	–	–				9	1.24	
Trachurus symmetricus	jack mackerel	0	0				7	0.48	
Sebastes miniatus	vermilion rockfish	0	0				7	0.01	
Invertebrates									
Octopus spp.	California two-spot octopus	–	–				353	57.88	
Aplysia californica	California seahare	–	–				221	93.13	
Loligo opalescens	market squid	0.3	–				78	1.37	

[1] *standardized impingement adult equivalent mortality*
[2] *only cheekspot goby collected in impingement samples*
[3] *only topsmelt was collected in abundance in impingement samples*
[4] *Engraulis mordax larvae collected from impingement sampling are combined with adults*
Model estimates indicate whether the number was based on eggs (E), larvae (L), or both combined (C).

6.3 ASSESSMENT OF TAXA BY HABITAT TYPE

The following sections present assessments for taxa from the five habitat types simplified from Allen and Pondella (2006). A general discussion of the habitat and the potential risk to the habitat due to HnGS 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 of 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 1970’s that was completed by the end of the 1982–1984 El Niño, the largest El Niño recorded at that time (Stephens et al. 1984; Holbrook et al. 1997).

The 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. This was followed by a series of four cold water years (1999–2002) including the strongest La Niña on record (Schwing et al. 2000; Goericke et al. 2005). The possible return to the cold water phase of the PDO did not occur since 2003–2004 was described as a 'normal' year (Goericke et al. 2005). This normal year turned out to be the beginning of an extended warm phase that has persisted through 2006 (Peterson et al. 2006; Figure 6.3-1). Thus, the oceanographic context for this study can best be described as a warm phase of the PDO that has persisted for three years. Prior to this warm phase were four unusually cool years.

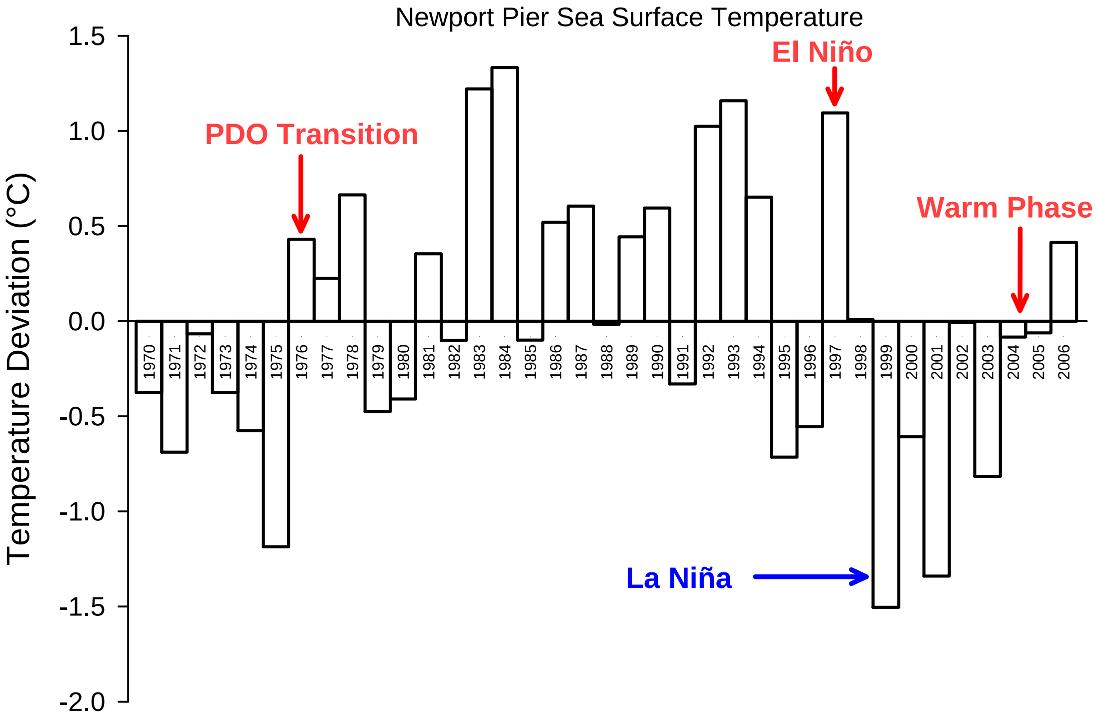


Figure 6.3-1. Sea surface temperature anomalies for Newport Pier, California. Values are ± the long-term average (1925-2006).

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

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

6.3.1.1 Habitat Associations and Fisheries

Entrained larvae were categorized in terms of the habitat types typically utilized by juveniles and adults, and the type of fishery, if any, that the species supports. Most larval taxa were from species typically found associated with the types of habitats in close proximity to the intake: bay, shelf sand bottom, and rocky reef. Species primarily associated with the bays and harbor habitat (e.g., gobies, blennies) had the highest number of taxa entrained and impinged (66.7%; Table 6.3-1) and the greatest number entrained and impinged (98.7% and 75.0% respectively). Sport fishery species accounted for approximately 27.4% of the total number of larvae entrained and commercial fishery species accounted for 28.4%, while species with no direct fishery value comprised the majority (71.5%) of the larvae entrained. (Note that some species such as white croaker were classified as both a sport and commercial fishery species). Approximately 80% of the impinged species and biomass were from fish and rays that have no direct fishery value.

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

Attributes	Entrained % of taxa	Entrained % of abundance	Impinged % of taxa	Impinged % of biomass
Habitat Association				
Continental shelf / slope	39.39	2.55	31.67	28.62
Bays, Harbors	66.67	98.71	66.67	74.97
Rocky reef, Kelp	39.39	21.23	33.33	8.89
Coastal pelagic	27.27	28.31	30.00	15.32
Deep pelagic	3.03	0.01	0.00	0.00
Fishery				
Sport	39.39	27.43	36.67	18.56
Commercial	33.33	28.35	33.33	15.18
None	45.45	71.51	53.33	79.72

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 losses from HnGS will be the taxa that only occur in that habitat such as gobies and pipefishes (Table 6.1-1).

6.3.2 Bay and Harbor Habitats

This habitat type includes, bay, harbors and estuaries that are either entirely marine and largely influenced by tidal movement of seawater, or estuarine areas where seasonal freshwater input lowers salinities in some areas of the habitat. Much of the nearshore habitat in the vicinity of HnGS is of the bay and harbor type including Alamitos Bay, Anaheim Bay and the much larger Los Angeles-Long Beach Harbor Complex nearby. Although no undisturbed wetland areas still exist within the highly developed Harbor Complex, there is a small wetlands area, Cerritos Wetland, inside Alamitos Bay, and extensive salt marsh areas within Anaheim Bay. Characteristic fishes from these habitats in Alamitos Bay would include deepbody anchovy, bay pipefish, and bay blenny (Allen and Pondella 2006). 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 six fish taxa included in this assessment: CIQ gobies, silversides, combtooth blennies, specklefin midshipman, shiner perch, and pipefishes (Table 6.1-1). While CIQ gobies and pipefishes 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 silversides, specklefin midshipman, and shiner perch also occur on the outer coast.

Annual entrainment of goby larvae was estimated to be 1.8 billion larvae based on actual flow volumes and 2.3 billion larvae based on design flow volumes (Tables 6.2-4 and 6.2-5). No goby eggs were entrained because eggs are laid in nests and are not vulnerable to entrainment until they hatch as larvae. The entrainment and source water data on larval concentrations were used to estimate that 25% of the larval goby populations were potentially lost due to entrainment based on actual flows (Table 6.2-4). Based on the design flows, this estimate increases to 31.7% (Table 6.2-5). The entrainment losses were also used to estimate that the larvae entrained would have resulted in the production of 1.7-3.9 million adult gobies based on actual flow volumes. Gobies were not common in impingement sampling because they generally occur on the bottom and not in the water column where they would be subject to impingement. A single cheekspot goby was collected during impingement sampling, which extrapolated out to seven cheekspot gobies impinged at HnGS using actual or design flow volumes in 2006.

Silversides were the second most abundant species entrained and impinged at HnGS in 2006, represented by topsmelt, jacksmelt and grunion. An estimated 920.3 million larvae and 11.5 million eggs were entrained at HnGS in 2006 based on actual flows. Based on design flows, these numbers increased to 1,062.8 million larvae and 20.8 million eggs. An estimated 41-47% of the larval silverside population in Alamitos Bay was lost due to entrainment based on actual and design flows. Only topsmelt was collected in abundance in the impingement samples, with an estimated 6,315 topsmelt weighing 29.4 kg (64.9 lbs) impinged at HnGS in 2006 based on actual flows; or based on design flows, an estimated 6,747 individuals weighing 32.4 kg (71.4 lbs) were impinged. Topsmelt and jacksmelt deposit their eggs on submerged aquatic vegetation or shallow structures in bays and harbors, and the larvae were much more abundant on the east side of Alamitos Bay at the entrainment station location than in other parts of the bay (Figure 6.3-2). The greatest concentrations were entrained during nighttime surveys in May, and it is possible that the high concentrations of newly-hatched larvae within the marina area were attracted to the brightly lighted areas within the marina near the HnGS intake where they were subsequently entrained into the cooling water flows.

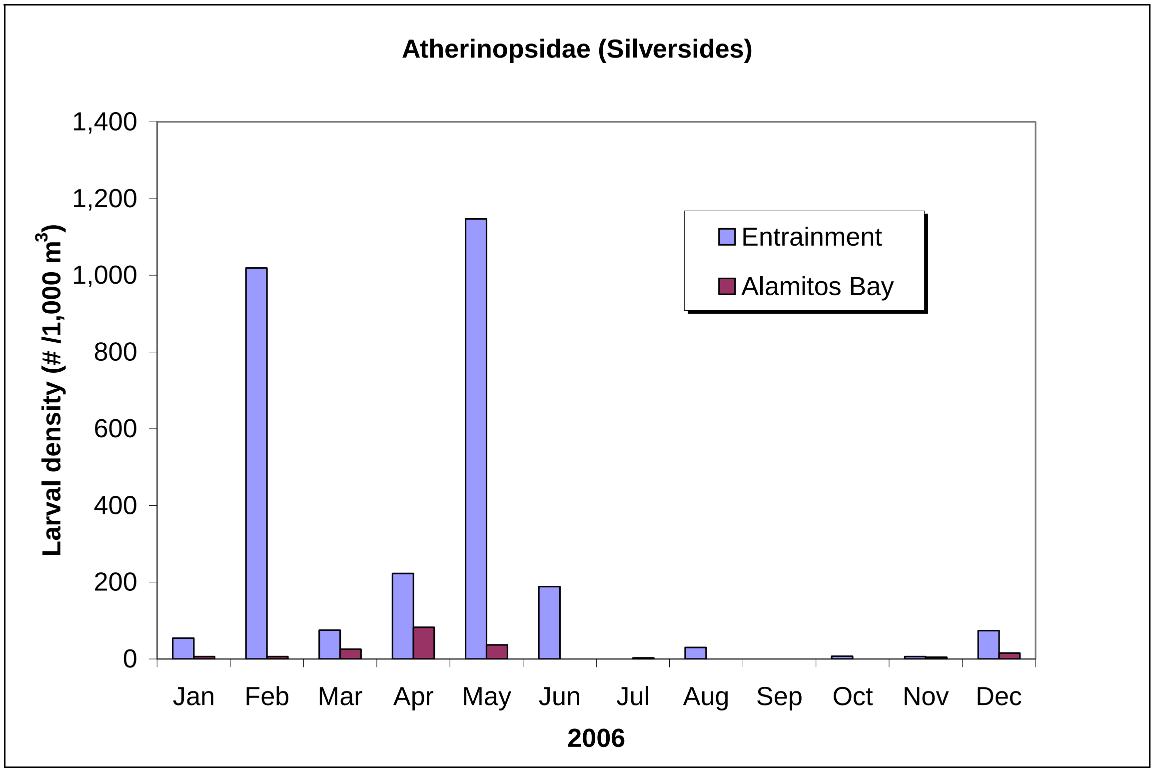


Figure 6.3-2. Comparison between silverside larval densities at entrainment station (E3) and Alamitos Bay stations (H2-H4) during monthly plankton tows in 2006.

Annual entrainment of combtooth blennies larvae was estimated at 732.0 million based on actual flows and 915.3 million based on design flows. An estimated 0.8-1.8 million adult equivalents were lost due to entrainment at HnGS and approximately 14% of the larval combtooth blenny populations were lost due to entrainment based on actual flow volumes. Using the design flow volumes, an estimated 1.0-2.2 million adult equivalents were lost due to entrainment, and approximately 18% of the larval populations were lost due to the CWIS at HnGS. Combtooth blennies are similar to gobies in that they have adhesive demersal eggs that are not vulnerable to entrainment. Adult combtooth blennies, which could be identified to the species level, were impinged in low numbers. The largest impingement occurred for the rockpool blenny, which has a broader distribution than the other two species that includes nearshore rocky habitat. The total estimated annual impingement for all species of blenny was 32 (25 rockpool blennies and 7 mussel blennies). Combtooth blennies, especially mussel blennies, can utilize submerged artificial substrates (pier pilings, dock floats, breakwater material) and their associated fouling communities for shelter and spawning habitat. The slips for approximately 4,000 boats in Alamitos Bay provide abundant habitat for a large local population of combtooth blennies and this explains why their larvae were entrained in large numbers. Most blenny larvae that were captured were recently hatched, based on size frequency distributions, and reached peak concentrations during summer months.

An estimated 3.1-3.8 million pipefish larvae were also entrained at HnGS using actual and design flows, respectively. In addition, 4,553-4,801 juvenile or adult pipefishes were impinged (Tables 6.2–4 and 6.2-5). Other bay and harbor species that were collected in the impingement sampling, but were not susceptible to entrainment, included specklefin midshipman and shiner perch. Specklefin midshipman had the highest impingement biomass with 157.2 kg (346.6 lbs) with a total of 620 individuals estimated to be impinged based on actual flows. Using the design flows, this number increases to 161.8 kg (356.7 lbs) with 632 individuals impinged. Shiner perch were the fifth most abundant species in the impingement sampling, with 582-632 individuals impinged using actual and design flows, respectively. Shiner perch are highly mobile species and are widespread among nearshore sandy habitats as well as rocky reef and kelp habitats.

If additional mortality rates from IM&E from both HnGS and nearby Alamitos Generating Station were causing long-term declines in fishes within Alamitos Bay, this should be reflected in overall changes to larval densities. Most of these organisms are affected through entrainment since the juveniles and adults of species such as gobies and blennies occupy benthic habitats within the bay where they are less susceptible to the effects of impingement. However, there is uncertainty regarding the magnitude of the impacts in relation to environmental variables and other stressors that can cause population changes. However, the earlier 316(b) study in 1978–1979 documented average entrainment densities of silverside larvae at <10 per 1,000 m^3 (264,172 gal), but in 2006 the average densities had increased to 778 per 1,000 m^3 (264,172 gal). CIQ goby and combtooth blenny densities, on the other hand, were lower than recorded during the earlier study, so the historical data are ambiguous in this regard. There are no long-term historical data available on blenny or goby populations within Alamitos Bay, although the higher larval densities from the earlier study (ca. 4,000 per 1,000 m^3 [264,172 gal] for blennies and 3,000 per 1,000 m^3 [264,172 gal] for gobies) suggests a substantially greater spawning biomass in the late 1970s as compared to 2006 when larval densities were 16% and 55% of the 1978–1979 densities, respectively.

Even with a substantial fraction of the source larval production in Alamitos Bay cropped by power plant entrainment, the bay habitat continues to sustain a thriving population of gobies, blennies, and silversides as evidenced by their abundant larval concentrations. In a lagoon or bay such as Alamitos Bay that is significantly affected by tidal exchange, many of the larvae are inevitably lost to the system due to export by outgoing tidal currents despite behavioral adaptations that cause larvae to migrate toward the bottom or move to areas with less current and minimize export (Barlow 1963; Pearcy and Myers 1974; Brothers 1975) or, in larger systems, have mechanisms that allow some larvae to return to the bay after a period of development in offshore waters. Larvae that are transported into coastal waters can provide genetic exchange between estuarine areas along the coast by moving back into bays with incoming tidal currents (Dawson et al. 2002), but most of these exported larvae experience much higher mortality rates in the open ocean than those that are retained in their natal estuaries.

Demographic-based estimates of projected losses assume that there is available habitat to support the additional production in the source water area, which is not usually the case in the example of substrate-oriented or territorial species like gobies. In contrast, species that live in open water environments, such as silversides, are generally not limited by habitat availability but by other factors such as food availability, oceanographic conditions, or predation. In Alamitos Bay where there is a limited amount of benthic habitat, density–dependent mortality may be a substantial factor affecting post-settlement recruits, similar to the conclusions of Brothers (1975) on goby populations in Mission Bay, San Diego. Therefore, projections of adult equivalents based on larval entrainment likely overestimate actual adult losses. For example, similar levels of entrainment mortality were estimated for the South Bay Power Plant in south San Diego Bay (Tenera 2004). Data from a previous entrainment data and long-term data on adults indicated that the population in south San Diego Bay was stable and not affected by the additional larval mortality due to entrainment. Unfortunately, complementary data on adult abundances for these studies, including HnGS, are usually not available.

In terms of potential economic losses resulting from CIQ goby, combtooth blenny, and topsmelt IM&E, there are no direct impacts because they have no fishery value, except for the occasional use of larger specimens as fishing bait and a small recreational fishery for topsmelt. 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 Alamitos Bay consists of hard intertidal and subtidal substrates, such as concrete bulkheads and piers. Common species in these assemblages include kelp bass, barred sand bass, black perch, opaleye, halfmoon, California sheephead, senorita, garibaldi, salema and zebraperch (Stephens et al. 2006). Although the presence and extent of giant kelp affects the abundance of some reef fishes, many other factors can also affect their distributions, and it is not unusual to find many of the species characteristic of kelp bed habitats in other shallow water locations. Common species of fishes and target invertebrates that are typically associated with rocky reef habitats that were impinged at HnGS included the vermilion rockfish, California seahare and California two-spot octopus (Table 6.1-1). No species primarily associated from this habitat were entrained because there are no significant patches of kelp bed and outer coastal reef habitat in Alamitos Bay. Impacts to representative species from this habitat are briefly discussed.

The intake structure at HnGS is located in a sand and mud habitat within Alamitos Bay. Species associated with rocky reef and kelp habitats do migrate between areas and occasionally find suitable habitat in bays and harbors due to the presence of eelgrass, rock jetties, and other structures that provide shelter, especially for juveniles that may recruit into these habitats after being transported into Alamitos Bay as larvae. While some individuals may recruit and grow within small habitat patches it is more likely that adults take up temporary residence when they encounter such habitat patches during their movements. For example, a single juvenile vermilion rockfish, usually associated with deeper offshore reefs, was collected in the impingement sampling, resulting in an estimated seven vermilion rockfish impinged at HnGS based on actual or design cooling water flows. None were collected during impingement sampling from 2001-2005. Thus, impacts to this species due to the CWIS at HnGS are minimal.

Whereas vermilion rockfish are exclusively usually associated with rocky reef habitat, octopus and California seahare have broader habitat distributions and do occur in bays and harbors. An estimated 337 octopus with a biomass of 55 kg (121 lbs) were estimated to be impinged at HnGS in 2006 based on actual flows. Based on design flows, these numbers increased to an estimated 353 individuals at 58 kg (128 lbs). A total of 195 California seahares weighing 79 kg (175 lbs) was impinged at HnGS in 2006 and these numbers increased to an estimated 221 individuals weighing 93 kg (205 lbs) using the design flows.

The annual losses due to impingement of invertebrate species associated with rock reefs and kelp habitats were low in comparison to the fishery take for these species. In 2005, an estimated 183 kg and 4,783 kg of octopus and seahare was commercially harvested (CDFG 2006). Taxa such as octopus, California seahare and others that occur across a number of habitats will be less susceptible to CWIS impacts than species with more specific associations with habitats directly affected by the CWIS.

6.3.4 Coastal Pelagic Habitats

Several species entrained or impinged at HnGS are characteristic of the coastal pelagic zone, which was expanded to include the surf zone for the purposes of this assessment. These included northern anchovy, white croaker, Pacific sardines, queenfish, jack mackerel, and market squid (Table 6.1-1). Some of these species, such as northern anchovy and white croaker, can be considered habitat generalists because they are also be found in bays and a variety of other shallow water locations (Allen and Pondella 2006). Juveniles of most of these species also tend to be abundant in the shallower depths of the habitat range as demonstrated by the small size distributions collected during the impingement sampling.

The estimated annual loss of northern anchovy due to operation of the HnGS CWIS included 22.7 million larvae based on actual flow volumes, and 27.3 million based on design flow volumes (Table 6.2-5). An estimated 11.1 million eggs were entrained using the actual flow volumes, or 14 million based on the design flow volumes. These estimates were used to calculate a loss of 8,600-20,600 adult equivalents using actual flows and a loss of 10,000-25,000 adult equivalents based on design flows. Northern anchovy ranges widely throughout the southern California bight and the proportion of larvae entrained in the source waters from Alamitos Bay were correspondingly low (less than 1%). Annual impingement of northern anchovy was estimated as 5,794 individuals with a combined weight of 6.3 kg (13.3 lbs) based on actual flows and an estimated 6,513 individuals weighing 7.3 kg (16.1 lbs) based on design flows (Tables 6.2-4 and 6.2-5). An estimated 1,840-2,117 equivalent adults were lost due to impingement at HnGS in 2006 based an actual and design flows, respectively. An estimated 0.3 million Pacific sardine larvae were entrained at HnGS in 2006 (Table 6.2-4). Annual impingement of Pacific sardine ranged from an estimated 90-98 individuals weighing 0.61-0.68 kg (1.3-1.5 lbs) based on actual and design flow volumes respectively. Based upon the impingement estimates, 69-75 equivalent adult Pacific sardine were lost due to impingement.

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

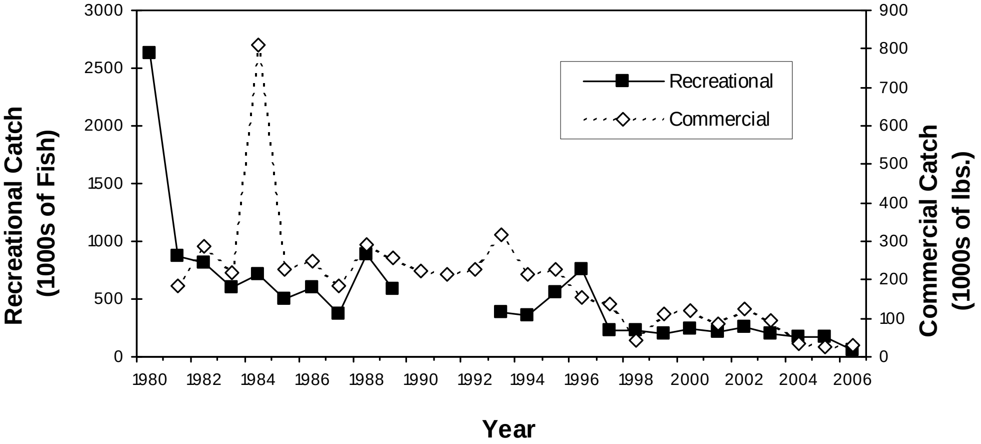
The difference in the entrainment estimates for northern anchovy between the 1979–1980 (IRC 1981) and the 2006 studies probably reflects changes in the oceanographic environment. The estimated annual entrainment during the previous study was 580 million compared with 23–27 million from the 2006 study. The recent entrainment estimate is approximately 4% of the estimate from the previous study. This reduction is similar to the decrease in the landings from Los Angeles area ports over the same period which were 38,383,362 kg (84,620,828 lbs) in 1981 (data before 1981 not available from PACFIN) and averaged only 1,351,669 kg (2,979,921 lbs) from 2000–2006 (Table 4.5-7) or 2% of the 1981 landings. The total losses from both entrainment and impingement from the 2006 study were extrapolated to 23,000–27,000 fishes at the age of 50% maturity. 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 weigh data for the northern anchovy collected from the HnGS 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 eleven to thirteen dollars. These values do not represent significant AEI to northern anchovy, especially since this species has a broad distribution throughout the SCB.

White croaker and queenfish are two common members of the croaker family that are found in Alamitos Bay and also in the nearshore sand bottom habitat—queenfish as a pelagic species and white croaker as a bottom-associated species. White croaker was the fourth most abundant larvae entrained with 75.4-96.2 million larvae entrained based on actual or design flows. An estimated 57.8-86.5 million white croaker eggs were also entrained at HnGS in 2006. This taxa group was the ninth most abundant species impinged at HnGS in 2006, with 861-877 individuals weighing 5.8-7.5 kg (12.8-16.5 lbs) respectively based on actual and design flows. Using the egg entrainment, an estimated 64-96 adult equivalents were lost due to entrainment at HnGS (Tables 6.2-4 and 6.2-5). Proportional mortality due to entrainment was less than 1% using either actual or design flows in the calculations. Queenfish larvae were the fourteenth most abundant larvae entrained with 2.5-2.9 million larvae based on actual or design flow volumes (Tables 6.2-4 and 6.2-5), but were the most abundant species impinged with approximately 31,000-32,000 individuals weighing 19.5-20.4 kg (42.9-45.0 lbs) respectively. These estimates were used to calculate that 13,971-14,595 equivalent adults were lost due to impingement at HnGS in 2006. The majority of the queenfish impinged were small young-of-the-year and likely use the habitat within Alamitos Bay as nursery grounds.

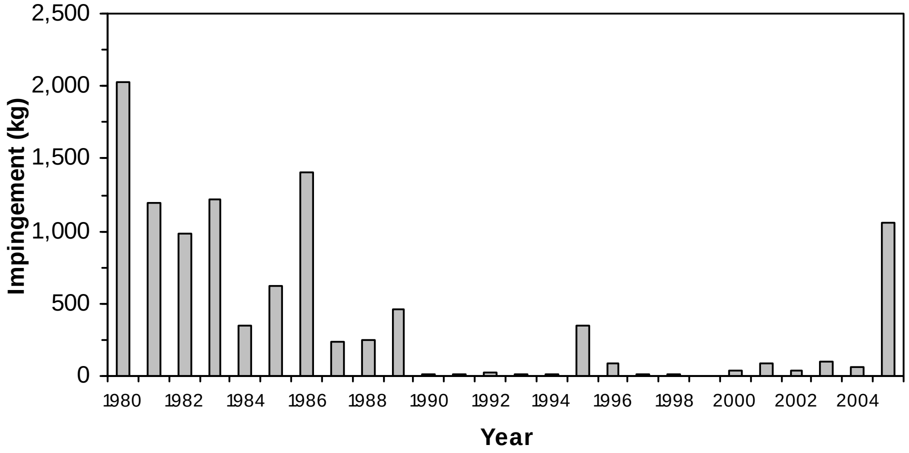
Recreational and commercial catch data for white croaker indicating a declining fishery were not consistent with the fishery independent data. Recreational and commercial catches both declined from 1980-2006 (Figure 6.3-3a). Overall, the declines in white croaker recreational and commercial catch, especially 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 trawls are collected just outside the 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.

Catches of queenfish fluctuated over time in the various time-series analyses, but have shown increases in recent years that, similar to white croaker, may be in response to the prolonged cooler water temperatures since 1999 (Peterson et al. 2006). In the recreational fishery, catches were relatively consistent over time, fluctuating between 38,000 and 292,000 fish per year with the exception of one peak in 2002 (Figure 6.3-4a). Impingement of queenfish at the HBGS downcoast from Alamitos Bay shows a sharp drop through the 1980s with low fluctuating levels through the 1990s until after 2000 when levels began increasing (Figure 6.3-4b). Although this may be a response to the cooling trends in ocean temperatures, Herbinson et al. (2001) do not report a similar decline for queenfish in their analysis of impingement data from several southern California power plants. Both the catch data and impingement data are not adjusted for numbers of fishers and plant cooling water flow. This may explain why the data from trawls conducted off Huntington Beach and Alamitos Bay show much more variable results (Figure 6.3-4c). All three data sets show increases in recent years that may be a response to ocean conditions.

a) Recreational and Commercial Catch



b) HBGS Impingement



c) Huntington Beach and LA Harbor-Alamitos Trawls

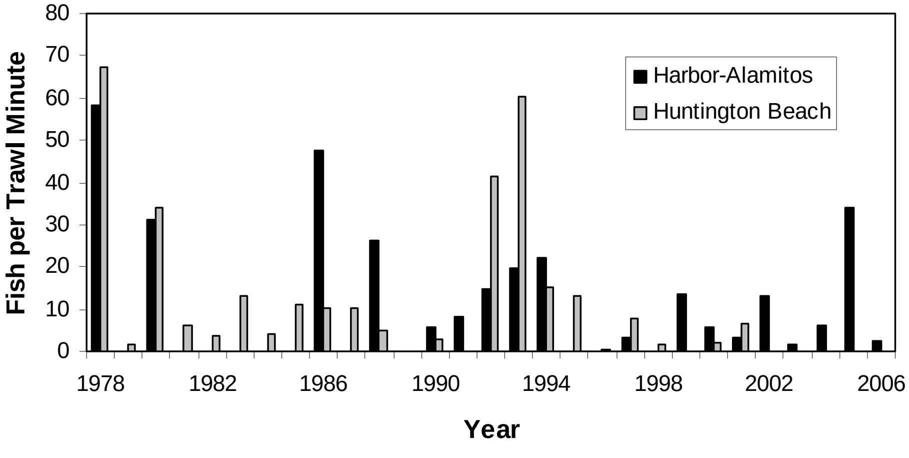
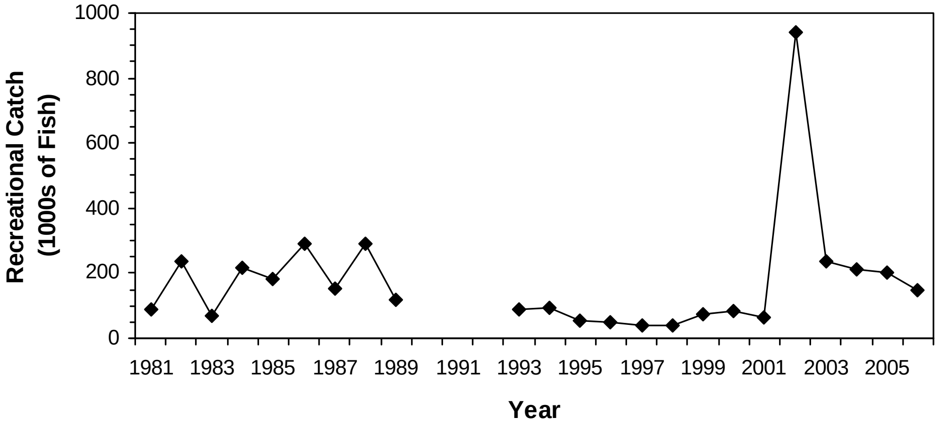
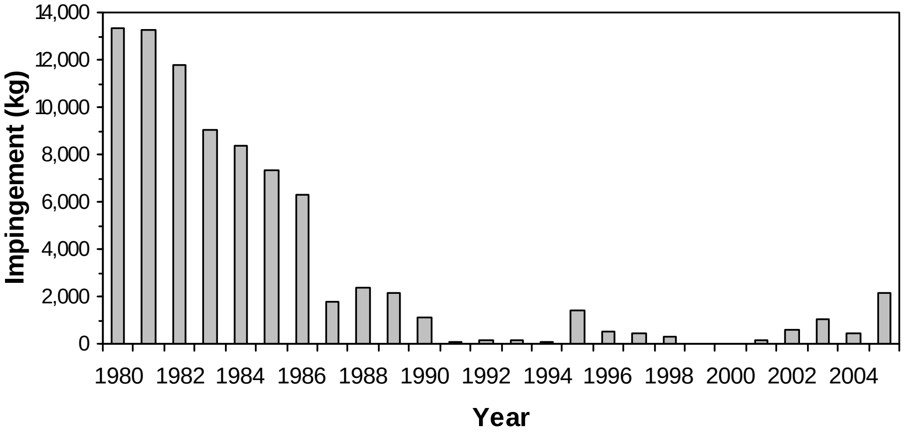


Figure 6.3-3. White croaker fishery and population trends: a) recreational and commercial landings for Los Angeles area ports from RecFIN and PacFIN databases; b) Huntington Beach Generating Station (HBGS) impingement average annual biomass; and c) NPDES trawl data with average number of fish per trawl minute for HBGS and Harbor, Haynes and Alamitos Generating Stations, collected off Huntington Beach and inside the Los Angeles-Long Beach Harbor breakwaters, respectively.

a) Recreational Catch



b) HBGS Impingement



c) Huntington Beach and LA Harbor-Alamitos Trawls

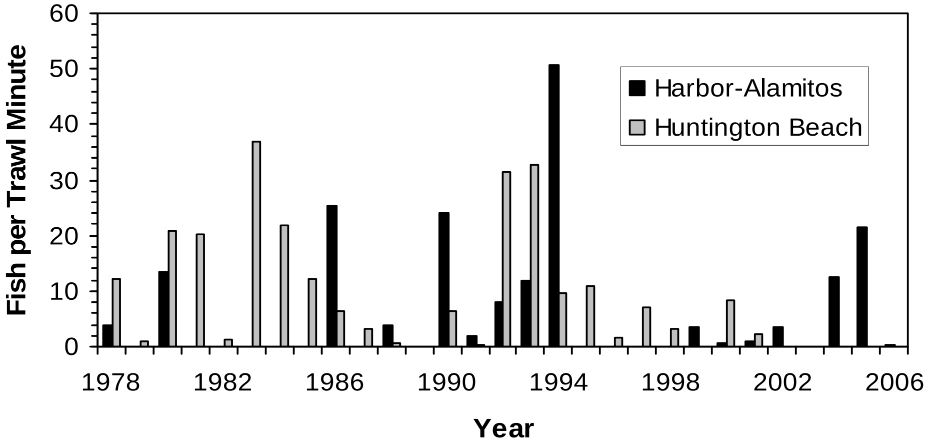


Figure 6.3-4. Queenfish fishery and population trends: a) recreational landings for Los Angeles area ports from RecFIN database; b) HBGS impingement average annual biomass; and c) average number of fish per trawl minute for HBGS and Harbor, Haynes and Alamitos Generating Stations, collected off Huntington Beach and inside the Los Angeles-Long Beach Harbor breakwaters, respectively.

One of the target invertebrates selected for analysis was the market squid, *Loligo opalescens,* because of its wide distribution and commercial fishery importance. Large-scale fluctuations are characteristic of the squid stock, due primarily to its short life span and the influence of variations in oceanographic conditions (NMFS 1999). Los Angeles area commercial landings ranged between 7.7 and 44.8 million kg (16.9 and 98.8 million pounds) annually from 2000–2006 with both the total catch and market value increasing substantially during the last two years (PacFIN 2007). Projected annual losses of squid paralarvae due to entrainment was from an estimated 0.2–0.3 million larvae for actual and design flows, respectively. There was not enough information available on natural mortality rates to project adult equivalents from this number of larvae, but the total impingement was estimated as 78 adults annually using either actual or design flows. This is very small compared to the annual take from the commercial fishery, which has grown over recent years to be the largest fishery in California.

In summary, the coastal pelagic habitat is extensive within the southern California bight, and most of the common fish species that are part of this assemblage are wide-ranging. Most have a directed commercial or sport fishery and their populations are generally sensitive to large-scale oceanographic influences. The changes in abundance that appear to fluctuate in response to ocean conditions indicate that the effects of impingement or entrainment are probably not significant since power plant impacts should occur as a long-term downward trend in abundance. Since the HnGS is located in Alamitos Bay it does not affect this habitat directly and given the wide distributions of most of the component species, including distributions in other habitats where they are not as susceptible to CWIS effects, there is no indication that the facility adversely impacts these populations. Two coastal pelagic fishes, Pacific sardine and jack mackerel, were included in the assessment because they are under federal management. Both were collected in very low numbers during the impingement sampling and only a single Pacific sardine larva was collected during entrainment sampling, mainly because of their primarily offshore distribution.

6.3.5 Shelf Habitats

Shelf habitats include several different habitats from Allen and Pondella (2006) including inner, middle, and outer shelf, and shallow slope habitats. The abundance, biomass, and other population attributes of the fish assemblages in these habitats increase from the inner to outer shelf (Allen 2006). Allen attributed this gradient to the increased variability in ocean conditions on the inner shelf due to runoff, pollution, and a variety of other factors. A variety of flatfishes and other species dominate the fish assemblages on the soft mud and sandy bottoms in these habitats. Fishes characteristic of the inner and middle shelf include California halibut, bay goby, California tonguefish, bigmouth sole, hornyhead turbot, and California skate (Allen and Pondella 2006). Fishes characteristic of the outer shelf and slope include plainfin midshipman, Pacific sanddab, pink seaperch, curlfin turbot, Dover sole, longspine thornyhead, and California rattail (Allen and Pondella 2006).

While the shelf species are treated in this assessment as an assemblage, it is apparent that the only potential impacts from HnGS entrainment and impingement would occur to fishes that inhabit the inner shelf close to shore. As pointed out by Allen (2006) the inner shelf is also more subject to highly variable ocean conditions caused by runoff, pollution, etc. Although this would increase the potential for impacts to these species, the location of the HnGS intake inside Alamitos Bay reduces the potential impacts to these species. As a result, the estimated effects of entrainment and impingement on the fishes from shelf habitats were low relative to species from other habitat types that occur in the vicinity of the intake.

The only taxa included in the assessment that is predominately distributed on the inner shelf was the California skate (Table 6.1-1). California skate would only be affected by impingement since they do not have planktonic larvae. They lay egg cases where the larvae develop until they hatch as small fully formed juveniles, which would not be subject to entrainment. Based on actual flows, an estimated 8 individuals weighing 1.1 kg (2.4 lbs) were impinged at HnGS in 2006. Using the design flows, this estimate increased to 9 individuals weighing 1.2 kg (2.7 lbs). Since California skate is a highly mobile species, impacts to this group are considered insignificant. Impingement of other shelf species was low relative to other habitat types because these fishes are largely bottom dwellers and generally do not occur in the water column where the intakes are located. Entrainment was very low for shelf species since the larvae would have to be transported from offshore areas into Alamitos Bay. 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 Alamitos Bay (Table 6.3-1).

6.3.6 Deep Pelagic Habitats

Deep pelagic habitats include several different habitats described by Allen and Pondella (2006) including deep slope, deep bank, and deep rocky reef habitats. This category also includes open ocean pelagic habitats. Some of these habitats are extremely productive and the fishes inhabiting these areas are the basis of large commercial fisheries. The fisheries in the areas outside the three-mile limit of California state waters are federally managed by the PFMC. Fishes characteristic of the deep shelf, bank and slope habitats include Pacific hake, splitnose rockfish, rex sole, sablefish, blackgill rockfish, and shortspine thornyhead. Several different species of rockfishes dominate the fish assemblages on the deep reef, shelf and canyon habitats including bocaccio, chilipepper, and greenspotted, greenstripe, rosethorn, and pinkrose rockfishes. Fishes characteristic of open ocean pelagic habitats include swordfish, striped marlin, several species of shark, albacore, and bluefin bigeye, and yellowfin tuna. Although the fishes characteristic of these habitats occasionally occur closer to shore their primary habitats are offshore in open water or at deep ocean depths. Only one larval fish associated with the deep pelagic habitat (*Stenobrachius leucopsarus*, 0.01%; Table 4.5-1) was 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 HnGS would impact species from this habitat.

6.4 CONCLUSIONS AND DISCUSSION

Impacts to SCB fish and invertebrate populations caused by the entrainment of planktonic larvae through the HnGS CWIS can only be assessed indirectly through modeling. The estimates from these models can be added to impingement estimates of juvenile and adult losses to estimate the total losses due to the HnGS CWIS. Three taxa (CIQ goby complex, combtooth blennies, and silversides) comprised 95% of all entrained fish larvae. Of the ten most abundant fish species entrained at HnGS, 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 45% of the 33 different fish taxa entrained belonged to species with some direct fishery value (e.g., anchovies, silversides, croakers, sand basses, California halibut) even though most of those (except silversides and anchovies) were in very low abundance in the samples and as a result were not assessed for potential impacts.

The *ETM* procedure estimates the annual probability of mortality due to entrainment (P_M). It puts the entrainment estimate into context by comparing it with a known source population at risk of entrainment. The greatest P_M estimate for a target taxon was for the silverside complex with a predicted fractional larval loss of 40.9%. The next greatest probabilities of mortality were for CIQ gobies (25.2%) and combtooth blennies (13.9%). The spatial extent of the habitats potentially affected by entrainment is directly proportional to the estimate of time that the larvae are exposed to entrainment. All three of these species had local populations primarily located in the habitats of Alamitos Bay, and most larvae were entrained at sizes that indicated they were recently hatched. For example, the relatively high silverside mortality estimate resulted from of a single large pulse of larvae entrained in late May, probably from eggs that had been deposited on dock structures in the marina adjacent to the HnGS intakes. 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).

Compared to the IM&E study conducted at HnGS in 1978–1979 (IRC 1981), silverside larvae were nearly two orders of magnitude more abundant in the recent 2006 entrainment samples while other taxa analyzed in both studies were less abundant in 2006 (Table 6.4-1). Anchovy and croaker 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 populations of these taxa. The most abundant impinged species in 1978–1979 were shiner perch (38%), Pacific pompano (14.9%), and white seaperch (12.5%), while in the 2006 samples queenfish, topsmelt and northern anchovy were the numerically dominant species accounting for 75% of all impinged fishes. Annual fish biomass impingement (normal operations and heat treatments) was 1,344 kg (2,964 lbs) in 1978–1979 compared to 529.8 kg (1,168 lbs) in 2006. The operations and configuration of the HnGS cooling water system have remained largely unchanged since all units went into service with the exception of the replacement of the cooling water pumps at Units 3 & 4 (now Unit 8). Therefore, changes in impingement and entrainment through time are most likely due to natural biological changes and not due to substantial changes in plant operations.

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

Species	Common Name	Mean Average Annual Density (#/1,000 m^3) 1978–79	Mean Average Annual Density (#/1,000 m^3) 2006	Actual Annual Entrainment (millions) 1978–79	Actual Annual Entrainment (millions) 2006
Larval Fishes					
Atherinopsidae	silversides	<10	778	12	920
Engraulidae	anchovies	560	20	580	22
Gobiidae	gobies	2,975	1,661	3,200	1,828
Hypsoblennius spp.	combtooth blennies	3,990	652	4,400	732
Genyonemus lineatus	white croaker	215	68	210	75
Seriphus politus	queenfish	60	2	53	3
Pleuronichthys guttulatus	diamond turbot	<10	2	5	3
Fish Eggs					
Engraulis mordax	northern anchovy	420	10	230	11
Sciaenid complex	croakers	2,555	37	2,600	41

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

6.4.1 IM&E Losses Relative to 1977 USEPA AEI Criteria

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

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

Fishes in the vicinity of the HnGS intake structure in Alamitos Bay are characteristic of the fish assemblages found in other bays and harbors in southern California, as defined by Allen and Pondella (2006). The structural complexity of Alamitos Bay contributes to the habitat value of the area as a spawning and nursery ground for numerous species. The area in which the HnGS intake structure is located is the Long Beach Marina within Alamitos Bay which is a highly modified, dredged embayment that was once part of a natural wetland system. Of the three taxa (CIQ gobies, combtooth blennies, and silversides) that comprised 95% of all entrained larvae, all use embayments as primary spawning and nursery areas. For example, gobies are abundant in quiet-water areas with soft substrates where they inhabit burrows and lay their eggs. Blennies utilize the complex fouling communities on pilings, floating docks, and boat moorings to seek shelter and spawn demersal eggs, while silversides deposit adhesive egg masses to eelgrass or man-made structures. For the abundantly impinged species, size-frequency distributions indicated that almost all of the queenfish and most of the silversides were small, young-of-the-year fishes. Similar habitat complexity also occurs in the much larger Los Angeles-Long Beach Harbor complex west of Alamitos Bay, and so this type of habitat, although productive, is not unique to the area. Because these species have short life spans and their populations are likely limited by the availability of adult habitat (for gobies and blennies), the additional mortality due to entrainment would not be expected to substantially affect their local populations. Similar levels of entrainment mortality were estimated for gobies at the South Bay Power Plant in south San Diego Bay (Tenera 2004). Although, data from a previous entrainment data and long-term data on adults indicated that the population in south San Diego Bay was stable and not affected by the additional larval mortality due to entrainment, the populations in Alamitos Bay are affected by the operations of both the HnGS and Alamitos Generating Station.

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

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

No federal/state threatened or endangered fish/shellfish species were identified in entrainment and impingement samples collected from HnGS. This is consistent with past entrainment and impingement sampling conducted at HnGS. 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. Nine species covered under the two FMPs that occurred in entrainment and/or impingement samples at the HnGS 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 HnGS in 2006 based on actual flow volumes.

Species	**Common Name**	**Management Group**	**Estimated No. Larvae (based on Entrainment Samples)**	**Juveniles/Adults (based on Impingement Samples)***
Engraulis mordax	northern anchovy	Coastal Pelagics	22,673,541	5,794
Parophrys vetulus	English sole	Pacific Groundfish	260,975	–
Loligo opalescens	market squid	Coastal Pelagics	231,898	78
Hypsypops rubicundus	garibaldi	CDFG	985,374	–
Sardinops sagax	Pacific sardine	Coastal Pelagics	255,242	90
Merluccius productus	Pacific hake	Pacific Groundfish	243,832	–
Citharichthys sordidus	Pacific sanddab	Pacific Groundfish	304,664	–
Leuresthes tenuis	California grunion	CDFG	90,595,407	382
Raja inornata	California skate	Pacific Groundfish	–	8
Sebastes miniatus	vermilion rockfish	Pacific Groundfish		7
Trachurus symmetricus	Jack mackerel	Coastal Pelagics		7

* *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 HnGS included:

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

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

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

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

These taxa seem to be responding to factors other than power plant impacts and several types of effects over time were found for the species in the detailed evaluation (Table 6.4-2). Anchovies disappeared from the commercial fishery after the regime shift and were essentially absent during the last two decades. Any time series data that extends to before or during this regime shift has evidence of this change. Other fisheries were declining (white croaker) while catch in the fishery independent monitoring programs found them to be either increasing or stable over time. Fisheries that were not declining (queenfish) had some type of positive correlation with ENSO's and/or SST, while the declining fisheries did not. This indicates that the fishing effects may be masking the natural variation for these taxa.

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

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

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

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

The low potential for AEI for most of the taxa entrained and impinged at HnGS is consistent with a recent review on population level effects of IM&E on harvested fish stocks (Newbold and Iovanna 2007). They modeled the potential effects of IM&E on populations of 15 East Coast fish stocks that are targeted by either commercial or recreational fisheries using empirical data on entrainment and impingement, life history, and stock size. For 12 of the 15 species, the effects of removing all of the sources of power plant entrainment and impingement were very low (less than 2.5%). For the other three species, the effects ranged from 22.8% for striped bass on the Atlantic coast to 79.4% for Atlantic croaker. Their overall conclusions were that population level effects were negligible for most fish stocks but could be severe for a few. They attributed the absence of large effects for most species to compensatory effects that are probably acting on the populations at some level. If there is strong density dependence acting on these populations during the life stages from the period when they are vulnerable to entrainment as larvae through the age of maturity, then they concluded that there should be very little potential for population level effects due to entrainment and impingement.

The greatest potential for AEI at HnGS was for two groups of fishes, silversides and gobies, that are small, non-harvested species. Proportional mortality rates for the vast majority of other entrained species, including all species with fishery value, were much lower and closer in value to the levels that Newbold and Iovanna (2007) concluded represented little risk to the populations.

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